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TELEVISION DEVELOPMENT AND APPLICATION IN GERMANY

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BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

TELEVISION DEVELOPMENT AND APPLICATION IN GERMANY

Reported by

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BRITISH INTELLIGENCE OBJECTIVES SUB-COMMITTEE
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Note:-

The original reports from which the above appendices were taken have been lodged with:-

Board of Trade,
German Division, (Documents Unit),
Lansdowne House,
Berkeley Square, W.1. Telephone. Grosvenor 4060. Ext. 29

All applications for permission to inspect these reports must quo the following reference number:- BIOS/DOCS/1892/1986.

See FD 299/47.
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ENERAL.

This report is based upon information obtained during an investigation of the development and application of Television and associated equipment in Germany. The investigation started at Frankfurt on the 16th February 1946 and terminated at Bad Oeynhausen on the 20th March 1946.

The targets notified in London were supplemented by several others discovered by examination of records and reports in the library at F.I.A.T., Frankfurt, and the complete tour involved visits to Research Establishments of the Deutsch Reichpost (D.R.P.) and/or factories in or near the following towns:-

Nürnberg, New Drossenfeld (Nr. Bayeuth), Stadsteinach (Nr. Kulmbach), Neustadt (Nr. Coburg), Taufkirchen (Nr. Munich), Aach (Nr. Signen), Berlin, Göttingen, Brunswick and Hildesheim.

In some instances the visit did not justify a detailed technical report.

Throughout the tour the personnel interviewed at the various establishments were helpful and co-operative in discussing the technical problems involved in their work and in showing and, where possible, demonstrating such equipment as remained available. In certain instances this attitude was attributed to the fact that some members of the investigating team had been known, prior to hostilities, to the person being interviewed.

During the war research and development of television equipment as such was virtually at a standstill, although the public television service was maintained in operation until well into 1943. As disclosed in the detailed reports which follow, television technique and equipment suitably modified, were applied to war projects and fairly extensive development work was carried on in this field.

It was planned to include further details of some interesting items of equipment which were not available for inspection at the time of the visit. For this purpose copies of specifications and circuit diagrams were to be sent to the U.K., together with certain items of equipment, but these have not been received prior to the completion of this Report.

Te Ka De,
Allersberg Strasse,
Nürnberg.

Date of visit - 21.2.46.

This firm was originally engaged in the manufacture of telephone and television repeaters, public address and soundfilm amplifiers, telephone and power cables (not concentric cables). During the war they had manufactured radio receivers and valves fo Telefunken. Research work was originally carried out in Berlin an was dispersed to Schwarzenbach near Hof in 1941, and all the equip ment relating to television was, at the time of the visit, in transit to Nürnberg.

70 per cent of the factory was stated to have been seriously damaged by air bombardment. Inspection confirmed most extensive damage. No gas supply was available and no work of any kind was i progress, except for the clearance of debris.

The following persons were interviewed at this factory:-

Dr. Max Muschweek	(Director)
Dr. Theodor Baum	(Chief of Development)
Fraulein Riedner	(Secretary - interpreter)

Co-axial Repeater (TF.100).

This equipment was described as a 4-wire multi-channel repeat covering the band 100-700 kc/s for use with co-axial cable having channel band-width of 300-3600 cycles, the channel spacing being 4000 cycles. The repeater stations were to be situated 35 KM apart. Each repeater was designed for 100-channel operation, and was used experimentally in connection with a frequency-modulated centimetre radio link (point-to-point) and 30 equipments had been manufactured. Crystal filters were not used. The signal-to-noise ratio on the repeater was claimed to be 33 db with an outpu voltage of 0.75 volt to a 70 ohm cable.

Television Repeater.

This equipment had been designed to the requirements of D.R.P (Dr. Bannitz and Dr. Hertz). An experimental link consisting of three repeaters spaced 17 Km apart between Berlin and Leipzig was

/used

used to transmit the 441-line television programme (single side-band) on a 70 ohm co-axial cable. It was claimed that the experiments were successful and no special difficulties were experienced. This installation was different from the previous Berlin-Leipzig service which carried telephone-television at 200-line definition on a band-width of 1.3 - 2.5 Mc/s.

The new television repeater was designed for use on the same co-axial cable, the intention being to transmit both the 441-line television signal and the 100-channel carrier simultaneously. However, no evidence was given of this having been accomplished.

The co-axial cable was supplied by Feldten and Guillaume of Cologne Mulheim. A sample of the cable has been asked for.

The following are brief characteristics of the repeater:-

Band-width 1 - 4 Mc/s.
Gain 60 db
Stages 4 pentodes (Siemens E2C, 10 ma/volt)
Input and Output capacities of valves 8.5 - 10 picafarads.
Valve life 4000 hours.
Frequency characteristic rising 5 db. over the band to compensate for line characteristics (effected by negative feed-back over the 4 stages through a compensating network)
Output Transformer coupling to line provided with third winding for voltage feed-back.
Anode resistances were wound on mica.
Each stage - resistance capacity coupled and inductively compensated - resistance value 700 - 800 ohms.

The output transformer had a step-down ratio of 1000/70 ohms, and was of shell-type construction. The laminations were of nickel iron 0.6 mm. thick and were supplied by Heraeus of Frankfort. The outside dimensions of the assembled core was 42 mm. square. The output winding was wound first and consisted of copper strip (1 mm. by 0.1 mm.) with silk insulation. The anode winding was added next and the feed-back winding was placed on the outside.

Secondary Emission Valves.

Dr. Baum mentioned that EE50 valves had been supplied by Philips, but he had no knowledge or experience of any further development in Germany of Secondary emission valves. He was aware that Dr. Weiss had been working with secondary emission multipliers, but

/only

only as part of a photo-electric system. Dr. Baum understood that the thermionic multipliers failed owing to "noise".

Other Manufacturing Activities.

The following types of radio receiving valves were produced at this factory during the war, as a daughter company of Telefunken:-

EF3, EF7, CF3, CF7, AL4, AL7, and AZ1.

Pre-war the firm had also shared in the development of the Ein empfanger (cheap television receiver). Copper-oxide rectifiers fo modulators in carrier telephony were also developed.

As the development equipment and records were at the time of the visit in transit to Nürnberg, F.I.A.T. has been asked to obtain and evacuate the following:-

1. Specification and circuit diagram of television amplifier.

2. A sample of the co-axial cable.

3. A sample output transformer.

4. A sample E2C valve.

Fernseh and Blaupunkt,
Kapurziner Strasse 27,
Taufkichen. (VIIS)
Nr. Munich.

Date of visit - 28.2.46.

The following persons were interviewed:-

Dr. Rolf Möller.
Dr. Behne } Not at present with
Dipl. Ing. F. Rudert } Fernseh.
Dipl. Ing. Mulert.
Dipl. Ing. Dillenburger.

Up tothe early part of 1940 the above group of workers (total strength of personnel 850) were employed by Fernseh in Berlin on Television work. All the television equipments produced were sol to D.R.P. for the Berlin and Paris television stations. In 1940

/the

the entire group was removed to Obertannwald, near Reichenberg, Czecho-Slovakia, and in April 1945 was brought to Taufkirchen. They had been working on "Tonne I" and "Tonne II" and on a radar project known as "Jagdschoss". The work was nominally under the direction of D.R.P. and included cameras, transmitters, and receivers.

Any apparatus which had remained in the Berlin Laboratories had since been removed by the Russians.

Col. French B.A.O.R. 20 W.T.S.F.F. was in contact with Fernseh and had been informed by Dr. Möller that some of the uncompleted war-time developments should be further explored. At present the group (now totalling only 35) were authorised to work on the repair of radio receivers and thermionic valves.

Television Cameras.

Owing to the difficulty of obtaining the quality of mica necessary for storage elements, experiments had been conducted with a substitute material made of quartz and magnesium oxide. The proportion of quartz to magnesia was varied according to the leakage required to give the correct time-constant. A special feature of the production of this material was the use of a supersonic vibrator for "breaking up" the particles. Lack of time precluded a detailed investigation of this process but the following information was obtained. A quartz crystal 30 mm. in diameter and 10 mm. thick was driven at a frequency of 300 Kc/s at a potential of 12 K.V. for a period of several hours.

The signal plate was formed by evaporation of silver direct on to the glass base of the tube and was coated with the insulating material by settlement from a liquid (presumably relying on molecular adhesion for permanence). This also resulted in a simplified tube construction.

Another attempt to replace mica involved the use of finely divided Al_2O_3 (separated in a centrifuge), and deposited on to an aluminium signal plate. These experiments were initiated as an insurance against the possible failure of the mica supply. So far however, films produced by this method were not as good as those on mica owing to irregularities of thickness resulting in a "patchy" effect on a plain field. Incidentally there was a difference of opinion between Dr. Möller and Dr. Behne with regard to future possibilities of the methods described as an improvement upon mica.

/At

At the beginning of the work on the miniature super-iconoscope the definition was inferior to that of the normal full-sized iconoscope, but, at the conclusion of the work the definition was equal and the tubes reproduced adequately a 441-line picture. In order to determine ultimate definition the tube had been operated with 4000 volts on the scanning beam and the resultant smaller spot size gave a definition of about 700 lines with somewhat improved contrast, and no appreciable loss of sensitivity.

The life of the production models of miniature super-iconoscopes was claimed to be 300 to 400 hours under normal conditions, but only 100 to 200 hours in bright sunlight owing to evaporation of caesium.

Tonne.

A system was developed for guided missiles employing a television camera and radio link carried in the missile and reporting back to a television receiver in a parent aircraft. In the initial work, use was made of the German standard 441-line system with 50 frames inter-laced. The system was found to give about 200-line definition owing to the complication of interlacing under the working conditions of the project.

Tonne I therefore used a 220-line sequential scan with 50 frames per second, for simplification of the missile equipment and for economy of band-width.

For use in similar missiles a further system (Tonne II) was developed employing a diagonal scan of 400 lines and 10 frames per second, with further economy of size in the missile equipment. Neither of these systems was considered capable of giving results comparable with those of normal broadcast practice, but they were nevertheless adequate for their military purpose.

The method of synchronisation in Tonne I differs from that employed in broadcast practice by the omission of frame synchronising pulses in the transmitted waveform - See Fig. 1. A block schematic diagram of this system is given in Fig. 2, showing the use of a locked-in sine-wave oscillator.

The advantage claimed for the use of this type of oscillator is greater stability under conditions of severe and rapid fading. Owing to the "fly-wheel" effect of such a system, it is less affected by interference and omission of groups of synchronising pulses. The system requires manual adjustment of the "lines" and

/"frames"

"frames" at the receiving end.

Tonne II, employed two locked-in sinewave oscillators (frequencies 2000 and 2010) for synchronisation of the diagonal scanning. The block schematic diagram is given in Fig. 3.

Simplification of the missile equipment was effected by the omission of the dividing chain and large condensers rendered redundant by the absence of low-frequency scanning circuits. Manual picture adjustment is required as in the case of Tonne I. The system was never put into operational use.

Cameras for Tonne.

The camera tube which was developed for Tonne I was a miniaturised super-iconoscope. Fig. 4 - drawn from memory - shows details, and a report on this tube with drawings giving full constructional details and manufacturing process has been asked for.

During the final months of production 300 tubes per month were being manufactured by semi-skilled labour (women) with a yield of approximately 200 completely satisfactory tubes - i.e. tubes having good definition and contrast, no spots, and non-microphonic. In the initial manufacturing stages the "shrinkage" was 90 per cent.

Mosaics of both caesium on silver and caesium-antimony were used, the latter for bulk production.

Cathode-Ray Tubes for Tonne.

A cathode-ray tube, 16 cms. in diameter and 30 cms. overall length (approximately) was used for Tonne I having a normal sprayed white television screen, the powder being supplied by Auer. This tube operated at 6 K.V., the line-width (50 per cent. intensity curve) was 1/300th of the picture height. Later experimental tubes were operated at 12 K.V. The only special features were those required to reduce vibration effects. The tube had a neck of very small diameter (18 mm. external, 14 mm. internal), and the modulator was sealed in the glass of the neck. The tube was magnetically focussed and deflected, and the line-scan coils were interesting in that they were moulded in polystyrene.

E.H.T. for Receiver Unit (Tonne).

The 6000-volt supply for the cathode-ray tube is derived from the flyback voltage of the line-scanning circuit. Three additional

/windings

windings on the line-scanning transformers are connected to three rectifiers (DH 6/5 - Fernseh), the outputs of which are connected in series. The 6 KV supply is stabilised. The heater power for these rectifiers (100 mW per rectifier) is also supplied from this transformer.

Transmitter and Receiver (Tonne I and II).

The focussing current for the cathode-ray tube in the receiver is stabilised by a series barretter. In the case of the inconoscope, where the requirement is more rigid, a gas discharge tube is employed. For simplification in the missile equipment, Fernseh were experimenting with electrostatic deflection for the iconoscope. A broken sample was inspected. The circuit and description of the diode modulator used for the transmitter are given in Fig. 5.

Projection System.

Dr. Möller was asked about the development situation in German of large aperture optical systems for television projection. No further projects had been initiated after 1939, but equipment which was available at that time was used until 1943, particularly the small projection receiver for entertainment in hospitals. He had had little experience of the Schmidt system, but stated that he had experimented with what was understood to be a mirror of small diameter, with a 5 cm. diameter target, working at f/1.0($\frac{\text{diameter}}{\text{focal length}}$) and came to the conclusion that the definition was satisfactory for 441 lines over a field of from 6 - 10 degrees diameter, but deteriorated rapidly beyond this field.

He had also experimented with a Maksutov or Gabor type of system made by Busch employing a spherical meniscus lens as a correction plate, from which he had obtained much the same performance as from the Schmidt. He had also tested a Busch Mangin mirror with field lens and reported that chromatic aberration was very bad. This mirror was 40 cms. in diameter with a focal length of 60 cms. and aperture f/1.5 to cover a target 3 cms. sq.

The small projection receiver employed a Busch lens in conjunct with a metal base cathode-ray tube, which projected the image via. a plane mirror on to a reflecting screen, as illustrated in Fig. 6. T dimensions of the screen were 40 cms. by 50 cms, the surface being suitably curved and inclined so as to project the light horizontally This screen was of glass bent to the required shape by heating in an anealing oven and allowing to sag on to a carbonised wooden frame. The front surface was ground and the back surface was embossed with

/vertical

vertical cylindrical lenticules and silvered. There were three lenticules per picture element.

This screen gave a polar distribution of light which was approximately rectangular (80 degrees horizontal by 20 degrees vertical), the lenticules producing a divergence of 60 degrees. No further work had been done in connection with cinema projection since the last Berlin Exhibition (1939).

Dr. Möller stated that no perceptable difference in contrast ratio had been measured between the rounded and flat-ended projection tubes. He considered it far more important that consideration should be given to the efficient blacking of the flare of the tube, and stated that a change of from 20 to 10 per cent reflection coefficient in this region gave noticeable improvement in contrast. Riedel de Haen made a collodial graphite which was superior to ordinary Aquadag for this purpose. No work had been carried out on projection cathode-ray tube screens with conducting films, although these had been used in large diameter radar tubes. He mentioned that with powders deposited direct upon the glass no trouble had been experienced with screen charges even at a working voltage of 15 KV.

Higher Definition.

Dr. Möller gave no information on the 729-line system which he was reported to have been developing in 1939, but stated that he had produced a picture of 1029 lines using a transparency with a Farnsworth dissector with specially designed and adjusted deflecting coil. A photograph of the resulting picture was examined and was considered sufficiently interesting to warrant the removal of a specimen negative to enable an enlarged print to be made. The print in question accompanies this report. The definition in this example, was thought by Dr. Möller to be limited by the photographic processes. Dr. Möller also referred to the Telefunken experiments with 2000-line scanning with cathode-ray tubes (See Telefunken C.I.O.S. Report No. XXXII/95). (See also Page 15 of this report.)

One member of this group, Dr. Frenselau, claims to have succeeded in making thin film diaphragms (50 mm. sq. and 0.005 mm. thick) pierced with 1600 holes per sq. mm., the purpose of which was unspecified. (For further details see Page 33 of this report)

Deutsche Reichspost,
Aach,
Nr. Singen.

Date of visit - 4.3.1946.

This laboratory was established at Aach in 1943, having been dispersed from Berlin, and there was originally employed a staff of 70 to 75, only about 30 of whom now remained. Work is now confined to the manufacture of school laboratory apparatus and studio equipment for the radio broadcasting station at Baden-Baden. The organisation is shortly to be moved to Rastatt, and the staff will probably be increased to about 50, depending upon policy in regard to German reconstruction. The laboratory appeared to be fairly well equipped.

During the war the group - under Dr. Weiss - has worked on the following projects:-

1. Television, including wide-band amplifiers, secondary-emission multipliers, and the establishment and maintenance of the hospital service in Berlin.

2. "Naxos", a search receiver for use on submarines to detect enemy radar transmission.

3. Radar, including aerials and feeders, also copies of American 9 c.m. and 3 c.m. magnetrons and klystrons.

4. Testing and trial of "Tonne".

The following persons were interviewed,

Dr. Georg Weiss - Chief of the Laboratory.
Dr. Gossel - Deputy to Dr. Weiss.
Dr. Herman Weber.

Capt. Munsch of the French Marine Nationale was present throughout the discussion.

Berlin Hospital Television Service (Transmitter).

The Berlin transmitter at Witzleben was operated until it was destroyed by bombing in 1943 and supplied a six-hour programme daily - 1½ hours of which was "live" programme - for entertainment of troops in hospital. A total of 25 cameras (including one super-iconoscope) and 3 pairs of film scanners were available, together with 2 vans for outside televising.

/Studio

Studio illumination was normally 1500 to 2000 lux with amaximum of 4000. The super-iconoscope had been found to be five times more sensitive than the normal iconoscope, and on outside broadcasts had been operated on 180 lux with 10 per cent noise level.

Of the film scanners, one pair were Mechau projectors using iconoscopes. Additional constant illumination was used to reduce "tilt" and "bend". This combination gave best results when specially printed light-density films (γ= 1.3 to 1.5) were available. The other film scanners were two of the Ernemann system (presumably the double-prism apparatus previously described in "Fernsehhausmitteilungen" (April 1939) supplied by Fernseh A.G., and two Mechau projectors with cathode-ray tube scanning. The scanning tubes were made by Telefunken with calcium silicate screens, the after-glow being corrected by a three-section electrical filter. The maximum attainable frequency with CRT scanning was 2.4 Mc/s.

The larger O.B. van and the installation at the Deutschlandhaus were provided with synchronising pulse generators, the synchronising signal being carried on separate cables. Tests had been made on O.B. using a system in which the synchronising pulses for camera scanning were picked up by radio from the main transmitter by means of a receiver in the van. A variable delay for the synchronising pulses was included in the van equipment to allow for propogation time. This was effected by means of a sine waveform.

