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INTERNATIONAL RECTIFIER CORPORATION

RECTIFIER NEWS

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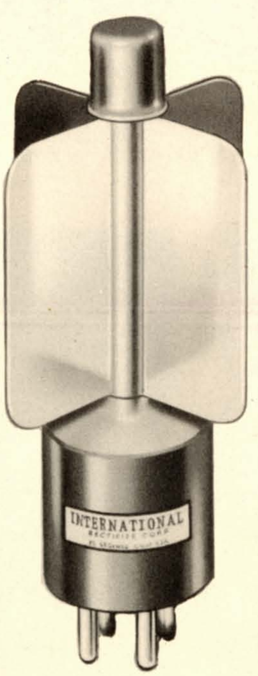
SILICON EQUIVALENT OF THE 866 TUBE

...for broadcast, television, airline, police and other communication equipment

...physically rugged, weighs less, smaller, **OFFERS VIRTUALLY UNLIMITED LIFE!**



International Rectifier TYPE ST-7

See Page 5

By George Porter, International Rectifier Corporation

DESIGNING FOR OPTIMUM PERFORMANCE

SOLID STATE REFERENCE ELEMENTS

Designers of precision electrical equipment are depending more than ever on the zener reference element to replace standard cells, glow discharge tubes and dry batteries as a stable voltage reference source. This is especially true where extremes in environmental conditions are encountered.

In order to realize the full stability capabilities of the zener element, considerable precaution must be taken to insure operation at its optimum operating point.

For those who are engaged in "electrical hair-splitting," this article is intended to show the importance of maintaining proper operating currents and to suggest methods by which this may be accomplished.

* * *

The stability of a silicon zener voltage reference element is only as good as the stability of the current though the element.

This is true of any zener diode in general, but is of particular concern when employing reference elements where a drift of only a few millivolts is of major importance.

The 1N430A Reference Element

The type of silicon reference element currently used in most military and quality commercial applications is the 1N430A. This device is actually three series-connected zener diodes; one operating in the reverse direction and possessing a positive temperature coefficient; the other two diodes being connected to operate in the forward direction, and exhibiting negative temperature coefficient characteristics. The net result is an almost exact cancellation of diode drifts with temperature changes. For example, if the reverse connected diode drifts + 200 millivolts with an increase of 75° in temperature, the forward operating diodes would each have to change by 100 millivolts in a negative direction for exact cancellation.

Thermal Stability

The military specification to which the 1N430A is manufactured states that the thermal stability factor for this reference element must be better than ±.001% per degree centigrade over the temperature range of —55°C to +100°C. This specification is graphically represented by Figure 1.

From an initial voltage drop across the element at the 25°C reference temperature, the voltage cannot change by more than that indicated by the con-

