A Guide to Processing 16mm B/W Reversal Film

with assorted wisdom on troubleshooting and technical experiments

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Overview

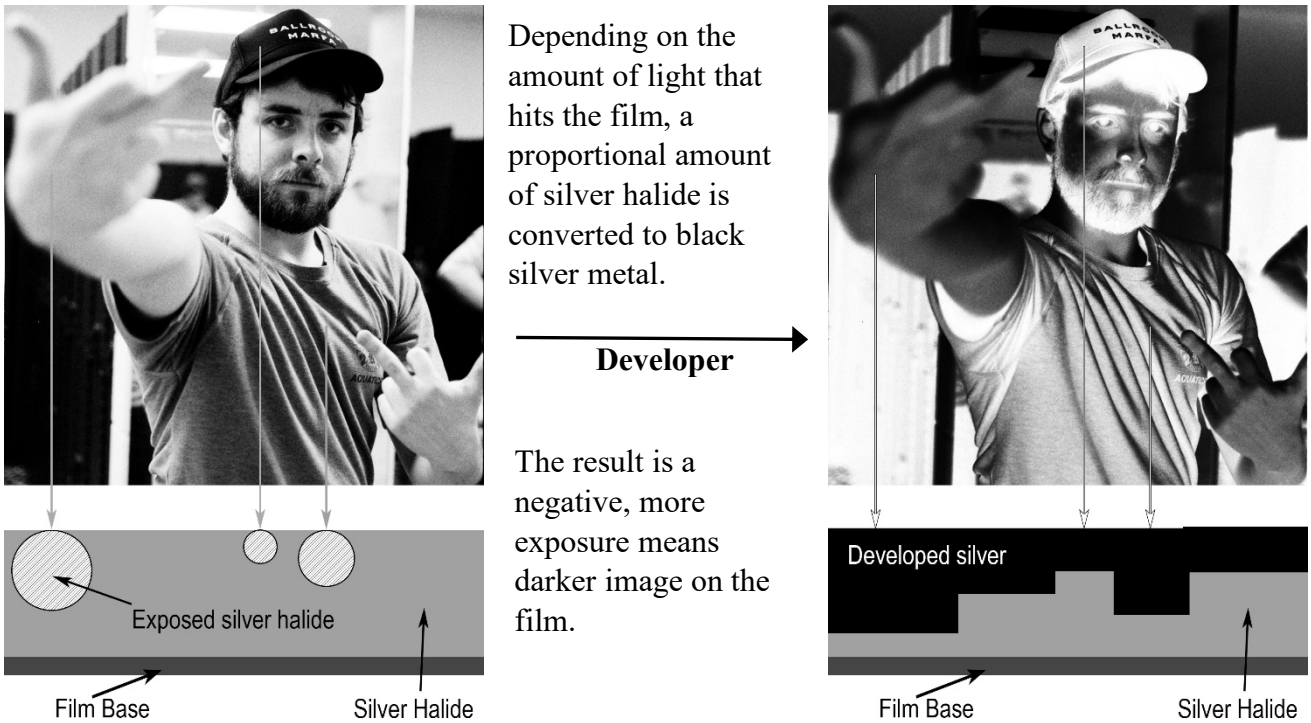
Processing 16mm b/w cine film can be a daunting challenge and often, one is forced to settle for less than ideal results when faced by the numerous variables they have to keep in mind. Any deviation from the standardized development procedure will result in a poorer image. However, we are experimentalists, and those deviations are tools and free us to play with the medium. With a few precautions, one should be alleviated of the fear of developing and can focus on the image, story, composition, and plot of their film, rather than being weighed down with worries.

We believe that a rudimentary but fundamental understanding of the physical processes enables an instinctive response to problems. We intend to provide both a descriptive procedure for the dedicated few and a "cheat sheet" processing and troubleshooting guide for those who wish to make films, as well as to include some practical tips and experiments.

A crash course in photographic physics and chemistry

Black and white film is made up of a film emulsion (which contains light-sensitive silver halides AgX in gelatin) and a film base, made of plastic. You can tell them apart in the dark by putting the strip between your lips. The side that sticks to your lip is the emulsion, which has a matte luster, whereas the base side is slick and shiny.

When you correctly **expose** and **develop** ANY black-and-white emulsion, you will get a NEGATIVE image, made of silver.

