Mr Somerville

BBC

ENGINEERING DIVISION

MONOGRAPH

NUMBER 30: MAY 1960

Film Processing and After-processing Treatment of 16-mm Films

by

L. J. WHEELER, F.R.P.S.

Part I: Film-Processing Equipment in the BBC Television News Service
Part II: After-processing Treatment of 16-mm Films

BRITISH BROADCASTING CORPORATION

PRICE FIVE SHILLINGS

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FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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FILM PROCESSING AND AFTER-PROCESSING TREATMENT OF 16-MM FILMS

SUMMARY

This monograph, which is based on a paper read at the SMPTE Convention in May 1960, describes daylight-operated continuous film-processing equipment used in the BBC Television News Film Service, a series of experiments designed to test and compare after-processing treatments, the adoption of Eastman Over-all Wax treatment as a protective coating immediately following the processing operation, and the installation of suitable equipment to provide this service.

Lawley Junior film-processing machines have been used to process BBC Television News films since February 1958. Since that time a number of modifications and improvements have been proposed by the BBC and carried out by the manufacturers to convert these machines from 16/35-mm friction-driven machines having a maximum speed of 30 ft per minute to 16-mm sprocket-driven machines with a maximum speed of 60 ft per minute. Various liquids are available to provide 'after-processing' treatment to prevent emulsion scratches, to assist 'green' films through projectors, and to retard dirt and dust, etc. Tests have been made to measure the value of several liquids and the protection created by them.

PART 1

FILM-PROCESSING EQUIPMENT IN THE BBC TELEVISION NEWS SERVICE

1. General Introduction

The BBC Television News Service originates at Alexandra Palace, North London, in the premises from which the first regular public service television programmes were radiated in 1936. The bulk of the material used to provide the present service consists of motion picture films of actual news events and 'film interviews' of personalities associated with current affairs.

For some years BBC technical staff have been studying problems related to continuous film processing and, in 1955, news-film processing facilities were made available at Alexandra Palace. During February 1958, the original machines installed for this purpose were replaced by three 16/35-mm dual-gauge friction-driven film-processing machines. These were to provide a reliable processing service which would handle the bulk of the film used in the Television News programmes.

From that date approximately 1,750,000 ft of film has been processed on these machines—an average of 3,000 ft of film per day. During this period a great deal of experience has been gained concerning the performance of the 'Lawley Junior' processing machines which were installed for this purpose, the types of film which must be processed and the techniques which must be adopted to maintain the highest possible picture quality coupled with freedom from handling defects, such as scratches, etc.

Part 1 of this monograph gives details of a number of improvements which have been made to these machines as a result of our experience. Part 2 describes apparatus which has been installed to provide an 'after-processing' treatment service whereby films are given a wax-based protective coating to prevent emulsion scratches, to assist 'green' film through projection equipment, and to retard dirt and dust deposits—thus maintaining a high standard of film processing under the urgent conditions associated with news-film work.

2. Types of Film Processed at Alexandra Palace

All the film currently processed at Alexandra Palace is manufactured by either Ilford Ltd., or Kodak Ltd., and by far the greater portion of the work is carried out on 16-mm negative stocks coated with a magnetic edge-stripe on which the accompanying sound is recorded.

Apart from the actual 'recording stripe', which is applied to the film base beyond the picture area and near to the unperforated edge of the film, a second ribbon—known as the 'balancing stripe'—is also applied to the film base but near to the opposite edge and beyond the perforations. This ensures that such films will wind on to spools and take-up bobbins without becoming unduly loose.

Magnetic striping is not carried out by the film manufacturers in England, but is applied afterwards for the BBC as a subsidiary process by Zonal Film Facilities Ltd. Films carrying magnetic edge-coatings of this type are handled in Lawley processing machines without any difficulty or special precautions and at no time have such coatings suffered in any way as a result of this treatment.

Due to the wide range of lighting conditions under which news films must be exposed, a great variety of film emulsions are encountered each day and, of necessity, each type of film requires processing conditions different from the others if optimum results are to be achieved. Apart from films exposed by the cameraman in the field, the processing machines at Alexandra Palace are also required to process telerecordings made on the Marconi equipment installed there.

Thus it is currently necessary to be able to process any one of the following types of film immediately and to a specified machine condition established by sensitometry so as to yield optimum results: Ilford F.P.3, H.P.3, and H.P.S.; Kodak Plus-X, Tri-X, and Type 8374 telerecording film developed as either a negative or positive image.

When telerecordings are processed the recorded image may be either negative or positive and so selected by tonal inversion within the recording equipment; optimum processing is then achieved by developing the film to one of two degrees of image contrast dependent upon the type of recording which has been made.

3. Basic Principles of the Lawley Junior Processing Machines

3.1. *General Description*

The Lawley Junior film-processing machines are of British manufacture and were originally installed at Alexandra Palace as daylight-operated machines capable of processing either 16-mm or 35-mm films. Films were transported through the mechanisms by a series of friction-driving rollers and free-running rollers and at a maximum speed of 30 ft per minute.

Three machines were installed and two of these have since been modified to process 16-mm film only at speeds up to 60 ft per minute. Film transport in these latter machines has been modified and is now by means of a series of positive sprocket-driving rollers interspaced between free-running plain rollers.

The following brief description is not intended to give complete operating and maintenance details of the equipment—these are contained in a comprehensive manual supplied by Newman & Guardia Ltd., the manufacturers. It applies to the one machine which has remained unaltered and, incidentally, is now only used to process 35-mm film very occasionally, and also to the two machines which have been modified to process 16-mm film at high speed.

The machines are operated in normal room lighting but receive film via light-tight magazines, which must be loaded in a darkroom. They are continuous machines with provision to attach any number of films one after the other without interrupting the smooth passage of film through the various solutions. This is made possible by the use of a reservoir or feeding compartment between the film magazine and the solution tanks and from which the machine may draw a supply of film whilst an exhausted magazine is being replaced with one containing a second film. A general view of the equipment installed at Alexandra Palace is shown in Fig. 1.

Since approximately 600 ft of film is needed to thread the 16-mm machine it is only allowed to become empty when maintenance work is in progress. When the end of a film is reached—and if no further films are awaiting development—a specially tough 'machine leader film' is attached to the end of the 'story film' and thus automatically threaded into the machine so as to leave it in readiness to accept further work at any time.

Film is transported through the machine in a series of long vertical loops arranged in continuous spiral formation and so that the emulsion surface never comes into contact with the driving mechanism. Loops are formed in the film by mounting several rollers together on one upper shaft and another group of rollers on a lower shaft. The upper shaft is driven by a chain-and-sprocket system and is supported at one end in a cantilever fashion by two ball-races mounted in bearing blocks.

The position of the upper shaft always remains constant and is above the level of the solution in the processing tank, but the lower shaft, immersed in the solution tank, is mounted in a cradle assembly arranged to ride vertically in a guide-way mounted near to the rear wall of the solution tank. The depth at which this lower shaft operates may be varied, and this feature is used both as a means to adjust the time film remains in any one solution and also to allow film loop-length to change as the emulsion absorbs liquid and consequently increases in length—it also facilitates the passage of joins and changes from one type of film to another when the shrinking or expanding characteristics may be different.

The loops formed between rollers mounted on one upper shaft and one lower shaft are known as one 'bank' of film. In the Lawley Junior, fourteen banks of film exist between the supply magazine and the take-up shaft where the processed and dried film is wound on to a standard 2-in. plastic core. These banks are arranged in the following order:

Bank No. 1. In the reservoir between the supply magazine and the first solution tank. The lower rollers in this assembly normally remain at the bottom of the reservoir. They are provided with a guide-way in which they may slowly rise to the top of the unit as the machine consumes film. This occurs when the supply is temporarily interrupted because an exhausted magazine is being replaced by one containing a new supply of film. Films are joined together by wire staples and the time allowed to complete this operation varies between 45 seconds and $2\frac{1}{2}$ minutes, depending upon the machine speed.

Banks No. 2 *and* 3. In the developing solution. Here the exposed silver halide is reduced to metallic silver. The number of loops of film in these banks, combined with the length to which they are adjusted and the overall control on the machine speed, provide a range of developing times between 45 seconds and 4 minutes. When using May & Baker 'Teknol' developer diluted 6:1 at 73°F this range enables all currently used films to be processed to the required gamma and density values.

Bank No. 4. In the rinse tank between the developing and fixing solutions. Continuously running water passes through this tank and removes surplus developing solution from the film emulsion before it enters the fixing solution.

Banks No. 5 *and* 6. In the fixing solution. Here those sections of the emulsion which were not reduced to metallic silver by the action of the developing agent are now dissolved away. The amount of film in these banks is such that a range of fixing times between $1\frac{1}{4}$ and $3\frac{1}{2}$ minutes is available.

Bank No. 7. In the rinse tank immediately following the fixing solution. Here the surplus fixing solution is washed from the surface of the film by continuously running water.

