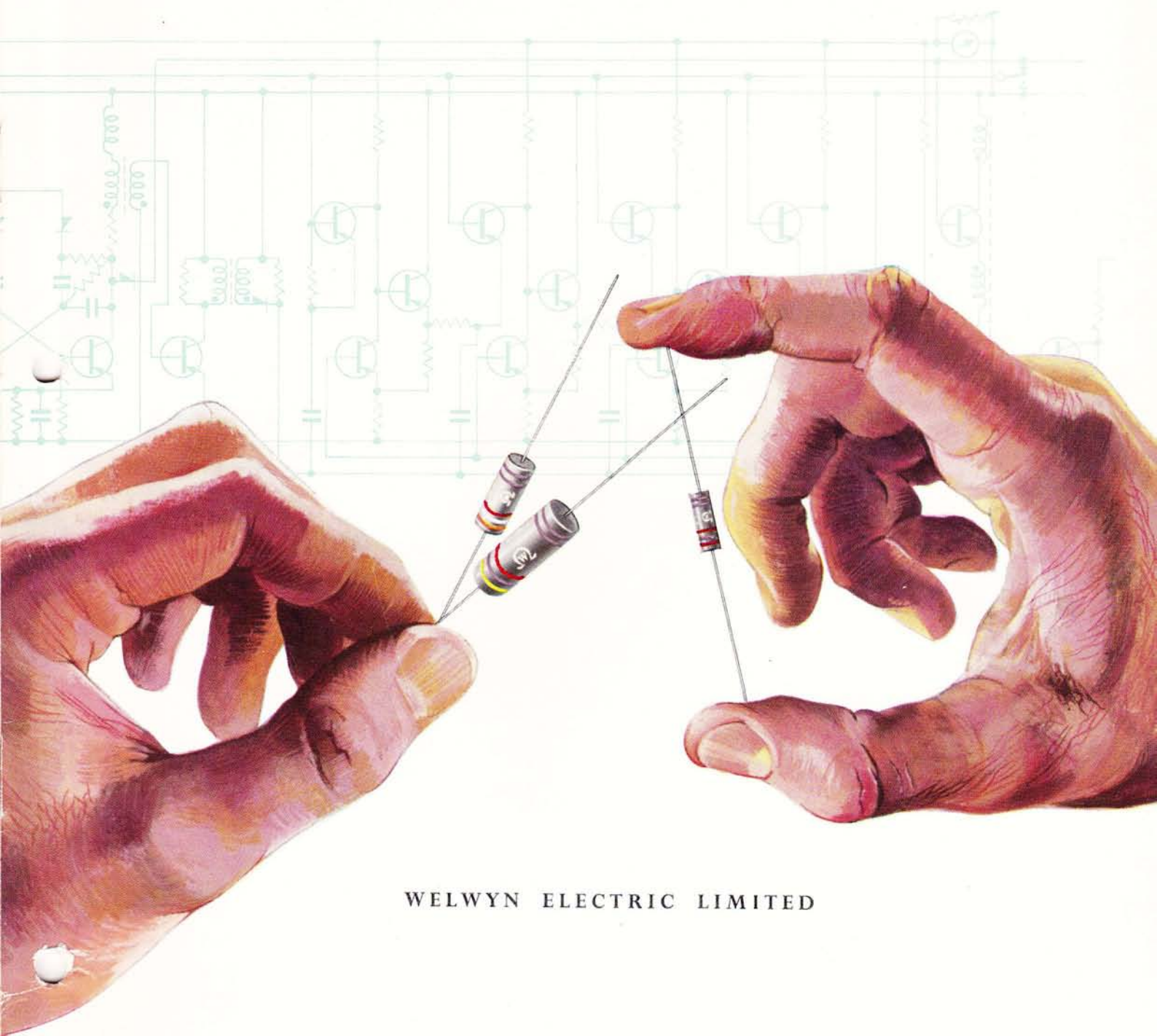




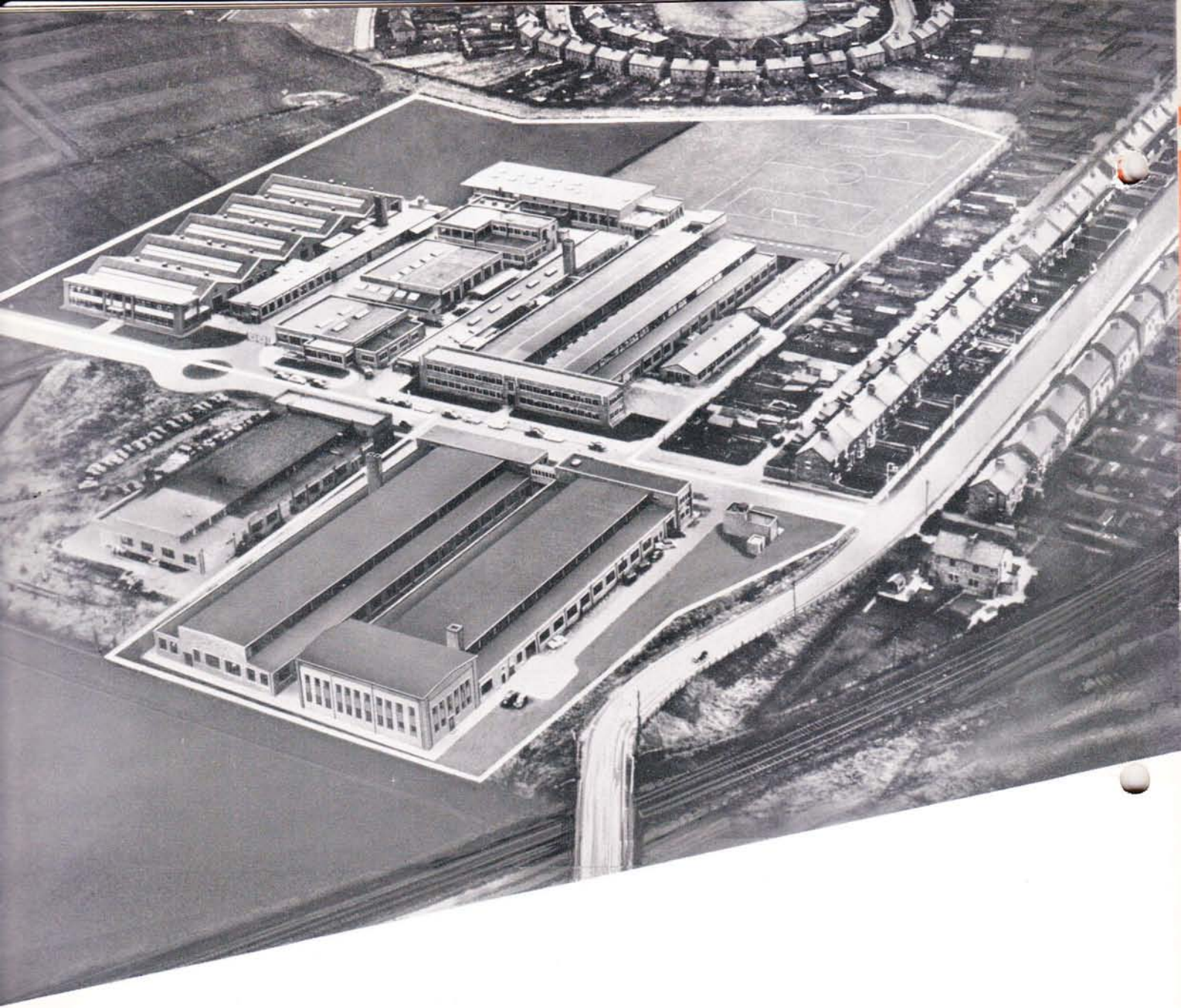
METOX

WELWYN

MINIATURE OXIDE RESISTORS



WELWYN ELECTRIC LIMITED



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THE TOTAL EXCURSION RESISTOR

The Problem

In any circuit the nominal resistance value of the resistors will be the optimum value, but designers recognize that a certain variation of resistance must be tolerated if reasonably priced components are to be used. Accordingly resistors at every point are allotted a tolerance, the tolerance being the variation of resistance value which has been found to be acceptable without the apparatus giving a performance below specification limits.

Different selection tolerances are laid down for various types of resistors and, in general, the established tolerances are 1, 2 and 5 per cent for film resistors and 5, 10 and 20 per cent for carbon composition. Of course precision wire wound resistors are customarily offered at much closer tolerances.

Designers have long recognized that they must have something in reserve when specifying selection tolerances. This reserve is necessary in order to provide for any change in resistance value in use, either due to permanent or secular changes, or to cyclic changes such as arise from temperature changes. Accordingly engineers have to specify the type of component to be used so that the amount of deviation from the original value is under some sort of control. Thus a 20 per cent resistance requirement in a non-critical position could be met by the use of a 5 per cent selection tolerance carbon composition resistor which could have an additional instability of between 5 and 15 per cent. On the other hand, where a resistor has to be held very closely to the optimum value one of the more stable types such as the pyrolytic carbon, metal film, or wire-wound precision resistor would be specified, probably at ± 1 per cent selection tolerance.

With the advent of more complicated equipment however it becomes much more difficult to analyse each component in terms of initial tolerance and stability. A major difficulty is that the designer cannot be familiar with the detailed performance of all resistors to the extent that he could specify those most suitable for his purpose taking into account performance and cost.

The 'Total Excursion' Resistor

The proper approach is that all electronic components should be supplied to meet not only the initial requirements of the designer, but the ultimate requirements under all conditions.

It follows therefore that the resistor manufacturer cannot supply a resistor to an initial selection tolerance, together with data concerning the behaviour of the resistor under various hypothetical conditions from which the user must make deductions concerning its ultimate resistance. The manufacturer should, in fact, collaborate with the user to establish the operating conditions and the expected working life of the equipment, and supply a resistor which will be within the tolerable resistance range for its expected working life. After considerable research in this direction there is now available a 'Total Excursion Resistor'; a component which is manufactured and selected in such a way that throughout its life it will always be within the range of resistance which is guaranteed by the supplier. As is now the case for selection tolerances, a range of 'Total Excursions' should be standardized, and 5, 7, 10 and 20 per cent are proposed as a preliminary range of Total Excursion Resistors for general purpose use, with the expectation that it will be necessary to extend the range to 1, 2 and 3 per cent Total Excursions for special applications.

