TESTING SHUTTER SPEEDS

CAMERA TECHNICIAN COURSE

Emp

TESTING SHUTTER SPEEDS

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TESTING SHUTTER SPEEDS

WHY SHUTTER SPEEDS VARY

Depending on the type of shutter, there are many variations in the speeds which a shutter delivers. You have learned that shutter speeds can be controlled in several ways: type and amount of retard, tension of springs, and size of openings in shutter discs. The methods aid the designer, in his original calculations, to provide the desirable exposures. But, once the shutter is designed and produced, the shutter may not deliver correct speeds indefinitely.

Again you may draw a comparison between the shutter and the watch. Probably the greatest cause of shutter speed variation is dirt. Unlike a watch, a shutter does not operate constantly so that even over a considerable length of time wear may be a negligible factor in shutter speed errors. Once it is properly adjusted, and until it gets dirty or gummy, it is very likely that the shutter will remain as accurate as it was when it was first built.

Frequently, because of the many adjustments which will cause shutter speeds to vary, the adjustments are made by inexperienced hands and the shutter is thereafter inaccurate.

So the first question you should ask when a shutter is not delivering accurate speeds concerns cleanliness. NEVER make any adjustment affecting the shutter speeds unless it is absolutely necessary. Some Shutters, such as the Compur and the Argus C Models, require thet the shutter be thrown out of adjustment during disassembly. The proper adjustments to return the shutter to accuracy must be made during reassembly and, unless experience enables easy resetting of the adjustments, or a system is used to do it (such as was described for the reassembly of the Argus C-3), it is necessary to measure those shutter speeds to prove the accuracy of any adjustments. In any case, the checking of shutter speeds is good practice. For that reason this text will present several different methods of testing shutter speeds so that you will be able to currect and adjust shutters properly.

Some cumbersome and time-consuming techniques will be discussed because you should be able to describe such techniques to your clients. There may even be occasions when you'll have to use such a technique simply because no other system is available. In addition you'll learn of instrument test methods that make inspection of shutters a routine process that involves only a few seconds so that you can verify the condition of equipment when it enters and leaves your shop.

Proper testing of shutters in your shop serves a multiple purpose. A good test procedure can be demonstrated to your customer in order that he might better know the system you use and through it do a better photographic job. A good test procedure reveals facts about a shutter's operation that will eliminate many "kick-backs" or jobs that must be redone.

Naturally, a good test procedure eliminates setting speed adjustments by guess so that you can do a good job in a minimum amount of time. Today's skilled camera craftsman never makes such a "guessment" - make your adjustments on the basis of knowledge.

"EFFICIENCY" IN A SHUTTER

In any mechanical device some function can be described as either "efficient" or "inefficient." In a gasoline engine, for example, there is a certain amount of power that a quantity of fuel is capable of delivering. No engine, however, can remove all the power from the fuel, and the ratio of power delivered by the engine to the power that was available in the fuel is termed the efficiency of that engine. Such is the case with any machine which requires some kind of power or fuel to operate it. Certainly electric motors deliver only a part of the power that they use in the form of electricity. Electrical energy is changed into other electrical energy with a transformer in one of the most efficient transfers of power that is known. The use of the atom to obtain power is a modern approach to greater efficiency, when the power that is inherent in the atom can be used to do other work.

You've even thought of the efficiency of a human being, saying that "so and so is very efficient" or "inefficient." By this is usually meant that the person conserves or wastes his motions. If a housewife, for example, completes her work with a minimum amount of running about the house to pick up her tools and materials, she is called "efficient." Time study in modern industrial plants is an aid toward improving the efficiency of workers, of cutting down their "lost motion."

When efficiency is referred to in a shutter, the reference is not usually to lost power, for the power that is placed into the shutter is muscle power in setting the shutter to put tension on one or several springs. Although some of the power which is thus loaded into the shutter is lost because of friction or inefficient design of the working parts, the amount of power lost is relatively unimportant. Lost motion in a shutter is the basic premise upon which its efficiency is based.

The purpose of the shutter, after all, is to permit a predetermined amount of light to pass through the lens and expose the film. The amount of light is the important factor. You have already seen that whether a lens is of six inch or twenty inch focal length, if it is marked, say, f-3.5, a definite amount of light from the lens will reach the film to expose it. The image will be of the same intensity or brightness when any lens is set at f-3.5, regardless of the focal length. This is the result of standardization with the "f" number system.

There would be, on the other hand, certain cases where the shutters used with these two lenses would not give exactly the same exposure. Why this is so you'll learn soon.

If an exposure of 1/100 second is intended, then an immediate assumption must be made. It simply means that light will pass through the lens for 1/100 second, a very definite period of time. It makes no difference again whether the lens is 20 or 6 inches from the film. The light passing through the shutter passes through for a definite length of time.

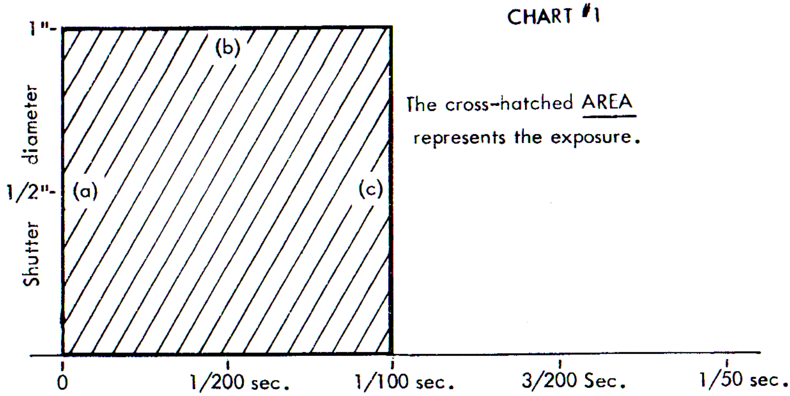
This seems obvious - you need simply open the shutter - keep it open for 1/100 second, and then close it again.

But, is such a thing possible? In order to get such an exposure it would be necessary that the shutter leaves open completely to the full diameter of the lens without taking any time in doing it. It would then be necessary to stop the leaves, hold them in the open position for the total period of the exposure, and finally it would be required that the leaves close again completely, without using any time for that action.

Immediately a fallacy becomes obvious. Nothing can move without taking time to do it. Some period of time is needed for the shutter blades to move from the closed position to the open position, and similarly, some time is required when the leaves move from the open to the closed position. This is the lost motion mentioned earlier. If a shutter could be designed so that its leaves required absolutely no time when moving from shut to open or open to shut, the shutter could be rated as 100% efficient.

Now here is where all shutters differ. In order for a less efficient shutter to pass the amount of light which a 100% efficient shutter would pass in 1/100 of a second, it has to be open for a longer period of time. Thus, a typical shutter set at 1/100 second may actually use, from the time it starts to open until the time it completely closes, 1/50 second to deliver an accurate exposure.

CHART #1



The cross-hatched AREA represents the exposure.

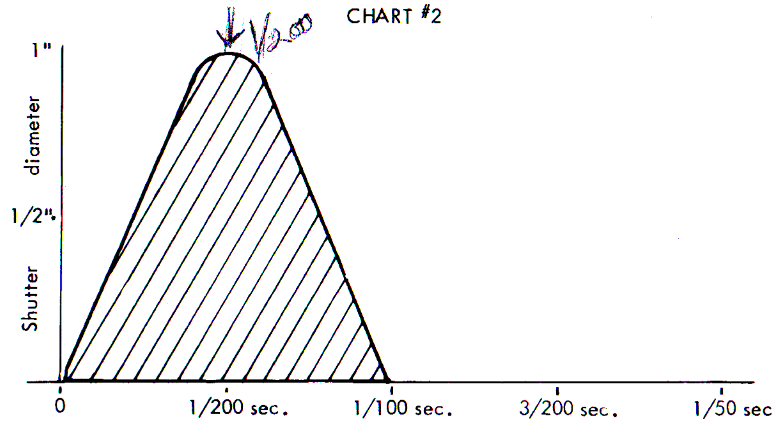
This graph illustrates the movement of the shutter blades of a one inch diameter shutter giving a perfect exposure of 1/100 sec.

(a) Shutter blades open to full diameter instantaneously.
(b) Shutter blades remain open for 1/100 sec.
(c) Shutter blades close instantaneously.

TESTING SHUTTER SPEEDS

Now is the time to clearly understand the difference between efficiency and accuracy. Our imaginary 100% efficient shutter would give an exposure of 1/100 second by opening instantaneously, remaining open for 1/100 second and then closing instantaneously. Only 1/100 second would elapse during the entire action. An inefficient shutter whose total operating time is only 1/100 second would yield an exposure of much less than 1/100 second and would, therefore, not be accurate. An inefficient shutter must remain open for a longer period of time in order to deliver enough light for an accurate exposure.

CHART #2



This graph illustrates the blade movement of an average shutter opening and closing within 1/100 sec. The cross-hatched area is about half of that in Chart #1, indicating an exposure of approximately 1/200 sec.

Remember - there are many instances where this peculiarity has no bearing on the quality of the pictures that result. Accuracy is important to yield well-exposed negatives. But efficiency only becomes important when pictures of moving objects are made, where the time that the shutter remains open actually affects the photographic quality. Your first concern will rest on between-the-lens, behind-the-lens, or front-of-lens shutters operating on the multiple leaf principle, but you will discover that focal plane shutters have inherently greater efficiency, because of their design. Why this is so you'll learn later. But this greater efficiency will explain one advantage of photographing action with a focal plane shutter as compared with photographing the same action using a between-the-lens shutter.

There is also another important relationship between efficiency and accuracy. Any inefficient shutter gives differing exposures according to the aperture at which its diaphragm is set. While an inefficient shutter may be adjusted so that it is accurate at a particular f/ stop, the true exposure will change as soon as the diameter of the f/ stop is changed. While this idea may appear confusing now, you'll soon learn why it is true.

Different between-the-lens shutters vary considerably in efficiency.

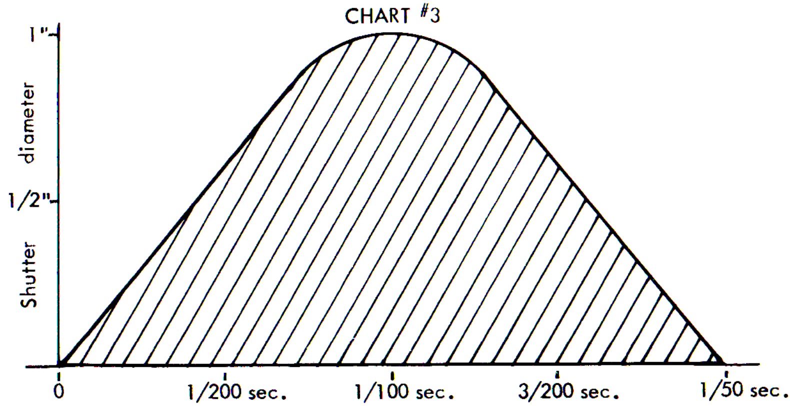
TIME REQUIRED FOR SHUTTER TO OPEN AND CLOSE

The variation in efficiency among between-the-lens shutters is due primarily to the varying amounts of time that different shutters need to open and close. It becomes clear when you compare the action of the 100% efficient shutter with any other shutter, that the faster a shutter opens and/or closes, the nearer that shutter comes to being ideal in efficiency.

In general, in any one shutter, the time the blades take to open is the same at all shutter speeds. This is true because the shutter opens similarly, regardless of speed setting, the variations in exposure usually being determined by such things as amount of retard. Some shutters do change exposure by altering the tensions on main springs, and many employ a high speed spring for top speeds. Changing spring tensions affects not only the total amount of time required for the shutter to operate, but also the time required for the leaves to open or close.

When the difference between two exposures is obtained only by means of spring tension or even an auxiliary spring, the pattern of shutter operation will remain the same for both speeds. In other words, at either setting the shutter will be opening and closing during a similar portion of the cycle of operation without any extended period being allotted to a wide open position. Thus, if a shutter opens and closes in 1/50 of a second without remaining completely open for an extended period of time, the true exposure can be computed as 1/100 second. Half of the time, the shutter is half or more than half open. When the exposure is shortened by using more spring tension, the total length of time for the shutter action may be only 1/100 second. During that period the leaves are again in constant motion, yielding an exposure of 1/200 second. The graphs in charts #2 and #3 illustrate the action of the leaves at these two speeds respectively and show how a definite exposure time can be computed despite the fact the leaves are in constant motion.

CHART #3



This graph illustrates the blade movement of a shutter operating more slowly than Chart #2 describes. The actual exposure delivered in this case is 1/100 sec., even though the total time involved is 1/50 sec.

The efficiency of the shutter in both instances (1/100 and 1/200 second) is 50%, since the shutter is in motion for twice the duration of the actual exposure.

TESTING SHUTTER SPEEDS

In each case, when determining the efficiency of a shutter, there is a comparison of the action of the shutter in question with one of 100% efficient design.

In discussing shutter speeds and other short time intervals it is desirable to use a small unit of time. A convenient time unit is 1/1000 second. This time unit is called a millisecond. 1/50 second is equal to 20 milliseconds, and 1/200 second is 5 milliseconds.

The shutter shown in chart #3 required 1/100 second to open, and an additional 1/100 second to close, or 10 milliseconds to open and 10 milliseconds to close. An average medium sized shutter will open or close in approximately 5 milliseconds, at an exposure setting of 1/100 second.

Thus, when checking a typical shutter, operating at 1/100 second setting, it might be found that the shutter opens in 5 milliseconds, remains open for 5 more milliseconds, and closes during an additional 5 milliseconds.

A calculation can easily be made from these facts to determine actual exposure: The time needed for opening and closing is 10 milliseconds. Since the shutter is, on the average, only half open during this time, the exposure acquired during the opening and closing movement of the shutter is half of 10; 5 milliseconds or 1/200 second. In addition to the opening and closing phases, the shutter remains open for 5 milliseconds (or 1/200 second) yielding a total exposure of 1/100 second even though the shutter is in action for 15 milliseconds or about 1/75 second.

