# An Automatic Control System for a High-Speed Cine Camera

PAPER M—3

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*The short effective taking time of a high-speed cine camera, such as the Fastax, demands accurate synchronization of events necessary to initiate and control the phenomenon being photographed. The equipment described enables up to six events to be controlled for sequence and duration in accurate relation to the camera film run. Automatic telephone techniques and components are employed and the sequences are set up on a ring-and-socket board. A stepless accelerator is provided for the camera motors allowing high rates of acceleration in relation to stress on the film.*

*The case under consideration is the photography of injection and combustion phenomena in a compression ignition engine; but the equipment is flexible and can be applied to other problems and can control more events or longer periods by appropriate design modifications. An ancillary technique is also described for converting half-frame-height 16mm records to standard 16mm format and stretching, by frame repetition, of vital sequences in a film if required.*

A WF-1 Fastax camera at top speed has little over 0.25 sec of useful run. Hence, it is necessary to time the event being filmed accurately in relation to the camera operation.

Where the event is repetitive and the cycle time is appreciably less than the taking time, no problem arises except perhaps to initiate high-intensity lighting shortly before the camera starts.

However, many events which are studied by high-speed cinematography require a complex sequence of preliminary events occurring in a specified order and timing to initiate them. At high camera speeds, manual control of such sequences becomes impossible and some form of automatic control is essential.

In an ideal control system, complete flexibility of programming is available and events can overlap each other in time. Sufficient control channels are available to cover the largest number of events likely to be needed.

The accuracy of timing should be sufficient to ensure the success of every run, as often the cost of the test is high or it may end in the destruction of the subject. It is obvious that realistic limits must be set to the above requirements, otherwise the cost and complexity may be out of proportion to the results achieved.

Although the system under review is capable of more general application, it will be described in relation to the purpose for which it was originally designed. This was the filming of injection and combustion phenomena in a compression ignition engine. A special single-cylinder engine had been built with a large window of quartz or plastic allowing a view of the combustion chamber and fuel injection nozzle. Owing to the fouling of the window by combustion products, it was not possible to fire the engine long before the recording period. In order to achieve realistic surface temperatures it was necessary to pass very hot pure air through the engine but to revert to air of normal temperature just prior to the injection of fuel. High-intensity lighting was needed to study fuel distribution prior to or in the absence of combustion and this lighting had only a short life.

An auxiliary camera was employed to record pressures and events displayed on an oscillograph and this had to be started and synchronized with the Fastax so that the records could be coordinated. The instant of starting injection of fuel into the engine had to be closely timed in relation to these other events. The relative timing and duration of each had to be easily changed and any event omitted at will.

The engine speed did not require any control as the unit was coupled to a regenerative synchronous motor maintaining constant conditions whether absorbing or producing power.

For convenience and uniformity of control, all events are initiated by closing a low-voltage a-c circuit. In the case of the hot air changeover, a pneumatic servo system was employed controlled by a solenoid valve and needing manual resetting after use.

In order to synchronize the two cameras, a small filament lamp was arranged in the field of each and a relay discharged a capacitor through each on receiving the control signal.

The normal event sequence was as follows:

(1) Raise lighting from standby to full intensity
(2) Start oscillograph camera
(3) Change from hot to cold air feed
(4) Start Fastax accelerator unit
(5) Commence injection of fuel into engine
(6) Produce flash signals for synchronizing camera records
(7) Stop Fastax
(8) End fuel injection
(9) Terminate other events except (3) which requires manual reset before the next take.

The duration of the events is defined in engine cycles rather than absolute time so signals are produced every engine cycle by means of a contact breaker and fed to the control unit.

### The Control Unit

This depends on two basic components borrowed from automatic telephone practice. They are the Uniselector and the Remanent Core Relay. The Uniselector is a high-speed multipole multiway stepping switch capable of continuous rotation. The Remanent Core Relay is a normal British Post Office relay but fitted with a core of high remanence although low coercivity. When a current pulse is applied to the coil of such a relay, it

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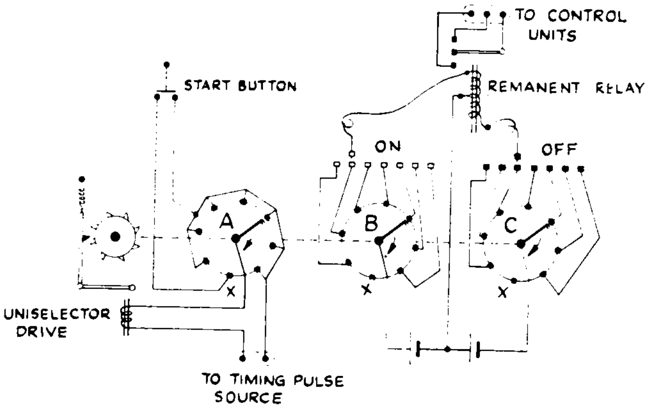


