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Wet film sensitometry with an infrared scanning densitometer

Anthony Casinelli

John Hisler

WET FILM SENSITOMETRY WITH AN INFRARED SCANNING DENSITOMETER

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Anthony V. Casinelli
John S. Hisler

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in the School of Photographic Science in the College of Graphic Arts and Photography of the Rochester Institute of Technology

June, 1970

Thesis Advisor: Dr. Schumann

ACKNOWLEDGMENTS

We wish to express our deep appreciation to all of the people who have aided us in the execution of this research project.

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WET FILM SENSITOMETRY WITH AN INFRARED SCANNING DENSITOMETER

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An Abstract

A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in the School of Photographic Science in the College of Graphic Arts and Photography of the Rochester Institute of Technology

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This project was to design and operate an infrared scanning densitometer to monitor the growth of the characteristic curve of a film during development.

An aparatus was constructed which enabled us to pass repeatedly, a sensitometric strip through a beam of radiation during development. This radiation was focused on the film plane of the development container. The spot on the film plane was relayed, after transmission through the sample, to a photomultiplier tube. The response of the tube was displayed on an oscilloscope and this was photographed.

We were able to obtain a trace of the characteristic curve of a fully processed snesitometric strip in the above manner. However, we were unable to obtain the characteristic curve of a test strip during development even with the antihalation dyes removed. We believe that if more time were available we would go to radiation of higher intensity and longer wavelength, with an appropriate change in photomultiplier tube. It is our opinion that with these changes we would have had success.

INTRODUCTION

Process control is an extremely important facet in the Photographic Industry. In particular, the relationship between development time and the resulting H & D curve for a particular film is of great value.

There are several methods of obtaining this information. Time development series may be made in one of two ways to yield this relationship. One is to develop several pieces of film, exposed under the same exposure conditions, for different specified times. An alternative to this is to use one sample of film, arresting development at specific times and measuring the density with an infrared densitometer. Then by use of a buffer solution, development may be re-induced and allowed to continue until the next point in development time selected for examination.

With the advent of rapid access processing, these methods of monitoring do not meet the new requirements. Aside from being tedious, they are also inaccurate. It is impossible to pinpoint the development characteristics of a film using these methods inasmuch as a few seconds change in processing time is critical. Therefore, an

improved means of monitoring is required.

This problem was first approached in 1964 by Jerry C. Hughes, for his senior research thesis at Rochester Institute of Technology. He proposed to scan film during development by the use of infrared illumination. His apparatus was composed of an infrared source, a diffusing glass, a specially constructed processing tray, a photo-voltaic cell and an oscilloscope. The process tray was drilled and fitted with eighty-four "light pipes" which were arranged in twenty-one rows of four to coincide with the twenty-one steps of a sensitometric strip.

A sensitometric strip was placed in the processing tray, which was evenly illuminated with infrared radiation by means of the diffusing glass. The "light pipes" were scanned at a rate of forty scans per second from beneath the tray by a rotating drum, which collected the transmitted radiation and relayed it to the photo-voltaic cell. The signal from the cell was attenuated by a logarithmic amplifier to relate the response directly to density and then used as the input signal for the oscilloscope, from which transmission curves were taken, by means of a motion picture camera. The curves obtained were then correlated with H & D curves obtained by conventional means.

The work done by Mr. Hughes indicated this method

was applicable. He was able to correlate his data to previous data as had been desired. Through his work it was found that the response sensitivity of the photovoltaic cell should be high is order to respond to the low amounts of radiation transmitted.

It is the purpose of this research project to modify the ideas of Mr. Hughes and design an infrared scanning densitometer. The densitometer will consist of a beam of red and infrared radiation directed through a cylindrical container in which our film sample is being developed. This beam, after transmission, will be collected and imaged on the face of the photomultiplier tube in a Macbeth TD-102 Densitometer. Since we are using visible radiation, as well as infrared radiation, we feel that the S-4 response of the tube will be sufficient for our project. Our method of recording the transmission curves will be the photographing of the signal traces on an oscilloscope, much as Mr. Hughes had done.

INSTRUMENTATION

The infrared scanning densitometer that we have designed is constructed using a micro-optical bench for the source of illumination and the optical train. (Refer to Figure 1) The source of radiation is a six volt, fifty watt tungsten lamp with a four volt regulated power supply. The source is entirely enclosed with an aperture in one face of the housing, giving us a spot source. Heat from the lamp is dispelled through a chimney at the top of the enclosure. A Wratten 29 filter of triple thickness is placed in the aperture to yield radiation of 6100 Å and above at an intensity at which it will not fog the film.

