July 6, 1965 M. WRIGHT 3,192,846

DATA PROCESSING APPARATUS

Filed Aug. 22, 1961 4 Sheets-Sheet 1

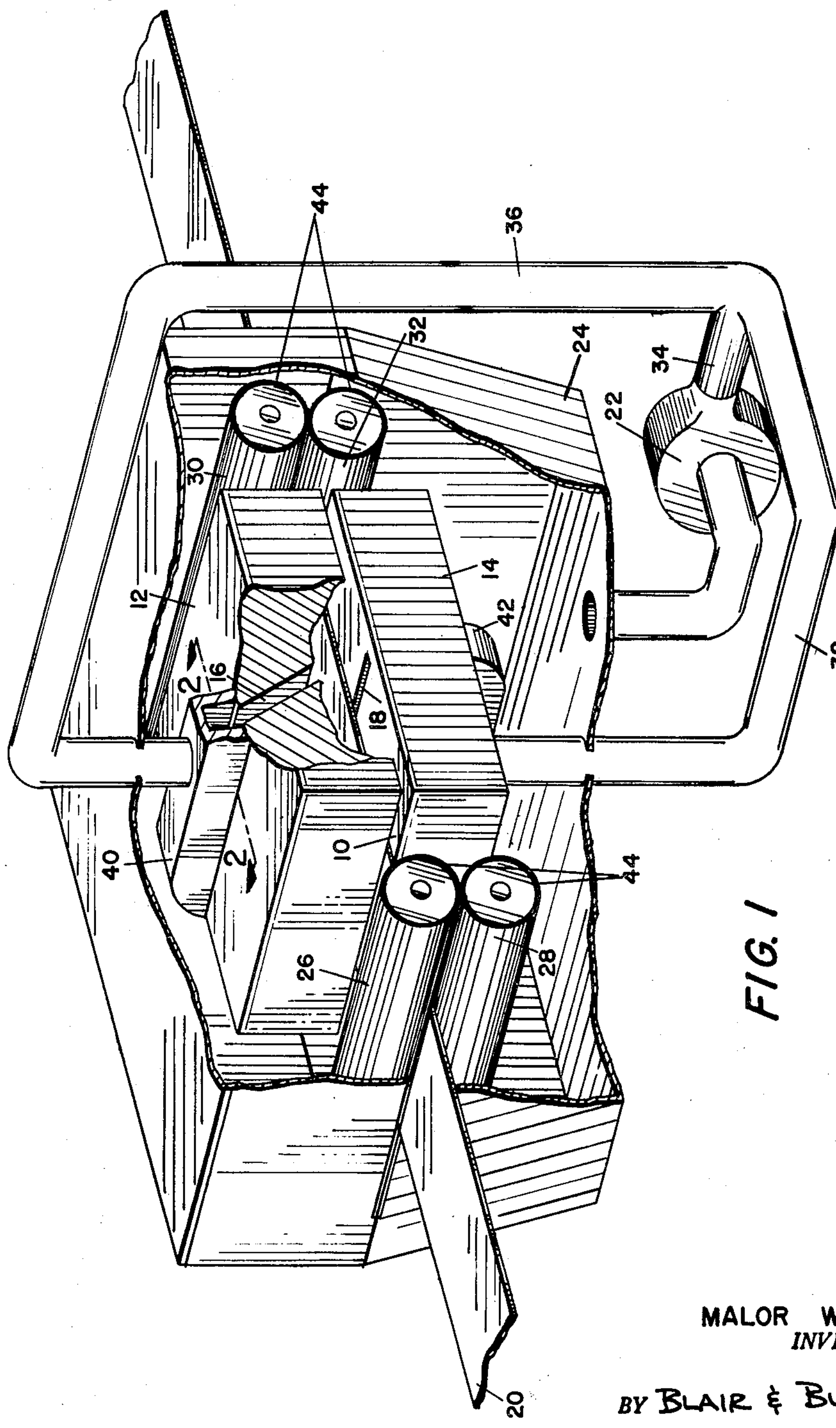

