Section 11—Focal-Plane Shutters

You've seen that the blade-type shutter sits behind the lens or between lens elements. By contrast, the focal-plane shutter sits just in front of the camera's film aperture.

Some early focal-plane designs, such as the Speed Graphics, use a single curtain with multiple openings ("slits"), Fig. FP1. Selecting a shutter speed determines which opening is used to expose the film.

Moving the curtain in the cocking direction also tensions a spring—a spring located within the lower roller, Fig. FP2 (A). The tensioned spring is now ready to draw the curtain in the release direction.

When you release the shutter, the spring pulls the curtain in the direction of the arrow, Fig. FP2 (B). The film gets exposed as the curtain opening moves across the film opening, Fig. FP2 (C). At the end of the exposure cycle, the curtain opening rests below the focal-plane aperture, Fig. FP2 (D).

But notice that the entire frame doesn't get exposed at the same time. First the top of the film is exposed, Fig. FP2 (D). Then, as the curtain continues moving in the release direction, the rest of the film frame is exposed, Fig. FP2 (C). In effect, the slit wipes the exposure onto the film.

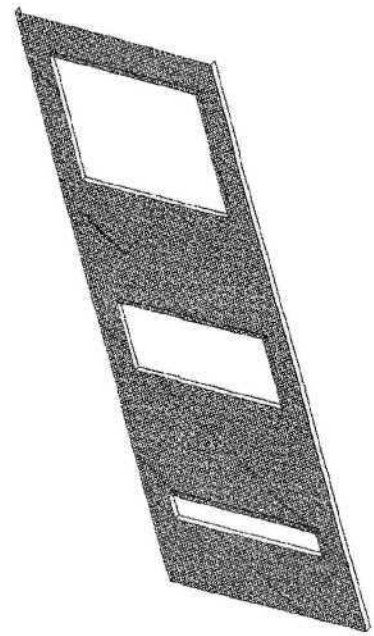


Fig. FP1 A curtain with multiple slits.

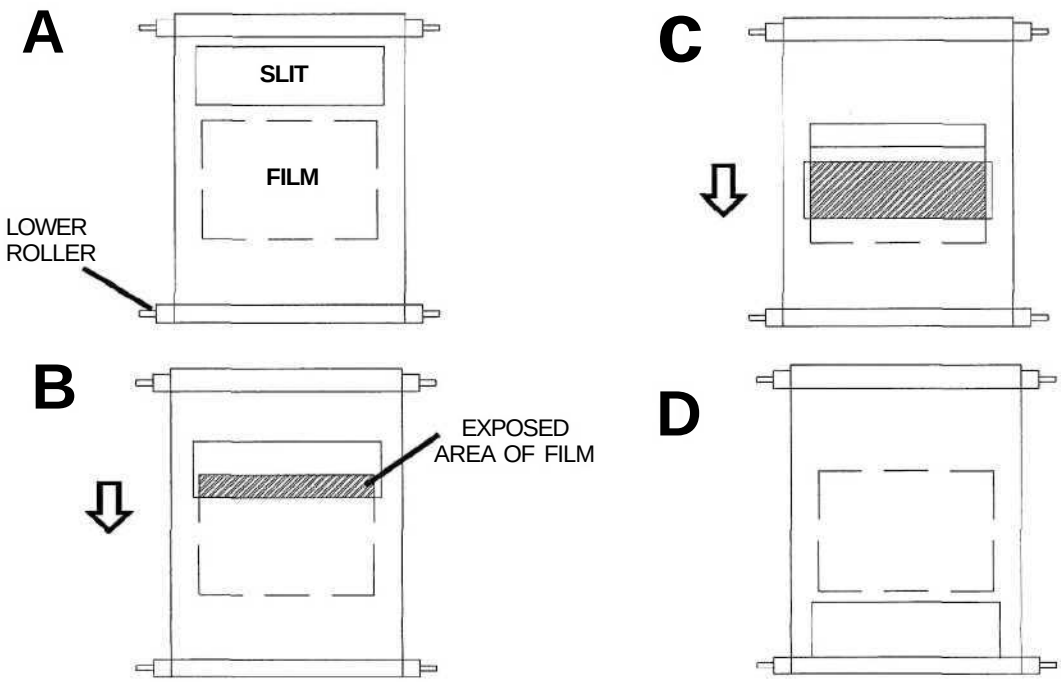


Fig. FP2 Exposure sequence with a multiple-slit curtain (view from front of camera).

Two factors determine the actual exposure time (shutter speed):

1. the width of the opening used to expose the film
2. the speed at which the curtain travels.

For the slowest shutter speed, the curtain opening is as large as the focal-plane aperture—the top slit in Fig. FPL As the curtain moves in the release direction, the film is completely uncovered—now the entire film frame sees the maximum amount of light. But the curtain continues moving in the release direction until it completely recovers the film.

As the curtain recovers the film, the top of the film frame gets cut off first. The bottom of the film frame continues to see light until the curtain opening moves below the aperture.

The fastest shutter-speed setting uses the smallest opening—the bottom slit in Fig. FP1. Here, only a small section of film sees light at a given moment.

Selecting a smaller slit decreases the amount of time that any given film section receives light. Similarly, moving the curtain at a faster speed decreases the length of time that the film sees light. Either or both techniques may then be used to provide different shutter speeds—providing different curtain openings or changing the speed at which the curtain travels.

The way most focal-plane shutters vary the exposure is by changing the size of the curtain opening. Very few cameras change the exposure time by speeding up or slowing down the curtain. Varying the curtain-travel time (curtain speed) requires changing the tension on the spring—the spring that draws the curtain in the release direction.

A single-curtain design has a limited range of shutter speeds—the number of shutter speeds equals the number of openings in the curtain. To achieve a full range of shutter speeds, most focal-plane shutters use two curtains—the 1st curtain and the 2nd curtain.

Each curtain connects to a spring-loaded roller—the tension (or take-up) roller, Fig. FP3. Each curtain has a pair of thin cloth tapes—the tapes of the 2nd curtain are cemented to the 2nd-curtain tension roller. The 1st curtain, however, is cemented directly to its tension roller.

The other end of the 2nd-curtain is cemented to the 2nd-curtain winding roller (not shown). Similarly, the tapes of the 1st curtain are cemented to the lst-curtain winding roller. The curtains and tapes are also cemented to the thin, metal curtain bars, Fig. FP3.

With the shutter released, the 1st curtain wraps around the 1st-curtain tension roller. The tapes of the 2nd curtain wrap around the 2nd-curtain tension roller. The 2nd curtain covers the film aperture, Fig. FP4 (A). As you cock toe shutter, both curtains move from the released position, Fig. FP4 (A), to the charged position, Fig. FP4 (B). Now the 2nd curtain wraps around its winding roller. The tapes of the 1st

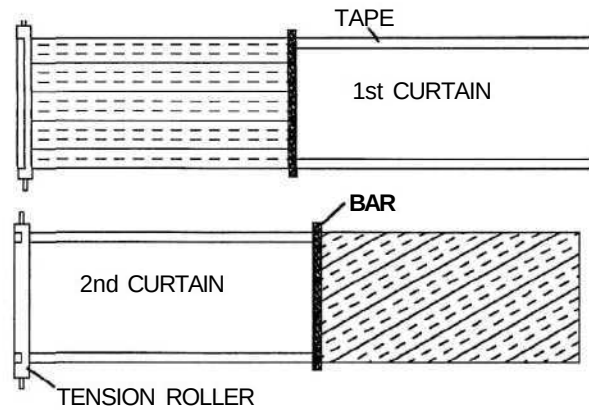


FIG. FP3 Curtains in a two-curtain focal-plane shutter.

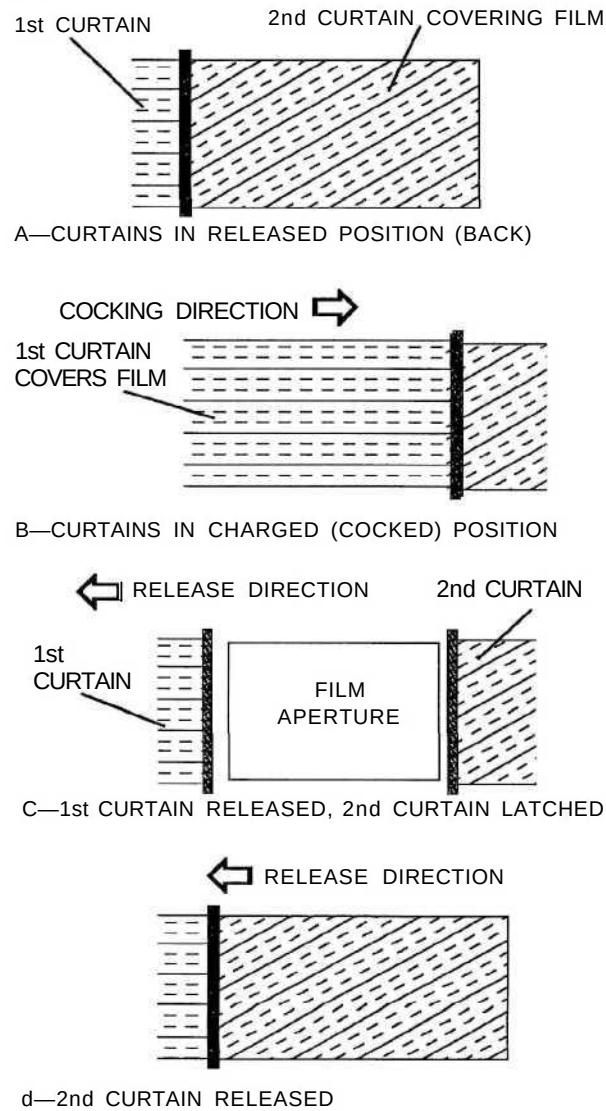


FIG. FP4 Exposure sequence with a two-curtain focal-plane shutter.

curtain wrap around the lst-curtain winding roller. Notice that the curtains overlap one another during the cocking movement. This curtain overlap prevents light from reaching the film.

