Process Specifications

What are process specifications? They are guidelines by which you make decisions about process control. Specifications generally include an ***aim***, or center point, and ***tolerances,*** or control limits. Many specifications for Process E-6 also include an ***acceptable range***.

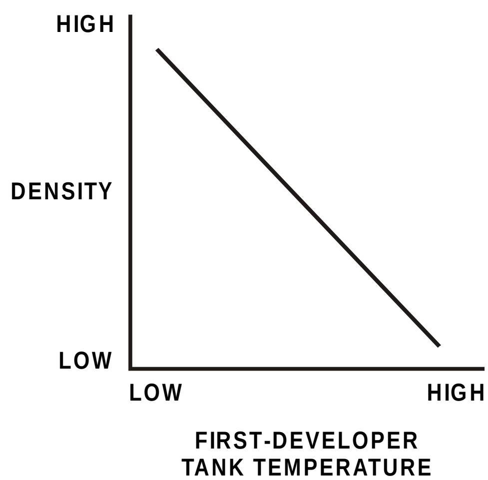
AIMS AND TOLERANCES

The ***aim*** in a specification is the ideal operating value for a particular process parameter; it is usually determined after extensive testing. If all parameters in a process are operating "on aim," the product should be of optimum quality.

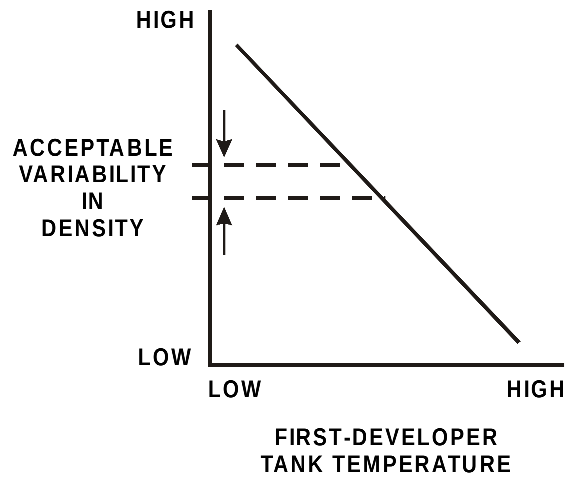
All data have some inherent variability. If a process is in control, the variability shown by the control plots should be random, i.e., it will include no distinguishable patterns. The data should also be equally distributed around the aim. In other words, for every 10 data points, 5 should be on or above the aim, and 5 should be on or below the aim. An average of all the data points should equal the aim or be very close to it.

The ***tolerance*** is the maximum allowable variability from the aim. Tolerances are determined from the acceptable level of variability in the final product. For Process E-6, tolerances for process parameters are set at the point where the photographic effects of process variations on the final image are discernible.

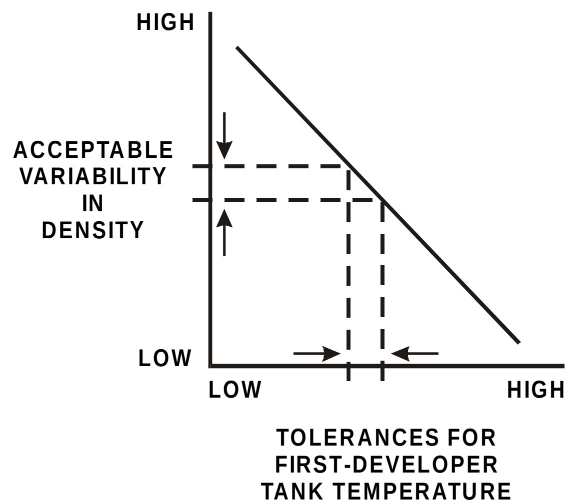
For example, this figure shows the effect on first-developer temperature on film density. The steep slope of the line indicates that density decreases rapidly in proportion to increasing temperature.



