Surge Withstand Capability of Various Devices

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Significance:
Part 7 – Mitigation techniques

The present interest in this report is historical as the experiments and devices it describes represent the initial efforts in addressing the emerging problems associated with the introduction of semiconductors in the consumer market.

This report was prepared to document experiments performed in the early sixties to assess the surge withstand capability of devices available at that time for use in residential circuits. The context was that the emerging electronic appliances were found vulnerable to transient overvoltages and therefore in need of some form of protection.

The findings arose sufficient interest to continue on the path of research in transient occurrence, propagation, effects, and mitigation. With hindsight they might be qualified as "quaint" but they contain the seeds of later findings such as debunking the then-prevalent expectation that increasing the PIV rating of a semiconductor would increase its surge withstand capability, and the failure mechanism of light bulbs (it took 30 years of latent and only mild interest in that subject to come up with the definitive study of lamp failure mechanisms reported in the paper "*Using Incandescent Lamp Failure Levels for Assessment of the Surge Environment*" (See "Lamp Failure" in Part 2) that was motivated by the need for a "Reality Check" to be submitted to a working group of the IEC developing a technical report on the surge environment.

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SUMMARY

During the 1963 Transient Overvoltage Pooled Program, various devices were subjected to surges, either deliberately as the result of a specific interest or indirectly as a result of being part of a larger system.

This report documents the observations made during the year. The results are not otherwise related to each other.

Data are reported on the failure level of the following devices, and are offered as "for instance" bench marks rather than transient ratings:

Silicon rectifiers

Silicon Controlled Rectifiers

Incandescent light bulbs

Delco Cadmium Sulfide photo cell

KEY WORDS

INFORMATION PREPARED FOR Transient Overvoltage Pooled Program

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TIS 63GL133

SURGE WITHSTAND CAPABILITY OF VARIOUS DEVICES

BACKGROUND

During the 1963 Transient Overvoltage Pooled Program, various devices were subjected to surges, either deliberately as a result of a specific interest in their failure level, or indirectly as a result of their presence in a larger system being subjected to surges (for instance, light bulbs). This report documents and records the observations made during the year.

The value of these results should be to disseminate a better appreciation of the capabilities or limitations of some devices. The numerical values given for the failure levels are limited to the specific device under the stated conditions, and should not be construed as ratings.

CONCLUSIONS

The failure level of these devices under transient overvoltage falls within the range of surges recorded on typical 100 V AC distribution systems. (See TIS 62GL191). Therefore, continued caution is in order when applying these devices in circuits exposed to such surges.

Surge suppressions have been investigated, as previously reported; they can reduce the surge levels to harmless values. (See TIS 63GL97).

SILICON RECTIFIERS

Various rectifiers were subjected to the surges described under the test condtions shown for each type of rectifier. The criterion of failure was chopping of the surge wave or short circuit of the rectifier circuit.

RECTIFIER	TEST CONDITION	TYPICAL FAILURE
GE 1N679 (Glass Subminiature, Diffused junction 200 and 600V PIV)	Reverse voltage surge of 0.1 x 5 µs applied at peak of 60 cps inverse voltage, at room temp.	Fails at 1700 volts in 1 µs or less
"	Reverse voltage surge of 0.1 x 5 µs applied during conduction time junction at 150°C	Fails at 800 volts in 1 µs or less
GE 4JA4 low current alloyed junction 200 and 600V PIV	Reverse voltage surge with various rates of rise at room temperature	Fails at 1500 volts in 1 µs or more Fails at 2500 volts in 0.1 µs or less
GE 4JA10 low current alloyed junction 400 and 500V PIV	Reverse voltage surge of 1 x 3 us applied at peak of 60 cps inverse voltage in capacitor input halfwave DC rectifier	Fails at 1300 volts
GE 1N1696 low current alloyed junction 500V PIV	"	Fails at 1200 volts
Mallory 1N2070 (400V PIV)	"	Fail at 1500 volts following overshoot of 1800 volts at front of surge
Semtech SC4 (400V PIV)	"	Fail at 1200 volts
Mallory LA 400	"	Fail at 750 volts*
Mallory TX400	"	Fail at 7500 volts*
Solitron Type 400	"	Fail at 500-700 volts*

*data from very small samples (less than 5) compared to minimum of 10 on other data

SILICON CONTROLLED RECTIFIERS

C-20 Silicon rectifiers have been subjected to a transient reverse voltage surges of .1 x 5 μs wave shape, applied at room temperature and with no other steady-state voltage.

The surges were applied as single shot, with 10 surges at the same level before increasing the voltage to the next level.

At surge levels in the order of 1500 volts, the wave shape of the applied surge was distorted, showing a loading effect on the surge generator. However, no change in the room temperature characteristis of the SCR was found.

Towards 2000 volts, the surge voltage was actually chopped after .15 μs. No change in the SCR characteristics were found after 10 surges. However, after about 300 surges at 60 per second, the SCR had failed by short circuit.

Further tests are planned, so that at this time it appears that the failure level is situated between 1500 and 2000 volts.

INCANDESCENT LIGHT BULBS

Test Conditions

The bulbs were installed in the laboratory model of a typical house wiring system in which surges simulating those measured in field tests were injected from a capacitor discharge circuit (see Reference 2)

The surges, 2 to 3 microseconds wide, were applied at the peak of the 60 cps voltage with the same polarity as the instantaneous AC voltage.

Tests were made at various line voltage values on a GE 100 watt bulb, also at constant line voltage for various ratings of GE bulbs and various brands of 100 watt bulbs.

