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SILICON RECTIFIER HANDBOOK

$1.00

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Sarkes Tarzian

Silicon Rectifier Handbook

Contents

To help keep you informed on the latest information on Silicon Rectifiers, the Sarkes Tarzian Sales and Engineering Departments have spent countless hours on this handbook to make the information as complete as possible. We realize many new applications are developed daily, and we invite your inquiry on the proper rectifier for your application. We hope this handbook serves you well.

G. Eannarino

Sarkes Tarzian®

Silicon Area Rectifiers

INTRODUCTION

Of all recent developments and improvements in the fields of power conversion and semi-conductors, silicon rectifiers offer the most promising range of applications; from extreme cold to high temperature, and from a few watts of output power to very high voltages and currents. Inherent characteristics of silicon allow junction temperatures in the order of 200°C before the material exhibits intrinsic properties. This extends silicon's operating range beyond that of any other efficient semi-conductor and the excellent thermal range coupled with very small size per watt of output power, and extremely high efficiency because of high inverse resistance, make silicon rectifiers applicable where other semi-conductor rectifiers were previously considered impractical. In this handbook we have tried to cover a few basic concepts of design and application. Any questions or problems that you may forward will be carefully considered and promptly answered.

Theory of Operation

The solid state physics and quantum mechanics involved in the complete explanation of semi-conductor devices, and particularly the behavior of silicon, are beyond the scope of this booklet; however, we will consider a few of the elementary concepts and phenomena to give the electrical and electronic engineers and technicians some insight into the physical background of the silicon rectifier. Nearly all developments and knowledge in the semi-conductor field have, to date, been contributed by physicists and metallurgists; however, the state of the art has now reached the "practical" stage and it is necessary to bridge the gap between the laboratory scientist and design engineer to completely realize the truly great potential this new field has opened. While it is not necessary for the design engineer to be completely versed on semi-conductor theory, it is desirable that he have some understanding of fundamental concepts to realize limitations and strong points thus design for optimum results.

Silicon as used in silicon rectifiers is a nearly perfect single crystal of pure metal to which has been added an element from either group III or group V of the Periodic Table. (Silicon is in group IV). Silicon doped with a group III element conducts electrical current by means of holes and is designated as "P" Type. In Silicon doped with a group V element, the current conduction is by means of electrons and the semi-conductor is "N" Type. Actually, since it is impossible to control, introduction of all undesired elements, there are both group III and group V elements present and the overall effect is that of the net difference. Thus, in "N" Type silicon the difference in the number of group V atoms minus the number of group III atoms determines the number of conduction electrons. The most numerous carriers are designated as majority carriers, therefore, for example, electrons are majority carriers in "N" Type silicon and holes (positive charges) are minority carriers.

The silicon junction rectifier or diode consists of a "P"-"N" boundary within the lattice of a single crystal of silicon. This boundary can be formed by any one of several methods and individual practices follow those that produce the most satisfactory product for intended fields of application. In silicon area type rectifiers the body of the wafer generally consists of "N" Type silicon on which a very thin layer of "P" is formed by either alloying or diffusing a suitable material. The boundary, or barrier layer thus formed is very thin, less than 10^{-3} centimeters, therefore, on a junction capable of blocking a potential of 1000 volts the space charge across the barrier layer is greater than 10^6 volts per centimeter. It is obvious, therefore, that to produce high voltage junctions extreme care must be taken to eliminate all unwanted impurities that tend to ionize at high potentials.

At zero bias diffusion effects of electrons and holes are opposed by an electrostatic space charge and the junction is at equilibrium, however, as external voltage is applied the junction exhibits unilateral characteristics of current flow. Current flows readily when a positive potential is connected to the "P" side of the junction, and very low currents flow when the potential is reversed and the positive connected to the "N" side of the junction. This unilateral effect defines the area of usefulness of a silicon rectifier and the ratio of conductive to blocking resistance establishes the rectification ratio of the rectifier cell. Blocking resistances are as high as 10^9 ohms while the forward resistances are measured in fractions of ohms, therefore, the rectification efficiency is greater than 99% with forward drop contributing nearly the total loss. These phenomena can be understood when one considers the electrostatic space charge mentioned above. This space charge is analogous to a constant internal bias that can be considered a potential "hill" that requires finite energy to overcome. The potential "hill" has polarity and can be represented as a battery with the positive end connected to the "N" side of the junction and the negative end to the "P" side. When an external voltage source is connected with positive polarity to the "N" side, the external and internal potentials are additive and tend to increase the potential "hill". This will allow very little current flow, most of which is due to diffusion of minority carriers and identifies the "reverse" connection where high resistance is encountered. When the source polarity is reversed, however, the source potential opposes the internal potential, and assuming that sufficient potential is applied, relatively large amounts of current will flow. This establishes the "forward" connection, or the direction of low resistance.

The voltage required to overcome the internal space charge is quite low, and while it will vary somewhat depending on process and cell temperature, will range from 0.4 to 0.7 volts. It is significant only on consideration of forward current since it limits the minimum voltage applications. On reverse characteristics the space charge is additive and contributes slightly to the effect of the total inverse potential.

Much of todays semi-conductor theory is based on hypothesis and results on relatively limited tests since the state of the art has less than a decade of background. Truly qualified personnel are limited in number but as we and others like us start to produce and use silicon rectifiers in large quantities, information will be added at an ever increasing rate. We believe that in very few years silicon devices will be the most popular in use in fields of power conversion and amplification.

Manufacturing Process

Silicon does not readily lend itself to zone refining, therefore, the most popular method to produce single crystals of pure silicon is crystal "pulling" where a seed of pure single crystal silicon is dipped into molten silicon, rotated slowly and withdrawn at a predetermined rate. A major problem in crystal "pulling" is to keep the resultant crystal free from contaminants. Molten silicon is very active and attacks the materials used in containers and holders. Quartz crucibles are commonly used and the entire process is conducted in an inert atmosphere to reduce the possibility of contamination. Temperature is also very important and plus or minus 0.1°C at approximately 1430°C must be maintained.

When it is determined that the crystal has resulted in the desired type, (either "P" or "N") and that the resistivity is within the range that will produce suitable voltage ratings, the crystal is cut into thin slices, and finally into small wafers or dice of desired size and thickness.

After suitable etching and grading to separate wafers that do not conform to established thickness specifications, the dice are alloyed by a special process. Alloying is conducted at high temperatures and provides not only a "P"-"N" junction on one side of the wafer but a low ohmic contact on the base. Low resistance contacts are important, since once the internal space charge is overcome the resistance of the cell decreases exponentially and contact and lead resistances become factors limiting current flow.

Alloyed dice are brazed to a base and then sealed after a contact is provided to the alloyed side. Extreme care must be taken during the mounting and assembly operations to keep the surface free from contamination of any type since contaminants will ionize and shunt the junction.

Final electrical and mechanical tests are performed before and after successive heat cycles to make certain that the rectifier is stable under all conditions of temperature, humidity, altitude and shock.

Characteristics

FORWARD

The direction of low resistance or high current flow is defined as the "forward" of the silicon rectifier and since the majority of the power losses within the device are concentrated in the conduction cycle we will consider this carefully. Figure 1 shows the classic static forward current characteristics versus applied voltage. These data show the effect of the space charge that establishes a threshold voltage at approximately 0.6 volts D.C. Note that once the device starts conducting the current increases exponentially with small increments of voltage, then nearly linearly on a very steep slope.

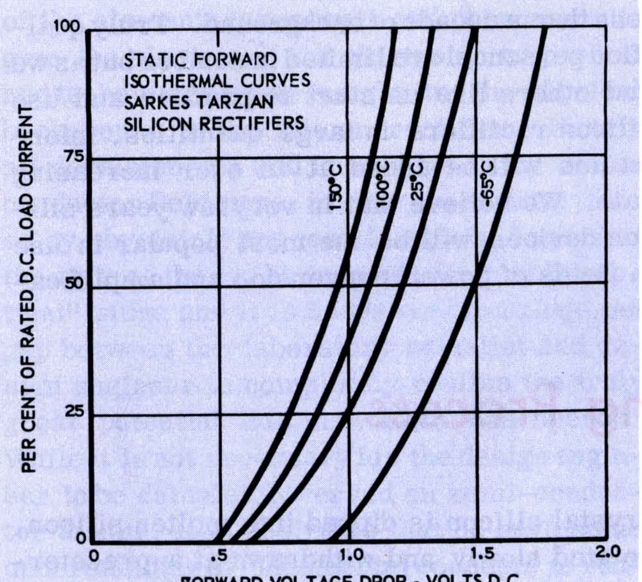


FIGURE 1

The current density of a silicon rectifier is very high and on present designs ranges between 600 and 900 amperes per square inch of effective barrier layer area. This depends to a great extent on the general construction of the enclosure and particularly on the ability of the heat sink to conduct heat from the crystal. To give some insight into the problems involved, a rectifier rated at one ampere D.C. and 5 amperes of peak surge current contains a cell that has a total volume of .0000112 cubic inches. A rectifier rated at 15 amperes D.C. and 150 amperes of peak surge current has a total cell volume of .000227 cubic inches. Peak currents are extremely critical because the small mass of the cell will heat instantaneously and could conceivably reach failure temperatures within a time lapse of a few microseconds.

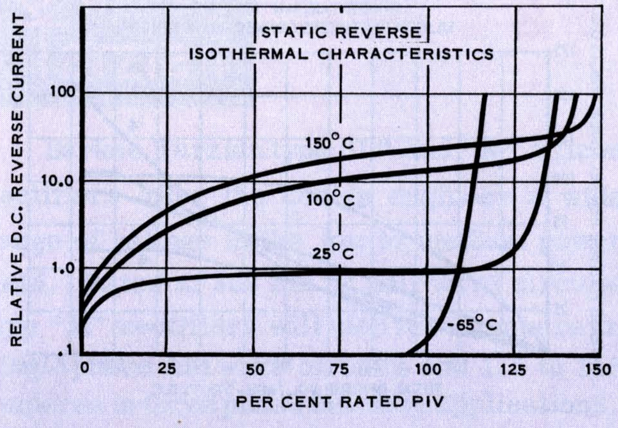


FIGURE 2

REVERSE

The reverse direction of a silicon rectifier is characterized by extremely high resistance, up to 10^9 ohms, below avalanche voltage, then at avalanche a very sharp break and rapidly decreasing resistance. This characteristic is graphically illustrated in Figure 2 that shows typical reverse current versus reverse voltage. Note the initially low values of reverse current, and sharp break as the critical voltage is reached. Because of this it is good practice to rate the peak inverse working voltage at least 20% below the avalanche point to provide a safety factor.

The avalanche point varies even between rectifiers produced from the same crystal and depends to a great extent on two factors; the resistivity of the segment of crystal from which the wafer is cut with crystal resistivity depending on distributed impurities within the crystal lattice, and secondly, surface contamination introduced during alloying, brazing, assembly, or sealing. Contaminants will ionize at relatively low voltages and shunt the junction. In a high voltage silicon rectifier that is virtually free of surface contamination and with uniform impurity distribution, the avalanche is caused by ionization of atoms within the crystal and the junction assumes characteristics similar to those that apply to ionization of gases.

Isothermal reverse curves are shown in Figure 2. These show that the avalanche voltage increases with an increase in temperature and a general softening of characteristics is noted.

OPERATING TEMPERATURES

Sarkes Tarzian Silicon Rectifiers are designed to operate in ambients from -55°C to 100°C without derating and to 150°C with moderate derating. Figure 3 shows rating curves on Type M and N rectifiers; Figure 4 shows rating curves on Type L and P rectifiers and Figure 5 shows rating curve on Type Q rectifier. On all three the maximum case temperature is 170°C with a 20°C thermal gradient anticipated between the case and the cell.

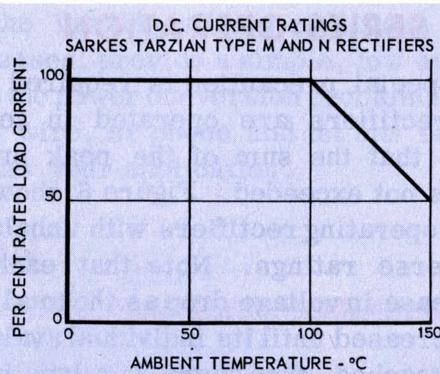


FIGURE 3

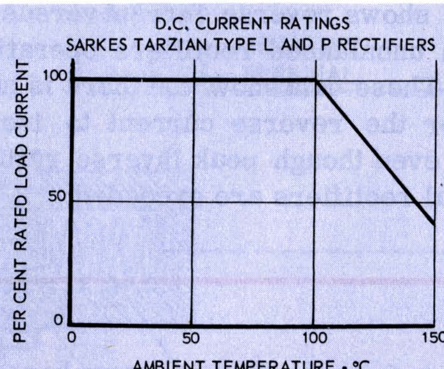


FIGURE 4

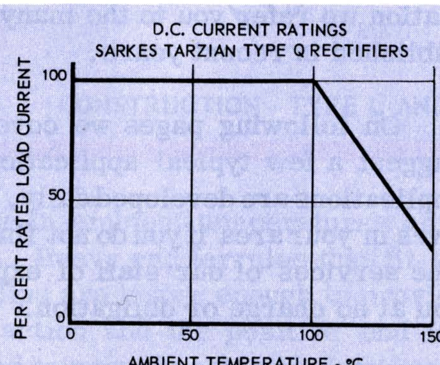


FIGURE 5

PARALLEL OPERATION

Since all silicon rectifiers are produced as half wave units with maximum current limits, it is at times necessary to use individual rectifiers in parallel to get sufficient output. Because the forward resistance is very low once a silicon rectifier starts to conduct, any unbalance between threshold voltages or internal voltage drop would cause serious unbalance of load distribution and ultimate failure of the overloaded section. For this reason we recommend a small series resistance with each half wave section operating in parallel.