An image of the first aperture is relayed to a second aperture by means of a sixty millimeter, double convex lens. This aperture immediately preceeds a right-angle prism, which re-directs the radiation from the vertical axis to the horizontal axis of the optical train. The image of the second aperture is reduced to a two millimeter spot at the film plane by means of a twenty millimeter, double convex lens. A third lens, also a twenty millimeter double convex, collects the radiation

OPTICAL SYSTEM DIAGRAM
CASINELLI-HISLER PROJECT

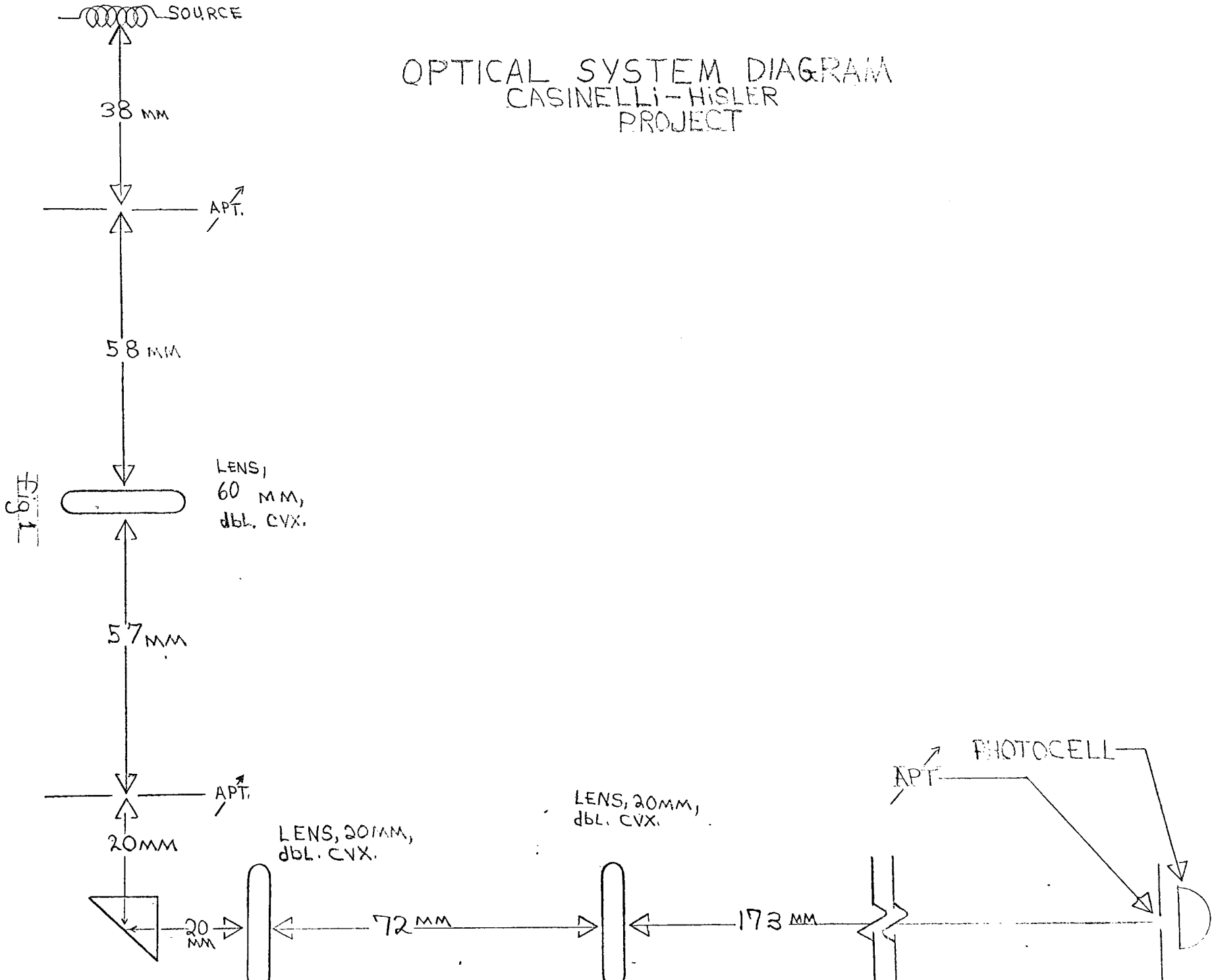

FIG. 1

transmitted by the sample and images it on an aperture immediately preceeding the photomultiplier tube in the Macbeth Densitometer. There is an image magnification of 2.4 times the spot at the film plane such that the illumination at the third aperture will just fill the photomultiplier tube.

