B.I.O.S. FINAL REPORT No. 1203

ITEM Nos. 7 and 21

IRON CORED D.F. LOOPS AND MANUFACTURE OF IRON DUST

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BRITISH INTELLIGENCE OBJECTIVES

SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

IRON CORED D.F. LOOPS AND MANUFACTURE OF IRON DUST.

Reported by:-

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B.I.O.S. Team No.2226.

BIOS Target Numbers:
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BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE,
32, Bryanston Square, London, W.1.

Refer to FD 1194/47.

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Information obtained by B.I.O.S. Team No.2226 on a visit to Germany, 12th May - 1st June 1946, to investigate the design and development of iron-cored D.F. loops and the manufacture of dust iron with particular reference to its use in the above.

Investigation carried out by Mr. K.F. Umpleby, R.A.E., Mr. G.R. Polgreen S.E.I. Ltd. and F/O F.G. Overbury R.A.E.

Summary

Information contained in this note is obtained from interview with the following:-

Dr. Hoffman	Siemens & Halske, Berlin.
Dr. Tamm	" " "
Mr. Kesselring	" " "
Dr. Jenss	" " "
Mr. Friedrich Meyer	" " "
Mr. Kruger	Technical Manager, Hans Vogt & Co., Lahn Str., Berlin-Neukolln.
Dr. Muckenthaler	Siemens Plania, Meitingen, Augsburg.
Dr. Kornetski	Siemens Halske, Heidenheim.
Dr. Schlecht	I.G. Farben, Oppau.
Dr. Bergmann	" " "

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ILLUSTRATIONS

TARGET NO. 1. Visited 16th and 17th May 1946.

Address: SIEMENS AND HALSKE, SIEMENSTADT, BERLIN

1. Personalities:

Dr. Hoffmann - Director - Speaks excellent English.
Dr. Tamm

Mr. Kesselring
Dr. Jenss
Mr. Friedrich Meyer) - ZL Dept. Zentrallaboratorium. Specialists on magnetic materials and dust cores.

Dr. Kersten, formerly in charge of the Magnetic Materials Development Department (ZL) of S & H has recently left to become Professor of Physics at Dresden (in the Russian Zone) and was thus not available for interrogation. He is still in touch with his previous work at Siemens and makes occasional visits there.

None of the above members of S & H staff speaks English except Dr. Hoffman.

2. General:

S & H represent the largest manufacturers of magnetic dust cores for all telephone and radio applications in Germany. Formerly, all development and production were carried out in the various Berlin Works as follows:-

(a) Production of dust cores for telephone and radio purposes and loading coils at Wernerwerk III, nr. Jungfernheide, Berlin (destroyed in air raids).

(b) Production of all press tools for making loading coil cores and radio cores of all types was carried out at Wernerwerk R in Charlottenburg (partially destroyed).

(c) All development was carried out in ZL Department (formerly under Mr. Horning - died in 1944) and later under Dr. Kersten. ZL Department specialises in dust cores and all other magnetic materials and is one of six main development groups in S & H Research Department, the former head of which (Dr. Kupfmuller) has now been replaced by Dr. H.F. Mayer. The team intended to see Dr. Mayer but he had been taken to U.S. by the American authorities for a special mission.

No visits to production departments or to laboratories were made in Berlin because all plant had been removed by the Russians but Mr. Kesselring said that one or two experimental machines had been obtained or renovated and research work was being renewed. (A total of 40 machines remained out of a war time maximum of 11,000, the rest having been destroyed or removed).

During the latter part of the war after Berlin had been severely bombed the dust core production was dispersed to Pirmasens (SAAR). After the invasion of France, this plant was removed to Gera (Thuringia), where it was captured by the Americans. It is now in the Russian zone, and all the original plant is being operated by the Russians.

The original plant at Wernerwerk III in Berlin was stated by Dr. Muckenthaler to be

3 600 ton presses and associated equipment
for pressing loading coil cores
1 1000 ton press for special production
Associated Mixing machines (Werner-Pfleiderer type)
ovens, impregnating plants etc.
12 automatic squirting machines for making radio cores.

3. Production of Dust Cores:

All dust cores were made from Iron Carbonyl Powder supplied by I.G. Co. Oppau (near Ludwigshaven) in various grades.

S & H Code.	I.G. Code	Use.	Size.	Remarks.
X	H	UHF Cores. Low hysteresis Cores.	2-5 microns.	Fine production powder.
D	E	H.F. Cores. General applications.	2-10 "	Original product unheat-treated.
F	C_{st}	Small loading coils with good inductance stability with heavy magnetisation.	3-10 "	Special heat treatment by I.G.
A	C	High permeability (50-70u) cores for radio, D.F. Loops.	3-10 "	Anneal by I.G.

S & H Code.	I.G. Code.	Use.	Size.	Remarks.
I	-	Mixtures of above grades by S & H	3-10 microns.	
B	-	(not important)		
G	Sonder-pulver (special)	Low loss cores.	2 "	Screened in inert gas current, limited quantity obtained.

No special acceptance testing, particle size measurement or chemical analyses of these powders was undertaken by S & H who relied on I.G. tests made to their instructions and with their test equipment at the Oppau Works (see report of later visit).

Cores are made by the wet mixing of the powder with the appropriate percentage of insulating materials in a Pfleiderer Mixer. Dr. F. Meyer undertook to prepare a report (which has since been received and a translation of which appears as Appendix A) giving details of the processes, a summary of which is as follows:-

F powder + 1/3% water glass to give $\mu = 50$ with low eddy current cores for D.F. Loops etc.

(The above report disclosed that 0.3% sugar is also used, a fact not disclosed in discussion).

The powder is pressed at 12-15 tons (metric) per sq. cm and the surface of the core is subsequently sand-blasted in order to reduce the eddy currents resulting from the conducting layer of metal on the surface of the core after ejection from the mould.

Attempts were made to obtain a sample set of press tools for this core but these were unsuccessful since S & H stated that the equipment and tools in Wernerwerk R had either been destroyed or removed. S & H had limited production facilities for making Permalloy with a small percentage of copper included in the alloy. They claimed that this gave lower eddy current loss and better mechanical properties than the material used in Great Britain.

Dr. Hoffman stated that S & H had made plans for recommencing the manufacture of loading coils at the end of the year but no plans had been made for producing radio cores in Berlin.

4. Development Work on Dust Cores:

This has been partly covered by earlier teams and reference

* should be made to B.I.O.S. Team No. 1875, M.W. Foulkes-Roberts on a visit to S & H on the 11th March 1946. Copies of these reports were supplied as follows:-

(1) Properties of Magnetic Materials (21.3.46).

