



Process Control—A Better Way

The KODAK Q-LAB Process Monitoring Service has been created to serve you, the professional processing lab. Your final product is the color transparency. Your professional customers—the photographer, the art director, the publisher, etc—dictate the degree of excellence required in the transparencies you process. These customers judge the quality of the final images by viewing the processed transparencies. Many factors contribute to the variability of the final image: film, exposure, processing, and viewing conditions. The variability in each of these factors must be minimized to improve the quality and consistency of the image. Considerable effort is being made to continue reducing film variability. Exposure is controlled by the photographer. Viewing conditions are controlled by the end user. Q-LAB Service concentrates on what you, the professional lab, can control: Process E-6.

This section describes the process-control approach to achieving and maintaining high-quality results. It answers the following questions:

What is process control?

Why is process control necessary?

How do I achieve and maintain process control?

PROCESS CONTROL VS PRODUCT CONTROL

Suppliers of manufactured goods and services have historically monitored and assured the quality of their products through **product control**. They have monitored the final product and made adjustments to the process to maintain quality. Products have been visually and physically inspected and accepted for shipping to customers or rejected. Modifications made to a process that are based on the quality of the final product are curative and are oriented toward events that have already taken place.

For example, suppose you are monitoring your weight by weighing yourself once a week. If your weight is down, you might eat more; if it's up, you'd go on a crash diet. This way, you would be making continuous adjustments to your diet after monitoring the final product, your weight. The adjustments are curative, and do correct your weight, but they take place after the weight fluctuations have already occurred.

In Process E-6, the final product is the color transparency. Control strips for Process E-6 are *samples* of the final product. If you make an adjustment such as adding sodium hydroxide or increasing solution temperature *after* your control-strip plots indicate a problem, you are using *product control* rather than *process control*.

As new films are introduced and older ones are improved, films are made with newer, state-of-the-art emulsions. Today, many different films with varying emulsion technologies are processed in Process E-6 chemicals, and film sensitivities to variations in the process differ.



Businesses around the world are learning that the more economical method of quality assurance is **process control**. They ensure the quality of the final product primarily by monitoring the key variables in the manufacturing process to achieve consistency and stability. When they detect a change in the variable, they find the cause and correct it. This type of control allows them to detect and correct problems *before* they have any detrimental effects on the product.

For example, instead of simply monitoring your weight once a week, you could monitor the process of food intake. You would plan well-balanced meals, and keep track of your intake of calories. If you go off your diet by eating a hot-fudge sundae, you can reduce your intake of calories the following day. By monitoring the key variables in weight control and making adjustments before your weight is affected, you are taking preventive action.

In Process E-6, the key variables or process **parameters** are solution times, temperatures, replenishment rates, specific gravity, agitation, and

concentrations of certain chemicals such as bromide (in the first developer), reversal agent (in the reversal bath), and sulfite (in the color developer). When one of these parameters changes, you can find the cause and correct it before it has an adverse effect on the final product—the control strip or customer film.

When a process is in control chemically and mechanically, all the films will perform well and respond similarly to the small random variations that occur in a well-controlled process. In a process that is not in good chemical and mechanical control, all the films may not perform well, and may not respond in the same way as the control strip.

When you exercise process control, you will be able to fix the cause of the problem rather than compensate for its effect. Controlling the process by monitoring the key parameters—time, temperature, specific gravity, replenishment rates, etc—will provide optimum quality in the final images. You will still use control strips as a check on the process, but you'll place the emphasis on monitoring key parameters.

Process control reduces variability, which improves product conformance and consistency. Both the lab and its customers can rely on a consistent quality level. This provides the following benefits:

- Overall quality of processed film increases.
- The total yield of acceptable film, or processing capacity, increases.
- Waste of time, chemicals, and film decreases.
- Customer satisfaction increases.

Process control provides a common language between shifts, line production, suppliers, and customers when they communicate about performance. Experience shows that process control accomplishes two things: (1) costs are reduced; and (2) once process control is achieved, it tends to continue.

CONTROL CHARTS

A control chart is probably the simplest and most effective tool in achieving process control. The operator—the person closest to the process—maintains the chart at the job site. Lines indicating aims and

tolerances (or control limits) provide a standard of evaluation. Measurements plotted on the chart quickly show the distribution of data, and quickly identify an abnormal situation. The chart also tracks the influences of other factors such as materials, manpower, and machines,

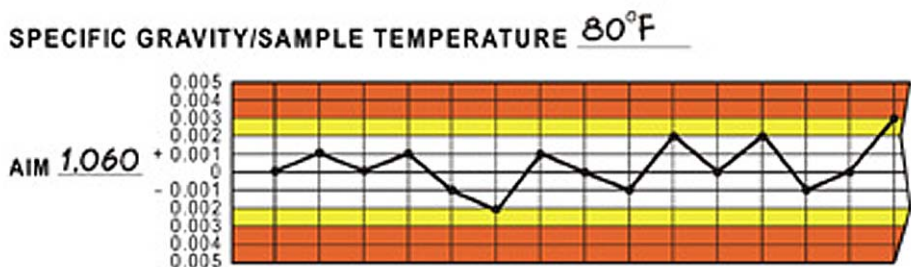
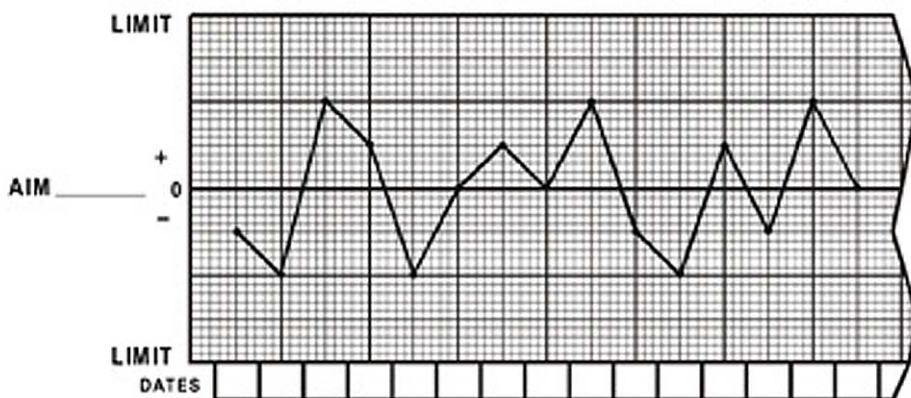
and shows the nature of changes over time. In process E-6, time, temperature, specific gravity, replenishment rates, and concentrations of certain chemical components are plotted against aims and tolerances.

Control charts are attractively simple. For every type of measurement you plot, the parts of the charts are similar: the aim line, the upper and lower tolerances (control limits), and the time axis.

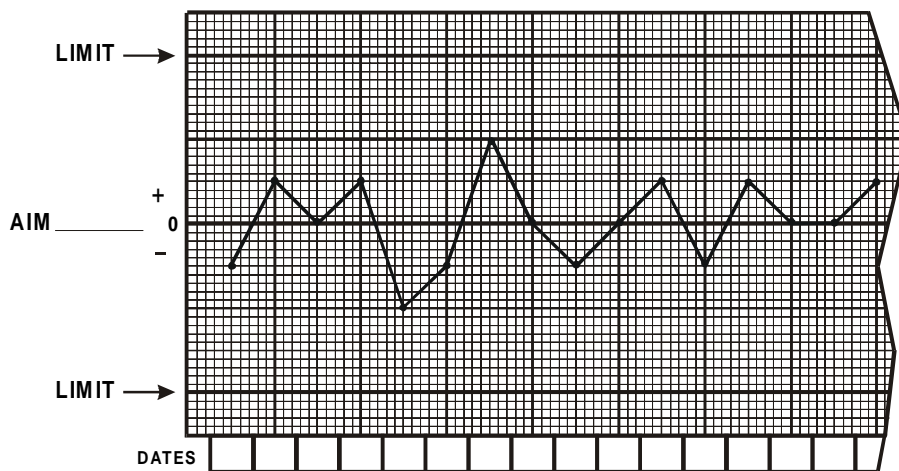
The **aim** line represents the degree of excellence required: the specification or standard. The **tolerance** lines define the range of acceptable variability from the aim.

For example, the specific-gravity aim for Process E-6 first developer is 1.060 (measured at 80°F [27°C]). The tolerance is ± 0.003 , so the lower limit is 1.057, and the upper limit is 1.063.

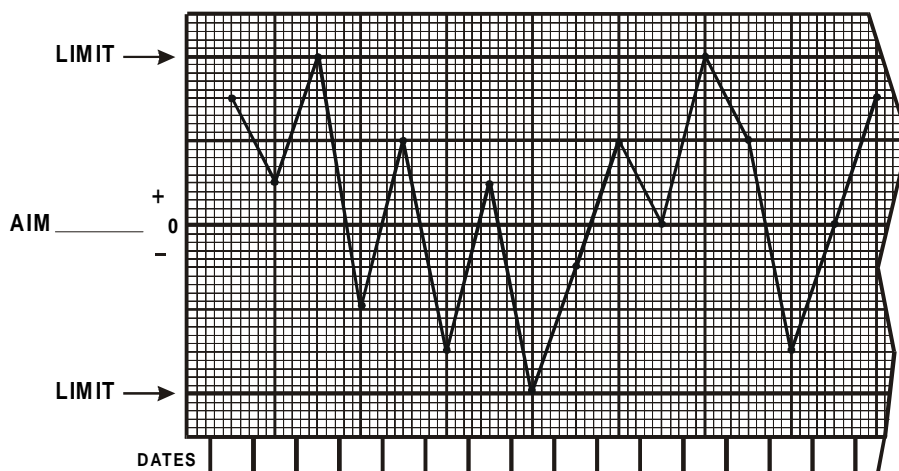
The **time** axis define the frequency of measurement. Sampling can occur at intervals of minutes, hours, shifts, days, or weeks. The sampling rate is important. Sampling should occur more frequently than typical process fluctuations; otherwise, changes in the process won't be detected. For example, if fluctuations occur hourly, sampling should be by the minute; sampling on a daily basis cannot detect hourly fluctuations.



