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THE STATUS OF Cu_2S-CdS SOLAR CELL DEVELOPMENT

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ABSTRACT

The goal of the effort on the Cu_2S-CdS thin film solar cell is the development of a low-cost alternate to the silicon solar cell for space applications. Pilot line production of cells has been underway for several years. The main problems now are reproducibility and degradation in a simulated space environment. The performance of current production cells and the results of various environmental tests are presented. Solutions to some past problems are discussed. A movie describes how the cell is made and tested.

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(NASA movie C-270, The Cadmium Sulfide Thin Film Solar Cell, provides the introduction and description of how the Cu_2S-CdS thin film solar cell is made.)

Up until March 31, 1971 the Gould Laboratories (earlier known as the Clevite Corporation) was operating the pilot line shown in the movie and supplied Cu_2S-CdS solar cells commercially. As of April 1, they have dropped all their development and production of these cells. At this time the only supplier of Cu_2S-CdS cells is SAT in France. Nearly all the NASA development work has been with the Gould cell. However, our limited knowledge of the SAT cell indicates it has similar properties. Therefore we would expect that the results I will present for the Gould cells should hold in general for SAT cells.

Slide 1 shows average values of cell efficiency under various conditions of illumination and temperature. The efficiency of silicon cells is shown for comparison. Under terrestrial conditions, air mass one (AM1), 25°C, and with a clear cover (Mylar) the efficiency is about 5%. The transmittance of Mylar degrades markedly under the ultraviolet of space, so Kapton is used as the cover, although its transmission is initially lower. The Kapton results in a reduction of the efficiency to 4% at AM1, 25°C. Irradiated with the solar spectrum in space (AMO), the efficiency drops further to 3.5% at 25°C and to 3% at 60°C, the approximate cell temperature in space. For all these conditions the efficiency of the Cu_2S-CdS cell is about 1/3 that of the silicon cell. The highest efficiency we have seen for the Gould Kapton-covered cells, at AMO, 60°C is 3.6%, which is equivalent to about 6% for Mylar covered cells at AM1, 25°C. These were made in the same way as the run-of-the-mill cells; why they were so much better is not understood. Throughout the development of this cell, reproducibility has been a problem.

Another problem has been that the cells degrade under simulated space conditions. Our evaluation tests have generally been conducted in space simulation facilities like those shown in the movie. Slide 2 shows the results of an early test where four cells made in October 1967 were exposed to 300 cycles, where each cycle consisted of 1 hour of light and 1/2 hour of dark. One cell had lost more than half its power during the test while the most stable had lost only 10%. During an interruption in the test they had recovered somewhat and redegraded when the test was resumed. Not only was the rapid degradation disturbing, but also the great differences between cells. Soon after, we found that when the cells were operated above a certain threshold voltage, they degraded rapidly. The copper sulfide decomposed and metallic copper formed short-circuits in the cell. Slide 3 shows the results of a test where the cells were deliberately loaded at different voltages and tested for 1429 cycles. The cells loaded at 0.4 volts or more degraded considerably more than those at lower voltages. Luckily the voltage for maximum power lies below the 0.4 volt threshold. In the earlier tests little attention was given to cell loading, and presumably the cells that degraded severely were operating above the threshold voltage.

In subsequent tests the cells were carefully loaded at the maximum power point. The results of the longest duration test are shown in slide 4. In this test 4 cells made in November 1968 were exposed to 10,000 cycles (15,000 hours) in a vacuum solar simulator at The Boeing Company. At the end of the test the degradation ranged from 9% to 24%, with the average for the four cells at 18%. The results of the earlier test are shown in the figure also and clearly show how much less degradation is seen now. However, we do not know the cause of the residual degradation, nor why there is a difference among the cells.

