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VERY LOW COST THIN FILM $CdS-Cu_2S$ SOLAR CELL DEVELOPMENT USING CHEMICAL SPRAYING

D. H. Baldwin Company, El Paso, Texas

and

Sandia Laboratories, Albuquerque, New Mexico

Grant Number: (Not Finalized)

Grant Period: ? (6 Months)

Grant Amount: Baldwin $110,000
Sandia 30,000

by

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Principal Investigators: J. F. Jordan - Baldwin
G. A. Samara - Sandia

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ABSTRACT

Over the past four years the D. H. Baldwin Company has developed a chemical spray process for the production of thin film CdS-Cu_2S solar cells projected to cost less than $60/kW in very large scale production. The average efficiency of these cells has been improved from < 0.3% in 1971 to about 4.5% at present.

The overall objectives of this program are to further develop the process, to raise the efficiency, and to attain long life stability. In the joint program Sandia Laboratories is to provide the technical support necessary to help achieve these objectives.

The cell consists of a glass substrate onto which is sprayed a thin tin oxide transparent electrode followed by a sprayed film (2-3 μm) of CdS. A very thin film of Cu_xS is then formed by either spraying, dipping, or electrolytic ion exchange. Finally a copper/lead electrode is evaporated on top the Cu_xS layer.

Discussion between Baldwin and Sandia defined several areas for initial investigation by Sandia. These are:

1 - Chemical analysis of the starting chemicals and resulting thin films with emphasis on impurities likely to be electrically active and their effects on cell properties.

2 - Determination of the morphology and crystallography of the various layers.

3 - Determination of the location, depth profile and form of dopants and contaminants known to be in the device and their effects on the morphology and crystallography.

4 - Studies of the electrical and optical properties of the various films and the device.

The results of this work should form the basis for process modification and control and for improving device characteristics and conversion efficiency.

The Sandia effort was recently initiated and the work thus far, on the limited number of available samples, has consisted of a general survey of the potential usefulness of a wide variety of analytical techniques to the understanding of the structure, composition and properties of the films and devices. It is often observed that corroborative results from a combination of techniques are necessary to be able to draw definitive conclusions. Our preliminary findings are summarized in one of the accompanying tables.

It is expected that a more detailed and broader range of studies along with more definitive conclusions will be accomplished by the next Review Meeting.