FIG. 1

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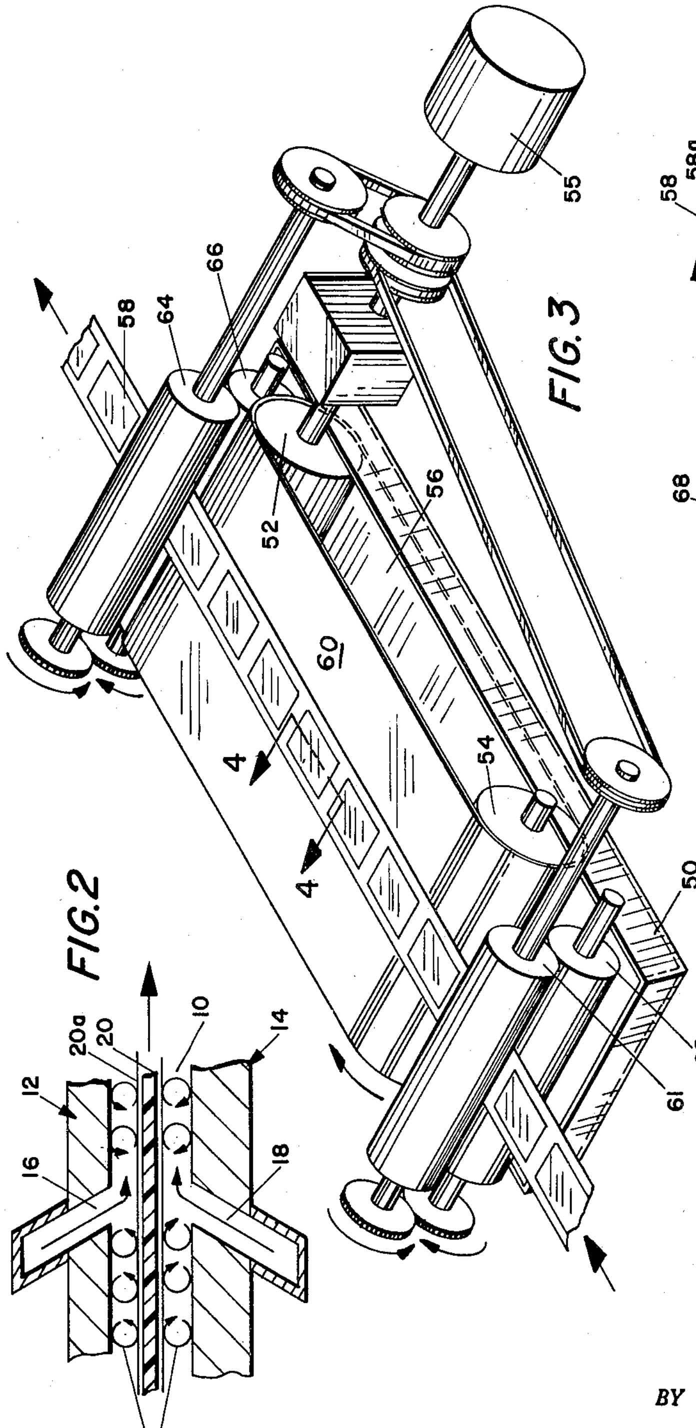

