Processing KODAK Motion Picture Films, Module 1

Process Control

Table of Contents

1 PROCESS CONTROL

INTRODUCTION

Purpose

This is Module 1 of H-24, "Process Control," and a very important component of the *Manual for Processing KODAK Motion Picture Films*. It offers details on controlling the processes for all KODAK Films. Modules 7 through 15 cover the individual mechanical and chemical variations of recommended Kodak motion picture processes for negative, positive, and reversal films.

This module will serve at least two purposes: (1) to provide process control information for KODAK Motion Picture Films and processes; and (2) as a support tool for motion picture laboratory personnel training.

A process control system will enhance a process in laboratory operation by: (1) establishing a process standard or process aim; (2) maintaining a check on the day-to-day status of the process; (3) providing a record of behavior for the process; and (4) providing a diagnostic tool if the process needs to be adjusted back to the established standard of process aim.

Quality and Cost

Equipment and labor costs incurred in a process control system are easily justified by savings realized through decreases in makeovers, savings in chemical costs, and by continued laboratory customer satisfaction. Chemical and/or mechanical shifts that can occur during the processing of motion picture film are complicated and numerous. Some factors that affect the final appearance of the processed film quality are: chemical composition of processing solutions, temperature of solutions, film immersion time, agitation, and conditions particular to the processing machine used. Other areas, such as developer aeration, submerged or non-submerged rollers, and film alignment at crossovers, are also important considerations.

The film manufacturer determines and controls the unprocessed film quality to the point of delivery to the customer. The process designer determines and specifies process factors, but the laboratory user must control them. The machine manufacturer sets processing machine conditions as specified within machine design constraints specified by the process designer and the film manufacturer, but the laboratory user must control these also. By defining and establishing values for as many of these factors as possible, the process control system will ensure repeatability in processed film quality.

Selecting a satisfactory operating range, or process level in a process control system is essential. Then, with the correct amount of control, producing acceptable, processed film becomes routine. Attempting to process within too restricted an operating range can lead to an over-controlled process, which usually increases variability. Measurements taken and acted upon before the system has stabilized from the last change result in a control system that is never truly dependable.

Deriving Specifications

During the research and development work on KODAK Motion Picture Films, scientists and engineers evaluate various possible modifications in both film and process. Experienced film designers and evaluators select the film/process combination that gives the best overall end product. From these results come the recommended mechanical, chemical, and sensitometric specifications for processing KODAK Motion Picture Films. The individual processes are presented in specific modules of the *Manual for Processing KODAK Motion Picture Films*, KODAK Publication H-24.

When setting up a process in your laboratory, you carry out a similar evaluation and testing program on a smaller scale. This evaluation serves to fine-tune the film/process combination and to achieve the desired sensitometric level of the process. A known standard film is the nonvariant; and conditions of the laboratory operation, processing machine, and preferences of experienced observers are the variables.

Once you establish processing specifications that produce satisfactory results, you must maintain these specifications in day-to-day operations. Recommended mechanical specifications with defined tolerances are presented in the H-24 module that describes your process. However, in all likelihood, these recommendations will need to be slightly altered because of equipment and operating considerations, and this is accepted as normal for any operation. It is extremely rare for any laboratory operation to match the exact criterion as recommended by the manufacturer. The goal is to achieve a desired quality level that very closely approximates the aim established by the film manufacturer.

Any uncontrolled deviations from specifications usually affect all films, but to a different extent. Do not assume that a corrective change in one specification can be compensated for by a change in another, or that any combination of changes that worked in the past will always produce satisfactory results for the future.

As a service to customers, Kodak periodically conducts process surveys. Not only are these surveys meant to help the customer, but to help Kodak scientists and engineers better understand product performance with the many and varied processes, worldwide.

If you would like to participate in a survey or have a concern about the quality of the KODAK Motion Picture Film products that you are producing, contact your Kodak representative.

DAY-TO-DAY PROCESS CONTROL

Process Control Tools

Some key tools of process control are:

- mechanical controls
- chemical analysis
- sensitometry
- densitometry
- picture evaluation
- interpretation

To obtain consistently high-quality film processing, your laboratory must employ dedicated personnel, observe methodical procedures, and have adequate control equipment.

Mechanical control and chemical analysis provide information on the condition of the non-film components of the process. Sensitometry/densitometry and picture evaluation report on the film/process combination. Record keeping is the unifying agent of a process control system that provides a history of the process and allows an objective evaluation of day-to-day variations in the process. Interpretation and good judgment determine the consistency of acceptable results.

Mechanical Control

There are many mechanical factors that affect the quality of processed film. The individual modules of this manual for each process specify the mechanical necessities for that process. Periodically, check machine parameters such as solution immersion times and temperatures, replenisher flow rates, recirculation rates, and turbulation pressures; always make adjustments if necessary. Be sure all of these specifications are recorded and kept in a safe place for each piece of equipment. Enter actual out-of-spec readings on the sensitometric Process Record Form H24F or Y-55 (discussed later) to aid in interpretation of process fluctuations. Use the checklist shown in the appropriate H-24 process module at start-up, during processing, and shutdown. Module 2, *Equipment and Procedures*, contains a method for measuring and calibrating flow rates, and shows a typical flowmeter calibration curve.

