Product Data

SECTION 9201
THYRITE® VARISTORS
QUICK CATALOG

DESCRIPTION:

THYRITE® is a nonlinear resistance material in which the current varies as a power of the applied voltage. Because of this notable electrical property, Thyrite has found important applications in the electric-power, communications, and electronic industries. The benefits derived from its use would be difficult, if not impossible, to obtain without Thyrite.

APPLICATIONS:

- For protective purposes (to limit voltage surges)
- As a stabilizing influence on circuits supplied by rectifiers
- As a potentiometer (the division of voltage can be made substantially independent of load current)
- For the control of voltage-selective circuits, either independent of, or in combination with, electronic devices.

SALES AND SERVICE:

GENERAL ELECTRIC OFFICES:

EDMORE, MICHIGAN 48829
P. O. Box 72
(517) 427-5151

CHICAGO, ILLINOIS 60641
3800 N. Milwaukee
(312) 777-1600

CLIFTON, NEW JERSEY 07014
200 Main Avenue
(201) 947-4065

LOS ANGELES, CALIFORNIA 90018
2106 W. Washington Blvd.
(213) 735-1001

ROCHESTER, NEW YORK 14618
3100 Monroe Avenue
(716) 381-6540

WELLESLEY, MASSACHUSETTS 02181
468 Washington Street
(617) 235-5521

(or contact your nearest G. E. Sales Engineer)

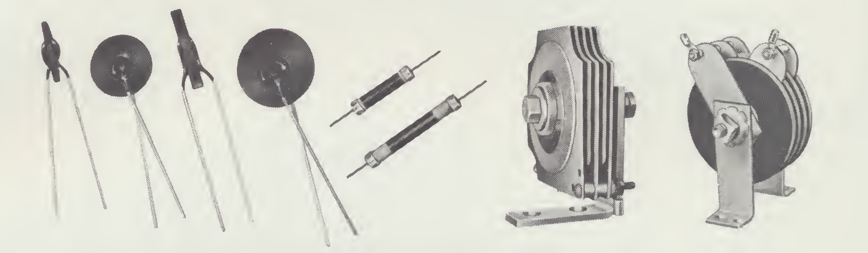

FIG. 1 TYPICAL THYRITE VARISTOR UNITS

OUTLINE DRAWINGS

(Dimensions in Inches)