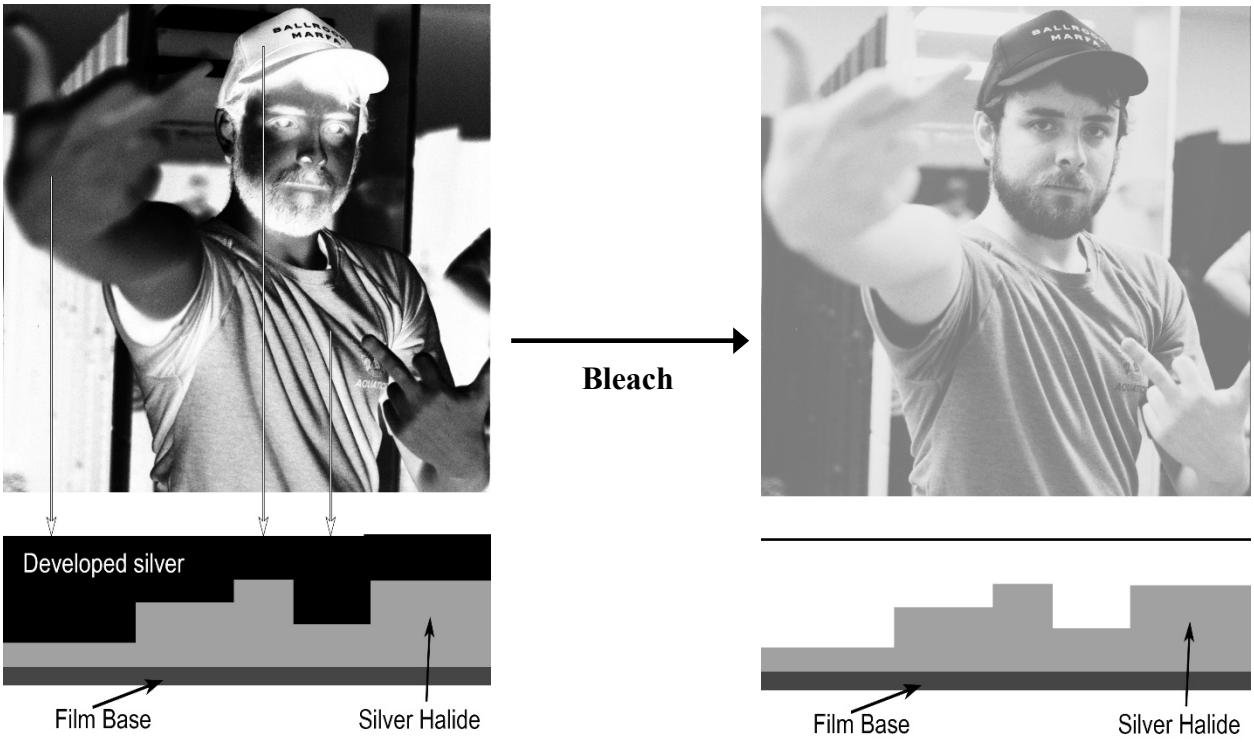


Depending on the amount of light that hits the film, a proportional amount of silver halide is converted to black silver metal.

