PROCESS MONITORING AND TROUBLESHOOTING

This section describes:

- Terms used in process monitoring
- How to use control strips
- Troubleshooting your process

If you mix chemicals properly and use the correct settings for the process cycles, your process should plot in control, and your minilab will produce high-quality customer orders—provided that your printer is set correctly. Deviations from standard conditions for the processing solutions, time, temperature, agitation, replenishment, filtration, wash water, or drying can cause processing problems.

Deviations from normal conditions produce either under- or overdevelopment.

- *Underdevelopment* in the film or paper process will produce a decrease in density in your control strips for your film or paper process. It may also produce a color shift, depending on the cause of the problem.
- *Overdevelopment* will produce an increase in density in your control strips. It may also produce a color shift, depending on the cause of the problem.

When the control plot shows a problem, you may also see the problem in customer orders. However, remember that customer orders reflect the entire system—i.e., the film process, paper process, and printer settings. For example, too much activity in the film process (overdevelopment of negatives), too little activity in the paper process (underdevelopment of prints), an incorrect printer setting, or a combination of these factors may cause the prints to be light. Checking only the control plots may not always isolate the problem, because using the wrong control strip or improperly stored strips may give false information. To determine the cause of any problem, check the control plots of your film and paper processes and customer orders.

The following terms are frequently used in process monitoring.

Action Limits—The action limits are the boundaries of the desired operating range of the process. As long as the density values remain between the upper and lower action limits, your process is operating correctly. If a density value exceeds the action limit, it is an "early warning." You can still safely process customer work, but you should check for the cause of the shift and correct it. When the density values plot between the upper and lower action limits (i.e., the "aim zone"), your process is in control.

Aim Values—These are the values to which you compare your control-strip densities. To obtain aim values, read the reference-strip densities; then apply the correction factors to the density readings. Enter these values in the spaces provided on the left side of your control chart.

Color-Balance Spread Limits—A color spread is the density difference between the two most widely separated densities of the HD – LD plot. If the process exceeds the color spread limit, stop processing customer work, and take corrective action.

Control Limits—The control limits define the maximum tolerances that are acceptable for processing customer work. If any density value of your process plots beyond the control limit, the process is out of control, and results will be unsatisfactory for color, density, and/or contrast. When any density value plots beyond the control limits, stop processing customer work until you find the cause of the shift and correct it.

Control Strips—These are precisely exposed strips used to monitor your process.

Correction Factors—Numbers used to adjust the densities of the reference strip to obtain aim values. They are printed in the instruction sheet packaged with each box of control strips. Correction factors usually differ for each code number.

Reference Strips—This is a control strip that is precisely processed by Kodak at standard conditions. A reference strip is packaged with each batch of control strips. To obtain aim values, measure the reference-strip densities and apply the correction factors for that batch of control strips.

Tolerances and Limits—Tolerances and limits are density variations allowed before you must take corrective action; they include an aim-value adjustment tolerance, and action and control limits.

Tolerances and Limits for KODAK Control Strips, Process C-41

Measurement	Aim-Value Adjustment Tolerance	Action Limits	Control Limits	Color-Balance Spread Limit
D-min	± 0.03	+ 0.03	+ 0.05	—
LD	± 0.04	± ±0.06	± 0.08	—
HD – LD	± 0.03	± 0.07	± 0.09	0.09
D-max$_B$ – Y$_B$	± 0.07	+ 0.10	+ 0.12	—

Tolerances and Limits for KODAK Control Strips, Process RA-4

Measurement	Aim-Value Adjustment Tolerance	Action Limits	Control Limits
D-min	—	—	+ 0.02
LD	± 0.04	± ±0.07	± 0.10
HD – LD	± 0.03	± 0.07	± 0.10
BP	± 0.05	– 0.10	– 0.15