Chemical Control

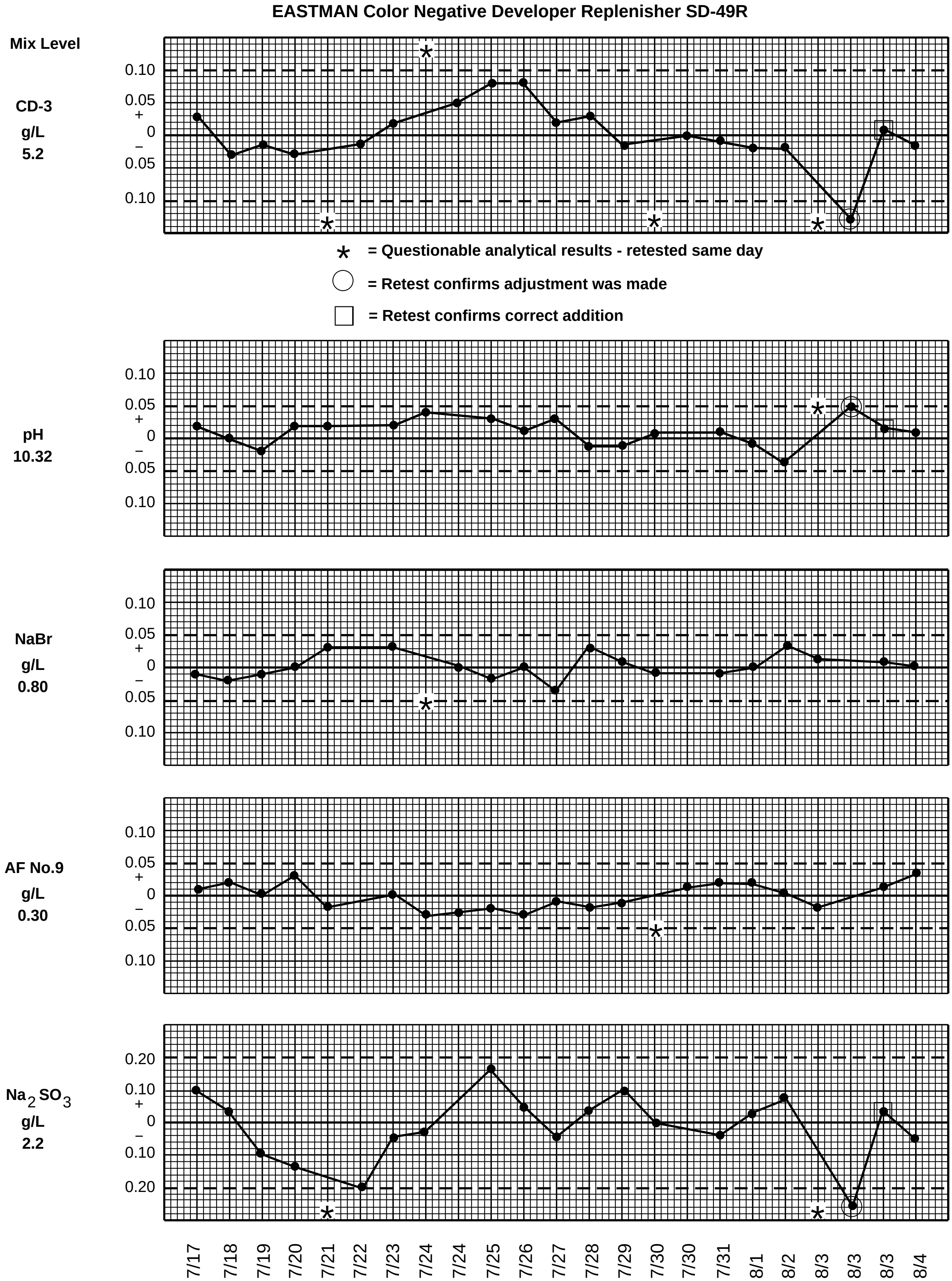
It is strongly recommended that you perform chemical analysis on all newly mixed fresh tank solutions and replenishers (if mixed from individual bulk chemicals before introducing them into the system) and periodically on each working tank solution. This routine analysis and relatively simple procedure will save invaluable time and money if an error is discovered. Record the analytical results graphically on a process record form as illustrated in Figure 1-1, *Chemical Analysis Record*. An incorrectly mixed replenisher solution that enters the machine will cause process control problems and could damage customer film. Gross mixing errors can require dumping of both machine and replenishers tanks and replacement of expensive chemicals, which cause lost machine production time (two serious and costly events). Regular analysis of machine-tank chemistry aids in actual process control, provides clues necessary to troubleshoot a process that is shifting sensitometrically, and may indicate a need for a replenisher chemical or flow adjustment. H-24 Modules 8, 10, 12, and 15, on effects of process variations (mechanical and chemical) for each process, give recommended analytical method numbers and frequency of analysis. Modules 3 and 4 contain analytical methods and reagent preparations.

Sensitometric Control

The word sensitometry is derived from two Latin words meaning “sensitivity” and “measurement;” it is the procedure of measuring how photographic emulsions respond to exposure and processing.

The chemical reactions involved in processing motion picture films are so complex that it is difficult, and in some processes, impossible to evaluate and control a process with mechanical and formulation data alone. Processed film is the most sensitive indicator of the film and process combination, and this is where the first indications of any change in the process will be noticed. A change will also be noted if the control strips are poorly stored or solutions are mixed with inferior chemicals. Sensitometric control strips, a process-monitoring tool, provide a quantitative measure of the entire processing system—film, process solutions, and machine. If there is more than one processor for the same type of process (e.g. ECP-2D), use separate control strips for each machine to ensure consistent results.

Figure 1-1 Chemical Analysis Record



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Densitometry

Densitometry is a measurement of the density, or opaqueness, of a photographic film, and is necessary in the practical application of sensitometry.

Plotting your sensitometric control-strip data on an *EASTMAN Process Record Form*, H-24F or *EASTMAN Process Record Form*, Y-55*, with the application of densitometry provides a continuing record of your process condition and helps to determine the type and degree of remedial action required to maintain the process within tolerance limits. These control data numbers are obtained with the use of a precision transmission densitometer.

A densitometer is a complex electronic instrument that must be calibrated and maintained properly. The use of a densitometer is the only precise method of judging the quality of processed films.

At the start of each work day, carefully set up and calibrate the densitometer as recommended by the manufacturer. Pay particular attention to the settings, the method of zeroing and calibrating, and the maximum densities. Once the densitometer operation is certified, periodically monitor it with a standardized check plaque to ensure repeatability. A reading of any reliable plaque measures the stability of the instrument as a whole (the filters and photometric components specifically). Handle and store the check plaque carefully to avoid fingerprints or scratches which will affect the calibration of the densitometer.

If a pattern of erratic readings or a trend away from normal is determined by inspection of the check plaque readings, some action is required. This action may include readjustment of the densitometer, or replacing faulty components, such as filters or electronic parts. If any equipment changes or adjustments are made, you must re-calibrate the instrument. You must also re-establish the reference aims numbers for the process control charts.

Densitometers are not absolute instruments and can vary from one to another. For this reason, the process control strip must be read on the same instrument as the control reference strip. Comparative readings on the same instrument are the only ones that are valid. Do not use one densitometer for the reference and another for the control readings for any tests or comparisons, regardless of how close the instruments match.

It is possible that variations in control plots can also be caused by reading procedures. Always read control and reference strips with the emulsion side up, or towards the receptor. While reference and control strips have been designed to provide minimum variation within each patch, always read the center of the patch to lessen the effects of potential development variations at the edges.

* Available from Eastman Kodak Company, Advertising Distribution, Rochester NY 14650-3009. (H-24F CAT No. 818 9607; Y-55 CAT No. 155 7164.)

Pictures

In addition to sensitometry and densitometry, picture tests are essential to evaluate subjective aspects such as color reproduction, sharpness, graininess, and processing uniformity, since the eye is the final judge of both quality and desired screen color balance. Design the test pictures to contain high and low brightness scenes, and colors with hues easily remembered. Also, always include typical scenes as exposed and supplied by your customers. These scenes will represent the appearance of the film as expected by the customer, and will give you a reference that you have both agreed upon.

