



Stabilizing, Adjusting, and Optimizing Your Process

As you measure and plot the key chemical, mechanical, and sensorimetric parameters, you will learn how your process is operating in relation to chemical and mechanical specifications, and how consistent it is. The next steps in obtaining optimum performance for Process E-6 are stabilizing, adjusting, and optimizing your process.

STABILIZING YOUR PROCESS

As you measure each parameter, you will establish a base line to determine the performance of the parameter. Once you establish a base line, you can take steps to eliminate any sources of variability and stabilize your process.

Establishing a Base Line

To establish a base line, make 10 measurements of each key parameter and plot the data. Make the measurements as frequently as possible for at least one week. We recommend that you make two measurements a day (or shift) for one week or one measurement a day (or shift) for two weeks.

Important: Do not use the base-line data to make process-control decisions, such as adjusting temperature aims or replenishment rates. If you make adjustments before the process is stable, you can increase its variability or move it out of chemical or mechanical specifications (or both). If you clearly identify the cause of a process problem as you are establishing your base line, take the appropriate corrective action to eliminate the cause. Then resume establishing your base line.

Evaluating Variability

After you have made the 10 measurements for each parameter, you can estimate variability by examining plots of each parameter or calculate the variability of your process mathematically by following the procedure on page 6-3.

To estimate variability visually, plot the data points for the 10 measurements you made for each parameter. Examine the plots to make an initial assessment of variability.

Most of the data points (approximately 7 out of 10) should plot within one half of the total tolerance range.

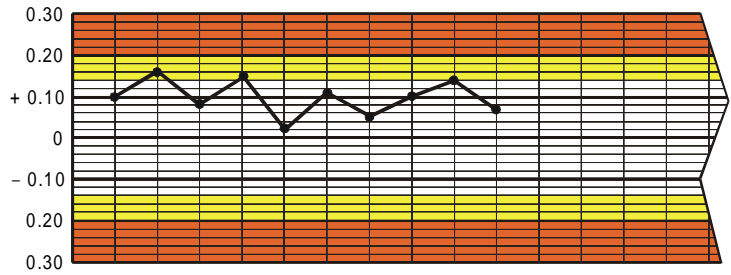
The graphs on page 6-2 show three different levels of variability.



Variability is acceptable, even though data is not centered around the aim.

REVERSAL AGENT (g/L)

AIM 1.2

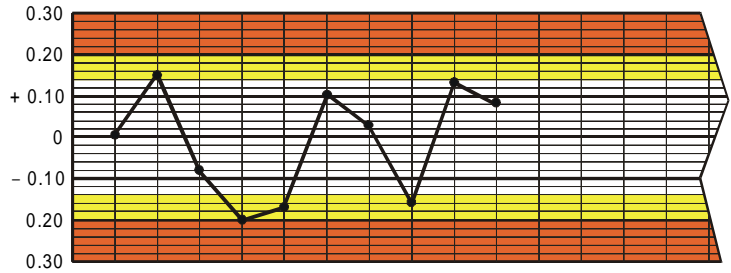


MACHINE X

Variability is marginal, even though data is centered around the aim.

REVERSAL AGENT (g/L)

AIM 1.2

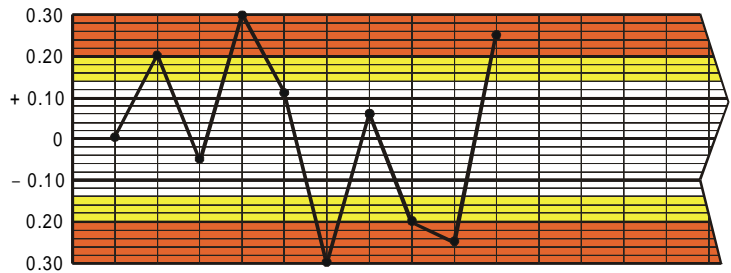


MACHINE Y

Variability is too high.

REVERSAL AGENT (g/L)

AIM 1.2



MACHINE Z

If most of your data plots of the key process parameters clearly fall within one half of the tolerance range, proceed to “Adjusting Your Process to Aim,” page 6-5.

