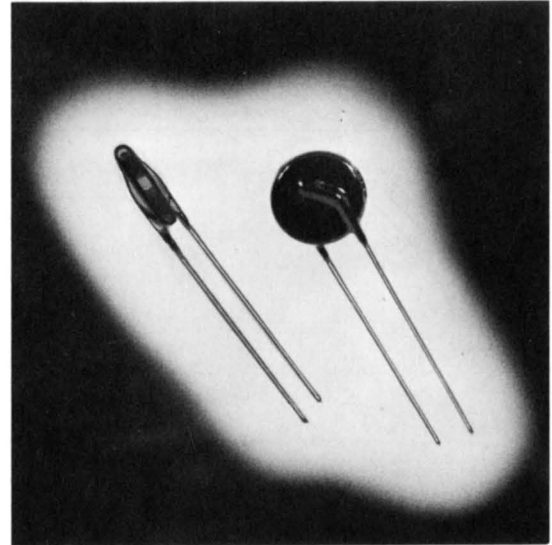


Discharge varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.



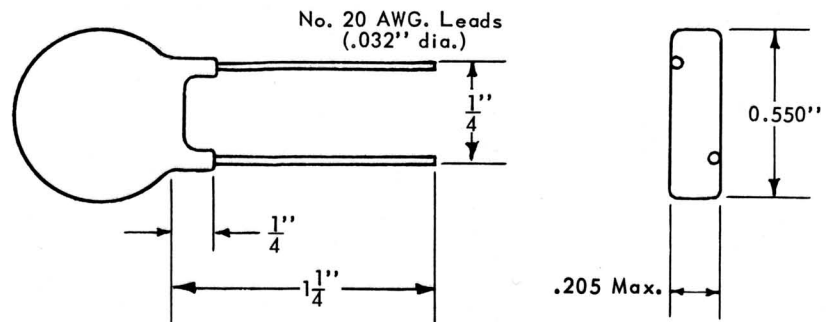
Characteristics at 25°C.

CATALOG NUMBER	MAXIMUM VALUES					SPECIFICATIONS		
	CONTINUOUS OPERATING VOLTAGE VOLTS		CONTINUOUS POWER RATING WATTS	DISCHARGE CAPACITY WATT-SECONDS	PEAK DISCHARGE VOLTAGE FOR GIVEN DC DISCHARGE CURRENT		DC TEST VOLTAGE & CURRENT	
	DC	AC			AMPS	VOLTS	VOLTS	AMPERES
70D-5010	150	135	.25	30	.10	400	175 ±20%	.001
68D-5010	60	54	.25	30	.10	200	75 ±20%	.0025
67D-5010	30	27	.25	30	.25	100	35 ±20%	.005
65D-5010	15	13.5	.25	20	.25	60	15 ±20%	.010

MAXIMUM RATINGS

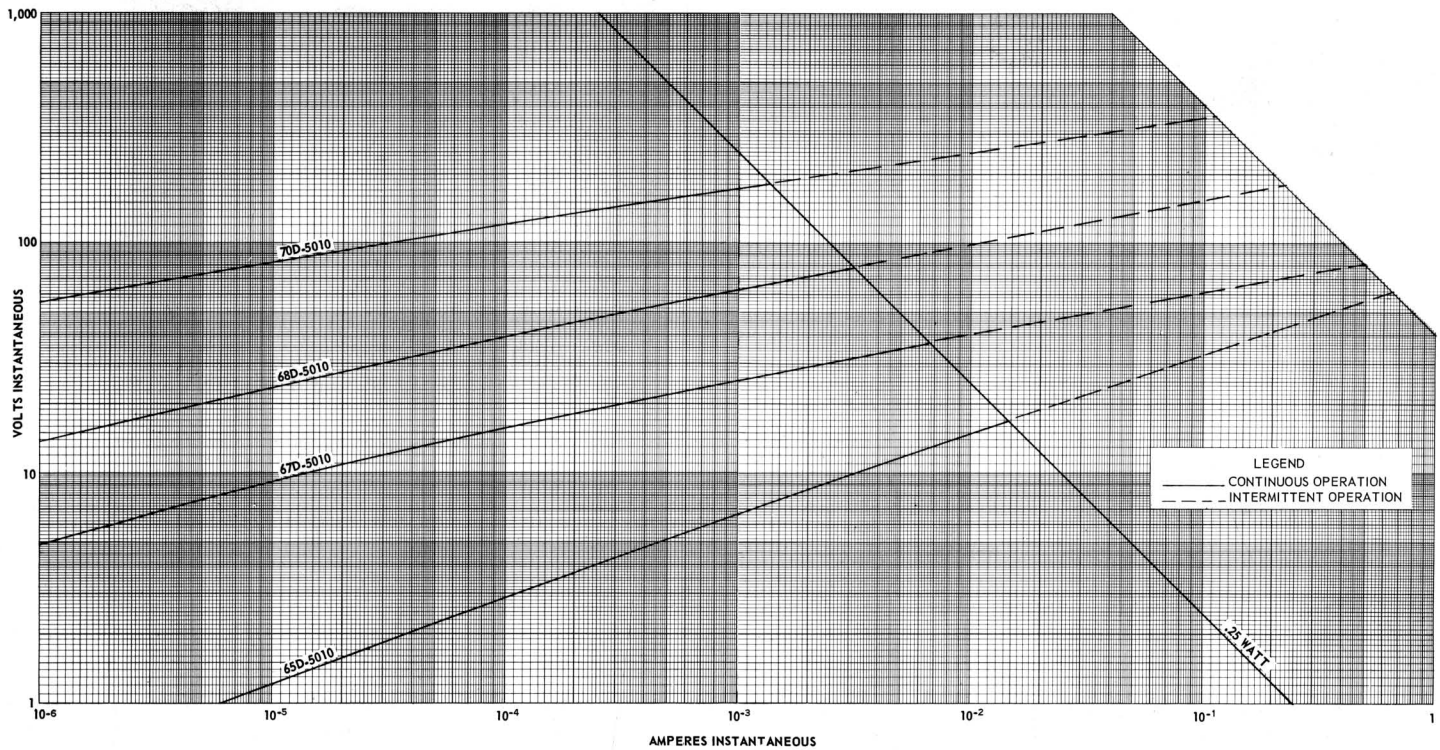
Continuous Body Temperature—110°C
 Short-time Body Temperature — 150°C

OUTLINE DRAWING



NOTE: Black dielectric coating applied after impregnation for moisture protection.

0.50" VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS

**SPECIAL VARISTORS:**

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

- Tolerances down to $\pm 10\%$ on resistance.*
- Voltage values other than stock standard.*
- Protective and/or Identification Coating.*
- Special Mounting or Assembly.*
- Different Lead Arrangement.*

ELECTRONICS
DEPARTMENT

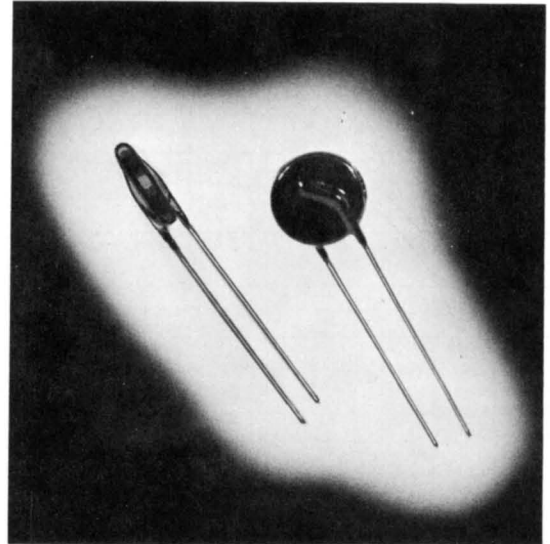


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Discharge varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.



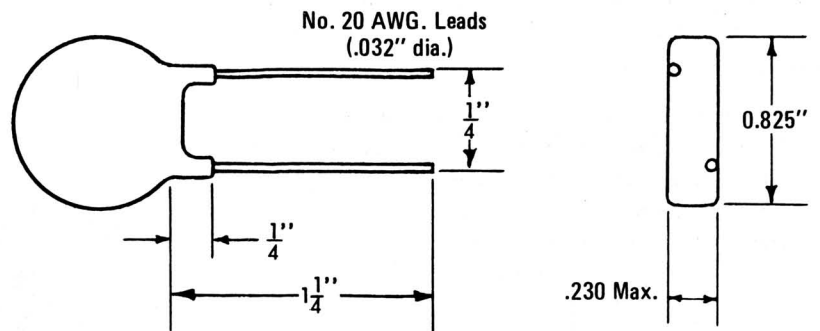
Characteristics at 25°C.

