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The Movie Projector

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The Movie Projector

contents

1085

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rewind the film onto the supply reel with the film wound with the emulsion side out and ready for the next projection.

Most of the techniques used to meet these conditions were developed some years ago, so modern projectors are quite similar in construction to each other. As long as you understand that all movie projectors are designed to meet these conditions and must meet them when you have finished your repair, you will be successful in all your movie projector repairs.

THE FILM PATH THROUGH THE PROJECTOR

By following the film path through the projector we can better understand how the basic elements work together. The film is wound on the supply reel with the emulsion side out. As the film leaves the supply reel, it passes first over the upper sprocket; the sprocket teeth engage the perforations in the film, Fig. 1. When the film leaves the upper sprocket it is curled to form a **loop** before entering the film gate. This is done to isolate the intermittent action of the claw from the continuous rotation of the sprocket. The film gate consists of a **guide plate** and a **pressure plate.** The guide plate keeps the film aligned horizontally with the **frame aperture.** The pressure plate is spring loaded to keep the film flat and to gently hold

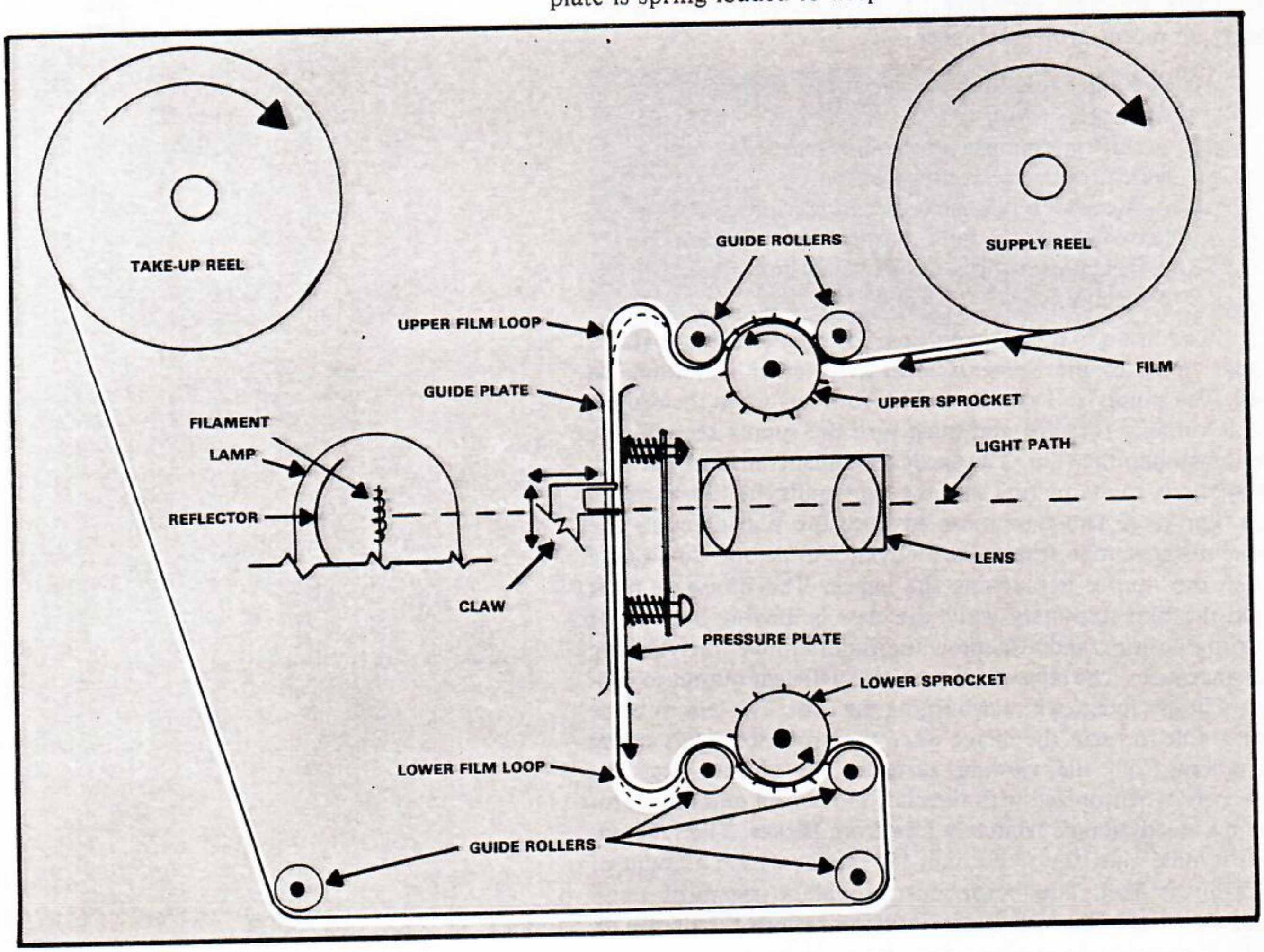


Figure 1

the film still as it is being projected. As the film leaves the film gate, it is curled again to form the **lower loop.** The film then passes under the lower sprocket and around the **guide rollers** to the take-up reel.

The formation of the loop is crucial to the operation of any projector. In Fig. 1, notice the dashed lines underneath the upper-film loop and beneath the lower-film loop. These lines indicate the position of the film immediately after the claw has advanced the film. While the claw is retrenching, the sprocket continues to advance the film. When the claw is ready to advance the next frame, the loops have expanded to the shape indicated by the solid film line. When the claw advances the film, the loops are again in the positions indicated by the dashed lines. The sprockets help to maintain the loops -- especially the lower sprocket which isolates the tension of the take-up reel from the loop.

Most claws you will see have two sprocket teeth as shown in Fig. 1. The teeth are separated by the height of one frame. With two teeth pulling on the film, the stress on each sprocket hole is cut in half. This is important when you consider the speed with which each frame is advanced in the projector compared to the camera.

As the film is pulled through the film gate, it rides in a track recessed into the guide plate. The film is pushed to the claw side of the track by the spring-loaded **edge guide,** Fig. 2. This assures that the claw will line up with the sprocket holes every time.

The frame aperture in the pressure plate determines the area on the film to be projected. The pressure plate can move independently of the guide plate without affecting the position of the film. This means that by providing a mechanism to move the pressure plate up and down by very small amounts, we can adjust the frame aperture to project only the image and block out the black lines between frames, Fig. 2.

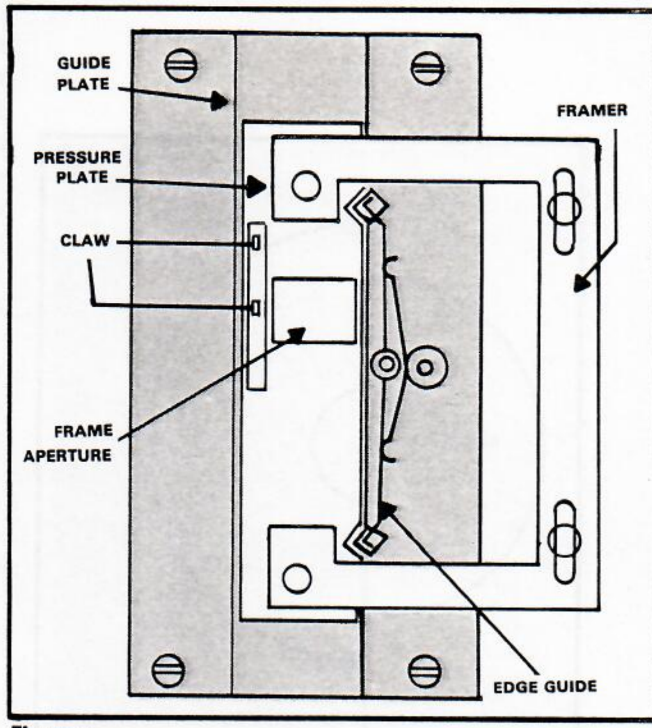


Figure 2

TEST YOURSELF QUIZ #1

1. The nine basic elements of a movie projector are:

   ___________ ___________ ___________

   ___________ ___________ ___________

   ___________ ___________ ___________

2. The framer adjusts the position of the ________ to block out the black lines between frames.

3. The film loops are constant in their size, shape and position

   True______ False______

4. The film is wound on the supply reel with the __________facing out.

THE SHUTTER IN THE MOVIE PROJECTOR

As you know from your lesson on movie cameras, the illusion of motion created by viewing rapidly changing images in succession is due to a phenomenon of the human eye called persistence of vision. Many factors affect the creation of the illusion of motion including; the rate the image changes, the dark time between frames (flicker) and the brightness of the image. In the early days of motion pictures, it was discovered that projecting a movie at 10 to 12 frames per second (FPS) created the illusion of continuous motion; however, at this rate there was an annoying amount of flicker. At 16 FPS the flicker seemed to disappear for most people. Increasing the framing rate above 16 FPS reduces the perception of flicker; however, film is expensive so the slowest acceptable framing rate is desirable in terms of economics. In professional film making, where the increase in viewing pleasure can be justified economically, the accepted standard is 24 or 25 FPS. The home movie maker, on the other hand, wants to be able to make his films as inexpensively as possible, so most amateur cameras are adjusted for either 16 or 18 FPS.

While the flicker of 18 FPS is not objectionable, it is noticeable. This brought about the development of the **multiple-blade shutter** in the projector. Most modern amateur projectors have a three-blade shutter.

The claw still advances the film one frame for each rotation of the shutter, but because the shutter has three blades, each frame is flashed on the projection screen three times. The framing rate remains the same, but flicker is reduced because the dark time between each flash of image on the screen is reduced. The intensity of the projection bulb can also be increased without damaging the film because each frame has a chance to cool slightly between the three projections.

If you were to test the framing rate of a projector employing a three-blade shutter with a tester such as the Comparascope, the rate you would measure would be 3 times faster than the actual framing rate. The Comparascope measures the number of exposures per second. Since each frame is exposed 3 times, the actual framing rate would be 1/3 the number of exposures per second.

Fig. 3 shows two different shutter discs. Disc A is a typical example of a shutter disc found in a movie camera. The opening is 180°. Disc B is typical of a shutter disc found in a projector. Its opening is also 180° per revolution broken into three 60° segments. Disc B rotating at a rate of 18 FPS would generate an effective shutter speed of 1/108 second for each of the three openings. If you then add the three exposures together, you find that disc B generates a total exposure time equal to the 1/36-second exposure time of disc A rotating at 18 FPS:

$$\frac{1}{108} + \frac{1}{108} + \frac{1}{108} = \frac{3}{108} = \frac{1}{36 \text{ sec.}}$$

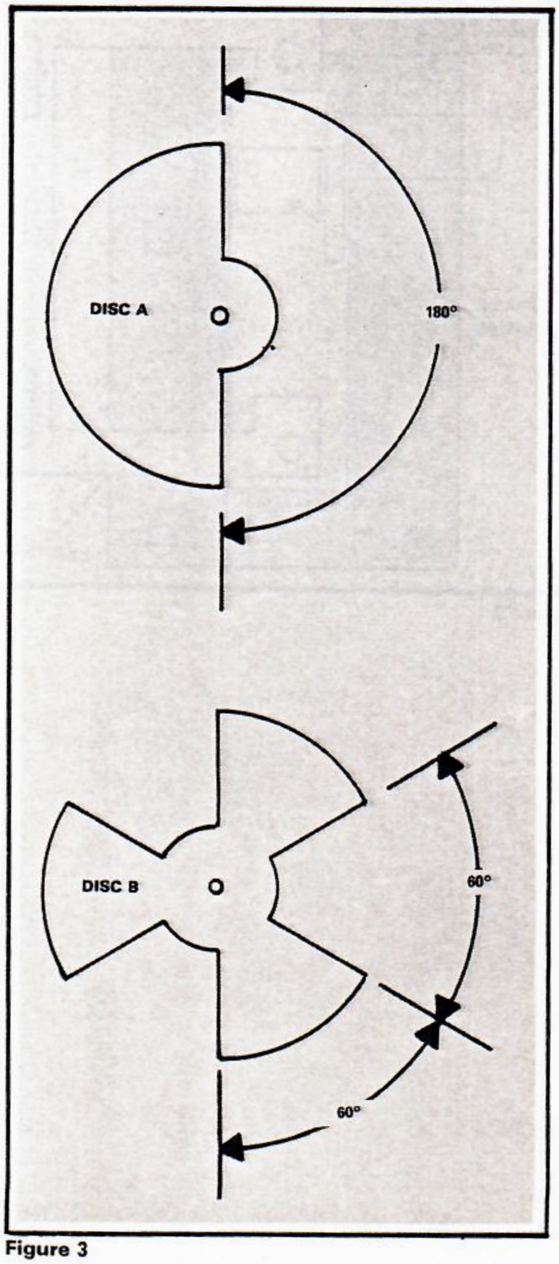


Figure 3

The important thing to remember is that the same speed calculations hold true for the dark time between frames, and it is the duration of the dark time -- not the duration of the exposure -- that causes flicker.

Fig. 4 shows the shutter disc from a Bell and Howell projector. Notice that the blades cover only a small portion of the disc when compared with the openings. Each blade is 42° wide and each opening is 78° wide. This means each image is projected on the screen almost twice as long as it is blocked by the blades. Each time the image is blocked by one of the blades, the screen is dark for only 6.5 ms, which would be equivalent to the flicker produced by a framing rate of 77 FPS for a 180° shutter disc.

42° ÷ 360° = 11.67% of shutter rotation
18 FPS = 55.56 ms/shutter rotation
11.67% x 55.56 ms = 6.5 ms
6.5 ms x 2 = 13 ms = 76.9 FPS

The narrower blades on the three-blade shutter also make it necessary for the claw to move the film faster. On the Bell and Howell projector, the claw has only 6.5 ms to move the film as opposed to almost 28 ms available to a mechanism with a 180° shutter blade. Fig. 5 shows the timing relationships between shutter and claw for the Bell and Howell projector and a

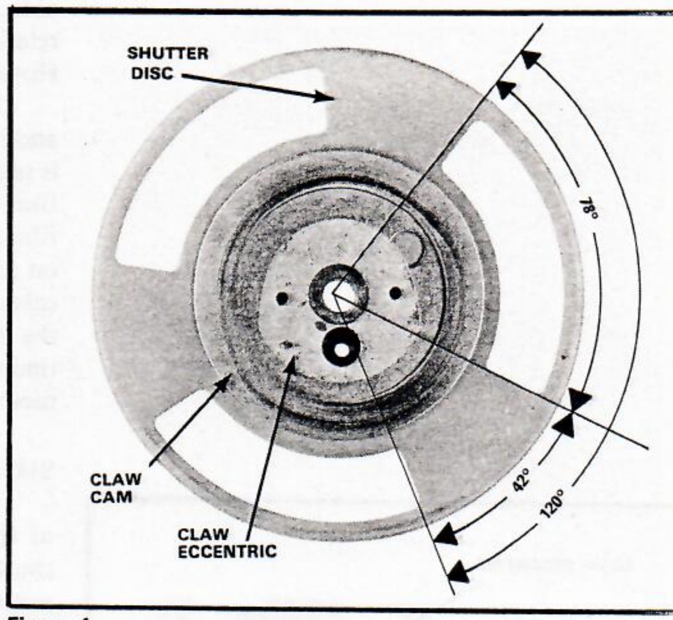


Figure 4

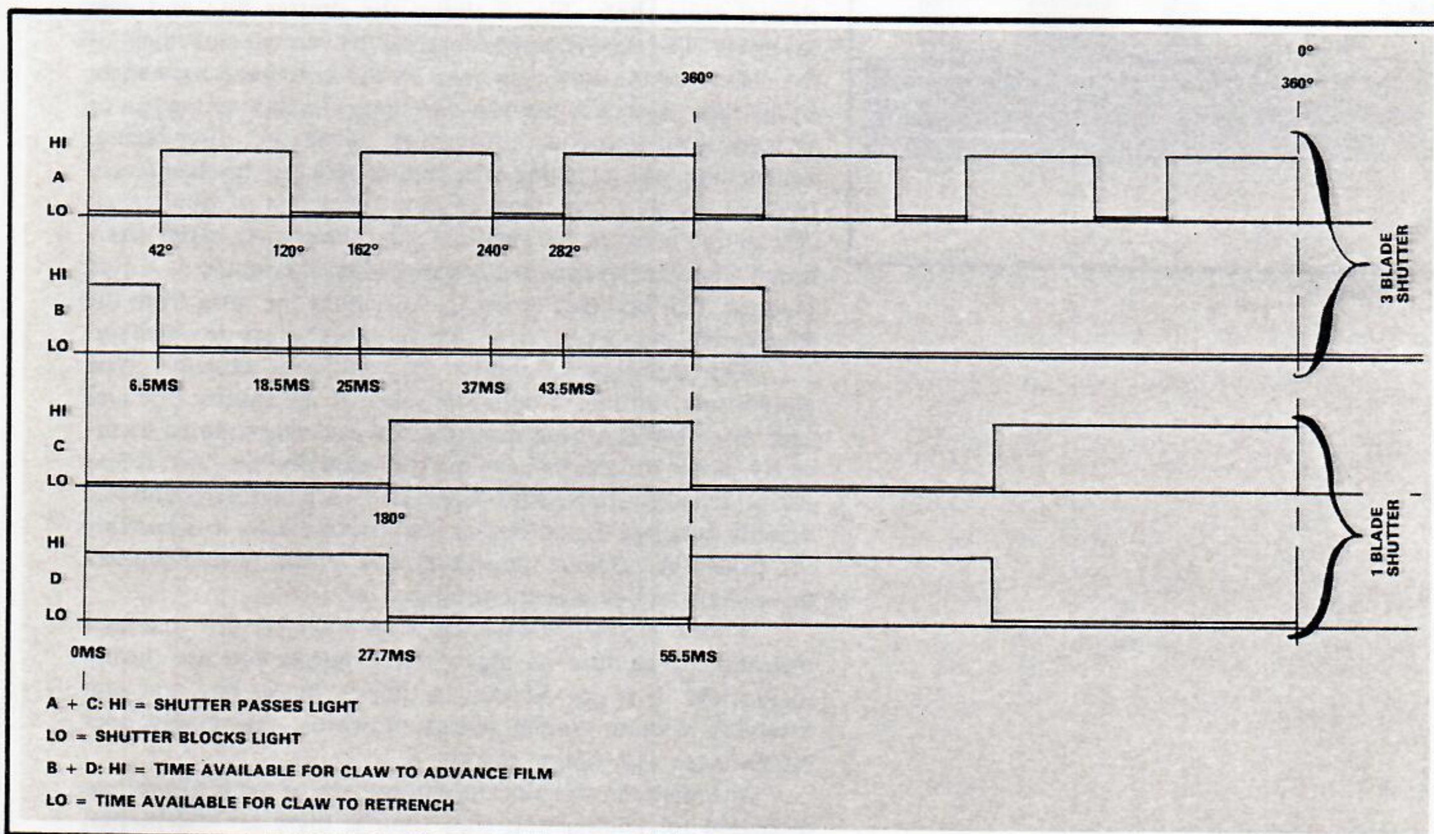


Figure 5

standard 180° shutter. Graph A represents the shutter action of the Bell and Howell. The "Lo's" correspond to the shutter blades and the "Hi's" correspond to the shutter openings. Graph B indicates when the claw advances the film in relation to the shutter rotation and how much time the claw has available to advance the film. Graphs C & D show the same relationships for a 180° shutter as compared to the Bell and Howell.

It is not important for you to know the shutter openings and blade widths in degrees for every projector you work on. It is important that you know the claw must finish advancing the film before the shutter opens, and must begin advancing the film after the shutter closes. This timing is much more critical on a three-blade shutter than on a one-blade shutter. In many cases the timing between shutter and claw is set by the design of the parts themselves and cannot be changed. In other cases the timing between shutter and claw is set by gears in the mechanisms that require critical timing by the technician.

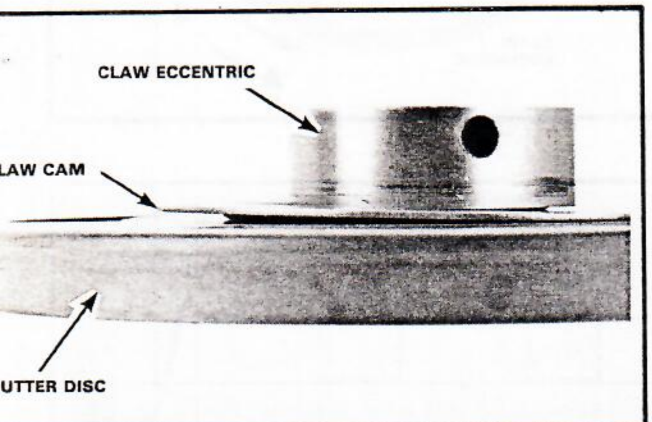


Figure 6

SHUTTER AND CLAW TIMING

Most projector mechanisms are designed so the movement of the claw is controlled by cams that are either part of the shutter disc or fixed to the **shutter-drive shaft.** Bell and Howell projectors employ two cams that are fastened to the shutter disc. The shutter disc and cam assembly is then attached to the shutter-drive shaft. Fig. 6 shows the shutter disc and cam assembly. The **claw eccentric** controls the vertical movement of the claw, and the **claw cam** controls the horizontal movement of the claw. Just as in the movie camera, the claw action can be broken down into four movements; advancing, disengaging, retrenching, and engaging. The timing between the claw eccentric and the claw cam determines the direction of film travel. The timing between the two cams and the shutter blade determines whether the film is advanced when the shutter is closed or open. If it becomes necessary to remove the cams from the shutter disc, be sure to scribe timing marks before disassembly.

With this type of shutter disc and cam assembly, you would only run into a timing problem if the shutter disc and cam assembly had been disassembled and reassembled incorrectly. Some projectors have the claw cam and the claw eccentric attached to the shutter-drive shaft with setscrews and not directly attached to the shutter disc. In this case, it is possible for either the cams or the shutter disc to slip on the shutter-drive shaft and change the timing.

Whenever you are disassembling a shutter disc and cam mechanism, be sure to make scribe marks for use during reassembly. It is not difficult to time a shutter disc and cam assembly without timing marks; however, reassembly goes much faster with timing marks.

Although most projectors employ one of the methods just discussed for shutter and claw timing, there are exceptions. Some projectors employ gears to drive the claw cam and claw eccentric off of the shutter-drive shaft. The Kodak Instamatic

M-70 projector is a good example of projectors that use this technique. We will examine the mechanism of the Kodak Instamatic M-70 to see how the gears are timed.

The claw eccentric is permanently attached to the shutter-drive shaft. The shutter disc is free to rotate on the shutter-drive shaft. The shutter disc is driven by the **shutter-drive foot** on the claw eccentric. The shutter disc has a single blade which is 120° wide. To reduce flicker, the shutter rotates three times for each frame projected at 18 FPS. This means the shutter is rotating at a speed of 54 revolutions per second (RPS), creating the same effect on flicker as a three-blade shutter disc. The dark time for each revolution of the shutter is 6.2 ms. The Bell and Howell projector has a dark time of 6.5 ms for each blade of the shutter.

Since the shutter and claw are operating at a speed of 54 RPS and the film is advanced at 18 FPS, there must be some mechanism to reduce the 54 RPS to 18 FPS. Well, there is a gear molded into the shutter disc that drives the larger gear, called the **claw-cam gear,** at a reduction of 9:1. In other words, the claw-cam gear rotates once for every nine revolutions of the shutter disc, or 6 RPS.

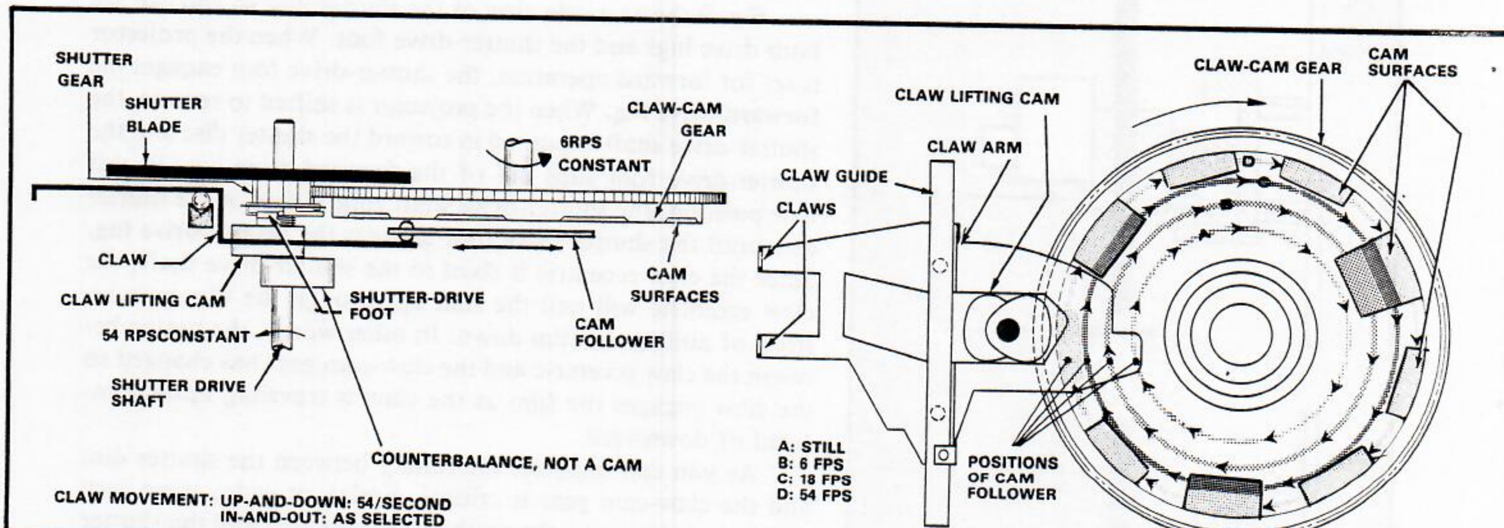


Figure 7

On the face of the claw-cam gear are nine cam surfaces, Fig. 7. These cam surfaces control the engagement and disengagement of the claw with the film. The cam surfaces are depressions in the gear, as shown in Fig. 8. The **claw arm** is spring loaded toward the claw-cam gear. Sandwiched between the claw arm and the claw-cam gear is the **cam follower.** When the cam follower falls into one of the depressions in the claw-cam, the claw engages the film and advances it one frame.

