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PROTECTIVE LEVEL COMPARISONS OF VOLTAGE TRANSIENT SUPPRESSORS (120 V, AC TYPE)

by

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SUMMARY

Transient overvoltages on a residential 120-V, ac service can decisively limit the life of connected electronic equipment. To extend equipment life and reliability, designers must use a form of transient voltage suppression. This report compares test results of voltage clamping levels for a selected number of suppressors subjected to a 0.5-μs, 100-kHz ring wave (IEEE proposal) and to a 2 μs x 10-μs voltage wave suggested by the Federal Communications Commission (FCC). Tests were also performed with an EMI filter present. These results are then analyzed in conjunction with cost considerations.

The devices tested represent a cross section of suppressor types divided into three major categories: voltage clamping, crowbar, and filter. Of the types tested, the GE-MOV® provided the best overall reliability, cost, and protection.

KEY WORDS

transients, spikes, surges, suppressions, arrestors, varistors, coordination

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PROTECTIVE LEVEL COMPARISONS OF VOLTAGE TRANSIENT SUPPRESSORS (120 V, AC TYPE)

D.C. Hopkins

INTRODUCTION

Voltage transients on a 120-V power system may be fatal to connected electronic equipment. These transients are seldom predictable and occur with varying rise time, magnitude, and duration.[1,2] As a safeguard one must overdesign the equipment or protect it with a transient suppressor device.[3,4] Low cost is a major design criterion and should dominate this choice when both methods provide acceptable protection.

The majority of manufacturers characterize their devices by their response to the 10 μs x 1000 μs- or 8 μs x 20 μs-current waveforms.[5] With this information, a designer can choose the suppressor with the best characteristic response. However, problems can arise in determining whether that suppressor can actually survive in the application environment.[6]

Tables 1 and 2 show the protection levels achieved in tests of 25 different device types. These suppressors were subjected to two basic and two modified test waves. These tests provided such a wide range of environmental extremes that individual device limitations became evident.

TEST WAVES

A recently proposed Transient Control Level[7] (TCL) philosophy suggests a test voltage wave of 0.5-μs rise time to crest, followed by a 100-kHz, damped sinusoidal ring with the peak voltage decreasing by 40% with each successive peak, that is, a 0.5 μs - 100-kHz ring wave called Test Wave 1. Figure 1 illustrates Test Wave 1. This wave represents the major worst-case stress factors found in the different types of naturally

Table 1
PERFORMANCE DATA WITHOUT AN EMI FILTER

Candidate	Item No.	Wave 1 0.5 μs × 100 kHz Ring Wave 5 kV o.c.				Wave 2 2 μs × 10 μs Wave 2.5 kV o.c.			
		Average Protective Level		Fail Short/ No. Tested	Fail Catastrophic/ No. Tested	Average Protective Level		Fail Short/ No. Tested	Fail Catastrophic/ No. Tested
		(kV)	(σ)			(kV)	(σ)		
Voltage Clamping Device									
General Electric	V130LA1	0.51	0.01			0.60	0.04		
(GE-MOV)	V130LA10	0.51	0.02			0.50	0.03		
	V130LA20	0.51	0.02			0.47	0.03		
General Semiconductor (TRANSZORB)	15KE200C	0.47	0.11	2/10		—	—	5/5	
Sarkes Tarzian	VR200B	—	—	4/4		—	—	3/3	
(Voltage Regulator)	2VR200B	—	—	3/3		—	—	3/3	
	3VR200B	—	—	3/3		—	—	3/3	
Sarkes Tarzian	S255	2.2	0.46			1.7	0.13		
(KLIPVOLT)	S256	1.6	0.11			1.5	0.21		
Semtech	1N6137	—	—	4/5	1/5	—	—	1/3	2/3
(Bipolarity Silicon)	1N6173	0.31	0.06			—	—		3/3
Crowbar Type Device									
C.P. Clare	CG2-230	0.67	0.06			1.0	0.05		
(Comm Gaps)	CG2-350	0.69	0.04			0.71	0.08		
Siemens	B2-B270	1.7	0.36			1.5	0.07		
(SVP)	G41-C350	1.2	0.15		2/10	1.6	0.10		
Signalite (Neon bulb)	A240F	4.1	0.79			2.5	0.25	(no suppression)	
Filter Type									
Mepco	C280AEA4K7	1.3	0.28			—	—		2/2
(Capacitor)	C280AEA10K	0.73	0.08			—	—		2/2
	C280AEA47K	0.85	0.15			—	—		2/2
	C280AEA100K	0.76	0.17			—	—		2/2
	C280AEA330K	0.57	0.03			—	—		2/2
Sprague	Z5U0.005M	—	—	2/2		2.5	—	(no suppression)	
(CERA-MITE)	Z5U0.01M	—	—	2/2		2.5	—	(no suppression)	
	Z5U0.05M	—	—	2/2		2.5	—	1/5	
	Z5U0.1M	—	—	2/2		—	—		2/2