Using components having a guaranteed Total Excursion, the designer of equipment leaves the problem of behaviour in the hands of the component manufacturer. During the development of his equipment he finds the optimum value

of resistance which he needs, ensures that it will be adequately efficient at the maximum Total Excursion and, having established that this is the case, installs the requisite component without doubts as to its ability to meet his requirements.

With a knowledge of the various Total Excursions available, the designer needs only to decide the correct one for his apparatus, rather than attempt to balance tolerance and problematic stability on the one hand against target price for the equipment on the other. If investigation shows that one Total Excursion, at a certain price level, will not quite meet his technical need he knows immediately the cost of going to the next grade up.

While there is no doubt that the availability of such components will relieve the electronic designer of doubts as to the long-term behaviour of his equipment, it places an equivalent responsibility on the component manufacturer.

Design of the Resistor

Although manufacturers may not be willing to admit all the shortcomings of their products, it is necessary to avoid any tendency to self-deception about the characteristics of the unit when they are required to guarantee their behaviour under all possible conditions. Therefore, the preliminary to offering such a product must be a rigorous programme of testing to establish its properties under various operating conditions.

The first thing to decide is over what period the guaranteed Total Excursion must be operative, and it is proposed that the minimum should be 10,000 hours operation for most equipments with 25,000 hours for certain types. This latter period corresponds to three years' continuous operation. Accordingly, numbers of resistors have been placed on continuous load and their behaviour has been studied for such periods. It has become apparent that there are a number of factors which must be taken into account to explain the ultimate resistance value of the resistor. It has been found that these factors conform to patterns which are typical (and therefore recognizable) in at least two types of film resistor, namely pyrolytic carbon and tin oxide films.

The factors which have to be taken into account are as follows:

- (a) Temperature change.
- (b) Initial stability.
- (c) Long-term stability.
- (d) Voltage coefficient.

Voltage coefficient is important only in certain composition resistors of high ohmic value.

Except for military applications the effect of moisture is not an important matter since it is now recognized that electronic instruments are both more efficient and reliable, as well as cheaper, if they are used in conditions which have no extremes of temperature or high humidity.

The results which emerge from the investigation are (a) that the initial load stability can be up to 5 per cent for carbon composition resistors, up to 1 per cent for pyrolytic carbon or tin oxide film resistors and up to 0.25 per cent for metal films; (b) that the long term drift in terms of per cent per thousand hours varies very much with resistance value and between ranges, but with typical values as follows:

- (1) Composition resistors 1 per cent per thousand hours.
- (2) Pyrolytic carbon or tin oxide film resistors 0.1 per cent or less per thousand hours.
- (3) Metal film resistors 0.05 per cent per thousand hours.