Referring to Fig. 7, when the cam follower is in position D, the claw engages the film nine times per revolution of the claw-cam gear. Since the claw-cam gear rotates at 6 RPS, when the cam follower is in position D, the film is advanced at 54 FPS:

$$9 \times 6 \text{ RPS} = 54 \text{ FPS}$$

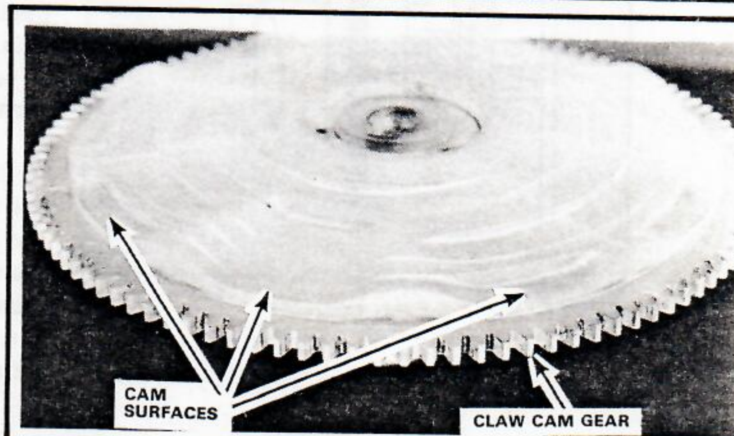


Figure 8

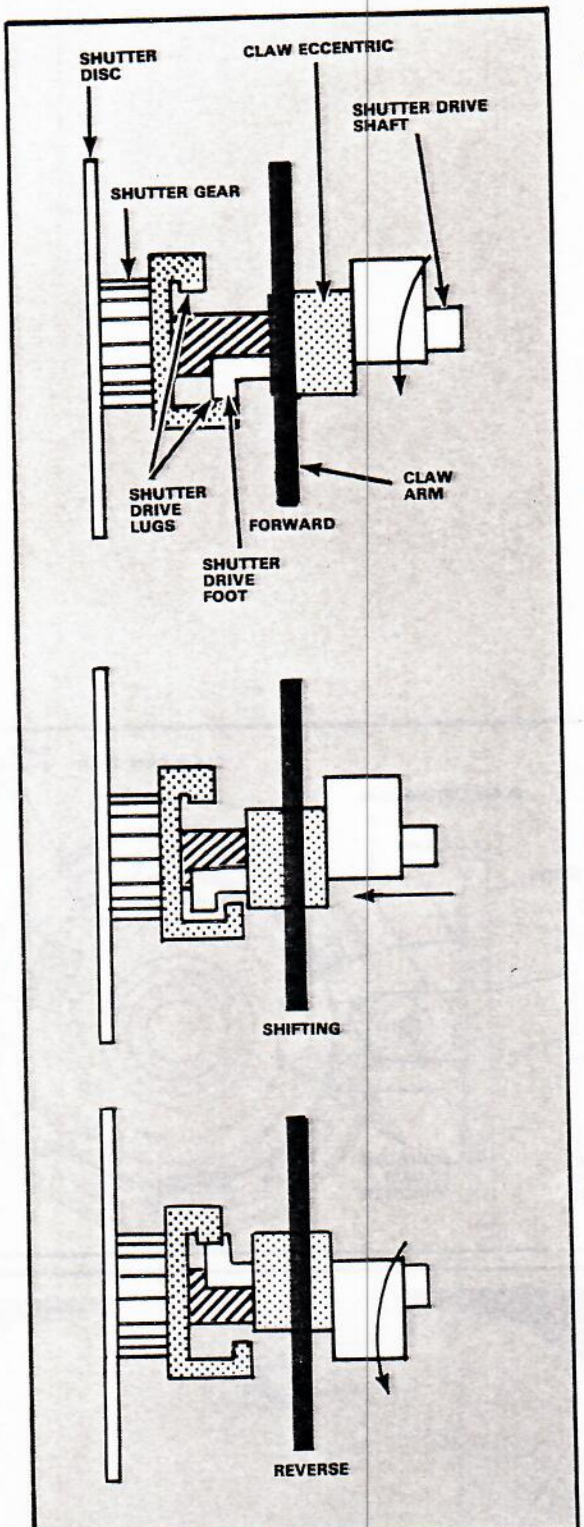


Figure 9

When the cam follower is in position C, it falls into every third depression or three depressions per revolution, advancing the film at 18 FPS:

$$3 \times 6 \text{ RPS} = 18 \text{ FPS}$$

When the cam follower is in position B, it falls into only one depression per revolution advancing the film at 6 FPS:

$$1 \times 6 \text{ RPS} = 6 \text{ FPS}$$

When the cam follower is in position A, it does not fall into any depressions and the film remains stationary.

As we mentioned earlier, the shutter disc is driven by the shutter-drive foot on the claw-eccentric and is free to rotate on the shutter-drive shaft. There is a very good reason for this. The projector controls change the timing between the shutter disc and the shutter-drive shaft to run the film in reverse. The shutter disc has two drive lugs that are 180° apart. The forward-drive lug protrudes farther from the rear of the shutter disc than the reverse-drive lug does.

Fig. 9 shows a side view of the shutter disc so you can see both drive lugs and the shutter-drive foot. When the projector is set for forward operation, the shutter-drive foot engages the **forward-drive lug.** When the projector is shifted to reverse, the shutter-drive shaft is pushed in toward the shutter disc and the shutter-drive foot slips off of the forward-drive lug. In this new position, the shutter-drive shaft rotates free of the shutter disc until the shutter-drive foot engages the **reverse-drive lug.** Since the claw eccentric is fixed to the shutter-drive shaft, the claw eccentric will pull the film up through the film gate instead of pulling the film down. In other words, the timing between the claw eccentric and the claw-cam gear has changed so the claw engages the film as the claw is traveling upward instead of downward.

As you can imagine, the timing between the shutter disc and the claw-cam gear is critical. Kodak provides some very convenient timing marks on the claw-cam gear and the shutter blade for use during reassembly. They also provide a very detailed procedure for reassembly in their service manual. This is very fortunate, as one of the most common repairs performed on this projector is replacement of the shutter disc.

As the projector ages the plastic gear molded to the shutter disc becomes brittle and breaks. The usual symptom is that the film will not transport at all because the claw never engages the film. You may also see a projector that will accept the first frame of film and just move it up and down continually. Replacing the shutter disc requires major disassembly, so be sure to look the projector over carefully before giving an estimate of repair costs.

TEST YOURSELF QUIZ #2

1. Flicker is caused by:
   a. The length of the projection time for each frame.
   b. The speed with which the claw advances the film.
   c. The length of the dark time between each projection.
   d. Using one shutter blade.

2. To determine the framing rate of a three-blade shutter, ________ the number of projections per second by three.

3. The horizontal movement (engagement and disengagement) of the claw is controlled by the ________.

4. When the Kodak M-70 projector is set for 18 FPS, the cam follower falls into ________ depressions in the claw-cam gear per revolution.

5. Shifting the M-70 projector from forward to reverse changes the timing between the ________ and the ________.

THE OPTICAL SYSTEM

Now that you know how the projector transports the film, you need to know how the projector gets the image onto the screen. First you need a light source. Projection lamps come in many different configurations, but they all must meet certain requirements. The lamp must produce enough light so the image can be seen with the projector at a convenient distance from the screen. Most manufacturers assume that the projector will be 15 or 30 feet from the screen for home use. It has been found that a 100-watt bulb provides sufficient output at this distance, although you will see wattage ratings range from 50W-150W.

This may not sound like very much, especially considering losses through the film and lens; however, since the light only needs to go in one direction, we can boost the useful amount of light available by placing a reflector behind the lamp. The reflector directs the light that would normally be lost off the back of the bulb onto the film.

The alignment of the lamp and the reflector with the film gate and lens is important if you are going to use the bulb to its greatest advantage. The filament must be directly in line with the film gate and the lens, and the reflector must focus the light with different bulbs without damaging the film. This means each bulb must be made so that the filament is positioned precisely from bulb to bulb. This is one reason why projector bulbs are so expensive.

Even if the filament is positioned correctly, if the reflector is not, severe light loss may occur. A poorly positioned reflector may even burn the film if the light is focused directly on the film. In an effort to overcome this problem, most projectors now use lamps with built-in reflectors. Fig. 10 shows the proper alignment of the reflector, lamp, film, and lens.

A tungsten filament lamp radiates a considerable amount of heat -- enough to damage the film if it were stationary. When the film is moving through the film gate, each frame is in front of the lamp for such a short period of time that the film does not absorb enough heat to melt. When the film is stationary, it does not take long for the heat from the lamp to melt the film base. To prevent damage to the film, projectors that have a still projection setting also have a fire screen. The fire screen usually consists of a metal plate with many small holes in it. The holes only let pass a small portion of the light as well as the heat. Some fire screens may also have a small piece of heat absorbing glass, similar to a slide projector. Obviously, the brightness of the image on the screen is cut noticeably; however, that is much preferable to burning the film.

Fig. 11 shows the fire screen in a Bell and Howell projector in the forward running position. The fire screen is controlled by the shift lever and is moved out of light path when the projector is set for forward or reverse. When the projector is set for still projection, the fire screen is moved into the light path as shown in Fig. 12.

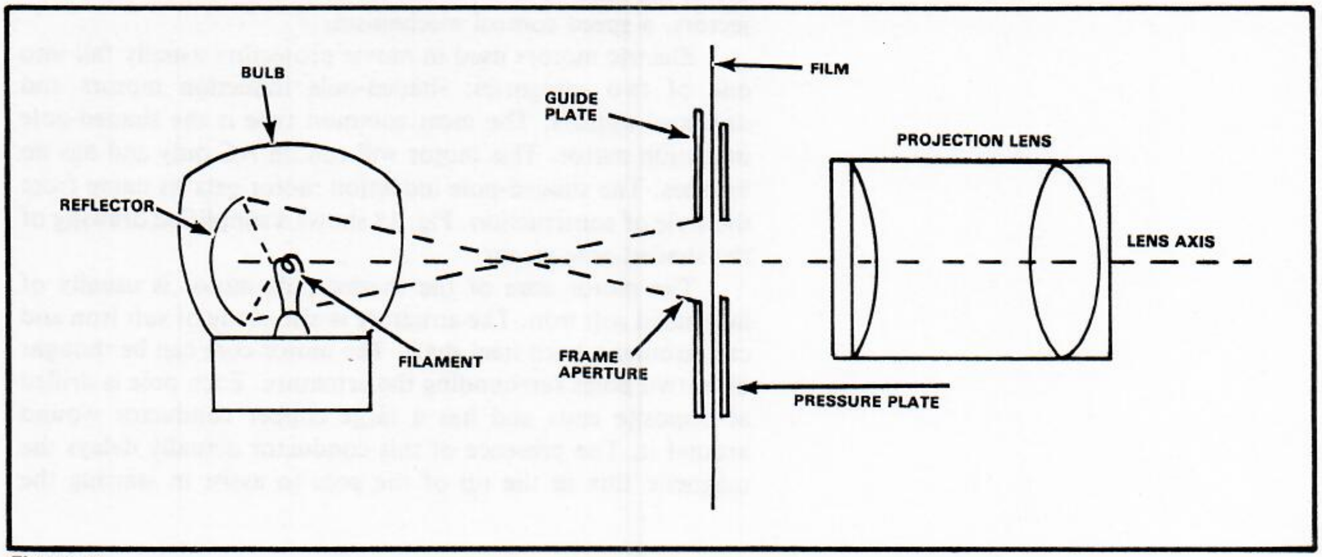


Figure 10

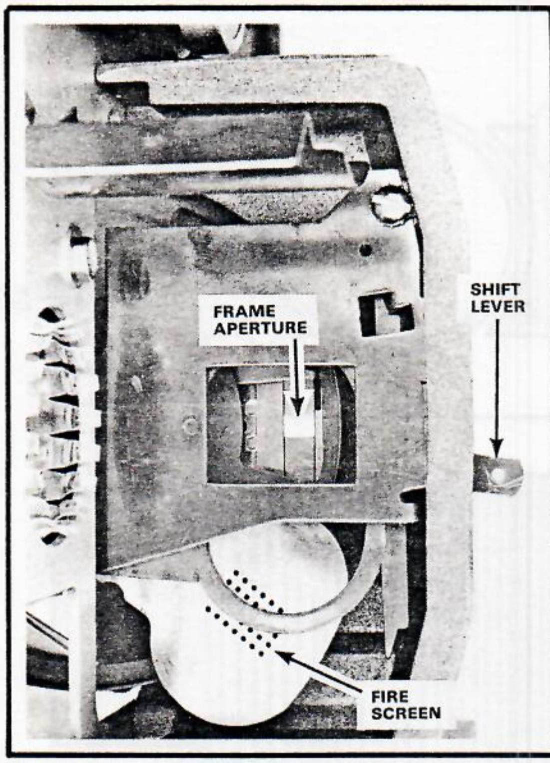


Figure 11

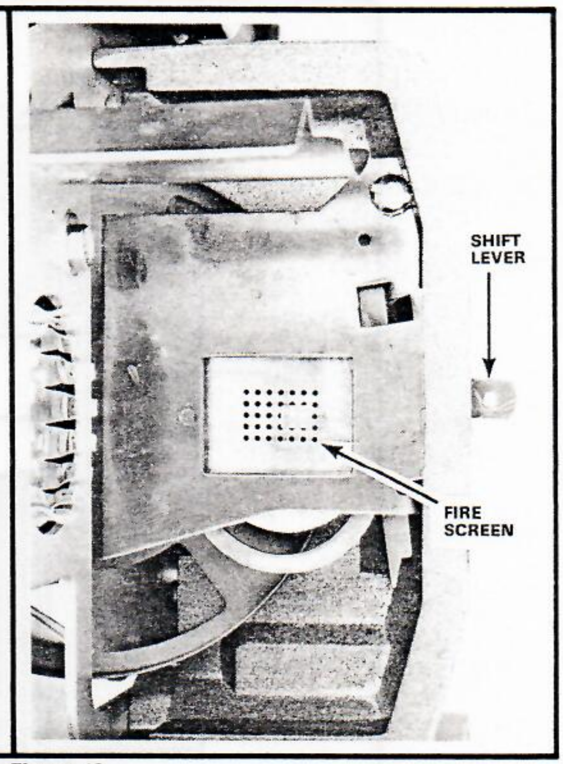


Figure 12

THE DRIVE SYSTEM

The drive system of a movie projector usually consists of the following mechanisms: the motor and blower, the shutter drive, the take-up and rewind mechanism, and, on some projectors, a speed control mechanism.

Electric motors used in movie projectors usually fall into one of two categories; shaded-pole induction motors and universal motors. The most common type is the shaded-pole induction motor. This motor will run on AC only and has no brushes. The shaded-pole induction motor gets its name from the style of construction. Fig. 13 shows a simplified drawing of the shaded-pole motor.

The motor core of the shaded-pole motor is usually of laminated soft iron. The armature is also made of soft iron and cast around a hard steel shaft. The motor core can be thought of as two poles surrounding the armature. Each pole is drilled at opposite ends and has a large copper conductor wound around it. The presence of this conductor actually delays the magnetic flux in the tip of the pole to assist in starting the

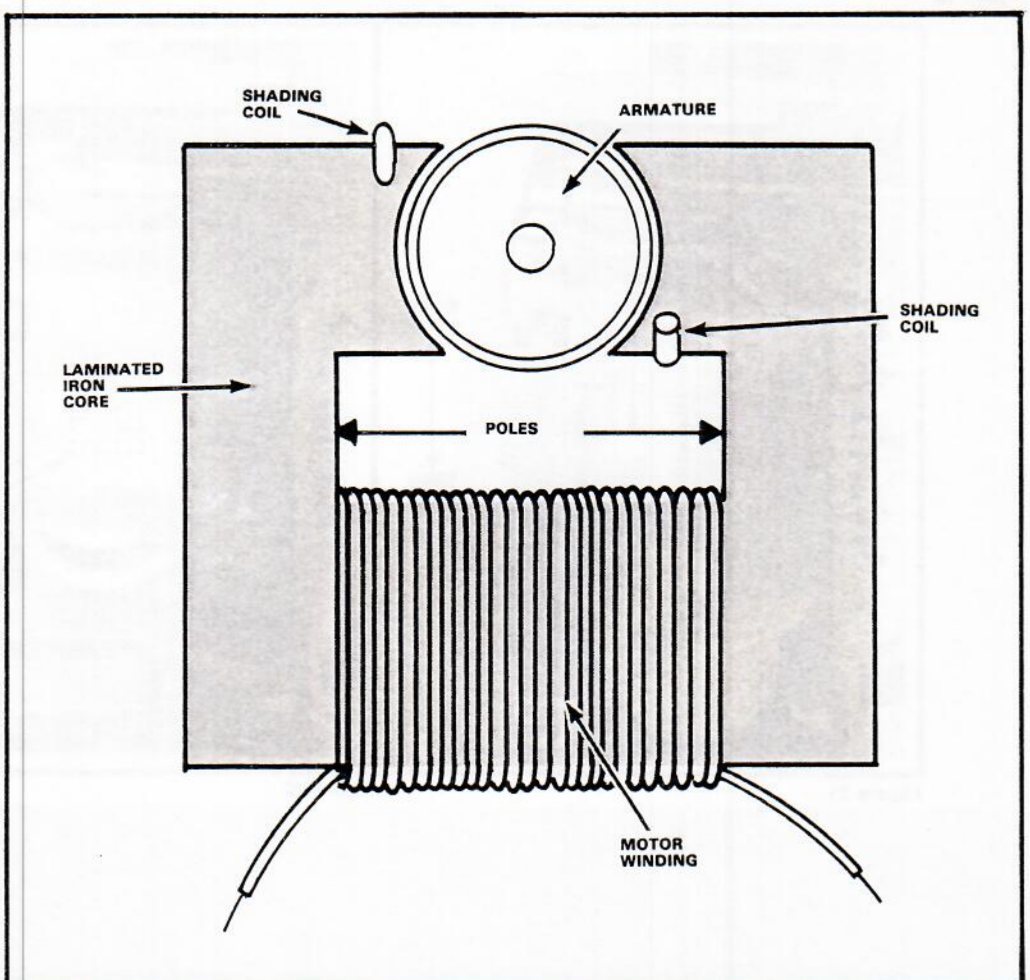


Figure 13 **Shaded-pole induction motor**

motor. The winding of the conductor around the pole is called shading, and since the motor has no brushes, the rotation of the armature is induced by the magnetic flux in the poles. Fig. 14 shows a shaded-pole induction motor in a Bell and Howell projector. The motor core surrounds the armature completely, however the operation is the same as the motor in our drawing in Fig. 13.

The universal motor is used in projectors that electrically vary the motor speed. The universal motor gets its name from the fact that it will run on AC or DC. Most projectors that use universal motors run them on AC. The universal motor has brushes, a comutator, an armature and field windings like most DC motors. By varying the current to the field, the motor speed will vary over a very wide range. Universal motors can be reversed by reversing the polarity of the current to the field winding. An induction motor will synchronize roughly with the line frequency and will vary only a small amount before stalling and cannot be reversed.

Brush type motors must be checked periodically for brush wear and cleanliness of the comutator, so be sure to check these items whenever you are working on a projector that uses a universal motor.

The blower in the projector is usually attached directly to the motor shaft, Fig. 15. The stream of air from the blower is directed over the lamp to cool it. As we mentioned earlier, the heat produced by the lamp is considerable and if it were not dissipated, the lamp would burn out very quickly. Many projectors employ cardboard inserts to direct the air flow. At first glance, these inserts may seem insignificant, but be sure to install them on reassembly.

With very few exceptions, most projectors use a round rubber belt to drive the shutter mechanism. There are v-shaped pullies attached to both the motor shaft and the shutter-drive shaft. Normally the shutter-drive shaft speed is less than the motor speed, because the motor pulley is smaller than the shutter drive pulley, Fig. 15.

One variation of this shutter drive method is found on most Bell and Howell projectors. On these projectors, the drive belt does not drive the shutter drive shaft directly. The drive belt turns two rubber drive wheels and the wheels, in turn, drive the shutter disc. The shutter disc has a rim around its outer diameter that stands out from the plane of the shutter disc at a 90° angle. One of the drive wheels is positioned to ride on the inside of the rim while the other drive wheel is positioned to ride on the outside of the rim. Since both drive wheels rotate in the same direction, the two wheels drive the shutter disc in opposite directions.

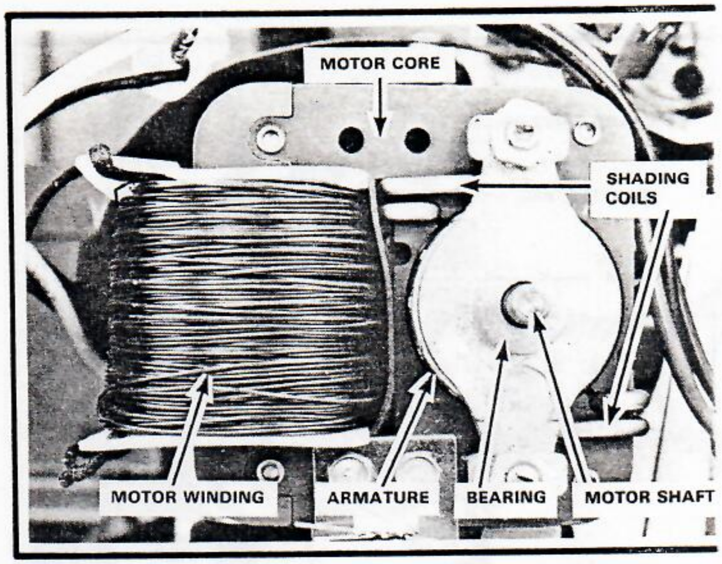


Figure 14

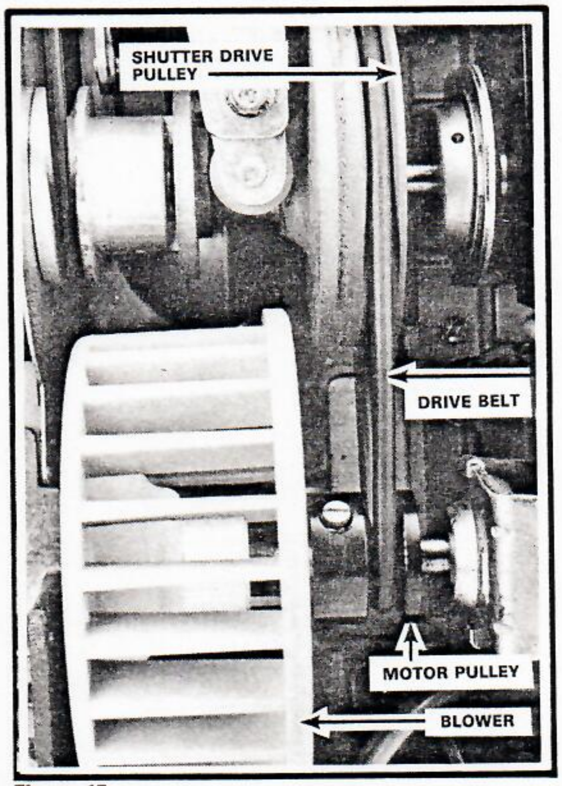


Figure 15

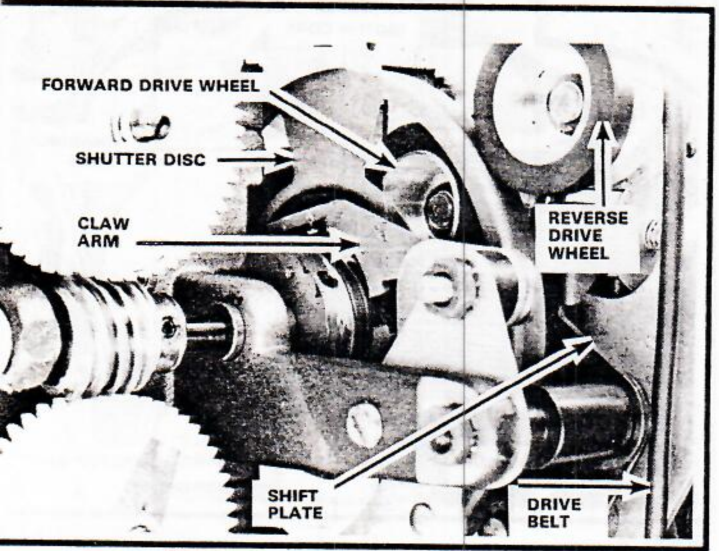


Figure 16

Fig. 16 shows the shutter drive mechanism in a Bell and Howell projector. The inner drive wheel is touching the shutter disc so the projector will run forward. If the outer drive wheel were touching the shutter disc, the projector would run in reverse. When neither drive wheel is touching the shutter disc, the shutter stops and the film is stationary. Both drive wheels are attached to the shift plate which is controlled by the shift lever.

When the shift lever is in its highest position, the shift plate is moved toward the back of the projector, which brings the inner drive wheel into contact with the shutter disc. When the shift lever is moved downward, the shift plate moves toward the front of the projector, bringing the outer drive wheel into contact with the shutter disc. When the shift lever is in the center position, neither drive wheel contacts the shutter disc.

Fujica chose a different technique to provide forward, still and reverse projection. The Fujica uses a universal motor and the phase of the current to the field winding is reversed to provide reverse projection. So the drive mechanism, itself, does not need to reverse -- the motor does that. But that still leaves still projection. Well, the drive belt does not drive the shutter-drive shaft directly; it drives the **intermediate shaft,** and the intermediate shaft drives the shutter-drive shaft through a clutch.

Fig. 17 shows the drive mechanism of the Fujica with the clutch engaged to drive the shutter. When the projector is set for still projection the **clutch disc** is pulled away from the **clutch plate.** The clutch plate is still rotating but the clutch disc is not. Fig. 18 shows the clutch disengaged for still projection. Comparing Fig. 17 with Fig. 18 you can also see the movement of the fire screen lever. It is not possible to shift to still without the fire screen moving into the light path.