Table 2
PERFORMANCE DATA WITH AN EMI FILTER

Candidate	Item No.	Wave 2 0.5 μs × 100 kHz Ring Wave (Filtered, 0.66 kV, o.c.) Average Protective Level (kV)	Wave 2 Average Protective Level (σ)	Wave 2 Fail Short/ No. Tested	Wave 2 Fail Catastrophic/ No. Tested	Wave 4 2 μs × 10 μs Wave (Filtered, 3.5 kV, o.c.) Average Protective Level (kV)	Wave 4 Average Protective Level (σ)	Wave 4 Fail Short/ No. Tested	Wave 4 Fail Catastrophic/ No. Tested
Voltage Clamping Device									
General Electric (GE-MOV)	V130LA1	0.39	0.01			0.44	0.01		
	V130LA10	0.36	0.01			0.40	0.02		
	V130LA20	0.35	0.01			0.38	0.02		
General Semiconductor (TRANSZORB)	1.5KE200C	0.26	0.02			—	—	4/4	
Sarkes Tarzian (Voltage Regulator)	VR200B	0.39	0.02			—	—	3/3	
	2VR200B	0.37	0.01			—	—	3/3	
	3VR200B	0.30	0.01			—	—	3/3	
Sarkes Tarzian (KLIPVOLT)	S255	0.60	0.01			1.5	0.37		
	S256	0.58	0.02			1.4	0.18		
Semtech (Bipolarity Silicon)	1N6137	—	—	10/10		—	—	1/3	2/3
	1N6173	0.26	0.01			—	—	3/3	
C.P. Clare (Comm Gaps)	CG2-230	0.38	0.03		1/10	0.59	0.01		
	CG2-350	0.47	0.02		1/10	0.51	0.03		
Siemens (SVP)	B2-B270	0.66	0.00			1.3	0.47		
	G41-C350	0.59	0.05		5/10	0.92	0.05		1/10
Signalite (Neon bulb)	A240F	0.66	0.00			2.9	0.46		

occurring transients that exist in residential distribution systems. It has a high crest value of 5 kV and a source impedance of 30 Ω.

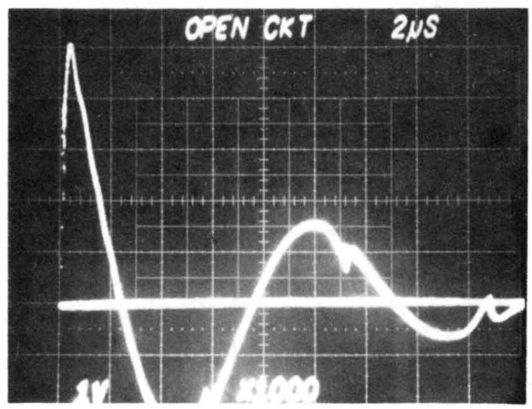
A second test wave was defined by passing Test Wave 1 through an EMI (L) filter as Figure 6 shows. Because of conducted and transmitted EMI problems with consumer electronic equipment, special filters are often used with suppressors at the power line input. These filters reshape and attenuate the impinging surge, thereby aiding suppressor performance. Test Wave 2, then, simulates this condition, as Figure 2 shows. This modified wave (Test Wave 2) exhibits a much slower rate of rise and lower crest value and imposes a lower stress on the suppressor under test.

In 1977 the FCC[8] required that registered communication terminal equipment be capable of withstanding certain electrical stress tests, the most severe of which is "Six 2500 volt peak surges having a 2 μs maximum rise time to crest and a 10 μs minimum decay time to half crest. . . the peak current drawn from the surge generator must not be limited to less than 1000 amperes. . . ." This FCC wave (Figure 3) is Test Wave 3. However, only one of the six surges is used for this test. One should note that the effective source impedance of the wave generator is 2.5 Ω (realistic in an industrial environment) and that the amount of available energy impinging on the suppressor can be quite high.

Figure 4 shows Test Wave 4. This test wave is used for the same reason and produced by the same method as Test Wave 2; Test Wave 3 passes through the EMI filter.