It would be interesting to study with complete thoroughness all types of resistors, but as the author has been very much concerned with finding one solution to a problem rather than amassing information for its own sake, it was deduced from the data available that the tightest Total Excursions having most appeal to equipment users could best, and probably only, be met by the use of tin oxide or pyrolytic carbon resistors. On the one hand carbon composition resistors, because of their relatively high long-term drift could be suitable only for a total excursion of

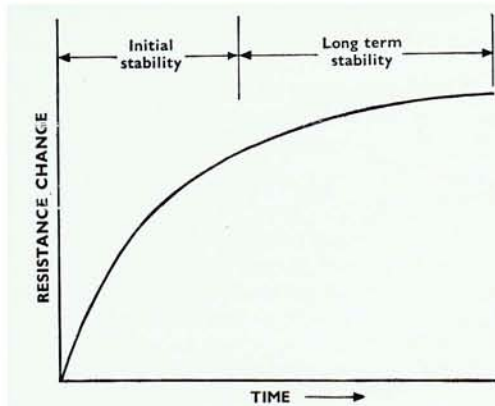


Fig. 1. Typical stability curve for a carbon or tin oxide film resistor.

20 per cent or greater, and to meet a figure of 15 per cent, or even 10 per cent, would involve an uneconomically restricted initial selection tolerance. On the other hand, metal film resistors would meet the requirements for the closer total excursions but, at the present time, they would be very expensive, and there is a certain degree of doubt as to their reliability. This subject of reliability will, however, be dealt with later.

Essential Characteristics of Film Resistors for this Application

Two important features emerge from the study of the behaviour of film resistors under long-term load. The first feature is that there is initially some incidence of resistors giving rise to anomalous changes of resistance or even becoming open-circuit. This soon falls to the point where it is negligible. This aspect has been pursued further and it is found that a pre-conditioning or stabilization process can be devised which can ensure that the incidence of such defective resistors is negligible, even initially. In passing it is necessary to point out that the occurrence of defectives in tin oxide resistors is very much lower than with pyrolytic carbon resistors. The second feature is that film resistors have a characteristic behaviour pattern. It is found that with both pyrolytic carbon and tin oxide resistors there is a settling down period during which the rate of change of resistance is fairly high and this is the 'initial stability' of the component. This period may be as short as 50 hours for low resistance values and up to 500 hours for higher values. After this the changes are very much smaller and they appear to be a linear function of time. Fig. 1 shows the characteristic pattern of stability and it will be clear that there are two parts to the curve; substantial initial change and, after that, a very much slower drift. In order to predict the resistance of a resistor these two effects must be separated. Thus, the initial stability, once it has been achieved, is no longer a factor in the behaviour of the component and thereafter one is essentially concerned with the long-term stability. If the magnitude of this stability is established in terms of per cent per thousand hours it

follows that for given operating conditions the total magnitude of this change can be computed.

A further factor which must be taken into account is the load characteristic, i.e. the change of resistance which takes place because of the combined effect of temperature rise and temperature coefficient. As a resistor subject to load will reach its steady state temperature in a matter of a few minutes it is convenient, from the user's point of view, to regard this as an instantaneous change.

Thus, in attempting to predict the behaviour of the component one has to take into account:

- (a) The instantaneous change due to load application.
- (b) The initial stability which is completed in 50 to 500 hours.
- (c) The long-term stability.

Table 1 gives observed values for these parameters on current pyrolytic carbon film and tin oxide resistors.

It can be seen that with a long-term stability of better than 0.1 per cent/1,000 hours one is in a position to predict the effect of 10,000 or 25,000 hours use.

Unfortunately, in any class of resistor the characteristics of the resistor will change with resistance value as well as with resistor dimensions, so that a different figure for these various factors must be adopted for each resistance value. There is, of course, no point of discontinuity in the relationship except that which arises at the critical resistance value, that is the resistance value above which the power dissipation is limited by the voltage limitation, so that it is not necessary to test every resistor in the spectrum. It is sufficient to test only representative values and the curve may be drawn by interpolation.

In order to illustrate the sort of calculation which the resistor engineer needs to perform, two examples are given:

TABLE 1

	PYROLYTIC CARBON FILM	TIN OXIDE FILM
Temperature coefficient (parts per million)	-180 to -250 for low values -500 to -700 for high values	0 to +500 for low values 0 to -500 for high values
Initial load stability (per cent.)	0 to ± 0.2 for low values $+0.25$ to $+0.75$ for high values	± 0.5 to ± 1 for low values ± 1 to ± 2 for high values
Long-term load stability (per cent./1000 hours)	0 to $+0.02$ for low values 0 to $+0.04$ for high values	Less than 0.1 for all values

It should be noted that the figures for Tin Oxide Films relate to bulk production components with no stabilization. Much better performances can be obtained when required (i.e. RCS/114 standards).

EXAMPLE 1

A tin oxide resistor has an average film temperature rise of 50°C . a temperature coefficient between zero and $300/10^6$ positive, a maximum initial stability of ± 1 per cent and a maximum long-term stability of up to -0.06 per cent/1,000 hours. Fig. 2 indicates the expected relationship between resistance and time. It can be seen that the maximum range of change of resistance is from 2.5 per cent positive to 2.5 per cent negative. Accordingly, it is possible to construct Fig. 3 which shows the changes of Fig. 2 subtracted from a proposed total excursion of ± 7 per cent

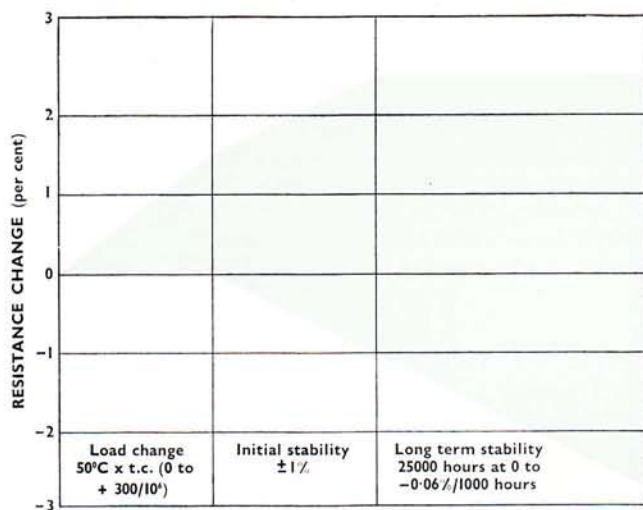


Fig. 2. Maximum range of variation of a typical tin oxide film resistor.