FIG. 3

FIG. 2

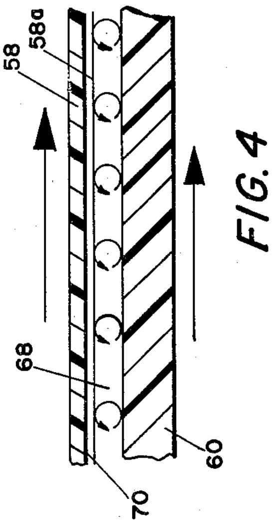

FIG. 4

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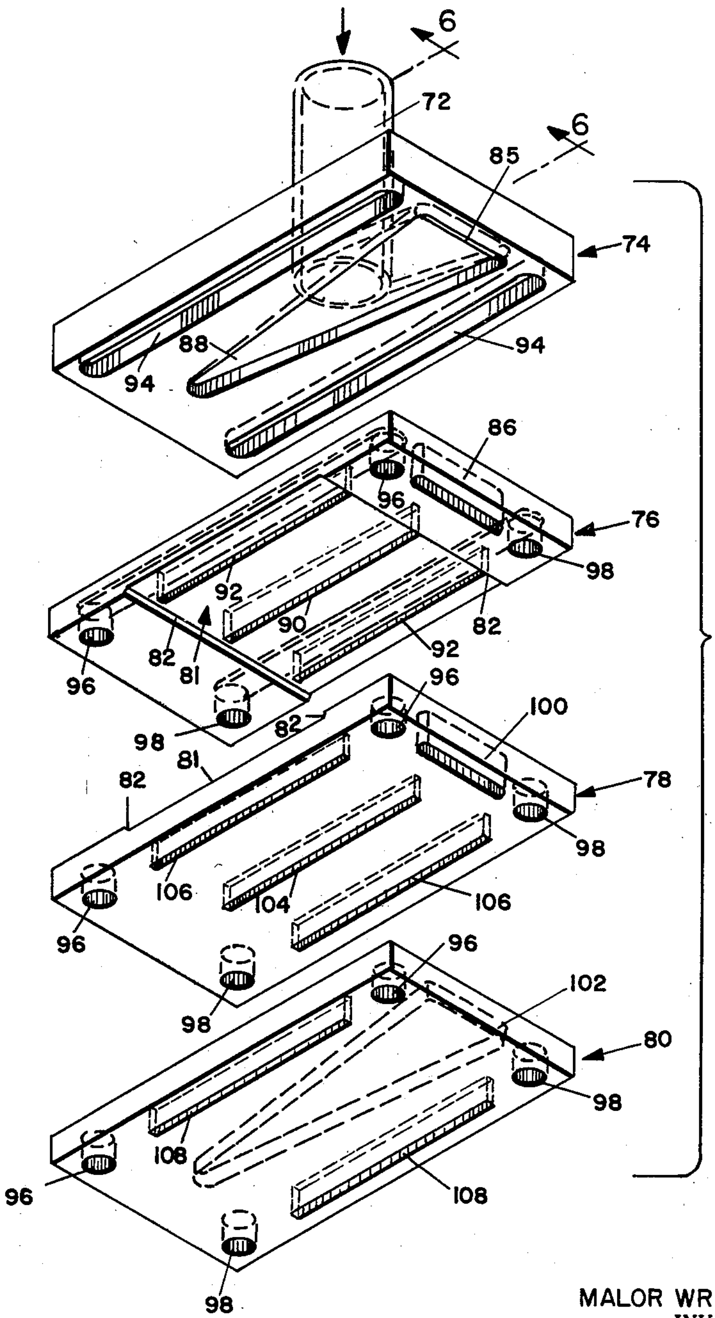