Now that we know how the motor drives the shutter, we need to look at how the sprockets are driven. In most cases the sprockets are driven directly off a worm gear on the shutter-drive shaft. Gears are used instead of belts because there can be no slippage between the shutter and sprockets. Remember the sprockets and shutter must advance the film at precisely the same speed, or the loops will be lost.

Fig. 19 shows the worm and sprocket drive gears in a Bell and Howell projector that is typical of most sprocket drive mechanisms. Notice that the sprocket-drive gears are made in two sections. The inner section engages the worm gear and the outer section of the upper sprocket drive gear drives the large gear above it. This gear, the **main-wind gear,** drives the take-up and rewind mechanisms.

In Fig. 20 the main-wind gear is engaged with the take-up mechanism. When the projector is running in reverse, the torque from the upper sprocket drive gear moves the main-wind gear to the left into engagement with the rewind mechanism. This way the projector shifts from take-up to rewind whenever it is shifted from forward to reverse and vice versa.

Remember, earlier we mentioned that one of the requirements of the take-up and rewind mechanisms was that they pull the film in one direction but let the film move freely

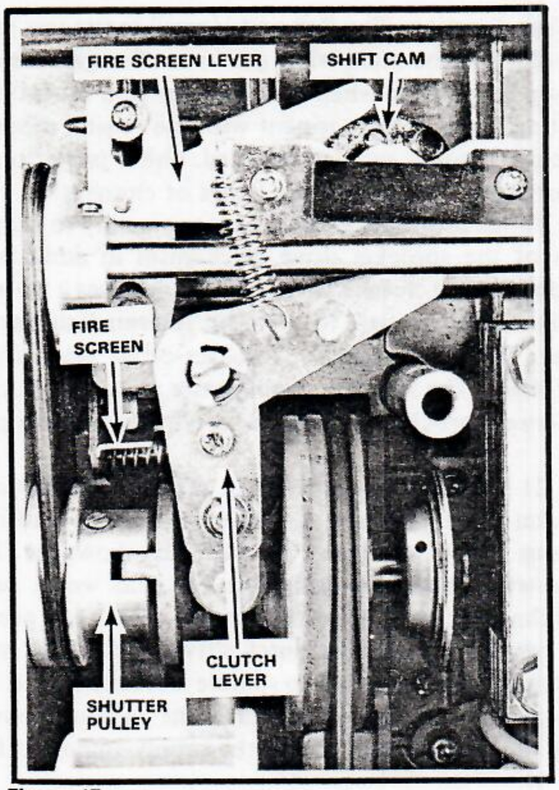


Figure 17

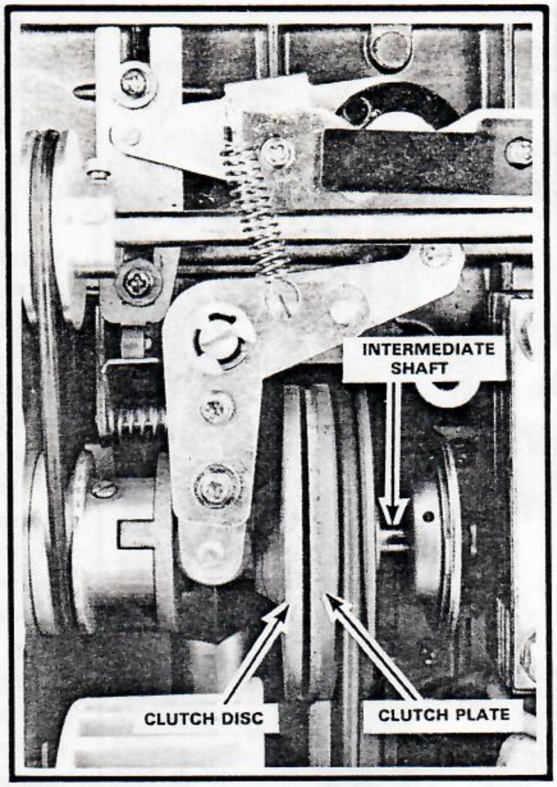


Figure 18

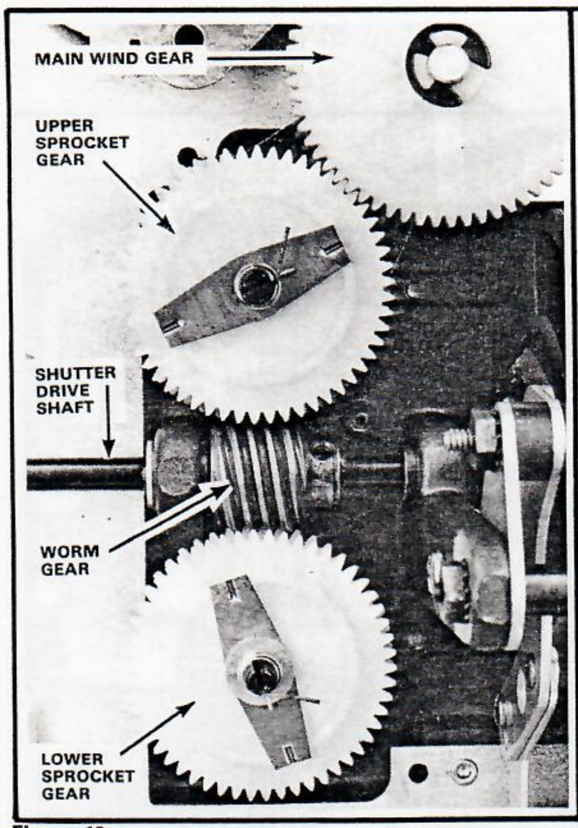


Figure 19

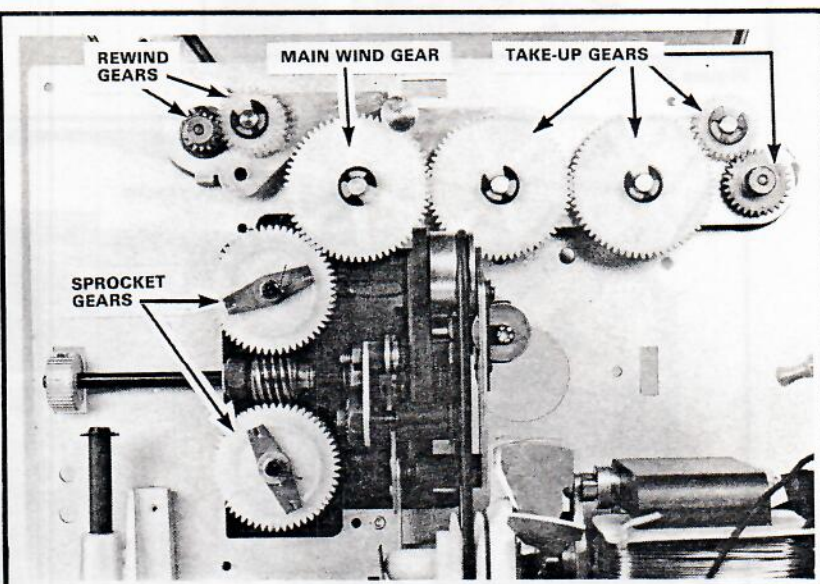


Figure 20

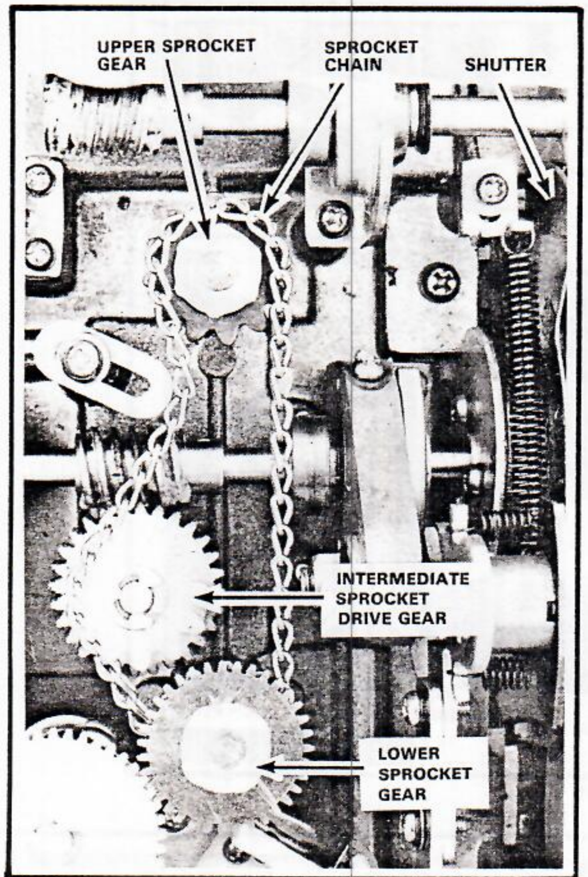


Figure 21

in the other direction. The Bell and Howell meets this requirement by shifting the main-wind gear out of engagement with the take-up mechanism when the projector is in rewind and by also shifting it out of engagement with the rewind mechanism when the projector is running forward. Other projectors meet this requirement by employing a series of clutches.

The Fujica projector gives us an opportunity to examine a variation of the sprocket drive mechanism in addition to a take-up and rewind clutch system. The Fujica uses a worm gear on the shutter drive shaft to drive an **intermediate sprocket-drive-gear.** The intermediate sprocket-drive gear drives a **sprocket chain.** The sprocket chain passes around both the upper and lower sprocket-drive gears, driving them with perfect timing.

Fig. 21 shows the sprocket drive mechanism. Notice that the sprocket drive gears do not drive the take-up and rewind mechanisms. These are driven by a belt, as shown in Fig. 22. The **main-wind shaft,** driven by the belt, has worm gears at each end that drive two one-way clutches. When the projector is set to rewind, the **rewind clutch** drives the rewind spindle (supply spindle), and the take-up spindle is free to rotate. When the projector is running in forward, the take-up spindle is driven by the take-up clutch, and the supply spindle is free to rotate.

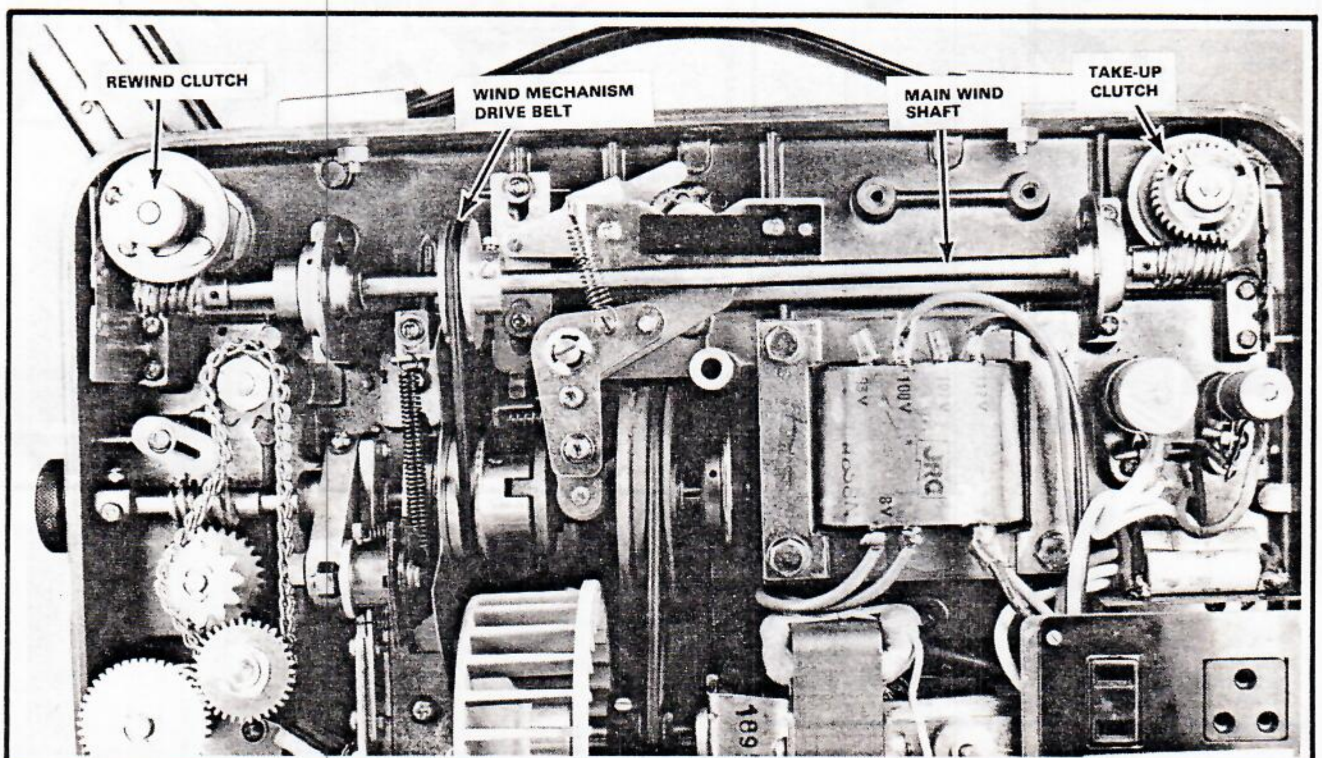


Figure 22

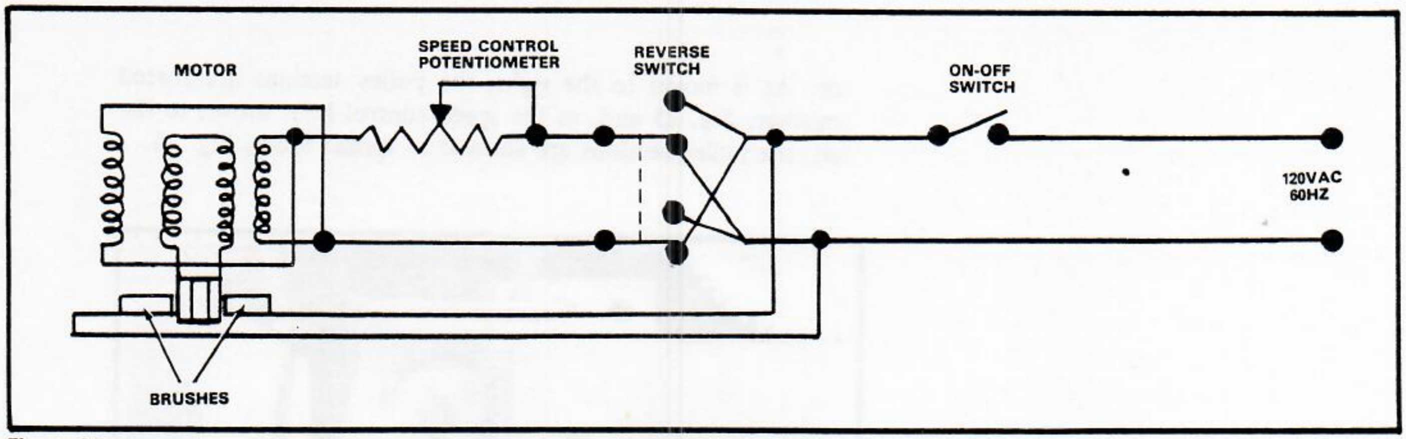


Figure 23

We mentioned earlier that there are two reasons why a manufacturer would want to use a universal motor. One is that the motor can be reversed. The other is that the speed of the motor can be varied by changing the current to the field winding. This second reason is what we will concern ourselves with now.

Fig. 23 shows how a projector could be wired to provide both reverse motor operation and variable speed control. Notice that the current to the brushes is constant in its polarity as well as its amount. The reverse switch can reverse the polarity of the field winding and the potentiometer can vary the amount of current to the field winding.

Since the motor draws between 1 and 1.5A when it is near full speed and the voltage is a full 115VAC, the potentiometer must be able to dissipate quite a large amount of power. The potentiometer used will probably be a large wire-wound type. Fig. 24 shows the potentiometer found in a Fujica projector that is typical of the type you will see.

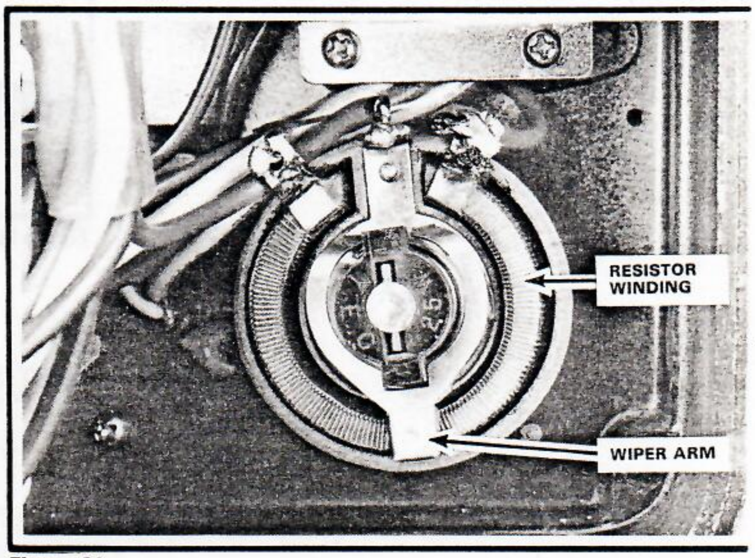


Figure 24

In most of their late model projectors, Bell and Howell uses a shaded-pole induction motor. On the models that feature variable speed control, they use a mechanical system to vary the speed of the shutter-drive shaft. The drive pulley on the motor shaft is split into two sections.

By varying the distance between the two sections you can change the width of the "V" in the pulley. As the two sections are brought together the "V" narrows -- causing the drive belt to ride higher on the pulley which effectively increases the pulley diameter. The tension of the belt on the pulley tries to force the two sections apart and, when this is allowed to happen, the belt rides deeper in the "V" of the pulley, effectively decreasing the pulley diameter. Increasing the pulley diameter increases the speed of the shutter drive shaft, while decreasing the pulley diameter decreases the speed of the shutter-drive shaft.

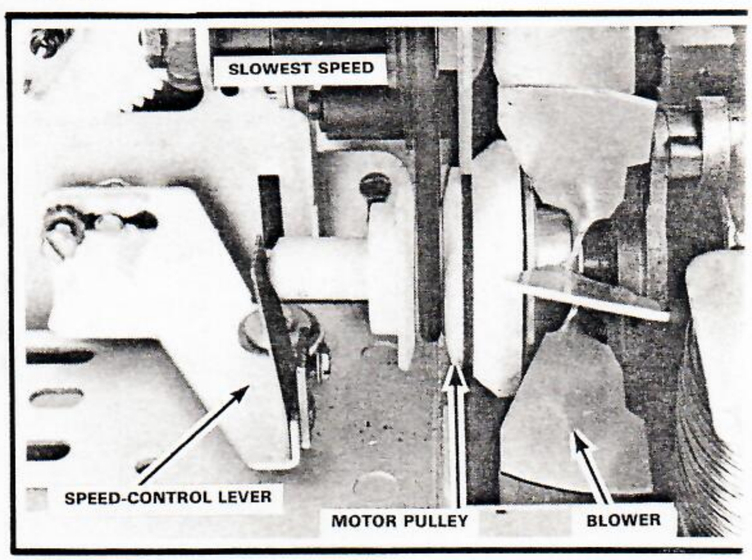


Figure 25

Fig. 25 shows the speed-control mechanism of a Bell and Howell projector. The **speed-control lever** is moved in the direction of the arrow by a screw control on the front of the projector. As it moves to the right, the pulley sections are forced together, Fig. 25 and, as the speed-control lever moves to the left, the pulley sections are allowed to spread apart, Fig. 26.

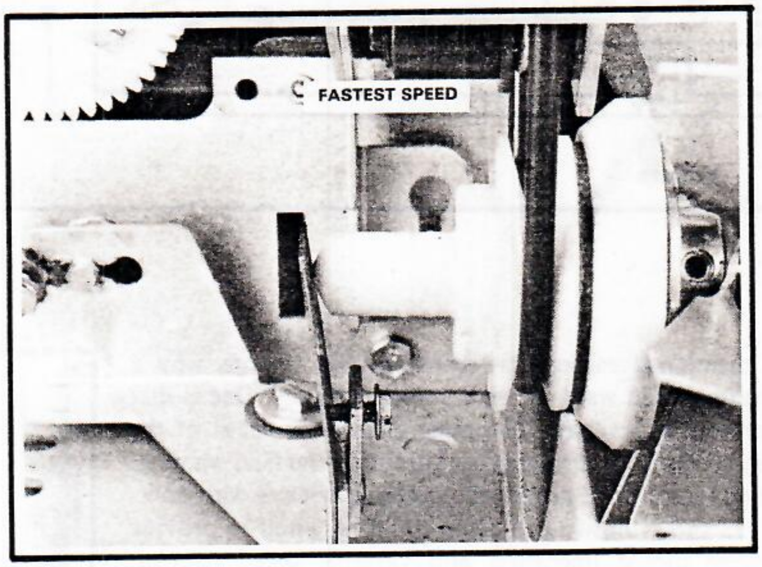


Figure 26

TEST YOURSELF QUIZ #3

1. The fire screen prevents the film from ___________ when the projector is set for ___________ projection.

2. If you are examining the motor in a projector and you notice that the motor has no brushes, it is probably a ___________.

3. Name two advantages of a universal motor.

4. On a Bell and Howell projector, the inner drive wheel is in contact with the shutter disc. The projector is set for ___________ projection.

5. The main wind gear on the Bell and Howell projector shifts position to provide both ________ and ________ action.

SUPER-8 AND REGULAR-8 COMPATIBLE PROJECTORS

When super-8 cameras were first introduced, many manufacturers made projectors that would accept both super-8 and regular-8 film formats, called **compatible projectors,** to ease the transition to the new format. To understand what changes need to be made in the projector so it can accept both formats, we need to examine the differences between the formats. The basic difference is the size of each frame.

Super-8 cameras have a larger film plane aperture and so expose more of the film on each frame. So, the first change the projector must make is in the area it projects. Compatible projectors have two different size aperture masks that can be switched into position behind the film gate.

The second change in super-8 film is due to the larger frame size. In order to fit the larger image on the film, the sprocket holes are made narrower and moved closer to the edge of the film during manufacturing. This means that the sprocket teeth on the projector need to be smaller for super-8 projection than for regular-8 projection. It also means the film claw must be smaller and closer to the edge of the guide track in the film gate. Many of the first compatible projectors made had an interchangeable set of sprockets: one set for super-8 and one set for regular-8. Moving the claw closer to the edge of the film is usually accomplished by shifting the pivot point of the claw arm.

Fig. 27 shows the aperture mask and claw movement when

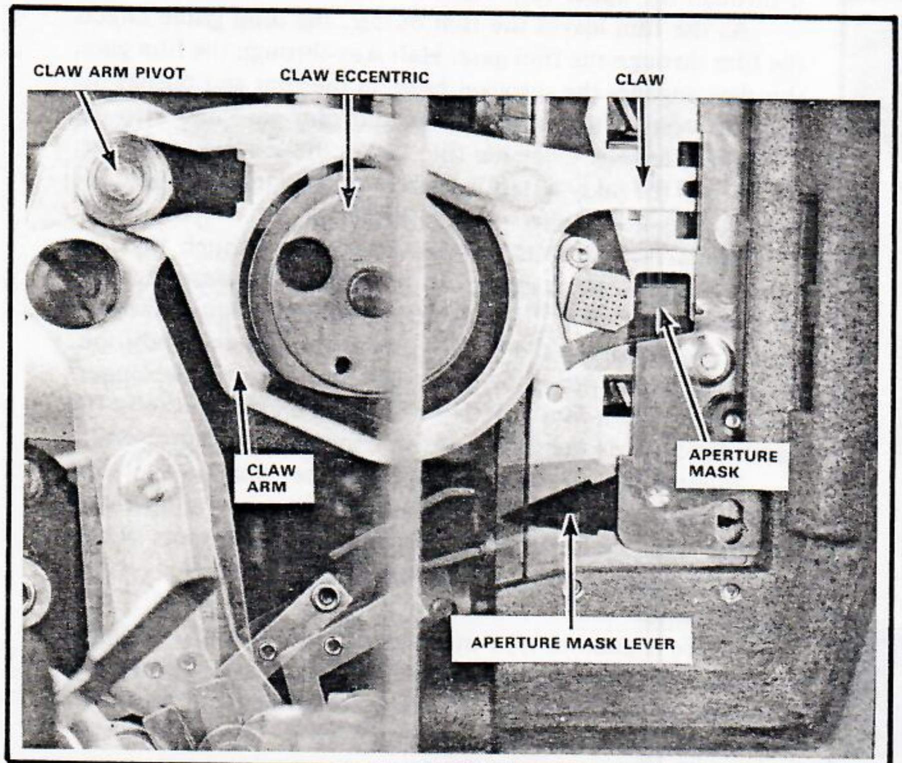


Figure 27

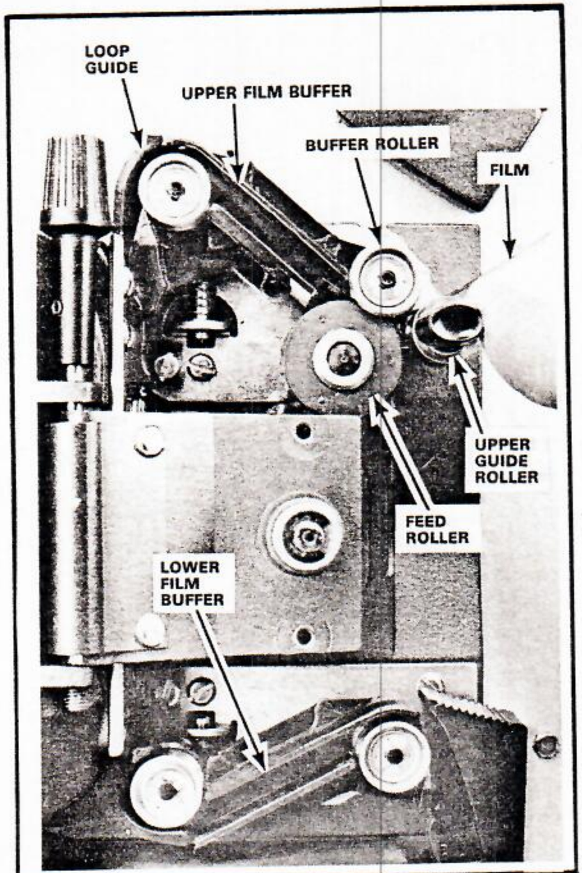


Figure 28

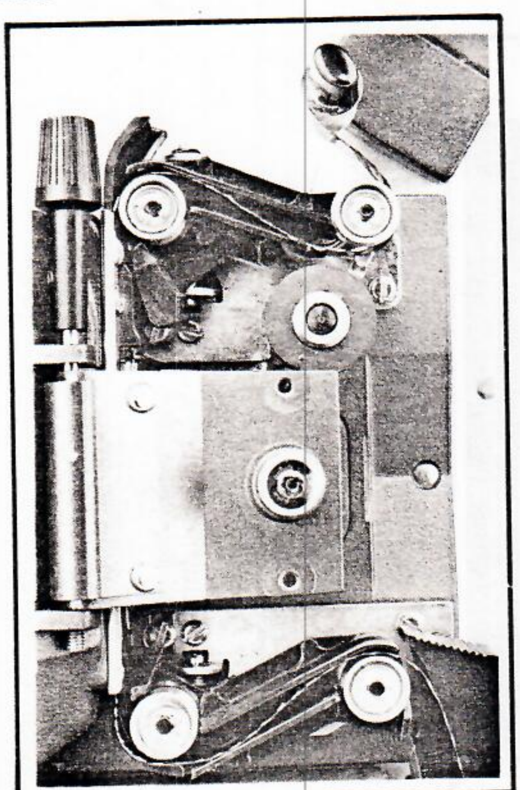


Figure 29

shifting a Bell and Howell projector from regular-8 to super-8. Notice that the projector does not change to a smaller claw but uses the same small claw for both formats. The projector simply moves the claw to the right for super-8 projection. You can also see the movement of the aperture mask.