When the shutter speed is stepped up to 1/200 second by means of an auxiliary spring, measurement might reveal that the time required for the shutter to open and close would be cut down to a total of 7.5 milliseconds. If, then, the blades remained wide open for 2-1/2 milliseconds, the exposure given by the shutter at that setting would be an accurate 1/200 second. The formula for calculating true exposure:

$$E_t = \frac{To + Tc}{2} + Two$$

Where

E_t = True exposure

To = Opening Time

Tc = Closing Time

Two = Time wide open

ms = (milliseconds)

$$E_t = \frac{5\,ms}{2} + 2\frac{1}{2}\ ms$$

$$E_t = 2\text{-}1/2\ ms + 2\text{-}1/2\ ms$$

$$E_t = 5 \text{ milliseconds}$$

$$E_t = 1/200 \text{ second}$$

The imaginary shutters discussed earlier opened and closed without actually having the leaves halted at any time, the blades being in motion during the entire period of the exposure. Such action is impossible since the direction of movement of the shutter blades must reverse when they reach the wide open position. Shutter blades have a certain amount of inertia.

That is, they resist any change in their rate of movement. When they are closed, they tend to remain closed, and they start to open slowly, gaining momentum as they go. As they reverse direction after reaching the wide open position the movement is slowed somewhat, with the net result that the blades remain wide open for a small fraction of time no matter how fast the springs tend to move them.

Inertia holds the blades open briefly even though no retard action is provided to hold them open.

Various developments have speeded up the motion of shutter blades, and modern shutters use short stubby blades which offer little resistance to change in movement.

Around the turn of the century a design was developed by Wollensak to eliminate the change in direction of blade motion at the wide open position. This was done by shaping the blades with symetrical ends. When such a shutter leaf turns through 180°, one end opens and the other end closes the aperture. The design provided much higher shutter speeds than existed in other between-the-lens shutters and this 1910 vintage shutter was capable of exposures as short as 1/300 second. A modern shutter, the Kodak Synchro 800, with the same principle but a more refined mechanical action, has a top speed calibrated as 1/800 second. At the 1/800 second setting, the blades are in action for about 3/1000 second, from full closed through wide open to full closed again.

Moving the blades this way, of course, does not increase efficiency, but rather decreases it, because of the peculiar action of the blades. It does make high shutter speeds possible, however.

Two new approaches to high-speed shutter design have resulted in shutters capable of delivering speeds up to 1/2000 second.

The first design provides higher speeds just by overcoming the initial shutter blade inertia. By allowing the blades to overlap in their closed position, considerably more than is necessary to block out light, normal operation of the shutter permits the blades to reach virtually maximum speed before they have moved far enough to separate and admit the first ray of light. This technique is used to some degree in all modern shutters. One Japanese shutter has extended the principle to the point where the blade overlap is changed as the shutter speed is increased. Indeed, the overlap is so great that at 1/1000 second, the blades do not open enough to clear the full aperture and only an exposure at a reduced aperture is possible. At 1/2000 second, the maximum aperture uncovered is about half the full diameter.

Most high speed shutters have been small in physical size. The inertia of moving parts becomes even more difficult to overcome as the size of the shutter increases. Nevertheless, Graflex has developed a design which provides excellent high speed results in a larger shutter having an aperture greater than 1" in diameter. The Graflex shutter applies a different approach to the problem. First they recognize that the parts operating the shutter blades, having more mass than the blades themselves, contributed greatest to the inertia effect. Instead of trying to swing a double ended blade (which, by the way, requires somewhat more space internally) Graflex developed a driving mechanism which moves in one direction through the entire operating cycle. Instead of the customary blade-operating ring which moves first in one direction and then in the other to open

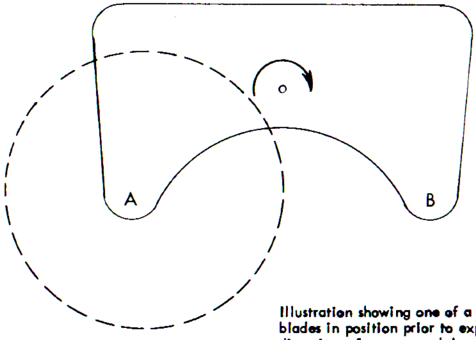


Illustration showing one of a set of double ended shutter blades in position prior to exposure. As blade rotates in direction of arrow, end A opens and then end B closes the aperture.

and close the shutter blades, the Graflex shutter uses a ring gear which turns in one direction during the shutter cycle. Each shutter blade is driven through an independent pinion meshed with the ring gear. The pinions, also rotating in one direction during the shutter cycle, turn eccentric cams to open and close the blades in an elliptical path. The relatively heavy ring gear and pinions tend to overcome the inertia of the blades so that extremely high speed can be obtained. As in the smaller shutter designs, most of the inertia is overcome before the blades actually separate. Because of the unique movement, a braking action can be applied to the shutter blades just after they reach the full closed position and before they come to a complete stop. The "braking" action minimizes jarring and makes for amazingly smooth shutter blade action, especially considering the size of the shutter and the high speed at which it operates. The Graflex 1000 shutter requires but approximately .0007 second to open or close.

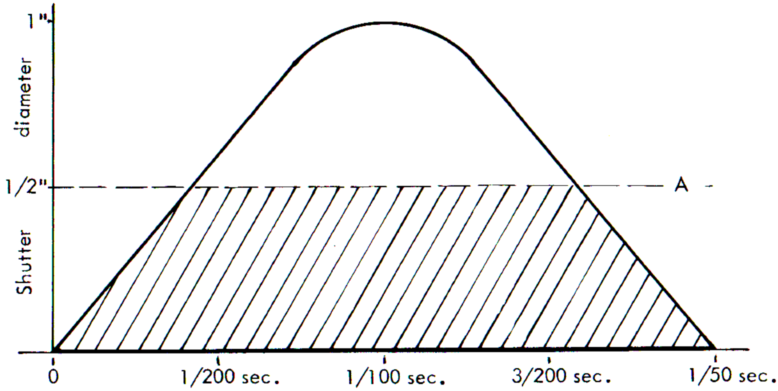
Thus, modern, well-designed shutters require a time interval ranging from about .7 to 5 milliseconds for the leaves to move from shut to open, or vise versa. Shutters which rely on spring tension exclusively to obtain a variation in shutter speed may take even longer to operate.

Some shutters introduce at least part of the retard action when the leaves are still opening and slow down the movement of the blades. The affect of this design discrepancy is to decrease the efficiency of the shutter.

EFFECT OF EFFICIENCY ON EXPOSURE

One might assume that as long as a shutter is designed to deliver an accurate speed its efficiency would not affect the photographic qualities of the shutter except for action stopping ability. This is not always true. Thus far, you have analyzed the action of a shutter opening to its full aperture, and then closing. This is how a shutter works with a wide open diaphragm. However, when the diaphragm is not wide open, the effect on the shutter's action is to increase its efficiency. Examine chart #4 which illustrates the action of the shutter leaves and notice a line parallel to the base of the diagram (line A) indicating the position of the diaphragm at some point mid-way between fully closed and fully opened. The exposure result is like holding the shutter at its wide open position for a longer period of time, while decreasing the time used during opening and closing.

CHART #4



This graph illustrates the increase in exposure given by the shutter in Chart #3 when the diaphragm is stopped down. The new exposure is approximately 1/66 sec.

A shutter that provides an accurate exposure of 1/100 second with its diaphragm wide open might deliver an actual exposure of 1/66 second when the diaphragm is set at f/8 or f/16.

The thought may at first seem illogical. But repeat the same calculations that were made before, (add up the time required to open and close, divide by 2 and add the time the shutter is wide open) and you will find that such a result is indeed true every time.

The more inefficient the shutter, the more extensive this variation in exposure due to diaphragm setting.

That's why one shutter used with two lenses of different focal lengths might give different exposures. The two lenses of different focal lengths would be different in diameter, and a shutter gains efficiency as the diameter of the lens (or the diaphragm) becomes smaller.

For this reason it is often wise to check the speed of a shutter with its diaphragm set at a mid-point, perhaps f/8 or f/11, so that an average exposure can be measured. Actual results in the camera will then not vary excessively when a photograph is made at some other diaphragm setting.

MAKING A SHUTTER TESTING DISC

Because of these facts any shutter-testing method used must incorporate a means of either calculating or compensating for the inefficiency of the shutter. It is not enough merely to measure the amount of time that it takes for the shutter to operate. Two shutters may remain open exactly the same length of time yet give quite different exposures. Indeed, one shutter at one speed setting can vary in exposure depending upon the diaphragm setting.

One of the most common methods used to test a shutter takes advantage of the fact that a photographic image is blurred if the subject moves during the time that the shutter is open. You need only plan the photograph so that the speed of the image on the film is known, and the amount of blur can be measured. A constant speed device becomes the basis of such a tester. An immediately available constant speed device is a phonograph turntable - - which might operate at 33, 45 or 78 RPM (revolutions per minute). A black disc, similar to a phonograph record, with a streak of white painted radially on the disc like the spoke of a wheel is placed on the turntable. It will move at a constant rate and can be photographed at the shutter speed to be tested. The angle through which the image blurs may be measured and the shutter speed calculated from the amount (angle) of the blur.

If, for example, the streaked disc is rotating at 45 RPM, it is making 3/4 of a revolution in one second. If an imaginary 100% efficient shutter, set at one second, is used to make a picture of that spinning disc, the resultant image would be a blur of the line occupying 3/4 of the circle or 270°. This is so since the line moves 270° during the one second that the shutter is open. It can be further calculated that 1° is equal to approximately 4 milliseconds, or 4/1000 of a second (accurately -3.7ms). The shutter, being a perfectly efficient one, would begin making its picture as soon as the exposure started, and create an image of equal tone over the entire 270° of blur. If, however, the shutter is not completely efficient, then, at the beginning and the end of the blurred radial image, there will be an area of underexposure (on the negative, a lighter gray or on the print, a darker white). By measuring the angle of the off-tone portion of the blur it is possible to get some indication of the time required for the shutter to open and close.

You can see that a turntable operating at 45 RPM is ideal for a long exposure since the turntable revolves less that 1 revolution in I second. For faster shutter speeds, a turntable revolving at a faster rate is easier to work with. The faster the turntable revolves, the wider (and easier to measure) blur you'll get at any particular exposure.

At 78 RPM, 1° is equal to 2.13 milliseconds. In 1 second the turntable will rotate about 1-1/3 revolutions.

At 1/100 second exposure, with an average shutter, the photograph will look like figure #3. For more accurate studies of high shutter speeds a disc attached to the shaft of a synchronous motor turning 3600 RPM will move over 2° in one millisecond.

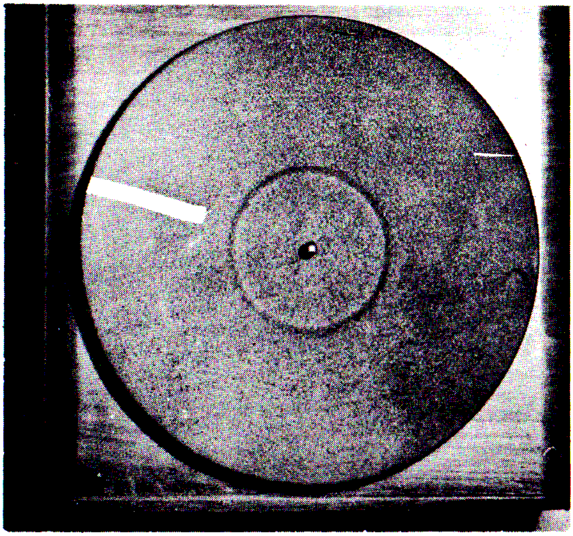
Using this principle, moderately accurate measurements of shutter speeds can be made.

COMPARING THE IMAGES WITH THE SHUTTER SPEEDS

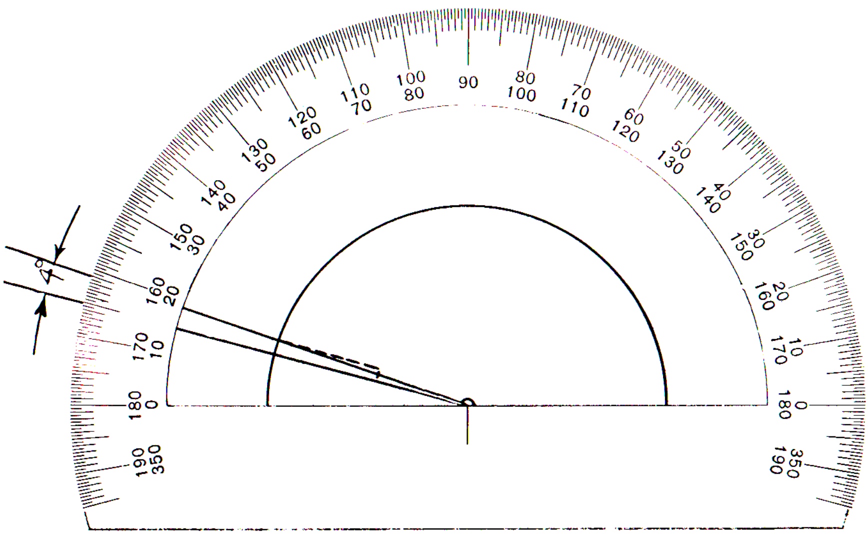
Testing a shutter using the constant speed disc system requires taking a series of photographs at the various shutter settings of appropriately rotating discs. Negatives or enlarged prints from the negatives can then be measured with a protractor to calculate both total duration of shutter action and time required for the shutter to open and close. Included in each picture should be an information card indicating the speed at which the shutter was set as well as the speed at which the test disc was turning.

