B.I.O.S. FINAL REPORT No. 1658 (Interrogation Report No. 600)

ITEM No. 9

INTERROGATION OF ERWIN WEISE

Research and Development of Semi-Conducting Materials

Practical Applications for Ultra-Sensitive Temperature Measuring Equipment and Automatic Control and Stabilizing Problems

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BRITISH INTELLIGENCE OBJECTIVES

SUB-COMMITTEE

LONDON—H.M. STATIONERY OFFICE

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Interrogation Report No. 600.
7th February, 1946.

British Intelligence Objectives Sub-Committee
Instrument Panel Group 2

Interrogation of:

Erwin Weise, Dipl. - Ing. (Director of the Semi-Conductivity Laboratory at Osram 1939 - 1945. Research work in the Rerhen Lab Technical High School Berlin evacuated to Bad Liebenstein 1943 to end of hostilities.

Target No. C9/627.

Interrogated by:- P. S. Brackenbury, Directorate of Instrument Production.

Main Interest: Research and Development of Semi-Conducting materials, practical applications for ultra-sensitive temperature measuring equipment and automatic control and stabilizing problems.

Semi-Conducting materials: The semi-conductors in which Weise had carried out research were in a material known as Magnesium Titanium Spinel ($MgO.TiO_2$) bearing the trade name of Urdox. This material is made in the form of sheet, rod and tube. The most common sizes being in rods or tubes about one centimetre long with a diameter of from one to two millimetres. It was also possible to make them in the form of fine filaments of about seventy microns diameter formed on a thread of silk of about thirty microns diameter. Attempts to make a finer filament than this were unsuccessful as the material tended to form into globules and so became discontinuous. It should be noted that the filaments are in reality very fine tubes with a wall thickness of about twenty microns, as the silk core is burnt away during processing. In the case of sheet it was not possible to go below a thickness of about ten microns.

The material has a negative temperature coefficient ranging from 0 to 10% per degree Centigrade with a time constant of as low as half a second for 90% of the total change. The temperature coefficient can be varied at will during manufacture by varying the TiO_2 content, higher proportions of TiO_2 give the greatest negative temperature coefficient. A mixture containing less than 10% TiO_2 fails to give the desired spinel crystal structure. The specific resistance ranges from 10 ohms/centimetre to 10^8 ohms/centimetre and is a function of the temperature and baking time during manufacture.

The method of manufacture is as follows: Titanium dioxide and manganese oxide are mixed with starch and water to a fine paste and extruded in the form of rod or spread over a flat glass plate to form films. The starch used is a brand known as "Calloresin" prepared by I.G. Farben, this is used solely as a binder. It is important that the grain size of the materials used should be as small as possible, about two to five microns. After spreading on a flat surface as described the films are then allowed to dry in air with or without the application of heat. When dry the material may be peeled off like paper and cut to size with scissors. The film is then baked in air at a temperature of from 1050° to 1100° Centigrade and afterwards in hydrogen at atmospheric pressure at a temperature of 1200° to 1500° Centigrade. The pieces are laid on tungsten or molybdenum sheet or if fired in air in a crucible containing very pure aluminium oxide powder.

The length of time and the temperature of this second baking operation are the determining factors of its resistance characteristics.

Filaments are prepared by running a thread of silk over pulleys through the solution which is then air dried and baked as above.

Rods are extruded under a pressure of 100 to 200 atmospheres and processed as for filaments. For contact purposes the ends of the rods are dipped in paste of molybdenum powder before the first baking and in copper paste before the second baking. Metal caps may be attached by brazing with copper in a hydrogen flame.

Books and Papers on the subject are as under:

Technical Uses of semi-conductors	publisher J. A. Barth
Science of semi-conductors	" "
Electrical Conductivity in Solids	" Springer
Physical Pocket Book	" "
Modern Methods of measuring vacuum between 760 and 10 Torr.	Zeitschr. f. tech. Physik.
The temperature - Resistance function of semi-conductors.	No.4 1943 p.66
An application of semi-conductors for measuring small slopes	"
Measuring the velocity of gases with semi-conductors	"
Manometer for high-low gas pressures using semi-conductors	"
Physical properties and applications of semi-conductors	No.59 1938 p.1085
Semi-conducting materials and resistors	Tech. wiss Abh. Osram No. 5 1938
Example of Bridge Networks incorporating semi-conductors	Zeitschr.f.tech.Physik No.18 1937 p. 467
Accuracy and Time factors in Mathematical Calculations of Equalisation	No. 20 1939 p. 59.