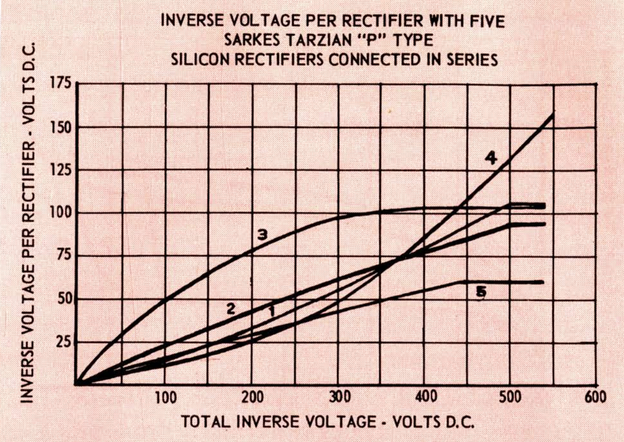


FIGURE 6

SERIES OPERATION

No special precaution is required when silicon rectifiers are operated in series, provided that the sum of the peak inverse ratings is not exceeded. Figure 6 shows the effect of operating rectifiers with unbalanced peak inverse ratings. Note that each unit will increase in voltage drop as the total voltage is increased until its individual avalanche point is reached, then there is a leveling off regardless of increase of source voltage. Figure 7 shows reverse current versus voltage with unbalanced rectifiers operating in series. These data show that there is no tendency for the reverse current to increase sharply even though peak inverse ratings of individual rectifiers are exceeded.

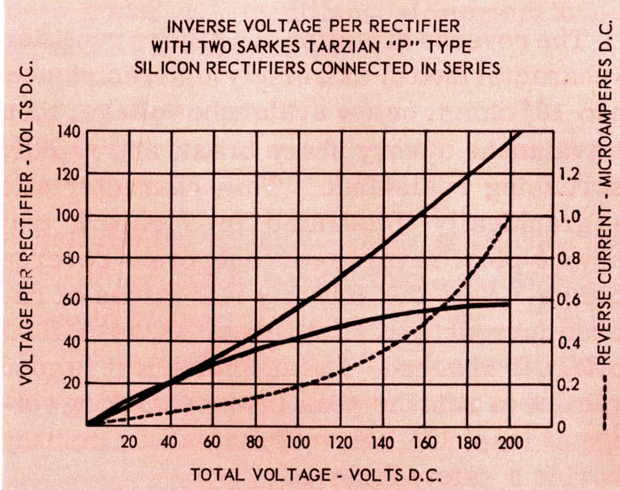


FIGURE 7

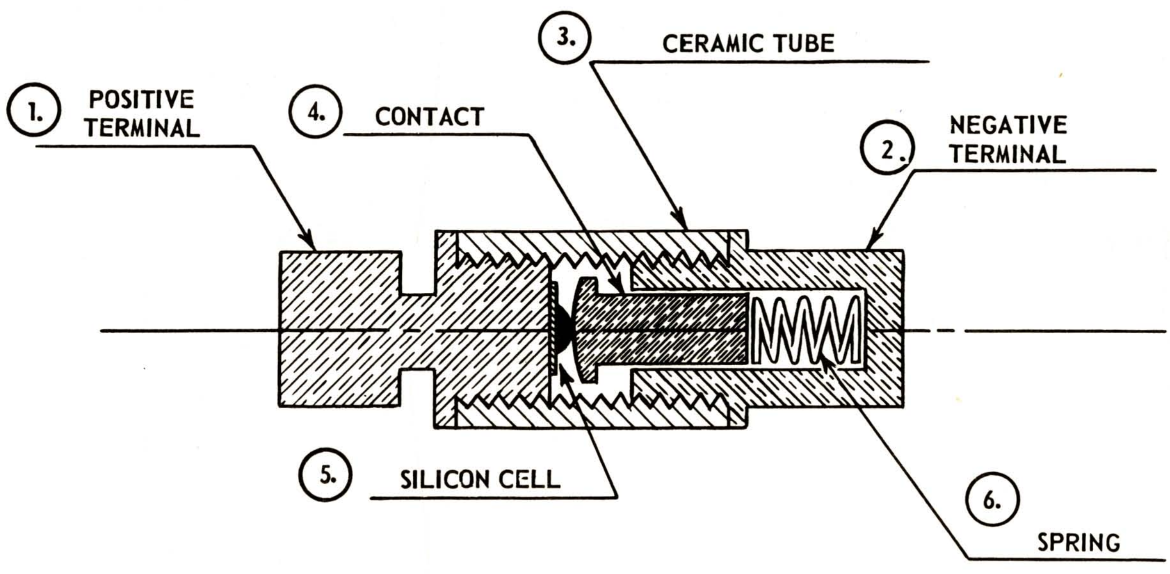
On preceding pages we have sketchily covered a few basic concepts of design and manufacturing techniques on silicon rectifiers. For more complete information we refer you to the many various textbooks and handbooks that have been published in recent years.

On following pages we cover the individual types that we manufacture and suggest a few typical applications. Since the art is so new and new types and applications are developed daily, we suggest that you contact us or our representatives in your area if you do not find the exact type that seems to fit your application. The services of our staff of expert semi-conductor engineers are available to you at no charge or obligation.

TYPE L & M SILICON RECTIFIERS

Sarkes Tarzian type "L" and "M" silicon rectifiers offer the design engineer a wide range of ratings in the low to medium power field. Rated at 500 ma in half wave circuits type "M" rectifiers will deliver 1 ampere in single phase full wave circuits and 1.5 to 1.8 amperes in three phase full wave applications. The voltage range is from 100 to 400 volts peak inverse. Type "L" rectifiers are rated from 1.25 amperes in half wave circuits to 7.5 amperes in three phase circuits depending on cooling. Voltage ratings range from 100 through 400 volts peak inverse. The Tarzian type "L" and "M" silicon rectifiers are the first to offer the designer of commercial equipment low cost silicon devices that embody the advantages offered by silicon rectifiers. Development of a special process that lends itself to automatic production has resulted in mass production of these high quality, low cost rectifiers. A few suggested applications are shown on following pages, many more are practical ---- remember wherever D.C. is either required or desirable the Tarzian silicon rectifiers will, in most cases, provide a simple, low cost solution to the power conversion problems. Please write, wire, or phone and let our engineers consider your application.

CONSTRUCTION



PATENT APPLIED FOR

CONSTRUCTION

CONSTRUCTION - TYPE L AND M

As in all Sarkes Tarzian Silicon Rectifiers, the "L" and "M" types are pressure contact devices that lend themselves to application over a wide range of external conditions. The case of special ceramic can operate in ambient temperatures as high as 150°C. Heavy end ferrules that fit standard fuse clips are heavy enough to provide "heat sink" action and the positive end ferule is grooved to provide polarity identification and prevent incorrect mounting.

Characteristics

Figure 8 shows typical forward isothermal curves and Figure 9 shows typical reverse current versus applied voltage on type L-1250 and Figures 10 and 11 show the same characteristics on types M-500.

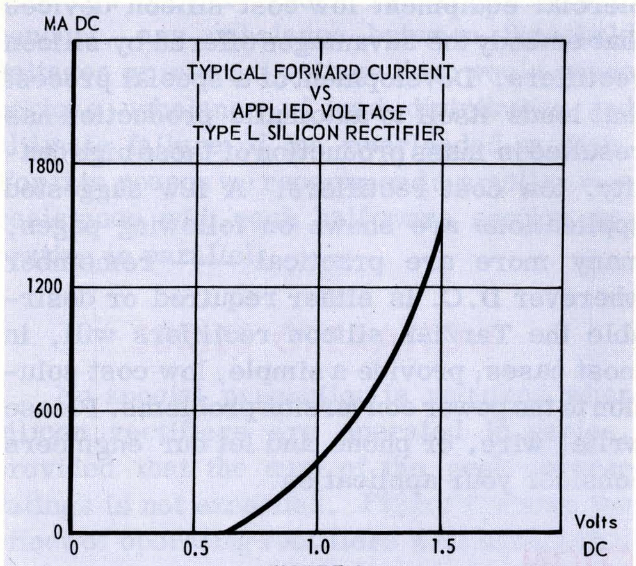


FIGURE 8

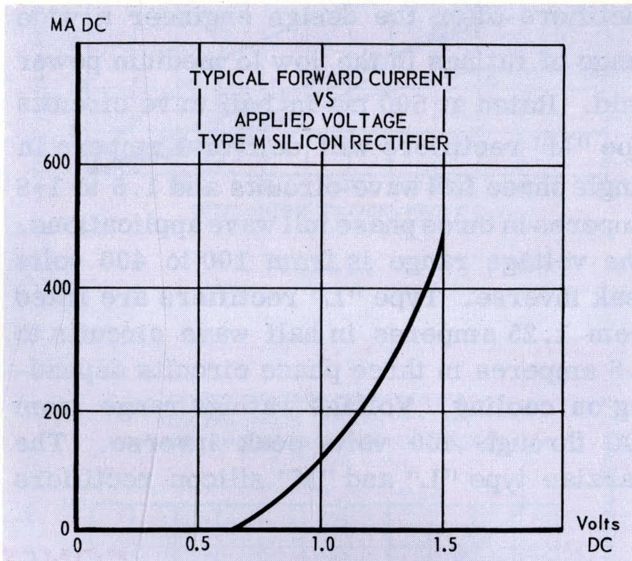


FIGURE 10

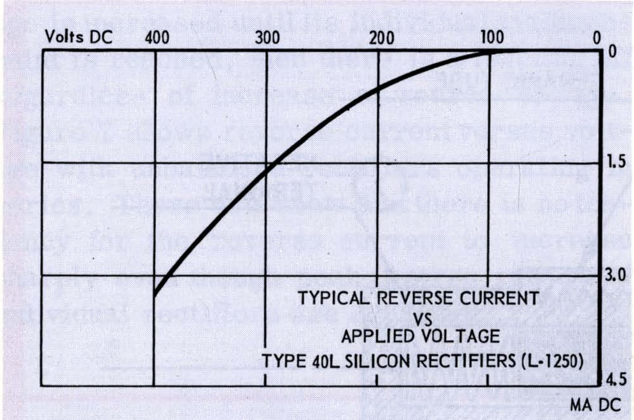


FIGURE 9

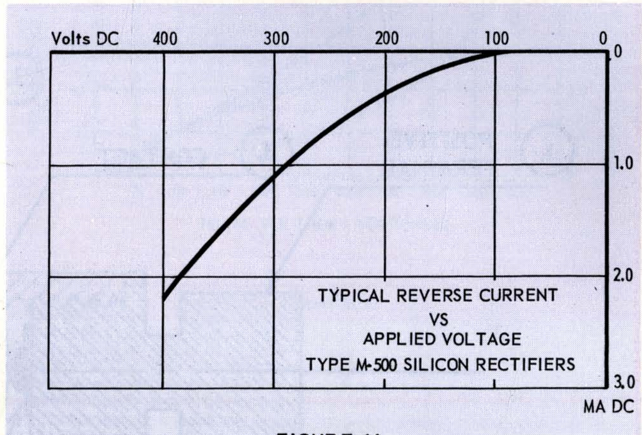
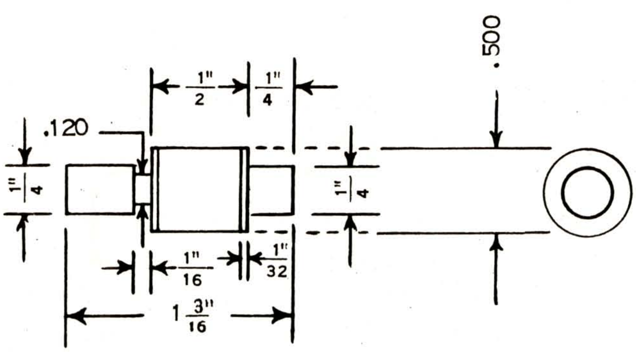
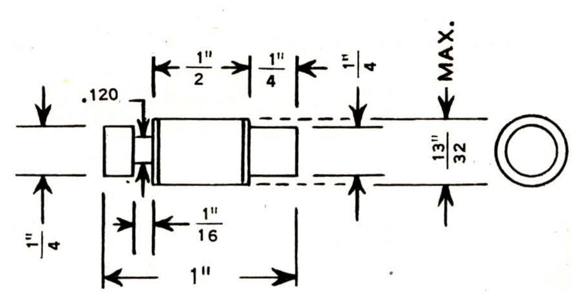


FIGURE 11

Dimensions



DIMENSIONS TYPE L AND LF RECTIFIERS



DIMENSIONS TYPE M - SILICON RECTIFIERS

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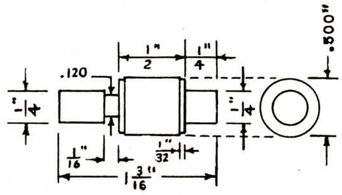
TYPE L SILICON RECTIFIERS

Dimensions



Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
10L	100	70	1.5	.6	3.75	1.5	30	12	60	24	1N1085
20L	200	140	1.5	.6	3.75	1.5	30	12	60	24	1N1086
30L	300	210	1.5	.6	3.75	1.5	30	12	60	24	1N1087
40L	400	280	1.5	.6	3.75	1.5	30	12	60	24	1N1088

For capacitive, motor, or battery loads, derate d.c. current by 20%.

Output Voltages Single Phase Connections

	Half Wave 1.5 Amps. D.C.		Full Wave Bridge 3 Amps. D.C. (4 Required)		Full Wave Center Tap 3 Amps. D.C. (2 Required)		
S.T. Type	Max. Input Volts RMS *	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
10L	70	30	70	60	70	30	1N1085
20L	140	65	140	125	140	65	1N1086
30L	210	95	210	185	210	95	1N1087
40L	280	125	280	250	280	125	1N1088

* Derate 50% for capacitive load.

Output Voltages Three Phase Connections

	Half Wave 4 Amps. D.C. (3 Required)		Full Wave Bridge 4.5 Amps. D.C. (6 Required)		Full Wave Center Tap 5.4 Amps. D.C. (6 Required)		
S.T. Type	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
10L	70	45	70	90	70	45	1N1085
20L	140	95	140	185	140	95	1N1086
30L	210	140	210	280	210	140	1N1087
40L	280	185	280	375	280	185	1N1088

Note: Above ratings are for ambients to 100°C.

Special Applications

Half Wave

Figure 12 shows voltage regulation curves for a single L-1250 silicon rectifier operating in a half wave circuit with capacitive input. Note that only two ohms of surge limiting resistance is required because of improved processing and construction.