The micro-optical bench is suspended from the positioning arms of an Omega D enlarger. This works very well in that vibrations do not affect the stability of the optical train as might be expected and also allows easy access to the developing container for cleaning and loading. The positioning of the film sample is not as critical or difficult as it would be with a stationary arrangement as the optical train may be raised while loading the film sample and lowered to a position that alligns properly with the film.

The stability of the optical train is very good. The support members of the assembly are reinforced with extra braces to keep the optical train in exact alignment even though it is being moved regularly to change film samples.

The processing tray is constructed of two lengths of glass tubing, one having a diameter of 113 millimeters and the other a diameter of 154 millimeters. (Refer to Figure 2.) These are mounted on a circular piece of reinforced glass 175 millimeters in diameter. The central

DEVELOPMENT TANK

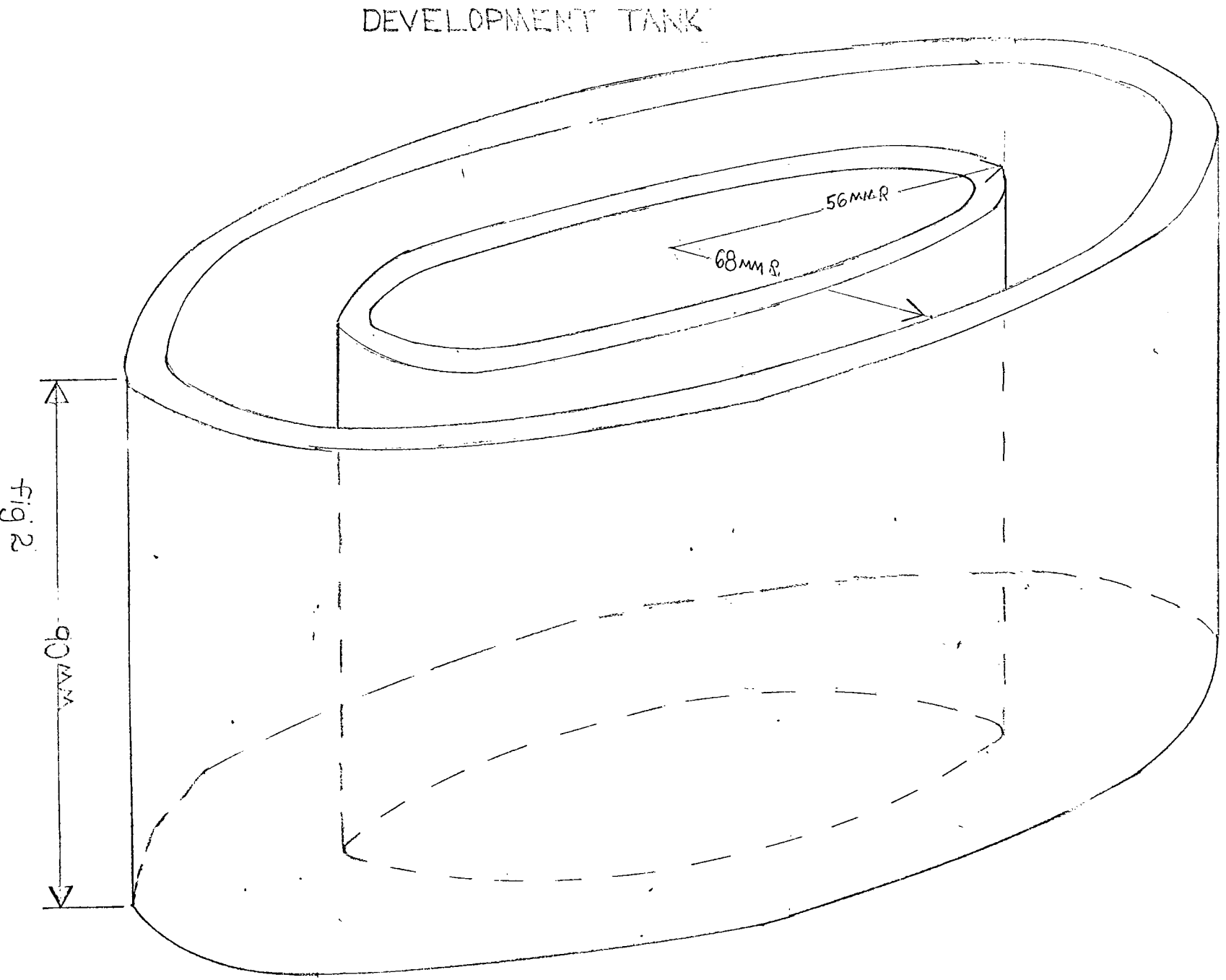

fig 2

CASINELLI-HISLER PROJECT
DRAWN BY ハンスラー

cylinder of the tank is of such a size that the housing holding the right-angle prism and the first twenty millimeter lens fits into it with sufficient clearence for rotating the tray. The film sample is held in this container by the use of transparent tape.