If tolerances are wide and control is tight, the sampling rate can be decreased. If data are plotting well within the limits, fewer measurements are needed to verify that the process is in control.



If data are scattered out close to the limits, the sampling should be more frequent. The probability of exceeding the limits is high, so more measurements are needed to detect data that are on or outside the limits as quickly as possible.



Follow these steps when you use control charts...

1. Determine the process specifications: aims and tolerances. (Specifications for the Process E-6 solutions and washes are given in Sections 7 through 15.)

2. Regularly make the required measurements, and plot the data on the control charts. Make measurements carefully so that the data will be accurate. Procedures for making the measurements are given in *Process Monitoring: Chemical and Mechanical Parameters* (Section 4) and *Process Monitoring: Sensitometric Parameters* (Section 5).

3. Evaluate the results; look at the control charts for changes caused by out-of-control situations.
 4. Investigate causes of change.
 5. Take corrective action to eliminate the cause.
 6. Take steps to prevent recurrence.

Evaluating Control-Chart Plots

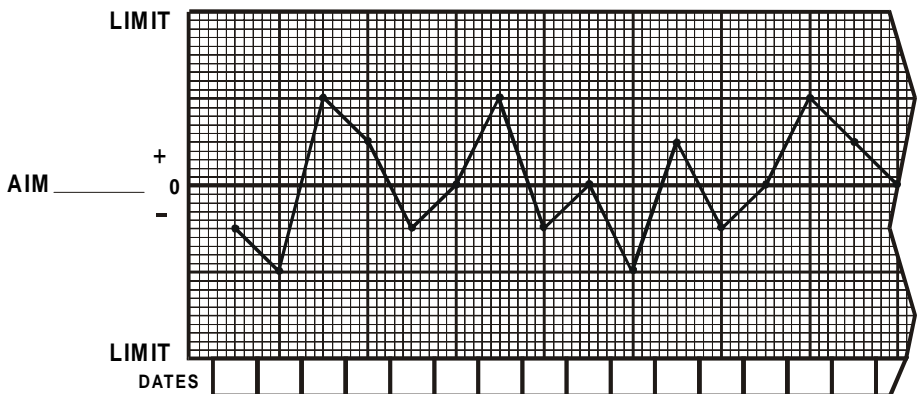
Plots can indicate two types of variations in a process: random and non-random. **Random variations** are inherent in any process, and they occur even when the process is running at peak performance.

Random variations are caused by chance and are normal; they are often called “process noise.”

Non-random variations have an identifiable cause: a change that is occurring in the process. These variations are abnormal and require investigation.

Process variations, both random and non-random, influence the distribution of data points on the control charts and identify the **state of control**.

Random variations plot within the limits. They do not form any particular pattern, and they are distributed equally above and below the aim line. A process is in control when the only type of variation is random. No corrective action is required. In fact, it is important to avoid *over-controlling* a process by reacting to random variations.



Non-random variations indicate a change in the process that requires investigation and correction. These types of plots indicate non-random data:

- Outliers (data on or outside the tolerance lines)
- Level shifts
- Trends
- Cycling

Pages 1-6 and 1-7 give examples of non-random data taken from measurements of the specific gravity of Process E-6 first developer.

Outlier (data on or outside the tolerance lines): A change occurs that causes a data point to plot on or outside the tolerance line.

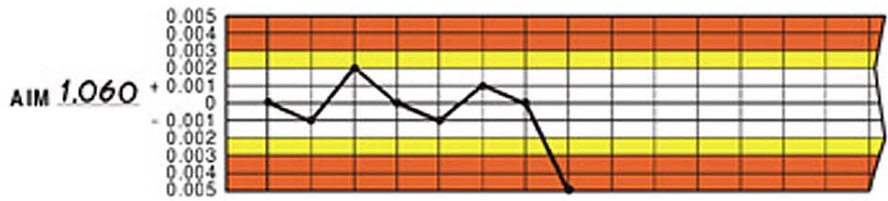
In this example, investigation led to a leaking pump, which allowed too much water to enter the tank and dilute the solution.

Important: Whenever a point plots on or outside the tolerance line, repeat the measurement to be sure the reading is accurate.

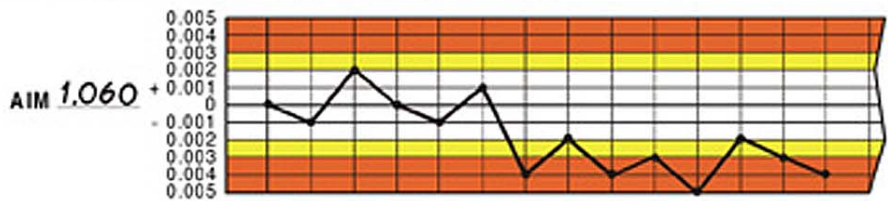
Level shift: Four to 8 consecutive data points fall on one side of the aim line. (Data points are not distributed equally above and below the aim line.) Something changes in the process to create the shift. The more consecutive points that plot above or below the aim line, the higher the probability that a process change occurred that requires investigation. If only 2 or 3 points plot on one side of the aim line, those points may be random noise. However, if a fourth point plots on the same side, a shift is likely. A fifth point increases the probability, etc.

In this example, the upward shift indicated a problem that required investigation. The cause was overconcentrated replenisher, which increased the concentration of the tank solution.

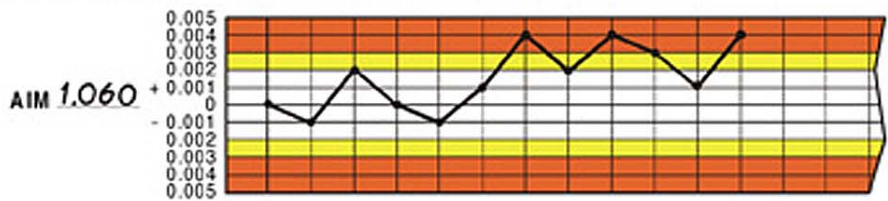
SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



The frequency of data collection determines how early a problem will be detected. In these two situations, the measurements were taken weekly. With

daily measurements, the leaking pump and the overconcentrated replenisher would have plotted as a trend, and would have been identified much sooner.

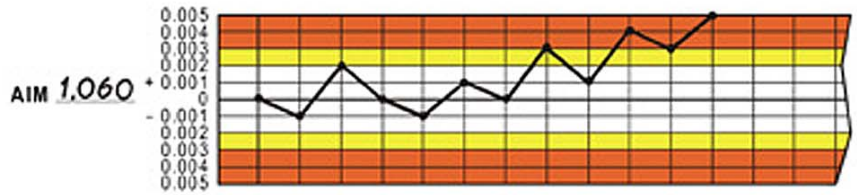
Trend: Four to 8 data points plot in an ascending or descending row. The higher the number of points in the row, the more likely that it indicates a trend.

In this example, the downward trend indicated a change that required investigation. The cause was underconcentrated replenisher.

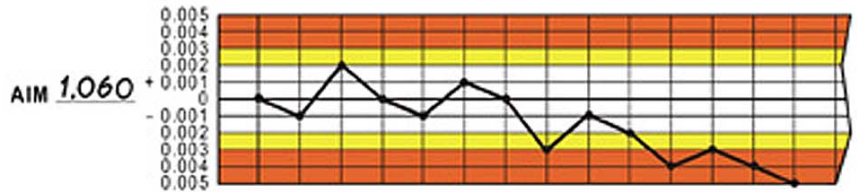
Cycling: The same pattern is repeated over equal intervals.

This example clearly shows a cycling pattern that required investigation. The upward spikes were caused by evaporation occurring during the day. Every morning, the operator topped off the tank with water, which produced the downward spikes. Routine specific-gravity measurements would have revealed evaporation as the probable cause, and permitted the lab to compensate for it by adjusting the replenisher and replenishment rate.

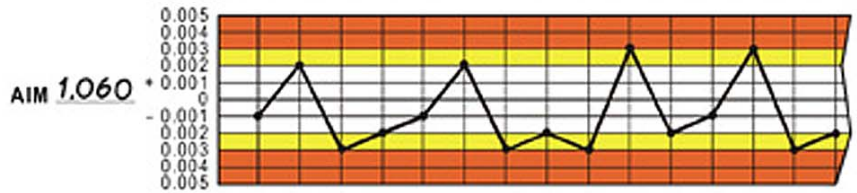
SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



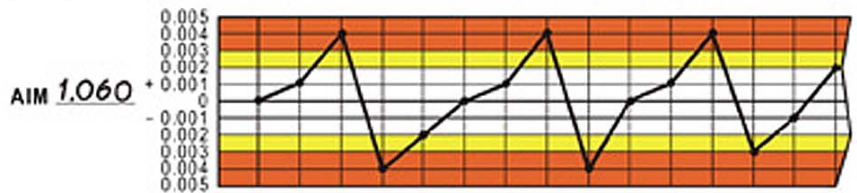
SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



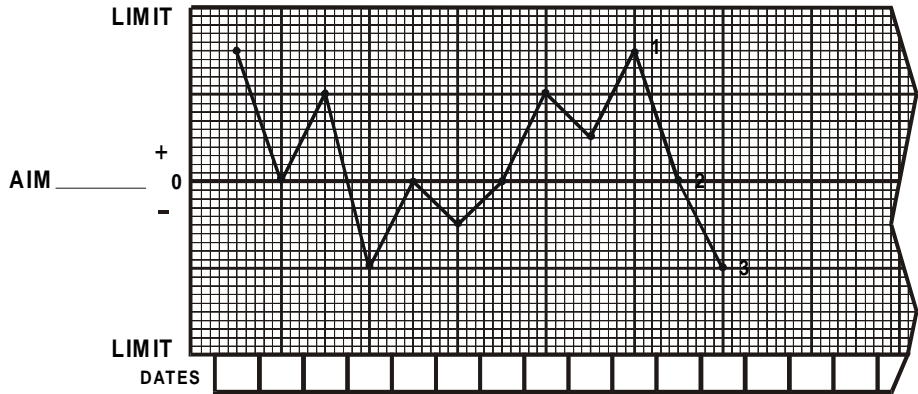
GOALS OF PROCESS CONTROL

Process control provides a means of finding and eliminating non-random process changes so that only random variability (noise) remains. If data