(2) Sendust : Properties of Nickel-free Magnetic Material of high permeability made by Japanese methods.

(3) Development of Nickel-free dust core for high frequency variometer using D.C. Magnetisation.

The first report is a general summary of all types of magnetic materials developed and produced by S & H The second refers to development of small scale production of sendust alloy of 85% Fe, 9.5% Si and 5.5% Al. This had been made in quantities of a few hundred kilogrammes and no large-scale production had been undertaken or planned. The chief interest was that this material gave better quality for loading coils than the annealed grades of iron carbonyl powder but from the results it appeared to be not so good as the permalloy series of nickel iron dust cores in general use in Great Britain and America.

The third report describes an alloy of 80% Fe, 10% Si and 10% Al, which is made in the form of powder and pressed in dust cores of rectangular bar shape weighing a few grammes. The coil surrounding this core consists of one H.F. winding and one winding for D.C. magnetisation; by altering the current in the latter the inductance is changed over a wide range. This arrangement contained the advantages of permeability tuning but without the disadvantage of moving parts and complicated operating mechanisms. Mr. Kesselring said that this had been used only on a small scale in production for some aircraft equipment but that they regarded this mainly as a subject for further development.

A further report dealing with the hysteresis loss at low magnetic fields, based on the Rayleigh principle, had been written by Dr. Kornetski in ENT.Bd 20 H.1 1943, a photostat copy of which was obtained later in England.

5. Production of D.F. Loops.

Development and production of the D.F. Loops for aircraft was formerly carried out entirely by S & H in Berlin in technical association with Telefunken. The original work was done at Zentrallaboratorium by Dr. Kersten and Dr. Kornetski (interrogated 27th May at Heidenheim) and included work on the coil mounting and the associated dust cores and followed up by extensive testing

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* BIOS Final Report No. 682

in the field. The mechanical operating devices were purchased outside and the completed unit was supplied to Telefunken, who made electronic and indicating equipment.

APPENDIX A

TRANSLATION: by G.R. Polgreen (not necessarily accurate in detail)
20.8.46.

Siemensstadt, 24th May 1946.
ZL 110a/8 Mey.
Author: F. Meyer, S & H ZL.

Report on the Magnetic Properties of Powder cores of our construction.

SUMMARY:

This report summarises the magnetic properties of the most important dust core materials, which we use, as well as the methods for manufacturing the cores. The principal material for our core manufacture consists of the various types of powder supplied by I.G. Farbenindustrie of the properties of the different iron carbonyl powders are well known. For making dust cores with alloy powders it is necessary to include details of the manufacture of the powder also.

(1) Cores of Carbonyl Iron.

The carbonyl iron powders supplied from the I.G. Farbenindustrie, Ludwigshaven fall into two groups (high and low permeability powder). The high permeability types B, F and A (corresponding I.G. references S, ^{C}normal, ^{C}stabil) for an average particle size of 5-8 um (micron), whereas the low permeability powders D and K (I.G. Reference E & H) is a finer powder, average particle size about 4-5 um (4-5 microns). In special cases in a few instances of specially fine powder, type G (2 micron) is supplied.

(a) Pressed Cores. The supplied powder is first insulated with waterglass (sodium silicate) or sugar and waterglass and dried at 60°C, then a binding material (bakelite lacquer) is added and dried at 40°C. The mix is broken down in an Edge Runner mill and then pressed into cores at a pressure of 10-15 tons per sq. cm. The cores containing bakelite are hardened at 114°C for 12 hours.

(b) Injection Moulded Cores. After the pre-insulation of the powder with waterglass a thermo plastic binder (trolitul) is mixed in place of bakelite. The mix is injection moulded into cores at 180 - 200°C in an Isoma-Automat machine supplied by the firm Brown, Zerbst.

(2) Powder Cores made from Alloy Materials.

(a) Permalloy (Fe-Ni-Cu).

The alloy powder is made by the reduction of the oxides at a reduction temperature of 700°C and then concentrated in hydrogen at 900°C. The material is broken down in a Ball Mill and annealed at 800-850°C in hydrogen. The particle size of the powder is about 50 microns. The powder is insulated with chromic anhydride (CRO_3) and dried. The pressed cores are heat-treated in air at 500°C for 40 minutes.

(b) Sendust (Fe-Si-Al).

The alloy is cased in an ingot of 40mm diameter and 500-700mm long and heat-treated at 1000°C for one hour in hydrogen. After grinding to a particle size of 50 microns the powder particles are re-crystallised at 750°C for one hour in hydrogen and insulated with ammonium per sulphate, $(NH_4)_2S_2O_8$. The pressed cores (pressure 14 tons per sq.cm) are heat-treated in air at 700°C for 40 minutes, immersed in bakelite at room temperature and then aged at 140°C for 12 hours.

APPENDIX B

Translation. (GRP) (PRB).

Siemensstadt, 21st March, 1946.
ZL. 110a 136/8 KM. Mey.

Workers - Karl Maier.
Friedr. Mayer. (125).

Report on Magnetic Materials

Mr. Foulkes-Roberts BIOS. 1875 investigated through our Drs. Hoffman, Lauth and Tamm on 11.3.46. the development work on transformer materials especially for lower frequencies. He wanted the following information:-

(1) Impulse Transformers
(2) Use of Sendust.
(3) Replacement of special materials for cores.

On (1) Magnetic Materials for Impulse Transformers.

For attaining a high maximum permeability, the first transformers were made with M89 alloy (40% Ni, 60% Fe). The high permeability is important in order that the necessary coil inductance of the impulse transformer can be obtained with few turns so that the leakage inductance remains small while the impulse dies away. So that the impulse transformer will not become hot with eddy-current, the core is made of 0.1 mm thick sheet. Also the core of an American impulse transformer we have tested was made from thinner stampings of nickel iron (see Summary 1).

Because the use of nickel is restricted, tests were made with nickel free core sheets. It transpired that the best type of transformer iron could be used but special heat treatment would be necessary. (see Summary 2).

On (2) Fe-Si-Al alloy (Sendust) for Magnetic Powder Cores.

High u powder cores (u 50) of IG Carbonyl iron powder on account of their higher loss values can be used only in limited circumstances. A notable improvement can be made by making Sendust powder cores (use of smaller cores for same results). As a result of our research experience (see Summary 3) a reduction in size of 30% can be effected if a Sendust core of 70u can be used instead of a core of carbonyl iron of 50u.