How to Monitor Your Process

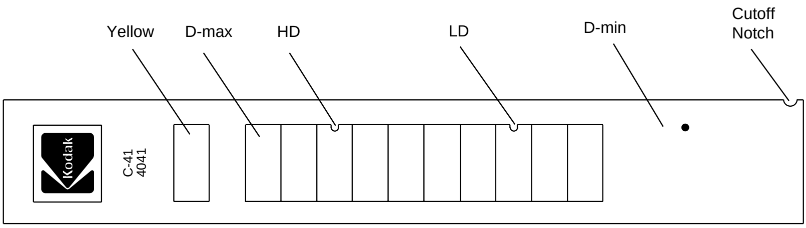
To begin process monitoring, you will need—

- KODAK Control Strips, Process C-41
- KODAK Control Strips, Process RA-4
- An electronic densitometer equipped with Status M filters to read the film-process control strips and Status A filters to read the paper-process control strips
- KODAK Process Record Form Y-55 or similar graph paper
- Red, green, and blue pencils

KODAK Control Strips are the Basic Control Material

KODAK Control Strips are available for monitoring your processes. For a film process that uses KODAK FLEXICOLOR Chemicals, use KODAK Control Strips, Process C-41. For a paper process that uses KODAK EKTACOLOR Chemicals, use KODAK Control Strips, Process RA-4. A pre-processed reference strip is packaged with each type of control strip.

KODAK Control Strips, Process C-41 (35 mm)—These 35 mm strips are supplied in 100-foot rolls of approximately 120 strips with cutoff notches at 9½-inch (24.1 cm) intervals. The roll is wound *emulsion side in*, with the D-min ends of the strips toward the outer end of the roll.



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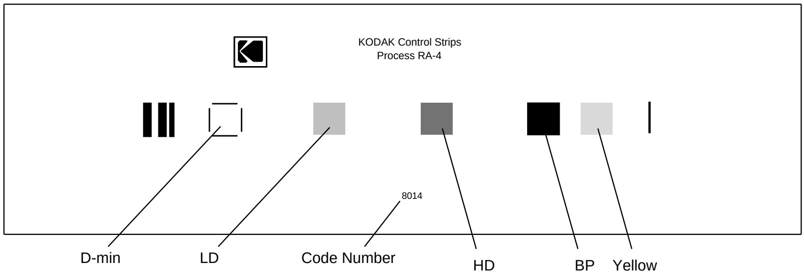
Each strip has 12 steps; a yellow step, a D-max step, and 10 equal-increment density steps. The LD and HD steps are marked by a “U” in the step. Measure the area adjacent to the black dot to obtain the D-min density.

KODAK Control Strips, Process RA-4—Use KODAK Control Strips, Process RA-4, to monitor your process. These strips are available in a box of ten moisture-resistant envelopes that contain five strips each. Each control strip, reference strip, and box label is marked with a code number. The code number identifies the strips as part of a particular batch. Each box contains correction factors for that particular code number. Use these correction factors to calculate the aim values for this batch of strips.



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Each strip measures $3\frac{1}{2}$ x 12 inches, and contains three neutral patches, a yellow patch, and an unexposed area. Measure the neutral patches to obtain density values for LD (low density), HD (high density), and BP (black patch). Measure the unexposed patch to obtain the density value for D-min. Use the yellow patch as a visual indicator of retained silver caused by low bleach-fix activity. When retained silver is present, the yellow patch will appear brown and less saturated than normal.

Storing and Handling Control Strips

Store unused control strips at –18°C (0°F) or lower. Handle unprocessed strips in total darkness. Remove only a day's supply from one package at a time; reseal and return the package to the freezer as quickly as possible. (**Do not** keep the package out of the freezer for more than 1 hour per day.) Store your daily supply of control strips in a lighttight container at room temperature. At the end of the day, discard any unprocessed strips that you removed from storage.

Handle control strips by the edges to prevent fingerprints and surface damage. If film sticking, static marking, or moisture mottle occurs, allow the strips to warm up to room temperature before you process them.