If your plots marginally fall within the range, investigate the causes of the variability, but proceed to “Adjusting Your Process to Aim.”

If your plots indicate variability that is too high, find and eliminate the causes of the excessive variability before proceeding to “Adjusting Your Process to Aim.”

To calculate variability mathematically by using standard deviation, follow the procedure below:

With a scientific calculator, calculate the standard deviation of the 10 measurements you made for each process parameter. Compare each standard-deviation value to the total tolerance specified for that parameter.

Comparison	Variability	Recommended Action
Standard deviation $\leq \frac{1}{6}$ total tolerance	Good	Proceed to "Adjusting Your Process to Aim," page 6-5.
Standard deviation = $\frac{1}{6}$ to $\frac{1}{3}$ total tolerance	Marginal	Investigate potential sources of variability, but proceed to "Adjusting Your Process to Aim."
Standard deviation $> \frac{1}{3}$ total tolerance	Too high	Find and eliminate sources of excessive variability before proceeding to "Adjusting Your Process to Aim."

Here are sample calculations for reversal-agent concentration in Machines X, Y, and Z (the data plots are shown on page 6-2). The standard-deviation values were calculated from 10 measurements for each machine:

Machine X	Machine Y	Machine Z
1.30	1.20	1.20
1.36	1.35	1.40
1.28	1.12	1.15
1.35	1.00	1.50
1.22	1.03	1.31
1.31	1.30	0.90
1.25	1.23	1.26
1.30	1.04	1.00
1.34	1.33	0.95
1.27	1.28	1.45
Standard deviation = 0.04	Standard deviation = 0.12	Standard deviation = 0.21

The specified reversal-agent concentration = 1.2 ± 0.2 g/L

The total tolerance = 0.4

$\frac{1}{6}$ of 0.4 = 0.07

$\frac{1}{3}$ of 0.4 = 0.13

The standard deviation for Machine X < 0.07 ($\frac{1}{6}$ total tolerance); its variability is "good."

The standard deviation for Machine Y < 0.13 ($\frac{1}{3}$ total tolerance); its variability is "marginal."

The standard deviation for Machine Z > 0.13 ($\frac{1}{3}$ total tolerance); its variability is "too high."

Identifying Causes of Variability

If you determine that the degree of variability of one or more process parameters is too high or marginal, use the following tables as a guide to help identify the causes; then eliminate the causes to correct the variability. (These tables include the most common causes of variability.)

Key Parameter	Cause of Variability
Temperature	Measurements made at different locations in tank. Measurements made at different times during day/shift (e.g., too soon after start-up). Measurements made near replenisher input. Tank solution cooled by cold replenisher. Insufficient recirculation. Fluctuations in voltage to temperature controller. Faulty temperature controller. Faulty heater.
Specific gravity	Variations in measurement technique (e.g., measurements made at different temperatures, in tank vs cylinder, with different hydrometers, with dirty hydrometers, etc). Measurements not made correctly. Variations in rate of evaporation. Variations in processor utilization (low utilization causes specific gravity to increase). Water additions made inconsistently or incorrectly. Replenisher concentrate/water pumps not working correctly. Uncalibrated mixing tanks. Improperly mixed replenisher.
Time	Processor motor speed or transport speed not consistent. Fluctuations in voltage to motor. Film slippage on rollers or within rack. Improper machine settings. Variations in measurement technique. Measurements not made correctly.
Replenishment rate	Pumps not working properly. Check/poppet valves leaking. Film sensor not working properly. Calculations not done correctly. Amount of film processed not recorded accurately. Measurement of film footage or solution volumes not consistent. Waste and amounts used for calibrations not included in calculations.