Assemblies

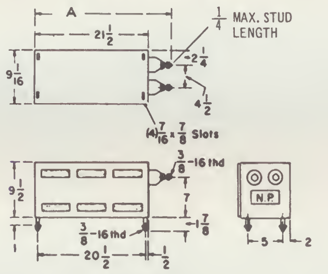

Fig. 2

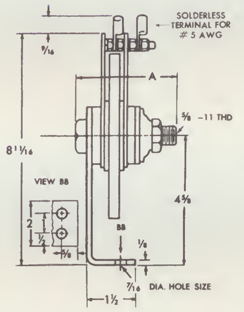

Fig. 3

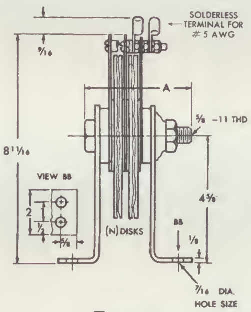

Fig. 4

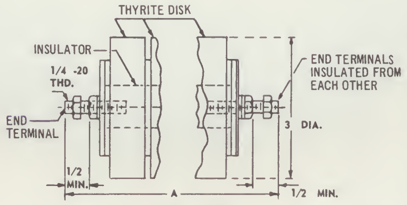

Fig. 5

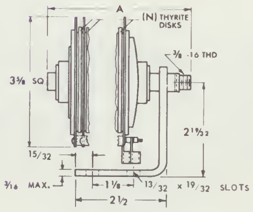

Fig. 6

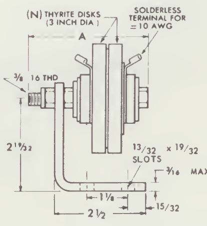

Fig. 7

Elements

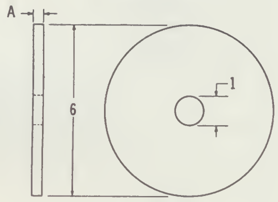

Fig. 8

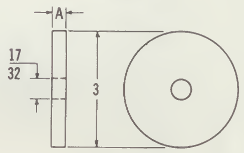

Fig. 9

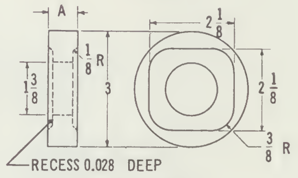

Fig. 10

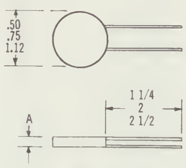

Fig. 11

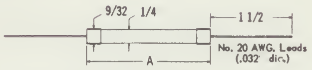

Fig. 12

NOTE: Most bracket mounted assemblies also available for stud mounting.

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QUICK CATALOG DATA

SPECIFICATIONS

Type	CATALOG NO.	MAXIMUM VALUES: Continuous Operating Voltage (Volts) DC	Continuous Operating Voltage (Volts) AC	Continuous Power Rating (Watts)	Peak Discharge Voltage For Given DC Discharge Current (Amps)	Peak Discharge Voltage For Given DC Discharge Current (Volts)	Discharge Capacity** (Watt-Seconds)	SPECIFICATIONS: DC Test Voltage & Current (Volts ±20%)	DC Test Voltage & Current (Amps)	Overall Length or Thickness "A" (In.)	Outline Fig. No. (Page 1)	Product Data Section
ROD 1/4"	72R-2200	3,300	2,950	0.4	.010	10,500		3,800	.0001	2-1/16	12	9252
	72R-2100	1,700	1,525	0.25	.001	3,700		2,000	.0001	1-1/8	12	9252
	71R-2100	1,100	1,000	0.25	.005	3,300		1,125	.0001	1-1/8	12	9252
	69R-2100	600	540	0.25	.010	1,900		920	.0010	1-1/8	12	9252
	68R-2100	300	275	0.25	.025	1,000		400	.0010	1-1/8	12	9252
	66R-2100	150	135	0.25	.050	600		165	.0010	1-1/8	12	9252
DISK 1/2"	70D-5010	150	135	.25	.10	400	30	175	.001	0.205	11	9211
	68D-5010	60	54	.25	.10	200	30	75	.0025	0.205	11	9211
	67D-5010	30	27	.25	.25	100	30	35	.005	0.205	11	9211
	65D-5010	15	13.5	.25	.25	60	20	15	.010	0.205	11	9211
DISK 3/4"	71D-7000	150	135	.75	.125	400	50	175	.005	0.060	11	9212
	68D-7000	60	54	.75	.25	185	50	70	.0125	0.060	11	9212
	66D-7000	30	27	.75	.50	100	50	35	.025	0.060	11	9212
	63D-7000	15	13.5	.75	1.00	52	50	17.5	.050	0.060	11	9212
DISK 1-1/8"	71D10000	300	270	1.5	.25	1,000	275	350	.005	0.150	11	9214
	68D10000	150	135	1.5	.50	575	275	175	.010	0.150	11	9214
	66D10000	60	54	1.5	1.0	305	275	70	.025	0.150	11	9214
	63D10000	30	27	1.5	1.5	175	275	35	.050	0.150	11	9214
WASHER 3"	71W30100	1,500	1,350	3.5	10	7,500	9,250	1,800	.0025	0.78	10	9217
	69W30100	300	270	3.0	1.5	1,350	5,100	520	.050	0.375	9	9217
	68W30100	150	135	3.0	2.5	800	5,100	230	.050	0.375	9	9217
	67W30100	60	54	3.0	5.0	250	1,700	85	0.100	0.125	9	9217
	66W30100	30	27	3.0	5.0	150	1,700	36	0.100	0.125	9	9217
	63W30100	15	13.5	3.0	10	100	1,350	25	0.500	0.100	9	9217
	62W30100	7	6.3	3.0	10	40	1,100	9	0.500	0.090	9	9217
WASHER 6"	69W60100	275	250	10	10	1,200	22,500	550	.500	0.375	8	9218
	68W60200	200	180	10	12.5	990	22,500	400	.500	0.375	8	9218
	68W60100	150	135	10	15	780	22,500	300	.500	0.375	8	9218