Owing to lack of line facilities the programme was, on occasion, transmitted back to Witzleben via a 76 cm. radio link over distances up to 3 Km. thence by cable on 4.2 Mc/s. carrier using the lower sideband for a further distance of up to 4 Km. to the main transmitter. When these arrangements were in use the modulation was restricted to between 10 and 90 per cent but quality was stated to have been very good. The band-width of all the video apparatus extended to 3 Mc/s, but this was limited for carrier working with vision and sound to a vision band width of 2.2 Mc/s.

In addition to the normal broadcast transmitter, co-axial cables were provided for connection to certain centres. The programme was transmitted on a carrier frequency of 4.2 Mc/s (lower side-band only). This was the standard I.F. for receivers and could be fed direct to their I.F. amplifiers. Repeaters built by Siemens were used where necessary with compensation for cable characteristics. From these centres connection was sometimes provided to other groups of receivers over normal 600 ohm telephone circuits, provision being made for compensation every 1.7 Km. of approximately 30/1 over the band. In one particular case, a large cinema equipped with

/projection

projection apparatus, the signal was supplied by co-axial cable at a carrier frequency of 8.4 Mc/s.

Berlin Hospital Television Service Receivers.

When production of receivers was stopped in 1940, approximately 600 Einheits-empfanger were in service and about 1000 other sets of earlier proprietary designs. Details of the Einheits-empfanger and manufacturing arrangements have been described in "Telegraphen - Fernsprech - Funk und Fernseh Technik" Vol. 28 July 1939. (A full report by Dr. Graupner (Blaupunkt) is given at Appendix B.)

Berlin Hospital Service Projection Apparatus.

In order to provide entertainment for the maximum number of troops several centres in Berlin were fitted with projection equipment. The following information was obtained relative to four types of projectors employed.

1. The largest cinema (in Turmstrasse) with 800 seats was equipped with the Fernseh apparatus first shown at the Funkausstellung in 1938. The special Fernseh directional lenticular screen measuring 5 metres by 4 metres was installed here.

   The projection tube had a water-cooled metal-based screen, approximately 10 cms by 10 cms, with a final anode potential of 80 KV. Dr. Weiss thought the peak beam current was about 20 m.a. The only part of this apparatus now remaining is the E.H.T. rectifier unit which was seen at Aach.

2. A smaller cinema with seating capacity for 300, was provided with a 2.5 by 2 metre screen (probably Telefunken) formed by bending a glass sheet 8 m.m. thick to a spherical surface of about 10 metres radius. The glass was silvered on the back and no treatment other than slight grinding of the front surface seems to have been attempted, but this apparently gave no improvement in results. Approximately 10 to 12 lux was measured incident on the screen and the image as seen by the spectators was stated to be about 1/10th of the brightness of a normal cinema picture. These spectators were accommodated in a particular section of the cinema

/where

where the image was satisfactory.

As the picture was not visible from the projector, remote control was provided for the operator who occupied a position amongst the spectators.

The optical system and general arrangement of the cinema are shown in Fig. 7. The projection lens was an Astro f/0.9 consisting of 4 dioptric elements. The tube image measured 10 cms. by 10 cms. on a flat-ended glass base as in normal practice, and in colour was yellow to yellow-green. The final anode voltage was 60 to 80 K.V. and the peak beam current about 1 m.a. The normal life of the tube was of the order of 400 hours, but extremes were 10 hours in many cases, and as much as 1,000 hours in one case. Ion spot appeared after about 400 hours. The tube neck was 30 mm. in diameter and both scanning and focussing were done magnetically. (See footnote)

The scan generators employed the Farnsworth circuit with four special E.L.12 valves, with top cap anodes, for each direction. It was claimed that no "sticking" was observed in the phosphor at 80 K.V. although no conducting layer was provided. The tubes were developed by Dr. Diels of Telefunken, believed to be at present in Hanover, and the powders were produced by the same firm at Max Strasse, Berlin.

3. The next smaller size of projector was made by Fernseh and employed a directional reflecting screen 1 metre square with a horizontal angle of 50 degrees and vertical angle of 20 degrees. This screen consisted of a flexible sheet of transparent material, 1.5 m.m. thick backed by white linen and embossed on the front surface with horizontal cylindrical lenticules, three per picture line. Small glass "pearls" were embedded in the screen material, several of them in the height of each lenticule. The cost of this screen was estimated by Dr. Weiss to be about 800RM. (£25. sterling) when not in use the screen could be rolled up.

<u>NOTE:-</u> Dr. Weber was most insistent that the best results were obtained with a polished glass surface. In view of this the investigators were at a loss to understand the system.

/The

The projection cathode-ray tube (operating at 20 K.V.) had an optically flat window and the fluorescent powder was carried upon a metal plate (electron optics similar to iconoscope). The target measured 8 cms. by 8 cms. Projection was via a dioptric lens developed by Dr. Zschau of Fernseh. The illumination incident upon the screen was from 4 to 5 lux. The projector had been designed by Drs. Schubert and Schunach.

4. Another small type of projection set was used in Berlin. This employed a ground-glass translucent screen but results were not completely satisfactory, owing to "flare spot". The cathode-ray tube target measured 5 cms by 5 cms, and the tube operated at from 20 to 30 K.V.

<u>1029-line Television System.</u>

Some experimental work was carried out early in the war on a 1029-line system, but was stopped at an early stage, as it had no direct military application of sufficient importance. Dr. Weiss was of the opinion that directly-viewed cathode-ray tubes were, in general, good enough to deal satisfactorily with 1000-line definition but that better focus was required on the associated iconoscopes than that normally obtained. The main problem, however, was the loss in sensitivity of the camera. Because of this, 10,000 lux was required in the studio to produce results similar to those obtained on a 441-line system with only 2,000 lux in the studio, a normal type of iconoscope being in use in both cases. Little work had been done in Germany on orthicon development but the Compagnie des Compteurs in Paris had done some work on these tubes under the direction of D.R.P. Some tests had been made using a direct connection from the iconoscope to the viewing tube and employing an amplifier having a band-width of 20 Mc/s. with Telefunken EL2 tubes. An amplifier with a band-width of 40 Mc/s. has been built (by Dr. Dillenburger of Fernseh) for testing the spot size of iconoscopes. Type AF.100 Telefunken tubes were used in this amplifier and are said to have a slope of about 12 mA. per volt, and to be similar to the E.F.14 tubes. A gain of 1.8 times per stage was obtained using a two-section Wheeler coupling circuit (dead-end filter). The amplifier consisted of 12 stages and gave an overall gain of 60 db.

Dr. Wunderlich of D.R.P. had also made some wide-band amplifiers using LV.1 Telefunken tubes. (No further information was available as Dr. Wunderlich was temporarily absent at Innsburg).

/Note

NOTE:- Further information relative to the 1029-line project is contained in the report on Fernseh at Taufkirchen on Page 9 .

Facsimile Transmission.

Dr. Weiss referred to a project developed by Telefunken for facsimile transmission of telegrams in which the image was scanned and transmitted once only - presumably for reasons of secrecy.

In the preliminary apparatus the image was scanned by 2,000 lines and the complete transmission occurred in 1 second. In the second apparatus, 441 lines were used and the transmission time was 1/25 second.

It was understood that cathode-ray tube scanning was employed in the transmitter and that the receiving record was produced by photographing the receiving cathode-ray tube and using a rapid developing process, which was completed in 7 seconds.

Photo-electric Multiplier Cell (Weiss Type).

This was a caesium-on-silver oxide photo-electric cell having 16 electrodes, and giving 14 stages of secondary multiplication by means of permeable grids on the Weiss principle. The cell was intended for use on a light-operated proximity-fused projectile.

The special feature of this cell was the mechanical construction designed for rapid and accurate production. (See Fig. 8.) The electrodes were welded in the centre of copper discs which were assembled in jigs with soda-glass rings placed between each pair of electrodes. By heating the complete assembly the glass fused to the copper, resulting in a glass-copper seal. The heating was done in a gas-heated oven to within a few degrees of fusion point, and the final operation was performed by high-frequency heating. The percentage of satisfactory seals produced by this method was claimed to be very high.

Caesium vapour was passed into the multiplier from the anode end during the sensitising process and passed forward through the grids. The first grid (i.e. that farthest from the anode) became the photo-sensitive surface. The cell operated at 100V per stage with a total gain of 100,000, the maximum output being 30 mA. It was intended to make multipliers with silver-magnesium alloy grids (3 to 5 per cent magnesium).

Demonstration of Tonne.

According to Dr. Weiss, the 441-line system was never employed for Tonne owing to difficulties of interlaced scanning. The diagonal scanning system never got beyond the laboratory stage at Fernseh and many difficulties were anticipated by Dr. Weiss.

The alignment of the missile equipment with the parent receiver in Tonne I was effected, before the release of the missile, by means of a small circle on the iconoscope mosaic which was centred on the receiver cathode-ray tube by controls which operated, in the case of the line scan, by phase shift of the synchronising signal and in the frame scan by interruption at some point in the divider chain, until the frame attained the correct position.

The operation of a complete Tonne I equipment was demonstrated, the video connection only being employed, but including the Tonne synchronising system.

The subject was a picture of a girl's head, about 9 inches square, at a distance of about 6 ft. from the head of the projectile, (i.e. the front lens of the camera), the illumination being provided by a 500-watt lamp with reflector placed about 8 ft away from the subject. The standard Tonne lens used (f/3.5).

The picture was very steady and phase adjustment appeared to be easy. Contrast on the receiver tube was good, and the focus capable of dealing with at least twice the number of lines used. Definition along the line was estimated to be equivalent to 300-line quality.

It was explained that vertical scanning was preferred since the subject usually consisted of a horizontally divided field, half white and half dark, (i.e. the sky and sea divided by the line of the horizon). By scanning vertically the low-frequency content of the transmitted waveform was kept low with consequent avoidance of large components in the amplifier.

Bildwandler with Multiplier.

Dr. Weiss referred to development work in connection with intensifying the image of the Bildwandler tube by the assembly of a series of permeable-grid electrodes between the photo-electric cathode and the fluorescent screen.

The spacing and voltages between the electrodes influenced the degree of definition obtainable and Dr. Weiss stated that in the

/working

working models only 30-line definition resulted when five stages were used. It was not found possible to improve upon this for higher definition although strong magnetic fields had been applied to reduce the "circle of confusion". The quality was then changed only slightly and the presence of the coil was a disadvantage.

The gauze used had a mesh of 10,000 per square c.m., the diameter of the wire being equal to that of the aperture. Attempts were made to pierce holes in silver foil but this proved too difficult to warrant continuation.

Thermionic Multipliers.

The development of thermionic multipliers was stopped at the beginning of the D.R.P. war programme. The last tubes made had a slope of 100 mA. per volt and were intended for 20 Mc/s amplifiers.

Dr. Weiss had made (and exhibited) a voltage-controlled multiplier with silver-magnesium alloy electrodes from which a secondary gain of 50 per stage at 500 volts was claimed. The life of this multiplier was more than 1,000 hours. The high sensitivity was obtained by heating the electrodes of pure silver-magnesium alloy (3.5 per cent Mg.) in vacuo, and allowing the magnesium to come to the surface without oxidisation. This was described in "Fortschritte der Naturwissenschaften" in 1939, (Much difficulty had been experienced in obtaining a satisfactory "life" and it was essential to outgas the whole tube with extreme thoroughness).

Gas-discharge tubes were used as potential dividers for the multiplying stages with separate gas-discharge tubes to control the bias on the first grid. These multipliers were stable up to an output of 40 m.A. Stabilisation of the control grid by means of a high resistance in the cathode circuit proved satisfactory.

Image Storage Device.

The development had been carried out, under Dr. Krawinkel at Peschagen Laboratory, of an image storage device for use on submarines for recording enemy radar transmissions, so that the information could be observed for some time after reception.

The device was understood to consist of a tube containing two screens and two electron guns. The first screen - the storage screen - consisted of a mica plate having a uniform photo-electric

/film,

film, in which were embedded a large number of small particles of insulating material (e.g. quartz). The second screen was the norma fluorescent viewing screen. The two screens were arranged in a system similar to that of an image converter, with the viewing scree about 1000V positive to the storage screen.

The storage screen was initially scanned by one of the electron beams which was modulated in accordance with the incoming signal. After the requisite number of scans the beam was switched off leavin the insulated particles negatively charged - according to the modulation information. It was stated that this charged image woul remain for as long as 30 minutes.

When it was desired to observe the image the photo-electric surface was irradiated - presumably by uniform infra-red radiation. The photo electrons thus released from the storage screen were then focussed on to the viewing screen and produced a fluorescent image. The charges on the insulated particles produced local suppression of the photo emission in varying degrees according to their retained charges, and therefore controlled the brightness over the picture area.

The second beam of electrons - having a velocity different from those in the modulated beam - was used to neutralise the charges on the insulated particles thus eliminating the original image.

Fig. 9 shows the general arrangement of the image storage device and is based upon the description obtained from Dr. Weiss.

Blaupunkt, Forckenbeck Strasse,
Berlin, Wilmersdorf.

Date of visit - 13.3.1946.

In general, the work carried out by this firm, both before and during the war, was the manufacture of apparatus designed elsewhere, together with the pre-production development work necessary in most cases. In 1939 they were engaged in production of the Einheits - empfanger (the German standard Television Receiver). All work in connection with television was stopped early in 1940, except for manufacture of the camera unit for "Tonne" (referred to elsewhere in this report), which was carried out at a dispersal site at Reichenberg in Czechoslovakia (Nr. Fernseh A.G. at Obertannwald). Ing. Weiland was in charge of this work in association with Dr. Graupner (both of whom were interviewed), but none of their other television engineers had been contacted since the Russian occupation, and they were thought to be working for the Russians. An attempt had been made to evacuate equipment from Reichenberg to Salzwedel in 1945, but the equipment had all been lost in transit. At present the firm has approximately 500 employees, engaged upon the production of a cheap Radio Receiver, Electric Cooker, and Electric Hair Waver. The following persons were interviewed at this factory:-

Dr. Güllner	-	Director.
Dr. Graupner	-	In charge of pre-production.
Ing. Weiland	-	Chief of development.

and the details given below were furnished by them.

Wide-Band Amplifiers for "Korfu".

This firm manufactured parts for "Korfu" during the war. The project appeared of some television interest because of the Wide-Band I.F. Amplifiers, but the only available details of these Amplifiers were as follows:-

Overall band-width	...	10 Mc/s
Mean frequency	...	45 Mc/s
Gain per stage	...	10 db
Valves employed	...	Philips EFF.50

If these figures are accurate, the performance appears to be rather poor.

/Note.

NOTE:- The EFF.50 is a double-pentode push-pull valve equivalent to two EF.50 valves. According to Dr. Zickermann of Telefunken, the yield in the manufacture of these valves was only 15%, the valves being manufactured by Valvo in Hamburg.

Einheits-empfanger.

The following information was furnished relative to the production of these equipments, by Blaupunkt.

(a) The production programme provided for 5,000 sets, but only about 150 sets were actually made.

(b) The advertised price of Rm.650 was not related to actual production costs. Dr. Graupner estimated that each set could not be produced for sale at less than Rm.1000.

(c) The design was not sufficiently stabilised before production began; e.g. the design of the focus and deflection coils changed many times.

(d) Special individual adjustment in the laboratory was necessary to realise the performance claimed.

The general impression gained was that production had been rushed. Dr. Graupner considered that the fundamental design was sound and that a further six months spent upon its development would have enabled production difficulties to be overcome.

NOTE:- A technical description of the Cathode-Ray Tube and other parts of this equipment had been prepared by Dr. Graupner at the request of the Russian authorities. A translation of this report, with copies of original drawings, is included at Appendix B.

Television Aerials.

In reply to enquiries concerning aerials for television recep ion Dr. Güllner said he thought that only a few of the Telefunken 1939 "Flag-pole" type of aerial had been made. (For technical details see "Telegraphen Fernspech-funk und Fernsecktechnich" July 1939 and "Telefunken Hausmitteilungen" July 1939).

The performance of this aerial was said to be superior

/to

to that of other types, particularly in the matter of interference suppression.

Lorenz,
Lorenzweg 1,
Berlin, Tempelhof.

Date of visit - 14.3.46.

Prior to the war this firm had been engaged on the development of several television projection systems employing screens of different sizes. One experimental installation had been set up in a cinema in the Reichskanslerplatz, but was subsequently destroyed by Allied air action.

The firm's premises in Lorenzweg-Tempelhof were also seriously damaged and any television equipment which remained on hand had since been removed by the Russians. Stocks of raw materials were not actually examined but the quantity involved is understood to be quite small. Dr. Walter Schnabel, Engineer, originally in charge of television development, was interviewed, the discussion being confined almost entirely to the topic of projection type apparatus. No work had been done on this subject since the beginning of the war, Dr. Schnabel having been engaged on Radar work during the war period.

Television Projection Screens.

The largest screen described by Dr. Schnabel had an area of 10 sq. metres, and consisted of an assembly of a large number of glass plates, each 5 cms. sq. cemented to a plywood form to produce a concave spherical surface. Each plate was from 5 to 8 m.m. thick and was embossed on the front surface with toridal lenticules, having a major axis of 2 m.m. The back surface was silvered and the construction gave a wide horizontal and narrow vertical distribution of light. It had been proposed to grind and polish the rear surface of each plate before silvering, but the surface finish as the plate came from the mould appeared to give satisfactory results. The plates were additionally secured to their cement backing by four wires which passed through holes moulded in the corners of the plates, and initial adjustment of the position of the plates was done by hand before the cement set, the complete screen being laid horizontally on the ground during this process. The mirror was illuminated (presumably from a point source), and the relative brightness of the individual plates was judged by an observer situated at a suitable distance above the screen. Because of the small size of the

/plates

plates no trouble had been experienced from buckling during their moulding.

Cathode-Ray Projection Tube.

The Cathode-Ray tube employed with the screen just described was of the demountable type, operating at 80 KV. with beam currents of up to 2 mA. A rotatable metal screen, water-cooled, was used, a 10°C rise of temperature of the cooling water being permissible. The body of the Cathode-Ray tube was made of Aluminium.

The primary picture size was 9 cms. by 11 cms, and a total ou put of from 200 to 250 Heffner candles was obtained, the tube life being of the order of 100 hours.

An interesting point which emerged was that, although an ion spot appeared on the tube, it did not cause any trouble because of the high penetrative power of electrons under an 80 KV. accelerati

An X-Ray intensity level of 10^{-5} Roentgens was measured adjac to the tube and screens of lead glass were provided for the protection of the operator. The cathode employed was of the plain Tungsten Hairpin type and was replaceable as a complete unit with the modulator electrode. The signal voltage required for full mo ulation was approximately 200 volts. The tube was operated with the screen grounded. The I.F. signal was fed through high-voltag condensers and the rectifier and video amplifier were at a potenti of 80 KV. to ground.

The projection lens used was the Astro dioptric objective of aperture f/1.4.

Small Screen Projection.

Asecond system was described by Dr. Schnabel, giving a picture 1 metre square, intended for domestic use and employin a straight-through type of Cathode-Ray tube with the fluorescent screen deposited direct on the glass. This, however, had been found to give trouble owing to screen charges and the expedient of depositing a transparent silver film upon the glass before applyin the fluorescent coating had not resulted in much improvement.