With the previous experience, the following method of preparation has been found to be successful:-

1. The alloy (85% Fe, 9.5% Si, 5.5% Al) is made in 7Kg. melts of cast rods of 40 mm diameter.

2. The rods are heat treated at 1000°C for 1 hour in hydrogen.

3. The cast pieces are broken and ballmilled to a particle size of 10 to 100 micron (average particle size 50 microns).

4. Heat treatment for re-crystallisation at 750° for 1 hour in hydrogen.

5. Insertion of powder with 0.2% ammonium per sulphate $(NH4)_2S_2O_8$.

6. After pressing by existing methods (ring core) the cores are heat treated at 700°C for 40 minutes.

7. Immerse the cores in bakelite varnish and dry at 140°C.

(3) Special Material for Transformers.

The magnetic soft iron types for transformers in electrical telecommunications are summarised with their most important magnetic properties (see Summary 4). These measures have led to an appreciable limitation of soft iron. We have in table DIN.E. 41301 summarised the following materials.

Class	Name.	Composition.
A1.	Trafoperm 25.	2.5% Si. Rest. iron.
A2.	Dynamo sheet IV U. (selected sheets)	4% Si. " "
B1.	Rotraperm und Fe 8.	3.5% Si. Rest iron unalloyed iron.
D1.	M.89 0.35mm 0.1mm.	36 - 40% Ni, rest iron.
D2.	M.89 0.05mm	36 - 40% Ni, rest iron.
E3.	Mumetal.	76% Ni. 5% Cu. 2% Cr.Rest iron.

The nickel-free silicon alloys should be used for preference. Developments were made in order that high permeabilities at low field strength could be obtained with cold-rolled Si-iron sheet by means of final heattreatment and also to diminish the variation of permeability with field strength. The results of this development were the following materials -

A1.	Silitex 850	3.5% Si.
C2.	Silitex 1200	3.5% Si.

The preparation of these materials has been discontinued.

For cores intended for high inductance, Dynamo sheet III and IV are in many cases unsuitable. Thus for the switch-chokes in the conjunction with contact-rectifiers, a silicon-iron alloy (2.5% Si) and a nickel iron (50% Ni, 50% Fe) with magnetic anistropy were used. It was also desired to produce material similar to the American "Kypersil", having low iron losses.

Special material for magnetvariometer from Fe-Ni-Cv alloy.

Induction-regulation by variation of a DC. field superimposed on the H.F. field (0.35 ... 4 Mc/s.)

The inductance of an iron-cored coil can be varied in a simple manner, since the permeability of the core material can be altered by DC. magnetisation. The DC. controlling current used for this purpose should be as small as possible. A core-material with low saturation value is used. Further a core-material with the lowest possible coercive-force is required, so that the irreversible inductance-variation brought about by the passage of the controlling flux remains as small as possible.

For this purpose core-materials CO 50 and CO 35 (initial permeability ua = 50 or 35 uo) have been developed with the following compositions . 63% Ni, 12% fe, 25% Cu. The insulation-content of the CO 35 (to reduce eddy-current loss) is about 2% by weight (Cro3 plus talc) greater than for CO 50.

Their magnetic properties are summarised below -

	Br/Gauss	He/Oersted	u/uo	"ec" loss	"h"	"v"
CO 50	4000	2 ... 5	45 ... 50	0.08 .. 0.12	50	10
CO 35	4000	2 ... 5	30 ... 35	0.05 .. 0.08	35	8

u - permeability measured in uo.

ec - eddy-current loss, measured in u sec.

h - hysteresis loss, measured in cm/kA.

v - viscosity in 0.00 (i.e. parts per thousand.)

APPENDIX C

Translation. (PRB).

Siemensstadt, 6th March, 1941.
ZL. 1852/2 Mey.

Author: Meyer (7856).

Report on the properties of a nickel-free dust core material with high permeability made according to the Japanese Sendust-material technique.

General remarks.

Investigation of Fe-Si-Al alloys in the development of a new high permeability dust core material has resulted in somewhat better electromagnetic properties than for dust cores of the same permeability made of carbonyl iron. Laboratory results so far obtained on the new material are:-

u-70...75 u0, w-0.3...0.5 us. h-40...50 $\frac{cm}{kA}$, n-6...10°/oo

u-90..100 u0, w-0.7...3.5 us. h-110.120 $\frac{cm}{kA}$, n-10..15°/oo

Samples core can be made in small batches as in Z.L.2.

Production, made after the development of different methods of preparation, was started not earlier than 1942.

For some time development of Fe-Si-Al alloys in Z.L.2. (Zentral-lab.2.) relied on Japanese publications and test results on samples core from Japan in order to assess the magnetic data for material made under ordinary production conditions. It was necessary to undertake a special development, the results of which were reported elsewhere. The following information is a special collection of results obtained in the Laboratory, for laboratory use, on the electromagnetic factors hitherto obtained for this material.

The new material was provided in the form of ingots (7 kg. melts) by the Z.L.2. of the Abtl.f.El.Chemie. According to the particular heat treatment used at the time, the ingots were broken down under a press and comminuted to a powder. The powder was subjected to a further heat treatment and after insulation was pressed into cores. Finally a core heat treatment was necessary.

The investigations were finally carried out on a K19 core with a pressure of 14 tons per sq. cm. In the following table are collected the values arrived at in the laboratory. For comparison, values for Bt.70 and FT.55, made with carbonyl iron as the magnetic material are also given.

The difference in inductance resulting from a heavy current overload (magnetic instability S) was measured in terms of 100 amp. turn per cm. The time delay in fall of inductance following the magnetisation was after 2 day 0.2 ... 0.3%

Material	u/uo	w/us	h/$\frac{\text{cm}}{\text{kA}}$	n/o/oo	S%
Carbonyl Ft.55.	55	55	50	7.8	1..2
" Bt.70.	70 .. 75	1.0 . 2.0	90 ... 100	10..15	10
Sendust TS.70	70 .. 75	0.3 . 0.5	40 ... 50	6..10	0.5
" TS.90	90 ..100	0.7 . 3.5	110 ...120	10..15	1

The table shows that, as compared with carbonyl iron, Sendust besides having lower eddy-current loss (w), for the same permeability shows improvement also as regards hysteresis loss and magnetic instability. Current development work indicates the possibility of all-round improvement in properties.