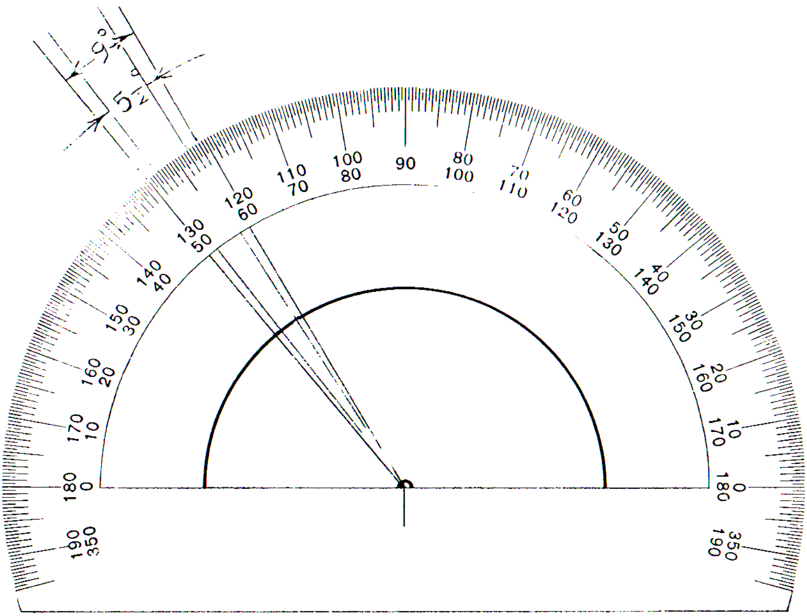
By analyzing the images and the measurements you can learn certain facts about shutter accuracy and efficiency at each setting.

The most difficult part of the photographs to interpret are the underexposed areas at the beginning and the end of the blurred segment, made



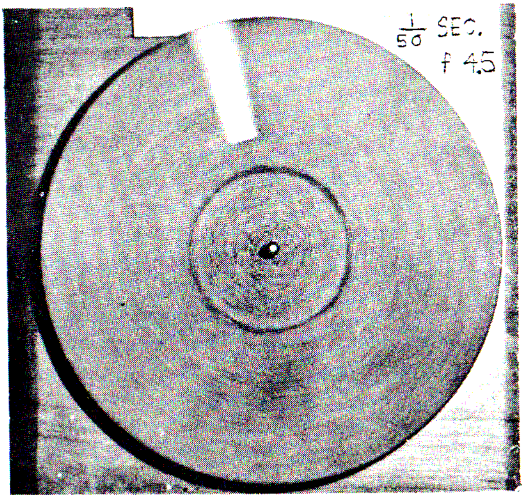
#1 Width of mark at standstill = 4°
A simplified test setup using tape as a mark on a phonograph turntable. Showing how the protractor is used to measure the angle of the mark at the edge of the turntable for best accuracy.

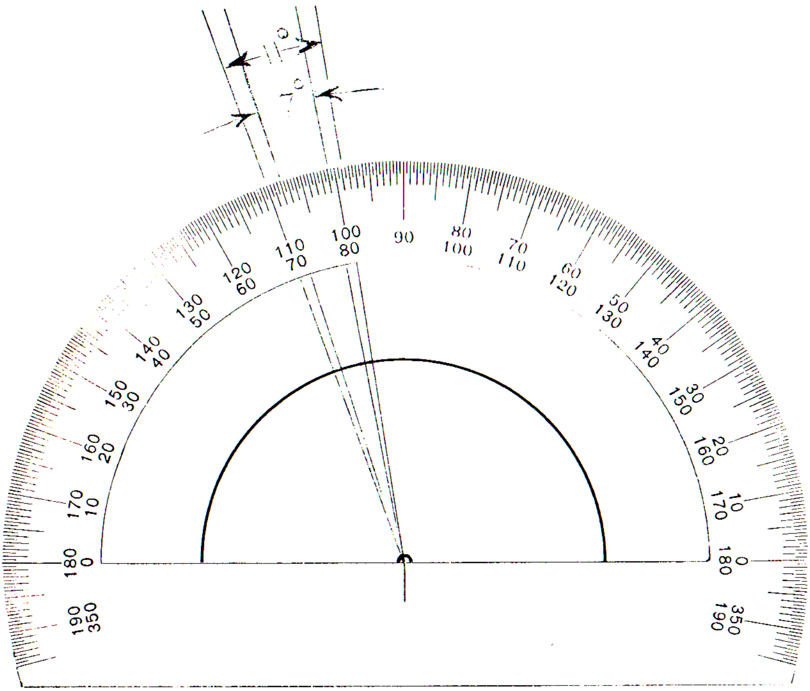




#3 Width of blur: $9^\circ - 4^\circ = 5^\circ$
$9^\circ - 5\ 1/2^\circ = 3\ 1/2^\circ$ opening and closing time.
$1\ 3/4^\circ = 1/2$ opening and closing time.
$5^\circ - 1\ 3/4^\circ = 3\ 1/4^\circ$ actual exposure.
$3\ 1/4^\circ = 7$ ms. $= 1/143$ sec. actual exposure.

TESTING SHUTTER SPEEDS





#2 The calculation for a typical shutter speed test width of blur: $11^\circ - 4^\circ = 7^\circ$ (subtracting width of mark shown in Figure #1)
Opening and closing time (subtracting fully-exposed width from total width): $11^\circ - 7^\circ = 4^\circ$
During opening and closing phases, shutter yields average of 1/2 exposure. 2° = 1/2 opening and closing time.
Actual exposure: $7^\circ - 2^\circ = 5^\circ$
5° = 10.7 ms or 1/91 sec. actual exposure.

when the shutter is opening or closing. The dividing line between the area when the shutter is still opening and when it is fully open is quite hard to distinguish. Only if the disc is rotating at a high rate of speed can you make accurate calculations to determine opening or closing time.

By interpretation of negatives made in a disc operating at about 45 RPM, you can make average calculations which will give an indication of the effective exposure speed without a great error. By combining the facts gathered from the image, with the knowledge you have about "normal" time for a shutter to open and close, you may fill in a shutter speed table with an error of perhaps 10%. Most shutters will open or close in from 3 to 6 milliseconds, depending on the shutter size. If the shutter is not operating smoothly there will be other indications besides the shutter speed test which will help evaluate the test images more accurately. For example, a shutter may give indications of being dirty, and sound inaccurate or erratic. In such instances you will probably discover proof in the photographs that the shutter is taking longer than normal to open and close.

In order to be able to interpret the photographs with some accuracy, the camera must be set up so that it is squarely aligned with the turntable and with the lens on the axis of the turntable. Otherwise, some perspective distortion will be introduced so that a protractor measurement can't be made. There have been some gadgets manufactured to make such tests as this simpler. For example, a large protractor printed on card stock and having a central hole large enough to accept the turntable can be placed right on the turntable base. Then the amount of blur can be read directly from the photograph without extensive additional calculations. Another advantage of this technique is that, providing the oversized protractor and the turntable surface are carefully aligned, the precision of the camera set-up is not so important. In other words, even though the turntable might be photographed at a slight angle the blur can still be read, providing no parallax error is introduced.

There have been testing discs manufactured or suggested with a series of printed wedges, like a stroboscope disc. When there is more than one line on the disc, you become even more limited in the number of shutter speeds that you can test. Using the 78 RPM turntable, as you saw, it becomes somewhat difficult to check a shutter speed as long as one second. In a tenth of a second, a 78 RPM disc will turn about 40 degrees. Were there more than eight stripes on the disc, such a photograph might become a hopeless jumble of blurred marks, quite difficult to interpret.

ANOTHER SHUTTER SPEED TESTING SYSTEM

Any moving object whose image speed can be measured or calculated makes a good shutter test subject. One which is generally available, and accurate, is the "scanning beam" on a television picture tube. The picture on the face of the tube, as you may know, is formed of a series of lines, "scanned" by an electron beam, which literally leaps across the screen at a rate of 525 lines in 1/30 second! Actually, the beam "covers" the tube twice, in each 1/30 second, scanning every other line in 1/60 second, and then going back to fill in the remaining lines in another 1/60 second. The action is so rapid that your eye cannot follow what is happening but a camera can! If a photograph is made of the screen at an exposure of 1/60 second or less, it will show only those lines which were scanned during the time that the shutter was open.

So, if there is a television set available, you have a handy shutter speed tester. You need only make a picture of the tube, using the speed setting which you wish to test. Then just count the lines revealed in the photograph and an easy calculation will give the total time that the shutter remained open at speeds of 1/60 second or faster.

The number of "frames" per second (one frame is one complete scanning of the tube) depends on the type of current going into the TV set. 60 cycle AC will give the results described above - other cycles per second will change the results. In any case the following formula can be used to determine the shutter speed:

$$\text{Exposure} = \frac{\text{Number of lines on the test photograph}}{\text{Frames per second (times) Lines per frame}}$$

or with 60 cycle AC:

Exposure = .0000635 times the number of lines on the test photo

It takes .0000635 second for the moving electron beam to scan one line! One millisecond is equal to approximately 15-3/4 lines!

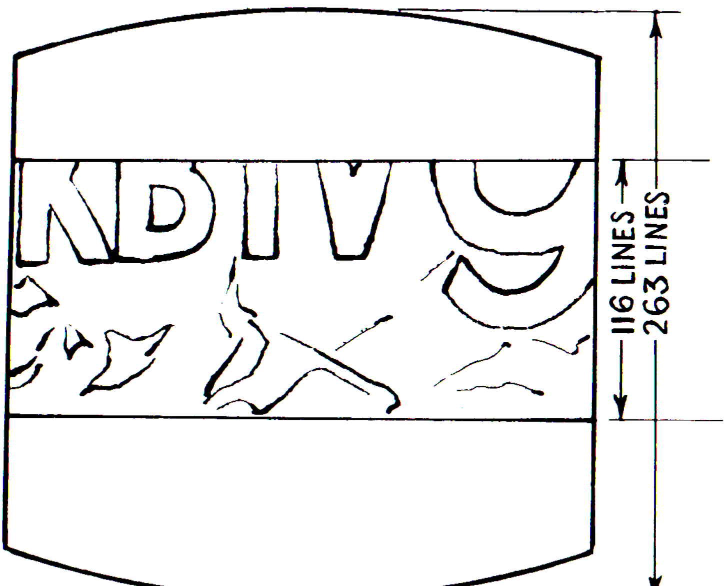
The actual mechanics of the test are equally simple. A test pattern on the TV screen makes a fine subject since it is constant, bright, and evenly illuminated. Set the brightness control as high as it will go since you will need as much light as possible to make the exposure. For similar reasons the camera should be set at its maximum aperture, and a fast film, over-developed should be used for maximum contrast. Of course the camera should be set up as close to the screen as possible (and still cover the whole tube face) and focused carefully to get a picture which will be easy to interpret.

The test, as are others of the "moving subject" type, is difficult to interpret as far as shutter efficiency is concerned. Underexposure of the lines while the blades are opening or closing is apparent, as in the pictures, but accurate measurement of those parts of the operating cycle is next to impossible. Estimations, based on your knowledge of the "normal" opening or closing times, will help in evaluating results.

Interpretation of opening and closing time is further hampered because of the "persistence" of the scanned lines on the face of the screen. As you probably know, the screen glows because an electron beam excites a phosphorescent material on the inside surface of the glass. For a short time after the beam scans a line, the screen continues to glow. Your camera is just as capable of photographing this "afterglow" as when the electron beam is actually striking the surface.

Provided the vertical size of the TV picture is adjusted so that it is the same as the actual glass area, you can eliminate the tedius counting of individual lines. Since one scanning of the screen takes 1/60 second, you can actually measure the exposed area and estimate the proportion of 1/60 that is the effective exposure of the shutter.

For example, suppose that in your print the TV screen measures just 2" high. If, then, the image lines are visible over a 1" height, the true



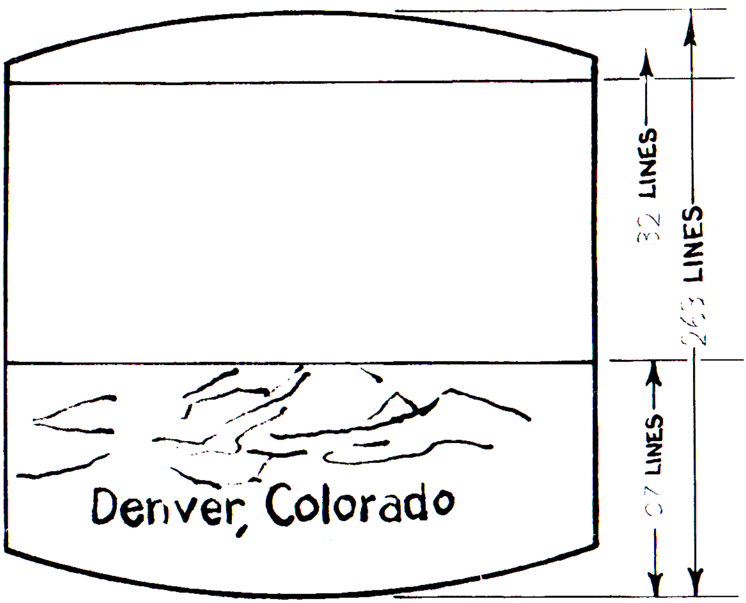
A typical TV test using a between-the-lens shutter.

Test with #3 Rapax Shutter set at $\frac{1}{200}$ sec.

Total time: 116 lines X .0000635 sec./line

Exposure = .0075 secs. = 7.5 ms. = $\frac{1}{133}$ sec.

correction for inefficiency brings exposure to 1/200 sec.



Because the shutter may start operating at any time, some of the scanned lines may appear at the top and some at bottom of TV screen.

test with #3 Rapax Shutter set at $\frac{1}{100}$ sec.