Now, with the shutter charged, the 1st curtain covers the film aperture. The springs insided the tension rollers have been tensioned—both springs want to pull their respective curtains in the release direction. But each curtain is now latched—the 1st-curtain latch holds the 1st curtain, and the 2nd-curtain latch holds the 2nd curtain. The latches prevent the springs from pulling the curtains in the release direction.

Releasing the shutter disengages the lst-curtain latch. Now the 1st curtain moves across the aperture in the release direction, Fig. FP4 (C). Since the 2nd curtain remains latched by the 2nd-curtain latch, the shutter opens—the film sees light as the 1st curtain moves.

The right-hand edge of the film in Fig. FP4 (C) sees light first, The film then gets progressively uncovered as the 1st curtain moves. Finally, the 1st curtain reaches the other side of the aperture, completely uncovering the film.

Next the speed-control mechanism of the camera disengages the 2nd-curtain latch. Now the 2nd curtain moves across the aperture. The 2nd curtain progressively covers the film, ending the exposure to each part of the film in turn. Finally, the 2nd curtain reaches the end of its travel at the other side of the aperture, Fig. FP4 (D).

The sequence we've just described is called the full-aperture shutter speed—the 2nd curtain is released when the 1st curtain reaches the closing side of the aperture. For a moinenl, the entire film frame receives light. The full-aperture shutter speed depends on how fast the curtains travel and the exact moment that the 2nd curtain is released. In the classics and antiques, the full-aperture shutter speed is typically around 1/30 to 1/60 second.

For a faster shutter speed, the speed-control mechanism releases the 2nd curtain before the 1st curtain reaches the end of the aperture. Consider that the 2nd curtain releases when the 1st curtain reaches the position shown in Fig. FP5. The 1st curtain is then still in the aperture—still partially covering the film—when the 2nd curtain starts its release movement.

As a result, a slit formed between the two curtains moves across the film, Fig. FP6. The sooner the 2nd curtain is released, the narrower this slit becomes—and, as a result, the faster the shutter speed.

At the fastest shutter-speed setting, the 1st curtain just starts to move when the 2nd curtain releases. A very narrow slit then moves across the film. The shutter speed depends on the actual slit width and the speed that the curtains travel.

Changing the slit width can provide a wide range of shutter speeds. The classic cameras may provide speeds of 1/60 second (the full-aperture speed), 1/125 second, 1/250 second, and 1/500 second (or 1/1000 second) just by changing the release point of the 2nd curtain. Modern cameras rely on the same principle to provide shutter speeds as fast as 1/8000 second.

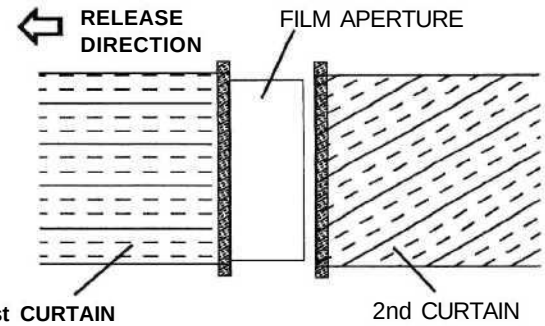


FIG. FP5 1st curtain released, 2nd curtain latched.

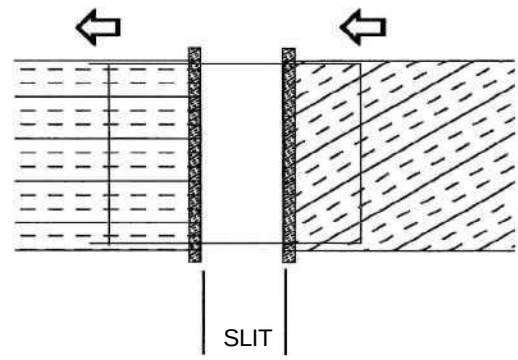


FIG. FP6 Both curtains released and traveling across film.

The two-curtain design also allows shutter speeds slower than the full-aperture speed. Here, the 1st curtain completely uncovers the film aperture—just as with the full-aperture speed. A mechanical speeds governor—similar to the speeds governor in blade-type shutters—then delays the release of the 2nd curtain. As a result, the film aperture remains completely uncovered for the length of the exposure time.

With a mechanical speeds governor, the slowest shutter speed is typically 1 second. The camera may provide shutter speeds of 1/2 second, 1/4 second, 1/15 second, and 1/30 second just by changing the engagement of the speeds governor. Modern cameras again rely on the same principle. But the electronic controls of today may provide even longer exposure times—perhaps 30 full seconds.

THE CURTAIN ROLLERS

Each curtain has its own spring-loaded tension roller—when the curtain is released, its tension roller pulls it to the released position. Each curtain also has its own winding roller to draw the curtain to the cocked position.

The drum design

Some focal-plane shutters combine the two winding rollers into a single curtain drum, Fig. FP7. The classic screw-mount and M-series Leicas use the curtain drum. Another classic—the Nikon F—also uses the drum.

The center section of the curtain drum, Fig. FP7, turns independently of the end sections. But the end sections turn together as one unit.

Fig. FF8 shows the construction of the drum. A shaft joins the two end sections. But the center section can rotate freely around the shaft.

One curtain—the 2nd curtain—is cemented to the center section of the curtain drum, Fig. FP9. The tapes of the 2nd curtain then cement to the 2nd-curtain tension roller.

The tapes of the 1st curtain are cemented to the end sections of the curtain drum, Fig. FP9. The 1st curtain is then cemented to the lst-curtain tension roller.

Note that the two end sections of the drum are slightly larger in diameter than the center section, Fig, FP9. The larger diameter of the end sections provides a slight separation between the curtains.

As you cock the shutter, the curtain drum rotates as a unit—the center section is locked to the end sections. The 2nd curtain wraps around the center section of the drum. At the same lime, the tapes of the 1 st curtain wrap around the end sections of the drum. As the drum rotates, it draws both curtains to the cocked position—against the tension of the tension rollers.

Fig. FP10 shows how the two sections of the drum are locked together during the charge cycle. Note the pin on top of the center drum, Fig. FP8. The pin passes through a cutout in the top section of the lst-curtain drum, Fig. FP10.

As you cock the shutter, the cocking mechanism turns the lst-curtain drum as shown by the curved arrow, Fig. FP10 (B). The lst-curtain drum then comes against the pin on the center drum. So, as the lst-curtain drum turns counterclockwise, it turns the center drum in the same direction.

Both curtains now move to the cocked position. The curtains overlap to prevent light from reaching the film. When the curtains reach the cocked position, a latch—the 2nd-curtain latch—engages and holds the center drum (you'll see the 2nd-curtain latch in the next section). The 2nd-curtain latch prevents the 2nd-curtain tension roller from pulling the 2nd curtain to the released position.

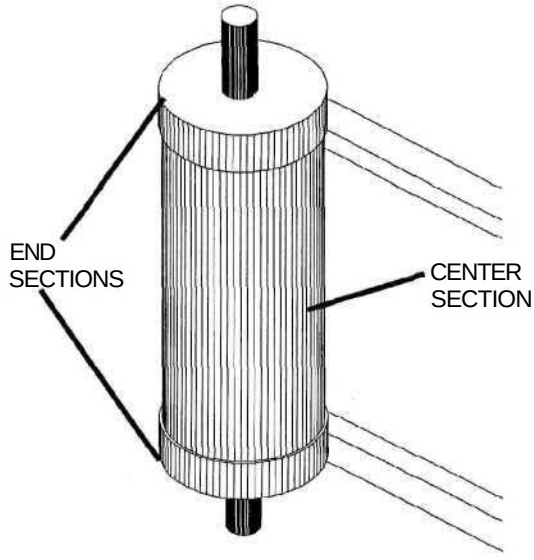


FIG. FP7The curtain drum.

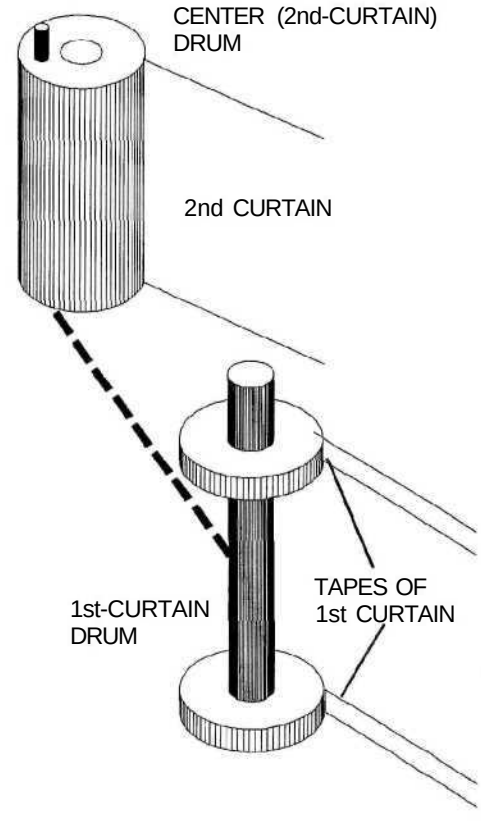


FIG. FP8 Construction of the curtain drum.

