ANNUAL PROGRESS REPORT

CONTRACT Nonr-808(00)

ANOXIA WARNING SYSTEM

REPORT NO. 5209-4

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ANNUAL PROGRESS REPORT

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For the Development of

an Anoxia Warning System

Contents

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SUMMARY

The development of an Anoxia Warning System, based on photometric information obtained by transilluminating, or reflecting light from, the subject and using this information electronically has been undertaken.

An Engineering Model of the electronic system has been completed.

Efforts up to June 30, 1953 to develop a pickup system suited to service conditions failed because of the inadequacy of available photo-cells. More recent efforts have been concentrated on the study of Cadmium Sulfide cells to produce a satisfactory pickup. Based on the results using these cells, the decision was made not to undertake a hard tube development program as originally proposed, and to continue work with these cells.

1. Introduction

1.1 The objective of this contract is to develop an anoxia warning system, based on photometric examination of the blood of the user. This warning system is to be suitable for use in aircraft by flying personnel with a minimum of attention and a maximum of reliability, giving a maximum of time between detectable onset of anoxia and loss of consciousness.

1.2 The problems presented by the above contract objectives are:

1.2.1 To determine the best system for field use utilizing reliable principles which will form the basis for the construction of such a device.

1.2.2 To develop, first using normal components, electronic circuits to instrument the system chosen. Having demonstrated the practicality of the system, to develop a sub-miniature system suitable for airborne use, using as far as practicable techniques and components suitable for manufacture of the device in large quantities.

1.2.3 To investigate the pick-up system and components for use in this part of the device and to develop a pick-up head to be used with the above system.

2. System Progress

2.1 A detailed explanation of the system under development, with an analysis of the principles involved, was presented in the June 1952 Semiannual Report on this contract. (reference 5.1) A review of various possible systems together with notes on their complexity and suitability to service conditions is given in the June 1953 Semiannual Report. (reference 5.3)

2.2 Development effort was divided between the two major problems outlined in 1.2.2 and 1.2.3, with the successful conclusion of the electronic circuitry being achieved prior to the Semiannual Report of 5 January, 1953 (reference 5.2). A full description of the Electronic Unit is to be found in that report.

After January 1953 some improved components became available, allowing for some improvements in circuitry for this unit, which are described in detail in section 3 of reference 5.3.

2.3 Development of a pick-up device has progressed through various stages. Reference 5.3 shows a reflection unit, gives results using Selenium cells, discusses a method for drift compensation, and presents data on the use of vacuum photo-cells in the pickup. Reference 5.3 concludes with a recommendation that efforts be directed towards the development of a subminiature vacuum photo-electric cell.

2.4 Just before embarking on the vacuum photo-electric cell, Cadmium Sulfide cells became available for test. These cells showed so much promise that the hard tube development was not undertaken and further work has been concentrated on the Cadmium Sulfide Cells. Section 3 below gives data on the Cadmium Sulfide cells, including the reasons for the decision to work with these cells.

3. Cadmium Sulfide Cells

3.1 Reasons for decision to work with CdS cells

After receipt of extension of this contract in October 1953 the first part of the work (reference 5.3) consisted of obtaining CdS cells from the David Sarnoff Research Laboratories of RCA and investigating as carefully and as quickly as pos-

sible the characteristics of these cells for oximetry use. The first schedule included the following:

(1) A time limit was set for deciding whether or not these CdS cells are suitable.

(2) If they showed definite promise of being satisfactory, the hard tube development would not be undertaken.