Store the reference strip in its envelope when you are not using it.

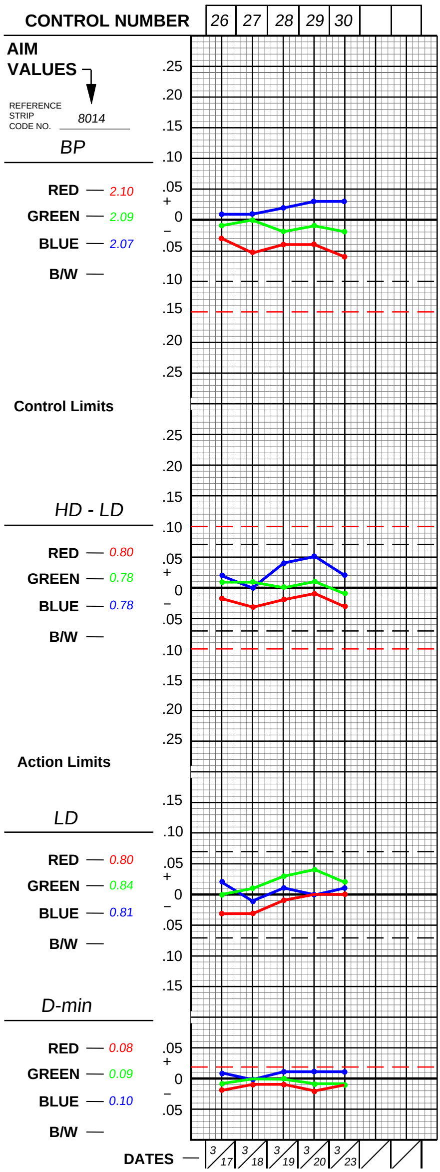
Processing Control Strips

Each time you process a control strip, position it in the same location in your processor. Process a control strip—

- At the beginning of the day or shift, before processing customer work
- At regular intervals with customer work
- At the end of the day or shift

Plotting Control-Strip Densities

Create a control chart by using the KODAK Process Record Form Y-55 or similar graph paper. Follow the procedure given on pages 53 and 54. Your chart will look like the example shown below.



1. Draw in the action and control limits given in the appropriate table on page 47. Use black for the action limits and red for the control limits.
2. Remove the reference strip from the box of control strips. If you removed the box from cold storage, allow the reference strip to warm up to room temperature before you remove it from its envelope (about 15 minutes). Exposing a frozen reference strip to warm, moist air can cause low readings, particularly in the higher density patches. If this occurs, re-wash the reference strip in warm water to return the readings to normal values.
3. Use a precision electronic densitometer to measure the densities in the center of each of the patches on the reference strip. **Do not** move the strip as you make the density readings or you may affect the precision and repeatability of the measurements.

   For the film process, measure the following densities of the reference strips. Set your densitometer to the transmission mode, and use the Status M filters.

Measurement	Step	Filter
HD	notched step closest to D-max	red, green, blue
LD	notched step closest to D-min	red, green, blue
D-min	clear area next to a black dot	red, green, blue
Y_B	yellow patch	blue
D-max_B	maximum density patch	blue

For the paper process, measure the following densities of the reference strips. Set your densitometer to the reflection mode, and use the Status A filters.

Measurement	Step	Filter
D-min	unexposed patch	red, green, blue
LD	low density	red, green, blue
HD	high density	red, green, blue
BP	black	red, green, blue

If you have several boxes of strips with the same code number, average the readings of all of the reference strips. A code number on the box label and the reference and control strips identifies each batch.

4. To calculate aim values, apply the correction factors supplied in the instruction sheet packaged with each box of control strips to the reference-strip densities. If you averaged the reference-strip readings from several boxes of the same code number, apply the correction factors to the average. These corrected density values are the aim values for that batch of control strips. Record them in the proper spaces in the left margin of Form Y-55.