Type	CATALOG NO.	MAXIMUM VALUES: Continuous DC Operating* Voltage Rating (Volts)	Continuous Power Loss in Operation (Watts)	Discharge Capacity** (Watt-Seconds)	Peak Discharge Voltage For Given DC Discharge Current (Amps)	Peak Discharge Voltage For Given DC Discharge Current (Volts)	SPECIFICATIONS: No. of Disks (N)	Outline Fig. No. (Page 1)	Overall Length "A" (In.)	Approx. Wt. in Lbs. Net	Approx. Wt. in Lbs. Shipping	Product Data Section
3" ASSEMBLY	9RV3A1	6	3	1,100	10	40	1	7	2	3/4	1-1/4	9237
	9RV3A2	6	6	2,200	20	40	2	6	2-1/4	1-1/2	2	9237
	9RV3A3	6	12	4,400	40	40	4	6	2-1/2	1-1/2	2	9237
	9RV3A4	12	3	1,350	10	80	1	7	2	3/4	1-1/2	9237
	9RV3A5	12	6	2,700	20	80	2	6	2-1/4	1-1/2	2	9237
	9RV3A6	12	12	5,400	40	80	4	6	2-1/2	1-1/2	2	9237
	9RV3A7	25	6	2,700	10	160	2	7	2-1/4	3/4	1-1/2	9237
	9RV3A8	50	3	1,700	5	200	1	7	2-1/4	3/4	1-1/4	9237
	9RV3A9	50	6	3,400	10	200	2	6	2-1/4	1-1/2	2	9237
	9RV3A10	50	12	6,800	20	200	4	6	2-1/2	1-1/2	2	9237
	9RV3A11	100	6	3,400	5	400	2	7	2-1/4	3/4	1-1/2	9237
	9RV3A12	150	3	5,100	2.5	775	1	7	2-1/4	3/4	1-1/2	9237
	9RV3A14	300	3	5,100	1.5	1,350	1	7	2-3/4	3/4	1-1/2	9237
	9RV3A15	600	6	10,200	0.5	2,300	2	7	3-1/4	1	1-1/2	9237
	9RV3B3	12	6	2,200	10	80	2	7	2-1/4	3/4	1-1/2	9237
	9RV3B4	15	3	1,350	10	100	1	7	2	3/4	1-1/2	9237
	9RV3B5	15	6	2,700	20	100	2	6	2-1/4	1-1/2	2	9237
	9RV3B6	30	3	1,700	5	150	1	7	2-1/4	3/4	1-1/4	9237
	9RV3B7	30	6	3,400	10	150	2	6	1-1/4	1-1/2	2	9237
	9RV3B8	60	3	1,700	5	250	1	7	2-1/4	3/4	1-1/4	9237
	9RV3B9	60	6	3,400	10	250	2	6	2-1/4	1-1/2	2	9237
	9RV3B10	60	12	6,800	20	250	4	6	2-1/2	1-1/2	2	9237
	9RV3B11	100	6	3,400	5	400	2	7	2-1/4	3/4	1-1/2	9237
	9RV3A51	1,500	3.5	9,250	10	7,500	1	5	3-1/4	3/4	1-1/4	9240