ORDER NUMBER	MAXIMUM VALUES						SPECIFICATIONS	
	CONTINUOUS OPERATING VOLTAGE (VOLTS)		CONTINUOUS POWER RATING (WATTS)	DISCHARGE CAPACITY (WATT-SECONDS)	PEAK DISCHARGE VOLTAGE FOR GIVEN DC DISCHARGE CURRENT		DC TEST VOLTAGE & CURRENT	
	DC	AC			(AMPS)	(VOLTS)	VOLTS	AMPERES
71D-7000	150	135	.75	50	.125	400	175 ±20%	.005
68D-7000	60	54	.75	50	.25	185	70 ±20%	.0125
66D-7000	30	27	.75	50	.50	100	35 ±20%	.025
63D-7000	15	13.5	.75	50	1.00	52	17.5 ±20%	.050

MAXIMUM RATINGS

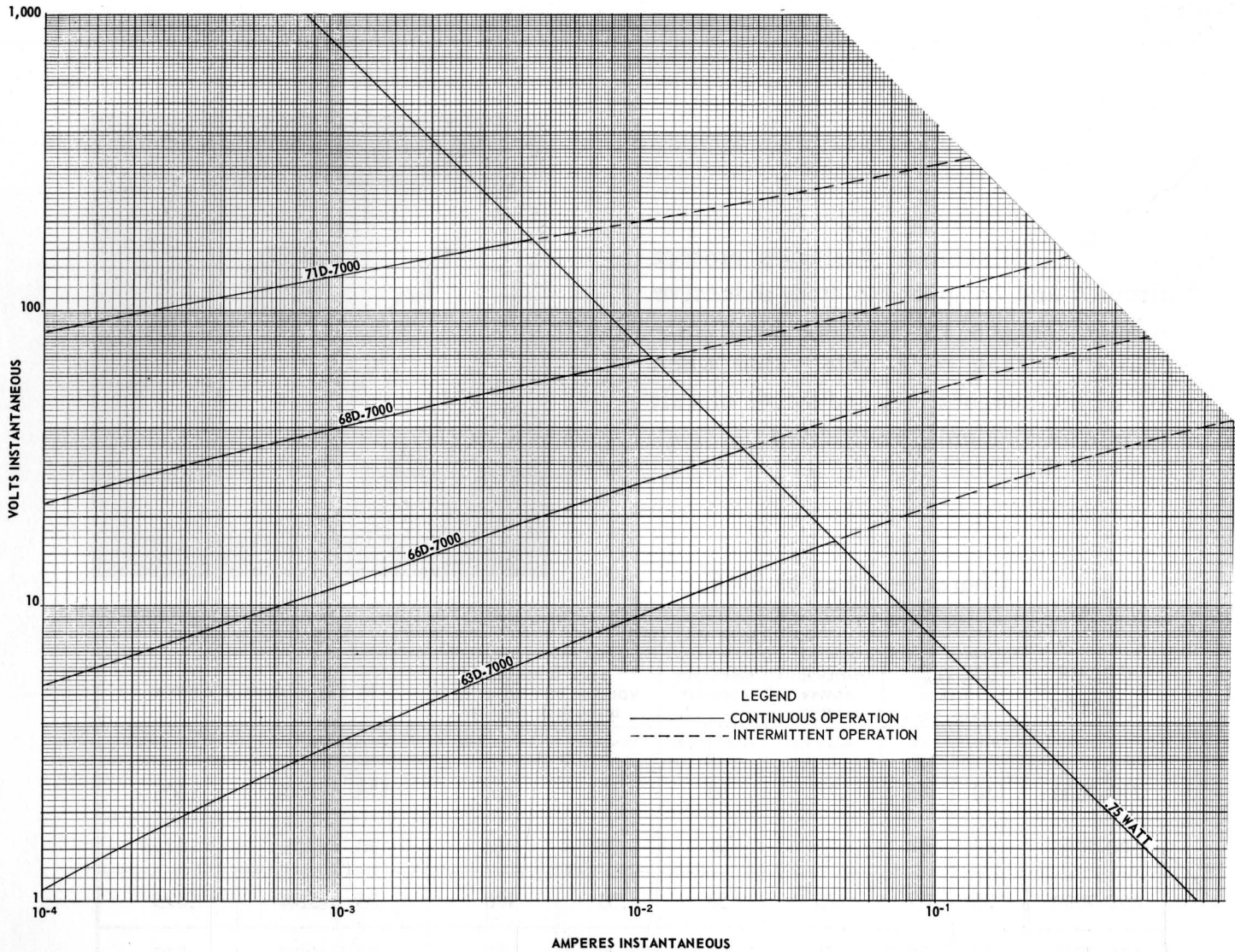
Continuous Body Temperature—110°C
Short-time Body Temperature — 150°C

OUTLINE DRAWING



NOTE: Black dielectric coating applied after impregnation for moisture protection.

0.75" VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS

**SPECIAL VARISTORS:**

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

Tolerances down to ±10% on resistance.
Voltage values other than stock standard.
Protective and/or Identification Coating.
Special Mounting or Assembly.
Different Lead Arrangement.

ELECTRONICS
DEPARTMENT

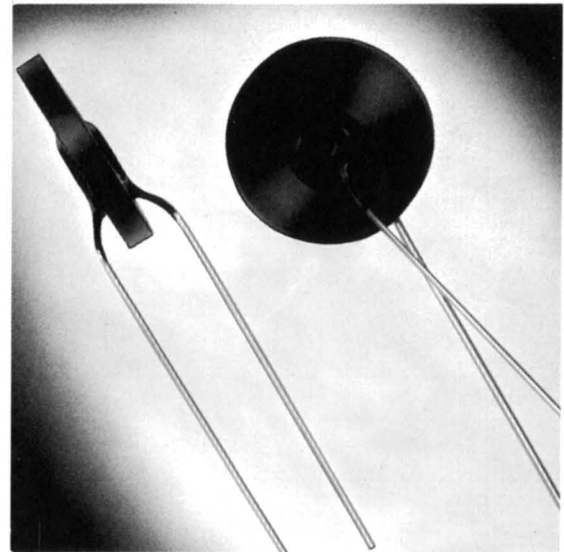


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Discharge varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.



Characteristics at 25°C.

ORDER NUMBER	MAXIMUM VALUES						SPECIFICATIONS	
	CONTINUOUS OPERATING VOLTAGE (VOLTS)		CONTINUOUS POWER RATING (WATTS)	DISCHARGE CAPACITY (WATT-SECONDS)	PEAK DISCHARGE VOLTAGE FOR GIVEN DC DISCHARGE CURRENT		DC TEST VOLTAGE & CURRENT	
	DC	AC			(AMPS)	(VOLTS)	VOLTS	AMPERES
71D10000	300	270	1.5	275	.25	1000	350 ±20%	.005
68D10000	150	135	1.5	275	.50	575	175 ±20%	.010
66D10000	60	54	1.5	275	1.0	305	70 ±20%	.025
63D10000	30	27	1.5	275	1.5	175	35 ±20%	.050

MAXIMUM RATINGS

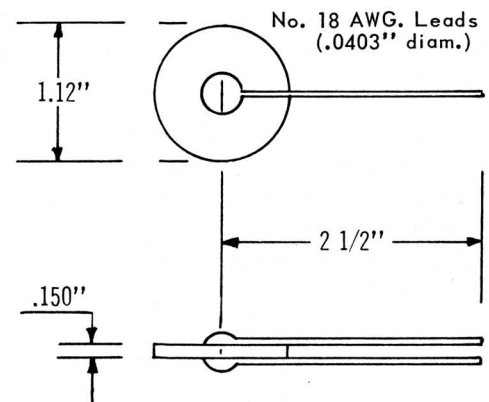
Continuous Body Temperature—110°C

Short-time Body Temperature — 150°C

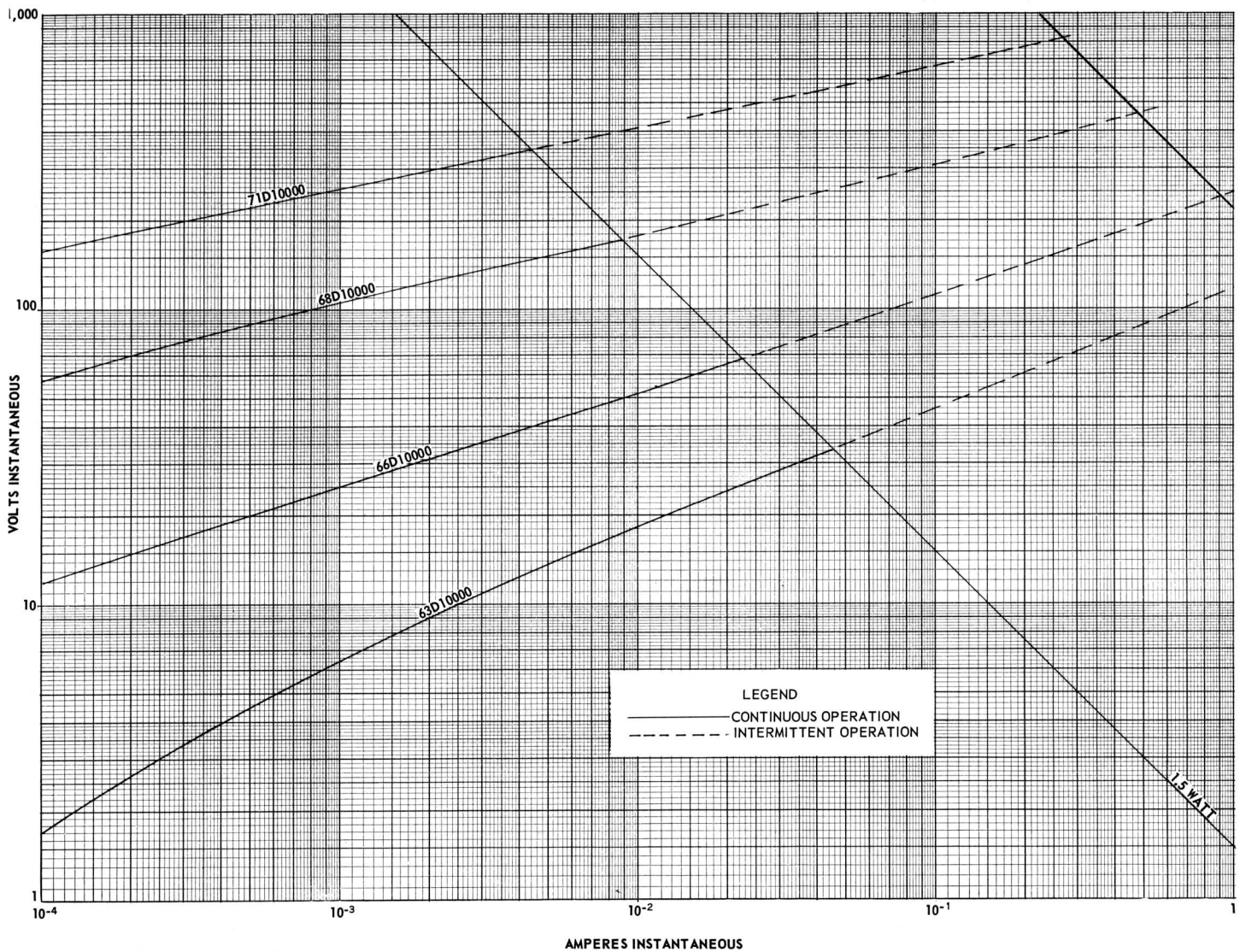
NOTE:

Black Glyptal Coated after Moisture Protection with Silicone Impregnation.

