Visibility Laboratory
University of California
Scripps Institution of Oceanography
San Diego 52, California

# REPORT ON THE DEVELOPMENT OF A COLORED TELETYPE TAPE DISCRIMINATION SYSTEM

by

Richard L. Ensminger

March 1963

SIO Reference 63-12

BuShips Contract NObs-84075
Assignment No. 3
Project S F018 02 01
Task 0538

Approved for Distribution:

S. Q. Duntley

S. Q. Duntley, Director
Visibility Laboratory

# REPORT ON THE DEVELOPMENT OF A COLORED TELETYPE TAPE DISCRIMINATION SYSTEM

By

Richard L. Ensminger

## 1. INTRODUCTION

The following report describes a device developed at the Visibility Laboratory capable of discriminating between red and yellow teletype tapes of the type commonly being employed by the Navy. Development of the Colored Tape Discriminator (CTD) was in response to the problem of maintaining unclassified tape readers inoperable in the presence of classified tape. Since there are four colors of tape currently in use (red, green, blue, and yellow) the question arose as to the feasibility of installing a device on tape readers that would discriminate on a color basis and automatically guard against the event of a classified tape being fed into an unclassified reader.

Two ground rules in the problem statement as it was presented to the Visibility Laboratory were: (1) any two of the tapes now being employed could be used as the classified or unclassified tapes, respectively, and (2) the device must be fail safe.

The CTD has been designed to operate with the yellow and red tapes as the unclassified and classified tapes, respectively. In practice it is envisioned that the device will be attached to unclassified tape readers. The CTD will render the tape reader operable only under the logical condition that a yellow tape is fed into the reader and there is no failure of any kind in the CTD. Either a circuit or power failure or the presence of a red tape will render the device imoperable.

Emphasis is made of the circuit design and construction philosophy adapted. A device has been designed and constructed from materials already at hand in the lab to demonstrate that there is a sufficient spectral difference in the two tapes to serve as a reliable basis for automatic discrimination. No attempt was made to miniaturise the device nor to build in the long term reliability that would be required for continued use.

## 2. THEORETICAL BASIS

The first step taken toward the solution of the problem was to obtain the reflection spectra of the tapes by means of a recording spectrophotometer. An examination of these curves revealed a two to one ratio in transmission reflectance between the yellow and red tapes in the green region of the spectrum. A comparison of these two spectra with the response of the green filter in the Ansco Reflection Head bears this out. In Fig. 1, one sees a composite curve of the reflectance of the red and yellow type together with the green Ansco filter.