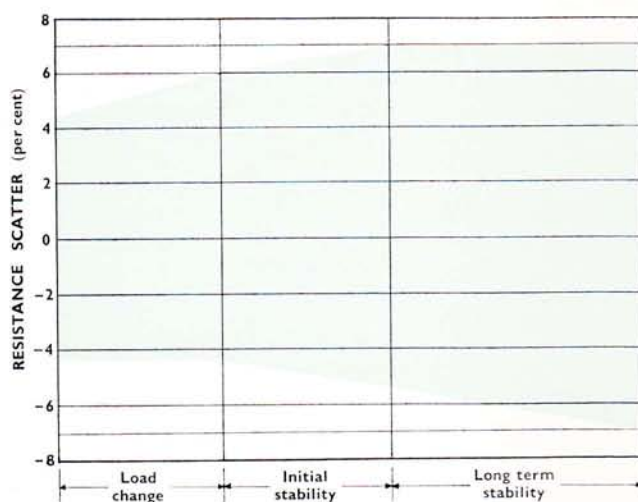


Fig. 3. Range of variation of a 7% total excursion tin oxide resistor.

so as to ensure the resistors remain within the ± 7 per cent of their nominal value at the end of 25,000 hours. This shows that the selection tolerance of the resistor must be between $+4.5$ per cent and -4.5 per cent.

EXAMPLE 2

A pyrolytic carbon film resistor has an average film temperature rise of 50°C ., a temperature coefficient of between 250 and $350/10^{\circ}$ negative, an initial stability of ± 0.3 per cent and a long-term stability of up to $+0.04$ per cent/1,000 hours. The calculations are similar and from Fig. 4 it will be seen that the initial selection tolerances must be $+4.9$ per cent to -2.9 per cent if the resistor is to remain within ± 5 per cent for the duration of a 25,000 hour life.

It would appear that if the manufacturer of the resistor can hold these initial selection tolerances, he can then give the total excursion guarantee that the customer requires. This may be simple to the user, but there are many problems for the manufacturer. He must understand his process to the point where he can guarantee that the drift rates are held to the limits which he is specifying, and this guarantee must operate on his bulk production, that is for every

resistor. The bulk production must be sufficiently controlled to enable him to hold selection tolerances necessary to produce an economic yield at the guaranteed total excursion. If these resistors are marketed only in the preferred resistance values and the initial selection tolerance is closer than ± 5 per cent, then any resistors outside his initial selection

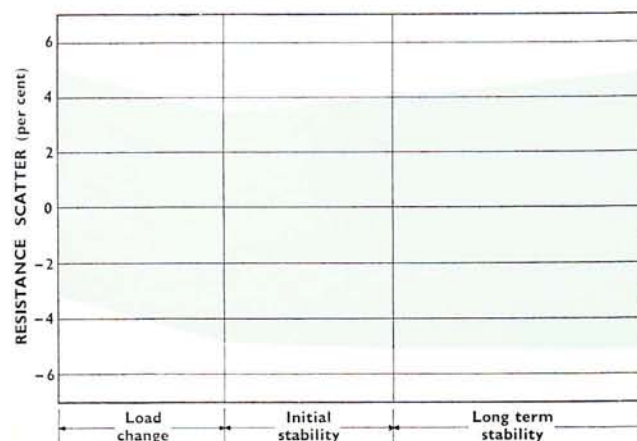


Fig. 4. Range of variation of a typical 5% total excursion carbon film resistor.

tolerances are not likely to be sold. This must be remedied by ensuring the accuracy of the control of production or by encouraging the use of a wider total excursion by a suitable price advantage.

Finally it is necessary for the manufacturer to market such resistors at a price that will encourage their use in the appropriate equipment.

Clearly, the desirable features of a total excursion resistor cannot be achieved unless the manufacturer is in bulk production, and with the necessary organization to control the processes and the quality of the product to the necessary degree.

Reliability

As mentioned earlier, reliability is not less important than stability. While a resistor must be regarded as a failure if it has drifted out of accuracy it is also useless if it is open-circuit or has changed in resistance value in a substantial or dramatic fashion at any part of its life. It is therefore necessary to give thought to the material which should be used for total excursion resistors.

With proper stabilization the reliability of pyrolytic carbon film resistors can be rendered better than 1 in 10,000 individual resistors or much better than 1 in 10,000,000 resistor-hours. This performance is adequate for even the most complicated equipments since it must be remembered that defective components will occur in the settling down period of the apparatus possibly even before installation. Thus, one can expect in any apparatus employing 10,000 resistors the chance of one resistor failure in the settling-in period, and thereafter the failure rate due to defective resistors to be much better than once in a thousand hours of continuous use, i.e., very much less frequently than once every six weeks. For part-time use that figure is very much improved. One must, however, give consideration to the acceptability of the product. Because of lack of understanding by users, the pyrolytic carbon film resistor has been given a reputation for unreliability and there are certain engineers who cannot be persuaded that the reputation is undeserved.

The tin oxide film is an excellent basis for the total excursion resistor. With this material the defective rates are

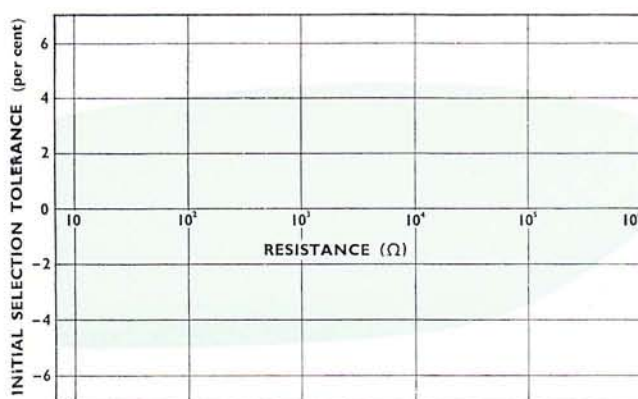


Fig. 5. Range of initial selection tolerance for $\pm 7\%$ total excursion.

very much lower than with carbon films, possibly because of the method of manufacture and possibly because of the affinity that the film has for the substrate. The tin oxide film is much less affected by atmospheric moisture and, what is more important still, should a hot spot develop for any reason there is no fear that it would burn out. In fact, as such films when subject to very high temperatures tend to produce a reduction in resistance value, the formation of a hot spot brings into action certain compensatory changes. It is for these reasons that the tin oxide film is considered to be the best basis for the first total excursion resistors. Field experience indicates that film resistors should have a substantial mechanical protection, which means that they must be moulded with a relatively thick coat of resin. As tin oxide resistors generally run at fairly high temperatures such resins must necessarily be high temperature resins so that the choice is somewhat limited. Nevertheless it is possible to fabricate a resistor of this type with satisfactory insulation.

Size is a matter of major importance and it requires very special processing methods to fabricate resistors small enough to meet current demands.

