Fig. 5.
This invention provides apparatus for applying liquid films to solid materials, and is particularly useful in high speed developing of photosensitive emulsions, such as is required for rapid access photographic recording. Because of this utility the invention is described in its application to this field although it is not so limited.

As dynamic recording has increased in application and importance, there have evolved fields of use in which a very short access time is desirable. The term "access time" is used to indicate the time interval between the exposure of a photosensitive recording paper to a light stimulus to be recorded and the presentation of the resultant record for visual observation. The terms "photographic paper" and "recording paper" are used to include photosensitive emulsions disposed on any suitable support such as paper, film or other usable medium.

Wind tunnel and flight testing are examples of testing procedures wherein rapid access is of considerable value, because conditions of operation can be changed with greater facility, and flexibility of the conditions undergoing test can be recorded and visually observed in a brief rather than a prolonged interval of time.

Previously, conventional photographic recording techniques generally referred to as "oscillography" have involved the exposure of an entire roll, say 200-400 feet, of a record paper to the information to be recorded, with subsequent removal of the exposed roll from the oscillographic recorder, and separate chemical development of the roll. This conventional procedure requires a relatively long access time of minutes or even hours.

Co-pending application Serial No. 681,804, filed September 3, 1957, owned by the same assignee, discloses and claims apparatus and methods for developing a latent image produced by exposure of a photosensitive medium within a very brief interval subsequent to exposure. Even more importantly, the latent image is developed continuously and concurrently with exposure of succeeding increments of the medium. Using the invention described in the co-pending application, a photographic record of excellent resolution and contrast is produced with an access time of approximately one second, providing the record transport is maintained at a rate sufficient for the medium to emerge from the process in this interval.

By way of explanation, it takes a finite space in which to carry out the process and access time is dependent not only on the developing speed of the processing solution but also on the record transport speed through the required space. At low recording speeds, say a paper speed of 2 in./sec., paper travel, not the developing technique, is the limiting factor in access time.

Briefly, the method disclosed and claimed in the co-pending application is a process for developing a photographic material having a photosensitive emulsion supported on a backing such as paper. The method comprises an initial step of applying a thin film of a processing solution to the emulsion surface. The applied film of processing solution is carefully controlled to be sufficiently thin so as to wet substantially only the emulsion, leaving the emulsion support essentially dry. Immediately after application of the processing solution, heat is applied to accelerate development of the exposed emulsion and simultaneous drying of the processing solution from the emulsion.

The term "processing solution" is used to designate primarily a developing solution, but which may also include various additives such as silver halide stabilizers and the like.

The developing procedures generally outlined above can be done substantially simultaneously with the exposure of the recording medium to the light beams to be recorded. In fact, the processing solution may be applied as a thin film directly after such exposure or even prior thereto, but it is desirable that exposure precede the application of heat as described.

An essential limitation to the success of the process of the co-pending application is the use of a thin film of the processing solution on the recording medium, as contrasted to previously conventional procedures of dipping or spraying the record so as to saturate both the photosensitive emulsion and the paper with developer solution. By limiting the thickness of the applied film so that substantially only the emulsion is moistened, this film being not in excess of .0005 inch and preferably in the neighborhood of .0002 to .0003 inch thick, not only is drying facilitated, but the record by reason of its dry back surface may be immediately passed over a stationary hot plate with a minimum of distortion or wrinkling, which could impair heat transfer from the plate into the record. Since it is necessary that the record be substantially dry before exposure to ambient light conditions for visual observation, the importance of the thin film principle in permitting very rapid drying speed is obvious. Also, the application of heat to accelerate drying of the film has the additional advantage of causing changes in the processing solution so that residual developer remaining in the paper is rendered relatively inert.

As a consequence of all of the factors mentioned above, development is more rapid than any previously known process, and a comparatively stable developed record is obtained.