Figure 1. 1N430A Thermal Stability Specification of ±.001%/°C

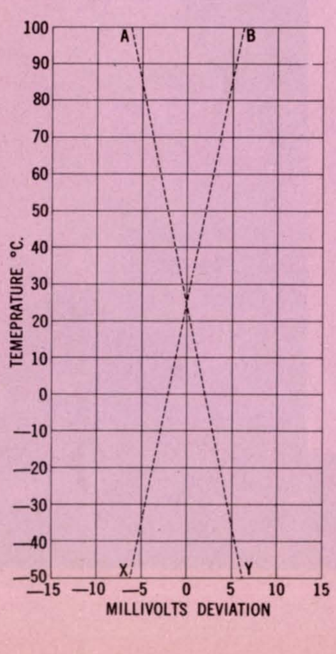


Figure 2. Typical 1N430A Thermal Stability Calibration Curve

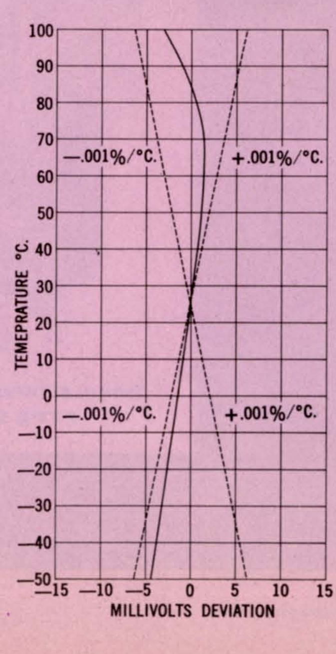
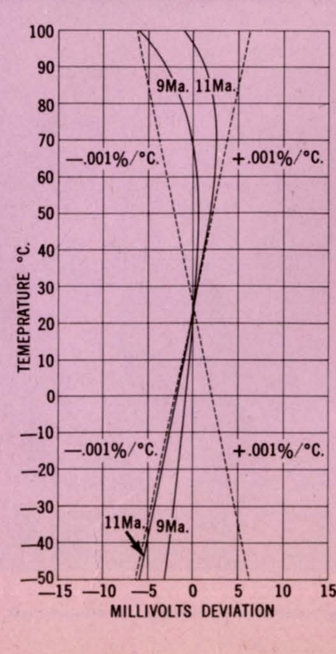
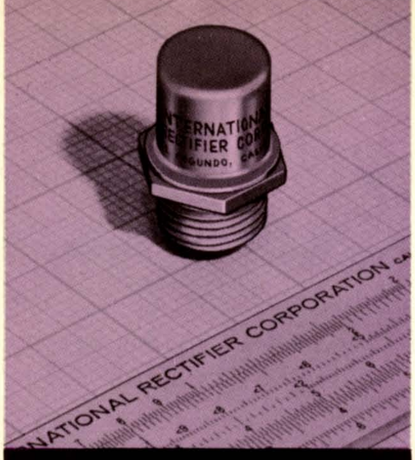


Figure 3. 1N430A Stability Factor at 9 and 11 ma Reverse Current





The 1N430A Reference Element

fines of triangles AOB and XOY. In other words, an element having a voltage drop of 8.4000 volts D.C. at 25°C may not vary from this initial value by more than ±.0021 volts at a temperature of +50°C. At either +100°C or —50°C the maximum allowable deviation would be only ±.0063 volts.

The specification also states that this qualification test be made at a reverse current (I_z) of exactly 10.0 milliamperes. Figure 2 shows a calibration curve made of a typical 1N430A operating with this reverse current of 10.0 milliamperes over the prescribed temperature range. These units can and do possess this high degree of thermal stability, providing the current is held at exactly 10.0 ma. If the current is allowed to deviate from this value during the qualification test, it is unlikely that the element will exhibit the high degree of stability that is called for in the specification. This holds true for any reference element of the zener type, 1N430A or otherwise.

Although not precisely stated by the military specification, the various manufacturers of this device guarantee that these elements still possess this stability factor of ±.001%/°C at ±1 milliampere from the design center rating of 10.0 ma. From Figure 3 we see that this is true. A current of either 9.0 ma or 11.0 ma will keep the element stability within the required specification. However, this stability at any of these specific currents is only possible if the particular value of reverse current is held absolutely constant at all times.

What the 1N430 specification does not state is the expected stability with regard to variations in the value of reverse operating current. The stability of this current should be of as much concern to the design engineer as the specific value. Figure 4 illustrates how the voltage across this device will vary as the current is changed, the temperature being held constant. If the element has a drop of 8.4000 volts at 10.0 ma the drop at 9.00 and 11.00 ma will be 8.389 volts and 8.411 volts respectively. This is a net change of ±11 millivolts and represents a change of about 1 millivolt per 100 microamperes deviation from the design center of 10.00 ma. Referring again to Figure 3, it can be seen that if, in addition to the normal allowable drift with temperature, a simultaneous change in reverse current from 10.0 ma to 9.0 ma would result in an additional voltage variation corresponding to —11 millivolts. At +100°C the voltage across the reference element could possibly have varied from its original value at ±25°C by as much as —17.3 millivolts (11 plus 6.3 mv). This represents a stability factor of only about ±.003%/°C; three times more than the specification allows! Therefore, if the current through the element is allowed to vary during operation, this otherwise stable device loses much of its value as a precise voltage reference. Any precision electronic system dependent on the zener reference for stable operational characteristics would be degraded considerably if more than minute current variations were allowed to exist.