Key Parameter	Cause of Variability
Bromide concentration	Distilled water not used for test. Replenisher pumps not consistent. Film sensor not working properly. Check/poppet valves leaking. Variations in average exposure level of film processed. Variations in rate of evaporation. Variations in measurement technique. Test not done correctly. Variations in replenishment rate. Variations in amount of film push-processed. Replenisher concentrate/water pumps not working correctly.
Reversal-agent concentration	Distilled water not used for test. Incorrect light source used for sample comparison. Sample comparison made before waiting 5 minutes or after 8 minutes. Replenisher concentrate/water pumps not working correctly. Variations in processor utilization. Variations in replenishment rate. Variations in carry-in from first wash. Variations in measurement technique. Test not done correctly.
Sulfite concentration	Distilled water not used for test. Variations in rate of oxidation. Variations in processor utilization. Variations in replenishment rate. Variations in replenisher concentration. Variations in ratio of Part A to Part B. Variations in rate of evaporation. Variations in measurement technique. Test not done correctly. Replenisher concentrate/water pumps not working correctly.

ADJUSTING YOUR PROCESS TO AIM

After you have stabilized each parameter, assess the level of it, and adjust it to aim if necessary. To assess the level of each parameter, estimate the average value by evaluating the data plots or by calculating the average value from the base-line data.

To determine if you need to adjust a parameter to aim, consider the questions below. Then proceed to the appropriate section following the questions.

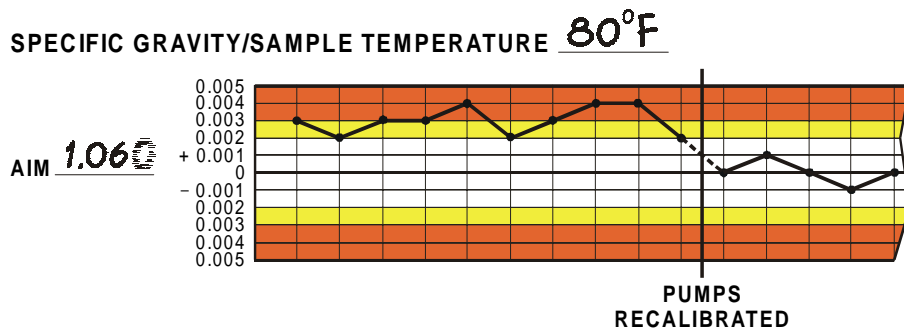
1. Is the average level of the parameter within the acceptable range given in the specifications for the individual solutions? Or if there is no acceptable range, is the average level within the tolerances specified?
2. If the answer to the question 1 is yes, are the speed, contrast, color balance, etc, of processed film at the required level?

If the parameter is not on aim and is not within the acceptable range or tolerances specified, you must adjust it so that it is closer to aim. Consider the parameter to be out of control due to a level shift, and make adjustments based on the appropriate diagnostic chart in the sections on the individual solutions (e.g., “First Developer—Specific Gravity—Level Shift High” or “First Developer—Specific Gravity—Level Shift Low”).

For example, let's look at the specific gravity of a first-developer tank solution. On the left side of the illustration, the specific gravity looks stable (variability appears to be low), but the average level is higher than the aim. The average level is also outside the specific tolerance of ± 0.003 (there is no acceptable range for first-developer specific gravity).

From the diagnostic chart on page 7-9, the operator determines the possible causes: “Replenisher too concentrated,” “Improper ratio of concentrate to water from in-line dilution pumps,” and “Excessive evaporation.”

For this processor, evaporation is not a problem. The lab uses floating lids and maintains proper humidity with a humidifier.



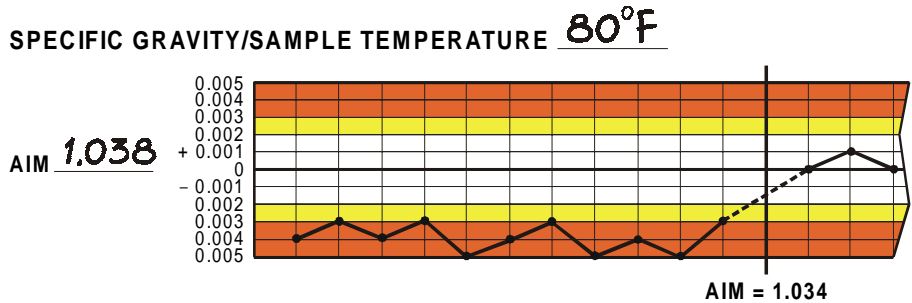
When a pump calibration was performed on the in-line dilution system, the operator determined that the concentrate pump was delivering too much solution for each replenishment cycle. Because too much concentrate will cause the specific gravity of the tank solution to be high, the operator recalibrated the pumps

to provide the proper ratio of concentrate to water. To adjust the tank concentration to the proper level (to eliminate the symptom), the operator adds water to the tank solution (according to the diagnostic chart). The specific gravity then returns to the aim (see the right side of the illustration above).