Record Keeping

Record keeping preserves the results of observed mechanical factors, chemical analysis, and sensitometry. Your records show a history of the process, give indications of repeating problems, and document the corrective actions that have been tried, successfully or not. Records of machine-tank analysis help to provide the answers when sensitometric controls indicate that the process is shifting. Inaccurate or incomplete record keeping can invalidate a process control system, and every detail is essential.

Interpretation

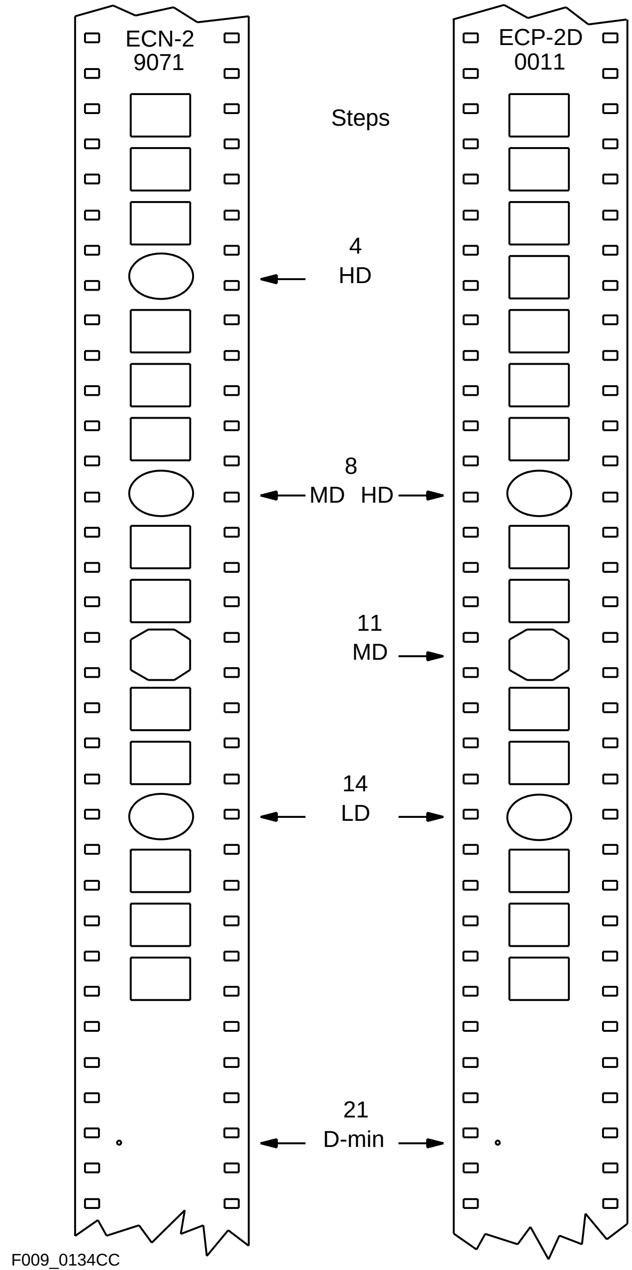
Interpreting control values requires evaluation consistency in all parts of process control. You must understand the meaning of the various changes or trends noted on the control plot, whether they are known changes, or a process problem. One trend indicator may show a need for a processing adjustment, while the cause is known to be the result of low or high daily product volume, where simply a temporary change of replenishment rate may be called for. Another common trend may be an indication showing a shift the first day of processing after a long shutdown, where additional leader run time may stabilize the process. These two examples of trends must be recognized because of their specific and somewhat routine or repetitive behavior. Being familiar with routine swings in the control plot structure will help greatly with the interpretation of the control chart so that overreaction does not take place. Expertise in the matter of interpretation is an important key for a smooth process control operation.

Control Strips (pre-exposed)

For the convenience of laboratory customers, Eastman Kodak Company provides convenient sensitometrically exposed control strips, confined within manufacturability limits for Process ECN-2, ECP-2D, VNF-1, RVNP, and black-and-white reversal motion picture film processing. These strips are provided as a tool to assist laboratory operators obtain the best possible pictures and to match the quality of the manufacturing limits as produced in KODAK Motion Picture Films. The film manufacturer is best qualified to recommend methods of obtaining the superior quality built into their products, and the use of these control strips will ensure this quality, if all appropriate processing action is adhered to as specified. Kodak does not provide control strips for the black-and-white negative (D-96) or positive (D-97) processes. Process VNF-1 control strips are also used for Process RVNP. To be a reliable control tool, all control strips in a batch must be alike. Therefore, control strips and reference strips are prepared from carefully selected emulsions and exposed and calibrated under precise conditions. Each strip is exposed with a consistent light source through an unchanging standard attenuator, such as the photographic step tablet.

Kodak produces process control strips in 16 mm and/or 35 mm rolls for the processes listed above. Each control-strip package contains a 30.5 metre (100-foot) roll having at least 120 exposures and a processed reference strip. Individual strips are 240 mm (9.5-inches) long with a 25 mm (1-inch) space between strips. Control strips for Processes ECP-2D have 21 gray-scale steps (1/2 camera stop, 0.15 log H increments). Control strips for Processes ECN-2 have 21 gray-scale steps (2/3 camera stop, 0.20 log H increments). There are actually 20 exposed steps, plus the minimum density. Control strips for Processes VNF-1 or RVNP and black-and-white reversal processing have 11 gray-scale steps (1 stop, 0.30 log H increments), and 10 exposed steps, plus maximum density. The reference strip accompanying each roll is exposed along with all other control strips; it is then processed under specified well-controlled conditions. An instruction sheet enclosed with the package contains process correction factors, if they are required, to determine your laboratory process aim numbers. A four-digit code number appearing on the carton, can, control strips, reference strips, and instruction sheet, identifies each production batch of strips. Figure 1-2, *Process Control Strips*, shows simulated typical 35 mm control strips for Process ECN-2 and Process ECP-2D.

Figure 1-2 Process Control Strips



Control Strip Expiration Dates

It is very important to always use fresh control strips to ensure consistency in process monitoring. Because the exposed latent image on all film changes to some degree with age, each control-strip package is dated at the time of manufacture, and the strips must not be used beyond the expiration date indicated. This expiration date is also very important when ordering the control strips to prevent over-ordering. Initially, you should order a quantity that will last well within the expiration date of that particular batch. This is easily determined by the average number of strips used each day and the length of each strip. However, with some experience of quantity needs, it is always advantageous to order as large a supply as possible of the same batch (code) number to continue on the same aim numbers as long as possible.

The control strips are latent-image stabilized to some extent during manufacture, but cannot be permanently stabilized, and this is why expiration dates are necessary. It is very important to keep the control-strip supply frozen (-18°C, 0°F) to slow the aging process.

Currently, Kodak produces process control strips for five motion picture film processes. When a new batch of control strips is manufactured, a representative product and emulsion is chosen to give the best results for process/film interaction sensitivity for each of the five processes.