OVERALL OBJECTIVES

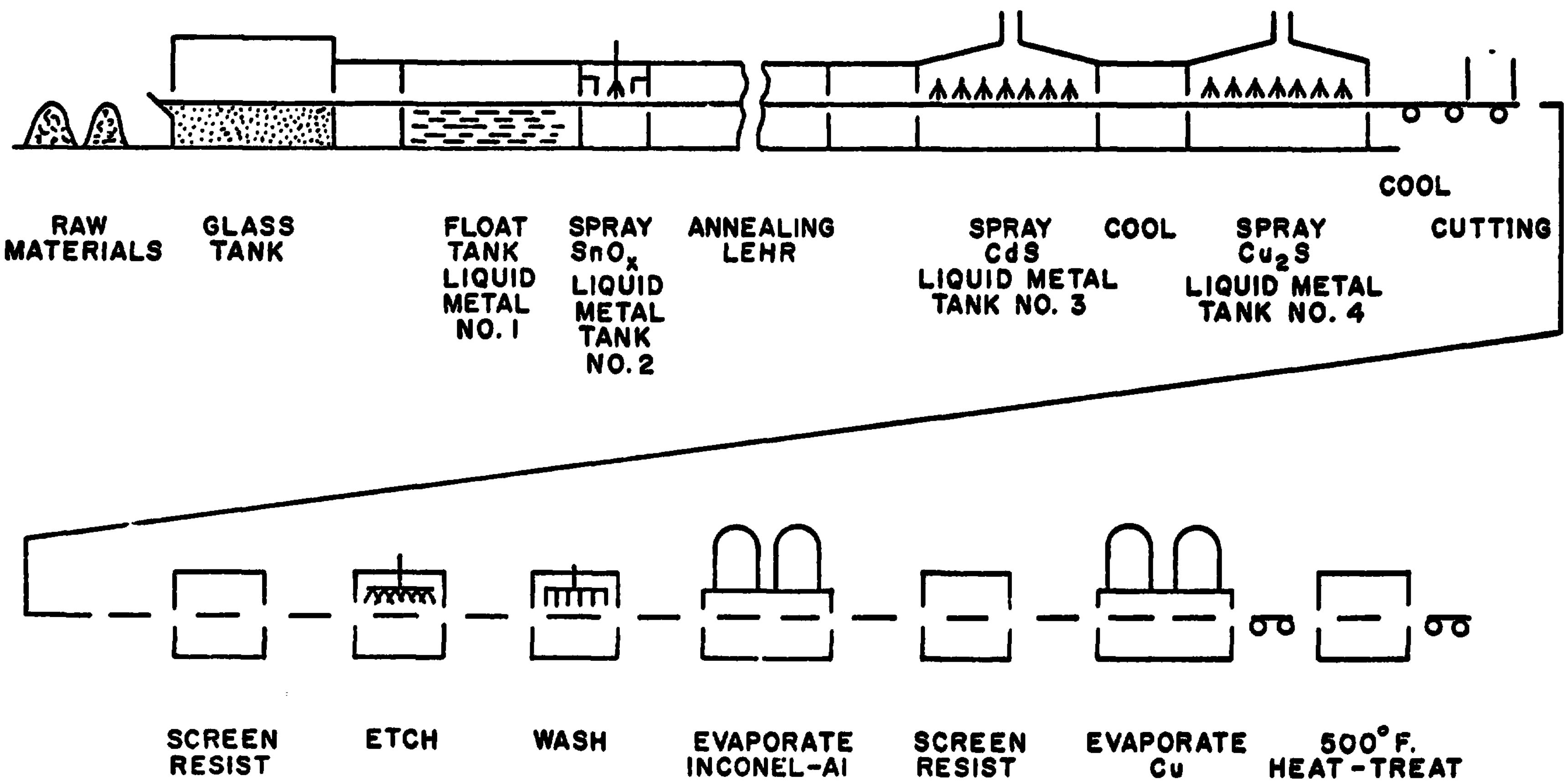
To Further Develop a Process for the Manufacture, on a Large Scale, of Solar Cells Costing Less than 6 Cents per Watt ($60/KW). This Envisages Adapting Chem'cal Spraying Processes to a Float Glass Plant.

Goal 1. Increase Present Efficiency (4.3-4.72%) to 5% Average.

