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RECTIFIER NEWS

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PROTECTION OF SILICON RECTIFIER CELLS DURING DIELECTRIC TESTING OF EQUIPMENT...

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INTERNATIONAL POWER NEWS

TRACTION

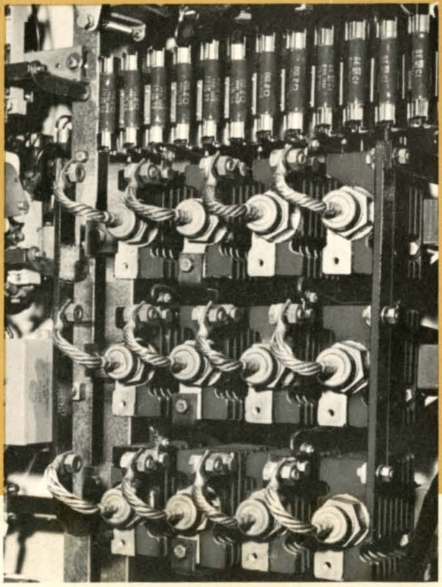
Now, by a new application of an old principle of transmitting electricity, a revolutionary plan for railroads is under way in Europe.

Silicon rectifiers manufactured by International Rectifier Corporation are in use in Italy for energy conversion aboard experimental locomotives. In the new method of railroad electrification, alternating current for the electric locomotives would be carried by existing utility lines, transformed to direct current at planned transformer stations, and then carried along short lines for use only where required by the locomotives. This method, which is under extensive study, will be more economical and effective than present methods. For four months, the locomotive pictured has been making daily runs through steep mountainous country between Genoa and Tortona, a distance of 400 kilometers.