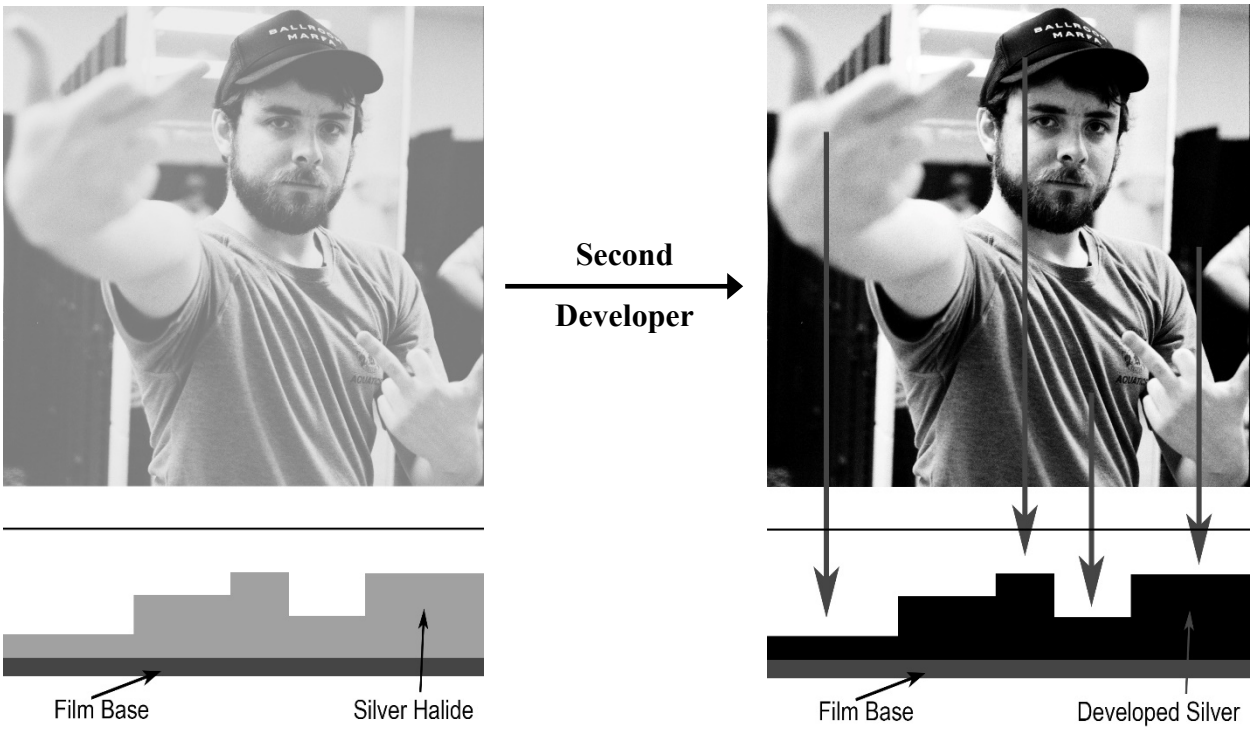
The result is a negative, more exposure means darker image on the film.

After the image is developed, we would normally dissolve away the remaining AgX in a **fixer**, because AgX are milky in color and our image will look blurry. This makes a black and white NEGATIVE.

Of course, we want a POSITIVE image, where the amount of silver is **inversely** proportional to the amount of light. And the solution is pretty trivial. Turns out, the amount of AgX that remains and we would normally remove by fixing is the **inverse**! So, imagine we could remove JUST the silver we have developed, and retain the halide. And we can, using a **bleach** (not the household variety, but just as dangerous).



We are almost there! Notice that we don't have a perfect image. It's still made of AgX, and if you look at the film, it will look like a milky-white-yellow pale POSITIVE.



Now, we give our film so much light that all of the remaining AgX is exposed and we develop it again. And there it is, a POSITIVE in all its projection glory and detail on our 16mm strip. We then **fix** the film (out of habit and for archival reasons), wash it really well and dry the stock.

That is it! There are essentially four steps to processing reversal film – **develop, bleach, expose to light, redevelop (second developer)**. In reality, we will include more steps, which are necessary so that our image looks good and does not degrade and to make sure our chemicals can be reused. All the steps are listed below in sequence with their purpose.

#	Name	Role	In the dark?
1	**Water Presoak**	Allows the gelatin to swell and let chemicals in and out. Prevents blotches.	**YES**
2	**First developer**	Develops the NEGATIVE image. MOST IMPORTANT STEP. MAKES OR BREAKS THE IMAGE	**YES**
3	**Water Rinse**	Washes away the developer chemicals	**YES**
4	**Bleach**	Etches away the negative image, leaves a positive.	**YES**
5	Water Rinse	The bleach is nasty stuff. We want to remove as much as possible.	NO
6	Clearing Bath	The bleach stains the film orange. This “clears” the stain.	NO
7	Water Rinse	You get the point…	NO
8	Re-exposure	We give the film a ton of light, to make sure all AgX is exposed.	DEF NO
9	Second Developer	Develops the final POSITIVE image.	NO
10	Acid Fixer	Makes the image stable, and the gelatin more durable	NO
11	Final Rinse	The longer the better. Any fixer that remains in the film will slowly eat away at your masterpiece and in a decade’s time, it will be faded.	NO
12	Photo Flo	This is like dish soap for film. It lets the water drip away faster and not form any spots when you hang it to dry.	NO

About a dozen steps! With some exercise, the whole process can be done in a few laid-back hours to some good music. Just PAY ATTENTION to the order of chemicals and the FIRST DEVELOPER, because it determines much if not everything about your final image.