	9RV3A52	3,000	7.0	18,500	10	15,000	2	5	4	1-1/4	2	9240
	9RV3A53	4,500	10.5	27,750	1	14,250	3	5	4-3/4	1-3/4	2-1/2	9240
	9BV3A54	6,000	14.0	37,000	1	19,000	4	5	5-5/8	2	3	9240
	9RV3A55	7,500	17.5	46,250	1	23,750	5	5	6-1/2	2-1/2	3-3/4	9240
	9RV3A56	9,000	21.0	55,500	0.5	25,200	6	5	7-3/8	2-3/4	4-1/4	9240
	9RV3A57	10,500	24.5	64,750	0.25	26,000	7	5	8-1/4	3-1/4	5	9240
6" ASSEMBLY	9RV6A1	150	10	22,500	15	780	1	3	3-7/16	2-3/4	5-1/4	9238
	9RV6A2	150	20	45,000	30	780	2	4	3-15/16	4-1/2	7	9238
	9RV6A3	150	30	67,500	45	780	3	4	4-15/16	5-3/4	8-1/2	9238
	9RV6A4	150	40	90,000	60	780	4	4	5-7/16	7	9-1/2	9238
	9RV6A5	300	20	45,000	10	1,440	2	4	4-11/16	4-1/2	7	9238
	9RV6A6	275	10	22,500	10	1,200	1	3	3-7/16	2-3/4	5-1/4	9238
	9RV6A7	275	20	45,000	20	1,200	2	4	3-15/16	4-1/2	7	9238
	9RV6A8	275	30	67,500	30	1,200	3	4	4-15/16	5-3/4	8-1/2	9238
	9RV6A9	275	40	90,000	40	1,200	4	4	5-7/16	7	9-1/2	9238
	9RV6A10	550	20	45,000	5	2,160	2	4	4-11/16	4-1/2	7	9238
	9RV6A50	150	200	450,000	300	780	20	2	23-7/8	52	59	9238
	9RV6A51	200	200	450,000	250	990	20	2	23-7/8	52	59	9238
	9RV6A52	275	200	450,000	200	1,200	20	2	23-7/8	52	59	9238
	9RV6A53	300	240	540,000	170	1,550	24	2	23-7/8	57	64	9238
	9RV6A54	400	240	540,000	140	1,900	24	2	23-7/8	57	64	9238
	9RV6A55	550	240	540,000	60	2,160	24	2	23-7/8	57	64	9238
	9RV6A60	150	100	225,000	150	780	10	†	17-3/4	33	40	9238
	9RV6A61	200	100	225,000	125	990	10	†	17-3/4	33	40	9238
	9RV6A62	275	100	225,000	100	1,200	10	†	17-3/4	33	40	9238
	9RV6A63	300	120	270,000	135	1,550	12	†	17-3/4	35	42	9238
	9RV6A64	400	120	270,000	70	1,900	12	†	17-3/4	35	42	9238
	9RV6A65	550	120	270,000	30	2,160	12	†	17-3/4	35	42	9238