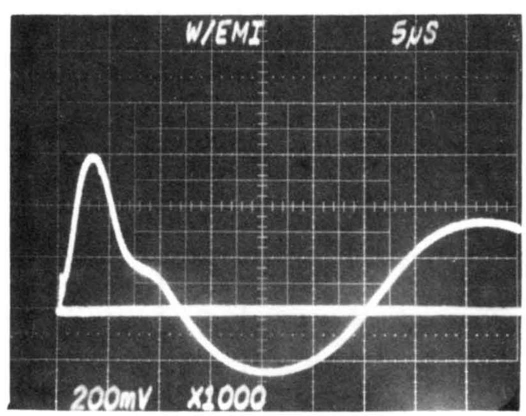
SUPPRESSORS

A cross section of suppressors (Figure 5) was chosen for study and grouped into three categories: voltage



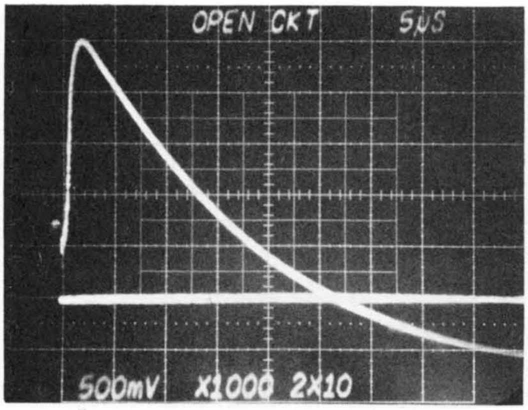
kV/div
μs/div

Figure 1. Test Wave 1: 0.5 μs × 100 kHz ring wave (voltage).



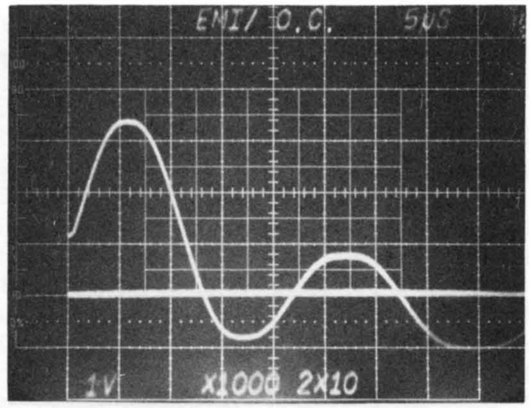
200 V/div
5 μs/div

Figure 2. Test Wave 2: filtered 0.5 μs × 100 kHz ring wave (voltage).



500 V/div
5 μs/div

Figure 3. Test Wave 3: 2 μs $\times$ 10 μs voltage wave.



1 kV/div
5 μs/div

Figure 4. Test Wave 4: filtered 2 μs $\times$ 10 μs voitage wave.