- To obtain the HD – LD aim values, subtract the adjusted LD values from the adjusted HD values.
- To obtain the D-max$_B$ – Y$_B$ aim value, subtract the adjusted blue-filter density of the yellow step from the adjusted blue-filter density of the D-max step.

5. Process a control strip and measure the same patches that you measured in step 3.
6. Calculate the variations from aim by subtracting the aim densities from your control-strip densities. Plot the variations on your control chart.
   - Plot differences that are **larger** than the corresponding aim values (+ values) **above** the aim line.
   - Plot differences that are **smaller** than the aim values (– values) **below** the aim line.
7. If any of the variations from aim plot beyond the action or control limits, process another control strip. If the second strip confirms the results of the first strip, determine the cause of the problem. The information on pages 56 and 57 will help you troubleshoot your process problems.
8. Whenever you take corrective action, process another control strip to confirm that the change you made returned the process to control before you resume normal processing.

Changing to a New Batch of Control Strips

When you change from your current batch of control strips to strips with a different code number, make a crossover to confirm that both code numbers provide the same information. *Be sure that your process is stable and in control before you begin using a new batch of control strips.*

1. While you still have a week's supply of control strips of the current code, process one control strip from the new batch of strips with one strip from the current batch *in three separate runs.*
2. Read and record the densities of the processed strips.
3. Determine aim values for the new batch of control strips; follow steps 2 through 4 on pages 53 through 54.
4. For your current batch of control strips, calculate the variations from aim by subtracting your current aim densities from the densities of the three strips. Plot the variations on your control chart.
5. For the new batch of strips, calculate the variations from aim by subtracting the new aim densities (calculated in step 3) from the densities of the three strips. Plot the variations on your control chart.
6. Calculate the differences between the variations from aim of the current strips and the new strips. Average these differences, then divide the result by 2.
7. Add or subtract the results of step 6 from the aim values for the new batch of strips determined in step 3. The amount of the adjustment should not exceed the aim-value adjustment tolerances given in the appropriate table on page 47. If the adjustment is greater than the tolerance, determine the cause. Check your calculations, densitometer, and control strips.
8. Record the new aim values and the code number of the new batch of strips on your control chart, and begin using the new strips.

Troubleshooting Your Process

When one or more process parameters exceeds the control limits, stop processing customer work until you find and correct the cause of the problem. It is important to become familiar with control-chart patterns and cause-and-effect relationships. Control-chart patterns can generally be separated into three categories: high activity, low activity, and high D-min. Also, check your control chart to determine if the process drifted out of control slowly or suddenly.

High Activity—The process is out of control with process parameters plotting above aim. This condition can be caused by:

- Developer temperature that is too high
- Developer time that is too long
- Overreplenished developer (i.e., the solution is replenished at a rate that is too high)
- Mixing error
- Developer contamination
- Overconcentrated developer (from evaporation or insufficient topping off with water)

Low Activity—The process is out of control with process parameters plotting below aim. This condition can be caused by:

- Developer temperature that is too low
- Developer time that is too short
- Underreplenished developer (i.e., the solution is replenished at a rate that is too low)
- Mixing error
- Developer contamination
- Developer tank solution diluted with water

High D-min—This condition can be caused by:

- Developer oxidation caused by low utilization
- Developer contamination
- Overconcentrated developer
- Excessive aeration of bleach
- Inadequate washing

Trend—An out-of-control condition that has occurred *slowly* over time indicates a problem such as:
Improper replenishment—caused by an incorrect replenishment rate, an incorrectly mixed replenisher, or a defective replenisher pump.
Evaporation or oxidation—caused by low utilization or air drawn into the processing solutions by a bad pump, a recirculation system leak, or a poorly placed ventilation fan.
Contamination—caused by photographically active materials that leach slowly into the solutions and cause the process to drift out of control. The contaminants may be in any material the solutions contact, such as the filters, plumbing, etc.
Incorrect mixing—if you suspect that the problem was caused by replenisher solution that was mixed incorrectly, mix a new batch of replenisher to see if a fresh mix gradually corrects the problem.

