

image, but since all the control procedures are densitometric, this does not matter, as long as the curves match.

Each new emulsion, and for that matter, each roll number within a given emulsion number is tested and a print is made which will match the standard characteristic for that emulsion type. This print characteristic is checked on each emulsion before production begins and is checked periodically throughout the supply of that film.

Using a test emulsion that is stored under controlled conditions, we also check out the printer each day to insure the reproducibility of the printer. This emulsion is also used for any testing of printer functions or to check the printer after any repairs or changes.

Control Program

The control program as outlined, necessarily consists of a large number of densitometric plots and takes considerable time in the evaluation.

With ideal film and with ideal densitometry, one would, when trying to make one set of curves match another, merely place one set of curves over the other and shift each curve for each color until it matches the desired characteristic. The displacement of the curves along the log exposure axis would be the required log exposure change to make in the printer setup. In actual practice, this results in a series of successive approximations. When the green exposure is changed by a large amount it also changes the blue and red curves by a smaller amount. When the desired change is small, the displacement of the other two curves is slight and can be estimated directly. When

the desired change is large or consists of more than one correction at a time, the effect on the other curves is sometimes difficult to evaluate.

These secondary effects were measured by printing each film type in the following manner:

- (1) basic exposure,
- (2) basic exposure plus a blue increase,
- (3) basic exposure plus a green increase.
- (4) basic exposure plus a red increase.

All four tests were than processed, read and plotted. Taking the basic exposure graph as a base, the shifts of the other curves in the accompanying tests were tabulated.

<i>Log E change from basic exposure</i>	<i>Densitometric curve shift</i>
delta Blue	$Y_b \quad M_b \quad C_b$
delta Green	$Y_g \quad M_g \quad C_g$
delta Red	$Y_r \quad M_r \quad C_r$

Where Y_b is the shift of the yellow dye layer due to the change in blue exposure, M_b is the shift of the magenta layer due to the blue exposure, C_b is the shift of the cyan layer due to the blue exposure, and so on.

If each of these changes is divided by the log exposure change, the resulting matrix describes the amount of curve shift for each color for a given exposure.

$$\begin{array}{ccc} \frac{Y_b}{\Delta B} & \frac{M_b}{\Delta B} & \frac{C_b}{\Delta B} \\ \frac{Y_g}{\Delta G} & \frac{M_g}{\Delta G} & \frac{C_g}{\Delta G} \\ \frac{Y_r}{\Delta R} & \frac{M_r}{\Delta R} & \frac{C_r}{\Delta R} \end{array} = \begin{array}{ccc} Y_b & M_b & C_b \\ Y_g & M_g & C_g \\ Y_r & M_r & C_r \end{array} = M$$

<i>Curve shift</i>	<i>Inverse matrix</i>	<i>Log exposure change</i>
B'	$yB \quad mB \quad cB$	$B'yB + B'mB + B'cB = \text{Blue}$
G'	$yG \quad mG \quad cG$	$G'yG + G'mG + G'cG = \text{Green}$
R'	$yR \quad mR \quad cR$	$R'yR + R'mR + R'cR = \text{Red}$

The actual information desired is not the amount of curve shift for a given exposure change, but the amount of exposure change necessary to give a known curve shift, that is, the inverse matrix. This can be found by classical matrix manipulations.

$$\begin{array}{ccc} yB & mB & cB \\ yG & mG & cG \\ yR & mR & cR \end{array} = M^{-1}$$

After a test has been run and plotted, it is compared with the desired curve. The curve shifts parallel to the log exposure axis are noted. Each of these desired curve shifts is multiplied by all the terms in the corresponding row of the matrix. The algebraic sum of all the product terms in a row is the change in exposure necessary for that color (see formula below).

Conclusion

The author has not attempted to describe many of the specifics of printing operations, but has chosen to emphasize some of the methods in use that are different from conventional techniques. Some of the reasons for such changes are due to the differences in film types and certain problems associated with these films. These methods were developed to help meet the goals set for the Lakeside Laboratory's 16mm program.