With a total excursion resistor the initial selection tolerance is bound to depend upon the resistance value since stability and temperature coefficient will vary. Fig. 5 gives an artificial example of the way selection tolerance might vary with resistance on a typical tin oxide film resistor. The band of initial selection tolerance becomes narrower with increasing resistance value, because the 25,000 hour stability deteriorates from about ± 2.0 per cent for low values to ± 3.5 per cent for high values. It is asymmetrical with respect to the axis on account of the variation in temperature coefficient from 0 to $+300/10^6$ for low values to 0 to $-500/10^6$ for high values. In actual practice the picture would be more complicated because the permanent resistance changes tend to be negative rather than positive. In addition the changes due to the effect of temperature coefficient may be reduced at high resistance values because power dissipation would be reduced because of a possible voltage limitation.

Where an apparatus is likely to operate over a wide range of temperatures then it would be necessary to take this into account and the limits of initial selection tolerance suitably adjusted. Fortunately, the adjustment necessary is bound

to be less than expected since low temperatures will be compensated for by the temperature rise of the resistor.

Identification of Total Excursion

It is clearly necessary to distinguish a resistor sold as a 'total excursion' component from one which is sold only to a selection tolerance. It is suggested that a total excursion resistor be indicated by using the normal three band colour

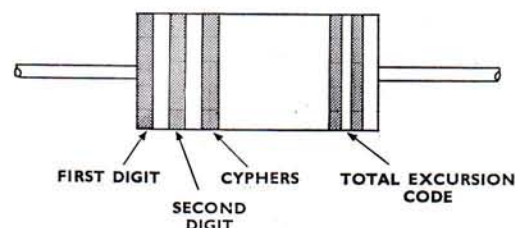


Fig. 6. Colour coding for total excursion resistor.

code at one end of the resistor to indicate the nominal resistance value with a double band of suitable colour and situated at the opposite end of the resistor to indicate the total excursion. The double band is considered to convey the conception of a limited range of resistance value and has the advantage that it can be applied by existing methods. The diagram of Fig. 6 indicates the general appearance of a component marked in this way.

The double bands would have colours as follows:

Brown	1 per cent total excursion
Red	2 per cent total excursion
Orange	3 per cent total excursion
Gold (or Green)	5 per cent total excursion
Violet	7 per cent total excursion
Silver	10 per cent total excursion

A 20 per cent total excursion might be indicated by a red and black band, though this may prove to be impracticable.

There may be other methods of indicating a total excursion resistor which will find preference to the double band method. There is something to be said for the use of a wavy line or a dotted line as alternative methods. The ultimate decision will necessarily depend upon the ready acceptance by the user and ease of application by the manufacturer.

Acknowledgments

The author wishes to thank his colleagues at Welwyn Electric Limited who have provided the test data upon which this article is based.

* Author's Note :

This article first appeared in the July 1959 issue of "Electronic Engineering", and the typical performance figures quoted for various types of resistors were intended to serve as comparisons and to illustrate the concept of Total Excursion.

The actual characteristics and Total Excursion performance of "Metox" Miniature Oxide Resistors are detailed on pages 5 to 9 of this brochure, and the full technical specification for Welwyn High Stability Carbon Resistors is contained in a new catalogue available on request.

WELWYN "METOX" RESISTORS

WELWYN ELECTRIC first became interested in the power handling properties, reliability and stability of tin oxide as a resistance element as early as 1954, and extensive research and development has been carried out since . . . and is, of course, continuing. "Metox" is the Trade Name given to all Welwyn metal oxide resistors, and the first "Metox" range was marketed in mid-1957, in the form of Power Oxide Resistors with ratings of 3 watts and over. These were designed for the Radio and Television Industry, to which millions have been supplied to date, and the reliability of this new type of resistor proved nothing short of exceptional, yielding no known failures in service when correctly used.

In 1957, development was proceeding also on a range of Precision Oxide resistors to conform to RCS(PROV.)114: Resistors, Fixed, High Stability (Metal and Oxide Film Types). R.C.S.C. Type Approval was obtained, and a range of "Metox" Precision Oxide Resistors has been available now for almost three years.

These two ranges of "Metox" Resistors were, however, for specialised applications; the first was to replace wire-wound resistors in Radio and Television receivers, and the second was to meet the Services' requirements for resistors with better performance characteristics than would be expected from those conforming to RCS 112: Resistors, Fixed, Film (Carbon).



"METOX" MINIATURE OXIDE RESISTORS

It was realised that another range of "Metox" resistors would be necessary to meet the special requirements of electronic computers and telephone exchanges. With the kind co-operation of many Computer Manufacturers, extensive market research was carried out to assess the reliability, stability, ohmic-range, size, and price required for a range of resistors suitable for these computer-type equipments. Based on these data, the new range of "Metox" Miniature Oxide Resistors was designed. These are inherently much more stable than carbon-composition resistors, and the design ensures extreme reliability.

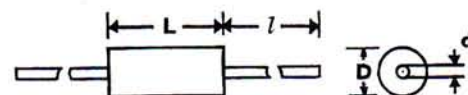
With such performance, it is obvious that the applications for this new range of resistors are now much wider than originally envisaged in the survey of the Computer and Telephone Industries.

With the introduction of "Metox" Miniature Oxide Resistors, Welwyn Electric is the first in the world to specify the performance of resistors in terms of Total Excursion stability, extending over three-years' continuous use. With this new concept, circuit designers no longer require to consider the separate variables of selection tolerance, load characteristic, initial stability and long term drift.

Now they need ensure only the correct and economic choice of Total Excursion resistor for the satisfactory operation of the circuit.

It is appreciated, however, that many Companies who are committed to extensive standardisation policies will not be able to adopt immediately the concept of Total Excursion as the all-embracing definition of resistor performance, and for this reason a more conventional Specification for "Metox" Miniature Oxide Resistors is detailed on page 9.

DIMENSIONS OF "METOX" MINIATURE OXIDE RESISTORS



Moulded Insulated Range	Type	Length (L)		Diameter (D)		Lead					Approx Weight in Gms.
		Inches	Milli-metres	Inches	Milli-metres	Length (l)		Diameter (d)			
						Inches	Milli-metres	S.W.G.	Inches	Milli-metres	
F20	.375 ± .025	9.5 ± 0.6	.145 ± .003	3.7 ± 0.1	1.5 ± 0.125	38.1 ± 3.1	21	.032	0.813	0.6	
F22	.585 ± .005	14.9 ± 0.1	.232 ± .003	5.9 ± 0.1	1.5 ± 0.125	38.1 ± 3.1	20	.036	0.914	1.0	
F23	.680 ± .005	17.3 ± 0.1	.307 ± .003	7.8 ± 0.1	1.5 ± 0.125	38.1 ± 3.1	20	.036	0.914	2.0	

Note: The dimensions of F20, F22 and F23 resistors conform to MIL-R11C; Styles RC20, RC32 and RC42 respectively.