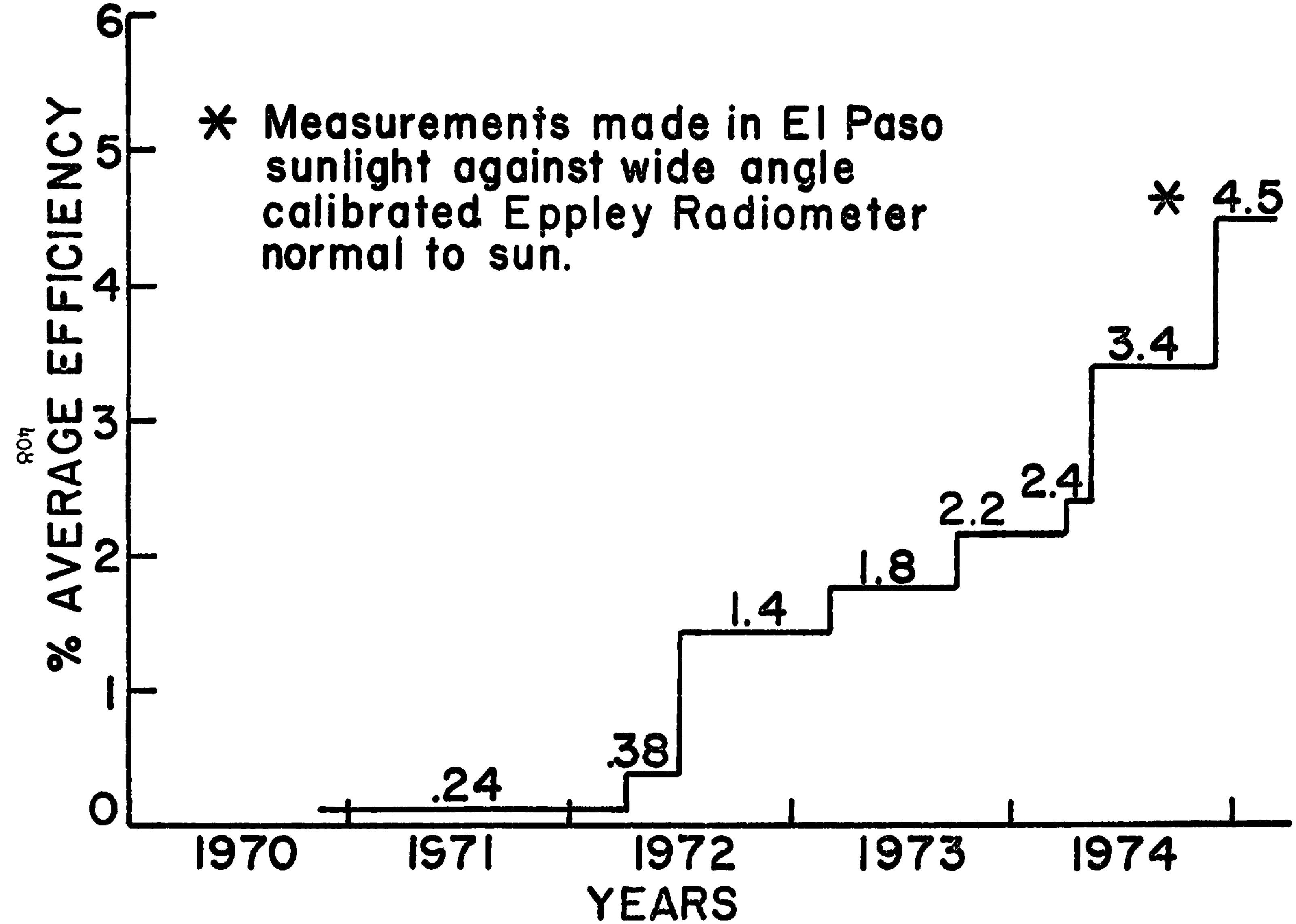
Goal 2. Attain Stability, .. rove by Life Test, Cells of 5% Effic

Goal 3. Obtain Efficiencies Substantially Higher than 5%.