Preparation and tests: advice

0. **The essentials – darkroom, equipment, supplies**

- In an ideal world, everyone would have access to a dedicated permanent **darkroom**. These have become an endangered species in the 21st century, but many creative solutions exist. If a room can be made completely dark, is spacious enough for 1-2 people to work comfortably in, and has running water (a big sink is nice), it is a good candidate. Although kitchens often fit this description, we deal with chemicals you do not want in your food, so **kitchen ≠ darkroom.**
- **Vessels** and accoutrements: in processing, we need to store, measure, and transfer a lot of liquids. Plastic bottles and jugs made from HDPE or PET are airtight and don't break if you drop them. Other essentials are graduated cylinders and beakers in different sizes, funnels, stirring rods.
- **Tools** – a good **digital scale** (capacity 500-1000g, resolution 0.1/0.01 g). Kitchen scales are a last resort and source of errors and doubt, avoid. A **timer**/darkroom clock with luminous dial is useful, but not critical (nowadays, we have excellent timers in our phones). A hotplate/magnetic **stirrer** removes the burden of manual mixing.
- **Materials** – photographic chemistry can be obtained online or locally from numerous providers. Dedicated chemical reagent suppliers exist, but they often sell in bulk, have higher prices, and do not service individuals. For preparing solutions, distilled, deionized, or reverse-osmosis water is recommended and preferred.

1. Once you have shot your reel of film, there are two ways to process it:

- **The BUCKET process**: unspool 100ft of film in a large bucket (IN THE DARK), pour the chemical and slosh around with your (gloved) hands, pour the chemical out, pour in the next chemical, etc.
    - Pros: less threatening, simple, a bucket with a well-fitting lid is obtainable from paint or restaurant supply stores
    - Cons: your film WILL get scratched, more or less, even development is not guaranteed, uses WAY too much chemicals, messy. You have to work in ABSOLUTE DARKNESS for the first 4 steps.

- **The LOMO tank process**: load 100ft of film in two plastic reels of 50ft (IN THE DARK), put them in the Russian tank, put on the lid (LIGHTS ON), add/drain the chemicals in order, etc.
    - Pros: clean & even development, uses less chemicals, no mess.
    - Cons: *OHMYY HOW DO I USE THIS SOVIET CONTRAPTION??!? The loading process is kind of complicated…Youtube and dry runs with exposed film in the light are your friends, because it's worth it!

2. **Tests are everything!** How do you know your chemicals work? A blank roll of film where your senior thesis footage should be? NO!!! There are several simple tests to make sure the chemicals you have are functional (at ROOM TEMPEATURE: 69-74 F, check with a thermometer)

- The CLIP test: grab a piece of scrap UNEXPOSED film (from the end of a spool or while loading the camera). Get 5-8 inches, it will be plenty. **Soak the film in some water and simply dip it in the FIRST developer for a minute and agitate it.** Does it turn black all

the way? Your developer is good to go. If it just turns gray or stays the same, DO NOT USE the developer, as it is exhausted or expired! Don't throw the black strip away, though. Wash it with water and dip it in the bleach; it should slowly dissolve all the black and leave you a clear film strip, stained orange. If it does, then you're golden; if not – something is wrong! These two tests take less time to carry out than to read the instructions for doing them, so DO THEM!
It doesn't hurt to check the SECOND developer too, but you will be inspecting the film in the light, you'd know on the spot if it doesn't work well.

- The SNIP test: shoot 5-10 feet of correctly exposed film (whatever you deem correct, for Kodak 7266, it is 200ASA, but you may want to be a deviant, see below..). Shoot a scene with a good range of light – shadows, gray tones, bright areas (an exterior with sky, land, and buildings works well). Cut away this strip in total darkness and store it in a light-tight bag or container. When you want to test your chemicals, use a film tank or beaker for the solutions and 5-10 inches of your correctly exposed film. Carry out the complete processing steps with the recommended times. This lets you troubleshoot any problems and adjust for them yourself (maybe you need less time in the first developer, or more in the second, etc…**follow the troubleshooting guide for adjustments**).
  Clearly, this is more involved and time consuming, but can still be done in 30-40 minutes and can save you days of filming and expensive film stock. It is also a way to familiarize yourself with the entire process before you develop your first reel. Your call.

