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SMALL-BATCH PROCESSING OF *KODAK PLUS-X, TRI-X,* AND *4-X* REVERSAL FILMS

TABLE OF CONTENTS

Safelight 2
Processing Equipment 2
Agitation 3
Processing Temperature 3
Processing Control 3
Table I — Outline of Reversal Process for KODAK PLUS-X, TRI-X, and 4-X Reversal Films in Reel-and-Trough or Rack-and-Tank Equipment 4
Table II — Outline of Reversal Process for KODAK PLUS-X, TRI-X, and 4-X Reversal Films in Rewind Processing Equipment 5
Notes on Processing Steps in Tables I and II 6
Capacity of Solutions 7
Processing in the KODAK Direct Positive Film Developing Outfit 7
Table III — Outline of Reversal Process for KODAK PLUS-X, TRI-X, and 4-X Reversal Films in the KODAK Direct Positive Film Developing Outfit at 68 F (20 C) 7
Formulas 8-10
Some Suppliers of Equipment Suitable for Small-Batch Processing 11

SMALL-BATCH PROCESSING OF *KODAK PLUS-X, TRI-X,* AND *4-X* REVERSAL FILMS

Reversal processing is a method of producing a positive projection image directly on the film exposed in the camera. Best results are obtained with film designed especially for reversal, such as:

- KODAK PLUS-X Reversal Film 7276
- KODAK TRI-X Reversal Film 7278
- KODAK 4-X Reversal Film 7277

The reversal process consists of several steps. The exposed film is first developed to a negative. The developed silver negative image is then removed by a bleaching solution, leaving a positive image consisting of the remaining silver halide in the emulsion. After treatment in a clearing bath, these residual silver salts are exposed to light and developed in a second developer to form the positive black-and-white image, toned to silver sulfide to form a sepia positive without re-exposure, or redeveloped in a fogging-type developer to a black-and-white positive image without re-exposure.

In these various steps there are many factors which can affect the final quality, and the best results can be obtained only when the processing is carried out under carefully controlled conditions. Control of the first development is particularly critical since there is little opportunity in the later steps to compensate for variations in the development of the negative image. The time in the first developer should be checked by trial (discussed later) for each processing situation as the results will depend upon the film and developer formula, as well as the design and manipulation of the processing equipment.

SAFELIGHT

Carry out all operations in total darkness until after the bleaching step has been completed. If necessary, the film can be examined *for a few seconds only* after development is 50 percent complete. Use a KODAK Safelight Filter, No. 3 (dark green), in a suitable safelight lamp with a 15-watt bulb at a distance of not less than 4 feet.

After the bleaching step, normal room lights can be used.

PROCESSING EQUIPMENT

Various types of equipment are available for processing 16mm film. Most of this equipment is capable of producing results of good quality if the particular model is properly designed and the processing formulas and the solution handling and agitation techniques are properly adapted to the equipment.

The bleach is a strong acid-oxidizing solution that will rapidly attack most metals. Therefore, any metal parts of the equipment that will come in contact with the bleach solution should be made of corrosion-resistant material, such as Type 316 stainless steel or titanium.

With some types of equipment, it is necessary to manipulate the film while it is laden with processing solution, to take up slack and prevent overlapping. Wear goggles, rubber gloves, and protective clothing, especially when working with developers containing sodium hydroxide and with bleaches.

Rack-and-tank equipment can be horizontal (with the film wound into a flat rack or spiral reel, as with the Nikor or Kindermann reels) or vertical (with the film wound on racks to fit deep tanks). In either case the film is completely immersed in the solution. The deep tanks require comparatively large volumes of solution for a given length of film and thus may be less economical to use.

Reel-and-trough equipment carries the film on a reel or drum which dips into a trough or tray of solution and is rotated continuously during processing. With properly designed troughs, this equipment requires comparatively small volumes of solutions. There may be some trouble from aerial oxidation of the solutions, however, and there is some tendency for uneven processing where the film crosses the reel slats.

Rewind tanks, in which the film is wound back and forth between two reels immersed in the solution, require only small volumes of solution. Such tanks are capable of producing acceptable results, provided the proper procedure and operating technique are followed. Because the access of the solutions to any particular portion of the film is restricted to the very short time required to cross from one reel to the other, much longer times of treatment are needed. Also, the composition of the solutions must be closely adjusted to suit the characteristics of each film.