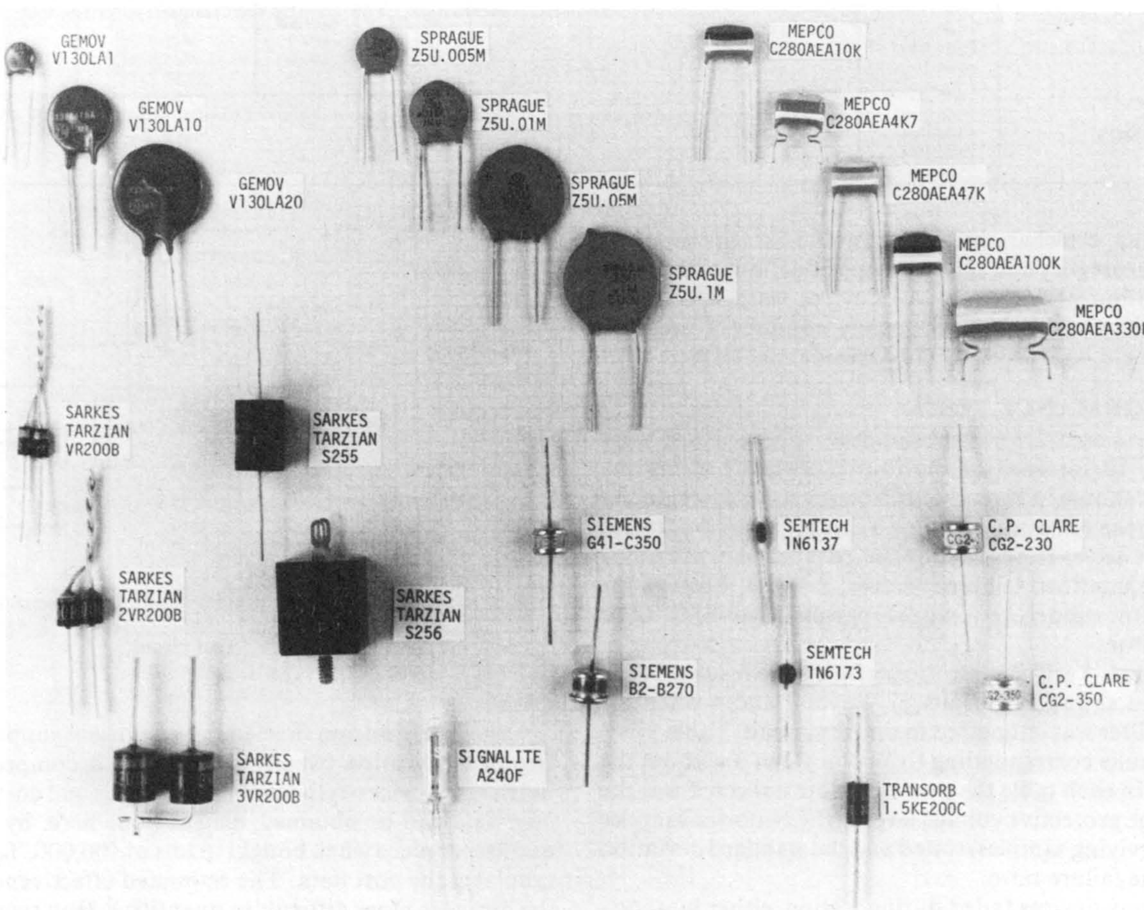


Figure 5. Suppressor devices tested.

Table 3
SUMMARY OF SUPPRESSOR SPECIFICATIONS

Candidates	Item No.	Characteristics
Voltage Clamping Device		
General Electric (GE-MOV)	V130LA1 V130LA10 V13-LA20	Zinc oxide semiconductor encapsulated in epoxy. Rated for 130 V rms continuous. Energy capacity of 4, 30, and 50 J and peak current of 500, 4000, and 6,000 A, respectively.
General Semiconductor (TRANSZORB)	1.5KE200C	Bipolar silicon semiconductor, encapsulated in epoxy. Rated break-down voltage of 200 V and wattage ratings of 1, 2, and 3 W respectively.
Sarkes Tarzian (Voltage Regulator)	VR200B 2VR200B 3VR200B	Voltage regulator type, bipolar silicon semiconductor. Rated breakdown voltage of 200 V and wattage ratings of 1, 2, and 3 W respectively.
Sarkes Tarzian (KLIPVOLT)	S255 S256	Bidirectional selenium suppressor encased in phenolic. Rated for 130 V rms operation and to protect coils having 0.62 and 2.22 A coil current.
Semtech (Bipolarity Silicon)	IN6137 IN6173	Bipolar silicon semiconductor, encased in Semtech's Metoxilite. Rated minimum breakdown voltage of 180 V dc. Energy capacity of 500 and 1500 W respectively for 1 μs, and peak surge currents of 1.7 and 5.2 A.
Crowbar Type Device		
C'P. Clare (Comm Gaps)	CG2-230 CG2-350	Metal-ceramic, hermetically sealed, two-electrode arrestors. Rated dc breakdown voltage of 230 and 350 V, and surge currents of 500 A each.
Siemens (SVP)	B2-B270 G41-C350	Gas-filled, two-electrode, protector encapsulatd in either glass or ceramic. Rated breakdown voltages of 270 and 250 V dc, surge currents of 5 kA for both, and maximum follow-on currents of 35 and 30 A respectively.
Signalite (Neon bulb)	A240F	Glass encapsulated neon lamp. Breakdown voltage of 360 V dc and maintaining voltage of 200 V dc.
Filter Type		
Mepco (Capacitor)	C280AEA4K7 C280AEA10K C280AEA47K C280AEA100K C280AEA330K	Metallized polyester and polycarbonate capacitors. All rated at 250 WV dc and 160 V ac. Capacitance values respectively are 4700, 10000, 47000 pF, etc.
Sprague (CERA-MITE)	Z5U0.005M Z5U0.10M Z5U0.05M Z5U0.1M	Flate plate ceramic capacitors. All rated at 100 WV dc. Respective product numbers are 5GA-D10, 5GA-D50, 5GA-S10, 5GA-S50, and 5GA-P10.

clamping, crowbar, and filter. Table 3 lists the suppressors by category and shows the specifications and a breif description of each one. All devices were selected as being characteristic of the many commonly used on equipment connected to 120-V residential service.