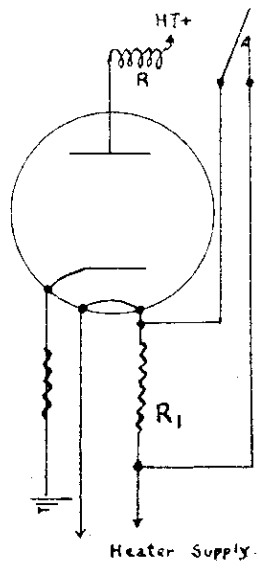
All the above publications were written by Weise either alone or in collaboration with another.

The following patents relate to inventions made by Weise:

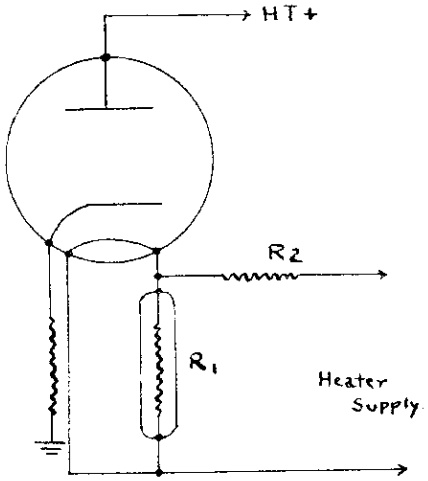
DRP. 607 444 Carrier with two records of oscillations in one trace
" 618 982 Control resistor to diminish the starting time of cathodes
" 632 820 Network for the quick starting of cathodes in discharge tubes
" 641 680 Pipe-shaped high frequency furnace.
" 696 463 Manufacture of very thin semi-conductors.
" 697 174 Resistors of semi-conducting materials.
" 701 478 Electrical measurement of low gas and steam pressures
" 716 052 Equipment for fitting very thin semi-conductors
" 721 677 Stabiliser for D.C. and A.C. voltages.
" 730 251 Equipment for fitting very thin semi-conductors.
" 743 780 Measurements of the velocity of gases, slight changes in air pressure, and altitudes of aircraft.
" 743 575 Network to raise the slope of the characteristics of electron tubes.
Secret 1 Use of resistance controller as an amplifier and generator of slow electrical oscillations.
Secret 2 Instrument for measuring the inclination of ships, incorporating semi-conductors of little inertia.

I questioned Weise as to details of some of these patents and obtained the following explanations:-

DRP 618 982. This patent relates to method of accelerating the warming up of indirectly heated cathodes. A voltage of some two or three times the working voltage of the heater is applied. The relay R at this stage is resting on its back contacts thereby short circuiting R_1. As soon as anode current commences R operates leaving R_1 in series thereby dropping the heater voltage to its normal value.



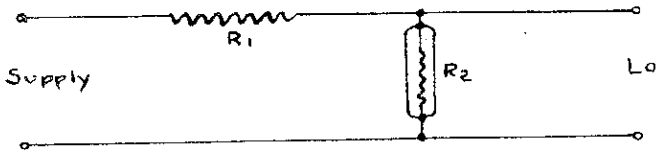
DRP 632 820. This patent is similar to the one described above but attains the same end in a somewhat safer manner. Resistor R_1 is made of semi-conducting material. R_2 is a standard type of metallic resistor. The heater supply voltage is fixed at some suitable value above the normal working voltage of the heater. When applied in the first instance R_1 being cold will offer a high resistance so that a comparatively high voltage will be available across the heater terminals. As R_1 warms up its resistance will drop thereby reducing the voltage across the heater by virtue of the presence of R_2 in series with the supply.



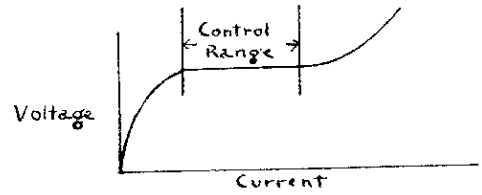
Remarks. Variations of the two above patents might well be used in such cases as Sound Ranging Recorders, Automatic Plotters, Power Packs of Electrical Predictors and other electronically operated equipment which might be required to go into action with the minimum possible delay.

DRP 721 677. This is an application of semi-conductors to voltage stabilisation by very simple means. R_1 is an ordinary fixed metallic resistor or even barretter, R_2 is a resistance made of semi-conducting material. Any variation in voltage across R_1 caused by a change in supply voltage or variations of load on the controlled supply will affect the value of R_2 due to its negative temperature/resistance coefficient, thereby giving a high degree of smoothing.

The semi-conducting material is mounted in a glass bulb which is filled with hydrogen, by changing this pressure the "throttling range" may be narrowed or widened thereby providing for a degree of control to suit different purposes.