Continuous processing machines provide the most efficient handling of large footages, but are hardly practical for small amounts of film. If you need help with a particular installation, write your specific questions to Eastman Kodak Company, Motion Picture and Education Markets Division, Dept. 641, Rochester, N.Y. 14650.

AGITATION

Good agitation is necessary to produce uniform development throughout the roll. How this is achieved will depend on the design of the particular equipment used. Vigorous agitation by air-bubbling or mechanical means is also important in the bleaching step.

The following general recommendations should be modified to suit specific cases:

Rack-and-tank. With a flat spiral reel, secure the end of the film with a rubber band or waterproof tape to keep it from unwinding in processing. Lower the reel into the developer, giving it a vigorous turning motion sufficient to rotate it one-half to one revolution in the developer. Repeatedly raise and lower the reel approximately ½ inch (keeping it in the solution) for the first 15 seconds of the development, tapping it against the bottom of the tank to release air bubbles from the film. Then agitate once each minute by lifting the reel out of the solution, tilting it 30 degrees to drain 5 to 10 seconds, and reimmersing it with a vigorous turning motion as before. Alternate the direction of rotation each minute. Agitate in the same manner in the other tanks.

In a vertical rack in a deep tank, agitate the rack 15 seconds under the solution when it is first immersed. At 1-minute intervals, lift the rack out of the solution, drain it for a few seconds, and reimmerse it.

Rocking-trough. Rotate the reel at a convenient rate through to effect good agitation, but not so rapidly as to splash solution out of the trough. Reverse the direction of rotation periodically during development.

Rotary tanks. Wind the film back and forth continuously at a rate which will pass 100 feet of film from one reel to the other in approximately 60 seconds. The rate of winding should be adjusted to provide a whole number of round trips (complete transfer from one reel to the other and back again) in each bath, so that all portions of the roll will have the same time of contact with the bath. Because of the large amount of time that the film is tightly wound as compared to the time it is in free contact with the solution, the times required in the various steps will depend on the length of the roll. A 50-foot roll will require about 75 percent, and a 25-foot roll about 50 percent of the time for the 100-foot roll. In the various rinses and final wash, the water should either run into the tank continuously or be changed at least after each two passes of the film. The re-exposure should be given while the film is in the rinse water.

PROCESSING TEMPERATURE

The first developer should be used at a temperature of 68 F ±0.5 (20 C ±0.3). The other baths should be between 65 and 70 F (18 and 21 C).

PROCESSING CONTROL

The degree of development in the first developer is important in determining the quality of the final positive. Best results usually are obtained when the first development is just sufficient to give clean highlights in the final positive with the recommended camera exposure. The contrast of the positive cannot be changed appreciably by varying first development. Overdevelopment produces an effect similar to overexposure, that is, decreased maximum density in the shadows of the positive and loss of highlight detail. Underdevelopment gives veiled highlights and a general effect similar to underexposure.

All of the steps after the first developer are less critical and offer little chance for alteration of the picture contrast and density by processing variations. The times shown in the processing tables, pages 4, 5, and 7, are generally adequate, but they can be modified in specific cases if experience indicates that a change is desirable.

The proper development time for any film in the first developer will depend on the temperature of the solution and the degree of agitation. The degree of agitation, in turn, will depend on the type of equipment and the operating technique used. Therefore, when using new equipment, run a series of tests to determine the proper time of first development, preferably checking the results with sensitometric strips. Standardize the agitation for repeatability, and maintain the temperature accurately, so that the time determined by the experimental tests can be used with confidence for the camera films.