If the parameter is not on aim, but is within the acceptable range or tolerances specified, you must make a decision based on the quality of the film you process. If the film quality is at the required level, you should use the current level of the parameter as your aim and plot subsequent measurements in relation to the adjusted aim. If the film quality is **not** at the required level, you must adjust your process for optimum quality by following the procedure given in “Optimizing Your Process.”

For example, let’s look at the specific gravity of a color-developer tank solution. In the illustration, the white and yellow zones indicate the specified tolerance of ± 0.003 .

The data plots have an average level of about 1.034 with acceptable variability. Because the average is not on aim, but is within the acceptable range of 1.032 to 1.043 at 80°F (27°C), the operator must decide whether or not to adjust it based on the quality of the processed film. If the speed, contrast, color balance, etc. of the processed film are at the required level, the operator uses the average as the new aim—so, the new aim is 1.034 and the new limits are 1.031 and 1.037. The operator indicates the



new aim on the plotting form, and connects the last point plotted against the “old” aim with the first point plotted against the new aim with a dotted line to indicate an aim change. The parameter is then maintained at the new level to maintain consistent

film quality. If the speed, contrast, color balance, etc. of the processed film are unacceptable, the operator must adjust the process according to the procedure given in “Optimizing Your Process.”

Note: Once you have stabilized your process and adjusted it to aim, most of your data should plot within the white zone on the plotting forms (Y-34, Y-35, and Y-36). Even if most of your plots are within this zone, always strive to reduce variability by investigating and eliminating its causes.

OPTIMIZING YOUR PROCESS

Once your process is stable, and the key parameters are at (or close to) the aim, you can optimize your process to obtain optimum film quality. We recognize that you may have to make some minor adjustments from aim for some of the key parameters (due to differences in machine design) to obtain optimum speed, contrast, and color balance. It is important to understand that in most situations you will **not** have to make adjustments from aim to obtain optimum film quality. If your process is providing optimum film quality, follow the recommendations under “Frequency of Measurements” on page 4-12, and then proceed to *Maintenance*, Section 16.

If you determine that your process requires adjustments, follow the steps given below. **Do not** make these adjustments to your process to optimize it until it is stable and the key parameters are at (or close to) aim (see “Stabilizing Your Process” and “Adjusting Your Process to Aim”).

1. Adjust to obtain optimum density (film speed).
2. Adjust to obtain optimum film contrast.
3. Adjust to obtain optimum color balance.

Important: Perform these steps in the order given, because the effects of some of the adjustments may be additive.

To obtain optimum density (film speed), adjust either the first-developer temperature or the first-developer time. Base your adjustments on the green density of the **LD** step of your control strip.

1. If the green LD density is on aim, the density (film speed) is acceptable; your process does not require adjustments for density. Proceed directly to “To obtain optimum film contrast...”
2. If the green LD density is lower than aim (film speed is “fast”), decrease the first-developer temperature to slow down the reaction or decrease the time to shorten the development reaction and increase film densities.
3. If the green LD density is higher than aim (film speed is “slow”), increase the first-developer temperature to speed up the reaction or increase the time to lengthen the development reaction and decrease film densities.

After you have adjusted the first-developer temperature or time, and the green LD density is on aim, maintain the time or temperature within the specified tolerances.

To obtain optimum film contrast, adjust the concentration of the color developer. Base your adjustments on the green density of the **HD** step of your control strip. (Make sure that the green LD density is on aim before you adjust the concentration of the color developer.)