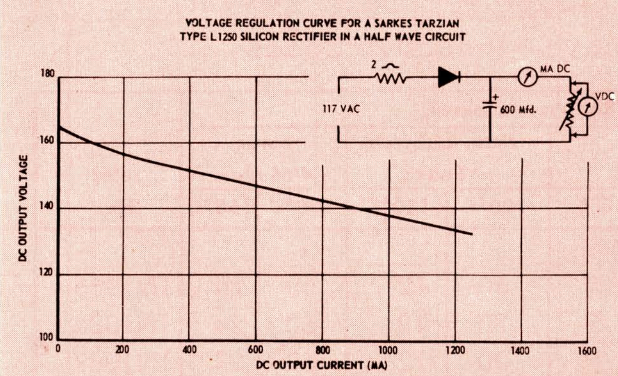


FIGURE 12

Doubler-Half Wave

Regulation curves of a half wave voltage doubler are shown in Figure 13. Here too, a surge limiting resistor of approximately 2 ohms is sufficient to protect the rectifier.

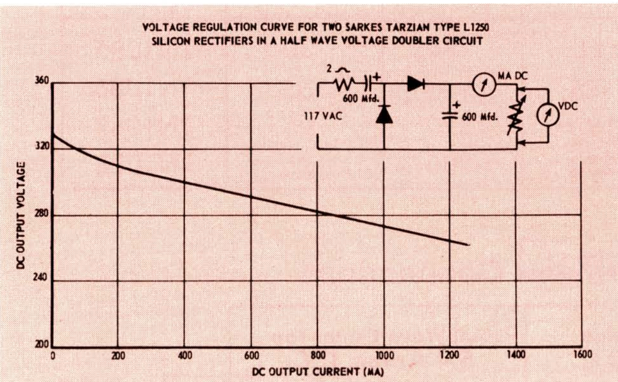


FIGURE 13

Doubler-Full Wave

The full wave voltage doubler delivers approximately 4% more output voltage than a half wave doubler. A problem exists, however, on providing a B- bus throughout the set or equipment. The resultant ripple frequency is twice the source frequency, therefore, is easier to filter. Also, each capacitor in the doubler circuit needs a D.C. rating only 1/2 the output voltage since the capacitors are in series. Voltage regulation is shown in Figure 14.

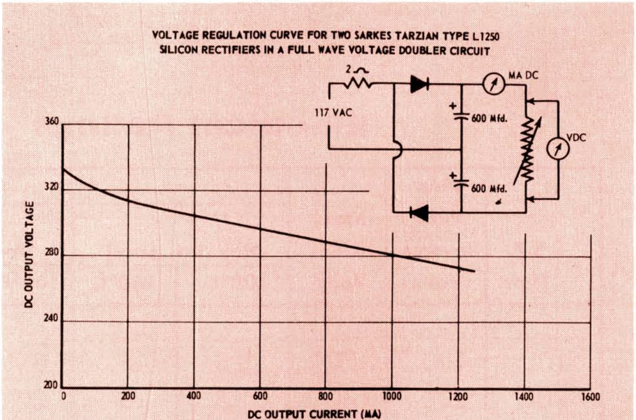


FIGURE 14

Tripler

It is possible to triple source voltage by using the circuit shown in Figure 15. Note that even at full load the output voltage with 600 microfarads of capacity is 370 volts D.C. with 117 volts A.C. applied. While it is practical to keep multiplying voltage by adding successive stages of rectifier-capacitor combinations in cascade, the tripler or perhaps quadrupler circuit offers the practical limit with regard to cost and efficiency. For higher voltages we recommend the high voltage circuit shown on following page.

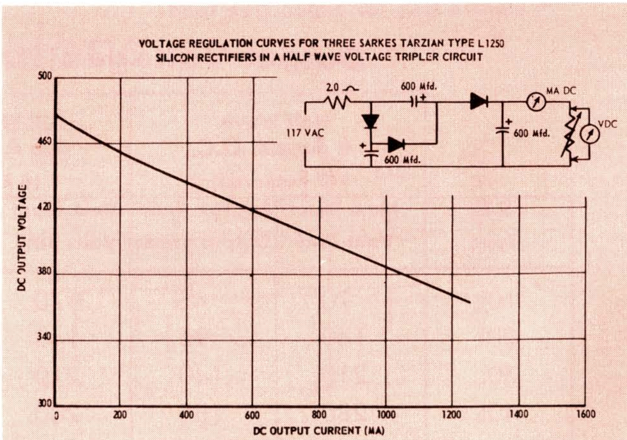
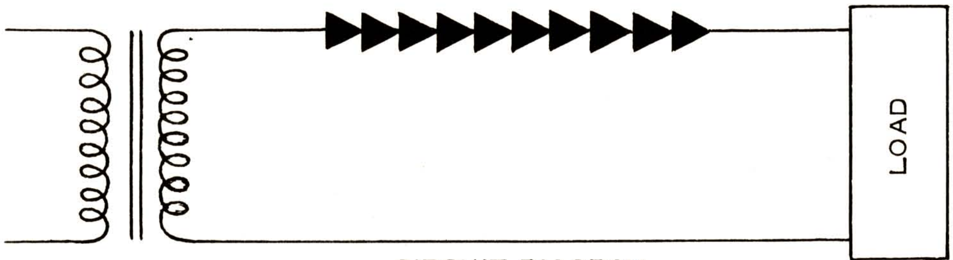


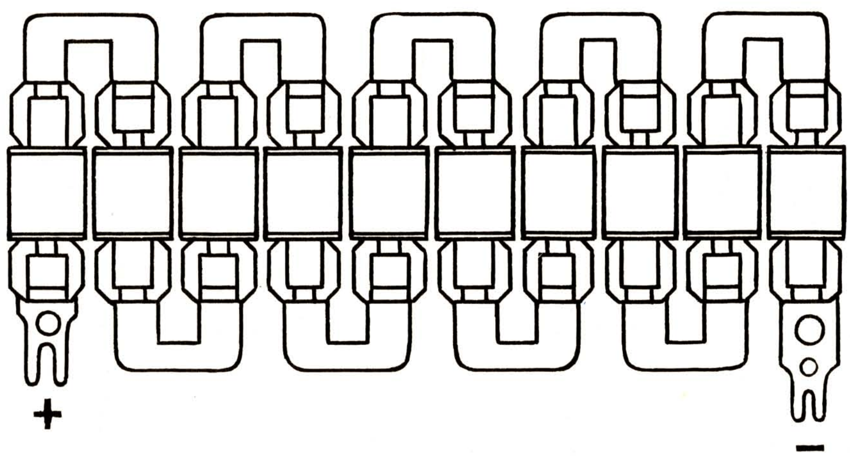
FIGURE 15

HIGH VOLTAGE CONNECTIONS

Sarkes Tarzian Silicon Rectifiers can be operated in series with no special selection or circuit changes required. It is possible, therefore, to provide compact and inexpensive high voltage connections by connecting a number of Type L rectifiers in series for the required voltage rating. Shown below are a circuit diagram and stack connection layout for a circuit rated at 4,000 volts peak inverse at 1500 milliamperes D.C. output current to a resistive load or 1250 to a capacitive load. The total envelope dimensions for the rectifier are approximately 6" x 2" x 3/4". Higher voltages can be obtained by adding series rectifiers.



CIRCUIT DIAGRAM



STACK CONNECTIONS

D.C. Blocking

In many applications it is necessary to exclude D.C. current from portions of a circuit. Silicon Rectifiers provide a nearly perfect valve action because of their very high reverse to forward resistance ratio. The allowable conduction current in a blocking application is 1.5 amperes D.C. on all Type "L" rectifiers and the blocking voltage is equal to the peak inverse rating. Ratings of various "L" Types are:

Type	Blocking Volts D.C.	Conduction Current AMPS
10L	100	1.5
20L	200	1.5
30L	300	1.5
40L	400	1.5

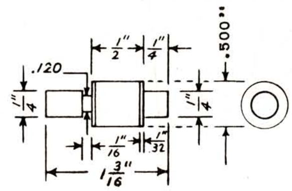
We have discussed only a few special applications for the "L" Type Silicon Rectifier. If you need information or assistance on your specific application, just write, wire, or phone.

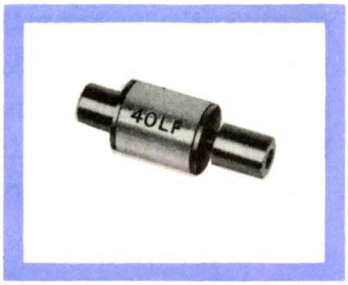
Sarkes Tarzian

TYPE LF SILICON RECTIFIERS

Sarkes Tarzian type "LF" rectifiers utilizes the standard "L" type rectifier mounted on a heat sink. This allows an increase of the D. C. load current from 1.5 to 5.0 amperes in single units. The heat sink area for any particular application may be determined as indicated under "Operation With Heat Sink" page 35. A recommended mounting is shown below.

Dimensions





Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
10LF	100	70	5.	2.	10	4.	40	16	60	24	1N1089
20LF	200	140	5.	2.	10	4.	40	16	60	24	1N1090
30LF	300	210	5.	2.	10	4.	40	16	60	24	1N1091
40LF	400	280	5.	2.	10	4.	40	16	60	24	1N1092

For capacitive, motor, or battery loads, derate d.c. current by 20%.

Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

Output Voltages Single Phase Connections

	Half Wave 5 Amps. D.C.		Full Wave Bridge 10 Amps. D.C. (4 Required)		Full Wave Center Tap 10 Amps. D.C. (2 Required)		
S.T. Type	Max. Input Volts RMS *	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
10LF	70	30	70	60	70	30	1N1089
20LF	140	65	140	125	140	65	1N1090
30LF	210	95	210	185	210	95	1N1091
40LF	280	125	280	250	280	125	1N1092

* Derate 50% for capacitive load.

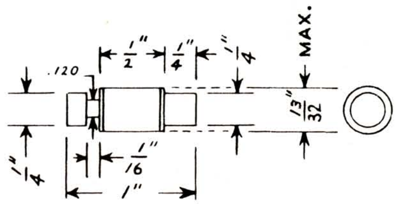
Output Voltages Three Phase Connections

	Half Wave 13.5 Amps. D.C. (3 Required)		Full Wave Bridge 15 Amps. D.C. (6 Required)		Full Wave Center Tap 18 Amps. D.C. (6 Required)		
S.T. Type	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
10LF	70	45	70	90	70	45	1N1089
20LF	140	95	140	185	140	95	1N1090
30LF	210	140	210	280	210	140	1N1091
40LF	280	185	280	375	280	185	1N1092

Sarkes Tarzian

TYPE M SILICON RECTIFIERS

Dimensions



Electrical Ratings Resistive—Inductive – Capacitive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	150°C	Max. RMS 100°C	150°C	Max. Recurrent Peak 100°C	150°C	Surge 4MS Max. 100°C	150°C	Jetec No.
10M	100	70	.5	.25	1.25	.625	5.	2.5	30	15	1N1081
20M	200	140	.5	.25	1.25	.625	5.	2.5	30	15	1N1082
30M	300	210	.5	.25	1.25	.625	5.	2.5	30	15	1N1083
40M	400	280	.5	.25	1.25	.625	5.	2.5	30	15	1N1084
M-500	400	280	.5	.25	1.25	.625	5.	2.5	30	15	1N1084

Output Voltages Single Phase Connections

S.T. Type	Half Wave 0.5 Amp. D.C.: Max. Input Volts RMS *	Approx. D.C. Output Volts	Full Wave Bridge 1 Amp. D.C. (4 Required): Max. Input Volts RMS	Approx. D.C. Output Volts	Full Wave Center Tap 1 Amp. D.C. (2 Required): Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
10M	70	30	70	60	70	30	1N1081
20M	140	65	140	125	140	65	1N1082
30M	210	95	210	185	210	95	1N1083
40M	280	125	280	250	280	125	1N1084
M-500	280	125	280	250	280	125	1N1084

* Derate 50% for capacitive load.

Output Voltages Three Phase Connections

S.T. Type	Half Wave 1.35 Amps. D.C. (3 Required): Max. Input Volts RMS	Approx. D.C. Output Volts	Full Wave Bridge 1.5 Amps. D.C. (6 Required): Max. Input Volts RMS	Approx. D.C. Output Volts	Full Wave Center Tap 1.8 Amps. D.C. (6 Required): Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
10M	70	45	70	90	70	45	1N1081
20M	140	95	140	185	140	95	1N1082
30M	210	140	210	280	210	140	1N1083
40M	280	185	280	375	280	185	1N1084
M-500	280	185	280	375	280	185	1N1084

Note: Above ratings are for ambients to 100°C

Special Applications

Half Wave

Figure 16 shows voltage regulation curves for a single M-500 silicon rectifier operating in a half wave circuit with capacitive input. Note that only five ohms of surge limiting resistance is required because of improved processing and construction.

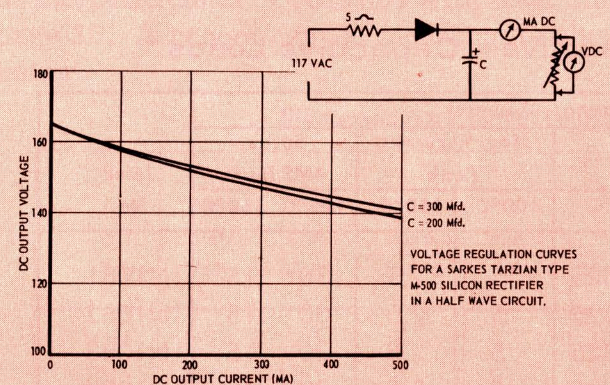


FIGURE 16

Doubler - Half Wave

Regulation curves of a half wave voltage doubler are shown in Figure 17. Here too, a surge limiting resistor of approximately five ohms is sufficient to protect the rectifier.

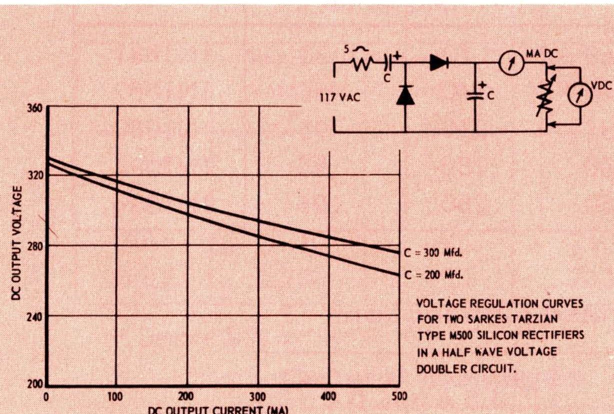


FIGURE 17

Doubler - Full Wave

The full wave voltage doubler delivers approximately 4% more output voltage than a half wave doubler. A problem exists, however, on providing a B- bus throughout the set or equipment. The resultant ripple frequency is twice the source frequency, therefore, is easier to filter. Also, each capacitor in the doubler circuit needs a D.C. rating only 1/2 the output voltage since the capacitors are in series. Regulation curves are shown in Figure 18.