The wide range of speeds over which the recording medium travels in a typical oscillograph places stringent requirements on the applicator used to deposit the thin layer of processing solution. At high speeds, say more than 25 in./sec., the applicator must supply processing solution at a rate adequate to provide a film of satisfactory thickness. But for low paper speeds, say less than 2 in./sec., the applicator must supply solution at a reduced rate to avoid excessive wetting of the recording medium.

This invention provides apparatus which is well suited for applying a uniform thin film of processing solution, regardless of recording medium speed. Briefly, the invention contemplates a liquid applicator which includes a body having a slit in it, and a reservoir connected to the
slit for supplying liquid to it. The apparatus also includes means for supporting the material to be coated across the slit, and means for moving the material relative to the slit so liquid is transferred from the slit to the material.

In the preferred form of the invention, such as is used for applying a thin liquid film to a flexible strip of photographic recording medium, the medium and slit portion of the body are disposed so they bear against each other to form a leakproof seal across the slit. This side in the application of a liquid film whose thickness is substantially independent of the rate at which the recording medium moves past the slit. Also in the preferred form, the body of the applicator is made up of two blades which are spaced apart by a shim that controls the width of the slit. The blades and shim are detachably secured together so the parts can be replaced when required due to wear, and also to change the dimension of the slit to accommodate different types of processing solutions and recording media.

The and other aspects of the invention will be more fully understood from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a schematic elevation of the invention as used in a rapid access oscillograph;

Fig. 2 is an enlarged view taken on line 2—2 of Fig. 1;

Fig. 3 is a view taken on line 3—3 of Fig. 2;

Fig. 4 is a view taken on line 4—4 of Fig. 2;

Fig. 5 is a view taken on line 5—5 of Fig. 2;

Fig. 6 is an enlarged view of the applicator shim taken on line 6—6 of Fig. 5; and

Fig. 7 is an enlarged view of one of the applicator blades taken on line 7—7 of Fig. 5.

Referring to Fig. 1, a record processing unit 9 is enclosed in a magazine 10 having on one side a window 11 through which a light beam 12 produced in a conventional recording camera enters the magazine incident on the record therein. The camera is illustrated schematically as a light source 13 and a modulator 14 represented as a galvanometer mirror. The camera as such forms no part of the present invention and is conventional in the process of oscillography. In the usual commercially employed oscillograph a number of channels of data may be recorded at the same time by the expedient of using a plurality of light modulators and recording the modulations responsive to separate signals applied to the respective modulators and representing a plurality of parameters to be recorded.

Typically, a plurality of pressure transducers may be incorporated in various locations of a wind tunnel with their outputs separately connected to a different one of a plurality of galvanometers in a multi-channel oscillograph. For the purposes of describing the invention I single galvanometer mirror 14 is shown as illustrative of the phenomena involved with the intention that this be representative of any number of separate channels of recording.

The magazine 10 houses a supply roll 16 on which a strip of unexposed photographic paper 17 is mounted. The record is carried over a metering roller 18 driven by conventional roller drive means (not shown) to determine the speed of travel of the recording medium through the magazine. From the metering roller the record is carried around an idling or tension roller 19 and from there past a processing solution applicator 20, which applies a thin film of processing solution to the exposed paper. The applicator 20, as shown schematically in Fig. 1, includes an elongated horizontal tubular processing solution reservoir 21, which is mounted to be pivotable about a horizontal axis as shown more clearly in Fig. 2. An elongated and horizontal body 22 having a longitudinal horizontal slit 23 opening out of one edge is connected by screws 24 (see Fig. 5) to the underside of an elongated and horizontal adapter 25 which in turn is connected by screws 26 to the underside of the reservoir 21. The right hand (as viewed in Figs. 1 and 5) edge of the slit body 22 has a tapered portion 26 which extends into an elongated horizontal recess 27 formed in the upper portion of an inclined and horizontal back bar 32 mounted to pivot about a horizontal axis as described in more detail below in connection with Fig. 2. The paper is adapted to slide across the upper edges of the recess in the back bar, and the tapered portion of the slit body bears against the paper to deflect it from a flat plane slightly into the paper slit.