16mm Internegative and Color Positive Processing Controls

Processing control of 16mm color internegative and color positive is necessary to produce a high-quality product. This paper deals with methods of photographic and chemical processing production controls and their coordination with motion-picture printing controls.

WHEN EASTMAN Color Positive and Color Internegative films were introduced several years ago, the Calvin Company had had previous processing experience with color film. Eastman Kodachrome duplicating film had been processed in our laboratory since 1950. The experience in processing controls

Presented on October 20, 1958, at the Society's Convention in Detroit by William Hedden, Calvin Productions, Inc., 1105 Truman Rd., Kansas City 6, Mo.
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gained through the developing of Kodachrome has been applied to the internegative and color positive films. In some cases, it has been found that these two films do not require as extensive or as complicated control as does Kodachrome in its duplicate processing. In other instances, previous experience proved inadequate, and new control methods and procedures were required. This paper is intended as a report on the application of generally accepted methods of processing control and procedures found useful in our produc-

By WILLIAM HEDDEN

tion for developing the internegative and color positive films.

Processing controls generally are classified into chemical, photographic, and mechanical applications. Mechanical and photographic control methods have been known and used for several decades; however, the method of chemical control through analytical procedures has been extensively utilized only within the last few years. We learned that the internegative/positive system does not require as many or as involved chemical controls as Kodachrome duplicate processing; also, we learned that by placing first emphasis on a highly accurate chemical control system, the photographic and mechanical control phases are simplified. Process variations seem

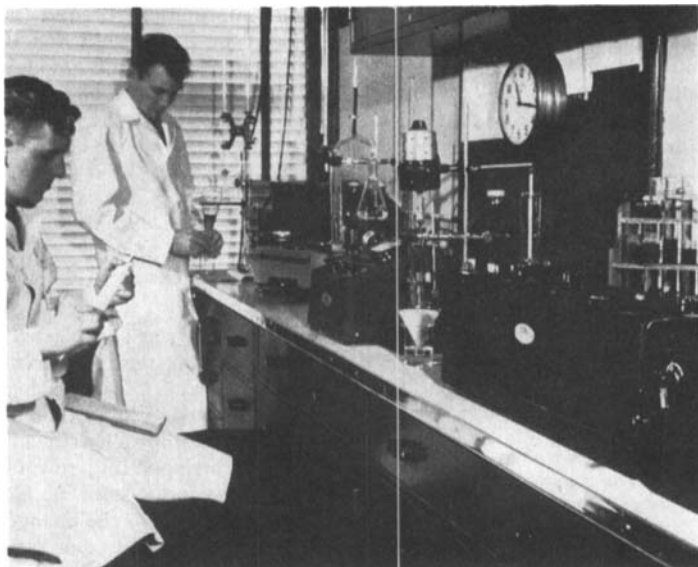


Fig. 1. Use of chemical controls simplifies photographic and mechanical control phases.

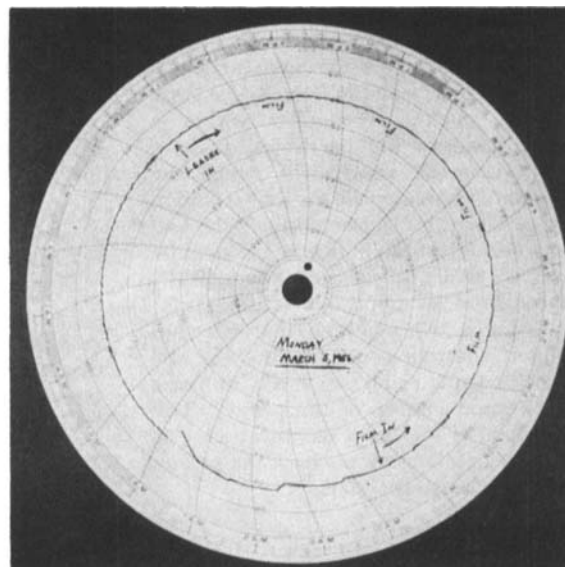


Fig. 2. Chart of temperature variations.

to be most frequently caused by chemical changes. By controlling the process chemically, the photographic and mechanical controls serve mainly as checks on the accuracy of the chemical control and physical operation of the developing equipment (Fig. 1).