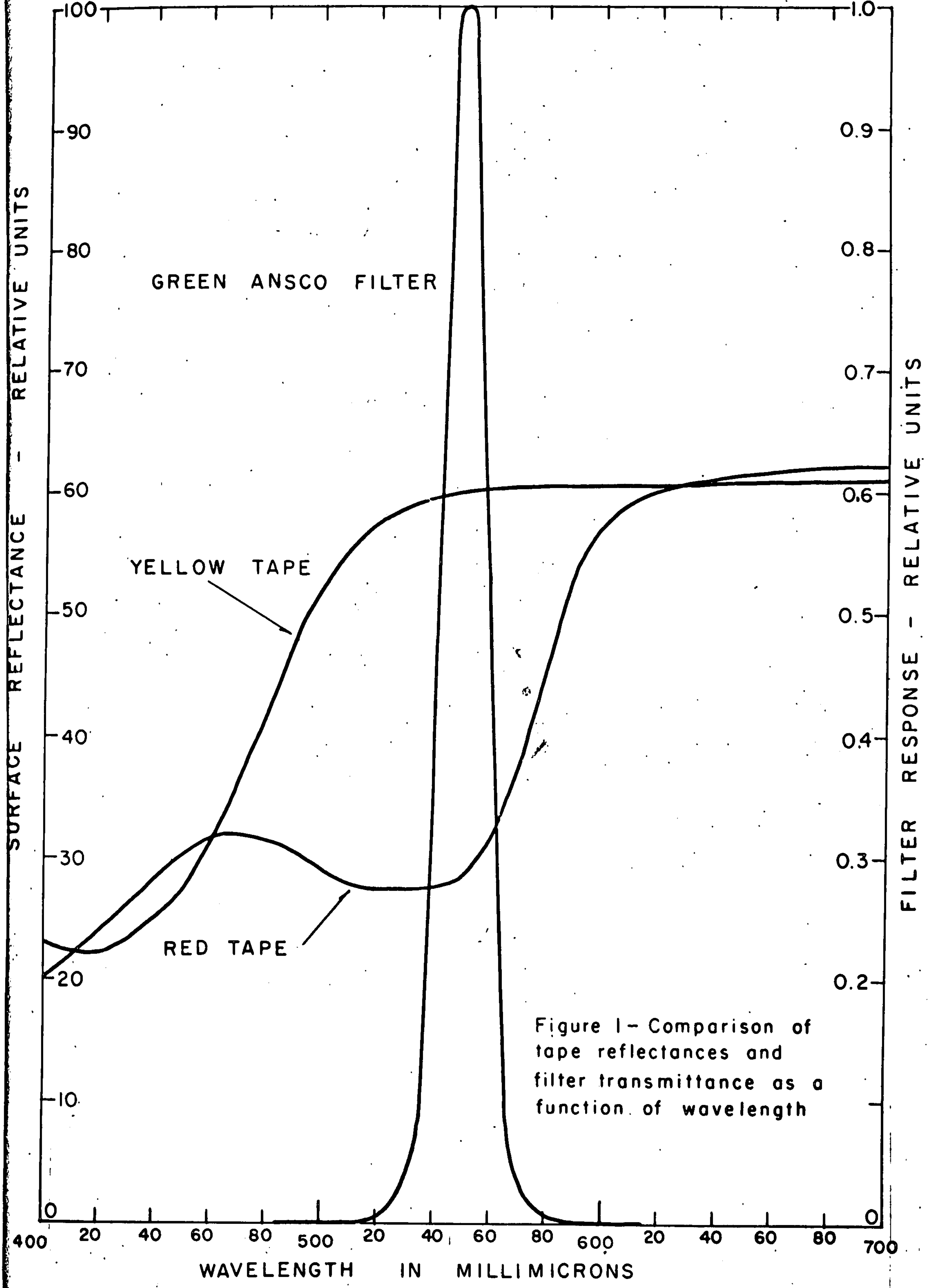

Figure 1 - Comparison of tape reflectances and filter transmittance as a function of wavelength

The Kodak Wratten Filter No. 93 was also considered. The peak of this filter occurs at 540 millimicrons as compared to 550 for the Ansco. No better ratio between the tapes results from a comparison at this point since both have fallen off about the same amount. In addition the peak transmission of the No. 93 filter is much lower than the Ansco.

Some consideration was initially given to a two color system. For example, if one were to sample with a green filter and then with a red filter, one would find that both the blue and the green tapes are higher in the green and lower in the red. The yellow tape is the same in both regions, whereas the red tape is higher in the red and lower in the green. Hence by setting up a logic criterion of higher in the red and lower in the green, the red tape could be differentiated from all of the rest. This system would have the advantage of enabling one to use all of the tapes but it would be more complex. For a system where only two tapes are used, it is felt that a single color comparison in the green part of the spectrum has more to offer in terms of simplicity and reliability.

It should be mentioned that the reflectance of the tapes was also investigated in the ultraviolet. A significant difference was not found in this part of the spectrum, however.

## 3. DUAL FILTER-PHOTOCONDUCTOR SYSTEM

The first attempt at implementing a system was centered around the idea of sampling the reflected flux from the tape in two parts of the spectrum, the red and the green. To do this, two miniature incandescent lamps were to be connected to a solid state multivibrator. It was then planned to direct the flux from these lamps through red and green filters, respectively, onto the tape. The reflected flux was then to have been collected by a photoconductor. The electrical signal would consist of a square wave, the amplitude of which would correspond to the difference in flux as seen through the red and green filters.

This system was implemented only to the extent of mounting two lamps on the scanning plate (Fig. 2). It was then realized that such a system would be impracticable from an operating life standpoint. The lamps chosen were the Sylvania Mite-T-Lite that has a life expectancy of $10^6$ flashes. Even at a minimal flash rate on the order of 10 flashes per second, the overall life would be 1.05 days. Extending the life by a reduction in operating voltage would only exaggerate the other problem of insufficient flux density.

As an alternate proposal to the above system of two lamps and one receptor, it was suggested that a similar system could be designed consisting of one lamp and two receptors. Each receptor would be filtered by a red and green filter, respectively. Such a system was constructed and is shown in Fig. 2. In this case, the intent was to alternately sample each receptor, creating a difference signal as before that would represent the difference between the flux received by the two filters.

