Fixed Resistors for Use at High Temperatures

NOBLE METAL FILMS PROVIDE SATISFACTORY RESISTIVE ELEMENTS IN ELECTRONIC EQUIPMENT

One of the major problems encountered by the designer of electronic equipment for missiles and other defence applications is the progressively increasing temperatures at which his equipment must operate. At temperatures up to 150°C the choice of resistors for such equipment is wide; at higher temperatures the choice is far more limited. However, a temperature limit of 150°C is already too low for much of the equipment already in production and it is reasonable to assume that the demand for components capable of working at temperatures above 150°C will increase still further over the next few years. In view of this, a report (1) published on part of the research work carried out by the International Resistance Company of Philadelphia, under a U.S. Air Force Contract, on ultra-high temperature resistive elements capable of withstanding specified nuclear radiation, is of particular interest.

The work was mainly concerned with the investigation of components capable of operating at temperatures of 500°C or more, which is appreciably higher than the maximum operating temperature of any components in current production, and was directed primarily towards studying basic materials and methods that showed promise in achieving this objective.

No results are published in the report of tests carried out under irradiating conditions, but in the great majority of applications this information would not be relevant. There are, however, a number of gaps to be filled in the section of the report that has been published.

The work covered three main aspects: ceramic resistivity evaluation, resistive element investigation and investigation of terminations and enclosures.

Ceramic Resistivity Evaluation

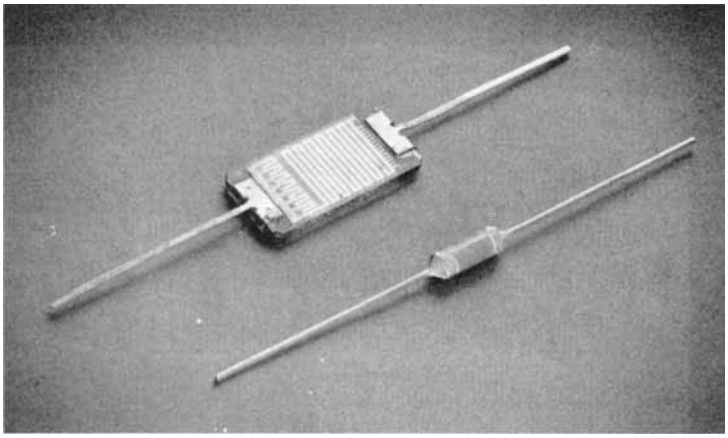
Ceramic materials are of interest here for two purposes: as substrate materials which support the resistive element and as enclosure materials to protect the element and, in some cases, to seal it hermetically.

This evaluation was directed towards finding substrate and enclosure ceramics that maintained suitably high values of surface and volume resistance at temperatures up to 600°C. Numerous commercial ceramics were examined: for tests under load Alsimag 652 (high alumina) and Alsimag 243 (forsterite) were chosen. For most of the tests carried out without load Alsimag 531 (alkali earth) was used—principally on grounds of lower cost and more ready availability. All these materials are manufactured by the American Lava Corporation.

Resistive Element Investigation

Two types of resistive element were investigated: fired-film and evaporated film.

Fired-film resistors on glass substrates for lower temperature use are already established and have been in production in Britain for some time. The films are produced by the same basic technique that is employed in the decoration of glass or ceramic ware. Solutions of the resinates or sulpho-resinates of the required metals in essential oils are applied to the surface to be metallised and the parts are fired in a mildly oxidising atmosphere. This burns away the organic materials present



Two fired-film resistors by Painton & Company Limited, shown without external protection. That on the left employs a flat glass substrate; that on the right is wound with metallised glass fibre.

and leaves behind a thin, homogeneous film of alloy.

The need for noble metals is obvious. In Britain, alloys of gold and platinum have been most favoured since these produce films of tolerably high resistivity and acceptable temperature coefficient of resistance. Up to now the majority of the work has been concentrated on films fired on flat or tubular glass bodies, the film being cut or helixed to increase the total resistance. However, a recent article by Dummer and Benham (2) describes a new approach to the problem—the use of metallised glass fibre which makes possible the production of fired-film resistors in the megohm range.

However, in the work covered by the IRC report, ceramic substrates were used because of the obvious temperature limitation of glass.

Evaporated films are produced by the evaporation under vacuum of the required metals—a technique already in general use for a variety of purposes. This technique has already been employed, on a limited scale, in the production of base metal resistors on glass bodies.

The IRC report shows that initial work on fired films was conducted with a commercially available palladium-based solution which showed excellent stability of resistance at 550°C but which was too low in resistivity to be of interest.