The developing container is rotated on a motorized turntable. It is rotated at the rate of forty-five revolutions per minute allowing us to make a scan of the test strip every 1.31 seconds. It is possible, with our turntable, to make seventy-eight scans per minute or one scan every .77 seconds.

The radiation incident on the face of the photomultiplier produces a density signal which would normally be displayed on the ammeter of the densitometer. This ammeter has an internal impedence of six thousand ohms. The leads to the ammeter are connected across a six thousand ohm parallel resistive network which matches the impedence of the ammeter. The voltage drop across this network is the density signal that would be displayed as a meter reading normally, and has a negative polarity.

The leads of an oscilloscope are connected across this resistor network. The oscilloscope is set up for internal triggering so that when a negative signal is recieved, the cathode ray tube will be triggered, thus producing a trace representing the density curve from the film sample being scanned. The film is held in the

processing container with transparent tape. Thus, the first density "seen" by the photomultiplier will be the film sample itself. Therefore, the aparatus will be automatically synchronized.

Images of the screen of the oscilloscope are taken by means of a Polaroid scope camera. This is manually operated but the exposure is easily synchronized with the trace by watching the triggering indicator on the face of the oscilloscope.

RESULTS

DuPont Cronalith film was used in this project. It was processed with Kodalith A-B developer at 75° F for three minutes.

In our first attempts to use the aparatus a Wratten 21 filter was used in place of the Wratten 29. However, the light transmitted by this filter seriously fogged the film. We next tried a Wratten 29 filter at single, double, and triple thickness. The single and double thicknesses transmitted enough radiation to again fog the film. However, we found that a triple thickness of Wratten 29 filter worked satisfactorily.

We next placed a processed sensitometric strip in the scanning position and the characteristic curve was displayed on the oscilloscope. The amplitude and time scales of the oscilloscope were adjusted to display the curve in a perspective with which we were familiar.

An undeveloped test sample was next placed in the scanning position of the developing container. During development we obtained only a maximum density reading in the form of a straight horizontal trace at maximum negative deflection. We suspected that this was caused

by the presence of the antihalation dye on the film back and attempted to remove it by rinsing with water and scrubbing with a nylon scrubber. This proved unsatisfactory. We contacted Mr. W. B. Wyman of the DuPont Photographic Products Department in Wilmington, Deleware. Mr. Wyman suggested a controlled wash with clorox. This application of clorox to the back only, satisfactorily removed the dyes. However, under a "1 A" safelight, the film remained translucent overall.

The clorox-washed sample was placed in the developer tray and processing was begun. Again the horizontal line representing maximum density was displayed on the oscilloscope. The exposed and unexposed silver-emulsion complex was still preventing transmission in the exposed sensitometric scale.

As a point of curiosity, a sensitometric strip was developed and stop-bathed. This strip was then placed in the scanning position and fixer added at normal strength. The film cleared in less than a second and the desired density versus time curve was displayed on the oscilloscope screen.

CONCLUSIONS

The project did not produce the desired results because we could not project a beam of radiation at the wavelength used at the intensity necessary for transmission without fogging the film. We therefore need to go to radiation of longer wavelength and higher intensity and to a photoreciever with peak intensity in that region. The wavelength of the radiation should be well beyond the sensitivity of the film to enable the researcher to increase the intensity of the scanning radiation to a suitable level.

RECOMMENDATIONS

We recommend that a radiation of, and a reciever with peak sensitivity at, a longer wavelength be used in this apparatus. We feel that radiation between 7000 Å and 8000 Å could be used at a higher intensity and would transmit through the film, being blocked only by the density of the exposed silver. The photomultiplier of the Macbeth TD-102 Densitometer has an S-4 response. The sensitivity of this tube is quite low beyond about 6500 Å. A photomultiplier with an S-20 response is suggested.

An alternative might be to substitute a photo-resistor circuit in the TD-102. A photo-resistor would be selected with the desired spectral sensitivity. The response of this circuit to light transmitted through the film would be displayed on the oscilloscope. An RCA tube, the Quanticon, has an S-20 response and should fit the TD-102. However, the cost of this tube is about $900.00 and a photo-resistor with the desired sensitivity costs about $2.00.