1. If the green HD density is on aim, the contrast is acceptable; your process does not require adjustments for optimum film contrast. Proceed directly to “To obtain optimum color balance...”
2. If the green HD density is lower than aim, the contrast is low. To raise the contrast (increase the green HD density), first if sodium hydroxide is being added to the color developer, lower the color developer pH by reducing the amount of sodium hydroxide that is being added to the color developer working tank and replenisher solutions. If after reducing or eliminating the amount of sodium hydroxide being added to the color developer solution, the contrast still remains low, dilute the color developer solution.
3. If the green HD density is higher than aim, the contrast is high. To lower the contrast (decrease the green HD density), first, if acetic acid or sulfuric acid is being added to the color developer, increase the color developer pH by reducing the amount of acid being added to the color developer. If after reducing or eliminating the amount of acetic acid (or sulfuric acid) being added to the color developer, the contrast remains high, increase the concentration of the color developer.

Decreasing the concentration of the color developer decreases the concentration of CZA and increases the amount of dye formed, so film contrast increases.

Increasing the concentration of the color developer increases the concentration of CZA and decreases the amount of dye formed, so film contrast decreases. Any adjustment to the concentration of the color developer must be within the acceptable range for specific gravity: 1.032 to 1.043 at 80°F (27°C). Keep the adjusted aim as close as possible to the recommended aim (1.038 at 80°F [27°C]).

After you have adjusted the concentration of the color developer, and the green HD density is on aim, measure the specific gravity of the tank solution. Use the specific-gravity measurement as your new aim. Make the same adjustment and aim change to your replenisher.

Important: Most professional labs will not have to adjust the concentration of the color developer to obtain optimum contrast. For labs that must make an adjustment, it is important to maintain the color-developer replenishment rate at 200 mL/sq ft. The best way to do this is to adjust the concentration (specific gravity) of the color developer replenisher and maintain the recommended replenishment rate. (If you adjust only the tank concentration, and **do not** adjust the replenisher concentration, your process will become unstable.) **Do not adjust the ratio of Part A to Part B from the specified ratio of 1 to 1.**

To obtain optimum color balance; adjust the reversal bath reversal agent concentration (as measured by the KODAK Q-LAB Reversal Agent Test) to alter the yellow/blue color balance; adjust the pH of the color developer to alter the magenta/green color balance. Base your adjustments on the color balance of the HD and LD steps of your control strips.

Adjust the yellow/blue color balance first. Changing the reversal bath reversal agent concentration will affect the blue/yellow color balance. Increasing the concentration of the reversal agent within the acceptable range of 1.00 g/L to 1.40 g/L will shift the color balance in the blue direction. Reducing the reversal agent concentration within the acceptable range will shift the color balance in the yellow direction.

Remember to maintain and monitor the reversal agent concentration to detect changes *before* they affect the film you process.

Adjust the magenta/green color balance second. Adjusting the pH of the color developer will shift the color balance toward the magenta or green direction. To decrease the pH of the color developer, add 28% acetic acid or sulfuric acid (5N H₂SO₄) to shift the color balance in the magenta direction.

To increase the pH of the color developer, add sodium hydroxide (5N NaOH) to shift the color balance in the green direction.

If you adjust the pH of the color-developer tank solution, also make the same adjustments to the color developer replenisher. Add 28% acetic acid, sulfuric acid (5N H₂SO₄) or sodium hydroxide (5N NaOH) to the replenisher in the same proportion that you use to modify the tank solution.

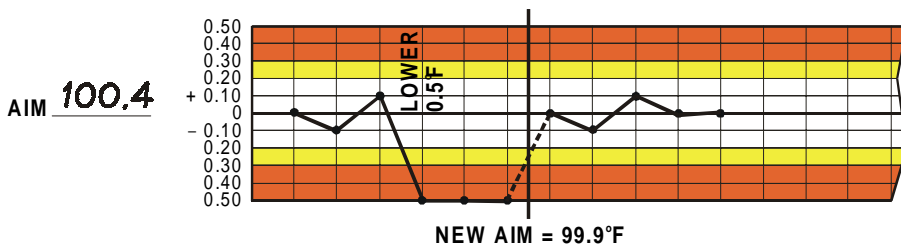
Note: For in-line dilution systems, add sodium hydroxide to **Part A** (increase pH); add 28% acetic acid or sulfuric acid to **Part B** (lower pH). **Do not** adjust the ratio of Part A to Part B.