The cells also degrade under terrestrial conditions. Slide 5 shows a qualitative comparison of the stability of cells with different plastic covers and adhesives under dry and humid shelf storage and exposure to the elements on the roof. In all cases the cover was 1-mil thick and the edges of the cell were unprotected. All the combinations were very good on dry shelf storage. They degraded less than 10% per year. At one time Nylon was used as the adhesive to hold down the Kapton and Mylar covers. It was discontinued because the cells were so sensitive to humidity. Kapton with Astroepoxy adhesive was later adopted as the standard design because of its tolerance to ultraviolet, electron and proton radiation. This combination also showed improved stability under humidity. Recently some cells were made with FEP, a clear, ultraviolet-resistant plastic, that was bonded to the cell without an adhesive. These cells also were very sensitive to humidity. Surprisingly, they degraded rapidly under ultraviolet light despite the fact that the FEP cover did not discolor. None of the combinations fared well in the roof-top tests, although Kapton with Astroepoxy was the best. The obvious conclusion from these results is that cells with these covers will not do well when exposed to the elements in a terrestrial application. However, notice that there was a difference in stability among the cover-adhesive combinations. Also keep in mind that the candidates for the space cell were greatly restricted by the requirements for low weight and tolerance to electron, proton, and space ultraviolet radiation. Also, the samples tested had unprotected edges. There remains the possibility that with the proper encapsulation the degradation in a terrestrial environment can be reduced or eliminated.

There is some evidence to support this hope. Heavily encapsulated thin film Cu_2S-CdS cells have been used as calibration standards for performance measurements. Slide 6 shows a cross section of an encapsulated standard cell. The Kapton covered 1 x 2 cm thin film cell was mounted between a brass block and a glass microscope slide with epoxy and the assembly was encased with the same clear, castable epoxy. About forty of these were made, calibrated and recalibrated in an airplane, and periodically checked against each other. When not in use they are stored in dark, unsealed boxes, exposed to laboratory humidity. They are from two to five years old and none have shown any degradation.

Another example is that thin film cells have been used successfully on long-life weather balloons. These cells were doubly encapsulated in Mylar with Astroepoxy adhesive and the edges were completely sealed. At least 30 balloons have been launched and no failures were attributed to the solar cells. The longest flight was over a year and the solar cells functioned adequately throughout the flight.

SUMMARY

The efficiency of the Cu_2S-CdS, thin film cell is about 1/3 that of the silicon cell. The cause of severe degradation that was seen in the past can be avoided by operating the cell at its maximum power conditions. However, even then some degradation takes place in space simulation tests. No space-type cells have done well in roof-top tests. However, there is hope that encapsulation techniques, selected for the terrestrial environment, may make the cells more durable.

SOLAR CELL EFFICIENCIES

TEST CONDITIONS	CdS		Si	
	EFFICIENCY, %	COVER	EFFICIENCY, %	COVER
AM1, 25^0 C	5.0	MYLAR	13.0	NONE
AM1, 25^0 C	4.0	KAPTON	12.3	GLASS
AM0, 25^0 C	3.5	KAPTON	10.2	GLASS
AM0, 60^0 C	3.0	KAPTON	8.7	GLASS