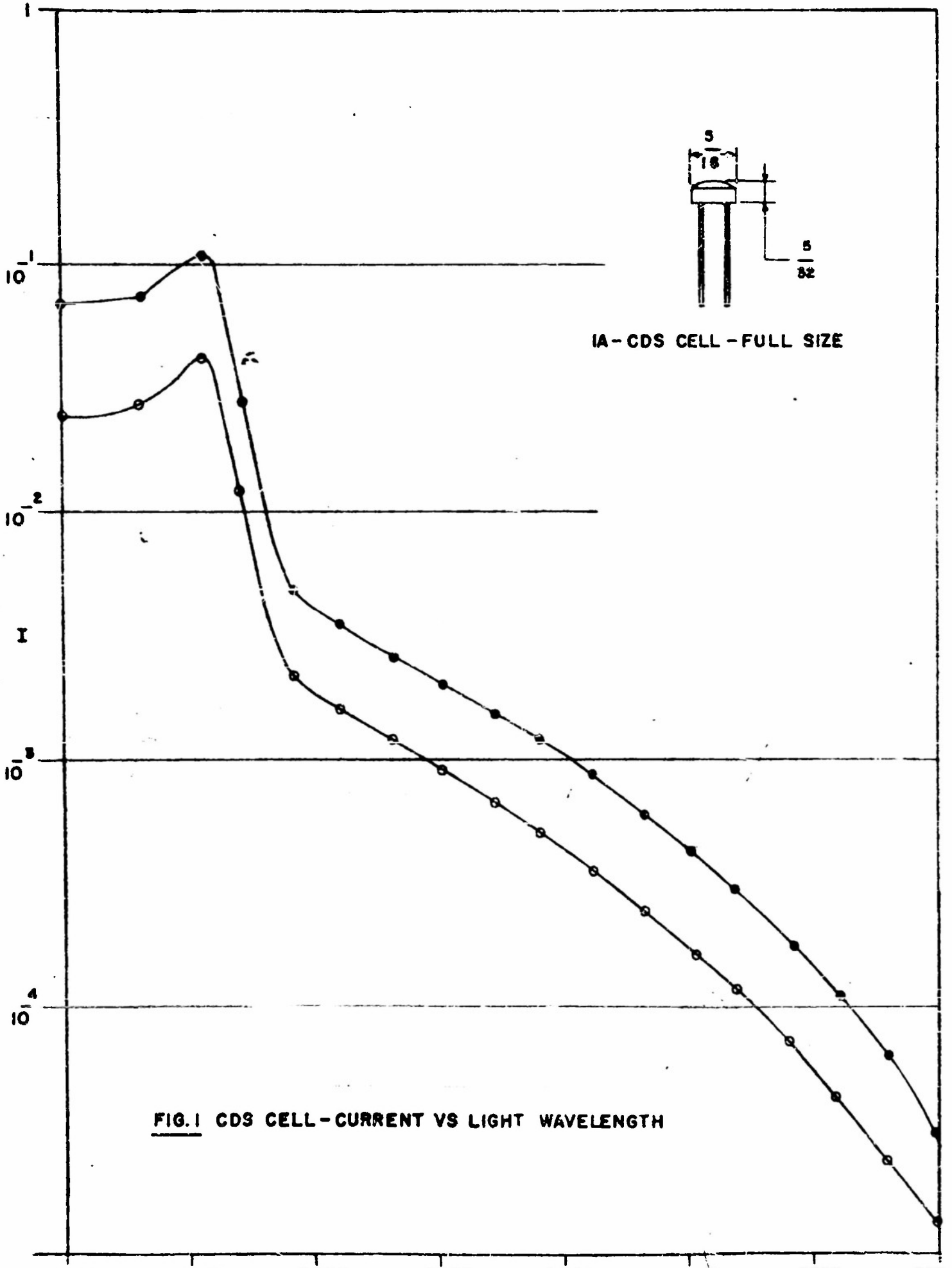
(3) If they were unsatisfactory, the hard tube development program would be undertaken.

Tests made up to December 15, 1953 showed that the CdS cells showed definite promise of proving successful in the oximeter application; this promise of success, coupled with the facts that the hard tube development would not produce any usable models for at least three months and would not produce a device as convenient in size as the CdS cells, led to the decision to work with CdS cells.

The decision to use the CdS cells was based on the following characteristics of the cells:

1. The size factor is excellent; the pre-production cell used consists of a small crystal mounted on a glass base and covered with a protective plastic. The crystal is connected electrically to leads through the base. See Figure 1-A

2. Temperature effects are much less than those of selenium cells. For selenium, temperature effects are greater than a 20% anoxia signal; for CdS, temperature effects are less than a 5% anoxia signal.



1A - CDS CELL - FULL SIZE

FIG. 1 CDS CELL - CURRENT VS LIGHT WAVELENGTH

3. Sensitivity of the cells to anoxia is greater than that of selenium cells. Selenium cells change by 2% while CdS cells change by 8% for 10% anoxia.

4. The cells seem to be true photoconductive resistors with little or no barrier at the contacts. Their resistance varied at most by 10% from the correct value for voltages of +20, +2.0, +0.2, -0.2, -2.0, -20 volts.

3.2 CdS Cell Sensitivity

Once the decision was made to use CdS cells, the next part of the work was concentrated on obtaining more cells from RCA and making tests to determine more completely their characteristics in order to be able to attack the problems of their application better. Spectral tests were made on the cells to permit selection of cells with higher sensitivity in the higher spectral regions of interest. Figure 1 shows an absolute sensitivity curve. It should be noted that the important characteristic of a cell is not its absolute sensitivity to light but it relative sensitivity to light. One cell can be lower in resistance than another cell (higher absolute sensitivity), but have a smaller percentage change of resistance with a change in light intensity (lower relative sensitivity); for this application, large relative sensitivity is desired. From Figure 1 it can be seen that the absolute sensitivity is down rather low in the upper end of the region used (850-900 mμ); the interesting point is that the relative sensitivity is still large enough to give usable sensitivity to anoxia and blood volume effects.

