THE M02A STRONG-MOTION ACCELEROGRAPH

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ABSTRACT:

The improved M02A version of the M0 (mechanical and optical) type of accelerograph, currently in use in the N.Z. strong-motion recorder network is described. The improvements relate mainly to the mechanical drive, including the film rewind, and to the electronics for the timing features. In particular the elapsed time from a previous visit to the instrument is obtained by interrogating a clock during the running of the film. Production of the M02 instrument has been suspended in favour of the M02A and all the instruments in the N.Z. network will be converted to M02As.

INTRODUCTION:

The mechanical and optical (M0) type of strong-motion accelerograph was first installed in New Zealand in mid-1965 in the M01 form, and later in 1967 the M02 type was introduced(1-3). The latter was more compact than the M01, was completely sealed and had the addition of 50 Hz time marks recorded on the film. A total of 20 M01s and 120 M02s are now in operation or committed to operation throughout New Zealand and approximately 250 M02s have been exported. The instruments are installed both in the field and in buildings and structures.

The network of instruments has been maintained to a high standard of efficiency by servicing at regular intervals, six-monthly up to 1973 and eight-monthly thereafter(4). During this time the necessity for improvement in the mechanical and electronic features has become apparent, particularly as some of the components in the M02s are either obsolete or unobtainable. In addition the need to correlate earthquake records with information from the Seismological Observatory and with records from other M02 sites, necessary where a swarm of earthquakes or a sequence of aftershocks is involved, highlighted the requirement to establish the time of an earthquake event on the film.

DESCRIPTION OF THE M02A:

General -

The M02A (Figure 1) employs the same sensing system as the M02, viz pendulums operating in three orthogonal directions with oil damping (Figure 2) with optical recording. In operation a vertical trigger senses the P wave, starts the film drive motor, turns on the main trace lamp, and the timing lamp for 50 Hz time marks. Light from the main lamp is deflected by mirrors on the three pendulums and projected, together with a static reference trace, on to photographic film. The improvements in the M02A relate mainly to the mechanical drive, including the film rewind, and to the electronics for the timing features. Detail photographs of the underside of the new instrument with the base removed are shown in Figures 3 and 4.

Mechanical Features -

An electric motor of a more modern specification has been incorporated in the film drive and a new gearbox has been fitted to give an appropriate film speed. Whereas in the original M02 rewinding of the film was carried out against the drag of a clutch, in the M02A the clutch is omitted and the drive disconnected by means of a release button, on top of the gearbox, which disengages the gears in much the same way as on a 35 mm camera, thus facilitating rewinding. At the same time an electronic limiter for the motor current ensures that, in the event of all the film in the cassette being used, when the motor is pulling against the fastened end of the film, the motor torque will not be excessive.

Electronic Features -

The block diagram (Figure 5) outlines the logic of the instrument. Power is supplied by 12 V dry batteries as in the M02 but with a continuous current drain of 50 μA to maintain a crystal clock in continuous operation. The elapsed time from the previous visit to each triggering is obtained by interrogating this clock during the running of the film; an image of the display, is projected on to the film through a line of pinholes when the film stops running. The image appears about 2 cm along the film from the end of the earthquake referred to. Thus the image appears across the start of the next earthquake as shown in the enlarged record (Figure 6). This display gives the elapsed time in units of 6 seconds. The instrument clock is checked against a reference clock carried by the operator during his site visits and any necessary corrections made to the recorded times. The recorded times can then be converted to event dates and times by a simple computer programme.

The output from the crystal is also used to generate time marks on the film via an LED timing lamp (Figure 2). In