Projection was by means of a Busch "spiegeloptik" of aperture f/1 and 30-35 cms in diameter.

This device comprised a special back-silvered mirror together with a dioptric system of several components, one of which was 'wrung' on to the optically flat end of the cathode-ray tube (See Fig. 10).

The back-silvered surface of the mirror was plane, or virtually plane, and the front surface was of aspherical form. The mathematical design of this system had been worked out by Herr Flugge, and the system developed by Dr. Naumann for astronomical work in 1936/7. It had been first adapted for television in 1938.

NOTE:- Dr. Schnabel thought that a full description of the system was likely to be found only in the Patent literature.

A further projection receiver was described, having a built-in viewing screen hinged to form a lid for the receiver and employing a pipe-shaped cathode-ray tube with lens projection via a mirror. The angle between the planes of the tube screen, mirror, and viewing screen were chosen so as to provide optical correction of the keystone distortion produced in the tube.

The Cathode-Ray tube was electrostatically focused and scanned, as it was found that coils necessary for magnetic operation were too large and obstructed the light in transit from the mirror, past the tube, to the screen. As large scanning voltages could not be produced economically, the tube anode voltage was limited to 12 K.V. A maximum beam current of 0.5 mA was used which gave a light output of from 10 to 15 Heffner candles from a primary picture area of 36 sq. cms., with a screen temperature of from 60° to 80°C, and a useful life of from 25 to 30 hours. The tubes were usually rendered useless owing to electron burn, replacement being effected when the loss exceeded 20 per cent. A translucent ground-glass viewing screen was initially provided in this type of receiver. Owing to the disadvantages involved, the use of this system was discontinued, and the pipe-shaped Cathode-Ray tube (operating at 25 KV.), in conjunction with a dioptric lens, was substituted. (See Fig. 11.).

Dr. Schnabel was unable to give details of any of the phosphors used as these were supplied to him under Auer or other trade reference. The glass-work of the tubes was of 'soft' glass, and had been made by Osram Glassworks at Weisswasser. The fluorescent screen was deposited on a copper end-plate.

Rectangular-Ended Tubes.

Before the war Lorenz had had some experience in the production

/of

of the rectangular-ended tube used in the Einheitsempfanger. The principal source of the glasswork for these was the Osram works at Weisswasser, although several other glassworks were able to supply them. Lead glass was used and the main difficulty had been the jointing of the neck of the tube to the rectangular end. It had been found impossible to remove the strain completely at this point, and the percentage of rejected tubes was high, but no actual figure was given. The tubes were accepted after a pressure test giving a differential pressure of only one atmosphere - i.e. the working condition.

Physikalisches Institut,
Bunsen Strasse,
Göttingen.

Date of visit - 18.3. 1946.

The work undertaken at these premises has been - and still is - related entirely to instructional and academic research work carried out in well-equipped laboratories. The premises have not suffered any war damage.

The following persons were interviewed:-

Professor R.W. Pohl,
Dr. F. Stöckmann,
Dipl. Ing. P. Mayer.

and the following information was obtained from them.

Screens for 'Bildwandler' Tubes.

The process of producing uniform and firmly adherent screens of Zinc Oxide on glass for use in the 'Bildwandler' (image) tubes was discussed with Dr. Stöckmann. This has already been described by previous investigators (B.I.O.S. Report XXX1-2) but additional information was obtained. It was stated that the resolution of the screen was 1 micron, the screen thickness being 10-20 microns. Dr. Stöckmann confirmed a statement by von Ardenne that fine resolution could be obtained with large grain size - even with crystals measuring 1 mm. Zinc powder was evaporated and burnt in an oxidising flame and deposited upon a heated glass plate so that a thin film was produced strongly adherent to the glass.

/The

The efficiency of the screen was stated to have been 70% of the best Zinc Sulphide Screen, but no figures were available with regard to the absolute efficiency, the experiments having been conducted quite without regard to any practical requirements for fluorescent powders, this aspect of the matter evidentally being considered to be quite outside the field of the research in question.

<u>NOTE:-</u> The efficiency figure of 70% - quoted above - is not in agreement with the figure reported by the previous investigators which was only 20%.

A second method of producing Zinc oxide films (0.1 micron thick) was described in which a zinc mirror-like surface was formed on a glass plate by evaporation in vacuo and subsequent oxidisation in a combustion tube. The resultant tube showed fluorescence equal to that of the 'burner' screens. The thin screen however, had the disadvantage that electrons with velocities higher than 10 KV. dissipated much of their energy in the glass.

On the practical question of after-glow time for Zinc Oxide films produced by the two methods described above, a figure of 10^{-4} sec. (?10^{-6} sec.) was quoted. Dr. Stockmann had not measured this time-constant himself but quoted this figure as given by Dr. Schlede in Berlin.

The life of the zinc oxide screen was claimed to exceed that of the zinc sulphide screen.

The crystals of zinc oxide contain some free metallic zinc which evaporates during life until eventually there is no fluorescence. Pure zinc oxide has a white body colour; with free zinc present the colour becomes yellowish. The work carried out in the laboratory was concerned with the electrical conductivity of the screen. There were possibilities of changing conductivity by the following means:-

(i) The addition of more metallic Zinc in the Oxide. (Zinc Oxide alone has zero conductivity)

(ii) By irradiation with light, preferably with a wave-length of the order of 4050 - 4350 A.U. Dr. Stöckmann was working to find a relation between photo-conductivity and fluorescence but, so far, without success. He had ascertained, however, that at 3660 A.U. the screen fluorescence was good while at 4050 - 4350 A.U., the fluorescence had deteriorated but the photo-conductivity had increased.

(iii) By electronic bombardment of the film. This has the effect of increasing by some 10,000 times the conductivity of a zinc oxide film which originally was of poor conductivity. The treatment does not affect the fluorescence. If this treatment is carried out in a good vacuum the electrical conductivity remains for a considerable time after bombardment - of the order of minutes. The photo-conductivity is also increased by bombardment.

Asked for an indication of the order of loading for the electronic bombardment Dr. Stöckmann quoted a figure of 10 mA. on 1 sq. cm. at 5 - 7 KV. The improvement in conductivity is proportionate to time up to 10 to 20 seconds, after which a saturation effect sets in. Conductivity of a zinc oxide film 1 micron thick and 1 cm. sq. measured with a potential of 100V applied between opposite sides was 10^{-7} mho at 10^{-5} ampere. Additional to the increase in conductivity produced by electronic bombardment, a further increase may be obtained by illumination but this persists only for a short time after the illumination is removed.

Dr. Stöckmann had no definite ideas as to the possibility of using these effects to provide a new type of photo-electric cell. Research work on the chances of photo conductivity in alkali halides was carried out in the laboratory for some years prior to the war (R.W. Pohl, Proc. Phy. Soc. 1937).

The interview with Dr. Stöckmann was followed by a general discussion on the subject with Professor Pohl, who confirmed that the work of the Institute was purely academic, and had no immediate practical application to television. Pressed on the question of reducing the time-constant of zinc oxide films, he suggested that this might be effected by the introduction of free Oxygen held in minute cavities in the fluorescent crystals, which would tend to accelerate the decay of after-glow.

Professor Pohl also stated that he had found the time-constant of decay of colouration produced in potassium bromide crystals under bombardment ('skiatron'), had been reduced by the inclusion of a small percentage of potassium Hydride which also increased the depth of colouration (Proc: Phy: Soc: 1937).

/Copies

Copies of reprints (in German) of three technical articles were obtained from Professor Pohl. These have been read and are summarised below.

"Über die Ausscheidung von Gasen in Alkalihalogenidkristallen"

"The Separation of Gases in Crystals of Alkali-halides" by E. Mollwo.

The paper describes experiments in which KBr crystals containing a small admixture of KNO_2 are heated in an atmosphere of Br vapour of 60 to 700 lbs./Sq.in. to a temperature of 690°C. As the Br diffuses into the crystals small cubic gas bubbles of NOBr are formed according to the reaction formula

$$2\ KNO_2 + Br_2 = KNO_3 + KBr + NOBr.$$

The size and distribution of these bubbles is studied as a function of the Br-pressure and the duration of the heating process.

Some photographs of light reflections and refractions in the bubbles (called "hollow crystals") are given.

"Nachrichten aus der Physik, Astronomie, Geophysik, Technik"
"Über die Natur der U-Zentren in Alkalihalogenidkristallen"

"The Nature of the U-centres in crystals of the Alkali-halides" by R. Hilsch and R.W. Pohl.

The paper describes experiments which prove that these centres are molecules of Alkali-Hydride. For example a K-Br crystal showing the U-band of absorption is characterised by the fact that some of the Br-ions have been replaced by H-ions.

"Eine neue Lichtabsorption in Alkalihalogenidkristallen"

"A New Absorption Band in Alkali-halide Crystals" by R. Hilsch and R.W. Pohl. (1933)

In addition to the well-known absorption band in the visible range (called the F-band) a new band in the

/far

far UV is described in this paper. Both bands are produced by the entry of electrons into the crystal lattice. They are interconnected, i.e., they can be transformed into each other; the U-band into the F-band by absorption of light of a wavelength near the maximum of the U-band, and the reverse transformation by heat treatment. In the latter case emission of blue violet light takes place.

These phenomena are considered important in connection with the problems of:

Phosphorescence

Latent image in photography

Photoelectric conduction in crystals.

A small sample zinc oxide screen was obtained from Dr. Stöckmann and has been tested by Cinema Television Ltd., (Sydenham) in a demountable cathode-ray tube. It gave very poor fluorescence in comparison with zinc oxide produced normally. There may have been a deterioration owing to the sample having been open to the air for so long after preparation. In any event the results were very feeble and certainly not equal to those indicated in the discussion.

Technische Hochschule,
High-Frequency Department,
Braunschweig.

Date of visit - 18.3.1946.

Person Interviewed. Dr. Lambert.

This target had already been investigated by Cdr. Ratsey and F/Lt. Absom representing C.I.O.S., C.A.F.T.1. The object of the present visit was to discuss in greater detail the experiments on wide-band antennae carried out by Dr. Lambert, since it was felt that the designs might have some television application.

The work was initially undertaken in connection with a directional aerial for F.M.B. (a search receiver for collecting

/information

information on enemy radar) and was later applied to the design of an omnidirectional aerial for a similar purpose on submarines. It was intended to cover the band from 120 to 180 cms. wavelength.

Method of Measurement.

The work was confined to the measurement of aerial impedance over the range of frequency required, since the radiation patterns were not in any case likely to be sensitive to frequency change.

The aerial was connected to an open balanced transmission line and the real and imaginary components of impedance calculated from standing-wave measurements. This procedure was later discarded as insufficiently accurate in favour of a resonance method very similar to that of Essen. (See Journal I.E.E. Part III, June 1944). The aerials were spaced about one quarter wavelength from a reflector plate which also served to shield the measuring apparatus and the observer. To avoid interference from surrounding bodies the whole apparatus was located on the roof of the laboratory building. The balanced to unbalanced connection from the signal generator to transmission line was effected with a quarter-wave sleeve. This required careful adjustment every time the frequency was changed and made the measurements extremely slow and laborious.

Results.

The experiments were conducted over a long period and resulted in a considerable collection of detailed information on the characteristics of wide-band aerials of many types.

It was claimed that appreciable control of bandwidth could be obtained only by use of the voltage-fed type of aerial. The work had therefore been devoted entirely to this type with the object of reducing the feeding point impedance at resonance to the minimum value, and hence increasing the bandwidth to a maximum.

A study had been made of the effect of length-to-diameter ratio on the bandwidth of fat cylindrical antennae consisting of two half-wave elements centre fed. Cylinder diameters up to 8 cm. had been used giving a resistive component at resonance of about 300 to 400 ohms. The cylinders were then replaced by flat sheets (having their major dimensions in the plane of the dipole major axis) of various shapes since the arrangement has some advantage in mechanical construction, particularly in multi-element arrays. Best results

/were

were obtained with circular discs for which a bandwidth of ± 10% was obtained for a 10% change in the real component of impedance. It was then found that an appreciable section of the disc could be cut away with only a small effect on performance. This left a ribbon-shaped aerial of which each half had a length of about three times the width. The resistance at resonance was about 300 ohms.

Dr. Lambert was familiar with the methods of reactance compensation and had tried a section of line shunted across the aerial terminals for this purpose. In general the method was found to give an improvement in response over a limited frequency range but did not admit appreciable extension of the bandwidth.

Some experiments had been directed to the design of a wideband aerial having omnidirectional radiation in the plane of polarisation. The ribbon aerial, however, was found to lose most of its advantages when bent round to form a circle in order to give such a radiation pattern. Thus bending it to forms a "U" increased the resistance to about one thousand ohms and reduced the bandwidth considerably. Further bending to form a circle gave still further increase of resonant resistance and decrease of bandwidth. The arrangement was, however, the best that could be obtained at that time and an aerial of this type had been fitted to submarines.

Later experiments used a form of Alford loop with flat radiators, which consisted of two flat dipoles disposed so that the radiating elements of each formed the opposite sides of a square. Both dipoles were fed at a point corresponding to the ends of one of the diagonals of the square. The best arrangement of this kind gave a 25% change in resistance for ± 10% frequency band, and had a polar diagram in the plane of the square that was very nearly circular (within ± 5%) at resonance and did not depart very appreciably from this over the frequency band. (See Fig. 12.).

Telefunken,
Nicholasbergersweg 55,
Göttingen.

Date of visit - 19.3.46.

These premises are used merely as a Telefunken Office in Göttingen There are no factory premises and no production or practical work is carried out there.

/The

The object of the visit was to interview Dr. Diels who had made cathode-ray tubes at Telefunken prior to the war. Dr. Diels, however, was not available and the following personnel were interviewed instead.

Dr. K. Muller,
Dr. Theile and
Herr W. Hárm.

Projection Systems.

The latest type of projection tube used by Telefunken consisted of a normal flat-faced cathode-ray tube with fluorescent screen on glass operated at a potential of 50 KV., the image being projected by a lens on to a directional screen 2 metres square. The screen was built up of a number of elements, each 10 cms. sq. which were coated with slightly crumpled tin foil, and each element was subsequently adjusted to its correct angular position.

No actual figures were available to indicate performance or efficiency, but Dr. Theile said the results were very good with a 441-line picture. He also stated that, in the opinion of Telefunken, mirror projection systems were not good enough, the reason given being that, in their experience, small projection tubes as used with mirrors could not give the definition of larger tubes with a lens optical system - presumably owing to tube limitations.

Dr. Theile knew of no experiments having been made in the Telefunken Laboratory with high power screen-on-metal tubes or with Diavisor systems, although he knew of the Swiss projection system using the Schlieren effect.

In reply to an enquiry as to the possibilities of recent developments of the zinc oxide screen for cathode-ray tube scanning, it was stated that this had been used on 441-line transmission - as described in Telefunken Hausmitteilungen 1938. The screen had an after-glow time constant of 1 microsecond and required three correction circuits. It was also stated that Prof. Karolus had developed an 800-line system using cathode-ray tube scanning, in which he had modulated the cathode-ray beam so as to produce a carrier frequency for the photo-cell response and thus reduced the effect of after-glow.

/Fernseh

Fernseh and Blaupunkt,
Trilkewerke,
Hildesheim,
Nr. Hanover.

Date of visit - 19.3.1946.

The Trilkewerke factory is situated about a mile from Hildesheim, and had previously been operated by the Bosch Company for the production of motor accessories - magnetos, lamps, etc.

The building had not suffered any damage by air attack.

The group of engineers at the factory are from Fernseh and Blaupunkt, and have been collected by Lt. Col. French (of 20 WTSFF at Bad Oeynhausen), who arranged the visit and accompanied the present investigators.

The object of the visit was to discuss experiments carried out by Fernseh A.G. between 1940 and 1945 on mosaics for iconoscopes, supericonoscopes, and orthicons. It was learned that the group had not been concerned with development of camera tubes for any specific military applications. Work on tubes for "Tonne" projects was carried out at Obertannwald, and is referred to elsewhere in this report (See Page 5).

The following personnel were interviewed at this factory:-

Dr. Goerz.	Dr. Flechsig.
Dr. Frensalau.	Fraulein Simon.

Of particular interest is Dr. Flechsig's work on orthicons, which started in 1944. Fraulein Simon was responsible for a special geometrical mosaic intended to increase the sensitivity of these tubes.

Iconoscope Mosaics.

The method employed by Fernseh in the preparation of mosaics for normal iconoscopes was, in general, similar to British practice, but differed in some details. The processes adopted are as follows:-

(a) A thin continuous film of silver (rather less than 1 micron thick) was evaporated on to a selected mica sheet or plate.

(b) The plate was then heated to approximately 400°C for a few seconds to form the elements of the mosaic. It was stated that neither the temperature nor the time of "baking" were at all critical, the size of the particles being controlled almost entirely by the thickness of the initial deposit. The lower limit of size was determined by the requirement of sufficient material to permit oxidisation of photo-sensitisation in subsequent processes. The upper limit was determined by the failure of the silver to separate into discrete particles which resulted in a "patchy" mosaic. The maximum mean diameter of the particles was 3 to 4 microns.

(c) Oxidisation and subsequent sensitisation with caesium. During this process a potential of 1,000V was applied between a ring electrode in front of the mosaic and the internal graphite coating of the bulb. (Apparently this was intended to ensure a uniform condensation). Caesium was evaporated on to the mosaic in a number of stages, the photo-sensitivity being measured at each stage. This made the process lengthy, owing to the necessity of cooling before each measurement, but it ensured optimum sensitisation of each mosaic.

Normal iconoscope mosaics for 441-line operation measured approximately 100 mm. by 80 mm. with nearly the whole of this area operative. The number of particles per picture point was stated to be about 70. The sensitivity of the mosaic was 30 micro-amps per lumen for the sensitised areas and 10 micro-amps per lumen overall (since only about 30 per cent of the total area was covered by the silver particles).

Supericonoscopes.

The design of supericonoscopes was not discussed in detail, but appeared to be on the lines of normal British practice. It was stated that an electron optical magnification of 5 to 1 in area was usual, and the light loss in transmission through the photo-cathode was given as about 50 per cent.

Orthicon Mosaics.

Work upon orthicons was begun about mid 1944, and some satisfactory tubes were produced by the Spring of 1945. Contact had been maintained with the Compagnie des Competeurs in Paris, and Dr. Flechsig was familiar with the work of Bartholemy.

/In

In preparing mosaics by the usual method of silver aggregation a considerable loss in sensitivity - owing to back illumination - was observed. About 50 per cent loss of light occurred in transmission through the signal plate formed by a thin layer of nickel on the mica plate.

A more serious loss, however, was due to the opacity of the silver elements of the mosaic, since only the sides of each globule were then illuminated by light transmitted through the plate. A difference of 10 to 1 was measured in the photo-sensitivity by front and back illumination.