3. **Prepare your chemicals.**
- Check the TEMPERATURE! Chemical processes run slower in the cold and faster when it's hot! The only step that is temperature sensitive is, of course, the first developer (FD). Check the FD temperature and the chart on the instruction sheet for determining how long to develop.
- Put your solutions in order! Instead of worrying which step comes next, order the bottles and jugs in sequence in the sink. Left-to-right works for me, but come up with your own system, as long as it does not involve color-coding or mnemonics.
- Run a CLIP test. Just do it.

4. **During processing.**
- Agitation is important. Slosh your film around with your (gloved) hands if using buckets or turn the LOMO reel clockwise (slow is ok) continually. The LOMO tank also lets you lift and lower the reel a tiny bit. That helps dislodge air bubbles that could ruin the perfect look you're going for. Tapping the bucket or tank gently on the sink/table also helps.
- Filling and draining the LOMO tank can be done from the top lid or the draining hose. I prefer using the hose with a funnel stuck inside it. With the tank empty, lift the hose **above the tank with one hand and pour the chemical though the funnel with the other.** Then, pinch the end of the hose so it doesn't leak and secure it in the little loop. To drain, lift the tank (spill danger!), pinch the hose, take it out of the hoop and into the mouth of the CORRECT container, unpinch and let gravity take its course. Tilt the tank so that you get as much of the liquid out as possible.
- Always start the timer AFTER the entire bucket/tank is full and all the film is submerged. Always drain AFTER the timer ends. The times listed take this into account.

- Drain your chemicals completely to avoid contamination. Again, the FD is most sensitive to contaminants, so make sure you either have it in the clean bucket/tank or its storage container.
- Pay attention to the image on your film. After step 4, you can turn the lights on (for bucket development) or remove the lid (LOMO tank). All following steps can be done by inspection (you can still timer them but decide to end earlier). Visual indicators are mentioned in the instruction sheet and the troubleshooting guide.
- How to perform the water rinses:
    - Bucket**:** fill the bucket to completely cover the film, agitate and set the timer. After 1 minute, drain the water, fill again, repeat until timer ends. Alternatively, place a water hose reaching the bottom of the bucket and allow the water to overflow, agitate with your (gloved) hands.
    - LOMO: fill the LOMO tank with water using the LOMO tank drain hose, so that the water exits from the top or through the lid if it still is closed). A gentle, tame flow is sufficient. Turn the reel clockwise every minute for the duration of the timer.

- How to perform the re-exposure step:
    - Use a 100W tungsten (or equivalent CFL/LED) bulb. The while light in the darkroom may be sufficient, depending on its power and distance. A desk lamp with a 15W LED bulb is convenient and portable. Alternatively use a 500W floodlight.
    - Bucket**:** you can either drain the last water rinse or leave the film submerged. I prefer the second option. Bring the bucket up to the light (or vise versa) for **1 minute at a distance of 1ft**. Then move the film around and bring it up for 1 minute. Repeat for a total of **5 min**. If using a floodlight (careful – water and electricity!!!) place the bucket on the floor and shine the floodlamp from a distance **of at least 2ft for 30 seconds**. Agitate and repeat three more times for a total of **2:00 min**.
    - LOMO: take the spool out of the tank, drain the water and bring it to the lamp. Rotate the spool **at a distance of 1ft for 6 min**. Try to get **3 min** on both sides of the reel. Alternatively, expose with a floodlamp (!!!) from a distance of at least 2ft for 30 sec on each side for a total of 2 min. Rotate the reel for even exposure!