OUTLINE DRAWING



1.12" VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS



SPECIAL VARISTORS:

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

- Tolerances down to ±10% on resistance.*
- Voltage values other than stock standard.*
- Protective and/or Identification Coating.*
- Special Mounting or Assembly.*
- Different Lead Arrangement.*

ELECTRONICS DEPARTMENT

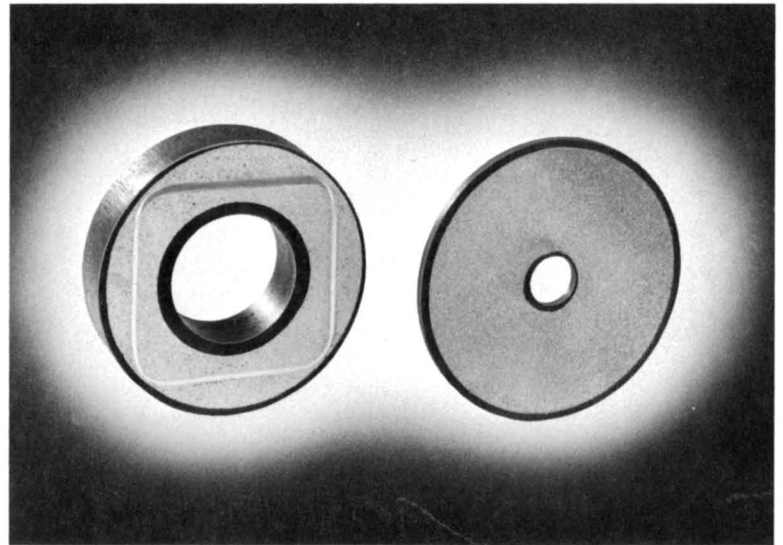


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Discharge varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.



Characteristics at 25°C.

ORDER NUMBER	MAXIMUM VALUES						SPECIFICATIONS		DIMENSIONS	
	CONTINUOUS OPERATING VOLTAGE VOLTS		CONTINUOUS POWER RATING WATTS	DISCHARGE CAPACITY WATT-SECONDS	PEAK DISCHARGE VOLTAGE FOR GIVEN DC DISCHARGE CURRENT		DC TEST VOLTAGE & CURRENT		HOLE DIAMETER INCHES	THICKNESS B INCHES
	DC	AC			AMPERES	VOLTS	VOLTS	AMPERES		
71W30100	1,500	1,350	3.5	9,250	10	7,500	1,800 ±20%	0.0025	Fig. 1	0.78
69W30100	300	270	3.0	5,100	1.5	1,350	520 ±20%	0.050	Fig. 2	0.375
68W30100	150	135	3.0	5,100	2.5	800	230 ±20%	0.050		0.375
67W30100	60	54	3.0	1,700	5.0	250	85 ±20%	0.100		0.125
66W30100	30	27	3.0	1,700	5.0	150	36 ±20%	0.100		0.125
63W30100	15	13.5	3.0	1,350	10	100	25 ±20%	0.500		0.100
62W30100	7	6.3	3.0	1,100	10	40	9 ±20%	0.500		0.090

MAXIMUM RATINGS

Continuous Body Temperature—110°C
 Short-time Body Temperature — 150°C

NOTE: Silicone Impregnation provided to insure protection against moisture.

OUTLINE DRAWINGS

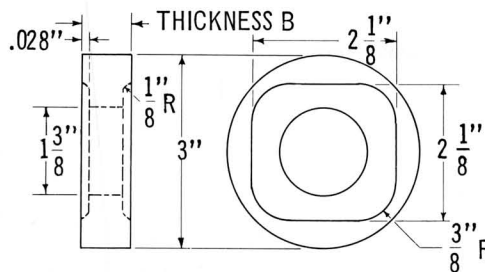


Fig. 1

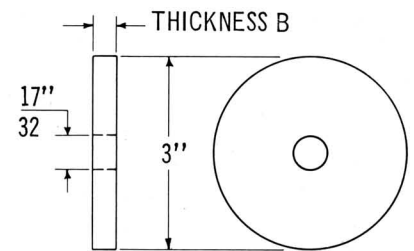
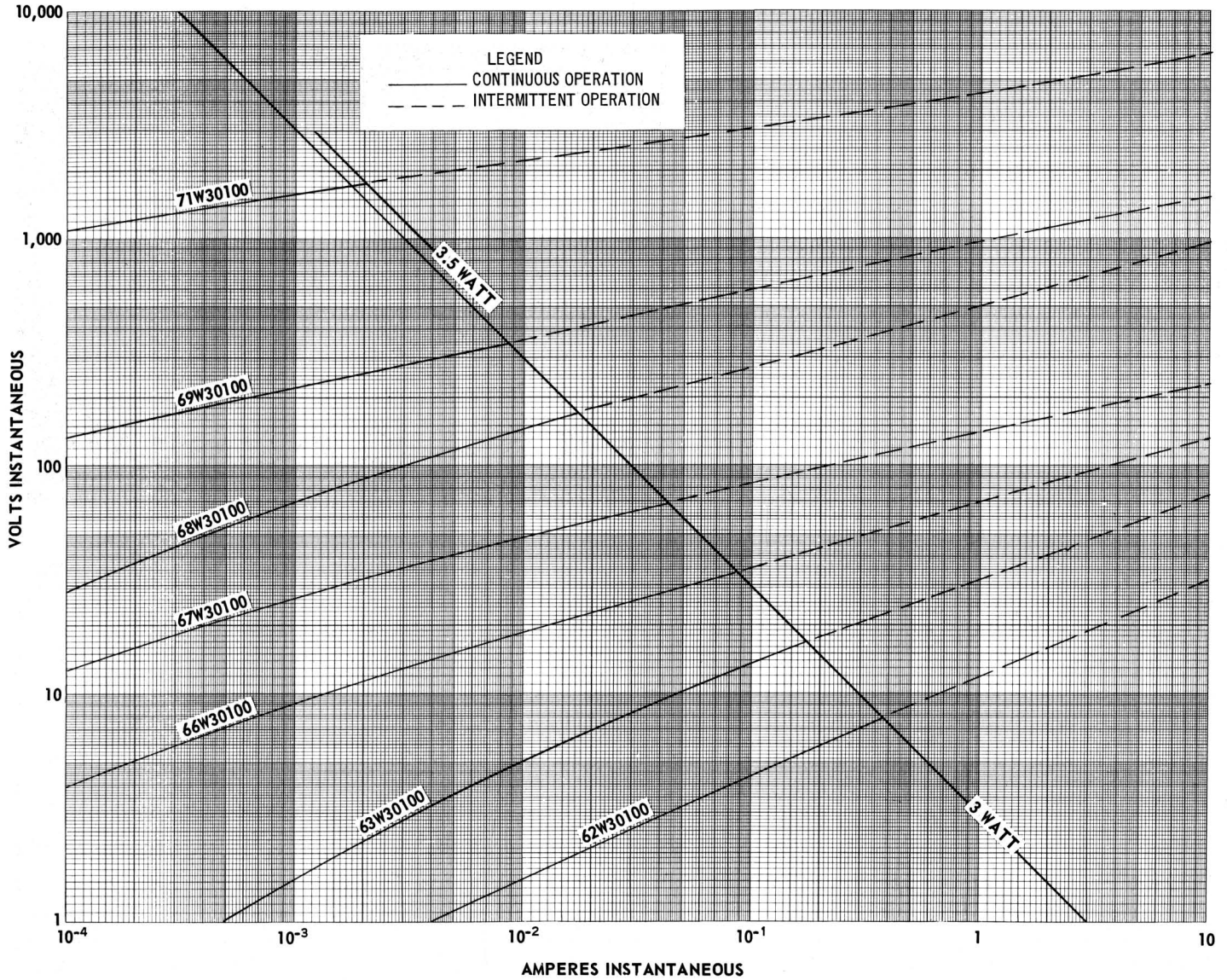


Fig. 2

3" VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS



SPECIAL VARISTORS:

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

- Tolerances down to ±10% on resistance.*
- Voltage values other than stock standard.*
- Protective and/or Identification Coating.*
- Special Mounting or Assembly.*

ELECTRONICS
 DEPARTMENT

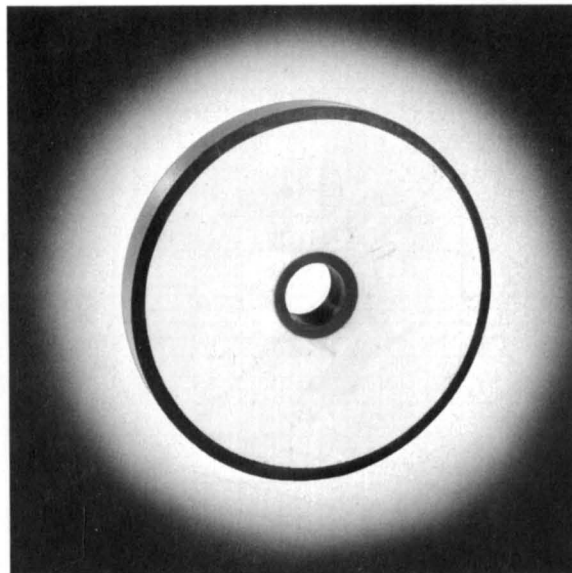


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Discharge varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.



Characteristics at 25°C.