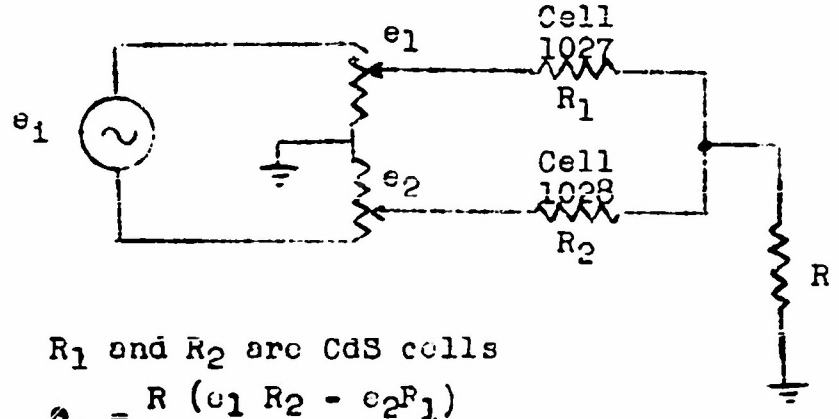
Figure 2 gives data on relative sensitivity.

Tests of the cells showed wide variation of resistance and spectral sensitivity. The cells having very high resistance or very low sensitivity in the 600-850 mμ region were not satisfactory for the oximeter application. (Six out of 13 cells were suitable)

3.3 Present status of oximeter

Figures on an oximeter using two of the selected cells are useful in discussing the present status of the oximeter and the work remaining to be done.

The experimental circuit is given below with cell 1027 covered by a single layer of Wratten 29F (red) and cell 1028 covered by a single layer of Wratten 88A (infrared)



R_1 and R_2 are CdS cells

$$e_o = \frac{R\,(e_1 R_2 - e_2 R_1)}{R\,(R_1 + R_2) + R_1 R_2}$$

If e_o is fed directly into the grid of a tube, R is large compared to R_1 and R_2 and