5. **After processing**

- Transfer the film to a drying rack, making sure it does not twist or knot. This can be tricky. Practice. For the LOMO tank, the easiest thing to do is disassemble the LOMO reel and take out the film as one (2x50ft) wet roll, place it in a clean bucket with water and a bit of Photo Flo and spool it from there! If a rack is not available, the wet film can be spooled onto a 16mm reel and transferred to the drying location.
- **Drying the film**: just give your film time. You can touch the emulsion side to determine when its dry and the gelatin is smooth and not sticky. Several hours works well. Don't go check on your film every 10 minutes. The less movement in the room, the less dust on your film. If you do want dust on your film, then get creative

Kodak 7266 Reversal Film Processing Guide

(Exposed at 200ASA, fresh chemistry, 70F)

Step #	Chemical	Time (min)	Notes
LIGHTS OUT **(unspool in bucket/ load film in LOMO, put lid on)** LIGHTS ON (LOMO ONLY)			
1	**Presoak (WATER @ 70F)**	**2:00**	
2	**First Developer (D67 @ 70F)**	**7:00**	See chart below for temperatures.
3	**Water Rinse**	**5:00**	
4	**Bleach (R-9)**	**3:00**	Turn lights on (remove LOMO lid) after pouring bleach. Bleaching is complete when the film looks pale orange and no black remains.
5	**Water Rinse**	**5:00**	Wash until no more yellow washes out.
6	**Clearing Bath (CB-1)**	**3:00**	
7	**Water Rinse**	**1:00**	
8	**Re-Exposure**	**1:00 to 4:00**	Bucket+Lamp = 5:00 min Bucket+Floodlamp = 2:00 min LOMO+Lamp = 6:00 min LOMO+FloodLamp = 2:00 min
9	**Second Developer (D-19)**	**4:00**	Observe darkening visually.
10	**Water Rinse**	**2:00**	
11	**Fixer (Kodak Rapid Hardening Fix)**	**5:00**	
12	**Final Rinse**	**10-15:00**	Running Water > 70F
13	**Photo Flo**	**1:00**	Bucket: 10 ml PhotoFlo LOMO: 5.0 ml PhotoFlo
SPOOL AND DRY FILM			

Temperature conversion for fresh D-67 First Developer

Temperature	**64°**	**66°**	**68°**	**70°**	**72°**	**74°**	**76°**	**80°**
Time	**NO**	9:00	8:00	7:00	6:30	6:00	5:15	**NO**

TROUBLESHOOTING GUIDE

Problem	Causes	Notes
Film is blank. No image	Film was grossly overexposed	Check light meter settings.
	Film was grossly overdeveloped	Did you forget the film in the FD?
	Film was exposed to light	
	Incorrect order of processing	CLIP test on developers and bleach. Inspect film after bleach, there should be a milky-tan positive image.
Film is black. No image.	Film was grossly underexposed.	Check light meter settings.
	Film was grossly underdeveloped in first developer	CLIP test on first developer.
	Film was not exposed.	
	Incorrect order of processing.	
Image is very pale throughout film.	Film was overexposed.	Check light meter settings.
	Film was overdeveloped.	Reduce first developer time by 30%.
	Second developer weak.	CLIP test on second developer.
Image is very dark throughout film.	Film was underexposed.	Check light meter settings.
	Film was underdeveloped.	Increase first developer time by 40%.
	First developer weak.	CLIP test on first developer.
Dark, even, grainy staining of film.	Film was not washed and cleared properly after bleach.	Make sure to thoroughly rinse film and no yellow staining remains on the emulsion.
Uneven development. Blotchy images.	Film was not presoaked.	
	Poor agitation.	
	Insufficient water rinses.	
Low contrast dark image	First developer weak.	CLIP test on first developer. Increase time by 25%.
Low contrast light image	Too long in first developer.	Decrease time by 30%.
High contrast image	First developer too strong.	
	Temperature too high.	
Dark or clear spots on film of various sizes.	Air bubbles on emulsion.	Increase presoak to 5 min with continuous agitation. A drop of Photo Flo might help

Chemical Formulations

A word on safety and chemical mix-ups:

Some of the chemicals involved in reversal processing are nasty and mean molecules. The developer can cause contact dermatitis after prolonged use, the fixer is acidic, and the bleach contains heavy metal (and not the good kind). However, with the correct safety measures, there are no significant health hazards involved.

Washing hands after exposure is the single most important precaution one can take, and gloves can offer a false sense of security, because you can't tell what chemicals are on them. Nevertheless, wear gloves and always WASH YOUR (gloved) HANDS.

Make sure all containers are labeled. My approach is to include the formula I used, any additional changes that I have, as well as the date of preparation and my initials. This avoids confusion. Labeling the caps avoids cross-contamination.

