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Modification of the inprocess infrared densitometer

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MODIFICATION OF THE INPROCESS
INFRARED DENSITOMETER

by

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

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Thesis advisor: Professor John Carson
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ABSTRACT

A model of an infrared scanning densitometer was constructed using the basic designs developed by Hisler and Casinelli in their 1970 research work, and by Beaupre and Jasper in their 1971 research work, plus several new ideas which greatly improved the reliability and usefulness of the machine. Among the changes were: use of an infrared sensitive photomultiplier tube on recommendation of Hisler and Casinelli; Z axis modulation for oscilloscope display, a new idea; and addition of a diffuser to illuminate the sample to provide better correlation between wet and dry densities, on recommendation of Dr. Schumann.
INTRODUCTION

Infrared densitometry has recently become useful in the study of photographic development. Several methods have been described in published photographic literature describing methods of using infrared radiation to monitor photographic development. However, none have described a method which reads out direct D-Log H curves.

In the past, three unpublished research projects at the Rochester Institute of Technology have been geared toward building scanning infrared densitometers in order to obtain direct readouts of D-Log H curves. Hughes used a drum scanning device to read a stationary strip with infrared radiation. In 1970, Hisler and Casinelli developed an instrument which read a rotating strip in a doughnut shaped tank using a phonograph turntable and the electronics from a Macbeth TD 102 densitometer. In 1971, Beaupre and Jasper developed a similar instrument using solid state electronics.

The latest version of this instrument most clearly resembles that of Hisler and Casinelli's. Beaupre and Jasper's approach set out using solid state devices which are sensitive to infrared radiation. This innovation solved the problem of the 931 photomultiplier tube, used in the Macbeth densitometer by Hisler and Casinelli, not being sensitive enough in the infrared region. The new version incorporates the electronics of an old Macbeth
universal densitometer, an infrared sensitive photomultiplier tube, a source similar to the one developed by Beaupre and Jasper, and a new electronic system which makes the oscilloscope display only discrete data. Wet densities which correlate more closely to dry densities are obtained by use of diffuse source illumination of the sensi-strip, which corrects for the effect of the film emulsion swelling as it is immersed in the developer. An operation manual and a complete set of engineering drawings are provided for future reference.
INSTRUMENTATION

Design:

The paper by Hisler and Casinelli suggested using a photomultiplier tube with a S-20 response to increase the sensitivity into the infrared region over the standard 931 tube which has an S-4 response. A photomultiplier tube having an S-1 response (RCA C31004) was chosen because the infrared sensitivity range was sufficient for the present needs. The photomultiplier tube was the approach used as opposed to that of the solid state receiver. It was considered simpler to adapt a working densitometer rather than develop a whole new solid state system. Also, the photomultiplier tube was considered more sensitive than a solid state receiver.

A new tank, made from 3" OD and 5" OD acrylic plastic tubes .165" thick and .165" thick acrylic sheet, was fabricated. A film holder was made of 4" OD tube of the same material. (see Appendix p v-vi for sketch) The film holder was keyed so that it would fit in the tank only one right way. Registration pins were set on the inside of the film holder to hold the sensi-strip in position with the the emulsion facing in. Matching registration pins were set in a sensitometer head to insure that the exposed strip is in register with the instrument. The tank is keyed to a piece of acrylic sheet which is glued on the top of a piece of 8" OD acrylic tube. This base tube is keyed with
the turntable. Ten strips of 1/8" chrome mapping tape were placed on the edge of the turntable so that they pass the timing device as predetermined steps on the sensi-strip pass through the infrared beam. The blanking circuit suppresses the oscilloscope display until a metallic strip passes the timing device. (see Appendix p vii-ix for schematics and diagrams of parts of this system) This creates dot readings on the oscilloscope tube as compared to the vertical spikes created by the Beaupre-Jasper instrument. The metallic strips are placed so that the dots displayed represent the density of every other step on a 21 step step-tablet. Each time a strip is run, the same steps are read because of the complex registration system. The timing device is also used to trigger the oscilloscope so that the horizontal position of the D-Log H curve is the same each time. The first metallic strip starts the reading of the sensi-strip. Beaupre and Jasper had a problem with this because they triggered with the least dense strip which was hindered by the antihalation backing and the fact that undeveloped film is almost opaque. The timing circuit also makes possible the display of time v.s. density readout as well as real time D-Log H curves. (see manual for details) Acrylic restrainers were glued on the inside of the film holder to hold the ends of the film down as the tank rotates. A .8" X .6" portion was cut from the film
holder where the sensi-strip was to be held. A piece of .063" translucent polyethylene sheet was glued in place in the slot of the film holder to provide diffused illumination on the sensi-strip. This diffuser essentially causes the instrument to read the strip the same way a normally set up TD 102 would read a dry strip. Agitation during development was provided by a piece of acetate suspended in the tank on the film side of the film holder.