For example the following results have been obtained on cores made by different mixing experiments -

u - 80 uo, w - 0.45 us, h - 40 $\frac{\text{cm}}{\text{KA}}$, n - 8°/oo

u - 105 uo, w - 3.5 us, h -110 $\frac{\text{cm}}{\text{KA}}$, n - 15°/oo

The material was further investigated as regards the variation of its properties with temperature. The temperature coefficient was measured between 10° and 50°. the experiments showed a large temperature coefficient of inductance having a value of - -1 10-3 °C-1. The variation with temperature itself is approximately linear with relatively small repetitive errors ($\frac{L}{Lo}$ - 0.2 ... 0.4. 10-3 after 4 to 5 temperature cycles). For many purposes (e.g. Filter coils) the high value of temperature coefficient is a drawback. There seems little prospect of lowering the value. An improvement might be possible later when the dependence of temperature coefficient on alloy composition can be studied. The aim would then be to approach low values of small temperature coefficient by adding a second alloy having a strongly positive temperature coefficient. The process methods given by Z.L.2. naturally only apply to preparation of cores in small batches for experimental purposes, now the urgent necessity for developing large scale production is no longer present and further experimental work can be undertaken.

It is hoped that the separate organisations making use of the material in the future will keep in close touch with Lab 2. so that the necessary planning can be directed in the best possible way to serve future needs.

TARGET NO.2. **Visited 16th May, 1946.**

Address: HANS VOGT AND CO., 11-23 LAHN STR., BERLIN-NEUKOLLN.
(Russian Sector of Berlin)

1. **Persons interrogated:**

Mr. Krüger - Technical Manager - Speaks English

2. **General:**

This firm was recommended by G(T) and CW but had no information to offer regarding the particular iron core that the team was interested in. They were, however, in production various types of iron core, and the plant was inspected as a matter of general interest. The firm has been visited before by an M.O.S. mission about 18th March 1946.

3. **Information gained:**

The firm is in the Russian sector, and although some machines, including the bigger presses, had been removed, considerable quantities of iron cores were being turned out for R.F. and I.F. use and carrier telephony including a special high permeability type ($\mu = 30$) for permeability tuned domestic receivers and a variometer type of core with permeability 50 giving an inductance change of 15/1. Cores are made in screw, pot, bar giving an inductance change of 15/1 and toroid shapes with permeabilities up to 60. The maximum pressure used is 20 - 22 tons/sq.cm. using mainly phenolic resin as binder. The firm make their own tools out of 12% chromium steel known as R.C.C. steel. The biggest press was 450 ton.

All the iron dust is obtained from I.G. Farben and is of course carbonyl and the firm appeared to be working on stock.

The plant was small and rather dilapidated, employing about 50 workers. Another plant exists at ERLAU near PASSAU in Bavaria. The Berlin plant manufactures only radio cores, and the Erlau plant only sintered iron.

TARGET NO. 3. Visited 24th May, 1946.

Address: SIEMENS AND HALSKE, ERLANGEN, Nr. NUREMBERG.
(U.S. Zone)

It was understood that Dr. Kornetski and/or Dr. Muckenthaler was at this plant, but on arrival it was learned that Dr. Muckenthaler was at Meitingen, Near Augsburg and Dr. Kornetski was at Heidenheim, Near Ulm. The plant was therefore not inspected, but was seen to be undamaged, and producing valves.

TARGET NO. 4. Visited 24th May, 1946.

Address: SIEMENS-PLANIA, MEITINGEN, Nr. AUGSBURG.
(U.S. Zone)

1. Persons interrogated:

Dr. Muckenthaler (Speaks no English).

2. General:

The factory is primarily employed on carbon electrodes, brushes, etc., but Siemens-Halske are starting production of iron cores in a vacant wing. The whole factory was undamaged. Dr. Muckenthaler, who was one of the designers of the P.R.E.6, had been evacuated from Gera (Russian zone) by the Americans.

3. Information gained:

Dr. Muckenthaler had been chiefly concerned with the manufacture of the P.R.E.6, and although he was able to give some information on the development, he had lost all his records, and such information as he was able to give was repeated by Dr. Kornetski, who was more informative (see report on visit to Dr. Kornetski).

Dr. Muckenthaler gave particulars of the production methods and indicated the special difficulties associated with the winding and testing in order to obtain the uniformity required by the specifications. The technical performance and particulars of these loops is already available at R.A.E. as a result of tests carried out on captured German aircraft equipment (Tech. Minute Rad. 157). The latest type has the reference number P.R.E.6, (Peil Rahmen Eisen 6) and was put into service just before the end of the war. It is a flattened solenoid about 6" x 1½" x 12" with rods of iron of semi-cylindrical section of 1" diameter running down the sides. The whole is mounted in a metal dishpan sunk just below the aircraft skin, and covered with a perspex cover, flush with the skin. The P.R.E.6 has 80% of the efficiency of the early external air-cored loop, while the reduction in drag produced by the flush mounting is equivalent to an additional 100 H.P. in some new high speed aircraft.

The electrical characteristics of the loop are as follows:-

Inductance L = 24,000 cms.
Effective permeability = 6.5
(Toroidal permeability = 55)
Minimum Q = 150

Dr. Muckenthaler disclosed that supplies of carbonyl iron powder from I.G. Farben were coming from the Oppau works in limited amounts, but said that an I.G. dispersal factory in undamaged condition was operating at GAPEL, Near RATHENOW, Brandenburg (Russian zone) (see report of visit to I.G. on 29th May 1946).

At Meitingen production of cores for all radio and telephone purposes was just starting. Plant was already running for making 20,000 radio screw cores per week by an injection process, see attached photographs, and three 200 ton presses were being installed for making toroid cores for loading coils. Arrangements were being made to instal winding machines and test equipment for making loading coils.

TARGET NO. 5. Visited 27th May, 1946.

Address: SIEMENS-HALSKE - HEIDENHEIM - MERGELSTETTEN,
BRENZSTRASSE 29 (SCHULHAUS).

1. Persons interrogated:

Dr. M. Kornetski - Speaks English.

2. General:

Some members of the Siemens-Halske staff are located in rooms at a school at the above address. There are no laboratories or works, only offices. The situation was not clear, but it seemed that these persons were being held pending de-Nazification.

3. Information gained:

Dr. Kornetski was one of the principals in the development of the range of German iron-cored D/F loops for aircraft, culminating in the P.R.E.6. The main reason for the development of the P.R.E.6 was to reduce weight and drag, and development seems to have been largely empirical.

I. Iron Weight

Tests had been made to determine the optimum weight of iron required. The inductance was maintained constant throughout by adjusting the number of turns, and a broadcast transmitter was used as the signal source. The output voltage from a receiver correctly matched to the loop was measured for differing weights of iron. This was compared with the output from the old type German air cored loop (assigned 100%). It was found that the output from the early P.R.E.3 was about 100%, using 6.5 kg. of iron. The output from the P.R.E.6 was 80%, using 3 kg. of iron. The curve of output volts against iron weight was substantially linear up to 3 kg. and thereafter flattened out, a disproportionate increase in iron weight being required to produce an increase in output. It was decided to limit the iron weight to 3 kg. and tolerate the 20% loss in performance.