Referring to Fig. 2, the right hand end of the reservoir tube is journaled in a wall 34 of the magazine 10 and includes an enlarged section 36 which has a filler spout 38 formed in its upper portion outside the magazine. An outwardly extending shaft 40 on the left hand end of the reservoir tube is journaled through a vertical bracket 41 mounted by suitable means (not shown) in the magazine 10.

As shown most clearly in Fig. 5, the slit body includes a lower horizontal blade 42 secured by bolts 44 to an upper horizontal blade 43 which in turn is held by the screws 42 against the underside of the adapter 25. The blades are accurately spaced apart by a shim 46 disposed between them.

Referring to Fig. 6, the shim is an elongated flat strip with a separate projection 45 at each end perpendicular to the length of the strip. The projections 45 form a seal at each end of the slit body and the open space between the projections forms the slit 23 which opens out the tapered portion of the body. The shim has eight longitudinally spaced holes 46, each of which receives a respective screw. The slit can be made of any suitable material, but it should be durable and not change its dimensions due to use and operation. A satisfactory shim has been made from a strip of brass shim stock .002 inch thick, nickel plated and gold plated to a thickness of .0021 to .0025 inch. The material for the blades is also preferably a durable material such as stainless steel. Preferably, the tapered portions or tips of the blades are treated to increase their hardness and useful life. For example, the blade tips may be flame coated with tungsten carbide, or aluminum oxide, or case hardened. Alternatively, sapphire strips may be bonded on the tips with a suitable epoxy resin, the sapphire strips being lapped to the required shape after application to the tips. In a typical assembly, the following surfaces are parallel to within .005 inch and flat to within .010—12 inches to provide proper film application: (1) the lower and upper respective surfaces of the adapter and upper blade where they are in contact; (2) the lower surface of the upper blade where it bears against the upper surface of the shim; and (3) the upper surface of the lower blade where it bears against the lower surface of the shim.

As shown most clearly in Fig. 7, the lower surface of the upper blade includes a longitudinal groove 46 near its tapered edge, and four longitudinally spaced large bores 49 terminating at their upper ends about one-half way into the upper blade, each bore 49 opening into the groove 46. A separate smaller bore 50 in each larger bore 49 opens out of the upper surface of the upper blade into a respective bore 52 in the adapter. Each bore 52 is stepped down medium at its upper end to match the size of a respective opening 53 in the bottom of the reservoir tube. The joints between the reservoir tube, adapter, and upper blade are made leak-tight by the use of a suitable sealing compound 54, which may be an epoxy resin that is inert to the processing solution in the reservoir.

With the apparatus set in the position shown in the drawings, the recording paper makes a tight sliding seal over the slit opening at the tapered end of the slit body. As shown most clearly in Fig. 5, the paper being fed from end 46 of the elongated and horizontal back bar 32 is in contact with the upper blade sharply. This arrangement avoids the application of too much fluid on the surface at low speeds.
Referring to Figs. 1 and 2, the shaft 40 on the left hand end of the reservoir tube extends through the upper portion of a downwardly extending dog 56 which has a downwardly extending leg 57 that carries on its lower end an outwardly extending traveling guide pin 58. The guide pin is adapted to slide longitudinally in a guide slot 60 formed in the upper portion of an upwardly extending end plate 61 mounted on the left hand end of the back-up bar 23, which in turn is attached by screws 62 to the upper portion of a support 64 mounted to pivot about horizontal shafts 65 and 66 at its right hand ends, respectively, as viewed in Fig. 2. Support shaft 65 is journaled through wall 34 of the magazine, and support shaft 66 is journaled through the upright bracket 41 mounted in the magazine.