Banks No. 8 *and* 9. In the spray-washing tank. Here intense washing by spray-jets of water removes the residual hypo still retained within the film emulsion. Unless this operation is effective the films will have poor keeping quality, the emulsion will become discoloured, and will

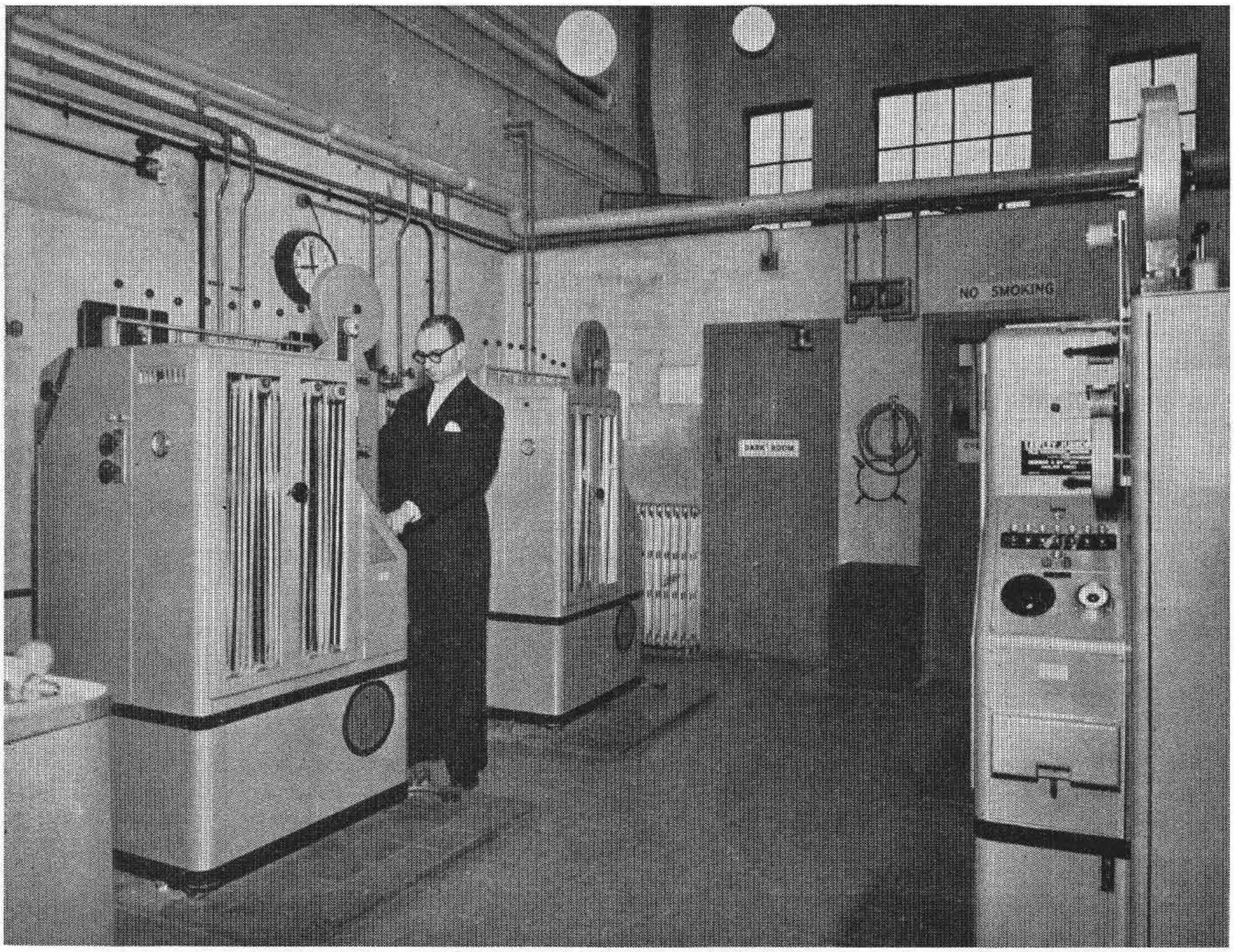

Fig. 1 — The Film Processing Room at Alexandra Palace

ultimately break away from the supporting base as a powder. The effectiveness of washing is measured in terms of the residual hypo content left in a film after processing and, for normal commercial work (having an anticipated life of at least twenty years), should not exceed 200 microgrammes per square inch; for archival work (having an anticipated life of at least fifty years) this figure should not exceed 50 microgrammes per square inch. In the Lawley Junior, under BBC working conditions, the residual hypo content is maintained at 150 microgrammes per square inch.

Banks No. 10–14. In the film drying compartment. Here pre-heated air passes over the film at high velocity and completely dries it in readiness for the final operation of automatically winding on to a take-up bobbin beyond the drying compartment. The amount of film in the drying compartment provides a range of drying times between 4 and 12 minutes.

3.2. *Ancillary Equipment*

Apart from the basic provision to develop, fix, wash, and dry films of any length continuously, the machine contains a number of services designed to control these operations within closely defined limits and also to safeguard against errors in operation. These are briefly described below.

3.2.1. *Developer Circulation*

When film is passing at relatively high speed through a developing solution it tends to carry an intimate skin of solution along with it. Unless this skin is removed, and the film is continually presented with fresh solution, local developer exhaustion will occur and what is known as 'developer drag' will result. This causes uneven development, and the well-known 'directional effect' in which an area of the film image carrying a low density is underdeveloped if it follows an area of high density through the developing solution. These defects are overcome in the Lawley Junior by continuously pumping the developing solution through the tank at a high speed. Care must be taken to prevent surface foaming when this technique is employed, and, therefore, the solution is drawn off from a point just below the surface and, after passing through the pump, is injected again at the bottom of the tank. The developing tank contains a total of 7 gallons and this is circulated at the rate of 24 gallons per minute.

3.2.2. *Solution Temperature Control*

Film can only be processed to specified and reproducible densities and contrast levels if the developing solution is maintained to within $\pm\frac{1}{2}$°F of the chosen temperature. This is achieved by the combined action of immersion heaters within the solution tank and a refrigeration system applied externally to the rear wall of the tank.

Refrigeration is needed even when the ambient temperature is equal to that of the developing solution, because the developer circulating pump creates heat due to friction between the solution and the moving parts; this is sufficient to raise the solution temperature by 1°F in 30 minutes.

Immersion heating and refrigeration are also applied to the fixing solution because the time required to complete fixation increases rapidly at low temperatures and, conversely, the solution does not remain stable at very high temperatures.

The combined action of immersion heaters and the refrigerator is controlled by a pair of distant-operating thermostats arranged to monitor the developing solution temperature in a small chamber connected between the main developing tank and the developer circulating pump. In practice one thermostat brings the immersion heater into operation when the temperature of the solution falls below 72½°F and the other brings the refrigerator into operation when the solution temperature rises above 73½°F. These tolerances are adjustable and may be arranged to occur at any selected temperature between 60°F and 90°F.

3.2.3. *Prevention of Solution 'Carry Over'*

It is essential to prevent the contamination of one solution by the exhausted chemicals from another being carried over with the film as it passes from one tank to the next. This is achieved by employing 'air knives' as squeegees at three points in the machine. One knife is mounted at the point where the film leaves the developing solution, a second at the point where it leaves the fixing solution, and a third where the film leaves the final washing tank before entering the drying compartment.

Each 'air knife' consists of two plastic tubes fitted with stainless steel slit-controlling aperture plates—one tube being mounted to face the film emulsion and the other to face the film base. These apertures cover the entire width of the film and are adjusted to create a slit of 0·005 in. This directs a fine jet of compressed air at 45° to the direction of film travel—thus blowing against the liquid which is rising with the film as it leaves the solution tank.

Compressed air is obtained from three DeVilbiss compressors (one for each processing machine) mounted in the basement area at Alexandra Palace to prevent undue noise in the processing room.

3.2.4. *Drying Cabinet Heating Unit*

The rate at which film dries depends upon the type of emulsion, its thickness, the manner in which it is attached to the base support, the speed at which it is travelling through the drying compartment, and the temperature and velocity of the air passing through that compartment.

Because of this some films will dry perfectly well without any heat—the operation being completed by air at room temperature passing over the film at high speed—whilst other films require the air to be pre-heated before drying can be effected in this type of machine.

Air is drawn into the machine through an efficient filter unit and is forced through the drying compartment by a centrifugal fan. Wire-wound heating mats are mounted in the ducting between this fan and the drying cabinet and are so arranged that either 2 kW or 4 kW may be used to raise the air temperature when drying some types of film.