II. Iron Permeability

It was established theoretically, and by experiment, that the output voltage for constant inductance was proportional to $\sqrt{\mu}$ where μ is the working permeability. This increases with increasing toroidal permeability, and also with increasing length/width ratio of the iron because of the reduction in demagnetisation. In the P.R.E.6 a working permeability of 6.5 was achieved using iron with a ring permeability of 55. A high permeability is also necessary especially with a submerged loop, in order that a low reluctance path may be presented to the field.

III. Iron Position

The only requirements are that the iron shall be placed as close as possible to the winding to achieve maximum flux linkage, and that the separate sections of the iron shall be separated as far as possible over the cross section so that each part has a good "view" of the field, and is thus able to collect as much of the flux as possible without detracting from that collected by the other section. (Dielectric loss and increased self capacity had either not been considered or were comparatively unimportant). Dr. Kornetski agreed that it might have been better to place the iron near the (longer) horizontal wires rather than the vertical wires, and experiments were to have been done on this matter. The semi-cylindrical bars were, however, an easy production job, and a bar with a greater surface area might have involved a prohibitively large press to achieve the same permeability.

IV. Loop Dimensions

The turning circle of the loop had been specified and it was therefore a matter of determining the relative importance of cross sectional area and length. It was found experimentally that it was most important to keep the length as large as possible and it was stated that an increase in output of 40% would be obtained if the length could be increased from 300 - 400 mm. Having specified the turning circle, however, a point is reached where further increase in length reduces the output in a submerged loop because the surrounding metal prevents the field entering the end of the iron section and it becomes unprofitable to proceed beyond this point. The final dimensions had been fixed by trial and error and were considered to be optimum.

V. Iron Loss

The effect of eddy current loss had been found to be far more important than hysteresis loss, and the cores were sand-blasted after moulding to remove the surface glaze.

VI. Wire Size

In a loop of this type which is matched to the receiver input, a high Q is desirable and Litz wire was used to achieve this. However, no special experiments were performed to determine optimum gauge, and number of strands, but a wire was chosen which was in large scale production.

The loop had been designed to work into a maximum length of cable of 17 metres. In all the experiments 7 metres of cable had been used.

Dr. Kornetski had practically no records of the development beyond a paper entitled FEILRAHMEN MIT MASSE KERNEN - SIEMENS ZEITSCHRIFT BD.22, OCT/DEC 42, HEFT 4 (Appendix D), but believed that Telefunken, Dachau, had done some mathematical analysis after the experimental work had been done. Unfortunately time did not permit a visit to Telefunken.

APPENDIX D

TRANSLATION FROM SIEMENS ZEITSCHRIFT

D.F. Loop Aerial with Iron Dust Core.

By M. Kornetski.

For electrical reasons Direction Finding loops have to be fixed to the surface of the plane, preferably to its top. The projecting parts cause a certain amount of air resistance. This resistance has been negligible for planes of older designs which travel at considerably lower speeds. With modern planes, however, which travel at high speeds, this air resistance is not negligible. With a directional aerial of usual dimensions at a speed of 250 kilometres per hour the air resistance is about 7 Kgs. This pressure corresponds to a loss of 7 B.H.P. At a speed of 500 kilometres per hour the air pressure is roughly 20 Kgs corresponding to a B.H.P. of 40. If the speed is increased to even 700 Kilometres per hour then the air pressure becomes 30 kgs. Roughly 100 h.p. of the engine output are then lost.

As such a decrease in effective power results in a considerable loss of flying speed, means were sought to place the directional aerial in such a manner that the wind resistance effect was completely avoided or at least decreased. A possible way would be to decrease the dimensions of the directional aerial. This, however, does not give the required results as a decrease of the diameter of the directional aerial brings about a decrease in output of the aerial. The output voltage from the directional aerial to a receiver keeping constant electrical values, e.g. damping, inductance, etc. is roughly proportional to the diameter of the directional aerial to the power 3/2. A considerable decrease in dimensions of the directional aerial would, therefore, result in a considerable decrease of its effective range. A second possibility which was tried out experimentally and which completely avoids any air resistance is to build the directional aerial into the plane. In order to make access for the screened directional aerial possible through the metal hull of the plane, the compartment of the plane must be given as large as possible an opening, which can be covered by insulation material. If this opening is to be avoided, the directional aerial frame has to be mounted in a place which, for other reasons, is already made of insulating material as in the cockpit of the plane. This generally is not a practical proposition due to lack of space. If it is built in an opening of the hull, e.g. behind the wings, then the output of the receiver decreases considerably, assuming the opening in the hull is not too large. Even in this case, difficulties, due to lack of space, will be experienced. In addition, in this case, the screening will not be very effective.

Taking all these difficulties into account the following problems have to be solved:-

The height of the directional aerial must be decreased considerably so that it takes up less space when built into the hull, than the usual type of directional aerial. At the same time care has to be taken that the output, decreased by building the aerial into the hull, has to be increased by other means. This cannot be achieved by trying to compensate the decrease in output of the directional aerial by increasing the output of the directional receiver. The quality of a directional system is not dependent on the voltage output of the directional receiver but on the signal to noise ratio at the input of the receiver. There should not be greater noise output than that which is normally due to circuit thermal noise. This originates from the disorderly motion which electrons perform due to heat energy. Care must be taken to ensure that the diminished output of the smaller built-in directional aerial is again completely or nearly raised to the value which it was when the aerial was fixed on to the plane. For this purpose, a magnetic core is inserted into the aerial frame.

What increase of output is effected by the addition of this core? If the effective permeability of the core is $\mu w \cdot \mu_0$ (μ_0 is the permeability of the empty space) then the output voltage in a definite high frequency field increased by a factor μw. Simultaneously, the inductance increases by a factor μ_L, this being generally smaller than μw. To obtain a rough idea of the output we assume that the damping of the plane by building in the core is only slightly changed which is nearly true enough in practice. Then the noise output is not altered by inserting the core, so that we can use the output with and without core for the sake of comparison. If the output without the magnetic core is N_0, the output with the core will be

$$N_K = N_0 \frac{\mu w^2}{\mu_L} \qquad (1)$$

The increase in voltage with the same inductance (ratio of effective heights) is, therefore,

$$\frac{U_K}{U_O} = \frac{\mu_W}{\sqrt{\mu_L}} \qquad (2)$$

With the above assumption $\frac{U_K}{U_O}$ is equal to the ratio of the reciprocal minimum width. For a rough approximation we can put:-

$$\mu_L \approx \mu_W \qquad (3)$$

then we obtain

$$\frac{U_K}{U_O} \approx \sqrt{\mu_W} \qquad (4)$$

The frame can, therefore, be decreased to such an extent that, when it is built in, a voltage, is obtained which is reduced by the factor $\frac{1}{\sqrt{\mu_W}}$, this loss in voltage is then compensated by inserting the magnetic core. The factor μ_W is about 6.5 with the directional frame aerials with magnetic core described below while μ_L is roughly 5. The increase in voltage due to insertion of the core calculated by means of equation (2) corresponds to a factor of about 3.

