Pin Registration

A TUTORIAL PAPER

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The use of pin registration is almost necessary in making good motion pictures and is indispensable where process photography or double-exposure techniques are used. Demands for camera steadiness are discussed and pertinent factors in construction and operation are described. The importance of controlling relative humidity and temperature is stressed. Pin design and positioning are discussed with reference to the big pin–little pin system and style of perforations is considered. Guiding methods are discussed, with emphasis on the edge-and-point system. Errors caused by faults in design, workmanship and maintenance are cited.

Pin registration describes the techniques employed in positioning film in most professional motion-picture cameras. Other schemes have been used for careful work in motion-picture photography but the use of pin registration dominates the field.

The work done by professional cameras falls into several fields. One is the taking of original negatives which may be used for newsreel work, documentary stories, or other pictures where special effects or "process" photography[1] is not employed subsequently. The "wild" cameras (Fig. 1), used without sound synchronization and sometimes without tripods, fall into this classification. These cameras produce action shots complete in themselves. The demands for steadiness in cases of this kind are not very critical and would be masked by the motion of the camera itself, in any event, as it follows the action. The stimulation of interest by the rapid development of the story distracts the viewers' attention from any minor movements of the picture as a whole.

The usual run of entertainment pictures employs process photography to a large extent. Accordingly, the original negatives used in such pictures must be steadier than those used for news or travel-type shots and a good "studio camera" is used (shown in Fig. 2).

However, the greatest demands for steadiness are made by the work done in special effects cameras. These are the devices used in making 35mm mattes or to photograph the somewhat larger process drawings. They are also used as projectors which produce the images thrown on huge background projection screens. The reason that great precision is needed with these techniques is that process photography takes two images from different sources and places them next to each other in the final picture in a way that produces a desirable illusion. Relative motion between these two adjacent images is much more easily perceived than the movement of the whole picture and too much motion will destroy the illusion. In the case where the whole picture moves on the screen, there is generally nothing very definite within the picture with which to make comparison. On the contrary, the techniques which use double exposure demand the utmost dimensional accuracy because of the side by side comparison between components, which results in what may be called a vernier effect.

For this reason, the cameras and films used in special-effects photography must be well made, well tested, and used under favorable conditions. There must be nothing neglected. The workmanship on most professional cameras leaves little to be desired, although the small size of some parts presents some problems in the shop. Among these problems is the task of measuring small, round pieces. This operation can result in more variation in size than the measurement of a large rectangular piece. The unit pressures applied during measurement are larger and friction produces less leverage on the faces of the micrometer. Accordingly, it is easy to turn the micrometer too far. The variation in dimensions obtained by comparing the results of different observers may be only one or two ten-thousandths, but this difference is not negligible. Consider that the maximum allowable range of perforation hole-size allowed by the standards is 0.0008 in. and the variation in actual manufacture is generally much less.

The design of cameras for special-effects photography is something of an art, for not too many have been made and there has not been a great deal of information exchanged on the subject. For a long time they were made by the user,[2] and there was no source of commercial supply[3,4] as there is today. There are a number of requirements for a process camera which are shown schematically in Fig. 3. In actual practice, the cameras are more complicated as shown in Figs 4 and 5. Certainly the equipment must be rigid. The film-handling elements are much like those of conventional cameras except that the clearances are smaller. The effects printers differ also for the reason that the entire equipment ought to be kept cool so that the essential elements do not change their relative location as metal parts expand. The lens must be kept cool, or its focus may change. The film used in the equipment also must be kept cool because the film base has a thermal coefficient of expansion greater than that of metal (Fig. 6). Note, however, that it is the difference between the thermal coefficient of the film and the associated structural or metal parts that counts and not the absolute value alone.

Relative Humidity

This variation of size with temperature seems important, but changes in the size of film caused by changes of relative humidity are even greater. See Fig. 7 and note the more extensive treatment Drs. Calhoun and Adelstein have given this matter in another paper.[5] Accord-

Fig. 1. Wild Camera (on tripod).

Fig. 2. Studio camera in sound-proof blimp.

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(This paper received on November 27, 1962.)