As mentioned before, early models of compatible projectors used two sets of sprockets. This technique has been abandoned for newer techniques. Most late model compatible projectors do not use sprockets at all. They use either **rubber-drive** rollers in place of the sprockets or an arrangement of spring-loaded levers to isolate the intermittent movement of the film through the film gate.

The other changes in the compatible projector have to do with the film transport system. First, the take-up and supply spindles are usually the smaller, regular-8 size, and the take-up reel supplied with the projector is a regular-8 take-up reel. The projector is also supplied with an adapter that fits over the supply-reel spindle so that super-8 film reels will fit tightly.

As mentioned before, most compatible projectors do not use standard sprockets to transport the film. To understand how this type of transport system works, we will use a Bell and Howell projector as an example. This will also give you an opportunity to study a typical autoload system.

Moving the **upper-guide roller** into the threading position, Fig. 28, brings the **buffer roller** into contact with the rubber **feed roller.** To thread the projector, insert the film between the upper-guide roller and the buffer roller. The feed roller, which is driven off the shutter-drive shaft, grabs the film and pushes it through the **upper-film buffer.**

As the film leaves the film buffer, the **loop guide** directs the film through the film gate. Half way through the film gate, the claw engages the sprocket holes in the film and pushes the film the rest of the way through the film gate and into the **lower-film buffer.** Once the film leaves the lower-film buffer, the path to the take-up reel is nearly the same in the compatible projector as it is in the standard projector.

When the film has finished threading through the film gate, the upper-guide roller can be released because the claw will do all the work of transporting the film through the projector. Fig. 29 shows the upper-guide roller in the run position. Releasing the upper-guide roller has also released the upper-film buffer. Both film buffers pivot in the middle and serve the same function as the film loops in conventional projectors.

Eliminating the sprockets from the transport system makes the design of the compatible projector simple and reliable. You may even see this style of film-transport system on some single format projectors because it is so easy to manufacture.

There is another type of autoload system that is designed around a conventional transport using sprockets. This system amounts to nothing more than a set of guides that direct the film through the projector automatically. The guides even form the film loops. Fig. 30 shows the autoload system of a

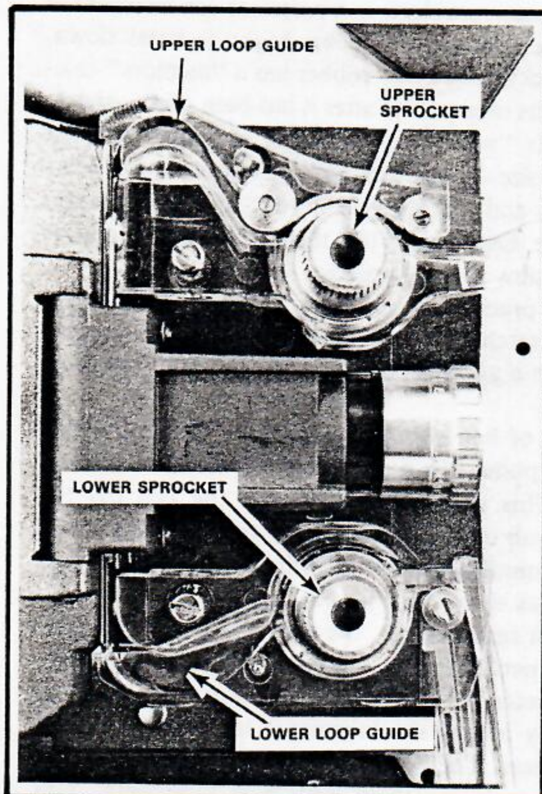


Figure 30

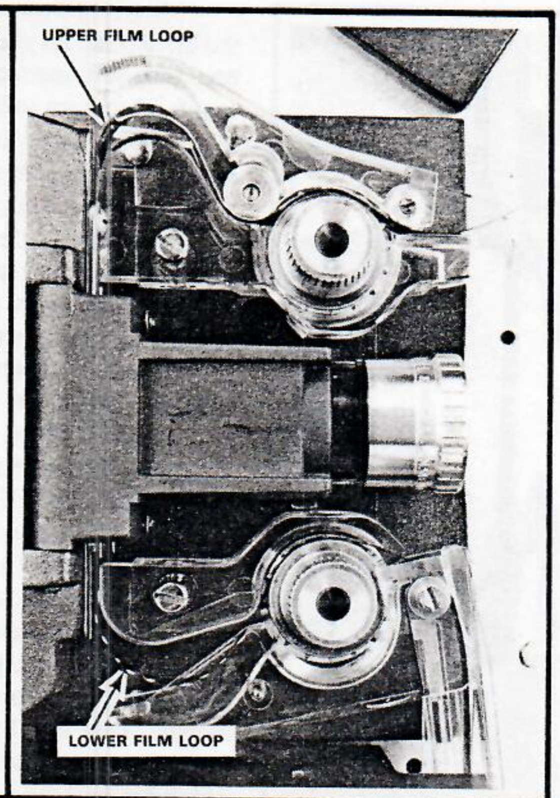


Figure 31

Bell and Howell ready for threading with the **loop guides** held in thread position. By holding the **upper-loop guide** down, the **lower-loop guide** is automatically pulled up. With the projector running, the film is fed into the upper sprocket, and the loop guides do the rest of the work.

The upper sprocket pushes the film through the upper film guide which directs the film down into the film gate. The claw then engages the sprocket holes, pushing the film on through the film gate and into the lower loop guide. The lower loop guide directs the film to the lower sprocket which pushes the film onto the guide rollers. Once the film has passed the lower sprocket, the loop guides can be released. This gives the loops the room to oscillate normally. Essentially the loop guides shape the loops during threading and have no effect during the regular running of the film. Fig. 31 shows the position of the film loops and loop guides during normal projection.

SERVICING THE MOVIE PROJECTOR

The most important step in your servicing procedure should be the test run before you begin any disassembly. If this can be done while the customer is present, by all means, do so. The test should consist of running a test film through the projector and operating every feature so you know all the problems before you begin work.

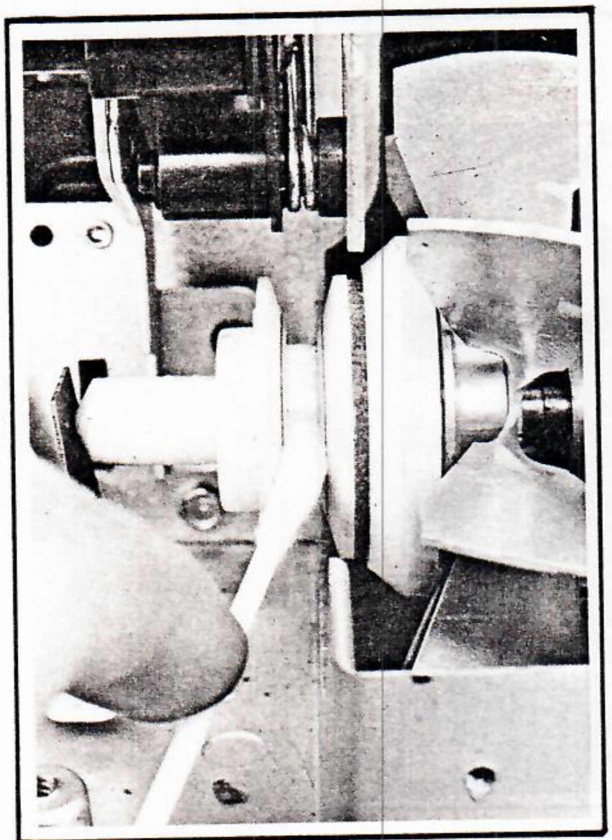


Figure 32

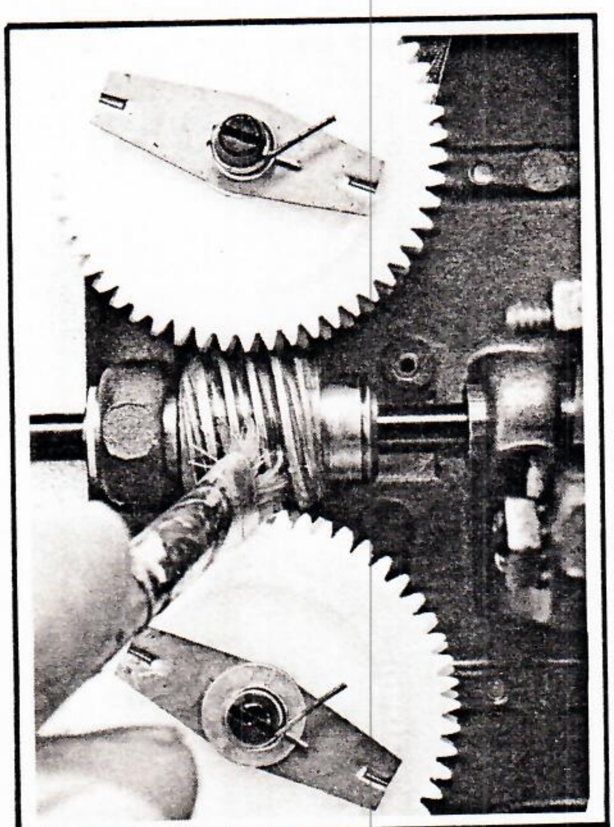


Figure 33

Most of the common problems in a projector can be traced to the drive belts. As the belts age, the rubber begins to break down, becoming soft and tacky. Good new rubber has a "memory" that causes it to return to its original size after it has been stretched out. Aged rubber loses its "memory" and when stretched, will not return to its original size. A belt that has aged beyond usefulness will stretch very easily and contract very slowly, never quite returning to its original size. Obviously a belt that has become too large will cause erratic or slow running speeds.

A good shop practice is to replace any belt that you suspect of having stretched. Most drive belts are very inexpensive so you can keep a good supply on hand for the projectors you see most often.

Another cause of belt slippage is dirty or greasy pulleys. Cleaning the drive pulleys in a projector should be a part of every repair job. This should be done with the belt off the pulley. A cotton swab dipped in alcohol works very well. The tip of the swab is small enough to reach even to the deepest part of the pulley, as shown in Fig. 32.

Aside from belt replacement, the next most common projector repair is a general cleaning. Often a customer will complain that the projector is too noisy and runs erratically or slowly. This usually means the lubricants have oxidized and become almost useless. The repair consists of cleaning out all old lubricants and replacing them with new lubricants. You should already be familiar with cleaning solvents and techniques for cleaning smaller mechanisms; however, there are other procedures that work very well with larger mechanisms such as projectors.

Fig. 33 shows the wind gears of a projector being cleaned with a stiff short-bristle artist's brush. This technique assures that the valleys between the teeth are just as clean as the rest of the gear.

Figure 34 shows the same brush being used to apply a light grease to the sprocket-drive-worm gear. Here again the grease will be forced into the gear by the bristles on the brush.

Most manufacturers supply a lubrication chart for their projectors in their service manuals. Whenever possible, this chart should be followed; however, you can use the following list as a guide to lubrication when the manufacturer's recommendations are unavailable.

Use a light, all-temperature grease on these points:

- Claw Cams
- Claw Eccentrics
- Worm Gears
- Screw-type speed and frame controls
- All Metal Gears

Use a heavy to medium weight machine oil on these points:

- Shutter-Drive Shafts
- Motor Shafts
- Gear Shafts
- Drive-Wheel Shafts
- Sprocket Shafts
- All Pivot Points

Use only plastic-safe greases and oils on plastic gears. Always use lubricants sparingly. Too much grease on a part that rotates at high speed will only be flung off and probably land somewhere it shouldn't.

Cleaning the film gate is also a very important step in any cleaning procedure. Using a cotton swab dipped in alcohol, as shown in Fig. 35, will remove any build-up of residue in the film gate. Nothing is more disappointing than seeing a favorite film scratched through its entire length by a small piece of grit in the film gate.

Induction-type motors require no service other than occasional oiling of the bearings. Universal motors require regular cleaning of the comutator and inspection of the brushes as well as bearing lubrication. Cleaning of the comutator can be done with a cottom swab and alcohol as shown in Fig. 36. If after

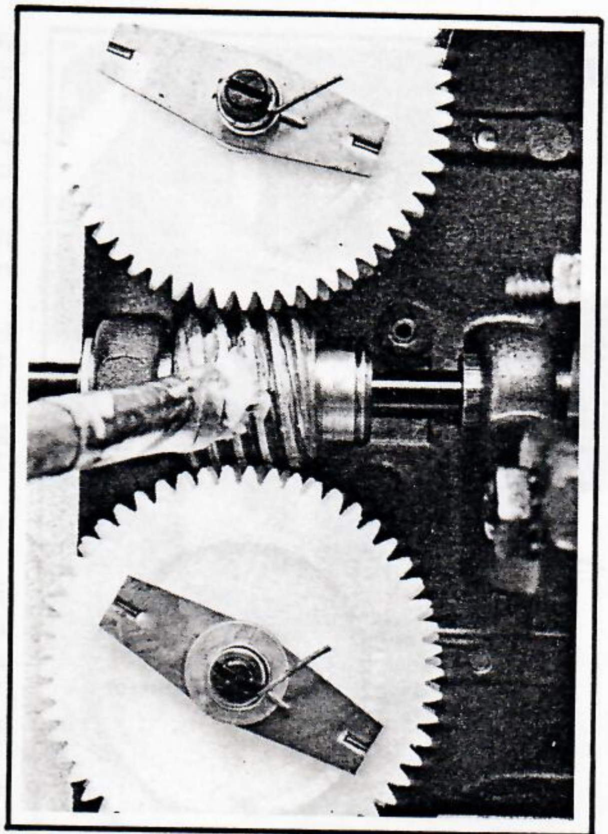


Figure 34

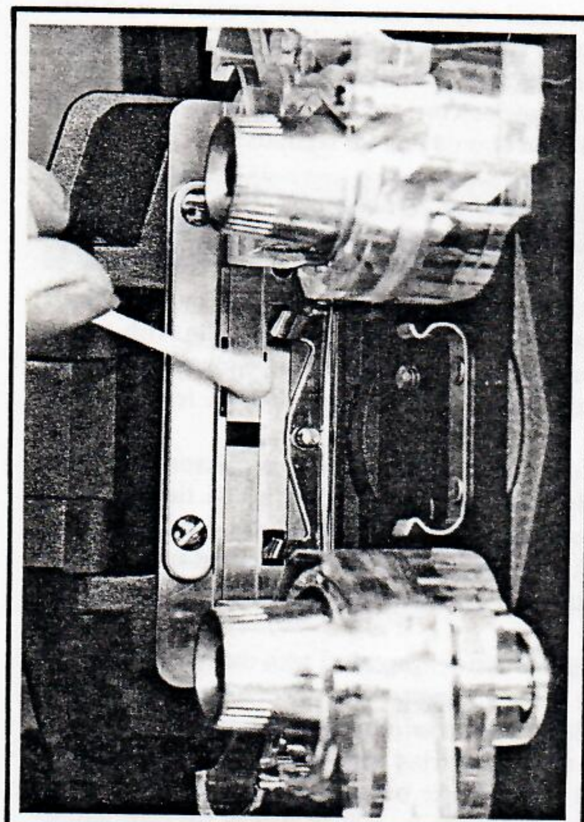


Figure 35

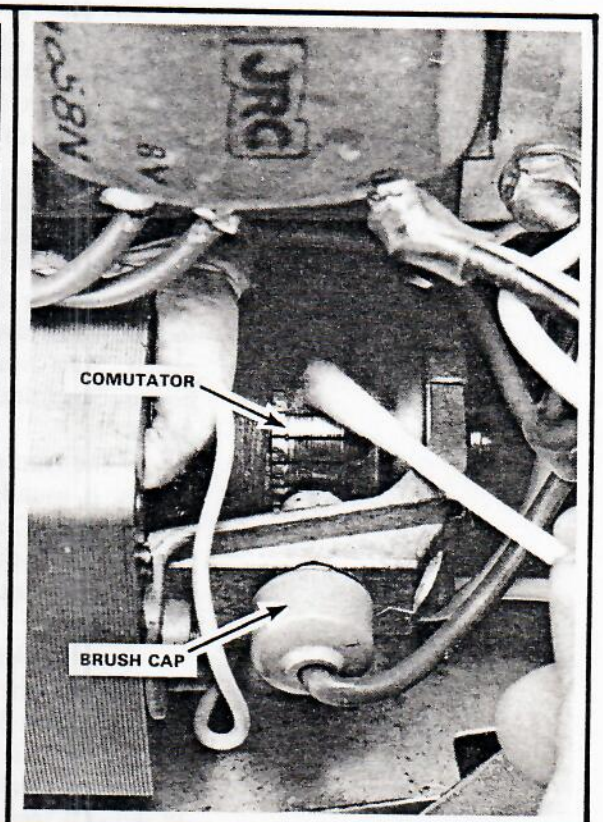


Figure 36

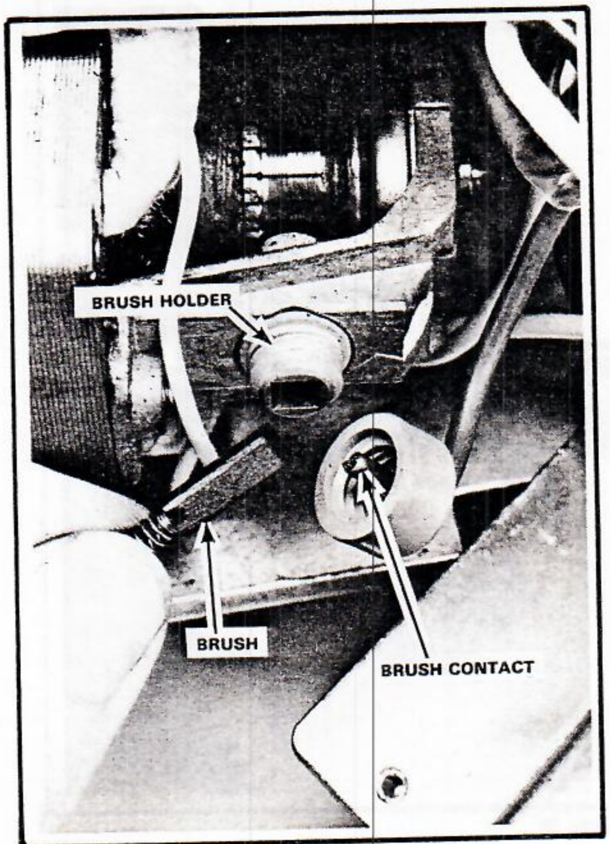


Figure 37

cleaning you can see grooves all the way around the comutator, it may be necessary to polish it with very fine emery or crocus cloth. Do not attempt this if the grooves are very deep. The diameter of the comutator and the width of each contact are critical to the motor operation. Reducing the diameter of the comutator too much will ruin the motor. The purpose of polishing the comutator is simply to smooth the surface to reduce brush wear.

The brushes on most universal motors are easily accessible. Fig. 37 shows the brush assembly on a Fujica projector. The brush cap simply unscrews and the brush and its spring can be pulled out for inspection. The brush itself is made of graphite and should be replaced when it wears down to about 3/16 of an inch.

TESTING AND ADJUSTING

There are many different techniques for testing and adjusting a movie projector. Most manufacturers have claw depth gages to measure claw engagement depth. You can use an electronic tester to check framing rate and shutter speed. You can even purchase a tester that measures the slip clutch tension on the take-up and rewind reels. You may choose to get very elaborate in your testing procedure, but keep in mind what the projector is supposed to do. Generally, if the image that the projector creates when showing a film is pleasing to you, it will be pleasing to your customer.

The most practical way to test a movie projector is to turn a film. If you use a film of a predetermined length, you can calculate the framing rate by timing how long the film runs. Super-8 has six frames per inch or 72 frames per foot. At 18 FPS, five feet of film should run 20 seconds.

5 ft. x 72 frames/ft = 360 frames
360 frames ÷ 18 FPS = 20 seconds

By cutting a piece of film to exactly 5 feet and splicing 2 feet of leader on each end, you can time the film with a stop watch. Start timing as soon as the leader ends and the film begins. Stop timing when the film ends and the leader begins again.

If the framing rate is incorrect on a projector with fixed speeds, it usually indicates some extra drag on the motor or belt slippage. On projectors with continuously variable speeds, the user adjusts the speed himself, so the nominal speed for the film format should just be near the middle of the speed adjustment control.

Since the depth of claw engagement with the film is set by the claw cam and the shape of the claw arm, there is rarely any need to adjust the claw depth. On most projectors the only way to adjust the claw depth is to bend the claw arm. Some manufacturers even provide a special tool to make bending the claw arm easier. Fig. 38 shows a special tool made by Bell & Howell for claw adjustment. This is just one example of the many special tools available from manufacturers to speed up repair work on their equipment. If you find yourself working on a large number of projectors of the same make, you may want to check into what tools are available from the manufacturer.

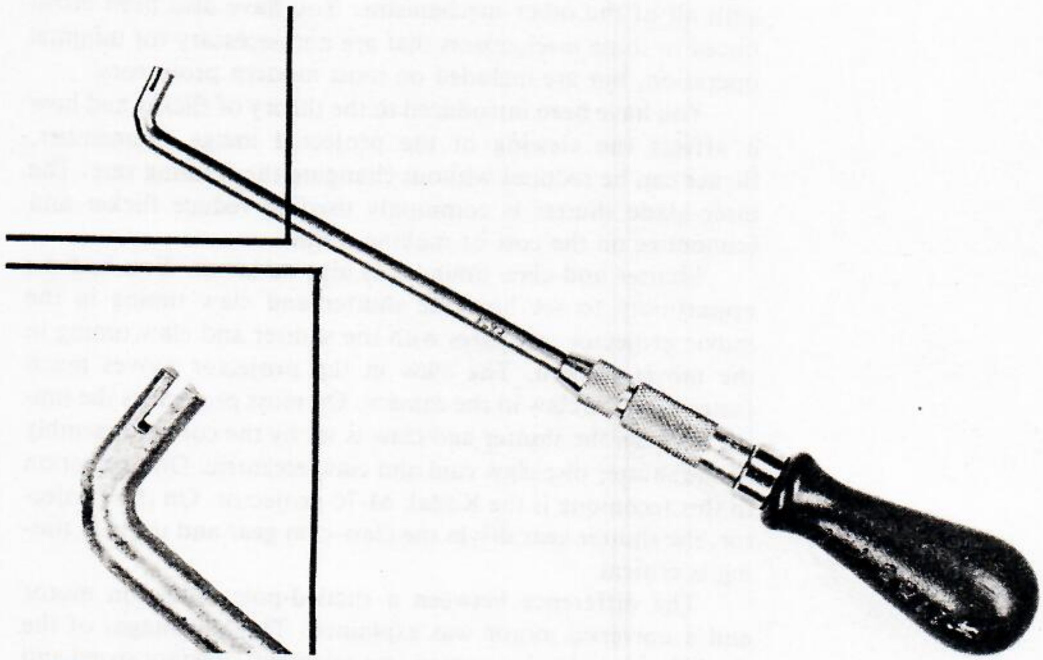


Figure 38

TEST YOURSELF QUIZ #4

1. Which of the following is **not** a difference between super-8 and regular-8 films?
   a. Image size
   b. Sprocket hole size
   c. Overall film width
   d. Spacing between frames (frame line width)

2. The Bell & Howell Autoload projector uses the ______________ and the ______________, instead of film loops, to isolate the intermittent movement of the film through the film gate.

3. Most of the common problems in a projector can be traced to the ______________.

4. Which of the following is not a proper lubrication point?
   a. Claw Cams
   b. Motor Brushes
   c. Worm Gears
   d. Motor Shafts

5. A super-8 projector was timed when running a 7-foot strip of test film. The film ran for 34 seconds. Was the projector running too fast or too slow?

SUMMARY

SUMMARY

In this assignment, you have covered the basic elements necessary for the operation of a movie projector. Each of the basic elements must meet certain conditions and synchronize with all of the other mechanisms. You have also been introduced to some mechanisms that are not necessary for minimal operation, but are included on most modern projectors.

You have been introduced to the theory of flicker and how it affects the viewing of the projected image. Remember, flicker can be reduced without changing the framing rate. The three-blade shutter is commonly used to reduce flicker and economize on the cost of making a film.

