Reference Image Formed on 8mm Film and Film Positioning Characteristics of B&H 414 P Camera

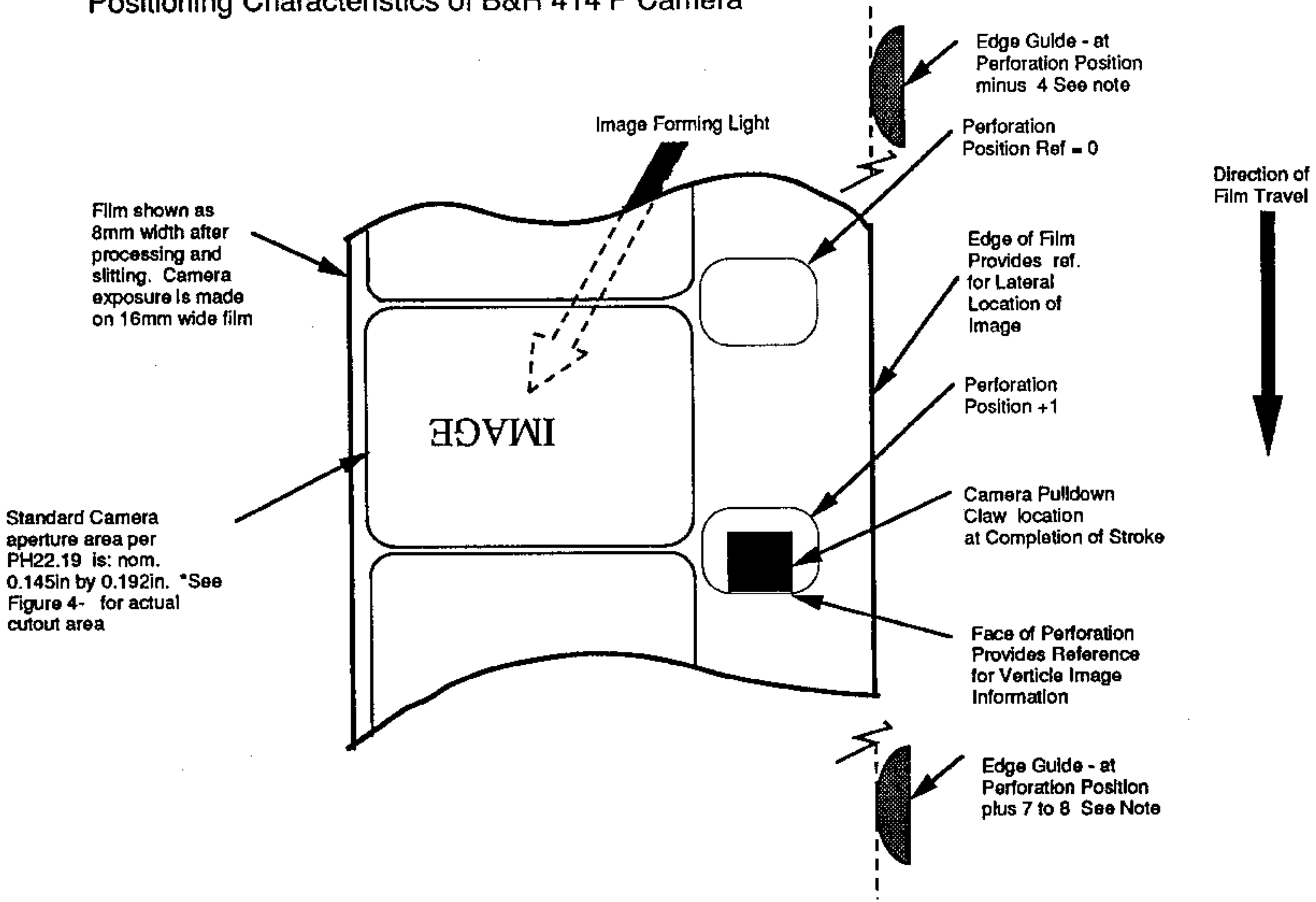


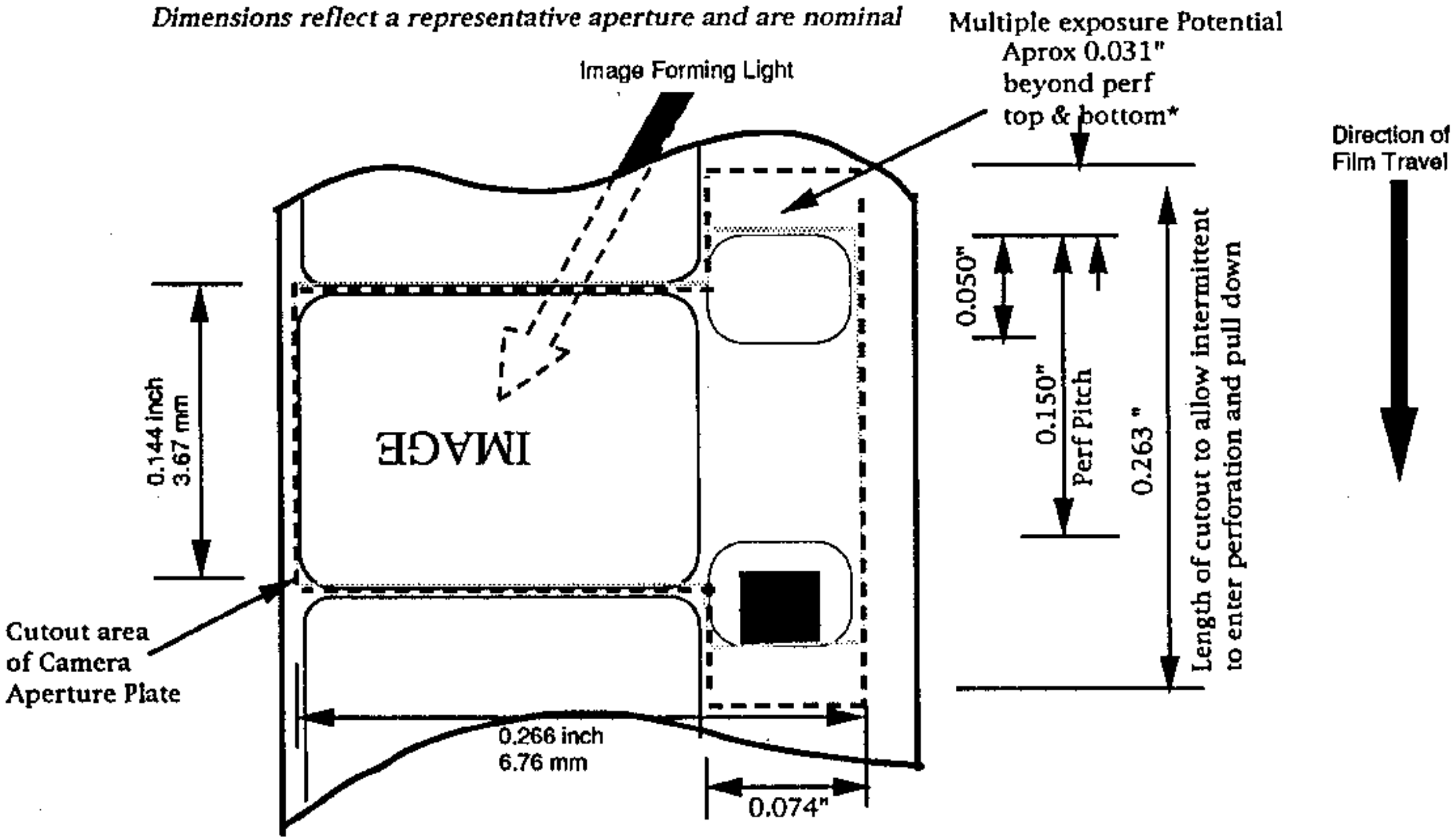
Figure 4-8 - Reference information

Note: The Edge Guides shown are spring loaded. The fixed guides are opposite - for the 16mm width of camera raw stock