USING PROCESS CONTROL STRIPS

Control Parameters

The objective control-strip parameters used for process control evaluation are the measured density values of the designated control steps and calculations from the density values. The control parameters are: a base or Minimum-Density step (D-min); a Low-Density (LD) step, which represents the characteristic curve toe; a film speed step, which is the Mid-Density (MD); a High-Density (HD) step, representing the picture blacks but not necessarily the maximum density (D-max); a calculated contrast parameter (black-and-white films); and a calculated Color-contrast and Balance parameter (CB). The contrast parameter is the difference between a high density and the designated lower density for a particular product, and is a very important indicator of process performance. The color balance parameter (CB) is the density spread or difference between any two colors of an individual step.

The control steps for Processes ECN-2, ECP-2D, VNF-1/RVNP, and black-and-white reversal control strips are listed in Table 1-1, *Control Steps*, and shown in Figure 1-3, *KODAK VISION Color Negative Film*, Figure 1-4, *EASTMAN Color Print Film*, and Figure 1-5, *EASTMAN EKTACHROME Film*.

Table 1-1 Control Steps

Process ECN-2	Process ECP-2D	Processes VNF-1/RVNP	Black-and-White Reversal
D-min (opposite dot)	D-min (opposite dot)	D-min (Step 1)	D-min (Step 1)
LD (Step 14)	LD (Step 14)	LD (Step 4)	LD (Step 5)
MD (Step 8)	MD (Step 11)	HD (Step 7)	HD (Step 7)
HD (Step 4)	HD (Step 8)	D-max (opposite dot)	D-max (opposite dot)
HD – LD (Steps 4-14)	HD – MD (Steps 8-11)	HD – LD (Steps 7-4)	HD – LD (Steps 7-5)
(Use Status M Densitometry)	(Use Status A Densitometry)	(Use Status A Densitometry for color, Visual for black and white)	(Use Status A Densitometry for color, Visual for black and white)

Figure 1-3 KODAK VISION Color Negative Film

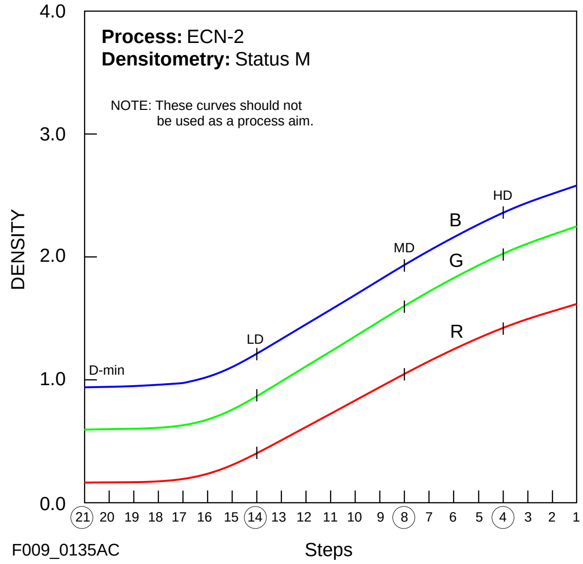


Figure 1-4 EASTMAN Color Print Film

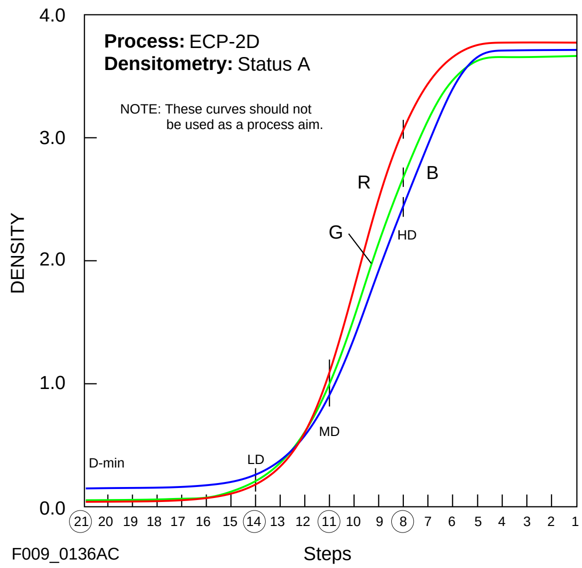
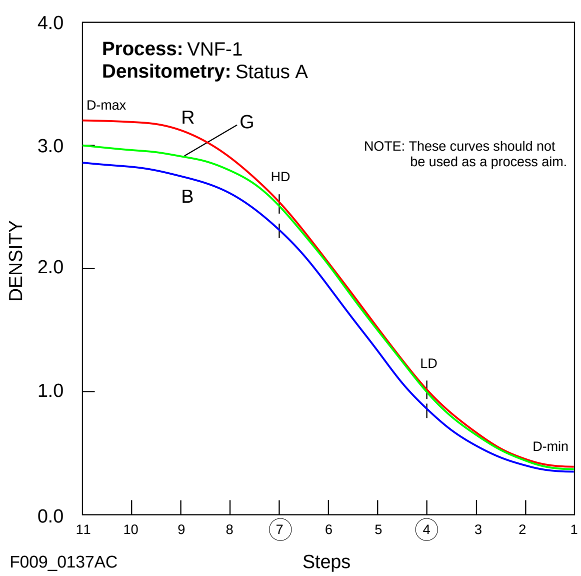


Figure 1-5 EASTMAN EKTACHROME Film



Store your supply of control strips in a freezer at -18°C (0°F) or lower. Always allow the can of control strips to attain room temperature before opening (possibly $^{1}/_{2}$ to 1 hour). Do not use a source of heat to accelerate equilibrium; however, placing the can in front of a fan that is circulating room-temperature air is acceptable. Handle control strips only in total darkness and by the edges to avoid fingerprints and surface damage. At the beginning of each day, and in the dark, remove only a day's supply at a time from the control-strip package and place in a lighttight container. Reseal and return all unused strips to the freezer as quickly as possible. Store the "working" strips at room temperature, 27°C (80°F), or lower, until they are processed.

A highly recommended way to prepare the strips for processing is to break down the entire batch (or at least one 30.5 metre [100-foot] roll), into individual containers (35 mm film cassette containers are ideal) and then place all containers into the freezer until needed. They should require no, or very little warm-up time prior to processing. This method eliminates repeated thawing and refreezing, lessening the potential latent-image change due to aging at room temperature.

There are no physical indicators on the exposed control-strip roll, such as dimples or notches denoting the location of the exposures. To be sure you have a complete 11- or 21-step exposure, the control film length to be processed should be at least 690 mm (27 inches). This yields about 45 strips from each 30.5 metre (100-foot) roll. As a precaution against possible latent-image fading that can affect reliability of the sensitometric information, discard any unused control strips, which were kept at room temperature, at the end of the day. If film sticking, static markings or moisture spots occur, allow the package to stabilize to room temperature longer than normal before opening, but do not keep the package out of the freezer longer than necessary when removing the day's supply.