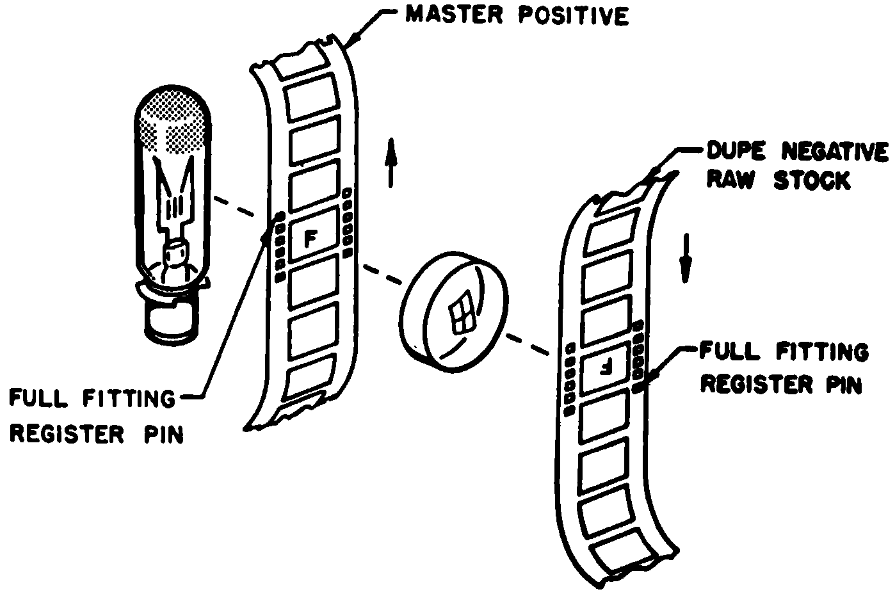

Fig. 3. Schematic drawing of optical printer.

ingly, the process camera should be used in air-conditioned rooms so that the films stored with it remain at the same relative humidity. This has not always been done and the only explanation that satisfactory process photography has been accomplished under non-ideal conditions is that all operations have been carried out the same way on the associated masks. Accordingly, the errors have affected all the films in the same way.

The size of the errors caused by variation in relative humidity merits consideration. Film contracts about 0.006% to 0.008% for each decrease of a R.H. percentage point in relative humidity.[6] By a change of one R.H. percentage point, we mean for example, a change from 60% to 59% R.H. The distances we have to deal with are about 0.7 in. vertically and 1.0 in. horizontally. Let us assume a value of 0.8 in. for film width since the viewer does not give a great deal of attention to details near the extreme edge of the picture.

Now let us assume that a matte was made in the morning and that a counter-matte was then printed from it in the afternoon. Before this operation was performed, the day grew hotter and accordingly the humidity in the non-air-conditioned printer room dropped ten R.H. percentage points. This naturally means the matte would shrink and become smaller than it was originally. The change in size caused by shrinkage would be

$$10 \times (0.007/100) \times 0.8 \text{ in. or } 0.00056 \text{ in.}$$

wherein we used a value of 0.007% which is midway between the 0.006% and 0.008% values cited for the widthwise and lengthwise coefficients. This change in size exceeds the value of 0.00030 in. which seems to be the limit at which this kind of unsteadiness becomes objectionable when two images are close to each other. We feel that an error of this size makes a joint visible where the two images are supposed to match exactly. Therefore, a change in humidity of 10 R.H. percentage units would produce a distinctly visible mismatch.

Another way of considering the effect of varying relative humidity relationship is to say that the permissible range of dimensions allowed for the width of film is 0.002 in. according to most ASA standards. This range extends from the nominal value to values 0.001 in. greater and to 0.001 in. smaller in size. If we divide this range by the change in dimensions caused by a variation in relative humidity, we find that a change of 21 R.H. percentage points is equivalent to a change in the width of the film from the smallest value allowed the manufacturer by ASA standards to the largest value permitted.

Another example is the dimension *L*, which represents the length of 100 consecutive pitches. This is 18.700 in. ±0.015 in. and the range allowed is therefore 0.030 in. or 0.16% This range divided by the humidity coefficient of 0.007 in. per R.H. percentage point is $(0.16\%/0.007\%) = 23$ R. H. percentage points.

Changes of relative humidity of 20 R.H. percentage points are not uncommon during the day. Changes of 30% can occur near the ocean, depending on the direction of the wind. Obviously, control of relative humidity in the process-camera room is necessary.

Also note in connection with the need for air-conditioning in process-camera rooms that the conditions that count are

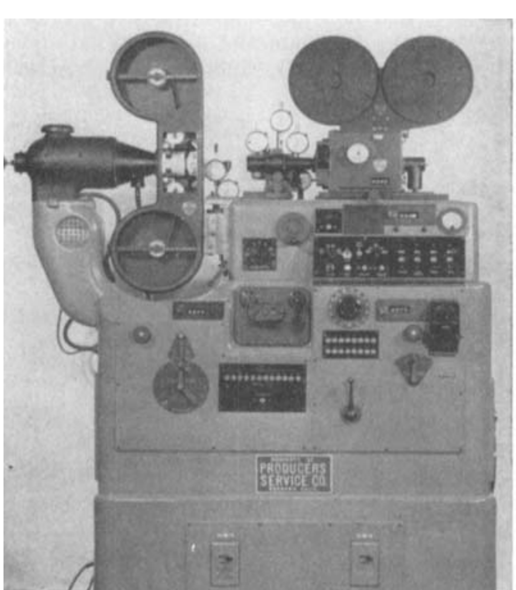

Fig. 4. View of actual optical printer.

