3 SINK-LINE, BATCH, AND ROTARY-TUBE PROCESSORS

This section gives the steps and conditions for using KODAK FLEXICOLOR Chemicals to process Kodak color negative films in sink-line, batch, and rotary-tube processes with Process C-41.

USING SINK-LINE PROCESSORS

Equipment

The basic equipment that you'll need for this type of processing includes the following:

Sink—To maintain a solution processing temperature of 37.8°C (100°F), use a tempered-water bath for the processing tanks. You can use a deep sink with a standpipe of sufficient length to surround the tank to solution level with tempered water.

Processing Tank—Tanks made of stainless steel provide the best heat transfer for solution temperature control. You can also use tanks such as KODAK Hard Rubber Tanks or tanks supplied with the processing line.

Processing Reels—Use commercially available wire or plastic reels. Be sure that the reels fit the reel holders properly.

Reel Holders—Use reel holders such as the KODAK Processing Rack. Sizes are not standard; be sure that the reel holders and processing tanks are compatible.

Sheet-Film Hangers and Separators—Typical equipment should include film hangers for the sheet-film sizes that you process. During processing, use separators to provide a space of approximately 13 mm ($^1/_2$ in.) between hangers.

Gaseous-Burst Agitation Equipment—Use a gas valve that you can adjust to vary the length of the burst and the interval between bursts, and a gas distributor that provides uniform gas distribution. For the developer, use only compressed nitrogen gas that has a purity of 99 percent (or higher).

Steps and Conditions

The processing steps and conditions for Process C-41 in sink-line processors are similar to those for other types of processors. However, with sink-line processing, most of the operation, such as agitation, transferring the film between solutions, temperature control, and replenishment, are done manually.

Table 3-1 Steps and Conditions—Sink-Line Processors

Solution/Step	Time* min:sec	Temperature °C (°F)	Comment
FLEXICOLOR Developer	3:15	37.8 ±0.15 (100.0 ±0.25)†	Agitate with nitrogen and/or manual agitation.
FLEXICOLOR Bleach III‡	6:30	24 to 41 (75 to 105)	Agitate and aerate with oil-free air and/ or manual agitation.
Wash	3:15	24 to 41 (75 to 105)	Agitate with oil-free air or nitrogen or manual agitation.
FLEXICOLOR Fixer and Replenisher	6:30	24 to 41 (75 to 105)	Agitate with oil-free air or nitrogen or manual agitation.
Wash	3:15	24 to 41 (75 to 105)	Agitate with oil-free air or nitrogen or manual agitation.
FLEXICOLOR Stabilizer III	1:30	24 to 41 (75 to 105)	Manual agitation only.
Dry	As needed	24 to 43 (75 to 110)	Remove roll film from reel.

* Times include a 10-second drain time at the end of each step.

† The developer temperature given is the recommended temperature *during development;* it is *not* the recommended starting temperature for the developer (see *Developer Starting Temperature*).

‡ You can turn on the lights after the bleach step.

Temperature Control

A temperature-control valve on the water supply for the tempered-water bath will help you maintain solution temperature. Tanks made of stainless steel provide the best heat transfer.

Developer Starting Temperature—The developer temperature given in Table 3-1 is the recommended temperature during development. (It is not the recommended starting temperature for the developer.)

To determine the starting temperature of the developer, follow this procedure:

1. Measure and record the room temperature near the developer tank.
2. Adjust the developer temperature to 37.8°C (100.0°F). Use an unshielded thermometer with an expanded range calibrated in 0.1°C units, such as the ASTM No. 91C, or Fahrenheit equivalent. Put the thermometer in the developer for several minutes until it registers an equilibrium temperature. Record the temperature and replace the thermometer in the developer.
3. Lower a full rack of processed scrap film similar to what you normally process into the developer. Provide the same initial agitation that you normally use in processing. After 60 seconds (measured from the time when you first placed the film in the developer), record the solution temperature.
4. Calculate the difference in the developer temperature between steps 2 and 3.
5. Add the temperature difference you calculated in step 4 to the recommended temperature of 37.8°C (100°F) to obtain the *starting temperature.* As long as the processing conditions (room temperature and amount and type of film) remain the same, you can use this as the starting temperature for subsequent processes. If the processing conditions change, repeat this procedure for the new conditions.