Total time = 139 lines X .0000635 secs./line

Exposure = .009 secs. = 9 ms. - $\frac{1}{111}$ sec.

correction for inefficiency brings exposure to 1/133 sec.

exposure in this particular test would be one-half of 1/60 second or 1/120 second. Here is the formula that you can use:

$$\frac{\text{Actual size of screen}}{\text{Actual size of visable scanning}} = \frac{1/60 \text{ second}}{\text{total exposure}}$$

$$\text{Or: Total exposure time} = \frac{\text{Scanned Area}}{60 \times \text{size of screen}}$$

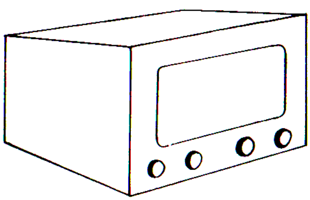
As an example, using the illustration made with a number 3 Rapax shutter set at 1/200 second:

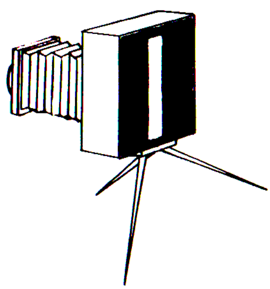
$$\text{Total exposure} = \frac{1\text{-}3/8'' \text{ (or } 1.375'')}{60 \times 3\text{-}1/8'' \text{ (or } 3.125'')}$$

Making the calculation shows that the total exposure equals .00734 seconds, closely equivalent to the test method using actual lines that are visibly scanned.

As you can see, either technique introduces certain errors but the final result is nonetheless a good indication of the action of the shutter under test.

Focal-plane shutters may also be checked using the television screen. The camera must be positioned so that the slit is perpendicular to the lines on the screen, and the results will be as shown on p. 23. Measurements on the film or a contact print (so that actual distances are considered) will reveal how far the curtain moves within 1/60 second. The following formula will result in the speed of the curtain:





How a focal-plane camera is set up for a "TV" exposure test.

Note vertical position of focal plane aperture

Set camera close for large image

Speed of curtain (in inches/second) = distance "X" (in inches) times 60

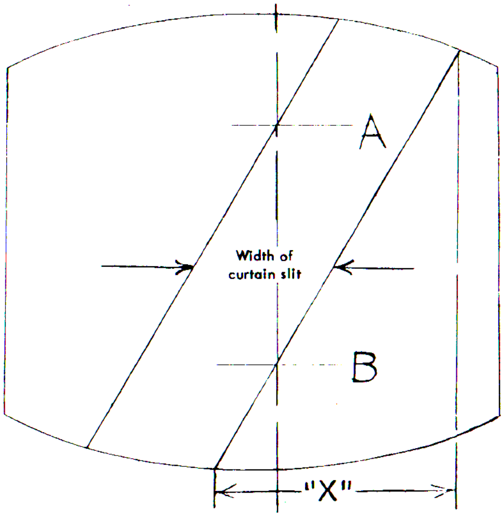
Then:

$$\text{Exposure(seconds)} = \frac{\text{Width of curtain slit (inches)}}{\text{Speed of curtain (inches/second)}}$$

The curtain slit width of some shutters can be taken directly from the shutter. The width may also be measured directly from the negative or contact print, of course.

A second method of calculation is:

The number of lines between "A" and "B" times .0000635. This distance can also be used as in a between-the-lens shutter test in the calculation described on page 19.



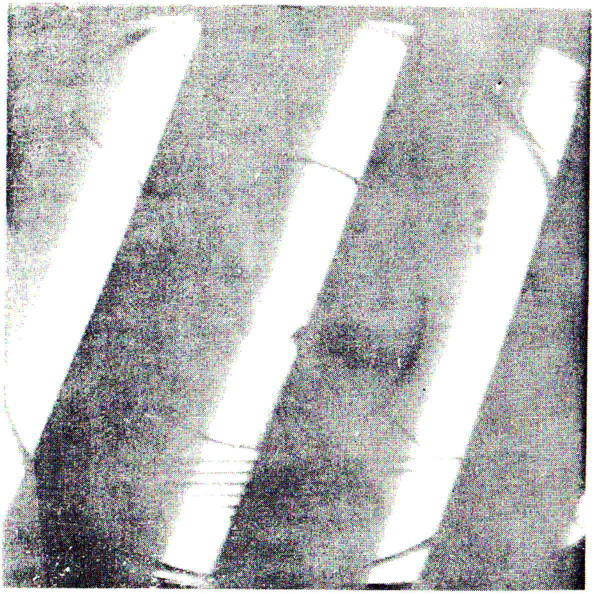
Some measurements used in a Focal-plane Shutter test.
The Shutter moves "x" inches in 1/60 second.

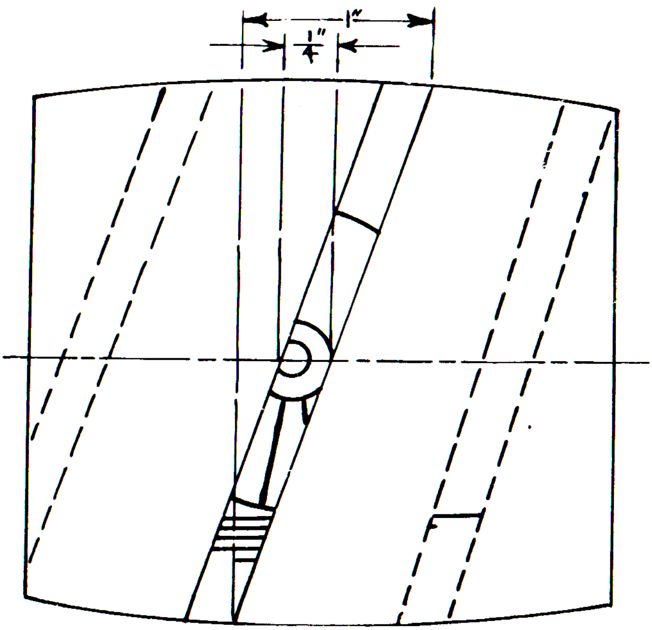
TV-photo tests of focal-plane shutters reveal a number of interesting facts. For example, in the illustrations here, you'll notice a series of exposed stripes across the TV screen. This simply indicates that the curtain requires more than 1/60 second to completely cross the film area. Each stripe is a successive scanning of the TV screen. For example, four stripes positioned as in the test at 1/80 second indicate that the shutter aperture required four times 1/60 or 1/16 second to cross the area represented by the TV image.

The angle of the exposed stripes may change as they progress across the screen, as may the width of the unexposed stripes. These indicate that the curtain is picking up speed as it crosses the screen. Some focal-plane shutters compensate for this change in speed with an opposite change in the width of the slit. When making such a test with a Leica camera, for example, the results will be curved stripes that actually vary in width from top to bottom.

HOW MUCH ERROR IS TOLERABLE

A shutter which operates with similar accuracy over its entire range of speeds is rare. In fact, you'll find many shutters vary as much as 50% from the calibrated shutter speeds all the way down the line. The fact that the shutter speeds are not accurate, however, need not be an indication that the shutter is beyond repair or use. If the shutter is clean and operating uniformly for every exposure there is little reason to alter the shutter speeds, regardless of whether or not they are accurate. If you give the photographer a chart listing the exact exposure that his shutter is delivering at each setting, it is possible for him to compensate for those errors

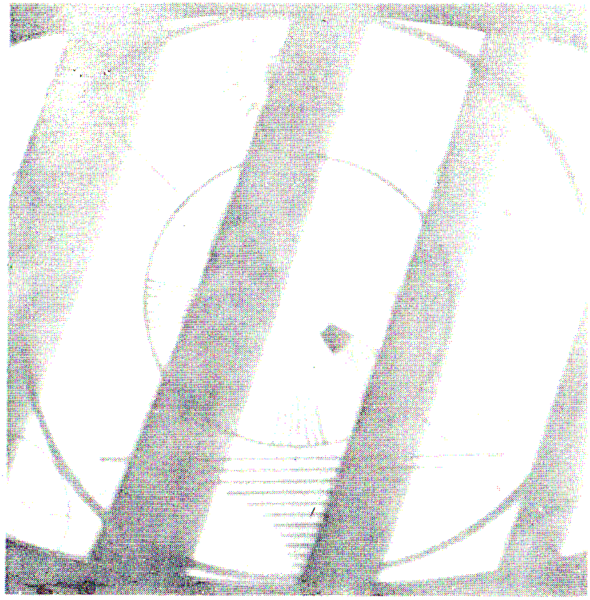


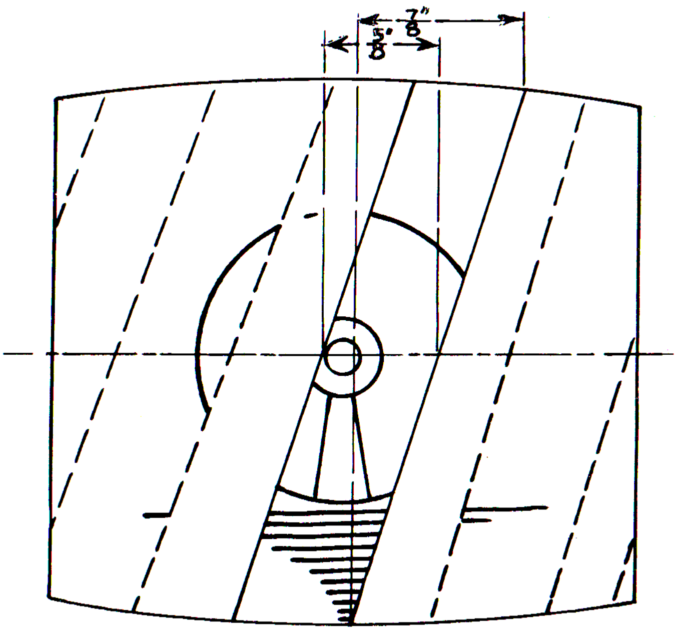


Test with 4 X 5 Graphic focal plane shutter set at $\frac{1}{240}$ sec.

speed of curtain = $\frac{1"}{1/60 \text{ sec.}}$ = 1" X 60 sec.

exposure = $\frac{.250"}{1" \times 60}$ = .0042 secs. = $\frac{1}{250}$ sec.



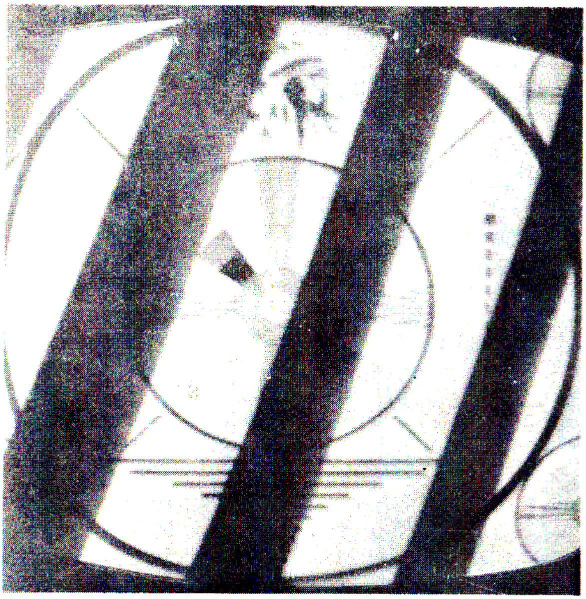


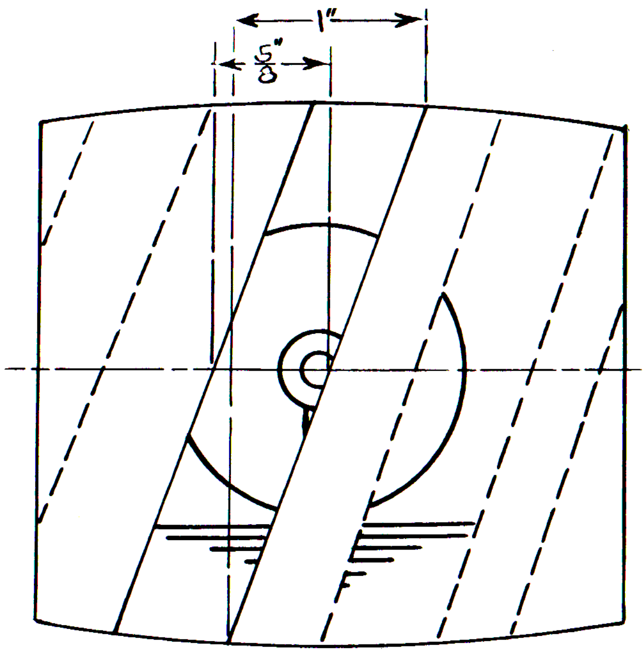
Test with 4 X 5 Graphic focal plane shutter

set at $\frac{1}{80}$ sec.

exposure = $\frac{.625"}{.875 \times 60}$ = .0119 secs. = $\frac{1}{83}$ sec.

TESTING SHUTTER SPEEDS





Test with 4 X 5 Graphic focal plane shutter

set at $\frac{1}{90}$ sec.

exposure = $\frac{.625}{1'' \times 60}$ = .0105 secs. = $\frac{1}{95}$ sec.

and his pictures will not suffer from the loss of accuracy. Especially when a photographer owns but one or a few cameras, he knows the speeds that his equipment is delivering and he can make pictures with precise exposures.

NATIONAL CAMERA ServiShop

SHUTTER SPEED RECORD CHART

Customer's Name JOHN DOE Job Number 00001

Address 100 MAIN ST. Date JAN 1, 1955

Camera Voight Brilliant Shutter Compur 381645c Lens Voigtar 1:4.5 F=7.5 cm

Aperture Setting f/4.5 Remarks High Speeds slow – relubrication may help

Shutter Speed Setting	1	1/2	1/5	1/10	1/25	1/50	1/100	1/300	
Actual Exposure	1.2	1/2	1/5	1/9	1/23	1/45	1/90	1/150	

 Form # 55815

A Typical Shutter-Speed Chart

There are some cases, however, where shutter error is hazardous. For example, if a camera is being used by several people, they may not all be aware of the exact exposures that the shutter is making, and it is well that the shutter be corrected so that it is acceptably accurate. Similarly, if a photographer owns many cameras, he is inviting unnecessary mistakes by attempting to compensate for the errors in the various shutters, and it would be wise for him to have all, or most of his cameras precisely adjusted.

Modern shutters, using LVS Systems or similar exposure computation techniques must similarly be accurate from speed to speed and aperture to aperture. Otherwise, errors that creep in could destroy the system completely.

It is obvious then that if the photographer knows that his shutter is giving a 1/100 second exposure when it is set at 1/200 second it will make no appreciable difference. However, there are certain standards of accuracy set up by the American Standards Association, as well as by other agencies which are concerned with such facts.