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TABLE I

OUTLINE OF REVERSAL PROCESS FOR *KODAK PLUS-X, TRI-X,* AND *4-X* REVERSAL FILMS IN REEL-AND-TROUGH OR RACK-AND-TANK EQUIPMENT

Operation	Formula	Approximate Time (Minutes) At 68 F (20 C)
1. First development	D-94	2*
2. Rinse	Water only	2
3. Bleach	R-9	3
4. Rinse	Water	1
5. Clearing Bath	CB-3	3†
6. Rinse	Water	1
7. Re-exposure	About 800 footcandle seconds‡	
8. Redevelopment	KODAK Developer D-19	3
9. Rinse	Water or SB-1a	1
10. Fix	F-6	5
11. Wash	Water§	As required
12. Dry		As required

*2 minutes for reel-and-trough and 2½ minutes for rack-and-tank equipment. Also, KODAK 4-X Reversal Film can be exposed at twice the recommended exposure index if the time of its first development is extended to 3 minutes 20 seconds. However, a slight loss of image quality will result.

†Do not exceed the specified time because this bath has a tendency to dissolve the silver halide, with consequent loss of density in the positive image.

‡A re-exposure can be given to the film on a 15-inch-diameter reel (drum) in about ½ minute using an opal-glass illuminator. The illuminator should be fitted with eight 25-watt tungsten lamps spaced 4 inches apart and located 7 inches from the nearest point of approach of the film.

§Washing time can be greatly shortened by using KODAK Hypo Clearing Agent. Proceed as follows:

Rinse in water	2 min
Treat in KODAK Hypo Clearing Agent	2 min
Wash	5 min

NOTE: When it is not convenient to re-expose the film (Step 7) and a sepia-tone image is acceptable, you can substitute the use of Kodak Sulfide Redeveloper T-19 for Steps 7 and 8.

PROCESSING: The following starting-point recommendations are for a typical continuous-strand processing machine.

Processing Step	Temperature	Time	Replenishment Rate (ml per 100')	
			35 mm	16 mm
Kodak Developer D-96	21°C ± .3 (70°F ± ½)	approx. 7½ min *	D96-R 1200	D-96R 600
Stop Rinse†	21°C ± 1 (70°F ± 2)	60 sec	12,000	6000
Kodak Fixing Bath F-5	21°C ± 1 (70°F ± 2)	7 min	800	400
Countercurrent Wash	21°C ± 1 (70°F ± 2)	10½ min	12,000	6000
Dry	35°C (95°F)	‡		

* Develop to recommended control gamma.

† Fixer-laden water from wash tank, pH about 6.

‡ Many factors affect the drying: air temperature, relative humidity (RH); volume, rate, and distribution pattern of the air flow; final squeegeeing, etc.

In a conventional convection-type drying cabinet with air at about 35°C (95°F) and 40 to 50 percent RH, drying will take 15 to 20 minutes. With an impingement-type drying cabinet, however, with a higher temperature and lower RH, drying time is greatly reduced. With either type of dryer, the film should be dry without tackiness 1/2 to 2/3 of the way through. Upon cooling to room temperature after leaving the dryer, the film should be in equilibrium with room air at approximately 50 percent RH.

ROLLS AVAILABLE

5224 (35 mm)

CAT. No.	Iden No.	Description	Perf. Type
147 4220	4XN417	100 ft; Camera Spool	BH-1866
183 7954	4XN415	100 ft; Camera Spool, High Speed	KS-1870
173 7378	4XN718	400 ft; On Core	BH-1866
149 3048	4XN718	1000 ft; On Core	BH-1866

All rolls have edge numbering and frame-line marking.

7224 (16 mm)

147 4444	4XN449	100 ft; Camera Spool	2R-2994
147 4501	4XN455	100 ft; Camera Spool, Winding B	1R-2994
147 4428	4XN430	100 ft; Camera Spool, High Speed	2R-3000
173 9341	4XN451	400 ft; On Core	2R-2994
184 2863	4XN434	400 ft; Camera Spool, High Speed	2R-3000

All rolls have edge numbering and frame-line marking.

NOTE: Agitation in the developer and the fixing bath should be by recirculation through submerged spray-jets that impinge on the film strands.

RECOMMENDED CONTROL GAMMA: 0.65 to 0.70

The sensitometric curves and data in this publication represent product tested under the conditions of exposure and processing specified. They are representative of production coatings and, therefore, do not apply directly to a particular box or roll of photographic material. They do not represent standards or specifications that must be met by Eastman Kodak Company. The company reserves the right to change and improve product characteristics at any time.