In the following example, each machine requires a different adjustment to achieve optimum quality. Keep in mind that not every process will require optimization or adjustments to process parameters to achieve optimum quality.

Machine A and Machine B are initially set up to meet all the specified aims. At these settings, Machine A produces transparencies that are low in density (light), and Machine B produces transparencies that are high in density (dark) with a magenta color balance.

To adjust Machine A for optimum film quality, the aim for first-developer temperature is lowered to 99.9°F (37.7°C). The tolerance remains the same (at ± 0.3°F [± 0.2°C]). The process, optimized for Machine A, produces good results.

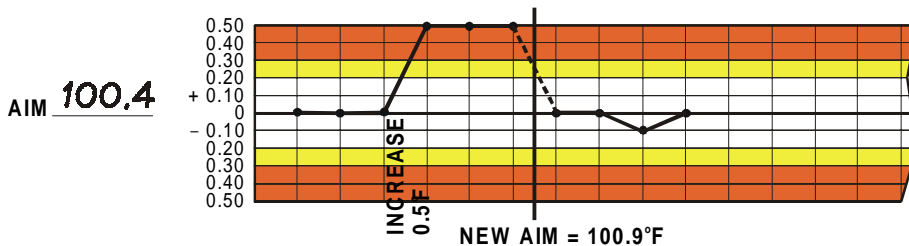
TANK TEMPERATURE (°F)



MACHINE A

To adjust Machine B to produce optimum film quality, the first-developer temperature is increased. This corrects the process for density, but produces low contrast.

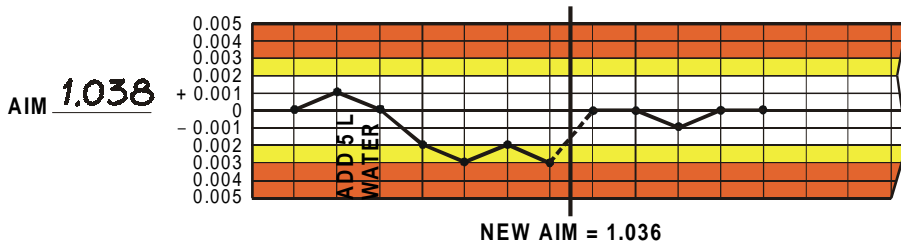
TANK TEMPERATURE (°F)



MACHINE B

To correct the contrast, an adjustment is made to the color-developer concentration (specific gravity), and sodium hydroxide is added to the color developer replenisher to correct the magenta color balance.

SPECIFIC GRAVITY/SAMPLE TEMPERATURE 80°F



MACHINE B

For Machine B, new aims were established for first-developer temperature and color-developer specific gravity, and new mixing procedures were established for the color developer replenisher:

- Adjusted first-developer temperature: $100.9 \pm 0.3^{\circ}\text{F}$ ($38.3 \pm 0.17^{\circ}\text{C}$)
- Adjusted color-developer specific gravity: 1.036 ± 0.003 (at 80°F [27°C])
- Modified mixing procedure for color developer replenisher for this example: Mix the replenisher according to the instructions packaged with the chemicals. Then dilute the replenisher solution by 5 percent (to maintain the specific gravity of the tank solution) and add 5N sodium hydroxide to the replenisher.