B&H 414 P Camera Image Limiting Aperture & 8mm Film

Figure 4-9 - Reference information View from Inside the Camera looking Toward Lens

Dimensions reflect a representative aperture and are nominal



The primary light limiting aperture appropriately establishes the left, top and bottom edges of the standardized camera aperture image area (shown). However the cutout provision for the intermittent claw entry and pull down is necessarily longer than the length of the perforation pitch plus the height of an additional perforation. As a result, it is possible for image forming light (depending on focal length and aperture opening) to reach these areas (between the perforations) of the preceding and succeeding frames - allowing double or multiple exposure. Depending on scene content, these multiple exposed areas may appear as perforation like images or flare.

* Note: 0.031 inch is more than half a perforation height.

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It should be noted that the aperture plate is in close proximity, but not in direct contact, with the emulsion of the film. Consequently, the dimensions of the resulting image will be slightly different (larger) than the aperture opening. This difference will depend on the distance of the emulsion surface from the aperture opening and the f/value and focal length of the lenses used.

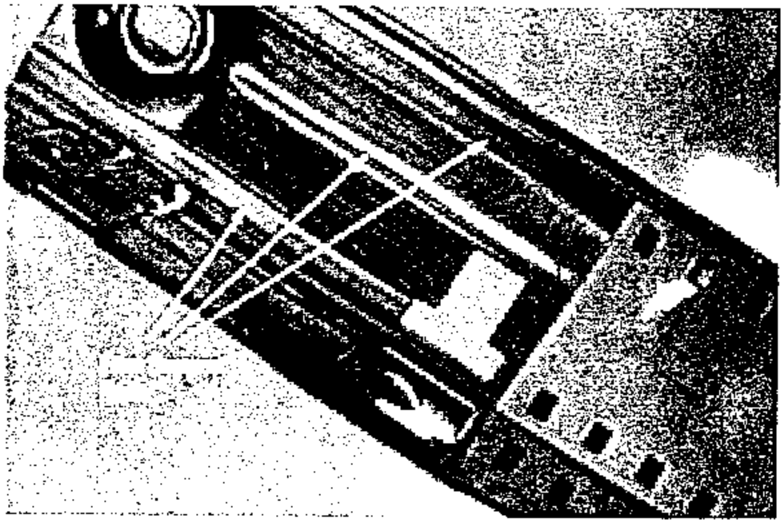

Figure 4-10 Camera Aperture Plate – Film Support Rails

The measured values of a representative aperture plate from a Bell & Howell 414 camera shows the film rails hold the film about 0.010 inch away from the primary image area and in direct contact with the film support rail in the claw cut-out area. The relationship of the film support rails and the aperture opening are shown in photo Figure 4-10.