One can compute the flux received by the receptor as follows:

pies

Assuming that the tape is a Lambert reflector, the brightness of the projected spot on the tape is a function of the incident flux and surface reflectance (see Fig. 3).

$$B = E\,r = \frac{F\,r}{A_t}$$

where $F$ = Luminous flux

$r$ = Surface reflectance

$A_t$ = Target area

also,

$$F = I\,\Omega$$

where $I$ = Lamp intensity in candles

$\Omega$ = Solid angle.

The flux collected by the receptor, F', is a function of the surface brightness, collector lens area and the solid angle.

$$F' = B\,\Omega A_L$$

where $F'$ = Luminous flux received by the receptor

$A_L$ = Lens area

Combining these results,

$$F' = \frac{I\,\Omega^2 A_L}{A_t}\,r = I\,\Omega^2\left(\frac{D_L}{D_t}\right)^2 r$$

The lamp employed is a G.E. 222 rated at 2.25 volts at .25 amps. Using the quoted luminous efficiency figure of .5 candles per watt, one has,

I = 2.25 volts x .25 amps x .5 candles/watt = .28 candles

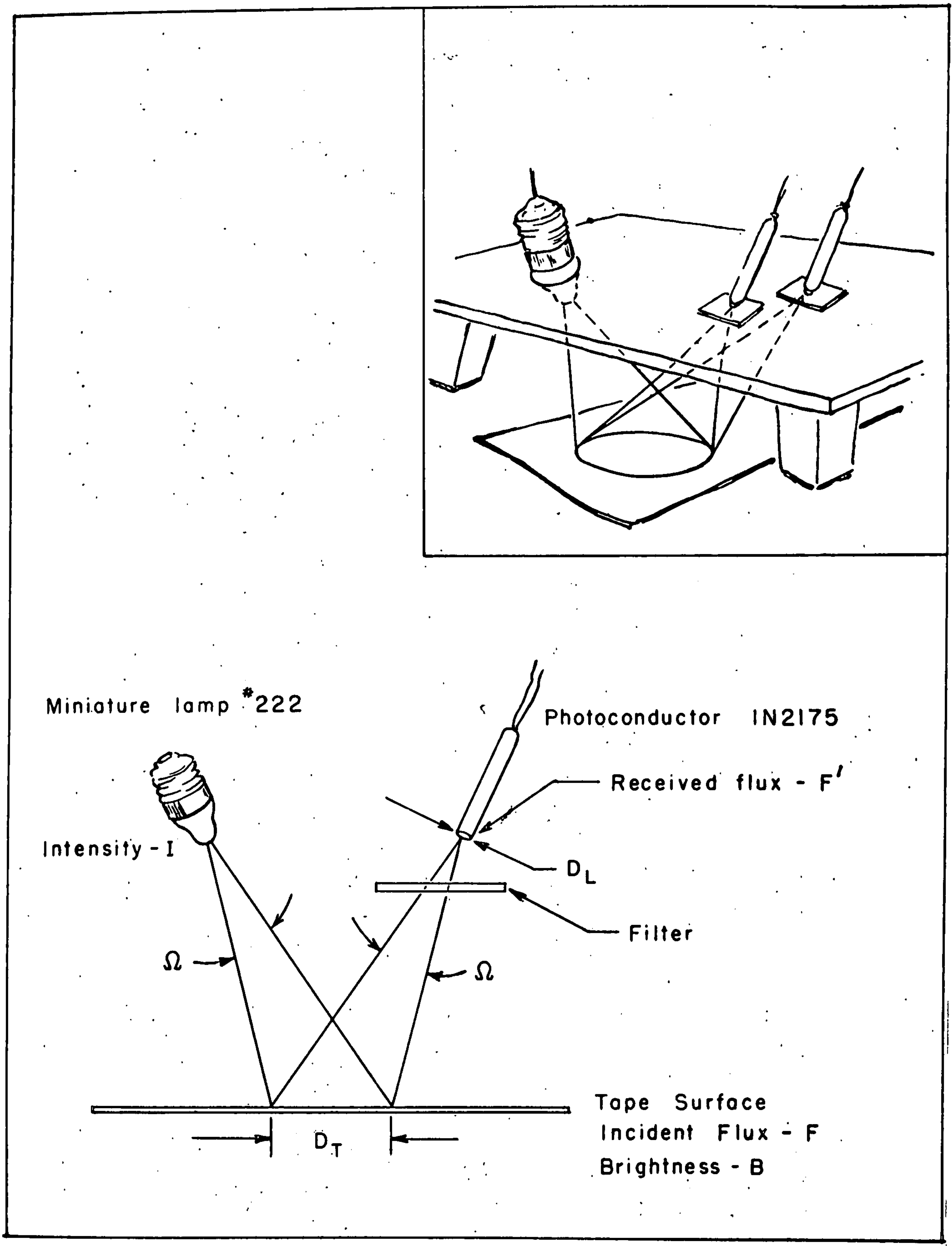

Figure 3 - Photoconductor Dual Filter System

The flux received by the IN 2175 photoconductor can now be calculated from the physical constants of the systems. The tape reflectance has been taken to be unity.