When a shutter is set for long exposures it is possible to obtain better accuracy than when it is operating at the fast shutter speeds. For this reason there are generally two sets of standards set up. For shutter speeds of longer duration than 1/100 second, 20% plus or minus of the calibrated shutter speed is usually permissable. For example, at an exposure setting of 1 second a shutter may deliver an exposure of from .8 second to 1.2 second, and be considered at like-new accuracy. For shutter speeds of 1/100 second or shorter duration, about 30% error is tolerable.

The United States Government accepts slightly larger errors in shutters which are government property.

Both ASA and US standard tolerances have something in common: each specifies that a shutter be tested at its maximum aperture. This apparently innocuous feature can have important consequences. Here is why:

At long exposures, most modern shutters are quite efficient. Since a shutter takes about the same amount of time to open and close regardless of the shutter speed at which it is set, the opening and closing phases of a shutter's operation are small relative to the total exposure at speeds of, say, 1/10 second or longer. In other words, if a shutter is opening and closing during 3% or 4% of its operating time (3 or 4 milliseconds during an exposure of 100 milliseconds) the shutter is quite efficient. The shutter operation is much like the theoretically 100% efficient shutter about which you have learned. But what happens at shorter exposures, when more and more of the total operating time of the shutter is devoted to simply getting the blades open and closed? Shutter efficiency changes. Then, as the diaphragm is stopped down, less of the total operating time is required to get the blades open to that smaller aperture. Thus, at intermediate speeds and certainly at high speeds, the shutter becomes more efficient as the aperture's diameter is decreased. This increase in efficiency, as you have seen, actually changes the exposure. Now let's see what effect this has on the standards adopted by ASA and various US services. In a typical shutter operating at 1/200 second, the shutter might be tested at maximum aperture and found to be giving an exposure of 25% more than 1/200 second. Under the standards, such an error would be tolerable, and would pass inspection. However, this shutter is only 65% efficient at the 1/200 top speed. As soon as the diaphragm is changed just one stop from maximum aperture, the exposure will actually exceed the 30% tolerance. With such a shutter, you would probably find that upon stopping down the lens to f/8 or f/11, it would no longer be delivering an exposure of 1/200 but rather 1/100 second. In fact, with such a shutter, operating at f/22 or f/32, it might be possible that the true exposure delivered would be in the neighborhood of 1/75 second. Remember that this is a shutter which meets specifications and tolerances and is supposed to be operating at an effective exposure of 1/200 second!

Whereas an error of 30%, even in exposing color film, is not likely to be detrimental or even apparent, an error of 125% would be excessive even in exposing a black and white negative.

The photographer who makes color exposures professionally often makes careful tests at the same aperture and shutter settings he intends using. Then he can be sure that all of the variables of his shutter, as well as other equipment, are properly compensated. When you provide this photographer with a shutter speed chart, it is wise to show true exposures at different apertures. Armed with this kind of information, a competent photographer can do a much better job.

You can also provide a calibration chart which shows average exposures. For most shutters, you can show the effective exposure, let's say at 1/200 second, which, though varying as the aperture is changed, will not be inaccurate enough to cause significant trouble, even in color film. In the hypothetical shutter just described, for example, you might show the photographer that his true exposure is actually 1/100 second when the shutter is set at 1/200 second. With wide open aperture, the shutter would deliver perhaps 25% over-exposure and stopped all the way down, perhaps 25% under-exposure. But the nominal effective exposure of 1/100 second would not be far wrong, regardless of the aperture at which the lens is set. The photographer could predict the results with that shutter whenever he plans an exposure with a "1/200" second setting.

Error in a shutter, then, is tolerable or not, depending upon the operator of the camera and the standards under which he works.

METHODS OF ALTERING SHUTTER SPEEDS

If you are to adjust shutter speeds competently, you must be familiar with the facts which govern changes in shutter speeds. You have learned of the various types of retards which are built into shutters; you know how a group of shutter speeds is obtained in a shutter; and you have seen how different methods are combined in order to have a wide selection of shutter speeds in any one shutter. Most of the designs have been proved and are basic. They are used to vary speeds in shutters of many styles and manufacturers. You've read again and again about variations, and not of definite shutter speeds because with any one type of retard you may find up to four variations in shutter speeds. Those variations might be exposures of 1 second, 1/2 second, 1/5 second, and 1/10 second in a shutter such as the Compur, while with exactly the same type of retard in an Ilex Acme shutter, it is possible to obtain shutter speeds of 1/25, 1/50, 1/100, and 1/200 second. The variations in these cases are obtained by adjustment of the retard section, and with proper adjustment you can change the amount of retard given at any one shutter speed setting.

IMPORTANT

Remember that when you're thinking of changing a shutter speed, you must accept one fact as being of primary importance: first of all, the shutter must be clean, and in good working order.

Naturally, if the shutter is acting poorly because it is dirty, gummy or otherwise malfunctioning, adjustment will serve no purpose. In general, when a shutter's speeds are inaccurate, your first job as a camera repairman is to clean it.

The most common reason for a shutter malfunction is dirt, lack of lubrication, or improper lubrication. Proper repair consists of nothing more than disassembling the shutter completely, washing the parts with a solvent and drying them carefully, reassembling the shutter, and relubricating as the particular shutter requires.

(When mention is made of washing parts, remember that this applies only to those parts which are metallic and do not have an important surface finish which may be removed by the solvent. Certain shutters, especially older Compur and Compound shutters, have fibre diaphragm wings which are very seriously damaged if they are washed in a solvent similar to Nat-Line Shutter cleaning solution.)

Lubrication of a shutter never requires more than a light film of Nat-Line grease (not oil) to certain sliding portions of the mechanism which rub during the setting or tripping cycles. For example, grease may be required on the part of a setting lever in contact with the main lever; the part of the main lever which contacts time and bulb levers; the part of the main lever which contacts release lever, leaf lever, or retard lever. Shutter blades and retard gear train pivots are sometimes lubricated by rubbing or dusting with NatLine molybdenum disulfide.

It is worth repeating: there is never an occasion to use oil in a shutter. Nat Line grease is sometimes needed on other parts of some shutters such as the speed cam when it encounters friction. The special grease with which you are supplied is designed to stay where it is applied locally and sparingly, and remain of uniform consistency regardless of the temperature. Certain greases flow in warm weather and would inevitably reach portions of the shutter where they could cause operating trouble.

Not long ago graphite was considered a satisfactory lubricant for shutter blades and certain other parts which must remain dry though lubricated. However, graphite has certain abrasive characteristics (which tend to wear the shutter parts) that molybdenum disulfide does not possess. For that reason, NATIONAL CAMERA REPAIR SCHOOL advocates the use of nothing but molybdenum disulfide when a dry powder lubricant is indicated.

There has been a tendency to suggest the use of so-called "clean" dry lubricants in shutters. Most of these contain powdered mica. This material also has the flat crystaline structure that serves so well as a lubricant. However, its abrasive qualities are even more damaging than graphite's and so is never desirable for fine mechanisms. The common objection to either graphite or molybdenum disulfide (MoO_2) is that the powders are black and can make "dirty" smudges. However, the amount of molybdenum disulfide needed for lubrication purposes is negligable and a properly treated shutter will show no sign of its use. The lubricant is first applied sparingly, and brushed into the important areas when necessary. The MoO_2 can be worked into the parts by operating the mechanism. The excess can then be carefully blown away. This thorough removal of the excess is important.

Graphite is somewhat sticky - molybdenum disulfide is not. While it is difficult to remove all traces of excess graphite, it is usually easy to finish the job properly with MoO_2.

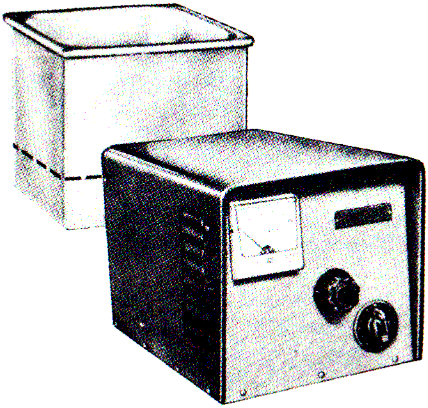
There have been a number of packaged aerosol (spray) dry lubricants marketed. These tend to make the lubricant more tenacious, so that it will stick where wanted. However, unless extreme caution is used, the tendency is to apply too thick a layer. Therefore, "spray" lubricants are not recommended, even though a spray MoO_2 lubricant would be acceptable if properly applied.

The cleaning of any device is a process that must be carried out carefully and with concern for specific results. Your goal is to remove all traces of dirt, old grease and other lubricants and similar foreign matter that might make the unit malfunction. A good cleaning solution is formulated so that agitating the part in the solution will remove much of the dirt and other accumulation fairly easily. It is best to select a solution that has been tested and found suitable for your purpose. Certain solvents serve well in cleaning camera and shutter parts. A few solvents that are commonly used for cleaning should be avoided since they are health hazards when used repeatedly. Carbon tetrachloride is one, for example, which is habitually used by many instrument and camera repairmen. Over a period of time, such a solvent's fumes can cause illness and possibly even death.

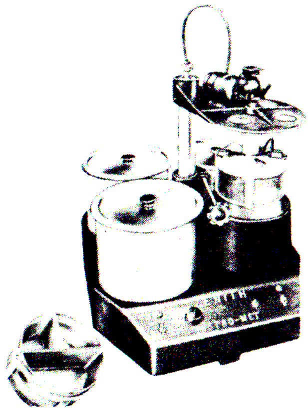
For occasional work, the parts to be cleaned are disassembled, strung on a wire and agitated in the cleaning solution until the dirt has been removed. Some stubborn dirt may actually require brushing with a solvent.

Many solvents evaporate quickly leaving a film of dissolved grease on the part just cleaned. A further rinse after cleaning is not only desirable, but necessary. Such a film may be so thin as to be invisible and yet can cause operating troubles that are difficult to find.

A good cleaning machine can usually eliminate at least part of the disassembly in a cleaning operation. A large watch-cleaning or standard instrument-cleaning machine provides such thorough agitation that a quality solvent can penetrate areas that might ordinarily have to be brushed clean even with the parts disassembled. A good ultra-sonic cleaning machine is similarly capable of removing dirt and soil from assembled parts with an obvious saving in time.



An Ultra-Sonic Cleaning Machine



A Mechanical Cleaning Machine

While the choice of solvents, even with a machine, is again dependent on the job you are trying to do, the use of certain solvents in an ultra-sonic machine is even more dangerous than normal. An ultra-sonic cleaning machine functions by passing high frequency sound waves through the solvent. These high frequency sound waves cause "cavitation" which, in effect, is the production of millions of microscopic vacuum bubbles which serve to agitate the solution and work the cleaner into the areas that are otherwise inaccessible. At the same time, this cavitation can chemically break down a solvent with possible deadly results.

At any rate, the shutter is clean, lubricated and operating properly prior to any shutter speed tests or adjustments. The variations in retard which are normally used to obtain different shutter speeds are also used to correct those shutter speeds, for it is simply amount of retard at each setting which determines how accurate that setting may be.

But there are means of altering shutter speed in addition to simply changing the amount of retard. Spring tension is, of course, an obvious factor, and certain changes in spring tensions in the shutter will naturally alter the speeds delivered by that shutter. Springs provide power to operate the shutter, and since they may become "fatigued" through use or misuse, the shutter may no longer deliver accurate speeds.

Some shutters use an adjustable pallet to obtain two sets of shutter speeds. The fact that the pallet is adjustable should immediately suggest a method of altering certain shutter speeds. The closer the engagement between the pallet and the star wheel, the more retard is provided.

The entire retard section of some shutters may be moved in order to correct or alter shutter speeds. You have found this true in the Compur shutter, as well as the Argus C-model shutters.

Since there are often several ways in which any one shutter speed may be changed, it is necessary to analyze very carefully the errors that are present in any shutter, in order to decide which method or methods will be used to correct the accuracy of the particular unit.

ANALYZING THE SHUTTER SPEEDS

In a complex, multiple-speed shutter the series of shutter speeds may be divided into groups, according to the method used to vary the exposures within each group.

The first group in a typical shutter may be that which is governed by an escapement retard gear train, and could consist of shutter speeds between one and 1/10 second, inclusive. The second group may be the speeds between 1/25 and 1/50 second, inclusive, when retard action is obtained using an inertia gear train only (without a pallet in engagement with a star wheel). One speed is possible with no retard whatsoever, perhaps 1/100 second. An additional speed may exist when a high-speed spring is incorporated to hasten the shutter action.

When you hold these facts in mind, your analysis of the errors becomes systematic. If all of the speeds are reasonably accurate, except for the slow speeds (between one and 1/10 second), you may assume that adjustment of the pallet engagement is necessary. This is true because the stroke of the retard lever is similar during the slow speeds and the intermediate speeds. The only basic difference between these two groups is the fact that the pallet is engaged for the slow speeds.

If all of the slow and intermediate speeds are similarly slow or fast, you would probably assume that the complete retard assembly is damaged or in bad adjustment. A maladjustment of the entire train may also be apparent at the next to the highest speed, if that setting is abnormally slow. The retard may be partially engaged when it should not be.

High-speed errors can be more confusing for there may be two springs acting in unison for that exposure. If the main spring is weak (through fatigue) all the speeds may be slow but correctable by altering the amount of retard at the slow speeds. Such an adjustment will not help the high speed or the next to the highest speed. Main-spring and/or high-speed spring fatigue, all other parts of the shutter being in good operating condition, is revealed in a slowing of the two highest speeds. Since the main spring usually supplies power to open and close the leaves, fatigue in this spring will decrease efficiency of the shutter.

Analyze the action of the shutter applying those ideas. Breaking down the various speeds into groups according to the method used to obtain those speed groups will aid in the rapid diagnosis of shutter speed errors. Here are the basic steps:

1. No diagnosis may be made unless the shutter is clean and properly lubricated.
2. The high speed and next slower speed are affected primarily by spring tension.
3. If the speeds in the intermediate or intermediate and slow speed groups are inaccurate, adjustment of the retard section is indicated.
4. If only the slow speeds are off, pallet engagement is probably faulty.