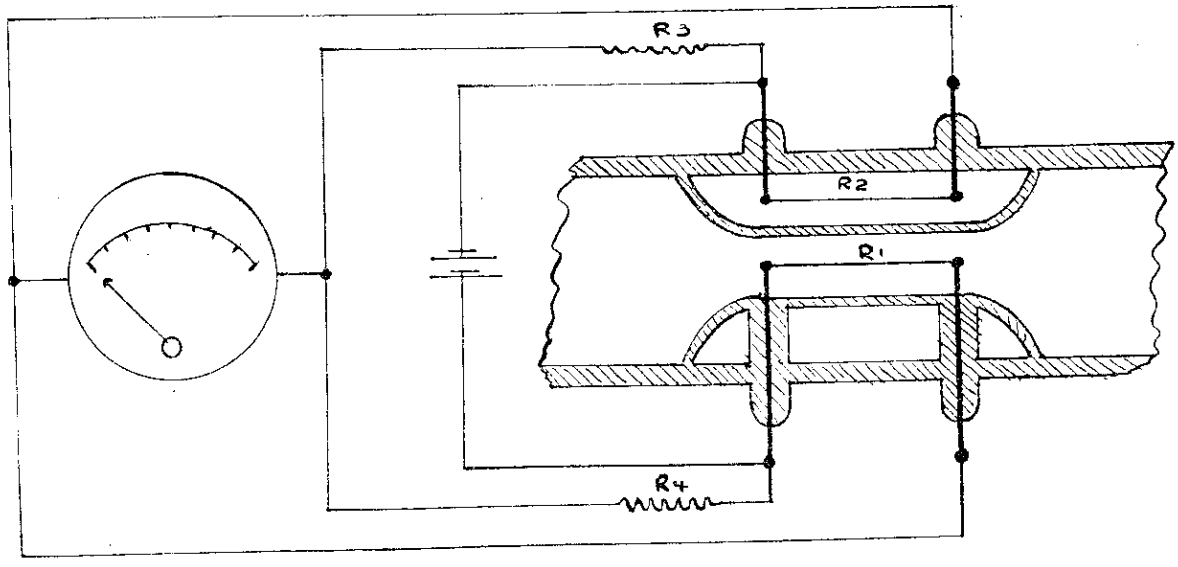
The voltage/current characteristics of the semi-conducting material are somewhat as under.



Calculation of values is somewhat involved and more easily arrived at by graphical methods. A full mathematical treatise on the subject has been written by K"o"r"os, entitled "Glimm Stabilisatoron".

Remarks. Use of this system in power packs, for Electronic equipment could be quite important in certain instances where the time values in the circuit are not too low.

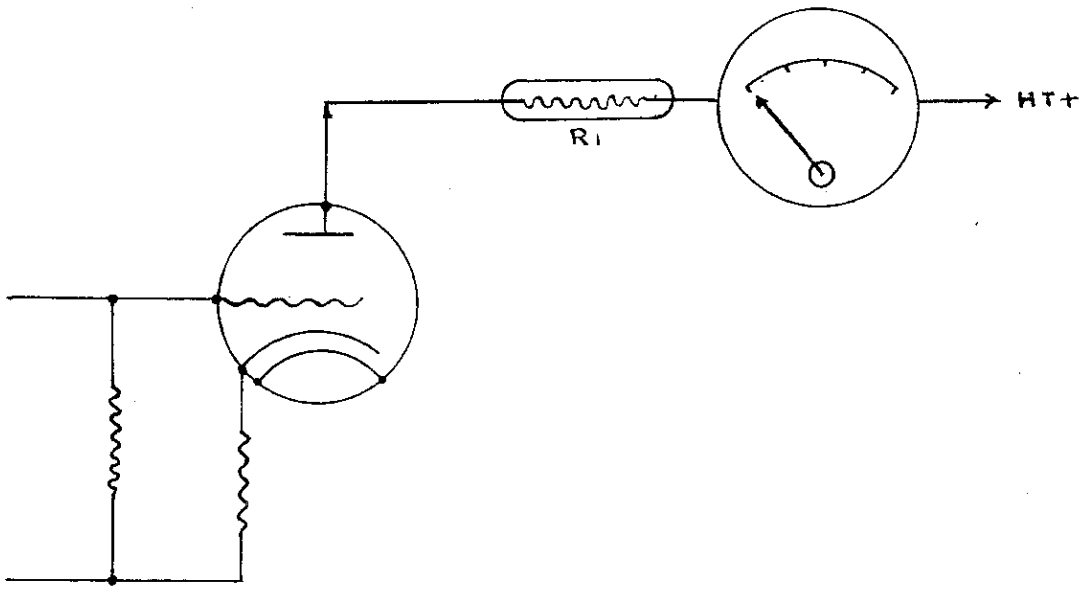
DRP. 743 780. Measurement of velocity of gases may be made by interposing a fine filament of semi-conducting material in a glass tube through which the gases to be measured are passing. R_1 and R_2 are semi-conductors, R_1 is the actual measuring element and R_2 corrects for ambient temperature. R_3 and R_4 form the two other arms of a bridge circuit.