The magnetic cores are made of solid metal, as cores made of sheet metal result in too big damping at the frequencies used.

The first experiments on directional frame aerials were carried out by the firm Telefunken. Such frames were then developed by Siemens & Halske together with Telefunken and have been manufactured for several years.

TARGET NO. 6. Visited 29th May, 1946.

Address: I.G. FARBEN - OPPAU - LUDWIGSHAVEN.

1. Personalties:

Dr. Schlecht. Head of Powder Department (seen for short time at beginning and end of visit). Abteilung Hochdruck Oppau (speaks English).

Dr. Bergmann. Physicist (speaks only German. Mr. Polgreen interpreted). In charge of development and test of iron powder. Laboratory in Ludwigshaven about two miles from iron powder works but inside I.G. grounds.

(N.B. Dr. Cramer, also recommended to team by Siemens and Halske for interrogation, recently committed suicide at dispersal factory at Gapel).

2. General:

The Ludwigshaven group of I.G. Works extend for about 4 miles along west bank of Rhine and the iron carbonyl powder is made in the northern part of the Works at Oppau. The offices are at the south end (BAU.1) in Ludwigshaven and anyone visiting the works must first obtain a "laissez-passer" from the French authorities in charge there. Col. Scheffer and Col. Romer are responsible for the plant and Commandant St. Blancar is the specialist on iron powder. This is in addition to the authority of French FIAT at Offenburg and the French Government at Baden-Baden, which were obtained by personal visits of the team on the 28th May. All samples and papers must be handled through Col. Scheffer.

The Works makes, in addition to nickel and iron carbonyl and powders, synthetic ammonia, artifical rubber and many other chemical materials. Much air-raid damage was in evidence and the whole place was in an extremely dilapidated condition. When working fully it employed about 18,000 workpeople.

Dr. Bergmann's Laboratory is about 1 mile north of the Main Offices in Ludwigshaven and the building is badly damaged. The powder test and development departments are now installed in the cellars under very untidy and difficult working conditions. The main powder works is divided into two separate groups:-

(A) The two plants for making nickel and iron carbonyl are situated in the north part at Oppau about 3 miles from the Main Offices.

(B) The iron powder plant is about ½ mile SW from the carbonyl plant. It employs about 50 people when fully operating but only about 18 were working there at the time of the visit.

These powder plants are apparently little damaged and are capable of large scale production, if adequate materials and power were available, but the output of iron carbonyl powder was stated to be about 25 tons/month at present, i.e. about one quarter of the total productive capacity of the plant.

Dr. Bergmann said that they had about 40 tons of powder in stock, much was being supplied to France, and the German electrical firms are starting to use the powder again for loading coils and radio receiver cores.

A dispersal factory was built during the war for making iron carbonyl powder at GAPEL (bei Rathenow) near Brandenburg, about 50 miles west of Berlin in the Russian zone. Dr. Schlecht said that this plant was now being dismantled and taken to Russia. It has a capacity of about 25 tons/month.

Part of the Oppau plant - one complete unit capable of making and heat treating about 10 tons of powder per month - was being dismantled for installation in France in order to supply their telephone and radio industries with powder for dust cores.

3. <u>Applications:</u>

Dr. Schlecht stated that over 90% of the iron powder was supplied for the electrical industry. The chief users are:-

(1) Telephone cores. Siemens & Halske, Felten & Guillaume, A.E.G.

(2) Radio cores. Siemens & Halske, Telefunken, A.E.G. Lorenz, Vogt, Neosid, Dralowid.

Some work had been done on the applications of iron carbonyl powder to powder metallurgy but without success because the powder was too expensive and not the right physical type. Attempts had been made, mainly before the war, to make nickel-iron alloy powder by the carbonyl process by mixing the gases before letting the powder settle in the vertical cylinders. The results were disappointing because the alloy was not homogeneous and the shape of the powder was not satisfactory.

The process for making iron carbonyl powder was developed about 1920-1924 as an anti-knock material but for this use it was unsuccessful. The first electrical work was done by FELTEN and GUILLAUME of Koln-Mulheim in 1926 and later by Siemens & Halske (1928) who formerly used a magnetically inferior iron powder made by Hartsoff-Metall A.G. of Berlin by a grinding process. Originally all the powder was heat treated before dispatch because it was too hard to press and too difficult to insulate in its original form (Gr.E).

4. Testing of Iron Carbonyl.

Powder to be used for telephone applications is tested by known methods using toroid test samples. About 1 kg of the batch of powder to be tested is insulated in a small laboratory type of Werner-Pfleiderer mixer with a synthetic shellac or bakelite type of insulating material. Ring shaped test cores are pressed at pressures up to 20 tons/sq.cm in large split dies of which the high pressure components are made from a Krupp molybdenum steel. This represents F & G technique because S & H do not work above 15 tons/sq.cm which corresponds to the maximum pressure used by British firms.

Two winding machines, one of S & H make and one made by Froitzheim and Rudert (Berlin), are used to wind the test toroids with enamel insulated wire. The German wire was of such poor quality that it gave excessive eddy current loss; hence a small lab. plant was fixed up to coat all the wire with polystyrene before winding.

The toroid cores are tested at L.F. on an old type of S & H slidewire bridge by comparing the test coil with a cylindrical air cored standard installed remotely to avoid coupling with the bridge and oscillator. Hysteresis factor is measured separately on a Maxwell bridge and a separate arrangement is used for stability testing. The test units are

h - hysterese (hysteresis).
w - wirbelstrom-verlust (eddy currents).
n - nachwirkung (viscosity).

and limits had been agreed with Siemens & Halske for the various materials. These were not available because both at Oppau and Siemenstadt most of their records, reports etc. had been damaged or burned in air raids but could be obtained if required.

Radio cores are tested by making E-shaped test cores, two of which are clamped around a test coil and the Q measured on a Rohde and Schwarz type of Q meter at 1200 kc/s.

As regards technical information Dr. Bergmann recommended an article by Dr. Kornetski (Siemens & Halske) ENT 1943 Bd 20 H.1. "Die Hysterese in Rayleigh-Bereich schwacher magnetischer Felder bei gescherter Magnetisierungskurve".