3.2.5. *Machine Speed Control*

The time necessary to develop a given film to the required degree of density and contrast varies considerably. For example, when using May & Baker 'Teknol' developer diluted 6:1 and at 73°F, it is possible to achieve a negative gamma of 0·65 on Ilford F.P.3 film when the 16-mm machine is operated at 53 ft per minute, whereas a similar gamma is achieved on Ilford H.P.S. when the machine is operated at 20 ft per minute. It is important to realize that these two films are used for widely different types of work and this comparison in no way suggests that one film is better than the other; it merely demonstrates that an emulsion designed for one purpose can only yield a satisfactory result when it is processed in a certain manner.

The motor driving the machine is controlled by a Variac and its speed is measured on a speed indicator calibrated in film feet per minute. The control is sufficiently accurate to enable machine speed to be maintained at ± 1 ft per minute at all speeds encountered in practice.

3.2.6. *Warning System and Auto Cut Out*

With a daylight-operated continuous machine of this type full advantage can only be taken of the magazine-changing system if due warning is given immediately the supply of film terminates. Remembering that under certain conditions only 45 seconds are allowed in which to change one film magazine for another, it is also essential to provide some automatic means of stopping the machine if the supply of film is not restored before this time has expired. Unless this provision is made the film may break, roller-guiding mechanisms may become distorted, or the machine may continue to run and so become unthreaded—thus causing considerable delay before any subsequent work can be processed.

Both these requirements are satisfied in the Lawley Junior by a pair of cam-operated microswitches mounted in the film reservoir. When the stock of film from one magazine ceases the machine draws on this reservoir for its supply and, in so doing, the lower cradle forming the film loops in this reservoir is caused to ride some 4 ft upwards in a guiding channel.

As this lower cradle begins to ride in the guide-way a cam attached to the cradle closes a microswitch and causes a warning bell to indicate to the operator that the film magazine is exhausted and must be replaced. Provisions in the form of safety light-locks and film clamps enable this operation to be performed with complete safety.

Just before the stock of film in the reservoir becomes exhausted, and as the lower cradle is approaching the top of the guide-way, the cam closes a second microswitch which, through a relay, stops the main driving motor and so prevents the film from breaking or the machine becoming damaged.

4. Modifications to the Original Design

4.1. *General*

When the Lawley machines were first installed at Alexandra Palace they were required to process either 16-mm or 35-mm films in any order and without the need to make any modifications to the layout of the equipment when changing from one width of film to the other.

As film travels through a continuous processing machine it first becomes swollen with liquid on passing from the dry state into the solutions and, in consequence, its length increases; on passing from the final washing compartment into the drying section the liquid content in the film is removed and, ideally, the film will return to its original length.

Consequently a continuous processing machine must provide some means to accommodate this increase in the length of film in the 'wet' side and the subsequent reduction in the 'dry' side of the machine. When this requirement is also coupled with the need to be able to process both 16-mm and 35-mm films without making any mechanical changes to the apparatus it becomes obligatory that the film shall be transported through the machine by some form of friction drive.

In the Lawley machine these problems were reconciled by employing three free-running rollers and one plain parallel-surface driving roller on the upper shaft of each bank of film in the processing sections and four free-running rollers and one clutch-driven roller on the upper shaft of each bank of film in the drying compartment. Thus, when the film length increased (as it absorbed liquid) the loops disengaged from the driving rollers in the processing section until a state of equilibrium was reached; when the film length decreased (as it gave up liquid in the drying compartment) the clutch-driven rollers merely slipped until sufficient film was available to permit drive to take place once more.

This system operated quite satisfactorily when all the rollers, clutches, and lower cradles were perfectly clean and maintained in exceptionally good condition. However, under routine operating conditions it proved to be somewhat critical and a certain amount of base-scratching and similar blemishes occurred from time to time. This was further aggravated because, in order to accommodate both 16-mm and 35-mm film, all the free-running rollers throughout the machine had to carry two film-guiding channels; the 16-mm guide being centrally placed in the roller and at a smaller diameter than the 35-mm guide surrounding it. To ensure that the 16-mm film always remained in the central groove springs were used to exert a downward pressure on the lower roller assemblies. However, unless these assemblies were exceptionally free-running in their guiding channels, the springs were inclined to be ineffective. When this happened, the 16-mm film sometimes escaped from the central guide channel and would ride midway between that channel and the edge of the 35-mm channel. Under these conditions most severe film abrasions would occur.

Fortunately it quickly became apparent that the dual-gauge feature of the machine was only very rarely required and, in fact, at least 90 per cent of all the film processed at Alexandra Palace is now 16 mm in width. Because of this it was possible to modify two of the three machines to operate with 16-mm film only and to change completely the roller design and film-driving system.

This, together with several other modifications, has now been carried out and has resulted in machines which are exceptionally reliable and free from film blemishes. All the modifications made at Alexandra Palace are recorded below, and resulted from very close co-operation between BBC engineers and Newman & Guardia Ltd.

4.2. *Improved Film Reservoir*

The film feed reservoir is a cabinet approximately 5 ft high, 9 in. wide, and 4 in. deep containing two sets of free-running film rollers. One set of rollers is mounted in a fixed position near the roof of the cabinet and the other is mounted in a movable cradle which normally rests on a buffer at the bottom of the cabinet when film is feeding from the supply magazine. The supply magazine is attached externally to the roof of the cabinet and may be quickly removed when replacement with a new supply is necessary. The action of removing a magazine automatically clamps the film in the roof of the reservoir cabinet and leaves a short length protruding which may be cut and stapled to the beginning of the next film.

The lower cradle of rollers is arranged to travel vertically up the reservoir cabinet when the supply of film is interrupted so that the machine may continue to operate during magazine 'change-over' periods. The cradle is weighted sufficiently to cause it automatically to return to the lower position in the cabinet immediately a new supply of film is provided; thus restoring the reservoir to its full capacity.

The mechanism originally employed to control the movement of the lower cradle consisted of a continuous belt of stainless steel Bowden cable arranged over a series of small guiding pulleys. This was attached to the cradle so as to cause parallel motion in a manner similar to that used to move a tee-square across a drawing-board. An improved mechanism has since been fitted to the equipment and is shown in Fig. 2, which is a view of the reservoir cabinet with the light-tight door open and the upper roller assembly omitted.

A stainless steel cradle guide-bar is mounted parallel to the right-hand wall of the cabinet and held away from this wall by two distance-pillars. The lower rollers are mounted in a new cradle having a roller-carriage formed at the right-hand end. This carriage contains four roller bearings which move smoothly along the vertical guide-bar.

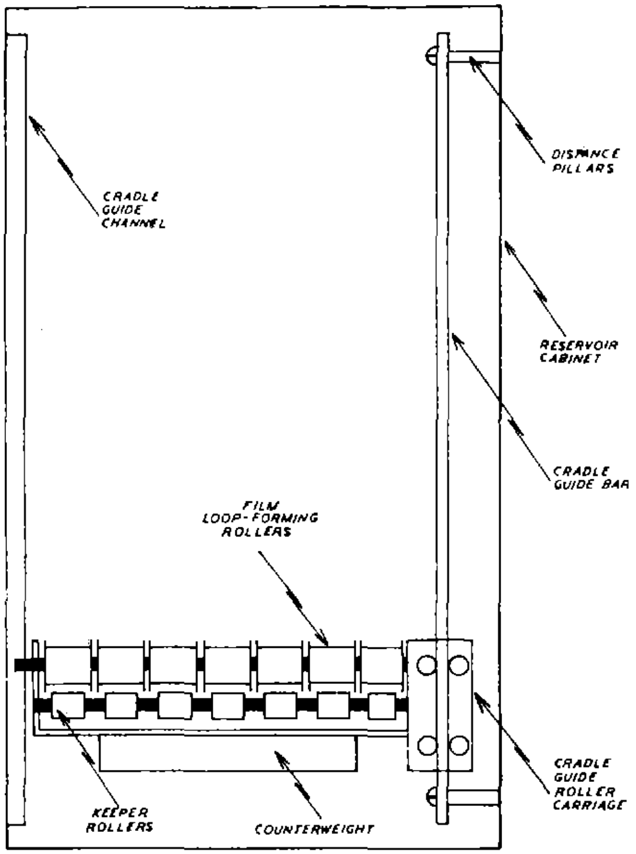

Fig. 2 — Improved mounting of lower film roller cradle in the reservoir compartment

The film-roller shaft extends towards the left-hand side of the cabinet and is arranged to run freely in a 'U'-shaped guideway so as to restrain any tendency to sideway whip as the carriage descends. The carriage is assisted in drawing film from the magazine and returning to its lower position by the addition of a 5-lb. counter-weight supported along the base of the assembly. A series of small 'keeper-rollers' are mounted close to the undersides of the film-guiding rollers to guard against film 'over-riding' and failing to engage with these rollers.

This mechanism is very reliable, simple to maintain, and is now used on all Lawley Junior processing machines.