Example: If the temperature change for a metal carrier filled with thirteen 8 x 10-inch sheets of film (on hangers) is 0.6°C (1.1°F) at a room temperature of 21°C (70°F), your actual starting developer temperature for this room temperature and amount of film should be

37.8° (100.0) + 0.6°C (1.1°F) = 38.4°C (101.1°F)

Although the temperature difference appears small, the effect will be significant, particularly if you are critical about your processing results and want to maintain consistency between processes.

Agitation

Although you can use manual or gaseous-burst agitation for sink-line processing, using a combination of both types will give the best uniformity, particularly for sheet films.

Unless you find the results satisfactory for your needs, do not use nitrogen-burst or manual agitation alone. Using only nitrogen-burst agitation in the developer may result in nonuniformity. The amount of nonuniformity may be affected by the distribution of the burst, burst frequency, and bubble size, as well as factors such as reel or hanger design and location of the reel or hanger in the tank.

Use only nitrogen for gaseous-burst agitation in the developer, because air will oxidize the developer. However, using air for agitation in the bleach is necessary to oxidize the exhausted bleach to a usable form, and to oxidize developer carried into the bleach. Without aeration, the bleach loses activity. If you cannot use air agitation in the bleach, you must use another method to aerate it.

In the fixer and washes, you can use either compressed air or nitrogen.

Combination of Manual and Gaseous-Burst Agitation—This is the recommended method of agitation for sink-line processing.

Developer—

1. When you first immerse the film in the developer, provide a continuous nitrogen burst for the first 15 seconds.
2. After the initial burst, provide a 2-second burst every 28 seconds.
3. At the end of each nitrogen burst, manually agitate for 13 seconds by lifting the rack from the developer, and tilting it toward the *front* of the tank. Tap the rack against the top edge of the tank and then reimmerse the rack. Then repeat this procedure, but after lifting the rack, tilt it toward the *back* of the tank. End this sequence by tapping the rack against the top edge of the tank and then reimmersing the rack.
4. Steps 2 and 3 make up a single 15-second agitation sequence. Repeat this sequence throughout development.

Bleach, First Wash, and Fixer—Use the same agitation procedure as you did for the developer, but use air instead of nitrogen for the gaseous-burst agitation in the bleach.

Final Wash—Use *only* gaseous-burst agitation (compressed air or nitrogen), with a 2-second burst every 28 seconds.

Stabilizer—**Do not** use gaseous-burst agitation. Provide continuous manual agitation for the first 15 seconds only. Use no other agitation during the rest of the step.

Manual Agitation—Use this type of agitation alone *only* if it provides satisfactory uniformity:

Developer—

1. Immerse the rack fully into the developer. Rapidly tap it on the bottom of the tank to dislodge any air bubbles. Raise the rack until the bottom is out of the developer; then reimmerse it. Do this once. This requires 4 to 5 seconds.
2. After the initial agitation, let the rack sit for 10 seconds. Then lift it straight up until the bottom is just out of the developer solution. Reimmerse it without draining. Do this with an even, uniform motion, taking 2 to 3 seconds to complete it. Repeat this procedure once every 10 seconds (6 times per minute).
3. Ten seconds before the end of the development time, raise the rack, tilt it about 30 degrees toward one corner, and drain it for 10 seconds. Then move the rack into the bleach.

This agitation procedure should produce satisfactory process control. However, if the contrast plots are slightly low, increase the frequency of agitation. If the plots are slightly high, reduce the frequency of agitation, but do not reduce the frequency to less than twice per minute.

Other Solutions—

1. Use the same *initial* agitation as you used for the developer.
2. Use four lifting cycles per minute at 15-second intervals. You may need to provide aeration for the bleach (see *Bleach Aeration*).

Washes—With a running-water wash, use the same *initial* agitation that you used for the developer. No other agitation is needed.

Gaseous-Burst Agitation—Use this type of agitation alone *only* if it provides satisfactory uniformity. Use only nitrogen in the developer.

Developer—

1. Immerse the rack fully into the developer. Rapidly tap it on the bottom of the tank to dislodge any air bubbles. Raise the rack until the bottom is out of the developer; then reimmerse it. Do this once. This requires 4 to 5 seconds.
2. Eight seconds after immersing the film, give a 2-second nitrogen burst. Repeat the 2-second burst at 10-second intervals (6 times per minute). If necessary, increase the frequency of the 2-second burst to 10 times per minute or decrease it to twice per minute to adjust the contrast (HD – LD values in the control plot).