To observe what happens to the stability of this reference element at reverse currents other than those specified, measurements were taken at a number of discreet current values from 8.0 ma through 12.0 ma. From Figure 5 it can be seen that currents above and below the 9 to 11 ma values result in the element exhibiting thermal stability characteristics that no longer conform to the ±.001%/°C requirements. Note that at 12 ma the stability is poor at both high and low temperatures. 8 ma operation shows excellent low temperature characteristics, but at high elevated temperatures the drift is excessively negative. However, if a particular application calls for good voltage stability

Figure 4. 1N430A Voltage Drop Variation from a 10 ma Reference Point (+25°C)

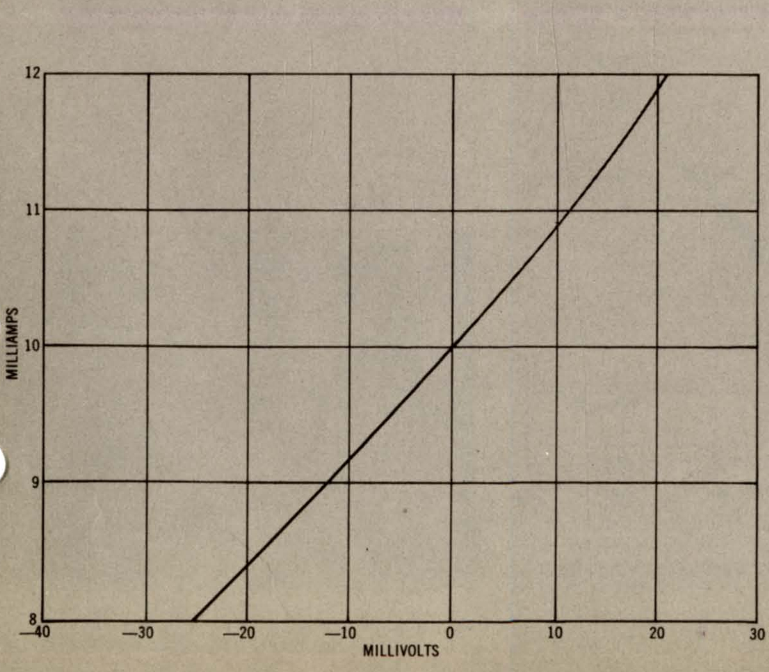
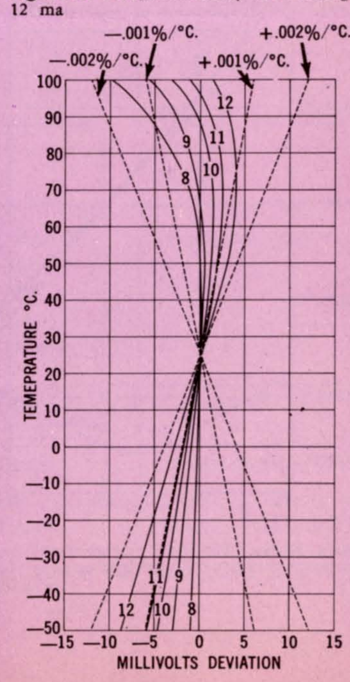


Figure 5. 1N430A Stability at 8 Through 12 ma



only over a limited temperature range . . . say —25°C through +75°C, it would seem definitely advantageous to limit the current through the element at 9 ma, 10% lower than its specified rating. For laboratory use, and in industrial equipment, where the temperature seldom exceeds +55°C, a stability of at least ±.0005%/°C could be expected. If operation at only very low temperatures is contemplated, a current of even less than 8 ma would prove optimum. The choice of current should be set by the expected operating environmental conditions.

Figure 6 illustrates thermal voltage stability vs reverse operating currents, and shows how anticipated operating temperature ranges should govern the choice of current.

Design of Current Source

The design engineer considering the use of the silicon reference element in precise equipment should certainly take special precautions in the design of the current source.

Four simple methods of obtaining a constant current that will be virtually unaffected by temperature are depicted in Figure 7. Circuit (a) is possible only if a high voltage, well-regulated source is available which has sufficient reserve current capacity to supply the additional requirements of the reference element. This power supply should be almost impervious to temperature effects. Variations in the value of R will, of course, result in undesirable current shifts.

In cases where no such separate regulated source is available, or where isolation is required, an independent supply may be designed making use of two series-connected 1N430s as pre-regulators. (b) Since these are also highly stable devices themselves, the end reference element is assured of an extremely constant current over a wide range of temperatures. The chief disadvantage is in the cost of the additional 1N430s.

Less costly zener diodes may be used as the pre-regulator in place of the 1N430s. (c) Three 5.5 volt diodes operating at their zero temperature coefficient current point* provide excellent stable regulation.