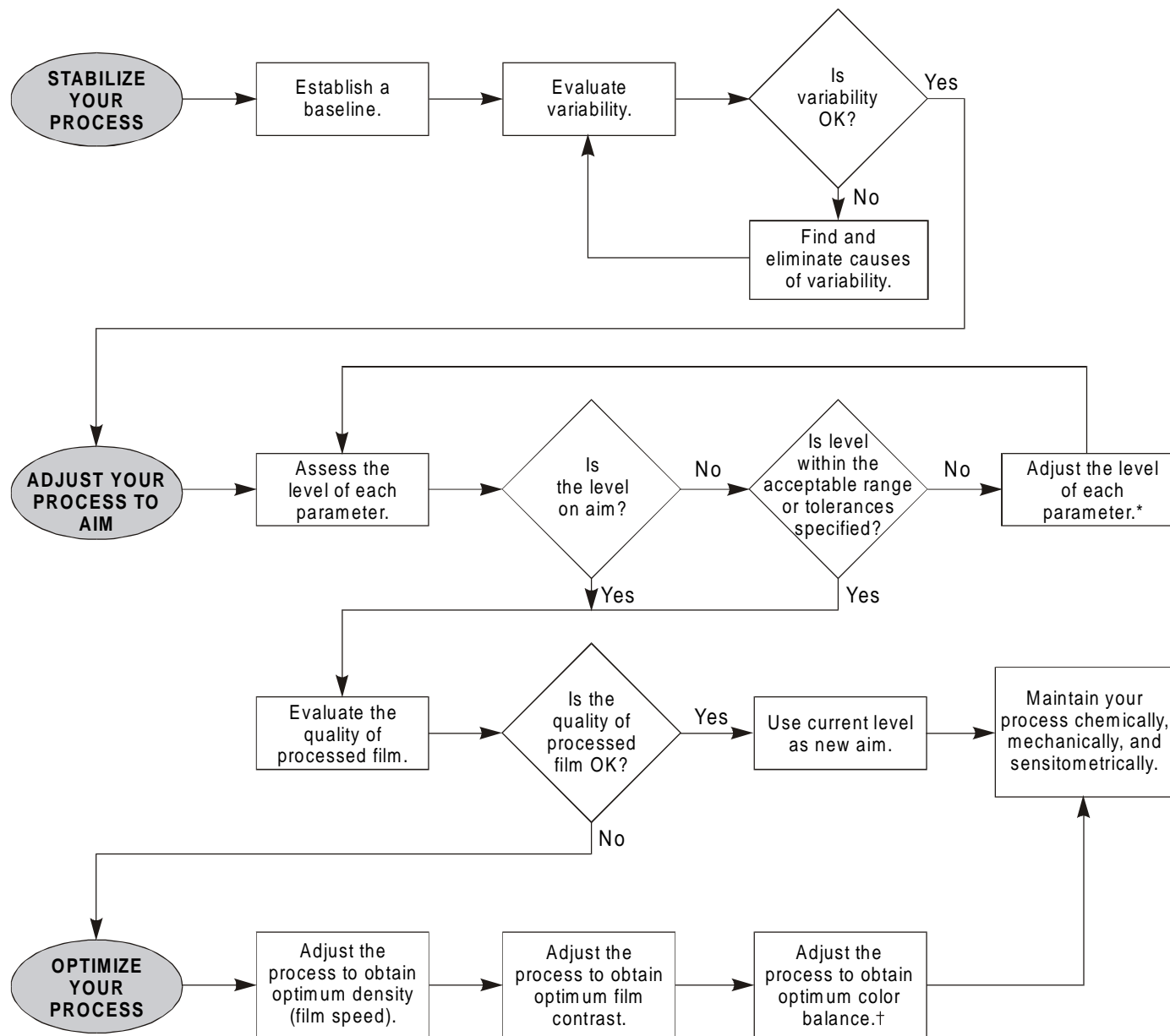
For both machines, the aims are adjusted once, and then maintained. The tolerances remain the same. Note that the adjustments are within the acceptable ranges for the process parameters.

Note: If you make process adjustments to optimize your process for density, contrast, *and* color balance, you may have to make a small adjustment to the first-developer temperature or time to adjust the LD back to aim.

After you have optimized your process, follow the recommendations under “Frequency of Measurements” on page 4-12, and then proceed to *Maintenance*, Section 16.

SUMMARY

The chart below summarizes the procedure for stabilizing, adjusting, and optimizing your process.



*Consider the parameter to be out of control due to a level shift, and make adjustments based on the appropriate diagnostic chart in the sections on the individual solutions.

†Adjust the yellow/blue color balance **first**. Then adjust the magenta/green color balance.