The 30.5 metre (100-foot) roll of control strips is wound with the emulsion side in and with the low-density end of each strip toward the outside of the roll. The low-density end comes off the roll first; enter it into the processor first. However, always have the strip enter the processor in an identical direction for each process run to minimize possible directional process effects.

For processing frequency, a rule of thumb is to process one strip every hour to maintain an adequate check on the process. Only experience will determine the ultimate control-strip processing frequency need.

Also, use the control strips to establish and monitor forced (pushed) processing.

Reading Control Strips

Use a precision transmission densitometer, as noted earlier, that provides Status M densitometry (as print film sees negative material) when reading the reference and control strips for Process ECN-2. Use Status A densitometry (as our eyes see an image) for Processes ECP-2D, VNF, and RVNP, and Visual for black and white.

It is very important to check the densitometer at the beginning of each day and also later in the day to keep it in calibration during use.

Determining Aim Values

1. The first time you use a new batch of control strips, remove the reference strips from all cartons and store them separately in a dry place, out of direct sunlight.
2. Using the appropriate status densitometry, read the densities of the designated steps as listed in Table 1-1, *Control Steps*. If there is more than one roll of the same batch, average the corresponding step densities for all reference strips in the batch, even though the differences should be minimal.
3. Apply (add or subtract) the supplied "correction factors" to these densities to obtain "aim number" values. These aim numbers are the zero (0) reference line on the process record form. The correction factors for each batch of strips are printed on the instruction sheets (Figure 1-6, *Sample Instruction Sheet*) enclosed in the carton with the control strips. Table 1-2, *Typical Correction Factors for Process ECN-2*, lists an example of correction factors for an individual control-strip batch or code number.

Table 1-2 Typical Correction Factors for Process ECN-2

Code Number 5122	Filter in Densitometer		
	Red	Green	Blue
D-min (opposite dot)	- 0.01	- 0.01	0.00
LD (Step 14)	0.00	0.00	+ 0.01
MD (Step 8)	0.01	+ 0.03	+ 0.03
HD (Step 4)	+ 0.02	+ 0.02	+ 0.04

Table 1-3, *Calculating Aim Values for Process ECN-2*, shows an example of the aim value number calculation. The "correction factors" bring this specific batch of control strips to an established aim which represents, in this example, an average process level for Process ECN-2. The correction factors also adjust for manufacturing inconsistencies, such as slight variations among emulsion batches, control-strip exposures, and reference-strip processing.

4. Calculate the aim values for your process contrast measurement. HD – LD (High Density minus Low Density) for Process ECN-2, Process VNF-1, RVNP, and black-and-white reversal. HD – MD (High Density minus Mid-Density) for Process ECP-2D. Table 1-3, *Calculating Aim Values for Process ECN-2*, shows an example for Process ECN-2.

Table 1-3 Calculating Aim Values for Process ECN-2

	D-min			LD			MD			HD			HD – LD		
	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Ref. Strip Dens. Reading	0.16	0.55	0.95	0.33	0.72	1.04	0.84	1.30	1.56	1.17	1.67	1.94	0.84	0.95	0.90
Corr. Factor	- 0.01	- 0.01	0.00	0.00	0.00	+ 0.01	+ 0.01	+ 0.03	+ 0.03	+ 0.02	+ 0.02	+ 0.04	+ 0.02	+ 0.02	+ 0.03
Aim Values	0.15	0.54	0.95	0.33	0.72	1.05	0.85	1.33	1.59	1.19	1.69	1.98	0.86	0.97	0.93

Note: Using Values from Table 1-2, *Typical Correction Factors for Process ECN-2*, and Figure 1-3, *KODAK VISION Color Negative Film*.

KODAK VISION Color Negative Control Strips

This package includes a Kodak-processed reference strip and a 100-foot roll containing approximately 120 control strips.

HANDLING: Handle in total darkness. Handle by the edges to avoid fingerprints and surface damage.

STORAGE: Store unused control strips at –18°C (0°F) or lower. In the dark, remove only a day's supply at a time from the frozen package; reseal and return the package to the freezer as quickly as possible. Place the daily supply in a lighttight container and store it at room temperature, below 27°C (80°F). At the end of the day, discard any remaining strips.

Keep the reference strip at room temperature, protected in its envelope when not in use.

USE: The low-density end of each strip is toward the outside of the roll and should go through the process first. The reference strip has been processed using UL bleach (ferricyanide bleach will result in the same values).

AIM VALUES:

1. Remove the reference strip from the carton.
2. Using Status M densitometry, read the red, green, and blue densities of the designated control steps on the strip.
3. Apply the correction factors below to these densities to obtain aim values.
4. Calculate the aim values for contrast (HD – LD).

Code No.	Correction Factors		
______	Red	Green	Blue
D-min (opp dot)	—	—	—
LD (Step 14	—	—	—
MD (Step 8)	—	—	—
HD (Step 4)	—	—	—

5. If the persulfate bleach is used, apply these Alternative Bleach Offset Factors to the aim values obtained in 3 and 4 above for all steps.

   (R = 0.00, G = – 0.11, B = – 0.02).

For further information on process control, refer to Module 1 of *The Manual for Processing KODAK Color Films*, KODAK Publication No. H-24.

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5. Using an alternative bleach requires additional density correction factors called *Alternate Bleach Offset Factors*, (Table 1-4). Apply these factors to the aim values determined in step (4).

Table 1-4 Alternate Bleach Offset Factors

Process Control Strip	Step Changed	Density Difference		
		Red	Green	Blue
ECN-2*	All	0.00	0.00	0.00
ECP-2D†	All	+ 0.01	+ 0.02	+ 0.03
VNF-1‡	11	+ 0.07	+ 0.10	+ 0.09
	7	+ 0.04	+ 0.05	+ 0.04
	4	+ 0.02	+ 0.03	+ 0.03
	1	+ 0.01	+ 0.03	+ 0.02