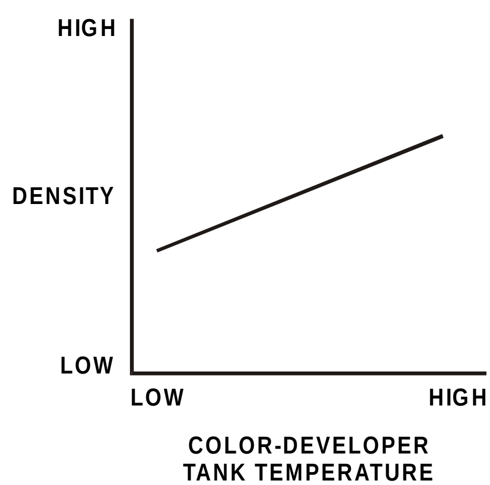
The acceptable level of variability in film density is shown here:



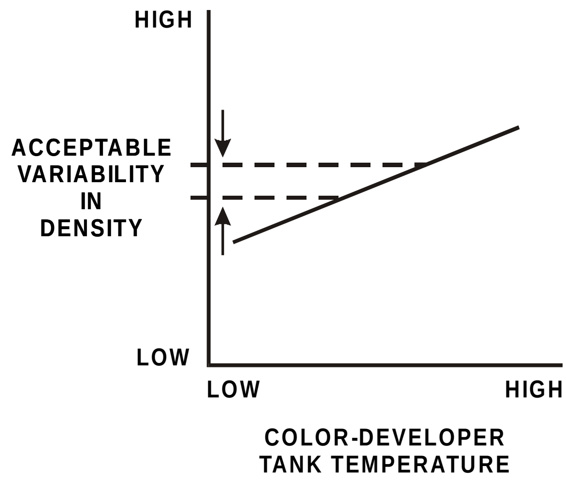
The tolerances (control limits) for first-developer temperature are determined from the acceptable level of density variability in the processed film. Note that the tolerances are narrow to maintain tight control of density.



This figure shows the effect of color-developer temperature on density. The gradual upward slope of the line indicates that as temperature increases, density also increases. However, the increase is not as rapid as the decrease is with first-developer temperature.



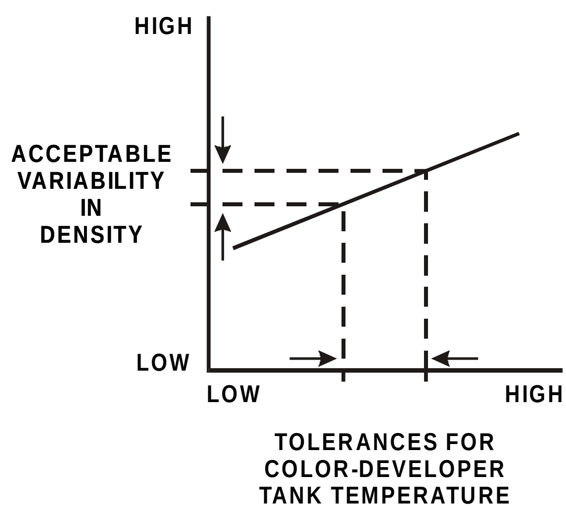
The same acceptable level of density variability is shown here:



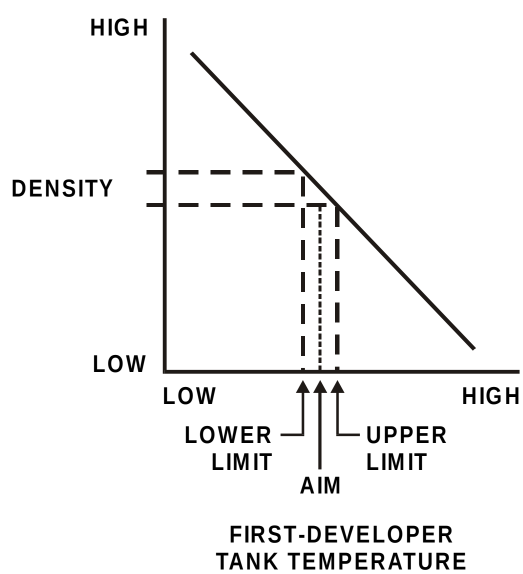
Tolerances for color-developer temperature are determined from the acceptable level of density variability in the same way that they are for first-developer temperature.