Sudden Change—An out-of-control condition that has occurs *suddenly* indicates a problem with your:

Control Strip—check that you used control strips of the same code number. Remember, if you change code numbers, you need to establish new aim values for that code number (see *Changing to a New Batch of Control Strips* on page 55). Check that the control-strip code numbers match those of the reference strip. Check that the strips were handled and stored properly.

Densitometer—if your densitometer is not working properly or is out of calibration, the density readings will be wrong. This can falsely signal that there was a process change. Check that you used the proper filters (Status A filters for paper and Status M filters for film).

Time or Temperature—check that the time and temperature were set correctly, particularly if they are easy to change.

Contamination—bleach-fix splashed into the developer while cleaning racks or removing jammed paper can cause sudden large spreads in your control plots.

Solution mixing—if the sudden change occurs after you have mixed a fresh tank solution, check that it was mixed correctly.

Aim values—check that you compared the control-strip densities with the correct aim values.

Note: When you troubleshoot a problem, check the easiest and most obvious causes first; then check the more difficult and less likely causes.

For complete information on diagnosing your process, see the control-chart examples in KODAK Publications No. Z-130, *Using KODAK EKTACOLOR RA Chemicals*, and Z-131, *Using KODAK FLEXICOLOR Chemicals*.

APPENDIX

Simplified Metric Conversion Charts

Because most laboratory measuring devices are calibrated in metric units, you can use the following table to convert U.S. units of volume, length, and weight to metric units. **Do not** use this table to convert from metric to U.S. values. Accuracy of the table is within one percent.

To use the table, find the number you are converting from at the top of the table for numbers from 1 to 9. For numbers greater than nine, find the number you are converting by using a combination of the number at the left side of the table and the number at the top.

Volume, Length, and Weight Conversion

U.S. Gallons to Litres

gal	0	1	2	3	4	5	6	7	8	9
0	—	3.8	7.6	11.4	15.1	18.9	22.7	26.5	30.3	34.1
10	37.8	41.6	45.4	49.2	53	56.8	60.6	64.4	68.1	71.9
20	75.7	79.5	83.3	87.1	90.8	94.6	98.4	102.2	106	107.8
30	113.6	117.3	121.1	124.9	128.7	132.5	136.3	140.1	143.8	147.6
40	151.4	155.2	159	162.8	166.6	170.3	174.1	177.9	81.7	185.5

U.S. Fluid Ounces to Millilitres

fl oz	0	1	2	3	4	5	6	7	8	9
0	—	29.5	59	89	118	148	177	207	237	265
10	295	325	355	385	415	445	475	500	530	560
20	590	620	650	680	710	740	770	800	830	860
30	890	920	950	980	1006	1035	1065	1094	1124	1153

Inches to Centimetres

in.	0	1	2	3	4	5	6	7	8	9
0	—	2.5	5.1	7.6	10.2	12.7	15.2	17.8	20.3	22.9
10	25.5	28.0	30.5	33.0	35.5	38.0	40.5	43.0	45.5	48.5
20	51	53	56	58	61	64	66	69	71	74
30	76	79	81	84	86	89	91	94	97	99

Ounces to Grams

oz	0	1	2	3	4	5	6	7	8	9
0	—	28.5	57	85	113	142	170	198	227	255
10	285	310	340	370	395	425	455	480	510	540
20	570	600	620	650	680	710	740	770	790	820
30	850	880	910	940	960	990	1021	1049	1077	1106

You can use the following to convert from metric to U.S. values or from U.S. to metric values. To do this, multiply the metric or U.S. units in column 1 by the number in column 2 (e.g., to convert 450 millilitres to fluid ounces, multiply 450 by .03382 = 15.22 fluid ounces).

