[Journal of the Minnesota Academy of Science](https://digitalcommons.morris.umn.edu/jmas)

Volume 25
Number 1 *Vol. 25/26*

Article 37

1957

# Applications of the Silicon Solar Cell in High Altitude Research

James G. Busse
*St. Mary's College*

**JAMES G. BUSSE**
*St. Mary's College, Winona*



# Applications of the Silicon Solar Cell in High Altitude Research

## BACKGROUND

The silicon solar cell or Bell Solar Battery, as it is commonly called, is a semiconductor device which converts light energy directly into electrical energy. It consists of two semiconductors, one semiconductor being of the excess electron or n-type, and the other being of the deficit electron or p-type. When placed in contact with each other they form a photovoltaic junction, designated as the p-n junction. When the p-n junction is illuminated, photoelectrons are produced in the cell. The energy states of the topmost electrons in both the n-type and p-type semiconductors cause these electrons to move through the cell and around any external circuit connected to it. Since solar cells do not require the consumption or cycling of any material, they offer a particularly attractive possibility for portable sources of electrical power. (Trivich, etc., 1955.)

## OBJECTIVES AND STUDIES

The results of earlier experimentation, such as those of Church, Demorest, and Thon, have suggested the possibility of employing solar cells to furnish electricity for extended high altitude research. The present study was initiated in October, 1955, to sound out this possibility and to gather data on the efficiency of solar cells operating at altitudes in excess of 80,000 feet. Using S-1 silicon solar cells developed by Bell Telephone and manufactured by National Fabricated Products, Inc., Chicago, six high altitude balloon flight tests were planned during 1956 and 1957 with the generous cooperation of the Balloon Activities Group of the Mechanical Division, General Mills, Inc., Minneapolis. The design of the recording apparatus that would accompany the solar cells on their high altitude flight into the stratosphere began in December, 1955, and the completed instrumentation was ready for flight testing in February, 1956. Unfortunately, due to a systems failure, the first balloon flight was unsuccessful and part of the apparatus was damaged. One month later, new apparatus was constructed and a successful flight was made to an altitude of 81,000 feet. Four more successful flights were made to altitudes in excess of 80,000 feet. The fifth flight was launched on July 2, 1956, and reached an altitude of 81,100 feet. The sixth flight was unsuccessful due to a balloon control system failure and the more important part of the apparatus was lost. Directly before or after each flight test, the solar cell efficiency measuring apparatus was put through a ground test in order to gather data on the comparative efficiency of the cell while operating on the ground.

Laboratory studies of the solar battery carried on by the Mechanical Division of General Mills disclosed the effect of temperature on its efficiency in converting sunlight to electricity. It was found that as the temperature decreased, the electrical output of the solar battery increased (Table 1). Measurements of the temperatures of the different layers of the atmosphere traversed by the balloon and the electrical output of the solar battery on the balloon gave a similar indication (Fig. 1) of the temperature-efficiency relationship. The

TABLE 1—*Effect of temperature upon silicon solar cell output.*

| Time | Temp. °F. | Constant Light Source Voltage | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 110 volts | | 100 volts | | 90 volts | | 80 volts | |
| | | volts | u.a. | volts | u.a. | volts | u.a. | volts | u.a. |
| 0800 | 65 | .1 | 62. | .08 | 49. | .06 | 34. | .03 | 22. |
| 0805 | 55 | .14 | 67. | .08 | 54. | .06 | 37. | .04 | 25. |
| 0812 | 45 | .17 | 73. | .09 | 57. | .065 | 40. | .04 | 25. |
| 0818 | 35 | .12 | 76. | .10 | 61. | .08 | 45. | .05 | 28. |
| 0825 | 25 | .13 | 82. | .11 | 66. | .085 | 48. | .05 | 32. |
| 0833 | 15 | .14 | 86. | .12 | 70. | .09 | 52. | .06 | 34. |
| 0839 | 5 | .15 | 90. | .12 | 75. | .10 | 56. | .07 | 38. |
| 0851 | -5 | .15 | 96. | .13 | 78. | .10 | 60. | .07 | 41. |
| 0905 | -15 | .16 | 100. | .14 | 82. | .11 | 62. | .08 | 45. |
| 0915 | -25 | .165 | 102. | .15 | 86. | .11 | 67. | .08 | 46. |
| 0922 | -35 | .17 | 105. | .15 | 88. | .11 | 68.5 | .08 | 49. |
| 0930 | -45 | .17 | 108. | .16 | 90.5 | .115 | 72. | .095 | 55. |
| 0940 | -55 | .18 | 110. | .16 | 92. | .13 | 73. | .10 | 53. |
| 0945 | -65 | .19 | 113. | .165 | 94. | .135 | 76. | .10 | 54. |
| 1015* | -65 | .19 | 113. | .16 | 94. | .13 | 75. | .10 | 54. |

*Simulating an altitude of 30,000 feet.

efficiency of the solar battery at 80,000 feet was actually almost twice that of a solar battery on the surface of the earth, while the flight temperature reached -60°C. at one point in the test.