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Lacquer Protected Range	Type	Length (L)		Diameter (D)		Lead					Approx Weight in Gms.
		Inches	Milli-metres	Inches	Milli-metres	Length (l)		Diameter (d)			
						Inches	Milli-metres	S.W.G.	Inches	Milli-metres	
F22A	.565 ± .025	14.3 ± 0.6	.175 ± .010	4.4 ± 0.25	1.5 ± .125	38.1 ± 3.1	20	.036	0.914	0.9	
F23A	.625 ± .025	15.9 ± 0.6	.240 ± .010	6.1 ± 0.25	1.5 ± .125	38.1 ± 3.1	20	.036	0.914	1.8	

Note:

Because of the preference for Insulated Resistors, the currently available Lacquer Protected Range should be regarded as obsolescent.
Designers are therefore requested to allow for the dimensions of the Moulded Insulated Range in all equipments.

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CONSTRUCTION OF "METOX" MINIATURE OXIDE RESISTORS

In the initial stages, the resistor as an integrated design was carefully considered, and by the correct choice and matching of materials and processes an overall construction of the highest performance and reliability has been achieved.

Ceramic Substrate

A ceramic is used for the resistor body for the following reasons: Firstly, because the ceramic and the tin oxide resistance element are compatible crystalline oxides (see photograph); secondly, the bond



Electron photo-micrograph of replica showing the crystalline structure of conducting tin oxide at 50,000 times magnification.

between the substrate and the resistance element is strong because the tin oxide is deposited at temperatures up to 1100°C.; thirdly, during processing, and in use, the resistor is not susceptible to mechanical damage; fourthly, ceramic bodies can be produced in a variety of intricate shapes so that the resistor construction can be designed to give the best mechanical and technical features.

Metal Oxide Film

An oxide is used because of its natural chemical stability in normal atmospheres at high temperatures and in humid conditions.

The nature of the tin oxide film is such that it has a natural affinity for the ceramic substrate, and when deposited, a molecular bond is produced.

Metallising

In order to achieve reliable electrical contact between the resistance element and the terminations, a pure-metal film is intimately bonded to each end of the oxide element.

Terminals

Copper axial terminal leads are located in each end of the body, and electrical continuity and mechanical strength are obtained by soldering the terminal leads to the metallising. The leads are solder coated to ensure immediate solderability on either manual or automatic assembly, even after extended storage periods.

Resistance Adjustment

The desired resistance value is obtained by cutting a helical groove through the oxide-film, and to ensure optimum reliability by even distribution of the electrical lead along the resistor, the helical groove always extends over a substantial length of the body of the resistor.

Resistor Protection and Insulation

The insulated versions have a moulded protection. The moulding provides increased terminal strength, and the intimate contact of the moulding with the resistance element, and the increased surface area, facilitates the removal of heat from the resistor.

In the lacquer-protected versions, a double coating of hard silicone lacquer is applied to the resistance element.

Coding and Identification

(A) Total Excursion Resistors

Three-colour-band coding is applied to one end of the resistors to indicate the ohmic value, and a two-band colour coding is applied to the other end of the resistors to indicate the Total Excursion.

(B) Selection Tolerance Resistors

Using the convention for colour coded resistors, four-colour-band coding is applied to one end of the resistors. The first three colours indicate the ohmic value, and the fourth colour indicates the selection tolerance.

TOTAL EXCURSION MINIATURE OXIDE RESISTORS

1 | Performance

In the article on pages 1-4, readers have been introduced to the principles of Total Excursion as a definition of resistor performance.

In "Metox" Miniature Oxide Resistors, the Total Excursion embraces the following Parameters which govern the actual value of a Resistor in use:

- (a) Initial Selection (or manufacturing) Tolerance.
- (b) Voltage Coefficient.
- (c) Temperature Coefficient.
- (d) Self Heating Effect.
- (e) Ambient Temperature of Operation.
- (f) Short-term Stability (Initial Drift).
- (g) Long-Term Stability.

2 |

Ratings and Ranges

Type	Rating @ 40°C.	Ohmic Range	Max. Voltage	Insulation Strength
F20	$\frac{1}{2}$ watt	10 Ω -270K	350v.	1000v.
F22 F22A	1 watt	10 Ω -270K	500v.	1000v. 500v.
F23 F23A	2 watts	10 Ω -270K	750v.	1000v. 500v.

Total Excursion Tolerances

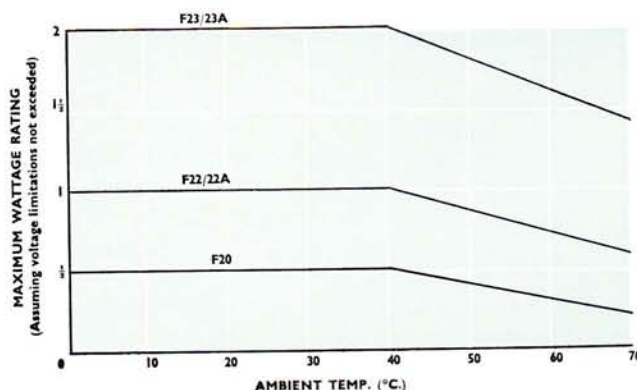
F20	$\pm 5\%$ T.E. and $\pm 7\%$ T.E. 47 Ω -270K
F22 F22A	$\pm 7\%$ T.E. and $\pm 10\%$ T.E. 47 Ω -270K
F23 F23A	$\pm 7\%$ T.E. and $\pm 10\%$ T.E. 47 Ω -270K

The appropriate Total Excursion specifies, for a period of up to three years (over 26,000 hours), the maximum deviation from the nominal resistance value of "Metox" Miniature Oxide Resistors dissipating up to full-load power continuously in ambient temperatures between 0-40°C. and relative-humidities not exceeding 80%.

In any production batch, however, the values and direction of the parameters which are embraced by Total Excursion are subject to statistical variation. As these parameters are unlikely all to be on the maximum limit and in the same direction at any one time, the majority of the resistors in a batch will always lie well within the permissible Total Excursion limits.