Shutter and claw timing was also reviewed. You had the opportunity to see how the shutter and claw timing in the movie projector compares with the shutter and claw timing in the movie camera. The claw in the projector moves much faster than the claw in the camera. On most projectors the timing between the shutter and claw is set by the correct assembly of the shutter disc claw cam and claw eccentric. One exception to this technique is the Kodak M-70 projector. On this projector, the shutter gear drives the claw-cam gear and the gear timing is critical.

The difference between a shaded-pole induction motor and a universal motor was explained. The advantages of the shaded pole induction motor are; relatively constant speed and low maintenance. The advantages of the universal motor are: electrically controllable speed and the ability to reverse direction. The universal motor requires periodic brush replacement and comutator cleaning for efficient operation.

The optical system is designed to provide the brightest possible projected image while protecting the film from heat damage. Filament position, reflector position and fire screen operation are all important parts of the optical system. The fire screen protects the film when the film is still, and the movement of the film itself prevents the film from burning during forward and reverse projection.

The rubber drive belt is a key to proper operation of the projector. If the belt has aged, it becomes soft and tacky and a replacement is called for. Belt slippage can also be caused by dirty or greasy pulleys. Cleanliness and proper lubrication of the entire transport system is essential for a consistant projection speed.

Testing the movie projector can be simplified by keeping in mind that the purpose of the projector is to create the illusion of motion. If the projected image is pleasing to you, it will probably be pleasing to your customer.

ANSWERS TO TEST YOURSELF QUIZZES

A N S W E R S

QUIZ #1

1. Supply Reel
   Sprockets
   Claw
   Lens
   Shutter
   Take-up Reel
   Film Gate
   Lamp
   Motor

2. Pressure Plate

3. False

4. Emulsion Side

QUIZ #2

1. C The length of the dark time between each projection.

2. Divide

3. Claw Cam

4. Three

5. Claw cam gear; claw eccentric

QUIZ #3

1. Burning; still

2. Shaded-pole induction motor

3. The universal motor is electrically reversible and its speed can be varied electrically over a wide range.

4. Forward

5. Take-up; rewind

QUIZ #4

1. C Overall Film Width

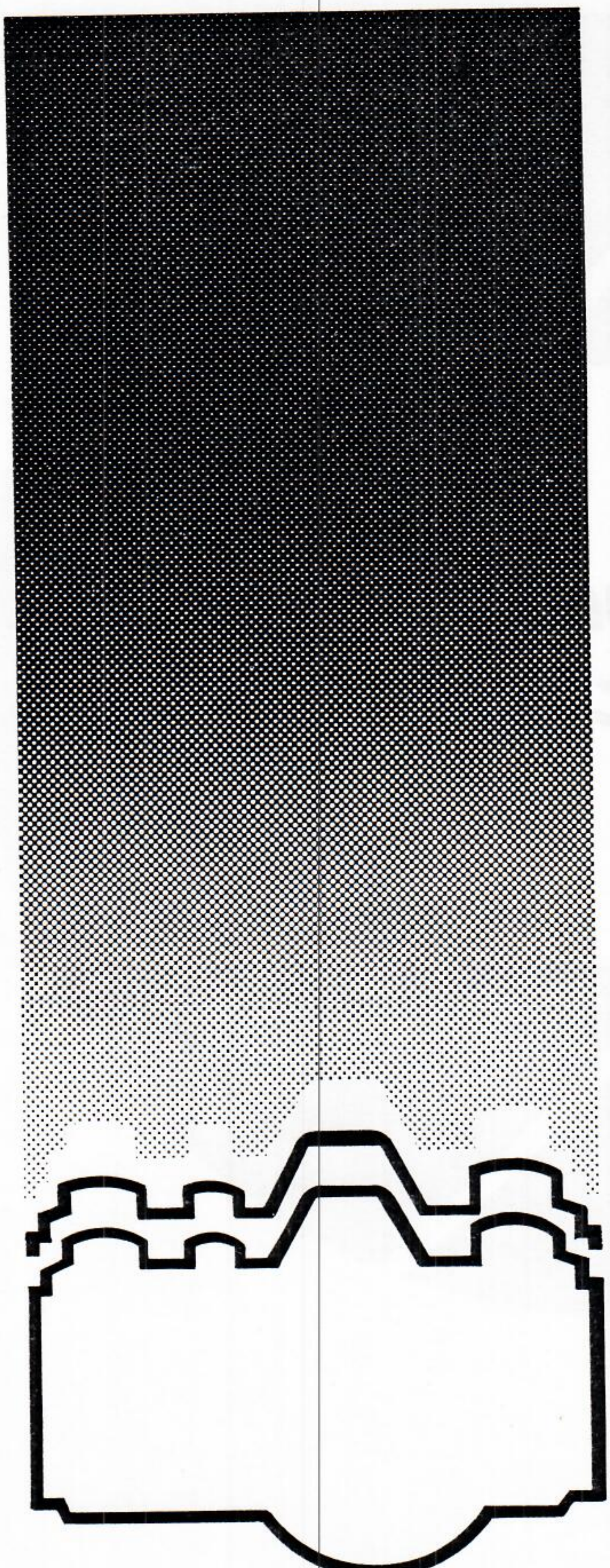
2. Upper Film Buffer & Lower Film Buffer

3. Rubber Drive Belt

4. B Motor Brushes

5. Too slow

Sound Projectors



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Sound Projectors

contents

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Sound Projectors

TRANSPORT SYSTEM IN THE SOUND PROJECTOR

The sound-motion-picture projector uses the same principles of operation to transport the film and shutter as the silent projector. However, the sound projector adds a tape head and amplifier for reproducing the recorded signal on the magnetic stripe. Just as in the sound-motion-picture camera, controlling the speed of the film passing the tape head is important in the projector as well. There are many variations between manufacturers for controlling the film speed, but most systems incorporate a capstan and flywheel. Many projectors feature recording capabilities as well. We will cover how each of these systems works including some of the more common variations.

Fig. 1 shows the film path of the Kodak Ektasound Projector. The **upper film loop** is created by passing the film over the **loop lever.** The loop lever is spring loaded and is used to maintain the loop because the projector does not use an upper sprocket. The film then passes through the film gate, past the **loop sensor,** over the record head, and between the capstan and roller. The lower loop size is maintained by varying the speed of the shutter and claw, while the speed of the capstan remains constant. The loop sensor is spring loaded to follow the contour of the lower loop. If the loop is too small, the loop sensor moves upward and causes the **speed-control mechanism** to speed up the shutter. This increases the size of the loop. If the loop is too large,the loop sensor moves downward and the speed control mechanism slows down the shutter.

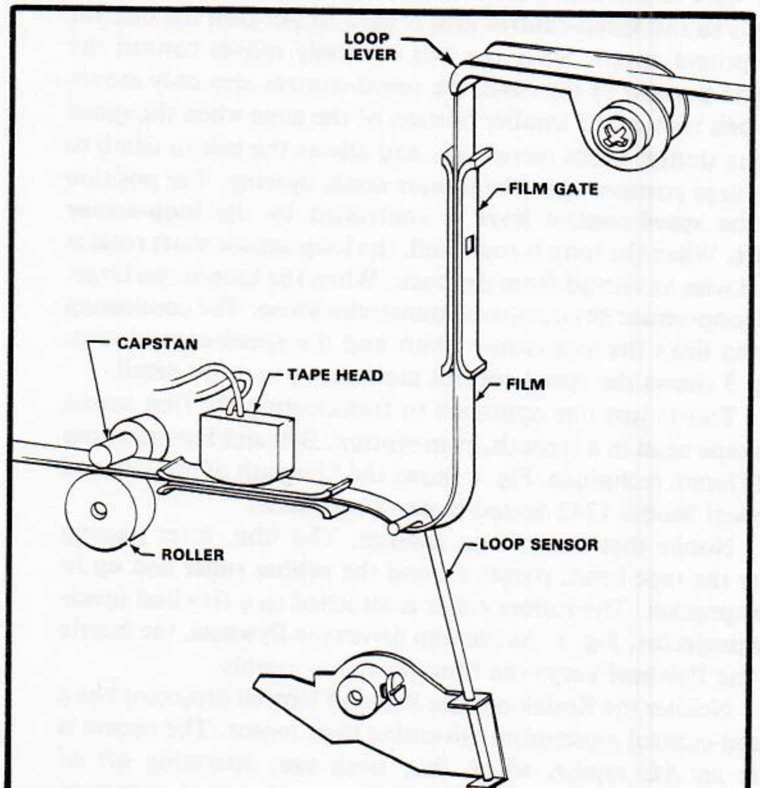

Figure 1

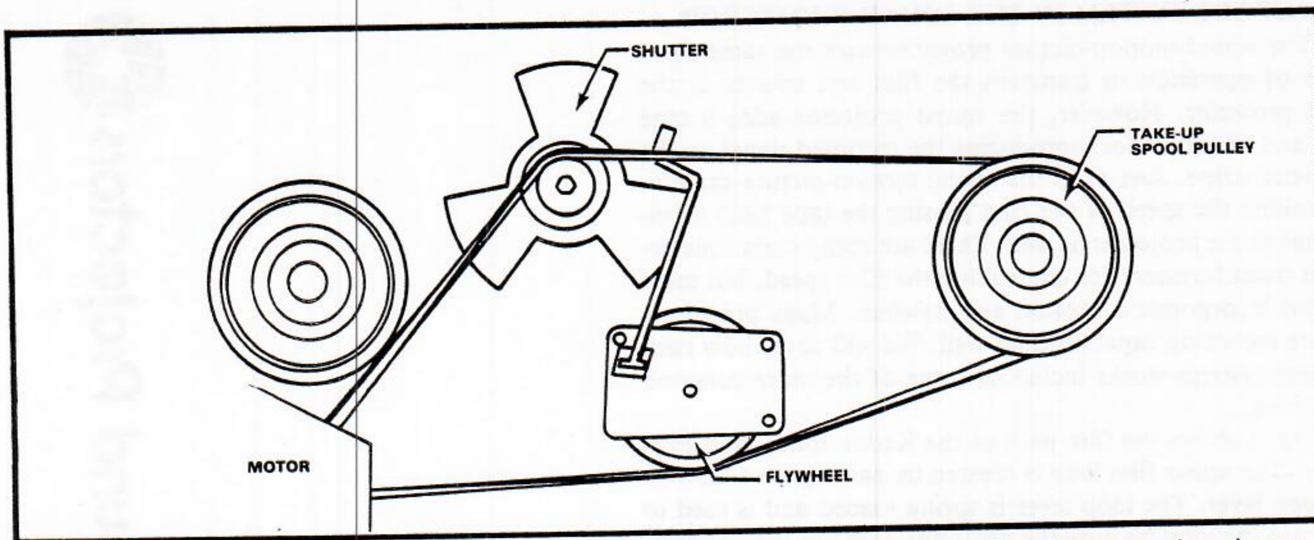

Figure 2

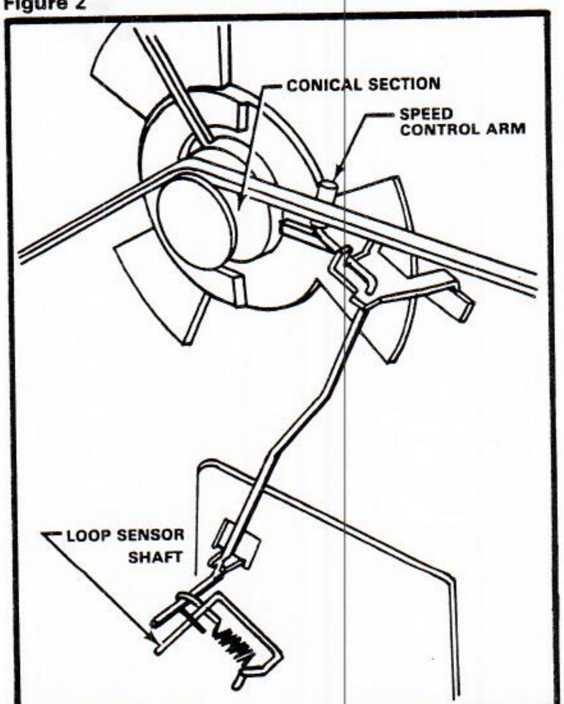

Figure 3

Fig. 2 shows the mechanism of the Ektasound projector. As the drive belt passes along the bottom of the projector, it rides against the edge of the flywheel driving it at a constant speed. The belt then passes around the take-up spool pulley, over to the shutter and back to the motor pulley. The section of the plastic shutter casting that the belt rides on is conical. This means that by changing the portion of the cone that the belt rides on will change the speed of the shutter rotation. Because of the twist of the belt, it will climb to the largest portion of the cone. This is the position that gives the slowest speed. If the belt were left in that position, the loop would continually expand, so the **speed-control arm** is used to position the belt for the proper speed. Since the belt naturally moves toward the largest portion of the cone, the speed-control arm only moves the belt toward the smaller portion of the cone when the speed of the shutter needs increasing, and allows the belt to climb to the large portion when the shutter needs slowing. The position of the **speed-control lever** is controlled by the **loop-sensor shaft.** When the loop is too small, the loop-sensor shaft rotates clockwise as viewed from the back. When the loop is too large, the loop-sensor shaft rotates counterclockwise. The connecting spring links the loop-sensor shaft and the speed-control arm. Fig. 3 shows the speed-control mechanism in more detail.

This is just one approach to transporting the film across the tape head in a smooth, even motion. Bell and Howell chose a different technique. Fig. 4 shows the film path of the Bell and Howell Model 1742 Sound Super-8 projector.

Notice that there is no capstan. The film, after passing over the tape head, passes around the **rubber roller** and up to the sprocket. The rubber roller is attached to a flywheel inside the projector, Fig. 5. As the film drives the flywheel, the inertia of the flywheel keeps the film moving smoothly.

Neither the Kodak nor the Bell and Howell projector has a speed-control mechanism governing their motor. The reason is that an **AC motor,** which they both use, operating off of household line current is not subject to wide speed variations due to decreasing battery current as the DC motor in a portable

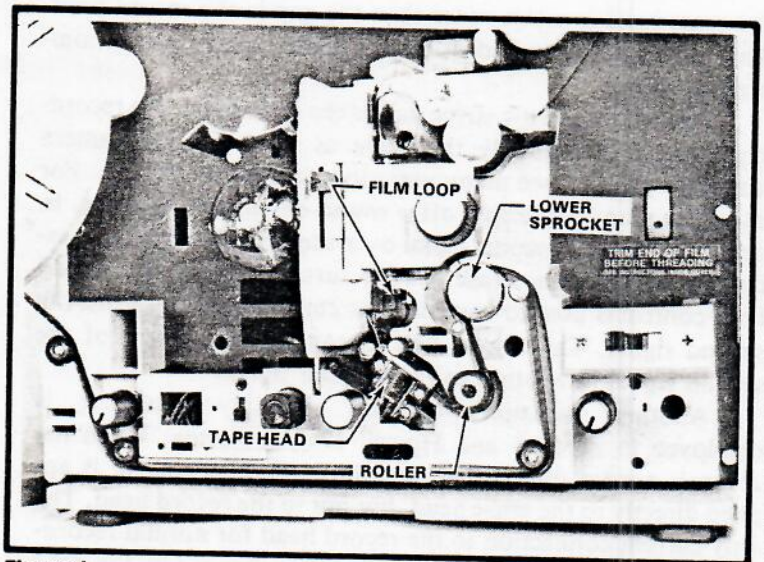

Figure 4

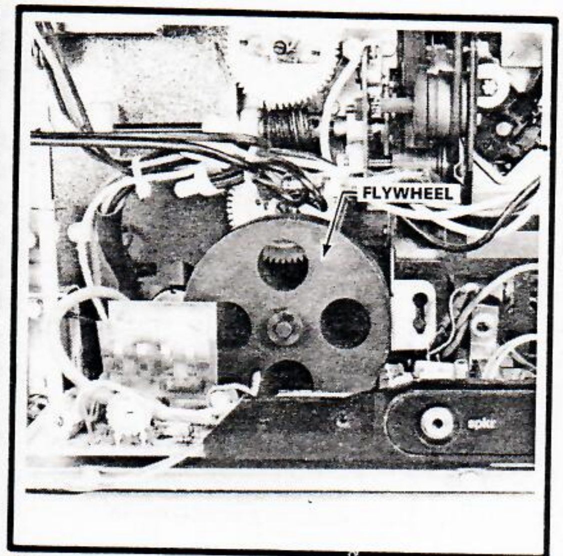

Figure 5

camera is. Another reason an AC motor will have a more consistent speed than a DC motor is the 60 Hz line frequency. This frequency tends to have a synchronizing effect on the motor speed. Although the speed will vary with the load, with a constant load like you have on a projector the line frequency will stabilize the motor speed.

Although the speed control in the projector is less critical than in the camera, there will always be some mechanism for providing a smooth even flow of film past the tape head.

THE TAPE HEAD

The tape head is actually three heads in one. The projector uses the same pole piece for both record and playback. This is a fairly common practice in most inexpensive tape recorders.

However, most regular tape recorders have a separate **erase head,** whereas it is common to see the erase and record/playback heads in the same housing on an 8mm sound projector, Fig. 6. The erase head is used when a new recording is being made. It clears the tape of any previous signal so the record head has clear tape to magnetize. Without an erase head you might hear an old recording along with the new one. A permanent magnet can be used to erase the tape as well; however, the permanent magnet is always "on" where the erase head can be turned off to reduce the possibility of accidental erasure during playback.

The bias signal that is applied to the erase head is the same that is applied to the record head; however, the bias current through the erase head is 10 times the bias current through the record head, and the magnetic field generated is proportionally higher on the erase head.

The sound super-8 cameras you studied previously did not have an erase head because the film cartridge comes fresh from the factory without any signal on the magnetic stripe.

Fig. 7 shows the position of the erase and record heads in relation to the direction of film travel. Notice that the gap in

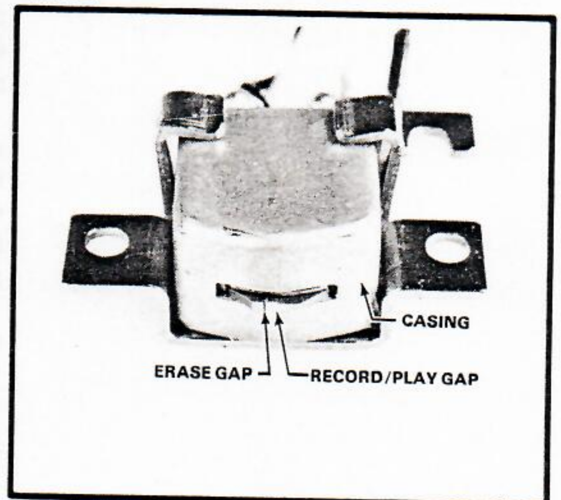

Figure 6

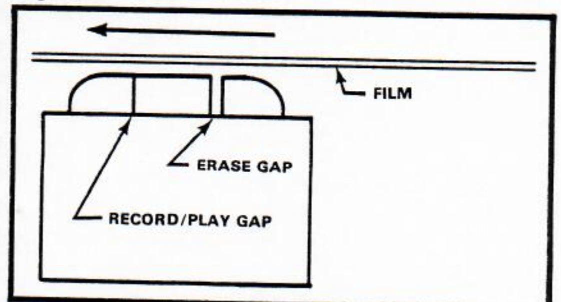

Figure 7

the erase head is much wider than the gap in the record head. This increases the spread of the magnetic field to insure complete erasure.

Once the magnetic stripe passes the erase head, the recording process is generally the same as in the sound camera although you will see many variations in specific circuits. For example; many projectors offer **sound-on-sound recording.** In order to record a second signal over the original without erasing the original, the erase head is turned off and the record level control is used to vary the bias current used to record the second signal. This allows you to control the volume of the second signal in relation to the original signal.

Another variation you will probably encounter is employed in the Bell and Howell 1742 projector. When the controls are set for normal recording, the bias current is applied directly to the erase head but not to the record head. The only current connection to the record head for normal recording is the audio signal. The bias current is induced by the close physical proximity of the erase pole to the record pole. This **inductive coupling** is the same phenomenon that makes transformers possible.

When the Bell and Howell projector is set for sound-on-sound recording, the bias signal is mixed with the audio signal in the circuit so that the level of the bias current can be controlled. In addition, there is no bias current in the erase head to induce a current in the record head. A detailed discussion of sound-on-sound recording will follow later in this text.

The dotted line around the heads in Fig. 8 indicates that the heads are **shielded.** This is to eliminate extraneous noise from the record or playback circuit. If the shielding is faulty, the most common problem is a 60 Hz hum heard over the speaker, caused by the strong magnetic field generated by the motor being picked up by the head.

When the projector is set to record, the record/playback head is disconnected from the input of the preamplifier and the external record inputs are hooked into the preamplifier. The external record inputs are a microphone jack and an auxiliary jack for recording directly from another source such as a phonograph or tape recorder. The microphone input is fed directly into the preamplifier, but the auxiliary input is fed through a dropping resistor. This is because most microphones have a very small signal, generally in the millivolt range, but the signal from a phonograph will have a much larger signal of several volts or more.

TEST YOURSELF QUIZ #1

1. On the Kodak Ektasound 245 the loop sensor causes the shutter to __________ when the loop is too small.

2. Most sound projectors have no speed control governing their drive motors because of the synchronizing effect of the __________.

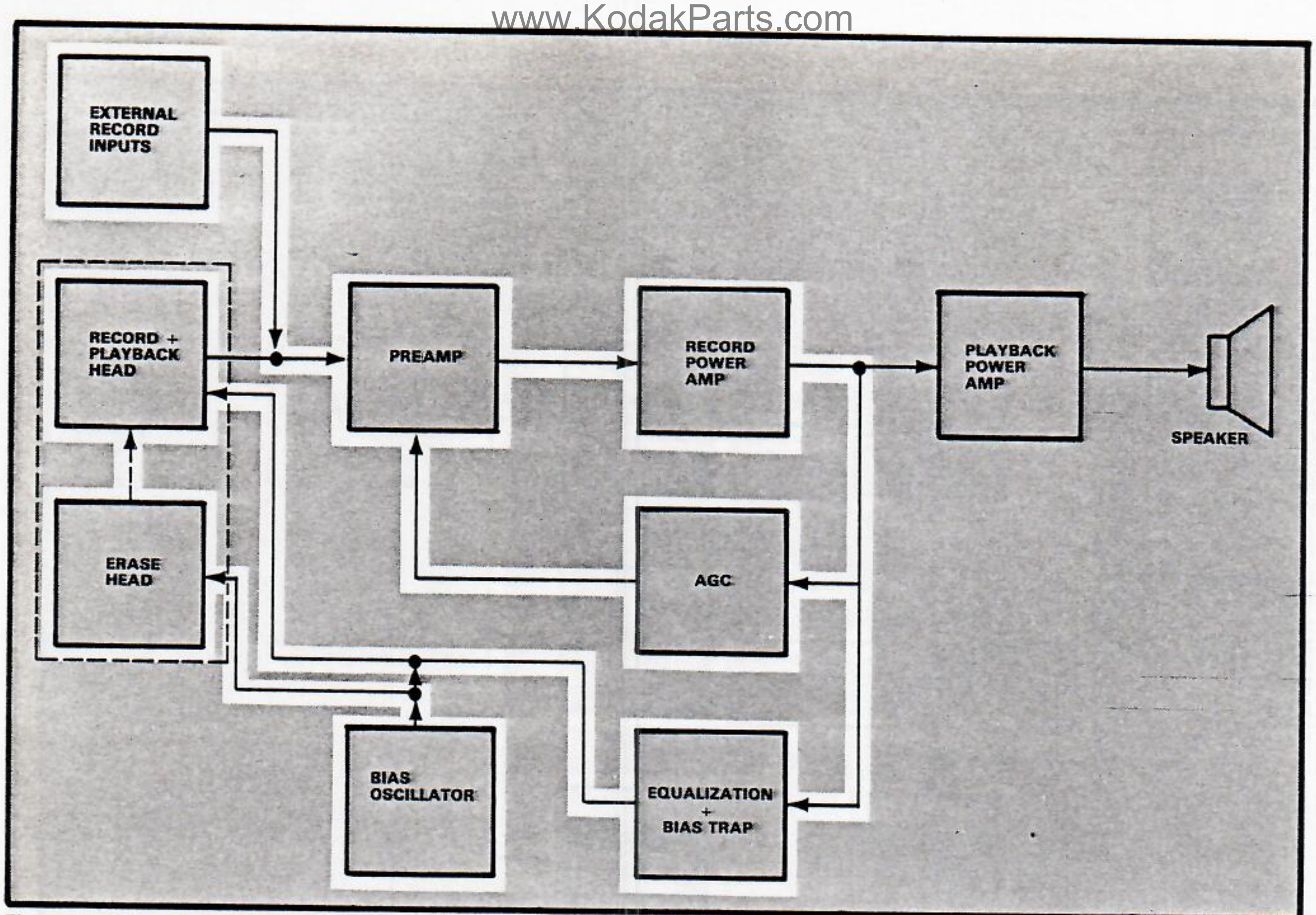

Figure 8 Regular Recording

3. When the Bell and Howell 1742 is set for normal recording the bias signal is transferred to the record head by __________.

4. The tape head on the Bell and Howell 1742 has two pole gaps. Which gap is larger? __________

THE AMPLIFIER

Fig. 8 shows a block diagram of the circuit in the Bell and Howell 1742 projector. Drawing the functional blocks as we have done here can aid you in diagnosing a problem in the circuit. Any circuit can be broken down this way. The Bell and Howell 1742 circuit has all the basic functional blocks that you will find in any sound projector, although you will see many sound projectors with more complex circuitry, such as stereo.

When the projector is set for recording, the signal flows through the circuit as shown in Fig. 8. The signal plugged into the external record jacks is fed to the preamp. If you were to apply 400 Hz signal of 1V peak to peak to the auxiliary input with the AGC off, the signal to the input of the preamp would be approximately 5mV peak to peak because of the dropping resistor we talked about earlier. The output of the preamp would then be .5V peak to peak. The gain of an amplifier is determined by the ratio of the input volts to the output volts.