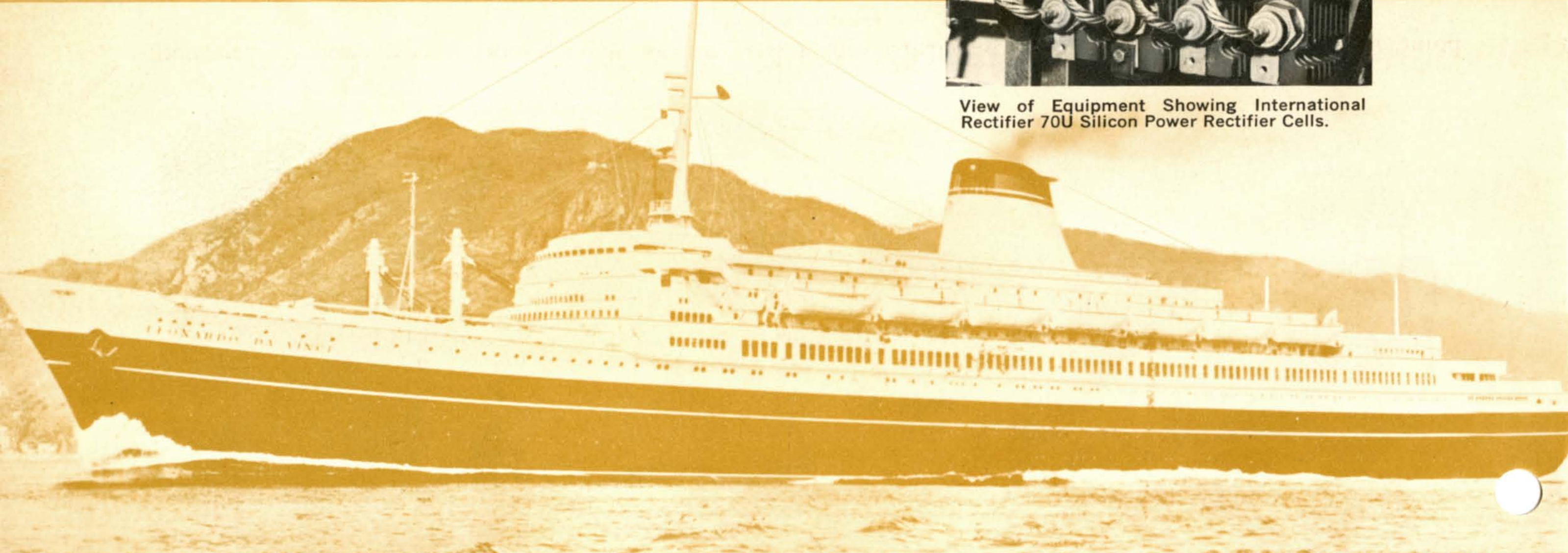
SHIPBOARD

Power silicon rectifiers supplied by International Rectifier Corporation help to make Italy's newest luxury liner, the Leonardo da Vinci, the most highly automatized passenger vessel afloat today. The ship, which recently completed her maiden voyage to New York, uses the silicon rectifiers to power d.c. motors.

The total rectifier installation is rated for 420 kw at 227 volts. It includes two rectifiers, rated at 65 kw each, to weigh the ship's two main anchors, eight rectifiers of 44 kw each to operate cargo winches, and four rectifiers of 24.2 kw each to run the kedges (floating drift anchors).



View of Equipment Showing International Rectifier 70U Silicon Power Rectifier Cells.



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FOUNDATION FOR RELIABILITY!

A Review of the Extensive Production Tests that Assure Maximum Performance of International Rectifier Silicon Power Rectifier Cells

BY FRANK GIFT, DIRECTOR, TEST ENGINEERING AND QUALITY ASSURANCE

Introduction

Before a new semiconductor device is acceptable for marketing, it is necessary to establish electrical ratings and to investigate its electrical and mechanical characteristics.

For power rectifier cells, the important ratings are (a) peak reverse voltage, (b) maximum current under various operating conditions, (c) maximum temperature of operation and of storage, and (d) maximum surge current capability. These ratings are established from design considerations and through the evaluation of a large number of samples under limited conditions, including life tests at peak proposed ratings and tests made to destruction.

The engineering effort required to market the device is incomplete at this point, however. Production testing techniques must also be developed which will insure that production line units are equal to the samples originally evaluated, if not better, and that each individual cell shipped will not fail when subjected to any combination of rated conditions.

PRV Test

One of the first tests to be performed is voltage grading, to determine the peak reverse voltage rating of the rectifier cell. A method generally used is to apply an alternating voltage to the cell, with another cell connected in opposition blocking the current during the forward half-cycle. The instantaneous reverse leakage vs applied voltage is pictured dynamically on an oscilloscope. Figure 1 shows a typical pattern.

While the reverse characteristic is being monitored, the voltage is increased up to the avalanche point, where the reverse leakage begins to rise rapidly with a small increase in voltage. A series current-limiting resistor must be used in the circuit to protect the cell from overheating and from destroying itself when the avalanche point is reached. The cell will be rated at a point sufficiently lower than the avalanche voltage so that this breakdown condition will be avoided during rated operation.

Since the reverse characteristics vary with temperature, the reverse trace is observed both at room ambient and at an elevated temperature (175°C). The maximum PRV rating assigned will be set by the worst condition observed. Figure 2 illustrates a reverse test console.

AC Leakage

During the time the cell is undergoing the PRV test, it is measured for full-cycle average leakage current at maximum voltage rating.

Evaluation testing has shown that reverse leakage must be maintained below certain values to permit long-

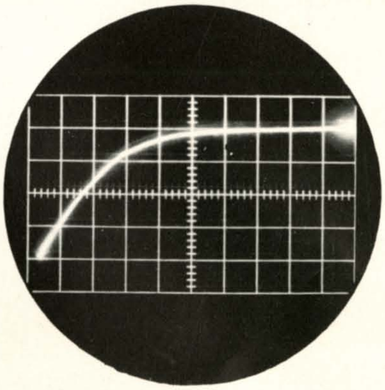

Figure 1. Oscilloscope photograph showing instantaneous reverse leakage in the vertical direction vs instantaneous applied voltage in the horizontal direction.