*A-c voltage rating of approximately 90 percent d-c voltage rating may be used.

**Watt-seconds discharge capacity should not be exceeded by the stored energy ($W = \frac{1}{2}LI^2$) in the magnetic or inductive field. Discharge of maximum stored energy (equal to discharge capacity value) will raise Thyrite varistor temperature about 80° C.

†Same as Fig. 2 except substitute 15-3/8" for 21-1/2" dimension, and 14-3/4" for 20-1/2" dimension.

MAXIMUM RATINGS:

Continuous Body Temperature – 110° C.
Short-Time Body Temperature – 150° C.

NOTE: All varistors moisture protected with silicone impregnation. All disks are furnished with black dielectric coating as standard.

For more detailed information on performance or specifications of a particular Thyrite® Varistor, refer to the Product Data Section listed in the right hand column for that Thyrite® Varistor.

9201/12/64/15M

GENERAL CHARACTERISTICS OF THYRITE® VARISTORS

DESCRIPTION:

Thyrite is a General Electric Trademark for a non-linear resistance material in which the current varies as a power of the applied voltage. Voltage sensitive Thyrite Varistors have been used to great advantage in many important applications in the electrical-power, communications, and electronic industries.

Thyrite material is made from electrical grade silicon carbide, milled and mixed in accurate proportions with a suitable ceramic binder. The material is pressed or extruded to the desired shape and sintered under carefully controlled atmospheric and temperature conditions to produce a hard ceramic-like material. Various types of electrode surfaces can be applied and lead wires attached when desired. Small sizes are usually supplied with wire leads; the larger sizes in washer assemblies either parallel and/or series connected.

Thyrite Varistors are available in disk, rod, and washer form in diameters of 0.25 to 6 inches. They are made in 0.15 to 0.5 inch diameter rods from 0.5 to 2 inches in length. Special shapes that can be produced by pressure molding or extrusion are also available.

PERFORMANCE:

ELECTRICAL CHARACTERISTICS

To understand the electrical characteristics of this material, its performance may first be compared with a linear resistance material where:

$$I = \frac{E}{R}$$

which can be generalized as

$$\text{Current density} = \frac{\text{voltage gradient}}{\text{resistivity}}$$

For a Thyrite Varistor

$$\text{Current density} = \frac{(\text{Voltage gradient})^n}{\text{constant}}$$

The more common present-day expression which approximates the volt-ampere characteristic is:

$$I = \left(\frac{E}{C}\right)^n = KE^n$$

Where I = Instantaneous a-c or d-c flow
E = Instantaneous a-c or d-c voltage applied
C = A constant (volts at one ampere)
K = A constant (amperes at one volt)
n = An exponent

The constants K and C depend upon the resistivity, the geometry, and the exponent for any unit under consideration.

The exponent n depends upon various factors in the manufacturing process, and will usually be at least 2, but in special cases may be as high as 6 with higher resistivity material. (For ordinary linear resistance n = 1.) The higher these exponents, the more non-linear the electrical characteristics, and, hence, the greater the departure from a linear resistance characteristic. For example, the effect of doubling the applied voltage is to increase the current by a ratio of 2 in a plain wire-wound resistor; but doubling the voltage applied to a Thyrite Varistor will increase the current by a ratio of 4, if n = 2, and by a ratio of 64, if n = 6. To realize the advantages of the high exponent, the applied voltage should not be too low. A reduction in voltage gradient is usually accompanied by a reduction in exponent. At voltages less than one volt it is impractical to supply material having an exponent greater than 2.

Other relationships are easily derived, and calculations can be made according to the particular requirements of the application. For example, an equation which is frequently used is:

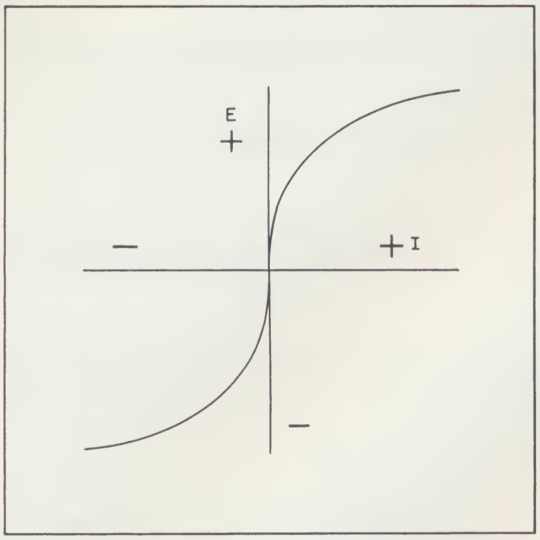
$$E = CI^{(1-a)}$$

whose symbols have already been defined, except a. The relationship between n and a is as follows:

$$n = \frac{1}{1-a}$$

Another form is $RI^a = C$

The volt-ampere characteristic curve, with both positive and negative values of voltage and current, is plotted on linear coordinates in Figure 1. It will be noted that the curve indicates essentially sym-

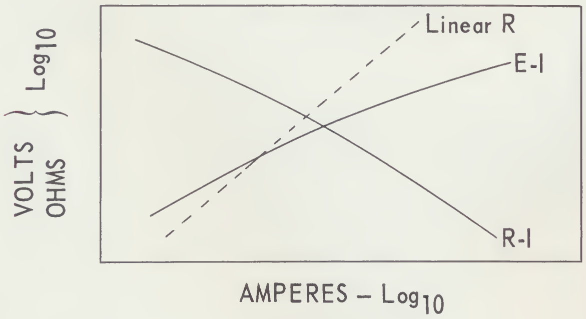


Characteristic E-I Curve

FIGURE 1

metrical characteristics for both positive and negative polarity.