4.3. *Conversion to 16-mm Sprocket-drive*

Some of the difficulties encountered with the original dual-gauge friction-driving system have already been mentioned (Section 4.1). It was also found that although, on installation, careful checks had been made to establish agreement between the machine speedometer reading and the precise footage of film delivered, this condition had not been maintained. The discrepancy became apparent after some 50,000 ft of film had passed through the machine.

Tests showed that a friction-driving system of the type employed could not accurately maintain film speed within the required photographic tolerances. Investigation of the telerecording system was being made at the time and it was abundantly clear that these tolerances should not be increased.

Because of this the entire friction- and clutch-driving system was replaced by a positive sprocket-drive. Under these conditions film speed through the machine became quite definite and reproducible. The final layout of positive driving sprockets and free-running rollers is shown in Fig. 3. This is a plan view of the upper roller assemblies in which each roller is indicated by a small box; those boxes marked thus X indicate the positions of the positive film-driving sprockets.

4.4. *Modification of Lower Roller Tensioning System*

In the original layout the lower rollers in the processing tanks were held at a selected position under spring tension. This tension was transmitted to the cradle supporting these rollers by a rod passing upwards through the tank and also through a 'bridge-piece' mounted above the machine. Collars between the top of the machine and the bridge-piece were held between two coil springs. When the lower cradles were at the desired depth the collars were locked in position on the rods so that the upper coil

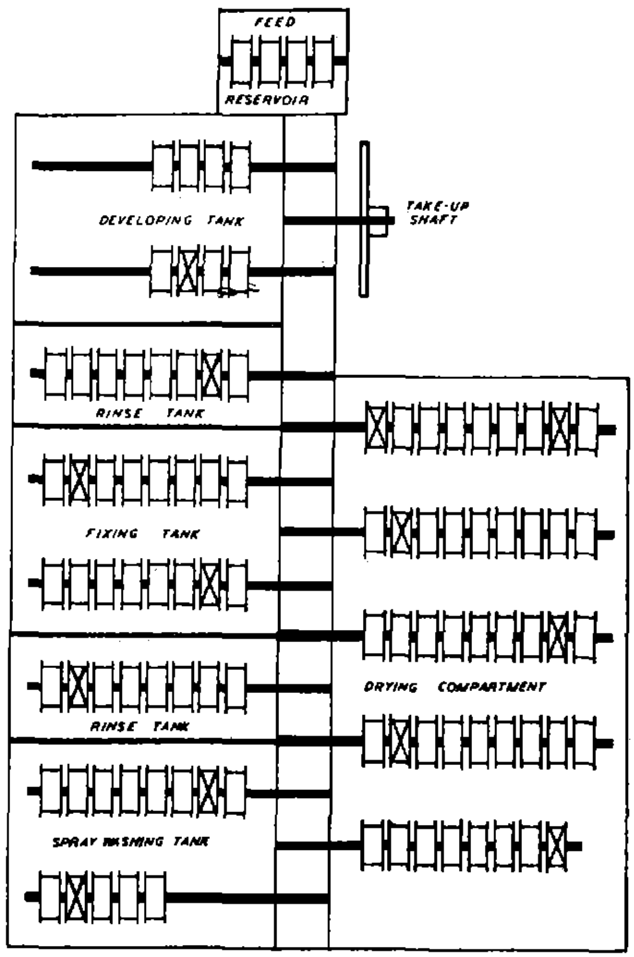

Fig. 3 — Plan view of upper roller assemblies showing positions of positive driving sprockets

spring exerted pressure on the cradle. Whilst this system could be made to function quite well, the operator was required to balance carefully the tension exerted by each spring on to each lower film cradle. Unless this was done films would either flap against the wall of the tank (when spring tension was too light) or become so taut that film perforations would become damaged or, in severe cases, film joins would break apart.

Accordingly, a system of constant weights was developed whereby the tension applied to each lower film cradle must remain fixed throughout the machine. Experiments were carried out to determine the minimum loading necessary to ensure that the film loops remained straight but, at the same time, were not subjected to undue tension. It was *found that a minimum of 4 lb. was required to maintain* the film perforations well seated down in the sprocket teeth and the associated loops well formed. The weight was then increased until perforation damage due to excessive loading just occurred. This condition was reached when the weight was increased to 8 lb.

It was therefore decided that weights of 5 lb. each would provide an adequate safeguard against poor engagement while not being heavy enough to cause perforation damage. It should be remembered that such a weight is supported by fourteen strands of film and, in fact, only represents a loading of approximately 6 oz. on each 3-ft strand of film.

It was neither practical nor desirable to locate all this weight below the lower roller cradle assemblies. Had that been done it would have meant that the operation of raising each cradle (when threading the machine) would have been somewhat difficult; the probability of suddenly dropping a cradle assembly to the bottom of a tank would have been increased and, most important of all, any film left in the machine overnight would have been under severe strain.

At the same time it was essential that part of the load should be attached to the cradle to assist its downward motion when threading the machine. The remainder of the weight should be removable to reduce the load on the film when the machine is not in use. Accordingly, the system shown in Fig. 4 was adopted.

Here it is seen that the lower film roller assembly is mounted complete with 'keeper rollers' in a cradle 'A', similar to that used in the film reservoir and shown in Fig. 2. Guide rollers allow the cradle to move freely along the guide-bar 'B'. The position-control rod 'C' is attached to the lower cradle and passes vertically upwards through the machine. A removable 3-lb. weight 'D' is attached to the top of the control rod and a fixed 2-lb. weight 'E' is attached to the lower cradle assembly.

In practice the 3-lb. weight 'D' is removed from the control rod when the machine is left stationary overnight. This reduces the load on the leader film which remains in the machine during this period. When the lower cradle is raised to its upper position (in order to thread the machine with film), weight 'D' is removed and the control rod is raised—a locking collar mounted on the control rod between the bridge-piece and the machine cover is used to lock the control rod in the upper position whilst threading.

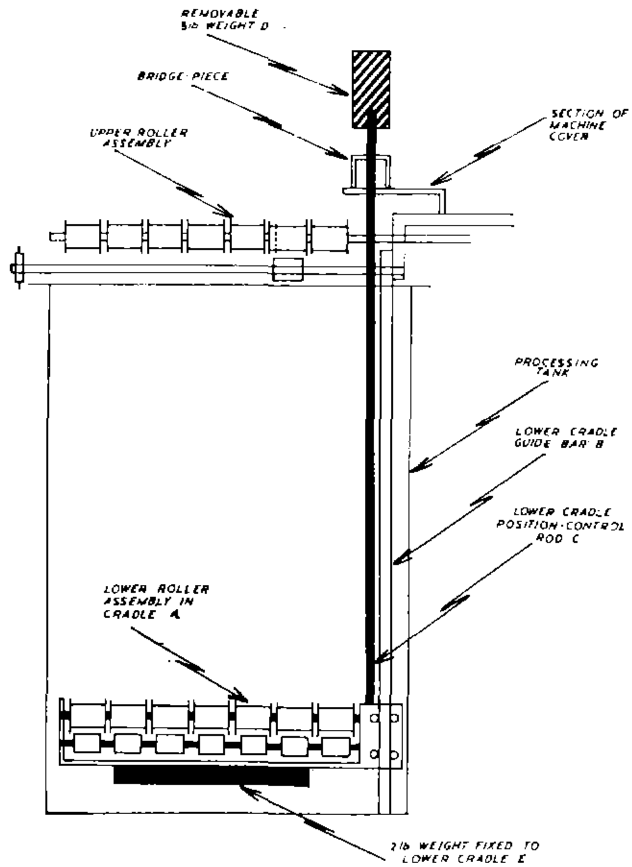

Fig. 4 — Arrangement of fixed and removable tensioning weights in the processing tanks

This collar is unlocked and remains perfectly free when film is being processed.

4.5. *Modification of Drying Cabinet Layout*

The system of clutch-driven rollers in the drying cabinet (4.1), used to accommodate the reduction in film length as drying proceeded, became unreliable after some 50,000 ft of film had passed through each machine. The main difficulty with this section centred around the clutch-driven rollers and, particularly, the continuous maintenance they required in order to ensure a satisfactory drive.

Because of this the clutch system was discarded and replaced with a positive sprocket-drive. Film shrinkage was then accommodated by mounting all the lower rollers in the drying cabinet in banks and cradle-formation similar to that used in the processing tanks. Vertical guide-bars were installed in the cabinet so that each bank of rollers was freely suspended by the film loops and could ride on these guide-bars as shrinkage occurred.

4.6. *Introduction of Stripper Plates*

It is always possible that films will become broken in any continuous processing machine. Whilst every precaution can be taken to minimize this happening, it may still be that film containing damaged perforations (not detected during inspection before processing), or badly made staple joins between one film and the next, may break within the machine.