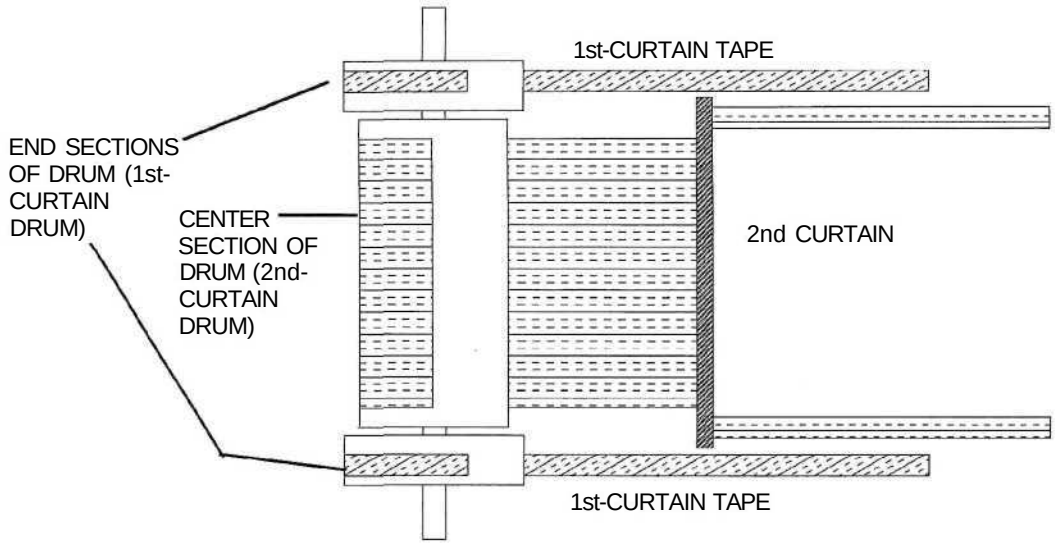
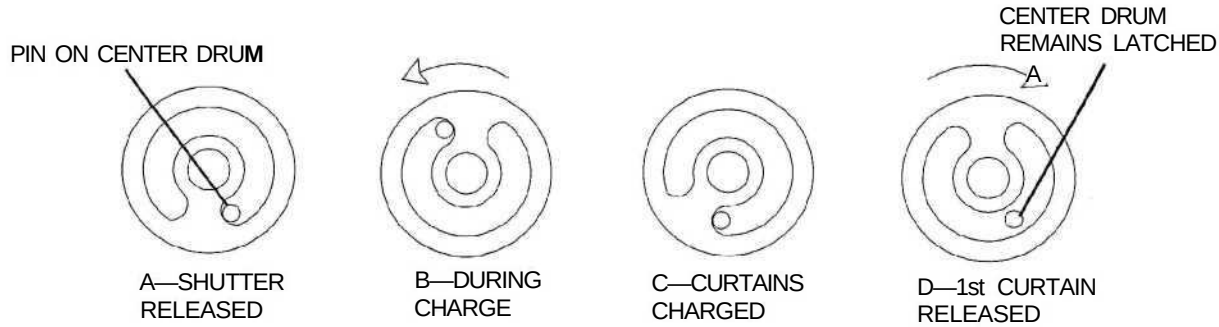


FIG. FP9 Curtain drum viewed from front of camera.



FIG, FP10 Top section of 1st-curtain drum.

The lst-curtain drum is also held in the cocked position—the lst-curtain drum is still engaged to the cocking mechanism.

When you release the shutter, the cocking mechanism disengages the lst-curtain drum. Now the 1st-curtain tension roller pulls the 1st curtain to the released position. The 2nd curtain remains in the charged position—it's still held by the 2nd-curtain latch.

For the full-aperture speed, the 1st curtain completely crosses the focal-plane aperture. A disengaging lever attached to the lst-curtain drum then strikes and disengages the 2nd-curtain latch. Now the center drum can rotate. Notice in Fig. FP10 (D) that the center drum can turn freely in a clockwise direction—its pin no longer comes against the upper section of the lst-curtain drum.

But for a slit-width speed, the center drum releases before the 1st curtain has completely crossed the focal-plane aperture. The disengaging lever on the lst-curtain drum strikes (the 2nd-curtain latch during the lst-curtain travel. The 2nd curtain then follows the 1st curtain as shown in Fig. FP11.

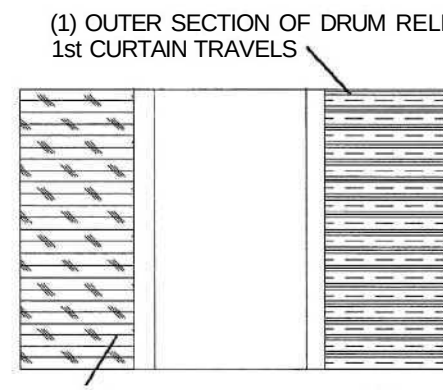


FIG. FP11 Curtains viewed from front of camera.

Selecting a slit-width shutter speed then determines the release point of the center drum. If you set a faster shutter speed, you select a smaller slit—the center drum releases sooner during the travel of the 1st curtain. The sooner the center drum releases, the narrower the slit—and the faster the resulting shutter speed.

From this description, we can determine a general rule for focal-plane shutters: The 1st curtain releases the 2nd curtain. Further, the slit width depends on how far the 1st curtain travels before releasing the 2nd curtain. For a full-aperture shutter speed, the 1st curtain completely crosses the focal-plane aperture; it then releases the 2nd curtain.

The sooner the 1st curtain releases the 2nd curtain, the narrower the slit—and, as a result, the faster the shutter speed.

The double-roller design

Other focal-plane shutters use two completely separate winding rollers rather than the drum. One winding roller sits directly in front of the other, Fig. FP12.

Fig. FP12 shows the mounting of the 2nd curtain—the curtain is cemented to the 2nd-curtain winding roller, while the tapes are cemented to the 2nd-curtain tension roller. The 1st-curtain tension roller has a free-turning small roller at each end to route the 2nd-cutain tapes.

The 2nd-curtain winding roller also has a small free-turning roller at each end, Fig. FP13. The tapes of the 1st curtain wrap around the small rollers en route to the Ist-curtain winding roller. The tapes then cement to (the ends of the lst-curtain winding roller. The 1st curtain is cemented to the 1st-curtain tension roller.

To charge the shutter, the cocking mechanism turns the two winding rollers together. But the two winding rollers turn individually on the release cycle.

There are several systems used to lock the winding rollers together during the cocking cycle. You'll see examples in the studies of actual cameras. Frequently, cameras use a pair of interlocking studs, Fig. FP14. One gear in Fig. FP14 couples to the charge mechanism; the other gear couples to the 1st-curtain winding roller.

As you cock the shutter, the wind mechanism turns the lower gear in Fig. FP14. The stud on the lower gear then turns the upper gear. And the upper gear turns the 1st-curtain winding roller. As in the drum design, the 1st-curtain winding roller turns the 2nd-curtain winding roller.

Pushing the release button moves down the lower gear—the interlocking studs disengage. The 1st curtain, now free, moves to the released position. But the 2nd curtain remains latched by the 2nd-curtain latch—just as with the drum design.

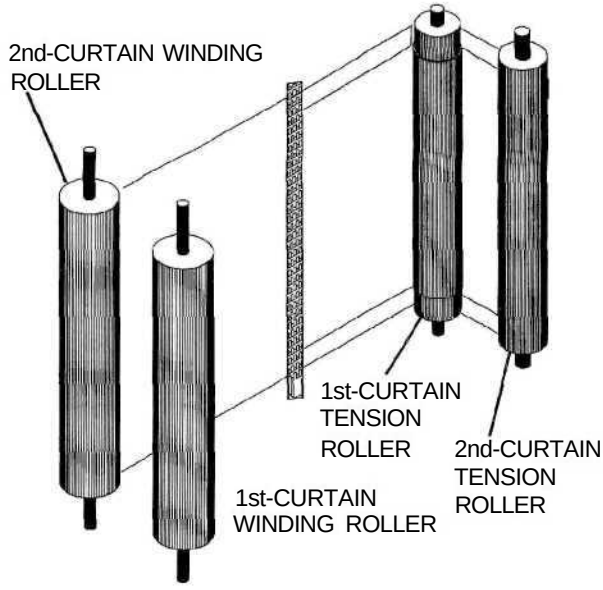


FIG. FP12 Position of the 2nd curtain in a double-roller design.

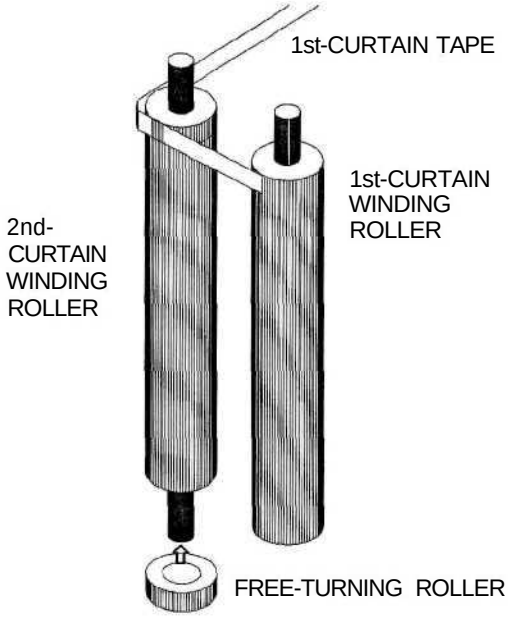


FIG. FP13 Mounting of the 1st curtain tapes in a double-roller design.

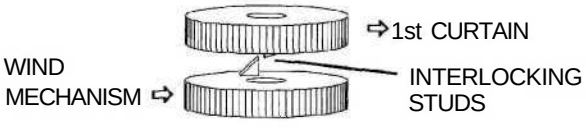


FIG. FP14 Gears that wind 1st curtain.

SPEED CONTROL IN THE FOCAL-PLANE SHUTTER

To control the release point of the 2nd curtain, we'll first add the latching system—the mechanism that latches the 2nd curtain in the charged position. In Fig. FP15, we've added a latching cam to the top pivot of the 2nd-curtain winding roller. Remember, the 2nd-curtain winding roller winds on the 2nd curtain during the cocking cycle.

We now need a latch—the 2nd-curtain latch—to engage the latching cam. Fig. FP16 shows the top view of the latching cam and the 2nd-curtain latch. In Fig. FP16 A, the curtains are in the released position. As you cock the shutter—and the 2nd-curtain winding roller winds on the 2nd curtain—the latching cam rotates as shown in Fig. FP16B.

As the latching cam nears the charged position, it pushes aside the 2nd-curtain latch, Fig. FP16B. The latching cam travels slightly further to the position shown in Fig. FP16C—the 2nd-curtain latch then drops into engagement with the latching cam.