Thus, when the apparatus is to be loaded with a strip of paper, the reservoir tube is rotated approximately 90° in a counterclockwise direction from the position shown in Fig. 5, causing thetraveling pin 58 to force the back-up bar and its support to pivot in a counterclockwise direction about shafts 65 and 66 until the support comes to rest on an inwardly extending first stop pin 68 mounted on the upright bracket 41. In this position, the slit opening out of the tapered portion of the body is above the liquid level in the reservoir, and the filler spout is also still above the liquid level. Thus, when the apparatus is not in use, there is no tendency for liquid to flow out of the reservoir and into the slit. Once the paper has been placed in the proper position for reloading, the reservoir tube is rotated in the opposite direction so that the traveling guide pin 58 re-enters the guide slot 60 on the upper portion of the support end plate and forces the support and back-up bar to rotate in a counterclockwise direction until the leg 57 comes to rest against an inwardly extending second stop pin 70 mounted on the upright bracket 41.

The final operating positions of the slit body and back-up bar are adjusted by means of a pair of vertical set screws 72 (see Fig. 3) located on opposite sides of the reservoir tube shaft 40 and threaded through an outwardly extending horizontal shelf 74 mounted on the left end (as viewed in Fig. 2) reservoir tube just above the upper surface of the dog 56. By screwing down on one set screw and up on the other, the depth of penetration of the tapered portion of the slit body into the space between the supports 30 on the back-up bar is determined.

A further benefit of the thin film technique heretofore mentioned can be appreciated by reference to Fig. 1. This additional benefit lies in the many-fold reduction in the consumption of processing solution over that occurring in conventional developing procedures. An entire roll of conventional photographic recording paper amounting to approximately 400 square feet can be processed with no more than 400 cubic centimeters of processing solution. The same roll processed by conventional procedure of paper dipping would not only take about 10 to 100 times the access time as stated above, but would involve the consumption of approximately 900 cubic centimeters of solution. A still further advantage of thin-film application of developing solution is that the developer in supply reservoir 21 remains always at full strength, there being no gradual exhaustion of developer in the process of developing a roll of paper as would be the case if the paper were immersed in the developer.

The latent image produced in the recording medium at the instant of exposure through window 11 would not be rapidly developed after application of the processing solution at the applicator 22 without further impetus. However, at this point, the record cannot be exposed to ambient light since the emulsion is highly active while it is developing. Accordingly, the crux of the rapid access achieved with the process described in the co-pending application is the ability to apply large quantities of heat relative to the amount of developer present to induce rapid development and simultaneous drying of the thin film of developer at a rapid rate. This is made possible not only because a small volume of developer is involved, but because the recording paper itself has not been wet.

For this purpose the record is carried from the applicator 20 over a guide roller 80 and across a curved face 81 of a heated platen 82. The dimensions of the platen are selected to achieve the desired degree of drying at the ranges of paper speed to be encountered and under acceptable conditions of temperature, and speaking, a typical record can be dried at a temperature in excess of about 90° C. and preferably in the neighborhood of 120° C., requiring a drying time of approximately 0.4 second.

The platen 82 may be heated in conventional fashion by insert heaters (not shown). To accomplish the rapid drying desired it is necessary to transfer relatively large quantities of heat to the record. This can be accomplished by high power input to the platen, but more economically is done by causing the platen to act as a heat sink storing relatively large amounts of heat developed at comparatively low power consumption during periods of inactivity, e.g., while the record roll is being changed. Any form of heated platen may be employed, there being many adequate to apply the necessary heat to the record.

From the platen the record is passed through compression rolls 83, 84, the roller 83 being driven through a slip clutch (not shown) to maintain a constant tension on the record strip between the metering roll 18 and the point of the compression rollers. The developed record is discharged from the magazine through an exit slit 85, where it is ready for immediate observation.