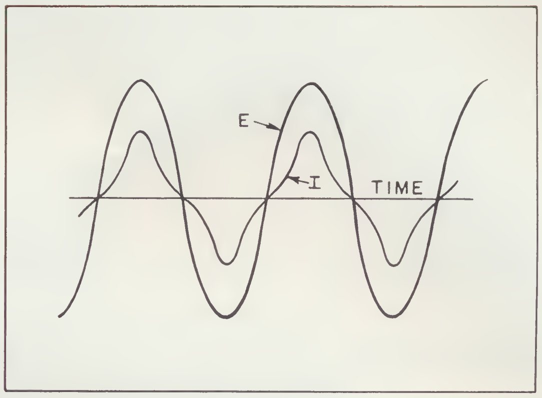
Since the non-linear voltage-current characteristic of Thyrite Varistors extends over an extremely wide current range, it is usually plotted on log-log coordinates (Figure 2). Moreover, when plotted on log-log coordinates, the volt-ampere characteristic approximates a straight line, which simplifies graphical work.



Characteristic E-I and R-I Curves for a Thyrite Varistor

FIGURE 2

Because of the variable resistance of this material, the wave shape of current is quite different from the wave shape of the voltage producing it. For example, if a sinewave form of voltage is applied, a typical wave form of current is shown in Figure 3, replotted from oscillograms. Note especially that each half cycle of current is also symmetrical with respect to time, as well as to polarity. With symmetrical a-c voltage applied, rectification effects are negligible.



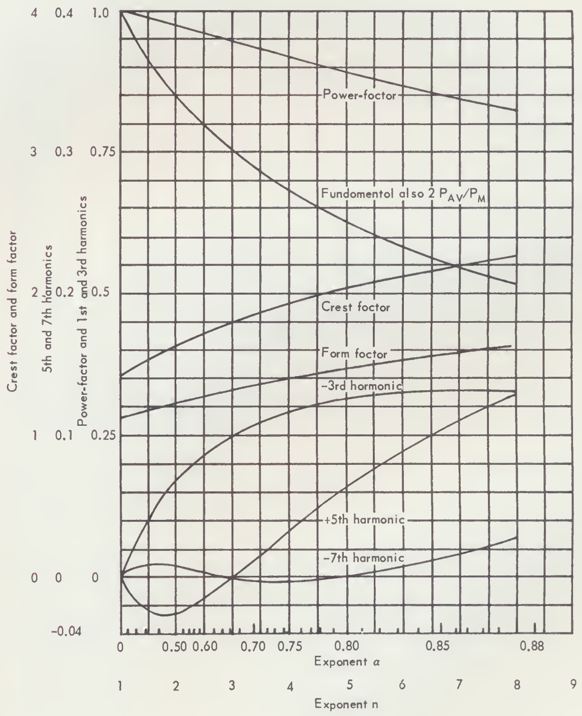
Plot of 60 Cycle A-C Voltage and Current Wave Form

FIGURE 3

The average power loss (P) in a Thyrite Varistor, with a-c voltage applied is obtained[1] from the usual formula:

$$P = E_{rms} \times I_{rms} \times (pf)$$

Although the voltage and current are exactly in phase, the power factor is somewhat less than unity, owing primarily to the fact that the wave shapes of voltage and current are different. For a typical n = 4, the power factor (pf) in the equation will be 0.92, from Figure 4.



Effect of Exponent Upon Harmonics, Power Factor, Crest Factor, and Form Factor for a Thyrite Varistor Subjected to a Sinusoidal Voltage.