FIG. 5

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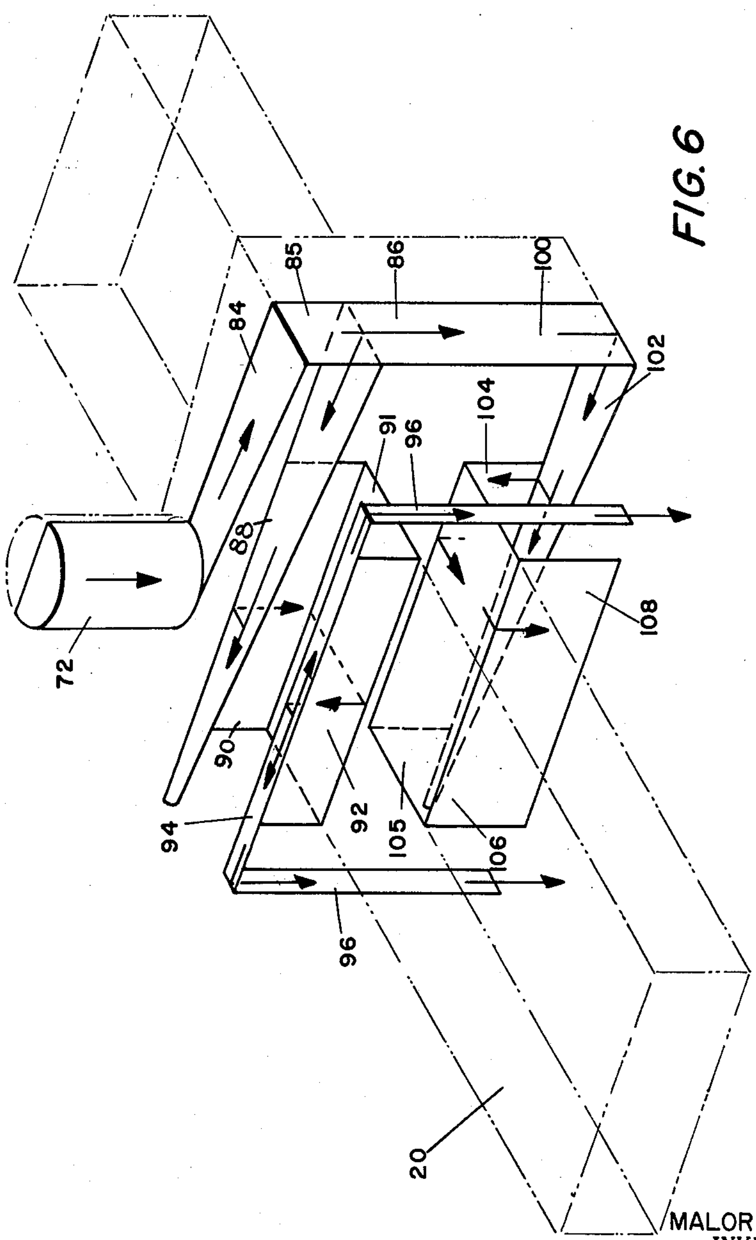

FIG. 6

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DATA PROCESSING APPARATUS

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5 Claims. (Cl. 95—94)

This invention relates to methods and apparatus for the fluid treatment of strip material, and more particularly to methods and apparatus for rapidly processing photographic film in which a layer of uniformly and vigorously agitated processing fluid contacts the gel surface to process the film and simultaneously acts as a scratch-free bearing support for the film during processing.

The rapid and accurate processing of photographic film poses a number of problems. In automatic film processing equipment, the requirements are even more critical, especially in applications such as data storage on film, microfilming and aerial photography. In such data storage techniques, there may be as many as one hundred lines of information per millimeter of film. Any uneven development of the film can result in a serious error when the stored data is recovered and printed out. For example, in processing of aerial photographs, development must be as even as possible, for subtleties of light and shade play a very important part in subsequent interpretation of these printed photographs.

The amount of displacement of the emulsion gel on the film is also quite crucial. Displacement may produce uneven refraction of light passing through the gel, with consequent distortion of the recorded images. Serious errors when the information on the film is printed out can thus occur. It is imperative that the emulsion gel be undisturbed during processing, not only in the illustrative examples given above, but in many other applications where a high degree of accuracy is required.

Another problem of prior art film processing equipment involves passage of the film over a plate, a roller or other surface. It is possible for dirt, grit, or imperfections in the plate or roller to scratch the film. Again even a minor scratch or burr may be critical where high accuracy of recorded information is required.

Prior art processes have also been found to be lacking in speed of processing. Usually microfilm and other data storage applications require speedy recovery of information thereon for efficient functioning of the system. Attempts have been made to step-up processing times by increasing the temperature of the developing bath. Unfortunately, however, such increased temperature frequently degrades the appearance and photographic response of the film. Increased fog is a typical example of such degradation.

It has been found that one of the principal causes of uneven development of photographic film in conventional processing systems is the lack of agitation of the fluid at the surface of the film in motion, or an uneven agitation. Uneven exposure to the processing fluid results in inaccurate development of the film, which is a great cause of error in recovering photographically recorded information.

Accordingly, it is an object of the present invention to provide film processing apparatus which provides for effective agitation of the processing fluid at the film surface.

Another object of the invention is to provide a film processing apparatus of the above character which applies processing fluid to a film with a minimum of displacement of the film emulsion.