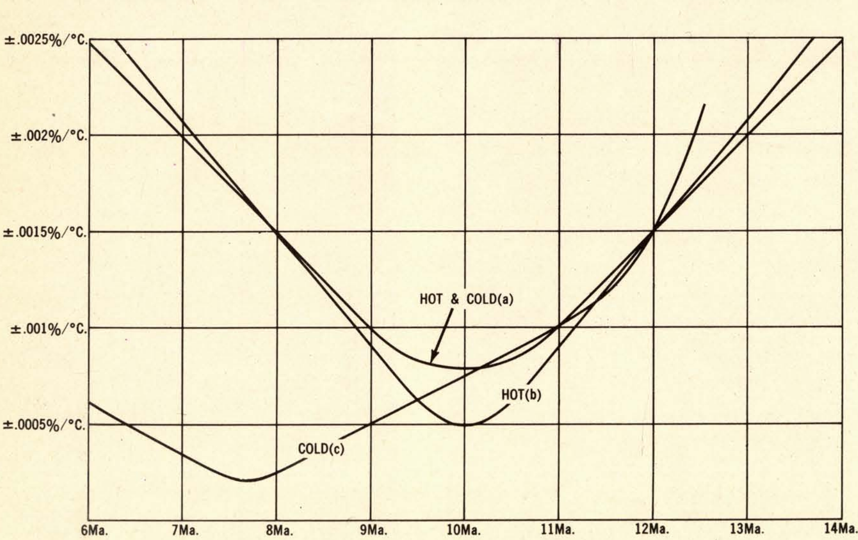
A fourth method involves only the use of a single zener diode in the range of 12 to 20 volts. (d) Such a diode, however, will suffer from an inherently positive temperature coefficient; i.e., its voltage will rise with temperature increasing the current through the reference element. This disadvantage fortunately can be overcome by compensating with a resistor, R, also having a positive coefficient. As the voltage across the zener regulator increases with temperature, the resistor will tend to increase in resistance so as to maintain a relatively constant current through the 1N430.

Summary

Perhaps there are many more schemes for accomplishing the same end than those presented here. Regardless of the method adopted, the designer will be well repaid for his careful circuit design . . . and realize the high degree of stability of which the silicon reference element is capable.

*"*The Zero Temperature Coefficient Zener Diode*" *Int. Rectifier News, Dec.-Jan. 1958-59*

Figure 6. 1N430A Thermal Voltage Stability vs. Reverse Operating Current



Editor's Note: *A happy "press-time" solution for those who may not have the time or inclination to create their own highly stable voltage reference circuitry appears on page 7.*

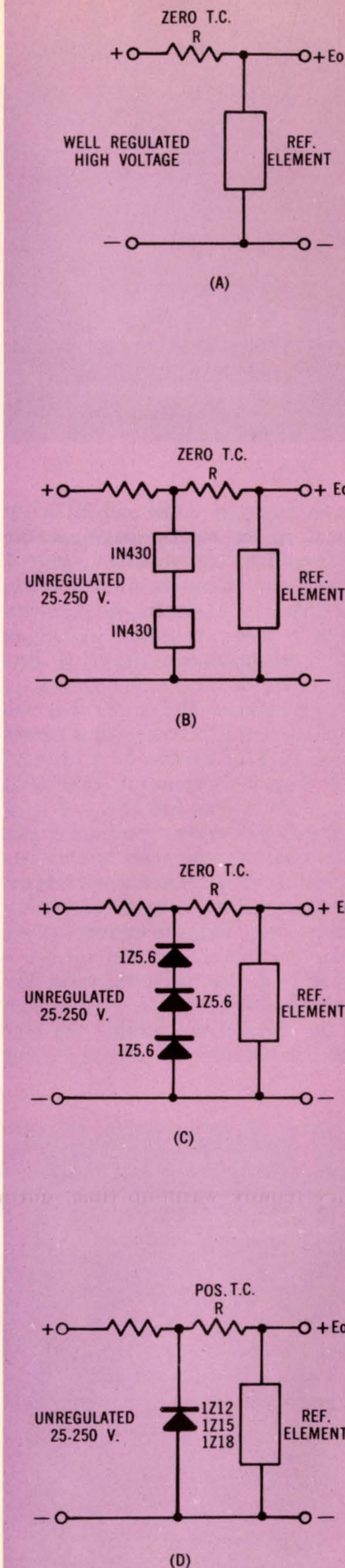
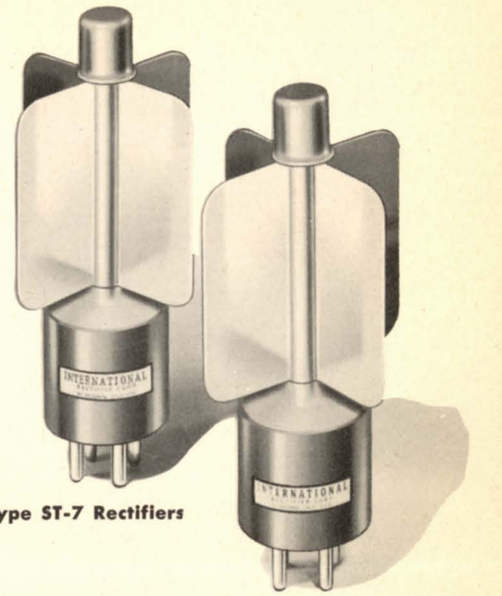