TESTING SHUTTER SPEEDS

If only part of the speeds in any particular group are inaccurate, or the speeds in one group vary both slow and fast, you may reasonably assume that the actual amount of retard is in error, and that the speed cam is improperly shaped.

Excessive wear of various parts of the shutter, though not common, can also cause erratic speeds in any one group. Wear of the shutter blades, main lever, and leaf lever usually results in erratic speeds toward the high speed end, along with lower shutter efficiency. Thus, excessive wear and spring fatigue go hand in hand and the symptoms are similar. A shutter which has fatigued springs may be old enough to include worn parts. You must inspect the shutter carefully to discover parts which have become worn through normal use. More common is the wear which results from inept tampering. Usually, parts which are damaged are beyond repair, and must be replaced in order to obtain accurate shutter speeds.

CAUTION IN SPEED CAM ALTERATIONS

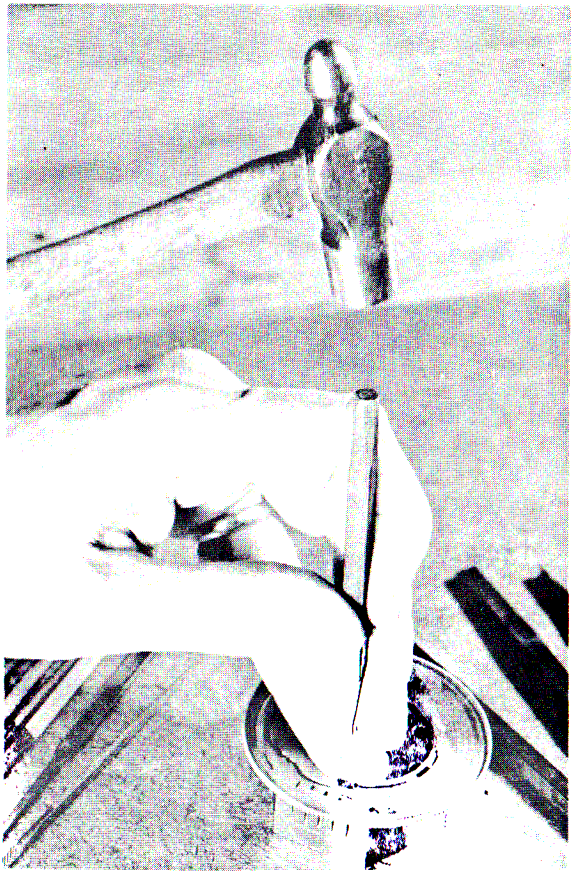
After analyzing the shutter speeds you'll see that there is only one error which warrants a change in the shape of the speed cam. This is when the shutter speeds in any one group are not uniform in accuracy. If, for example, in the one to 1/10 second range, one second is long and 1/2 second is short, with 1/5 and 1/10 second being fairly accurate, the speed cam is probably improperly shaped. But, you should always doubt such a conclusion. After all, when the shutter was manufactured, the cam was fitted and shaped to give accurate speeds at each setting. Although other parts of the shutter may change with time and handling, the speed cam has very little opportunity to vary.

Thus, when an analysis leads you to believe that the speed cam is inaccurate, it is imperative to check and recheck other portions of the shutter which might lead to erratic shutter speeds before making a final decision to change the speed cam. Even though the shutter is theoretically clean, it should be cleaned again. Though no worn parts were found, reinspect the retard pivots and bearings, the shutter blade operating parts, as well as all other parts which are subject to wear. Since the teeth on the gears in the retard gear train are small, a burred or damaged tooth on one gear can cause action such as has just been described.

When repeated examinations reveal no fault in the shutter other than an error in the speed cam's shape, then the position of the retard lever against the speed cam at any particular speed may be changed by either filing the cam very carefully to remove small amounts of material, or swaging to expand the material in the cam.

Know the speed cam and retard lever in question before any change is made - in some shutters, filing the speed cam will increase the exposure, and swaging will decrease it, while in other shutters similar operations on the speed cam will have an opposite effect. In the Acme Shutter, as an example, the two retard levers move in opposite directions, and the slow speed retard lever must be moved towards the outside of the shutter in order to decrease the amount of retard, while moving the intermediate speed lever toward the center has a similar effect.

This discussion of the alteration of the speed cam has come first, for



Swaging a speed cam to expand the metal. Lay the speed cam on a bench anvil and carefully place the swaging punch in position adjacent to the area to be expanded.
Choose an
Choose a punch of the proper shape and size to avoid changes except where desired.

emphasis, because it is the last thing you should do to alter a shutter speed. Remember:

1. The shutter speeds are obtained by variation of the amount of retard.
2. The speed cam has been factory adjusted to control the intervals between those variations.
3. The other adjustments will more than likely clear up any shutter errors that you discover.

THE PALLET ADJUSTMENTS

The only time that it is necessary to correct pallet position is when that pallet is designed to be adjustable. In a simple shutter (having only four or five speeds in all) the pallet is nonadjustable. Speeds are set as if a correction were being made on the intermediate retard of a multiple speed range shutter. The following section describes those adjustments. Where slow speeds result through engaging a pallet to the star wheel of an escapement gear train, an adjustment usually exists to limit the amount of engagement.

In the Rapax shutter, for example, an eccentric screw is used as a stop for the pallet base plate. This screw may be turned to vary the depth of engagement.

The greater the engagement between pallet and star wheel the slower all of the slow speeds will be. Altering the position of the pallet will change only the slow speeds, and if both slow and intermediate speeds are incorrect, the intermediate speeds should be corrected first, then the slow speeds brought up to accuracy via the pallet engagement.

You may now have made an important observation. When adjusting the accuracy of a shutter, always start with the fastest speeds and work down. In general, the factors which control the very highest speeds also control the slower speeds. For example, if the main spring is fatigued, the high speed may be slow. Correcting the fault will tend to speed up all the settings of the shutter. Similarly, correcting intermediate speeds (with the pallet disengaged) will change the slow speeds (with the pallet engaged). Even in a shutter like the Acme, where two separate retard trains are used for intermediate and slow speeds, the intermediate gear train activates the slow speed gear train, and adjustment of the intermediate retard lever may also alter the exposures given when the slow speed gear train is used.

In the Compur-type shutter, pallet adjustment is made by moving the entire retard section. The Compur's retard section is fastened through two elongated holes at either end of the Gear gard train. The retard lever is at one end of the gear train and the pallet control lever at the other. When the pallet control lever is pushed toward the outside of the shutter it is disengaged from the pallet. This takes place three ways:

1. Certain lobes on the speed cam keep the pallet disengaged from the star wheel except at the slow speeds.
2. A lobe on the main lever (setting ring) disengages the pallet from the star wheel when the main lever reaches the "set" position, so that the retard gear train may return to its "ready" position easily.
3. While the screws holding the retard section are loose the pallet-lever end may be moved towards the center of the shutter. This decreases pallet-wheel engagement.

The last adjustment is the one which is used to vary all of the slow speeds.

Some shutters offer no adjustment for pallet engagement except by bending the pallet lever stud (which rides on the speed cam). If such bending adjustment is normal, the stud is made of a malleable material so that it can be bent easily without breaking. If the stud does not seem to be made of such a material (as German silver or brass) it is very likely that there is a specific adjustment for changing the position of the pallet which was overlooked.

When making such a bend, remove the part to be bent from the shutter. The bend should be made a tiny amount at a time, reassembling and retesting the part after each small bend so that you won't have to bend the part back after an overadjustment. Metals like brass and nickel silver become fatigued or "work hardened" very easily when bent repeatedly, and if an over-correction is made, it is very possible that the part will break when you attempt to retrace your steps. If you must rebend a brass or German silver part, first anneal the part by heating it to about 800° to 900° F, and then quench it in water.

THE RETARD SECTION POSITION ADJUSTMENTS

When all intermediate and slow exposures are either long or short, it is likely that the retard is incorrect over that entire range and the position of either the retard lever or the entire retard section can be changed. In some shutters you can alter the position of the retard assembly to change the shutter speeds. In the Compur shutter the retard-lever end of the retard assembly may be moved to alter the amount of retard.

Although you can move the entire retard section for adjustment of some shutters, you may have to bend the retard lever stud (where it contacts the speed cam) to do the same job on others. Once again, the material and design of the retard lever stud is the best clue to whether it may be bent.

Annealing the brass or nickel silver part is highly recommended prior to any adjustment. After annealing, the material will be quite soft but rebending it for adjustment will tend to harden it again so that the adjustment will not be "lost."

Regardless of the adjustment, remember that each change should be small and tests should be frequent.

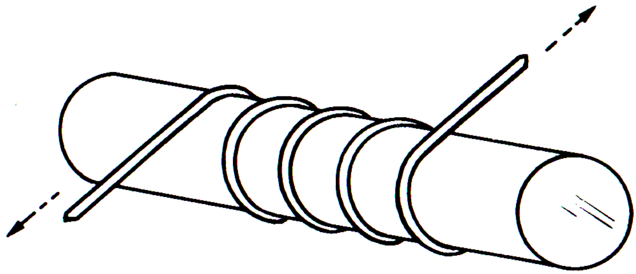
MAIN SPRING AND HIGH SPEED SPRING FATIGUE

With age, especially when the shutter has been carelessly left in the "set" position for long periods, the heavier springs in the shutter will tend to lose some of their power. There is only one proper way to correct this condition. Replace the spring. You cannot bend the spring to restore the power that was lost.

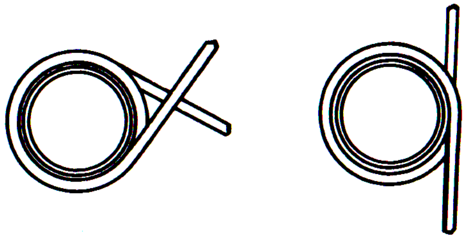
There will be times when you cannot replace the spring. Sometimes the spring can be hand made, and, if this is feasible, you should wind it using precisely the same diameter spring wire as was present in the original spring.

There is one way of increasing the tension on a torsion-type spring which tends to relieve fatigue. Do it like this: place the spring on a close fitting arbor passing through the coils, and clamp the arbor in a vise. Grasp both ends of the spring with appropriate instruments and pull on both ends simultaneously. This is an adjustment - test after each small change. When tension is exerted on the spring this way, the coils tend to reform themselves (in the case of a torsion spring) and fresh power is developed in the spring. You can't use this method, of course, with tension type springs, and in no case decrease the length of such a spring to increase its tension. A new spring must be made or purchased in every case of fatigue in a tension spring.

High speed springs are often of the torsion type. They are usually of



pulling the spring in the direction of the arrows will transform spring "A" to the "B" shape.



such heavy construction that fatigue rarely sets in, and power is difficult to restore once it does. Generally, you must replace a fatigued high-speed spring.

FRICTION AND LUBRICATION

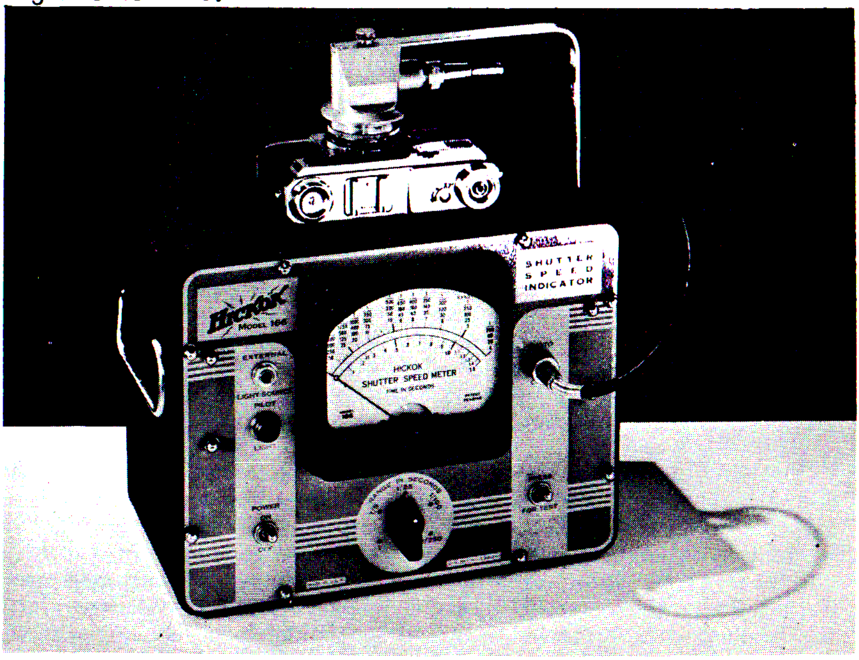
Well-designed shutters have no parts which exert a great deal of friction against each other. In a number of shutters, however, the main lever slides over the leaf lever during the setting operation, and often some sliding action takes place where the main lever touches the retard lever. Sometimes, the release lever holds the main lever in the set position using some sort of friction device, perhaps locking in a notch. Of course, the shutter blades contact each other while opening and closing. The blade ring, which controls the shutter blades, moves in a channel which is a friction type guide. Naturally, the pivots of gears, turning in bearings, encounter friction.

These are the parts which receive wear in the average shutter. Since the parts do not operate constantly, wear is slow and is seen but rarely. But, as in any machine, poor maintenance and improper lubrication will increase the amount of wear. You must be sure that parts subject to friction receive lubrication in the proper amount and kind. Already mentioned was the use of grease, graphite, and molybdenum disulfide. Shutters which develop heavy friction between main lever and leaf lever, etc., especially single action (automatic) shutters should be greased at the friction points. Just a small amount of NatLine grease will eliminate most of the friction at these points. Shutter blades should always be rubbed with a small amount of dry lubricant during assembly, and then wiped clean to remove all excess. Invisible particles of lubricant which remain in the pores of the metal will prevent excessive wear on the shutter blades. No rapidly moving friction point should be grease lubricated. This includes parts like the shutter blades, the blade operating ring and leaf lever, but does not include the part of the leaf lever which is contacted by the main lever as these parts slide across each other during the setting operation.