Read the MSDS/SDS for all chemicals. These exist for your health!

A note on nomenclature:

Do not confuse sodium SULFITE (Na2SO3) and sodium SULFATE (Na2SO4). Both are used in photographic chemistry but have very different functions! They are not interchangeable. This is very important for preparing the clearing bath, which requires SULFITE.

1. **Developers**

The First Developer (FD).

Probably the most sensitive and fickle solution that almost wholly determines the end result. Therefore, its capacity and preparation should be observed carefully. The standard formulation is provided below.

Kodak D-67		
Chemicals	Amounts (grams)	
Water (45C/120F)*	500 ml	2500 ml
Metol	2.0	8.0
Sodium Sulfite	90	360
Hydroquinone	8.0	32
Sodium Carbonate monohyd.	52.5	210
Potassium Bromide	5.0	20
Potassium Thiocyanate**	2.0 (1.5)	8.0 (6.0)
Water	to 1.00 L	to 4.00 L

* if room temperature water is used, dissolving the dry powders takes a very long time
**acts as a silver halide solvent. if SODIUM thiocyanate is used, the amounts in brackets should be added.

NOTE: D67 is conveniently prepared by mixing a batch of PHOTOGRAPHER'S FORMULARY "**SUBSTITUTE D-19**" and adding 2.0 g/L of Potassium Thiocyanate or 1.5 g/L of Sodium Thiocyanate.

Thiocyanate is important in the first developer. It CANNOT be omitted without image quality suffering.

The Second Developer (SD)

Any normal developer (without thiocyanate) works for this step. In a pinch, D76, Xtol, Rodinal, Ilford Multigrade Paper Developer, even Caffenol, will do. Conveniently, we can use the above formula without the silver halide solvent.

Kodak D-19		
Chemicals	Amounts (grams)	
Water (45C/120F)*	500 ml	2500 ml
Metol	2.0	8.0
Sodium Sulfite	90	360
Hydroquinone	8.0	32
Sodium Carbonate monohyd.	52.5	210
Potassium Bromide	5.0	20
Water	to 1.00 L	to 4.00 L

NOTE: Use PHOTOGRAPHER'S FORMULARY "SUBSTITUTE D-19" as prepared.

2. **The Bleach**

Kodak R-9		
Chemicals	Amounts (grams)	
Water (20C/68F)	500 ml	2500 ml
Potassium Bichromate (Anhydrous)	9.5	38.0
Sulfuric Acid (98%)	12 ml (22 g)	48 ml (88 g)
Water	to 1.00 L	to 4.00 L

NOTE: It is important to add sufficient acid of the right concentration. If lower strength acid is available, adjust the amount accordingly (e.g. 50% acid would require twice the amounts).

It is normal for a precipitate to form in the bleach during use; however, if the solution is not acidic enough, this will be excessive and hinder bleaching.

3. **The Clearing Bath**

Kodak CB-1		
Chemicals	Amounts (grams)	
Water (20C/68F)	500 ml	2500 ml
Sodium SULFITE (ANHYDROUS)	90	360
Water	to 1.00 L	to 4.00 L

4. **The Fixer**

It is recommended to use an acidic hardening fixer, such as **Kodak Rapid Fixer with Hardener.** Ilford Rapid Fixer can be substituted, but will result in a weaker emulsion that is more prone to scratches and damage.

Reversal Shenanigans and Anecdotal Evidence: Pushing Kodak 7266

Pushing film means setting the light meter at a film speed (sensitivity) higher than the manufacturer's recommendation, 200 ASA for Kodak 7266.

Pushing is commonly referred to in **stops.** Every stop increase is equal to doubling the film speed or underexposing by the same amount (1 stop push means setting the ASA to 400 or closing one f-stop, 2 stops – 800 ASA, 3 – 1600, etc).

Although b/w reversal film has the least latitude and "freedom" of the emulsions, it still allows for gross underexposure and will produce an image. The image will have high contrast and grain, more intense the more stops you push your stock.

Luckily, in terms of processing, the only adjustment we have to make is in the First Developer! A quick rule of thumb is that, for every stop we push the film, we increase FD time by 50%. And if you follow that, you will get a projectable image for up to 2 stops of pushing. However, for the best results, which in this case means the least bad image (although some may disagree), the developer formulation has to be changed, and the realm of experimentation begins.