When this occurs in a sprocket-driven machine it usually results in a quantity of film being wound up on to one or more of the driving sprockets. This is because the film loops become slack behind the point where the break occurs and are drawn into the sprockets by the driving teeth. To prevent this, short 'stripper plates' were mounted below each sprocket wheel and approximately $\frac{1}{16}$ in. away from the actual film path. Stripper plates are commonly used in motion picture equipment at points where this type of failure might occur. Normally they do not touch either the film or the sprocket wheel, but merely remain in position between the two and just below the point where the film leaves the sprocket teeth as it is driven forward.

Stripper plates have been fitted to the sprockets throughout all the processing tanks and also to the sprocket at the exit from the drying cabinet. In this last situation a 'lay-on' roller has also been fitted above the sprocket and, by the combination of this roller and the stripper plate, ensures that film must be positively fed from the cabinet—even when the parent roll of dried film has been removed from the take-up shaft to separate one 'story' from the next.

4.7. *Introduction of 'Splash Preventors'*

Two banks of film loops are provided in the developing tank. The layout of the film path in this tank is such that the position of the air knife (applied to the film leaving the last top roller on the second bank of film) is immediately behind the first roller on the first bank of film. This means that it is immediately behind dry film which is being drawn from the supply reservoir.

It was found that the increased film speed, made possible by adopting sprocket-drive, created solution 'blow-back' from the air knife. This resulted in a spray of developer droplets capable of reaching the incoming dry film. When this occurred small areas of emulsion became swollen with liquid and partially developed before the main area of film was immersed in the actual solution. In a machine where the total development time is of the order of one minute this naturally gave rise to the appearance of random dark over-developed spots in the final projected images. The defect was most pronounced when films requiring a high machine speed were processed. This indicated that the rate at which film perforations passed through the air knife affected the general disturbance which was being created.

Since it was not possible to reduce the machine speed, to reduce the air pressure in the air knife, or to locate the knife in a different position, some type of shield had to be provided. This took the form of a stainless steel baffle mounted between the two banks of film and easily detachable for cleaning, etc. Once this baffle had been fitted the trouble was immediately cleared.

4.8. *Final Arrangement*

By October 1959, the two machines used at Alexandra Palace to process 16-mm film only had been modified to contain all the improvements described herein and, since that time, have been operating very satisfactorily.

The volume of maintenance work required has been greatly reduced and the equipment has become very reliable. However, no film-processing machine can be made fully automatic and, to some extent, must rely on certain functions being performed with care and precision by the operators. It is believed that the modifications described in this monograph have reduced these 'operator functions' to a minimum for this type of machine.

PART 2

AFTER-PROCESSING TREATMENT OF 16-MM FILMS

5. Definition of Terms

The term 'after-treatment' is used to describe processes and applications carried out on motion picture films after they have been developed, fixed, washed, and dried. It refers to such operations as waxing, lubricating, buffing, or polishing the film. These operations are performed for a variety of reasons, such as the prevention of emulsion scratches, the assistance of 'green films' through projectors during their initial runs, the provision of anti-static coatings to retard dirt and dust deposits, etc.

The term 'green films' or 'green prints' is used to describe films immediately they leave the processing machine or laboratory. Such films may be dried in a manner which causes the humidity content within the emulsion layer to be unevenly distributed—the surface skin being overdried whilst the remainder of the layer retains excessive moisture. Whilst this condition is present to varying degrees in all films immediately after processing, it is accentuated if the drying temperature is unduly high and the drying time is correspondingly short. The physical dimensions of the film (particularly the 'pitch' between the perforations) are then less than when the film has normalized and the friction between the film and the gate runners surrounding the projector aperture is considerably higher than that encountered when films have been projected several times.

The term 'emulsion pile-up' is used to describe the deposit of emulsion on the runners and channels forming the 'film gate' which surrounds the aperture in a projector through which the picture is projected. This deposit is usually compacted into a solid mass, often referred to as a 'corn', which can develop a sharp cutting edge and which is extremely difficult to remove without damaging the polished surface of the gate runners. Once emulsion pile-up occurs the accurate positioning of successive film images is destroyed and 'picture unsteadiness' results. Apart from this visual defect, any film which is then allowed to pass over the deposit will become severely scratched; this process will liberate small particles of emulsion which may well be visible on subsequent projection and, of course, will create rough channels in the emulsion which tend to trap and embed any random dirt or dust which may be present in the atmosphere.

6. Purpose of this Investigation

The rapidly expanding use of 16-mm film in television work both in Britain and the U.S.A. has created many occasions when film must be transmitted via telecine projectors within a few hours of being processed, i.e. in a 'green' condition. This in turn has brought the attendant problems of emulsion pile-up and picture unsteadiness associated with green-print projection and has resulted in a number of technical papers in the professional journals advocating various remedies for these problems.[1,2]

Within the BBC irregularities due to green film have been encountered from time to time, and especially in that equipment operated at the Bristol Region. It is believed that the trouble is only more pronounced at this station because of the type of programmes involved and not because of any differences between the equipment at this region and elsewhere. Many programmes originating from Bristol involve the continuous use of 16-mm film for periods of up to 30 minutes' duration. Evidence tends to suggest that the considerable length of film used on these occasions reveals green-print troubles which may not appear at other regional centres where similar film and equipment are used for items of short duration only.

All the published work mentioned above, together with our own initial experiments, suggest that the problems associated with green film are overcome when the film is subjected to 'after-treatment' such as liquid waxing before it is projected.

The purpose of the present investigations was therefore firstly, to design and build a relatively simple machine to enable freshly processed films to be submitted to the various liquid treatments currently available. Secondly, to process and 'after-treat' sufficient film to be able to make reliable tests of the ability of each liquid (*a*) to assist green films through a projector, (*b*) to resist or reduce scratching, and (*c*) to give anti-static protection to such film. The third purpose of this work was to select an 'after-treatment' liquid and suitable equipment for applying it before projection to all 16-mm film used in the BBC.

7. After-treatment Techniques

7.1. *General*

With the exception of those treatments which claim to do more than assist the passage of green films through a projector, all after-treatment techniques involve the application of a paraffin derivative. This is usually dissolved in a volatile liquid such as carbon-tetrachloride or trichlorethylene but, in some instances, is applied in a solid form to the edge areas of the film.

In our experience, the application of solid wax is definitely not to be recommended since it is impossible to maintain a smooth, even layer of the required extremely thin coating. Equipment employing strips of solid wax has been marketed in an attempt to overcome these difficulties, but the results obtained in practice are not encouraging.

For some years the film industry has employed commercial 'liquid-wax' after-treatments on 35-mm 'feature film' material. Two of the most widely used processes employed in Britain apply the liquid to the entire width of the film. This can be done either via a rotating mop, or, when both the base-side and the emulsion surface are to be treated, by total immersion within a bath—the film then being guided below the surface of the liquid by a system of rollers. In each case the film is afterwards buffed by passing it through a series of rotating mops or stationary velvet pads.

Several film-processing laboratories in Britain also offer film-waxing or similar protective processes as an integral part of their service. These are applied at the time the film is being processed and by equipment built on to the processing machine.

The availability of these processes does not provide a complete answer so far as the BBC is concerned because, for News and other highly topical film material which we are obliged to process ourselves, we must be able to apply the liquid at any time, to any film, and within our own premises. Our investigations were therefore confined to readily available liquids and not to services available only by sending the film to commercial laboratories.

7.2. *Available Liquids*

7.2.1. *Eastman Over-all Waxing Solution*

Kodak Ltd. have recently marketed in Britain a waxing solution which has been in use for some time in their 16-mm film-processing plant at Harrow. It was produced as the result of extensive research by their Rochester Laboratories where, we understand, some seventy different liquids were tested.

Treatment in Eastman Over-all Wax is by total immersion of both emulsion and base side of the film and afterwards by passing these surfaces over stationary velvet buffing pads. The process is only claimed to overcome difficulties associated with the projection of 'green' films and, unlike some other treatments, does not claim to prolong the life of release prints, to render the film surface scratch-resistant, or to impart any anti-static properties. However, all these factors have been checked in our tests on film treated in this liquid. It is important to remember that Kodak Ltd. recommend the lubrication of both the base and emulsion sides of the film.

In Britain Eastman Over-all waxing solution costs 30s. per gallon—this is equivalent to approximately 0·75d. per 100 ft of film.

7.2.2. *Other Available Liquids*

It is not the purpose of this work to compare the merits of commercially named available liquids. However, Eastman wax has been named because it was the liquid finally chosen after our investigations had been completed. Several other liquid waxes are available in Britain and could be used on the site by any organization possessing suitable equipment. During our investigations these were examined but, for a variety of reasons, were not found suitable for our purposes.

8. The Experimental 'After-treatment' Machine

8.1. *General Description*

The machine built for this work was designed to be as flexible as possible. Because of this it was both larger than would ultimately be employed and capable of applying more than one liquid at a time so that, for example, film could first be cleaned in one bath and subsequently waxed in the second bath—a feature which has since been found to be unnecessary.