$$e_o \simeq \frac{e_1 R_2 - e_2 R_1}{R_1 + R_2}$$

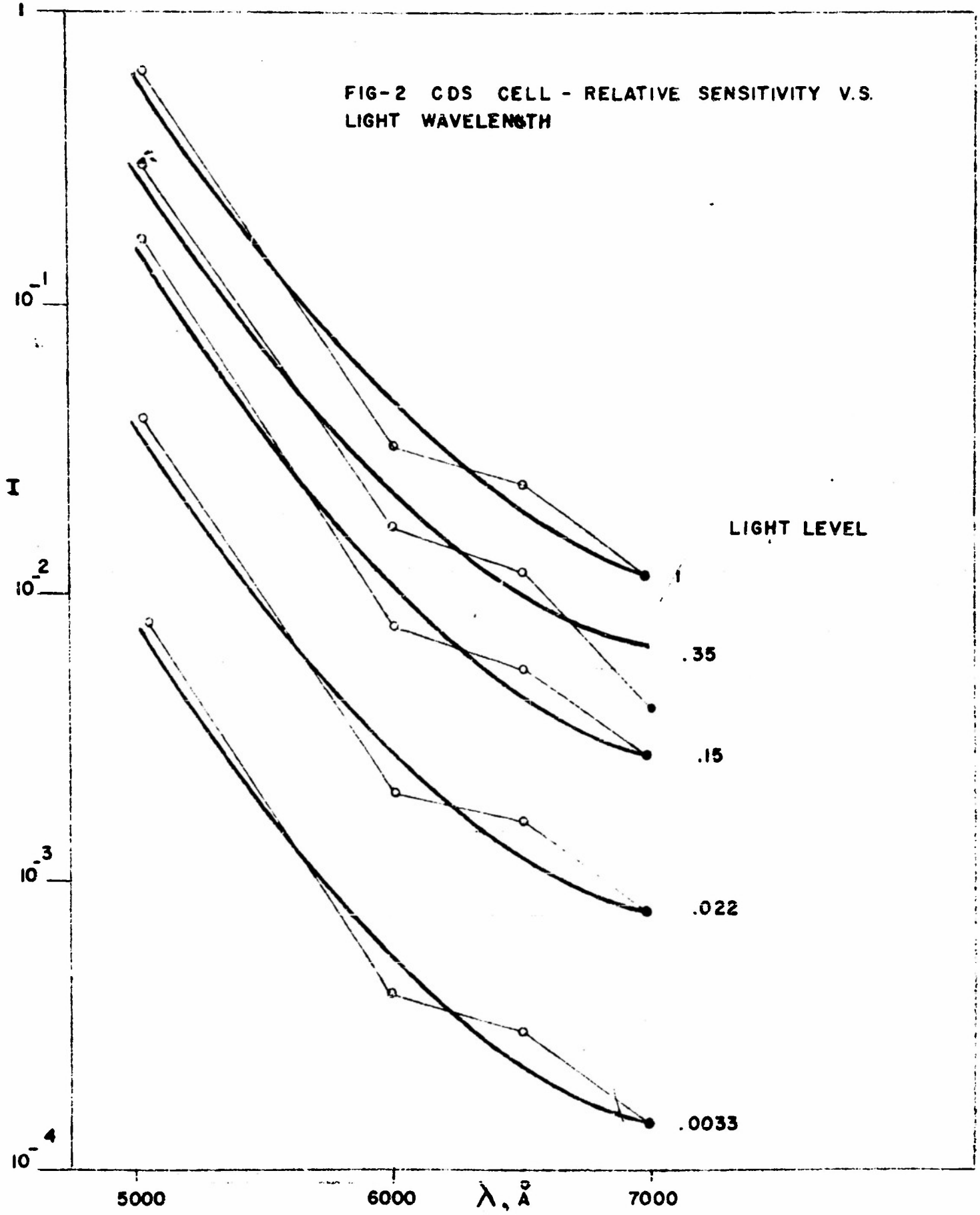


FIG-2 CDS CELL - RELATIVE SENSITIVITY V.S. LIGHT WAVELENGTH
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
I
LIGHT LEVEL
1
.35
.15
.022
.0033
5000
6000
7000
λ, Å

With e_i = 8 volts rms, the following e_o's are obtained (peak to peak values)

null.....	.015 volts
Blood volume + temperature changes...	.300 volts
10% anoxia.....	.600 volts

	% Change of Resistance		
Cell 1027-Red	Cell 1028-Infrared	Effect	Signal
3.3	4.6	Temperature + Blood volume	1.3
8.5	3.0	10% Anoxia	5.5

The white light resistance of cell 1027 was approximately twice that of cell 1028; behind the ear and with their respective filters (1027 red and 1028 infrared), the resistance of cell 1028 was approximately twice that of cell 1027 (2 megohms for 1027 red and 4 megohms for 1028 infrared). A Mazda 47 lamp was used for illumination.

The deflection for these cells caused by changes in blood volume was not in the same direction as the anoxia deflection. In anoxia, the red cell resistance increases more than the infrared cell resistance; temperature and increased blood volume cause the infrared cell resistance to increase more than the red cell resistance. This difference in direction of anoxia and blood volume change deflections is fortunate since a change in either red cell sensitivity or infrared cell sensitivity to compensate for blood volume changes will increase the anoxia deflection. Increasing the sensitivity of the red cell will increase the anoxia effect directly. Decreasing the sensitivity of the infrared cell will decrease the anoxia effect on the infrared cell; which will also increase the

overall anoxia effect.

It should be noted that whereas cell 1028 behind the ear and the infrared filter is more sensitive to blood volume changes than is cell 1027 behind the ear and the red filter, cell 1028 is less sensitive than cell 1027 to small changes of white light.

3.4 General Characteristics of CdS cells

1. There is no contact barrier.
2. D. C. resistance change is small as direction of current is reversed.
3. Resistance seems to change only slightly as voltage level changes.
4. There is no noticeable saturation effect with high light intensity.
5. Temperature sensitivity is very low (.25%/°C)

4. Work Remaining

4.1 Work will be done on equalizing the blood volume sensitivities of the two cells.

(a) One approach will be to find out if there is any change of sensitivity with light intensity. If such a change of sensitivity exists, there can be an accurate automatic balancing of blood volume effects.

(b) Another approach is to substitute $f(R_2)$ for R_2 in the expression $e_o = \frac{e_1 R_2 - e_2 R_1}{R_1 + R_2}$ giving

$$e_o = \frac{e_1 f(R_2) - e_2 R_1}{R_1 + f(R_2)}$$

If R_2 is the infrared resistance which is more sensitive to blood volume changes, $f(R_2)$ can be series and parallel combinations of resistors with R_2 which will make $f(R_2)$ less sensitive.

4.2 An investigation will be made of the practicability of using narrow band second order interference filters instead of high-pass Wratten filters.

4.3 Work will be done on trying to get a reflection unit.

4.4 Information will be sought on light sources which will produce light in the region 600-850 mμ more efficiently than the Mazda 47 Lamp.

5. Bibliography

5.1 Semiannual Progress Report, Contract Nonr-808(00), Report No. 5209-1, July 25, 1952

5.2 Semiannual Progress Report, Contract Nonr-808(00), Report No. 5209-2, January 5, 1953

5.3 Semiannual Progress Report, Contract Nonr-808(00), Report No. 5209-3, June 30, 1953