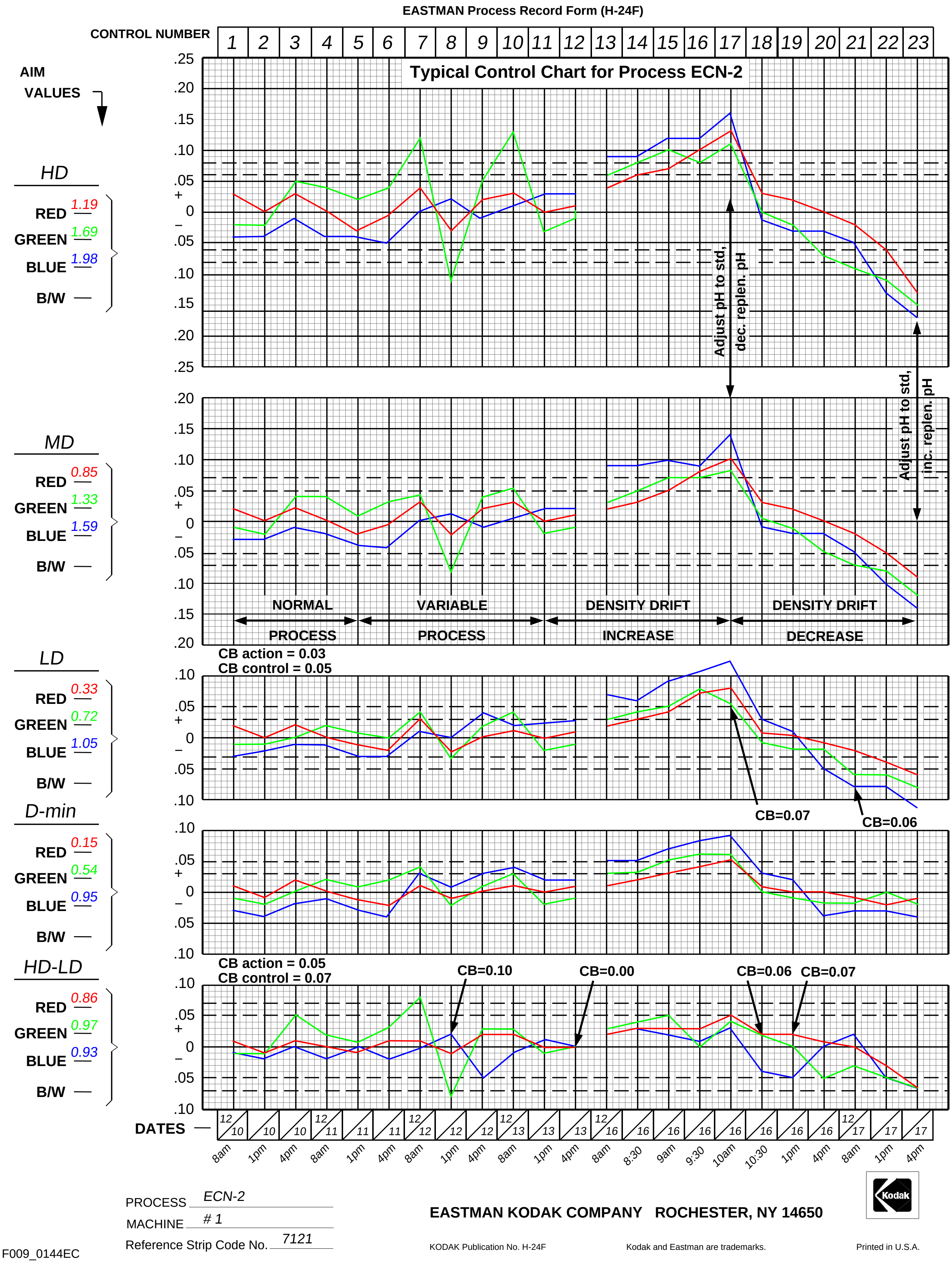
* There are no offset factors for Ferricyanide bleach. KODAK VISION Color Negative Film 5/7274 Control Film.
† Use of UL or Ferricyanide bleach as alternative bleach.
‡ Use of Ferricyanide bleach as alternative bleach.

As a special note with the use of bleaches, the black-and-white reversal process uses only dichromate bleach, and no offset factors are necessary.

6. Record the aim values determined in Step 4 or 5 on Process Record Form H-24F or Y-55 under AIM VALUES, as illustrated in Figure 1-7, *Typical Control Chart*. Record the "Code Number" of the batch of control/reference strips, in the lower left-hand corner of the form also.

7. Return the reference strips to their protective envelopes, and store in a dry, cool, safe place.

Figure 1-7 Typical Control Chart



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Control Values and Tolerances

Precise Action and Control limits for a given laboratory operation are based on statistical considerations and the quality demanded by your customer and reasonable costs to provide it. Recommended tolerance limits (action and control) for each process are given in Table 1-5, *Tolerance Limits*. Draw lines representing the action and control tolerance limits on the H-24F or Y-55 form as illustrated in Figure 1-7, *Typical Control Chart*. These limits are arbitrary, and could even change because of anticipated processing trends or experience. Once these limits are accepted, they should not be changed unless there is an agreement with all who have been relying upon them.

If reference strips, control strips, densitometer and processes were perfect, all correctly processed control strips would have densities identical to the reference strip densities, and all the control strip densities would plot on the zero (0) reference line. In practice, small but unavoidable variations in the process and control system (strips, desitometry, etc) contribute to variations in the control-strip densities. If the photographic effects that are associated with the plotted control values are not significant, the process can be considered in control. As the variations become larger, some limit (action limit) will be reached, at which time you should take corrective action. If the deviations increase to a wider limit (control limit) where photographic results fail to meet your quality standards, suspend film processing until you can confidently determine the precise cause of the off-standard process deviation. Be cautious however. At times, some plots will indicate an off-standard process even though the process may be acceptable. This is because of the many compounding variations in all aspects of process control. It is one reason for the note in the section on *Interpretation* about recognizing unusual control-plot swings that indicate an unacceptable process.

Table 1-5 Tolerance Limits

Process ECN-2

Step	D-min	LD	MD	HD	HD – LD	CB Spread Limits*	
	dot	14	8	4	4 – 14	LD	HD – LD
Action Limits	+ 0.03	± 0.03	± 0.05	± 0.06	± 0.05	0.03	0.05
Control Limits	+ 0.05	± 0.05	± 0.07	± 0.08	± 0.07	0.05	0.07

Process ECP-2D

Step	D-min	LD	MD	HD	HD – MD	CB Spread Limits*	
	dot	14	11	8	8 – 11	MD	HD – MD
Action Limits	+ 0.03	± 0.06	± 0.13	± 0.20	± 0.13	0.10	0.10
Control Limits	+ 0.05	± 0.08	± 0.15	± 0.25	± 0.15	0.13	0.13

Process VNF-1 and RVNP

Step	D-min	LD	HD	D-max	CB Spread Limits*	
	1	4	7	dot	HD	HD – LD
Action Limits	+ 0.03	± 0.08	± 0.13	– 0.20	0.10	0.11
Control Limits	+ 0.03	± 0.10	± 0.15	– 0.25	0.13	0.13

* The CB spread limits are the maximum allowable density differences between plotted control values of any two colors in a step (i.e. red-green, green-blue, or blue-red.

Determining and Plotting Control Values

Use the same densitometer to read your control strips that was used to read your reference strip, and always compare control strips and reference strips of the same code number only (unless crossing over to a new batch).