NOTES ON PROCESSING STEPS IN TABLES I AND II

Prebath. In rewind-type apparatus, a nonhardening prebath is recommended to provide uniform wetting of the emulsion surface at the start of development. To control fog, an antifoggant is used in this prebath together with enough carbonate for maximum wetting effect (Kodak Prebath PB-3).

Rinse. Follow with a water rinse to avoid carrying an excessive quantity of the prebath into the first developer. The rinse water should either run into the tank continuously or be replaced after every two passes of the film.

First Development. The proper developing time, just sufficient to give clean highlights with normal camera exposures, will usually be determined by trial with any particular equipment. When the recommended agitation procedures are used, the times shown in the tables are suggested for the first trials.

While other steps of the process can affect maximum density, minimum density, and contrast, the effect of excessive or insufficient first development cannot be compensated for in the later steps, and a loss in quality is almost inevitable.

Rinse. A water rinse is necessary to prevent carrying the first developer into the bleach and causing a staining reaction. In reel-and-trough or rack-and-tank equipment, an acid rinse should not be used at this point. With the rewind type of tank, all the water rinses should be continuous, or changed at least after each two passes of the film.

If water of satisfactory temperature and purity is not available, omit all rinses except after the first development. (See "Water Quality Criteria," by Lloyd E. West, *Photographic Science and Engineering*, Vol. 9, No. 6, pp. 398-413, November-December 1965.)

Bleach. In the black-and-white reversal process, the bleach must dissolve the metallic-silver negative image produced during first development without affecting the remaining undeveloped silver halide. Kodak Bleaching Bath R-9 or the packaged KODAK Bleach for KODAK Direct Positive Paper normally will work satisfactorily with all types of equipment, provided the concentration is adjusted as indicated in the tables.

A bleach that is too concentrated for a particular film can leave a residue in the form of a yellowish or brownish stain in the highlight and lower-density regions which is not very noticeable at the end of the bleaching stage, but usually contributes appreciable density after re-exposure and redevelopment. The situation is aggravated when replenishment of solution at the film surface is restricted as it is in rewind-type processing tanks. An increase in pH of the bleach, due to use of the bleach solution beyond its capacity limits, is another cause of stain. Excessive bleaching time can result in a depressed sensitivity to re-exposure which, with PLUS-X Film, can cause a selective loss in lower middletone densities and consequent excessive contrast. To avoid these difficulties, be sure to use the proper bleach concentration and time for the particular film and processing system. A high level of agitation is required in the bleach.

Rinse. A water rinse between bleaching and clearing baths is needed to minimize destruction of the sodium sulfite in the clearing bath by the carried-over bleach. Also see the note for *Rinse* after first development.

Clear. Treatment in the sodium sulfite clearing solution removes any bleach left after rinsing and prepares the residual silver salts for re-exposure or toning. A clearing solution stronger than recommended or an immersion time in excess of the recommendation will often cause a loss in density. A shortened time in the clearing bath or an exhausted bath can lead to stains.

Rinse and re-exposure. Rinse with running water and simultaneously re-expose. The second exposure should be sufficient to render the residual silver salts fully developable. The rack or reel should be rotated during the exposure to provide uniform exposure over the whole area of the film. Optimum re-exposure is about 800 foot-candle seconds. This will be provided by a 10-second exposure to a 60-watt lamp at 12 to 18 inches. With rewind equipment, the re-exposure should be given while the film is in the rinse following the clearing bath. For instance, with the Morse G-3 Tank, after rinsing with running water for 2 minutes (or one change of rinse water), open the window and expose for eight passes to a No. 1 photoflood lamp held about 12 inches from the window.

The amount of re-exposure is not critical. However, an excessive exposure (about 10 times the indicated amount) may cause a slight and undesirable increase in density. This will be most noticeable in the highlight areas of the projected image. Too little re-exposure (about 1/100 of the indicated amount) tends to reduce the maximum density objectionably. Check exposure levels by trial to be sure that no noticeable change in picture quality accompanies a two- to five-times change in re-exposure in either direction.

