Slide Rule for Analyzing High-Speed Motion Picture Data

By Karl W. Maier

In mechanics research, evaluation of high-speed motion picture records involves several basic calculations which have to be repeated very often. The Springfield Armory has developed a special slide rule which will mechanically perform these computations, as well as some precalculations before taking the picture. It is believed that the proposed slide rule permits more rapid evaluations with fewer errors and with less highly trained personnel.

This analysis covers standard 16- and 8-mm motion picture films, with the standard timing marks, 1000 or 60 timing units per second, as used in mechanics research (Fig. 1).

A motion picture engineer often has to make basic calculations in evaluating a given high-speed motion picture record. Of special interest are the operating time of a certain machine part and the cyclic rate of the mechanism to be investigated. Direct counting of the corresponding number of timing units is too tedious when the operating time, as is usual, extends over a great number of frames. Therefore, it is better instead to count the corresponding number of frames and the operating time is calculated from this. Although the formulae involved are comparatively simple, considerable time is consumed in reading values from the film as well as in the elementary calculations, and thus, series investigations, desirable for one reason or another, would appear to be impractical. Furthermore, the motion picture engineer must determine optimum operating conditions for the camera before taking a picture. In order to reduce time and errors, a mechanical method of computation would be of advantage and solve both problems.

R. F. Ledoux, head of the Springfield Armory Photographic Laboratory, expressed the desire for an instrument that would fulfill such requirements, and a beginning was made. First, charts were used and from them there was finally evolved a special slide rule, which should satisfy a long-felt need for more rapid evaluations. Although this slide rule was originally intended for weapon research and development, it is believed that it can be used equally well in the entire field of mechanics research. The first model has been fabricated and tested by the Photographic Laboratory of Springfield Armory, and has proved to be a great time saver. A patent application has been filed.

This proposed evaluation method is

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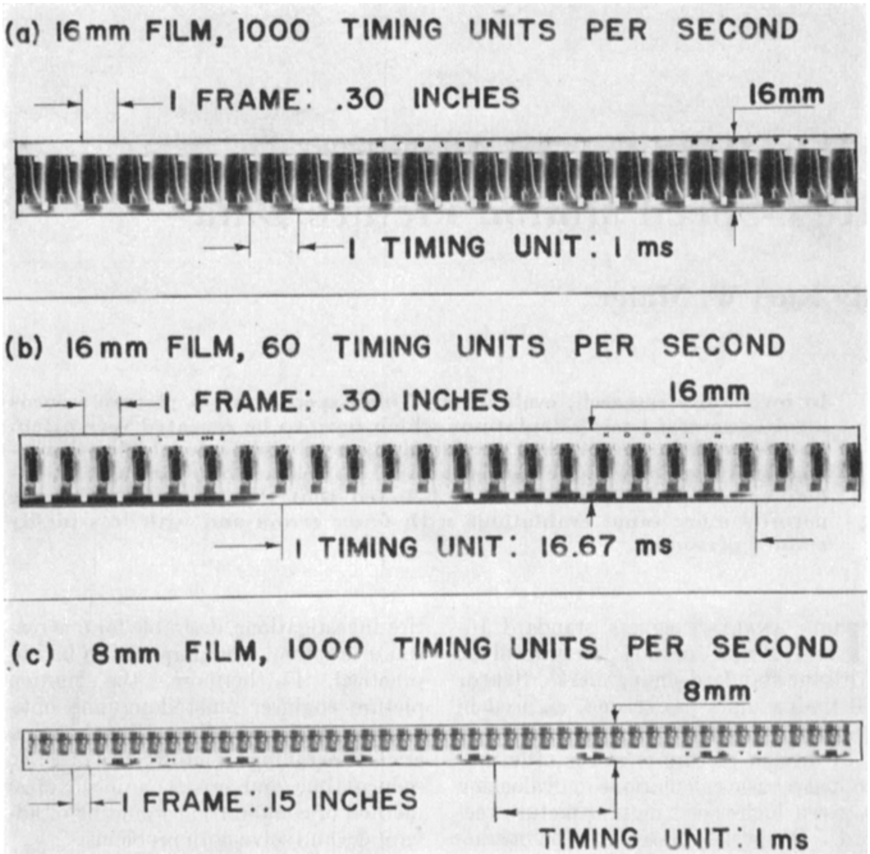

Fig. 1. Standard films with timing marks.

based on a simplified reading of values from the film. For evaluation purposes, the length of the film is divided into parts, over which the original film velocity (during film run in the camera) can be considered constant, depending on the acceleration of the film and accuracy desired. Within such a part of film, any time interval and the corresponding number of frames are in constant proportion. This can be designated as the "frame time," i.e., time value of one frame.