A further object of the invention is to provide a film processing apparatus of the above character in which the dangers of damage to the film during processing are minimized.

A further object of the invention is to provide a film processing method and apparatus of the above character in which the film is supported by a fluid bearing layer of processing fluid as the film goes through the processing stage.

A further object of the invention is to provide methods and apparatus for the processing of film in which relative movement between the film and a thin layer of processing fluid creates turbulences in the field adjacent the film.

A further object of the invention is to provide methods and apparatus for the fluid treatment of film in which the film is developed with a high degree of uniformity and accuracy.

A further object of the invention is to provide a method for processing photographic film in which the processing time has been substantially reduced.

Another object is to obtain greater controlled maximum density and contrast for a given temperature of developer solution.

Another object of the invention is to provide a method for continuously processing strips of photographic film.

Another object of the invention is to provide methods and apparatus of the above character which are inexpensive and reliable in operation.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the apparatus embodying features of construction, combinations of elements and arrangement of parts which are adapted to effect such steps, all as exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

For a better understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is a perspective schematic view, partially broken away, of one embodiment of the invention;

FIG. 2 is a fragmentary schematic view of a portion of the processing chamber taken along lines 2—2 of FIG. 1;

FIG. 3 is a perspective schematic view of another embodiment of the invention;

FIG. 4 is an enlarged fragmentary cross-sectional view taken along lines 4—4 of FIG. 3;

FIG. 5 is an exploded perspective view of another embodiment of a processing chamber plate assembly; and

FIG. 6 is a schematic perspective view of fluid flow through the forward half of the assembled plate group of FIG. 5, as indicated by the section line 6—6 in FIG. 5.

As stated above, it is essential for rapid and accurate film processing that the processing fluid be uniformly agitated as it contacts the film surface. In this invention, effective agitation of the processing fluid is achieved by relative movement between a thin layer of fluid and the film strip. This relative movement produces a "shear" effect in the fluid and provides a uniform and vigorous fluid turbulence over the surface of the film. This "shear" effect is enhanced because of the thinness of the fluid layer, and the resulting turbulence has been found to reduce processing time considerably.

The desired uniform agitation of the processing fluid is achieved in the various embodiments of the invention by moving the fluid over the film surface under pressure or by means of a carrier such as a moving belt. The embodiments shown in FIGS. 1, 2, 5 and 6 utilize relative movement of the developing fluid and the film being developed. The fluid acts as a top and bottom bearing for the film. Both the fluid and the film are passed between stationary plates, with the film being moved at a slower rate than the fluid. Transverse movement of the film within the fluid body is easily controlled by application of the fluid flow principle. Any tendency of the film to collapse will cause creation of uneven fluid pressure between the bottom and top layers of fluid. This will tend to return the film to its center position and therefore no scuffing of the film surface will occur.

In the embodiment of the invention shown in FIGS. 3 and 4, the processing fluid is moved as a thin layer by a belt, upon which the film rides with its emulsion face in contact with the layer of fluid. Thus, in all of the above embodiments, the moving film is supported by a thin layer of uniformly agitated processing fluid as the fluid moves relative to the film.

The embodiment of the invention shown in FIGS. 1 and 2 generally comprises a processing chamber **10** formed by a pair of spaced plates **12**, **14** which have fluid distributing inlet slots **16**, **18** positioned transversely to the direction of travel of the film **20**. Processing fluid is supplied to the fluid inlet slots by a pump **22** which recirculates processing fluid from a sump **24**. A replenishment system (not shown) may be incorporated into the system to maintain the concentration level of the processing fluid within a certain predetermined range. Additionally, a processing fluid temperature control system may also be incorporated to provide more accurate control over the processing conditions.

A pair of feed rollers **26**, **28** and a pair of delivery rollers **30**, **32** move the film through the processing chamber and aid in guiding between the plates **12**, **14**. The rollers are located within the processing chamber proper where they serve as squeegee rollers. They are constantly washed by the squirting action of the liquid leaving the back and front edges of the processing chamber **10**. This washing removes any dirt particles that may have lodged on the roll surface.