Conversion Factors

To Convert	Multiply By
Millilitres to Fluid Ounces	.03382
Fluid Ounces to Millilitres	29.573
Pints to Litres	.4732
Litres to Pints	2.113
Quarts to Litres	.9463
Litres to Quarts	1.057
Gallons to Litres	3.785
Litres to Gallons	.2642

Temperature Conversion

To convert a temperature from one unit of measure to another, use the following table. Find the temperature you are converting from in the "°F or °C" column; if you are converting to degrees Celsius, read the number from the "to °C" column. If you are converting to degrees Fahrenheit, read the number from the "to °F" column.

to °C	°F or °C	to °F	to °C	°F or °C	to °F	to °C	°F or °C	to °F
37.78	100	212.0	18.33	65	149.0	–1.11	30	86.0
37.22	99	210.2	17.78	64	147.2	–1.67	29	84.2
36.67	98	208.4	17.22	63	145.4	–2.22	28	82.4
36.11	97	206.6	16.67	62	143.6	–2.78	27	80.6
35.56	96	204.8	16.11	61	141.8	–3.33	26	78.8
35.00	95	203.0	15.56	60	140.0	–3.89	25	77.0
34.44	94	201.2	15.00	59	138.2	–4.44	24	75.2
33.89	93	199.4	14.44	58	136.4	–5.00	23	73.4
33.33	92	197.6	13.89	57	134.6	–5.56	22	71.6
32.78	91	195.8	13.33	56	132.8	–6.11	21	69.8
32.22	90	194.0	12.78	55	131.0	–6.67	20	68.0
31.67	89	192.2	12.22	54	129.2	–7.22	19	66.2
31.11	88	190.4	11.67	53	127.4	–7.78	18	64.4
30.56	87	188.6	11.11	52	125.6	–8.33	17	62.6
30.00	86	186.8	10.56	51	123.8	–8.89	16	60.8
29.44	85	185.0	10.00	50	122.0	–9.44	15	59.0
28.89	84	183.2	9.44	49	120.2	–10.00	14	57.2
28.33	83	181.4	8.89	48	118.4	–10.56	13	55.4
27.78	82	179.6	8.33	47	116.6	–11.11	12	53.6
27.22	81	177.8	7.78	46	114.8	–11.67	11	51.8
26.67	80	176.0	7.22	45	113.0	–12.22	10	50.0
26.11	79	174.2	6.67	44	111.2	–12.78	9	48.2
25.56	78	172.4	6.11	43	109.4	–13.33	8	46.4
25.00	77	170.6	5.56	42	107.6	–13.89	7	44.6
24.44	76	168.8	5.00	41	105.8	–14.44	6	42.8
23.89	75	167.0	4.44	40	104.0	–15.00	5	41.0
23.33	74	165.2	3.89	39	102.2	–15.56	4	39.2
22.78	73	163.4	3.33	38	100.4	–16.11	3	37.4
22.22	72	161.6	2.78	37	98.6	–16.67	2	35.6
21.67	71	159.8	2.22	36	96.8	–17.22	1	33.8
21.11	70	158.0	1.67	35	95.0	–17.78	0	32.0
20.56	69	156.2	1.11	34	93.2	–18.33	–1	30.2
20.00	68	154.4	0.56	33	91.4	–18.89	–2	28.4
19.44	67	152.6	0.00	32	89.6	–19.44	–3	26.6
18.89	66	150.8	–0.56	31	87.8	–20.00	–4	24.8

For temperatures not shown in the table on page 61, use the following formulas:

1. To convert to degrees Celsius, add 40 to the Fahrenheit temperature. Then divide by 1.8; subtract 40 from the result.
2. To convert to degrees Fahrenheit, add 40 to the Celsius temperature. Then multiply by 1.8; subtract 40 from the result.

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Consumer Imaging

EASTMAN KODAK COMPANY • ROCHESTER, NY 14650

KODAK Publication No. **Z-100**

CAT 806 9882

Minor Revision 10-01
Printed in U.S.A.