It was observed during the preparation of the plate that when only a small amount of caesium had been condensed, the sensitivity was greater for back illumination than for direct illumination of the mosaic, but in this condition the sensitivity was in any case low, and therefore not of practical value. Dr. Flechsig thought that this effect might be due to the initial condensation of caesium occurring more readily at points on the edges of the silver globules.

Experiments with this type of orthicon showed the sensitivity to be only about half that of the super-iconoscope in use at the time, with a similar figure for signal-to-noise ratio.

In view of the loss of sensitivity with this type of mosaic, an attempt was made to prepare a plate with transparent photo-sensitive elements and to reduce the insulating space between elements so that a greater proportion of the total area was photo-sensitised.

This was done by fixing a fine-mesh grid of copper to the surface of the mica plate and condensing silver on to the mica through this grid. The grid was then removed, leaving a mosaic consisting of small squares of silver arranged in a geometrical pattern. By avoidance of heat treatment in the formation of the mosaic, the thickness of the silver elements could be controlled so as to render them transparent.

The fine-mesh copper grid was prepared as follows:-

(a) A sheet of glass was silvered on one side to a thickness sufficient to render it opaque.

(b) The silvered surface was covered with horizontal and vertical lines (20 lines per mm.) the width

/of

of each line being about 4 microns. This was done by means of a ruling machine provided with a diamond point, care being taken to ensure that the silver was removed without scratching the surface of the glass. (Ruled plates were supplied to Fernseh by Albert Sass & Co.).

(c) The ruled plate was used as a negative to print direct on to a copper foil approximately 5 microns thick, and covered with photographic emulsion.

(d) The copper foil print was then developed by a process which dissolved the unexposed areas leaving a fine net of emulsion on the surface of the copper foil.

(e) The copper foil was etched with a suitable agent, leaving a grid structure of the required dimensions.

For a mosaic measuring 8 by 10 cms., a grid of 400 squares per square millimeter allows four elements per line in a 441-line system. At least 4 elements per line were considered necessary in the mosaic to obtain the required definition, and Dr. Flechsig thought that this number would avoid any "interference shading" effect which might have occurred owing to lack of accuracy in alignment of the scanning with the elements of the mosaic. No such effects had been observed, and with a mosaic providing 50 elements per picture point (development of which was in hand) it was thought that this effect would be entirely negligible.

Work on the geometrical mosaic was still in the experimental stage, but some plates had been constructed and found to give almost equal photo-sensitivity with either front or back illumination. Further specimens had been sent to Dr. Behne at Obertannwald.

The chief difficulties in manufacture were stated to be as follows:-

(a) Non-uniform varnishing in the photographic process, resulting in a patchy mosaic.

(b) Difficulty in supporting the copper grid on the mica plate during the process of silver deposition. The grid was stretched in a frame and pressed against the face of the mica, but it was found difficult to

/maintain

maintain good contact over the whole surface. Deposition of silver under the wires of the mesh resulted in interconnection of the elements of the mosaic which caused marks to appear in the television picture.

Orthicon Design.

(i) General. The methods of scanning and focussing employed had been similar to American practice. Electron velocities were somewhat greater however at 100 to 150V. Operation in the orthicon regime was generally satisfactory at the higher potential, but was found to be dependent upon the illumination level. Thus, if sufficient primary photo-electrons are emitted, the mosaic becomes sufficiently positive to cause secondary emission when scanned by the electron beam. Dr. Flechsig described the formation of a "patch" where the mosaic lapsed into iconoscope behaviour. It had not been found possible to operate the orthicon satisfactorily at the lower electron velocities of 20 to 30V quoted in American literature owing to the instability of the system in this region. The limit of voltage in the upward direction was about 150V and was determined by secondary emission and the change to iconoscope operation.

(ii) Stripe and Spot. Under conditions of no illumination certain irregularities were observed in the signal derived from the orthicon. Two vertical white stripes close to and symmetrical about the centre of the picture were found to be caused by reflection of electrons from the mica supports of the gun at the back of the tube. The beam electrons from the mica are normally collected by electrodes on either side of the gun assembly. By extending these electrodes to form a screen to cover the mica supports, the defect could be completely removed. This effect had been observed in orthicons made both by Fernseh and Bartholemy. In both cases it had been removed by the means described above.

There remained a mark in the centre of the screen which was thought to be due to reflection of returned

/electrons

electrons falling in the hole in the Wehnelt electrode through which the primary beam current passes. This defect was corrected by placing a small collector, at a suitable potential, in front of the hole. With these precautions, it had been found possible to produce an immaculate field.

(iii) Electron Multiplication. An attempt had been made to increase sensitivity by replacing the collector electrode by a grid structure used as an auxiliary cathode. This was found to give rise to "shading" of the picture owing to variation of sensitivity of the auxiliary cathode across its surface.

An alternative proposal to overcome this trouble is shown in the accompanying diagram (Figure 13). The electron beam is subjected initially to a constant magnetic deflection, and is then made to scan the mosaic in the normal manner. Returning electrons retrace their original path up to the point "B", and are then deflected away from the gun and enter the secondary emission multiplier system. An experimental system on these lines, using a multiplier of the Weiss multigrid type, had been constructed but had not been tried when the work was stopped at the end of hostilities.

Further practical information in regard to the methods of manufacture of these special camera tubes can be obtained only by actual observation during production. This, of course, was impossible as no production is in hand at present.

Some interesting features of the Cathode-Ray Tube for the German Standard Television Receiver (Einheitsempfanger), being a precis of the report Das Bildrohr des E 1, by Dr. Graupner of Blaupunkt-Werke.

1. The tube is an all-magnetic tube of roughly rectangular shape, of about 300 mm. diagonal, 396 mm. overall length, 35 mm. neck diameter, and 800 mm. radius of curvature for the face. (It is stated that the increase in production cost - about 75% - over a circular bulb, is practically made up for by a great reduction in rejects). *

The anode contact is on the neck near the cap. This position of the anode contact limits the possible anode voltage rather severely. Voltages higher than 6 KV. lead to brushing and breakdowns inside the neck.

2. The electrode system is an ordinary triode with the graphite coating acting as anode. A normal pinch is used in preference to a button base, mainly to provide space for the getter.

3. Characteristics of the gun system; cut-off voltage minus 30 to minus 60 volts. Length of base: maximum voltage necessary to produce 100 micro-amps beam current to be 30 volts. Alignment: the deviation of the un-focused beam from the mechanical centre of the tube to be not more than 1 degree.

4. The operating temperature of the cathode seems remarkably high at 950 degrees centigrade. The tubular cathode carrier is 5 mm. long and 2 mm. in diameter. The filament data are 4 volts and 0.8 amp. The diameter of the aperture in the modulator is 0.8.mm.

5. Life. The life of the tube is a minimum of 1,000 hours at 150 micro-amps beam current.

6. Screen. The screen is applied by "settling". It consists of a mixture of two powders, an orange zinc-cadium sulphide, and a blue zinc sulphide, which produces a white with a slight sepia tint. The efficiency of the screen is approximately 5 candles per watt in the light parts of the picture. A contrast of 1:40 to 1:50 is obtainable.

/7

7. Ion spot. This can be avoided by very good vacuum, that is, extreme cleanliness and conscientiousness in the making of the tube, and by choosing specially prepared powders. Large batches of powders are pre-tested for their sensitivity to ion damage.

8. Mounting of the tube. To remove danger to the observer by an occasional implosion, the conical part of the tube is covered throughout with "sticky tape". The screen is held in a frame with a plate of safety glass which also serves as a mask. The neck of the tube protudes about 50 mm. through the back of the cabinet.

* NOTE: From a conversation with Blaupunkt engineers it was understood that a pressure of only 1 atmosphere was applied to the bulbs and that a high percentage collapsed.

REPORT ON THE EINHEITSEMPFANGER FROM DR. GRAUPNER.

THE STANDARD TELEVISION RECEIVER E.1.

The standard television receiver E.1. was developed for reception of transmission using the German television wave-form of 1939. The character of this wave-form is fully shown in Fig.1.

The receiver is a superheterodyne for a carrier frequency of 47.8 Mc/s., with cathode-ray tube and 15 valves of which four are diodes. There are separate vision and sound I.F., amplifiers with a common oscillator. The vision channel uses double-side-band operation and requires a minimum signal of 230 microvolts at the aerial terminals. Fig.3 shows a block schematic of the receiver and Fig. 4 a complete circuit diagram.

The apparatus comprises the following main parts which are described in greater detail below.

(a) Antenna.
(b) R.F. Amplifier and Frequency Changer.
(c) Vision Amplifier. (I.F.)
(d) Video Amplifier.
(e) Synchronisation Separator.
(f) Line-Scan Generator.
(g) Frame-Scan Generator.
(h) Cathode-Ray Tube.
(i) Sound Receiver.
(k) Power Supplies.

(a) Antenna.

Various special types of aerial were developed to give maximum sensitivity and freedom from interference. The aerials designed by Telefunken and Fernseh are both of the resonant type. The former is fully described in "telegraphen-Fernsprech - Funk and Fernseh Technik", Vol. 28, July 1939. Fig. 5 shows the principle of operation of this type of aerial. It consists of a vertical quarter-wave element fed from a concentric line with horizontal quarter-wave elements intended to reduce the waves on the outer of the feeder. These stubs are tuned with inductance and are sufficiently effective to prevent the cable influencing the radiation diagram. The performance is further improved in this respect by the use of a quarter-wave sleeve.

The antenna developed by Fernseh consists of a resonant element and reflector and has no provision for balancing.

(b)

(b) R.F. Amplifier and Mixer.

The aerial plug and socket are designed with an impedance of 130 ohms (the cable impedance) to minimise reflections at this point. The R.F. amplifier and frequency changer are fixed tuned and built in a small unit which plugs in the receiver and can be replaced if operation is desired on some other carrier frequency. The coils in this unit are adjusted by iron cores and no capacitance is added to the circuits other than that of the valves and wiring. The gain to the grid of the mixer valve is 30 times for vision and 15 times for sound.

As already explained the R.F. amplifier and frequency changer are common to both sound and vision.

(c) Vision I.F. Amplifier.

Separation of sound and vision is effected in the anode circuit of the mixer stage. The local oscillator frequency is 39.4 Mc/s. so that the intermediate frequencies are 8.4 Mc/s for vision and 5.6 Mc/s for sound. Fig. 6 shows response curves of the sound and vision amplifiers, both of which use E.F. 14 valves. The flat response for the vision amplifier is obtained with two overcoupled band-pass circuits with peaks at a separation of 4 Mc/s., and one single damped circuit with a drop of 50% at ± 2 Mc/s. The response curve of the vision I.F. amplifier is shown in Fig. 7. An absorption circuit is connected in the second band-pass filter for more efficient rejection of the sound frequency.

As in the R.F. stage the tuning capacities are provided by the valves and wiring and tuning is effected by iron-dust cores. The stage gain varies from 14 times to 20 times and the gain is controlled by variation of the cathode potential of the first valve. A.V.C. is not provided.

(d) Video Amplifier.

The detector is required to have a low value of load on account of shunting capacitance and the high modulation frequency. A diode of low internal impedance, the EZ.11 is therefore used, connected for negative output. There is direct connection to the grid of the video amplifier and direct connection from its anode to the modulator electrode of the cathode-ray tube. D.C. restoration is not therefore necessary.

/(e)

(e) Synchronisation Separation.

The synchronisation separator is fed from the cathode resistor of the video amplifier valve where the synchronising pulses appear in positive sense. Separation occurs in the grid circuit of a high-slope pentode EF.14 which is normally biased to a low value of anode current, and is fully loaded by 3 volts of synchronising pulse. The grid of the synchronisation separator valve is fed through a condenser so that the bias is independent of the mean current in the video amplifier valve and the signals supplied to the saw-tooth generators remain constant under all circumstances.

Separation of line and frame pulses is effected by two transformers connected in series in the anode circuit. The secondary windings serve to invert the pulses since positive input is required to synchronise the saw-tooth generators. The line-pulse transformer differentiates the pulses to separate line synchronising from frame synchronising, and the frame pulse transformer is connected to an integrating circuit in which the frame pulse builds up to greater amplitude than the line pulse. Separation of the frame pulse is then effected in the saw-tooth generator itself by suitable bias on the synchronising grid.

(f) Line-Scan Generator.

The line scan is generated in a transformer-coupled relaxation oscillator using a special valve the ES.111. The deflector coils are fed direct from the oscillator circuit. The first two grids of the ES.111 form part of the oscillator circuit and the third is used for synchronisation. The pulses developed during fly-back are stepped up by a special winding on the oscillator transformer and used to supply 6,000 volts to the cathode-ray tube after rectification in a special diode RFG.5. The heater of the high-voltage rectifier is also supplied from the oscillator transformer. The advantages of this method of E.H.T. generation are:-

(i) Only small condensers are necessary in smoothing since the frequency is high.

(ii) Saving of a special high-voltage transformer.

The chief difficulty is high-voltage insulation of the line-scan transformer. A re-development of this transformer appears to be necessary.

(g) Frame-Scan Generator.

The circuit of the frame-scan generator is similar in principle

/to

to that of the line scan. However, the transformer irons are formed into a U-shaped yoke. The arms of the yoke enclose the neck of the tube and are provided with pole shoes between which is the deflection field (Fig. 10). Special shaping of the pole pieces is necessary to compensate for distortion of the raster consequent on the large deflection angle and the flat face of the tube. An ES.111 is used as oscillator in the frame-scan generator.

(h) The Cathode-Ray Tube.

The picture tube has a wide angle of flare and an almost flat rectangular screen. (Fig. 11). The picture size is 225 x 195 millimeters. Magnetic focussing is used and magnetic deflection in both directions. The tube therefore contains no electrodes other than the cathode, modulating cylinder, and anode. The control electrode is connected directly to the video amplifier. The focus coil is fed with direct current which may be adjusted for minimum spot size. The brightness is controlled by varying the cathode potential with a potentiometer connected to the H.T. supply for the receiver. The tube requires 30 volts at the grid for full modulation from black to white - i.e. 45 volts total voltage including the synchronisation level.

(i) Sound Amplifier.

The sound amplifier consists of two I.F. stages, diode detector, and output valve. (See Fig.4). A total of three single-tuned circuits are included in the I.F. amplifier after the mixer valve. They are tuned by iron-dust cores. The band-width is relatively large (150 Kc/s half band-width) since the local oscillator is fixed tuned.

The first I.F. valve is a variable-mu pentode (EF.11) of which the cathode potential is variable as a volume control. The detector is an EBF.11 and is condensor coupled to the grid of the output valve EL11. The tone control is connected at the grid of this valve, and the matching transformer in its anode circuit feeds a moving-coil speaker.

(k) Power Supplies.

The power unit is divided into two parts in order to allow the vision section of the receiver to be switched off for sound transmission without the accompanying picture. The first rectifier unit supplies the R.F. and frequency changer, the sound amplifier, and the loudspeaker. The second unit supplies the cathode-ray tube and all remaining valves with the exception of the first valve of the vision I.F. amplifier which is fed from the first unit.

/The

The main switch for the whole apparatus is on the sound volume control, and a second switch on the vision gain control enables the vision section to be switched on or off separately.

The receiver has a flat face with horizontally adjacent openings for the picture and loud speaker. The whole apparatus is built on one chassis to facilitate a favourable disposition of the leads between the various parts.

However, the cathode-ray tube, deflection system, and focussing coil form a sub-assembly that may be adjusted and tested out of the set.

The receiver is a table model with sliding door to cover the picture opening when not in use. Four controls on the front allow adjustment of sound volume, focus, brightness, and vision gain. Tone control is adjusted from the back. In the centre of the front panel is a small indicator lamp to show when the set is switched on or off.

Blaupunkt - Werke. G.M.B.H.

Berlin, 29th March, 1946.

Note:- Figures referred to in this appendix are not reproduced and reference must be made to them in the original German report:-

Fernseheinheitsempfänger E.1. Blaupunkt-Werke G.M.B.H.

Development of Infra-red-sensitive Photo-semi-conductors.

Condensed translation extracted from a report prepared by A.E.G, Neustadt (Nr. Coburg) at the request of U.S. Air Technical Intelligence.

Ordinary vacuum photocells are sensitive only up to 1.3 μ. Above this conductive cells must be used and lead sulphide, lead selenide and lead telluride are especially suitable. Coblentz showed long ago that natural lead sulphide was photoconductive, and Reynolds(2) Hauser and Biesalski (3), Smith (4), Beutel and Kutzelnigg (5), and others showed that lead sulphide could be deposited as a mirror on to glass by a wet process. Tiede showed in a Patent (D.R.P.566304,1930) that such layers could be made photo sensitive and shortly afterwards it was shown that photo sensitive layers could be formed by distillation using high-vacuum methods .....

Decided progress was made by A.E.G. in the discovery that pure lead sulphide, whether with excess lead or excess sulphur exhibited practically no photoelectric effect until oxygen was taken up.

The discovery of oxygen-activation and of the amphoteric nature of the normal conductivity of lead sulphide pointed the way to the production of highly-sensitive photo-semi-conductors. As is explained later in more detail, both the stoichiometrical variations and the additional oxygen content led to the formation of "disturbance centres" from which electrons and "defective" electrons could be separated out by thermal and photoelectric selection.

The concentration of "disturbance centres" is very low..... So far no optical difference has been detected between active and inactive PbS layers. Recent researches on the boundry layers occurring at the junction of metal and semi-conductor, which allow deductions to be made as to the concentration within the semi-conductor, show a concentration of about 10^{15} atoms per cubic centimetre.

/The

(2) J. Emerson-Reynolds, J.Chem. Soc. London 45, 162, 1884.
(3) Hauser & Biesalski, Chem.Z. 34, 1079, 1910
(4) H.L. Smith, J.Scient.Instr.4, 115, 1927
(5) Beutel & Kutzelnig., Z.F. elektrochem. 36, 523, 1930.

The content in excess or deficient Sulphur is established directly by the method of manufacture. In contrast to the more recently developed viewpoint there is a general inclination to strive after the attainment of as great as possible a "stoichiometrical sharpness".

The introduction of the oxygen into the lead sulphide (which is inactive per se) can be carried out by two different methods:

(1) subsequent treatment of inactive lead sulphide in an atmosphere of oxygen at temperatures of the order of 500°C.

(2) Direct insertion of the oxygen during the manufacture of the lead sulphide.

With the distillation method the activities with oxygen can be effected in an obvious way, whether it is a question of distilling lead sulphide or its components in an atmosphere containing oxygen, or of simultaneous evaporation of lead oxide and lead sulphide.

The behaviour with the wet process is far more obscure. At present peak results are obtained in individual cases as well as in batches. Since highest sensitivities were required this method of manufacture was adopted. From this work an extensive knowledge has been obtained and the way has been paved to systematic procedure.

Physical Chemical Fundamentals.