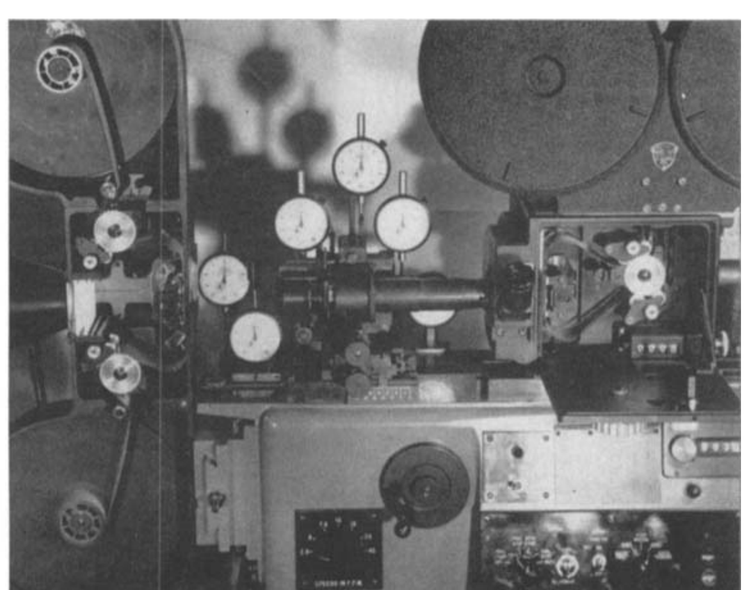

Fig. 5. Close-up of printer heads.

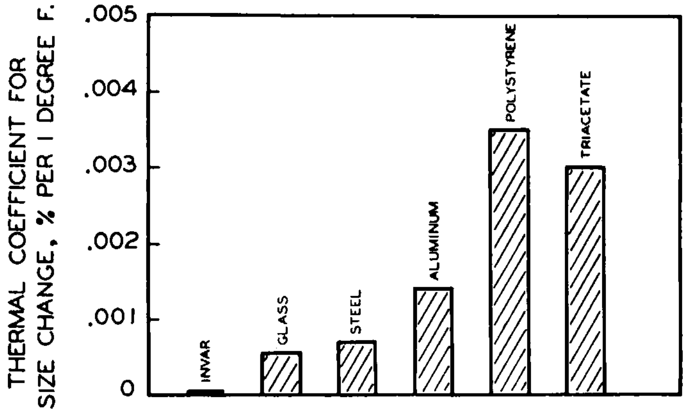

Fig. 6. Dimensional properties of various materials. Thermal coefficients of expansion per 1 degree F.

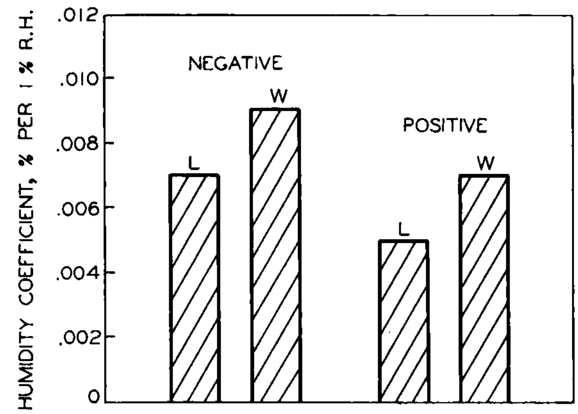

Fig. 7. Dimensional properties of various materials. Humidity coefficients per change of 1% in relative humidity.

those close to the film. Inevitably, if the film gets hot in the printer head, it gets dryer and contracts. Accordingly, the film ought to be exposed to conditioned air at the correct temperature long enough to become "conditioned" (or to reverse the contraction due to loss of moisture) before it is used again. The time for the amount of reconditioning that is necessary depends upon how much the film has shrunk. If the amount is small, complete recovery is not as necessary as it is if the shrinkage is large. The shortest time that will serve the purpose probably is close to 20 minutes for film fully exposed to the air, and the longest that is necessary is about two hours. However, film in a roll may take as much as 500 times as long to come to equilibrium (after the surroundings change in humidity) as film freely exposed to the air.

As a historical comment and sidelight, a complaint occurred in 1928[7] about mismatch in pictures caused by loss of solvents from the film. This trouble has not been a significant factor for a long time. Changes in water content are the important items today.

Another reason for controlling relative humidity in the process-camera or process-printer room is to control curl, which when excessive can cause trouble in "geometry," or narrowing of the image on curled film when referred to its size when flat. However, the greatest trouble from curl is that lack of flatness leads to poor contact.