Using a suitable processing solution, the record obtained from the magazine is sufficiently stable to permit leisurely visual observation. It is the general experience that a large percentage of the records produced in the testing procedures in which oscillographs are employed are of no permanent value, and once observed to evidence the conditions under investigation may be destroyed. As related to this large percentage of total record which is to be destroyed the thin-film processing technique which eliminates the more time consuming treatment in stabilizing solutions has not only the advantage of quick access but further eliminates stabilization of records which have no permanent value. At the same time, the record is of sufficient permanence that any segments of prolonged or permanent value may be selected and separately processed minutes, hours or days later for ultimate stabilization. At this point the time required to stabilize is of no concern since the record has already been observed and has served its immediate purpose.

It should be mentioned, however, that there is nothing in this developing process, rendering it incompatible with stabilization of the record. If desired, an additional liquid applicator may be employed downstream from the point of heating to apply a film of stabilizer such as hypo solution to the developed and dried record. Such a procedure, however, produces additional handling problems which are not generally justified in view of the facility of later subsequent stabilization of edited portions of the developed record.

The processing solution used in the above described application should have special characteristics. In particular, it should not fog the sensitive layer at the high temperatures used for rapid development and drying, and its oxidation products should be substantially colorless.

Further, the developer components or their pyrolysis and oxidation products should not react with constituents of the photosensitive layer or its support (for instance, the sensitizing dyes to be found in most photographic emulsions) to form markedly colored products. This being so, and bearing in mind the diversity of the constituents
which may be used in photographic media, optimum results are achieved by formulation of a particular developer to work with a desired type of photographic recording medium. Such a developer is disclosed and claimed in co-owning application Serial No. 699,601, filed November 29, 1957, by John H. Jacobs, and owned by the same assignee.

One suitable solution for recording paper such as Linowrite #1(w) (Du Pont) is shown in the following table:

<table>
<thead>
<tr>
<th>Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium sulfite (anhyd.)</td>
</tr>
<tr>
<td>Phenol</td>
</tr>
<tr>
<td>Hydroquinone, or chlor-hydroquinone, or mixture</td>
</tr>
<tr>
<td>Caustic soda</td>
</tr>
<tr>
<td>Benzotriazole</td>
</tr>
<tr>
<td>Potassium bromide</td>
</tr>
<tr>
<td>Teepol (stock solution)</td>
</tr>
<tr>
<td>Water to</td>
</tr>
</tbody>
</table>

In mixing the above solution, it is desirable to start with water, warmed to about 50° C, to the extent of about 80% of the final volume. When all the components have been added and dissolved, preferably in the order given, the solution is made up to the final volume. The exact composition of the processing solution can be varied considerably to obtain desired results under various operating conditions and on various types of photographic recording media.

A solution made in accordance with the table preferably has a pH of 12–13, and any suitable alkali, or mixture of alkalis, can be used as well as caustic soda. For example, sodium or potassium carbonate can also be used.

The various dimensions of the above-described slit applicator will vary with the type of processing solution, and recording medium used. However, using the above mentioned recording paper and the processing solution made in accordance with the table, a slit applicator having the following dimensions (see Fig. 3) proved to be very satisfactory:

- Angle A: 50–70°, and preferably about 65°.
- Slit width: 0.0013 inch.
- Slit length: 0.15 inch.

Using the slit applicator, processing solution, and recording medium described above, the film thickness of the applied processing solution did not vary significantly from about 0.0003 inch in the speed range from less than about 0.1 inch per second to more than 25 inches per second.

The above described slit applicator utilizes capillary action and adhesion between the processing solution and the emulsion on the recording medium to draw the solution through the slit, so that it works particularly well on surfaces which are wetted by the solution. At the higher speeds, the hydrostatic pressure in the solution at the point of application becomes somewhat less than atmospheric pressure. Thus, it is important to maintain firm contact between the blade tips of the slit opening and the recording medium, and to prevent leakage of air which would destroy the partial vacuum on which the operation of the slit depends at high speeds. To this end, the reservoir is suitably vented, say through the filling spout to permit air to enter the reservoir as liquid flows out of it, or by the use of a vacuum in the reservoir. The seal is also important at low speeds to prevent the slit from feeding processing solution at an excessive rate which would result in overwetting of the recording medium. This is the reason the shim is shaped to close the slit at each end. Also, the paper is of sufficient width to span the entire length of the slit.