Re-exposure can be applied at any point in the processing cycle from the latter part of the clearing treatment to the early part of redevelopment. If re-exposure is given in the clearing bath, no additional time of contact with that bath should be required. If given while the film is in the redeveloper, sufficient time must be allowed subsequently for the redeveloper to complete its work. In rewind-type processing, the re-exposure should be given while the film is in the rinse following clearing.

Fogging redeveloper. Re-exposure is preferred to redevelopment. However, in situations where re-exposure is difficult to apply or control, due to the limitations of

the apparatus, use a redevelopment procedure that acts without need for light exposure. A fogging redeveloper has the property of reacting with the remaining silver halide in the emulsion without its first having been exposed to light. Kodak Sulfide Redeveloper T-19 can be used with any type of processing apparatus if a brown image is acceptable. (Unless required by particular situations, preference should be given to re-exposure and then development.)

Redevelop after re-exposure. When the re-exposure and redevelopment method is used, the redeveloper can be any vigorous developer that completes its action in the time available with the equipment used. A first developer containing a silver halide solvent, such as sodium thiocyanate, should not be used as redeveloper, because it will lower the maximum density and may produce dichroic fog.

KODAK Developers D-19 and D-88 are commonly used as redevelopers. It is sometimes desirable to add a small quantity of antifoggant to reduce stain and lower the minimum density.

Rinse. See the note for *Rinse* after first development.

Fix. In the processes employing re-exposure, redevelopment leaves a small portion of the silver halide grains undeveloped. Also during processing, there may be deposits of silver salts or other hypo-soluble compounds that will darken and discolor the highlights after keeping and exposure to light. One of the functions of the fixing bath is to dissolve these residues and thus effect a reduction in minimum density and an improvement to overall brilliance and highlight quality.

For reel-and-trough processing, the odor of sulfur dioxide from most acid fixing baths may be objectionable. Kodak Fixer F-6 will minimize this difficulty.

Wash. The time of washing is determined by the efficiency of water application and the permissible residual hypo concentration for the intended use. Water can be run continuously or replaced in steps periodically during washing.

The use of KODAK Hypo Clearing Agent as described in the footnote to the processing tables will greatly shorten washing times.

CAPACITY OF SOLUTIONS

With reel-and-trough, spiral-reel, or rewind equipment, replace baths after each batch of film. Replenishment and reuse of solution is not recommended.

PROCESSING IN THE *KODAK* DIRECT POSITIVE FILM DEVELOPING OUTFIT

If you use only small amounts of KODAK PLUS-X, TRI-X, and 4-X Reversal Films and want the convenience of a kit of packaged chemicals for processing, you can use the KODAK Direct Positive Film Developing Outfit. This kit contains the chemicals for mixing all the necessary solutions except the fixing bath, which can be prepared from packaged KODAK Fixer. One roll of 16mm film up to 100 feet in length can be processed with the contents of one outfit.

The processing times are shown in Table III. Other details of the procedure are given in the instructions packaged with the Direct Positive Film Developing Outfit.

TABLE III

OUTLINE OF REVERSAL PROCESS FOR *KODAK PLUS-X, TRI-X,* AND *4-X* REVERSAL FILMS IN THE *KODAK* DIRECT POSITIVE FILM DEVELOPING OUTFIT AT 68 F (20 C)

The following processing times are for rack-and-tank equipment, either horizontal or vertical. Reel-and-trough and rewind processors are not recommended for this process.

Drain the film for 10 to 15 seconds between each bath.

Solution	Approximate Time (minutes)
1. First Developer	6
2. Water Rinse	2 to 5*
3. Bleach Bath	1
4. Clearing Bath	2†
5. Redeveloper‡	PLUS-X: 8
	TRI-X: 6
	4-X: 8
6. Water Rinse	1
7. Fixing Bath	5
8. Wash	20§
9. Dry	As required

*A 2-minute time is sufficient in a running-water wash with good agitation.

†Do not exceed the specified time because this bath has a tendency to dissolve the silver halide, with consequent loss of density in the positive image.

‡A fogging-type redeveloper; re-exposure to light is not required.

§Washing time can be greatly shortened by using KODAK Hypo Clearing Agent. Proceed as follows:

Rinse in water	2 min
Treat in KODAK Hypo Clearing Agent	2 min
Wash	5 min