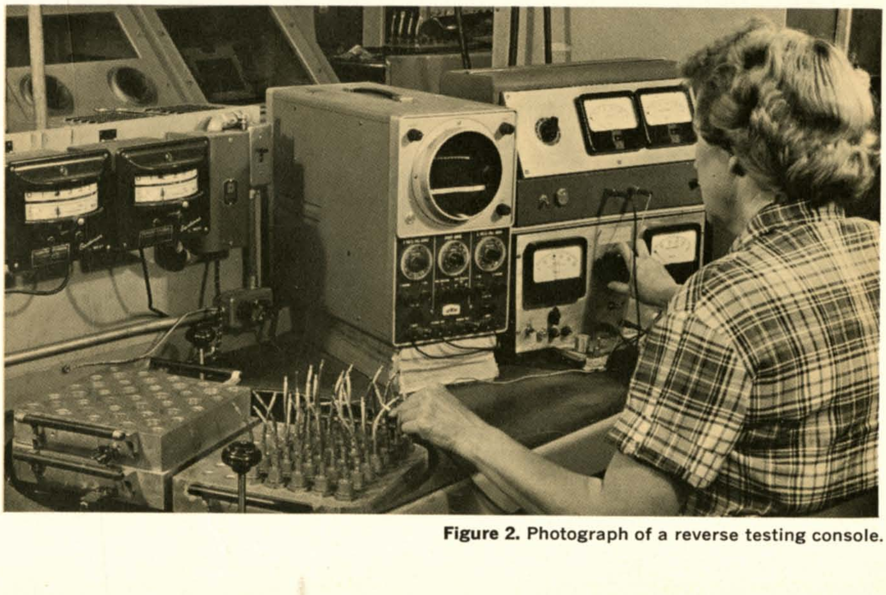

Figure 2. Photograph of a reverse testing console.

time operation without deterioration at thermal runaway. Again, this test must be performed at room temperature and at an elevated temperature, to insure satisfactory operation throughout all possible conditions within prescribed ratings.

DC Leakage Stability

While at elevated temperature, each cell is also subjected to a direct voltage and measured for stability of leakage current to insure that runaway conditions do not exist. If runaway leakage occurs, it is usually a sign of localized heating somewhere in the junction or over the surface. It is necessary, in such a case, to severely derate the cell in order to avoid trouble in operation.

Surge Test

Since the type of fuse protection required by the rectifier is important in equipment design, a vital rating of a cell is its surge current capacity. The danger to the cell from a high surge current is that heat is generated which may raise the temperature of some spot in the device above the melting point for one of the materials.

The ability of a given cell to withstand current depends upon the materials used in its construction. upon the thermal mass and thermal impedance of the components (that is, the ability to absorb high energy without causing excessive localized temperatures), and upon the amount of heat generated by the current (either in the junction area or in any soldered or crimped joints).

The normal surge current rating has previously been determined by destructive tests, and it only remains for the production line test to weed out abnormal cells incapable of withstanding rated surge currents. The method used by International Rectifier Corporation is to apply a very high current (500 amps peak for 25H series rectifier cells) over three successive cycles of 60 cycle power. The instantaneous forward voltage drop vs forward current is dynamically monitored on an oscilloscope.

The oscilloscope presentation is also designed to show borderline cases (those which are weak, but not bad enough to destroy themselves). The oscilloscope trace of a normal cell will appear as one solid curve. (See Fig. 3). However, since the forward characteristic of a cell is temperature sensitive, and since three successive pulses of current are applied to the cell, a family of three distinct curves will be observed when testing a cell showing high localized heating. (See Fig. 4). Such a cell is rejected.

Overload Test

The continuous current rating and extended-period overload ratings of rectifier cells depend upon the amount of heat generated in the junction and its associated parts, and upon the thermal impedance between the junction and the heat exchanger under consideration. Standards and ratings have been determined by evaluation testing, but it is still necessary to insure that no substandard cells are shipped.

To test for compliance to current ratings, the cells are operated in an actual operating circuit at full voltage rating and with an over-current. They are firmly mounted to a heat sink which is maintained at a constant 120°C temperature, and are operated for one minute, during which time the reverse leakage current is monitored for runaway. At the end of this time the temperature of each cell is recorded.