The mechanism of reaction in the production of photoelectric PbS by the wet process is hitherto incompletely explained. Generally it proceeds from solutions of plumbites (i.e. solutions of lead compound in excess alkali hydroxides) which are made to react with thiocarbamide. Formulations hitherto suggested, according to which plumbite molecules of the form $Na_2(Pb(OH)_4)$ or $Na(Pb(OH)_3)$ react with thiocarbamide according to the equation.

$$Na\left[Pb(OH)_3\right]^- + SC\begin{matrix} NH_2 \\ NH_2 \end{matrix} \longrightarrow PbS + C\begin{matrix} NH_2 \\ N \end{matrix} + NaOH$$

/are

are far from the truth. Extensive work in the sphere of the solubility of lead hydrates - rendered difficult by the extraordinarily slow movements to equilibrium points - have led, through the researches of Randall and Spencer(3) and Garrett, Valenga and Fontana(4), to the result that the abovementioned molecules are entirely absent from plumbite solutions. According to these workers, alkali plumbite solutions contain the main part of the lead as plumbite ions of the form

$$HPbO_2^-$$

apart from a very small amount of dissolved lead oxide or lead hydrate corresponding to

$$PbO(S) \rightleftarrows PbO(aq).$$

From the experiments it may be deduced that the alkali plumbite is almost entirely dissociated up to a concentration of 1 mol/litre. But, as Fig.1a shows, the rate of separating out increases with increasing alkali content despite constant lead content. (It should be present in all alkali concentrations as plumbite ions). Furthermore, the rate of separation varies with different kinds of alkali. This unexpected behaviour led to exhaustive experiments on the influence of acetate ions, which were introduced into the plumbite solution together with the lead ions in the form of lead acetate. Tests showed that there can be no doubt that

(1) the solubility of lead hydrate in alkalis is considerably increased by the presence of acetate ions.

(2) a certain content in acetate ions is absolutely essential to the formation of a dense lead-sulphide mirror.

The above results seem to show that a basic lead acetate, possibly of the form $CH_3COO(OH)Pb$ can exist well into the alkaline region and is broken down only with increasing alkali content. With

/the

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(3) Randall & Spencer, J.Am. Chem.Soc. 50, 1572, 1928.
(4) Garett, Valenga & Fontana. " " 61, 367, 1939.

the existence of the abovenamed basic molecule an equilibrium could be summed up in the form

$$HPb\,O_2^- + CH_3\,COO^- + H\,O \rightleftharpoons CH_3COO(OH)Pb + 2OH^-$$

However, the existence of a basic acetate is, on the other hand, discounted by Dossmann and Eich of the firm of Kast and Ehinger (in a report dated 28.2.45, Page 14.).

Actually the complicated reaction mechanism of Fig 1a cannot be completely explained with reference to the results just mentioned. The fact that the curves for the different alkali hydroxides do not cross - although according to Randell and Garrett, and collaborators, with high concentrations only the plumbite ion $HPbO_2^-$ should be present - is very difficult to explain without assuming specific alkali combinations.

The date at which the PbS separates out at a given temperature is by no means determined solely by the chemical conditions of the reaction partner. Of primary importance are the following:

1. Chemical Impurities.

Fig.1b shows the effect of impurities in the lithium hydroxide. The effectivness of these foreign bodies is especially marked at the first moment of separation as the nuclei are being formed......thus cupric ions can lead to complete suppression of homogeneous nuclei formation (See Fig.1d.).

2. The condition of growth of the deposited layer.

It is of outstanding importance to the further growth of the layer and to the size and type of crystallite (and hence to the entire electrical and photo-electrical behaviour of the completed layer) whether the initially deposited layer consists of quite fresh nuclei or of nuclei which have been growing for a short time. In other words whether the foundation of the layer came into contact with the reaction solution at the moment at which the reaction began or a few seconds afterwards. In this connection researches show that the precipitated layer does not grow solely by taking up molecularly dispersed PbS from the solution, but essentially by capturing already-formed PbS nuclei.

3. Acceleration forces in the solution.

The initially formed PbS nuclei have a strong tendency to form

/larger

larger secondary particles by coagulation...... The smaller particles which may be moving under gravitational or centrifugal forces drag along with them crystallite which happens to lie in their paths, thus forming larger particles. These orthokinetic coagulation phenomena are closely related to the dependence of the layer on the depth of immersion of the foundation in the solution, the velocity of agitation, etc. with constant temperature and composition.

With chemical conditions maintained constant, the reaction rate depends on the temperature and is shown in Fig.1c., the relationship being in agreement with the theory of Arrhenius......

While the chemistry of the fundamental reaction of the formation of lead sulphide in alkaline plumbite solutions is fraught with a series of doubtful points, this is even more true of the stoichiometric variations and of the insertion of oxygen already mentioned at the outset, owing to the inaccessibility, from the point of view of chemical analysis, of the small quantities which come into question.

As a result of researches the following points can be established:-

1. Stoichometric variations occur with the wet process exclusively on the side of excess sulphur. It is believed that the presence of excess sulphur is a necessary condition for the insertion of photoelectrically effective oxygen. Of course, the excess sulphur must be obtained by breakdown of the thiocarbamide molecule. The consequent energy expenditure can, if necessary, be drawn from the gain in energy when the sulphur is inserted into the PbS lattice ...$S \rightarrow S_{(PbS)}$

2. Hitherto colloidal lead hydrate has been primarily held responsible for the insertion of oxygen-bearing "disturbance centres". This idea led to the conception that very good results could doubtless be obtained with solutions having a high content in lead hydroxide suspensions and colloids. Researches show, however, that it is above all a question of a certain content in molecularly dispersed lead oxide. From considerations of equilibrium, plumbite solutions must always contain molecular PbO. In the presence of a lead hydrate base the content assumes, on thermodynamical grounds, a fixed value dependent only upon the temperature.

$$PbO.x\,H_2O\ (S) \rightleftarrows Pb\ (aq).$$

/Values

Values of concentration of dissolved PbO at 25°C have been shown to very between 0.4×10^{-4} and 1×10^{-4} Mol./1000g. H_2O.

It would appear that this dissolved lead oxide is directly built in to the growing PbS lattice in place of a PbS molecule. To this process would correspond an equation of the form

$$PbO\ (aq.) \rightleftarrows PbO_{(PbS)}$$

The PbO content of the plumbite solution is quite sufficient, with complete assimilation into the PbS lattice with the concentration used, to attain a content of at least 10^{18} molecules/cubic cm. in "disturbance Centres". Since this amount is several orders of magnitude greater than the required value, there should be sufficient energy available.

To what extent the PbO molecules used can be delivered from the plumbite ions according to the equation

$$HPbO_2^- \rightleftarrows PbO\ (aq.) + OH^-$$

depends on the rate at which lead sulphide can be formed. According to so-far unfinished experiments......this delivery......takes place relatively slowly even at high temperatures so that under certain circumstances exhaustion in the reaction zone can occur.

The reaction Zone - (i.e., that zone of the reactive mixture which lies immediately adjacent to the layer carrier and from which is drawn the material deposited on the foundation of the layer) has, according to theoretical and experimental investigations, a thickness of up to a few tenths of a millimetre under conditions obtaining in practice. The quantity precipitated in forming a single mirror is about 1 mg./square cm. The influence of the rate of agitation on both the quantity and on the electrical and photoelectric properties of the layer is to be attributed primarily to avoidance of exhaustion phenomena as well as, within certain limits, to the condition of coagulation.

(Review of the Physics of PbS photo-resistances.)

1. Photo-electrically active absorption.

The photo-electrically active absorption takes place in the Ground lattice of the PbS, since

/(a)

(a) the absorption constants for wavelengths below 1.5 μ assume a value with PbS so high that it can only be explained if all the components of the lattice participate.

(b) determination of the photo-electric yeild, using rigid methods of measurement, shows that this yield increases proportionally with the wavelength over a wide range, corresponding to a constant quantum yield.

2. Nature of the "disturbance centres"

As already mentioned, in PbS photo-resistances the sulphur content exceeds the stoichiometric value, and there is also an extra amount of oxygen. These added amounts are so small that the fundamental lattice structure of the lead sulphide is unaffected by them. Hence one finds

(a) Optically no difference between active and inactive PbS layers

(b) The X-ray structure is that of normal lead sulphide with certain small differences in the grid constants.

Excess sulphur cannot be introduced between the lattice on geometrical grounds. The apparent excess of sulphur is rather due to a deficiency in lead brought about by the formation of gaps in the lead. Since for the formation of a lead gap, two electrons as well as a Pb^{2+} ion must be removed from the ground lattice for electron- neutralising reasons, the question of from which of the ions adjoining the gap these electrons are drawn has no significance. As an amphoteric semi-conductor PbS should behave in the region of excess anion as an oxidation semi-conductor and accordingly, obeying the rule discussed by Schottky (1), should yield the required electrons from the lead kations with the formation of higher stages of oxidation like Pb^{3+} or Pb^{4+}, to which behaviour lead is eminently suited. Considerations of energy show, however, that the electrons can be taken much more

easily

(1) Schottky, Vorberichte Bunsentagung 28/29.10.38

easily from two adjacent S^{2-} ions with the formation of unit charge S^{-} ions symmetrically to the lead gap. Symbolically, the "disturbance centre" corresponds to the form

$$S^{-}\ \boxed{Pb^{2+}}\ S^{-}$$
$$Pb^{2+}$$

(electron-neutral lead-gap point in the PbS lattice)

Fig. 2b shows a three-dimensional representation.

The "disturbance centres" act as points to which the electrons adhere, by the assimilation by the S^{-} ions of the electrons separated thermally from the completely occupied conductivity link. The remaining electron gaps wander about as positively charged "defect" electrons.

2. Additional oxygen can be introduced

(a) By insertion into the inter-lattice, as the small diameter of the oxygen atom would permit.....

As far as can be ascertained at present, oxygen atoms built into the inter-lattice exhibit neither electrical nor photo-electric effect ...

(b) by substitution of a S^{2-} ion at a normal point of the lattice by an O^{2-} ion.

As already mentioned this occurs in practice as the substitution of a PbS molecule by a PbO molecule in the lattice.

No significant electrical photo-electric action can be attributed to the "disturbance centre"

$$Pb - S - Pb - O - Pb - S$$

on the grounds of the energy condition in the electron niveau (level) in lead sulphide with excess sulphur.

(c) By substitution of univalently charged S^{-} ions beside Pb^{2+} gaps by O^{-} ions with the formation of the "disturbance centres":

$$O^{-}\ \boxed{Pb^{2+}}\ S^{-} \qquad \text{and} \qquad O^{-}\ \boxed{Pb^{2+}}\ O^{-}$$
$$Pb2^{+} \qquad\qquad\qquad Pb^{2+}$$

/(electron

(electron-neutral lead-gap points with added oxygen in the PbS lattice)

A three-dimensional representation is shown in Fig.2c.

"Disturbance centres" of this kind act primarily as points of adhesion similar to the earlier mentioned gaps charged only with sulphur. However, the higher level of the associated electron niveau band considerably reduces the probability of transfer for electrons out of the fully occupied band. With this there is excellent agreement in the experimentally determined reduction in conductivity in lead sulphide charged with oxygen.

(d) by substitution of divalent S^{2-} ions at gaps already electron-neutral by O^{2-} ions with the formation of centres of the type

$$\begin{array}{ccc} S^{-} & \boxed{Pb^{2+}} & S^{-} \\ Pb^{2+} & O^{2-} & Pb^{2+} \end{array} \quad \text{or} \quad \begin{array}{ccc} C^{-} & \boxed{Pb^{2+}} & O^{-} \\ Pb^{2+} & O^{2-} & Pb^{2+} \end{array}$$

(electron-neutral lead-gap points with added oxygen)

such "disturbance centres" display their effectiveness primarily with the photo-electric effect, yielding electrons from the doubly charged oxygen ions, so as to occupy quickly gaps left by electron liberation owing to photoelectric effect in the occupied link of the lattice. It is only by such a process that premature recombination of the photo-electrons is avoided and a useful "life" attained.

3. Reactions of the "disturbance centres" and changes in the annealing process.

The temporary process consists in raising to 125°C in order to change the structure of the "disturbance points" in the lattice and to transfer into the most stable form from the energy point of view.

It is believed that the problem underlying an effective annealing process consists in bringing the oxygen distributed throughout the grid into the lead-gaps. These lead-gaps, it will be remembered, exist only when excess sulphur is present. If the annealing temperature is raised above 125°C, the electrical conductivity falls and the photo-electric conductivity disappears.

/4.

4. Inertia phenomena.

The photo current obtainable with a given number of light quanta is directly proportional to the "life" of the photo-electrically liberated electron. On the other hand, of course, the longer the life of the electron the greater the inertia effect...Hence high sensitivity can only be obtained with relatively large inertia and in this connection the frequency of modulation of the light must be borne in mind.

Apart from the chemical coupling up ("disturbance centres") the rate of recombination depends on the temperature...

It is the present practice to cool the cells for highest sensitivity especially with solid carbon dioxide. The "life" is raised from a few milliseconds to some hundredths of a second. The sensitivity is increased some twenty times, since the dark current is reduced; but this is at the cost of greatly increased inertia.

Noise phenomena.

The noise produced is dependent not only on the usual parameters, but also on the construction and properties of the semi-conductor itself. (Fundamental questions are treated by Kaspar in "Problems der Fotohalbleiter-Entwicklung, Forschungsarbeiten uber ultrarote Strahlungsempfänger" OKH WaF 1942). The observed noise is made up of the statistical sum of the following causes:

(a) Nyquist noise (See Physical Review 32, 110, 1928)...

(b) Semi-conductor noise

This was discovered by Kaspar (see above report)... It arises from the fact that the number of free electrons responsible for the current regarded per se undergoes a continual change between the free and bound conditions.

It can be shown that as long as nothing changes in the homogeneous electrical structure of the semi-conductor, and ignoring a possible dependence of frequency distribution on the temperature, the noise current is given by

$$i_r = i \sqrt{F} \int \alpha(\nu, T)\, d\nu$$

where i is the direct current flowing and F is the surface area.

/(c)

(c) Electrode Noise.

Variations in electron density of the kind described above, must of course, be especially marked in regions of small electron density. Such regions occur at the transition points from semi-conductor to metal and therefore at the electrodes. See Schottky, Schweizer-archiv fur angew. Wiss. Techn. 7,20,82.(1941). In certain circumstances the noise thus produced can far outweigh the semi-conductor noise..... There is a characteristic dependence of this noise on the material of which the electrodes are made.

Chemical reaction between metal and semi-conductor is greatly to be feared in practice as the generally small conductivity of the reaction products leads to very strong (semi-conductor) noise.

(d) Grain Noise.

The phenomena discussed in (c) above can occur in similar form at the boundaries of granularities in the crystallite of polycrystalline semi-conductors. The grain boundaries have not, in general, the same construction as the inside of the crystallite... Again the amount of noise produced by these boundary layers depends on whether there is a considerable deficiency in (defect-) electrons. As Davidor(1) has shown theoretically, the transfer resistance between crystallites increases with increasing current strength. The flooding of electrons over the boundary surfaces and surfaces of contact which thus results must therefore compensate to a certain extent for the noise which would increase with the strength of the current, had the structure remained the same throughout.....

Characteristic of this type of noise is its independence of electrode material and its less-than-proportional increase with a direct current, since, with the stronger current, a flooding of the transfer regions sets in.

(e) Breakthrough noise.

If a certain value of current through the semi-conductor is exceeded, pockets of charge occur at the transfer surfaces which cannot be dissipated in the normal way. The consequent breakdown phenomena lead to an extraordinary rise in the noise effects, which result in irreversible changes.

/Electro-

---

(1) Davidor. J.exp.theor. Physics (Moscow) 10,1342 (1941)

Electro-technical treatment of Photo-Resistances.

In modern apparatus photo resistances are used only with intermittent radiation. The frequency of "chopping" is chosen so that inconstancies of apparatus and cells are too slow to be of importance. (See Figs.3 and 3a.)

The Select Committee of the Commission on Fuses set up two specifications of sensitivity:

(a) an absolute: ... i.e. the attainable effective value of the voltage/watts of incident radiation with simultaneous peak sensitivity and with working resistance load matched to the source.

(b) a relative: ... i.e. that radiation power which produces a signal voltage equal to noise in a load resistance in the frequency range to be used.

The radiation to be modulated (300 cycles/sec) black body radiation at 300°C...

The most important measurement of sensitivity is (b) above, and (a) proved, in practice, of little use.

Note:-

The figures referred to in this Appendix are not reproduced and reference must be made to them in the original German report:-

Laboratory Work at A.E.G. Neustadt, Nr.Coberg.

Technological Questions on Cell Production.

Project "Uhr"

Condensed translation extracted from a report prepared by A.E.G., Neustadt (Nr. Coburg) at the request of U.S. Air Technical Intelligence.

The State Research Ministry gave the A.E.G. Company the order for development of the project "Uhr", which was intended to provide self-homing devices (explosive boats, rockets, etc.) with infra-red photo-cells. Above all, the foundations were to be laid for mass production after the existing select committees had established that the Elac Company had not the necessary technological facilities for it. The difficulties under which Elac was labouring lay primarily in the fact that its preliminary research work, as well as its vacuum technique development in the very important chemical and glass blowing spheres, could not be carried out by themselves but had to be left to firms like Kast and Ehlinger, Stuttgart; Hanff and buest, Berlin; and Schott, Jena. Thus they could never get beyond the stage of requiring skilled craftsmen. Therefore, in agreement with the Ministry of Supply, the A.E.G. was requested to take on the commitment in the "A" factory at Konstanz by the Commissions on "Fuses, Remote Firing and Munitions Ancilliaries", since this company had available the necessary scientific and technological experience. The problem facing the "A" factory was to carry out independently the scientific and technological development on the infra-red photo-semi-conductors and to prepare for a cell production of several thousands per month. Despite the great difficulties caused by the war the factory was successfully provided with all necessary equipment and it was found possible to push so far ahead with the difficult problems of mass production, employing untrained personnel, that the Commission on Fuses was able to confirm the complete success of the production in bulk.

Apart from the building of the apparatus a series of requirements were raised in the construction of the tubes. These were as follows:-

(a) As large a maximum as possible for black body radiation in the temperature range 80°C - 300°C, so as to attain as great as possible a range for the devices.

(b) Termination of the tube in a thin plane window in order to bring the wide aperture optical system near to the

/sensitive

sensitive surface with low absorption of the radiation,

(c) A distance between window and layer as far as possible not exceeding 2 mm., thus fulfilling condition (b),

(d) A cooling period of about 2 hours corresponding to the time of deposition,

(e) As few external fittings as possible in order to minimise space requirements in rockets,

(f) A sensitive surface of about 1 square cm., in order to attain as high a maximum sensitivity as possible with large aperture angle and optical image.

(g) Suppression of microphony.

The above requirements were simultaneously satisfied only with difficulty. However, by working out special methods of manufacture it was found possible to carry out production of the tubes by extensive installation of small machinery. The required large-scale manufacture was facilitated by development of special techniques. The overall methods of production were so simplified that the initial heavy demands on technical skill were later unnecessary, the work for the greater part being carried out by assistants.