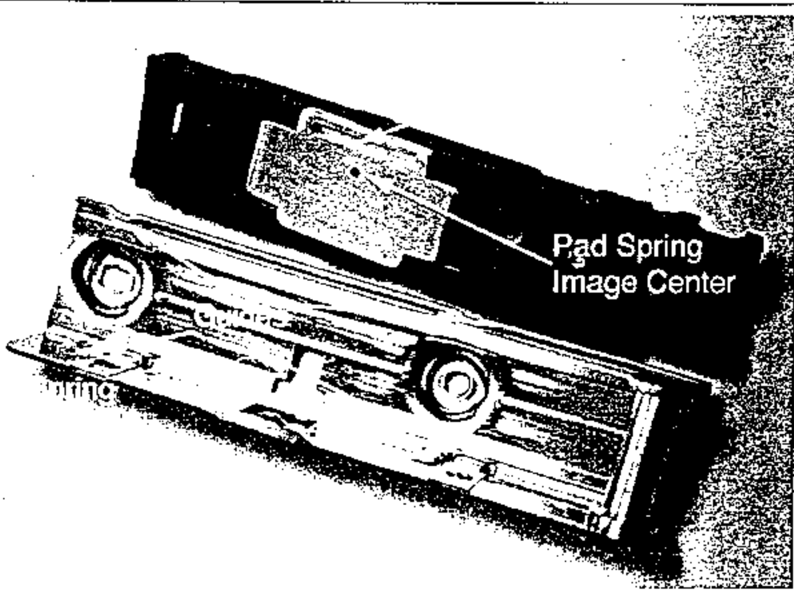

Figure 4-11 Camera Aperture Plate and Pressure Pad

Two other components are integral to the camera aperture; the film guides and the pressure plate. The film guides of the Bell & Howell 414 aperture are well apart to ensure good lateral stability. Further, they are established by two definitive guide points or pads rather than a flat rail, and thus more effectively accommodate variations in film width or curvature. The guides are spring loaded on the claw side and fixed on the opposite side. The spring loaded versus the fixed guide points are displaced by approximately one pitch length. The relationship of the spring loaded guide pads, the aperture opening and the fixed guide pads can be seen in photo Figure 4-11.

The other important aperture component is the pressure pad. The function of the pressure pad is to achieve the best possible film flatteners for good image sharpness and resolution, and to hold the film in position for exposure while the claw is ratcheting to the next perforation. The surface of the pressure pad is flat (ribbed and orange-peel are other possible surface treatments), and has a one-inch contact surface and has factory adjustable spring tension pivoting at the center of the image area. There is also a milled-out area to receive the claw protrusion through the film thickness during the pulldown stroke. Photo Figure 4-11 also shows the pressure pad. For comparison, a photograph of the aperture area of Wollensak Eight, Model 53 is shown as Figure 4-12.

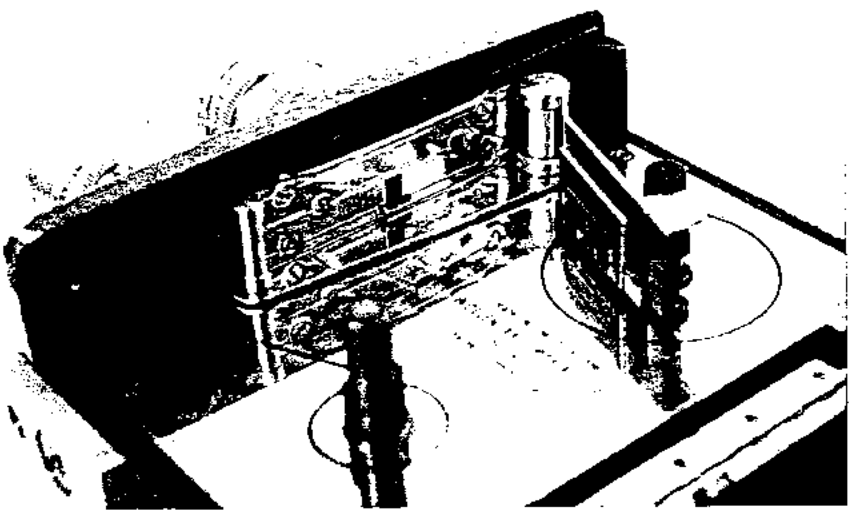

Figure 4-12 Wollensak Eight Model 53, Note similar aperture cutout

In summary, the film gate of the Bell & Howell 414 camera is designed to hold and reposition the film with effective precision to provide reproducible quality results with good image placement.

Shutter/Exposure Time:

The shutter, for the great majority of motion picture cameras, employs a rotating disc with an open sector to allow light from the lens to reach the film during its stationary exposure period. During the period when the opaque sector of the shutter obscures the light from the lens, the next frame of the film is moved and relocated by the intermittent.