- Set up a Process Record Form (H-24F or Y-55) by adding the following information: (a) reference-strip code number; (b) the red, green, blue, or visual aim values for each control step; (c) the action and control limits for each control step; and (d) the process designation and machine number.
- Using the appropriate status densitometry, read the red, green, blue, or visual density of each control-strip step.
- Calculate the contrast parameter.
- Find the control value numbers by adding or subtracting the aim number (zero reference line) from the control-strip density for each control step.
- For example, in Figure 1-7, *Typical Control Chart*, Process ECN-2 control numbers for strips 1 and 2 had LD Step 14 red densities of 0.35 and 0.33 respectively. Therefore, the difference between the control-strip densities and the aim values would be the control values of + 0.02 and 0.00, respectively, as plotted from the "0" reference line.
- Plot each control value on the Process Record Form.
- Connect the plots to give a continuous graph for all strips processed.
- Record the control number of the control strip at the top of the Process Record Form.
- Record the date and time of processing the strip at the bottom of the form.
- Whenever making changes to the process or when the process plots out of control, record on the Process Record Form: (a) the reason and (b) corrective action taken. Such notations and the observed effect of the corrective action will help in making future decisions. Keeping very accurate records of actions and reactions can be invaluable, as future deviations may occur.

Interpreting Control Charts

A plotted control chart provides a continuous record of process performance as compared to the Process Aim represented by the Aim Values. In Figure 1-7, *Typical Control Chart*, hypothetical results are plotted based on using Process ECN-2 control strips. Strips 1 to 6 show satisfactory process performance. Each Process ECN-2 control strip in this series plots randomly (normal trend) about the reference lines well within the action and control limits and without large fluctuations or variability. The variations shown are considered normal, and not significant. Because of the nature of film, processors, and film/process interaction, some degree of fluctuation will always occur.

The next series of plots on Figure 1-7, *Typical Control Chart* (strips 7 to 11) indicate a process with excessive variability. The process is averaging about the process aim line, but it is cycling from one action limit to the other. Therefore, the negative film being processed during this time will also show these fluctuations, which may or may not be photographically significant. Now is the time to investigate and understand the reason for these wider movements.

Sometimes it may be necessary to exercise unusual judgment while interpreting the plotted processed film record. As an example: if, after processing a significant amount of footage, it is noticed that the process has drifted toward one of the control limits (high or low) and has remained that way, processing the balance of the footage at this same level could be advantageous for this customer. It may be better to have the entire negative processing run at the same level for consistency of timing, maintaining color balance, and contrast. Carefully determine how far the process can deviate and still yield acceptable screen quality. As an example, if the control chart indicates high contrast, this contrast may be compounded as it is printed through the master positive and duplicate negative steps, possibly leading to unacceptable picture results. This type of judgment usually comes only with many years of processing experience and knowing the customer.

Plots of strips 11 to 17 show a process drifting upwards into an out-of-control situation where action must be taken.

Results of hypothetical corrective action as shown by plots of strips 21 to 23 indicate the adjustment was too large, falling outside the lower control limit.

Correcting Out-of-Control Conditions

If a control value plots outside the control limits (not part of a known trend), follow these procedures:

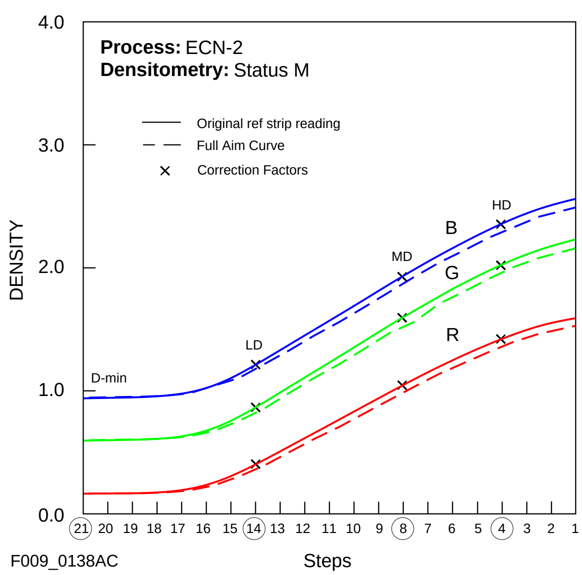
- Verify that the code number of the control strip is the same as the reference strip used to derive the aim values.
- Check the densitometer calibration by reading a densitometer check plaque. Then re-read the control reference strip.
- Check for obvious processing variations in machine speeds, temperatures, safelights, light leaks, replenishment rates, etc.
- Process another control strip to verify the data, since the earlier strip may have been scratched, fogged, etc. Read the new strip and plot the new control value.
- If the new control numbers plot within the action limits, take no action. The first control strip may have been handled incorrectly before or during processing.
- If the new control numbers plot outside the ACTION limit, you may continue processing customer film, but take action to bring the process back within the action limits.
- If the new control number plot outside the CONTROL limit, stop processing any film, and take immediate action to get the process back within the control limits, unless you deem it more beneficial to the customer not to, as outlined earlier.
- For various corrective actions, see the Diagnostic Scheme in the appropriate H-24 processing module for the product being processed.

Full Characteristic Curve Plot

To better grasp the performance of the products being processed, periodically compare a full plot of the entire process control characteristic curve to a full plot of the reference strip. To study the full characteristic curve, employ the reference strip that was used to determine the process aim values for the process being evaluated. Using the appropriate status densitometry, read all the densities of each control reference strip step (either 11 or 21 steps). Plot the density values and draw a smooth dotted line curve through the points as shown in Figure 1-8, *Full Characteristic Curve Plot—KODAK VISION Color Negative Film*. Apply the correction factors for the four control steps used to establish the aim values by marking with an X at the control steps above and below the dotted line curve. Using the dotted line as a guide, draw a smooth solid curve through the four new points, as appropriate, to somewhat follow the shape of the dotted curve. The new curve may not match the exact shape of the uncorrected dotted reference because the correction factor numbers may not be linear. This new solid curve is the full adjusted Aim Curve for this batch of control strips and your densitometer. Now make a full plot of the process control strip and compare it to the full plot of the corrected reference.

A full plot gives a much truer representation of how a particular process is performing than can be seen with only the four monitoring steps by seeing actual speed, density, color balance, and contrast differences. Periodically follow this procedure for each process. Contact your Kodak representative for assistance if questions arise.

Figure 1-8 Full Characteristic Curve Plot—KODAK VISION Color Negative Film



Control-Strip Crossover (using a new batch)

There will come a time when you will need to begin using a new batch of control strips. A new batch means a new code number, not a fresh box of strips with the same code number. **Please be aware** no two batches of control strips are identical. It is impossible to make them identical because of slight differences in product, exposures, process, etc. Therefore, the aim value numbers will not match (however, on rare occasions they could), even with the application of the correction factors.