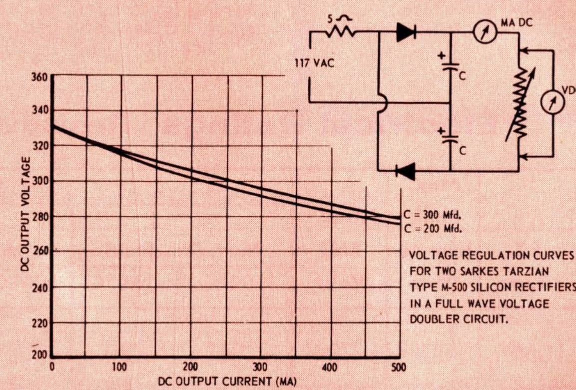


FIGURE 18

Tripler

It is possible to triple source voltage by using the circuit shown in Figure 19. Note that even at full load the output voltage with 200 microfarads of capacity is 370 volts D.C. with 117 volts A.C. applied. While it is practical to keep multiplying voltage by adding successive stages of rectifier-capacitor combinations in cascade, the tripler or perhaps quadrupler circuit offers the practical limit with regard to cost and efficiency. For higher voltages we recommend the high voltage circuit shown on the following page.

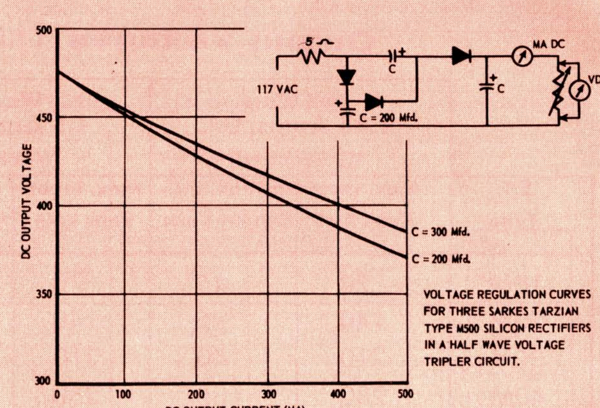
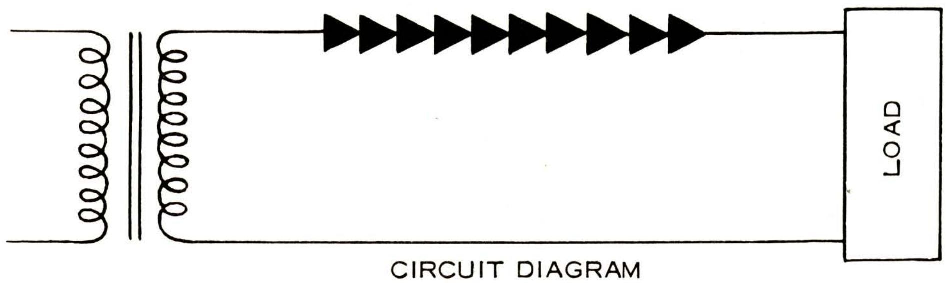


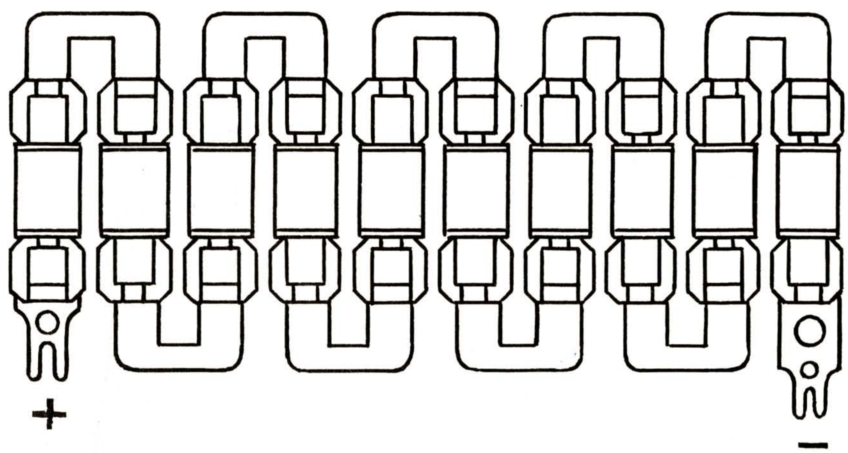
FIGURE 19

HIGH VOLTAGE CONNECTIONS

Sarkes Tarzian Silicon Rectifiers can be operated in series with no special selection or circuit changes required. It is possible therefore to provide compact and inexpensive high voltage connections by connecting a number of Type M rectifiers in series for the required voltage rating. Shown below are a circuit diagram and stack connection layout for a circuit rated at 4,000 volts peak inverse at 500 milliamperes D.C. output current. The total envelope dimensions for the rectifier are approximately 6" x 2" x 3/4". Higher voltages can be obtained by adding series rectifiers.



CIRCUIT DIAGRAM



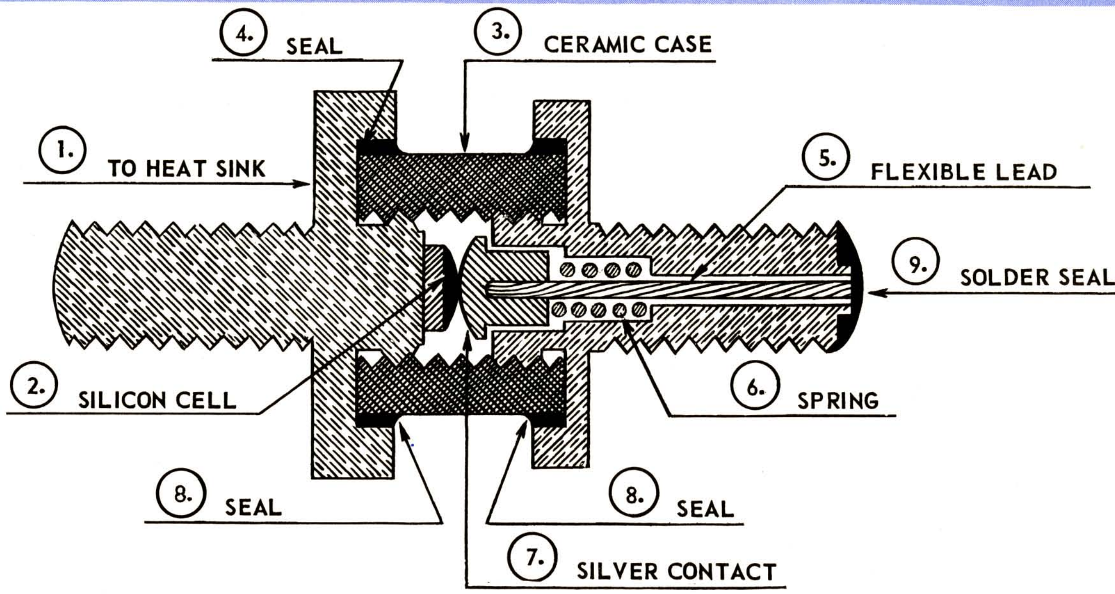
STACK CONNECTIONS

D.C. Blocking

In many applications it is necessary to exclude D.C. current from portions of a circuit. Silicon Rectifiers provide a nearly perfect valve action because of their very high reverse to forward resistance ratio. The allowable conduction current in a blocking application is 0.5 amperes D.C. on all Type "M" rectifiers and the blocking voltage is equal to the peak inverse rating. Ratings of various "M" Types are:

Type	Blocking Volts D.C.	Conduction Current AMPS.
10M	100	0.5
20M	200	0.5
30M	300	0.5
40M	400	0.5

We have discussed only a few special applications for the "M" Type Silicon Rectifier. If you need information or assistance on your specific application, just write, wire, or phone.



CONSTRUCTION - TYPE N, P AND Q

FIGURE 20

CONSTRUCTION

Figure 20 shows the construction details of a Sarkes Tarzian Silicon Rectifier, the most thoroughly engineered package in the field. Please note the following features found in no other line:

1. Heat sink end provides optimum heat transfer to chassis. Special designs are available that allow mounting with either positive or negative polarity to the chassis.
2. The Sarkes Tarzian silicon cell made by a special alloying process produces the best reverse to forward ratios available. Careful process control assures long life.
3. The ceramic case housing provides not only a rigid mechanical assembly but safe operation without flashover at high altitudes or excessive leakage under humid conditions.
4. To assure sealing under all operating conditions a special seal is used.
5. Flexible copper leads provide maximum current carrying capacity with negligible mechanical stress during thermal cycling and under shock or acceleration.
6. A special spring design provides positive contact under all conditions of temperature, shock, vibration and acceleration.
7. A pure silver contact is used for low ohmic resistance and elimination of possible contaminants.
8. A mechanical bond is provided as a double guarantee that the rectifier is sealed under all conditions.
9. The lead-contact assembly is sealed off by soldering. This not only provides the final seal but also a good thermal and electrical bond between cell and case.

Key to Coding - Types N, P, and Q

EXAMPLE:

30 N 2

Voltage Rating: (30)

Multiply by 10
for maximum PIV

Body Style (N)

Terminals: (2)

1. Pigtail Leads
2. Stud Pigtails
3. Stud - solder lug
4. Stud - stud

Special Purpose Silicon Rectifiers

MILITARY TYPES - HEAVY CURRENT TYPES
TUBE REPLACEMENT TYPES

The next section of this handbook can be divided into three basic categories of rectifiers, each category designed for specific fields of application. For example, types N, P and Q are specifically intended for use in military equipments where hermetic sealing is a specified requirement. These types are solder sealed - ceramic to base and top to meet even the most stringent requirements of environmental exposure and shelf storage.

Types R, S and V are a basic entry into the high current, heavy power fields with additional designs now being developed that will be rated to 500 or more amperes dc from a single junction. Here sealing is achieved by special resins and the intended fields of application lie where large power is required.

The tube replacement series that includes types S-5011, S-5017, S-5018 and S-5019 is intended as the solution to application problems where ruggedness and dependability requirements make it desirable to eliminate standard rectifier tubes. Type S-5019 is designed as a specific replacement for type 5R4 tubes and is hermetically sealed to meet the most stringent military requirements. Types S-5011, S-5017 and S-5018 are sealed with casting resin.

In the dynamic and ever changing semiconductor field, new types and applications are developed almost daily. If we have not covered your specific problem be sure to send us a detailed outline of your requirements. Chances are, we can recommend a satisfactory design.

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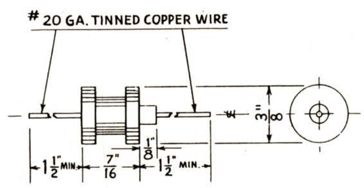
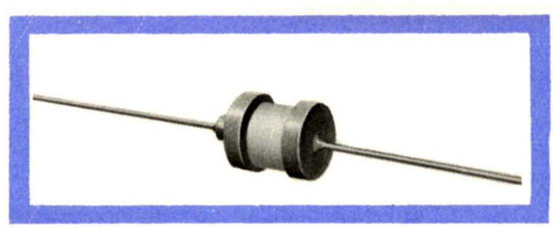
TYPE N1 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5N1	50	35	.5	.25	1.	.5	5.	2.5	30	15	1N1028
10N1	100	70	.5	.25	1.	.5	5.	2.5	30	15	1N1029
15N1	150	105	.5	.25	1.	.5	5.	2.5	30	15	1N1030
20N1	200	140	.5	.25	1.	.5	5.	2.5	30	15	1N1031
30N1	300	210	.5	.25	1.	.5	5.	2.5	30	15	1N1032
40N1	400	280	.5	.25	1.	.5	5.	2.5	30	15	1N1033

For capacitive, motor, or battery loads, derate d.c. current by 20%.

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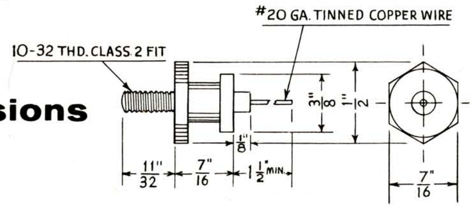
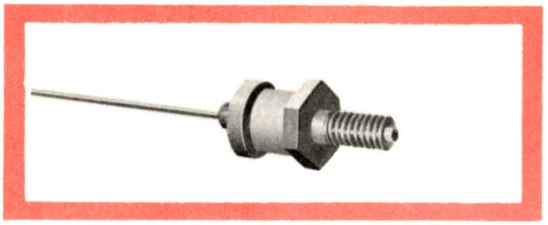
TYPE N2 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5N2	50	35	1.	.5	2.	1.	10	5	30	15	1N1034
10N2	100	70	1.	.5	2.	1.	10	5	30	15	1N1035
15N2	150	105	1.	.5	2.	1.	10	5	30	15	1N1036
20N2	200	140	1.	.5	2.	1.	10	5	30	15	1N1037
30N2	300	210	1.	.5	2.	1.	10	5	30	15	1N1038
40N2	400	280	1.	.5	2.	1.	10	5	30	15	1N1039

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

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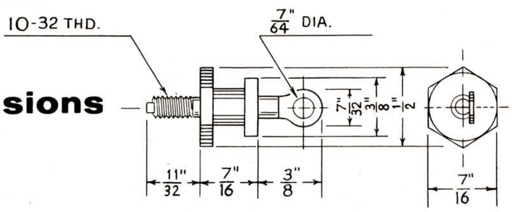
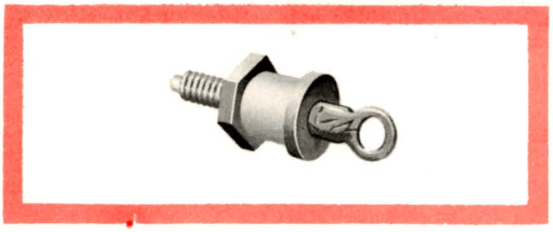
TYPE N3 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

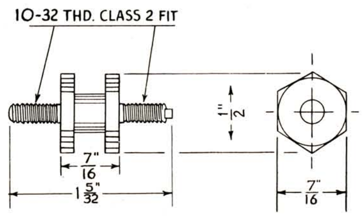
S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5N3	50	35	1.	.5	2.	1.	10	5	30	15	1N1040
10N3	100	70	1.	.5	2.	1.	10	5	30	15	1N1041
15N3	150	105	1.	.5	2.	1.	10	5	30	15	1N1042
20N3	200	140	1.	.5	2.	1.	10	5	30	15	1N1043
30N3	300	210	1.	.5	2.	1.	10	5	30	15	1N1044
40N3	400	280	1.	.5	2.	1.	10	5	30	15	1N1045