Excessive temperature rise of the anode is cause for rejection. Cells which are rejected on this test, when dissected, will be found to have a faulty solder joint or some other defect, and this condition cannot usually be detected by the forward voltage drop test. Figure 5 pictures a load tester in operation.

Forward Voltage Drop

The forward voltage drop may be measured and expressed in many different ways: Static dc, full-cycle average, average over the conductive portion of the cycle, equivalent rms, or instantaneous.

A good measurement method is to take a dynamic reading applying sufficient transformer voltage to promote 180° conduction in the forward direction without excessive wave shape distortion, and then to measure the voltage drop across the cell with a circuit which measures only the voltage drop during the forward conduction period, and has all voltage blocked from it during the reverse half-cycle. This measurement may be used for assuring adherence to specifications and for forward matching of cells.

Additional Production Tests

There are other production-line tests which are also performed, such

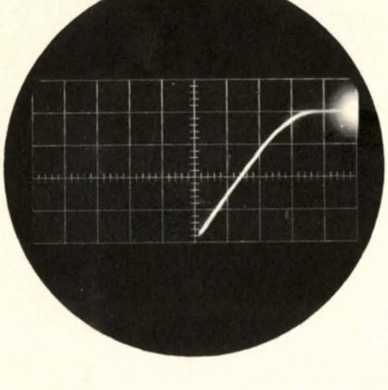

Figure 3. Oscilloscope photograph of a normal surge current trace, with instantaneous current in the vertical direction vs instantaneous forward voltage drop in the horizontal direction.

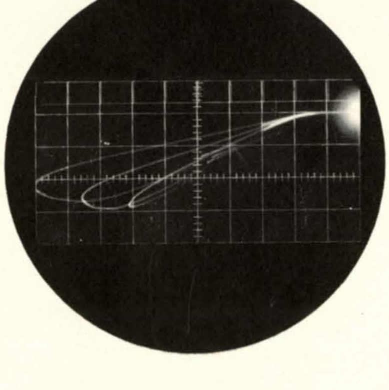

Figure 4. Oscilloscope photograph of a reject surge current trace.

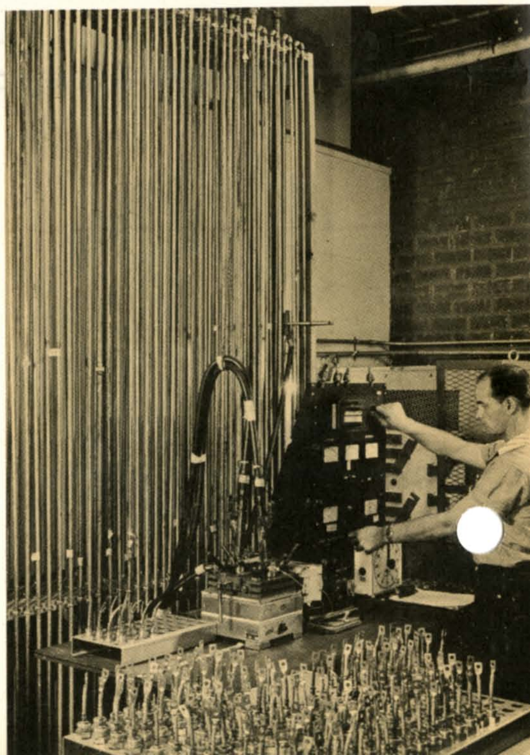

Figure 5. International Rectifier Corporation test station utilizing 280 kva load tester is shown at right.

as checks for hermetic seal and for torque capabilities, and when all these are completed it is necessary to repeat the PRV and leakage tests to insure that no damage has been sustained by the rectifier cells. Only the survivors of such a rigorous testing program qualify for shipment.

Quality Assurance Testing

In addition to the 100 per cent production testing, certain other tests must be performed periodically on a sampling basis. These checks begin with current-cycling tests on new hermetic seals, continue with temperature cycling, salt spray resistance, vibration, shock, thermal shock, and conclude with accelerated storage life tests and operating life tests under actual operating conditions, both in steady state load and in intermittent load conditions.