Figure 7. Reverse Current Supply Circuitry

Silicon Equivalent of the Standard Type 866 Mercury Vapor Rectifier Tube



Type ST-7 Rectifiers

Performance Evaluation and Physical Comparison shows many advantages offered by the ST-7 Silicon Cartridge for the design and maintenance of broadcast and communications equipment.

Fulfilling the need for a compact, reliable unit to replace cumbersome, short-lived Type 866 mercury vapor rectifier tubes, a silicon cartridge rectifier is now available to design engineers offering real miniaturization and the reliability long needed in a variety of communication and power supply applications.

Until now, nothing but the Type 866 tube could handle the extremely high surge currents and provide the rated output necessary on a multitude of high voltage, low current applications . . . ranging from virtually all communication uses (radio-TV broadcasting, teletype, telemetering, airline, police, etc.) to such varied industrial applications as motor control, induction heating and spot welding.

Unfortunately Type 866 tubes have a very limited temperature range (0°C to +50°C) and simply quit operating at sub-zero temperatures. They are short-lived and require frequent replacement. They require warm-up time, during which transient peak voltages can endanger the circuit. Finally, they generate a high degree of heat in operation and, along with the filament transformer necessary to their operation, they are bulky, space-consuming circuit components.

In a compact package 1/3 of the size of equivalent 866 tube circuitry, the new ST-7 silicon cartridge units provide virtually unlimited life, operating temperatures from —65°C to +75°C, require no warm-up time, and generate a minimum of heat.

The comparison table below points up the very definite advantages of the silicon units over the mercury vapor tube.

Basically, the silicon cartridge rectifier, (of which International Rectifier produces a complete line to meet almost any high voltage requirement) is an assembly of one or more silicon junctions in intimate contact, in series to obtain the required voltage rating. The junctions are packaged in a tube to meet the insulation requirements. The Type ST-7 is a multiple-junction cartridge, hermetically sealed for high reliability and equipped with radial cooling fins to provide optimum power dissipation. Rated at 6,400 PIV, these units will supply dc output currents of 250 ma at 75°C ambient temperature. The entire housing and cooling fins act as a highly efficient heat exchanger for maximum dissipation. Units measure 5 x 2 3/8 (diameter) inches, and are equipped with tube bases to allow direct insertion into existing tube sockets. For more detailed data, write for Bulletin SR-209.

Figure 1. Size and volume of Type ST-7 Rectifiers as compared to tube circuitry they replace.

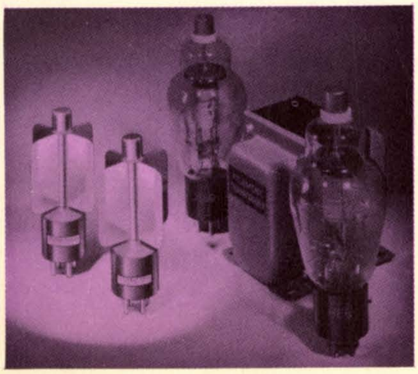
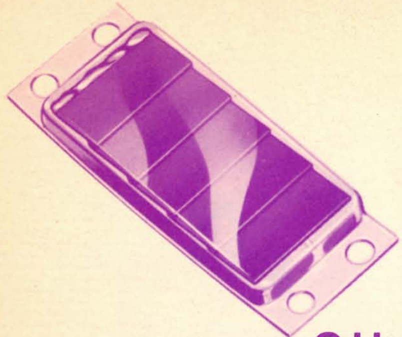


TABLE 1: COMPARISON FOR 2 RECTIFIERS IN FULL WAVE CIRCUIT

FUNCTION	TYPE 866 TUBE	ST-7 SILICON CARTRIDGE
Temperature range	0 to +50°C	—65° to +75°C
Life	Only 1000-hour guarantee	Virtually unlimited
Warm-up time	1 to 10 minutes	None
Heat generation	Considerable (25 watts)	Negligible (6.5 watts)
Additional components needed	Filament transformer and time delay relay	None
Max. occupied volume	(With filament transformer) 70 cu. in.	22 cu. in.
Weight	(With filament transformer) 7 pounds	7 ounces
Current rating at rated Peak Inverse Voltage	250 ma @ 2500 PIV to 10,000 PIV*	250 ma @ 6400 PIV
Mechanical construction	Fragile glass envelope	Rugged, shockproof package

*PIV rating dependent on temperature and frequency.