Slide 1

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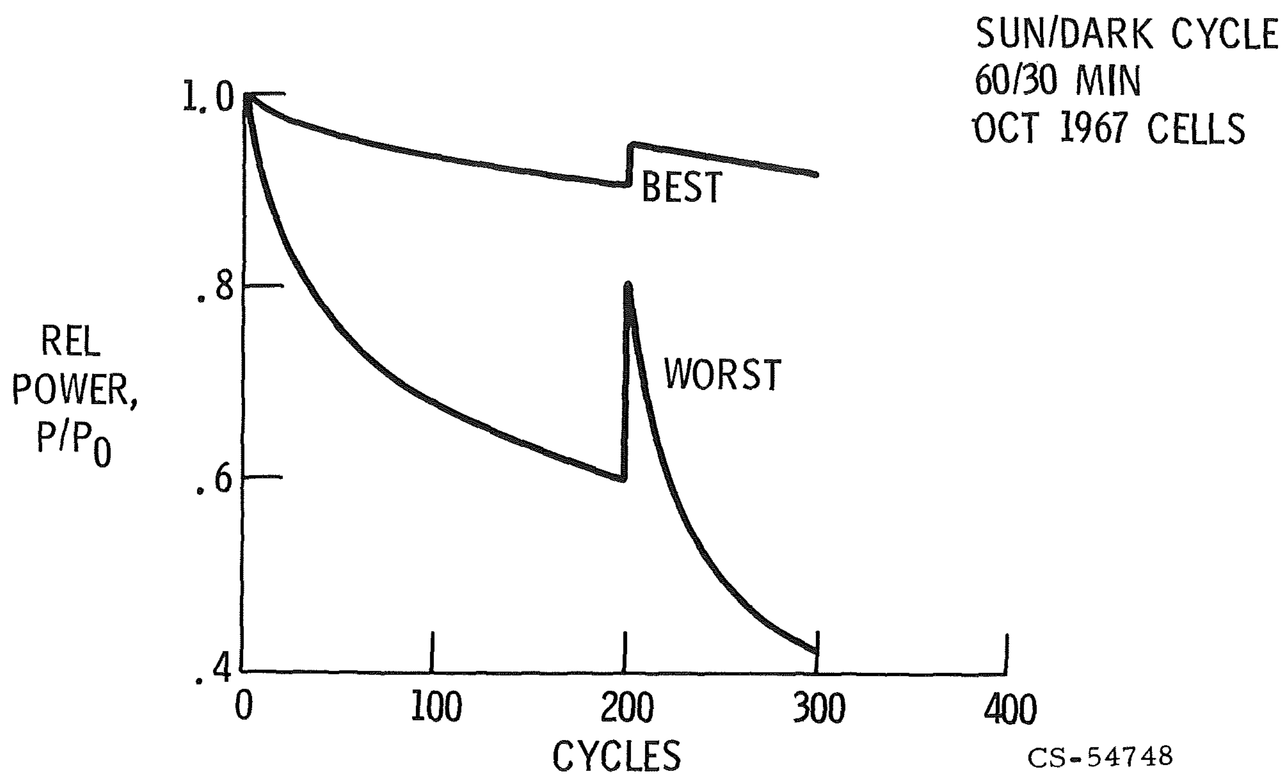
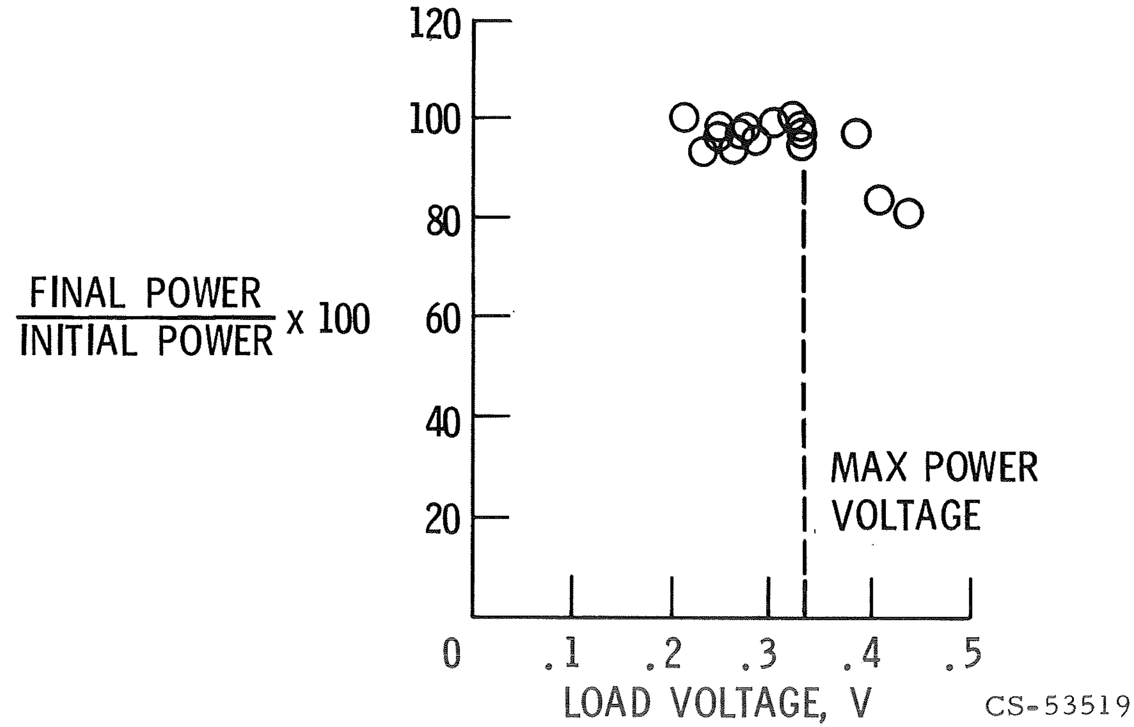
CYCLING OF CdS SOLAR CELLS
IN VACUUM–SOLAR SIMULATOR