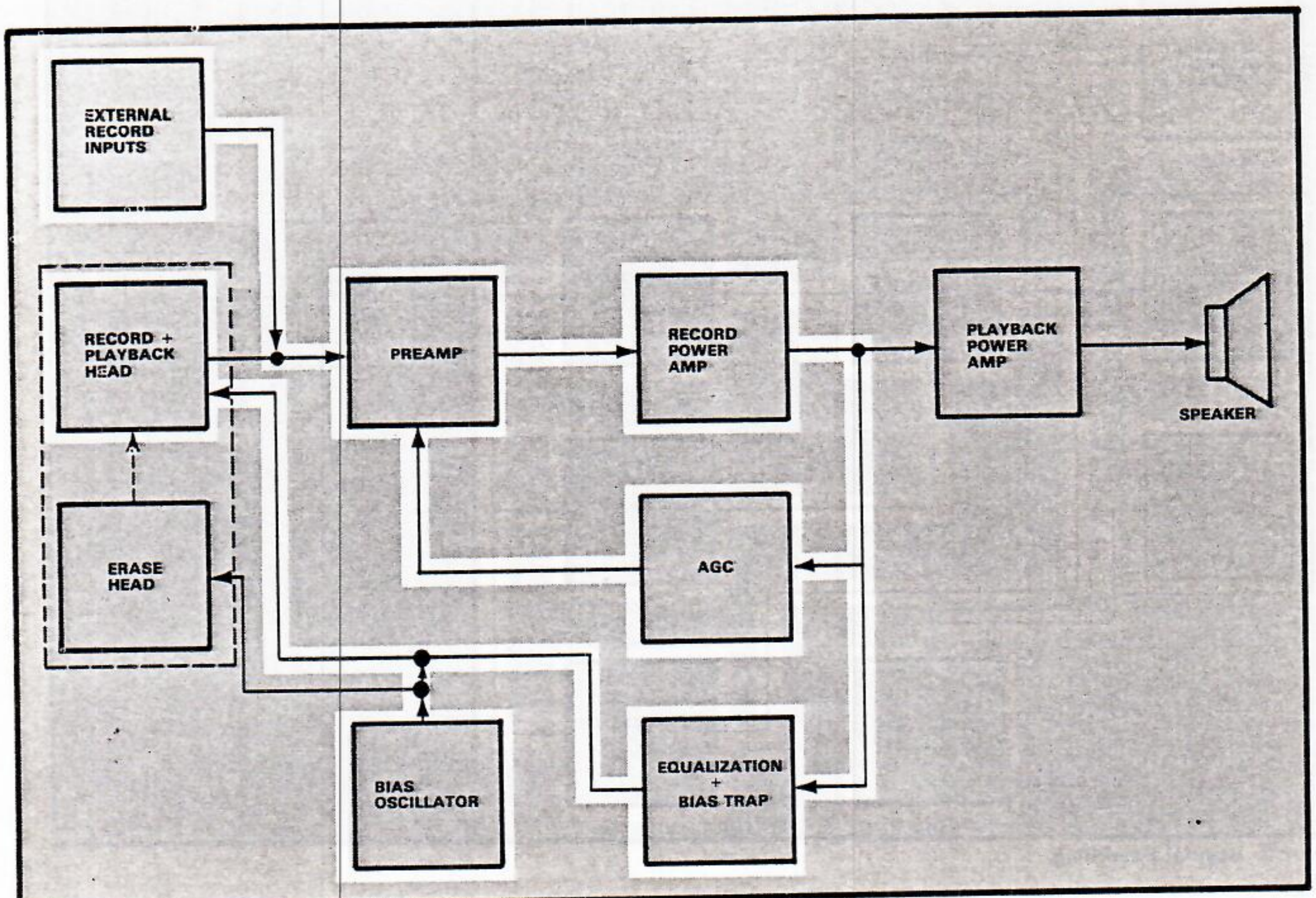

Figure 9 Sound-on-sound recording

$$\text{Gain} = \frac{\text{V output}}{\text{V input}} = \frac{.5 \text{ Vp-p}}{.005 \text{ Vp-p}} = 100$$

The output of the preamp is fed through the coupling capacitor C11 to the input of the record-power amp. The capacitor drops the 400 Hz signal to .14V peak to peak. This drop will change with frequency because the reactance of the capacitor changes with frequency. The record-power amp has a voltage gain of 29, so the output is 4V peak to peak. It also provides a current gain to drive the recording head.

Once the signal leaves the record-power amp, it is fed to the automatic gain control (AGC). This circuit senses the amplitude of the signal and controls the output of the preamp. If the signal at the preamp is too high, and would cause clipping in the record-power amp, the AGC shunts some of the signal current to ground.

The output signal from the record-power amp is also fed through the bias trap and equalization circuit to the record head. At the same time, the bias signal is fed to the erase head. Remember, this projector depends on the inductive coupling between the erase and record heads to provide the bias current for normal recording.

When the projector is set for sound-on-sound recording, the signal flows through the circuit as shown in Fig. 9. Notice

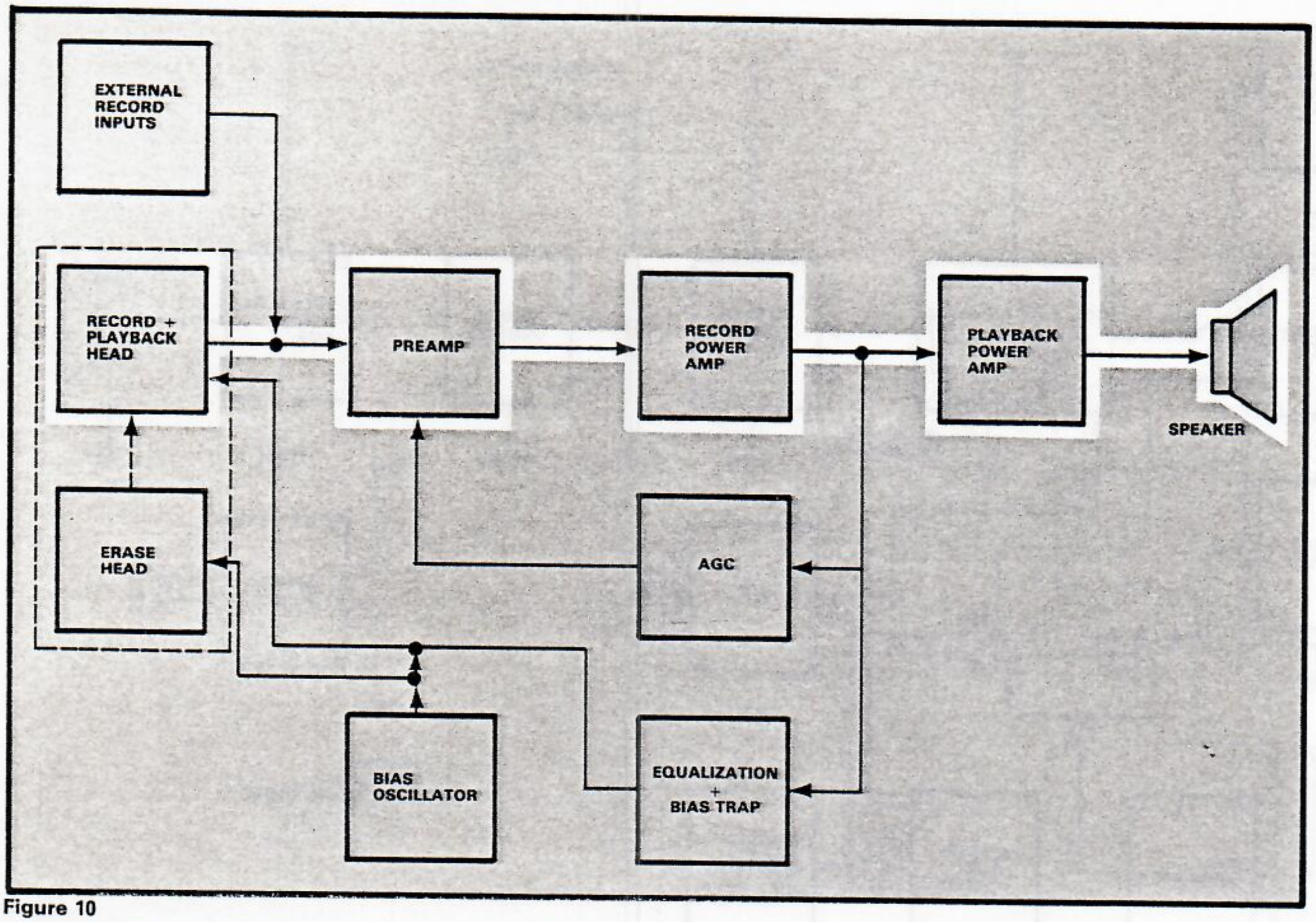

Figure 10

the bias signal does not go to the erase head. Instead the bias signal is mixed with the audio signal and fed to the record head.

When the projector is set for playback, the external record jacks are disconnected and the record/playback head is switched to the input of the preamp. Fig. 10 shows the signal path in the playback mode. The changing magnetic flux caused by the tape passing over the head creates a small signal current through the head-winding and to the preamp input. The output of the record-power amp passes through a coupling capacitor to the playback-power amp. The output of the playback-power amp is then fed to the speaker.

When the projector is switched to the playback mode the playback-equalization circuit is switched into operation in the preamp. Fig. 11 shows the block diagram with the switches we have talked about so far added to it. The dotted lines between the switches mean that the switches are part of the same multiple-pole switch. Switch 1 (S1 A through F) is the record switch. Switch 2 (S2 A through C) is the sound-on-sound switch.

Fig. 11 also includes the power supply and all the power connections to the amplifier circuit. Notice that the record switch connects the ground for the bias oscillator when in the record position. In the playback position, the record switch disconnects the oscillator ground and turns the oscillator off.

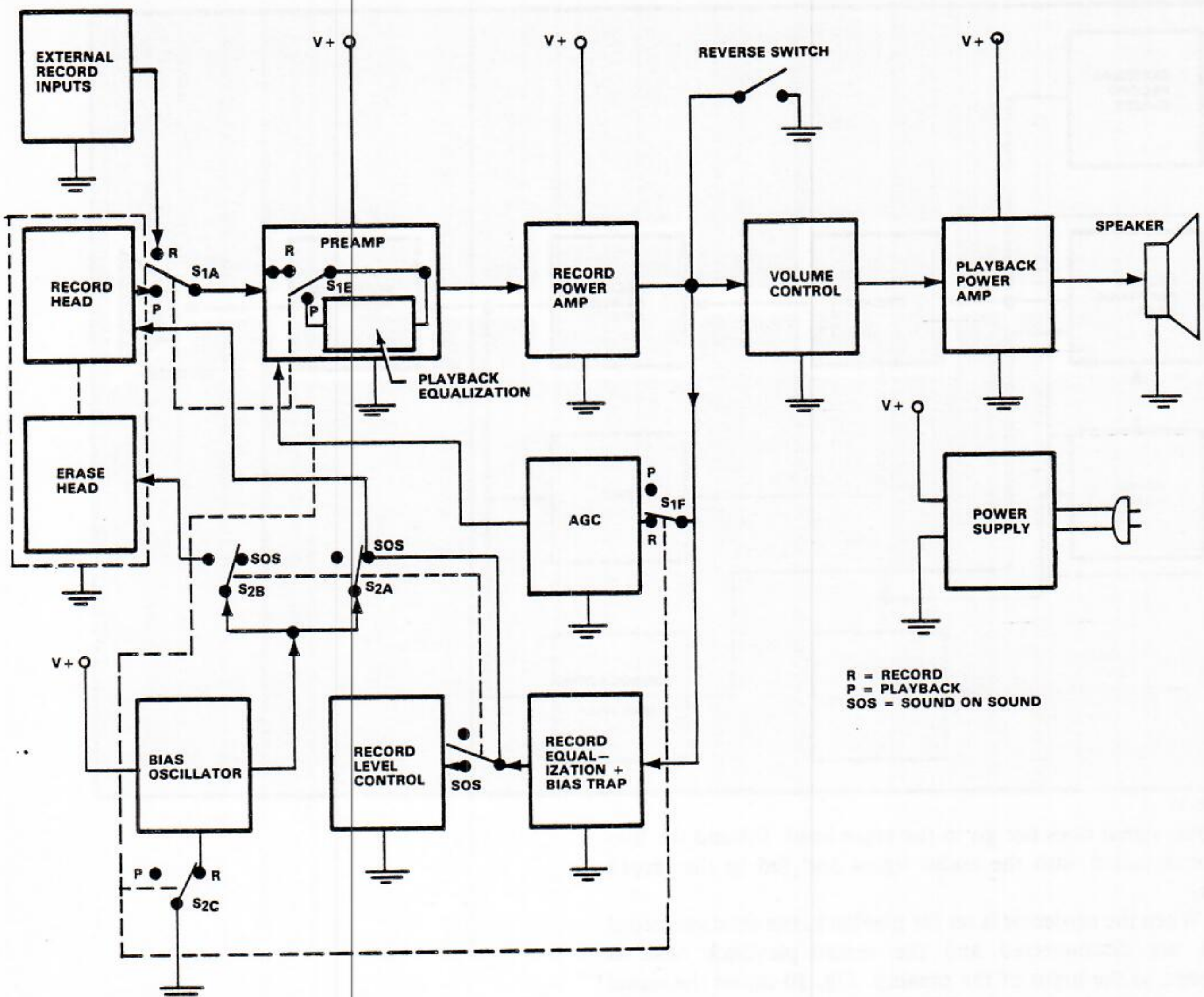

Figure 11

There is one other switch we have not mentioned yet. The reverse switch shown in Fig. 11 grounds the output of the second-stage amp when the projector is in reverse. This prevents the sound track from being played backwards.

The record level and playback-volume controls act as current shunts to ground, Fig. 11. The playback-volume control determines what portion of the output of the record-power amp is fed to the input of the playback-power amp. The playback power amp has a fixed gain so its output amplitude is determined only by the amplitude of the input signal. The volume control does not change the gain of the power amp; it changes the amplitude of the input.

The record-level control adjusts the amplitude of the combined audio and bias signals for sound-on-sound recording. When the record-level control is set to maximum, the amplitude of the combined audio and bias signals is greater than the amplitude of the regular record-bias signal and audio signal combined. This allows you to make the sound you are adding to the sound track louder than the original recording. As the record-level control is reduced, the amplitude of the combined bias and audio signals is reduced so it is less than the original recording, creating a background effect on the sound track.

TEST YOURSELF QUIZ #2

1. The preamp from a hypothetical projector has a signal of .004V peak to peak at the input of the preamp and an output of .6V peak to peak. What is the gain of the preamp? __________

2. The AGC circuit shunts some of the signal to ground if the amplitude of the signal is too great. This is to prevent __________ in the record-power amp.

3. The Bell and Howell 1742 has two switches that control the amplifier circuit. Name the switches and give their circuit designations.

   ____________ ______

   ____________ ______

4. The output of the record-power amp is fed to two different functional blocks at the same time. Name them.

   ____

   ____

ANALYZING THE CIRCUIT

When working on an unfamiliar circuit, it is best to examine the schematic closely before starting. A technique that can aid you in your troubleshooting procedure is to draw blocks around the components on the schematic that make up each of the functional blocks. You are familiar with each of the functional blocks required in a sound projector for playback and recording. When analyzing the schematic, look for each of the following functional blocks:

Record Head
Erase Head
External-Record Inputs
Preamp
Record-Power Amp
Playback-Power Amp
Automatic Gain Control
Bias Trap
Equalization Circuit(s)
Bias Oscillator
Power Supply

You will see many variations between projectors. For instance, Fig. 12 shows the block diagram for the Kodak Ektasound 245

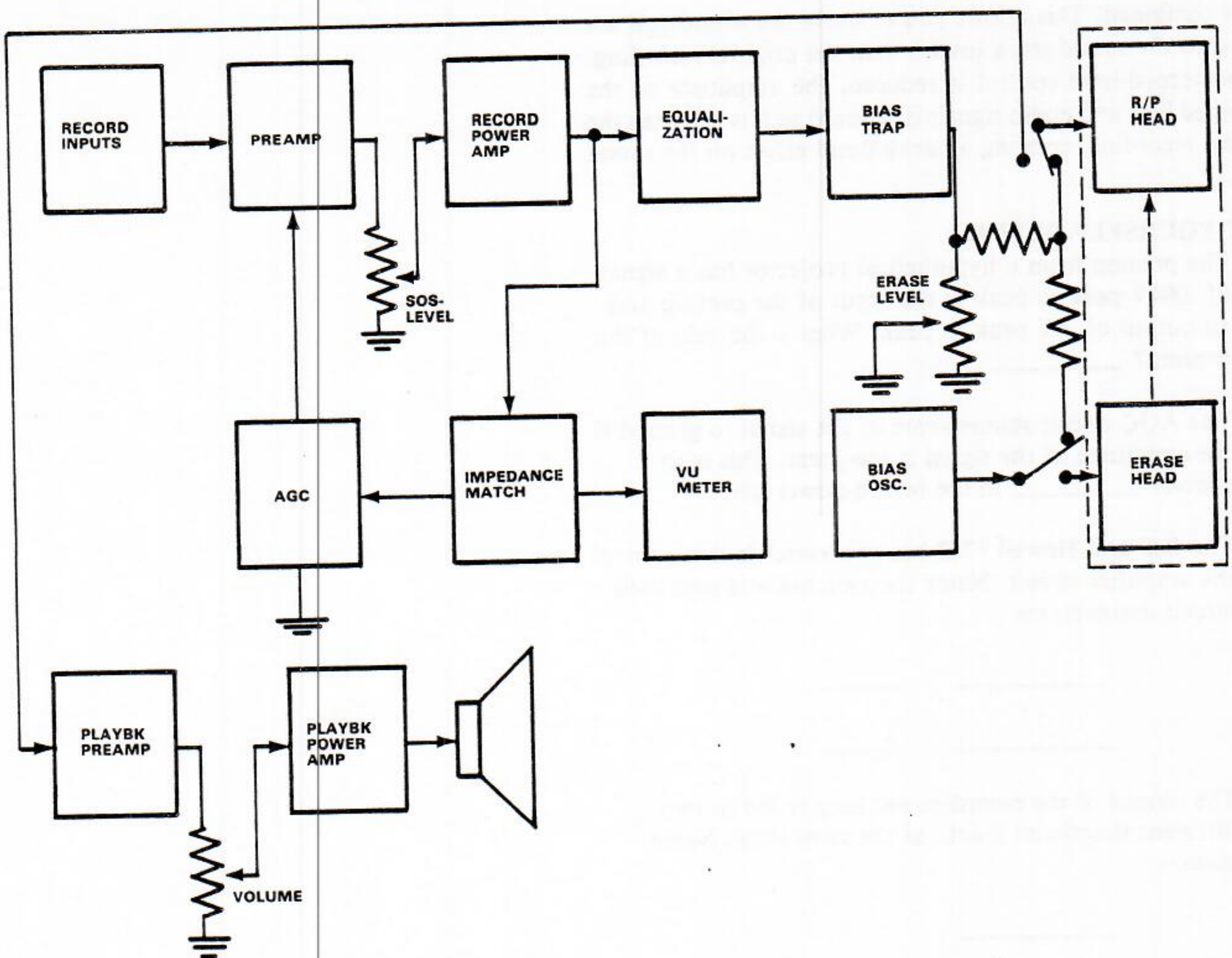

Figure 12

projector. Notice that it has two preamps and a VU meter that monitors the recording level.

Another interesting feature of the Kodak is its power transformer. The secondary winding is wound on the motor core so the projector has no separate transformer; however, the power supply operation is the same as if it did.

A preamp, whether it is used for recording or playback, will be hooked to either the external record inputs or the playback head. Normally, it consists of two transistors directly coupled, with the collector of the first transistor connected to the base of the second. You will usually see a feedback path from the emitter of the second transistor to the base of the first. Fig. 13 shows the record preamp of the Kodak Ektasound 245. The signal paths are shown with their corresponding phase angles. The signal at the collector of Q200 is 180 degrees out-of-phase with the input. The signal at the collector of Q202 is back in phase with the input; however, the signal at the emitter is 180 degrees out-of-phase with the input. The emitter signal from Q202 is fed back to the input to provide negative feedback. Q200 is the first stage of the preamp and Q202 is the second stage of the preamp.

A record-power amp in a projector usually consists of a single transistor although you may see IC amplifiers used also. Generally, you can use the coupling capacitors in determining where one amplifier block ends and another begins. In Fig. 13, C200 is the coupling capacitor for the input to the preamp. Fig. 14 shows the record-power amp for the same projector. C203 is the coupling capacitor between the preamp and the record-power amp. C212 couples the output of Q203 with the equalization and bias trap. The output of the record-power amp will almost always go directly to the equalization and bias trap through a coupling capacitor.

Your lesson on *Servicing Sound Camera Circuits* showed examples of bias oscillator and AGC circuits, so we will not cover them here. That lesson also covered impedance matching. Notice that the output of Q203 goes not only to the bias trap and equalization circuits but also to the base of Q204, Fig. 14. Q204 is an emitter follower used to match the output of the record-power amp with the AGC and VU monitoring circuits. Remember that an emitter follower has no voltage gain but provides a current gain. This increased current flow is fed to the AGC and VU monitor circuits through coupling capacitors C214 and C209.