Pin Design and Positioning

These various comments about the need for accurate positioning and the possibility of errors might make one wonder how registration is every achieved. Actually there is not much trouble with the mechanics of registration in process photography. Most of you know the reason: the use of a "big pin" and a "little pin"[7-9] system shown schematically in Fig. 8. The big pin fills the perforation tightly and defines a point on the film. The little pin actually fits tightly in a vertical direction and controls the rotation of the film about the geometric point just defined. Thus the position is defined in the circular sense. Since the small pin is narrow in a radial sense, it prevents any interference arising from minor changes in the size of the radius. The location along the other axis is controlled by pressure of the film against the surface of the gate. Some people say one gets "super-constraint" by using more elements than those needed to fix the position in the simplest possible way. Super-constraint leads to distortion, with two guiding elements "fighting" each other.

Anyone interested in this subject can find some material in a related field. There is literature on the theory of making "couplings" for accurate instruments but it is not very extensive.[16] The subject may seem abstract but it is worth further study.

The fit of the pins can be rather snug. In one unusual case, the big pin was 0.0010 in. oversize and no obvious trouble immediately ensued from its use. Several observers expected trouble from the stretching that took place, and trouble no doubt would have followed if the practice had been continued. Film is elastic and will return to its original size if the deformation is not too large or sustained. Designers generally use a fit which has less interference or produces less stretching of the film than the case cited. Probably the pins should be the size of the largest permissible perforation, which is generally 0.0004 in. larger than the nominal size. The use of pins smaller than this will give appreciable clearances most of the time and may lead to movement now and then from perforations falling at the outer extreme of their size class. Actually, the possibility of some movement is risked in studio cameras, because pins of the larger size cannot be used conveniently. The noise from the disengagement of tightly fitted pins is no disadvantage in a process camera, or in a camera which might be used to make negatives used for printing of background plates or for making special pictures of material intended for use in process photography. A studio camera using tight pins would make sufficient noise to call for a very large

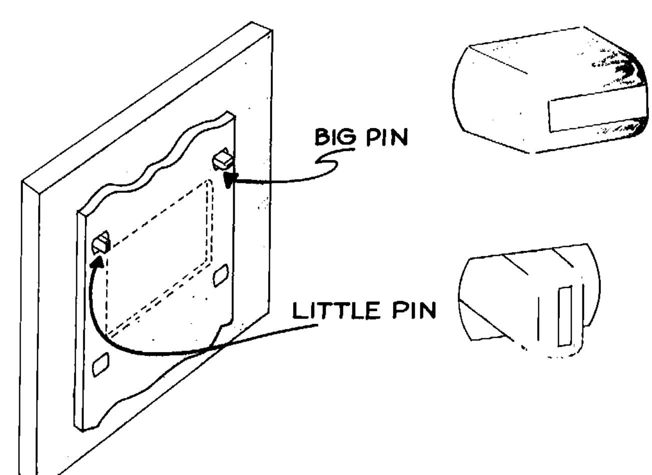

Fig. 8. Schematic description of "big pin – little pin" system of registration used mainly in 35mm equipment.

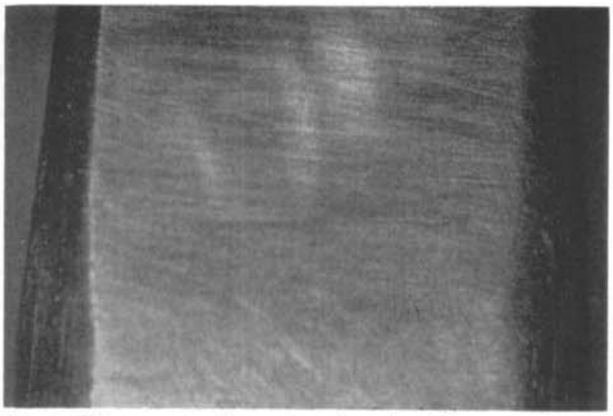

Fig. 9. Micrograph of a registration pin with a smooth surface (25× on photographic print).

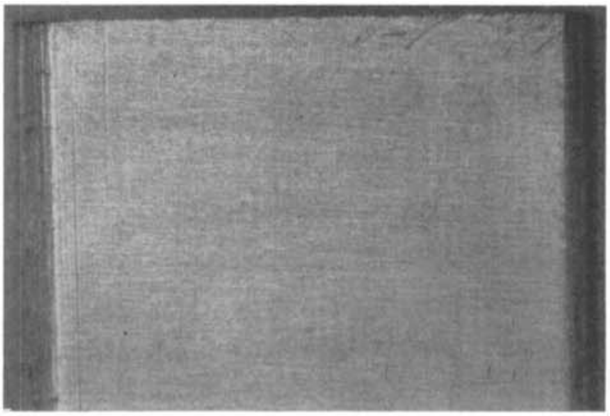

Fig. 10. Micrograph of a ground and lapped surface which is barely adequate in smoothness.