Conclusions

Production testing in some form is necessary to all semiconductor device fabrication, if only for categorizing, but at International Rectifier Corporation it is felt that rigorous and complete 100 per cent tests are among the most important tools for maintaining high quality levels.

The most obvious advantage is that sub-standard parts are rejected and not shipped. At the same time, by reporting and monitoring the percentage of rejects at any test position, and by performing post-mortem dissections on these rejects, information may quickly be fed back to the beginning of the production line, so that any process fault will not be allowed to continue unnoticed.

REFERENCE ARTICLES AND BULLETINS AVAILABLE

Use the enclosed information request card to order literature pertaining to silicon power rectifier cells and their application:

SILICON POWER RECTIFIER BULLETINS:

6 and 12 AMP RATED — **Circle No. 1 on Card**

25 to 35 AMP RATED — **Circle No. 2 on Card**

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Mounting Methods and Cooling Considerations for Silicon Stud Mounted Diodes **Circle No. 6 on Card**

Elimination of Surge Voltage Breakdowns of Semiconductor Diodes in Rectifier Units **Circle No. 7 on Card**

THE PROTECTION OF SILICON RECTIFIER CELLS DURING DIELECTRIC TESTING OF EQUIPMENT

By Glenn Geissinger, Sales Engineer, International Rectifier Corporation

Introduction

The use of *p-n* junction rectifier cells in electrical equipment has increased rapidly during the last few years. With the advent of the germanium and the silicon power rectifier cell came savings in size, weight, and efficiency; with increased production came savings in cost.

But along with the advantages of the new rectifier cells, problems also appeared in applying these devices properly. The current capacity, the reverse voltage rating, and the ability to withstand current overloads and voltage surges have to be carefully considered. In many cases, heat sinks are essential and have to be properly designed. And in the testing of equipment utilizing these devices, there is often the need to develop special techniques.

One of the standard tests on electrical equipment, for instance, is the measurement of electrical insulation. This is accomplished by applying a high potential between the current-carrying parts of the equipment and the non-current carrying metal parts, which may be grounded. This high-potential, or "hi-pot," test is defined either by the equipment specifications or by applicable standards of such societies as the NEMA, ASA, AIEE, or UL. International standards for this test are being attempted by the IEC.

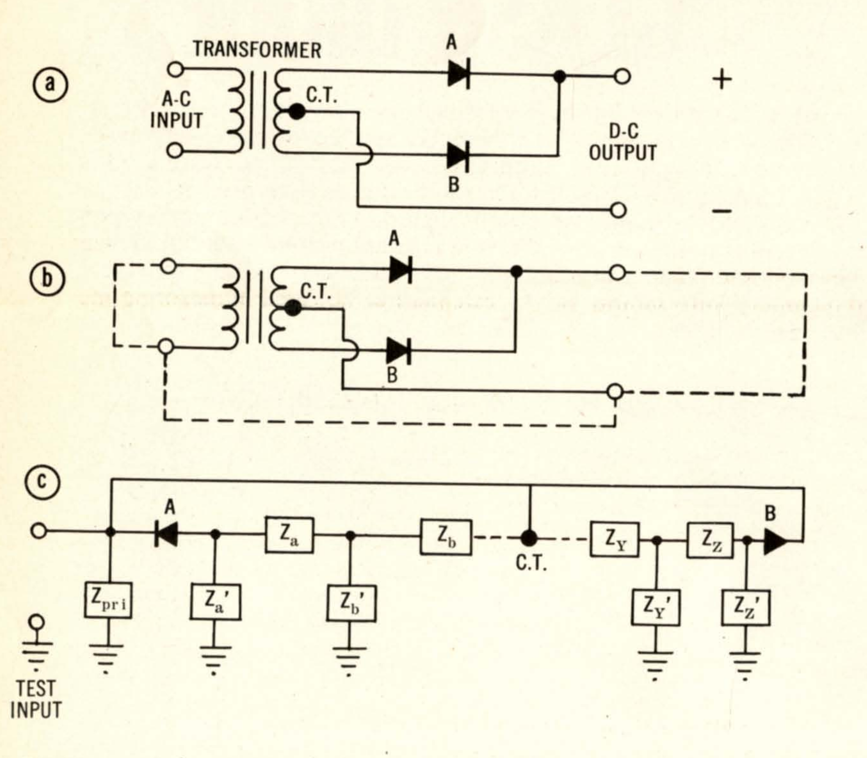

FIGURE 1 — (a) Typical power supply circuit; (b) Usual interconnections to prepare circuit (a) for the dielectric test; (c) Equivalent circuit of (b). If the rectifier cells are silicon or germanium, they must be individually short-circuited to protect them during the dielectric breakdown test.