Temperature Control of SILICON SOLAR CELLS *in Satellite Applications*

By Werner Luft, International Rectifier Corporation

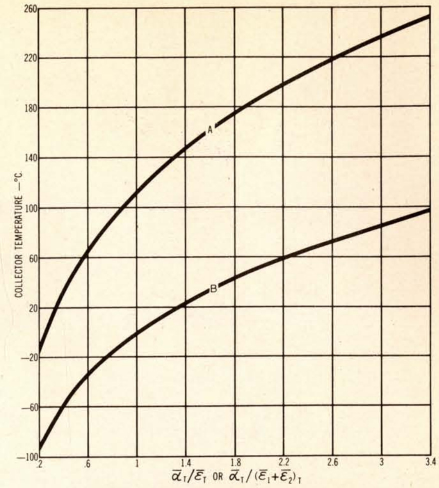


Figure 1. Collector Temperature vs. absorptivity/emissivity

Silicon solar cells have already been used, and in the near future will be used to a much larger extent, to provide electrical power for transmitting equipment in satellites.

In order to maintain a high energy conversion efficiency, the temperature of the solar cells must be controlled. It is desirable to maintain the cell temperature between −30°C and +50°C when exposed to solar radiation.

The temperature of a surface in space is a function of the ratio of average absorptivity to solar radiation of the surface ($\bar{\alpha}_T$) to the average emissivity at the stabilization temperature of the same surface. ($\bar{\varepsilon}_T$)

In Figure 1 this relationship is shown for two solar collector designs. Curve A is for a flat collector oriented normal to the sun, with the back surface insulated, and Curve B is for a spherical collector spinning around an axis normal to the solar radiation.

Curve A can also be used to determine the stabilization temperature for a flat oriented collector with re-radiation from both front and back surfaces. In this case the sum of the emissivities of both front and back surfaces $(\bar{\varepsilon}_1 + \bar{\varepsilon}_2)_T$ are used when determining the ratio of absorptivity to emissivity.

Both curves are based on solar radiation in space outside the earth atmosphere at the earth's mean distance from the sun, and assume a 10% energy conversion efficiency of the cells. Radiation effects from the earth or other stellar bodies are neglected.

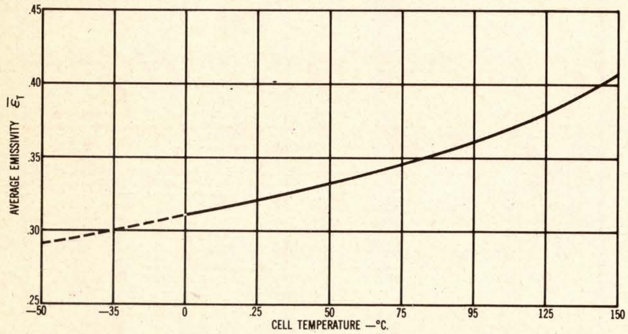
Standard solar cells have an average absorptivity of solar radiation outside the atmosphere of 0.91. The average emissivity of these cells varies with temperature, as shown in Figure 2.