FIGURE 4

For a sinusoidal voltage applied to a Thyrite Varistor Figure 4 also shows:

1. Crest Factor, the ratio of $\frac{\text{maximum current}}{\text{rms current}}$
2. Form Factor, the ratio of $\frac{\text{rms current}}{\text{average current}}$
3. Values for the fundamental, 3rd, 5th, 7th harmonics of current as fractions of the total maximum current.

RATINGS

Temperature:
Continuous Body Temperature – 110°C.
Short Time Body Temperature – 150°C.

An increase in body temperature tends to increase the current, the increase in current also being dependent upon the voltage applied. The change in resistance at constant voltage is from -0.4 per cent to -0.73 per cent per degree C, over the temperature range 0 to 100 °C.

Power:
CONTINUOUS
Ratings depend upon permissible temperature rise of Thyrite Varistors and provision made for dissipation of heat. A continuous rating of 0.25 watt per square inch of Thyrite Varistor surface is usually allowable in still air for separated disks and washers with the plane surfaces vertical. This conservative rating can be increased, where necessary, by the use of special provisions for cooling, such as radiating fins, forced-air draft, or immersion under oil or Pyranol®.

SHORT-TIME
Short-time ratings depend upon the volume of the disk. Assuming no time for radiation, a temperature rise of 80°C results from an energy input of 2000 watt-seconds per cubic inch of Thyrite Varistor.

PHYSICAL CHARACTERISTICS

Mechanical Strength:
Tensile – 1700 lbs. per sq. in.
Compressive – 23,000 lbs. per sq. in.

Porosity:
Up to 15 per cent (before impregnation).

Apparent Density:
39 grams per cubic inch.

Specific Heat:
0.17 gram-calories per degree C.

OTHER CHARACTERISTICS

Capacitance:
The dielectric constant ranges from 30 to 100 or more, depending on voltage applied and other factors.

Moisture Protection:
Moisture protection is provided by impregnation and/or coating with suitable materials.

Miscellaneous:
With proper application Thyrite Varistors:
Can be operated indefinitely without change in characteristic.
Are unaffected by pressure or vibration.
Have the same characteristics for impulses of microseconds duration as for d-c or a-c instantaneous values of current and voltage.
Have essentially equal non-linear characteristics for both polarities.

APPLICATIONS:

Many applications of Thyrite Varistors to electrical circuits involving inductance, capacitance, and other electronic components have evolved. A few general types of applications to basic circuits will be discussed below.

VOLTAGE SURGE PROTECTION

Thyrite Varistors can protect circuits and components from inductive voltage surges by limiting peak discharge voltage to an acceptable level when A-C or D-C magnetic or inductive circuit current is suddenly interrupted.

If an inductive direct current circuit is opened instantaneously without a discharge resistor connected across it, an infinite voltage could result and coil insulation would be punctured. When a contactor or knife switch opens the circuit, the circuit is partially protected by an arc following the switch blades, but at the instant the arc breaks, maximum discharge voltage is reached. The retarding effect of slow opening is not enough to protect most circuits. Some form of discharge resistor is needed to absorb the energy stored in the magnetic field; ($W = 1/2\ LI^2$, where L is the magnetic field inductance and I is the current interrupted).

If no protection is provided, circuit insulation is endangered. If a permanently connected linear resistor is used there is a consumption of power, under continuous operation, which may involve considerable expense. If a discharge resistor is inserted only on interruption of the circuit, additional wiring and other attachments are required to perform the operation.

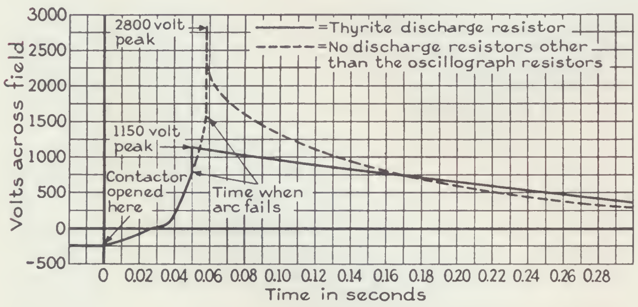
The non-linear resistance characteristics of Thyrite material, made first for lightning arrestors, makes it ideal for limiting "inductive kick" ($-L\frac{di}{dt}$) to a safe value. As shown in Figure 5, a Thyrite Varistor, when used as a discharge resistor permanently connected across a magnetic circuit, will be in a position to protect it whether the circuit is opened by an adjacent or remote switch, or the occurance of a fault. Resistance will decrease as the value of induced voltage increases, allowing more current to be drawn through the varistor. The magnetic field