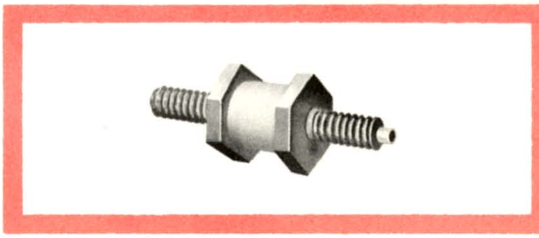
For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C

Sarkes Tarzian

TYPE N4 SILICON RECTIFIERS

Dimensions





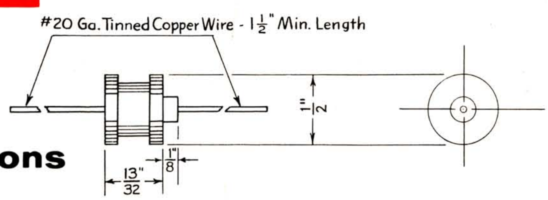
Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5N4	50	35	1.	.5	2.	1.	10	5	30	15	1N1046
10N4	100	70	1.	.5	2.	1.	10	5	30	15	1N1047
15N4	150	105	1.	.5	2.	1.	10	5	30	15	1N1048
20N4	200	140	1.	.5	2.	1.	10	5	30	15	1N1049
30N4	300	210	1.	.5	2.	1.	10	5	30	15	1N1050
40N4	400	280	1.	.5	2.	1.	10	5	30	15	1N1051

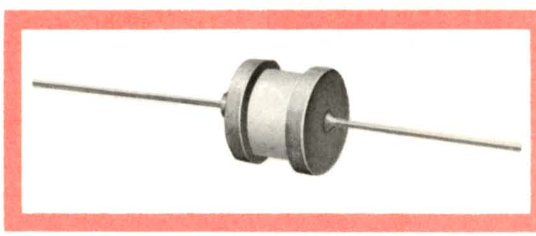
For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

Sarkes Tarzian

TYPE P1 SILICON RECTIFIERS



Dimensions



Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5P1	50	35	1.5	.5	3.	1.	30	10	60	20	1N1052
10P1	100	70	1.5	.5	3.	1.	30	10	60	20	1N1053
15P1	150	105	1.5	.5	3.	1.	30	10	60	20	1N1054
20P1	200	140	1.5	.5	3.	1.	30	10	60	20	1N1055
30P1	300	210	1.5	.5	3.	1.	30	10	60	20	1N1056
40P1	400	280	1.5	.5	3.	1.	30	10	60	20	1N1057

For capacitive, motor, or battery loads, derate d.c. current by 20%.

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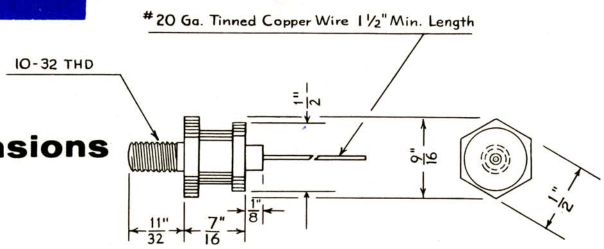
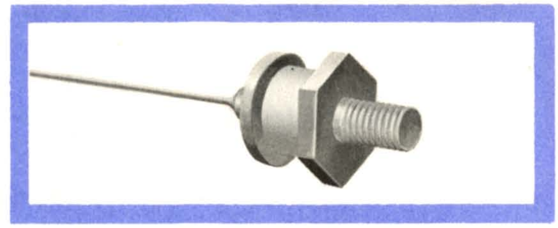
TYPE P2 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5P2	50	35	5.	1.5	10	3.	40	12	60	20	1N1058
10P2	100	70	5.	1.5	10	3.	40	12	60	20	1N1059
15P2	150	105	5.	1.5	10	3.	40	12	60	20	1N1060
20P2	200	140	5.	1.5	10	3.	40	12	60	20	1N1061
30P2	300	210	5.	1.5	10	3.	40	12	60	20	1N1062
40P2	400	280	5.	1.5	10	3.	40	12	60	20	1N1063

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

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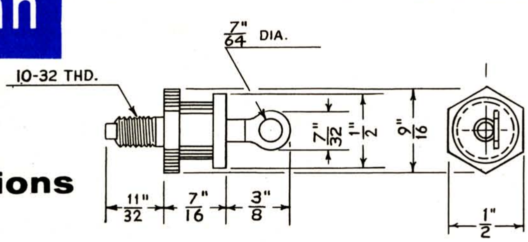
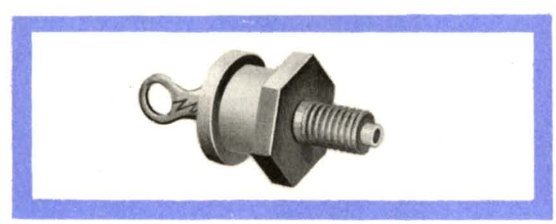
TYPE P3 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5P3	50	35	5.	1.5	10	3.	40	12	60	20	1N1064
10P3	100	70	5.	1.5	10	3.	40	12	60	20	1N1065
15P3	150	105	5.	1.5	10	3.	40	12	60	20	1N1066
20P3	200	140	5.	1.5	10	3.	40	12	60	20	1N1067
30P3	300	210	5.	1.5	10	3.	40	12	60	20	1N1068
40P3	400	280	5.	1.5	10	3.	40	12	60	20	1N1069

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

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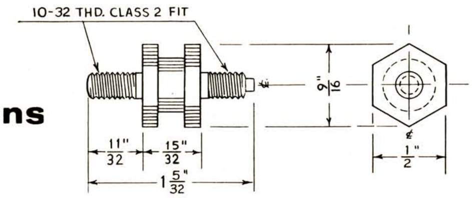
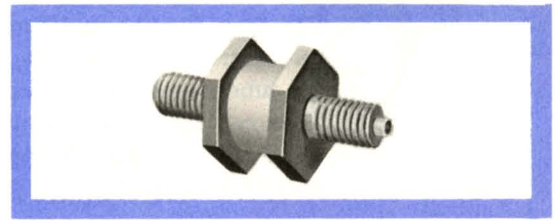
TYPE P4 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

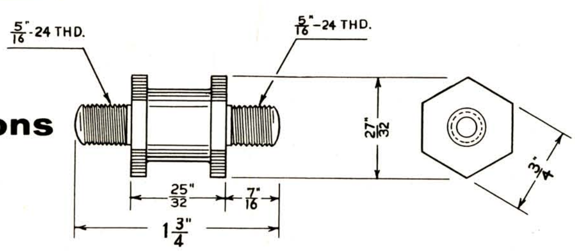
S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5P4	50	35	5.	1.5	10	3.	40	12	60	20	1N1070
10P4	100	70	5.	1.5	10	3.	40	12	60	20	1N1071
15P4	150	105	5.	1.5	10	3.	40	12	60	20	1N1072
20P4	200	140	5.	1.5	10	3.	40	12	60	20	1N1073
30P4	300	210	5.	1.5	10	3.	40	12	60	20	1N1074
40P4	400	280	5.	1.5	10	3.	40	12	60	20	1N1075

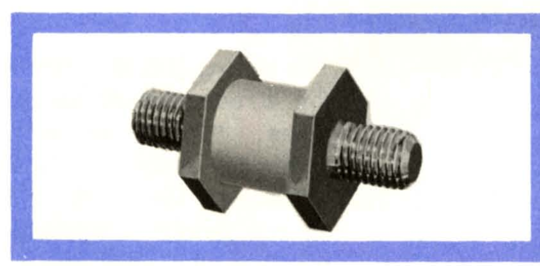
For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

Sarkes Tarzian

TYPE Q4 SILICON RECTIFIERS

Dimensions





Electrical Ratings Resistive—Inductive Loads

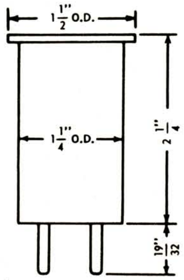
S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. D.C. Load 150°C	Max. RMS 100°C	Max. RMS 150°C	Max. Recurrent Peak 100°C	Max. Recurrent Peak 150°C	Surge 4MS Max. 100°C	Surge 4MS Max. 150°C	Jetec No.
5Q4	50	35	15	5.	30	10	100	33	150	50	1N1076
10Q4	100	70	15	5.	30	10	100	33	150	50	1N1077
15Q4	150	105	15	5.	30	10	100	33	150	50	1N1078
20Q4	200	140	15	5.	30	10	100	33	150	50	1N1079
30Q4	300	210	15	5.	30	10	100	33	150	50	1N1080

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 170°C.

On preceeding pages we have covered standard types. For special terminal or cooling fin arrangements, please send us complete details of your requirements.

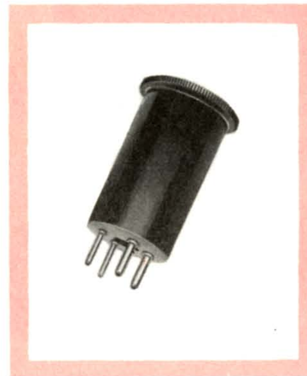
TYPE S-5011 SILICON RECTIFIERS
1N1150

Dimensions

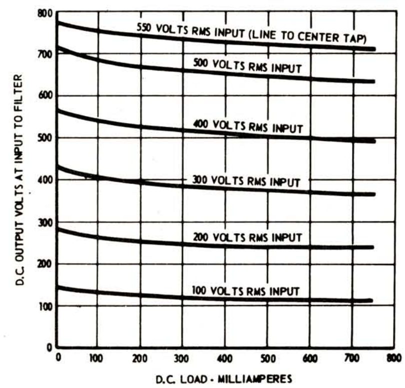


FOUR PIN BASE

The type S-5011 rectifier is used to supply up to 750 MA d.c. in electronic equipment. A four-pin socket is required and the tube can be mounted either vertically or horizontally. This rectifier was specifically designed to replace type 83 tubes in applications where reliability and long life are primary considerations.



Characteristics



Full Wave Rectifier

Maximum Ratings:

Peak Inverse Voltage Per Section	1600 Volts Max.
Peak Rectifier Current Per Section	8000 MA Max.
D. C. Output Current	750 MA Max.
Ambient Temperature	100°C Max.

Typical Operation With Capacitor-Input Filter:

AC Input Voltage to Rectifier (RMS)	1100 Volts Max.
DC Output Current	750 MA Max.
Minimum External Impedance per Section	5 Ohms

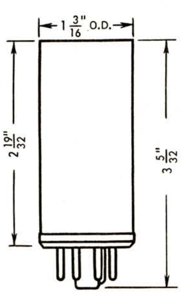
Typical Operation With Choke-Input Filter:

AC Input Voltage to Rectifier (RMS)	1100 Volts Max.
DC Output Current	750 MA Max.
Min. Filter Input Choke	1 Henry

Replacement for Types 80, 82, 83, 83V, 5Z3

TYPE S-5017 SILICON RECTIFIERS
1N1237

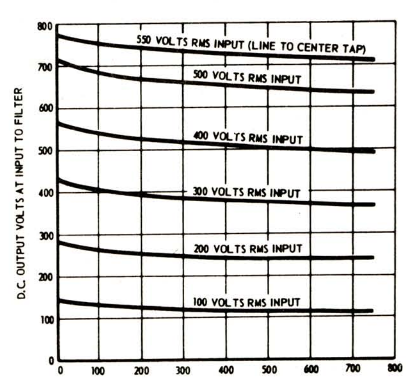
Dimensions



OCTAL BASE

The Sarkes Tarzian type S-5017 silicon rectifier is designed for direct replacement of 5 types of octal base rectifier tubes. "Plate" connections are to pins 3 and 5 and the "cathode" connection is to pin 8. No filament power is required and the rectifier delivers B+ voltage as soon as the source power is applied. For electrostatic shielding and positive tube mounting a standard fuse clamp can be used. Rugged design makes this type ideal for a wide range of applications.

Characteristics



Full Wave Rectifier

Maximum Ratings:

Peak Inverse Voltage Per Section	1600 Volts Max.
Peak Rectifier Current Per Section	8000 MA Max.
D. C. Output Current	750 MA Max.
Ambient Temperature	100°C Max.

Typical Operation With Capacitor-Input Filter:

AC Input Voltage to Rectifier (RMS)	1100 Volts Max.
DC Output Current	750 MA Max.
Minimum External Impedance per Section	5 Ohms

Typical Operation With Choke-Input Filter:

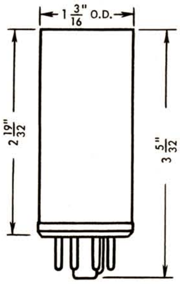
AC Input Voltage to Rectifier (RMS)	1100 Volts Max.
DC Output Current	750 MA Max.
Min. Filter Input Choke	1 Henry

Replacement for Types OZ4, 5X4, 5Y4, 6AX5, 6X5

TYPE S-5018 SILICON RECTIFIERS

1N1238

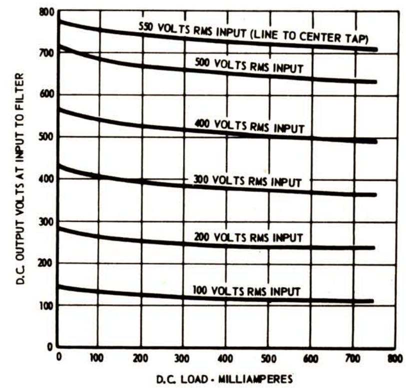
Dimensions



OCTAL BASE

The Sarkes Tarzian S-5018 silicon rectifier is designed to replace octal base, full wave rectifier tubes with plate connections to pins 4 and 6 and cathode connection to pin 8. No filament power is required and the rectifier delivers B+ voltage upon application of input power. A tube clamp is recommended for electrostatic shielding and positive mounting. Rugged construction and a high current rating make this type ideal for many applications.

Characteristics



Full Wave Rectifier

Maximum Ratings:

Peak Inverse Voltage Per Section	1600 Volts Max.
Peak Rectifier Current Per Section	8000 MA Max.
D. C. Output Current	750 MA Max.
Ambient Temperature	100°C Max.