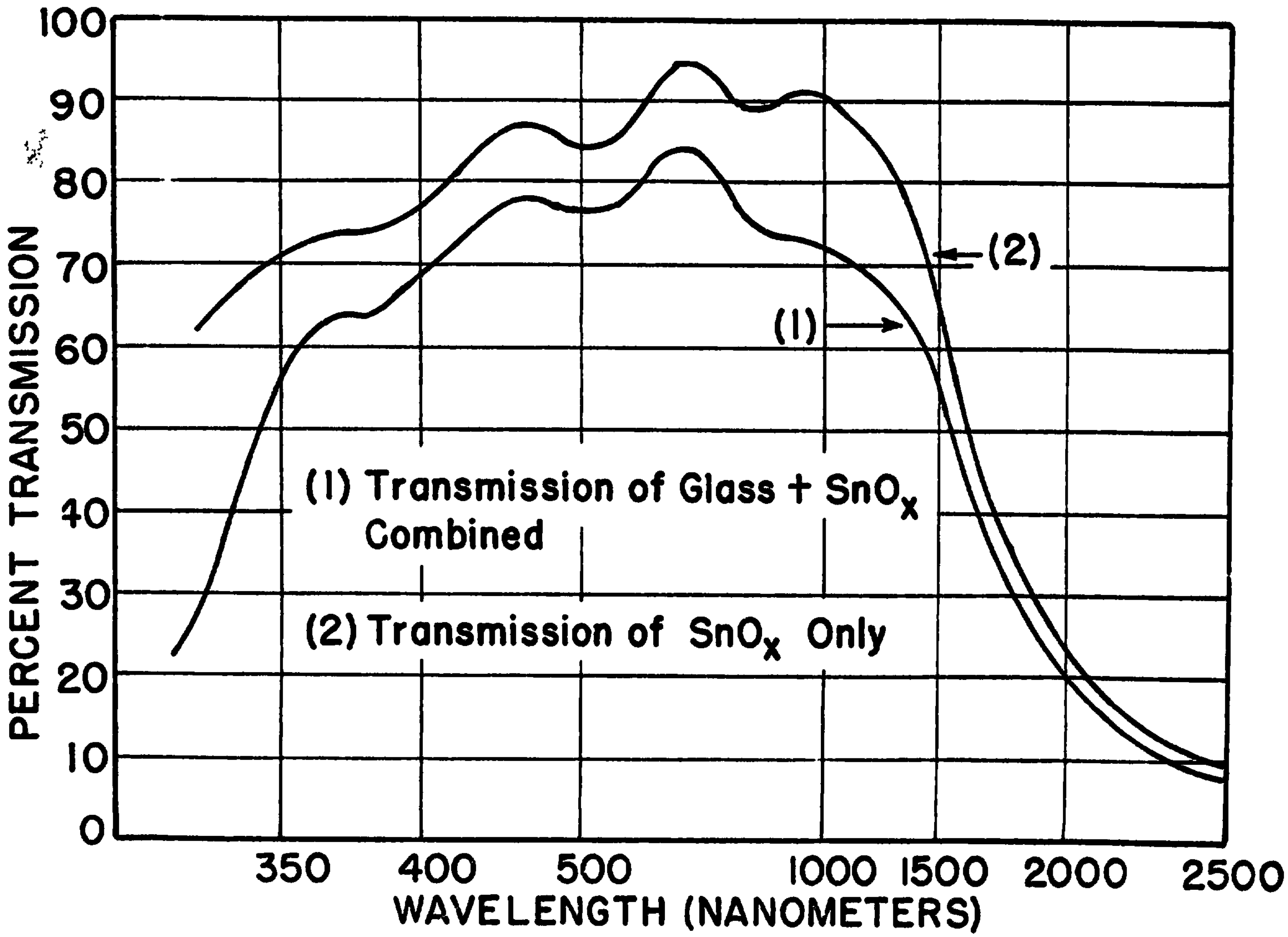
Goal 4. Life Test such Higher Efficiency Cells for Stability.