Slide 2

LOAD VOLTAGE EFFECT ON THIN-FILM CdS SOLAR CELLS

CONSTANT LOAD RESISTOR; 1429 CYCLES, SUN 60 MIN, DARK 30 MIN



Slide 3

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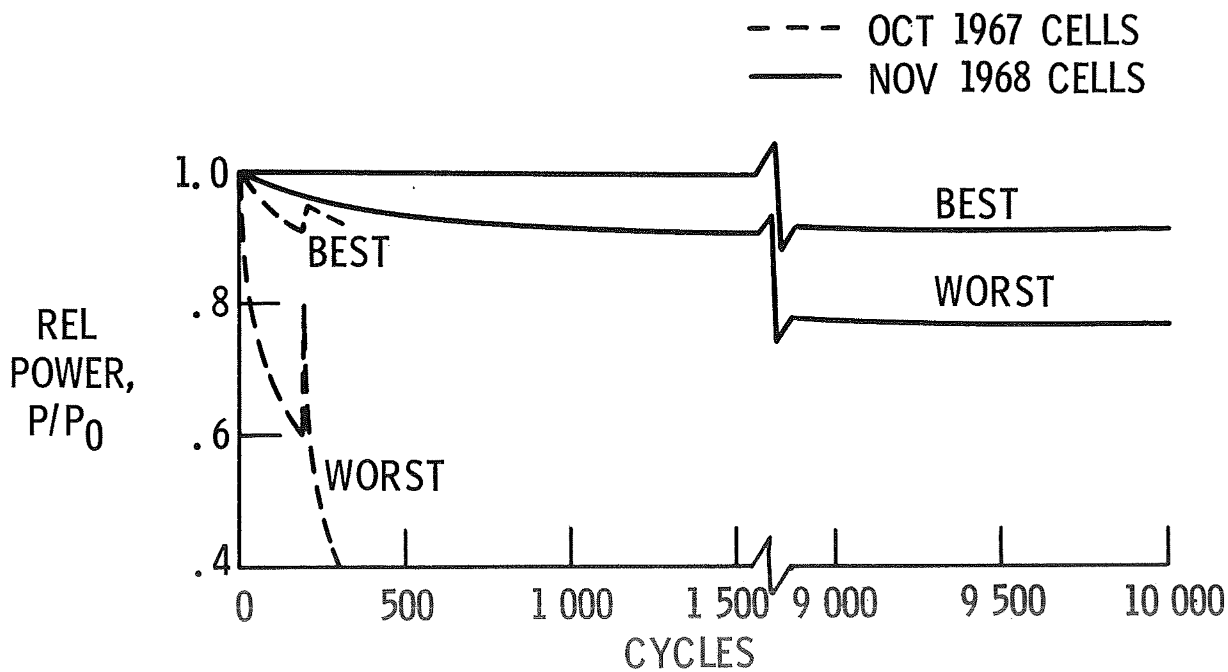
CYCLING OF CdS SOLAR CELLS IN VACUUM–SOLAR SIMULATOR