PERFORMANCE TESTS

Forty samples of each suppressor device type were tested, 10 for each of the four test waves, using the circuit shown in Figure 6. If 3 consecutive test samples failed, the remainder of the 10 samples were not tested by that wave. The capacitor device types were not tested on the modified (filtered) waves, 2 and 4, because the capacitor under test would parallel the EMI filter capacitor.

Tables 1 and 2 show the performance results. While Table 3 shows the results of Waves 2 and 4 when the EMI filter was connected in the test circuit, Table 2 lists the results corresponding to Waves 1 and 3 without the filter. In each table the pertinent data collected was the average protective voltage level of the 10 device samples (or surviving samples) tested and the standard deviation and the failure ratio.

Many devices failed during testing, either by shorting or fragmenting. Thus, listed are the ratios of the number of devices failed to the number of devices tested. The devices failed either short or catastrophically.

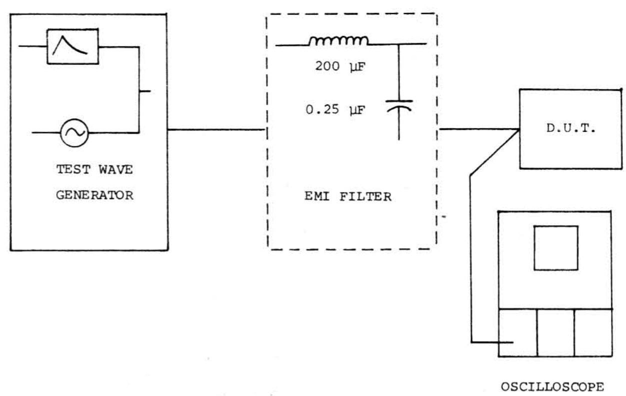


Figure 6. Test circuit.

COST

The final decision in selecting a transient suppressor for an application usually depends on a compromise between a devices-estimated effectiveness and cost. The cost data can be obtained, as was done here, by price quotes per piece when bought in lots of 100,000. Table 4 tabulates the cost data. The estimated effectiveness of the device is more difficult to quantitize. However, one important measure of effectiveness is its protective voltage level.

To aid in a selection process Figures 7 through 10 graphically present the cost versus protective voltage

Table 4
PRICE QUOTES

Candidate	Item No.	Each in 50 K lots	Each in 100 K lots	Quote Date
GE-MOV	V130LA1 V130LA10 V130LA20	$0.28 0.38 0.54	$0.25 0.32 0.45	6/77
TRANSZORB	1.5KE200C	$1.98	$1.92	6/77
Sarkes Tarzian	VR200B 2VR200B 3VR200B	$0.16 0.24 0.32	$0.14 0.22 0.29	6/77
KLIPVOLT	S255 S256	0.96 1.15	0.90 1.08	
Semtech	1N6137 1N6173	$2.38 5.00	$2.38 5.00	6/77
C.P. Clare	CG2-230 CG2-350	$0.65 0.65	$0.60 0.60	6/77
SVP	B2-B270 G41-C350	$0.61 0.52	$0.59 0.50	6/77
Signalite	A240F	$0.46	$0.41	6/77 (by phone)
Mepco	C280AEA4K7 C280AEA10K C280AEA47K C280AEA100K C280AEA330K	$0.05 0.0475 0.06 0.08 0.148	$0.048 0.046 0.058 0.078 0.144	6/77
CERA-MITE	Z5U 0.1M Z5U 0.05M Z5U 0.01M Z5U 0.005M	$0.164 0.094 0.041 0.027	$0.156 0.041 0.039 0.026	6/77

level, obtained from Tables 1, 2, and 3. Each point plotted (corresponding to a device's cost and protective voltage level) has a number which identifies the device listed on the right.

A preferred suppressor device can be chosen by the repeated location of data points near the origin (lower left corner) of the graphs. This general location indicates the device has the best protective level at the lowest cost in response to all four different transients, two of which are very stringent. If any device failed short or catastrophically during the protective level tests by Waves 1 to 4, then it is not listed in the corresponding graph. This is important since device failure certainly is part of suppressor effectiveness.