The number of frames representing a certain operating time is counted either visually (when small) or by means of a mechanical frame counter, the latter being either on the projector or separate. The height of one frame, 0.30 in. for 16-mm film and 0.15 in. for 8-mm film, is used as the unit of length for the film, thus eliminating any length measurements in the direction of film motion by means of a scale.

With regard to time, only small time intervals consisting of a few timing units are counted visually. Greater time intervals are calculated by means of the slide rule, using the frame time and the corresponding number of frames.

Nomenclature

Note: Whenever film velocities or time intervals on the film are given, the film run in the camera when the picture was taken is meant; the velocity of the film when being projected is not of interest here.

Symbol	*Description of Symbol*	*Unit*
N	Any number of frames or pictures in a given part of the film	frame
N′	Number of shots in a burst	shot
t	Any time interval of film	ms
t_1	Frame time, i.e., time value of one frame during the film run in the camera	ms/frame
T	Total running time of film	sec
T′	Duration of a burst fired or time to be recorded	sec
i_{1000}	Any (whole) number of timing units when using 1000 timing units per second (frequency 1000)	1 ms
i_{60}	Any (whole) number of timing units when using 60 timing units per second (frequency 60)	16.67 ms
v	Velocity of film in the camera	ft/sec
V	Velocity of film in the camera	frames/sec
v_{max} (V_{max})	Maximum film velocity near end of film run in the camera	ft/sec (frames/sec)
$\bar{v}$ ($\bar{V}$)	Average film velocity over total running time	ft/sec (frames/sec)
v_{min} (V_{min})	Minimum film velocity permissible for sharp pictures	ft/sec (frames/sec)
n	Cyclic rate of a mechanism	rpm
v^*	Maximum velocity of moving machine part	ft/sec
$\bar{v}^*$	Average velocity of moving machine part over given travel distance	ft/sec
s	Travel distance of machine part	in.
w	Width of field in the distance of moving parts covered by the effective width of the film (see Fig. 3)	in. (ft)

To establish the scales of this slide rule, some preparatory work, such as defining characteristic values and analyzing mathematical relationships used in the basic computations, had to be done first.

Basic Tasks for Evaluating Film Records and Formulae Used

With a given motion picture record, the relationship between a certain time interval and the corresponding number of frames is of general interest and will aid in standardizing evaluations. This time-length relationship can be indicated either by the "frame time" in ms/frame, or by the film velocity measured in ft/sec or frames/sec. Both values vary over the length of the film. This brings up the following questions:

What is the *frame time,* t_1, at any point of the record? N frames of the film may correspond to the time t, or i_{1000} timing units or i_{60} timing units (i_{60} and i_{1000} are whole numbers); the frame time then becomes:

$$t_1 = \frac{t}{N} = \frac{i_{1000}}{N} = \frac{50 \cdot i_{60}}{3N}, \text{ in ms/frame.} \quad (1)$$

For example: When 5 timing units of the 1000-cycles timing correspond to 8 frames, the frame time then becomes:

$$t_1 = 0.625 \text{ ms/frame.}$$

What was the *film velocity* in the camera, v, in ft/sec (or V, in frames/sec), at any point of the given record? N frames may correspond to the time t, or i_{1000} timing units or i_{60} timing units, then the film velocity is:

$$V = \frac{1000}{t_1} = \frac{1000 \cdot N}{t} = \frac{1000 \cdot N}{i_{1000}} = \frac{60 \cdot N}{i_{60}}, \text{ in frames/sec.} \quad (2)$$

For example: With 8 frames in i_{1000} = 5 timing units, a film velocity of 1600 frames/sec results. The corresponding film velocity v, measured in ft/sec, as well as the relationship between v and V, depends on the type of film.

16-Mm Film:
$$v = \frac{25}{t_1} = \frac{25 \cdot N}{t} = \frac{25 \cdot N}{i_{1000}} = \frac{1.5 \cdot N}{i_{60}}, \text{ in ft/sec,} \quad (3)$$

with the relationship

$$V = 40 \cdot v, \text{ in frames/sec.} \quad (4)$$

With 8 frames in 5 ms, a film velocity of 40 ft/sec results.

8-Mm Film:
$$v = \frac{12.5}{t_1} = \frac{12.5 \cdot N}{t} = \frac{12.5 \cdot N}{i_{1000}} = \frac{0.75 \cdot N}{i_{60}}, \text{ in ft/sec,} \quad (3')$$

with the relationship

$$V = 80 \cdot v, \text{ in frames/sec.} \quad (4')$$

With 8 frames in 5 ms, a film velocity of 20 ft/sec results.