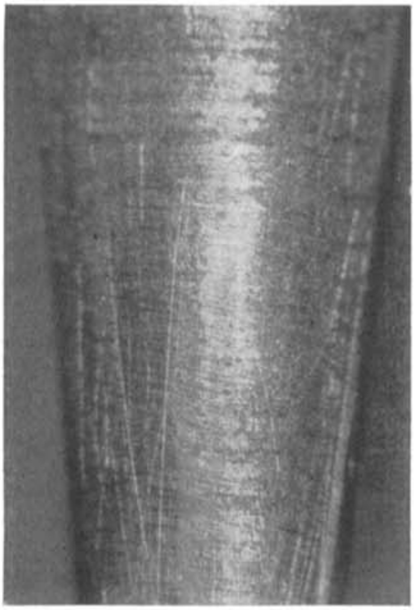

Fig. 11. Micrograph of roughly ground surface of registration pin.

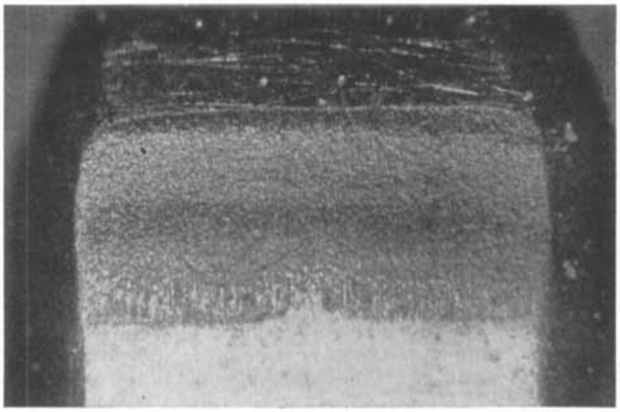

Fig. 12. Micrograph of corrosion which has penetrated chromium-plated surface of a registration pin.

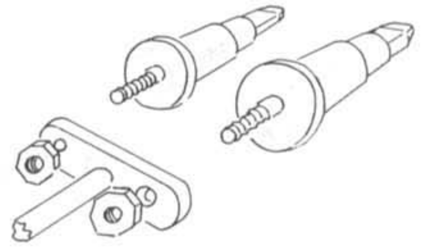

Fig. 13. Schematic drawing of conventional positioning-pin assembly.

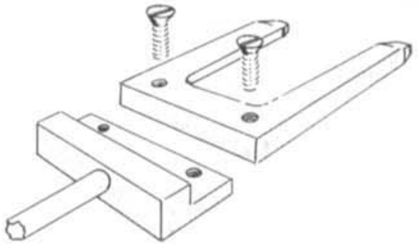

Fig. 14. Schematic drawing of monolithic positioning-pin assembly.

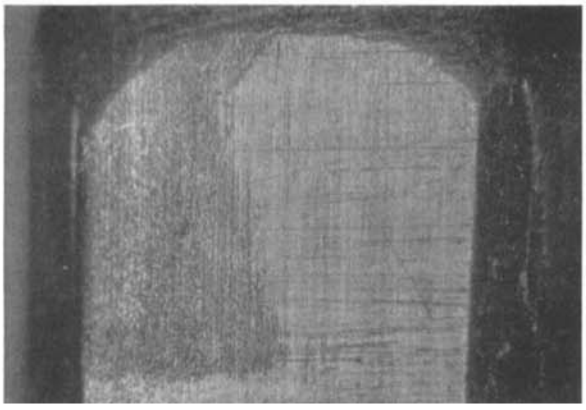

Fig. 15. Micrograph of corroded positioning pin which was incorrectly assembled, being twisted on its long axis.

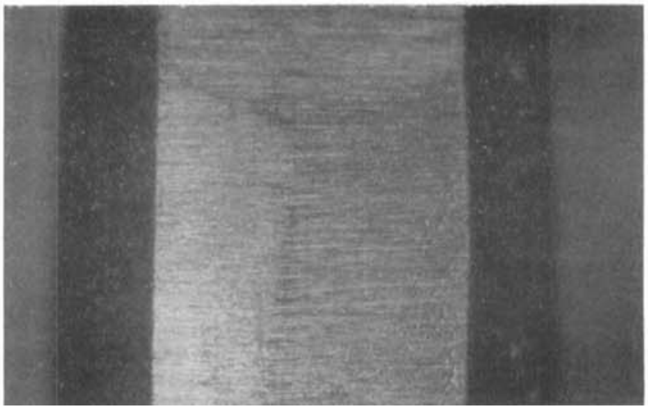

Fig. 16. Micrograph of roughly ground positioning pin with a cambered surface.

and effective blimp to control the sound.

After the size of the pins is settled upon, one must make them to the stated dimensions and maintain those dimensions in later use. The pins must be finished to a smooth surface and it is preferable to have the lines left by lapping or polishing to run in the same direction that the pin moves past the film. Figure 9 shows a surface smooth enough to reflect the filaments of the light used to photograph it. The photomicrographs show a magnification of about 25 times on the original print.