SUMMARY

The best way to summarize suppressor performance comparisons is to view the failure ratio columns of Tables 1 and 2:

- Only two manufacturers' groups survived all four test waves.
- The Sarkes-Tarzian selenium suppressors, S255 and S256, survived adequately but offered a very poor protective level.

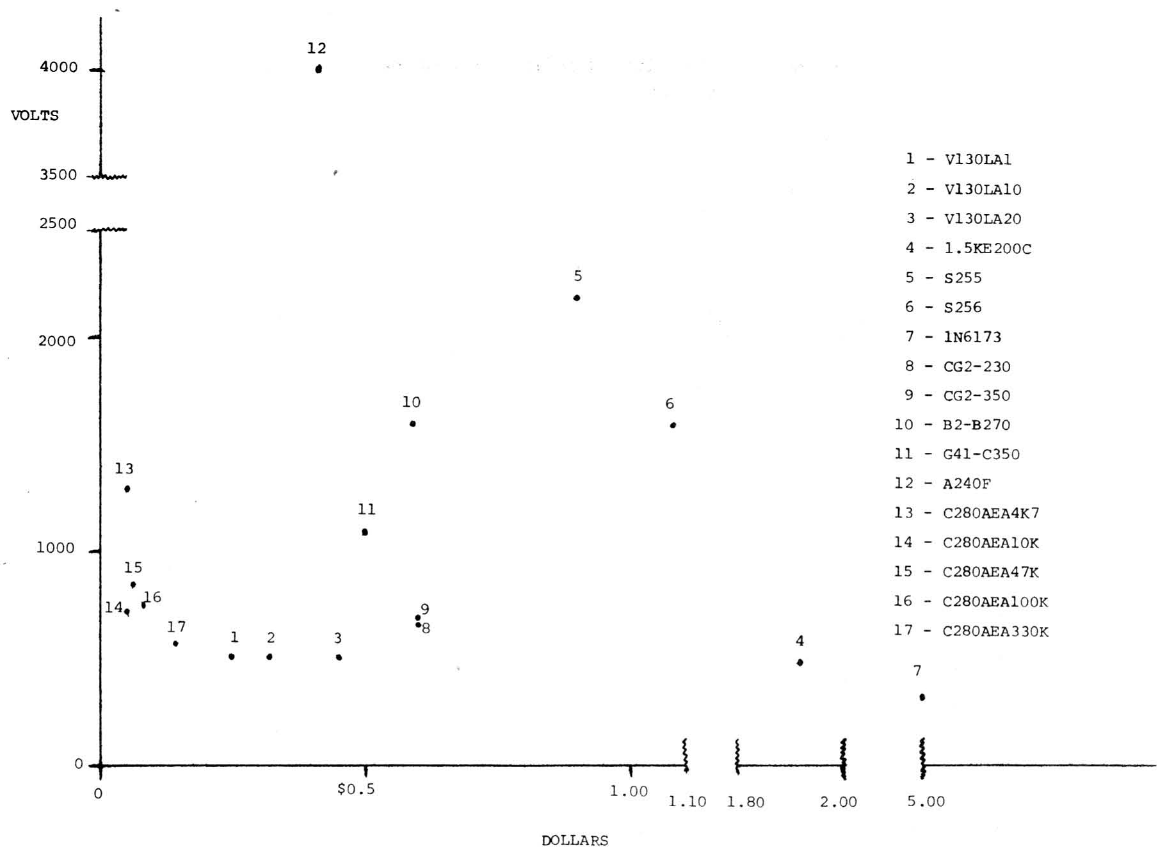


Figure 7. Protective voltage level vs. cost: Test Wave 1 (lots of 100 K).