Frame time and film velocity are related values. They always satisfy relationships (2), (3) and (3′). Both values are also used advantageously for special evaluation tasks, such as determining operating time of a machine part, cyclic rate of a mechanism, etc.

What is the *operating time of a machine part,* when the former comprises N frames on the film?

The beginning and ending of the operation have been marked and N frames have been counted for this time interval. First, the frame time, t_1, has to be determined according to (1), by evaluating a short time interval, consisting of a few timing units in the middle of operating time. Then the operating time, t, is:

$$t = N \cdot t_1, \text{ in ms.} \quad (5)$$

For example: With the above frame time of 0.625 ms/frame, an operation comprising 80 frames lasts 50 ms. For a long operating time, the frame time, t_1, may be taken at the beginning and at the end of operation and the average value thereof may be used for calculations.

What is the *cyclic rate* of a gun (or other mechanism) when N frames are counted for the cycle time, t? Using frame time t_1, the cycle time is given by Eq. (5) and the cyclic rate follows:

$$n = \frac{60{,}000}{t} = \frac{60{,}000}{N \cdot t_1}, \text{ in rpm.} \quad (6)$$

For example: With the above frame time of 0.625 ms/frame and 80 frames per cycle, the result is a cyclic rate of 1200 rpm.

What was the approximate *total running time of the film,* T, in seconds?

To answer this question, the average film velocity over the total running time, $\bar{v}$ or $\bar{V}$, should be known. Figure 2 illustrates the acceleration characteristic of film run, that is, the increase of film velocity during film run in the camera. The average film velocity, $\bar{V}$, is somewhat lower than the maximum film velocity near the end of the film run V_{max}. How much lower it is depends on the type of camera and, eventually, on the voltage used. For one type of high-speed motion picture camera the proportion

$$\frac{\bar{V}}{V_{max}} = \frac{\bar{v}}{v_{max}}$$

was found to be approximately 0.8. To have more accurate data available, the acceleration characteristics should be determined for all types of cameras and voltages used. Based on a film length of 100 ft, the total running time then is:

$$T = \frac{100}{\bar{v}} \text{ sec.} \quad (7)$$

When introducing the film velocity in frames/sec:

16-mm film: $$T = \frac{4000}{\bar{V}} \tag{8}$$

8-mm film: $$T = \frac{8000}{\bar{V}} \tag{8'}$$

For example: With a maximum film velocity, v_{max} = 70 ft/sec (V_{max} = 2800 frames/sec for a 16-mm film), the average film velocity is approximately 56 ft/sec or 2240 frames/sec, which means a total running time of 1.78 sec.

What is the *average velocity of a machine part*, $\bar{v}^*$, when its travel over a known distance of s inches corresponds to N frames on the film?

First, the corresponding time t, in ms, has to be determined according to equations (1) and (5). Then the average velocity is:

$$\bar{v}^* = 1000 \cdot \frac{s}{t} \text{ in./sec.} \tag{9}$$

or $$\bar{v}^* = 83.33 \cdot \frac{s}{t} \text{ ft/sec.} \tag{9'}$$

For example: With s = 4.8 in., and t = 25 ms, the average velocity is $\bar{v}^*$ = 16 ft/sec.

Basic Tasks for Precalculation and Formulae Used

This second group of tasks comprises calculations which must be made prior to taking a picture in order to determine optimum operating conditions for the camera.

1. Time to Be Recorded

What is the time of a burst of N′ shots, T′, when fired with a cyclic rate of n rpm?

$$T' = \frac{60 \cdot N'}{n} \text{ sec.} \tag{10}$$

For example: A burst of 25 shots, fired at a cyclic rate of 1200 rpm, lasts 1.25 sec. Since the initial run of the camera does not give sharp pictures due to the low film velocity in the beginning (see Fig. 2), the burst and its recording is started with a certain delay after the beginning of film run by means of an electronic timing device. Assuming that a delay of 0.50 sec is necessary, the total running time of the film, T, has to be at least 1.75 sec in order to cover the whole burst. Therefore, the time to be recorded, T′, prescribes a lower limit for the total running time, T, or, in other words, an upper limit for the maximum film velocity, V_{max}. To select the right maximum film velocity and corresponding voltage, the acceleration characteristic of the camera and some additional data must be given.