ORDER NUMBER	MAXIMUM VALUES						SPECIFICATIONS	
	CONTINUOUS OPERATING VOLTAGE VOLTS		CONTINUOUS POWER RATING WATTS	DISCHARGE CAPACITY WATT-SECONDS	PEAK DISCHARGE VOLTAGE FOR GIVEN DC DISCHARGE CURRENT		DC TEST VOLTAGE & CURRENT	
	DC	AC			AMPS	VOLTS	VOLTS	AMPERES
69W60100	275	250	10	22,500	10	1,200	550 ±20%	0.500
68W60200	200	180	10	22,500	12.5	990	400 ±20%	0.500
68W60100	150	135	10	22,500	15	780	300 ±20%	0.500

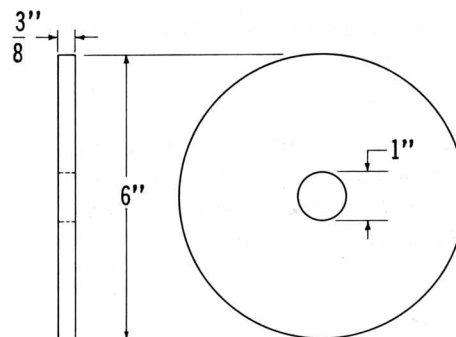
MAXIMUM RATINGS

Continuous Body Temperature—110°C

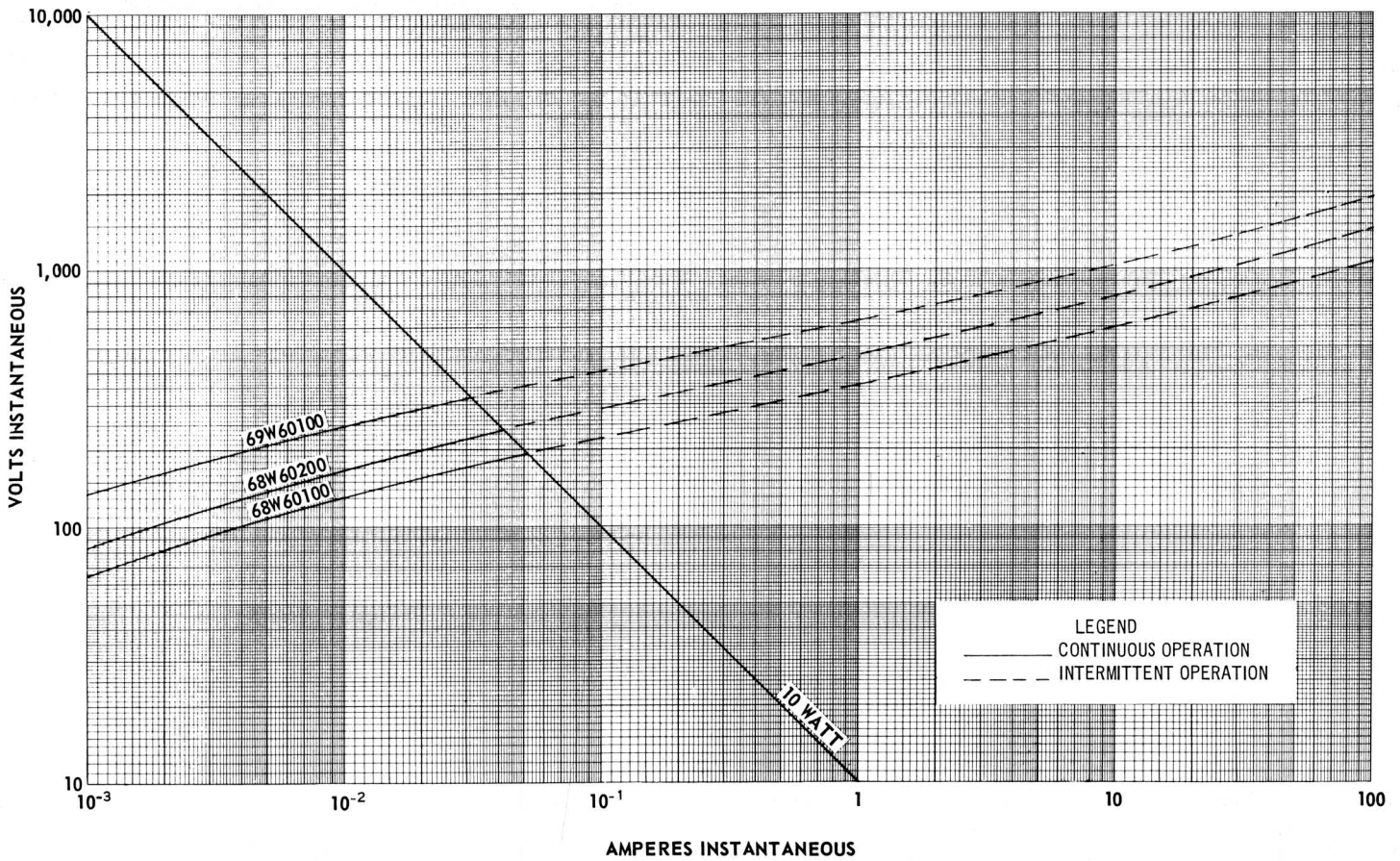
Short-time Body Temperature — 150°C

NOTE: Silicone Impregnation provided to insure protection against moisture.

OUTLINE DRAWING



VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS



SPECIAL VARISTORS:

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

- Tolerances down to ±10% on resistance.*
- Voltage values other than stock standard.*
- Protective and/or Identification Coating.*
- Special Mounting or Assembly.*

ELECTRONICS DEPARTMENT



FOR SALES AND SERVICE CONTACT

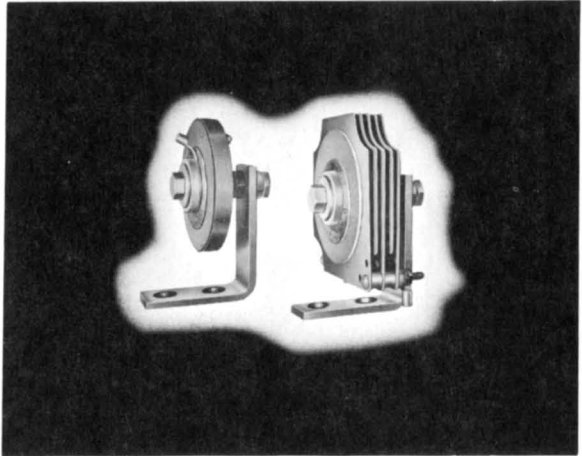
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9RV3 SERIES VARISTOR ASSEMBLIES

Varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.

These assemblies have one or more washers connected in series or parallel. Washers are bracket-mounted on a horizontal bolt with spring lock washer for contact pressure. Washers are insulated from central bolt and mounting brackets. Connections are made to terminals shown.



SPECIFICATIONS

CHARACTERISTICS AT 25°C:

Type	CATALOG NUMBER	MAXIMUM VALUES					SPECIFICATIONS				
		Continuous DC Operating* Voltage Rating (Volts)	Continuous Power Loss in Operation (Watts)	Discharge Capacity** (Watt-Seconds)	Peak Discharge Voltage For Given DC Discharge Current		No. of Disks (N)	Outline Fig. No.	Overall Length "A" (In.)	Approx. Wt. in Lbs.	
					(Amps)	(Volts)				Net	Shipping
A	9RV3A1	6	3	1,100	10	40	1	2	2	3/4	1-1/4
	9RV3A2	6	6	2,200	20	40	2	1	2-1/4	1-1/2	2
	9RV3A3	6	12	4,400	40	40	4	1	2-1/2	1-1/2	2
	9RV3A4	12	3	1,350	10	80	1	2	2	3/4	1-1/2
	9RV3A5	12	6	2,700	20	80	2	1	2-1/4	1-1/2	2
	9RV3A6	12	12	5,400	40	80	4	1	2-1/2	1-1/2	2
	9RV3A7	25	6	2,700	10	160	2	2	2-1/4	3/4	1-1/2
	9RV3A8	50	3	1,700	5	200	1	2	2-1/4	3/4	1-1/4
	9RV3A9	50	6	3,400	10	200	2	1	2-1/4	1-1/2	2
	9RV3A10	50	12	6,800	20	200	4	1	2-1/2	1-1/2	2
	9RV3A11	100	6	3,400	5	400	2	2	2-1/4	3/4	1-1/2
	9RV3A12	150	3	5,100	2.5	775	1	2	2-1/4	3/4	1-1/2
	9RV3A14	300	3	5,100	1.5	1,350	1	2	2-3/4	3/4	1-1/2
	9RV3A15	600	6	10,200	0.5	2,300	2	2	3-1/4	1	1-1/2
	B	9RV3B3	12	6	2,200	10	80	2	2	2-1/4	3/4
9RV3B4		15	3	1,350	10	100	1	2	2	3/4	1-1/2
9RV3B5		15	6	2,700	20	100	2	1	2-1/4	1-1/2	2
9RV3B6		30	3	1,700	5	150	1	2	2-1/4	3/4	1-1/4
9RV3B7		30	6	3,400	10	150	2	1	1-1/4	1-1/2	2
9RV3B8		60	3	1,700	5	250	1	2	2-1/4	3/4	1-1/4
9RV3B9		60	6	3,400	10	250	2	1	2-1/4	1-1/2	2
9RV3B10		60	12	6,800	20	250	4	1	2-1/2	1-1/2	2
9RV3B11		100	6	3,400	5	400	2	2	2-1/4	3/4	1-1/2

OUTLINE DRAWINGS: (Dimensions in Inches)

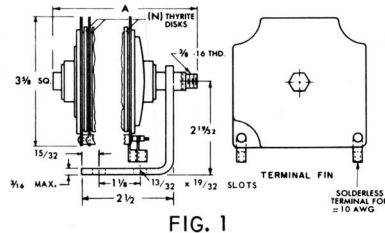


FIG. 1

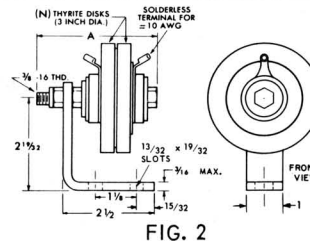
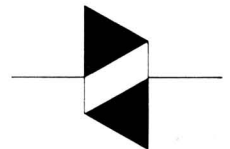


FIG. 2

VARISTOR SYMBOL



MAXIMUM RATINGS:

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

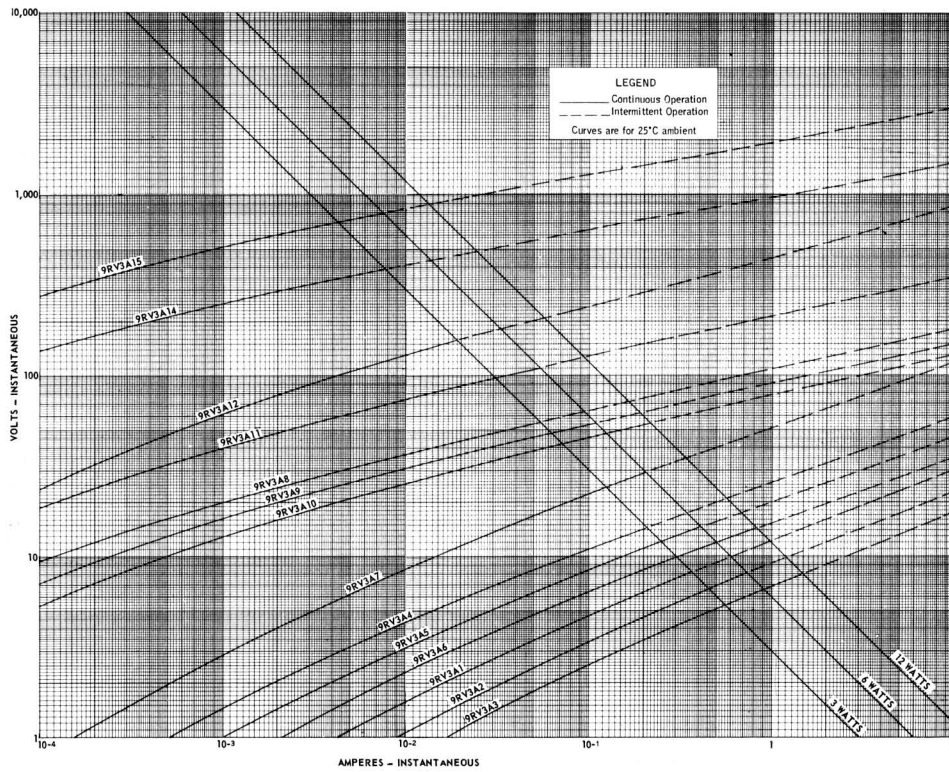
NOTES: Most bracket mounted assemblies also available for stud mounting. Substitute "C" for "A" or "B" in catalog number.
All varistors moisture protected with silicone impregnation.

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

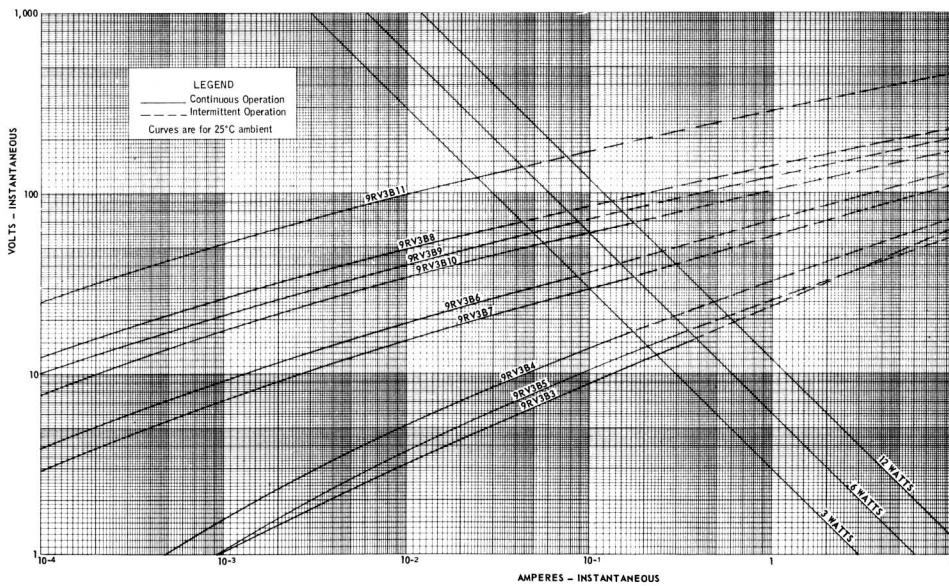
**Watt-seconds discharge capacity should not be exceeded by the stored energy ($W = \frac{1}{2}LI^2$) in the magnetic or inductive field. Discharge of maximum stored energy (equal to discharge capacity value) will raise varistor temperature about 80° C.

VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS

9RV3A SERIES



9RV3B SERIES



SPECIAL VARISTORS:

To meet special applications a "non-standard" Varistor may be required. Quotations will be provided for:

- Special *Tolerance* on Resistance.
- Special *Voltages*.
- Special *Power Ratings*.
- Special *Mountings*.



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NL INDUSTRIES, INC.

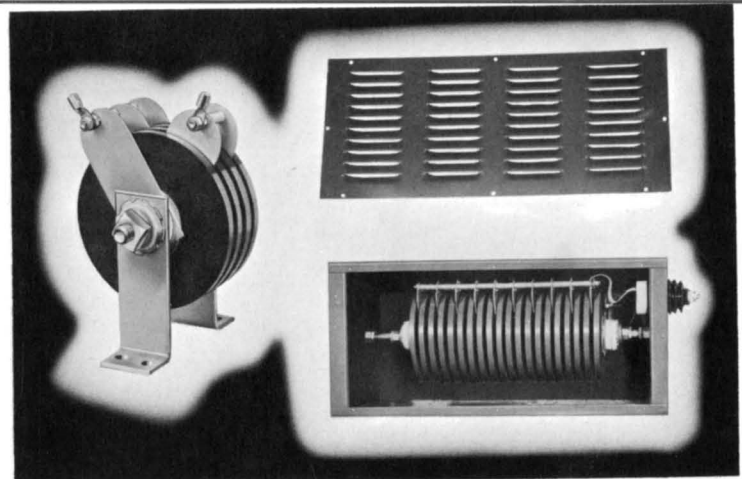
THERMISTORS

VARISTORS

9RV6 SERIES VARISTOR ASSEMBLIES

Varistors protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted.

These assemblies have one or more washers connected in series or parallel. Washers are bracket-mounted on a horizontal bolt with spring lock washer for contact pressure. Washers are insulated from central bolt and mounting brackets. Connections are made to terminals shown.



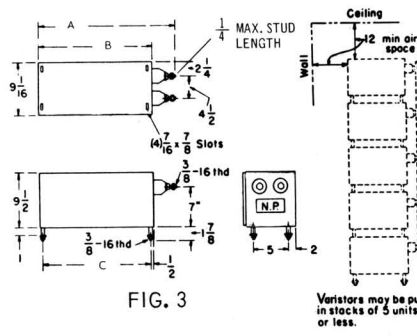
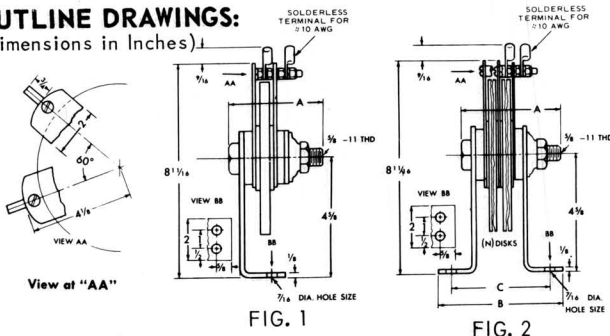
SPECIFICATIONS

CHARACTERISTICS AT 25°C:

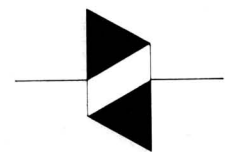
Type	CATALOG NUMBER	MAXIMUM VALUES					SPECIFICATIONS					Approx. Wt. in Lbs.	
		Continuous DC Operating* Voltage Rating (Volts)	Continuous Power Loss in Operation (Watts)	Discharge Capacity** (Watt-Seconds)	Peak Discharge Voltage For Given DC Discharge Current		No. of Disks (N)	Outline Fig. No.	Approx. Dimensions in Inches			Net	Shipping
					(Amps)	(Volts)			A	B	C		
BRACKET	9RV6A1	150	10	22,500	15	780	1	1	3-7/16	2-3/4	5-1/4
	9RV6A2	150	20	45,000	30	780	2	2	3-15/16	5	3-25/32	4-1/2	7
	9RV6A3	150	30	67,500	45	780	3	2	4-15/16	5-5/8	4-13/32	5-3/4	8-1/2
	9RV6A4	150	40	90,000	60	780	4	2	5-7/16	6-1/4	5-1/32	7	9-1/2
	9RV6A5	300	20	45,000	10	1,440	2	2	4-11/16	5-3/4	4-15/32	4-1/2	7
	9RV6A6	275	10	22,500	10	1,200	1	1	3-7/16	2-3/4	5-1/4
	9RV6A7	275	20	45,000	20	1,200	2	2	3-15/16	5	3-25/32	4-1/2	7
	9RV6A8	275	30	67,500	30	1,200	3	2	4-15/16	5-5/8	4-13/32	5-3/4	8-1/2
	9RV6A9	275	40	90,000	40	1,200	4	2	5-7/16	6-1/4	5-1/32	7	9-1/2
	9RV6A10	550	20	45,000	5	2,160	2	2	4-11/16	5-3/4	4-15/32	4-1/2	7
BOX	9RV6A50	150	200	450,000	300	780	20					52	59
	9RV6A51	200	200	450,000	250	990	20					52	59
	9RV6A52	275	200	450,000	200	1,200	20	3	23-7/8	21-1/2	20-1/2	52	59
	9RV6A53	300	240	540,000	170	1,550	24					57	64
	9RV6A54	400	240	540,000	140	1,900	24					57	64
	9RV6A55	550	240	540,000	60	2,160	24					57	64
	9RV6A60	150	100	225,000	150	780	10					33	40
	9RV6A61	200	100	225,000	125	990	10					33	40
	9RV6A62	275	100	225,000	100	1,200	10					33	40
	9RV6A63	300	120	270,000	135	1,550	12	3	17-3/4	15-3/4	14-3/4	35	42
	9RV6A64	400	120	270,000	70	1,900	12					35	42
	9RV6A65	550	120	270,000	30	2,160	12					35	42

OUTLINE DRAWINGS:

(Dimensions in Inches)



VARISTOR SYMBOL



MAXIMUM RATINGS:

Continuous Body Temperature - 110° C.