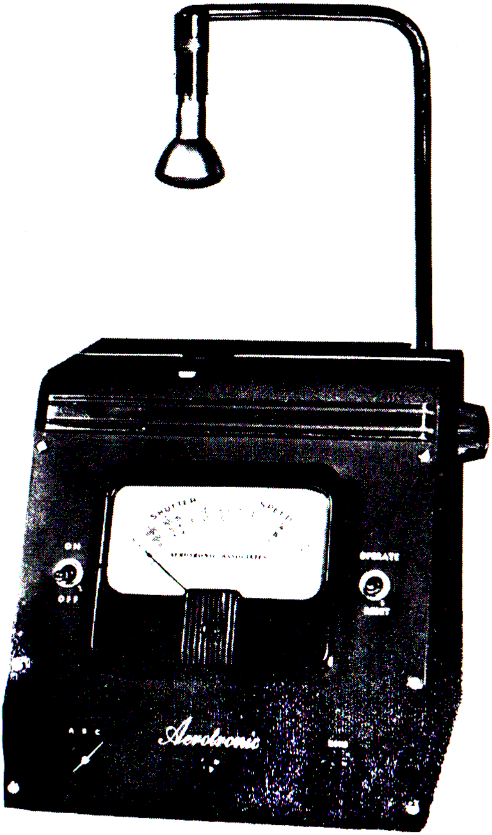
You may grease the speed cam where it contacts the various control-lever studs. The cam may also be greased (sparingly) on its large flat areas where it rubs against the shutter housing or front plate. Such lubrication provides for smoother setting of the speed cam.

THE ELECTRONIC SHUTTER SPEED TESTER

All of the shutter-speed tests you've learned about had one thing in common. Each involved making a photograph of some moving object, using the shutter in question. They are satisfactory systems, if time is of no value, and if the expense of processing and handling film can be borne by the customer. A good camera repair shop however, should be equipped to give the customer a shutter speed record which is not only accurate but inexpensive. A complete shutter speed test may require a total of 30 or 40 exposures, several checks at each shutter speed being necessary to make certain that the shutter speeds and the testing method are consistent. A test like this involves considerable expense which the average photographer might not tolerate.



The Hickok Shutter Speed tester. Probably the first instrument of its type integrating light passage and reading in shutter speed.



Typical instrument used exclusively for testing of shutter speeds. The amount of light passing through the shutter during its cycle is measured and read directly as shutter speed on the dial. The Hickok and Aerotronic instruments are similar in that they convert light passing through the shutter into electrical charge on a capacitor which is then read on the meter.

So, the "photographic" shutter speed tests, though satisfactory for the individual camera enthusiast, and perhaps also for experimental purposes, are far from practical for you.

That's why electronic devices have been developed which permit the technician to measure shutter speeds accurately, in minimum time, and at no expense other than the investment and maintenance of the shutter speed testing machine.

There are a few such devices available.

Slow shutter speeds (1 second or longer) wherein efficiency does not enter to a great extent can be measured with as crude a device as a stop watch. But the faster shutter speeds can only be tested accurately by using mechanical or electrical means.

One type of electronic shutter speed tester actually measures the amount of light which passes through the shutter while the shutter is open at any particular speed setting. Using a controlled light source and a photo-electric cell for this purpose, an electronic comparison is made to the amount of light which can pass through that shutter while it remains open (on a setting such as time).

Thus, a good electronic shutter speed tester takes efficiency into consideration and gives a reading of equivalent shutter speed regardless of the actual amount of time that the shutter remains open. This is desirable in that it reveals the accuracy of the shutter despite the shutter's efficiency.

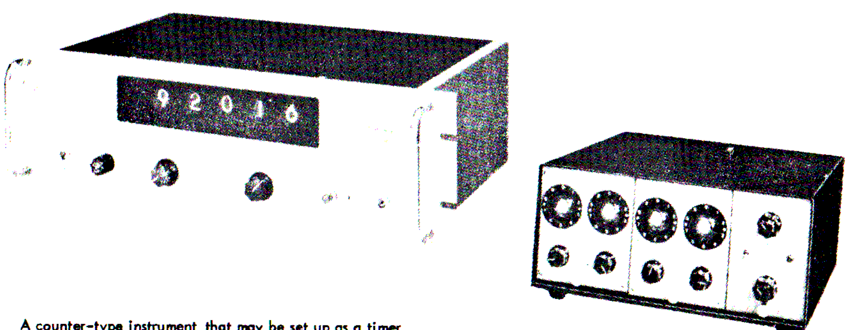
Unfortunately, this type of shutter tester cannot provide information concerning efficiency except by tedius calculation and difficult operation. In instances where a shutter delivers an effective exposure of 1/200th second, it might actually remain open for as long as 1/100 second, as you've seen. While this may have no effect on the exposure, it will obviously lower action-stopping ability of the particular shutter. It does also cause changes in exposure as the shutter aperture is decreased in size.

With an integrating type shutter tester, the process of measuring exposures at different apertures is quite complex as well as time consuming. The instrument must be re-adjusted for the particular shutter and aperture being tested and the precision of the adjustment determines the accuracy of the reading directly. Similarly, because the unit depends on the measurement of the light passing through the shutter, even the alignment of the shutter on the instrument has a considerable effect on the accuracy of the reading.

Generally, such instruments must be re-set between tests by the process of discharging a capacitor. A test must be made quickly after re-setting, since even small amounts of light leaking around the shutter can affect the final reading, especially when testing short exposures.

Despite disadvantages in operating convenience and accuracy, such testers can usually be built at moderate cost and when a single test is to be conducted, without concern for high accuracy or test information other than effective exposure, this type of instrument can be quite economical.

Another type of electronic test instrument often used on manufacturer's assembly lines is a "counter" type device. Such instruments are quite fast and convenient, because they measure the actual duration of shutter operation and provide the operator with a digital reading (a reading in



A counter-type instrument that may be set up as a timer with proper accessories. It requires an engineering set-up and is costly, but once set for a single test is fairly rapid as a production line instrument.

numbers) showing this time. When a shutter is tested on such a device, the instrument begins to count the milliseconds or ten-thousandths of a second during which light passes through the shutter. When the shutter closes, the instrument stops counting so that a reading may be made directly in thousandths or ten-thousandths of a second. Any instrument actually measuring the duration of shutter operation completely disregards efficiency. One of two conditions must be met in order to make such an instrument usable. First, on a production line, where all shutters being checked are identical or virtually so, their average efficiency may be pre-determined by laboratory tests. Then, the engineering laboratory may provide an acceptable range of readings for the counter type instrument on the production line so that all shutters operating within that range would be passed.

A second method is to set up the instrument for the particular shutter being tested so that it does not begin counting until the shutter blades are half way open and then stops counting when the shutter blades are half way closed. Such a technique automatically compensates for inefficiency and the time reading on the instrument at the end of the test is actual exposure.

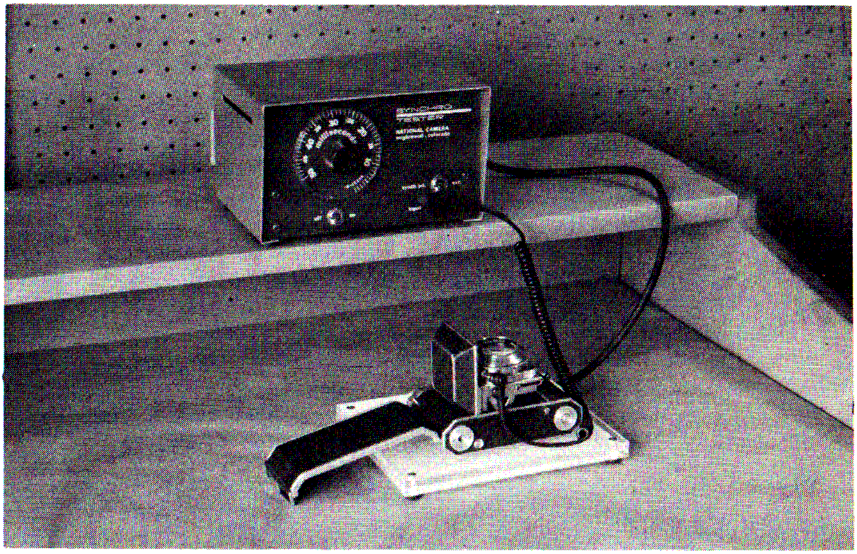
In either event, pre-testing is necessary in order to properly set up the counter type instrument. While a good quality counter can be set to "trigger" or start timing at any light level (when a certain amount of light passes through the shutter) it is difficult to determine this setting unless you already know something about the shutter or shutters under test. Obviously, changing from one shutter type to another shutter type; from one size shutter to another of the same type; or from one aperture to another in the same shutter is a difficult process at best.

In production line testing where hundreds or thousands of identical shutters are to be inspected, the costly original set-up is still economically practical.

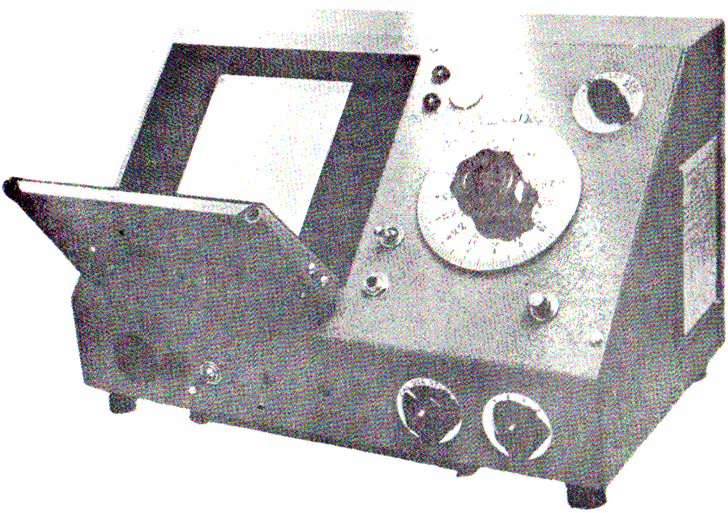
While there have been high cost counter-type instruments proposed for service use, these difficulties have not, to this point, been satisfactorily resolved.

If a shutter is synchronized for flash in any way, an indirect exposure test may be obtained using a synchronizer tester. A good flash-tube type synchronizer tester is basically a device which emits a short pulse of light, perhaps 1/10,000 second, at a pre-determined interval after a switch is closed. The time between the closing of the switch and the flashing of the light is varied by adjusting a dial, usually calibrated in milliseconds.

In testing, you look for the flash of light through the shutter opening. The trigger switch is the synchronizer circuit that is in or attached to the shutter. By varying the time interval between closing of the circuit and flashing of the light, you can measure the time interval between various phases of the operation of the shutter. Calculations are necessary to correct for shutter inefficiency when testing this way, but, since the time intervals can be measured, such calculations are reasonably simple. The actual "formula" is the same as was described earlier in this text. For example, in a typical test, the shutter may start to open at 15 milliseconds, be completely open at 20 milliseconds, remain open until 22-1/2 milliseconds, and then be completely closed at 27-1/2 milliseconds. The expo-



The ServiShops Synchrotester is a low-cost electronic "flash" type instrument most useful for testing synchronization. With some simple calculations it is possible to test shutter speeds (faster than 1/25 second) of synchronized shutters, also.



The Gardner Synchrotimer is a multiple-purpose instrument used for checking synchronization and shutter speeds. The calibrated delay is variable from 0 to 1200 milliseconds making shutter tests possible from 1/1000 sec. to 1 second. Standard model shown requires flash synchronization or cable release socket. Also available with photoelectric trip circuit which makes it valuable for testing shutter speeds of any shutter.

sure time may then be calculated as follows:

1. The shutter required a total of 10 milliseconds for the opening and closing cycles. Since it was only half open (on an average) during that time, the equivalent "full open" time was 5 milliseconds during this period.
2. The shutter remained fully open for 2-1/2 milliseconds.
3. Add 2-1/2 to 5 to get 7-1/2 milliseconds exposure. 7-1/2 milliseconds is approximately 1/130 second exposure delivered by the shutter for that particular setting.

THE AMERICAN STANDARDS ASSOCIATION SHUTTER SPEED TESTS.

The American Standards Association Committee on Shutter Testing continually investigates the problems inherent in reliable testing. This investigation resulted in the recommendation of a standardized system. The system took all the facts into account that should be determined by such a test. It is significant that their recommendation revolved around a test using an oscilloscope. With a high-quality oscilloscope coupled to a precision timing system, it is possible to make a shutter speed test that reveals all of the factors which have been discussed in this text: efficiency, variation in shutter action, true exposure and shutter idiosyncrasies, among others.

The test method is described in the American Standards Association publication No. PH3.4-1952.

For precision, such a test requires a versatile oscilloscope plus a precise oscillator with which it is set up. Such costly equipment is generally available in engineering departments operated by manufacturers, although it is economically beyond the scope of the average repair shop.

Set-up and interpretation generally requires engineering training. Each test requires a photograph of the oscilloscope screen plus a cumbersome calculation to reveal the facts.

Each of the testing systems using electronic equipment described thus far is a compromise with the ASA recommended procedure. The devices and methods are attempts to simplify the process but some precision or information is always lost.