Below I'll provide a starting point for pushing film from my personal experience, many hours of tests, some chemistry background, and developing a reel of film in my backpack for one hour whilst biking the streets of Houston. Feel free to use that information at your own risk.

Film Stock	Speed (Push)	Developer	Temp	Time	Notes
Kodak 7266	200 (0)	D67 (D19 + 2.0 g/L KSCN)	72 F	6:30	baseline
Kodak 7266	400 (1)	D67 (D19 + 2.0 g/L KSCN)	70 F	11:30	
Kodak 7266	400 (1)	D67 (D19 + 1.5 g/L KSCN)	72 F	12:00	better contrast
Kodak 7266	800 (2)	D67 (D19 + 2.0 g/L KSCN)	74 F	18:00	shadows pale
Kodak 7266	800 (2)	D67 (D19 + 1.0 g/L KSCN)	72 F	22:00	good
Kodak 7266	>1600 (3)	D67 (D19 + 0.3 g/L KSCN) low agitation	70 F	60:00	dark but visible image
Kodak 7266	>1600 (3)	Ilford MG Paper Developer 1+9 0.3 g/L KSCN constant agitation	70 F	45:00	good density but lower contrast
Kodak 7266	>1600 (3)	Ilford MG Paper Developer 1+7 0.3 g/L KSCN constant agitation	72 F	40:00	best result obtained

Note that I decrease the amount of thiocyanate (KSCN) as I increase development time. The role of KSCN is to improve image resolution, contrast, speed, by dissolving some of the undeveloped halide during development. However, this means reduced shadow density and an overall pale and low contrast image.
My recommendation is to decrease thiocyanate linearly with increasing development time. So, if you increase the development time twice from recommended, decrease KSCN by half, and so on.

Addendum: other notes for the intrepid

- **Avoid cross-contamination!** This is a common cause of problems. Introducing even small amounts of fixer or bleach into a developer can deteriorate its properties and ruin it. Have dedicated labeled containers for storing, measuring, and transferring the developer, bleach, and fix! It is good practice to wash every vessel and implement immediately after use.
- **A safer bleach:** Kodak R-9 is based on a hexavalent chromium salt, which is an environmental and health hazard. Kodak now recommends and sells a bleach based on **permanganate.** However, our attempts at formulating and using a permanganate bleach have not been able to match the results of bichromate and we cannot recommend a formula.
- Chemical Life, Capacity:
    - **Kodak D67** (**D19**) has a shelf life of **6 months** when unused and stored in an airtight container. Developer in use lasts about **1 month**. An estimate for its **useful capacity** is **1000 sq. in**. of film **per L** (**1 ft 16mm film = 7 sq. in**).
    - **Fixers** have a shelf-life of **6 months.** It is difficult to estimate capacity, but a simple test can be used – an unprocessed strip of film is dipped in the fresh fixer and the **clearing time** (the time for the film to become completely clear) is recorded. Before subsequent uses, the same test is run, and the clearing time will slowly increase, which is normal. When the time becomes **double** the beginning, the fixer is **exhausted**.
    - The **bleach** has an indefinite shelf life when unused. With use, it will become slower, acquire sediments and turns from yellow-orange to brown-green. Once the bleaching time exceeds **5:00-6:00 min**, the bleach is **exhausted**.
    - The **clearing bath** should be replaced when replacing the first developer.
- Depending on the amount of film a lab processes, it might be cost-effective to **replenish** the working solutions instead of preparing new batches by taking out a volume of the used solution and replacing it with **fresh stock**. Replenishment of the **developers**, **bleach and fixer** is possible. For every **7 rolls of 30ft. film** processed, replenish:
    - Kodak D67 – 500 ml
    - Kodak D19 (second developer) – 200 ml
    - Kodak R9 – 300 ml
    - Kodak Rapid Fixer – 300 ml
- Thiocyanate is a very important ingredient in the first developer! It is obtainable through most chemical and photography supply stores and a little goes a long way. Although it can be omitted or replaced with sodium thiosulfate (hypo), this is **highly advised against!**
- There is ample room for experimentation once the user is comfortable with the process. There are thousands of formulas and processes available in the literature and online, but it is always best to begin with a verified, known procedure before exploring these possibilities.