Methods of increasing the resistivity of gold-palladium solutions by additions were therefore investigated: the addition of inorganic solids was tried, but because of settling problems this was discarded in favour of soluble organic salts which dissociated during firing, the resultant product being co-deposited in the film with the noble metals. Salts of lead, aluminium, silicon and zinc were investigated. Of these, lead salts were found to be the most satisfactory. A gold-palladium solution, with a lead addition, applied to a forsterite type of ceramic showed reasonable stability under load in an oxidising atmosphere of 500°C but the low resistivity of the film would limit its use to low-value resistors.

Also investigated were the use of multiple applications, which in all cases improved stability at the expense of resistivity, and increasing the firing period of the solution with a view to stabilising the film. The effects of extended firing periods are still under investigation.

Initial work on evaporated films, for which quartz was used as the substrate, was concentrated on rhodium. This was found to be too unstable in air (presumably due to oxidation) to be of interest but showed promise for use in hermetically sealed enclosures. Nickel-chromium films were also investigated but their lack of stability showed them to be useless in this application. The most satisfactory evaporated film was found to be that of 'carbon-alloy'—a process developed earlier by the International Resistance Company–mounted in a hermetically sealed enclosure. The high resistivity of this film is such as to lend itself to the manufacture of megohn value resistors. Its composition is not disclosed.

For use in unsealed assemblies certain platinum alloys, 10 per cent rhodium-platinum, 10 per cent iridium-platinum and 11 per cent ruthenium-platinum, show great promise and further work on these has been initiated. These alloys compare extremely favourably with pure platinum in that they are far more stable and have lower temperature coefficients.

Iron-nickel caps with nickel leads were employed for the fired-film resistors, these caps being pushed onto gold-platinum bands fired onto each end of the body. The caps oxidised at 500°C but did not cause a discernible increase in resistance. Gold or platinum leads were used with the evaporated films.

The best method of sealing the enclosures to the caps was found to be that of metallising the enclosures with a nickel-plated molybdenum-manganese band and brazing them to the caps with a silver-free brazing alloy. Silver is objectionable because of its tendency at high temperatures to penetrate the seals and evaporate.

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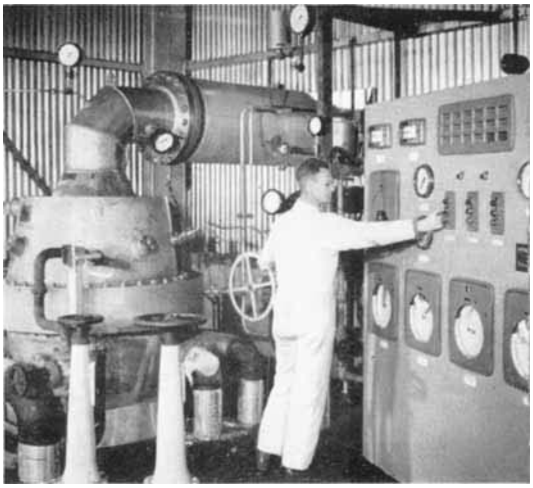
References

1 W. E. Hauth and R. E. Vanderhaar .. Research & Development of High Temperature, Radiation Resistant, Fixed Resistors. WADC Technical Report 57–363, Wright Air Development Centre, U.S.A.F., Ohio. February 1958

2 G. W. A. Dummer and C. M. Benham Metallised Glass-Fibre Resistors—a British Development, *Elect. Manufacturing*, 1959, **63**, (1), 135–137

A NEW NITRIC ACID PLANT



A high pressure ammonia oxidation unit with an output of 250 short tons of 100 per cent nitric acid per day forms part of the new ammonium nitrate factory recently built for Fisons Ltd. at Stanford-le-Hope on the Thames estuary. It employs a modification of the Du Pont process, and has been built under a contract placed with Chemical & Industrial International. Liquid ammonia from the neighbouring plant of the Shell Chemical Co. is stored in a 2,000 ton spherical tank. A 10 per cent mixture of ammonia in air at 120 lb. per square inch is preheated and passed through a pad of 36 hexagonal 10 per cent rhodium-platinum gauzes, 36 inches across flats, at a temperature of 950°C. After cooling, the nitrogen oxides are absorbed in a single stainless steel bubble-cap tower. The tail gases are treated in a fume eliminator containing a platinum catalyst and are then expanded through a gas turbine. All the power for the compressor is provided by gas and steam turbines on a common shaft which utilise heat derived from the process reactions.