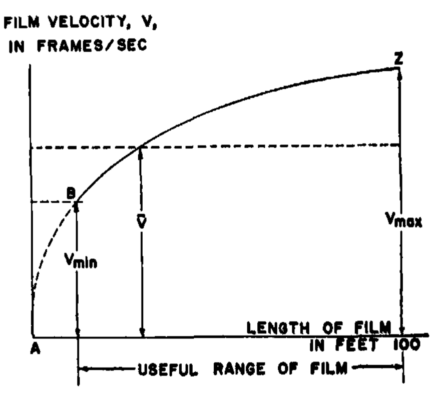

Fig. 2. Acceleration characteristic of film run.

2. Minimum Film Velocity

What is the minimum film velocity permissible for sharp pictures, v_{min} or V_{min}?

The image of a moving gun part on the film also moves during exposure time of the corresponding frame and brings about a blurred picture (see Fig. 3); therefore, the image travel per frame must be less than a certain limit, when sharp pictures are desired. The factors determining the image travel are:

Maximum velocity of machine part, v^*: The faster the machine part is moving, the greater will be the image travel during exposure time. Here, only the projection of the velocity onto a plane

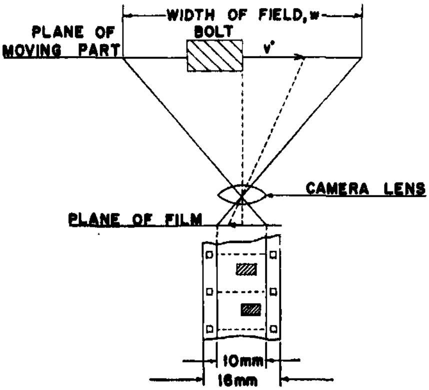

Fig. 3. Relationship between object and image.

through the moving part, parallel to the camera lens, has to be considered.

Reduction of image in camera: This defines the proportions of image to object dimensions (see Fig. 3). It can be expressed in terms of the width of field, w, which is covered by the effective width of the film, the latter being approximately 0.4 in. for the 16-mm film and 0.2 in. for the 8-mm film. The reduction itself then becomes 0.4/w and 0.2/w, respectively.

Exposure time of one frame and film velocity: The image travel per frame changes in proportion to the exposure time, i.e., in the inverse ratio to the film velocity (assuming a constant ratio of exposure time to frame time).

With one type of high-speed motion picture camera the permissible image travel during exposure time, which still guarantees sharp pictures, is 0.002 in. This means approximately 0.010-in. image travel per frame, since the exposure time is about one-fifth of the frame time. The film velocity, therefore, must be greater than a certain lower limit, V_{min}, in order to obtain sharp pictures. This means that the beginning of the film, moving with velocities less than V_{min} during exposure, cannot produce records meeting all requirements.

Based on an image travel of 0.010 in. per frame, the following formulae are obtained for the minimum film velocity (compare with chart for selecting speed given by Eastman Kodak Co.):

16-mm film:

$$v_{min} = 12 \cdot \frac{v^*}{w} \text{ ft/sec} \qquad (11)$$

$$V_{min} = 480 \cdot \frac{v^*}{w} \text{ frames/sec} \qquad (12)$$

8-mm film:

$$v_{min} = 3 \cdot \frac{v^*}{w} \text{ ft/sec} \qquad (11')$$

$$V_{min} = 240 \cdot \frac{v^*}{w} \text{ frames/sec} \qquad (12')$$

For example: When a machine part moving with a maximum velocity $v^* = 40$ ft/sec has to be photographed on 16-mm film within a field 10 in. wide, only film velocities greater than 48 ft/sec or 1920 frames/sec will guarantee sharp pictures. For 8-mm film, the film velocity must be greater than 12 ft/sec or 960 frames/sec, with the same velocity of machine part and width of field assumed.

3. Conclusion

The correct film velocity to be chosen for recording lies within a range where the lower limit is determined by claiming sharp pictures, while the upper limit is prescribed by the time to be recorded and possibly by the illumination required to obtain a suitable exposure. The acceleration characteristic of film run, illustrated in Fig. 2, should be known for each camera under various operating conditions.

Description of Slide Rule

Since the above formulae involve only multiplications and divisions, a slide rule based on logarithmic scales seems to be the best approach to a mechanical computer.