A general front elevation of the machine is shown in Fig. 5. Film awaiting treatment is supported at 'A', whilst that which has already been treated is wound up at 'B'. In passing from 'A' to 'B' the film travels under flanged guiding rollers mounted in the two tanks 'C' and 'D'. A film-cleaning fluid may be supplied to tank 'C' from reservoir 'E', whilst a film-waxing fluid is supplied to tank 'D' from reservoir 'F'. Constant head devices ensure that the liquid is automatically maintained at any desired level in the tanks.

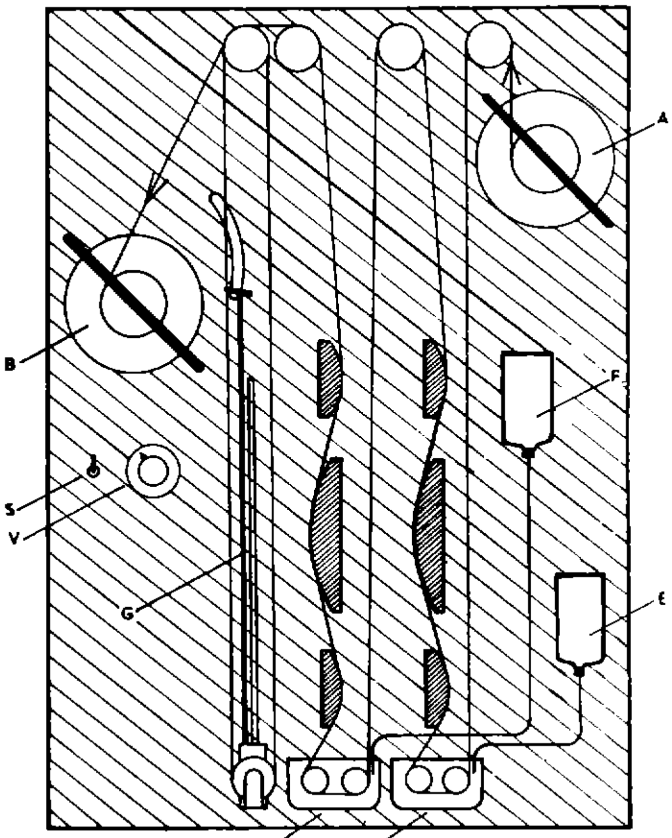

Fig. 5 — Front elevation of experimental after-treatment machine

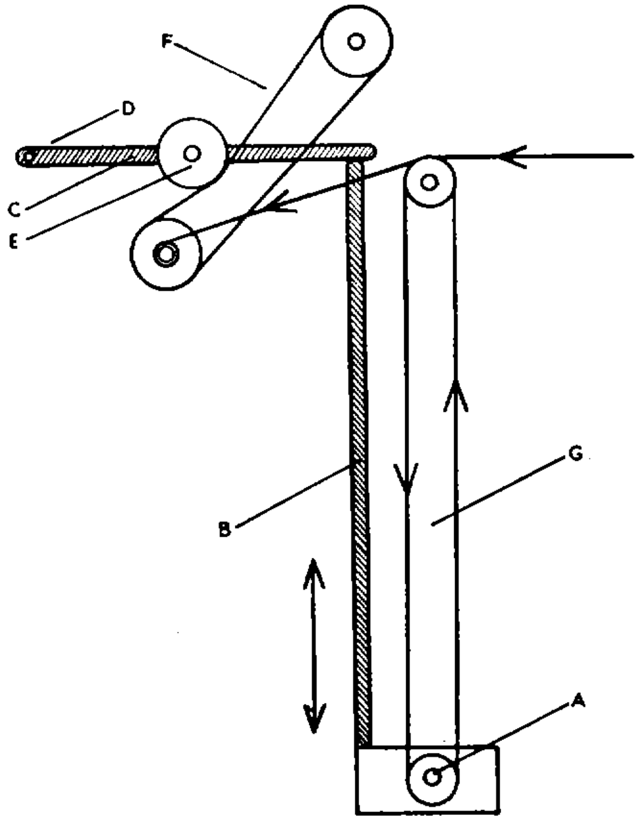

Fig. 6 — Constant tension take-up device

Two identical series of velvet buffing pads are mounted above the outlets from the tanks. These are so arranged that both sides of the film are buffed to an equal extent. Adequate drying time is provided between the last buffing pad and the take-up shaft by forming the film into two spiral loops shown at 'G', Fig. 5.

8.2. *Constant Tension Take-up Device*

It is essential that apparatus of this type does not scratch or damage the film in any way. Because of this a constant tension take-up system is employed to ensure that each convolution of film is applied to its neighbour without the possibility of slip taking place between them.

The principle of this system is shown diagrammatically in Fig. 6. The two spiral loops 'G', Fig. 5, are again represented at 'G' in this figure. The lower film-guiding rollers 'A' are mounted in a cradle which is free to move vertically within a channel. Attached to this cradle is a vertical rod 'B' arranged to rotate lever 'C' about pivot point 'D'. This action causes a jockey pulley 'E' to vary the tension on driving belt 'F'. The driving belt is connected between the main motor and the film take-up shaft.

By this system a constant torque is exerted on the film and changes in load as the roll size increases are accommodated by increasing the amount of slip taking place in the belt-driving system. Film wound up on this machine results in a tightly formed and perfectly flat roll.

8.3. *Method of Operation*

The machine remains loaded with film at all times. When the end of a film is reached the machine is stopped, a 30-ft length of 'machine leader film' is attached, and the machine restarted. This leader film is sufficient to thread completely the machine and so, as the end of the treated film arrives at the take-up shaft, the machine may be stopped and will remain threaded in readiness for the next roll to be treated.

The machine is powered by a single-phase 230-volt fractional horse-power motor controlled by switch 'S'. The speed is adjusted by the variac 'V' and, in practice, films were found to be well dried at a speed of 50 ft per minute.

It is realized that, for convenience, several refinements should be added to any production machine, such as 'keeper-rollers' to maintain the threaded formation whilst rolls of film are being exchanged, but these were not necessary in the experimental model.

During this work well over 10,000 ft of film passed through the mechanism which, at all times, performed very satisfactorily.

9. Experimental After-treatments

9.1. *Magnitude of Samples*

From previous experience it was known that conclusions drawn from the performance of one 400-ft reel of film in a projector can be very unreliable. To overcome this during our final tests on the selected liquid six 400-ft lengths of film were coated with Eastman liquid wax and a further six 400-ft lengths remained untreated and were used as controls for comparison purposes.

9.2. *Preparation of Film for Test*

The characteristics of a 'green' film which cause the troubles described earlier (6) are most pronounced at the moment the film leaves the processing machine. They can be preserved for some days if the film is immediately wrapped in paper, placed in a film-can, and sealed with adhesive tape. Since the major purpose of these experiments was to assess the ability of after-treatment liquids to overcome this green-print condition, it was essential that all the prints used in the tests should be of the same age and that they should reach the test projector as quickly as possible after processing.

To avoid possible confusion in assessing the visible steadiness of pictures containing different subject-matter, all the films used were prints made from the same original negative. Since printing was a longer operation than developing, arrangements were made for all the copies to be printed before any of them were developed. They were then held until the following morning so that development could be completed within two hours and the films immediately passed through the after-treatment machine. A further four hours were then needed in which to complete this operation. The whole consignment was then sealed in individual tins and transported to Bristol.

Since our experiences associated with 'green' films have been most pronounced at Bristol it was decided to assess these tests on the telecine equipment installed at that station. All the prints were projected within 28 hours from the time they were developed.

9.3. *Method of Projection*

The films were viewed via the normal telecine equipment and on a high-quality picture monitor. Precautions were taken to ensure that all parts of the projection mechanism which came in contact with the film were first thoroughly cleaned. It was equally important to clean the equipment thoroughly after each type of film treatment had been tested.

Once a series of six test films was started the whole batch was projected before the gate channels in the projector were cleaned in any way. By this means the effect created by each type of film treatment was well established and also any differences between one treatment and another were more likely to be revealed.

9.4. *Results of After-treatment Tests*

9.4.1. *Untreated Film*

From the beginning, the projection of these films was accompanied by a very high noise level in the projector mechanism.

All six reels produced picture images with severe vertical jump which would have been unacceptable in any programme. An attempt to run one of the reels a second time resulted in a picture jump so violent that it was quite unusable.

After projection all rolls were seen to have very heavy scratches corresponding to the position of the gate runners in the projector. Extremely heavy emulsion deposit had built up both on the spring-loaded aperture plate and the film-framing shoe. This deposit was so solid that it could not be removed by mechanical aid and, in fact, had to be dissolved away.

9.4.2. *Eastman Over-all Wax Treatment*

The first roll of this batch produced only a very low noise level in the projector mechanism and this remained constant throughout all six rolls.

The picture image throughout the whole test remained very steady from the outset and was in every way acceptable.