The result of this development work is an infra-red photo cell of which the construction is shown in section in Fig. 4. The tube satisfies the requirements enumerated above, for black body radiation of 300°C, and a modulation of 300 cycles/sec. it has a peak value of o.15 microwatt.

The requirement of placing the lens close to the sensitive surface is met by using a plane window of Duran glass o.5 mm. thick, with 1.5 mm separation from the photo-sensitive surface. The losses by reflection and absorption are kept below about 15% (with a 300°C radiation). The design of the inner tube allows of a cooling of the layer for a period of time of about two hours with solid carbon dioxide. In order to eliminate microphonic effects the wires leading to the electrodes are covered with glass throughout their whole length so that any period of oscillation would lie well above the frequency range being used. By virtue of the small length and width

/of

of the tongue-shaped platinum electrodes microphonic effects, caused by variation in the dielectric constants owing to mechanical agitation of the cooling medium, likewise remain small. If necessary the inner-part of the tube can be coated with a metallic layer up to a certain height for screening purposes.

The stringent demands made on the glass by thermal loading (removal by annealing of the strains existing in the glass after the fusion process is impossible owing to the occurrence of irreversible alterations of the layer at temperatures exceeding 60°C.) were met by using Duranglass made by Schott of Jena. This glass has a thermal coefficient of expansion of only 33.10^{-7} with a low absorptive power for infra-red radiation.

Summarised translation of extracts from a
Report prepared by A.E.G. Neustadt,
(Nr. Coburg).

The report was prepared at the request of the U.S. Air Technical Intelligence, and it contains information on the developments by A.E.G. in the sphere of infra-red cells as well as on the application of electro-optical methods to target-seeking devices and proximity fuses. Relevant scientific questions are discussed to some extent. The report falls within the project "Lusty", under which the greatest part of the apparatus developed in Neustadt has been requisitioned by the U.S. 29th Air Disarmament Squadron, Schweinfurt.

Development of Infra-Red-Sensitive Photo-semiconductors.

This section opens with a discussion on the feasibility of using detectors of the infra-red radiation from combustion motors, rockets etc., for their location for military purposes. Two types of detectors are possible - vacuum photo-cells or photo-conductive cells, of which the former are not as suitable as the latter owing to their higher work functions. For use in the latter type, lead sulphide, lead selenide, and lead telluride are particularly suitable.

Various methods of synthesising lead sulphide are next mentioned and it is pointed out that they were based largely on empirical considerations until the beginning of 1940, when A.E.G. discovered the importance of the presence of activating oxygen. At the same time the photo-conductive effect was clarified as a result of measurements on electrical conductivity, Hall effect, and thermo-potentials.

Two methods of introducing the necessary activating oxygen are described. The physical chemistry of the formation of photo-sensitive lead sulphide by the wet process is treated and theories hitherto current on its molecular form are discounted and two discoveries are mentioned relating to the manufacture of thick lead-sulphide mirrors.

The general basic reaction of the formation of lead sulphide in alkaline solutions of plumbites is considered with reference to the effect of even small traces of impurities and to the dependence of the photo-sensitivity on the history of the primary layer on which the remainder is deposited.

/Review

Review of the Physics of the PbS Photo-Resistances.

Fallacious conclusions hitherto held concerning the maxima and minima occurring in the PbS output distribution curves are exposed and the reason for them explained. The small traces of excess sulphur and oxygen which are known to exist in photo-sensitive lead sulphide are described with reference to crystal lattice models which, it is suggested, represent the structure of the photo-conductive material. Practical and theoretical considerations relating to the process of annealing are mentioned. The result of cooling the photo-conductive medium with solid carbon dioxide is to enhance the sensitivity greatly with, however, corresponding increase in the inertia effects.

The electrical noise produced by the semi-conducting layers is shown to consist of five kinds, each of which is discussed, namely Nyquist noise, semi-conductor noise, electrode noise, noise produced at boundaries of grains of crystal, and break-through noise.

Standards of sensitivity which were laid down in specifications for workers in the field are also discussed.

Technological Questions on Cell Production.

Project "Uhr"

The preamble deals with the A.E.G. commitment of mass producing, under wartime difficulties, several thousand infra-red cells per month, employing untrained personnel for the purpose. The requirements included the following:-

(a) Attainment of as large as possible a maximum sensitivity for black-body radiation in the 80 - 300°C. region,

(b) Termination of the tube in a thin plane window so as to be able to bring the large aperture optical system as near as possible to the sensitive surface,

(c) Keeping dimensions small,

(d) An area of sensitive surface of about 1 sq.cm. and

(e) Suppression of microphony.

The many difficulties were eventually overcome and a construction evolved which is represented in Fig.4.

Project "Linse"

This infra-red self-homing device was intended for automatically

/steering

steering explosive boats into ships. Its main feature is illustrated in Fig.5. of the original report.

Infra-red radiation from the target passes through chopper disc on to the sensitive surface of an infra-red cell. Since the disc is fitted with a different number of occulting segments on the two annuli shown, two signals of different frequencies will be produced at the output of an amplifier connected to the cell. Any unbalance in the signals is discriminated by the circuit of Fig.6, the output from which is used to correct the helm of the explosive boat via relay.

Detailed data relating to component parts of the equipment is given.

Ranges of 2000 metres were successfully covered on trials. Various possible improvements are suggested.

Project "Krebs"

This infra-red self-homing device was intended for the automatic steering of rockets launched from carrier aircraft against enemy aeroplanes.

In principle it corresponds closely to "Linse". In order to permit of automatic steering in azimuth and elevation two chopper discs are used arranged in such a manner that in the image field the chopping elements intersect at right angles and thus signals of four different frequencies are used. Ranges obtained varied greatly with orientation of the target aircraft owing to occulting of its exhaust pipe, etc. by the fuselage or wings at certain angles of approach.

Only one model of this equipment became available and this was removed by an American Commission of Investigation.

Project "Emden"

An improved arrangement in which the correction signals are linearly proportional to the displacement of the target off centre up to ± 10°, and which has a field of self-homing of ± 25° is shown in essentials in Fig. 9. The specially shaped occulting diaphragm is rotated in the image field and the length of time for which the target is exposed is proportional to the displacement from the centre, while its angular position is disclosed by the phase of the signal with respect to an alternating voltage produced by a generator coupled to the axle driving the shutter. This apparatus was called "Emden".

Another form of scanning device is shown in Fig. 10, in which a "cross" diaphragm moves in such a way that the centre of the cross

/circles

circles round the edge of the image field. As the arms of the cross move over the image field impulses are produced of which the displacement in time with respect to the horizontal and vertical limiting positions of the disphragm give the horizontal and vertical displacement of the target from the optical axis.

Project "Netzhaut".

A self-homing device developed for building into the A.A. rocket "Wasserfall". The main requirements were a range of at least 3000 metres and a field of ± 3°. A concave mirror system of f/1.8 and focal length 45 cm. was used at first but was superseded by an optical system of less weight.

No tests were carried out with this device.

General fundamental considerations applying to the design of infra-red self-homing devices.

This section of the Report discusses the advantages and disadvantages of infra-red detectors compared with radar. Thus, although the former suffers from certain weather conditions, it presents the great advantage of secrecy in operation and gives no warning to the target.

Various criteria for an efficient infra-red equipment are enunciated. The question of the variation of the sensitivity as a function of the size of the sensitive area is considered, results given by various investigators being quoted. There is an optimum size of surface above which the principle of diminishing returns applies, a figure of 8 mm. being considered a good compromise. The effect of microphony and noise produced by irregularities in the photosensitive surface is considered, as is the necessity for a condensing lens to focus the radiation from the target on to the surface.

Active Proximity Fuses - Project "Zossen".

This apparatus was intended for automatic launching from fast fighters. The proposed arrangement is shown in Fig.12, from which the method of attack is evident. The time of release is fixed automatically to an accuracy of about one-hundredth of a second. The transmitter sends out a chopped light beam which is reflected by the target when it comes into the field of view, the reflected light passing into a caesium vacuum cell. The amplified signal energizes a relay which operates the launching equipment.

/Differences

Differences in altitude of up to 80 metres were used on trials. It was found possible to hit a target 2 metres square with certainty at 45 metres range from a fighter aircraft.

Project "PiO"

This equipment was intended to detonate a torpedo as it passed under and several yards below the keel of a ship, detonation in such cases being most effective (see Fig. 13a). The light from a glowlamp is chopped by a rotating disc and projected upwards. Should any light be reflected into the receiver by the presence of a target, a signal is produced by the caesium vacuum cell, amplified by a tuned audio-frequency amplifier, the output of which operates the detonating gear. By suitable inclination of the outgoing light beam, light reflected from the surface of the water is prevented from entering the receiver (see Fig. 13b).

The chief difficulties were the low signal/noise ratio (as low as 4/1 in some cases) owing to waves, and the high coefficient of absorption of the radiation by sea water. Rather poor results seem to have been obtained with this apparatus.

Project "P.L."

This equipment was intended for building into the A.A. rocket "Wasserfall" and worked according to the same principles as "Zossen" and "PiO", but the distance at which detonation occurs is less, since the outgoing light is split up into a number of beams. A range of 30 metres was required. In Fig.15b is shown a section through the nose of the rocket. A motor rotates a lens drum at high speed, producing a series of rotating beams similar to that produced by a lighthouse. The presence of a target causes light to be reflected into the receiver photocell which is a caesium vacuum cell with semi-transparent cathode. The output from the cell passes through a tuned audio-frequency amplifier and operates the detonator. Fins are provided to screen side lights from the photo-cell.

On trials ranges of only 15 metres were obtained and since increasing this figure to 30 metres would have required a 500-watt lamp the outlook was poor. Work was therefore suspended at the beginning of 1945.

Project "Kegel"

This is a "passive" optical proximity fuse, to be employed against low-flying aircraft. (up to 50 metres altitude). Mines arranged in the neighbourhood are detonated by the equipment.

/The

The shadows principle is used. A shadow falling on the caesium-antimony gas-filled photocell produces a pulse which is amplified and used to detonate the mines. Shortage of petrol curtailed trials, but results were obtained with a slow-moving aircraft flying at 50 metres altitude.

Collaboration with other firms.

The names of the firms involved in the various projects are shown in section IV of the report.

In the final section measures are discussed which would be necessary for further development and completion of the various projects. Such question as library facilities, space, staff, apparatus, and raw materials required are discussed.

Note:- Figures referred to in this appendix are not reproduced and reference must be made to them in the original German report.-

Laboratory Work at A.E.G. Neustadt, Nr.Coberg.

FIGURE 1.

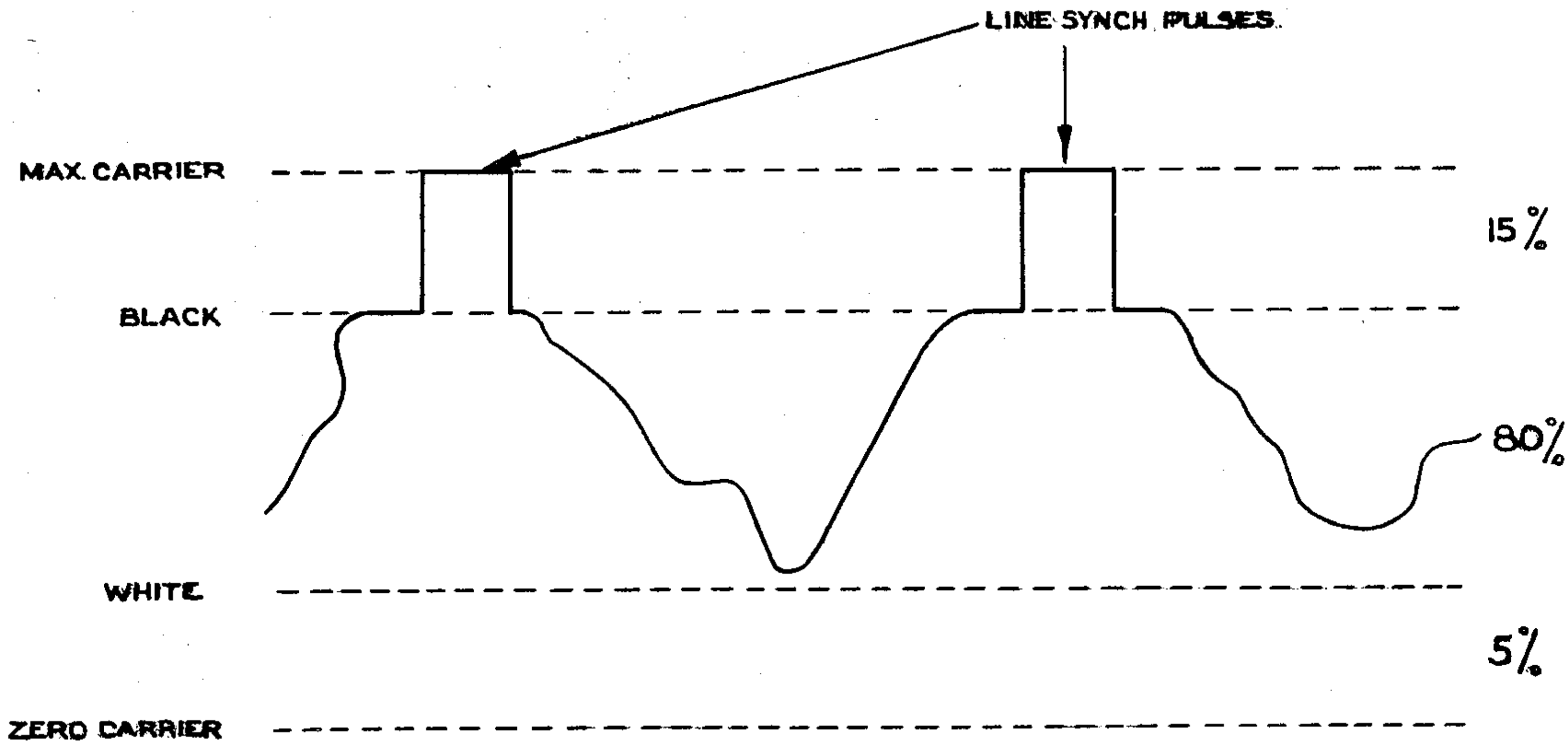
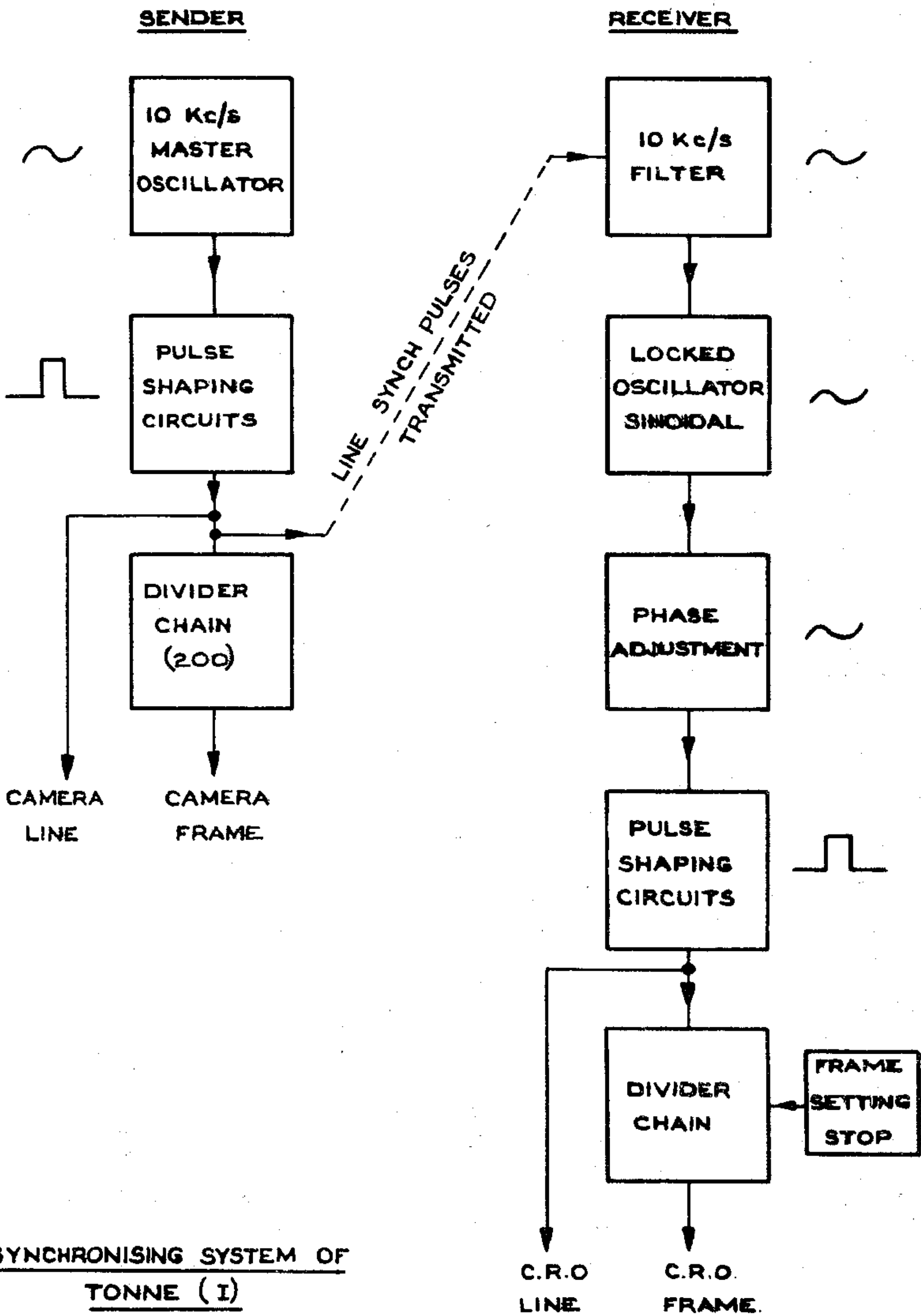
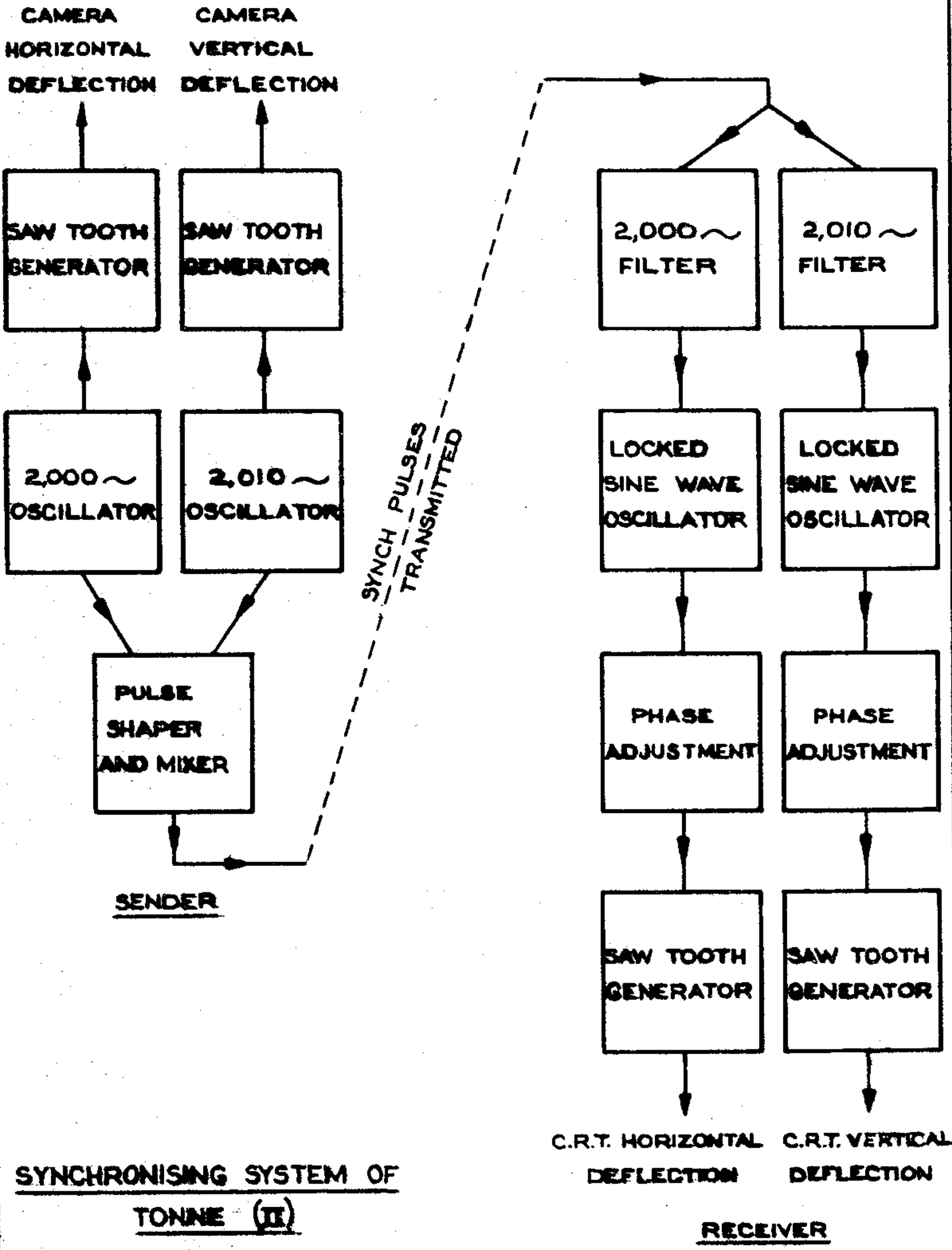