Now the 2nd-curtain tension roller tries to pull the 2nd-curtain winding roller in the release direction, Fig. FP16C. But the 2nd-curtain latch holds the latching cam, preventing the 2nd-curtain winding roller from turning.

Releasing the shutter disengages the 1st curtain—the 2nd curtain remains held by the 2nd-curtain latch, Fig. FP16C. Remember that the release point of the 2nd curtain depends on how far the 1st curtain has traveled. Consequently, the part that releases the 2nd curtain typically moves with the 1st curtain. For the full-aperture speed, the 1 st curtain completely crosses the focal-plane aperture. The part rotating with the lst-curtain winding roller then strikes the 2nd-curtain latch.

Disengaging the 2nd-curtain latch frees the 2nd curtain. As the 2nd curtain moves across the aperture, the latching cam rotates as shown in Fig. FP16D.

For a faster shutter speed, the 1st curtain disengages the 2nd-curtain latch sooner—before the 1st curtain has completely crossed the focal-plane aperture. The sooner the 1st curtain disengages the 2nd-curtain latch, the smaller the slit width—and the faster the exposure time.

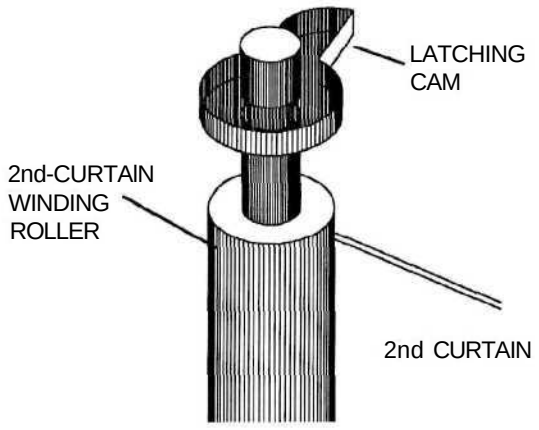


FIG. FP15 Top of 2nd-curtain winding roller.

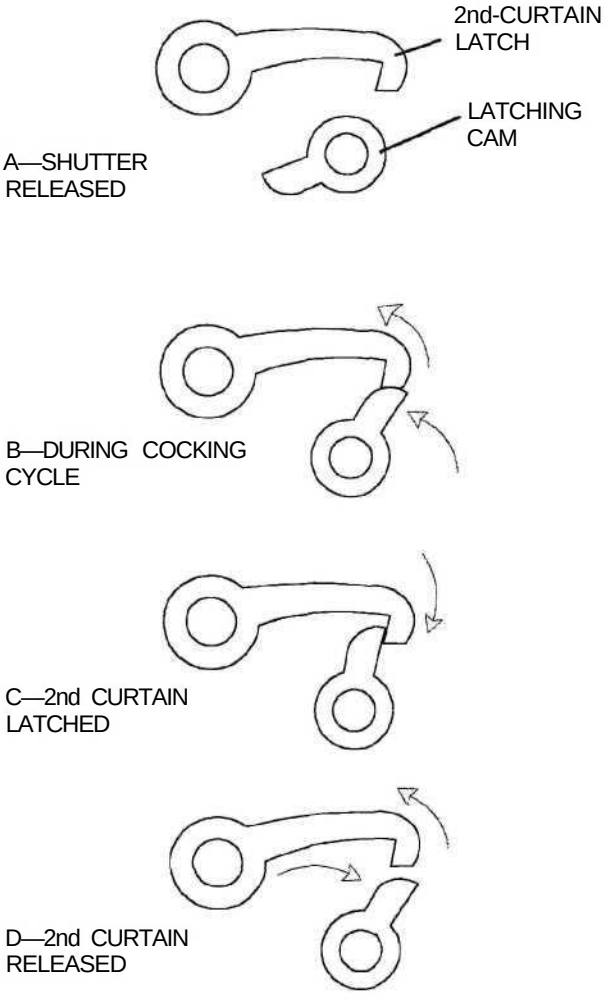


FIG. FP16 Latching sequence for 2nd-curtain winding roller.

Fig. FP16 shows a system similar to that used in the classic screw-mount Leicas. The speed-control disc attaches to the shaft at the top of the lst-curtain drum. As the 1st curtain crosses the aperture, the speed-control disc rotates.

The speed-control disc carries the 2nd-curtain release lever—a pin on the underside of the 2nd-curtain release lever fits into one of the holes in the speed-control disc. Each hole in the speed-control disc relates to a shutter speed.

To select a shutter speed, you lift and turn the shutter-speed knob at the top of the camera. The shutter-speed knob attaches to the top of the 2nd-curtain release lever. Align a calibration on the shutter-speed knob with the index—the pin on the 2nd-curtain release lever then aligns with a hole in the speed-control disc.

Setting the position of the 2nd-curtain release lever determines the release point of the 2nd-curtain—how far the 1st curtain travels before it releases the 2nd curtain. The 2nd-curtain release lever is the part that actually disengages the 2nd-curtain latch.

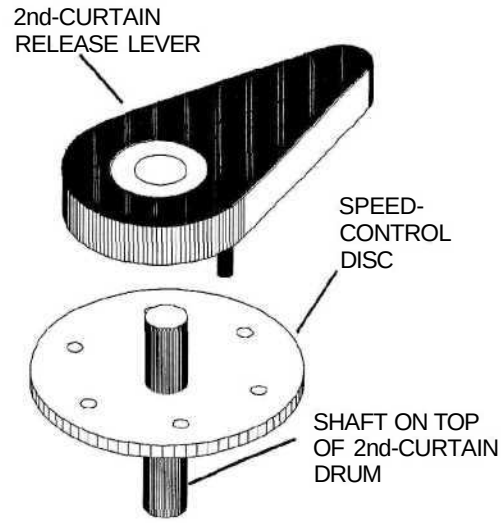


FIG. FP16

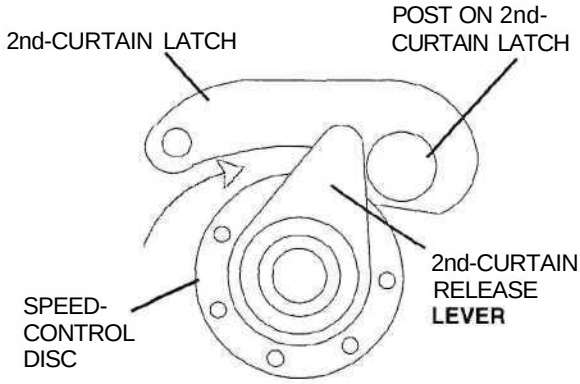


FIG. FP17 1st curtain released.

You can see how the 2nd-curtain latch is disengaged in Fig. FP17. Consider that the 2nd-curtain latch now holds the 2ndcurtain in the charged position. The 1st curtain has been released. As the 1st curtain crosses the focal-plane aperture, the speed-control disc rotates clockwise.

The 2nd-curtain release lever then strikes a post on the 2nd-curtain latch, Fig. FP17. Now the 2nd-curtain release lever drives the 2nd-curtain latch out of engagement with the latching cam, Fig. FP18. The 2nd curtain releases, following the 1st curtain across the film aperture.

Exactly how far the 1st curtain must travel to release the 2nd curtain depends on the starling position of the 2nd-curtain release lever. Perhaps you've set the fastest shutter speed—let's say 1/1000 second. With the shutter charged, the 2nd-curtain release lever sits at the position shown in Fig. FP19. The 2nd-curtain release lever must then rotate the distance shown by the curved arrow, Fig. FP 19, before

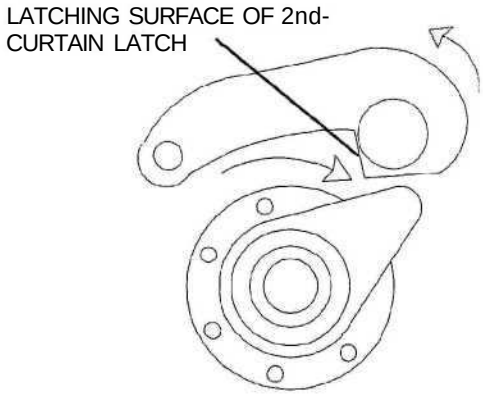


FIG. FP18 2nd curtain released.

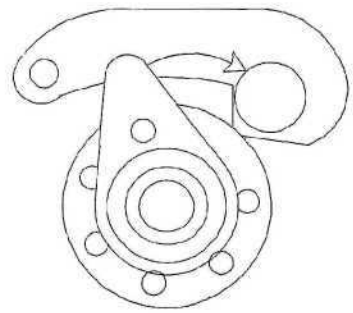


FIG. FP19 2nd-curtain release lever set to fastest shutter speed.

CHECKING AND ADJUSTING SHUTTER SPEEDS WITH A FOCAL-PLANE SHUTTER

A camera-repair shop uses a specialized electronic tester to check shutter speeds. If you're in the business of restoring antiques and classics, you may want to invest in such equipment. But if restoring antiques is a hobby, you probably can't justify the expense.

As with blade-type shutters, however, the important thing with antique focal-plane shutters may be proper operation—not point-blank accuracy. You should be able to visually detect a difference in the slow speeds. At the 1-second setting, the 2nd curtain should run smoothly through the slow-speed governor.

You can also visually check the fast speeds with a focal-plane shutter. Open the camera back and remove the lens. Now hold the lens opening to a light source. Watch through the focal-plane aperture at the back of the camera as you release the shutter.

As you change the shutter speeds in the slit-width range, you should be able to detect a difference—the light flash appears darker at each faster shutter-speed setting.

If you use a fluorescent lamp, you can even get a visual indication as to the accuracy of the shutter. The pulses of the fluorescent light capture the slit in different positions. At 1/1000 second, you should see three slits, Fig. FP23. At 1/500 second, you should see two slits.