No hard emulsion deposit occurred on either the gate runners or the framing shoe—only a very light fine powder which could be immediately removed by the finger. Two reels were projected for a second time and the noise and picture quality remained unaltered.

9.4.3. *Conclusions*

It was very evident that, in common with other liquids tested during the early stages of this investigation, Eastman Over-all waxing solution will solve the problems associated with the projection of 'green' prints.

Some people have expressed concern regarding the use of liquid wax treatments and, particularly, the probable effect on magnetic sound heads. It is interesting to note that no solid deposit of any kind was detected on the gate runners which, incidentally, are under a load of 5 oz. Since only 17 grammes of wax are contained in 27·5 litres of Eastman liquid, and 1 litre of this will treat 7,500 ft of film, the amount of wax deposited per foot of film is as follows:

$$\frac{17}{27\cdot 5\times 7{,}500}=0\cdot 000082 \text{ grammes.}$$

This deposit is divided between the base and emulsion sides of the film and, since the magnetic sound track only occupies approximately 15 per cent of the total film width, it is most unlikely that 'wax build-up' could ever cause concern.

10. Scratch Tests

10.1. *General*

The type of scratch created on film by compacted emulsion, dirt and dust, or poor surfaces on stationary film guides results from sharp contact areas approaching a needle-point. Because of this the tests devised for this investigation and described below are more severe than those mentioned by some manufacturers of after-treatment liquids, and are more closely related to practical conditions.

10.2. *Scratch-testing Equipment*

A conventional film-editing bench and synchronizing head were adapted so that film could be uniformly fed under a needle point. The needle was mounted in a disc reproducer pick-up arm which was counterweighted so that precise weights could be loaded above the needle point.

Fig. 7 shows the general layout of this equipment. The reel of film to be tested is mounted in a 'film horse' at 'A' and fed by hand always to preserve a free loop in the film-bin 'B'. By this means no irregular load is applied to the film under test due to any uneven motion of the parent roll.

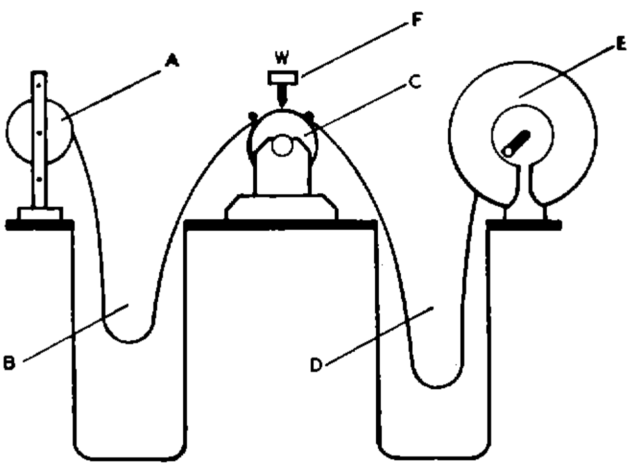

Fig. 7 — Scratch-testing equipment

With the emulsion side uppermost the film is guided over the large-diameter sprocket in the film synchronizer 'C' and held in exact relationship with this sprocket by the conventional guide-roller assembly. A second free loop 'D' is formed in the right-hand film-bin before the film is wound up on the take-up shaft 'E'. The exact footage subjected to each test weight is conveniently read from the automatic counter built into the film synchronizer.

A controlled scratch was produced by applying weights to the pick-up head 'F'—care being taken to remove any swarf which had collected around the needle point at the end of each test and before the next weight was applied.

The needle point was stoned down so as to produce a point of contact 0·010 in. in diameter.

10.3. *Method of Test*

The method adopted to measure the effectiveness of a scratch was to establish the load required to produce a first visible 'tram-line' in the projected picture.

This was done by loading the needle point in increments of 0·5 oz. at a time. In order to recognize each weight easily during projection the film was marked with a grease pencil at the start of each test. To provide sufficient film to give ample time to assess the results, each test was continued over a length of 25 ft of film. Thus, on one continuous roll, a whole series of tests could be made so as to pass through the threshold of the weight necessary to produce the first visible scratch.

10.4. *Results of Scratch Test*

The needle point was loaded in increments of 0·5 oz. up to a total of 3 oz. With Eastman Over-all wax treatment scratching first became visible on projection at a loading of $2\frac{1}{2}$ oz. By comparison, the best of the other liquids tested produced a visible scratch at a loading of $1\frac{1}{2}$ oz.

These tests were repeated many times and, eventually, were cross-checked by making up a composite roll containing alternate lengths of film coated with each type of treatment. This was done to ensure that a needle point of equal sharpness was presented to each film. Throughout all these tests the relationship remained unaltered. Similar tests with film which had received no after-treatment produced very deep scratches when minimum load was applied to the needle point.

11. Practical Handling Tests

11.1. *General*

In these tests two 400-ft reels of film were submitted to the normal routine of editing film at Alexandra Palace in order to assess the amount of dirt and dust collected during this process.

One reel of film remained untreated whilst the other was coated with Eastman Over-all wax. Each film was 'edited' so as to contain sixty joins, each at approximately 6-ft intervals.

To ensure that each film had equal treatment all the work was carried out on one Bell & Howell foot-operated joining machine and by one operator. Each film was then projected six times in order to 'collect' dirt and dust and, it was hoped, to reveal any differences in ability to withstand handling. It was also realized that the nature of the Eastman wax may in fact tend to retain dirt and dust more readily than films which had not been so treated.

11.2. *Results*

In this instance the amount of dirt was assessed after the seventh projection and by viewing the films under the normal conditions used by the editorial staff.

It was apparent that the amount of dirt present was very low in all cases. Because of this it was necessary to award a rating critically for each film as follows:

Good
Good—
Fair+
Fair
Fair—
Poor+
Poor.

It was then possible to compare the films but it is emphasized that the overall differences were, in any case, only marginal. The non-treated film was classified as 'Fair', and the Eastman treatment as 'Good—'. These results are particularly interesting and show that the treatment certainly did not result in a higher dirt content (as was originally feared).

11.3. *Possibility of Join Breakage*

During the above tests several film joins broke apart and the distribution of this failure was as follows:

Untreated film	4 breaks
Eastman treatment	1 break

This is, of course, a very low proportion when it is remembered that each roll contained sixty joins and was projected seven times and, in any event, it is impossible to attach any significance to these figures.

12. Anti-static Properties

12.1. *General*

Lengths of film were suspended over an editing bin and on either side of an editing horse. By this means two lengths of film which had both been treated with the same liquid wax could be suspended with the emulsion surfaces facing each other and approximately 1 in. apart.

Each length of film was then 'wiped down' with a folded Velvet Cloth so as to create static charges. Tests were carried out on non-treated film and on film treated with various liquids, including Eastman Over-all wax.

12.2. *Results*

In every case the opposing pairs of film received very considerable static charges which caused them to stand apart from each other by approximately 1 ft. There was no evidence to suggest that the behaviour of film subjected to any particular treatment was in any way different to that of the remaining test lengths.

New samples of film were then charged by a similar process and held horizontally 1 in. above a layer of fine loose dirt. In every case an extremely high concentration of dirt flew up to the film and no evidence was obtained to indicate that one treatment had any advantages over another.