**Fig. 1. Simplified diagram of Programmer.**

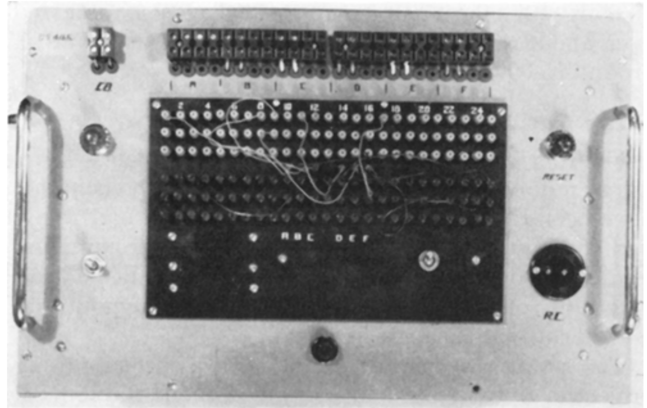

**Fig. 2. Programmer front panel and plug board.**

closes in the normal way but it remains closed after the pulse has ended. It can be released by sending another pulse of opposite polarity through the coil. In practice, it is often more convenient to provide two coils on each core so that the relay can be opened and closed by pulses from independent sources. The convenience of such a relay in programming systems is obvious for it performs the function of a latching relay with greater mechanical simplicity and higher operating speed. A much simplified diagram of the Programmer is shown in Fig. 1. A 3-bank 8-way Uniselector is shown with one control channel.

The driving pulses for the Uniselector are routed via one bank of its own contacts marked A. All contacts are linked except one marked X. If pulses are fed in to the drive coil, the relay will always move round to contact X and remain there until the "Start" button is pressed, bridging the gap and restarting the cycle which again will end on contact X.

Banks B and C provide sources of pulses of appropriate polarity for opening and closing the remanent relay at instants determined by the position of the plugs in the socket board.

It is realized that by having suitable direction of winding of the two sections of the relay coil a single bank could provide pulse sources for both opening and closing. However, the use of two banks allowed the pulses to be of different magnitude if this had been found necessary for highest operating speed.

The practical realization of such a control system is shown in Figs. 2 and 3. This unit has a 3-bank 48-contact Uniselector with a maximum speed of about 18 steps/sec after modification. Higher speed selectors are now available but the type used covered estimated requirements with an adequate margin. Only 25 steps of the 48 are at present used and the program board carries 75 sockets of each color, 3 per contact, allowing 3 events to be started or stopped at the same instant if required. Events can overlap each other without restriction.

### The Fastax Accelerator

Where maximum camera speed is needed, direct-on starting of the motors is not permissible and some form of step accelerator is needed to avoid overstrain and film breakage. The well-known "Goose" control uses two steps but in the design of the accelerator for this project, a continuous increase of voltage from zero to full value was decided on. This is simply accomplished by supplying the camera through a 2-kw Variac which is rotated via a 5/1 belt drive by a high torque a-c motor. Resilient stops and a limit switch prevent damage at the end of travel. A view of this unit is given in Fig. 4. The period from start to full voltage is about 0.25 sec and less than 10 ft of film has gone through in this time. Interlocks prevent the camera being restarted unless the Variac is returned to zero. It is difficult to compare the life and behavior of the camera using this