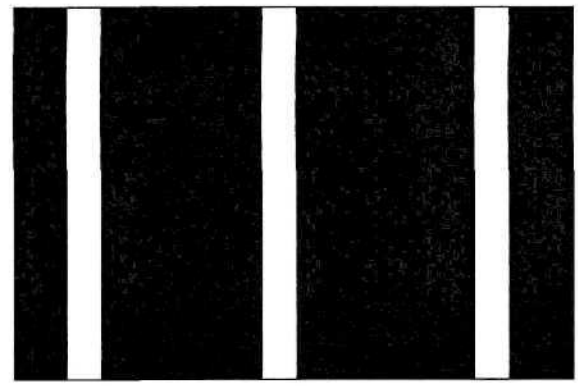


FIG. FP23 Exposure with a fluorescent lamp at 1/1000 second.

Another technique you can use is to watch the flash exposure at the slit-width shutter speeds. With electronic flash, you'll see only the portion of the aperture that's uncovered when you fire the flash. Point the electronic-flash unit toward a white wall. Set the camera to X sync, and watch the wall through the back of the focal-plane aperture as you release the shutter.

At the full-aperture shutter speed, you should see the full focal-plane aperture, Fig. FP24. But at each faster shutter speed, you should see only part of the aperture—a smaller portion illuminated at each faster shutter speed. At 1/500 second and 1/1000 second, you may see no flash through the aperture at all.

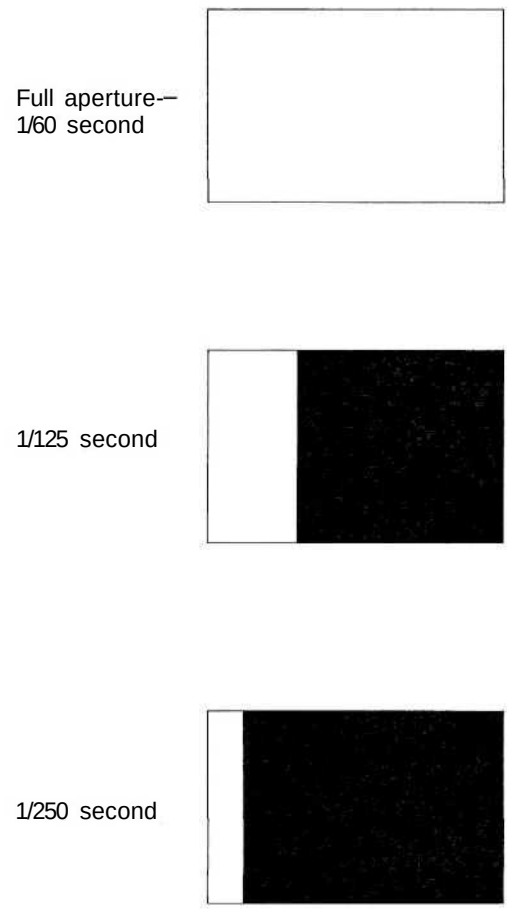


FIG. FP24 Exposure with an electronic-flash unit—curtain travel is from right to left.

Checking and adjusting curtain tensions—
Focal-plane shutters have individual tension adjustments for each curtain. The two curtains should be traveling at the same speed.

If the 1st curtain is traveling faster than the 2nd curtain, the slit gets wider as it crosses the aperture. The exposure on the closing side of the aperture is then longer than the exposure at the opening side of the aperture. The effect of the error is the most severe at the fastest shutter speed—the shutter speed with the narrowest slit.

The problem may even worse if the 2nd curtain travels faster than the 1st curtain. The slit then gets narrower as it crosses

striking the post on the 2nd-curtain latch. The 1st curtain barely enters the aperture before the 2nd curtain is released.

To set the next speed—1/500 second—lift and turn the 2nd-curtain release lever one position counterclockwise. The pin on the 2nd-curtain release lever now fits in the 1/500-second hole, Fig. FP21. Comparing Fig. FP20 with Fig. FP21, you can see that the 2nd-curtain release lever must now travel a greater distance clockwise before it strikes the 2nd-curtain latch. The 1st curtain travels that much further, resulting in a larger slit.

For the full-aperture shutter speed, the 2nd-curtain release lever sits in the 1/30-second hole, Fig. FP21. Now the 1st curtain completely crosses the focal-plane aperture before releasing the 2nd curtain.

SLOW SPEEDS WITH THE FOCAL-PLANE SHUTTER

For the slow speeds—the speeds slower than the full-aperture speed—the 2nd-curtain release lever sits at the full-aperture position—the 1/30-sccond hole in Fig. FP21. The 1st curtain then completely crosses the focal-plane aperture and releases the 2nd curtain.

So far, the operation is the same as it is at the full-aperture speed. But setting a slow shutter speed also engages the slow-speed governor. Once the 2nd curtain starts to move, the slow-speed governor engages some part that rotates with the 2nd-curtain winding roller. The slow-speed governor then prevents the 2nd curtain from entering the film aperture.

Now the action becomes similar to that with a blade-type shutter. With the blade-type shutter, you'll recall, the main lever must push its way through the resistance of the slow-speed governor. Similarly, before the 2nd curtain can enter the aperture, it must push its way through the resistance of the slow-speed governor.

All the governor action takes place *before* the 2nd curtain enters the focal-plane aperture. Consider that the 2nd-curtain latch holds the 2nd curtain at the position shown in Fig. FP22. When the 1st curtain crosses the film aperture, it disengages the 2nd-curtain latch. The 2nd curtain now moves slowly over the distance shown by the double-headed arrow in Fig. FP22—slowly because the 2nd curtain is now pushing its way through the resistance of the slow-speed governor.

Before the 2nd curtain actually enters the film aperture, it disengages from the slow-speed governor. The 2nd curtain now fires across the aperture at its normal speed to end the exposure. The shutter speed then depends on how long it takes for the 2nd curtain to reach the focal-plane aperture.

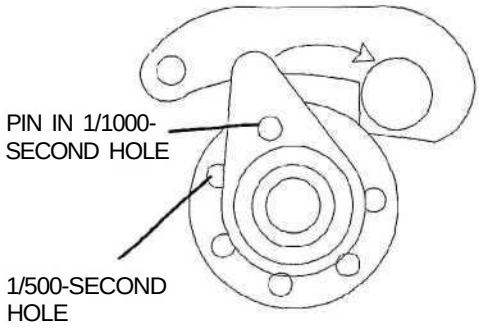


FIG. FP20 2nd-curtain release lever set at 1/1000 second.

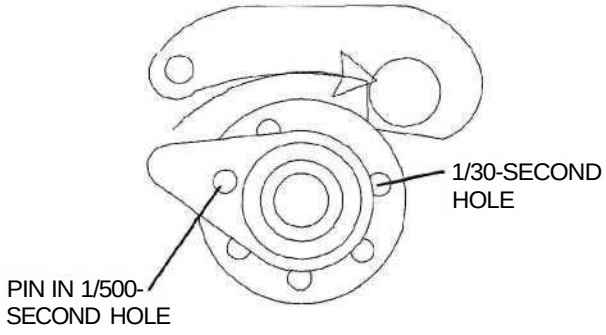


FIG. FP21 2nd-curtain release lever set at 1/500 second.

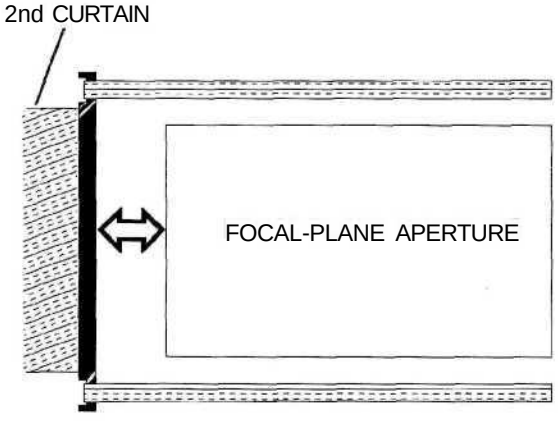


FIG. FP22 2nd curtain in latched position, viewed from front of camera.

the aperture. And the exposure time is shorter on the closing side of the aperture.

But if the 2nd curtain travels much faster than the 1st curtain, the slit may close completely. The 2nd curtain catches the 1st curtain—before the curtains have completely crossed the aperture.

Check at the fastest shutter speed. Hold the lens opening to a light source and watch through the back of the focal-plane aperture. When you release the shutter, make sure that you're getting an exposure all the way across the aperture. If you get an exposure at one side of the aperture—but not at the other side—the 2nd curtain is catching the 1st curtain.

For example, consider in Fig. FP25 that the curtains are traveling from right to left. And you get the result shown in Fig. FP25—exposure at the right side of the aperture, but nothing at the left side. The 2nd curtain is catching the 1st curtain—in Fig. FP25, the 2nd curtain catches the 1st curtain around half way across the aperture.

If you get light all the way across the aperture, you at least know that the slit isn't closing. But you still don't know if the curtains are traveling at uniform speeds. The fluorescent light source gives you a better indication. In Fig. , notice that the three light slits are the same width—that means the curtains are traveling at the same speed. If the light slits are uneven in width, the curtains are traveling at different speeds.

But the best way to check curtain speeds is with a commercial shutter-speed tester. Most shutter-speed testers provide a function for measuring the curtain speeds—the curtain-travel time. The shutter-speed tester may show you both curtain-travel times simultaneously. You can then check to see that the travel times are the same. The readings of the travel times are in milliseconds.

Camera manufacturers now provide specifications for the curtain-travel times. For example, the manufacturer may specify 12ms as the curtain-travel time for a particular model. Both curtains should then cross the focal-plane aperture in 12ms. But it's more critical that both curtains are traveling at the same speed—even if that speed doesn't exactly match the manufacturer's specification.

You'll usually find the curtain-tension adjustments at the bottom of the camera, Fig. FP26. The camera in Fig. FP26 uses worm-gear adjustments. To adjust the curtain travel time, you first loosen the locking setscrew at the top of the worm housing. You then turn the worm—and the worm turns the worm gear to increase or decrease the spring tension of the tension (take-up) roller.

Other focal-plane shutters may use ratchet gears to set the curtain-travel times. In Fig. FP27, you can turn the ratchet gear freely in one direction—the direction that adds tension. To let off tension, hold the ratchet gear and disengage the locking spring. Allow the tension-roller spring to unwind slightly.