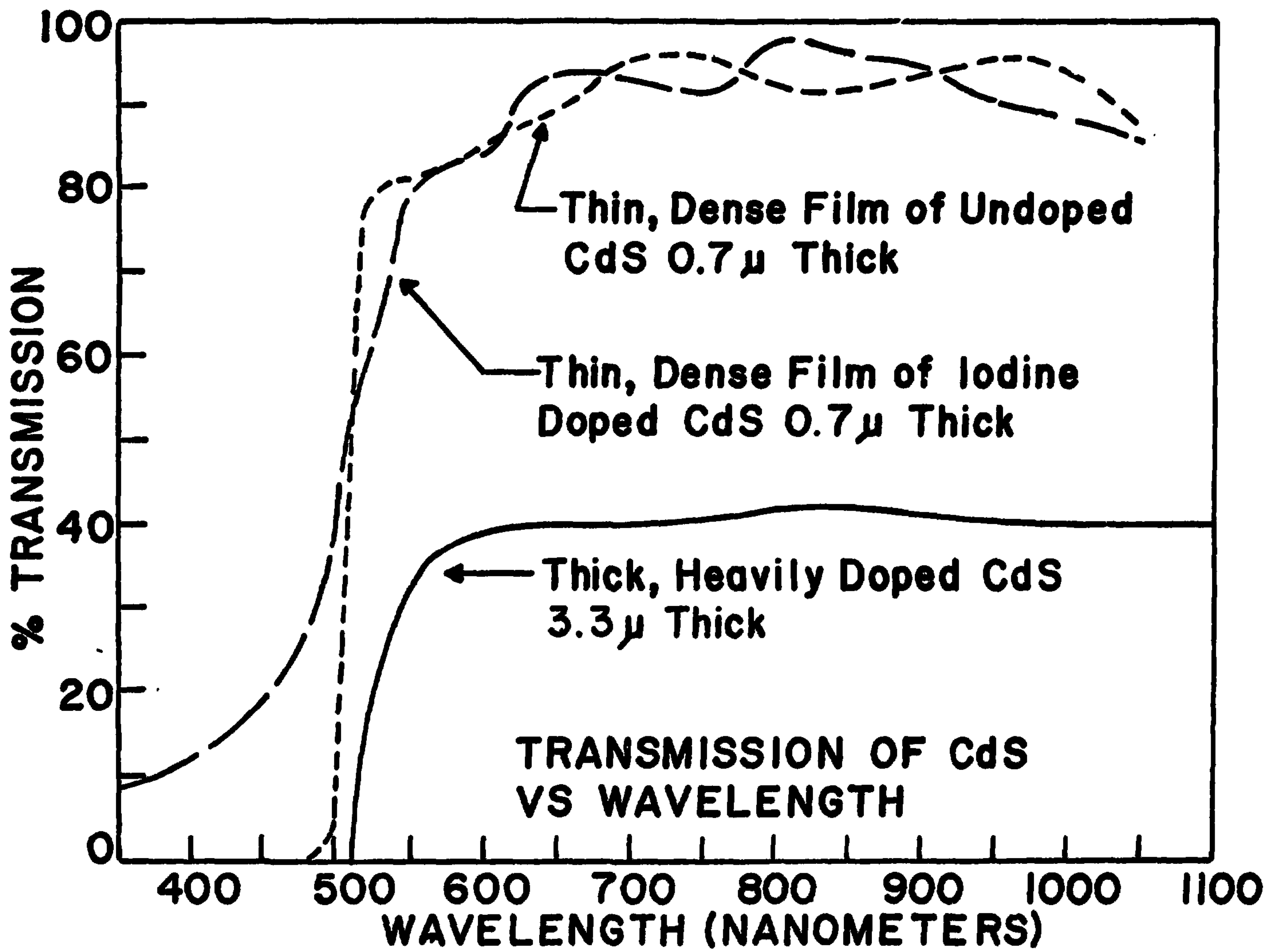


-SCHEMATIC OF A FLOAT-GLASS SOLAR-CELL PLANT

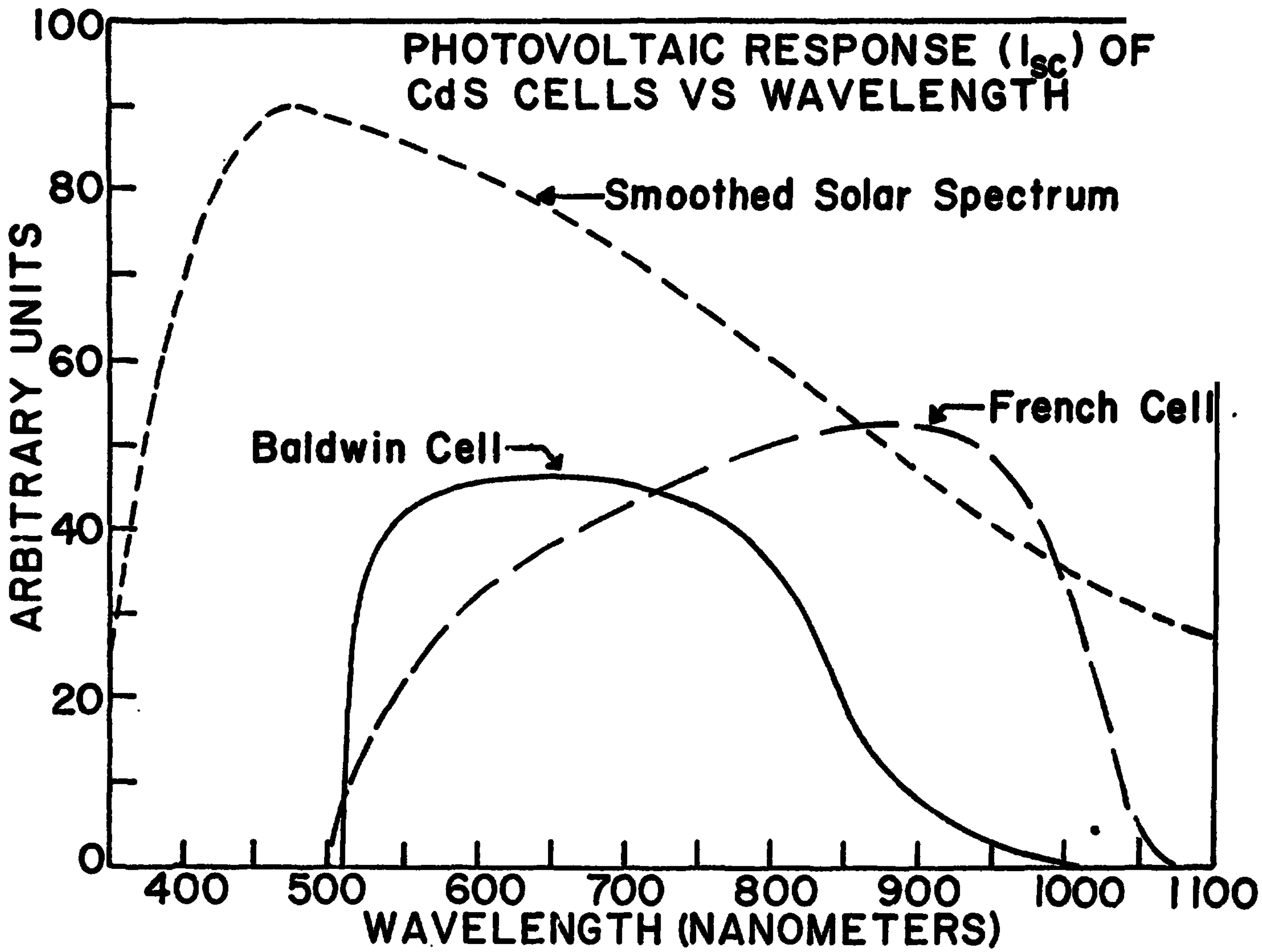


PROGRESS IN IMPROVEMENT OF EFFICIENCY FOR CHEMICAL SPRAY PROCESS (CELLS)


PERCENT TRANSMISSION
100
90
80
70
60
50
40
30
20
10
0
350
400
500
1000
1500
2000
2500
WAVELENGTH (NANOMETERS)
(1)
(2)
(1) Transmission of Glass + SnOx Combined
(2) Transmission of SnOx Only