In professional cameras, high speed intermittents are used which permit double bladed shutters with the open sector adjustable up to 300° to vary the exposure time and the film repositioning accomplished in about 60° of rotation. Amateur cameras generally employed shutter blades having openings of about 165° to 180°.

An exception to the general practice occurred when Eastman Kodak developed a Kodak XL Super 8 camera and Ektachrome movie film with an ASA speed of 160 to introduce available light motion picture photography. The XL camera employed a 230° shutter opening thereby requiring the film to be repositioned in one-third of the shutter rotation. The Bell & Howell 414PD camera uses a shutter having an open sector the equivalent of about 165° to 170°. (See Figures 4-4 and 4-5.)

The Camera Owners Manual, page 13, shows a shutter speed of 1/35 second for the normal run time of 16fps. If the shutter were 180°, the exposure time should have been listed as 1/32 second. We note above that the shutter opening cutout is less than 180° or which accounts for the 9% shorter exposure time. If we apply the equivalent ratios used to the establish the published shutter speed for 16 fps, or if we calculate the exposure time based on the measured shutter open time (and use the FBI measured actual run speed of 18.3 fps), the exposure time or shutter speed for Zapruder's camera would have been about 1/40th of a second. In 1975, it is reported[2] that CBS contracted Itek to study the assassination film for a projected telecast. In their report, Itek also calculated the exposure time to be 0.025 second (or 1/40th of a second) per frame.

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[2] Trask, Richard, Pictures of the Pain, Yeoman Press 1994, pp122 and 123.

Motor/Governor:

Early spring wound movie cameras were limited by their clock-spring wind-up motors which were a challenge to designers to maintain constant torque to transport the film at a uniform velocity because of inertial (acceleration) effects from the start of the clutched spring motor. Their run time was relatively short. In the late 50's and early 60's a major change occurred for the high-end cameras with the introduction of the negator spring.

The B&H 414 Camera series was the first of the Bell & Howell line to incorporate the negator spring. The negator spring motor provided an almost constant torque throughout its effective run time and essentially "negated" transport speed effects. Further, the run time was extended significantly. The differences in run time were in the order of double, from 25 - 30 seconds to more than a minute (15feet of film).

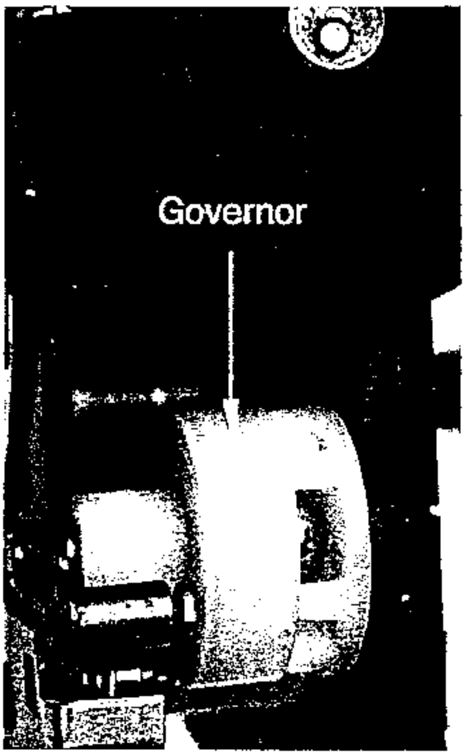

Figure 4-13 Multi-speed Governor

We are fortunate to have located MacMillin patent #3044347 (appended) describing the multi-speed governor (Figure 4-13) used on the Bell & Howell 414 series of cameras. Reference to this patent and its claims will provide the reader with a clear and detailed comprehension of the function of the exposure control mechanism and how simple and effective it was to shift from normal to slow-motion exposure speeds.