Processing machine tanks are analyzed chemically at least once during each shift. Analysis is made immediately before any internegatives are processed; and, if necessary, machine additions are made and tanks are reanalyzed to provide the most complete approach to chemical standards possible before internegatives are processed.

This high degree of chemical control has been reflected in a similarly high degree of negative photographic uniformity. In the printing operation it is important that a negative, printed and processed today, produce an identical print under the same positive printing conditions as similar negatives printed and processed in the past or in the future. Extremely close chemical control is essential if this goal is to be reached.

Replenishing solutions are mixed by on-center mixers and stored in tanks with floating covers to reduce oxidation. These solutions are, of course, analyzed before being accepted for production use. Again, critical chemical control of replenishers is reflected in low chemical variability in tank solutions. Long-range statistical controls also are used both for machine tank and replenisher systems.

Mechanical control of the processing machine and its allied equipment is necessary if the conditions for a standard process are desired. Traditionally, time, temperature and agitation are controlled mechanical conditions, but the mechanical feature of replenishment additions is of equal importance. Processing

time is easily checked with a stop watch, and very little time variation is noticed on our rigid-rack constant-speed machines. Temperature control within $\frac{1}{2}$ F is not a great problem with the commercial equipment that is available today. The recording temperature control equipment is important to show temperature variations or malfunctions of the equipment (Fig. 2). Checking the calibration of the automatic temperature control equipment with a mercury thermometer frequently placed in the machine tank is a long-range method of temperature control that cannot be neglected.

Recirculation of the developing solution with adequate filtering is undertaken to provide uniform agitation of film in the machine tank. The degree of recirculation is measured on a flow meter. Replenishing solutions to all tanks, including washes, are regulated by flow meters. A periodic calibration check on replenishment flow meters is desirable. If this calibration check is omitted, a dirty flow meter may be identified by long-range chemical control methods indicating abnormal machine chemical additions. Frequent flow-meter calibration checks, therefore, will lead to more consistent chemical control (Figs. 3 and 4).

Chemical and mechanical controls establish definite processing conditions. Photographic control is necessary to enable the technician to evaluate these process conditions and to provide a means of measuring variability. Sensitometric strips exposed on a special densitometer are processed along with film at definite intervals. Our laboratory uses an Eastman Model 31A electronic densitometer to measure these processed strips (Fig. 5). Definite photographic standards of good print quality having

been established, these processed sensitometric strips indicate how well the process conforms at that time to a fixed standard. Readings from strips at time intervals are plotted consecutively to indicate a running process control. Processing trends can be determined by such a chart, and the laboratory can in relation to good quality set limits which should not be exceeded (Figs. 6-8).

A photographic picture strip con-

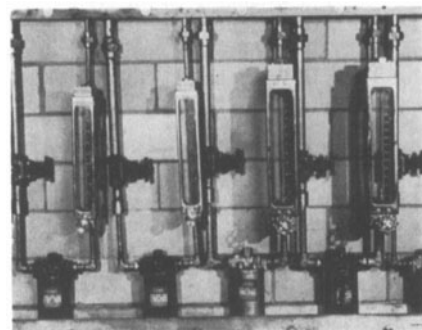


Fig. 3. Flowmeters.

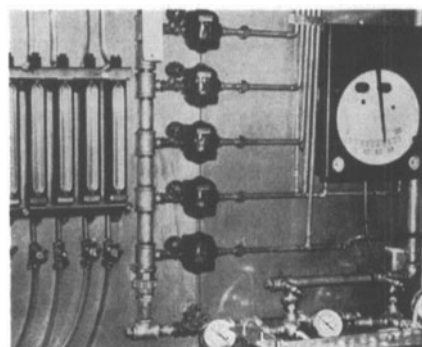


Fig. 4. Flowmeter calibration checks are made frequently for more consistent chemical control.



Fig. 5. Eastman Model 31A electronic densitometer used to measure processed strips.

taining a soundtrack is also processed along with each sensitometric strip. This picture strip is exposed on a production printer and provides a quick double check on sensitometric strips.