Note that tolerances for color-developer temperature are wider than those for first-developer temperature to maintain the *same level of density variability*.

The preceding examples illustrate how tolerances are set according to acceptable levels of variability in the final product.



The aim for a process parameter is centered within the tolerances, as shown here for first-developer temperature:



To maintain photographic control, you must:

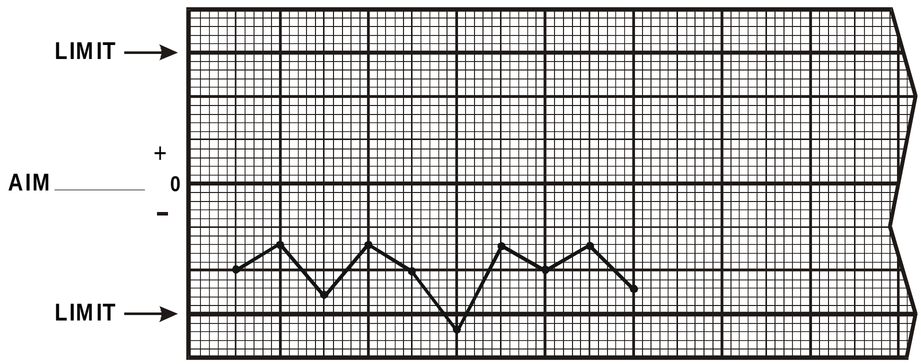
- ***Control the process to the aims***
- ***Minimize variability***

Note: Use measuring instruments that are sufficiently accurate to measure and control the process parameters to the specifications.

If a process is controlled to the aim, and only random variability exists, the process will operate within the tolerances.

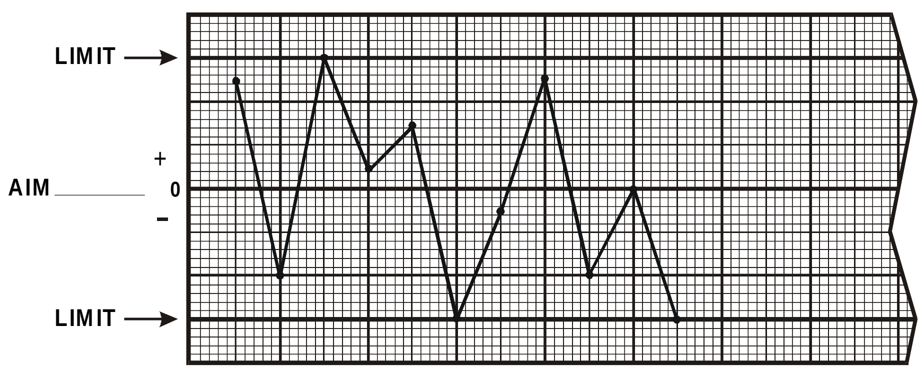
If the process is not controlled to the aim, or if variability is great, the process will sometimes operate outside the tolerances. When a process operates outside the chemical or mechanical tolerances (or both), the risk is high that the quality of the final film images will be degraded.

Here's an example of a process that is operating with the least possible variability but *not* on aim. Even with the smallest possible amount of variability, this process sometimes operates outside the tolerances



Here's an example of a process operating on aim but with a great deal of variability. Although this process is controlled to the aim, its variability is too great.

These examples show that simply being within the tolerances is ***not*** enough. The process must be controlled to the aim ***and*** have minimum variability.



You must control each process parameter to its aim. Do not try to compensate for one parameter that is not within tolerances by adjusting another parameter. For example, if the first-developer concentration is at or below the lower limit, you should not correct the problem by adjusting the first-developer temperature to the upper limit.

The effects of variability are additive. For example, if both the first-developer and the color-developer temperatures are variable, the adverse effects of the variable first-developer temperature add to the adverse effects of the variable color-developer temperature.