Other Solutions—

1. Immerse the rack fully into the solution. Rapidly tap it on the bottom of the tank to dislodge any air bubbles. Raise the rack until the bottom is out of the solution; then reimmerse it. Do this once. This requires 4 to 5 seconds.
2. After the initial agitation, provide a 2-second burst 4 times per minute. You *must* use air for bleach agitation. You can use air or nitrogen in the fixer.

Bleach Aeration

For efficient bleaching, you must aerate the bleach. Continuous gaseous-burst agitation in the bleach throughout the entire process cycle will provide the necessary aeration.

If you use manual agitation for your process, you must provide some other means of mixing air into the bleach. One way to do this is to bubble air from a compressed-air supply into the bleach through a sparger or by using an aquarium pump for about 5 minutes during each process. Use a valve pressure of about 2.5 lb/in^2 (17 kPa). You can also draw air into the bleach by vigorously stirring it with a mixer.

Replenishment Rates

Replenishment helps maintain the solutions at normal strength. Replenishment compensates for—

- carry-in from the preceding solution
- chemicals that dissolve out of the film during processing
- depletion of chemicals that occurs during chemical reactions

Table 3-2 gives starting-point replenishment rates for individual rolls, sheets, and film holders. Base your replenishment rates on the amount and type of film you process.

Table 3-2

Replenishment Rates—Sink-Line Processing*			
KODAK Film and Film Size	**FLEXICOLOR Developer Replenisher**	**FLEXICOLOR Developer Replenisher LORR**	**FLEXICOLOR Bleach III, Fixer, Stabilizer III Replenishers**
	mL/roll or sheet		
Bright Sun, Bright Sun & Flash, ROYAL GOLD 200, PROFESSIONAL PORTRA 160NC/VC, PROFESSIONAL PORTRA 100T			
135-12	19.3	9.6	37
135-24	35.6	17.8	52
135-36	52.1	26.1	69
120	50.0	25.4	72
220	102.4	51.2	144
4 x 5 inches	16.4	8.2	28
8 x 10 inches	65.6	32.8	87
MAX Versatility, MAX Versatility Plus, ROYAL GOLD 400, Black & White Film, GOLD (110), PROFESSIONAL PORTRA 400NC/VC/UC, PROFESSIONAL PORTRA 400BW, PROFESSIONAL PORTRA 800, PROFESSIONAL T400 CN, Commercial Internegative, VERICOLOR Slide and Print Film			
110-24	28.2	14.1	11
135-12	24.4	12.2	37
135-24	45.4	22.7	52
135-36	66.2	33.1	69
120	75.5	37.8	72
220	151.0	75.5	144
4 x 5 inches	22.4	11.2	28
8 x 10 inches	89.6	44.8	87
Reels or Holders Without Film			
Reel carrier	0	0	30
Sheet-film carrier	0	0	50
135-12/20	0	0	15
135-24/36	0	0	23
110-12/24	0	0	10
120	0	0	20
70 mm	0	0	25
4 x 5 inches (4 sheets)	0	0	15
5 x 7 inches (2 sheets)	0	0	10
8 x 10 inches	0	0	10

* Replenishment rates for film include the reel or sheet-film hanger. If empty reels or hangers are run through the process, include rates for reels or sheet-film hangers. The rates are for metal reels; plastic reels have a higher carryover rate and require an increase in bleach, fixer, and stabilizer replenishment rates of approximately 60 percent for 110-size reels and 25 percent for 135- and 120-size reels. For wash water, use a flow rate of 2 gallons per minute.

Capacity of Unreplenished Solutions

Instead of replenishing the solutions, you can use them until they are exhausted and then discard them. Table 3-3 shows you the number of rolls you can process before you must replace the developer. The developer capacity is the same for FLEXICOLOR Developer or a working solution made from FLEXICOLOR Developer LORR.