Short-Time Body Temperature - 150° C.

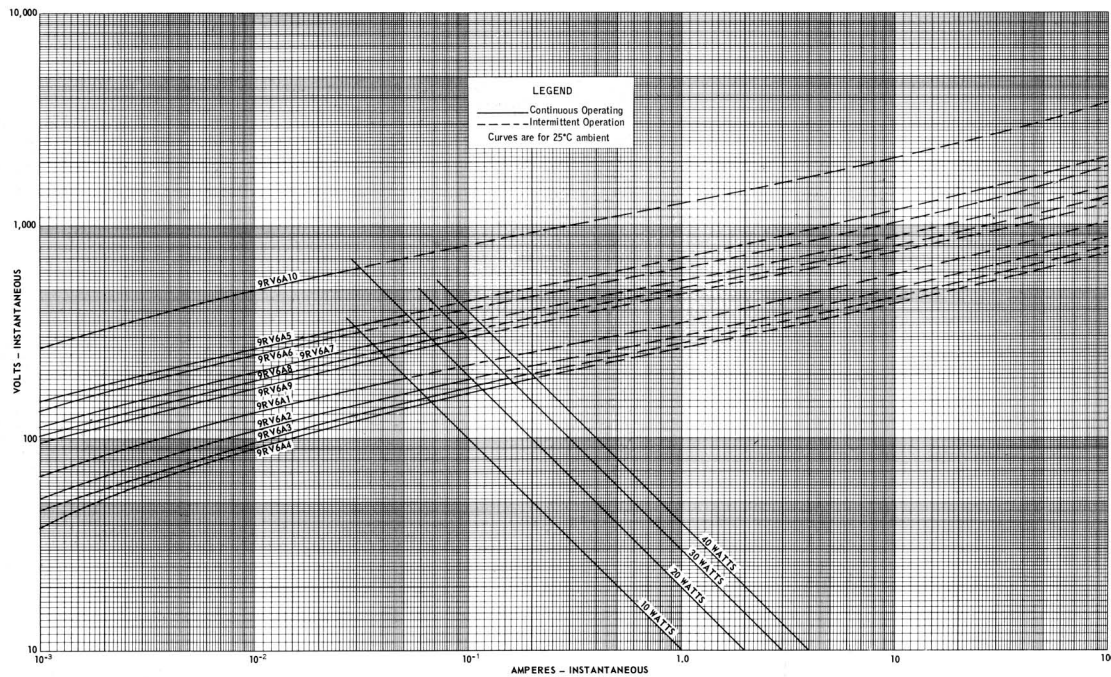
NOTES: Most bracket mounted assemblies also available for stud mounting. Substitute "C" for "A" in catalog number. All varistors moisture protected with silicone impregnation.

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

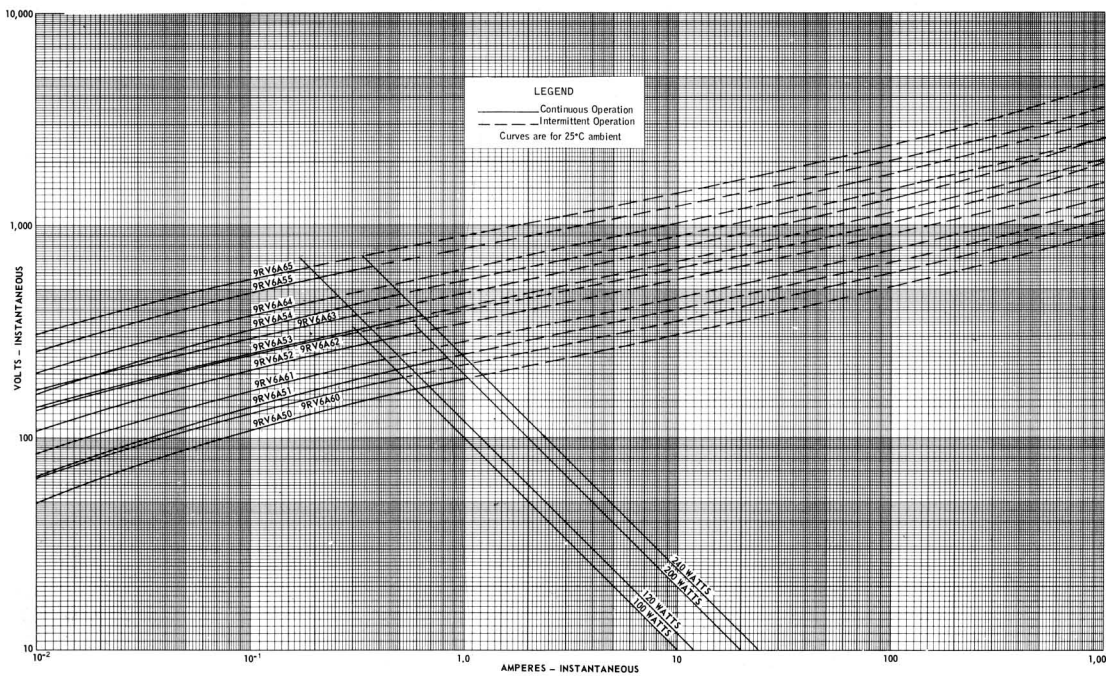
**Watt-seconds discharge capacity should not be exceeded by the stored energy ($W = \frac{1}{2}LI^2$) in the magnetic or inductive field. Discharge of maximum stored energy (equal to discharge capacity value) will raise varistor temperature about 80° C.

VARISTOR NOMINAL VOLT-AMPERE CHARACTERISTICS

9RV6A10 SERIES



9RV6A50 & 60 SERIES



SPECIAL VARISTORS:

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

- Special *Tolerance* on Resistance.
- Special *Voltages*.
- Special *Power Ratings*.
- Special *Mountings*.

ELECTRONICS DEPARTMENT



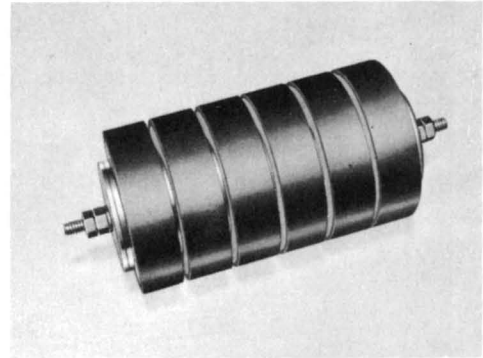
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NL INDUSTRIES, INC.

P. O. BOX 420 • WYCKOFF'S MILLS ROAD • PHONE 609 448-3200
 HIGHTSTOWN, NEW JERSEY 08520

9RV3A50 SERIES VARISTOR ASSEMBLIES

Medium voltage varistor assemblies have been designed for continuous operation on circuits up to 10.5 KV D-C. The assemblies utilize 3" washers catalog #71W30100 rated 1500 volts D-C and the washers are stacked in series to withstand higher voltages. Washers are mounted on a ceramic insulator, with a metal stud at each end for electrical connection and mounting. Each washer is silicone-impregnated for moisture protection.

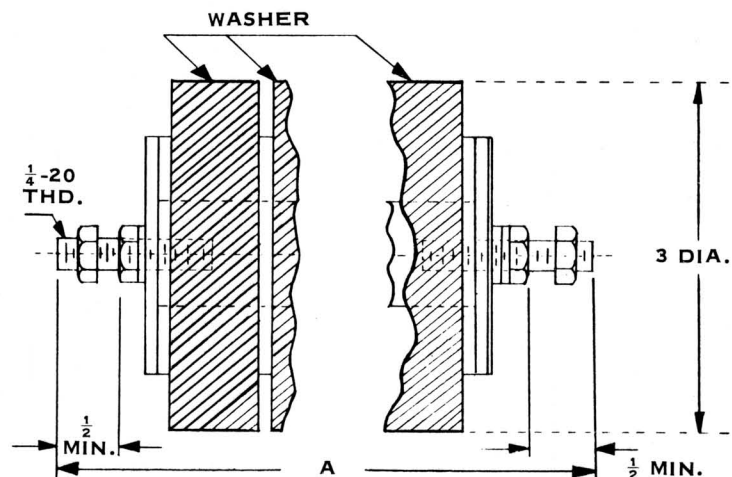


SPECIFICATIONS

CATALOG NUMBER 9RV3A56
Characteristics at 25°C.