$$F' = .28\ (\text{candles}) \times \frac{\quad}{.66\ (\text{steradians})}^{2} \times \left(\frac{.082}{.4}\right)^{2} \times 1 - 5.11\ \text{millilumens}$$

$I = .28$ candles

$\Omega = .66$ steradians

$D_L = .082$ inches

$D_t = .4$ inches

$r = 1$

The photoconductor current produced by a unity reflecting surface (no spectral filtering) is simply the product of the luminous flux and the photoconductor sensitivity as measured in the illumination system.

$i \doteq S F'$ where $S$ is the sensitivity in amps/lumen

$S$ is specified as .6 microamps/ft. candle. Converting this to microamps/lumen one has,

$$S\ (\text{amps/lumen}) = \frac{S\ (\text{amps/ft. candle})}{A_L}$$

.6 microamps/ft. candle = 16,400 microamps/lumen

$i = 5.11 \times 10^{-3}$ (lumens) $\times\ 1.64 \times 10^{4}$ (microamps/lumen)

= 84 microamps

The actual current that was measured from a white mat surface was 27 microamps. This is considered to be a pretty reasonable agreement considering that the system was analyzed from an ideal geometric standpoint and that the constants that were used were as quoted by the manufacturers.

The majority of the flux that a photoconductor of this type is responsive to occurs in the near infra-red part of the spectrum, as witnessed by Fig. 4. To obtain a figure for the resultant photoconductor current when the green filter is superimposed between the tape and the photoconductor, one must take the product of the sensitivity, the filter response, and the illuminant and integrate this as a function of wave length. Since the sensitivity to illuminant A has been quoted by the manufacturer, what is needed here is a ratio which specifies the reduction in flux that results when the green filter is in place.

$$\frac{S_1'}{S_1} = \frac{\int_0^\infty J(\lambda)\ S_1(\lambda)\ W(\lambda)\ d\lambda}{\int_0^\infty J(\lambda)\ S_1(\lambda)\ d\lambda}$$

where $J(\lambda)$ is the spectral emittance of a 2854°K full radiator in watts/cm$^2$/micron

$S_1(\lambda)$ is the normalised photoconductor response in amps/watt

$W(\lambda)$ is the normalised filter transmittance

$w$ is the peak filter transmittance

$S_1'$ and $S_1$ are the photoconductor sensitivities with and without the green filter