5. Iron Carbonyl Powder Production.

The separate building for making iron carbonyl powder from the liquid carbonyl has a total production capacity of 100 tons per month but during the visit was producing about one quarter of this quantity. The first part of the process consists of producing the hard unannealed type of iron carbonyl powder (Type E) which is the basic material for all other grades of powder.

Liquid iron carbonyl is pumped from the factory (A) in Oppau to storage tanks on the roof of the iron powder building. The total capacity of these tanks is about 10 tons, sufficient to make 3.3 tons of iron powder. The top floor contains boiling chambers for vapourising the liquid carbonyl at 103°C, the vapour being piped to the top of large vertical settling cylinders about 12 feet high and 3 feet diameter. The iron carbonyl powder particles are formed inside this cylinder and can be collected at the lower conical end. A special double "lock-type" valve is used to minimise the escape of carbon monoxide and in addition a supply of nitrogen is fed to this valve. The carbon monoxide gas released by this main reaction is led away by a branch pipe leading upwards from the conical base of the cylinders and is used again in other parts of the process.

The iron powder is collected at the bottom of the cylinders in iron drums which are connected by means of rubber sleeves. The powder has an average carbon content of 0.7% and requires grinding and sifting before it can be supplied to the electrical industry. The whole plant consisted of eight cylinders and auxiliary equipment, each with a monthly output of about 10/12 tons.

6. Powder Grinding and Finishing Processes.

The Grade E powder coming from the condensing process contains some agglomerates which have to be broken up in ball mills. This grinding process is carried out in a number of large horizontal cylindrical ball mills (made by Barbarossa Werk, Kaiserslautern), the drives and supports of which are installed under the floor to facilitate handling and loading. Each mill contains1.1 tons of powder and a similar quantity of iron balls of about 2½" diameter and smaller. Grade E powder is ground for 48 hours at 10 Turns/minute and a test is made on a sample obtained from the centre of the mill before the batch is removed. The powder is then sifted through a special sifting machine consisting of 70 x 70 sq.cm phosphor bronze mesh fixed to a rotatable hexagonal iron frame barrel about 6 feet long with 8 inch side of the large end, tapering to about 4 inch side at the smaller end. The powder is fed through the slowly rotating sieve and the powder is drawn off in four grades of size.

The size of the mesh opening is about 50 micron which is much larger than the maximum size of the particle but Dr. Bergmann stated that all the powder was inherently fine and it was chiefly necessary to break up aggregates in this process. Air sifting was apparently not used except on an experimental basis.

Carbonyl Grade C for higher permeability dust cores as used in DF loops etc. is obtained by heating Gr. E powder in large horizontal furnaces about 12 feet long x 3 feet wide x 1 foot high. The furnace consists of a large iron muffle with flanges at each end which is surrounded by a larger casting containing large numbers of carbon rods connected to a heavy current power supply through a regulating transformer. The top half of the casing is supported by wires and counterweights so that the iron muffle can be easily changed or moved. The charge is 1.1 tons (as for the ballmills) in four metal trays about 3 feet square and about 4 inches high. About six thermocouples are installed in a sealed tube fixed through the furnace door and which projects half way down the furnace.

The E powder is heat treated in the following manner to make Grade C powder:-

494°C in Nitrogen for 12 hours.
then 390°C in Hydrogen for 2 hours.
cooled in furnace - total time about 2 days.

The powder is removed from the trays in slab form and is broken up in a small oscillatory crusher and then ballmilled in the same mills as for E powder. The speed of rotation is however, 4 R.P.M. and the powder is milled for 20 hours, after which it is screened in the sifting machine described above.

The finished Grade C powder is given a chemical test for N & C and the heat treatment reduces the carbon content from 0.7 to (Grade E) 0.05% (Grade C) with N about 0.01%.

For iron powder used for loading coils and cores a slightly different heat treatment is given to produce a powder known as C_{st} (C_{stabil}) which makes high permeability cores with a small change in permeability with heavy superposed magnetising fields.

Dr. Bergmann said that this material had been discovered by trial and the reason for the good stability was not understood.

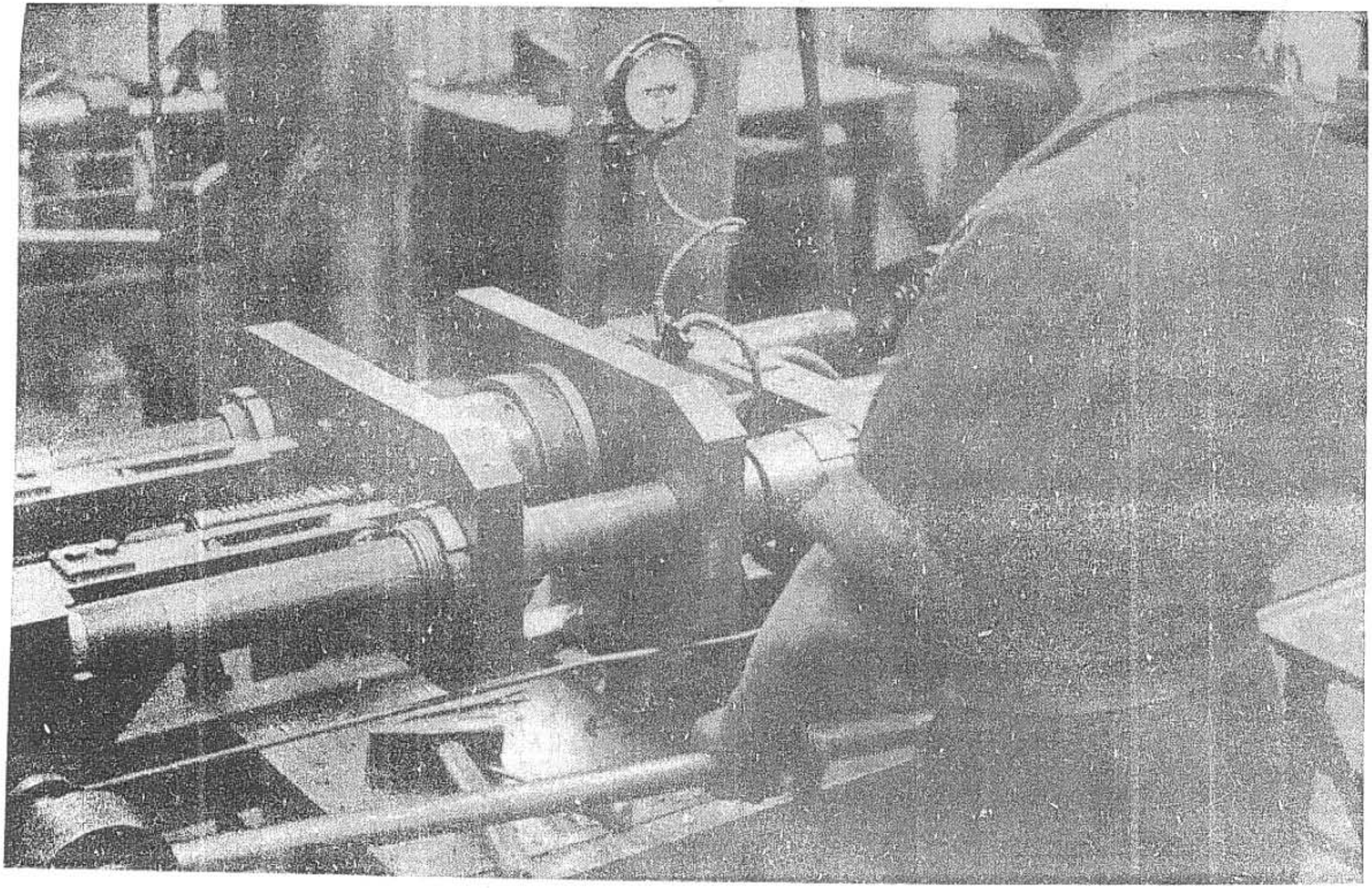
A specially fine powder (Grade H) was sold in limited quantities because it represented the super-fines after sifting Grade E (less than 2 microns) and this was a small proportion of the total production. This was used for U.H.F. radio dust cores and also was useful for making cores of very low permeability and low hysteresis factors.