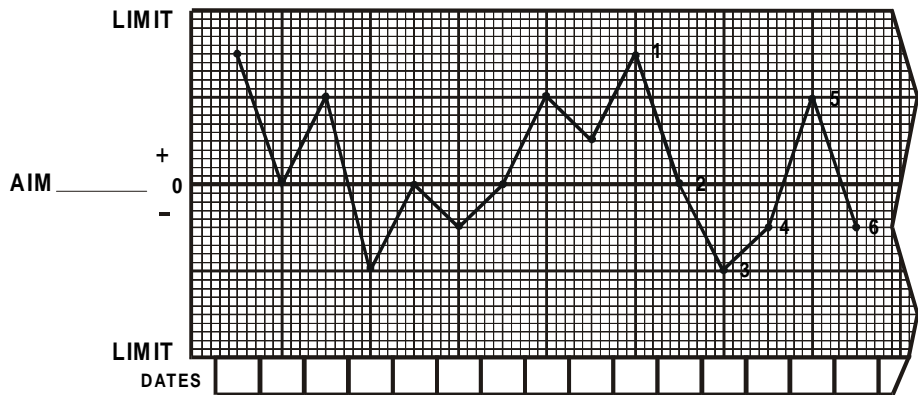
plot on or outside the limits or non-randomly (indicating shifts, trends, or cycling), the process change calls for prompt investigation. The more non-random data you encounter, the greater the likelihood of a significant process change.

Important: One to 3 data points may appear to be out of control, but can be just normal noise. Do not make process adjustments before investigating and confirming causes.

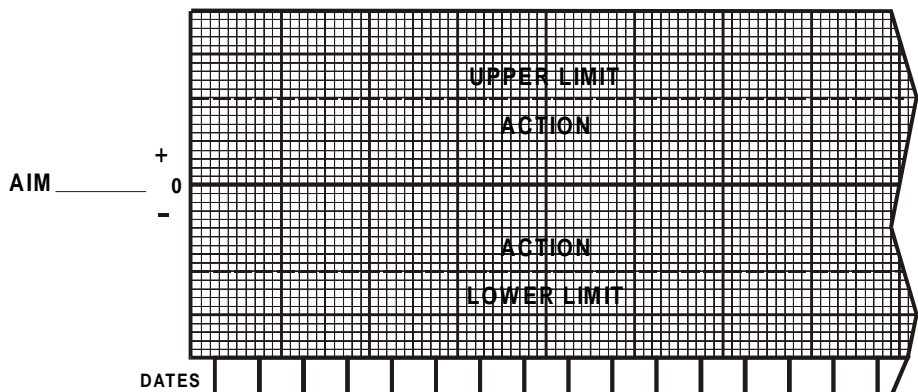
For example, this plot shows three points that appear to be part of a downward trend. You might be tempted to make an adjustment based on these points.



However, the next two measurements show that the three suspect points are process noise. An adjustment based on those three plots would have been unnecessary, or could even have adversely affected the process. Non-random data indicate investigations should take place; they do not necessarily mean process adjustments are needed. When in doubt, increase the frequency of measurement or sampling and see where the next several data points plot.



You will frequently use control charts with two sets of lines to help you determine when action is required. The inside lines (closest to the aim line) are usually called the *action* lines. When points plot on or beyond these lines, you must investigate the cause of the change. The higher the number of data points that plot beyond the action lines, the more likely that you will have to take action to prevent the process from going out of control.



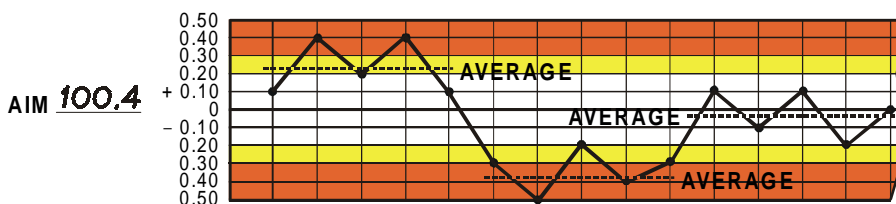
For successful process control, you must take corrective action to prevent recurrences of non-random variability. The action must be timely and correct to make the information you gather useful. To help identify causes of process problems, record all changes (in materials, operators,

methods, or machines) right on the control chart. For example, if a new operator takes over a process, write the information directly on the chart; if a new pump is installed, record it. If non-random data appears, the information on the chart can help to pinpoint the cause immediately.

When you first measure and record data for a process parameter, the data may not immediately plot around the aim line, and it may not be consistent. To establish process control, you must (1) make the process stable, and then (2) move the process toward the aim.

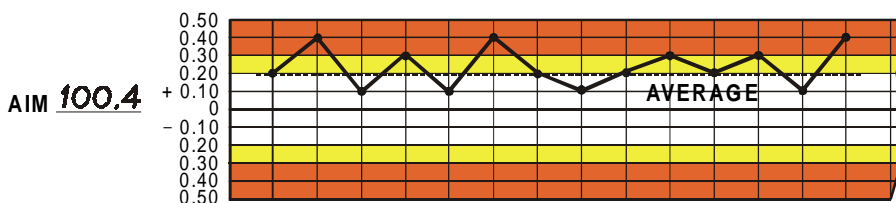
In this example, the process is not centered around the aim, and it is continuously changing, i.e., not stable. You can't move this process to the aim with one adjustment because the process average moves unpredictably. Every time the process average moves, another adjustment would be required to center the new average on aim.

TANK TEMPERATURE (°F)



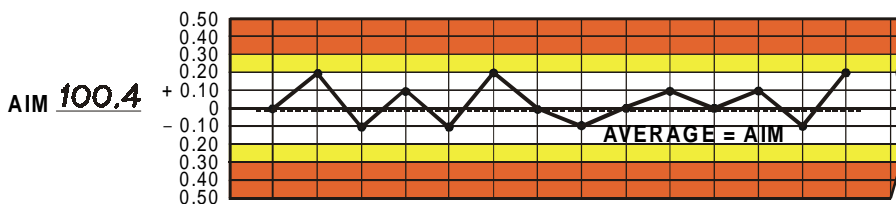
Your first step is to make the process stable by investigating and eliminating all causes of variation until the process has a predictable average.

TANK TEMPERATURE (°F)



Then you can make an adjustment to move the process to the aim.

TANK TEMPERATURE (°F)



Control charts provide information on process performance. If you gather and interpret the data properly, the chart will show you whether or not investigation and corrective action are needed.

A word of caution: Control charts cannot accept or reject the final product—the processed film. Charts only indicate whether or not you need to investigate changes and take action to adjust the process. You must evaluate the product yourself to decide whether you will accept or

reject it. For example, if specific gravity or temperature goes out of control, don't automatically assume that the product is unacceptable. But if you use process control properly, you should be able to correct any process changes before the problems affect the product.

PROCESS CONTROL FOR PROCESS E-6

As discussed earlier, *product* control involves monitoring the final product and making continuous adjustments to the process to maintain quality. In Process E-6, the control strip represents the final image. Unfortunately, if you base decisions about process

adjustments only on control-strip evaluation, the process can drift outside chemical and mechanical specifications. This causes three problems:

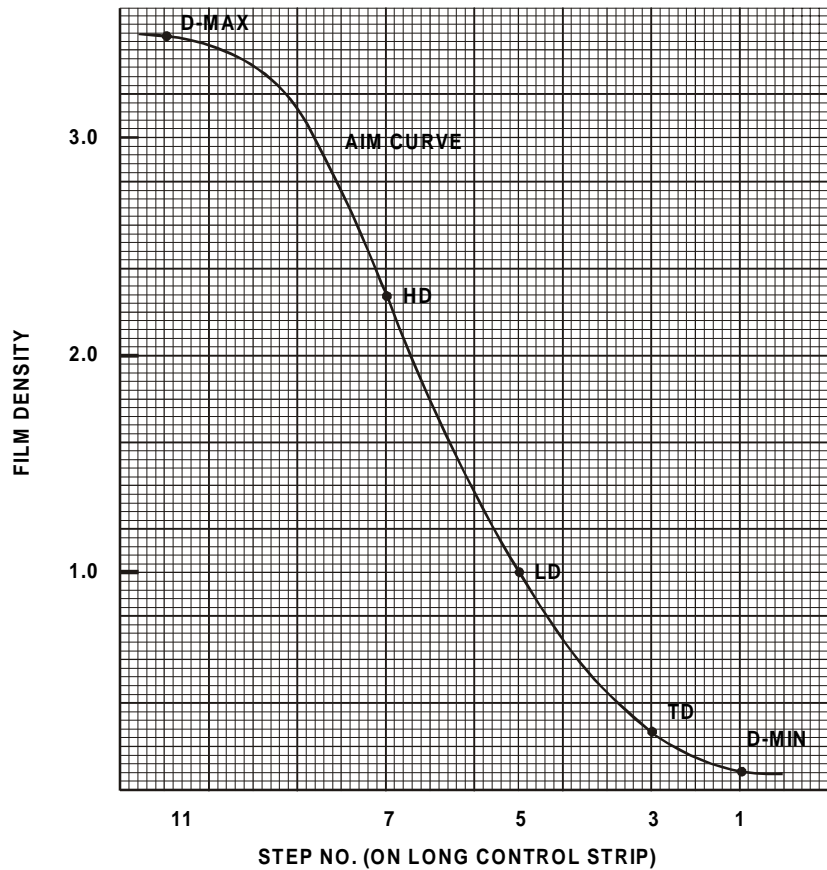
1. Possible reductions in film quality
2. Film-tracking problems
3. Increased process variability

Pages 1-10 through 1-16 provide a closer look at these problems.