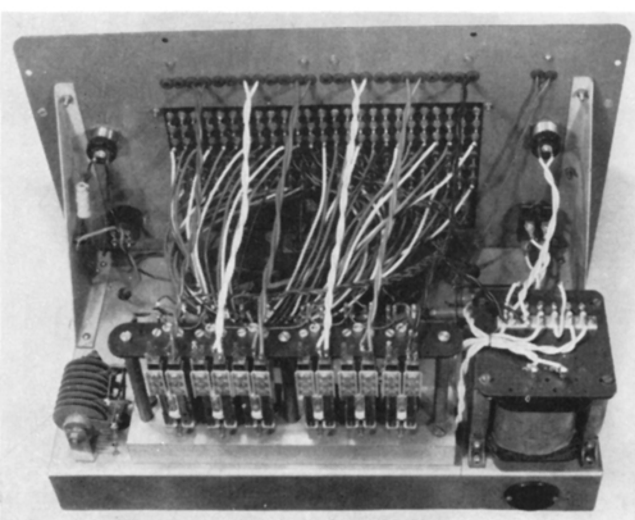

**Fig. 3. Programmer: Rear view showing relays.**

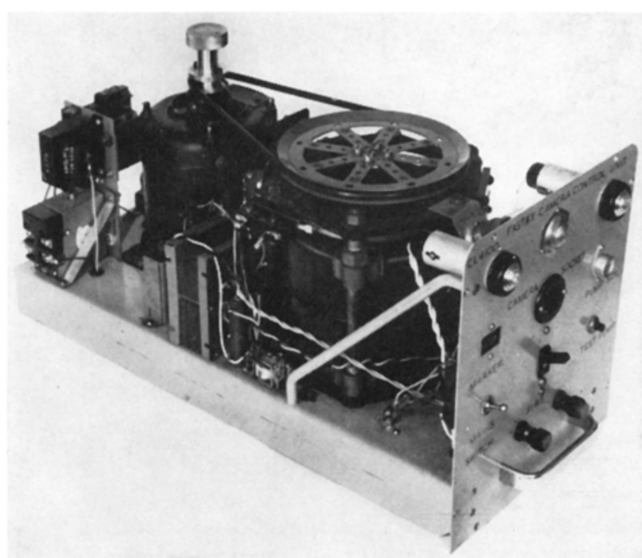

**Fig. 4. Camera accelerator.**

system with others but no film breakage has occurred over about three years use and 500 runs, nearly all at around 15,000 frames/sec.

### Other Ancillary Equipment

Figure 5 gives a general view of the complete system. Large numbers of color films using Super Anscochrome have been taken leading to valuable data on fuel sprays and combustion under conditions closely approximating to those found in practice. Due to the automatic controls described, only one operator is needed throughout and several runs can be made in a day.

The results are normally studied in a special editing projector giving stills and controlled single-frame feed, as well as low and standard speeds.

However, for education and informational purposes it is often desirable to send films to organizations which do not have special projectors for half-height 16mm frames. Hence, efforts were made to reprint the records on normal 16mm format. A somewhat crude arrangement was devised to make a copy of this kind and the results, although not of high quality, were encouraging.

Later the problem was referred to Rank Laboratories Ltd., the technical organization serving a large section of the British film industry, and they agreed to modify a standard 16mm projection printer to accomplish this. In addition it was now possible to "stretch" critical sequences in order to allow projection at normal speeds to nonspecialist audiences and yet give time for appreciation of interesting features.

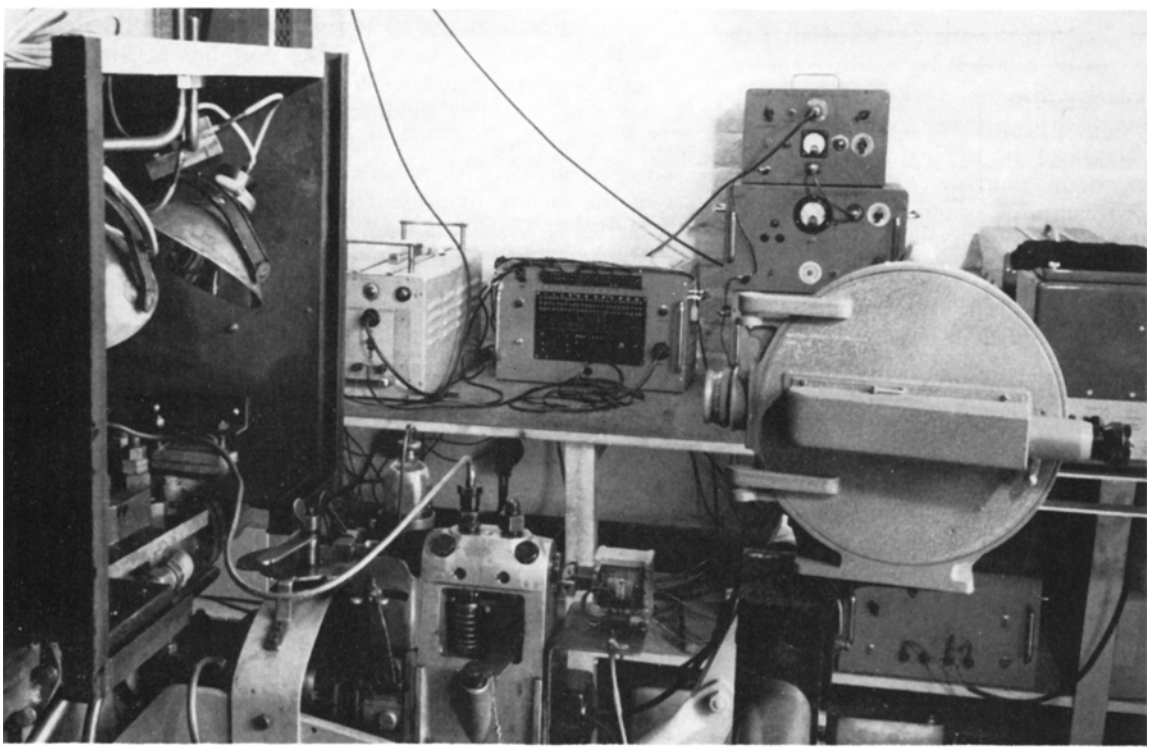

**Fig. 5. Combustion rig with camera and control gear.**