LINE SYNCH PULSES.
MAX. CARRIER
BLACK
WHITE
ZERO CARRIER
15%
80%
5%

FIGURE 2



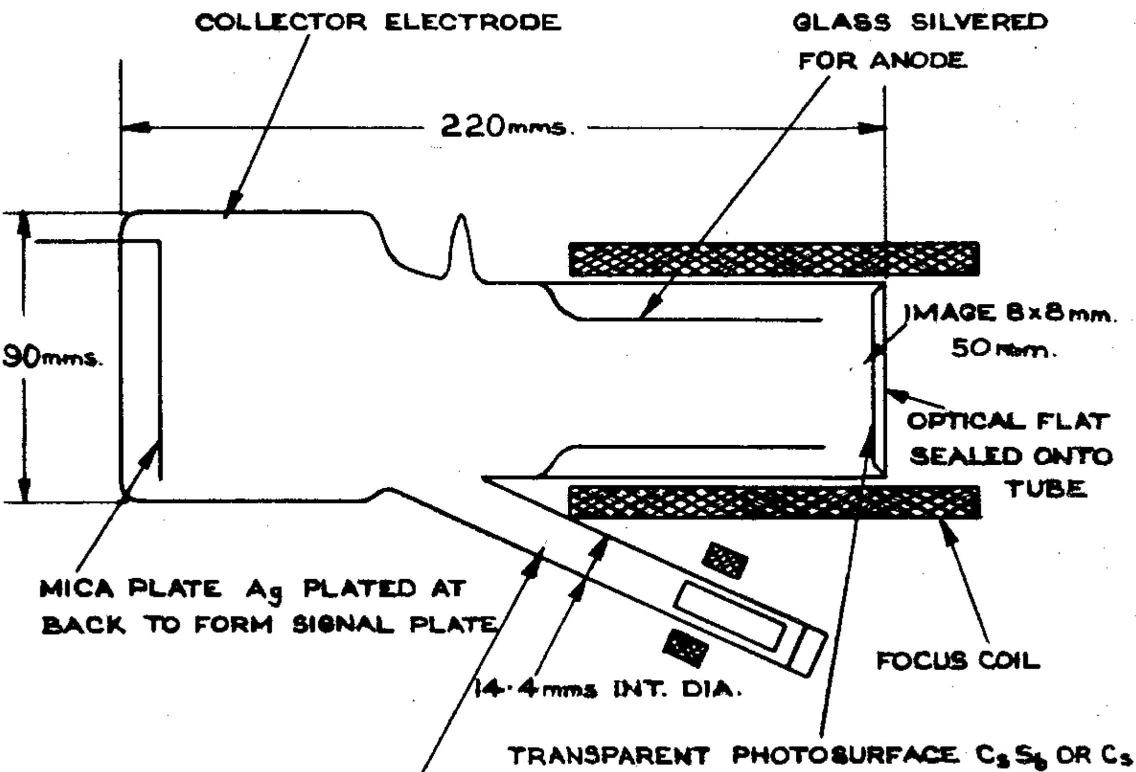
SYNCHRONISING SYSTEM OF TONNE (I)

FIGURE 3



SYNCHRONISING SYSTEM OF TONNE (II)

FIGURE 4



CAMERA TUBE

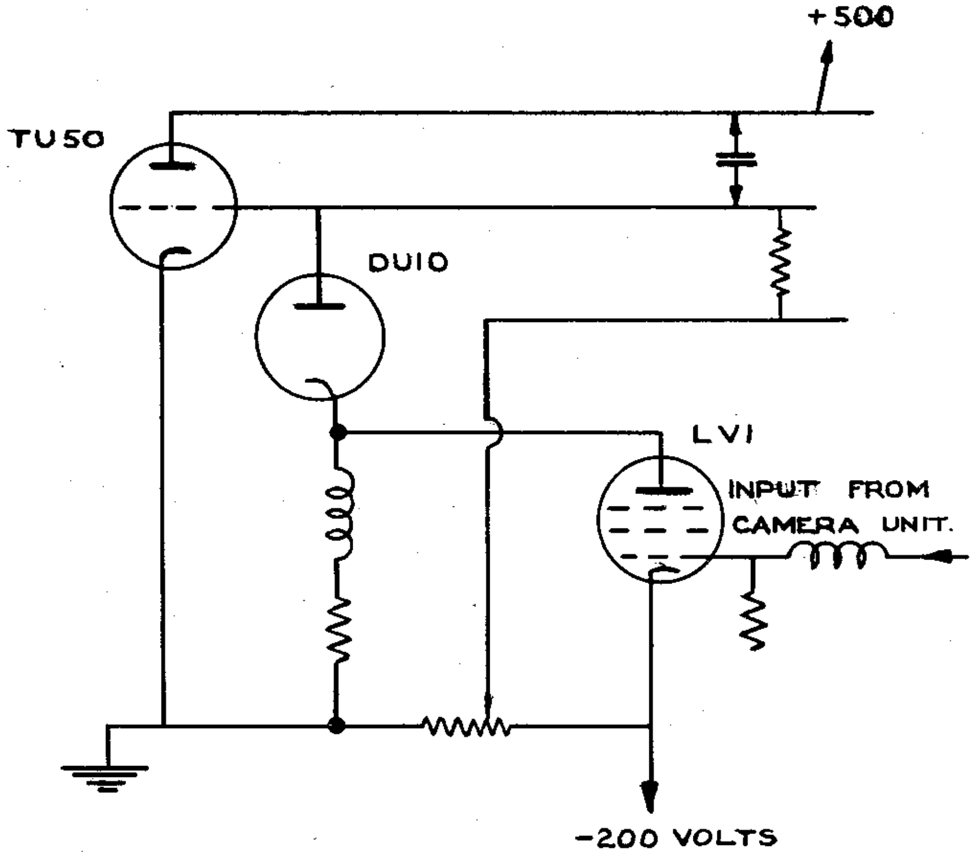
(FOR A GOOD PICTURE i.e. ADEQUATE CONTRAST & DEFINITION FOR TONNE I SUPER ICONOSCOPE. F 3·5 LENS. 2000 LUX.)

MADE OF SODA GLASS. (GLASS WORK TIME 50 MINS)

REPORT ON THE ABOVE LF 71 WITH ADDITIONAL DRAWINGS REQUESTED.

* BERICHT UBER DIE BILD AUFNAHMERÖHRE

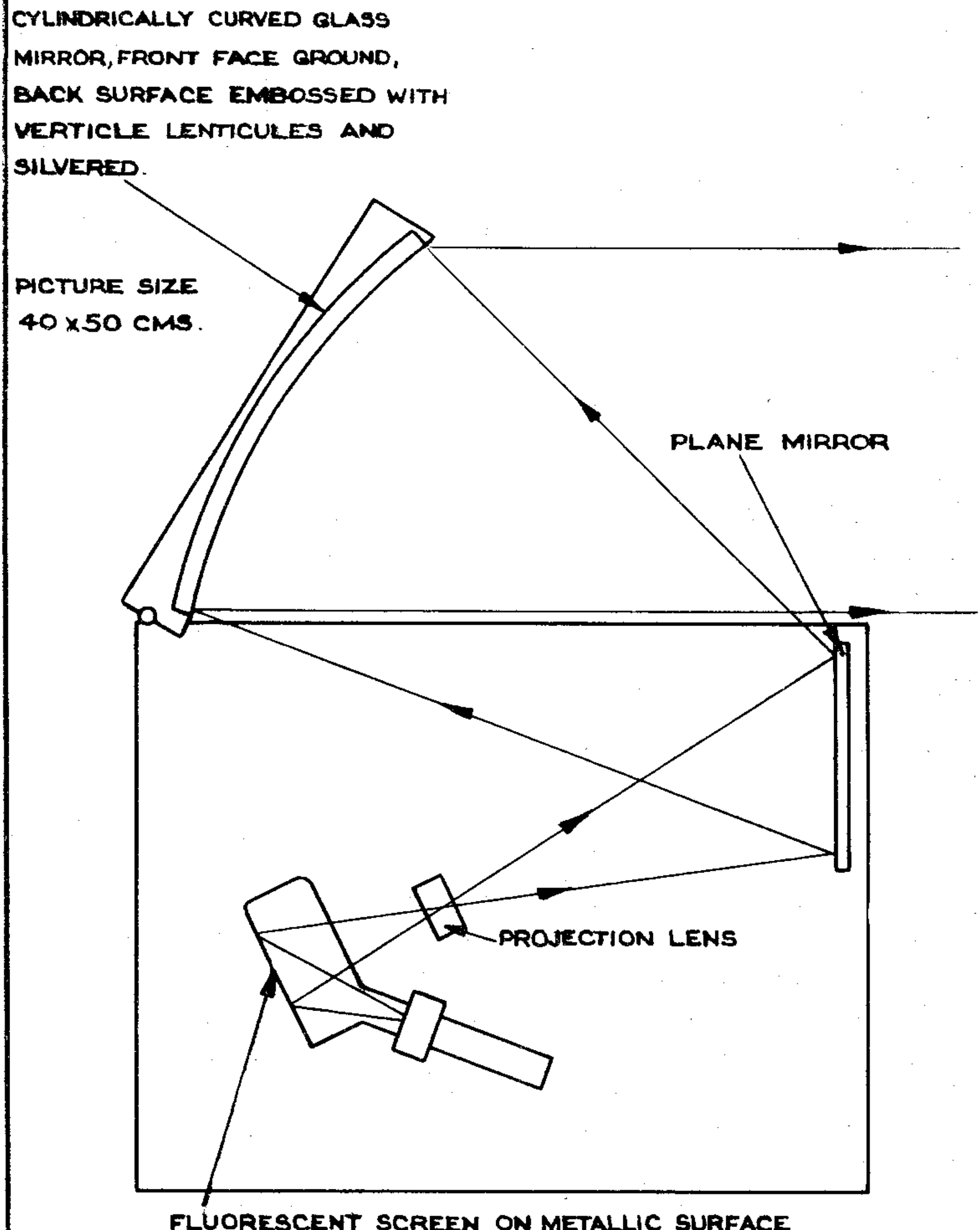
FIGURE 5



A SPECIAL DIODE DEVELOPED BY FEINSCH(DU10) OF LOW CAPACITANCE (1μμF) WAS CONNECTED CLOSE TO THE GRID OF THE 70 CM. OSCILLATOR TU50 AND FED ON THE CATHODE FROM THE FINAL MODULATOR TUBE (LV1 TELEFUNKEN). IN THE CONDITION OF MAX: CARRIER THE DIODE IS NON CONDUCTING; WHEN THE DIODE CATHODE POTENTIAL FALLS, MODULATION IS EFFECTED INITIALLY BY DAMPING OF THE LECHER LINE CIRCUIT, AND FURTHER, BY SHIFTING THE WORKING POINT OF THE TU50. DC RESTORATION IS NOT NECESSARY DUE TO DUAL-CONNECTION FROM THE TU50 GRID TO LV1 ANODE.

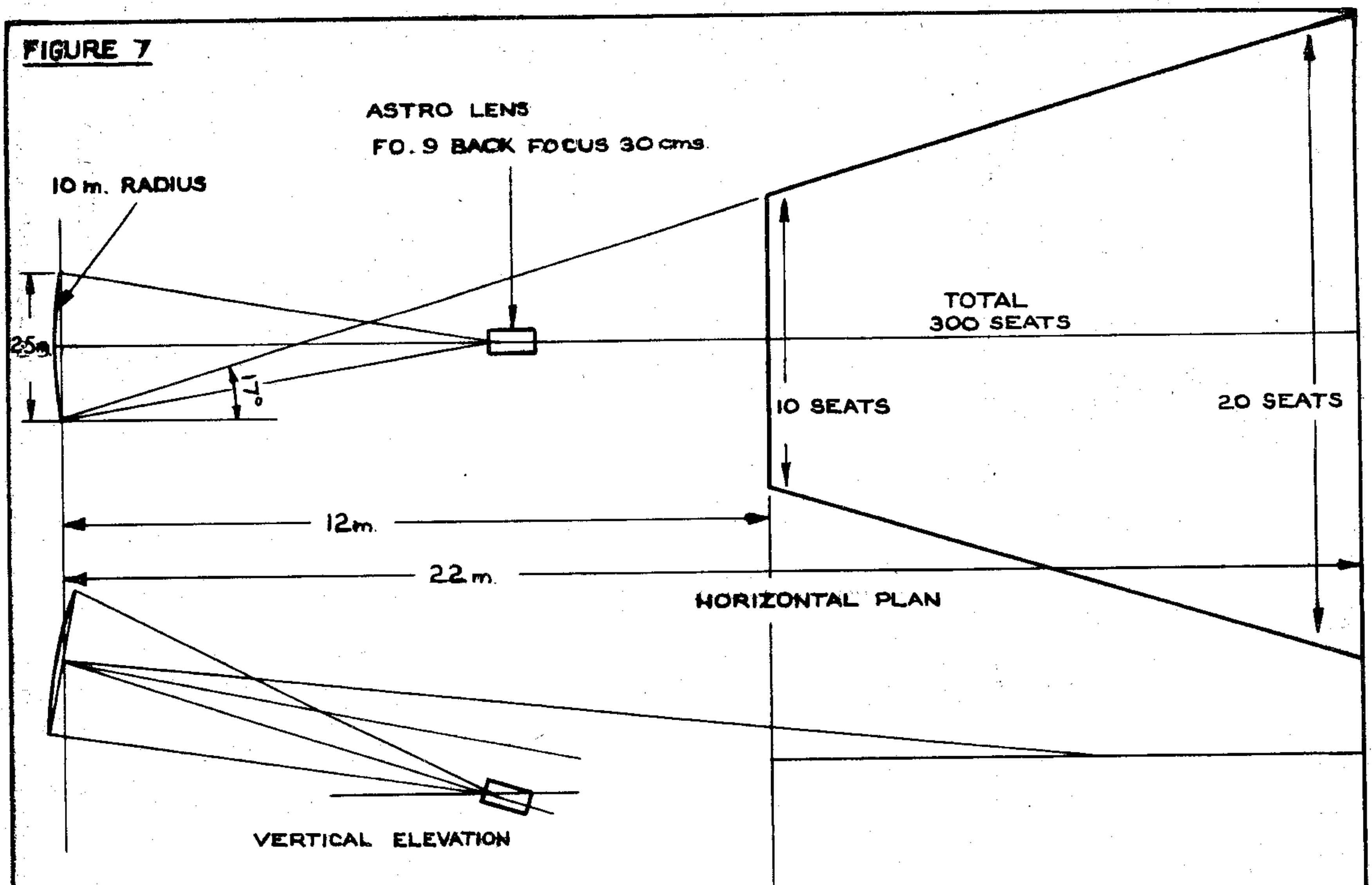
DIODE MODULATOR TONNE I & II

FIGURE 6.