The slide rule developed consists of three parts, the *body*, the *slide* and the

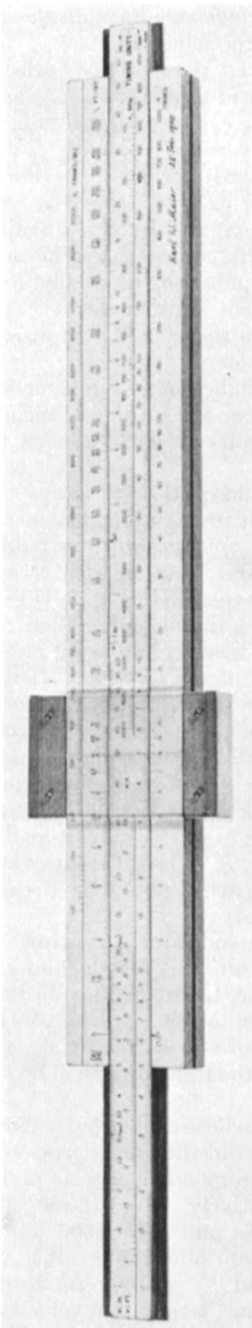

Fig. 4. Model of linear slide rule for analysis of high-speed motion picture films.

indicator, the latter two moving in longitudinal grooves of the slide rule body (see Fig. 4).

The slide rule *body* has three log scales, one below and two above the slide groove.

N-scale: This scale is used for the number of frames or pictures contained in any interval of film with a range from 1 to 1000 frames (additional use for the number of shots in a burst, N′). Index "1" of the scale has an arrow (t_1) for reading of the frame time, t_1, in the t-scale of the slide.

v-scale: This scale is used for the film velocity, v, as well as for the velocity of a moving part, v*, both measured in ft/sec. It has two readings, the lower one from 1 to 1000 ft/sec for 16-mm film only, the upper one with a range from 0.5 to 500 ft/sec for 8-mm film only. These are referred to as upper and lower v-scale.

V-scale: Here the film velocity, V, in frames/sec is shown for both 16-mm and 8-mm film. The range extends from 100 to 20,000 frames/sec.

The *slide* is purposely longer than the body in order to cover a wide range of time. It has five log scales.

t-scale: This scale has a double use, either for time, measured in ms, or for the number of timing units, i_{1000}, when using 1000 timing units/sec. The range extends from 0.1 to 1000 ms.

i_{60}-scale: This scale shows the number of timing units, i_{60}, when using timing frequency of 60/sec, with a range from 1 to 60, i.e., 16.67 ms to 1000 ms. At the 1.5 division of this scale, there is an arrow (v) for reading of the film velocity in the v-scale or V-scale.

n-scale: This scale shows the cyclic rate of an automatic gun or mechanism per minute, with a range from 100 to 10,000 rpm.

Upper w-scale: w indicates the width of field in inches, which is covered by the effective width of film as shown in Fig. 3. The range extends from 1 to 100 in. Arrows (8, v_{min}) and (16, v_{min}) point to the film velocity, v_{min}, in the corresponding v-scale, or V_{min} in the V-scale.

Lower w-scale: This scale is for the width of field, w, measured in feet, with a range from 0.1 to 2.5 ft, to be used together with the upper w-scale for conversion of inches into feet and vice versa.

The transparent *indicator* has a hairline, perpendicular to the direction of the log scales, for alignment of the corresponding values in various scales.

Use of Slide Rule for Evaluation Tasks

1. Correct Slide Position With Reading of Frame Time and Film Velocity

To find the frame time, t_1, and the film velocity, v or V, in a given part of the film record, the procedure outlined below should be followed.

A part of the film strip, short enough so that the film velocity during film run in the camera can be assumed constant for evaluation purposes, should be considered. Then any time interval within this film part, t, will have a constant proportion to the corresponding number of frames, N, where this proportion is identical with the frame time, t_1, defined previously. For example, when $i_{1000} = 5$ timing units or 5 ms correspond to 8 frames, 10 ms will correspond to 16 frames, and the frame time is 0.625 ms. The following, therefore, applies to the slide rule: When *any* time, t, on the t-scale of the slide is aligned with the corresponding number of frames, N, on the N-scale of the slide rule body, *all* time values, t, will be aligned with the corresponding number of frames, N. Especially, index "1" on the N-scale, indicated by arrow (t_1), will be aligned with the frame time, t_1, on the t-scale. This slide position with the proper alignment of t-scale and N-scale may be called "correct slide position" for the given part of film with constant velocity. For another part of film with a different velocity, another positioning of the slide within the slide rule body will be the correct one. The procedure for determining the correct slide position, therefore, includes readings on the film as well as on the slide rule.

In the given part of *film,* select a small number of timing units, i_{1000} or i_{60}, and count the corresponding number of frames, N, by visual approximation or by means of the frame counter. For example, it will be found when $i_{1000} = 5$ timing units, N = 8 frames. Reading fractions of frames increases the accuracy of computation, especially for a smaller number of frames. The procedure for the *slide rule* is comprised of the following steps:

Move the indicator to the value 8 on the N-scale, i.e., the hairline of the indicator must coincide with value 8 (see Fig. 5).