Film Velocity/Frame Rate[3]*:*

The question of frame rate of the Zapruder camera was an important technical consideration of the FBI in their investigation. The FBI reported that their studies showed the camera to be operating at 18.3 fps, or 2.3 fps fast according to the (then)

[3] An early history of the selection of film frame rate or velocity for taking and viewing motion pictures is contained in Mr. R. Zavada's article *"Managing" the Moving Image - from an Engineering Point of View*, SMPTE Journal, Vol. 101, No. 3, March 1992, pp. 153-156.

published standard and the reference in the owner's manual. This information is documented in the Warren Commission Report Volume VII. Typically the test would have incorporated filming a timing mechanism and evaluating the processed film, however, with the assistance of the ARRB, we could find no record of the FBI methodology.

Logic of a Film Velocity Greater than 16fps: For amateur motion pictures, and early commercial motion pictures, an objectionable feature was the flicker effect during projection. As more powerful projection lamps became available, the flicker effect became more objectionable. Although 16 fps was standardized for 8 and 16mm silent films, and was sufficient to provide a reasonable appearance of continuous motion, the eye was very much aware of the alteration of light and dark during projection at that frame rate. In the 1930's, 40's, and early 50's, projectors with variable speed control were not uncommon. Research shows that home movies were often projected at velocities greater than the standard 16 frames per second camera taking speed.

This concern led to the development of the three-blade projector shutter and an intermittent with a high-speed pull down. An accompanying increase in projection velocity to 18fps gave an acceptable flicker threshold of 54 cycles per second. The camera velocity increase followed projection practice.

Evolution of Standards to Higher Frame Rates: It has been acknowledged that Bell & Howell's[4] and Eastman Kodak's[5] engineering practice for cameras moved toward 18 fps in the late 50s, and that this velocity was not uncommon in USA practice. The committee action to change standards takes time. The published standard for camera velocity in use in 1963 issued in 1954. Standards reflect practice and the evolutionary change to the higher frame rate of 18 frames per second was subsequently recognized in American National Standards that issued October 26, 1964, for Camera and Projector Usage, PH22. 21 and PH22.22 (appended). Thus the FBI's report that Zapruder's camera was *"running 2.3fps fast"* was literally true but practically incorrect. Industry practice had changed, the standard was being revised and new documentation would follow within months.

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[4] Per David MacMillin, former Head of Bell & Howell Camera Design

[5] Per M. E. Brown, former Manager 16 & 8 mm Products Division, Eastman Kodak

Practical Tests – Old Cameras: Because the question of frame rate velocity with the Zapruder camera was so important to understanding the timing between shots, I was curious to know how the five old Bell & Howell 414P or PD cameras I acquired would perform. My tests showed an average 18.05fps, or 17.3fps with the high rate camera deleted. Age took a slight toll on the optimum film velocity.

Bell & Howell Camera Tests: It was reported in Mr. Trask's book that Bell & Howell tested the Zapruder camera when it was in their possession and reported the results.

- *It is reported that Bell & Howell did their own engineering test for speed. Bell & Howell president, P. G. Peterson, reportedly stated, "our results would appear to corroborate the FBI testimony before the Warren Commission that the average speed the film passed through the camera was at 18.3 frames per second and should be within less than 0.1 of a frame per second from the figures reported by the FBI".*[6]

Confirming Bell & Howell Testing: A year or so after the Warren Commission Report was issued, conspiracy theories began to emerge. The velocity of Mr. Zapruder's camera was understandably questioned. In the intervening time, Bell & Howell had acquired the Zapruder camera for their archives and there were questions about the accuracy of the FBI test results. Further investigation was needed to develop support for the reported film velocities.

The ARRB in a reexamination of evidence failed to locate the details of the FBI camera testing and wished, if possible, to substantiate the reported values. In my study of the B&H 414PD camera, I was very fortunate to locate several former members of the Photographic Division including Malcolm Townsley, former Engineering Vice President, David MacMillin, former Chief Camera Design, and Harold Miller, former Quality Control Engineer.