3 | Power Derating Necessary to Maintain Total Excursion Performance at Higher Ambient Temperatures

To maintain the Total Excursion performance at higher ambient temperatures, the power rating at 40°C. should be reduced as shown:

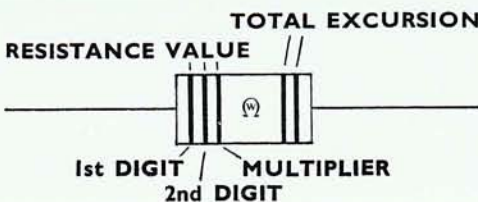


- 4 | Total Excursion Miniature-Oxide Resistors are available in the following preferred ohmic values:

Total Excursion	Range to BS 2488	Values in Decade 10-100 and decimal multiples or sub-multiples
$\pm 5\%$ and $\pm 7\%$	E24 Series	10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91
$\pm 10\%$	E12 Series	10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

5 | Resistor Marking

At one end of the resistor, the conventional resistor colour-bands to denote ohmic value are used for the first digit, second digit, and multiplier. At the other end of the resistor a double-band is used to denote the Total-Excursion:

RESISTOR MARKING		Total Excursion	Colour of Double Band
		$\pm 5\%$	Green (or Gold)
		$\pm 7\%$	Violet
		$\pm 10\%$	Silver

THE RELIABILITY OF "METOX" MINIATURE OXIDE RESISTORS

In many equipments such as Computers and Electronic Telephone Exchanges the reliability is of paramount importance because the services offered by these equipments are completely suspended in the event of operational failure. In choosing components, therefore, equipment designers have to evaluate the reliability with which the performance is maintained just as carefully as the performance itself.

With "Metox" Miniature Oxide Resistors, the reliability can be considered over three stages:

(a) Elimination of "Human Error" Faults

Such faults as wrong resistance marking, damage of resistors in transit, damage of resistor on insertion into equipments etc., can be classified as faults due to errors by operators. Such resistor faults are independent of value or performance and are normally discovered and rectified during the Inspection procedures of both the component and equipment manufacturers.

For "Metox" Miniature Oxide Resistors, faults would not exceed 0.05%; i.e. better than 1 in 2,000 resistors delivered.

(b) Elimination of "Rogue" Resistors

Any resistor in a batch exhibiting abnormal performance characteristics is classified as a "rogue". Generally, however, "rogue" performance becomes apparent and is rectified during the settling-in or acceptance-test period of the equipment.

In any batch of "Metox" Miniature Oxide Resistors, the incidence of "rogue" resistors in the first 100 hours of operation will not exceed 0.02%; i.e. better than 1 in 5,000 resistors.

(c) Long Term Reliability

After the "rogue" resistors have been eliminated, the long term reliability of "Metox" Miniature Oxide Resistors is such that the failure rate will not exceed 0.01% per 1,000 hours. This means that the probability of failure is not more than 1 in 10,000 hours of operation for every 1,000 Resistors incorporated in the equipment.

In this connection "failure" is not only complete breakdown of the resistor, but also means movement of the resistance value outside the specified Total Excursion limits. The probability is that any failures would be of this type, as any "rogue" resistors will have been eliminated early in the life of the equipment. Any resistor outside the Total Excursion limits after three-years' continuous operation and therefore classified as a "failure", is unlikely to have a drift rate exceeding 0.05% per 1,000 hours, and so a resistor "failure" will not necessarily cause breakdown of the equipment.

"METOX" MINIATURE OXIDE RESISTORS TO SELECTION TOLERANCES

In addition to the Total Excursion version, "Metox" Miniature Oxide Resistors are also available to normal Selection Tolerances.

1 Ratings and Ohmic Range:

Type	Rating @ 40°C.	Ohmic Range	Max. Voltage	Insulation Strength
F20	$\frac{1}{2}$ watt	1 Ω -270K	350v.	1000v.
F22 F22A	1 watt	1 Ω -270K	500v.	1000v. 500v.
F23 F23A	2 watts	1 Ω -270K	750v.	1000v. 500v.

2 Available Selection Tolerances

$\pm 5\%$ on values 10 Ω -270K in all sizes and
 $\pm 10\%$ on values 1 Ω -8.2 Ω in all sizes.

3 Preferred Ohmic Values Available:

Selection Tolerance	Range to BS 2488	Values in Decade 10-100 and decimal multiples or sub-multiples
$\pm 5\%$	E24 Series	10, 11, 12, 13, 15, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 43, 47, 51, 56, 62, 68, 75, 82, 91
$\pm 10\%$	E12 Series	10, 12, 15, 18, 22, 27, 33, 39, 47, 56, 68, 82

4 Resistor Marking

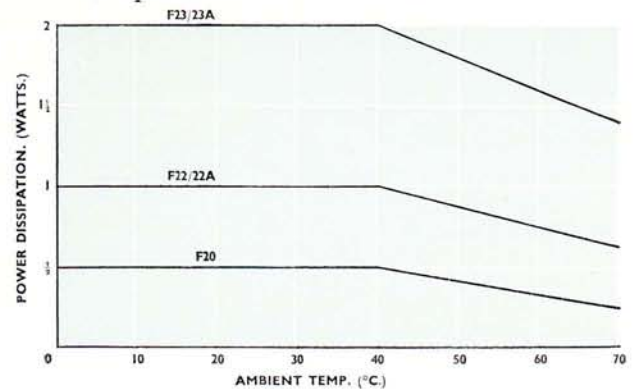
Conventional four-colour band marking:

SELECTION TOLERANCE			
1st Colour Band	2nd Colour Band	3rd Colour Band	4th Colour Band
Resistance value 1st Digit	Resistance value 2nd Digit	Resistance value Multiplier	$\pm 5\%$ Sel. Tol.: Gold $\pm 10\%$ Sel. Tol.: Silver

5 Surface Temperature Rise

Resistor Type	F20	F22/F22A	F23/F23A
Rating @ 40°C. (watts)	$\frac{1}{2}$	1	2
Max. Temperature Rise (°C.) at Nominal Rating	50	70	100

6 Variation of Maximum Permissible Power dissipation with Ambient Temperature:



7 Temperature Coefficient

The temperature coefficient will not exceed $\pm 0.05\%$ per °C. throughout the range.

8 Stability

- Maximum change in resistance due to ageing will not exceed 1% per year.
- For 10,000 hours operation under full load conditions at 40°C., or suitably derated for higher ambient temperatures, the stability is better than 2% for the lower values, and will not exceed 3% even for the highest values.
- The subsequent rate of change will not exceed 0.05% per 1,000 hours of operation.
- Under humid conditions, including light D.C. loading, the change will not exceed 2% in 2,000 hours.