Typical Operation With Capacitor-Input Filter:

AC Input Voltage to Rectifier (RMS)	1100 Volts Max.
DC Output Current	750 MA Max.
Minimum External Impedance per Section	5 Ohms

Typical Operation With Choke-Input Filter:

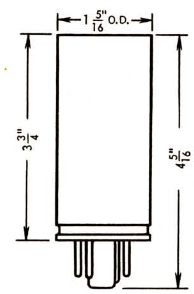
AC Input Voltage to Rectifier (RMS)	1100 Volts Max.
DC Output Current	750 MA Max.
Min. Filter Input Choke	1 Henry

Replacement for Types 5AU4, 5AW4, 5AZ4, 5T4, 5U4, 5V4, 5W4, 5Y3, 5Z4

TYPE S-5019 SILICON RECTIFIERS

1N1239

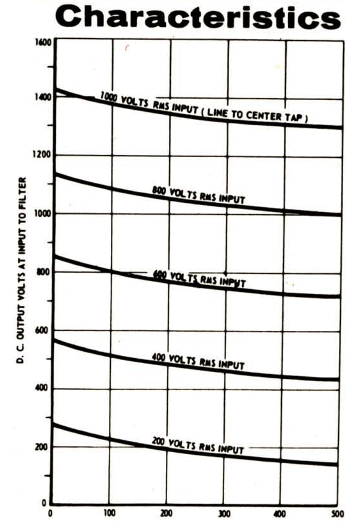
Dimensions



OCTAL BASE

The Sarkes Tarzian type S-5019 silicon rectifier is a full wave, hermetically sealed rectifier assembly designed to replace the type 5R4 rectifier tube. In addition to being hermetically sealed, the type S-5019 is filled with an embedment resin to allow safer operation under adverse shock or vibration. No filament power is required and B+ voltage is delivered upon application of source power. A standard fuse clamp can be used to provide electrostatic shielding and more positive mounting.

Characteristics



Full Wave Rectifier

Maximum Ratings:

Peak Inverse Voltage Per Section	2800 Volts Max.
Peak Rectifier Current Per Section	5000 MA Max.
D. C. Output Current	500 MA Max.
Ambient Temperature	100°C Max.

Typical Operation With Capacitor-Input Filter:

AC Input Voltage to Rectifier (RMS)	1950 Volts Max.
DC Output Current	500 MA Max.
Minimum External Impedance per Section	5 Ohms

Typical Operation With Choke-Input Filter:

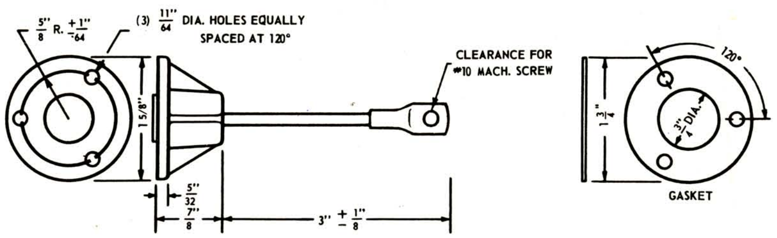
AC Input Voltage to Rectifier (RMS)	1950 Volts Max.
DC Output Current	500 MA Max.
Min. Filter Input Choke	1 Henry

Replacement for Type 5R4

Sarkes Tarzian

TYPE R SILICON RECTIFIERS

Dimensions



The R series of silicon rectifiers has a basic d.c. current rating of 20 amperes maximum. Peak inverse voltages range from 50 to 300 volts. The rugged embedded construction makes this series stable at normal shock and vibration requirements. Positive or negative base polarity is available to simplify connection in full wave or polyphase circuits. A special gasket seals the base contact from adverse environments.

Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°C	Max. RMS 100°C	Max. Recurrent Peak 100°C	Surge 4MS Max. 100°C	Jetec No.
5RN*	50	35	20	40	120	200	1N1157
10RN	100	70	20	40	120	200	1N1158
20RN	200	140	20	40	120	200	1N1159
30RN	300	210	20	40	120	200	1N1160
5RP**	50	35	20	40	120	200	1N1171
10RP	100	70	20	40	120	200	1N1172
20RP	200	140	20	40	120	200	1N1173
30RP	300	210	20	40	120	200	1N1174

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 125°C.

Output Voltages Single Phase Connections

	Half Wave 20 Amps. D.C.		Full Wave Bridge 40 Amps. D.C. (4 Required)		Full Wave Center Tap 40 Amps. D.C. (2 Required)		
S.T. Type	Max. Input Volts RMS*	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
5RN*	35	15	35	30	35	15	1N1157
10RN	70	30	70	60	70	30	1N1158
20RN	140	65	140	125	140	65	1N1159
30RN	210	95	210	185	210	95	1N1160
5RP**	35	15	35	30	35	15	1N1171
10RP	70	30	70	60	70	30	1N1172
20RP	140	65	140	125	140	65	1N1173
30RP	210	95	210	185	210	95	1N1174

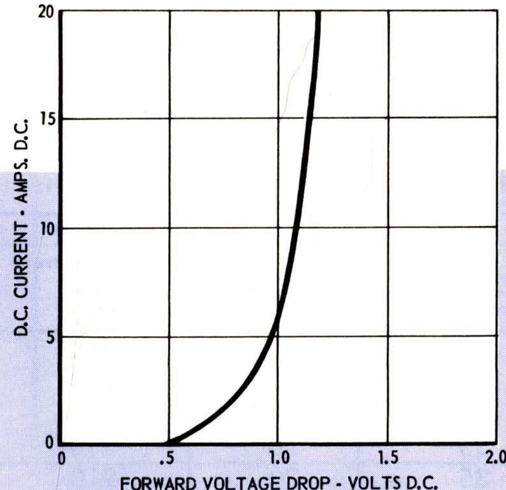
* Derate 50% for capacitive load.
* N after S.T. type number indicates negative base.
** P after S.T. type number indicates positive base.

Output Voltages Three Phase Connections

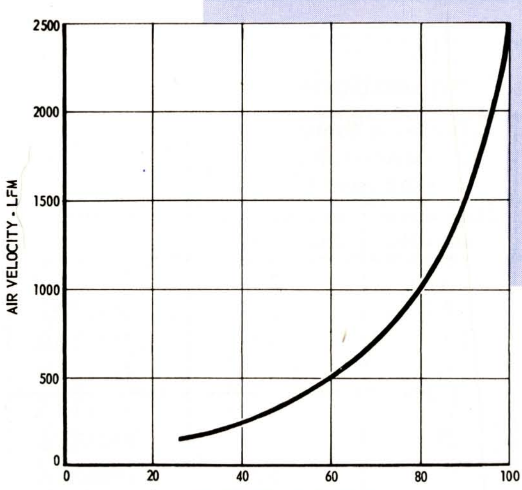
S.T. Type	Half Wave 54 Amps. D.C. (3 Required) Max. Input Volts RMS	Half Wave Approx. D.C. Output Volts	Full Wave Bridge 60 Amps. D.C. (6 Required) Max. Input Volts RMS	Full Wave Bridge Approx. D.C. Output Volts	Six Phase Star 90 Amps. D.C. (6 Required) Max. Input Volts RMS	Six Phase Star Approx. D.C. Output Volts	Jetec No.
5RN*	35	25	35	45	35	25	1N1157
10RN	70	45	70	90	70	45	1N1158
20RN	140	95	140	185	140	95	1N1159
30RN	210	140	210	280	210	140	1N1160
5RP**	35	25	35	45	35	25	1N1171
10RP	70	45	70	90	70	45	1N1172
20RP	140	95	140	185	140	95	1N1173
30RP	210	140	210	280	210	140	1N1174

* N after S.T. type number indicates negative base.
** P after S.T. type number indicates positive base.

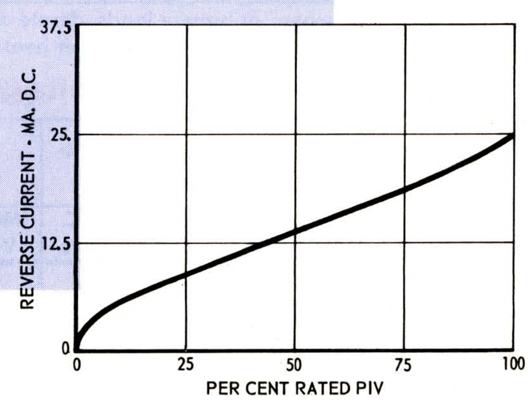
Characteristics



Forward voltage drop versus current for typical Sarkes Tarzian Type R Silicon Rectifier



Ambient Temperature versus air velocity for typical Sarkes Tarzian Type R Silicon Rectifier mounted on a 4" x 4" x 1/8" aluminum heat sink

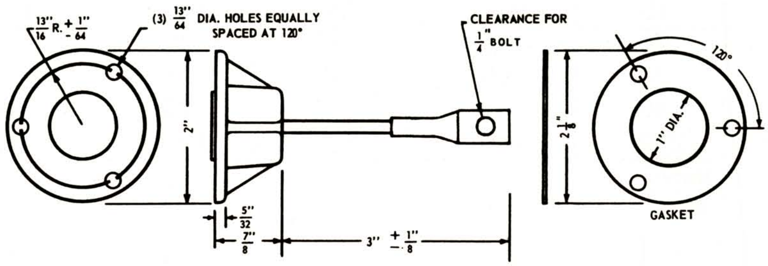


Reverse current versus voltage for typical Sarkes Tarzian Type R Silicon Rectifier

Sarkes Tarzian

TYPE S SILICON RECTIFIERS

Dimensions



The S series of silicon rectifiers is available with peak inverse voltage ratings of 50 to 300 volts and a d.c. current rating of 35 amperes, maximum. Positive or negative base polarity is available to simplify circuit connection. A special gasket seals the base contact against adverse atmospheric conditions. Forced air or convection cooling can be used.

Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes				Jetec No.
			Max. D.C. Load 100°C	Max. RMS 100°C	Max. Recurrent Peak 100°C	Surge 4MS Max. 100°C	
5SN*	50	35	35	70	210	350	1N1161
10SN	100	70	35	70	210	350	1N1162
20SN	200	140	35	70	210	350	1N1163
30SN	300	210	35	70	210	350	1N1164
5SP**	50	35	35	70	210	350	1N1175
10SP	100	70	35	70	210	350	1N1176
20SP	200	140	35	70	210	350	1N1177
30SP	300	210	35	70	210	350	1N1178

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 125°C.

Output Voltages Single Phase Connections

	Half Wave 35 Amps. D.C.		Full Wave Bridge 70 Amps. D.C. (4 Required)		Full Wave Center Tap 70 Amps. D.C. (2 Required)		
S.T. Type	Max. Input Volts RMS*	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
5SN*	35	15	35	30	35	15	1N1161
10SN	70	30	70	60	70	30	1N1162
20SN	140	65	140	125	140	65	1N1163
30SN	210	95	210	185	210	95	1N1164
5SP**	35	15	35	30	35	15	1N1175
10SP	70	30	70	60	70	30	1N1176
20SP	140	65	140	125	140	65	1N1177
30SP	210	95	210	185	210	95	1N1178

* Derate 50% for capacitive load.
* N after S.T. type number indicates negative base.
** P after S.T. type number indicates positive base.

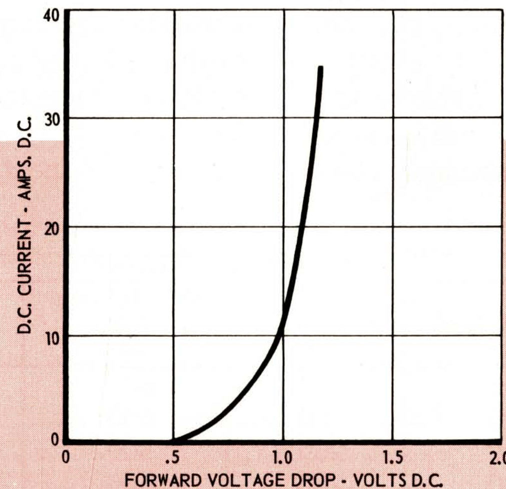
Output Voltages Three Phase Connections

S.T. Type	Half Wave 93 Amps. D.C. (3 Required) Max. Input Volts RMS	Half Wave Approx. D.C. Output Volts	Full Wave Bridge 105 Amps. D.C. (6 Required) Max. Input Volts RMS	Full Wave Bridge Approx. D.C. Output Volts	Six Phase Star 158 Amps. D.C. (6 Required) Max. Input Volts RMS	Six Phase Star Output Volts Approx. D.C.	Jetec No.
5SN*	35	25	35	45	35	25	1N1161
10SN	70	45	70	90	70	45	1N1162
20SN	140	95	140	185	140	95	1N1163
30SN	210	140	210	280	210	140	1N1164
5SP**	35	25	35	45	35	25	1N1175
10SP	70	45	70	90	70	45	1N1176
20SP	140	95	140	185	140	95	1N1177
30SP	210	140	210	280	210	140	1N1178

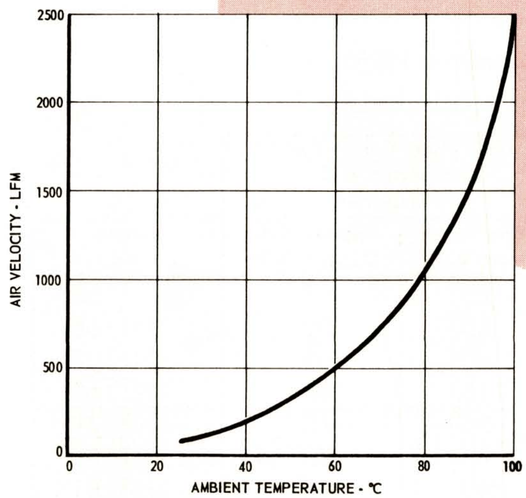
* N after S.T. type number indicates negative base.