A cross-grained finish gives too much friction though the surface shown in Fig. 10 is almost acceptable. The surface of the pin in Fig. 11 is obviously too rough. The use of chrome plating seems to minimize corrosion which can be great enough to remove so much metal that size is affected as well as smoothness. See Fig. 12 for an example of corrosion.

The design of most pins is not elegant, in the sense that the construction is simple. There are threaded portions, yokes and nuts wh'ch make up the conventional assembly shown in Fig. 13. I am glad I never had to install pins in a camera and line up the "flats" so that they would lie on the same plane. The pin shown in Fig. 15 apparently had been installed in a twisted position. It seems to me that the alignment of the flats could be done once and for all if we made the pin assembly a "monolithic" one, like that used in perforator pin assemblies. By monolithic, I mean that the pins are made of one piece of metal. Then the machining of the surfaces and the establishment of their spacing would be a fairly straightforward job on a relatively large piece of metal. See Fig. 14.

The pin shown in Fig. 16 shows what can happen when pins are ground to final form with inadequate equipment. This pin has a definite camber in cross section and is rough in addition.

Perforations

There has been discussion about the shape of perforations and their associated pins. I suppose some of you have seen early films with circular perforations described in historical reviews. One is shown in Fig. 17. This shape has obvious disadvantages connected with changes in lateral dimensions, so we can understand why the shape was changed. The Bell & Howell perforation which is really circular, with flattened portions on the top and base, can guide the film accurately in the camera even if lateral dimensions change. This style of perforation was used for 35mm release prints for many years. Since the old sample showing the circular perforation is a narrow one, we have shown in Fig. 18, a 16mm positive current film as a comparison.

About 1923, J. C. Jones devised a new

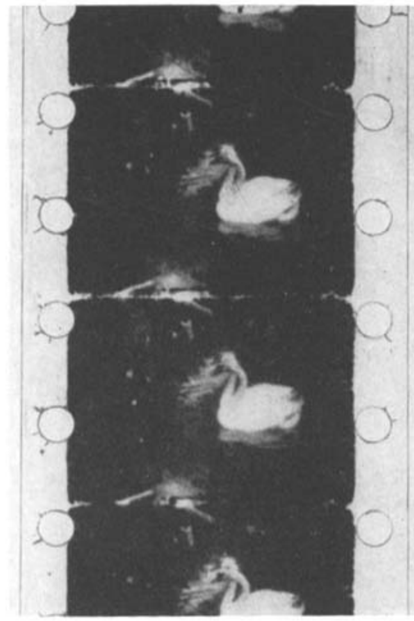

Fig. 17. Circular perforations used on early amateur film.

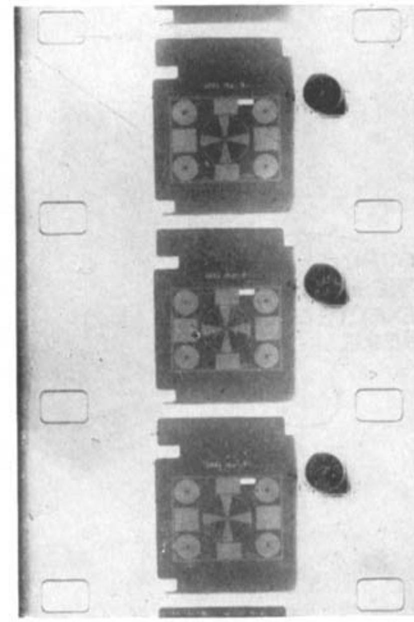

Fig. 18. Perforations on conventional 16mm film in use today.

style of perforation in order to improve the wear and tear life of film. This perforation was put into use by Kodak almost at once and it was standardized in 1930. The improvement came from the rounding of the corners. In the older style of perforation, the corners were sharper. A further "improvement" in this perforation was the increase in height from 0.073 in. to 0.078 in. which eliminated the mechanical interference which existed with one make of projector, when the film shrank to an extent that was considered a reasonable one in those days.

This enlargement of the perforat'on in the vertical direction did not affect printing on a sprocket printer but did preclude precision printing on a step printer. A few years later Dubray and Howell[11] suggested a perforation with the general contour of the Jones[12] positive perforation but the dimensions of a Bell & Howell perforation. Such perforations would be "universal" ones which could be used in making contact prints from Bell & Howell perforated negatives to print stock having Dubray-Howell perforations. See Fig. 19 for schematic drawings of the various styles of perforations.