9 Noise Level

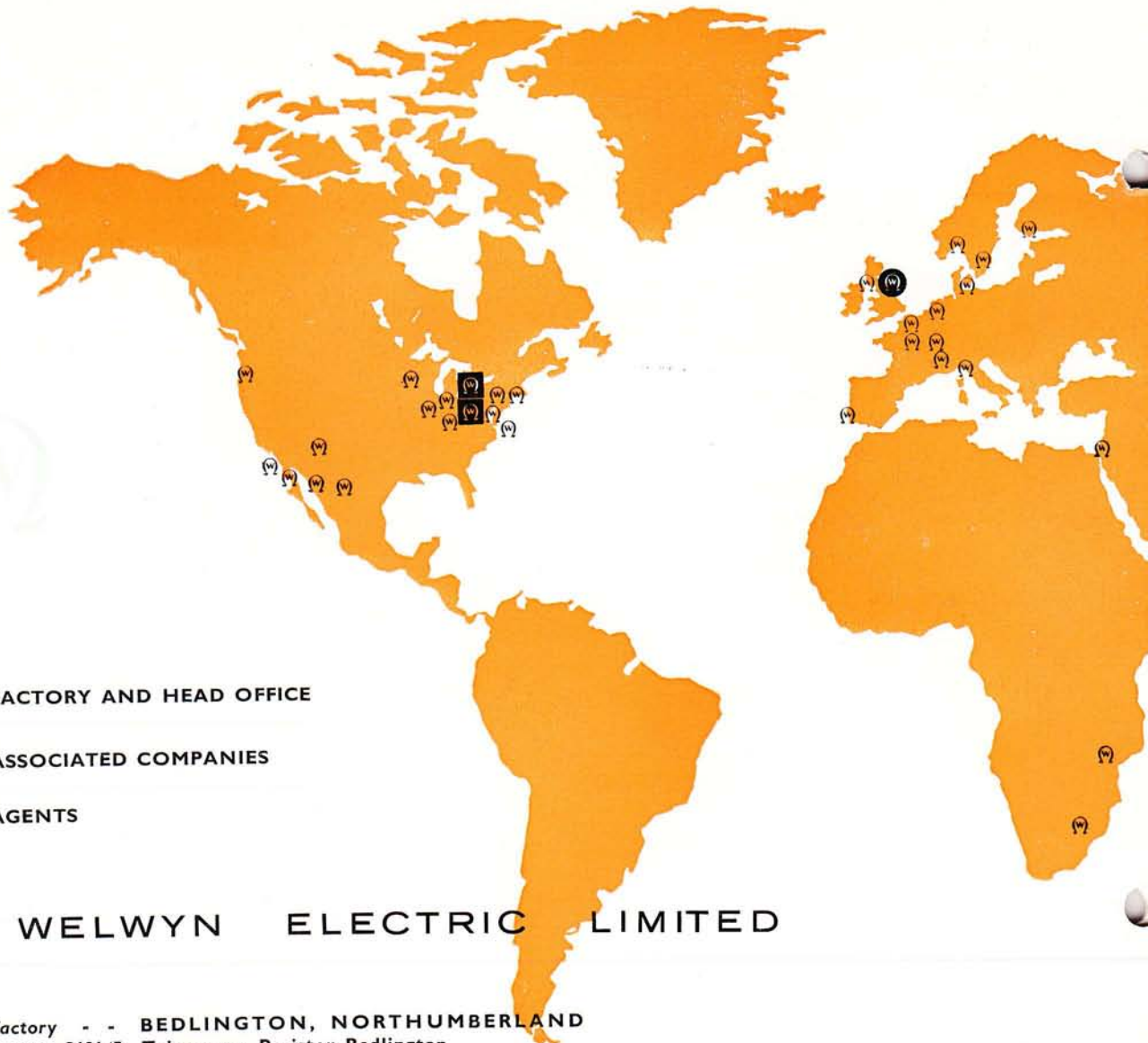
Less than 0.5 μ V per volt over a frequency decade. For multiple or sub-multiple decades, this figure should be multiplied by $\sqrt{N}$, where N = the number (or fraction) of frequency decades.

10 Voltage Coefficient

The voltage coefficient will not exceed 0.005% per volt applied.

11 Reactance

"Metox" Miniature Oxide Resistors have a very low distributed capacitance and inductance, which can be ignored for frequencies up to 20 Mc/s. The shunt capacitance will not exceed 0.5 μ F.



FACTORY AND HEAD OFFICE



ASSOCIATED COMPANIES



AGENTS

WELWYN ELECTRIC LIMITED

Head Office and Factory - - **BEDLINGTON, NORTHUMBERLAND**
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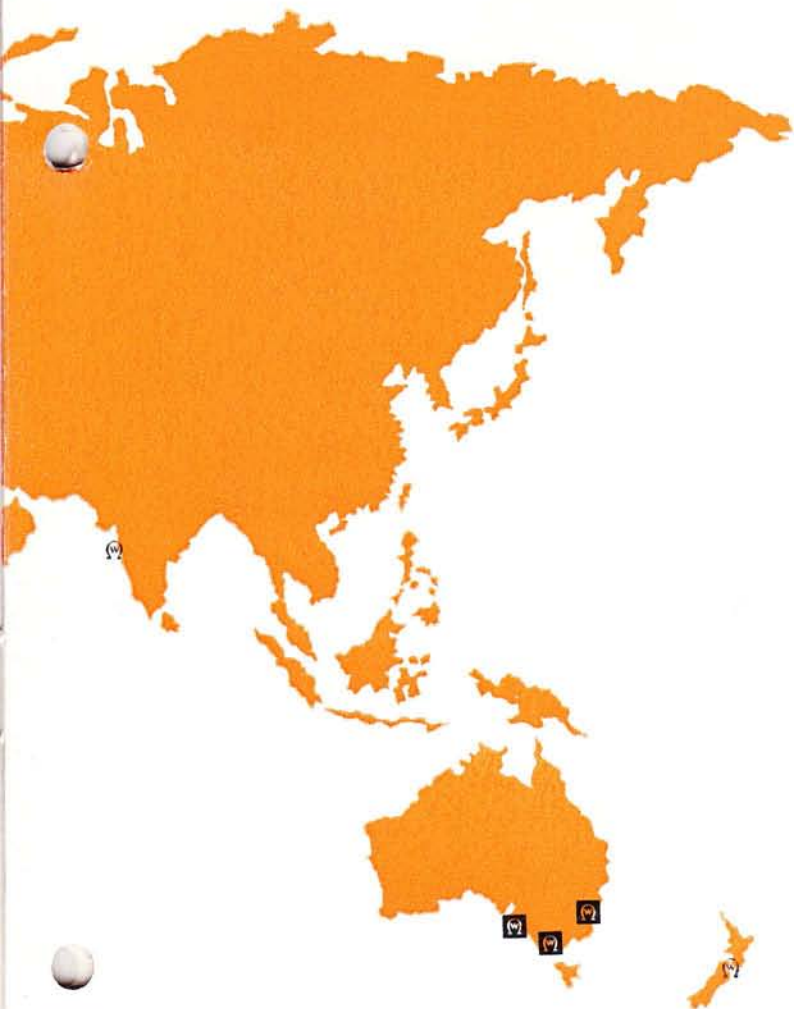
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METOX MINIATURE OXIDE RESISTORS