When you first started using control strips, you had no previous reference and you set up your aim value parameters by reading the densities of the specified (D-min, LD, MD, HD, or D-max) control reference steps and applying the correction numbers supplied with that batch. Using a new batch of strips is really no different, except you will have a new set of aim numbers,

As the time approaches to change to a new batch (code), you will want to make a "crossover" from the current, or old batch. Crossover simply means to adapt to a change in aim numbers, not a change in processing technique. You should begin the crossover with at least a week's supply of strips still available (never wait until you run out).

The crossover to a new batch lets you get a "feel" for the new set of aim numbers. Do **not** attempt to match the new aim numbers to the old ones. If you do, you probably will find it necessary to change the mechanical and/or chemical specifications of the process, and this will most likely lead to a non-conforming unacceptable process. You will notice some differences in the way the new batch trends as compared to the previous batch. This is a normal batch-to-batch variation, and is to be expected. If you are unable to maintain a plot within your action limits with the new control-strip batch, call your Kodak representative to assist you.

Use the following crossover procedure each time a new code number is put into service:

- Determine the aim values for the new batch, the same as you did for the current or old batch by reading the specified steps (D-min, LD, MD, and HD or D-max) of the reference strip and applying the correction factors. If there is more than one roll of the same batch, average the corresponding step densities for all reference strips in the batch, then apply the correction factors.
- Process an old and new control strip simultaneously at least three separate times. Do this at different times of the day, and better yet, on different days, until you have a number of pairs. During this time, continue to control the process with data from the old strips.
- Post the new aim values on the same form as the old, leaving an appropriate space between the two aim sets (as illustrated in Figure 1-9, *Control-Strip Crossover for Process ECN-2*. This way you can see the differences of each control strip reaction at a glance. You will observe the tracking of the "old" batch as compared to the "new" batch, with each plotted to its individual set of aim numbers. Both should be tracking in similar directions, but not exactly. However, they still should be within the same action and control limits. Please remember, no matter how the aim densities differ in numerical value, you still use each set as your zero (0) reference line.
- Once you are comfortable with the new batch of control strips, use a new H-24F or Y-55 form to separate and not confuse the old and new aim numbers while making the daily notations.
- If, for some reason, there is a need to adjust the process to conform the new batch of control strips to new action and control limits, cease processing and evaluate the entire system. Such a need for change indicates a fundamental system difficulty, which most likely involves all aspects of the process, not necessarily a problem with the new batch of control strips. If difficulty continues, contact your Kodak representative.

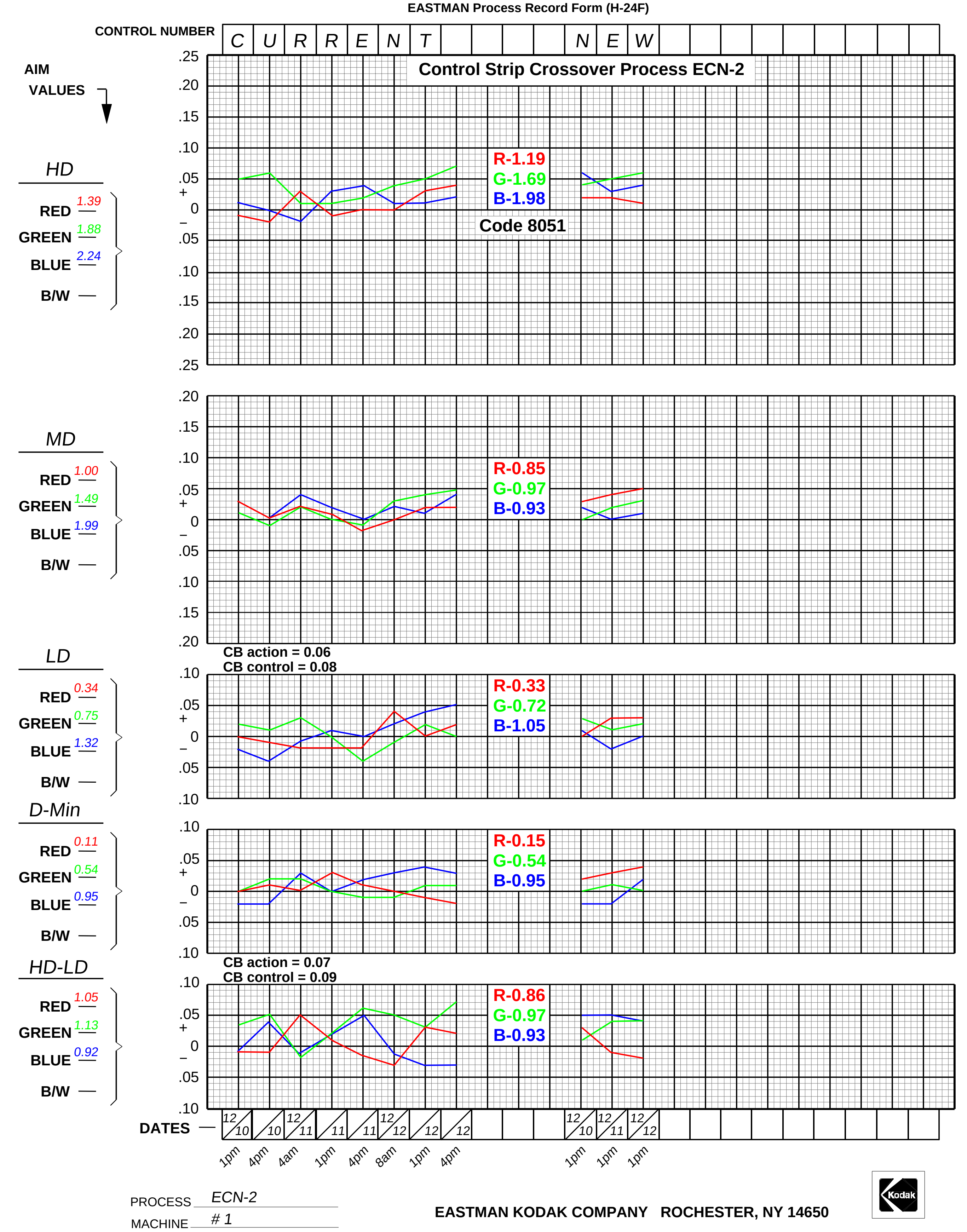
Summary

Every motion picture process designed for KODAK Films can be kept within accepted control limits with the use of Kodak's process control strips and close adherence to information in this publication. Knowledgeable monitoring and maintaining of process control will enhance repeatability in processed film quality and ensure consistent customer satisfaction.

Routinely using Kodak's process control strips should be a part of all quality film-processing operations. The use of these strips and the use of the Laboratory Aim Density (LAD)* system for printing and duplicating will ensure the highest screen quality of all KODAK Motion Picture Film products.

* KODAK Publication No. H-62, *LAD—Laboratory Aim Density*.

Figure 1-9 Control-Strip Crossover for Process ECN-2



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