NEMA Standards for Dielectric Tests

The NEMA standards for dielectric testing of semiconductor rectifier equipment are governed by the normal voltage in the system. For circuits with 60 volts or less, the insulation must not break down under a one minute application of a 60-cycle alternating potential of 500 volts rms. For circuits with voltages between 61 and 90 volts, the insulation must withstand 900 volts rms of the one-minute application. And for circuits with voltages exceeding 90 volts, the insulation must withstand 1000 volts rms plus twice the normal circuit voltage.

The NEMA dielectric test takes into consideration that some of the devices in the equipment may fall within the scope of other recognized standards that specify a lower dielectric test voltage. Such devices, which are to be disconnected before applying the NEMA test, are checked out separately by the applicable standard. For instance, fan motors and timers when located in the output circuit of a battery charger rated at 250 volts or less, are subjected to a dielectric test of 900 volts rms for one minute.

It is the usual procedure in performing dielectric tests to interconnect all of the current-carrying sections of the overall circuit, even though these sections may already be inductively or capacitively coupled. This short-circuiting permits the applied potential to reach freely all sections of the circuit, and in the event of insulation breakdown, prevents excessive voltages from being applied to critical components such as rectifier cells, capacitors, resistors, and coils.

Dielectric Testing of Silicon and Germanium Rectifiers

The electrical interconnection described in the preceding paragraph works well when the rectifier cells are selenium, copper oxide, or magnesium copper sulfide. These have a high capacitance in the reverse direction, and will pass a large reverse current when subjected to a high reverse voltage. The

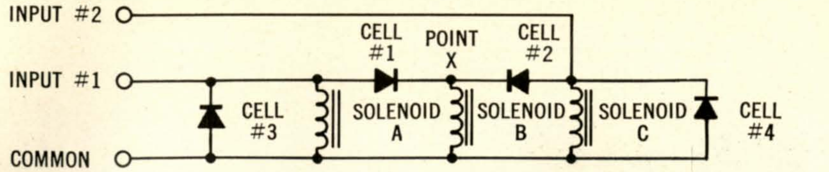

FIGURE 2 — Silicon cells used as blocking valves and as voltage surge protectors. During the dielectric breakdown test, a lead from point X to the common terminal is required in addition to the usual short-circuiting of the terminals.

capacitive and resistive current will effectively form a short circuit and prevent excessive voltage buildup.

Now that we are also employing silicon and germanium rectifier cells, the situation is different. These cells have a characteristically low capacitance in the reverse direction and pass only a relatively low reverse current when subjected to a high voltage. Because of the high reverse resistance, the voltage may build up to excessive values, and, consequently, unless the cells are individually short-circuited, they may be destroyed.

This leads us to the following rule:

When making a dielectric test on equipment that uses silicon or germanium rectifier cells, the cells must be individually short-circuited to prevent their destruction.

Example 1

Consider a typical power supply circuit, illustrated in Fig. 1(a). In performing the dielectric test, the operator may interconnect the various sections and tie the input and output leads together, as shown in Fig. 1(b). Since the high potential will be applied to either the jumpers or to one of the terminals, the equivalent circuit will be that shown in Fig. 1(c). Here, Z_{pri} represents the lumped impedance of the primary winding, whereas, Z_a, Z_b, etc. represent the individual impedance of each turn in the second-winding, and Z'_a, Z'_b, etc. represent the corresponding insulation impedance to ground.