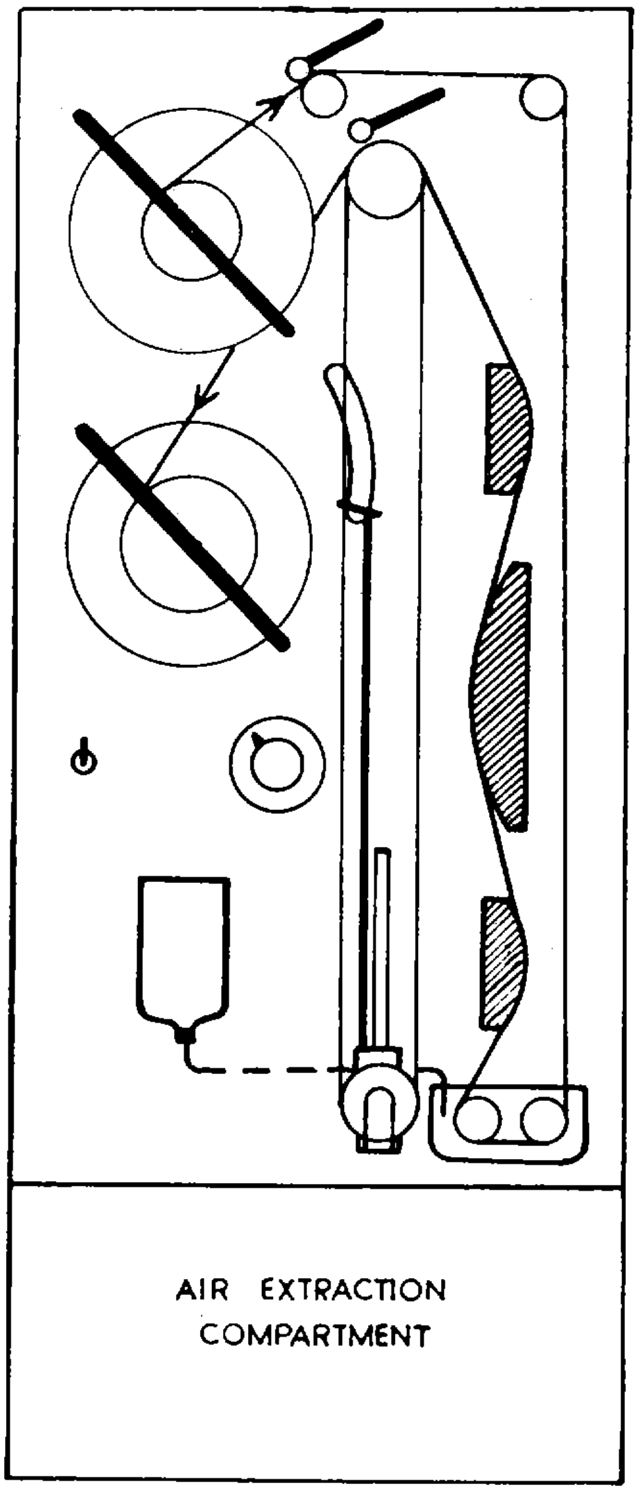

Fig. 8 — Final arrangement of after-treatment machine

13. General Conclusions

13.1. *Green-film Projection*

The problems related to the projection of green film are completely overcome when Eastman Over-all waxing solution is applied to the film immediately following the normal processing operations.

13.2. *Method of Applying After-treatment Liquids*

The experimental machine shown in Fig. 5 has proved to be very satisfactory but is unnecessarily large. One suggested layout in which all the basic operations may be carried out in the minimum of space is shown in Fig. 8. Here the film path 'doubles back' upon itself and space is provided to accommodate air-extraction equipment, if required. The apparatus may be fitted with glass-panelled doors to enclose the film against dirt and dust in the room during operation. Machines embodying these and other features are now being installed throughout the BBC and are illustrated in Fig. 9.

It has been suggested that after-treatment should take place within the Lawley film-processing machines but, for several reasons, this is not attractive. Firstly, such a practice would either require a considerable extension to the existing machine or greatly reduce the available space in the drying cabinet and, if the latter course were adopted, would make the drying of certain types of film very difficult.

Secondly, many of the films used in programmes are processed by commercial laboratories and may not be given any liquid wax treatment by them. Such films would then need to be passed through the Lawley machine for waxing if alternative equipment were not available.

Thirdly, since all films must be rewound after leaving the processing machine and before they can be projected, it would be advantageous to perform this operation in a separate waxing machine and at a controlled speed. Since the waxing machine operates at 50 ft per minute this represents no great difficulty and certainly prevents scratches due to 'cinching' and careless rewinding.

13.3. *Anti-scratch Properties*

Tests have shown that, whilst a certain degree of protection was obtained with the other liquids tested during this investigation, the greatest benefit was obtained when Eastman Over-all wax was used to prevent scratching.

13.4. *Film Handling and Anti-static Properties*

Evidence has been obtained to suggest that after-treatment liquid slightly reduces the amount of dirt collected by the film during the normal operations of editing but that no static-resistant properties are imparted to the film because of such treatment.

14. Acknowledgments

Acknowledgment is made to the Chief Engineer of the BBC for permission to publish this paper; to Kodak Ltd. for valuable discussions on methods of film protection; and to Newman & Guardia Ltd. for their co-operation in manufacturing experimental equipment during the progress of this work.

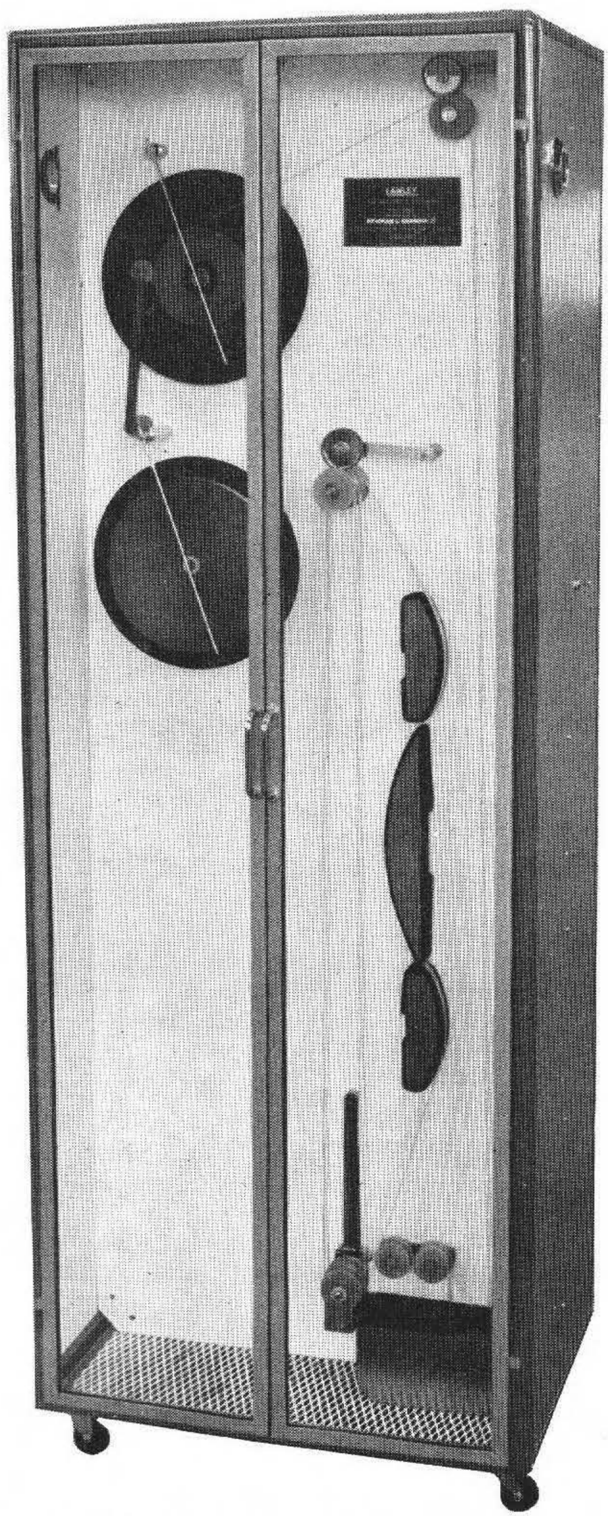

Fig. 9 — Photograph of after-treatment machine based on the arrangement of Fig. 8

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A RECENT BBC TECHNICAL SUGGESTION

A Multiple Iris Device

This device could be described as another addition to the multitude of optical effects used by the television and cine-film industry.

It is fundamentally extremely simple consisting of no more than a supplementary iris placed as close as possible before the front element of any camera photographic objective.

This iris is, of course, perforated but with several instead of only one hole. These holes are arranged symmetrically off the optical lens axis, three holes being a convenient number. The diameter of a circle with area equal to the total area of the holes related to the focal length of the lens gives us our effective aperture.

With the normal lens iris wide open and the camera focused up on some object the picture appears quite normal to a cursory inspection and even if the supplementary iris is slowly rotated, there is nothing unusual in the picture. But as the three separate bundles of rays from the holes produce three separate off-axis pictures when focus is altered one way or the other the effect is quite interesting. The picture then slowly splits up into three images which rotate round a common centre, eventually resolving into a rotating blur.

It will be apparent that this effect is somewhat different from the usual multiple images produced optically by the use of specially made lenses, or supplementaries with ground-on or cemented prisms, cylinders, etc., the main difference being, of course, that it is focus conscious and only operates by either racking focus or deliberately placing objects out of the hyperfocal area. We can thus obtain a large close-up of, say, a person's head with a rotating background if the background is broken and focusable, i.e. not flat or the converse of a diffuse rotating head and sharp background. The transition from one state to the other can be controlled over any period of time.

Several uses immediately come to mind, e.g. effect of a person undergoing anaesthesia prior to operation, over-indulgence in alcohol, onset of a dream or a transition backwards or forwards in time.

The size of the hole and distance from the lens axis are best determined by experiment bearing in mind the desired effective aperture of the objective. As the holes are moved farther from the axis towards the barrel, particularly with short-focus objectives, we get a kind of edge-cutting or shading caused by the lens barrel which becomes obvious in the picture when in rotation. This effect is negligible with the longer focus objectives.

For this reason the device must be as 'thin' as possible in a plane at right angles to the lens axis and as close to the front element as is practicable. It is also preferable that if a lens hood is used it be somewhat bigger than is normally necessary.

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