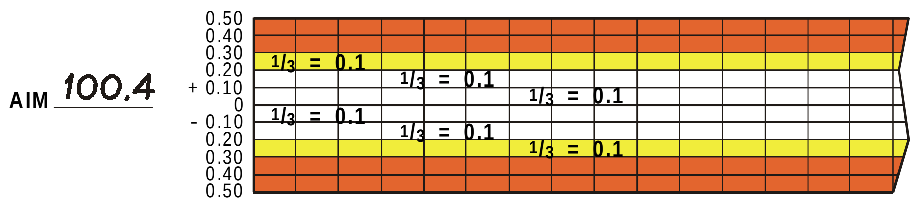
When a process is in control, most of the data will plot close to the aim.

Tolerances on control charts help you to determine the state of process control when you look at the data plots. The range within the tolerances can be divided into thirds (both above and below the aim).

Let's take first-developer temperature as an example. The tolerances is ± 0.3°F (± 0.2°C). One third of that tolerance equals ± 0.1°F (± 0.06°C).

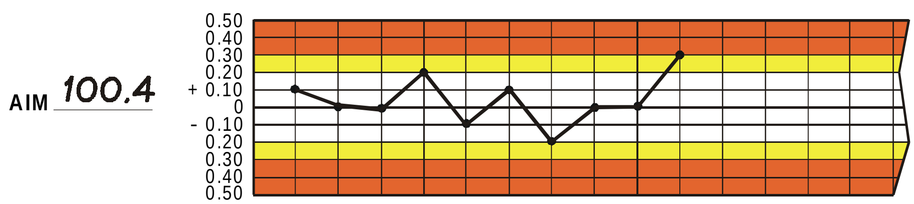
If a process parameter such as temperature is controlled properly, all of the data will plot between the tolerances. Within the tolerances, approximately 7 out of 10 points should plot within the third immediately above or below the aim.

TANK TEMPERATURE (°F)



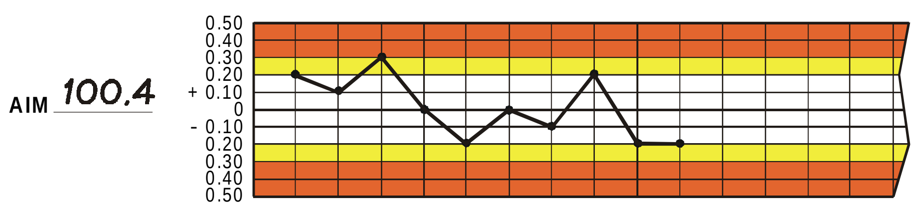
So if the process is in control, 7 out of 10 plots for first-developer temperature will plot within ± 0.1°F (± 0.06°C) of the aim.

TANK TEMPERATURE (°F)



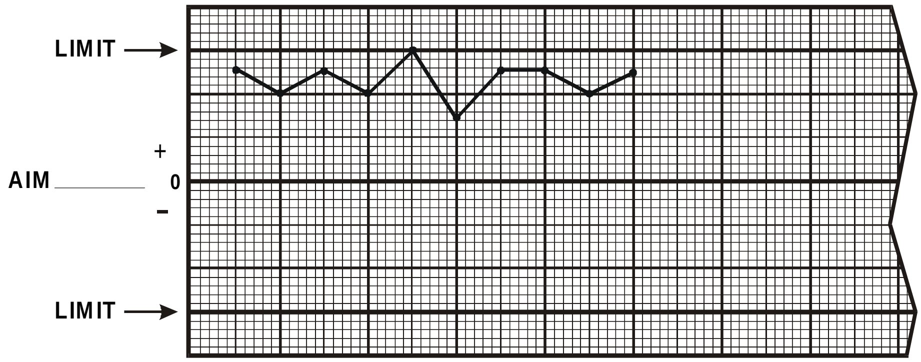
If fewer than 7 out of 10 plots fall within this area, the process is ***not*** in control, and requires investigation for the cause of the variation.

