

EFFICIENCY OF TANDEM SOLAR CELL SYSTEMS AS FUNCTION OF
TEMPERATURE AND SOLAR ENERGY CONCENTRATION RATIO

N. A. Gokcen
Bureau of Mines
U.S. Department of the Interior

and

J. J. Loferski
Division of Engineering
Brown University

ABSTRACT

This paper presents the results of a comprehensive theoretical analysis of tandem photovoltaic solar cells as a function of temperature and solar concentration ratio. The I-V characteristics of the solar cells were assumed to be governed by the relation

$$I = I_0 (e^{qV/AkT} - 1)$$

with $I_0 = Ke^{-E_G/BkT}$ and $A = B$. The overall efficiencies of tandem cell stacks consisting of as many as 24 cells having gaps in the 0.7- to 3.6-eV range were calculated for temperatures of 200, 300, 400, and 500 K and for illumination by an AM0 solar spectrum having concentration ratios C of 1, 100, 500, and 1000 suns. For ideal diodes ($A = B = 1$), the calculations show that the optimized overall efficiency has a limiting value η_{opt} of approximately 70 percent for $T = 200$ K and $C = 1000$. As shown in the accompanying figure, for $T = 300$ K and $C = 1000$, this limiting efficiency approaches 60 percent. The table shows the optimum combination of E_G values for various numbers of solar cells, $T = 300$ K, and various concentration ratios. Most of the gain in efficiency occurs with between 6 and 10 semiconductors in the tandem system (e. g., for $T = 300$ K and $C = 1000$ an optimized, six-cell system has a theoretical limit efficiency of about 53 percent). Calculations were also conducted for the $A = B = 2$ case (nonideal diode behavior); in this case the limiting value of η for a 24-cell system is about 65 percent at 200 K and 55 percent at 300 K.

Variation of optimum efficiency with number of cells

Bandgap Range: 0.7 to 3.0; A=B=1; 300K

100 Suns:

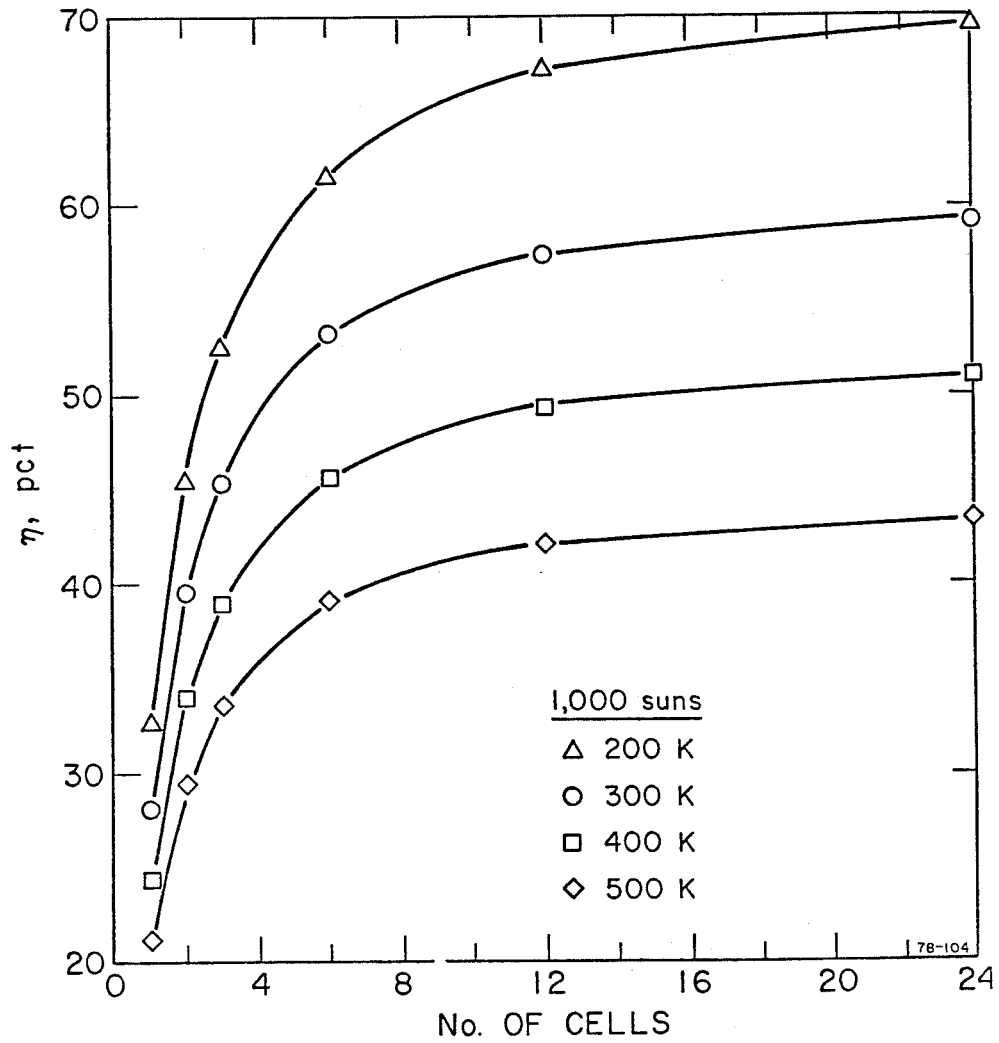
No. of Cells:	1	2	3	6	12	24
E_G values (eV):	1.4	1.8 & 1.0	2.3, 1.5 & 0.9	2.6, 2.1, 1.7 1.3, 1.0, 0.7	0.7 to 2.9 in intervals of 0.2	0.7 to 3.0 in intervals of 0.1
Efficiency:	26.43	37.05	42.52	40.13	54.10	55.96

500 Suns:

No. of Cells:	1	2	3	6	12	24
E_G values (eV):	1.3	1.8 & 1.0	2.2, 1.4 & 0.8	2.6, 2.2, 1.8 1.4, 1.0, 0.7	0.7 to 2.9 in in intervals of 0.2	0.7 to 3.0 in intervals of 0.2
Efficiency:	27.62	38.80	44.46	52.26	56.38	58.21

1000 Suns:

No. of Cells:	1	2	3	6	12	24
E_G values (eV):	1.3	1.8 & 1.0	2.2, 1.4 & 0.8	2.5, 2.1, 1.7 1.0 & 0.7	0.7 to 2.3 in intervals of 0.2	0.7 to 3.0 in intervals of 0.2
Efficiency:	28.18	39.56	45.37	53.21	57.37	59.22



Variation of efficiency with number of cells at various temperatures. C = 1000; AMO spectrum.