If both the sensitometric strip and the picture strip show a trend away from standard, the results have considerably more significance than when a single strip varies independently. This method of checking is often quite valuable in detecting processing variations. Picture control strips are also useful in observing the mechanical action of sound applying equipment.

While all methods of processing control are valuable and necessary, the importance of the interpretation of the

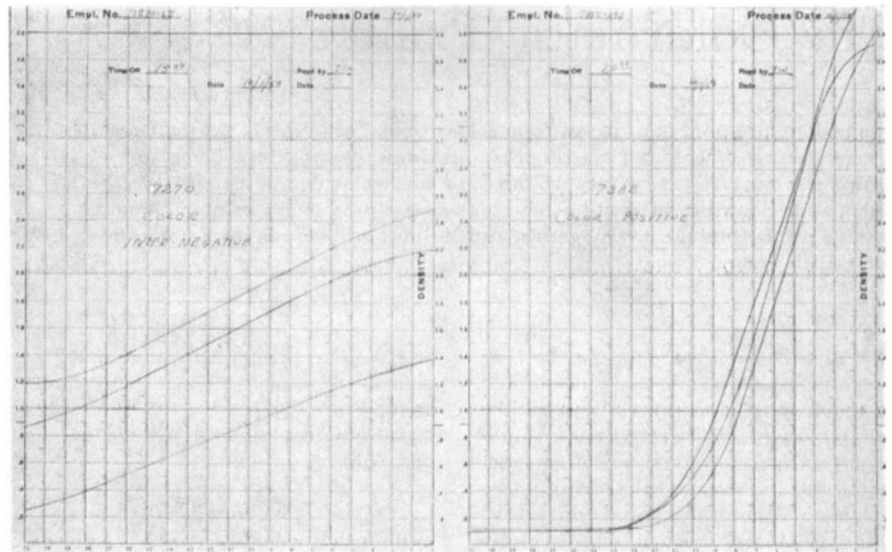


Fig. 6. Plots of internegative and color positive sensitometric strips.

data thus obtained must not be overlooked. We have found that processing control personnel must make a quite general, unbiased examination of all data received to maintain a consistent process. The chemist, the equipment maintenance technician, and the photographic control technician must work as a team with an open and inquisitive mind for the proper evaluation of control data.

All operations of printing and processing controls are closely interconnected, so for good print quality and

uniformity, the actual inspection of finished prints must be regarded as one phase of processing control equally as important as earlier phases.

It is the print that is delivered to the customer, so careful inspection of the finished print is necessary as a final point of processing control. It has been found that during the print inspection the observation of printing and processing conditions or changes is helpful in the evaluation of uniform operating conditions of both processing and printing controls.

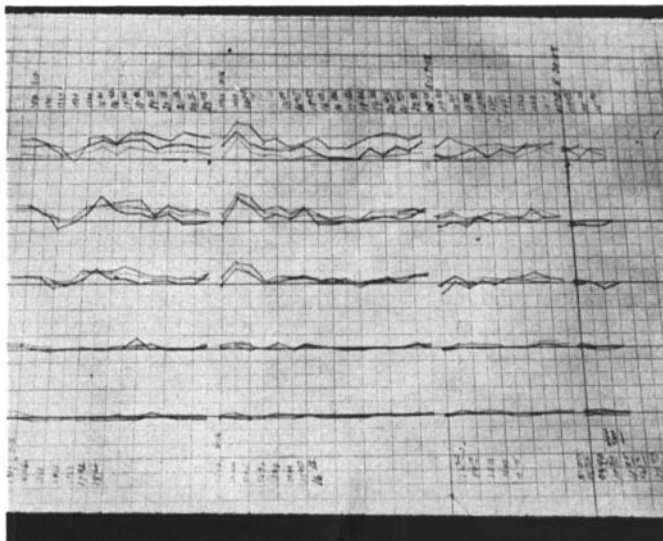


Fig. 7. Processing color control chart.



Fig. 8. Coordinating photographic and sensitometric control.