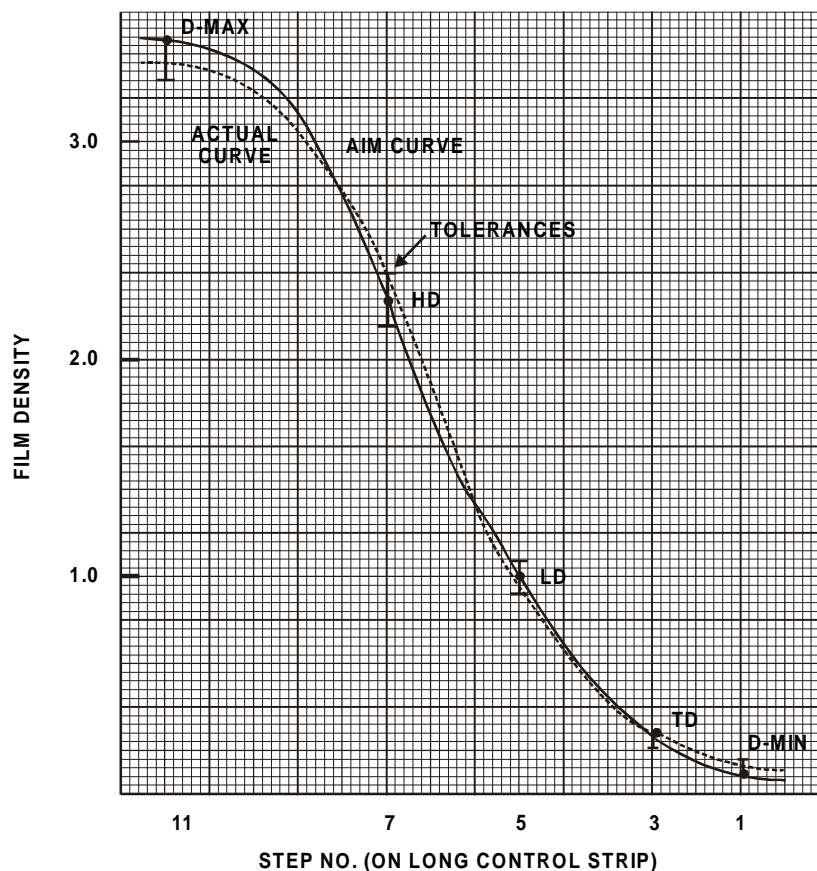
1. Reduction in film quality:

Monitoring the control-strip densities indicated at the right provides a measurement of five points on the sensitometric curve of only one of the many films for Process E-6. *

*See Section 5 for an explanation of plotting control-strip densities, including toe density (TD).



You can operate the process outside specifications and still have the five control-strip densities in control. However, the overall sensitometric curve may be degraded. In this example, the processed film appears higher in contrast, and color-balance shifts are apparent in the highlights and shadows.



2. Film-tracking problems: Film tracking describes how different films react in direction or magnitude to process variations compared to the control strip or to each other.

A control-strip plot is a graphic representation of the density and color-balance changes in processed film produced by chemical and mechanical process variations. When film tracking is good, if a control strip shows a color-balance change of 0.05 blue density, all the films being processed will also show a color-balance change of about 0.05 blue density. The control-strip plot will be a reliable indicator of the density and color balance of the other EKTACHROME Films processed in the same process as

the control strip. However, you can expect good film tracking only when the process is in good chemical and mechanical control.

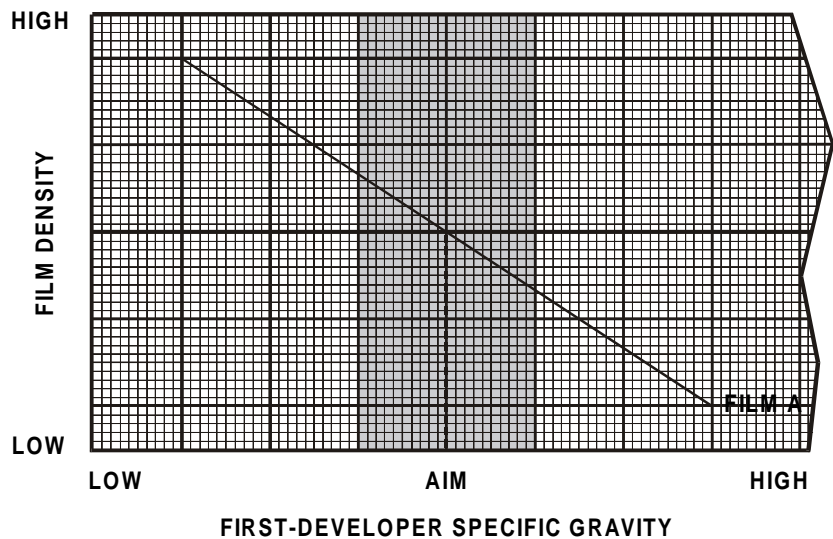
In a poorly controlled process—in which one or more chemical or mechanical parameters are not within tolerances—poor film tracking may result. Because all films have slightly different sensitivities to process variations, the control strip will not necessarily represent every film when one or more process parameters are operating outside the tolerances. In a poorly controlled process, the control strip may indicate a change of 0.05 blue density while another film may change by 0.10 blue and a third film may change by 0.03 green density.

The following graphs illustrate poor film tracking—how it can

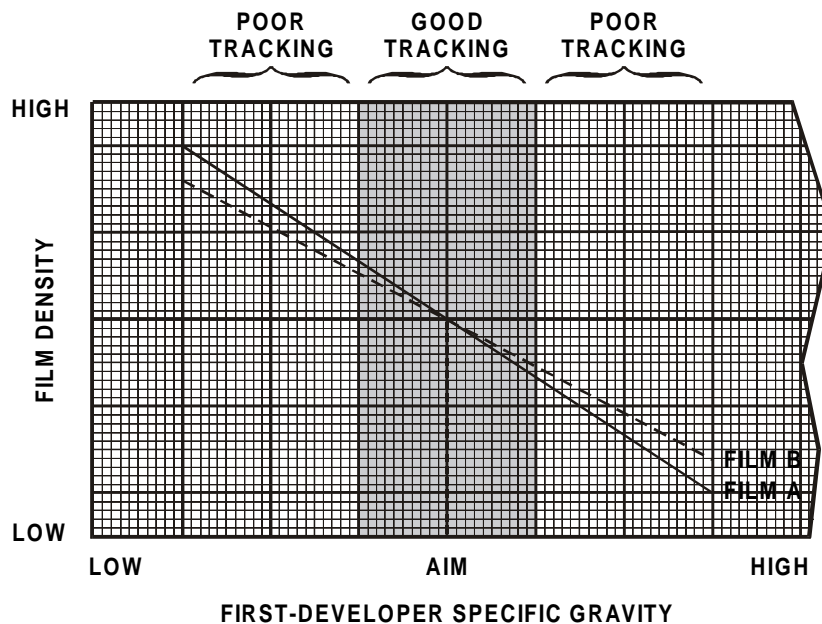
happen and why it causes problems. The graphs show how two different films, Film A and Film B, react to variations in processing conditions: (1) the process is in good chemical and mechanical control; (2) the first-developer specific gravity exceeds the upper control limit; and (3) the first-developer temperature is adjusted below the lower control limit to compensate for the high specific gravity (2).

To keep the graphs simple, only one color record (green density) is shown. However, all three film layers display different sensitivities to process changes. Under actual conditions, films exhibit both density and color shifts. The color shifts are most noticeable.

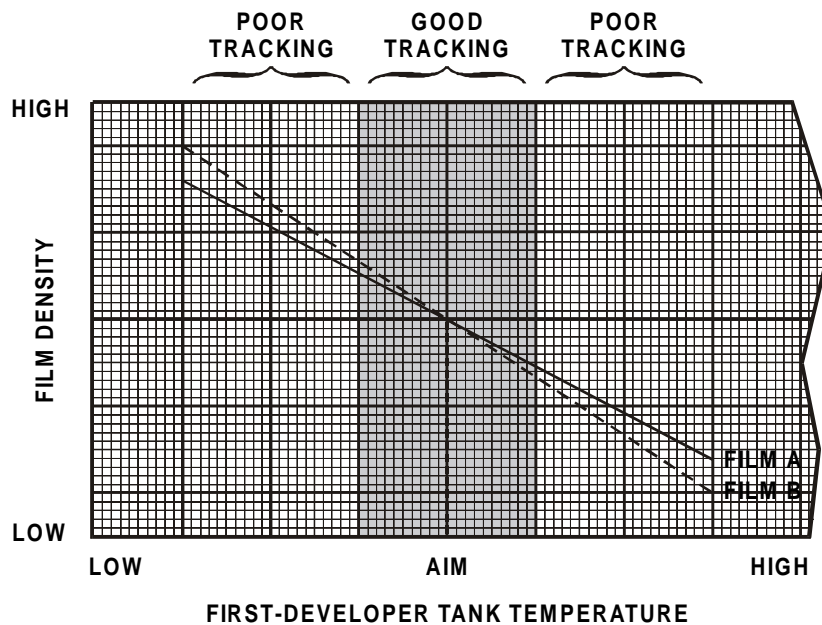
This plot shows how Film A density changes as a result of changes in first-developer specific gravity. The shaded area represents the tolerances for specific gravity. As specific gravity increases from aim, the film density decreases; transparencies appear lighter. Conversely, as specific gravity decreases from aim, film density increases; transparencies appear darker.



Film B exhibits a similar response to changes in first-developer specific gravity, but not exactly the same response as Film A. Note that within the tolerances, the responses of the two films are very similar. However, as specific gravity exceeds the limits, the two films do not respond to the same degree.