All knew that Bell & Howell had the camera in its archives, but none were directly aware of specific testing. As my investigation progressed, I surmised that if any department would be involved, it would be Quality Control. Subsequent discussions with Hal Miller turned up the fact that he had been working behind the scenes trying to gather information. Hal found an interesting letter that explained his reluctance to disclose details in our earlier discussions.

[6] Trask, Richard, Pictures of the Pain (Danvers, MA: Yeoman Press 1994), p. 108.

Hal had saved a letter (November 29, 1966) from former Engineering Vice President J. Reekie, who succeeded Mr. Townsley, complementing his testing efforts but admonishing silence. It read:

"Camera Speed Test. I want to record our thanks to Hal Miller for carrying out certain camera tests (emphasis added) with such efficiency and at distressingly short notice. These adequately served the purpose for which they were required. Please note that, should any person inquire, we are requested to make no comments on the test figures, nor to disclose the model of camera, nor to quote design specification figures on the camera."

I requested Hal to send me a copy of the letter with the assurance that I would contact current Bell & Howell management to "release him from his bonds".

I wrote to Mr. Roemer, CEO and President of Bell & Howell and was rewarded with permission to have former engineering personnel relate their recollections about the testing and specifications of the 414PD camera.

Hal's note to me, appended, gave a general description of the film velocity test and confirmed that he personally tested the Zapruder camera. Malcolm recalled that he had designed a camera velocity test and discussed the procedure used with Hal, and forwarded this description of the film velocity test procedure:

"Measurement of Camera speed

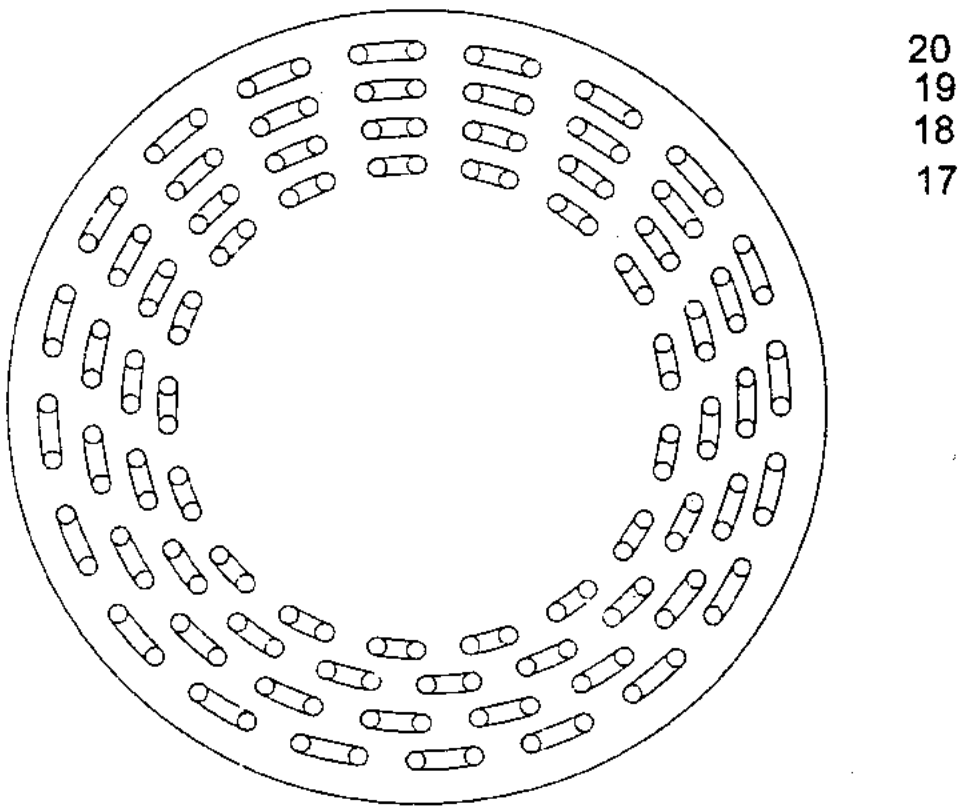
Miller gives a brief description of the test method used by Bell & Howell to measure the operating speed of the Zapruder camera.