CATALOG NUMBER	MAXIMUM VALUES					SPECIFICATIONS			
	CONTINUOUS D-C OPERATING VOLTAGE (VOLTS)	CONTINUOUS POWER LOSS IN OPERATION (WATTS)	DISCHARGE CAPACITY (WATT-SECONDS) *	PEAK DISCHARGE VOLTAGE FOR GIVEN D-C DISCHARGE CURRENT		NUMBER OF WASHERS	OVERALL LENGTH "A" (INS.)	APPROX. WEIGHT (LBS.)	
				(AMPS)	(VOLTS)			NET	SHIPPING
9RV3A51	1,500	3.5	9,250	10	7,500	1	3 1/4	3/4	1 1/4
9RV3A52	3,000	7.0	18,500	10	15,000	2	4	1 1/4	2
9RV3A53	4,500	10.5	27,750	1	14,250	3	4 3/4	1 3/4	2 1/2
9RV3A54	6,000	14.0	37,000	1	19,000	4	5 5/8	2	3
9RV3A55	7,500	17.5	46,250	1	23,750	5	6 1/2	2 1/2	3 3/4
9RV3A56	9,000	21.0	55,500	0.5	25,200	6	7 3/8	2 3/4	4 1/4
9RV3A57	10,500	24.5	64,750	0.25	26,000	7	8 1/4	3 1/4	5

OUTLINE DRAWING (Dimensions in Inches)



MAXIMUM RATINGS

Continuous Body Temperature—110°C

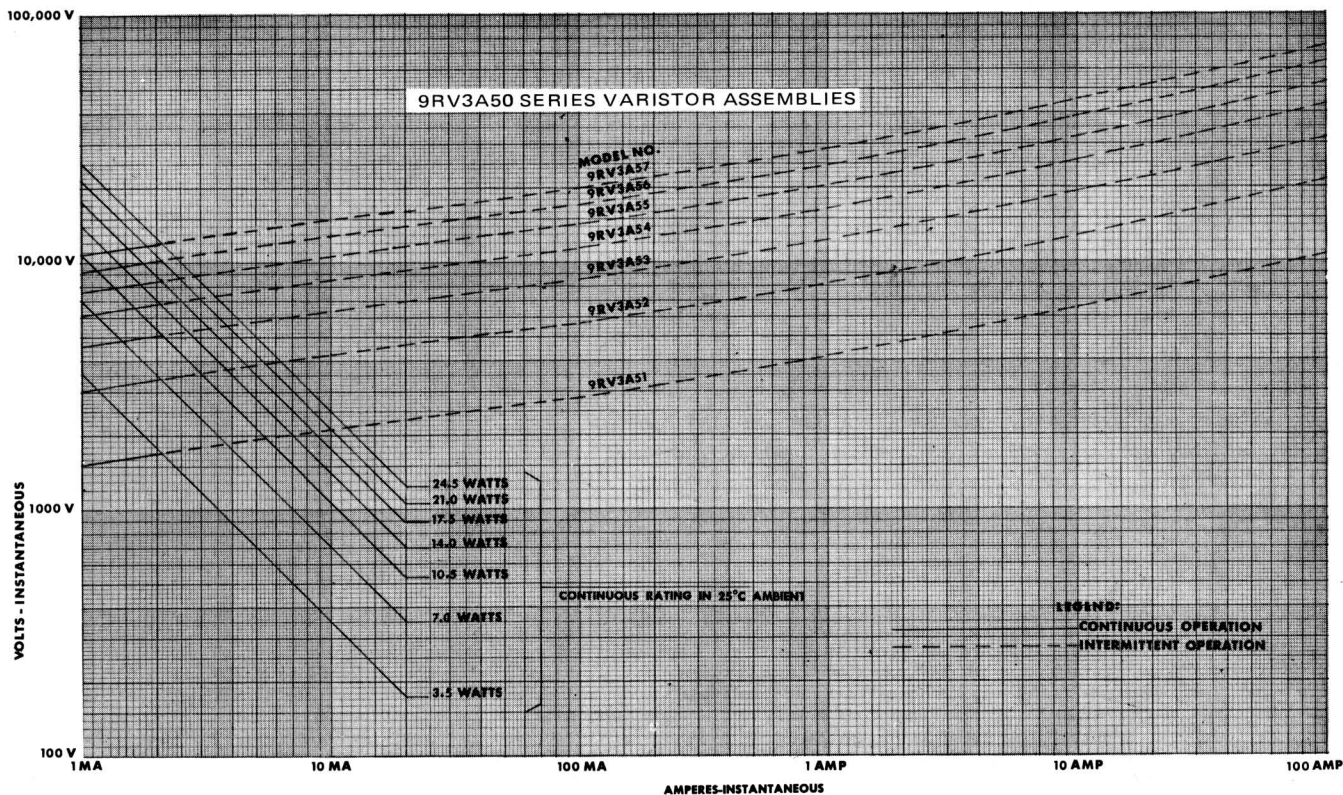
Short-time Body Temperature—150°C

Continuous RMS A-C Operating Voltage may not exceed 90% of permitted D-C value

*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 varistor temperature about 80° C.

VARISTOR ASSEMBLIES 9RV3A50 SERIES

VOLT-AMPERE CHARACTERISTICS



SPECIAL VARISTORS:

To meet special applications a "non-standard" assembly may be required. Quotations will be provided for:

- Tolerances down to ±10% on resistance.*
- Voltage values other than stock standard.*
- Protective and/or Identification Coating.*
- Special Mounting or Assembly.*

ELECTRONICS
DEPARTMENT

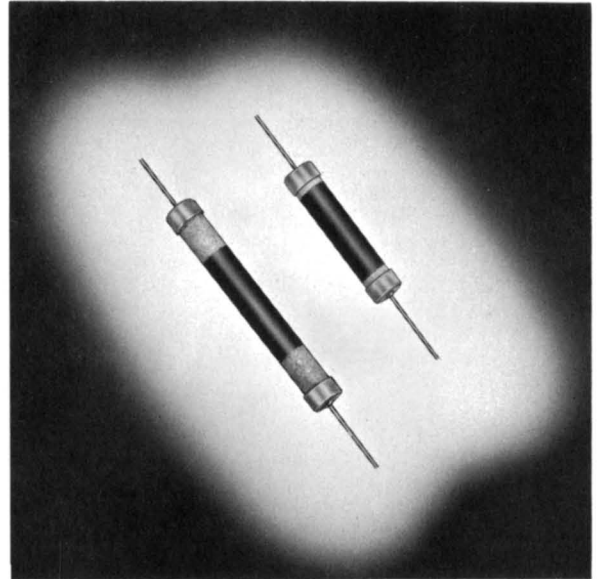


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Varistor rods protect circuits and components from inductive voltage surges by limiting peak discharge voltage to a safe value when AC or DC magnetic or inductive circuit current is suddenly interrupted. Other applications include rectification of asymmetrical waveforms in TV circuits to aid in High Voltage Regulation.



Characteristics at 25°C.

ORDER NUMBER	MAXIMUM VALUES					SPECIFICATIONS		LENGTH
	CONTINUOUS OPERATING VOLTAGE VOLTS		CONTINUOUS POWER RATING WATTS	PEAK DISCHARGE VOLTAGE FOR GIVEN DC DISCHARGE CURRENT		DC TEST VOLTAGE & CURRENT		L (MAX.)
	DC	AC		AMPERES	VOLTS	VOLTS	AMPERES	INCHES
72R-2200	3300	2950	0.4	.010	10,500	3,800 ±20%	.0001	2-1/16
72R-2100	1700	1525	0.25	.001	3,700	2,000 ±20%	.0001	1-1/8
71R-2100	1100	1000	0.25	.005	3,300	1,125 ±20%	.0001	
69R-2100	600	540	0.25	.010	1,900	920 ±20%	.0010	
68R-2100	300	275	0.25	.025	1,000	400 ±20%	.0010	
66R-2100	150	135	0.25	.050	600	165 ±20%	.0010	

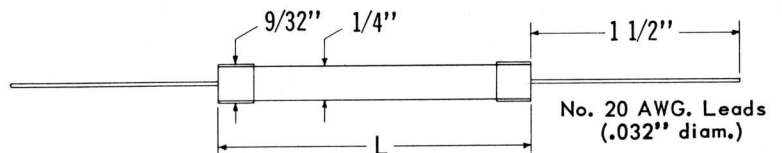
MAXIMUM RATINGS

Continuous Body Temperature—110°C

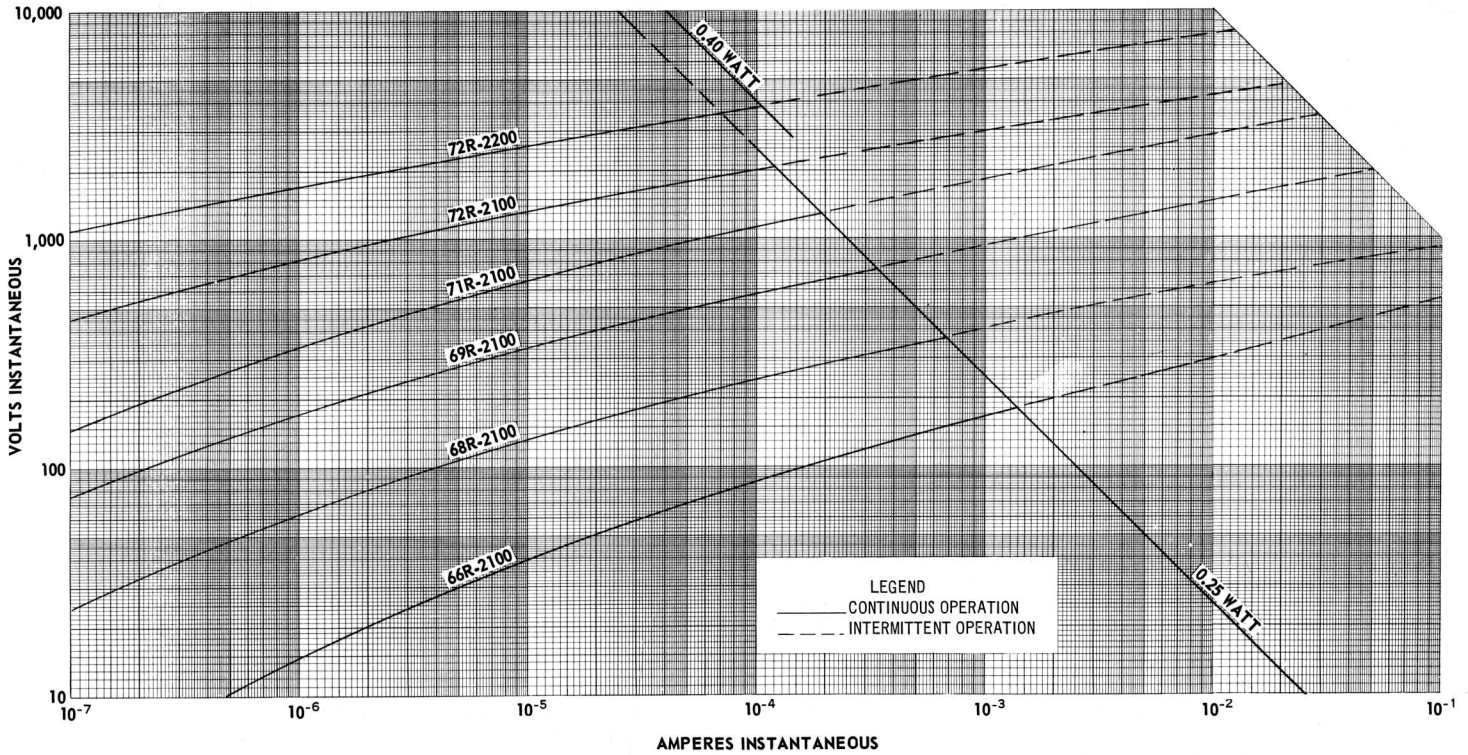
Short-time Body Temperature — 150°C

NOTE: Silicone Impregnation provided to insure protection against moisture.