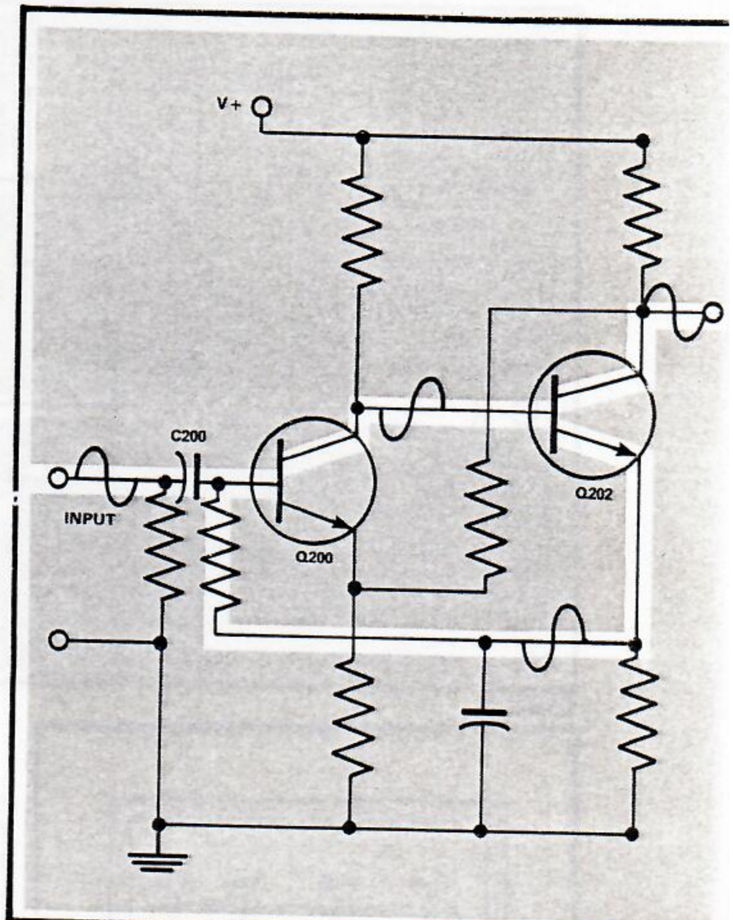

Figure 13

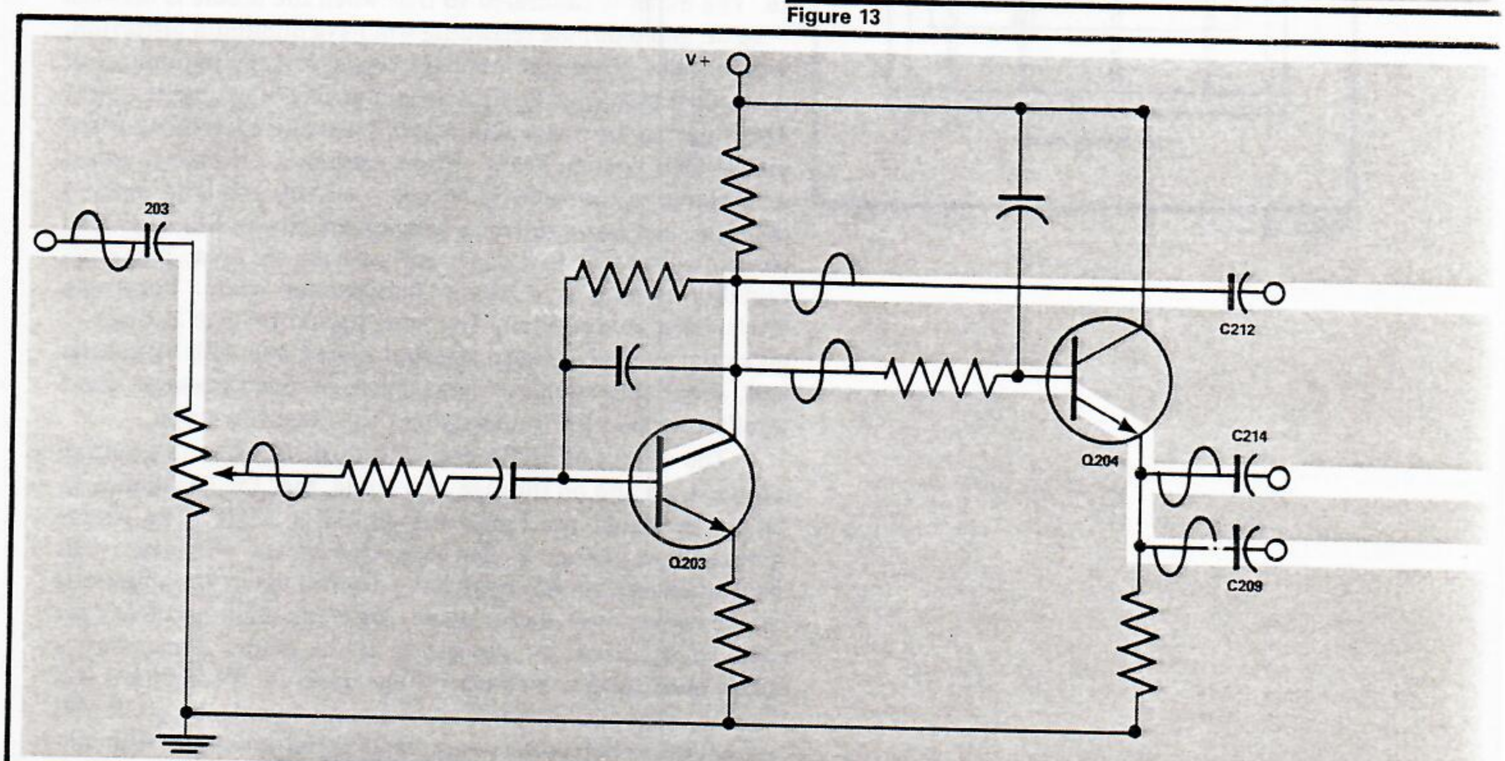

Figure 14

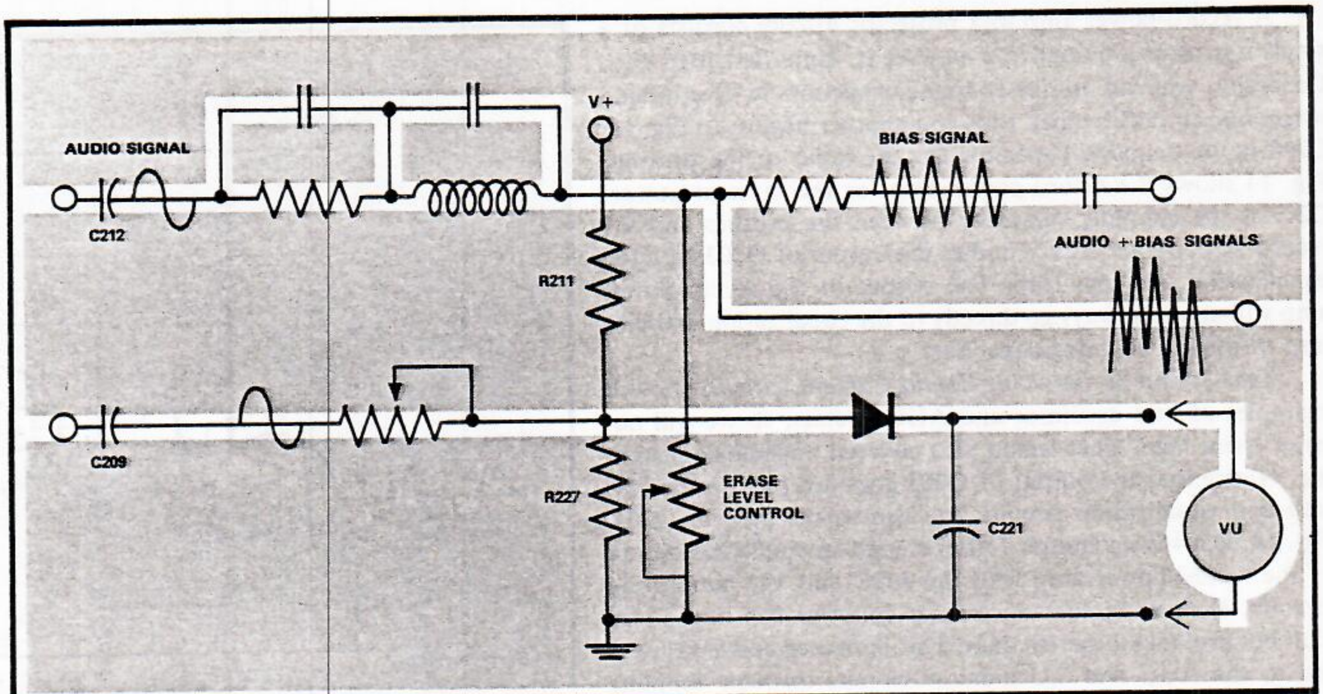

Figure 15

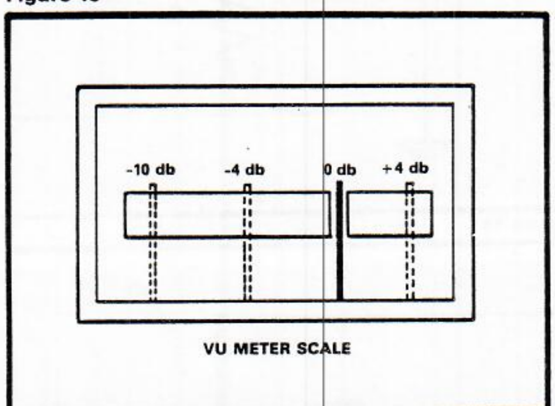

Figure 16

Fig. 15 shows the **VU (Volume Unit)** monitor circuit. The scale on the VU meter is marked in **decibels (db).** An increase of 6 db indicates that the volume has doubled. Conversely, a decrease of 6 db indicates that the volume has dropped by half. Most VU meters are marked similar to the one shown in Fig. 16. The meter is calibrated so that when the needle is between − 10 db and 0 db, the recording will have minimum distortion. Above 0 db, distortion increases because of the limitations of the record amplifier and the response of the magnetic stripe. The range on the meter above 0 db is usually red, indicating the undesirable volume levels. When making a recording, adjust the volume so the meter is between − 10 db and 0 db most of the time. In almost any recording situation, you will have loud moments that will drive the needle into the red area. This is acceptable as long as it doesn't happen too often. Recording levels are a compromise. The level should be high enough to make the average volume passages record well with little noise and, at the same time, low enough so the loud passages don't totally overload the amplifier and the magnetic stripe.

The output of Q204 passes through C209 to the calibration resistor and on through to a diode, Fig. 15. The diode rectifies the signal to charge the capacitor C221. The charge across the capacitor is then measured by the VU meter. The level of charge on the capacitor is determined by the amplitude of the peaks in the audio signal. Resistors R211 and R227 are used to set a bias on the anode of the diode. Remember, a diode must have a forward voltage drop of .6V before it will conduct. The bias is .59V, so without a signal, the diode will not conduct, but with even a small signal the diode will conduct on the positive peaks and charge the capacitor.

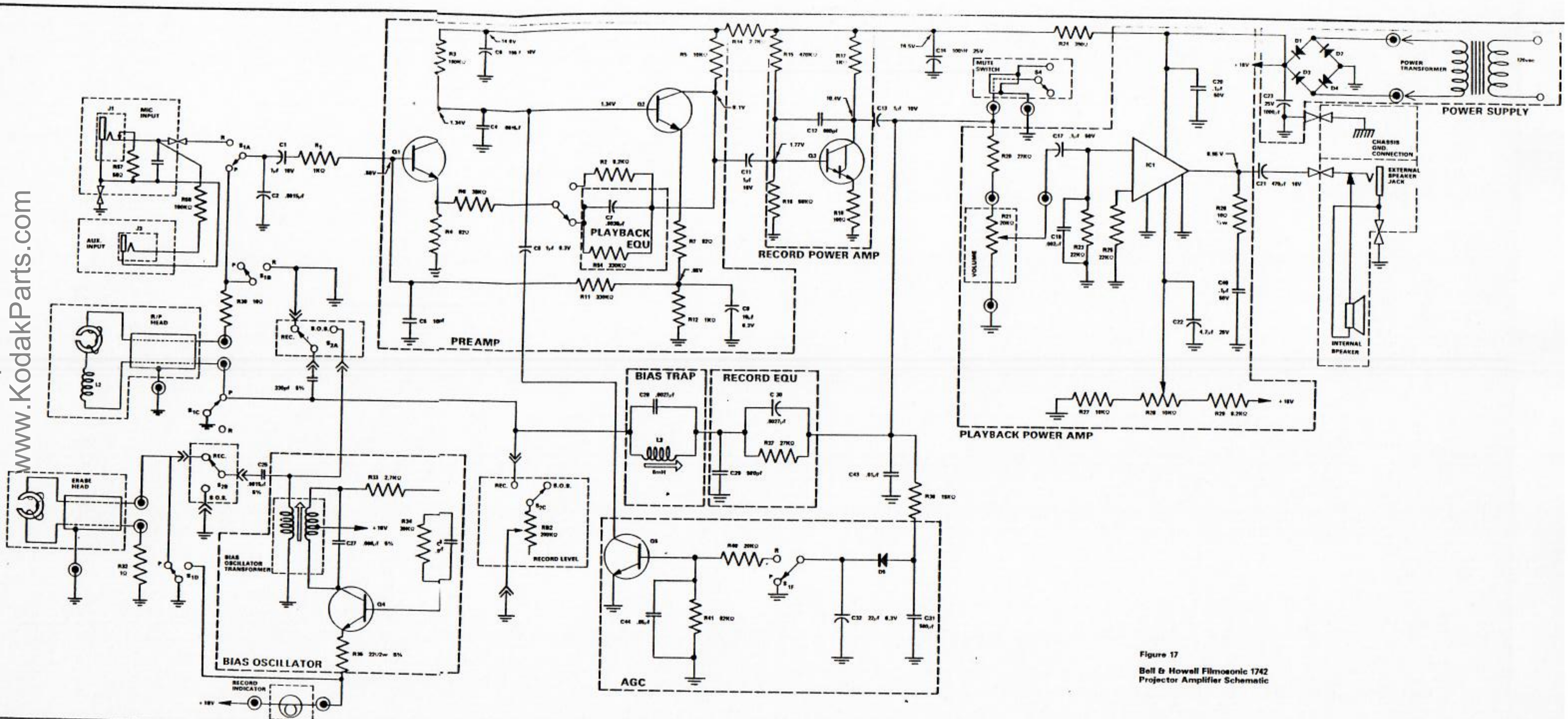

Figure 17
Bell & Howell Filmosonic 1742
Projector Amplifier Schematic

The complete schematic of the Bell and Howell Model 1742 projector with each of the functional blocks outlined is shown in Fig. 17. With the schematic blocked off this way, troubleshooting becomes easy. It is a simple procedure to block off any schematic, and doing so increases your understanding of the circuit. It also reduces the time you spend on studying the circuit when you come back to it at a later time for a different repair.

Fig. 18 shows the circuit board for the Bell and Howell with the functional blocks outlined. Once you have the schematic blocked off, it is easy to see the patterns on the circuit board and the test points become obvious.

One characteristic in amplifier circuit design that you will see often is filter capacitors. The capacitors pointed out in Fig. 18 are used to isolate the power supplied to different parts of the circuit. Locate capacitors C6 and C16 and resistors R14 and R24 in Fig. 17. As power is applied to the circuit, C6 and C16 charge to V+. If there is a heavy momentary current drain in the playback-power amp, the drop in V+ is isolated from the rest of the circuit by R24. Even though the voltage at the playback-power amp has dropped, the charge on C16 will make up the difference and supply the normal voltage to the record-power amp. The same applies to C6 and the preamp.

Another component we have not talked about yet is the humbuck coil. Fig. 17 shows a coil in series with the record/playback head coil. This coil is wound on a separate core outside of the record-head casing, and its position is adjustable. The humbuck coil cancels out undesirable hum picked up by the record/playback head. Adjustment of the humbuck coil will be covered later.

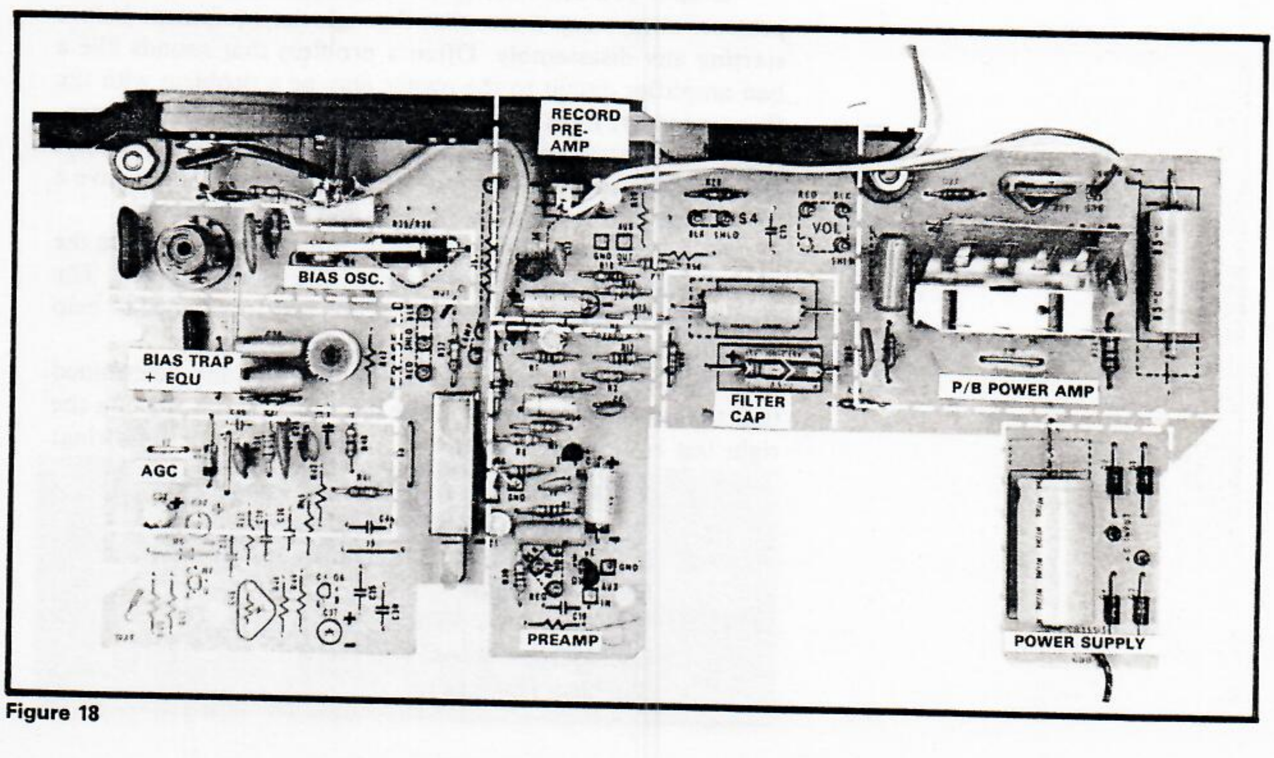

Figure 18

TEST YOURSELF QUIZ#3

1. The Kodak Ektasound 234 does not have a conventional transformer for powering the amplifier circuit. The ________ is used as a transformer.

2. Which one of the following functional blocks would not normally be found in a sound projector circuit.
   A. Bias Trap
   B. AGC
   C. Tach Generator Speed Control
   D. Record Power Amp

3. The output of one amplifier block is usually fed to the input of the next amplifier block by a ________.

4. On the Kodak Ektasound 245 the VU meter indicates the relative output of the ________.

5. Capacitors C6 and C16 are called ________.

6. The humbuck coil is used to cancel ________ picked up by the record/playback head.

SERVICING THE SOUND PROJECTOR

When accepting any sound projector for repair of the sound system, it is essential to get a complete description of the problem from the owner. If possible, run a test film through the projector while the owner is there so that the problem can be pinpointed from the start.

Even if you can't listen to the problem while the owner is present, always run a test film through the equipment before starting any disassembly. Often a problem that sounds like a bad amplifier circuit to the owner may be a problem with the film transport. Even something as simple as threading the projector incorrectly may have a big effect on sound quality. Developing a check-out procedure and sticking to it can save a lot of time and frustration for you and your customer.

When checking out any piece of equipment, start from the simple possibilities and move toward the more complex. The troubleshooting guide at the end of this text is designed to help you eliminate each possibility in a logical manner.

Once you have narrowed the possibilities and determined that the problem is indeed in the amplifier circuit, having the right test equipment is essential. You will need the following:

Prerecorded test film
Unrecorded test film
8 OHM non-inductive dummy speaker load
Signal generator
VTVM or FET VOM
Oscilloscope or AC volt meter
Shielded Test Leads

This equipment is the minimum necessary for tracing amplifier problems. Ideally, you should have both an oscilloscope and an AC voltmeter.

It is important to know the limitations of your equipment. For instance, a VTVM or FET VOM can be used for measuring audio frequency AC voltages; however, most have meter settings of 1-3V as their lowest voltage scale. Many specifications made by the projector's manufacturer will be in the 1-100 mV range. Trying to accurately read 50mV on a 3V full scale meter range is very difficult and not recommended. An AC voltmeter is designed to measure very low AC signals and will often have a 1mV range. Digital voltmeters (DVM's) will usually measure down in the millivolt range; however, their frequency response is limited. Some will only measure AC voltage accurately up to 1000 Hz. Projector manufacturers often specify measurements at 5000 Hz. When choosing a voltmeter always be sure it has a high input impedance, preferably 1M Ω or more. Most regular VOM's do not meet this standard and will load down the circuit.

Another disadvantage of the DVM is that there is no db scale. You will often see specifications in db. AC voltmeters, VTVM's and FET VOM's usually have db scales on the meter face.

An oscilloscope will usually have a 10mV/cm range that can be used to measure low level AC voltages, but like the DVM, the oscilloscope will not supply db readings directly. However, you can calculate what the change in your voltage reading should be for a specified change in db; db specifications are always given in reference to a voltage. This reference voltage is usually considered 0 db at a particular frequency which is also specified. When testing the frequency response of an amplifier, the specification usually gives an increase or decrease in db for different frequency settings. For instance, in the Kodak service manual on the Ektasound 245, the procedure for checking playback frequency response tells you to run a test film with several different frequencies prerecorded on it. The first frequency on the magnetic stripe is 400 Hz. When this segment is running, you adjust the output voltage across the speaker to 1 volt with the volume control. This is your 0 db reference. The second segment on the film has a 100 Hz signal. The specification says that, at 100 Hz, a change of +6 db to −6 db is acceptable. A change of 6 db either reduces or increases the 0 db voltage by a factor of approximately 2. If the change were +6 db, you would find the voltage increase by multiplying the reference voltage (in this case 1V) by 1.995.

$$1\text{V} \times 1.995 = 1.995\text{V} = +6 \text{ db}$$

If the change were −6 db, you would multiply the reference voltage by .5012.

$$1\text{V} \times .5012 = .5012\text{V} = -6 \text{ db}$$

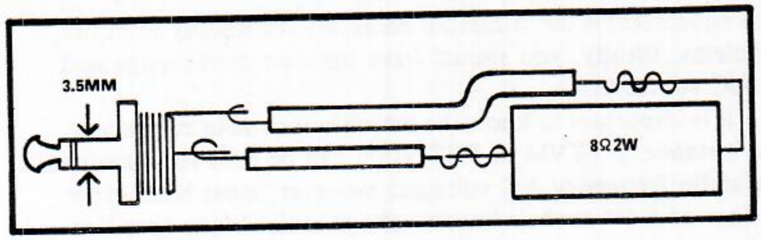

Figure 19

The chart at the back of this text shows the gain and loss factor for common db levels. This chart is brief but covers most of your needs. You can obtain more detailed charts; if you find it necessary, from an electronics hobby shop.

Another factor to keep in mind when reading service manuals is: the kind of test instrument that the specifications are given for. If the manual is written for a technician using an AC voltmeter, the specifications will be in RMS volts. If you are using an oscilloscope to measure the specified voltage, you must convert the RMS voltage to peak to peak voltage.

The prerecorded test film mentioned above is a standard service item available from both Bell and Howell and Kodak. Most service manuals will use the same test frequencies, so you can use the same test film for all brands. The standard frequencies are 100 Hz, 400 Hz, 3000 Hz and 5000 Hz. These films are recorded under very tight controls, and it is highly recommended that you obtain one.

The 8 OHM noninductive dummy speaker load is used to replace the speaker when making certain tests. This is done because the reactance of the speaker coil changes with frequency, which changes the load on the amplifier. The dummy load will not change its resistance with frequency, so the amplifier is operating under a constant load. There is another advantage to using the dummy load when testing: noise. Some playback-power amp tests are made at maximum output, and a 400 Hz signal at maximum output can be very annoying too if played for any length of time over the speaker.

You can make this dummy load by purchasing an 8 OHM 2-watt resistor at an electronic parts house. Be sure you get a resistor that is not wire-wound. The coil of wire in a wire-wound resistor becomes an inductor when an AC signal is applied to it and, as you know, inductors change their impedance with frequency.

Most projectors use a standard mini-phone jack for their external speaker connector. If you construct your dummy load using one of the plugs shown in Fig. 19, you will be able to connect the dummy load and disconnect the internal speaker simultaneously. As an additional safety precaution, cover the resistor and the bare leads with heat-shrink tubing.

CAUTION: Before connecting any test equipment powered by AC line current to any circuit powered by AC line current, check to see that the circuit is isolated from the power line.

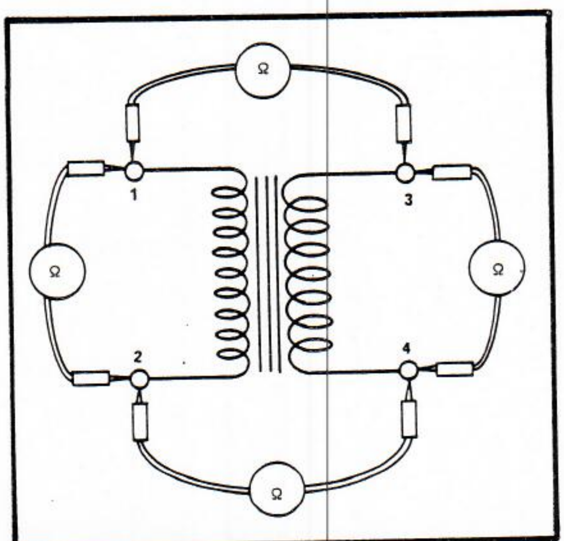

Figure 20 Isolation Transformer

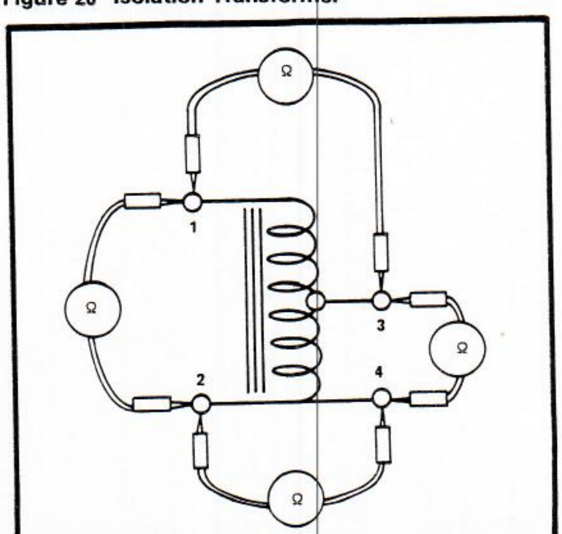

Figure 21 Auto Transformer

Most equipment you will see will use an isolation transformer like the one shown in Fig. 20. This type of transformer has no direct electrical connection between the primary and the secondary.

Fig. 21 shows an autotransformer. Notice that there is only one winding. The ratio of input voltage to output voltage is set by the point in the winding where the output is tapped off. The autotransformer is cheaper to make, so you may see it in some equipment. However, it can be dangerous to the technician. If the polarity of the line cord plug on the projector is the opposite of the polarity of the test instrument you are hooking to the circuit, you would have a dead short across the AC line. The results of this type of connection are very dramatic. At the very least, you will probably blow a fuse or a circuit breaker and possibly vaporize some wiring in the circuit under test.

Another situation where you may run into AC polarity problems is in vacuum-tube amplifiers. Although you will probably not see many vacuum-tube amplifiers, they often use straight AC line current in the circuit. The best way to circumvent a potential shock hazard is to hook any equipment, that uses either an autotransformer or straight AC to power the circuitry, through to a 1:1 isolation transformer. These have no voltage step-up or step-down, but they do isolate the circuit from the AC line.

If you suspect the equipment you are checking uses an autotransformer, you can tell for sure by checking the continuity between the leads with a VOM while the transformer is unplugged from the AC line. An isolation transformer there will have continuity only between leads 1 + 2 and 3 + 4, Fig. 20. There will be no continuity between 1 + 3, 1 + 4, 2 + 3 and 2 + 4. Checking an autotransformer the same way will show continuity between any combination of all 4 leads.

If you have any doubt about which type of transformer you are working with, check it to be sure. If you still have doubts after checking, use a 1:1 isolation transformer.

For most of the signal and voltage measurements you will make, regular unshielded test leads will be adequate. However, when making signal measurements directly from the head or the first stage of the preamp, extraneous noise can greatly affect your readings unless your test leads are shielded. You can make shielded test leads using what is called microphone cable. Do not use coaxial cables designed for use with CB or TV antennas. You can also purchase ready-made shielded test cables from a good electronic parts house.

TEST YOURSELF QUIZ#4

1. Name two advantages of an AC voltmeter over a DVM.

____

____

2. A manufacturer's service manual gives a reference voltage of 4V at 400 Hz for the output of the playback power amp. At 5,000 Hz the specified tolerance is −4db to −6db. What would the tolerance be if it were specified in volts. Use the db voltage factor chart to calculate the change in voltage.

   __________V to __________V

3. When working on a circuit powered by an auto transformer, the projector should be plugged into a __________ to protect you and your test equipment.

TESTING THE FILM-TRANSPORT SYSTEM

To test the transport system you will need a test film with both sound and images recorded on it. You can make such a film using a sound movie camera you know is operating correctly. A controlled setup will give you the best results, so follow this procedure if at all possible.

Set the camera on a tripod aimed at a lens test chart or similar target that will give you reference points for checking frame alignment in the projector. Light the target for correct exposure and set your focus very carefully. Your target should fill the viewfinder.

Connect the mircrophone to the camera and, as you expose the first 20 feet of film, speak into the microphone in a normal conversational tone. Reading from some kind of written material is the easiest way of coming up with something to say. As you expose the second 20 feet of film, record some easy listening music from a phonograph, tape player, or radio. As you expose the last 10 feet of film, disconnect the audio inputs and record nothing.