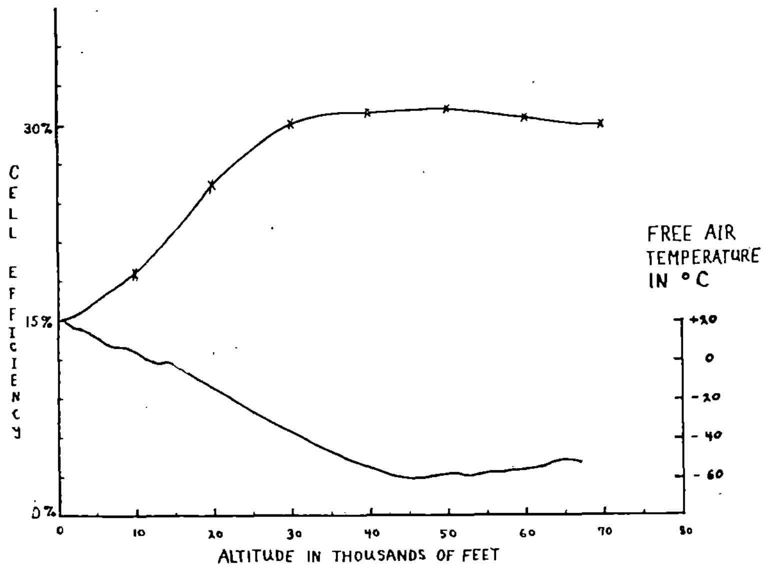


Fig. 1.

Although some of the increased efficiency of the solar battery at higher altitudes is due to the absence of the denser part of the atmosphere*, and thus the shielding of a portion of the sun's light, the frequency range of the light used by the solar cell is close to the red end of the visible spectrum (Fig. 2). Light of this frequency range penetrates the atmosphere with a minimum of energy loss.

Laboratory studies undertaken by the Physics Department of St. Mary's College of the effect of bombardment of solar cell by low energy sub-atomic particles indicated that this type of radiation had a negligible effect upon the electrical output of the solar cell. The solar cell, being about the size of two half-dollars held together, is quite transparent to high energy sub-atomic particles. High energy radiation does have a damaging effect upon the solar battery. Experimentation in this area has resulted in the following conclusions based upon our present knowledge of cosmic radiation densities above the

### SILICON SOLAR CELL PERFORMANCE
### VISIBILITY CURVES vs WAVELENGTH

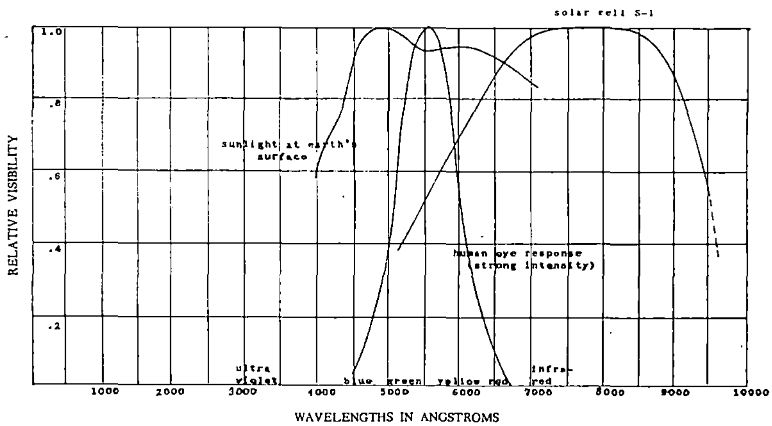


**Fig. 2.**

*At an altitude of 80,000 feet, approximately 90% of the atmosphere is below the balloon.

atmosphere. (Army Signal Corps.) Ultraviolet radiation should cause a 25 percent reduction of the solar battery's output in 85 years and xrays should cause the same output decrease in 6.7 years. Other subatomic particles have little effect on the cell. Therefore, no great damage to silicon solar cells operating above the earth's atmosphere appears probable for a number of years.

The effects of micrometeorite bombardment are not yet known. Data gathered in the past few months from the earth satellites should give an idea of the extent of the sandblasting effect of micrometeorite bombardment.

## APPLICATIONS

There are, at present, a number of applications of the silicon solar cell in high altitude research. Extended balloon flights can use the light-weight cells for electrical power sources. Special upper atmospheric studies, such as the solar telescope recently flown by the Balloon Activities Group at General Mills, require a portable power supply that is light-weight enough to avoid interfering with the smooth flight path of the balloon and thereby disturbing the scientific measuring instruments. By far the most spectacular application of the silicon solar battery in high altitude research to date is in the earth satellite. The first Vanguard Project satellite carried a radio transmitter powered by solar batteries. This radio is still transmitting, while the best battery-powered transmitters have already died. A recent news release estimated the lifetime of the Vanguard satellite to be over fifty years and all of the data at hand indicates that the solar cell power supply will outlive the earth satellite.

## LITERATURE CITED

D. TRIVICH, PAUL A. FLINN, H. J. BOWLDEN. 1955. Photovoltaic Cells in Solar Energy Conversion in *Solar Energy Research*. Madison, University of Wisconsin Press.

U. S. ARMY SIGNAL CORPS. Radiation Damage Study on Silicon Solar Energy Converters, (U. S. Army Signal Corps Contract with RCA Laboratories, Princeton, N. J., Contract No. Da-36-039-sc-64643).