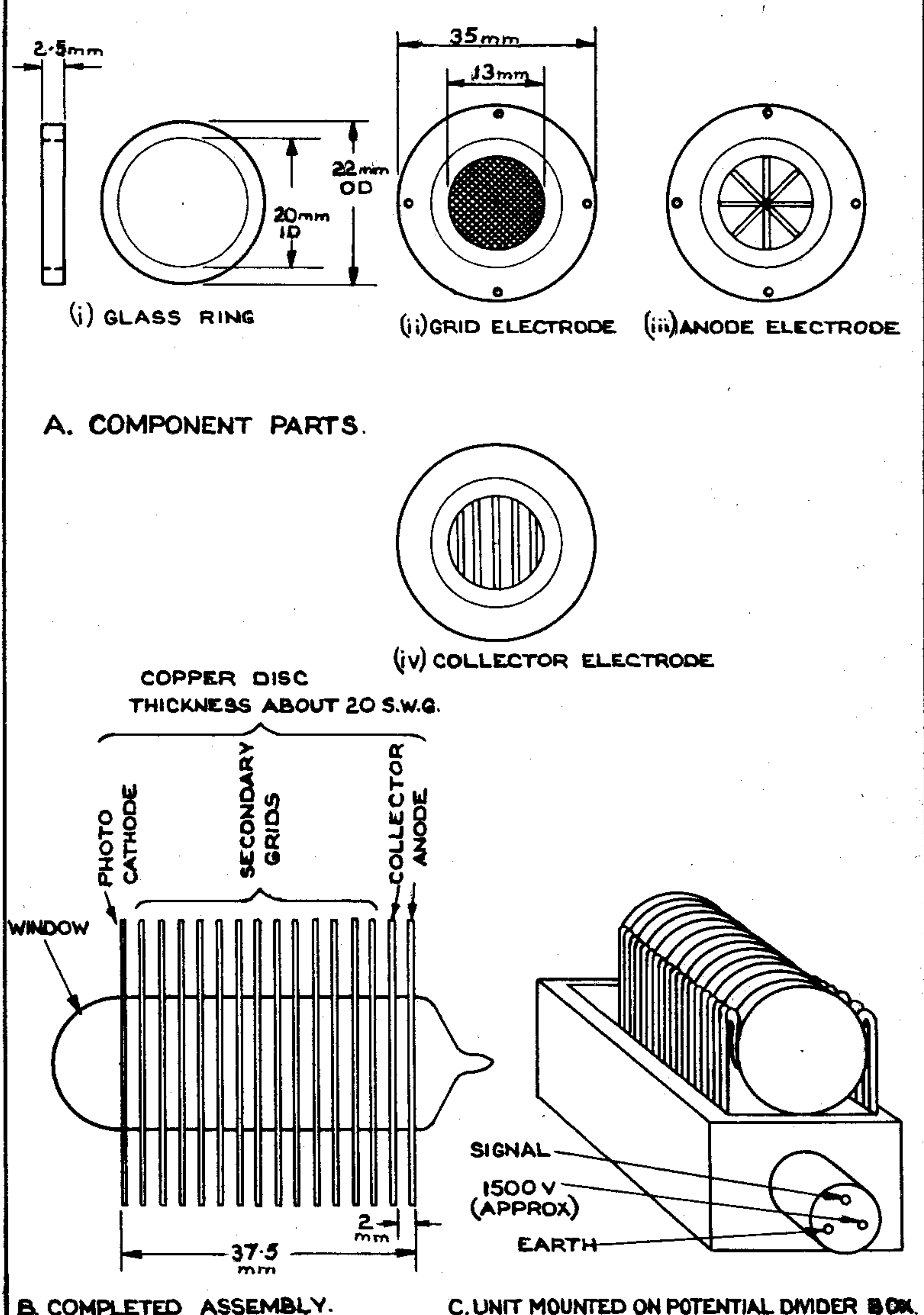
PROJECTION SYSTEM FOR FERNSEH HOME RECEIVER

FIGURE 7



SMALL CINEMA PROJECTION LAYOUT

FIGURE 8



2·5mm
22mm OD
20mm ID
(i) GLASS RING
35mm
13mm
(ii) GRID ELECTRODE
(iii) ANODE ELECTRODE
A. COMPONENT PARTS.
(iv) COLLECTOR ELECTRODE
COPPER DISC
THICKNESS ABOUT 20 S.W.G.
PHOTO CATHODE
SECONDARY GRIDS
COLLECTOR
ANODE
WINDOW
2 mm
37·5 mm
B. COMPLETED ASSEMBLY.
SIGNAL
1500 V (APPROX)
EARTH
C. UNIT MOUNTED ON POTENTIAL DIVIDER BOX.

FIGURE 9

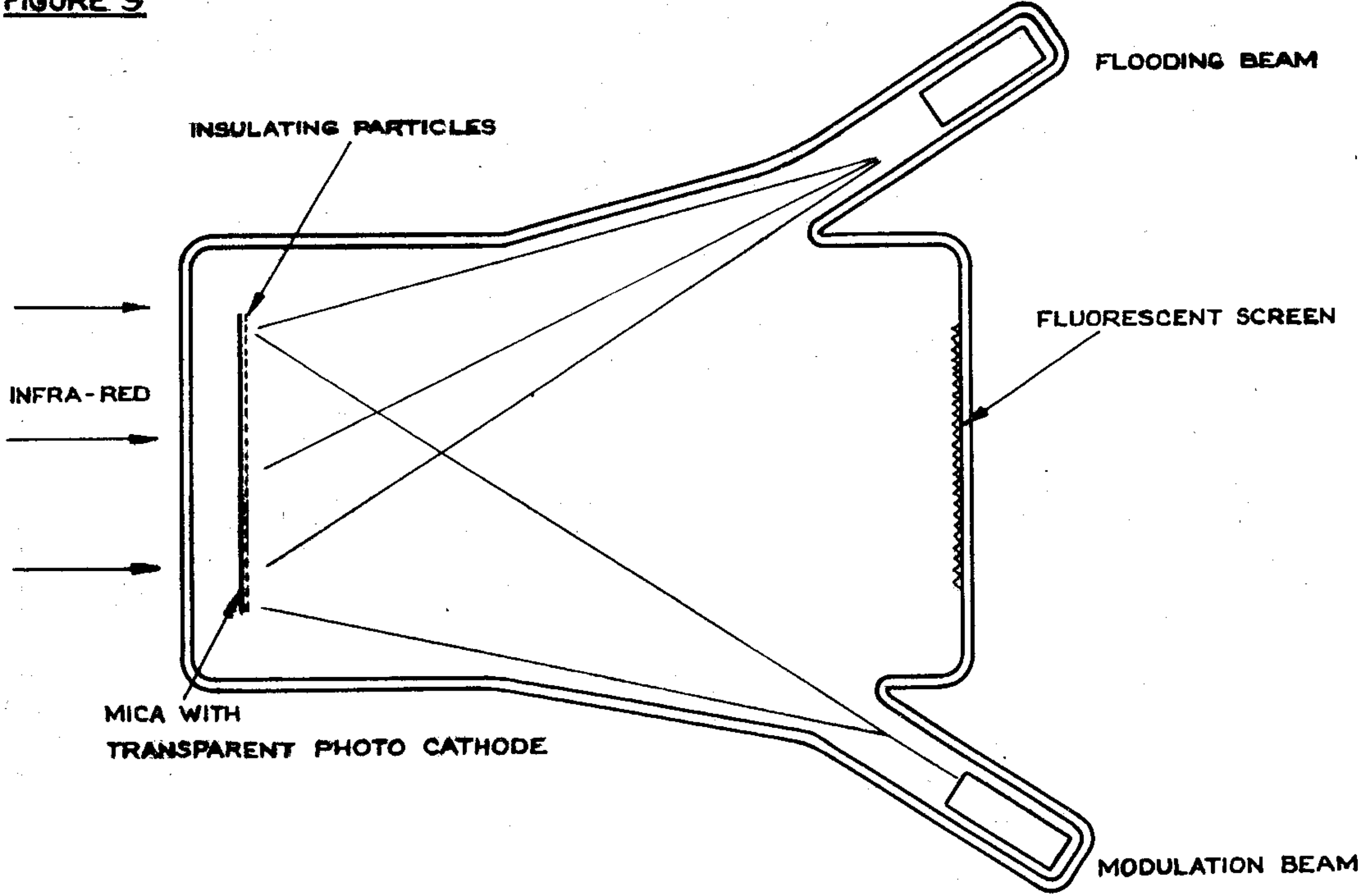
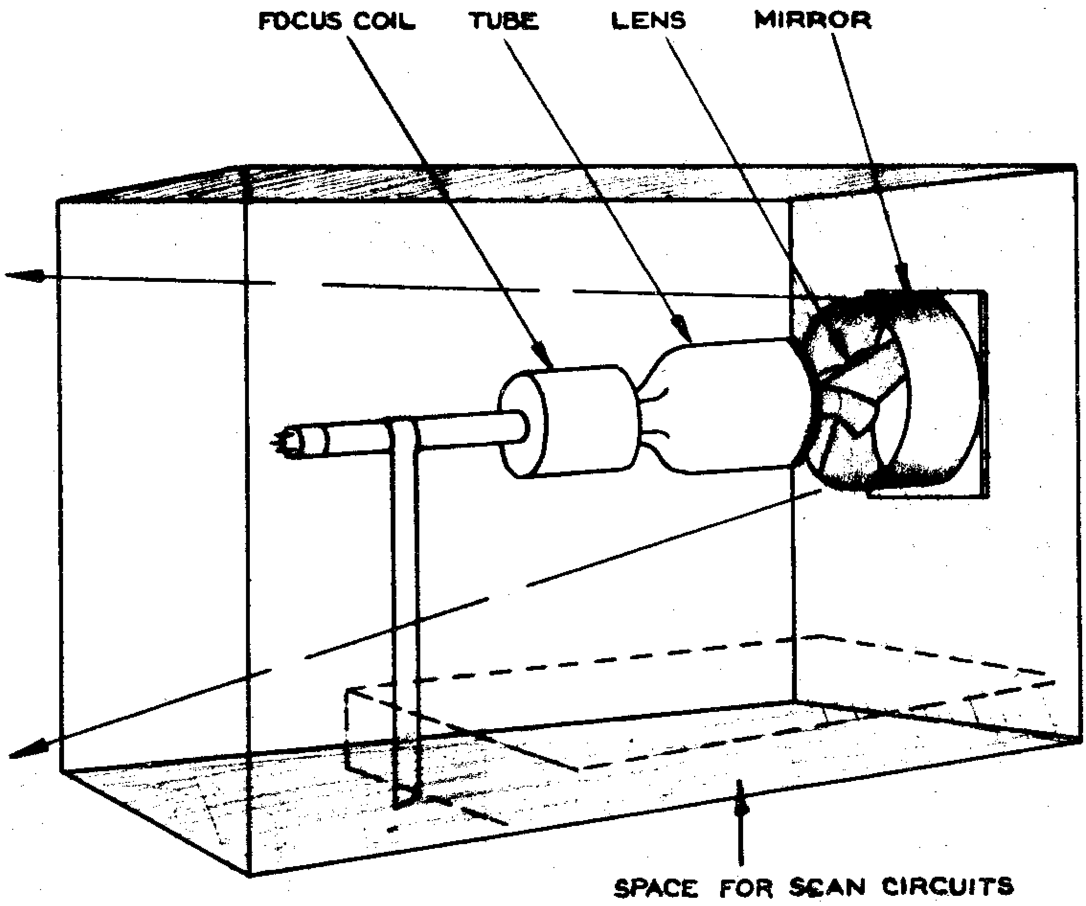


IMAGE STORAGE TUBE

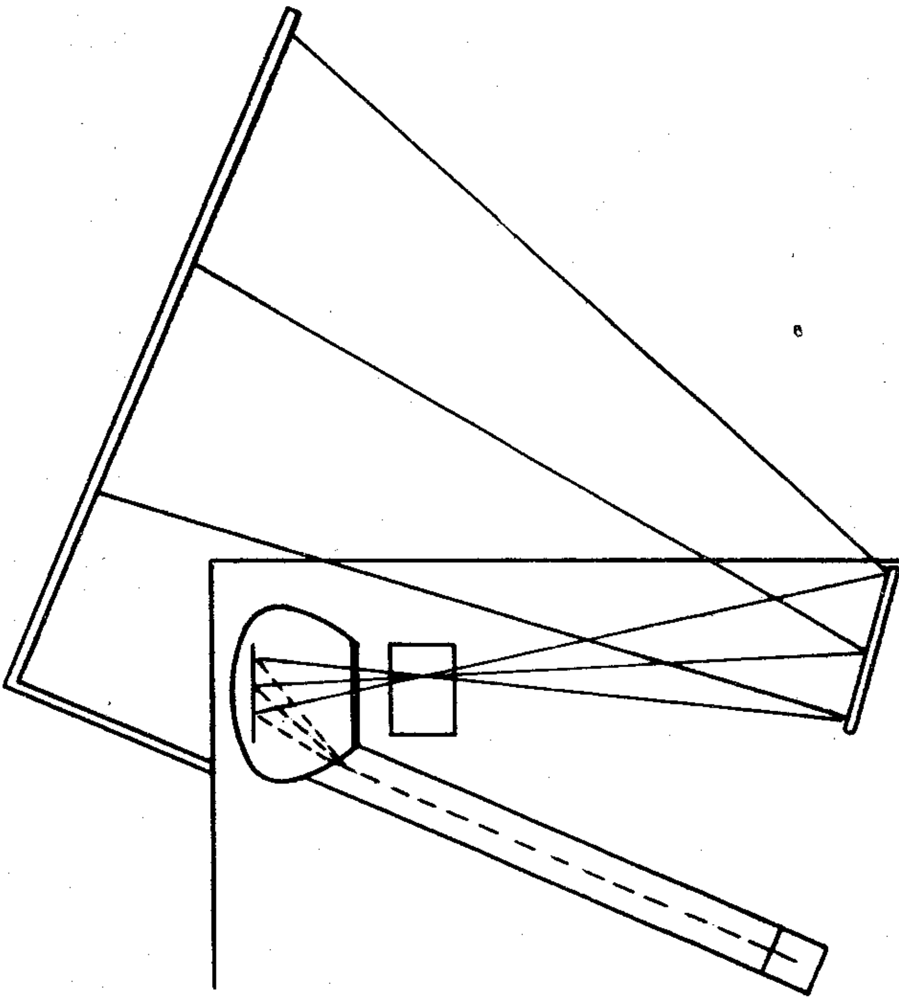
FIGURE 10.



LORENZ.

MIRROR OPTICAL SYSTEM FOR 2 x 2 m PICTURE.

FIGURE 11.



LORENZ TABLE MODEL
PROJECTION RECEIVER

FIGURE 12.

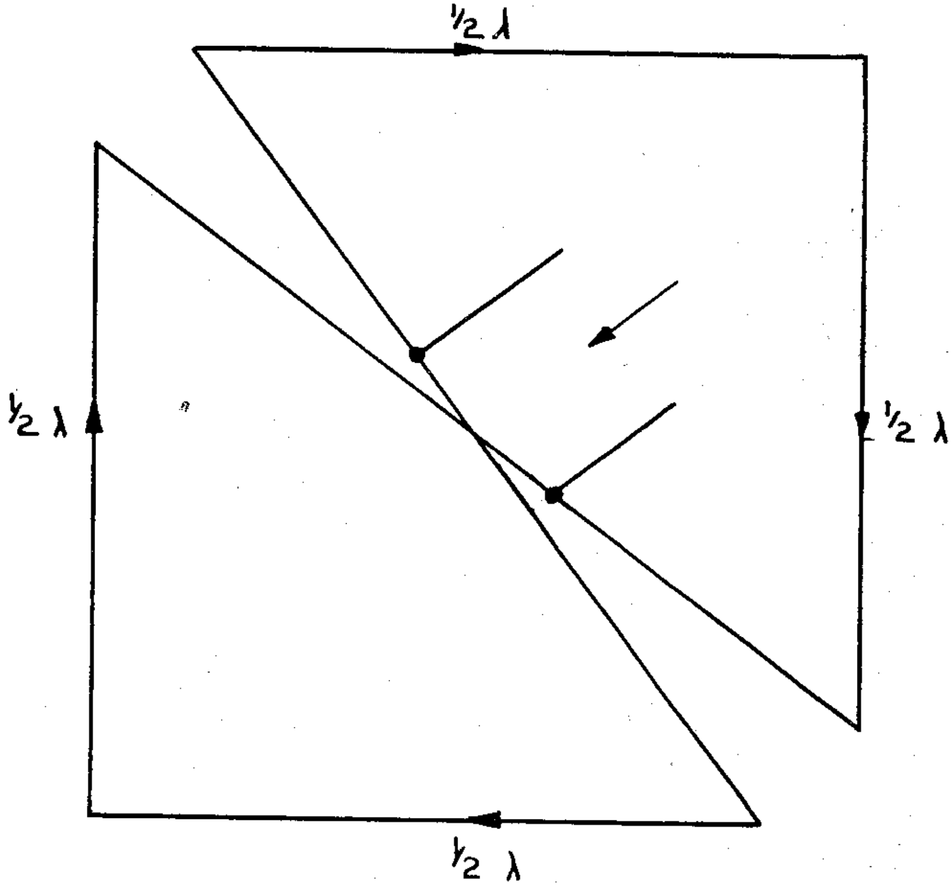
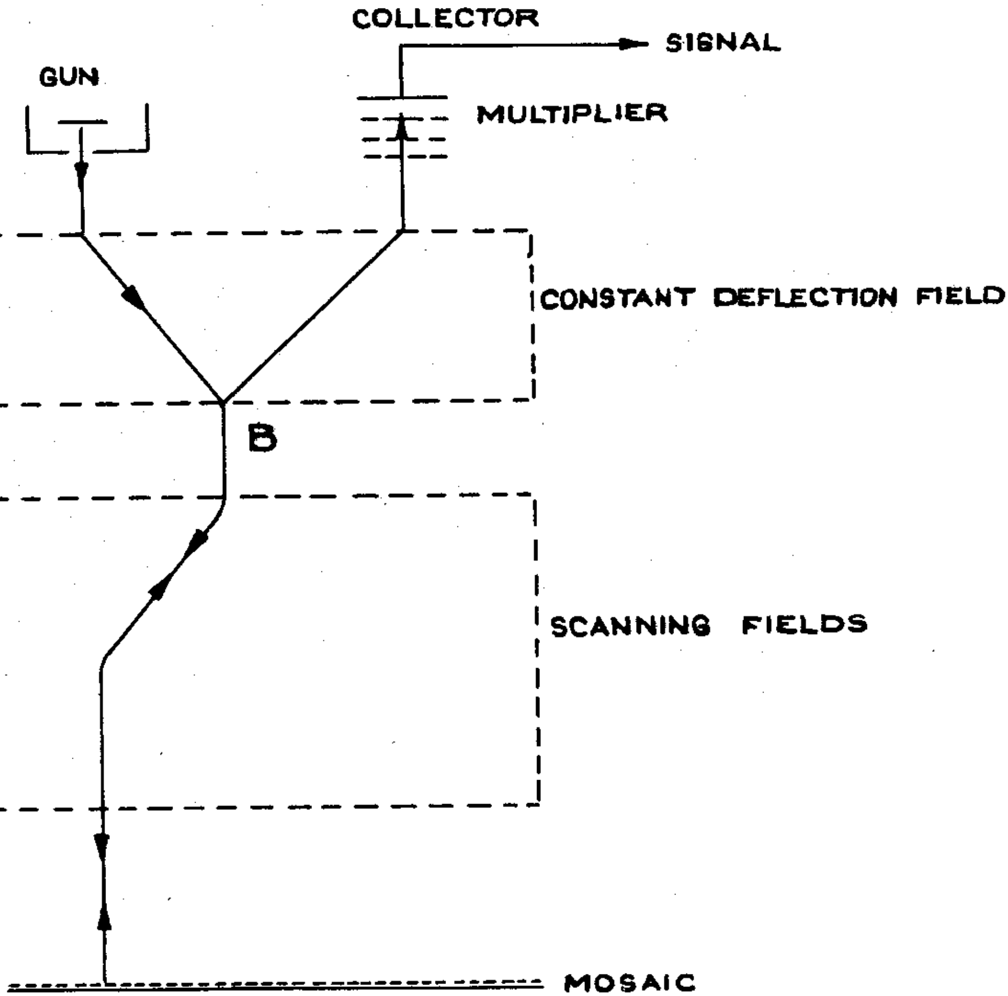


FIGURE 13.



ORTHICON WITH SECONDARY EMISSION MULTIPLIER.