Normally, the insulation impedance is lowest where the wiring is in intimate contact with a grounded metal part, such as in transformers, relays, chokes, and magnetic amplifier coils. In the circuit under consideration, the insulation impedance of the transformer, which will depend on the materials used and the construction techniques, is the only insulation impedance we need consider. The leakage current through it would generally be small and not of a magnitude corresponding to breakdown of insulation.

As noted in Fig. 1(c), however, the leakage path to ground is set up through the electrical insulation and also through the rectifier cells. If we assume that the equipment has a rated input of 115 volts rms, the dielectric test would be conducted by applying 1230 volts rms, which corresponds to a peak value of 1739 volts. By voltage divider action, it is conceivable that over a thousand volts may be impressed in the reverse direction across a given rectifier cell.

Now, a rectifier cell like silicon, is essentially a crystal slice which has been especially processed to form a *p-n* junction. This junction, which provides the rectification, is quite thin. If a large potential is applied across it, a high field will result, which may lead to dielectric puncture and short-circuiting of the cell. In addition, other phenomena may occur that could cause the cell to fail in service, as, for instance, arcing across the crystal surface or even changes in the nature of the surface.

All these undesirable effects can be prevented by short-circuiting each one of the silicon or germanium cells during the dielectric test. This is important to remember, and should be written into the test specifications.

Example 2

With the present trend in missile design to use a-c rather than d-c power sources, many manufacturers of solenoid valves utilize standard d-c solenoids together with silicon rectifiers. In a typical circuit, with four silicon cells in a full wave bridge, a 120 volt rms input will provide a rectified direct voltage of 103 volts to the solenoid.

With most solenoid designs, a filter is not required for smooth operation, and the rectifier cells are often potted in epoxy resins to form a compact rectifier-solenoid package. In these cases, the rectifier d-c connections should be brought out as terminals, and during the dielectric test the input and output connections of the bridge should be short-circuited.

Example 3

Besides converting a-c to d-c, silicon cells are being used in many other ways, as, for instance, in d-c blocking, in switching, and as voltage surge protectors across inductive elements.

Fig. 2 illustrates some of these functions. With a positive direct potential applied to input #1, solenoids *A* and *B* are energized; if the potential is applied to input #2, solenoids *B* and *C* are energized. Cells #1 and #2 act as valves to block current flow through the third solenoid in each case. When potential is removed from the input terminals, cells #3 and #4 prevent voltage buildup across the solenoids.

In making a dielectric test of the system in Fig. 2, it is not enough to connect the two input terminals to the common terminal. This would short-circuit cells #3 and #4 but would leave the other two open. A lead from point X to the common terminal is also required.

Example 4

In many low power rectifier installations using stud-mounted silicon or germanium cells, the cells are electrically insulated from cooling fins by means of thin materials of high dielectric strength. This way, the cooling fin and heat sink are at ground potential — they may even be the metal chassis or cabinet — but the resistance to heat transfer is greatly increased. Since the electric ratings of stud-mounted rectifier cells are usually determined by direct mounting on cooling fins, the cells will have to be derated here to some extent.

The insulating washers, which are usually mylar, mica, or mica bonded glass silicone, about 0.001 to 0.003 inches thick, are quite fragile and great care must be observed in mounting the cells to the heat sink. The device must be firm and tight against the heat sink to reduce thermal resistance as much as possible, and even though the manufacturer supplies maximum and minimum recommended tightening torques, care must be taken to eliminate any rough or sharp edges on the mating surfaces, for mechanical damage or cracking of the insulating washer may lead to breakdown on the dielectric test. Dielectric failure may also result from high field strength at burrs or other sharp edges and corners.

Conclusion

When performing a dielectric test on equipment that contains silicon or germanium rectifier cells, it is necessary to short-circuit each cell to prevent them from being damaged or destroyed from overvoltage.