Other powders were made by blending different proportions of Grade E and Grade C powder to give specially required results of permeability and losses (e.g. Grades I, B and G used by S & E).

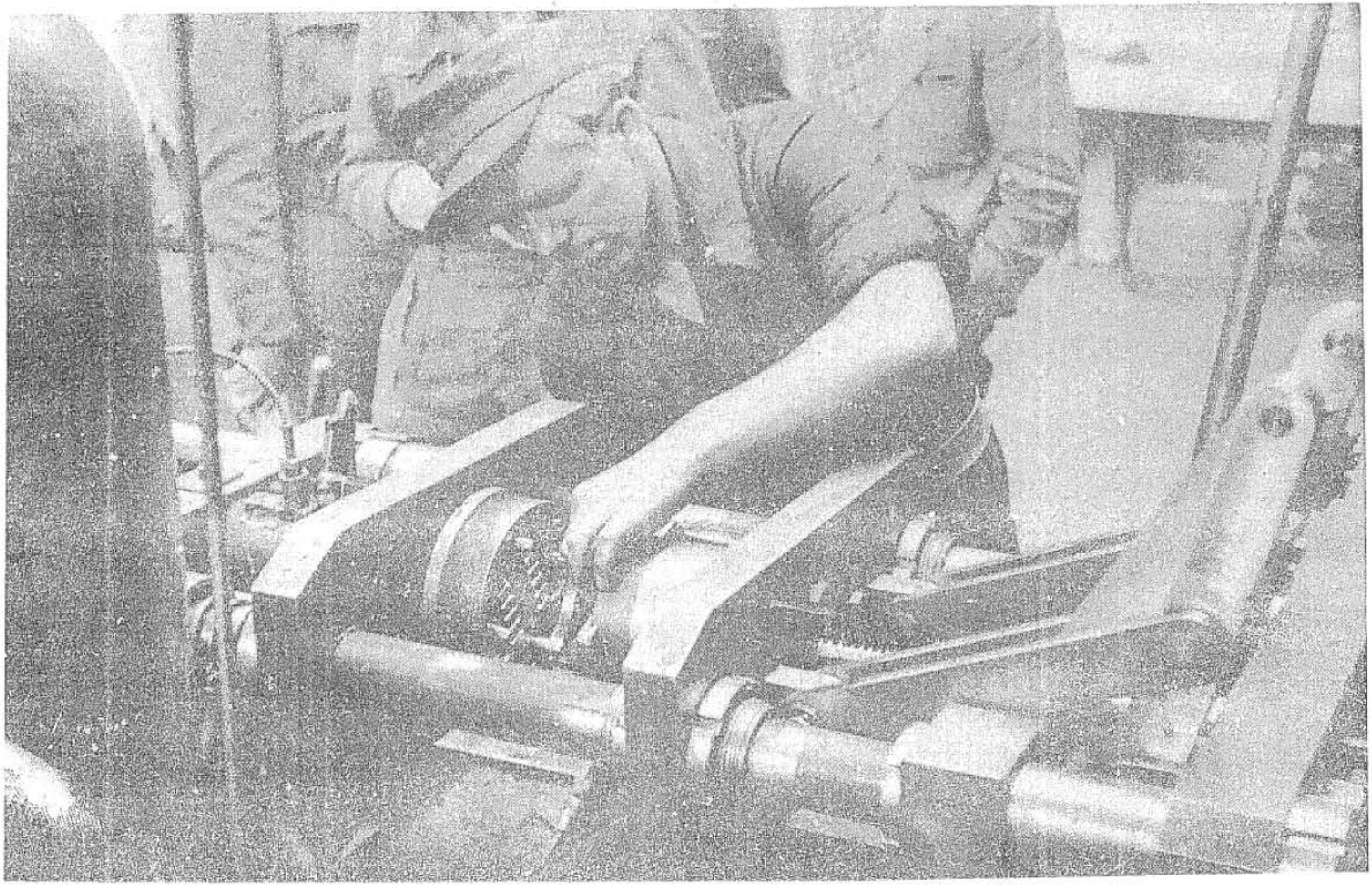
The quality of the various powders is assessed mainly by the electrical results and the pack density of the material which lies between 4.5 and 4.8 gm/cc. Apart from hand sieving of samples very little routine testing appears to be done on particle size and size distribution. The general impression conveyed during the visit was that the carbonyl decomposition process yields the iron powder as a uniform product of required magnetic and electrical properties and that the subsequent processes had comparatively little effect on the product, apart from sub-dividing it into suitable grades for different applications and to overcome small changes in properties between different batches of powder.

7. Manufacture of Iron Carbonyl.

The liquid iron carbonyl is made in another part of the plant from material called "Eisenstein" or alternatively from a pure Swedish reduced iron known as "iron sponge". The equipment is adjacent to and similar to the plant for making nickel carbonyl and this target has been thoroughly investigated by Dr. Colclough of M of S last year (see Metallurgy report CIOS XXIV-12). Dr. Schlecht gave a brief description of it but there was little time to examine it closely and reference should be made to the CIOS report for details.



PRODUCTION OF RADIO SCREW CORES AT MEITINGEN



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