This film will give you good results under most conditions. You can use a prerecorded test film made by a manufacturer such as Kodak; however, keep in mind that many of the projectors that will come in for repairs will have problems with the transport system and may damage the test film. Generally, it is safest and cheapest to use a test film you have made for the initial check-out, and reserve the manufacturer's test film for when you have isolated the problem to the amplifier circuit.

Once you have the projector threaded with your test film, run the film and watch carefully as the projector transports the film. At the same time, listen to the sound output. If the audio sounds good but it is out of sync with the projected image, the lower loop is probably not large enough or, less likely, too large. If the sound starts out good but gradually deteriorates until it is garbled and the image starts to jump, the film is losing its loop.

On the Kodak Ektasound 245 this could be caused by several problems. If the drive belt is slipping or the speed control mechanism damaged, the loop will gradually become smaller until the capstan is trying to pull the film through the gate. If the film is threaded so that the loop sensor is below the film instead of above it, the speed control mechanism thinks the loop is too large and slows down the shutter.

If you are running a test film through a projector and the image is good but the pitch of the sound varies, the drive belt is most likely at fault.

Just as in the sound camera, cleanliness of the capstan, roller and head are very important. When you have run the test film through once, clean the capstan, roller and head with a cotton swab and alcohol, and run the film again. Many times you will notice substantial improvement from just this simple procedure. Servicing a sound projector without cleaning the capstan, roller and head is like rebuilding an automobile engine and putting the old oil back in the crankcase.

If you get a projector in for repair, that does not run at all, the first component to suspect is the fuse. You will see two different kinds of fuses. One is current sensitive and one is temperature sensitive.

The current-sensitive fuse is found usually in a socket in one side of the AC line before the motor switch. The most common type of fuse is a 1-inch glass fuse with metal caps at each end. The filament is usually lead, which melts when the current rating is exceeded.

The temperature-sensitive fuse, or thermal fuse, is usually found cemented to the motor winding. If the motor overheats, the fuse link is broken which shuts off the motor and lamp. When replacing a thermal fuse, remember to use crimp connectors where they were originally used by the manufacturer. Using a soldering iron to install a thermal fuse will usually ruin the fuse.

TESTING AND ADJUSTING THE TAPE-HEAD ALIGNMENT

If the head alignment is off on his projector, your customer will generally complain that when he plays back a recording made on his camera, the sound is muffled and dull. You may also hear a customer say that recordings made on their camera sound muffled when played back, but recordings made on their projector sound great.

Aligning the head in a projector is much easier than in the camera, and it is not necessary to send the entire head assembly to the manufacturer. If you have the manufacturer's test film and can duplicate the test setup and procedure as specified in the service manual, follow the manufacturer's recommended procedure. If you do not have the manufacturer's test film and you cannot exactly duplicate the recommended procedure, you can still make the adjustment by followng these steps: Use a prerecorded test film that has the audio signal in the center of the magnetic stripe. You can pretty well assume that any manufacturer's test film is recorded this way. The test film should have several different calibrated frequencies on it.

Fig. 22 shows a head in relation to the film. Ideally, the magnetic stripe should touch all points along the flat surface of the head with equal pressure. If the head and magnetic stripe

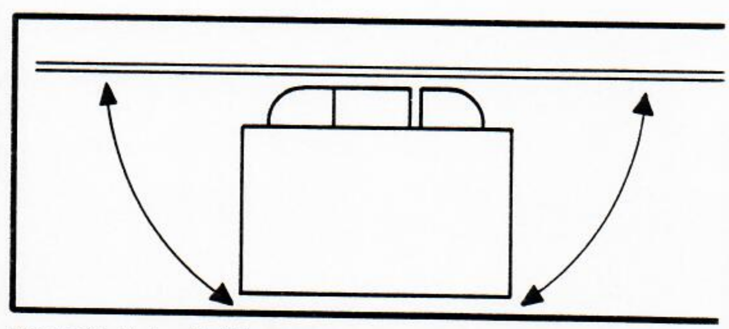

Figure 22 Azimuth Alignment

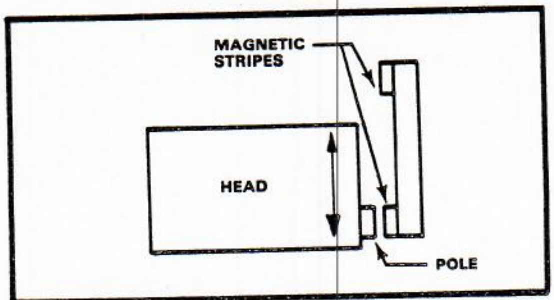

Figure 23 Zenith alignment

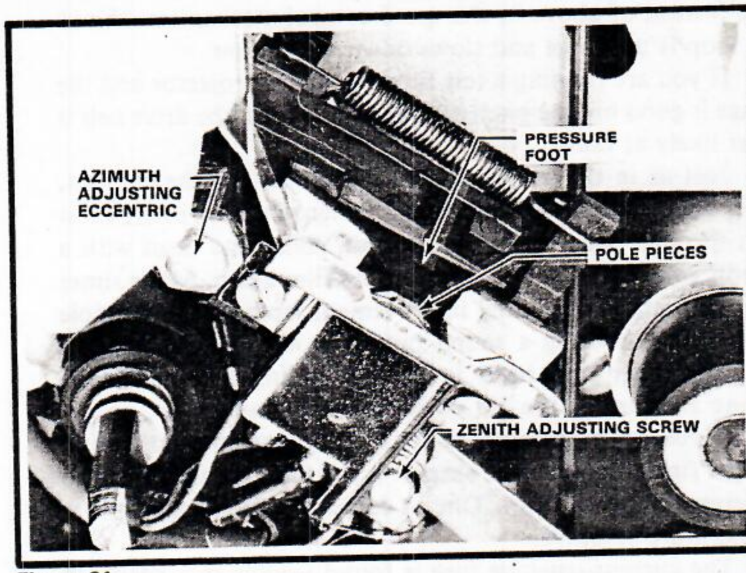

Figure 24

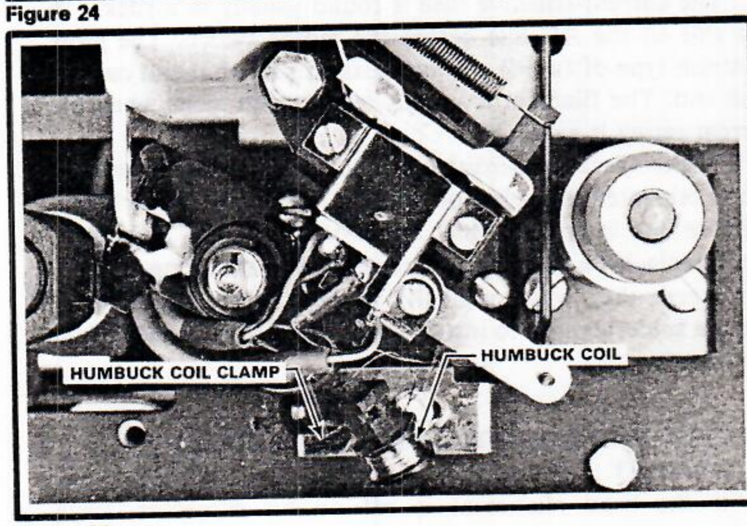

Figure 25

do not meet squarely, poor sound reproduction will result. The angle between the magnetic stripe and the head is called the **azimuth.** The azimuth alignment should be 0 degrees.

Fig. 23 shows the vertical alignment of the head with the magnetic stripe. Ideally, the center line of the pole should be aligned with the center line of the magnetic stripe. This is called the **zenith** alignment.

Fig. 24 shows the head assembly of the Bell and Howell 1742 projector. In this case, the **zenith-adjusting screw** changes the alignment of the pole pieces, and the **azimuth-adjusting eccentric** changes the angle of the **pressure foot** to adjust the azimuth alignment. Loosening the **slotted-azimuth-locking screw** allows you to turn the azimuth-adjusting eccentric. Simply turning the zenith-adjusting screw will adjust the zenith alignment.

Generally, both the azimuth and zenith alignments are made simultaneously. The first step in the adjustment procedure is to connect the dummy speaker load and connect a voltmeter or oscilloscope across the load. Thread the test film, and as the first test frequency passes the head (usually 400 Hz), adjust the output voltage to approximately 3/4 of maximum. Use the same test frequency throughout this adjustment procedure. Make a note of the reference voltage and begin rotating the azimuth-adjusting eccentric until you reach maximum output; then lock the azimuth-adjusting eccentric. Next, turn the zenith-adjusting screw until maximum output is achieved once again. Read the output voltage after making the adjustment and compare it with the starting voltage. If there is little or no change, there may be a problem in the camera or in the amplifier circuit itself.

This is a good time to adjust the humbuck coil. This adjustment is made with no input. As was mentioned earlier, the purpose of the humbuck coil is to eliminate extraneous noise from the head. Set the projector in the play position with the dummy speaker load in place of the speaker. Connect your AC voltmeter or oscilloscope across the speaker output and turn the projector on. With the volume control set between 3/4 and maximum, you will measure a voltage on your test instrument. This noise will affect the quality of the sound and should be reduced to a minimum.

Fig. 25 shows the humbuck coil on the Bell and Howell 1742 projector. Changing the position of the coil in relation to the head will change the amount of noise in the circuit. Loosen the humbuck coil clamp and move the coil around until the voltage on your test instrument is at its minimum. When moving the coil, combine the vertical and horizontal movement with rotation of the coil to obtain the best reading. Once the noise is at its minimum, tighten the humbuck coil clamp and seal the screw.

TESTING THE POWER SUPPLY

Most power supply units consist of a transformer, full-wave bridge rectifier and a filter capacitor. Even though the output of a full-wave bridge rectifier is probably the easiest of all rectifiers to filter, you will be able to measure some ripple current in the DC supplied to the circuit. This ripple should be less than 5% of the total DC voltage. If the ripple is more than 5%, audible distortion of the output will probably occur.

If the transformer in the power supply were faulty, there would usually be no output from the transformer. Occasionally a transformer winding will short two of its coils together and cause a change in the output voltage. This is a very rare occurance.

If one of the diodes in the rectifier were to burn up and cause an opening in one quarter of the rectifier circuit, it would increase ripple and decrease the current available. If one of the diodes were to short, AC would be fed directly to the circuit. If the capacitor had become leaky, ripple would be increased.

Although most circuits found in projectors of this type are fairly well shielded against picking up extraneous 60 Hz noise, large amounts of ripple in the power supply cannot be filtered out by the circuit and may cause considerable distortion.

If you are working on a projector that shows signs of power-supply failure as we have just talked about, the best means of locating the faulty component is by substitution. The most common culprit is the filter capacitor. It is a good idea to have a 2200 μf 35 WVDC electrolitic capacitor on hand to use as a quick test substitute. This size and voltage rating should be compared with the component in the circuit in question; however, it will be compatible with most power supply units.

To make a trial substitution, cut one lead on the capacitor in the circuit leaving enough length to resolder it if it is not at fault. Next, using test leads, clip the substitute capacitor in place of the original capacitor. Turn the projector on and test the output of the power supply for any change over the original capacitor.

If the original capacitor was rated 1000 μf at 25 WVDC, you can attribute a slight improvement in ripple to the larger rating of the substitute. However, if the ripple you measure with the original capacitor was 2V peak to peak and you measure only 200 mV peak to peak with the substitute, you can be relatively sure you have found a bad capacitor. The next step is to buy a replacement capacitor that matches the rating of the original.

When testing the power supply for ripple, be sure to take your readings under maximum load conditions. That generally means that the projector should be set to record with the volume maximum.

TESTING THE AMPLIFIER CIRCUIT DURING PLAYBACK

When you are working on a projector that operates fine mechanically but does not play back the recording on the magnetic stripe, the first step is to check the output of the preamp. With a standard frequency test film running past the head, you should be able to measure a signal between the output of the preamp and ground. If you do not, either the head winding is open or the preamp is not operating properly.

To determine if the head is at fault, check the head alignment as described earlier. If you still get no response, after checking the alignment, check the continuity of the head winding. The winding of a typical record/playback head will have a resistance of approximately 300Ω to 700Ω. Be sure to disconnect the head from the rest of the circuit while testing the continuity. If you do not get a good continuity reading, the head is most likely the reason you do not get a signal at the input to the preamp. To be sure, leave the head out of the circuit and connect the output of your signal generator across the playback-head terminals. Set the output of your signal generator to 400 Hz 1 mV peak to peak and turn on the amplifier. If the head was the only problem, you should be able to hear your signal at the speaker by adjusting the volume control. If you cannot, you have a problem in the amplifier circuit.

The output of the playback head is so small it is hard to use reliably when signal tracing, so use the ouput of your signal generator for testing the two transistors in the preamp. Referring to Fig. 17, with the playback head disconnected and a 400 Hz 1mV signal applied across the playback head terminals, you should be able to measure a signal at the base of Q1, although it will be very small.

Next check for a signal at the collector of Q1. It should be amplified with little or no distortion. If you do not see a signal at the collector of Q1, check the bias on the base of the transistor without a signal. A typical bias voltage would be between .4 VDC and 1 VDC. In this case, it should be between .5 and .6 VDC. If you get a good reading for the base bias, check the static voltage at the collector of the transistor. Because there is a bias voltage on the base, the transistor should be conducting even without a signal. This will cause a small voltage drop between the collector and ground, typically 1 VDC to 2 VDC, depending on the bias level and the value of the collector and emitter resistors. The correct static collector voltage for the Bell and Howell 1742 is 1.2 VDC to 1.4 VDC.

When measuring from the collector to ground, the higher the value of the emitter resistor, the greater the voltage drop. If you measure the supply voltage between the collector and ground, it means the transistor is not conducting; this indicates it is open and no good. If you measure no voltage drop, or a very small one (less than 1V), between the collector and ground, the transistor is shorted and no good. A transistor checker can tell you positively if the transistor is bad.

The static DC voltages with no input signal were measured with the projector set for playback and the volume at minimum, Fig. 17. The voltage you measure may be slightly different depending on the actual line voltage and components' tolerances. You will often see a manufacturer specify that the measurements be taken while the projector is plugged in to a Variac set for exactly 120 VAC. This eliminates the problem of varying line voltage; however, for most situations it is not critical as long as you allow a slight difference between the specified voltage and what you measure.

Of the voltages marked, only the DC balance on the output of the playback-power amp is adjustable. R28 is adjusted so the DC balance is precisely one-half of the maximum output voltage swing of the amp. The best way to adjust this is with a signal applied to the preamp. Thread the projector with a standard frequency test film and substitute your dummy speaker load for the internal speaker. With your oscilloscope across the load, adjust the volume control until you observe clipping of the waveform. If either the positive peaks are being clipped and the negative peaks are not, or if the inverse is true, the DC balance is not correct. Adjust R28 until both positive and negative peaks begin clipping at the same time.

When troubleshooting any transistor amplifier, you can use the same basic procedure as we used for checking the first transistor in the preamp. First check to be sure you have an input signal, then check for the signal at the output of that stage. If you get no output, check for the bias voltages. If you have improper bias voltages, check for a faulty resistor or capacitor. If the bias voltages seem okay, the transistor is probably at fault. To be sure, check the transistor with a transistor tester.

TESTING THE AMPLIFIER CIRCUIT DURING RECORD

When troubleshooting a projector that will play back a recording but will not record, your course of action will depend on whether the projector uses the same preamp for both record and playback. The Bell and Howell 1742 uses the same preamp for both record and playback. Knowing this, you can eliminate problems in the preamp and record-power amp; however, you do need to check the input to the preamp to be sure you are getting a signal from the external record inputs.

Once you are sure you are getting signal to the preamp, check the output of the record-power amp for a signal. If you don't get a signal at the output of the record-power amp, look for a problem in any switches that might have an effect on the circuit when switching from playback to record. If you do get a signal at the output of the record-power amp, trace the signal through the rest of the components until it disappears. Remember, as the signal passes through the bias trap it should be superimposed on the bias signal. The Kodak Ektasound 245 uses separate preamps for record and playback, so if the projector will play back but not record, you will have to check the record amplifier circuit completely.

If you get a projector that will not play back or record, chances are the problem is in one of the first two amplifier stages, although your first test should be of the power supply. No response from the amplifier at all — especially if you don't get the normal noise when you turn the volume up — puts the power supply under suspicion.

TESTING AND ADJUSTING THE BIAS OSCILLATOR

The output of the bias oscillator should be a steady sine wave. If the output varies either in frequency or amplitude, check each of the components carefully. Checking the value of the resistors is easy. Without a capacitor checker, however, the best way to test the capacitors is by substitution. Checking the transistor can be done by substitution, testing with a VOM out of the circuit or with a transistor tester. If the oscillator still operates but generates an inconsistent output, the transformer is probably not at fault. A simple continuity test of both the primary and the secondary is sufficient to tell whether or not it is at fault.

Adjusting the bias oscillator transformer is normally done in conjunction with the adjustment of the bias trap. Most manufacturers specify a minimum bias level at the head, but say nothing about a maximum level. For best performance, adjust the bias transformer and the bias trap for maximum bias current through the head, unless the manufacturer specifies a maximum bias signal. This can be done by measuring the voltage across the head with the projector set for record and no input signal. Starting with the transformer first, use a nylon or plastic tool to screw the slug up or down. Position the slug for maximum output. Next, turn the slug in the bias trap coil while watching the voltage across the head. Position the slug for maximum signal. The adjustable slugs are usually sealed, so apply some alcohol to the slug to soften the sealant before turning the slug.

TESTING THE AGC CIRCUIT

If the AGC circuit is malfunctioning it can look like there is a problem in the preamp. If the AGC transistor is on all the time, the signal from the first stage of the preamp would be shorted to ground and make it appear as if preamp is malfunctioning.

With no input signal to the preamp, there should be 0V at the base of the AGC transistor, and the voltage at the collector should be the same as the static voltage at the collector of the first stage of the preamp.

If you suspect the AGC is not working at all, check the signal at the cathode of the diode with an oscilloscope, a signal applied to the external record inputs, and the projector set to record. You should see a partial wave signal corresponding to the frequency of your input signal. Remember, the voltage across the diode must be at least .6V for the diode to conduct. Because there is a fairly good size capacitor between the cathode end of the diode and ground, you will not see a complete half wave, but you should see some signal. You will probably see a small audio signal superimposed on the bias signal. This is because although the bias trap has a very high impedence to the bias signal, it cannot block all of the bias signal, so some gets through.

Next test the AGC circuit to see if you have the same signal at the base of the transistor as you do at the cathode of the diode. If you don't, the AGC switch is probably not making contact. If you do, test the transistor, either in the circuit with a transistor tester or out of the circuit with a VOM.

SIGNAL INJECTION

The amplifier troubleshooting procedures we have covered so far consist of putting a signal on the input of the preamp and tracing it through until the problem is located. Another technique is to start at the other end of the circuit. For example, if you are working on a projector that does not play back a recording, you could inject a signal from your signal generator directly to the input of the playback-power amp to test it. If you get good response at that point, move back one step to the input of the record-power amp. If you still get an output signal, move back to the input of the preamp. If you still get an output signal, the problem is most likely in the head circuit.

db VOLTAGE FACTOR CHART

To find the correct voltage reading for a given change in db, multiply the reference voltage by the gain or loss factor corresponding to the change in db.

Change In db	Gain (+db)	Loss (−db)
1	1.122	.8913
2	1.259	.7943
3	1.413	.7079
4	1.585	.6310
5	1.778	.5623
6	1.995	.5012
7	2.239	.4467
8	2.512	.3981
9	2.818	.3548
10	3.162	.3162
15	5.623	.1778
20	10.00	.1000
40	100.0	.0100

Whenever you are using the signal injection technique, be sure to set the output of your signal generator to a level that approximates the level of the signal that would normally be present at that point in the circuit.

COMMON PROBLEMS

By far the most common problem on a sound projector will be mechanical in nature. The mechanical problems you will encounter the most are: faulty auto thread mechanisms, worn or broken drive belts and loop-forming mechanisms.

In the amplifier circuit, you will most often see poor switch or potentiometer contacts and leaky capacitors (especially electrolytic types). Open or shorted transistors are the next most common problems — especially oscillator transistors — although you will find a transistor at fault much less often than either switches or capacitors.

Try not to complicate your troubleshooting by overlooking the obvious. Look for the common problems first, and if you don't find any, begin looking for the more subtle malfunctions. Remember, the object of troubleshooting procedures is to eliminate all the possible malfunctions in a logical order to narrow down the area you have to pick through component by component.

TEST YOURSELF QUIZ #5

1. You have just taken in a projector for repair that does not run at all. What should you check first? ________

2. The zenith alignment refers to the ________ alignment of the head with the magnetic stripe.

3. The humbuck coil adjustment is made with ________ input to the external record jacks or the record head.

4. When testing the power supply for ripple, the test should be made under ________ conditions.

5. The voltages pointed out in Fig. 11 were made with ________ input signal.

THE TROUBLESHOOTING CHART

This chart can help you diagnose problems in a sound projector circuit. It is not a substitute for experience or common sense. You may want to use the chart just to begin your troubleshooting, and use your own judgement and experience to finish the procedure. The importance of this chart is in recognizing the logic behind troubleshooting and applying this logic to your own situation.

The chart is based on the assumption that you have already checked the fuse and the other obvious items covered previously. You must have some kind of input signal. If you are checking the playback operation, run a standard frequency test film. If you are checking record, you should have a signal generator plugged into the microphone input. You should also know to check transistor bias voltages with no input signal applied. If you have doubts about how to make a particular test, go back and reread the section in the text that covers that test.

Keep in mind that this chart is very general in scope. Depending on the equipment you are working on, you may have to skip a step or even add a step. For example, when checking the playback operation on the Kodak Ektasound 245, you would naturally skip the step that called for checking the record-power amp because the Kodak does not use the record-power amp during playback.

Procedure	If good Proceed to	If not good Proceed to
1. Check signal at input of preamp	2	11
2. Check signal at output of preamp	3	12 or 30
3. Check signal at input of record-power amp	4	13
4. Check signal at output of record-power amp	5 or 9	14
5. Check signal at input of playback power amp	6	15
6. Check signal at output of playback power amp	7	16
7. Check speaker coil continuity	8	17
8. Check continuity of external speaker socket switch	*	18
9. Check for audio plus bias signals at head side of bias trap	10	20 or 27
10. Check record/playback switch continuity	11	19
11. Check continuity of head coil	21	31
12. Check signal at output of 1st stage of preamp	22	32
13. Test coupling capacitor	23	33
14. Test bias voltage	24	33
15. Test coupling capacitor	25	33
16. Check DC balance voltage	26	34
17. Replace speaker		
18. Replace external speaker jack		
19. Clean switch contacts or replace switch		
20. Check output of bias oscillator transformer	28	29
21. Check all components between head and amplifier for shorts or opens	*	33
22. Check signal at input of 2nd stage of preamp	35	38
23. Check bias resistors for shorts or opens	*	33
24. Replace transistor		
25. Check volume control for continuity	36	39
26. Test output for shorts to ground	37	33
27. Test components in bias trap and equalization circuits for shorts or opens	*	33
28. Test coupling capacitor	*	33

	Procedure	If good Proceed to	If not good Proceed to
29.	Test bias oscillator components	10	33
30.	Test AGC components	10	33
31.	Replace head		
32.	Check bias voltage on transistor	24	33
33.	Replace faulty components		
34.	Adjust DC balance, replace adjusting resistors as necessary		
35.	Check bias voltages	24	33
36.	Check input resistors for short to ground	*	33
37.	Replace IC amp		
38.	Check all components between stages for opens or shorts	*	33
39.	Replace volume control		

* You have reached dead end. Go back to the beginning of the procedure and retrace your steps, being careful to make all test connections correctly. If you reach the * again, another approach is called for. See the section on signal injection in the text.

SUMMARY

SUMMARY

In this assignment, you have learned about some of the different kinds of projectors you will encounter. The Bell and Howell Filmosonic 1742 and the Kodak Ektasound 245 projectors are representative of the most common projectors and the same basic principles in these projectors can be applied to more and less sophisticated ones.

We have reviewed basic amplifier operation and added some new concepts, such as sound on sound recording. We also covered how the AC line current used to power the transport motor reduces the need for speed control mechanisms in the sound projector as opposed to the sound camera.

You have also been introduced to some very important techniques for analyzing circuit schematics. Knowing where in the circuit to go to make a test is just as important as knowing how to make the test. Having the manufacturer's service manual can also help you understand the circuits better.

We have covered the important considerations for deciding which test equipment you need to repair sound projectors reliably and economically. In addition, you have seen how to make several testing aides that you can use to simplify your test procedure.

The importance of completely checking out the operation of the projector before beginning disassembly was also pointed out. If for no other reason, make a complete test of all the projector's operations simply to familiarize yourself with its controls and features.

You have also learned how to pinpoint a problem in a circuit by following a troubleshooting chart. This is another area where the manufacturer's service information is helpful. Most sound projector manuals have troubleshooting charts included.

Remember to look for the most common problems first. Switches and potentiometers are much less reliable than most of the other components in the circuit. As you work on different models and brands of projectors, you will learn each of their particular trouble points and spend less time looking for the problem than you do fixing the problem.

ANSWERS TO TEST YOURSELF QUIZ #1

1. speed up
2. 60Hz AC line current
3. inductive coupling
4. erase gap

ANSWERS TO TEST YOURSELF QUIZ #2

1. gain = 150
2. clipping
3. A. record switch S1
   B. sound-on-sound switch S2
4. A. record equalization + bias trap
   B. AGC

ANSWERS TO TEST YOURSELF QUIZ #3

1. motor
2. C. tach generator speed control
3. coupling capacitor
4. record-power amp
5. filter capacitors
6. hum

ANSWERS

ANSWERS TO TEST YOURSELF QUIZ #4

1. Any two of the following answers are correct.
   A. Direct reading db scale.
   B. Accurate readings through the entire audio frequency range.
   C. Low AC voltage ranges.

2. 2.5V to 2.0V

3. 1:1 isolation transformer

ANSWERS TO TEST YOURSELF QUIZ #5

1. the fuse

2. vertical

3. no

4. maximum load

5. no