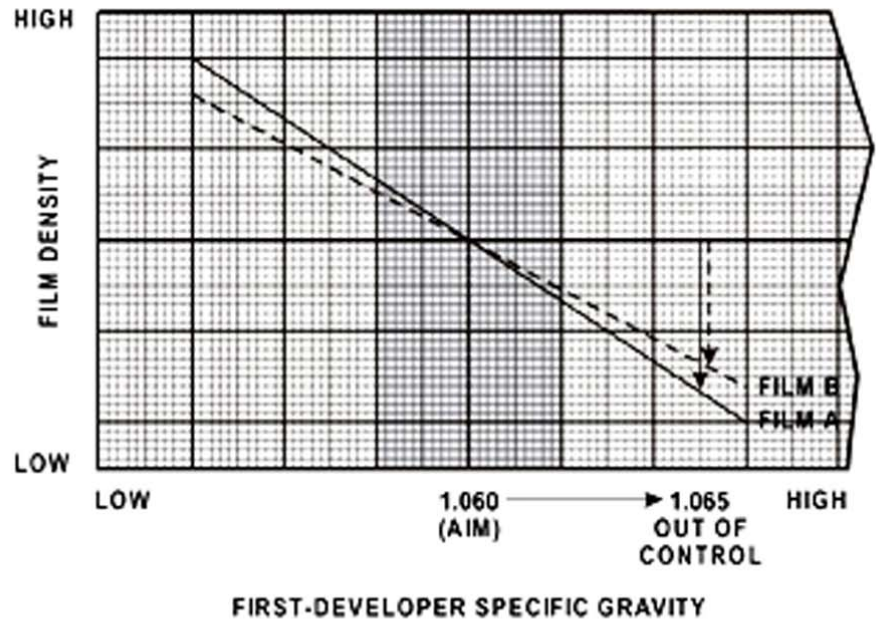


Changes in first-developer temperature produce a similar situation. This plot shows the responses of Film A and Film B to changes in first-developer temperature. Note again that within the tolerances, the films react similarly. However, when the temperature goes outside the tolerances, the response of Film A is less than the response of Film B.

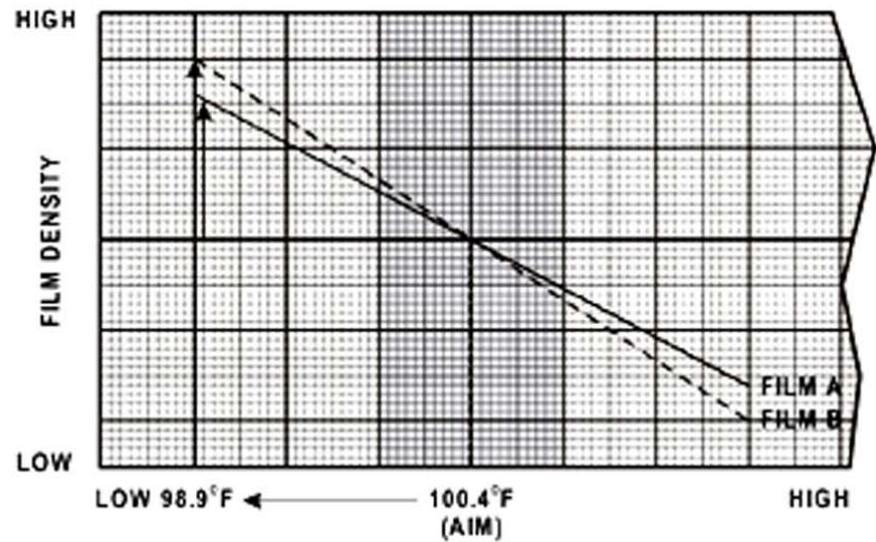


Suppose Film A is acting as the control strip in a process in which first-developer specific gravity exceeds the upper limit. The effects on Film A and B are shown in these plots.

When specific gravity increases to 1.068, Film A density decreases by 0.16. Film B density decreases by only 0.13.



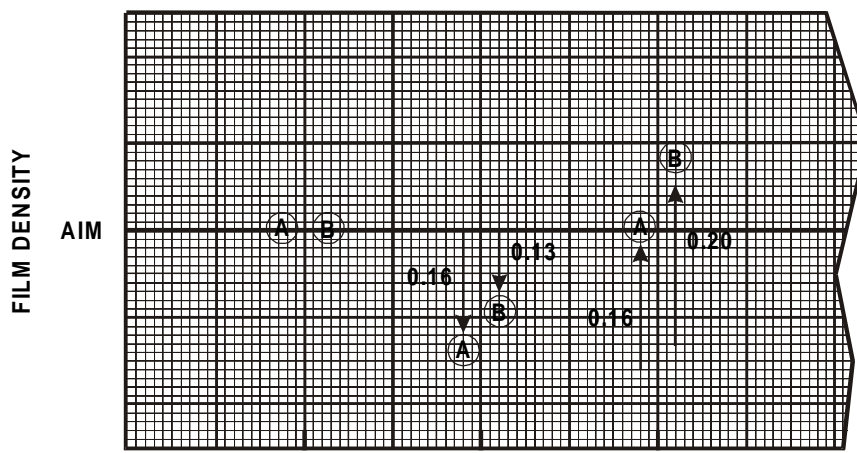
Suppose the lab is not using process control, and therefore does not know that the first-developer specific gravity is out of control. The operator changes the first-developer temperature to increase film density and bring the control strip (Film A) back into control. Again the effects on Film A and Film B are different. When first-developer temperature is lowered by 1.5°F (0.8°C), Film A density increases by 0.16, but Film B density increases by 0.20.



This graph summarizes the responses of Film A and Film B. When all process variables are within tolerances, Film A and Film B are in control and track well. When first-developer specific gravity exceeds the upper limit, the effect on Film A is greater than the effect on Film B, resulting in poor tracking. When the first-developer temperature is lowered to bring Film A (the control strip) back to the aim, the effect of temperature on Film A is equal and opposite to the effect of specific gravity, so the temperature adjustment brings the film back into control. However, the effects on Film B are not equal; the net effect leaves Film B out of control (density too high).

Now both first-developer specific gravity and first-developer temperature are out of control. But based on Film A (the control strip), the process appears to be on aim.

Film B responds less to the high first-developer specific gravity, but more to the low first-developer temperature. Unlike Film A, Film B does not return to aim. While Film A appears to be on aim, Film B does not track well, and has less than optimum quality. If the lab had corrected the specific-gravity problem instead of compensating by lowering the temperature, both Film A and Film B would have returned to optimum performance.



FIRST-DEVELOPER SPECIFIC GRAVITY:	AIM	TOO HIGH	TOO HIGH
FIRST-DEVELOPER TANK TEMPERATURE:	AIM	AIM	TOO LOW

These graphs illustrate the effect of poor film tracking as a result of improper process adjustment on a single color record (green density). In an actual situation, the films would exhibit color shifts as well as density shifts. It is critical to identify and correct problems rather than compensate for their effects by adjusting another parameter.

All EKTACHROME Films are tested and optimized in a tightly controlled

process that operates within the chemical and mechanical specifications. When Process E-6 is operated within specifications, all the films track the control strip well. However, if the process is not within chemical and mechanical tolerances, at least one film will be adversely affected and will not track the control strip properly.

3. Increased process variability:

This applies to variability within a lab and from lab to lab. A process that operates outside the tolerances for chemical and mechanical parameters will have the potential for unacceptable sensitometric variability. A process that operates with good chemical and mechanical control will have little variability.

For example, let's look at Lab ABC, which uses *product* control to maintain its Process E-6. The lab processes one control strip per day. The lab's control-strip plots are included on the chart on page 1-17.

Important: We do not recommend making the process adjustments used in the following example. *Never* use starter additions as an adjustment tool in the first developer unless low bromide concentration is confirmed with the KODAK Q-LAB Chemical Test Kit, Process E-6, and the diagnostic chart prescribes the addition of starter. *Never* use starter additions as an adjustment tool in the color developer. *Always* maintain the ratio of color developer Parts A and B at 1:1; do not make additions of Part A or B alone to the tank solution. Be sure that replenisher pumps in blender or in-line dilution systems deliver equal amounts of Parts A and B.

For the first few days, the process is operating properly and is in control.

On about day 5, the process begins to drift fast (densities are reduced). By day 7, the operator is certain that the trend is real, so he decides to make adjustment.

Based on his experience, the operator knows that adding starter to the first developer will increase densities in the LD, HD, and D-max steps of the control strip. He adds 100 mL of starter to the tank. Control strips on days 8 and 9 show a slight improvement, but not very much, so the operator adds another 75 mL of starter to the tank.

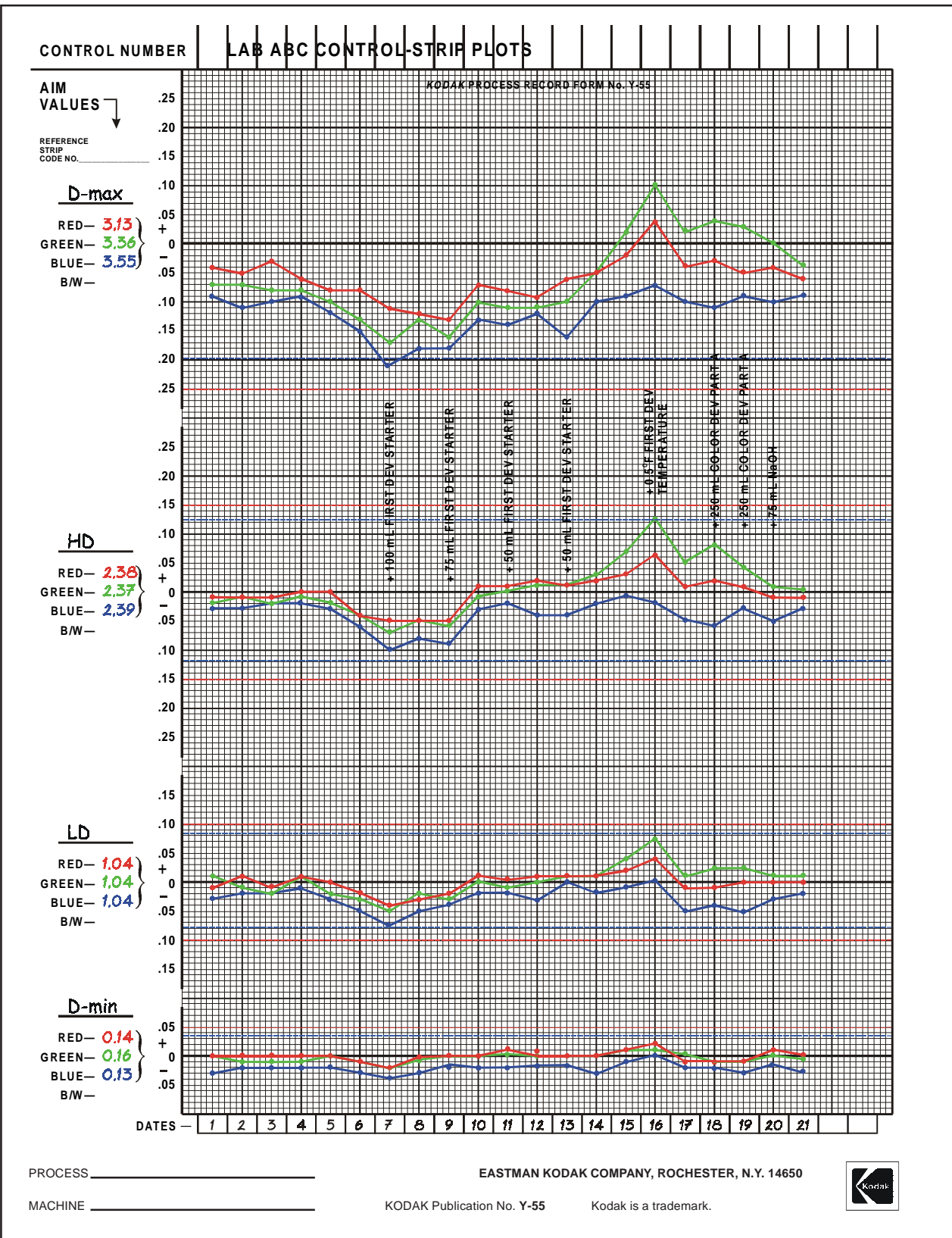
The next strip plots close to normal again, so he is confident that he has solved the problem. But to make sure that the process doesn't drift fast again, he adds 50 mL of starter to the tank every other day.