Move the slide so that the corresponding number of timing units, $i_{1000} = 5$, of the i_{1000}-scale converges with the hairline on the indicator, that is, with N = 8. (When the corresponding time is given in terms of i_{60} timing units, then that value of the i_{60}-scale has to be aligned with N = 8 of the N-scale.) This is now the "correct slide position" for all evaluations of time and velocity within the given part of film assumed to have constant velocity. Corresponding numbers of frames of the N-scale, and times of the t-scale, are in alignment as illustrated in Fig. 5. For different evaluations in this part of film, only the indicator is moved.

Move the indicator to arrow (t_1) (index "1") on the N-scale and read the *frame time,* $t_1 = 0.625$ ms, in the t-scale. (When arrow (t_1) on N-scale falls outside of t-scale, read time, t, at N = 10 and the frame time will be $t_1 = t/10$.)

Move the indicator to arrow (v) inside i_{60}-scale and read the *film velocity* v and V in the corresponding v-scale and V-scale, respectively. For 16-mm film, v = 40 ft/sec and V = 1600 frames/sec. For 8-mm film, the result is v = 20 ft/sec and V = 1600 frames/sec. The frame time, t_1, and film velocity, v, which are related, can be considered

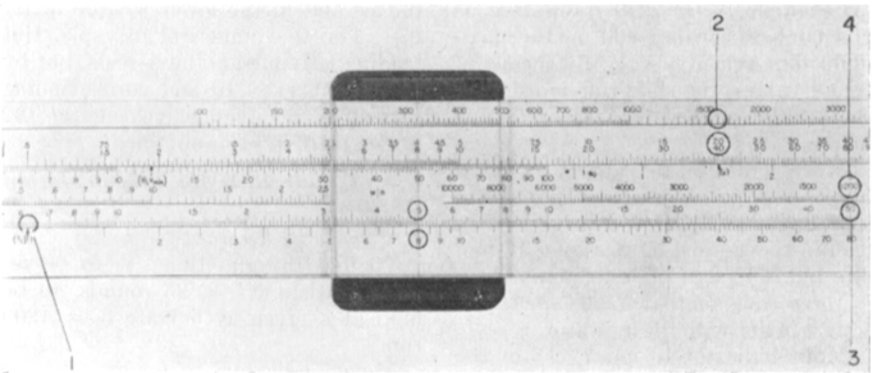

Fig. 5. Setting of slide rule to read.
(1) Frame time (2) Film velocity (3) Operating time (4) Cyclic rate

characteristic values for any such part of film with constant velocity.

2. Operating Time and Cyclic Rate

To find the operating time of a part, t, extending over N frames of the film and the cyclic rate, n, when one gun cycle comprises N frames:

Mark the beginning and end of operating time on the film.

Determine the correct slide position for this part of film according to Paragraph 1 above, by evaluating a time interval in the middle of operating time (or by taking the average of two evaluations, at the beginning and end of operation). The same slide position as in Paragraph 1 above, with frame time of 0.625 ms, may be assumed.

Count the number of frames corresponding to the given operation, N, in the film by visual approximation or by means of a frame counter. For example, N = 80 frames, may be found.

Move indicator to the numeral "80" in N-scale and read *time of operation*, t, in t-scale at the hairline. It will be found that t = 50 ms (compare with Fig. 5).

When this time of operation, t, is identical with the cycle time of the gun, read the corresponding cyclic rate, n = 1200 rpm, in the n-scale with the same indicator position, i.e., above t = 50 or N = 80 (see Fig. 5).

Note: The tasks described for determining frame time, film velocity, operating time and cyclic rate, represent the basic evaluation of a given film by means of the slide rule. All log scales, with exception of the two w-scales and at times the i_{60}-scale, are involved. When several operating times must be evaluated in the same part of film with constant velocity, the slide remains in its correct position, and only the indicator needs to be moved. Therefore, the timesaving value of the slide rule is increased with the number of evaluations to be made within such a film part of constant velocity. In addition to the basic evaluation tasks, listed above, the slide rule can also be used like a standard slide rule, for other evaluations. In these cases, the final slide position no longer means the correct alignment of the N-scale and t-scale, but rather the adjustment of other scales with other meanings. To show this, two examples will be given in the following.