TANK TEMPERATURE (°F)

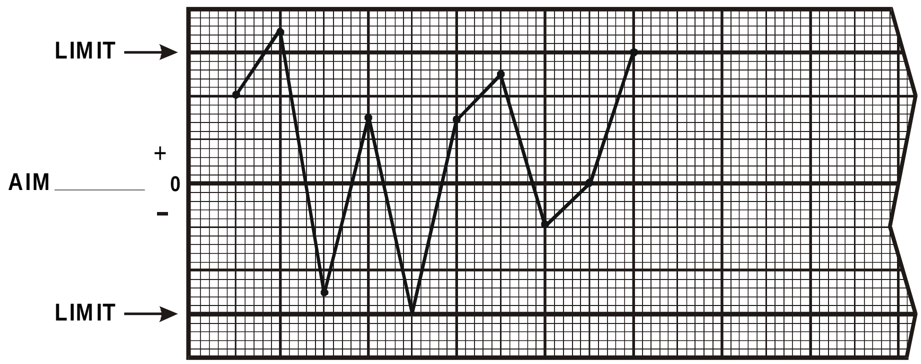


Page 2-6 gives some other process examples.

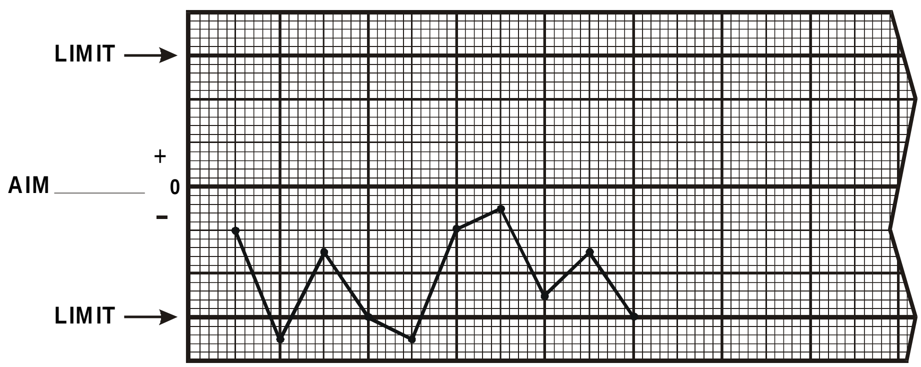
The variability in the process is acceptable, but the process is not on aim. An adjustment is required to center the process on aim.



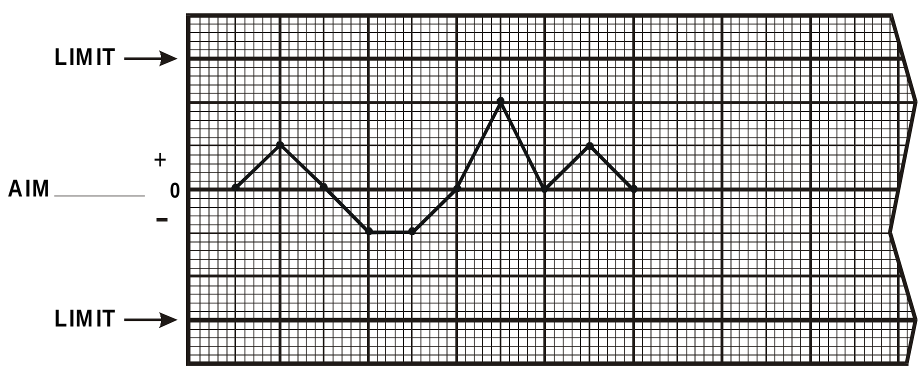
The process is on aim (an average of the data equals the aim), but variability is too great. Sources of variability must be eliminated to reduce it.



Variability is unacceptable, and the process is not on aim. Variability must be reduced first, and then an adjustment is required to move the process to the aim.



The process is in control for variability and is on aim. The data points are centered on the aim, and at least 7 out of 10 points plot within the third of the tolerance range immediately above or below the aim.



ACCEPTABLE RANGES

Many different types of processing machines with different configurations are used for Process E-6. Rack-and-tank, roller-transport, rotary-tube—all have different modes of operation. Machine differences may require operating the process with some parameters not on the specified aim to achieve optimum results. For these reason, Process E-6 specifications often include an acceptable range. The acceptable range for a parameter identifies the range in which you can adjust the aim for the parameter to produce optimum results.

For example, let's look at first-developer temperature:

Published aim = 100.4°F (38°C)
Tolerance = ± 0.3°F (± 0.2°C)

Using a temperature other than 100.4°F (38°C) may be necessary to obtain optimum density levels in processed film in a particular processor. Therefore, an acceptable range is provided for the first-developer temperature: 98 to 103°F (36.7 to 39.4°C).