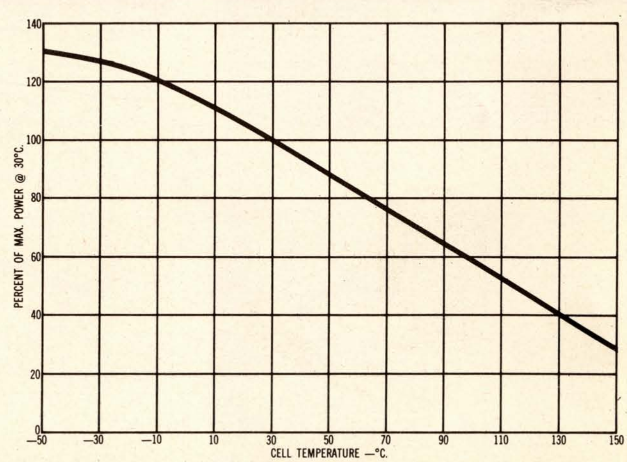
In a spherical collector the cell temperature would stabilize at 75°C, and for an oriented flat collector with insulated back, at approximately 180°C. If the flat collector could re-radiate also from the back surface, and this surface has an emissivity of .95, the cell temperature would be approximately 80°C. But these temperatures are too high. At 80°C the power output is 70%, and at 180°C only 11% of the output at 30°C as seen from Figure 3. In order to decrease the temperature of solar cells in satellites, International Rectifier Corporation has developed methods to increase the average emissivity of the cells, and is working on methods to reduce the average absorptivity to solar radiation by reflection of such parts of the solar spectrum which cannot be converted to electrical power by silicon solar cells.

At present, International Rectifier Corporation has special cells for satellite power supplies, which have an average emissivity of approximately 0.92. Such cells will have a temperature of approximately 0°C in a spinning spherical collector, and 45°C in an oriented flat collector with re-radiation from both sides. The increase in power output from these cells, compared with standard cells under the same conditions, is 47% and 20% respectively.

Below: Figure 2. Average emissivity of non-coated S1020 cells vs. cell temperature

Right: Figure 3. Maximum Power Output Index of S1020 cell vs. cell temperature



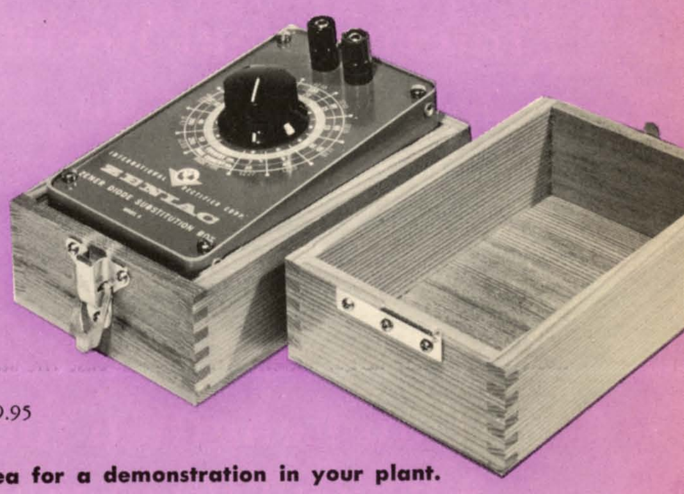


For data on International Rectifier Silicon Solar Cells, write to the Astro-Power Division.

new | developments

NEW 10-WATT SILICON ZENER DIODE SUBSTITUTION BOX — ZENIAC MODEL B

This second in a series of semiconductor substitution boxes makes the application of zener diodes in the 10-watt range a quick and easy operation. A flip of the Zeniac selector switch and you can interchange any one of 10 diodes, proving in a jiffy the exact type your circuit requires. The original Model A 1-watt Zeniac and the new 10-watt Model B are both in stock at our Authorized Distributors and Industrial Representatives. Both can save you hours of development time!



Model A — $89.95   Model B — $99.95

Contact our Representative in your area for a demonstration in your plant.

MINIATURIZED ULTRA-STABLE SILICON VOLTAGE REFERENCE PACKS

REF-PAK MODEL 4RV8
Standard MIL Transformer Case

Designed to replace standard cells or dry cell batteries, "Ref-Paks" will maintain voltage regulation to within ±0.01%!

Designed around the highly stable 1N430 silicon reference element, these miniature reference supplies may be considered to be the solid state equivalent of the standard cell. A high degree of stability is attained by maintaining a precise constant current through the reference element, regardless of temperature or line voltage variations.

These devices can withstand environmental extremes, and are operable at temperatures up to +125°C. They will operate directly from an unregulated power source. The table below gives output voltage, input voltage and frequency for the available types. Regulation, thermal stability and ripple factors are also given. Each unit is completely encapsulated. Special designs for both military and commercial applications are available on request. For complete data on Model 4RV8 and Model RV8-PC units, write on your letterhead or postcard for Bulletin SR-401.

REF-PAK MODEL RV8-PC
Special Housing for insertion into printed circuit boards.