It would be desirable, though not necessary, to replace our development container with one having thinner

walls and of more perfect circularity. Blaessig Glass Company of Rochester will make one of Pyrex for $60.00.

Finally, it would be interesting to run an experiment on fixation rate as a function of fixer concentration or temperature using this apparatus.

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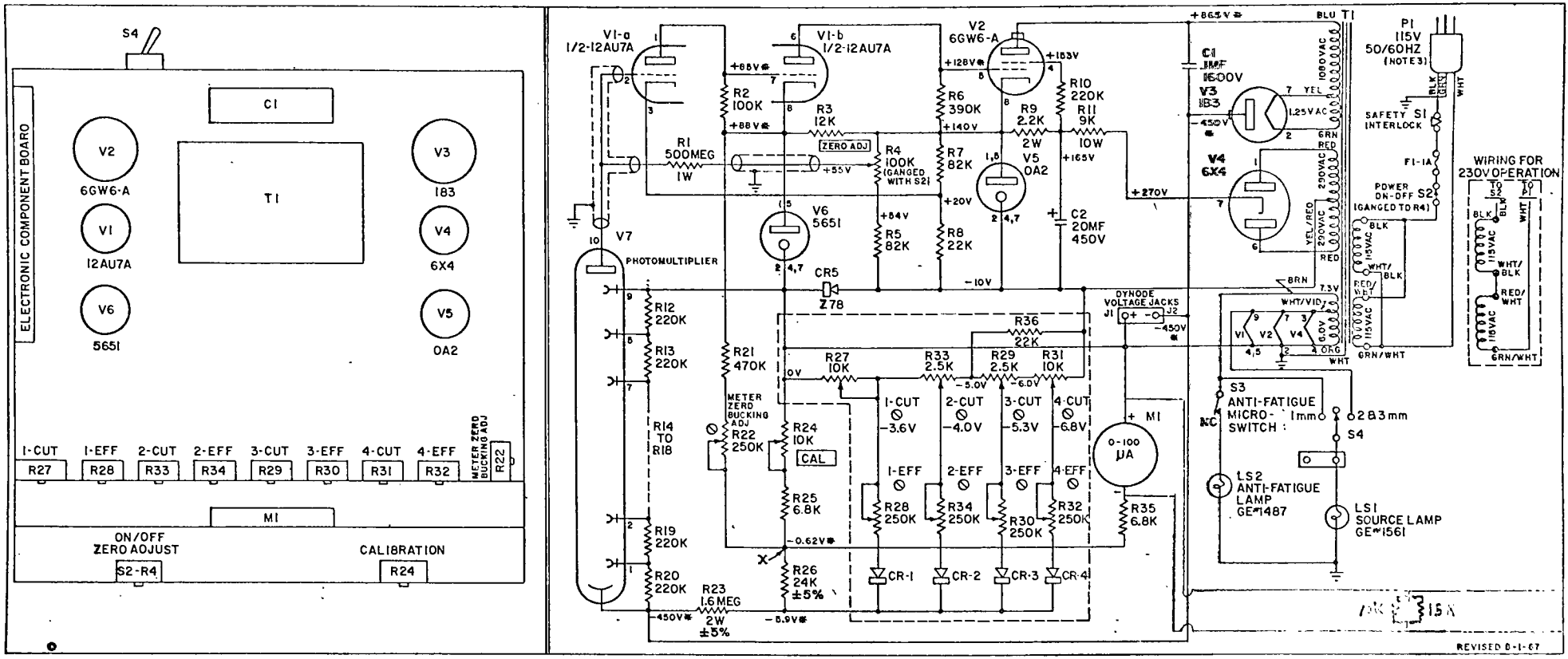
APPENDIX



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NOTES:

1. ALL DC VOLTAGES MEASURED WITH A 20,000Ω/V METER TO GROUND
2. ALL AC VOLTAGES MEASURED WITH A VTVM
3. INPUT LINE VOLTAGE STABLIZED WITH 60 V.A. SOLA (CAT# 20-13-060) REGULATOR OPERATED AT 115V
4. ALL VOLTAGES MEASURED WITH UNIT CALIBRATED AND PROBE SNOUT IN UP POSITION UNLESS MARKED *
5. * INDICATES TYPICAL SIGNAL VOLTAGES AT DENSITY = 2.0 (APPROX.)
6. ALL RESISTORS 1/2 WATT, 10%, UNLESS OTHERWISE INDICATED
7. THESE VALUES EFFECTIVE IN 51000-SERIES INSTRUMENTS
8. ▭ = OPERATOR CONTROL

Figure 7-1. Schematic Diagram, TD-102

Figure 3

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