THE SERVISHOPS MOTION ANALYZER

The development of the ServiShops Motion Analyzer began with the desire to solve these problems. Your school staff's efforts were to develop a test instrument that met all of the requirements of the American Standards Association while eliminating the disadvantages of the standard oscilloscope test described by ASA. The ServiShops Motion Analyzer provided these features:

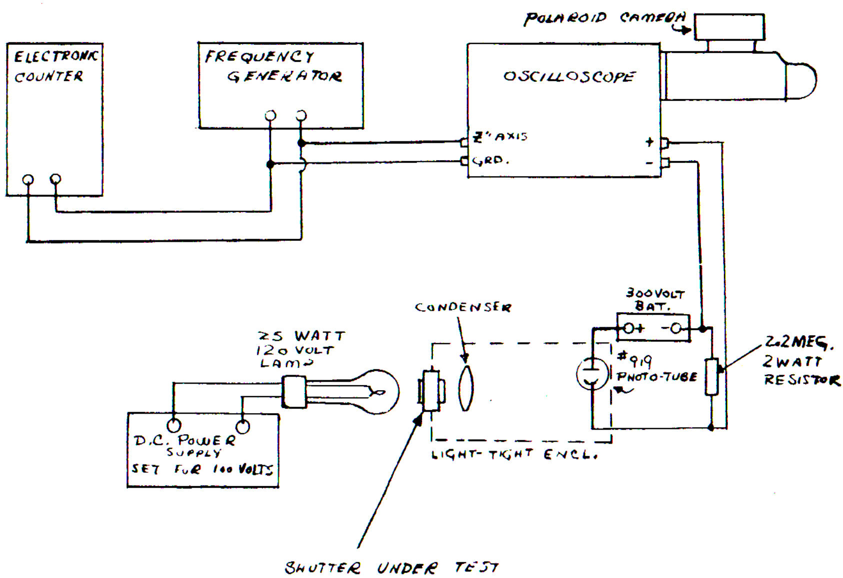
1. A visual display of shutter action.
2. Precise measurements of the various operating phases of the shutter.
3. The ability to determine such factors as efficiency, erratic action and similar data.

At the same time, these disadvantages have been eliminated:

1. High cost of test equipment.

TESTING SHUTTER SPEEDS

An A S A Shutter Speed Test



The diagrams and illustrations on this and the following page are from a report submitted by an NCRS student, using the ASA test method as described in NCRS Servi-Sheet #5592.

Equipment used: 5" Oscilloscope, Hewlett- Packard , Model 130D; Beat Frequency Generator, General Radio Model 1304B; Electronic Counter, Hewlett -Packard Model 521 A; 100 volt D.C. power supply; 25 watt, 120 volt lamp and socket; #919 high-vacuum photo-tube with condenser lens, both mounted in necessary light-tight case; 300 volt battery for photo-tube anode supply; Dumont Viewer and Polaroid Camera and attachment for Oscilloscope. (SEE ATTACHED DIAGRAM)

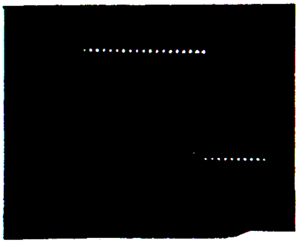
Notes on shutter test photos and data:

1. There are two sets of photos reproduced, four in each set. One set was made with diaphram set at f 3.5, the other at f 8. The vertical sensitivity on the oscilloscope was set to 2 volts per cm on both tests, so the height of the wave form can be viewed in a comparative manner, showing the shorter opening and closing time resulting from the smaller diaphram opening (because the blades do not travel so far to reach the circle of the diaphram opening).

2. In all cases the sweep time is given in terms of parts of a second per cm (each block on the calibrated face of the 'Scope is one centimeter square), so that a comparative double-check may be made on the results of the use of the formulas. This proved to be a wise provision. When the exposures were figured by counting the spaces between the dots and combining these quantities with the supposed frequencies shown on the calibrated dial of the generator, it was immediately apparent that something was wrong. Physically measured against the graduated 'Scope scale, the exposures were approximately correct , but the formulas showed them to be much longer. This was when the electronic counter was added to the circuit and a check was run on the generator's calibration. It was found that the generator had not been "zeroed in" before starting, resulting in a higher frequency, actually, than was appearing on the dial. This explains the odd numbered frequencies used, as they were calculated, rather than run another whole series of pictures.

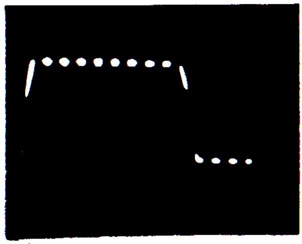
Included in the report was the statement "needless to say, I do not own all this equipment." (Total value about $4,000.00) "I was fortunate enough to be able to use what we had in the lab where I work."

As you will discover from some of these illustrations, there are some contradictory interpretations. It is clear that even with the use of costly equipment, some means is necessary to check the precision of one instrument against another and, even then, to properly interpret the results. Several more illustrations were in the original report but misleading interpretations indicated such incorrect facts as the shutter becoming less efficient as it was stopped down, etc. A higher frequency on the oscillator might have been desirable in some instances for further verification of the calibration of the individual instruments tied together for test purposes.



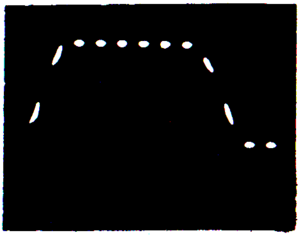
1/2 Sec. @ 40 cps.
.1 sec./cm S.T.
E - 95%
T - .50 sec.
t - .475 sec.

f/3.5



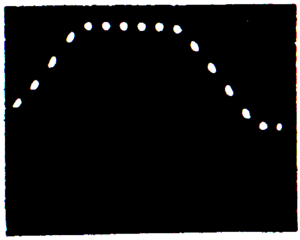
1/50 Sec. @ 320 cps.
.005 sec./cm S.T.
E - 90.9%
T - .034 sec.
t - .031 sec.

f/3.5



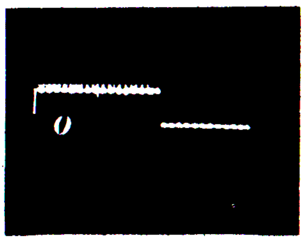
1/100 Sec. @ 625 cps.
.002 Sec./cm S.T.
E - 72.7%
T - .0176 sec.
t - .0128 sec.

f/3.5



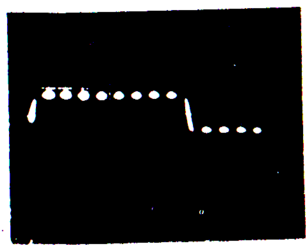
1/400 Sec. @ 3050 cps.
.0005 sec./cm S.T.
E - 66.7%
T - .005 sec.
t - .0033 sec.

f/3.5



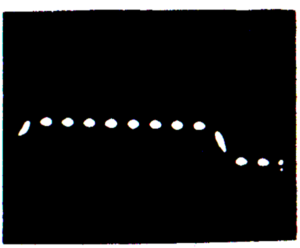
1/2 Sec. @ 40 cps.
.1 sec./cm S.T.
E - 94.3%
T - .450 sec.
t - .424 sec.

f/8



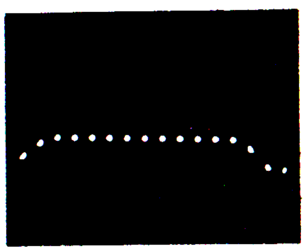
1/50 Sec. @ 320 cps.
.005 Sec./cm S.T.
E - 95%
T - .031 sec.
t - .029 sec.

f/8



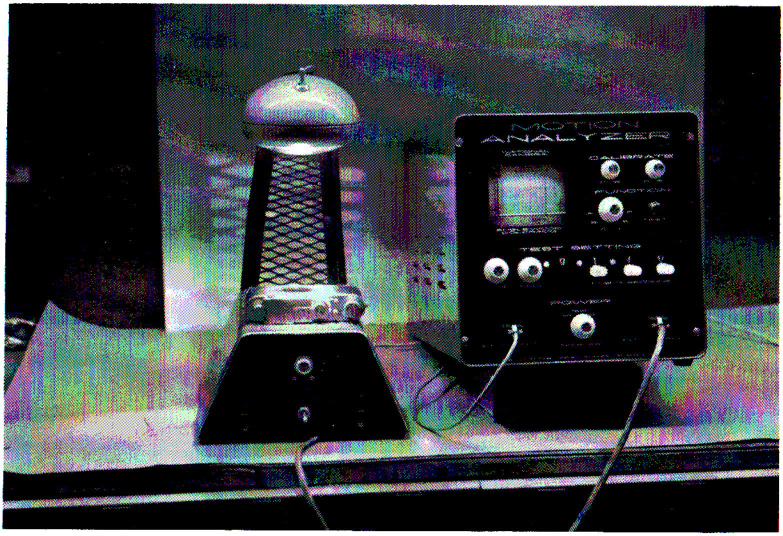
1/100 Sec. @ 625 cps.
.002 sec./cm S.T.
E - 95%
T - .016 sec.
t - .015 sec.

f/8



1/400 Sec. @ 3050 cps.
.0005 sec./cm S.T.
E - 85.7%
T - .0046 sec.
t - .0039 sec.

f/8



The ServiShops Motion Analyzer has been developed to provide accurate tests using the basic method suggested by A.S.A., but with ease of reading and small investment. It tests not only shutter speeds of all equipment but many other factors like contact action, flash synch, motion pictures, etc.

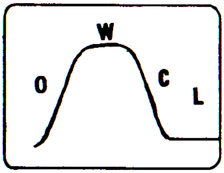
2. Engineering skill and knowledge for operation.
3. Elimination of all calculations.
4. Elimination of the need for photographs.
5. Cutting the time required for a test to a matter of seconds, less than required by any other system.

In addition to shutter speed tests, of course, the ServiShops Motion Analyzer includes many other functions, like shutter contact testing, motion picture equipment testing, flash synchronization testing, etc. The ServiShops Motion Analyzer was not designed as a compromise by skipping important features in order to gain any of the advantages of speed, ease of operation or cost. It was developed expressly for the testing of photographic equipment with all of the advantages and none of the disadvantages of existing ideas or equipment. It was developed expressly for the camera repair shop and it is only incidental that its advantages are so great that it is used in manufacturing plants and government testing facilities as well.

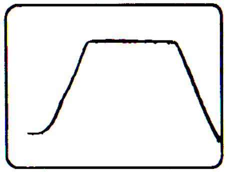
Tests of all types can be made with equal ease so that any focal plane or between-the-lens shutter can be checked quickly and simply.

The picture displayed on the screen of a ServiShops Motion Analyzer provides you with all of the information that you want, in a flash, without repeated tests to gather the data.

TESTING SHUTTER SPEEDS

1


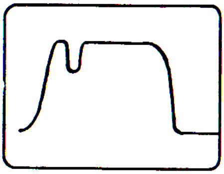
.0100

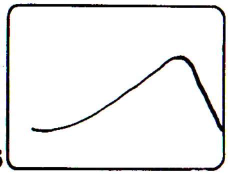
2

.0075

3

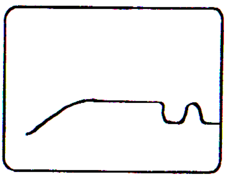
.0050

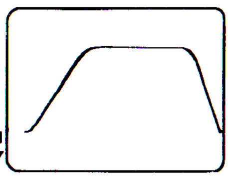
Typical traces produced by the Analyzer. Trace 1, upper left, analyzes a between-the-lens shutter with O indicating the opening time; W, the open period; C, the closing time. Trace 2 represents the same shutter after the sweep time has been decreased to .0075 seconds operating time. Decreasing the sweep time to 5 milliseconds results in the curve shown in trace 3.

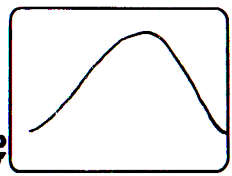
4

.0200

5

.0150

Trace 4 shows the graph traced by a shutter having poor leaf lever control. The trace illustrates that the shutter leaves open fully, bounce partially closed, and then re-open for the remainder of the exposure. Trace 5 illustrates the graph traced by a shutter having uneven opening and closing times. In this case, the shutter takes a great deal of time to open, but closes quickly.

6

.0200

7a

.0032

7b

.0040

Shutters with blade bounce can be detected merely by stopping the diaphragm down as far as it will go and choosing a sweep time 7 or 8 milliseconds longer than the total operating time of the shutter. Trace 6 shows the graph produced by a shutter having shutter blade bounce. Efficiency comparisons and measurements are, of course, nicely made. Trace 7 shows the graphs traced by two shutters, each set at 1/500 second, but having widely different efficiency characteristics.

You'll learn a number of ways in which Analyzer tests can be useful as you progress through the various phases of your training.

GIVING THE SHUTTER SPEED TEST RESULTS TO THE CUSTOMER

Your National Camera ServiShops Shutter-Speed-Record Chart forms are useful when tabulating the results of a shutter speed test. In the blocks labeled "Shutter Speed Setting," list the shutter speeds that are calibrated on the shutter. In the blocks labeled "Actual Exposure" list the exposures

NATIONAL CAMERA ServiShop

SHUTTER SPEED RECORD CHART

Customer's Name John C. Client Job Number 7359

Address Suburbia U.S.A. Date Anytime

Camera Click 35 Shutter Oakleaf 250 Lens Popshottle 50mm f3.5

Aperture Setting f5.6 Remarks Slow speeds out of tolerance — pallet should be adjusted.

Shutter Speed Setting	1 sec	1/2	1/4	1/8	1/15	1/30	1/60	1/125	1/250
Actual Exposure	1.5	3/4	1/2	1/5	1/10	1/33	1/65	1/130	1/255

A Typical Shutter-speed Chart

SHOULD THIS BE?

delivered at each shutter speed setting. The customer should be informed of any errors in his shutter regardless of how great or how small they are. However, the results should not be simply handed out without an explanation. The average photographer is surprised and somewhat unhappy when he first sees the results of a shutter speed test of his camera. But, as has been explained earlier, the shutter speeds need not be precise, providing they are known by the photographer so that he can compensate properly.

Explain to the customer how variation in aperture affects the shutter speed, depending on the particular shutter, and tell why the shutter speed test was made at a moderate aperture.

There may be occasions when a photographer will request several sets of shutter speed tests made at different apertures in order that he may be sure of accurate exposures. Only in the case of the photographer using a large amount of color film is such accurate testing necessary.

It is always worth while to explain the errors which are tolerable in new shutters and like-new shutters. Show him the variations in exposure which may be acceptable with the film that he happens to be using. Remind the photographer that although the shutter speeds may be accurate, as far as exposure is concerned, your test results do not necessarily refer to action stopping qualities of the shutter. Although a shutter may be delivering an accurate exposure of 1/200 second, it may remain open for a full 1/100 second, yielding blurred pictures of moving objects. Every photographer is interested in such facts, and your help to him in getting better pictures will be fully appreciated.

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