3. Total Running Time of Film (Approximate)

To find the *total running time* of the film, T, when the average film velocity, for example, $\bar{V}$ = 2240 frames/sec, is given or has been derived from the maximum film velocity, V_{max}, by means of tested values, the slide rule is used for the solution of Eq. (7), (8) or (8′) as follows:

Move indicator to value $\bar{V}$ = 2240 frames/sec in V-scale. The corresponding average film velocity is then read in the v-scale, 56 ft/sec for 16-mm film and 28 ft/sec for 8-mm film.

Move slide so that "100" on the t-scale is in line with the indicator.

Move indicator to index "1" of the corresponding v-scale and read the total running time, T, in seconds at the hairline in the t-scale. T will be 1.78 sec for 16-mm film and 3.56 sec for 8-mm film.

4. Average Velocity of a Machine Part

To find the average velocity of a machine part, $\bar{v}^*$, when its travel over s inches corresponds to N frames on the film, *for example,* s = 4.8 in., N = 40 frames:

Determine time of travel, t in ms, according to Paragraph 2 above. In the numerical example (which follows Eq. (9′) above), t = 25 ms.

Move indicator to number "25" on v-scale for 16-mm film.

Move slide until number "4.8" in the upper w-scale coincides with the hairline.

Move indicator to index "1" on v-scale for 16-mm film and read the average velocity, $\bar{v}^*$, in the upper w-scale in in./ms and in the lower w-scale in ft/ms. For the numerical example, this reading falls outside the w-scale, but by reading at v = 10 and corresponding correction, an average velocity of 192 in./sec or 16 ft/sec is obtained.

Use of Slide Rule for Precalculation Tasks

1. Time to Be Recorded

To find the gun time, T, to be recorded, when N′ = 25 rounds, to be fired at a given cyclic rate n = 1200 rpm:

Move indicator to arrow (t_1) of N-scale.

Move slide, so that the given cyclic rate, n = 1200, lines up with the indicator.

Read the cycle time of the gun, t = 50 ms, in t-scale above arrow (t_1) of N-scale.

Move indicator to N = 25 in N-scale and read the time of a burst of 25 shots in the t-scale at the indicator. Because this reading falls outside the t-scale, the value 125 is read at N = 2.5 and multiplied by 10, so that a burst time of 1250 ms or 1.25 sec is the answer.

2. Minimum Film Velocity

To find the minimum film velocity permissible for sharp pictures, when the maximum velocity of the moving part, v*, and the width of field to be covered by a 16-mm film, are given, *for example,* when v* = 40 ft/sec, and w = 10 in.:

Move indicator to number "40" on lower v-scale for 16-mm film (see Fig. 6).

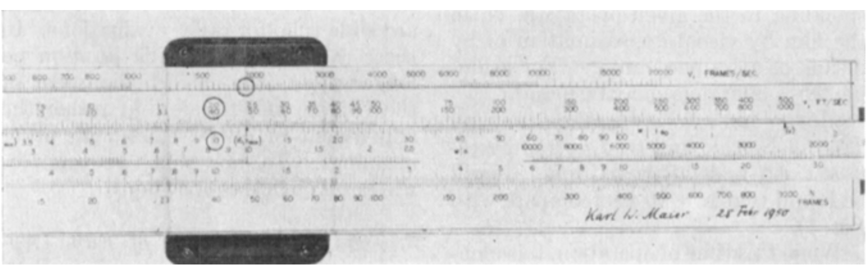

Fig. 6. Setting of slide rule to determine the minimum film velocity required to obtain sharp pictures.

Move slide so that number "10" in upper w-scale (in inches) comes under indicator.

Move indicator to arrow (16, v_{min}) in upper w-scale. The minimum film velocity permissible is then read at the hairline in the lower v-scale or V-scale and will be v_{min} = 48 ft/sec or V_{min} = 1920 frames/sec. For 8-mm film the *upper* v-scale and arrow (8, v_{min}) must be used for reading of both velocities, v* and v_{min}. The minimum film velocity permissible for the same values as in the above example will be 12 ft/sec or 960 frames/sec.

It should be borne in mind, however, that this calculation is based on a permissible image travel of 0.010 in. per frame, with only 0.002 in. image travel during exposure. For cameras with other image travel during exposure time, the location of the arrows (16, v_{min}) and (8, v_{min}), in the upper w-scale would have to be changed.

Value of Slide Rule

For many of the basic computations which must be made by a motion picture engineer, such as evaluations of given film records as well as precalculations for optimum operating conditions of the camera, the above-described slide rule eliminates all numerical calculations.