Table 3-3 Capacity of Unreplenished Solutions—Batch Processing

KODAK Film and Film Size	Developer Capacity* (rolls/sheets) per	
	1 gallon	1 litre
Bright Sun, Bright Sun & Flash, ROYAL GOLD 200, PROFESSIONAL PORTRA 160NC/VC, PROFESSIONAL PORTRA 100T		
135-12	48	12
135-24	22	5
135-36	15	4
110-24	32	8
120	11	3
220	5	1
4 x 5 inches	38	10
8 x 10 inches	10	3
MAX Versatility, MAX Versatility Plus, ROYAL GOLD 400, Black & White Film, GOLD (110), PROFESSIONAL PORTRA 400NC/VC/UC, PROFESSIONAL PORTRA 400BW, PROFESSIONAL PORTRA 800, PROFESSIONAL T400 CN, Commercial Internegative, VERICOLOR Slide and Print Film		
135-12	42	11
135-24	20	5
135-36	14	3
120	9	2
220	4	1
4 x 5 inches	33	8
8 x 10 inches	8	2

* The capacity for the other solutions (bleach, fixer, and stabilizer) is twice the number of rolls or sheets given for the developer.

Drying

Remove roll film from reels before drying. Hang film in a dust-free place with adequate air circulation. If you use a drying cabinet, be sure that the forced air is filtered, and do not let the temperature exceed 43°C (110°F). If curl is excessive, ambient conditions are probably too dry; increase the relative humidity.

Push-Processing KODAK PROFESSIONAL PORTRA Films in Sink-Line Processors

KODAK PROFESSIONAL PORTRA 400UC and PORTRA 800 Films are designed so that you can push-process them to higher exposure indexes. You can push-process PORTRA 400UC Film to an exposure index of 800, and PORTRA 800 film to exposure indexes of 1600 and 3200, and produce negatives that yield good-quality prints.

To push-process these films, extend the development time for the exposure index you used according to the table below. Keep the times for all other solutions the same as those for a normal process.

KODAK Film	Exposed at (EI)	Development Time (min:sec)
PROFESSIONAL PORTRA 400UC	400 800	3:15 3:45
PROFESSIONAL PORTRA 800	800 1600 3200	3:15 3:45 4:15

USING ROTARY-TUBE PROCESSORS

Steps and Conditions

Rotary-tube processors are another popular type of batch processor. You can use these processors for a variety of film sizes (rolls to large sheets) with good results. They also use a fairly small volume of chemicals, which are discarded after a single use. For Process C-41 chemicals suitable for use with rotary-tube and drum processors, see Section 1, *KODAK FLEXICOLOR Chemicals.*

Although all chemicals used in a rotary-tube processor are discarded after a single use, you can capture the used bleach solution and reuse it up to its capacity before discarding it. Use Table 3-3 to calculate how many films you can process before the bleach is exhausted. **Do not attempt to replenish or regenerate used bleach solution. Reuse it only to the batch capacity; then discard it. Also, do not reuse developer, fixer, or stabilizer. You must discard these solutions after a single use.**

Except for some additional steps required to maintain the correct processing temperature, the steps and conditions for most rotary-tube processors are similar to those for other types of processors. Although the results from batch-type systems may not be as consistent as those from replenished systems, they can be very satisfactory if you follow the manufacturer's recommendations for your processor and the processing recommendations in Tables 3-4 and 3-5. For information on monitoring your process, see Section 5, *Process Monitoring and Troubleshooting*.

Table 3-4 Steps and Conditions—Rotary-Tube Processors, Process C-41

Solution/Step	Time* (min:sec)	Temperature °C (°F)
Optional Warm-Up† tempered water bath or hot air	2:00 to 6:00	38 to 45 (100.4 to 113)
FLEXICOLOR Developer	3:15‡	37.8 ±0.15 (100.0 ±0.25)
FLEXICOLOR Bleach III	6:30	24 to 38 (75 to 100)
FLEXICOLOR Fixer	6:30	24 to 38 (75 to 100)
Wash	3:00	24 to 38 (75 to 100)
FLEXICOLOR Stabilizer III§	1:30	24 to 38 (75 to 100)
Dry	As needed	20 to 60 (68 to 140)

* Times include a 10-second drain time at the end of each step. Solution volume depends on the type of processor.

† Tube is loaded with film and ready for processing. Determine the best time by calibrating the tube. See *Process Control and Adjustment*. **Do not immerse the film in a warm water pre-soak. Warm-up step is done by warming the outside of the tube with hot air or in a tempered water bath**.

‡ Determine the correct time for your processor by running a test with your tube. See *Process Control and Adjustment*.

§ If stabilizer foaming in the tube is a problem, you can stabilize the film in a separate tank.