100
80
60
40
20
0
% TRANSMISSION
Thin, Dense Film of Undoped CdS 0.7μ Thick
Thin, Dense Film of Iodine Doped CdS 0.7μ Thick
Thick, Heavily Doped CdS 3.3μ Thick
TRANSMISSION OF CdS VS WAVELENGTH
400
500
600
700
800
900
1000
1100
WAVELENGTH (NANOMETERS)


PHOTOVOLTAIC RESPONSE (I_{sc}) OF
CdS CELLS VS WAVELENGTH
Smoothed Solar Spectrum
French Cell
Baldwin Cell
ARBITRARY UNITS
0
20
40
60
80
100
400
500
600
700
800
900
1000
1100
WAVELENGTH (NANOMETERS)

COST SUMMARY: (EXCLUSIVE OF INSTALLATION, SITE PREPARATION, AND POWER HANDLING EQUIPMENT, I.E., CELLS ONLY.)

COSTS AS OF SEPTEMBER 1973.

MATERIALS	DOLLARS PER SQUARE FOOT
GLASS	.1400
OTHER MATERIALS (CHEMICALS AND METALS)	.0509
TOTAL MATERIALS	.1909
ADDITIONAL LABOR COSTS INCIDENT TO CELL MANUFACTURE	.0019
CAPITAL COST-DEPRECIATION AND INTEREST	.0260
PLANT MAINTENANCE COST	.0102
POWER COSTS	.0253
ADDITIONAL G & A (ABOVE THAT INCLUDED IN GLASS COST)	.0068
TOTAL COST	.2611

AT 5% EFFICIENCY, ONE (1) SQUARE FOOT OF GLASS WILL PRODUCE A PEAK POWER OF 4.645 WATTS.

COST PER PEAK WATT	.0562
COST PER PEAK KILOWATT	56.20

JOINT BALDWIN/SANDIA PROGRAM

Sandia Responsibilities:

1. Studies of the Structure and Morphology of Thin Films of CdS, Cu_xS, and SnO_2 Prepared by Baldwin.
2. Chemical Analysis and Dopant Profiles of Above Films
3. Electrical Transport and Optical Properties of Above Films and Cells.
4. Recommendations for Process Modification and Control.

CHARACTERIZATION TECHNIQUES

Technique	Investigator
Electron Diffraction and Reflection	F. Gruelich
Electron Diffraction	R. Berg
Auge Electron Spectroscopy	P. Holloway
Secondary Ion Mass Spectrometry and Ion Scattering Spectroscopy	G. Nelson
Scanning Electron Microscopy	R. Berg
Rutherford Backscattering	J. Borders
Optical Spectroscopy	H. Stein R. Berg
Atomic Absorption Spectroscopy	S. Fuller
Emission Spectroscopy	J. Walcott J. Woodworth
Electrical Properties	R. Nasby
High Speed Photography	————

PRELIMINARY FINDINGS

1. Impurity Analysis of the Starting Chemicals for the Doped CdS Indicate the Presence of Some Impurities at Levels Potentially Harmful to the Device.

2. After Heating to SnO_x Deposition Temperature the Surface of the Glass (Soda Lime) Becomes Saturated with Na.

3. The Na Causes Fogging of the SnO_x Film and Effectively Limits the Thickness of this Film.

4. The SnO_x Contains Large Amounts of Na. There is Concern that the Na Might Migrate into the CdS Layer.

5. Al is Dispersed in the CdS Layer and Appears to be in the Form of an Oxide Rather than a Sulfide.

6. Morphological Features ("Balls" or Nodules") are Prominant in the CdS Layer, but these Involve no Chemical Inhomogeneities. This Suggests the Great Dominance of the Spray Process Itself in Determining the Film Morphology.

7. The Cu_xS is $\sim$ 400 Å Thick (Average). Surface Coverage of the CdS Layer Appears Incomplete.

8. Both Chalcocite and Djurleite Forms of Cu_xS were Detected. In "One of Better" Cells the Cu_xS Layer was Identified as Chalcocite.