Of important advantage in perform-

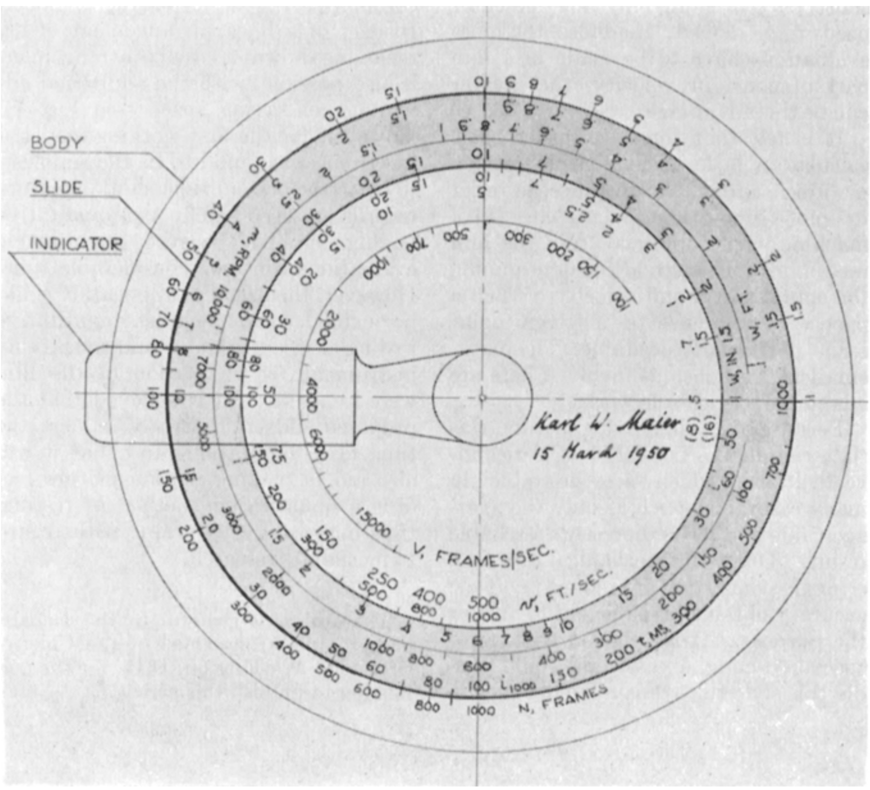

Fig. 7. Model of circular slide rule for analysis of high-speed motion picture films.

ing evaluation tasks by means of a scale is that any length measurements on the film are eliminated. Counting of frames is done simply by visual approximation (for smaller numbers) or by a frame counter (either on the projector or separate), using the frame height as a unit of film length. Measuring of time is done by counting a small number of timing units. In evaluation, the whole film strip is divided into parts of such length that the corresponding film velocity can be considered constant. Due to the constant proportion between length and time within such a short part of film, a definite position of the slide with regard to the slide rule body is prescribed. For evaluations within such a short part of film, only the indicator needs to be moved; therefore, the more evaluations have to be made in a film part of constant velocity, the greater will be this advantage.

It is felt that there are other basic calculation tasks in evaluating motion picture records. For instance, in order to plot time-displacement curves of machine parts, obtained from the film record, a rapid method for determining the actual travel and velocity of such a part with reference to a given point seems particularly desirable. The mathematical relationships involved here are adaptable to slide rule work.

Because of its timesaving feature, this slide rule makes possible long series investigations, which are desirable in many cases, inasmuch as only the average value of a series represents a reliable result. Due to its mechanical function, errors in computing are reduced and the accuracy obtained is sufficient to answer the purpose. It is believed that, after special training, an assistant could handle this slide rule, thus relieving the engineer from time-consuming elementary calculations.

Another use for the slide rule is in calculating optimum operating conditions of the camera prior to taking a picture. It is believed that the present value of the slide rule could be still further increased by adding a scale for the total running time, if more data, regarding acceleration characteristics of different cameras under different voltages, as functions of film travel and time, could be provided. These acceleration characteristics could be obtained by evaluations of film records.

Modification of the present model can be readily effected to include other types of film (35-mm) and timing according to the needs of the engineer. Instead of a linear arrangement of log scales, as shown, a circular arrangement is also possible, with the additional advantage of saving space (see Fig. 7). However, for the first working model, a linear one was found to be the simplest.

Up to the present time, motion picture records are used chiefly as a qualitative testing method, because quantitative evaluations consume considerable time. However, their field of application could be extended to include quantitative testing also, if a suitable and timesaving instrument for evaluation of the film were available. It is believed that the proposed slide rule greatly reduces the time for computations and that it will also aid in making motion picture records a quantitative method of testing, thus increasing their value with regard to mechanics research.

The author is grateful to the Department of the Army, Office of the Chief of Ordnance, Washington, D.C., for the permission to publish this article.