As the film strip **20** is moved through the processing chamber **10**, processing fluid under pressure is admitted through the transverse inlets **16**, **18** to provide a continually moving layer of fluid on both sides of the film. The film is thus supported at a distance from each of the plates **12**, **14** with thin layers of fluid acting as a scratch-free bearing surface. Thus, not only is the film protected by the liquid bearing-layers on both of its surfaces but also the fluid is thoroughly and uniformly agitated over the surface of the film, as will be explained more fully hereinafter.

The processing chamber shown in FIG. 1 will now be described with more particularity. Referring to FIGS. 1 and 2, it will be seen that the chamber **10** may be open on two sides to permit processing fluid to flow into it and then spill over the edges of the plate **14** to be recovered in the sump pan **24**. To facilitate the threading of the processor, the inlet slots **16**, **18** pass through their respective plates at an angle, as shown in FIG. 2, thus preventing entry of the film into one of the slots during the threading operation. The fluid is supplied under pressure by the pump **22** via conduits **34**, **36** and **38**, the fluid flow being split for equalized fluid pressure on both sides of the film strip as it passes through the processing chamber. The conduits **36**, **38** are connected to manifolds **40**, **42** which distribute the fluid evenly through the inlet slots.

The feed rollers **26**, **28** and the delivery rollers **30**, **32** are precisely made and accurately positioned with respect to their mates. They are preferably covered with soft rubber **44** (about .2 of an inch) to prevent scratching of the film or displacement of the emulsion gel. Polished metal rolls may also be used if desired for one of the rolls. The rollers are synchronously driven to avoid uneven pull on the film, especially the emulsion covering.

Referring now to FIG. 2, it will be seen that as the film **20** passes between blocks **12**, **14** and with processing fluid entering from the inlet slots **16**, **18** at substantially equal pressures, the flow, whether it be turbulent or laminar, substantially minimizes the thin layer **20***a* of motionless fluid immediately adjacent each side of the film. The thinner the layer, the less resistance to diffusion of reactants and reaction products. Obviously, the amount of turbulence or laminar flow in the processing fluid is variable, depending on the fluid pressure of the incoming liquid.

It has been found that very satisfactory results are obtainable in developing microfilm when a layer of fluid approximately $\frac{1}{32}$ of an inch thick is moved past each side of the film at a rate approximately one hundred times the rate of movement of the film through the chamber. A velocity of one-half to 2 feet per minute is the customary speed of the film. It should be understood, however, that the properties of the particular processing fluid being used and the properties of the film to be processed may necessitate variations in film speed and fluid pressures for the achievement of optimum results. As a specific example, the apparatus herein has been used to process microfilm at a rate of 30 pictures per minute.

The embodiment shown in FIGS. 3 and 4 also utilizes a thin layer of fluid in the processing chamber. The film is supported on one side by a fluid layer which in turn is carried by a belt. The rotation of the belt and the passage of the film through the chamber provides the relative movement between the fluid layer and the film, which creates the vigorous agitation necessary for good processing.

As shown in FIG. 3, the processor is provided with an open-topped tray **50** with a pair of rollers **52**, **54** positioned to move a continuous belt **56** through the processing fluid in the tray and then to convey an adhering layer of processing fluid into juxtaposition with the film **58**. The belt may be made of a number of materials including cloth, neoprene, silicone rubber or even stainless steel. A pair of feed rollers **61**, **62** and a pair of delivery rollers **64**, **66** are synchronously driven by drive means **55** to move the film strip **58** over the top run **60** of the belt **56**.

In operation, the belt **56** is continuously driven by the drive means **55** through at least one of the rollers **52**, **54** and preferably by the roller **52** so as to provide a flat run **60** under the film strip which is being passed thereover. The feed and delivery rollers are preferably of the same construction as those described above in reference to the FIG. 1 embodiment. Similarly, all the rollers **61**, **62**, **64** and **66** are powered by drive means **55** and synchronously driven.