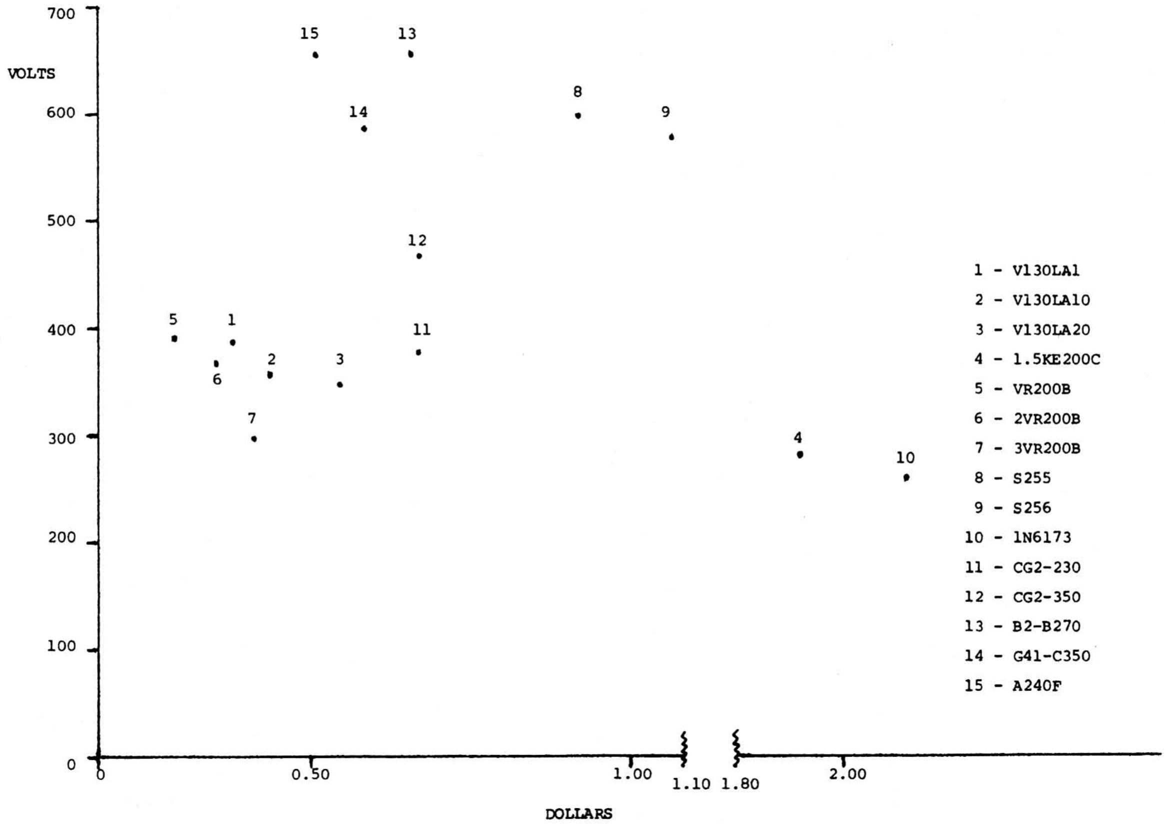


Figure 8. **Protective voltage level vs. cost: Test Wave 2 (lots of 100 K).**

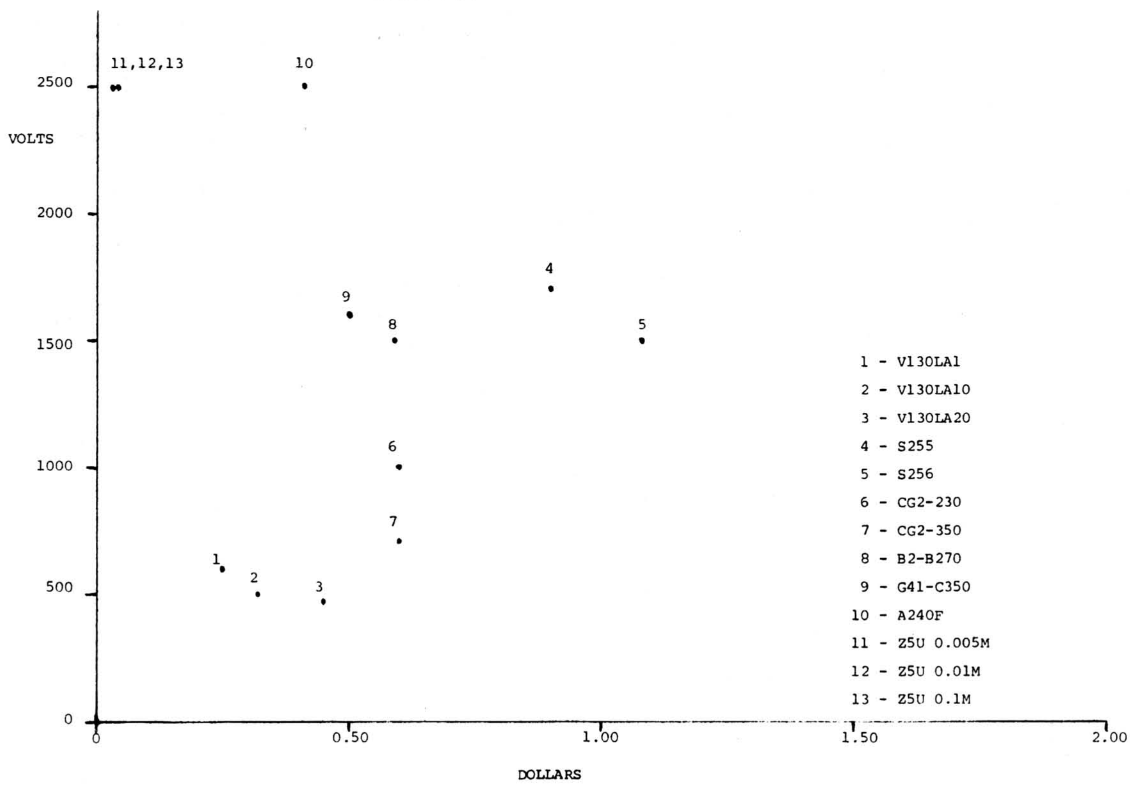


Figure 9. **Protective voltage level vs. cost: Test Wave 3 (lots of 100 K).**

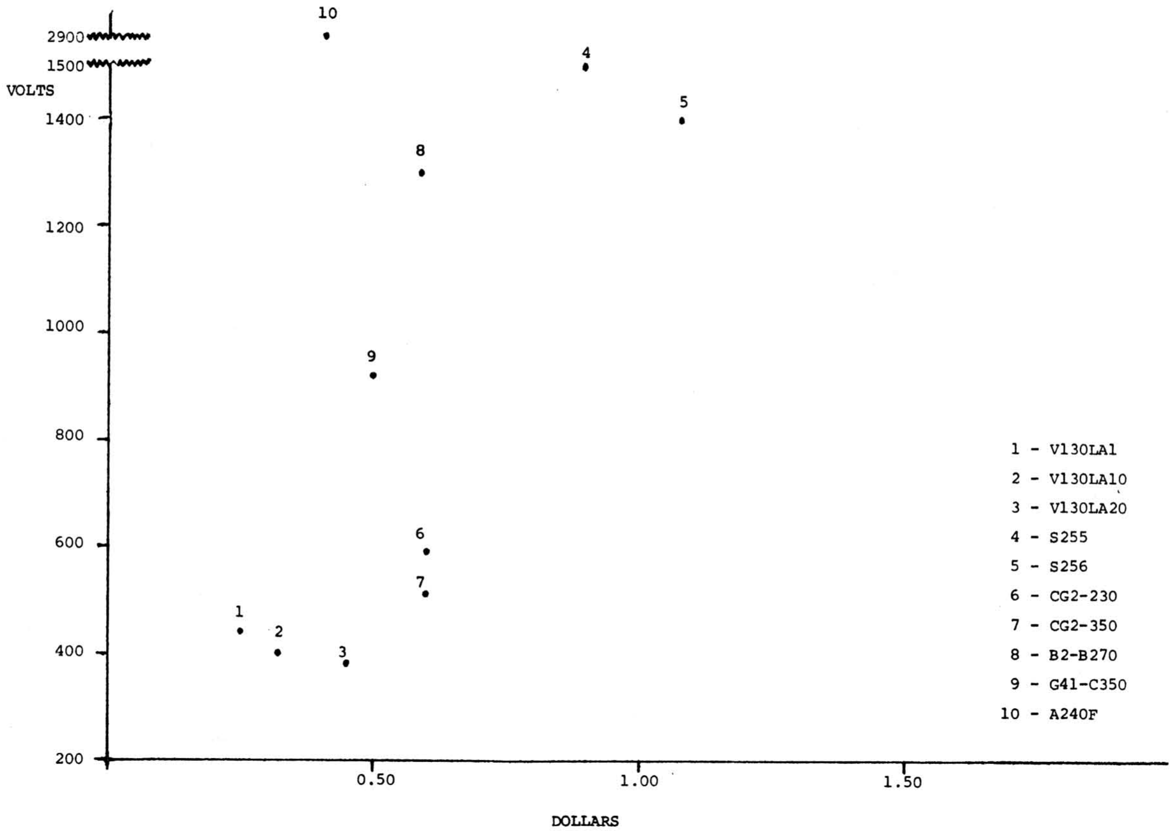


Figure 10. Protective voltage level vs. cost: Test Wave 4 (lots of 100 K).

- The GE-MOV® varistors withstood the four test waves and showed a good protective level at low cost.

Surprisingly, a number of devices that offered an exceptionally good response to the characterization tests (10 μs x 1000 μs current wave) failed when subjected to the harsh, higher energy transients.

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