** P after S.T. type number indicates positive base.

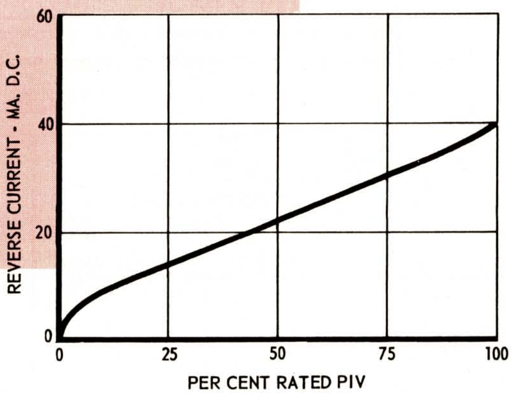
Characteristics



Forward voltage drop versus current for typical Sarkes Tarzian Type S Silicon Rectifier



Ambient Temperature versus air velocity for typical Sarkes Tarzian Type S Silicon Rectifier mounted on a 4" x 4" x 1/8" aluminum heat sink

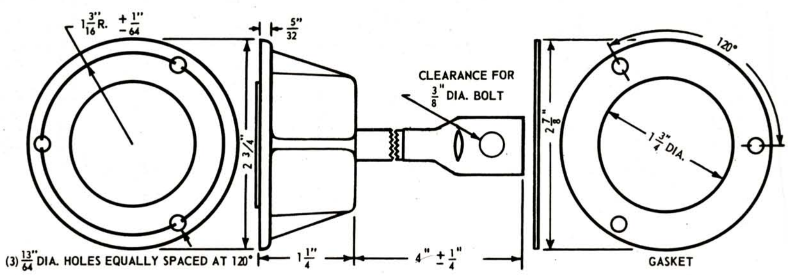


Reverse current versus voltage for typical Sarkes Tarzian Type S Silicon Rectifier

Sarkes Tarzian

TYPE V SILICON RECTIFIERS

Dimensions



The V series of silicon rectifiers includes peak inverse voltage ratings of 50, 100, 200 and 300 volts with a maximum d.c. current rating of 100 amperes. Special gaskets are provided to seal the base contact from adverse environments. The rugged embedded construction is well adapted to severe shock and vibration requirements. Because of the power involved, forced air cooling is recommended. Positive or negative base polarity is available to simplify mounting on full wave and polyphase connections.

Electrical Ratings Resistive—Inductive Loads

S.T. Type	Max. Peak Inverse Volts	Max. RMS Volts	Current Ratings—Amperes: Max. D.C. Load 100°	Max. RMS 100°C	Max. Recurrent Peak 100°C	Surge 4MS Max. 100°C	Jetec No.
5VN*	50	35	100	200	600	1000	1N1165
10VN	100	70	100	200	600	1000	1N1166
20VN	200	140	100	200	600	1000	1N1167
30VN	300	210	100	200	600	1000	1N1168
5VP**	50	35	100	200	600	1000	1N1179
10VP	100	70	100	200	600	1000	1N1180
20VP	200	140	100	200	600	1000	1N1181
30VP	300	210	100	200	600	1000	1N1182

For capacitive, motor, or battery loads, derate d.c. current by 20%.
Note: Current ratings are based on proper heat sink design to limit case temperature to 125°C.

Output Voltages Single Phase Connections

	Half Wave 100 Amps. D.C.		Full Wave Bridge 200 Amps D.C. (4 Required)		Full Wave Center Tap 200 Amps. D.C. (2 Required)		
S.T. Type	Max. Input Volts RMS*	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Jetec No.
5VN*	35	15	35	30	35	15	1N1165
10VN	70	30	70	60	70	30	1N1166
20VN	140	65	140	125	140	65	1N1167
30VN	210	95	210	185	210	95	1N1168
5VP**	35	15	35	30	35	15	1N1179
10VP	70	30	70	60	70	30	1N1180
20VP	140	65	140	125	140	65	1N1181
30VP	210	95	210	185	210	95	1N1182

* Derate 50% for capacitive load.

* N after S.T. type number indicates negative base.
** P after S.T. type number indicates positive base.

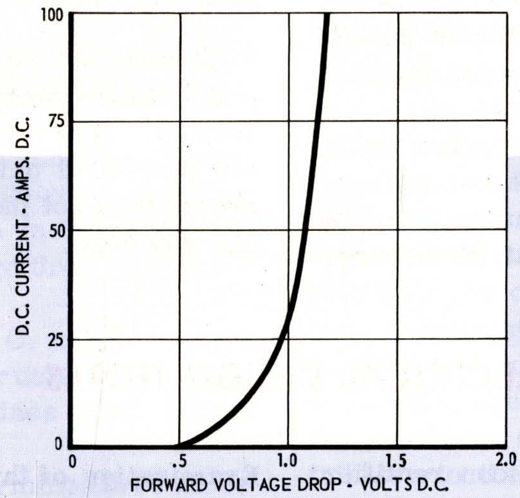
Output Voltages Three Phase Connections

S.T. Type	Half Wave 265 Amps. D.C. (3 Required)		Full Wave Bridge 300 Amps. D.C. (6 Required)		Six Phase Star 450 Amps. D.C. (6 Required)		Jetec No.
	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	Max. Input Volts RMS	Approx. D.C. Output Volts	
5VN*	35	25	35	45	35	25	1N1165
10VN	70	45	70	90	70	45	1N1166
20VN	140	95	140	185	140	95	1N1167
30VN	210	140	210	280	210	140	1N1168
5VP**	35	25	35	45	35	25	1N1179
10VP	70	45	70	90	70	45	1N1180
20VP	140	95	140	185	140	95	1N1181
30VP	210	140	210	280	210	140	1N1182

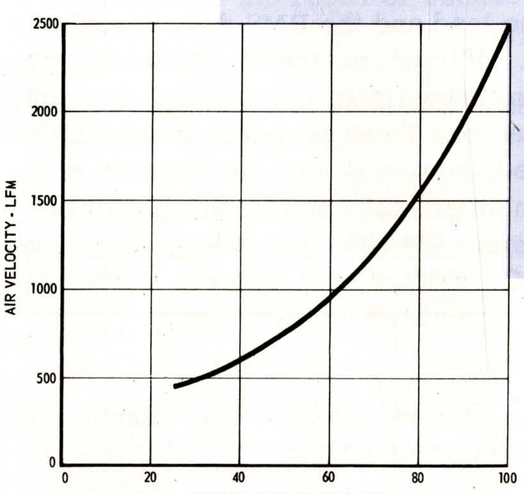
* N after S.T. type number indicates negative base.

** P after S.T. type number indicates positive base.

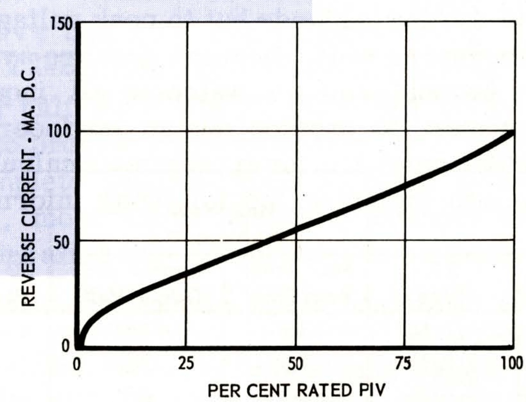
Characteristics



Forward voltage drop versus current for typical Sarkes Tarzian Type V Silicon Rectifier



Ambient Temperature versus air velocity for typical Sarkes Tarzian Type V Silicon Rectifier mounted on a 4" x 5" x 1/4" copper heat sink



Reverse current versus voltage for typical Sarkes Tarzian Type V Silicon Rectifier

Engineering Data

No device previously used as a rectifying element has offered the design engineer the flexibility of design that is offered by silicon rectifiers. Small size coupled with high efficiency make possible applications hereto considered impractical or reserved for less efficient and less reliable devices.

On following pages we cover a few basic concepts of rectifier design test and application. If you have any questions on the data we have listed or problems that we have not covered please do not hesitate to call on us for clarification or assistance. In many instances a simple phone call or letter will save you hours of time.

Remember too that silicon rectifiers are still in their infancy when compared to similar devices. New designs and new applications are developed daily. Be sure to call if our listing does not include the specific rectifier that you need.

ELECTRICAL DESIGN NOTES

The general design of a silicon rectifier depends on several factors to provide optimum results and long life. Careful consideration must be given not only to temperature and cooling methods but to peak voltages and currents as well. Detailed data are available on request and we welcome all inquiries, however, to provide design engineers with fundamental data for approximate calculations we are including the following information:

The fundamental design equation for silicon rectifiers is:

$$E_{RMS} = FE_{DC} + KNV$$

where

- E_{RMS} = Input Volts RMS
- E_{DC} = Output Volts D.C.
- V = Voltage drop per rectifier
- F = Form Factor (See Table 1)
- K = Circuit constant (See Table 2)
- N = No. of rectifiers in series per section

Examination of this equation shows that all terms are either given or converted to RMS values and indicates that the input voltage is equal to the sum of the RMS voltage appearing across the load and the RMS drop across the rectifier. If load balancing resistors are used as in connections with parallel sections, the drop across these resistors must also be considered, however, for the purpose of illustration we will not consider this possibility. To determine the AC input voltage for a desired D.C. voltage and current output the following procedure is followed:

1. Select a silicon rectifier that carries the desired current rating.
2. Obtain from Figure 21 the voltage drop per rectifier at the correct current density. Select the correct curve for the proposed circuit from Table I.

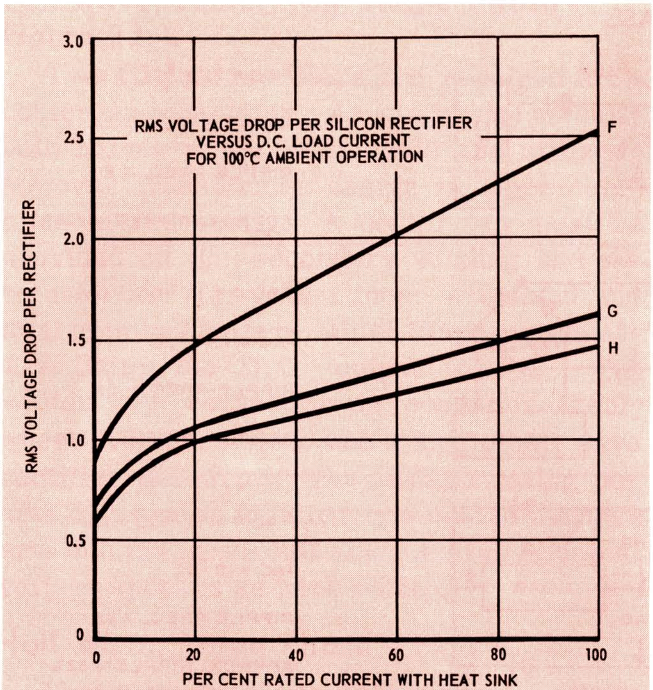


FIGURE 21

3. Determine the circuit constant from Table II and multiply the constant by the rectifier voltage drop determined in #2. This determines the RMS voltage drop per rectifier or junction.
4. Multiply the required D.C. output voltage by the circuit form factor determined from Table I. This determines RMS output voltage.
5. Multiply the product determined in #3 above by the number of rectifiers in series per arm. This will determine the RMS voltage drop through the rectifier connection. (If only 1 rectifier is used per arm, the results of #3 and #5 are equal.)
6. Add the products of #4 and #5 to determine the RMS input voltage.

TABLE I

Curve	Circuit	Load	Form Factor
F	Single Phase Half Wave	Battery	1
	Single Phase Bridge	Battery	0.8
	Single Phase Center Tap	Battery	0.8
G	Single Phase Half Wave	Resistive	2.22
	Single Phase Bridge	Resistive	1.11
	Single Phase Center Tap	Resistive	1.11
	Three Phase Half Wave	Resistive	0.85
H	Three Phase Bridge	Any	.74
	Three Phase Center Tap	Any	.74

TABLE II
Circuit Constants

Single Phase	Half Wave --- 1 Bridge ------- 2 Center Tap -- 2
Three Phase	Half Wave --- 1 Bridge ------- 2 Center Tap -- 2

CONVENTIONAL CIRCUITS

Silicon Rectifiers are generally produced as half wave units; however, it is possible to connect single units into a variety of single phase and polyphase combinations. A few typical circuits are discussed below:

Half Wave, Single Phase - Figure 22-A

Silicon Rectifiers are self contained half wave units -- therefore it is not necessary to use more than one unit per circuit unless load requirements for voltage and current exceed the ratings of a single unit. When an input capacitor filter is used, it is necessary to provide a few ohms of surge limiting resistance to prevent rectifier failure. Also, with capacitive load, it is necessary to exercise care not to exceed the peak voltage rating of the rectifier since the D.C. voltage contributes to the total back voltage. Special transformer design is required because of core saturation effects of unidirectional current and high RMS to D.C. ratios.

Full Wave Bridge, Single Phase - Figure 22-B

Four half wave silicon rectifiers are required to provide a bridge connection. While the complete assembly can be made at the factory, most users prefer to connect the rectifiers after they are mounted in the equipment. Full wave output reduces ripple and increases efficiency. Transformer design is simplified since both halves of the input cycle are utilized. Transformer secondary voltage is approximately 1.25 times the D.C. output voltage. Simplicity, flexibility of design and wide availability of single phase source voltage have made the single phase bridge the most popular circuit in use with semi-conductor rectifiers.

The reverse current test is made by applying a D.C. voltage equal to PIV rating of the rectifier, in the reverse (or blocking) direction, and measuring the resultant D.C. current flow. Proper type of D.C. instruments must be used as currents involved are in the order of microamperes and the reverse resistances vary from 10 to 200 megohms depending upon the PIV rating of the rectifier.

The reverse to forward current ratio of the rectifier may be determined from these test results.

Load Tests

This test is made by applying rated RMS voltage or less to the A.C. terminals of the rectifier connection and adjusting the load until rated D.C. current flows. Measuring the D.C. output voltage of the rectifier connection will determine whether the rectifier output is as specified. For engineering evaluation purposes a dynamic load test is useful in determining the forward voltage drop per half wave section at rated load and reverse leakage current at rated RMS input voltage. A schematic diagram, parts list, and operating instructions of a dynamic load tester are in Figure 23.

DYNAMIC TEST CIRCUIT FOR EVALUATING SILICON RECTIFIERS
USED IN POWER CIRCUITS

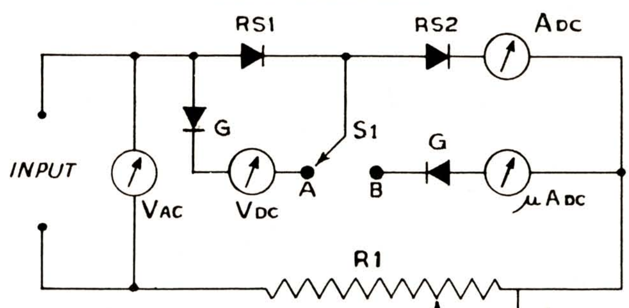


FIGURE 23

PARTS:

1. S1-DPDT Switch.
2. R1-Variable Load Resistor
3. RS2-Silicon Rectifier of same current and voltage rating as RS1.
4. G-Germanium Diode 1N93 or equivalent
5. VDC-DC Voltmeter 0-3 Volts 1000/Volt.
6. VAC-AC Voltmeter
7. ADC-DC Ammeter
8. RS1-Rectifier Under Test.
9. μADC-DC Microammeter

OPERATION:

With rated input voltage applied and SW1 in position "A", adjust R1 until ammeter Adc reads rated rectifier current. The forward voltage drop will be indicated on the voltmeter Vdc.