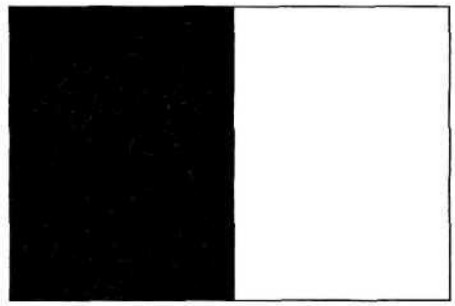


FIG. FP25 Results of the 2nd curtain overtaking the 1st curtain—curtain travel is from right to left.

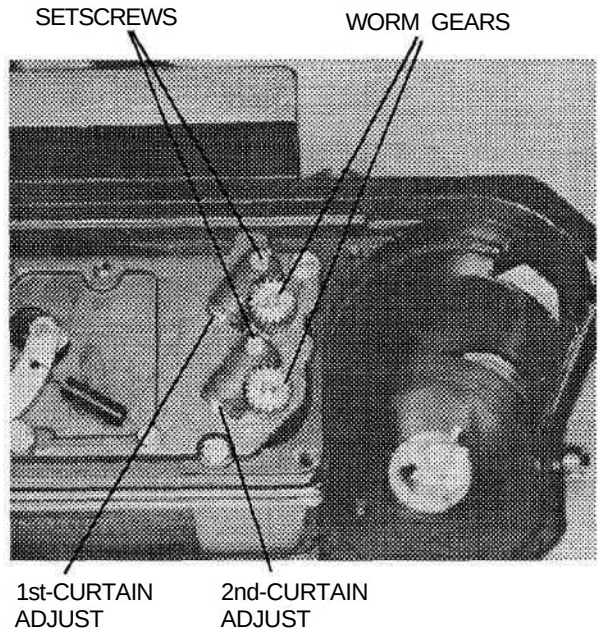


FIG. FP26 Bottom of Nikon F.

The curtain-adjustment positions in Fig. FP26 and FP27 are typical of focal-plane shutters—the 2nd-curtain adjustment is closer to the back of the camera. So, if the 2nd curtain is catching up with the 1st curtain, you can add tension to the 1st curtain—the 1st curtain then travels faster.

You could get the same results by letting off some of the tension from the 2nd curtain. However, a curtain tends to slow down as the camera ages due to spring fatigue. If the 2nd curtain is catching the 1st curtain, then, it's more likely that the 1st curtain is traveling too slowly.

If you have a way to actually measure the curtain-travel times, you can set the curtains according to the manufacturer's specifications. For example, if the manufacturer specifies 12ms, adjust each curtain to travel at 12ms.

ADJUSTING SHUTTER SPEEDS WITH THE FOCAL-PLANE SHUTTER

The curtain tensions do affect the shutter-speed accuracy—the faster the curtains travel, the faster the exposure time. But the slit width has a greater effect on the exposure time.

Most of the old focal-plane shutters provide an adjustment on the 2nd-curtain latch, Fig. FP28. The adjustment—usually an eccentric—determines when the 1st curtain releases the 2nd curtain. The sooner the 1st curtain releases the 2nd curtain, the narrower the slit—and the faster the exposure time.

The adjustment for the slow speeds is on the slow-speed governor. An eccentric or screw adjustment increases or decreases the retard-lever engagement. If you increase the retard-lever engagement, it takes longer for the 2nd curtain to run through the slow-speed governor—a slower shutter speed.

There may also be an adjustment on the pallet engagement. The adjustment for the pallet engagement may affect I second, 1/2 second, and 1/4 second. You would then use the retard-lever adjustment for 1/30 second. And use the pallet adjustment for the three slowest shutter speeds.

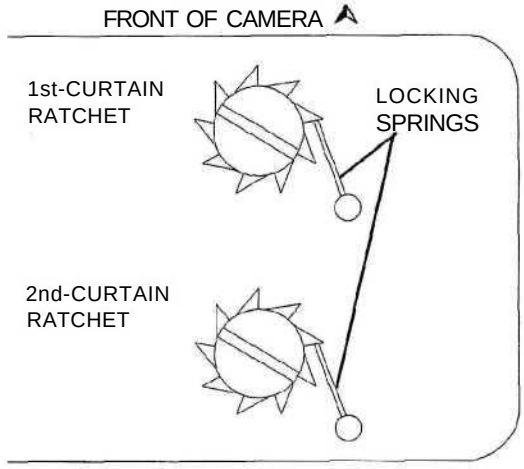


FIG. FP27 Bottom of camera with ratchet-type adjustments.

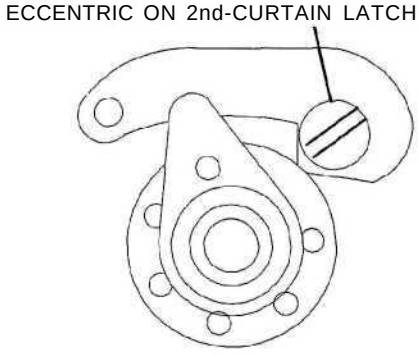


FIG. FP28 Top of drum-type focal-plane shutter.

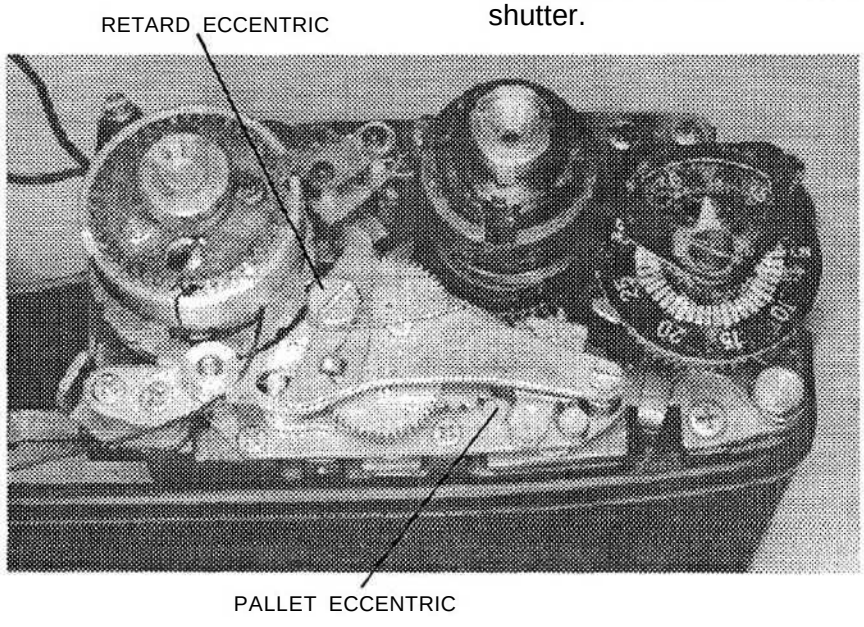


FIG. FP29 The slow-speed governor is at the top, release-button end of the Minolta SR-T 101, a classic with a double-roller focal-plane shutter.

MAKING AND REPLACING SHUTTER CURTAINS

Removing the old curtains—
With old cameras, you'll frequently find that the curtains have deteriorated. Curtains may have a rubber-like coaling on one side. The rubber-like material deteriorates with age, falling away in flakes.

Or you may find pin holes in the curtain. If you then hold the curtain to a light source, you'll see light passing through the curtain in several places. You may even find that the curtain has torn loose from the bar.

If the camera won't be used to take pictures, curtain damage may not be a problem. But damaged curtains do detract from the "perfection" of the camera—often a factor with collectors.

You probably won't be able to purchase replacement curtains. So, if you want to restore the camera to mint condition, you'll have to make new curtains.

Some companies do still provide curtain material—bulk material from which you can cut new curtains. Curtain material may be rubberized on one side. Or there may be no rubber-like coating. But you want to use a material that matches the original curtain.

Curtains aren't especially difficult to make. The problem is that you have to almost completely disassemble the camera to replace the curtains—a major job. You probably should not attempt such a restoration until you're intimately familiar with the particular camera.

Disassemble the camera far enough to reach the rollers—it may not be necessary to remove the rollers from the body. However, in some cameras, the position at which the. curtains cement to the rollers or drum is critical—the position at which you cement the curtain and tapes may be your only adjustment for the curtain positions. With other cameras, you can adjust the curtain positions by adjusting gear timing.

If the camera has a drum-type focal-plane shutter, you can be certain that the curtain positions are critical—both the position at which the curtain cements to the inner drum and the positions at which the tapes cement to the outer drum, Fig. FP30. The positions may also be critical in the double-roller design. But with many double-roller designs, you can change the gear timing to adjust the curtain positions.

Fig. FP31 shows the critical timing on the 2nd curtain—the distance between the curtain bar and the lead edge of the focal-plane aperture when the 2nd curtain is latched in the open position. The critical timing on the 1st curtain is the curtain overlap—how far the curtains overlap one another during the cocking cycle. Typically, the overlap is one bar. But that's not always the case.

It helps to check both timing points before you remove the curtains. Hold open the shutter on bulb. Then scribe the

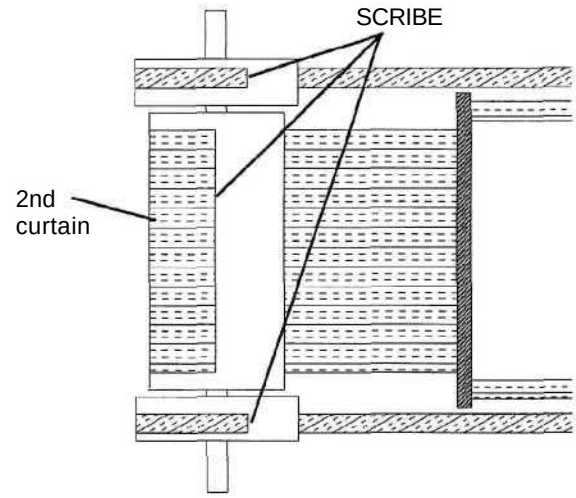


FIG. FP30 Front view of the curtain drum.

inside of the focal-plane aperture to note the edge of the 2nd-curtain bar, Fig. FP31.