This range indicates that to obtain optimum results in a particular machine, the aim for first-developer temperature can be adjusted to any temperature from 98 to 103°F (36.7 to 39.4°C). *The tolerance remains the same*. So if Machine X must operate with a first-developer temperature of 99.7°F (37.6°C), the tolerance is ± 0.3°F (± 0.2°C), or 99.4 to 100.4°F (37.4 to 37.8°C). If Machine Z must operate with a first-developer temperature of 102°F (38.9°C), the tolerance is still ± 0.3°F (± 0.2°C), or 101.7 to 102.3°F (38.7 to 39.1°C).

Another example of a parameter with an acceptable range is color-developer specific gravity. Color-developer concentration may need adjustment to produce optimum contrast with some machines (for information on adjusting film contrast, see "Optimizing Your Process" in Section 6). Therefore, an acceptable range is provided with the aim and tolerance:

Color-developer specific gravity:
Aim = 1.038 (at 80°F [27°C])
Tolerance = ± 0.003
Acceptable range = 1.032 to 1.043

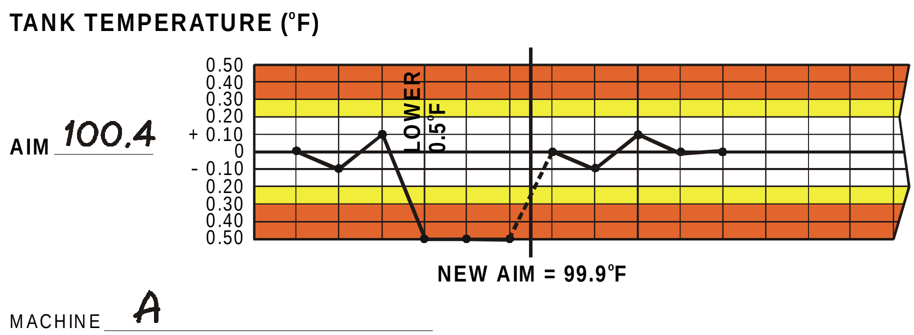
For example, using a less concentrated color developer in some machines to produce optimum film contrast is acceptable, as long as the specific gravity remains within the range 1.032 to 1.043. *The tolerance remains the same*. So if Machine W must operate with a less concentrated color developer for optimum results, the specific gravity must be controlled within ± 0.003 of the new aim. If the adjusted aim is 1.035, the new tolerance is 1.032 to 1.038.

You should adjust an aim within the acceptable range one time only, at start-up or when you optimize process performance. The new aim should as close as possible to the specified aim. Be sure that the need to adjust an aim is real, especially if the adjusted aim is at or near the upper or lower end of the acceptable range.

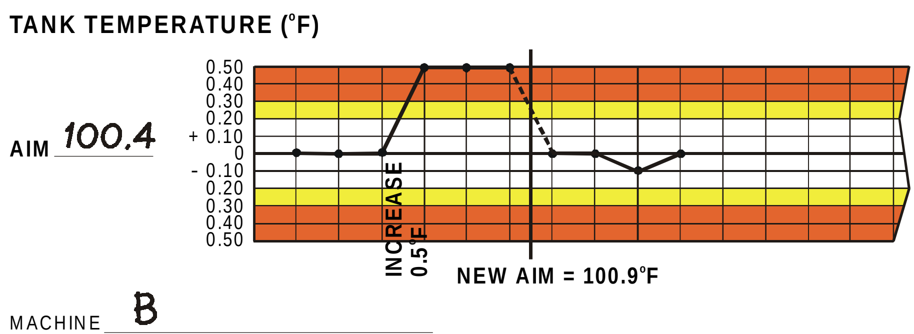
The graphs below show another *example* of adjusting process aims within the acceptable range to optimize performance.

Machine A and Machine B are initially set up to meet all the specified aims given in Sections 7 through 15. 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 blue color balance.