With switch SW1 in position "B", the reverse current will be indicated on the microammeter μADC.

Temperature Measurements

To measure the case temperature of a silicon rectifier, a copper-constatin thermocouple having a wire size of #30 A.W.G. or less is recommended. The thermocouple should be attached to positive end of the rectifier case. The placement of the thermocouple wires should be such that restriction of air flow in the vicinity of the rectifier is kept to a minimum.

PRECAUTIONS

In handling, testing, and installing rectifiers the following precautions should be followed:

1. Do not use an ohmmeter to test silicon rectifiers. The nonlinear resistance of the rectifier will give erroneous results.
2. Do not loosen assembly.
3. In installing stud mounted rectifiers use two wrenches for tightening mounting nut. Do not hold by ceramic housing or end opposite from stud.
4. In installing pigtail mounted rectifiers keep soldering iron from prolonged contact with pigtail lead. It is suggested where possible to hold wire with a pair of pliers between rectifier and solder joint to prevent heat flow into rectifier.
5. Mount rectifiers away from other heat radiating components.
6. Be sure that rectifier is mounted on an adequate heat sink before operating at heat sink ratings.

SERIES OPERATION

No special precautions are required on series operation of silicon rectifiers, except that the sum of the peak inverse voltages is not exceeded.

PARALLEL OPERATION

Operation of silicon rectifiers in parallel requires a series resistor with each half wave rectifier for proper balancing of individual currents in the conducting direction. The following resistance values and wattages are recommended:

Full Wave, Center Tap, Single Phase - Figure 22-C

Two silicon rectifiers are required for a center tap connection. As in a bridge circuit, both halves of the input cycle are utilized, however transformer design is more complicated and costly. A center tap must be provided on the secondary winding and the transformer insulation must withstand the total terminal voltage, which is approximately 2.7 times the D.C. output voltage. The center tap connection is economical only where it is possible to use a single half wave rectifier per arm. The voltage rating per arm of a center tap circuit is double that per arm in a bridge circuit since the full terminal voltage appears as back voltage.

Half Wave, Three Phase - Figure 22-D

Three single phase half wave rectifiers are required to connect a three phase half wave circuit. Better circuit utilization provides relatively high efficiency and low ripple at three times the fundamental frequency. Output voltage is approximately equal to phase voltage; however, the RMS voltage rating of each arm of the rectifier must be equal to the line to line voltage which is 1.73 times the phase voltage.

Full Wave Bridge, Three Phase- Figure 22-E

Six single phase half wave units are required to provide a three phase bridge connection. This circuit, however, delivers very high efficiency and is commonly used where D.C. power requirements are large. Due to overlapping of the three phases the ripple percentage is low, approximately 4%, and though additional filtering may be required, the resultant ripple that is six times the fundamental source frequency is easily filtered. The D.C. output voltage is approximately 25% higher than the input voltage.

Full Wave, Center Tap, Three Phase - Figure 22-F

Six half wave single phase silicon rectifier stacks are required to connect a three phase center tap circuit. The load current rating for this connection is approximately 20% higher than for a three phase bridge and 40% higher than for a three phase half wave. Transformer design is somewhat complicated since a center tap is required in each secondary winding. The D.C. output voltage is approximately 75% of the phase terminal voltage or approximately 1.5 times the center tap voltage. Each arm of the rectifier assembly is required to block the full voltage of the secondary winding.

D.C. Valves and Field Discharge

Many applications require a component to exclude D.C. from some portion of a circuit while allowing desired current to flow freely. Half wave silicon rectifiers provide excellent valve action because of their extremely high reverse to forward ratios. Silicon rectifiers are also useful to discharge the potential caused by the collapse of the lines of flux in the field surrounding the turns of wire in a coil. In this application half wave silicon rectifiers are used with a voltage rating sufficiently high to block the voltage impressed across the coil.

TEST PROCEDURES

General testing of silicon rectifiers consists of D.C. static forward and reverse tests, that indicate the instantaneous relationship between voltage and current. For engineering evaluation a dynamic load test is more indicative of the performance of the rectifier as it measures both the forward and reverse characteristics under load.

As is generally true, any quick test is not absolutely conclusive and only approximates the relative quality of the rectifier since stability of the characteristics throughout the life of the rectifier is of major importance.

Write for complete information on limits, applicable tests, and specific recommendations covering the following tests.

D.C. Tests

The D.C. forward test is made passing the applicable D.C. current through the rectifier in the conducting direction and measuring the D.C. voltage drop across the rectifier using suitable D'Arsonval type instruments.

Type Rectifier	Wire Resistance Ohms	Watts*
N	2.0	5
P	0.5	30
Q	0.15	100

* Wattage rating at 25°C ambient.

OPERATION WITH HEAT SINK

Conduction cooling of silicon rectifiers by means of suitable heat sink allows operation at higher currents than with convection cooling. Unless an "infinite" heat sink action is provided or simulated, the heat sink depends on radiation to dispose of the heat generated by watt losses within the junction. Heat sink design is, therefore, extremely important and all precautions must be taken to limit the temperature of the device to safe values.

Through experiment, we have determined that radiation is proportional to the temperature and area and since temperature is based on watt losses that are dependent on the D.C. current through the junction, we can use the following equation to determine required cooling area:

$$* \text{Area (in sq. inches)} = \frac{2\, I_{DC}}{.008\, T_R}$$

*Based on both sides of aluminum plate 1/8" thick or copper plate 1/16" thick.

Where T_R is the allowable temperature rise above ambient or cooling plate temperature, in degrees Centigrade and I_{DC} is the D.C. load current that the junction will carry.

For example - assume that a type P-2 silicon rectifier will be operated at 3 amperes D.C. in an ambient temperature of 125°C and it is desired to limit the temperature rise to 25°C. The area of cooling fin required is then:

$$\text{Area} = \frac{2 \times 3}{.008 \times 25} = \frac{6}{.2} = 30 \text{ Square Inches}$$

Since the area includes both sides of the cooling plate, the plate size should be approximately 3 7/8" x 3 7/8" of 1/8" aluminum.

For specific recommendation on your problem, please forward complete data for prompt recommendation.

Mounting Hardware for Stud Type Rectifiers

Figures 24 and 25 show mounting hardware and recommended hole sizes to accommodate N, P and Q type rectifiers. Hardware and special insulating washers and bushings are supplied on request with orders covering rectifiers that require heat sink cooling.

Figure 26 shows a suggested method for mounting Type LF silicon rectifiers.

A plus or minus 1/16" tolerance should be allowed on the "L" dimension to allow for variations in rectifier length.

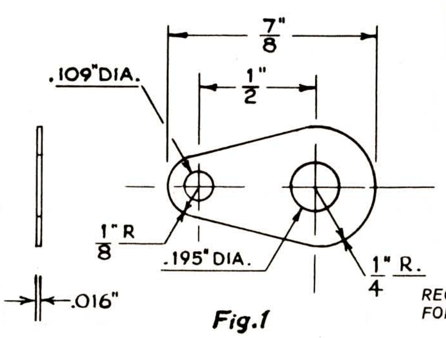
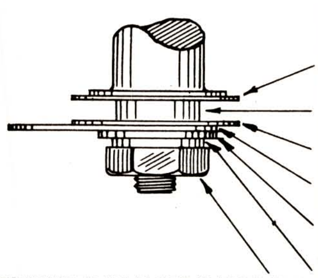


Fig.1



RECOMMENDED HOLE SIZE IN HEAT SINK FOR INSULATED MOUNTING:- 21/64"

ITEM	SIZE OD	SIZE ID	SIZE THK.	DESCRIPTION
Insulating Washer	11/16"	.203	.005	Mica
Insulating Bushing	5/16"	.203	3/64"	Teflon Base Plastic
Insulating Washer	11/16"	.203	.005	Mica
Terminal	See Fig 1			Brass Hot Tinned Dipped
Metal Washer	.500	.203	.032	Brass Cronak Finish
Internal Tooth Shakeproof Washer	.381 .370	.204 .195	.022	Phosphor Bronze Cronak Finish
Nut (10-32)	A.C. .433 .413	A.F. .375 .362	.125	Brass Cronak Finish

HEAT SINK MOUNTING - "N" AND "P" TYPES

FIGURE 24

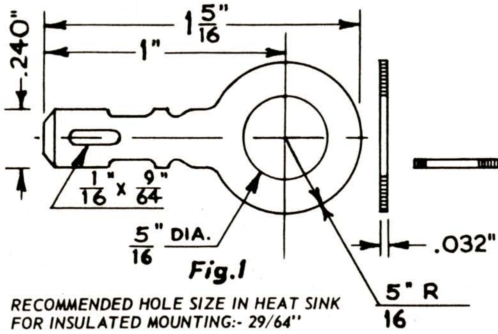
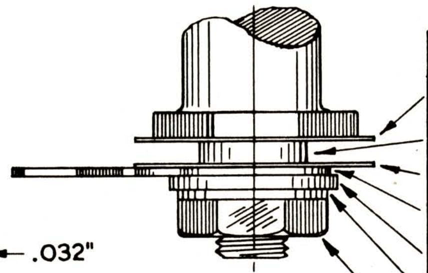


Fig.1

RECOMMENDED HOLE SIZE IN HEAT SINK FOR INSULATED MOUNTING:- 29/64"



HEAT SINK MOUNTING - "Q" TYPE

ITEM	SIZE OD	SIZE ID	SIZE THK.	DESCRIPTION
Insulating Washer	1"	.328	.005	*Mica*
Insulating Bushing	7/16"	.328	3/64"	*Teflon Base Plastic*
Insulating Washer	1"	.328	.005	*Mica*
Terminal	See Fig 1			*Brass Hot Tinned Dipped*
Metal Washer	11/16"	11/32"	.062	*Brass Cronak Finish*
Internal Tooth Shakeproof Washer	.610 .594	.320 .332	.030	*Phosphor Bronze Cronak Finish*
Jam Nut (5/16 - 24)	A.C. 5/8"	A.F. 9/16"	.156	*Brass Cronak Finish*

FIGURE 25

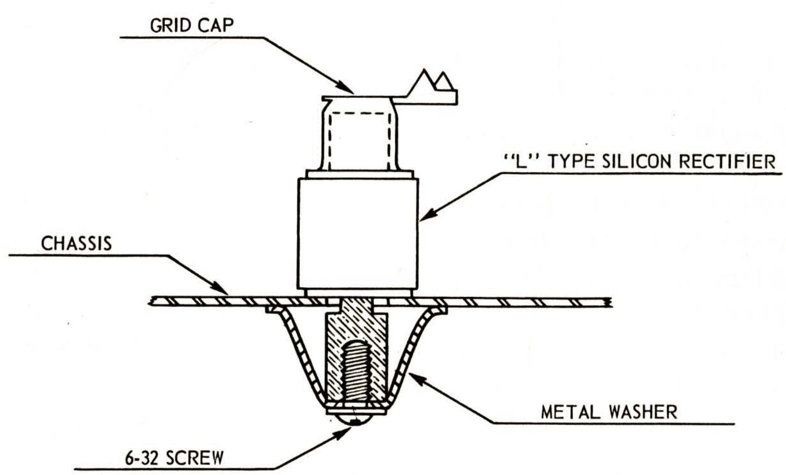
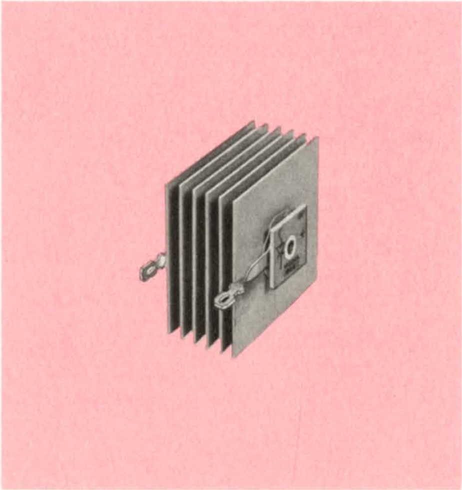
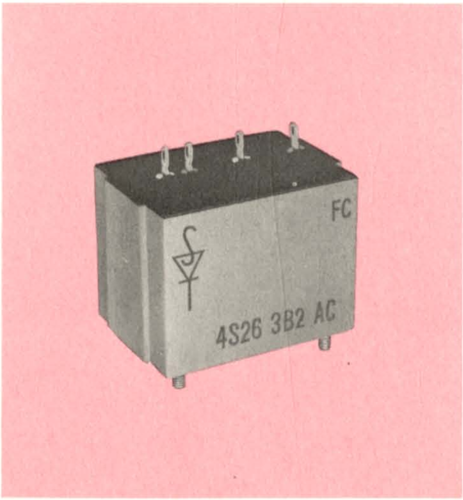


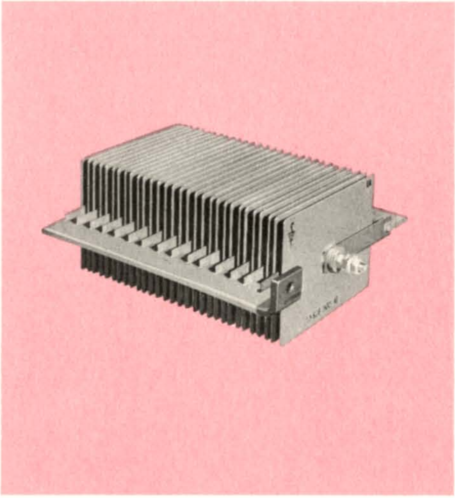
FIGURE 26 HEAT SINK MOUNTING - "LF" TYPE

LITHO IN USA

If your application requires selenium rectifiers please send us your specifications for prompt recommendation. Remember — the new Sarkes Tarzian High Temperature Selenium Rectifier permits cell temperatures as high as 150°C.







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