SUN/DARK CYCLE, 60/30 MIN



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Slide 4

STABILITY OF PLASTIC–COVERED Cu_2S–CdS SOLAR CELLS

COVER THICKNESS, 1 MIL

COVER	DRY SHELF (ROOM TEMP)	WET SHELF (ROOM TEMP 85% R. H.)	ROOF TOP
KAPTON OR MYLAR WITH NYLON ADHESIVE	VERY GOOD	BAD	NOT TESTED
MYLAR WITH ASTRO EPOXY	VERY GOOD	POOR	POOR
KAPTON WITH ASTRO EPOXY	VERY GOOD	GOOD TO POOR	FAIR
FEP SELF BONDED	VERY GOOD	BAD	BAD

Slide 5

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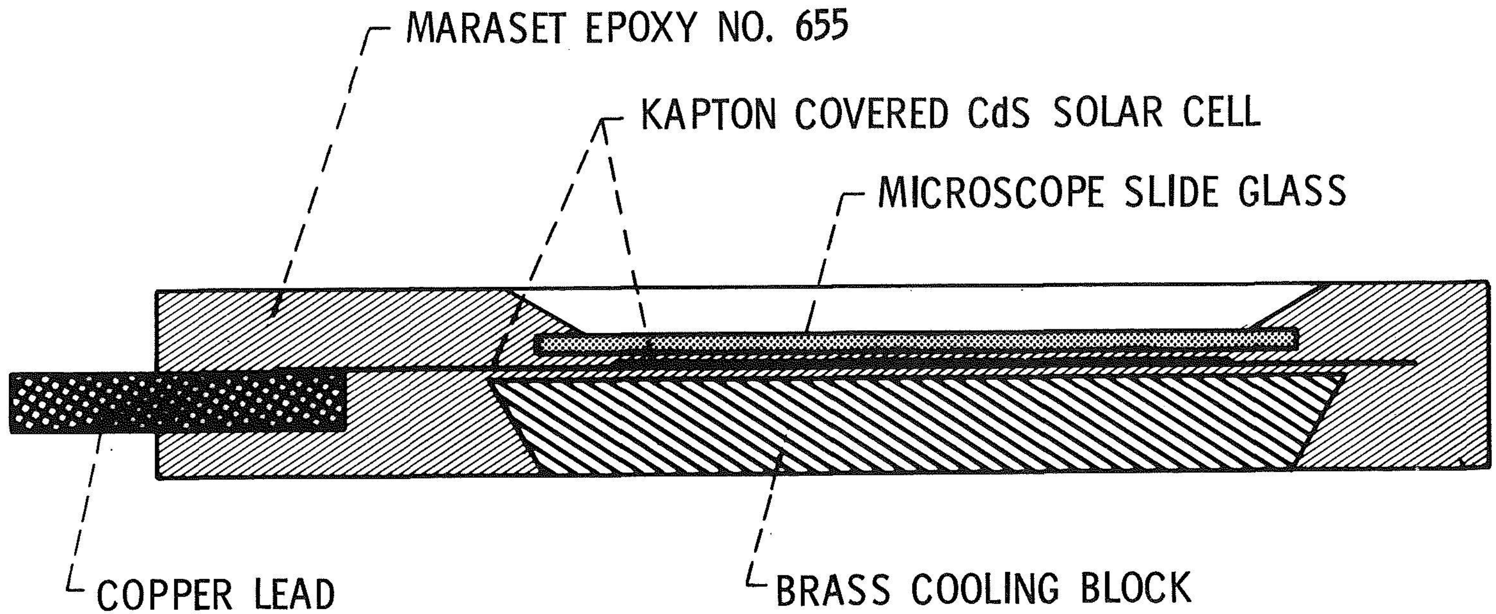
ENCAPSULATION OF CdS STANDARD CELL



Slide 6

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