Protective Circuit

FIGURE 5

energy which would ordinarily force the induced voltage higher, will be dissipated in the form of heat by the Thyrite Varistor.

Protective characteristics shown on product data sheets are planned with maximum discharge voltage peaks limited to values well within A.I.E.E. high-potential test standards. This product then, can safely be applied to old and new equipment. Maximum discharge voltage will be lower for any other point below maximum recommended current value, and higher for currents above this value. When connected across the circuit component to be protected, continuous power loss is approximately 2 to 5 per cent as compared to an equivalent fixed resistor that would give the same level of protection. Watt-seconds discharge capacity should not be exceeded by the stored energy ($W = 1/2\ LI^2$) in the magnetic or inductive field. Discharge of maximum stored energy equal to the discharge capacity value will raise the body temperature 80°C. In addition to personnel and insulation protection, switch life is extended by the suppression of contact arcing.



Voltage-time characteristic of a field discharging with and without a Thyrite Varistor. Curves are plotted from actual oscillograph records of an a-c motor field circuit being broken by a d-c contactor with blowout.

FIGURE 6

OTHER APPLICATIONS

Function Generation:

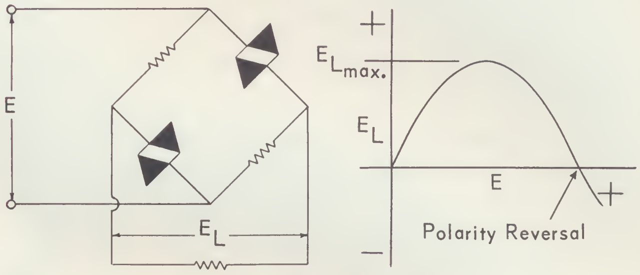
The circuit use of the non-linear E-I characteristic of this material permits simple circuits to perform relatively complex operations.

A network consisting of a Thyrite Varistor with shunt and series resistors will provide an output proportional to the square of the input. An input, off the series resistor to an amplifier, will allow direct squaring of the circuit input.

This material plus resistors in the input, output, and feedback circuits of operational amplifiers can also provide squaring and other non-linear functions including close approximations to sine and cosine functions.[3] The circuit function is dependent on the exponent n. Adjusting the n value of a particular unit downward by series or parallel addition of a resistor allows variation in the generation of non-linear functions.

Thyrite Bridge[2] Circuits:

Two Thyrite Varistors in the opposite arms of a bridge circuit cause E_L to depend on E in an entirely different manner, (Figure 7), than in a conven-al fixed resistor bridge.



Thyrite Varistor Bridge and Plot of Load Voltage E_L Vs. Input Voltage E.

FIGURE 7

In the region marked E_L max. there is a considerable range in E giving practically constant E_L. The polarity reversal of E_L is very sensitive to changes in E, making possible the use of this type of operation for detection purposes. Application of an alternating voltage input produces harmonics at E_L providing multiplication of the fundamental frequency of E.

REFERENCES:

(1) "The Calculation of Circuits Containing Thyrite® Varistors," by Theodore Brownlee; Application Data Section 9701

(2) "Thyrite Bridge Applications," by G. D. Barcus, Jr.; *Electrical Manufacturing,* Jan., 1958

(3) "Non-Linear Transfer Functions with Thyrite," by L. D. Kovach and W. Comley; I.R.E. Trans., Vol. EC-7, No. 2

For specifications of particular Thyrite Varistors refer to the Short Form Catalog Section 9201 or the specific Product Data Section.

MAGNETIC MATERIALS SECTION
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