It has been found that effective and uniform agitation of the processing fluid between the upper run of the belt and the film is achieved when the linear speed of the belt greatly exceeds the speed of film feed through the processor. A belt speed of approximately 100 times the film speed creates the desired flow to minimize the diffusion layer **58***a* of processing fluid **68** on the two faces of the film. The moving belt not only provides effective agitation of the thin layer of fluid between the film and the belt but also provides a constant stirring and mixing action of the processing fluid in the tray **50**.

It will also be quite evident from a study of the structure shown, that the relative positioning of film feed and delivery rollers **61**, **62**, **64** and **66** is independent of the belt rollers **52** and **54**. Thus, the clearance and hence the thickness of the layer of fluid between the film and the belt is adjustable. Indeed, this independence is a very attractive feature of the invention for it completely avoids film-roller or belt contact heretofore believed essential. Such contact frequently altered the acuity characteristics of the developed film.

In one instance, the clearance used was .001 inch between the belt and the film. This adequately accommodated the viscosity of the processing fluid, which was substantially similar to water. Typical processing compositions used were those indicated in Lange's Handbook of Chemistry, Handbook Publishers, Inc., Sandusky, Ohio, in the section entitled "Photographic Solutions."

It can be seen from FIG. 3 that the top run **60** of the belt is moving in the same direction as the film **58**. Thus, the processor is self-threading, for the belt **56** can carry a film leader from the feed rollers to the delivery rollers. This facilitates use of the apparatus for short lengths of film.

A more refined version of the processing chamber shown in FIG. 1 is shown in FIG. 5. The processing fluid is supplied through a single conduit **72** with flow split and directed to both sides of the film through a number of channels in the processing chamber assembly. The processing chamber assembly is comprised of a series of plates **74**, **76**, **78** and **80** for the directing of processing fluid evenly across the film. When assembled, the plates provide a series of channels which result in the fluid flow pattern shown in FIG. 6 when the processor is in operation.

The film is passed between plates **76** and **78**, in which mating cut-out portions **81** having shoulders **82** form an open-ended processing chamber to accommodate passage of the film. For a better understanding of the fluid path through the processing chamber of this embodiment, concurrent reference should be had to FIGS. 5 and 6. The fluid enters through conduit **72** and is routed through lateral channel **84** (FIG. 6) in the top of plate **74** and thence down a slot **85** through plate **74**. The flow is then split, a portion of the fluid being directed to vertical slots **86** to **100** in plates **76** and **78** and a portion of the fluid being directed in lateral channel **88** in the bottom of plate **74**. The fluid in channel **8** is then forced through a vertical inlet slot **90** in plate **76** and over the top of the film **20** (FIG. 6) beneath area **91** within the processing chamber. After moving over the top of the film, the fluid is received by exhaust outlet slots **92** in plate **76** and routed upwardly to lateral channels **94** in plate **74** and thence downwardly through aligned holes **96**, **98** in plates **76**, **78** and **80** for return to the sump **24** (FIG. 1).

Returning now to the fluid directed through the vertical slot **86** in plate **76**, it will be seen that this fluid continues downwardly through mating vertical slot **100** in plate **78** and is received in a lateral channel **102** in the top of plate **80**. From here the fluid is forced upwardly through vertical inlet slot **104** in plate **78** and thence past the bottom surface of the film **20** over area **105** within the processing chamber. The fluid is then received by vertical exhaust slots **106** and routed downwardly to the sump **24** through the mating slots **108**.

For a clearer understanding of the fluid flow through the processing chamber plates, the flow diagram has been halved along a central plane in FIG. 6, and the reference characters in FIG. 6 indicate the points at which fluid is flowing through the various slots and channels of FIG. 5.

The invention, in any of the above embodiments, may be employed as a single stage processor, i.e., with a "monobath" wherein only a single processing fluid is needed. Any of the above embodiments may also be included in a film processing system wherein a series of adjacent spaced units are employed to process film. In such a system, the film may be moved through several processors having different processing fluids for "conventional" film processing. Thus, successive processors may contain a developer, doctoring developer inhibitor, fixer and wash fluids, for example. The feed and the delivery rolls, coupled with appropriate wiper blades (not shown) acting thereon to wipe off fluid, inhibits dilution of each successive solution by the proceeding solution.