This works well until day 14, when the process begins to drift higher in contrast and D-max as it also goes slow (higher densities overall) and color balance goes magenta-blue. By day 16, the change in process is obvious, and the operator thinks it's time to make another adjustment.

First he adjusts the speed of the process back to aim by increasing the temperature of the first developer. He raises the temperature by 0.5°F (0.3°C); the control-strip plot returns close to the aim for LD. But he still needs to adjust the contrast and color balance. He knows from experience that increasing the proportion of color developer Part A to Part B will make the process lower in contrast. On day 18, he adds 250 mL of Part A to the tank solution. On day 19, he makes another addition of Part A, and on day 20, he adds sodium hydroxide to bring up the blue plot just a bit. By day 21, he is happy with his process again, because the control-strip plots look good.

However, the photographers and others who rely on the process are unhappy. The photographer using tungsten film in the studio has had to increase his exposure time from 90 seconds to 110 seconds and add CC05M filtration to maintain the density and color balance he had on day 1, at the start of his job. The duping technician has changed filter packs and exposure times, but still has a color-balance crossover between the upper and lower scale of the dupes. A sports photographer has changed labs altogether. He balanced to the process on days 8 and 9 for a job in an indoor stadium. He brought in his film for processing on day 15 and found that all his images were dark and magenta-blue.

The process operator did his best according to the information that was available to him: the control-strip plots. According to his plots, his process was running well, and he believed that he addressed each problem adequately because his plots always returned to the aim. However, if he had used *process* control rather than *product* control, he could have detected process problems before they affected the control strips. To understand how monitoring the key parameters would have helped the operator, see pages 1-18 and 1-19.



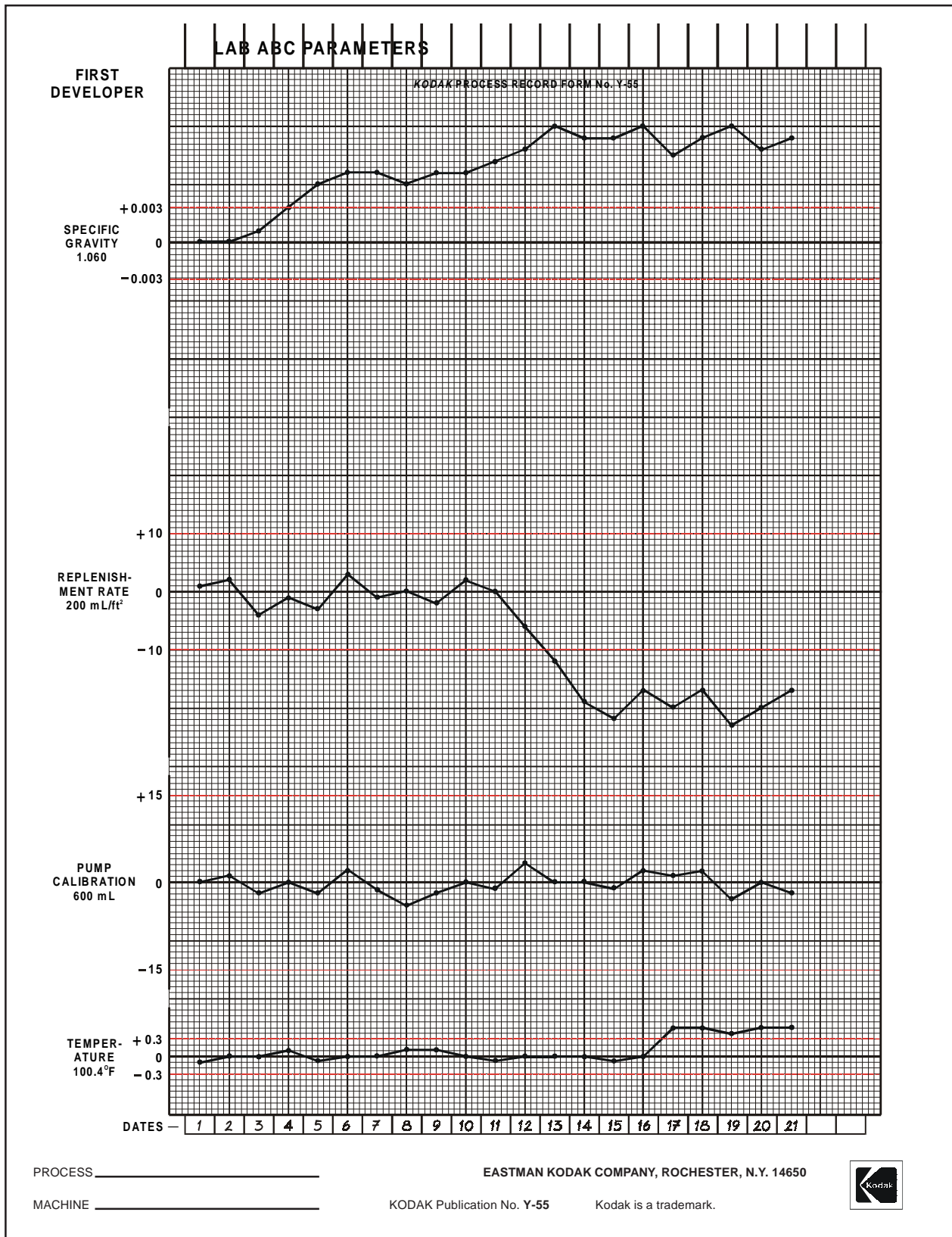
Plots of key parameters for the first and color developers are included on pages 1-19 and 1-20. They show that the parameters all started out in control. But on about day 3 or 4, the specific gravity of the first developer began to drift upward, and by day 5, a trend toward higher concentration is obvious. If the operator had eliminated the cause of the increased concentration at this point, he would have prevented the process shift that became noticeable on the control strip, and would have avoided the starter additions, which contributed to other problems later. He would have eliminated the cause of the problem instead of compensating for the effects. In this example, low humidity in the processing area caused increased evaporation, which increased solution concentration.

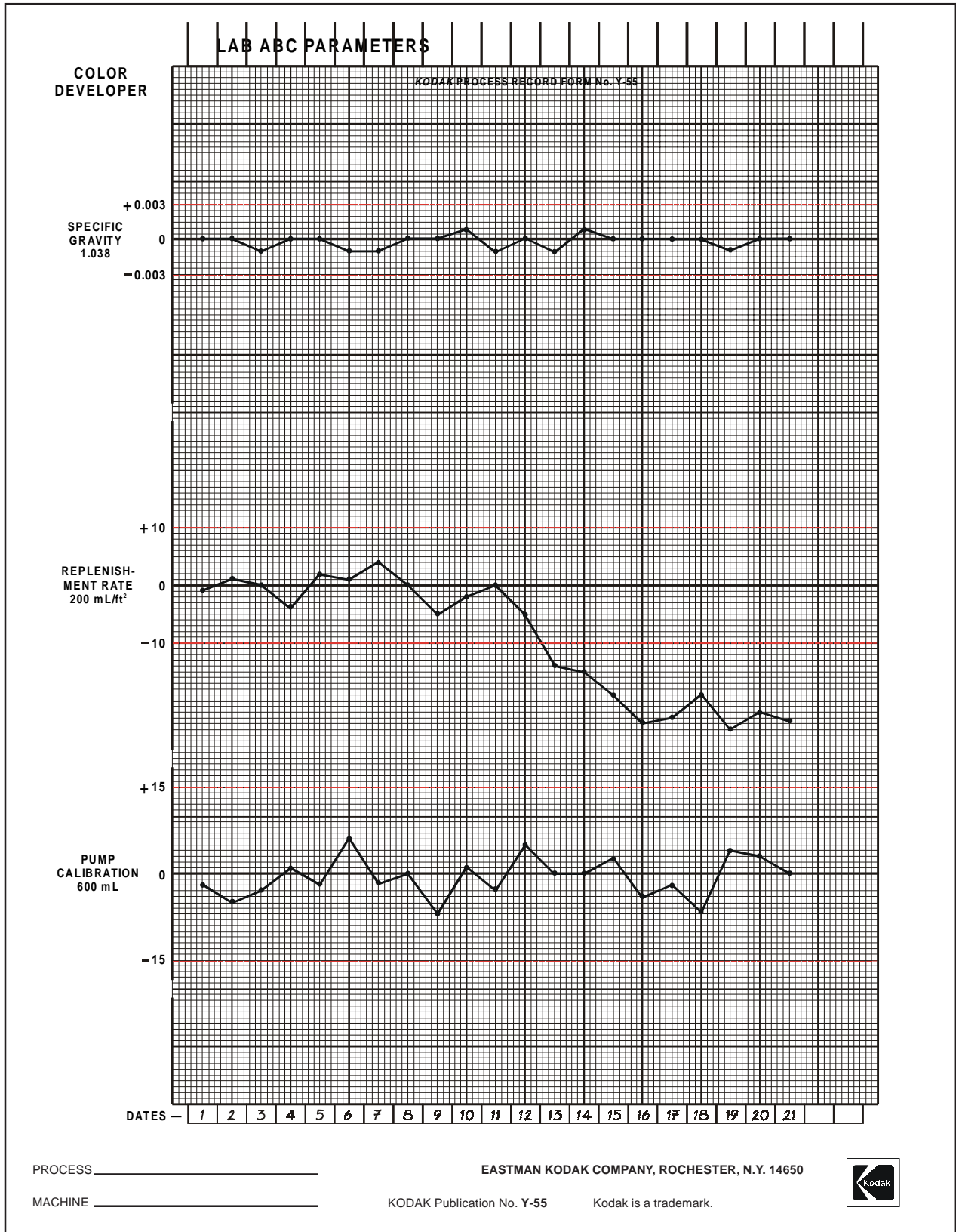
Later we see a drift in the replenishment rate for both the first developer and the color developer. The drift begins on about day 12 and is obviously a trend by day 13. Because the pumps were properly calibrated, the problem was probably in the film sensing or measuring technique. The pumps were delivering the correct volume of replenisher per cycle, but the cycles were too far apart. Because the operator was unaware that the replenishment rates were decreasing, he adjusted the temperature and the ratio of Part A to Part B.