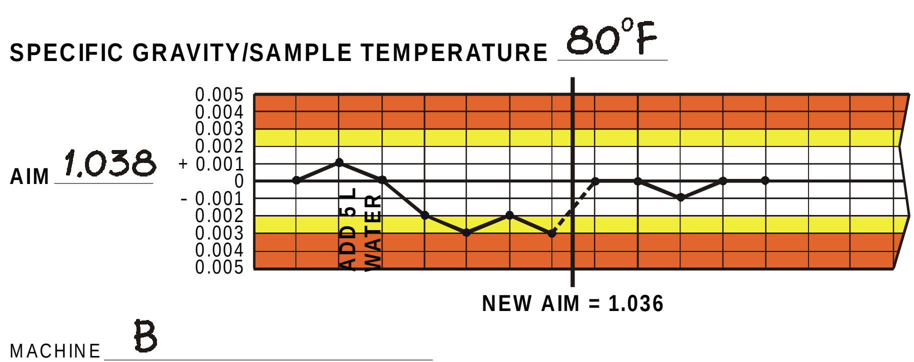
To adjust Machine A for optimum film quality, the aim for first-developer temperature is decreased to 99.9°F (37.7°C). The tolerance remains the same (at ± 0.3°F [± 0.2°C]). The process, optimized for Machine A, produces good results.



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



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



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 ± 0.3°F (38.3 ± 0.17°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 1.2 mL of 5N sodium hydroxide (NaOH) per litre of 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.

The plots on Form Y-33 on page 2-10 show the sensitometric effects of adjusting the aims for Machine A and Machine B.

KODAK PLOTTING FORM FOR PROCESS E-6

Y-33

CODE NO. ___________

D-MAX
RED___________
GREEN________
BLUE__________

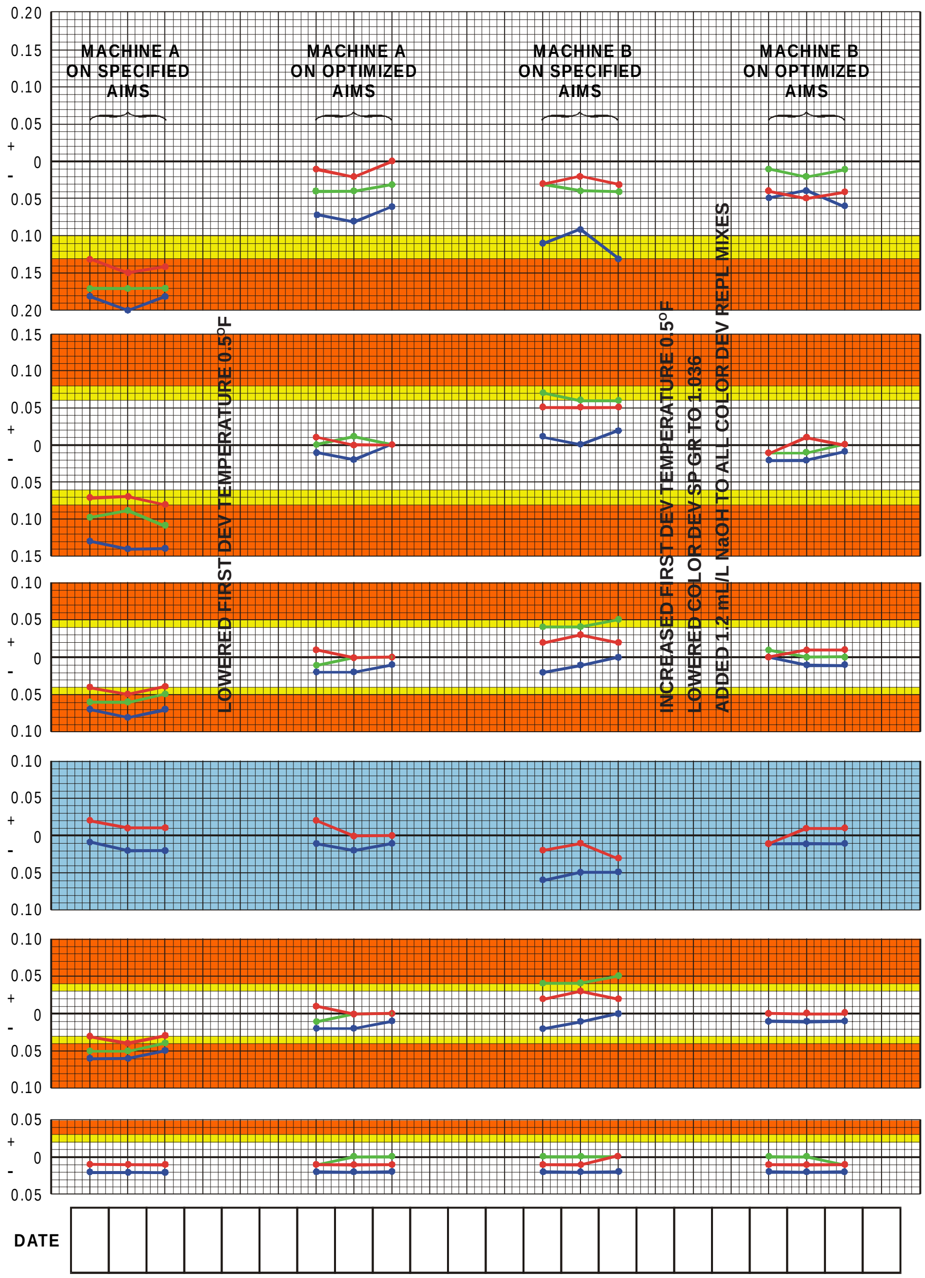
HD
RED___________
GREEN________
BLUE__________