The Dubray-Howell perforation was first used in practice in 1946–1954 in order to make prints on Eastman Duplitized Print Film, Type 5380 from two color separation negatives in a modified duplex printer. This process for printing Republic's "Trucolor" was dropped when new materials became available in the form of integral tripack emulsions. Conventional sprocket printers were used for this latter print stock. However, the Dubray-Howell perforation had proved so successful that it was retained for use in the new raw stock which used

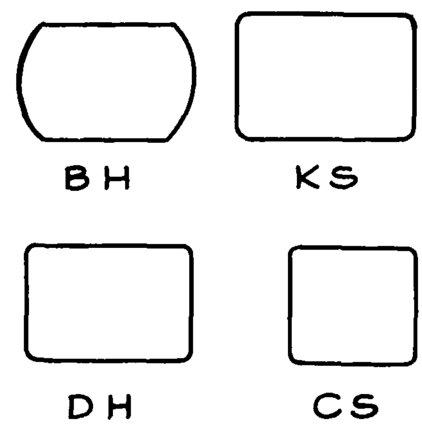

Fig. 19. Schematic drawings showing the characteristic shapes of various perforations used for 35mm film.

an integral tripack emulsion even if accurate registration on pins in a step printer was no longer required. It continues to be used on Eastman Color Print Film, Type 5382, and many people are unaware that the perforations are not KS-1870.

Guiding Methods

The utility of pin guiding in accurate printing is seen every day in the results attained on entertainment pictures, which commonly have from 10% to 30% of the footage printed by process photography.[8,13] Some advertising pictures today use in their releases an even greater fraction of film which has undergone some operation of process photography. Some adventure stories may have 80% of their "outdoor" shots done in the studio, as was the case for *Captains Courageous*.

However extensively pin guiding is used, equally good guiding can be done

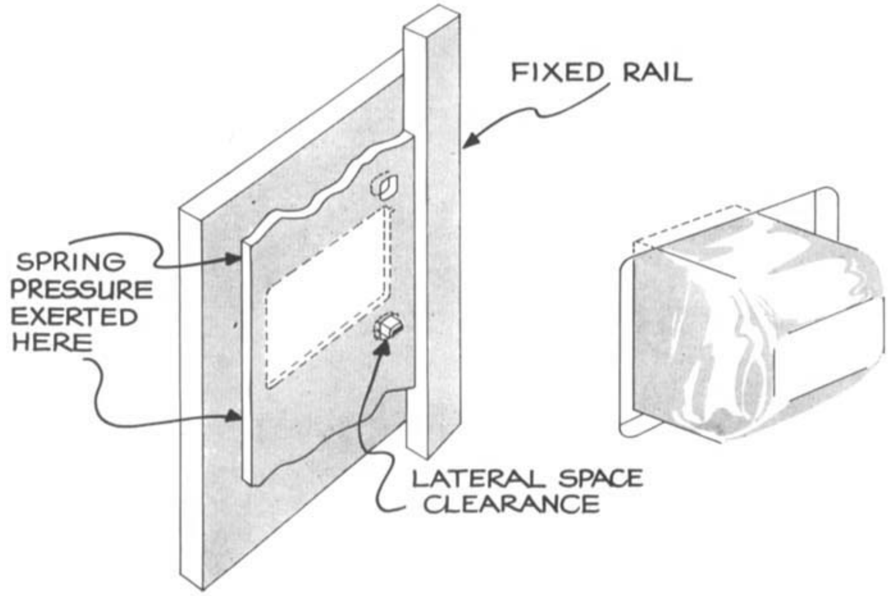

Fig. 20. Schematic drawing of edge and point guiding system frequently used for 16mm equipment.

by another scheme which can be called edge-and-point guiding. In this case, one edge of the film controls the rotation of the film in its own plane. A "small" pin controls the location of the film along this line but does not guide it in a lateral sense. This scheme is used in at least two professional 16mm cameras and works very well in making steady originals. See Fig. 20. Maybe it has been used for process photography but I do not know of any examples. Edge-and-point guiding is not really what the physicist calls kinematic[10] because it uses surfaces or lines instead of quite small areas or points for guiding. Edge-and-point guiding resembles the method a carpenter uses in laying out from a trued and marked face and edge. Metal workers, having (apparently) truer surfaces to deal with sometimes design or construct mechanisms badly because they measure from more than one reference face or edge. Note that edge-and-point guiding allows for variation in size just as well as pin guiding does.

Good as the method of pin guiding is, the use of this process sometimes produces unsteady pictures and it is not always easy to determine the cause. In one case the errors may arise from inaccurate perforating, which is a very uncommon occurrence. However, it is worth pointing out that one can have a film which is shown by test to have given perfect results in a camera double-exposure steadiness test, but which nevertheless will give an unsteady picture on the theater screen. This can happen because the camera has placed the film two (or more) times in exactly the same place with reference to the perforations, just as it is supposed to do. However, it may be that these perforations are not at the proper places! The inaccurate positioning of the perforations would still make it possible to have steady projection in a background projector that matched the camera exactly. We would have cancellation of these errors in such a combination of equipment since the pins are placed in the same place as they are in the original camera. (A demonstration of the effect of "cancellation" was given as a part of the session of the Convention.)

However, theater projectors generally do not guide in the same way. The vertical guiding is done by the teeth on a sprocket situated at a distance of several frames below the aperture. We suspect from the pattern of wear on the sprocket-teeth that no one tooth carries the total load. Accordingly, we expect no cancellation from a theater projector. The effect of not having cancellation can be noted by projecting with a "cut-out" gate that projects the image of the perforations on the screen along with the picture.