The action of course is that the cooling effect on R_1 will be a function of the velocity of the gas flowing through the narrow tube. Measurements of small changes in pressure are obtained by sealing the tube into a large hollow sphere, all other details as above. Any change in atmospheric pressure will cause a flow into or out of the sphere and so affect R_1.

Remarks. Exact details may not be quite as above, but will serve to illustrate the principle which no doubt is capable of considerable refinement. The system might be applied as a hot wire microphone in Sound Ranging if not already entirely superseded by the Moving Coil type.

DRP. 743 575. Where it is desired to raise the slope of a thermionic valve a resistor of high value made of semi-conductor material is placed in the anode lead as under:



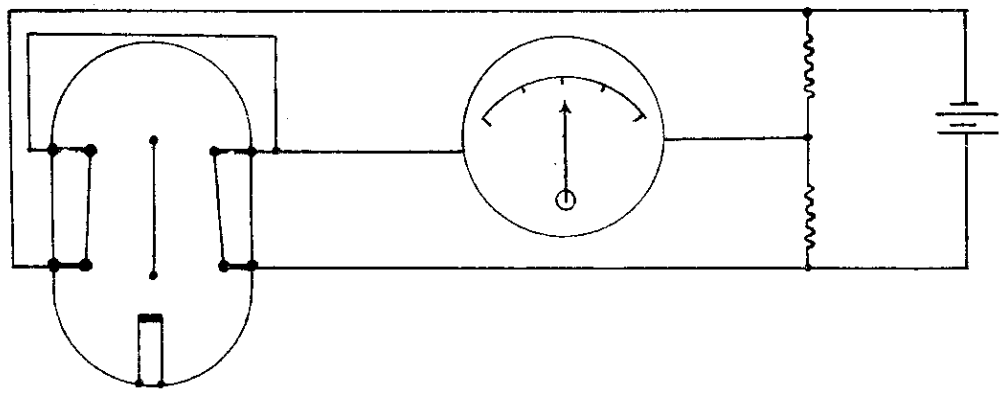
Any increase in anode current brought about variation of grid volts will raise the temperature of R_1 thereby lowering its resistance and bringing about a larger increase in anode current per unit change in grid volts than would have otherwise been the case.

Remarks. Only applicable where grid voltage changes are fairly slow such as in a Valve Voltmeter. Correction for ambient temperature may be obtained if required by connecting a suitable metallic resistor in series with R_1 although there is no material the exact counterpart of the semi-conducting material it is possible by careful selection of values to obtain almost exact compensation over a fairly useful range.

Secret 1. This application appears to be somewhat of an extension of the idea in the previous patent. By evolving a suitable valve/resistance/capacity network using semi-conductor resistors and their negative temperature/resistance characteristics it is possible to produce very slow and regular oscillations.

Remarks. Weise was unable to remember exact details of the circuit. It was not clear what the Germans proposed to use this for and as it was getting late the matter was not pursued further.

Secret 2. This is a method of obtaining electrically an exact vertical reference. It is based on the fact that a hot gas in a perfectly still atmosphere will always rise vertically with almost negligible inertia. The tube consists of a small heater with four electrodes placed somewhat as the plates in a cathode ray tube.



The tubes are exhausted and filled with hydrogen. When the heater is excited warm gas will rise, and if the tube is exactly vertical will affect all four electrodes equally. These electrodes are made of fine filaments or strips of semi-conducting material. Tilting of the tube will give an unbalance of resistance which when coupled with a bridge network will give an indication of the degree of tilt in either plane, one of which is illustrated above. Alternatively a circuit could be evolved which coupled with a suitable servo system could control the flight of aircraft or projectiles. Weise stated that this had been tried with V1 and V2 with great success, but time had been too short for it to be adopted operationally. Almost any degree of sensitivity could be attained by amplification.

Remarks. It seems possible that very wide use could be made of this invention such as applying a correction factor for the errors introduced when a gun mounting or gun carriage settles during action or navigational problems requiring accurate control of elevation as the system is obviously proof against radio jamming or magnetic errors. When compared with gyroscopic methods the system would appear to have much to recommend it as regards simplicity.

Power measurements. Power measurements at centimetre wavelengths have been attempted using semi-conducting material. Stability is good for very long periods with temperatures up to 400° centigrade.

The firm named Funkstrahl near Bodensee had obtained very good results, although Weise's own experiments in this direction had not proved quite so successful.

Infra Red Image Converters. Weise had been carrying out experiments in this direction using semi-conducting material and had made two such tubes. Work on this however was cut short owing to Allied bombing and destruction of the laboratories. It seems that these image converters were sensitive to the longer waves in the infra-red range as compared with our own tubes which probably are only sensitive between fairly narrow limits.

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