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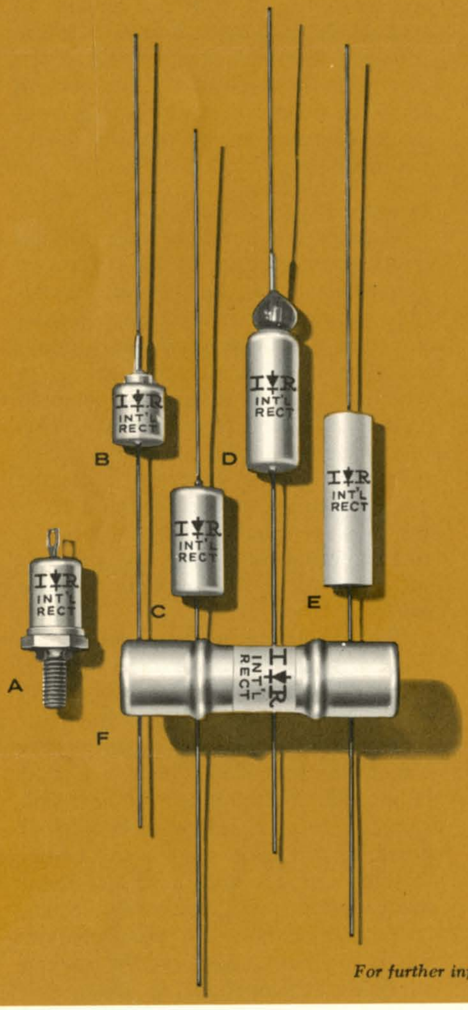

Type Number	Peak Inverse Voltage, Volts	Rectified DC Output Current, MA	Max. Voltage Drop @ Rated Current, Volts
A – 1500 PIV @ 300 MA			
1N1130	1500	300	4.5
1N1131	1500	300	4.5
B – 600 to 1000 Volts PIV @ 125 MA			
1N596	600	125	3.0
1N597	800	125	3.0
1N598	1000	125	3.0
C – 600 to 1000 PIV @ 100 MA			
1N1406	600	100	5.0
1N1407	800	100	5.0
1N1408	1000	100	5.0
D – 1200 to 2400 PIV @ 100 MA			
1N1409	1200	100	5.0
1N1410	1500	100	6.25
1N1411	1800	100	7.5
1N1412	2000	100	6.25
1N1413	2400	100	7.5
E – 600 to 10000 PIV @ 40 to 150 MA			
1N2373	600	150	3.0
1N2374	1000	150	3.0
1N2375	1500	130	4.5
1N2376	2000	130	7.5
1N2377	2400	100	9.0
1N2378	3000	100	9.0
1N2379	4000	65	15.0
1N2380	6000	65	22.5
1N2381	10000	40	37.5

Type Number	Peak Inverse Voltage, Volts	DC Output Current @ 75°C, MA	Max. Voltage Drop @ Rated Current, Volts
F – 1500 to 16000 PIV to 100 MA			
Standard Types – Convection Cooled			
1N1133	1500	75	15.0
1N1134	1500	100	7.5
1N1135	1800	65	18.0
1N1136	1800	85	9.0
1N1137	2400	50	24.0
1N1138	2400	60	12.0
1N1139	3600	65	27.0
1N1140	3600	65	18.0
1N1141	4800	60	36.0
1N1142	4800	50	24.0
1N1143	6000	50	45.0
1N1143A	6000	65	30.0
1N1144	7200	50	54.0
1N1145	7200	60	36.0
1N1146	8000	45	60.0
1N1147	12000	45	60.0
1N1148	14000	50	52.0
1N1149	16000	45	60.0
F – 1500 to 16000 PIV to 360 MA			
High Current Types – Forced Cooled at 2000 LFM			
1N1745	1500	300	15.0
1N1746	1500	360	7.5
1N1747	1800	270	18.0
1N1748	1800	330	9.0
1N1749	2400	220	24.0
1N1750	2400	270	12.0
1N1751	3600	290	27.0
1N1752	3600	280	18.0
1N1753	4800	230	36.0
1N1754	4800	220	24.0
1N1755	6000	210	45.0
1N1756	6000	280	30.0
1N1757	7200	240	54.0
1N1758	7200	230	36.0
1N1759	8000	220	60.0
1N1760	12000	220	60.0
1N1761	14000	240	52.0
1N1762	16000	220	60.0

When writing for individual data sheets, specify the series you are interested in, by voltage and current rang

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