At the higher paper speeds, the paper inertia tends to overcome the tension in the paper across the slit and cause the paper to "balloon" out as it leaves the trailing tip of the slit, or, in extreme cases, to lose contract with the trailing or upper blade altogether. Such a condition may permit leakage of liquid which caused the slit to stop feeding at the proper rate. For this reason the paper is supported by the back-up bar, whose function is to control the wrap angle of the paper around the slit, and to maintain a constant wrap angle through a wide range of speeds.

By employing the slit applicator of this invention, the above described high speed developing technique can be used so any portion of a record is visible in an interval determined only by the time required to travel from exposure to discharge, this being a function of the length of record in residence between the point of exposure and the outlet window of the magazine and the paper speed involved. At recording speeds in excess of about 25 inches per second an access time of less than 0.01 second is realized.

To facilitate an understanding of this unique applicator, it has been described as applied to the field of dynamic recording. However, the applicator is not limited in its usefulness to dynamic recording and the detailed description of such application should not be so construed.

1. Apparatus for applying a film of liquid to a strip of material, the apparatus comprising a body with a slit opening out of it, a liquid reservoir connected to the slit, an elongated back-up bar disposed adjacent the slit, the back-up bar having an elongated recess which extends in the same general direction of the slit, means for pivoting the body between a first position in which the slit is disposed exterior of and below a portion of the reservoir and a second position in which the slit is disposed above a portion of the reservoir, the slit portion of the body extending into the recess to contact the material when the body is in the first position and the material is disposed across the recess, and means for moving the material relative to the slit so liquid is transferred from the slit to the material.

2. Apparatus for applying a film of liquid to an elongated sheet of material, the apparatus comprising a body having a slit in it, the slit being bounded by rigid spaced walls, a reservoir connected to the slit for supplying liquid to it, means for sliding the material past the slit so liquid can flow from the slit to coat one side of the moving material, a back-up bar disposed adjacent the slit, the back-up bar having a recess extending in the same general direction of the slit and opening toward the upper, means for supporting the material using the back-up bar recess to be in contact with the body on all sides of the slit, the slit portion of the body being disposed to extend into the recessed portion of the bar for a distance at least several times greater than the length of the slit to maintain the angle between the plane of the material leaving the body and the normal to the plane of the material at the slit at less than about 70°, as measured from the side of the material being coated, over a wide range of speeds.

3. Apparatus according to claim 2 in which the slit portion of the body extends into the recessed portion of the bar to maintain the said angle between about 50° and about 70°.

4. Apparatus for applying a film of liquid to a strip of material, the apparatus comprising a frame, a body pivotally mounted on the frame and having a slit opening out of it, means to pivot the body on the frame between a first and a second position, a liquid-containing reservoir connected to the slit, a back-up bar disposed adjacent the slit and pivotally mounted on the frame, the back-up bar having a recess which extends in the same general direction as the slit, and opens toward the slit, means to pivot the back-up bar on the frame between a first and a second position, means interconnecting the body and the back-up bar so they pivot to their first and second positions simultaneously, the slit portion of the
body extending into the back-up bar recess to contact material disposed across the recess when the body and back-up bar are pivoted to their respective first positions, the slit portion of the body being clear of the recess and out of contact with the material when the body and back-up bar are pivoted to their respective second positions, and means for moving the material relative to the slit when the body and back-up bar are in their respective first positions.

5. Apparatus according to claim 4 in which the slit is located exterior of and below a portion of the liquid in the reservoir when the body is in the first position, and is located above the liquid when the body is in the second position.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,983,250

May 9, 1961

Michael D. Godfrey

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 7, line 13, for "76" read -- 6 --; line 35, for "porcessing" read -- processing --.

Signed and sealed this 9th day of January 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents
UNITED STATES PATENT OFFICE
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