By day 21, the operator thought the process was performing well and that it was in control based on the control plots. However, the first-developer specific gravity, replenishment rate, and temperature, as well as the color-developer replenishment rate, were out of control. The color developer also had an improper mix of Parts A and B, as well as an improper pH due to the sodium hydroxide addition. Because the process was out of control chemically and mechanically, the quality of some of the films was affected. That is why the photographers and duping technicians were unhappy with their processed film.

The plots of Lab ABC's key process parameters for the developers on Forms Y-34 and Y-36 (see pages 1-21 and 1-22) show the actions the operator would have taken if he had been using process control. All the adjustments eliminated the cause of the problem. Each time a parameter began to drift out of control, the operator would have corrected it before it had any significant effect on the control strip and customer film. The lab's control-strip plots on Form Y-33 confirm the state of control (see page 1-23).

To achieve control for Process E-6, your lab must measure, record, and control the key process parameters, and keep the process within specifications. Controlling the process parameters is the most important part of running a consistently high-quality process. Use KODAK Control Strips, Process E-6, to *confirm* that your process is in control.

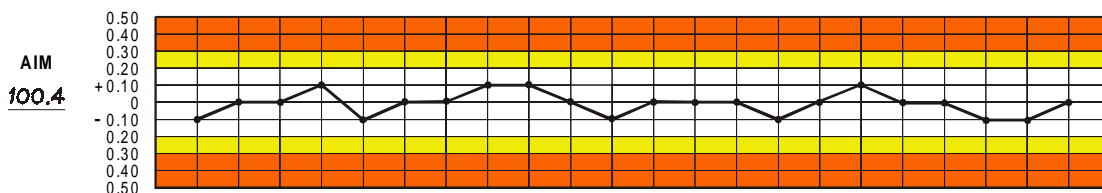




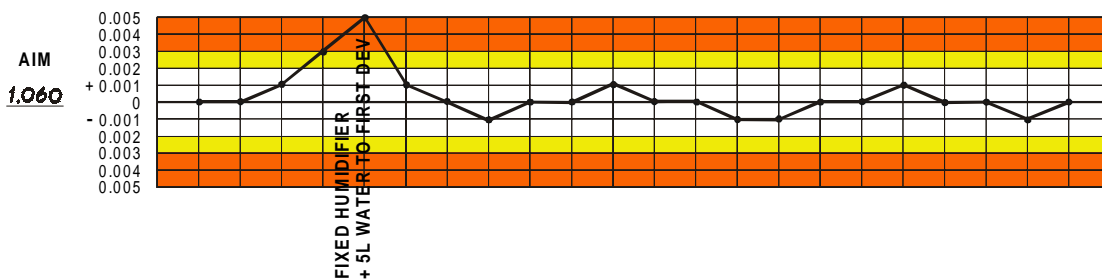


KODAK FIRST DEVELOPER PLOTTING FORM FOR PROCESS E-6

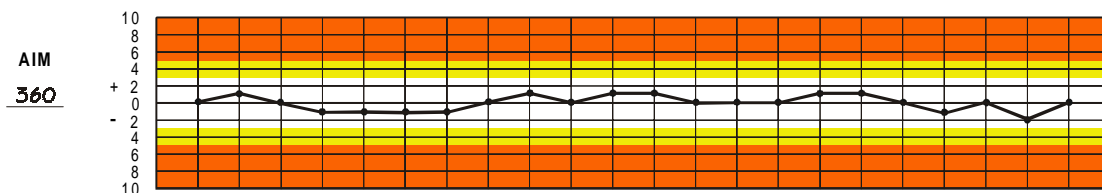
TANK TEMPERATURE (°F)



SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



TIME (seconds)

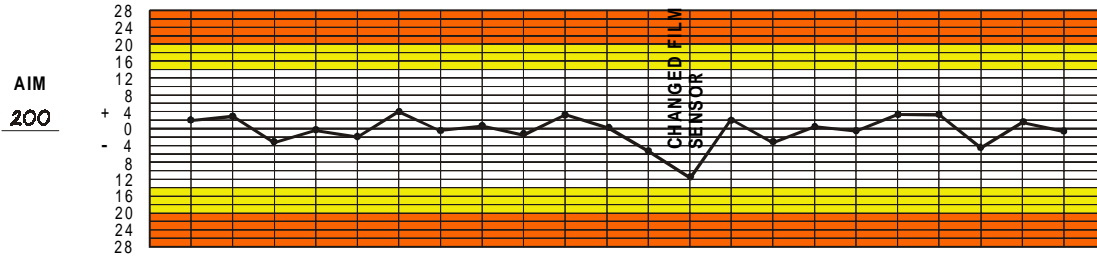


DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
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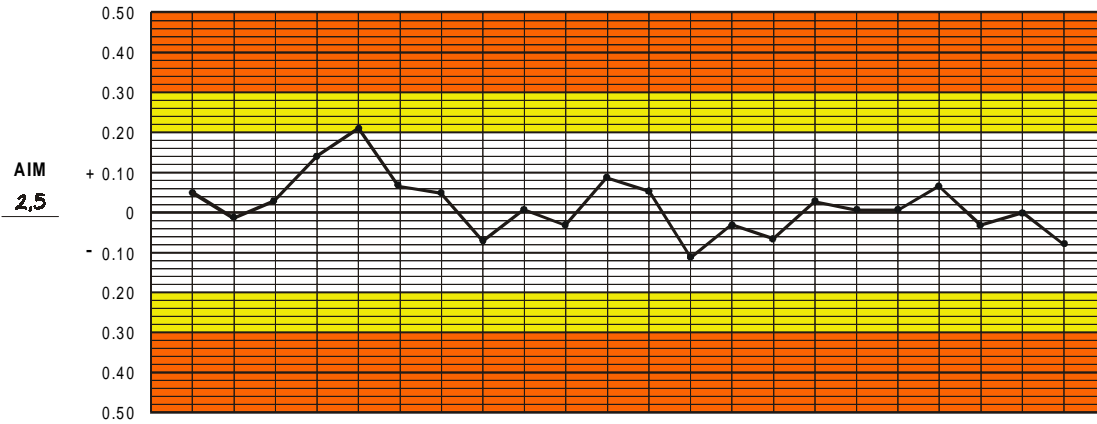
MACHINE _____

Y-34

REPLENISHMENT RATE (mL/ft²)



BROMIDE CONCENTRATION (g/L)



DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
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KODAK Publication No. Y-34

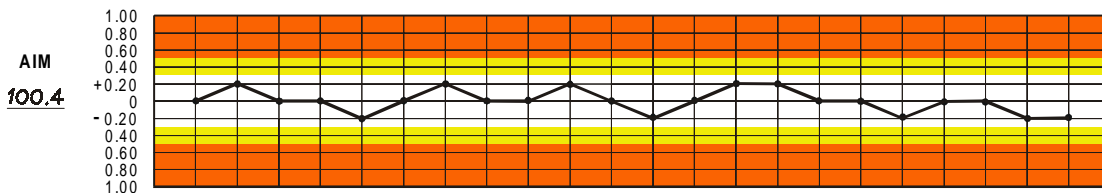
Kodak and Q-Lab are trademarks.