Check the curtain overlap during the cocking stroke. Advance the curtains until they are around half way across the aperture. Then make a note of the overlap.

Also make careful notes and sketches of the curtain positions. Does the rubberized side face the front or the back of the camera? Which curtain sits to the front of the camera—the 1st curtain or the 2nd curtain? You might also mark the old curtains to note which is the 1st curtain and which is the 2nd curtain—depending on the camera, the two curtains may be identical or slightly different.

You can now let off the curtain tensions. But count the turns as you let off the tension. You then have a starting point for reassembly.

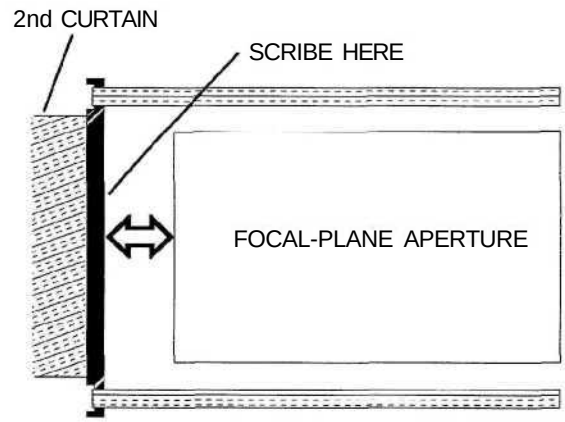


FIG. FP31 2nd curtain in latched position, viewed from front of camera.

For example, with the design shown in Fig. FP26, use your screwdriver to hold the ratchet gear in place. Then hold the lock spring away from the ratchet gear. Allow (he ratchet gear to rotate slowly clockwise as you count the turns of initial tension.

With the worm-gear design, Fig. FP25, loosen the setscrew that locks the worm. Hold the worm gear in place with your screwdriver. Now push the worm out of its housing. Count the turns on the worm gear as the tension-roller spring unwinds.

The starting positions of the curtain and tapes on the tension rollers aren't critical—there's no timing on the tension rollers. But it's very critical that the curtain and tapes are square to the tension rollers. If they aren't square to the rollers, the slit will be tapered as it moves across the aperture, Fig. FP32. In Fig. FP32, the top of the film frame receives more exposure than the bottom of the film frame.

You can use a straightedge to scribe the tension rollers—use the scribe line to align the end of the 1st curtain and to make sure both 2nd-curtain tapes start at the same position. Or you can scribe the old lst-curtain edge and the old 2nd-curtain tapes before you remove them. Then peel the 1st curtain and the 2nd-curtain tapes from the tension rollers.

Also scribe the positions of the old curtains and tapes before you remove them from the drum. With some drum designs, you can see the edge of the 2nd curtain, Fig. FP30, with the shutter released—scribe the center drum along the 2nd-curtain edge. You can normally see the 2nd-curtain edge in shutters that use titanium (metal) curtains.

But with drum-type shutters using cloth curtains, the 2nd curtain usually wraps over the edge. Reaching the edge of the 2nd curtain may then require that you remove the drum—something you want to avoid if possible. Fortunately, there's a shortcut you can use. Here's the shortcut:

First pec) the curtain and tapes from the tension rollers. Then, with the shutter in the released position, place a straightedge against the 2nd curtain and the drum—at the position of the 2nd-curtain edge in Fig. FP30). Using a sharp hobbyist knife, cut the 2nd curtain along the straight edge.

Work from the cut to peel the 2nd curtain from the drum. You can now remove the 2nd curtain from the camera. But the end of the 2nd curtain remains cemented to the drum—leave this material in place.

Use the 2nd curtain you just removed as a pattern. Cut the replacement 2nd curtain to the same length. You can then slide the replacement 2nd curtain around the hack of the drum, Fig. FP30. Bring the end of the replacement 2nd curtain against the cut end of the 2nd curtain that remains on the drum—that end of the old 2nd curtain serves as your scribe line.

You also want to scribe the ends of the lst-curtain tapes, Fig. FP30. But you won't be able to reach the ends without unwrapping the tapes from the outer drum.

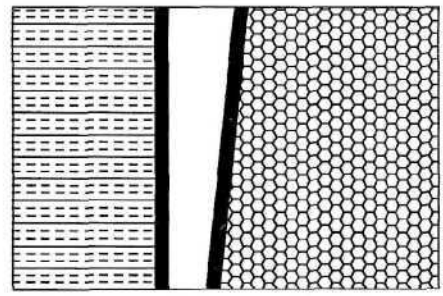


FIG. FP32 Tapered slit resulting from one curtain not being square to its roller.

FIG. FP33

FIG. FP34

With the 1st curtain peeled loose from its tension roller, you can unwrap the tapes. Or you can use the same technique as described for cutting the 2nd curtain—cut the old tapes and leave the ends cemented to the center drum. Be sure to cut the new tapes to the same lengths as the tapes remaining on the old 2nd curtain.

You may not have to scribe the old curtains in a double-roller design. If you can remove the wind gears (the gears that engage the winding-roller pinions), you can adjust the curtain timing—regardless of the starting position of the curtains. But if you can't remove the wind gears, scribe the 2nd-curtain winding roller to note the lead edge of the 2nd curtain. Scribe the lst-curtain winding roller to note the lead edge of each lst-curtain tape.

The scribe marks are useful even if the curtain positions aren't critical. As mentioned earlier, you can often adjust gear timing to correct the curtain positions. But you still want to make sure that the 2nd curtain is square to its winding roller. And the end of each lst-curtain tape must be on a straight line. If a curtain isn't square to the winding rollers, the curtain will sit at an angle as shown in Fig. FP32.

Making the curtains—

If possible, try to save the old curtain bars—just so you don't have to make new bars. Each curtain bar may be shaped similar to the one in Fig. FP33. The end of the curtain then fits inside the bar. And the bar is pressed closed to sandwich the curtain.

Here the manufacturer cements the end of the curtain to the bar. The bar is then pressed closed. Dimples may be added to the bar—punch marks into both the bar and the curtain—for added strength.

Carefully spread the bar, Fig. FP33, to free the curtain—remember, you're going to reuse the bar. Then peel the old curtain from the bar. You can now measure the curtain—the length and the width.

Or the curtain bar may be shaped like the one in Fig. FP34. The curtain and the tapes fold over the bar, Fig. FP35 and Fig. FP36.

The manufacturer cements the curtain to the bar. A row of stitches may then be added along the bar—at the position shown by the dashed line in Fig. FP36—for additional strength.

Before you peel the curtain from the bar, make careful measurements—the width of the curtain and the length of the curtain measured from the edge of the bar. When you cut the new curtain, leave sufficient material for the fold, Fig. FP35. But it's the length of the curtain measured from the bar that's critical.

Now check the curtain material. If you're using the rubberized curtain material, you'll find that the material will stretch in one direction but not in the other direction. Make your lengthwise cuts in the direction that the material will not stretch. Remember that the curtains are pulled from the ends. If they can stretch in the lengthwise direction, their lengths will change when tension is applied.

Be very critical as you cut the material—make the curtain cuts as square, clean, and straight as possible. Use a sharp knife such as a new single-edged razor blade or a hobbyist knife. If the knife isn't sharp, the edges of your curtains may be frayed.

Also be very critical when you cement the curtains to the bars—the curtains must be square to the bars. If the curtains aren't square, the slit will be tapered as it moves across the aperture, Fig. FP32.

With the type of curtain shown in Fig. FP36, apply Pliobond both to the curtain and to the bar. Then fold the curtain over the bar—make sure the length of the curtain from the edge of the bar matches your original measurement. While the cement is drying, make precise adjustments on the curtains—remember, the curtains must be 90° to the bars.

Then, after the cement dries, hand sew the curtains, Fig. FP36—keep the stitches very close to the bars,

The curtain tape also comes in bulk form—a roll from which you can cut off the length you need. Be just as critical in matching the lengths of the tapes to those of the old curtains—especially if the shutter provides no adjustments for curtain positions.

Installing the curtains—
If you're installing the curtains on a drum, Fig. FP30, remember that the 2nd curtain and the lst-curtain tapes must align with the scribe lines—or with the cut ends of the curtain and tapes remaining on the drum. Slide the 2nd curtain behind the drum. Bring the end of the 2nd curtain to the scribe line.

Apply a smooth coat of Pliobond both the back of the curtain and to the front of the center drum. Cementing both surfaces *(contact cementing)* strengthens the bond. You can determine how much of the curtain should be cemented by examining the old curtain. In general, the cement should extend around 1/4" from the end of the curtain.

Line up the 2nd curtain with your scribe line or the end of the original curtain and cement the curtain in place. Pliobond gives you a little time to shift the curtain position before the cement dries.

The lst-curtain tapes may wrap twice around the end sections of the drum. If you completely removed the tapes of the old curtain, wrap the new tapes around the outer drum—leave the tapes loose so you can reach the ends. Align the

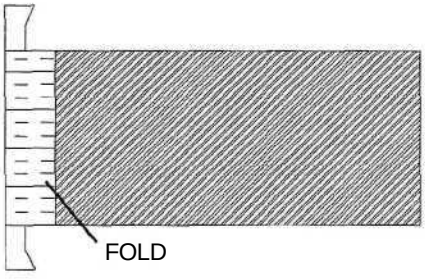


FIG. FP35

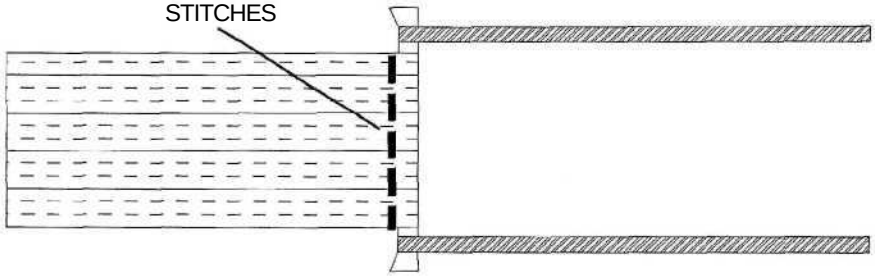


FIG. FP36

tape ends with your scribes and cement them to the outer drum.