The method is simple and straightforward, but an explanation of its geometry, action, and interpretation may be helpful.

The schematic drawing, (Figure 4-14), shows a sketched version of the appearance of a frame exposed while the disk with its illuminated points is rotating. Each illuminated point rotates through an angle while the shutter is open, so that its image is a short, bright, arc.

Bell & Howell Camera Velocity Test Target

Supplied by Malcolm Townsley,
Former Engineering Vice President
(see text)



Schematic of camera speed measuring target as photographed

Figure 4-14

In its simplest form, the disk has several circular rows of what Miller describes as rivet heads, which are illuminated to provide the bright points. Typically, there will be one row with 20 equally spaced rivet heads, one with 19, one with 18, and one with 17. If the speed expected to very widely during a run, there may be more rows.

If the camera is running at n frames per second, and the disk is rotating at 60 rpm, then the disk will rotate 360/n degrees between successive frames. If the angle 360/n matches the angle between points on one of the rings of points from one frame to the next, the disk will have advanced by exactly the angle between points, and the image in the second frame will coincide with the image in the first frame, as seen when the film is projected. This ring of bright arc images will then appear to be stationary, not rotating.

A ring with more points will advance by more than the angle between points, so that the image in the second frame will be slightly beyond the image in the first frame, and the ring will appear to rotate, on projection, in the direction of the disk rotation.

Similarly, a ring with fewer points will appear to have a retrograde rotation.

It is possible to make measurements of the apparent angle of advance between frames to get a very detailed picture of the speed of camera operation through the full run of the spring wind. Miller appears not to have done this, giving only a statement that the camera ran slightly faster than 18 frames per second.

The FBI numbers for the camera speed would appear to have come from a more detailed analysis of a target imaging procedure essentially similar to the one described here."

In my conversation with Hal, he recalls only that the camera was slightly faster than 18 fps with one group of tests run with five-second short bursts. A second set of tests was conducted, full-wind, start-stop and he reported that the velocity was fairly constant, dropping only a few tenths in frame rate from beginning to end, similar to the reported FBI results. Hal believes the results of his testing were "probably" communicated to the government in a non-recollected manner. Thus, we have substantiated Bell & Howell's testing of the Zapruder camera;

the recollected rate is close to that reported by the FBI; and we now know why the information was difficult to acquire.

Synopsis of Mechanical Characteristics:

Many of the mechanical characteristics of the Bell & Howell 414PD can be visualized by reviewing the Motion Picture Cameras patent[7] 3,200,411, August 10, 1965, by M.G. Townsley, former Engineering Vice President of Bell & Howell. The design is for an advanced form of the power zoom feature, not contained in the 414 model, however the drawings contain all the essential feature of the 414 model and the patent is an excellent reference. There the shuttle or film pull down claw is described as item 22 of Figures 6 and 7. The claw function and the camera's basic mechanical function are referenced in this *"paraphrased"* extract from the patent. (Please refer to the patent for full details.)

> *The camera mechanism includes a negator spring motor drive which, when released by pivotal movement of a control arm from its position (by pushing down on the start button), serves to rotate a scroll gear to drive a worm (gear). This worm serves to rotate a film footage indicator dial, and to rotate a gear carrying a crank pin to oscillate a shuttle or film pulldown claw and rotate a shutter, as well as drive a governor, and to rotate gears. The shuttle is urged by spring (pressed against the film) toward feeding engagement with film (i.e. to engage the perforation holes) in a position between an aperture plate incorporating an exposure aperture (area) and a pressure plate (to hold the film flat and motionless during exposure). The shuttle is pivoted on a pin. The gear also carries a known disc segment type of shutter which covers the aperture during frame-by-frame feed of the film and when the camera drive is stopped.*

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[7] Copy appended.