The apparatus of the invention also exhibits versatility in handling varying widths of film. The embodiments shown in FIGS. 1, 2 and 3, 4 can process film of 16, 35 or 70 millimeter widths without adjustment. With the embodiment shown in FIGS. 5 and 6, a separate set of plates may be used for each width of film or the cut-out portions **81** may be adjustable to handle varying widths of film.

The invention has a number of advantages. The apparatus is relatively simple and inexpensive to manufacture, and, the processing fluid may be recycled, thus cutting the operation costs of processors employing the invention.

Moreover, developing time has been substantially reduced, and this makes the apparatus very suitable for use with microfilm or with other data storage applications. The vigorous agitation of the processing fluid at the emulsion surface of the film is the primary factor in the increase in developing speed.

The quality of film processing is also exceptionally high, and therefore the invention may be used in applications where uniformity of tone of the finished film is critical. The agitation of the fluid over the film emulsion is uniform and develops film with accurate tone qualities.

It should be understood that the processing methods and apparatus of the invention may also be applicable for processing strip material other than photographic film in the strict sense. Data storage tapes may be treated for example, wherein the information is recorded magnetically or by a thermal process. The invention can thus be employed in these applications where it is desirable to agitate processing fluid at the surface of the information being material and where damage to the strip material should be minimized during processing.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in carrying out the above process and in the constructions set forth without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention, which, as a matter of language, might be said to fall therebetween.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. Processing apparatus for rapid fluid processing of photographic strip material moving through said apparatus in a predetermined direction, comprising:

a housing having inlet and exit openings formed therein;

a pair of spaced symmetrical fluid applicator means positioned within said housing and having opposed surfaces providing a passageway between said inlet and exit openings, said opposed surfaces each having fluid communications means formed therein for providing moving fluid layers between said opposed surfaces, along said predetermined direction, at a first velocity;

fluid supply means coupling said fluid communication means and a source of processing fluid for providing said fluid; and

transport means for transporting said strip of photographic material through said passageway at a second velocity with both surfaces of said strip in simultaneous contact with said moving fluid to establish relative velocity between said strip and said fluid for providing simultaneous fluid support for said strip and fluid agitation for the surface thereof, whereby said photographic material is processed.

2. Processing apparatus for rapid fluid processing of photographic strip material moving through said apparatus in a predetermined direction, comprising:

a housing having inlet and exit openings formed therein;

a pair of spaced symmetrical fluid applicator means positioned within said housing and having opposed surfaces providing a substantially straight passageway between said inlet and exit openings, said opposed surfaces each having fluid communication means formed therein for providing moving fluid layers between said opposed surfaces, along said predetermined direction, at a first velocity;

fluid supply means coupling said fluid communication means and a source of processing fluid for providing said fluid; and

transport means for transporting said strip of photographic material through said passageway at a second velocity with both surfaces of said strip in simultaneous contact with said moving fluid to establish relative velocity between said strip and said fluid for providing simultaneous fluid support for said strip and turbulent fluid action thereon, whereby said photographic material is processed.

3. Processing apparatus for rapid liquid processing of photographic strip material moving through said apparatus in a predetermined direction, comprising:

a housing having inlet and exit openings formed therein;

a pair of spaced symmetrical liquid applicator means positioned within said housing and having opposed surfaces providing a passageway between said inlet and exit openings, said opposed surfaces each having liquid communication means formed therein for providing moving liquid layers between said opposed surfaces, along said predetermined direction at a first velocity;

liquid supply means coupling said fluid communication means and a source of processing fluid for providing said liquid; and

first and second transport means adjacent said inlet opening and exit opening respectively for transporting said strip of photographic material through said passageway at a second velocity with both surfaces of said strip in simultaneous contact with said moving liquid to establish relative velocity between said strip and said liquid for providing simultaneous liquid support for said strip and turbulent liquid action thereon, whereby said photographic material is processed.

4. The combination of claim **3** wherein said passageway is substantially straight and wherein each of said transport means is a pair of rollers positioned with the nip thereof in the plane of said predetermined direction.

5. The combination of claim **4** wherein said liquid supply means provides liquid under pressure.

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