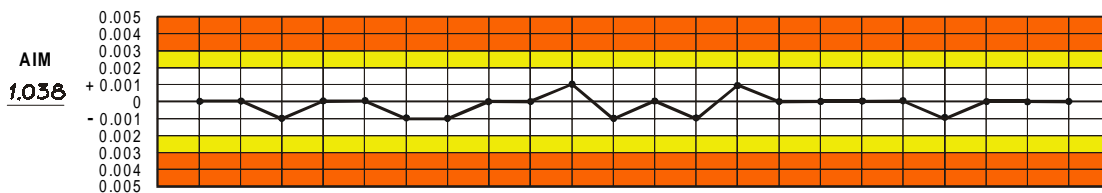
Y-36

KODAK COLOR DEVELOPER PLOTTING FORM FOR PROCESS E-6

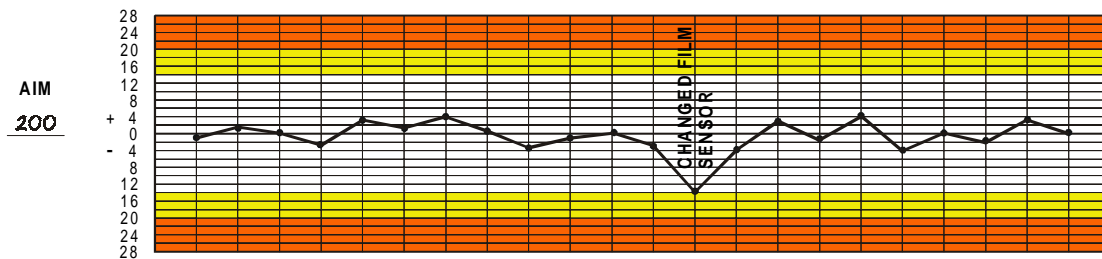
TANK TEMPERATURE (°F)



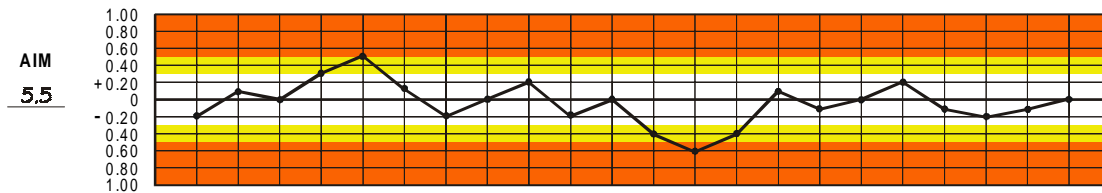
SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



REPLENISHMENT RATE (mL/ft²)



SULFITE CONCENTRATION (g/L)



DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
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MACHINE _____

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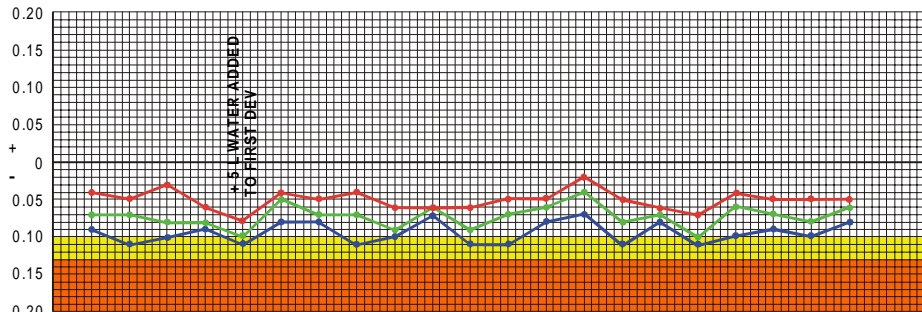


KODAK PLOTTING FORM FOR PROCESS E-6

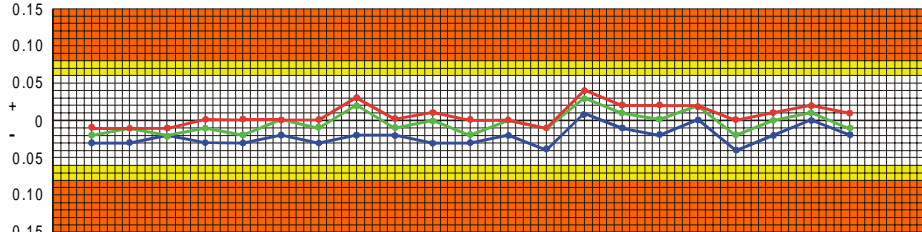
Y-33

CODE NO. _____

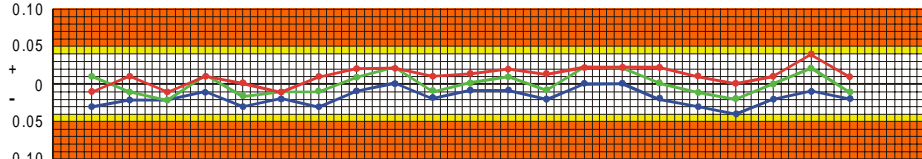
D-MAX
 RED 3.13
 GREEN 3.36
 BLUE 3.55



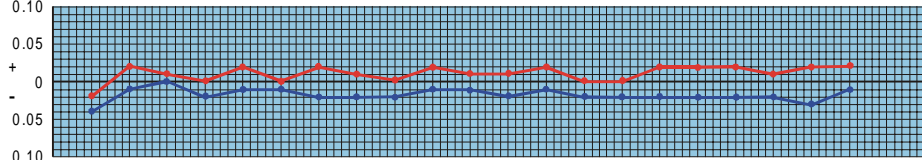
HD
 RED 2.38
 GREEN 2.36
 BLUE 2.39



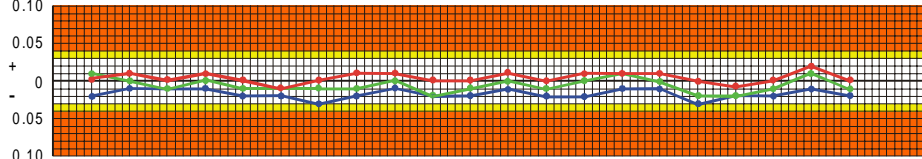
LD
 RED 1.04
 GREEN 1.04
 BLUE 1.04



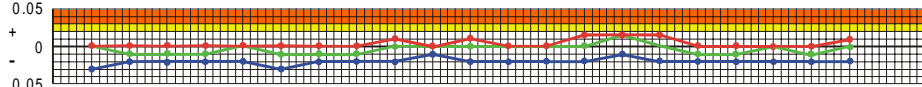
LD SPREAD
 R - G
 B - G



TD
 RED 0.34
 GREEN 0.35
 BLUE 0.33



D-MIN
 RED 0.14
 GREEN 0.16
 BLUE 0.13



DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
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MACHINE _____

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APPLYING PROCESS CONTROL

For process quality and consistency, you must measure, record, and control the key process parameters. However, first you must take two steps to move toward process control:

Eliminate or minimize all sources of oxidation. These include—

- Replenisher tanks without floating lids
- Malfunctioning recirculation pumps
- Poor mixing procedures
- Excessive exposure of solutions to air
- Extended idle periods (low processor utilization)
- Low solution levels that allow air to enter the recirculation system

Labs that don't correct these conditions will always have trouble running a good process. Techniques that compensate for problems caused by oxidation provide only temporary solutions. You must eliminate or minimize oxidation to run a reliable process.

Eliminate, or minimize as much as possible, all sources of evaporation. These include—

- Excessive air flow or exhaust over developer tanks
- Low humidity in the lab
- Excessive turbulence in the solutions
- Turbulence in the developers when no film is being processed
- Use of non-humidified nitrogen for developer agitation

After you eliminate or minimize as much as possible the sources of evaporation, you can compensate for any evaporation that is still occurring (see the procedure given in Appendix 4A, "Compensating for Evaporation").

Once you have corrected oxidation and evaporation problems, you can begin to monitor the key process parameters.

Key Parameters— Mechanical

Time: The first developer is the most sensitive to time variations. Changes in first-developer time have significant photographic effects; a change as small as ± 3 seconds can produce a density difference of about 0.01 at 1.00 density. Reactions in the other solutions go to completion. Therefore, the other solutions are much less sensitive to time variations, especially longer times.

Temperature: Temperature controls the rate of the reactions. The temperature of the first developer is most critical; a change as small as $\pm 0.2^\circ\text{F}$ ($\pm 0.1^\circ\text{C}$) can produce a density shift of about 0.01 at 1.00 density. Color-developer temperature is also important; a temperature change as small as $\pm 0.5^\circ\text{F}$ ($\pm 0.3^\circ\text{C}$) can produce density and color shifts.

Agitation: Agitation of the solution over the film surface controls the flow of fresh solution into the emulsion and the removal of reaction by-products. Proper agitation, especially in the first developer, first wash, and color developer, is critical for consistent process control and uniformity of processed film.

Key Parameters— Chemical

Specific Gravity: Specific-gravity measurements monitor the concentration of the solutions. If the specific gravity of a tank solution is outside the specification, the replenisher concentration may be incorrect, an evaporation problem may exist, or a water leak may be diluting the solution. Specific-gravity measurements do not detect incorrect replenishment rates. For Process E-6 solutions, the concentration of replenishers is approximately equal to the concentration of the seasoned tank solutions, so under- or overreplenishment will not change the specific-gravity

measurements even though the concentrations of certain chemical components in the solutions will change.

Replenishment Rate: Using proper replenishment rates is critical, especially for the first and color developers, to assure the proper ratio of fresh chemicals to development by-products. Calculate replenishment rates by dividing the volume of replenisher used by the number of square feet of film processed.

Concentrations of Key Chemical Components: Each Process E-6 solution contains key chemical components that control image quality.

Bromide concentration in the first developer is critical in controlling film densities. As bromide concentration increases, developer activity decreases, and film densities increase. As bromide concentration decreases, developer activity increases, and film densities decrease.

Reversal-agent concentration is critical in controlling film color balance. Too much reversal agent produces a blue color-balance shift; too little reversal agent produces a yellow shift. As the concentration gets very low, shadows will have a green color balance.

Sulfite concentration in the color developer is critical in controlling film contrast. As sulfite concentration increases, film contrast will be lower, especially in the high densities. As sulfite concentration decreases, film contrast will be higher, especially in high-density areas.

By using the KODAK Q-LAB Chemical Test Kit, Process E-6, you can measure the concentration of bromide, reversal agent, and sulfite directly from your tank solutions.

When you begin to monitor these chemical and mechanical parameters, you must be sure the process is stable before you make any adjustments. If the process isn't stable, investigate and eliminate all causes of variability. Only after the process is stable should you make adjustments to move the process toward the aim. Procedures for measuring and recording the parameters are given in *Process Monitoring: Chemical and Mechanical Parameters* (Section 4). Procedures for stabilizing your process are given in *Stabilizing, Adjusting, and Optimizing Your Process* (Section 6).

You should now have a good understanding of why monitoring the key chemical and mechanical parameters provides the most effective method of controlling Process E-6 and providing images of the highest possible quality to your customers.