LD
RED___________
GREEN________
BLUE__________

LD SPREAD
R – G
B – G

TD
RED___________
GREEN________
BLUE__________

D-MIN
RED___________
GREEN________
BLUE__________



MACHINE ________________________

EASTMAN KODAK COMPANY • ROCHESTER, NY 14650

KODAK Publication No. **Y-33**

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SUMMARY

Specifications for Process E-6 include an aim and a tolerance, and sometimes an acceptable range.

The ***aim*** is the ideal operating value for a process parameter.

The ***tolerance*** is the maximum variability above and below an aim that can occur without affecting the final image. The goal is to improve the process continuously, and to reduce variability as much as possible. Simply having all of the data plot within the tolerances is not enough.

If a specification has an ***acceptable range***, you can modify the recommended aim within the acceptable range if necessary to optimize the process. Make the change from the recommended aim only once. If you adjust an aim, the tolerance remains the same.

To implement process control for Process E-6, you must routinely monitor the key process parameters listed in Table 1, and plot the results on control charts.

Monitoring and controlling these key parameters is vital to maintaining optimum performance with Process E-6. Each parameter can lead to adverse photographic effects if it is not controlled properly.

In addition to the key parameters, you must be aware of many other process parameters; see Table 2. These additional parameters also affect photographic results, but not as greatly as the key parameters. Because these other parameters affect the key parameters directly, they are important in problem-solving. If a problem occurs that you cannot resolve by controlling the key parameters, monitoring the other parameters can help solve the problem. When you have established control of the key parameters, attention to the parameters listed in Table 2 will help you to achieve even greater process stability.

TABLE 1

Key Parameters	First Developer	Reversal Bath	Color Developer
Time	X		
Temperature	X		X
Replenishment rate	X	X	X
Specific gravity	X	X	X
Bromide concentration	X		
Reversal-agent concentration		X	
Sulfite concentration			X

TABLE 2

Additional Parameters	Solution
Temperature	First wash
Specific gravity of replenisher	First developer, reversal bath, color developer, pre-bleach, bleach, fixer
Replenisher-pump calibration	First developer, reversal bath, color developer, pre-bleach, bleach, fixer
Agitation	First developer, first wash, color developer, bleach, fixer
Recirculation	First developer, color developer, bleach, fixer
Replenishment rate	Pre-bleach, bleach, fixer
Specific gravity of tank solution	Bleach
Flow rate	First wash, final wash

The specifications for all Process E-6 parameters are given in Sections 7 through 15. Procedures for measuring each key parameter are given in Section 4, *Process Monitoring: Chemical and Mechanical Parameters*.