The difference between the two sources of trouble noted above is generally made clear by measuring the dimensions of the film. If the perforation uniformity is good, but the projected image is unsteady the projector is suspect.

Faults in Design or Maintenance

Still another form of image unsteadiness arises from an error in design of the camera, whereby the film is exposed while it is still moving, which may be before it is completely located in its proper position in the camera.[14] The word "cheating" is sometimes applied to this case, or to others like it, where the shutter opens or remains open while the pins (or shuttle) are still moving. In one design of camera "closing down" or decreasing the angular opening of the shutter removes this source of error. In another design, decreasing the shutter opening increases unsteadiness proportionately because the angular amount of cheating remains constant and the proportionate amount thereby increases. These differences arise since the shutter may close from the beginning or from the end portion of the exposure cycle. Cheating is generally detected by noticing a doubling or blurring of the brightest highlights in the scene. The use of a too abrupt taper on the pins, along with excessive resistance in the gate, may cause similar trouble. Too much load on the pressure pad, or "tackiness' of the film or dirt lodged in the gate may be the predisposing causes. Cheating is seldom rendered visible except when other trouble is present in some degree but it is nevertheless undesirable.

An associated trouble is caused by "drag" which can be caused by rough surfaces on the gate or pressure pad or by "tacky" film. Tackiness may be brought on by high humidities, either in tropical locations, or in northern marshes, or may be present in the film itself. Tackiness is seldom a factor unless the gate surfaces are very smooth.

The nature of the surfaces the films touch is a matter of compromise. Rough surfaces are bad; in our experience nearly every deposit of emulsion or dirt has under it a sharp scratch or a pin-hole in the plating. Therefore gates should be smooth to begin with and hard enough to stay that way. Nevertheless gates that are almost perfect optically flat surfaces will interact with very smooth film surfaces, the motion squeezing out all the air between. Consequently there is atmospheric pressure pushing the two parts together witn a resultant drag tending to hold back the moving film. The larger the flat surfaces, the greater the drag. Surfaces of gates and pressure pads need to be broken into smaller elements to decrease the total area and to give the dirt "a place to go." Without a scheme for routing dirt out of the way, the probability of getting a deposit of firmly adhering dirt is increased a great deal.

A pad that applies pressure only when needed has some advantages. Some of the older cameras had mechanically operated "clapper gates." A newer camera designed by Gillette and White uses vacuum to operate the mechanism,[15] though a camera recently described by O'Grady uses a mechanical scheme.[16]

Still another source of unsteadiness or mismatch occurs when perforations other than the ones employed originally in the camera are used for registration in the printing operation. This oversight is often allowed to persist because the accuracy of perforation of modern films does not make the basic error immediately obvious.

The register pin on a Mitchell camera lies below the picture aperture in the line of travel, but the pin in a Bell & Howell camera lies above the aperture. Accordingly, in an optical projection printer, one must have two sets of gates if negatives are used which were made on two styles of cameras with different positions for the pins. Two other gates are needed if the film has the faces reversed. Another set of four gates is needed to complete the set if film is also to be run in the opposite direction. The second set is like the first except for the location of the aperture.

This subject has been treated by Jackman,[17] Shea,[18] Anderson[19] and Henry[20] some time ago, and by Kiel[21] and discussed by Maurer in the discussion at the Convention at which this paper was presented. They emphasize the point that the most accurate work must employ the scheme of "cancellation" which prevails when all associated aperture is effectively the same and positions the film in exactly the same way each time. In process photography every operation must in effect have no "tolerance," or more exactly, introduce no unnecessary error. Accordingly, a consistent scheme of guiding throughout all operations is a vital matter. A test of how well the consistent guiding works can be made by using double exposure schemes for measuring the steadiness of the camera.[22-24] The examination using a double-exposure technique shows how well the camera places the film twice in the same place. This is a test of workmanship in the camera. An evaluation of the steadiness of the film printing operation will then allow one to decide the success of the whole operation of producing a good print.

Acknowledgments must be made to my colleagues at Kodak for much help, and especially to those people in the industry who have been at pains to explain their processes and to furnish illustrative material. The first two photographs were furnished by United Artists and Warner Bros. and the ones of modern process printers were used by courtesy of Producers Service Co. This paper is for information only and nothing herein is to be construed as a recommendation or inducement to infringe patents.

Summary

(1) The use of pin registration is almost necessary in making good motion pictures, and is indispensable where special-effects photography or double-exposure techniques are used. Several styles of guiding are described and the need for a set of different aperture plates in process printers is mentioned.

(2) Of the pertinent factors in construction and operation described, control of relative humidity and temperature are important.

(3) A type of guiding called edge-and-point guiding has some virtues and is successfully used in some 16mm cameras.

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