Table 3-5 Steps and Conditions—Rotary-Tube Processors, Process C-41RA

Solution/Step	Time* (min:sec)	Temperature °C (°F)
Optional Warm-Up† tempered water bath or hot air	2:00 to 6:00	38 to 45 (100.4 to 113)
FLEXICOLOR Developer	3:15‡	37.8 ±0.15 (100.0 ±0.25)
FLEXICOLOR RA Bleach NR§	1:00	38 ±3 (100.0 ±5)
FLEXICOLOR RA Fixer§	2:00	38 ±3 (100.0 ±5)
Wash	2:00	38 ±3 (100.0 ±5)
FLEXICOLOR Stabilizer III¶	1:00	24 to 38 (75 to 100)
Dry	As needed	20 to 60 (68 to 140)

* Times include a 10-second drain time at the end of each step. Solution volume depends on the type of processor.

† Tube is loaded with film and ready for processing. Determine the best time by calibrating the tube. See *Process Control and Adjustment*. **Do not immerse the film in a warm water pre-soak. Warm-up step is done by warming the outside of the tube with hot air or in a tempered water bath**.

‡ Determine the correct time for your processor by running a test with your tube. See *Process Control and Adjustment*.

§ Use only FLEXICOLOR RA Bleach Replenisher NR and FLEXICOLOR RA Fixer and Replenisher.

¶ If stabilizer foaming in the tube is a problem, you can stabilize the film in a separate tank.

Process Control and Adjustment

Determine Your Operating Conditions—In order to control and optimize the process, you need to establish consistent operating conditions. Choose the tube you use most frequently and select a location in the tube (preferably at either end) to position the film or control strip for testing. Process all test films or control strips in that position on all future processing runs. Using a different position or different tube may affect the results.

Monitoring Procedures—Follow the procedures for using KODAK Control Strips, Process C-41, given in Section 5, *Process Monitoring and Troubleshooting*. Include a control strip with each processing run and plot the control-strip density readings on a process control chart.

Developer Temperature and Time—In some rotary-tube processors, maintaining the developer temperature at 37.8 ± 0.15°C (100 ± 0.25°F) can be difficult, and often some loss of developer temperature occurs. The amount of developer-temperature loss can vary based on the design of the rotary-tube processor and the ambient conditions. Since the developer is the most critical step in the process, compensating for developer-temperature loss will help to optimize the performance of the process and improve the quality of the processed film.

The best way to compensate for loss of developer temperature is by increasing the developer time (from the standard time of 3:15). The amount of developer-time extension can be determined approximately by the visual appearance of the density of processed film. The preferred method for determining the exact amount of developer-time extension required is to use KODAK Controls Strips. Process C-41 to monitor the process.

If the control-strip density values plot within the process-control limits for LD and HD – LD, you do not need to adjust the developer time. If the LD and HD – LD parameters plot significantly low (out of control limits), then increase the developer time slightly on each subsequent process run until the control-strip plots are in control. Usually an adjusted developer time that produces good control-strip densities falls somewhere between 3:15 and 3:45.

If you find that you cannot get the control-strip densities to plot within the control limits by extending the developer time to 3:45, or if other unusual LD and HD – LD density readings occur, check for process conditions that may be abnormal. Check to make sure that the starting developer temperature and time are normal and check for developer mixing errors or developer contamination. Also check for mixing errors in the bleach or fixer, or loss of bleach or fixer activity. See Section 5, *Process Monitoring and Troubleshooting*, for more information about troubleshooting your process.

Push-Processing KODAK PROFESSIONAL PORTRA Films in Rotary-Tube Processors

KODAK PROFESSIONAL PORTRA 400UC AND PORTRA 800 Films are designed so that you can push-process them to higher exposure indexes. You can push-process PORTRA 400UC Film to an exposure index of 800, and PORTRA 800 Film to exposure indexes of 1600 and 3200, and produce negatives that yield good-quality prints.

To push-process these films, extend the development time for the exposure index you used according to the following table. Keep the times for all other solutions the same as those for a normal process.

KODAK Film	Exposed at (EI)	Development Time (min:sec)
PROFESSIONAL PORTRA 400UC	400	3:15*
	800	3:45
PROFESSIONAL PORTRA 800	800	3:15*
	1600	3:45
	3200	4:15

* You may need to adjust the normal development time as described in *Process Control and Adjustment*. Add the adjusted normal development time to the amount of time for push processing.

Note: These push-process times are starting points. Make tests to determine the best development time for your application.