If you left the ends of the old tapes on the drum, you don't have to wrap the tapes twice around the drum ends—just bring the ends of the new tapes against the cut ends of the old tapes.

You can determine if the curtains are in their proper positions before you cement them to the tension rollers. Let the cement dry for a few minutes. Then hold both curtains toward the tension-roller end of the camera—apply just enough pressure to remove the slack from the curtain and tapes. Then slowly cock the shutter. The drum turns, wrapping on the curtains.

As the curtains move to the cocked position, they should overlap—the overlap should be the amount you noted before removing the curtains (normally one bar). If there's a space gap between the curtain bars, you probably didn't wrap the lst-curtain tapes enough times around the drum ends. But if the overlap is excessive, you may have wrapped the tapes loo many times around the drum ends.

Next route the 1st curtain and the 2nd-curtain tapes to the tension rollers. Follow the same procedures to cement the curtain and tapes. Here the starting positions aren't critical. But it's very critical that the curtains are square to the tension rollers.

After the cement dries, you can put a couple of turns of tension on the tension rollers—just enough tension to draw the curtains taut. You can now check the curtain alignment to see if the curtains are square to their rollers.

Look from the back of the focal-plane aperture as you turn the center drum in the winding direction—you're now winding on the 2nd curtain. When the 2nd curtain enters the aperture, you can judge if it's straight, Fig. FP37. Use the end of the focal-plane aperture as a straight edge.

Use a similar technique to determine if the 1st curtain is straight. Cock the shutter. Then hold the drum and release the shutter. Allow the drum to turn slowly until the 1st curtain to just enter the aperture. Again use the end of the aperture as a straight edge to determine if the 1st curtain is straight.

If a curtain isn't square, you may be able to make a correction without removing and recementing that curtain—unless the error is severe. For a slight error, you can use extra curtain tape to "shim" the curtain.

For example, suppose you're looking at the hack of the focal-plane aperture. And you can see that the 2nd curtain isn't quite square—you need to move the upper end of the curtain toward the tension rollers, Fig. FP38.

Unwrap the upper end of the 2nd-curtain tape from the end of the tension roller—just enough so you can reach the tape end. Now insert a small section of tape at the end of the upper 2nd-curtain tape. Allow the 2nd-curtain tape to wrap

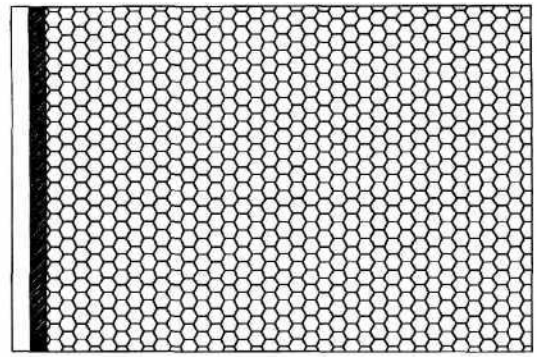


FIG. FP37 Here the 2nd curtain is square to the roller.

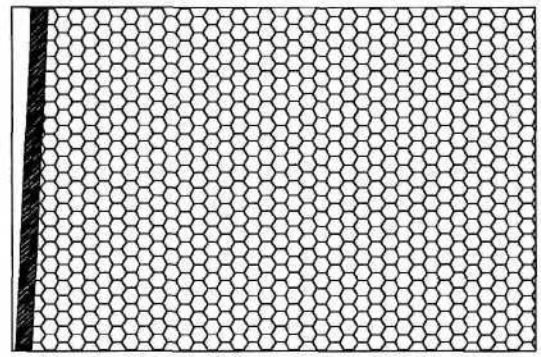


FIG. FP38 The 2nd curtain is not square to the roller—the upper end of the curtain must be pulled from right to left.

around the 2nd-curtain tension roller to hold your tape "shim" in place.

The extra chunk of tape increases the diameter of the tension roller at the top end. The result—the top end of the curtain is pulled a little further toward the tension rollers.

Again check the alignment of the 2nd curtain. If the 2nd curtain is now straight, your tape "shim" is the right size. But you may decide you need a slightly larger shim—or a slightly smaller shim. Once you've determined the proper size, cement your tape shim to the tension roller.

If the 1st curtain isn't straight, you can use a similar shimming procedure—but this time, shim the lst-curtain tapes where the tapes cement to the drum ends.

ADJUSTING CURTAIN TIMING

We mentioned that many double-roller designs allow you to adjust the curtain timing. The upper ends of the winding rollers engage the winding gears—the gears that rotate to wind on the curtains. If you can change the timing of these wind gears, you can adjust the curtain positions.

First adjust the timing of the 2nd-curtain wind gear—the gear that turns the 2nd-curtain winding roller. Remember

that the 2nd-curtain latch should hold the 2nd curtain in a certain position—the curtain bar should be a certain distance from the lead edge of the focal-plane aperture. You noted that distance before removing the curtains. Many cameras have factory scribe marks to note the 2nd-curtain position.

Wind on the 2nd curtain to the cocked position. And engage the 2nd-curtain latch with the 2nd-curtain wind gear. Now check the position of the 2nd curtain—the lead edge of the 2nd-curtain bar should be aligned with the scribe mark. Change the timing between the 2nd-curtain wind gear and the 2nd-curtain winding roller until the curtain is in the proper position.

Adjust the timing of the 1st curtain for the proper overlap. Start with both curtains in the released position. Then slowly cock the shutter. Check the curtain overlap as the curtains move to the cocked position. If the overlap isn't right, change the timing between the lst-curtain wind gear and the lst-curtain winding roller.

For example, Fig. FP39 and Fig. FP40 show the sequence in an early Pentax double-roller design, the H3v. The lst-curtain wind gear sits on top of the 2nd-curtain wind gear.

You would then first install the 2nd-curtain wind gear, Fig. FP39. Wind on the 2nd curtain to the charged position. And engage the 2nd-curtain wind gear with the 2nd-curtain latch., Fig. FP39. Now adjust the timing between the 2nd-curtain wind gear and the 2nd-curtain winding roller until the curtain is held the proper distance from the focal-plane aperture, Fig. FP31.

Disengage the 2nd-curtain latch to release the 2nd curtain. Then install the lst-curtain wind gear, Fig. FP40. As you turn the lst-curtain wind gear, the lst-curtain wind gear turns the 2nd-curtain wind gear. Both curtains travel simultaneously to the cocked position.

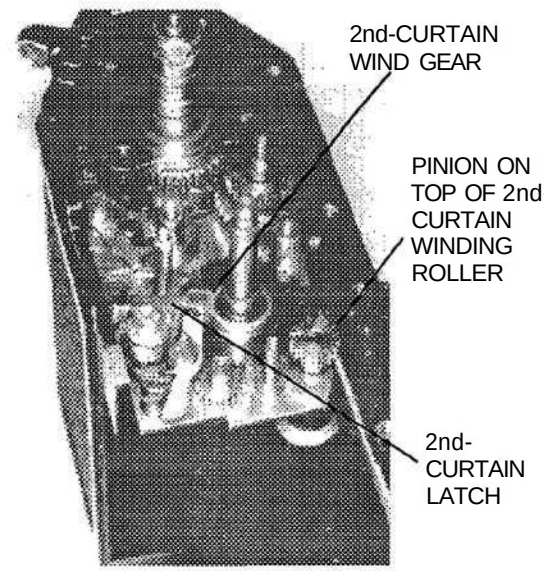


FIG. FP39 Adjusting the timing of the 2nd curtain.

Turn the 1st-curtain wind gear until the two curtains are around half way across the aperture. Then check the curtain overlap. In the Pentax, the curtains should overlap by one bar—one curtain bar sits directly in front of the other curtain bar. Adjust the overlap by changing the timing between the lst-curtain wind gear and the lst-curtain winding roller.

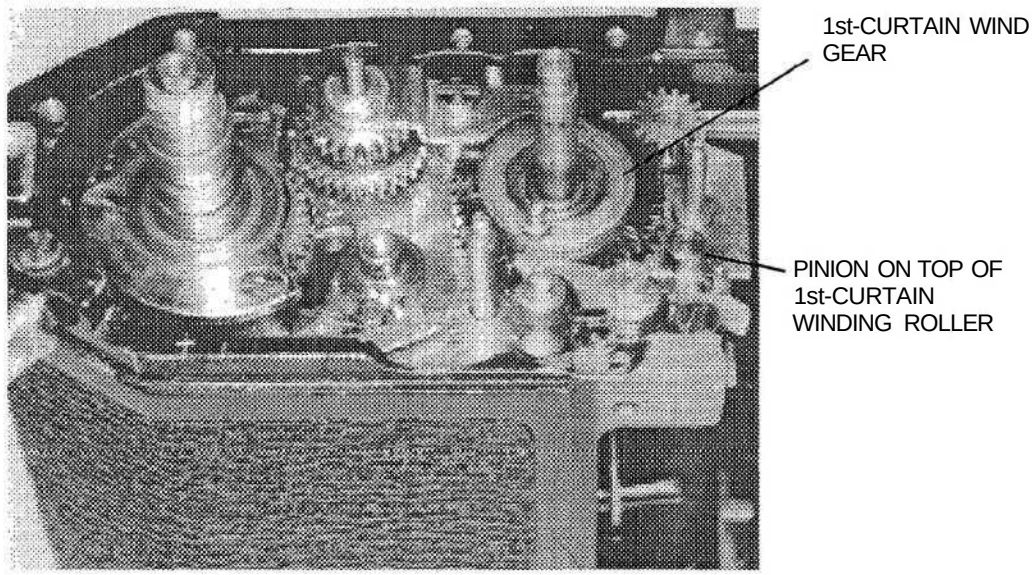


FIG. FP40 Adjusting the timing of the 1st curtain.