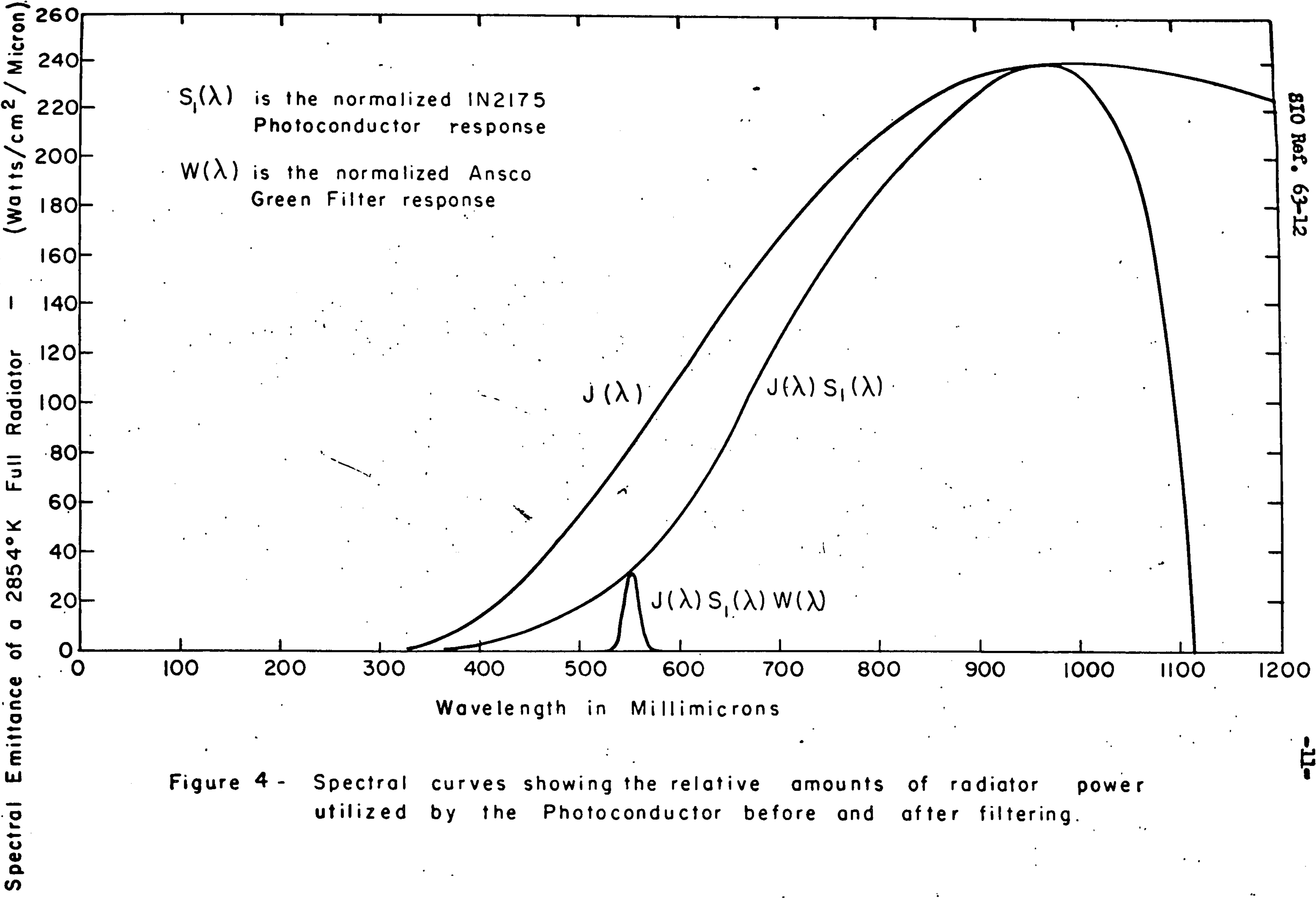

Figure 4 - Spectral curves showing the relative amounts of radiator power utilized by the Photoconductor before and after filtering.

By methods of graphical integration, this ratio has a value of,

$$\frac{S_1'}{S_1} = 6.15 \times 10^{-3} w$$

Hence the maximum current that would result from a perfectly reflecting diffuse surface and a peak filter transmittance of unity is,

$$i_{max} = 6.15 \times 10^{-3} \times 84 \text{ (microamps)} = .516 \text{ microamps}$$

An additional problem arose in this system because the Ansco filter, and indeed gelatin color filters in general, is transmittant in the near infra-red region. If steps were not taken to filter out this part of the spectrum, there would be very little change in output current from the red to the yellow tape. When this additional filtering was employed, the actual measured value of current was in the order of .05 microamps.

It was felt that this represents too small a value to afford a reliable discrimination capability. The reasons for this are as follows:

1. The value of the signal is in the order of the dark current which is listed by the manufacturer as .01 microamp typical, .5 microamp maximum.
2. The signal current would have to be increased in level to the order of 5 milliamps to operate a relay. This implies a stable current gain on the order of,

$$g = \frac{5 \times 10^{-3}}{.05 \times 10^{-6}} = 10^5$$

Achieving a stable gain of this order of magnitude would rule out simple circuit techniques.

3. Since the filtered part of the spectrum from the incandescent lamp represents such a small part of the total, shielding the photoconductor from direct radiation from the lamp becomes a problem.

Because of these difficulties it was felt that a photoconductor system did not represent the best solution to the problem.

## 4. THE SINGLE CHANNEL MULTIPLIER PHOTOTUBE SYSTEM

The system finally adopted was one utilizing one channel of green filtering and a 931-A multiplier phototube. An Ansco reflection densitometer head was used as the optical scanning system. Whereas a more compact system could undoubtedly be built, the Ansco head was available to the lab and convenient to use. Moreover, it is felt that its performance is typical of systems of this type.

Figure 5 shows a photograph of the Ansco head. A schematic representation has been made in Fig. 6. A cluster of four incandescent lamps illuminate a .25 inch diameter circle on the surface of the tape. Reflected flux from the tape is collected by a small lens located two inches from the tape surface. The flux collected by the lens can be