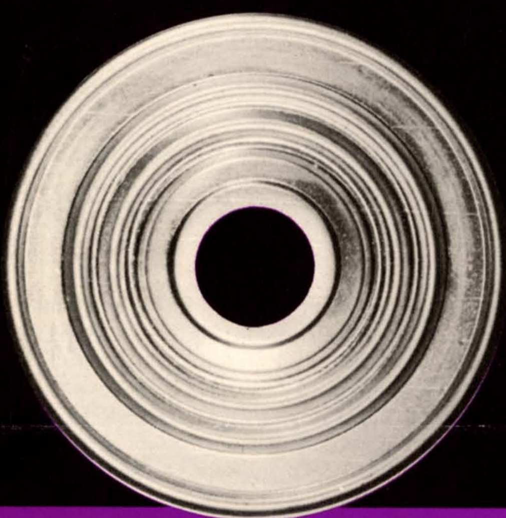
REF-PAK ELECTRICAL SPECIFICATIONS

MODEL NO.	INPUT	FRE-QUENCY	TYPICAL REGULATION (%)	OUTPUT VOLTAGE, VOLTS DC (±5%)	THERMAL STABILITY %/°C	RIPPLE (MAX.) %	TEMPERATURE RANGE, °C
RV8 RV8-A	28V ± 10% 0.84W	D.C. D.C.	±0.01 ±0.01	8.4 8.4	±0.002 ±0.001	— —	—55 to +125
4RV8 4RV8-A	115V ± 10% 1.25W	400~ 400~	±0.01 ±0.01	8.4 8.4	±0.002 ±0.001	0.004 0.004	—55 to +125
6RV8 6RV8-A	115V ± 10% 1.25W	60~ 60~	±0.01 ±0.01	8.4 8.4	±0.002 ±0.001	0.004 0.004	—55 to +75
4RV16 4RV16-A	115V ± 10% 2.5W	400~ 400~	±0.01 ±0.01	16.8 16.8	±0.002 ±0.001	0.004 0.004	—55 to +125
6RV16 6RV16-A	115V ± 10% 2.5W	60~ 60~	±0.01 ±0.01	16.8 16.8	±0.002 ±0.001	0.004 0.004	—55 to +75
RV8-PC RV8PC-A	28V ± 10% 0.84W	D.C. D.C.	±0.01 ±0.01	8.4 8.4	±0.002 ±0.001	— —	—55 to +125

This Patented International Rectifier Corporation Development for

SELENIUM POWER RECTIFIERS

Can Lengthen the Service Life of your Rectifier Equipment!



THE "BELLOWS SPRING"

THE MOST EFFICIENT ELECTRICAL CONTACT TO THE COUNTERELECTRODE OF A SELENIUM RECTIFIER PLATE YET DEVISED!

Here's How the Bellows Spring Safeguards a Contact Junction — Prevents Premature Failure

It Provides up to 2½ Times More Contact Area Than Other Types

The smaller the contact area, the greater the current density, thus the higher the temperature rise at the contact point. In high current applications, center blow-out of the plate often occurs with restricted area "line contact" springs. Greater area means lower dv . . . reduced ohmic drop between spring and counterelectrode.

It Assures Full Area Contact by Preventing Paint Seepage Under Spring

Capillary action causes protective finishes to seep beneath the outer periphery of other spring types, reducing the contact area . . . increasing contact resistance. It doesn't happen with the Bellows Spring as the photo below shows.

It Requires Less Assembly Pressure To Achieve Full, Uniform Contact

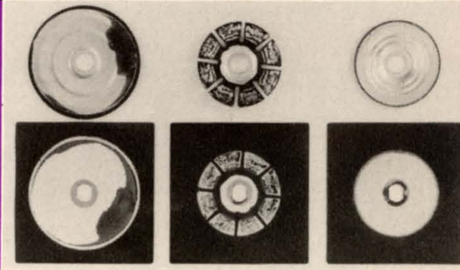
The heavy pressure demanded by some contact devices to make complete contact can cause the counterelectrode material to penetrate the selenium layer. Result? A dandy short circuit!

* * *

The Bellows Spring is an exclusive, standard part of every International Rectifier Power Stack. Because of it you get a far better stack . . . and it doesn't cost a penny more! It could save you many dollars!

If you are now designing equipment, let our Industrial Representative show you point-by-point why International Rectifier Selenium Stacks have become first choice with leading equipment manufacturers. If you're ready for a replacement, contact our Authorized Distributor. In either case, you can't buy a better stack!

Unretouched photo shows a comparison of paint seepage under open and closed type petal springs and the Bellows Spring (right).



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