Failure levels are tabulated below (volts at crest)

Test Results

A. Variable line voltage (2 samples of each)

100 watt GE Softwhite

Line Voltage	Failure
100	2000
108	1700
110	1400
125	1400

B. 110 V line voltage (3 samples of each)

GE Bulbs

Watts	Failure
40	none at 2500
50	1200
75	1500
100	1200
150	1700
200	1700
300	none at 2500

C. 110 V line voltage (3 samples of each)

100 watt various brands

GE	1600
Champion	2000
KenRad	1900
Sylvania	1400
W	2300

Comments

1. Failure occurs at voltage levels which have been observed in field measurements.
2. The failure mechanism is not obvious. Among possible causes, thermal shock in the leads, electromagnetic stresses in the filament coil, dielectric failure (flashover of the first coil turns) are possible causes.

3. Competitive bulbs are not significantly more immune to surge failure.

4. Starting around 1000 volts, a characteristic "click" can be heard when a surge is applied, while the bulb survives. The intensity of this clicking increases as the crest voltage is increased, and for a surge level 300 to 400 above that for which the click was first heard, the bulb will fail with a flash and a click. Therefore, it seems that this clicking may be a warning of incipient failure. It is interesting to note that no click was ever heard below 1000 volts so that even a mild attenuation of surges might be sufficient to protect the bulbs.

Delco Cadmium Sulfide Photo Cell
(see copy of spec. sheet)
EXHIBIT A

Test Conditions

Surges with 0.5 μs rise time and 50 μs tail were applied to a 25 watt light-dependent resistor. Criterion of failure was a significant change in the cell resistance before and after surge, combined with an apparent change in wave shape on the CRO display. The cell resistance is lower with incident light, causing greater regulation of the surge generator between the no-load and loaded output. The energy dissipated in the cell corresponds to that required to develop the instantaneous voltage displayed on the CRO across the resistance of the cell under the existing light conditions.

Test Results

A. Cell in dark, 500 KΩ initial resistance

Withstand: 1400 volts

Failure at 1700 volts (20 KΩ final resistance)

B. Cell with incident light, 150Ω initial resistance

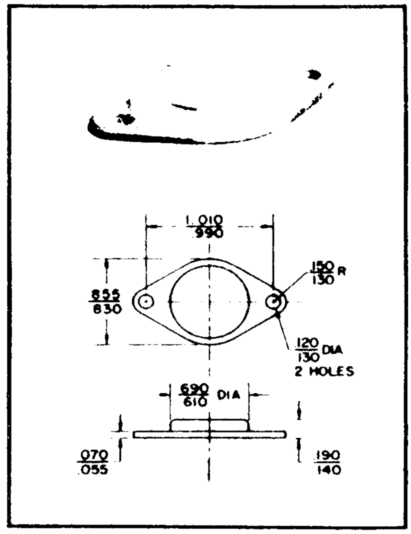
Withstand: 1200 volts

Failure at 1300 volts (200Ω final resistance, in darkness)

EXHIBIT A

ENGINEERING TENTATIVE DATA SHEET

25 WATT LIGHT DEPENDENT RESISTOR



GENERAL DESCRIPTION

The Delco Cadmium Sulfide Power Photocell is constructed of a thin layer of sintered semiconductor applied to an aluminum oxide substrate. Virtual hermetic sealing, which is necessary to protect the device from moisture is accomplished through the use of film adhesives and a glass cap. With this construction, it is possible to obtain power handling capabilities heretofore not available in this type of device. Sensitivity, speed of response, and dark resistance are representative of the present state of the art in this field. However, the current handling capability of 1 ampere and the power dissipation rating of 25 watts far exceed any announced rating by other manufacturers.

APPLICATION

The power photocell is intended primarily for medium or high power switching and control applications where turn-on and turn-off times of the order of tens of milliseconds are required. The device is designed to operate directly from 110VAC and is conservatively rated at 200 DC or peak AC volts. Because of its high voltage rating and inherently "slow" switching speed, the power photocell is particularly suited for control of inductive loads where voltage surges encountered with breaker points or junction devices are a problem. (Surge current of short duration up to 1 ampere can be tolerated in most applications).

When used with captive light sources, the power photocell can provide appreciable power gain as well as complete isolation between control and load circuits. With standard miniature incandescent lamps, continuous smooth control of up to 50 watts in the load circuit can be obtained with control inputs of 1 watt or less. Using miniature neon lamps it is possible to switch up to 40 watts with less than 500mw input power.

Except in those applications where size is a major factor, the power photocell will replace most currently available cadmium sulfide photocells.

ABSOLUTE MAXIMUM RATING

Current	500 ma max. (DC
Voltage	200 volts max. (DC or AC peak)
Dissipation	25 watts max.* (30°C ambient)
Operating Temperature	60°C max. (tentative)
Storage Temperature	60°C max. (tentative)

ELECTRICAL CHARACTERISTICS

Wavelength of Max. Sens.		6000 A°
Lumen Sensitivity		10 amps/lumen at 2 ft. C. and 50 VDC.
Resistance (typical D.C. values):		
Tungsten (2800°K)	10 foot candles	400 ohms
	100 foot candles	80 ohms
	1000 foot candles	15 ohms
Ne2h neon lamp with 10Kohm Series resistor (captive source)		75 ohms max.
Dark (10 sec. after removal of light)		500Kohms Min.
Approx. time for current to decay to 10% of illuminated value		20 millisec. (10 ft. C. and above)

MARCH 1963

REFERENCES

1. TIS 62GL191, Transient Overvoltages in Low Voltage Systems.
(For description of typical surges recorded in low voltage systems)

2. TIS 63GL97, Surge Suppression in Typical Home Wiring Systems.
(For description of the home wiring system model and performance of surge suppressor.