OUTLINE DRAWING



0.25" VARISTOR ROD NOMINAL VOLT-AMPERE CHARACTERISTICS



SPECIAL VARISTORS:

To meet special applications a "non-standard" varistor may be required. Quotations will be provided for:

- Tolerances down to ±10% on resistance.*
- Voltage values other than stock standard.*
- Protective and/or Identification Coating.*
- Special Mounting or Assembly.*
- Different Lead Arrangement.*

ELECTRONICS DEPARTMENT



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Application Data

SECTION 9702
VARISTOR
APPLICATION QUESTIONNAIRE

NL INDUSTRIES, INC.

THERMISTORS

VARISTORS

VARISTORS

Questionnaire to be used for obtaining application assistance

Name of Company Division

Address

Individual Dept. Date

Phone Number

By far the largest number of applications for varistors are for conventional surge voltage protection. In most cases only a few questions need to be answered, see below.

Other applications may demand more information, see back of this sheet.

CONVENTIONAL SURGE VOLTAGE PROTECTION

- 1. Supply voltage volts
 - a) if DC, give ripple or waveshape
 - b) if AC, is it sinewave, give frequency
 - c) if other, give details
- 2. Maximum current to be interrupted amperes
- 3. Maximum peak discharge voltage permitted volts
- 4. Inductance of associated equipment henries
- 5. Maximum duty cycle operations per second/minute/hour
- 6. Minimum and maximum ambient temperatures °C

PLEASE MAIL YOUR COMPLETED QUESTIONNAIRE TO THE FACTORY



OTHER APPLICATIONS FOR VARISTORS

1. Type and function of apparatus in which varistor is to be used.....
.....
2. (a) Brief statement of what is to be accomplished by use of varistor. Give numerical values where possible
.....
.....
 (b) **Please attach a circuit diagram showing circuit constants and proposed connections, including expected voltages and currents.**
3. (a) Specify range of voltage applied continuously to varistor.
 volts DC (..... per cent ripple)
 volts AC RMS (..... cycles per second)
 (b) **If voltage is intermittently applied to varistor, describe operating cycle fully**

 (c) Attach sketch of voltage wave to be applied to varistor
4. Give permissible continuous watts loss at maximum voltage
5. Inductance of associated equipment henries
6. Maximum duty cycle operations per second/minute/hour
7. Minimum and Maximum ambient temperature °C
8. In what media will varistor be used? Still Air Forced Air Pyranol Oil Wax
9. If in air, what maximum relative humidity
10. Space or weight limitations, if any
11. Approximate quantities required per year
12. If desired E vs I characteristics of varistors are known please indicate below specifying whether DC or AC - Crest
 DC { Volts _____ _____ _____
 AC - Crest { Amps _____ _____ _____

After completing questionnaire please send to:



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GENERAL CHARACTERISTICS OF VARISTORS

DESCRIPTION:

A Varistor is a non-linear resistance material in which the current varies as a power of the applied voltage. Voltage sensitive varistors have been used to great advantage in many important applications in the electrical-power, communications, and electronic industries.

Varistors are 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.

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 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 high 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 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:

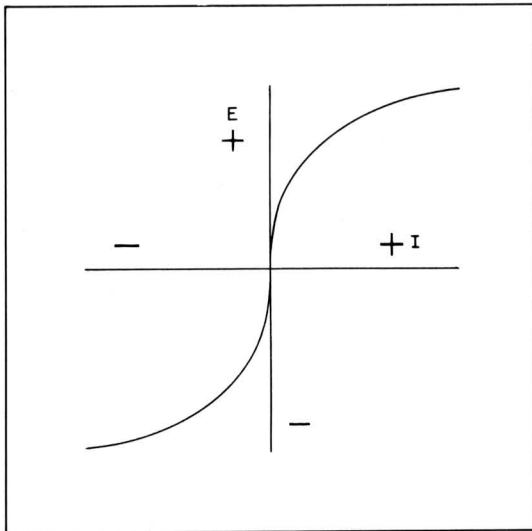
$$E = CI^{1-a}$$

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 $RI^a = C$

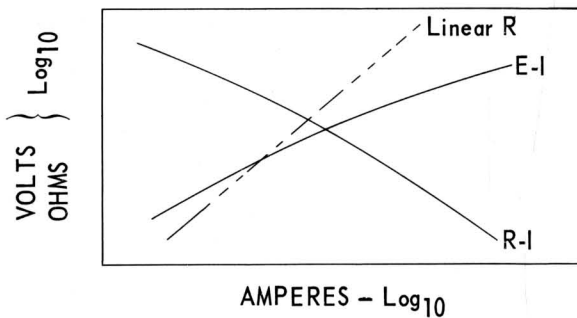
The volt-ampere characteristic curve, with both positive and negative values of voltage and current, is plotted on linear coordinates in Figure 1. It will be noted that the curve indicates essentially sym-



Characteristic E-I Curve
FIGURE 1

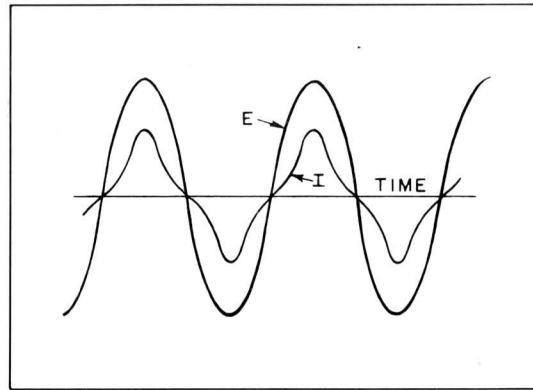
metrical characteristics for both positive and negative polarity.

Since the non-linear voltage-current characteristic of a varistor 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.

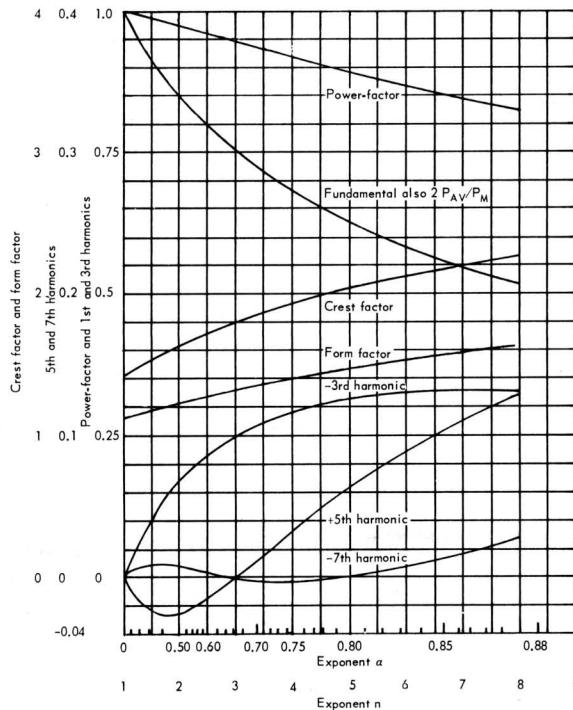


Plot of 60 Cycle A-C Voltage and Current Wave Form
FIGURE 3

The average power loss (P) in a 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 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 the varistors and provision made for dissipation of heat. A continuous rating of 0.25 watt per square inch of a 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 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 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 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.

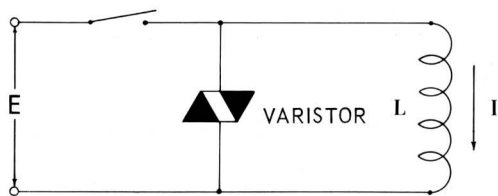
VOLTAGE SURGE PROTECTION

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 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 occurrence 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

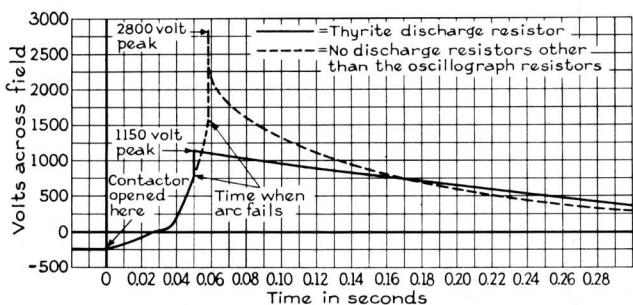


Protective Circuit

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 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:

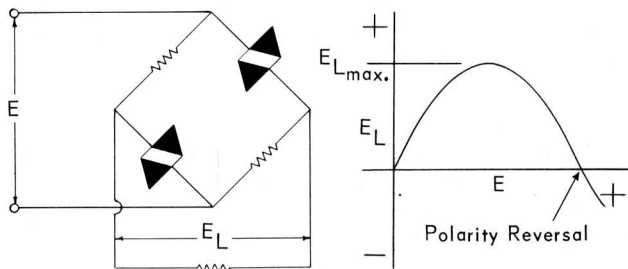
The circuit use of the non-linear E-I characteristic of this material permits simple circuits to perform relatively complex operations.

A network consisting of a 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.

Varistor Bridge⁽²⁾ Circuits:

Two 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 conventional fixed resistor bridge.



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 varistors refer to the Short Form Catalog 1082 or the specific Product Data Section.