The source was similar to the one used by Beaupre and Jasper in that it involved a high powered tungsten bulb used at 50% voltage reduction to increase the output ratio of infrared radiation to visible light. Kodak wratten 25 and 87 filters were used to filter out visible radiation. A smaller turntable was used to get the source closer to the tank.

Köhler illumination is used in both the influx and efflux optics. (see Appendix p iii for detailed diagram) A set of apertures and rectangular field stops are used to illuminate a .1" X .5" vertical area of the sensi-strip as it passes the beam of radiation. A front surface mirror was necessary to direct the radiation path into the base where the photomultiplier tube is mounted horizontally. This was necessary since the dimensions required of the optical system did not allow the photomultiplier tube to stand vertically within the inner walls of the tank.
Construction:

Building the unit proved to be the greatest challenge. The photomultiplier tube chosen was hard to obtain because it is made on special order only by RCA and is rarely stocked. The tank tubes were faced off in a lathe in order to insure concentricity of the tank walls and film holder. The sensitivity of the machine was less than it should have been since the densitometer failed to operate properly under standard operating conditions. The meter needle never zeroed even though large amounts of radiation were introduced on the photomultiplier tube. However, there was enough range to read with the oscilloscope. This problem did create more noise amplification with the necessary increase in sensitivity required from the oscilloscope to read the sensi-strip normally. The original design was supposed to have been workable with the standard 25 watt densitometer bulb. The lack of sensitivity caused the necessity for the same type of high output source used by Beaupre and Jasper in order for the unit to function properly. A 500 watt tungsten projection bulb was used instead of the tungsten halogen bulb used by Beaupre and Jasper. In the case of the latest model, the diffuser scatters a lot of energy, making the need for more energy more necessary. A fan was necessary to keep the source cool. One #25 and two #87 filters were used in the filter pack. The timing circuit
and power supply were mounted in the base of the turntable.

Calibration:

The timing circuit was aligned by first taking a piece of film, punching it with the register punch, emulsion side up, and then processing it. The filters were removed and the processed strip set in the film holder. The tank was then rotated until the first step was in the light path of the source. A piece of metallic tape was placed on the edge of the turntable at the point where the timing circuit would be tripped when that step is to be read. This was done for every other step on the step-tablet.

A standard test was made with a film strip which was processed in the apparatus with the camera recording the oscilloscope screen. The sensi-strip was fixed and the film in the recording camera processed. Dry densities were taken of the sensi-strip and their corresponding densities calibrated against the reticle on the oscilloscope. The illuminated reticle of the oscilloscope screen appears on the recording film.
RESULTS

The test films showed the curve trace reaching a maximum toward the shoulder end of the curve. This was due to lack of sensitivity at high density regions of the test strips. However, these steps are rather dense and are not very important in the cases of continuous tone materials. Samples of time v.s. density curves will be shown in a supplementary report.
CONCLUSIONS

The research work done by Hisler and Casinelli showed the feasibility of the general design of the scanning densitometer. Beaupre and Jasper demonstrated the need for an infrared source and detector. The discrete data produced by the latest model instrument, using the timing circuit, and the registration system in addition to the previous designs of scanning infrared densitometry, is more useful than data produced with previously designed instruments. This is so because, with data in the form of dots instead of vertical spikes, more traces can be recorded on one piece of film. Data sets of this type are important since many traces, especially those at very short development times, are necessary to make good inferences on development kinetics. The lack of the usual jump in the trace noticed on the previous instrument is attributed to the diffuser which was added to eliminate the effect of the film emulsion swelling as well as increase the wet to dry density correlation.
RECOMMENDATIONS

We suggest that a densitometer in better working order be substituted for the existing one or that the unit be repaired or recalibrated so that it functions properly. Better sources of infrared radiation would reduce the signal to noise ratio of the instrument and make it more accurate. The instrument could then be used to gather a great deal of useful data.
APPENDIX

Photograph of Apparatus .................. 1

Sketches

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VOLTAGE REGULATORS

+20-35 V

7805
5 VOLT REGULATOR

.01 μF
+ 10 μF

+20-35V 330

+12V

SCOPE BLANKING

12V
SAMPLES

Record

Sensi-Strip
Material: Fine Grain Pos
Filter: none
Net Exp.: 340 mcs
Developer: D-76
Time: 6 min
Illum: 1700 mc
Temp: 75°

Charac. Curve of Fine Grain Pos.
Prepared by: J. Chan

Title: Characteristic Curve of Fine Grain Pos.
Exp. Time: 15 sec
Agitation: Acetate Strip

Graph showing relative log exposure vs. density with step number and relative log exposure axes.
BIBLIOGRAPHY