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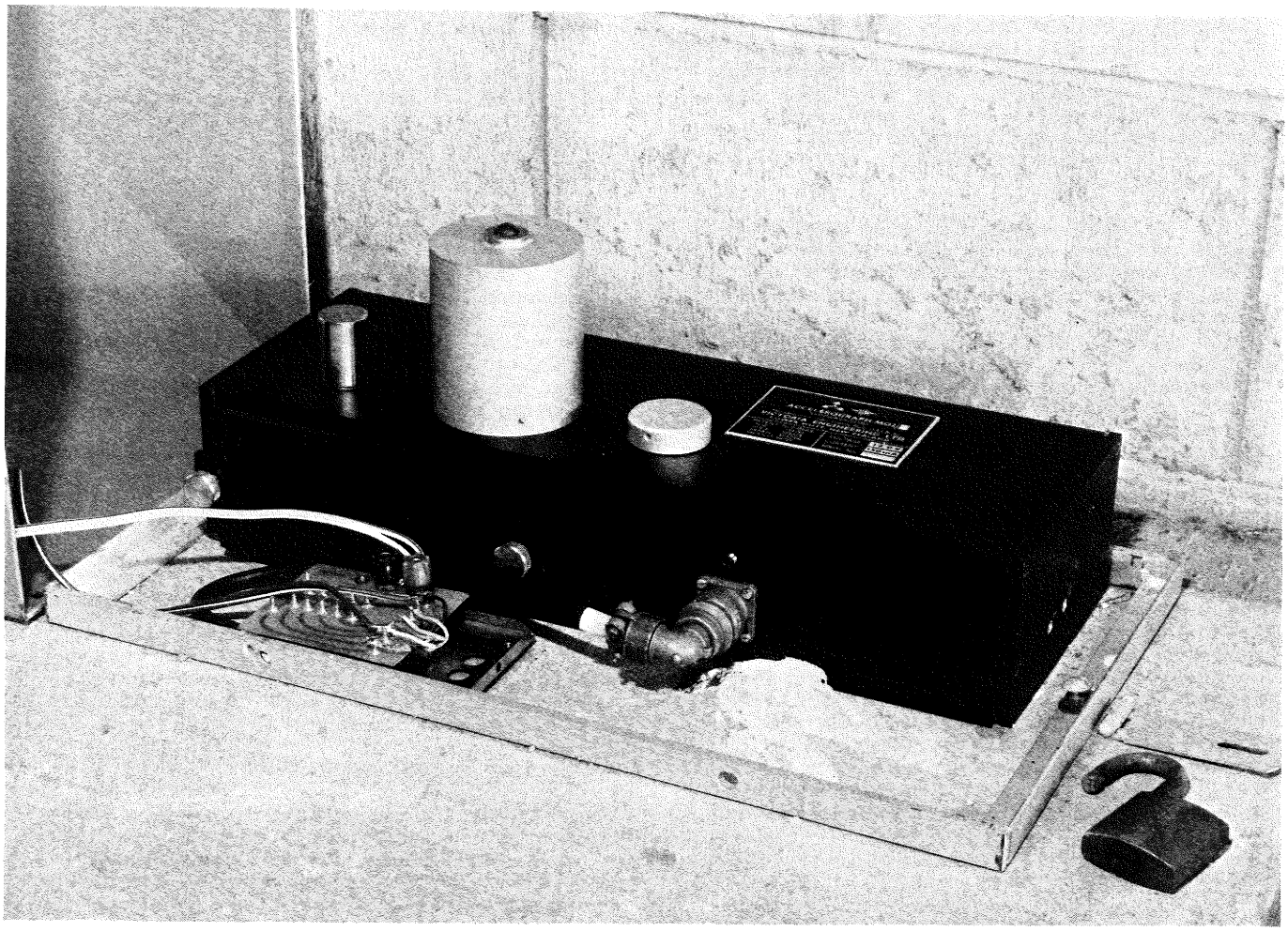

Fig. 1. – MO2A installed in basement at PEL with cover removed.

An interconnection board is shown in the front of the instrument.

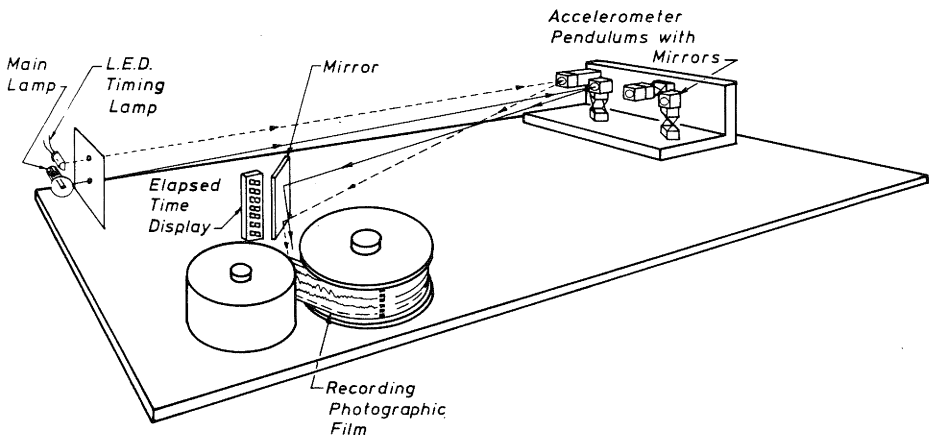

Fig. 2. – MO2A ACCELEROGRAPH OPTICAL SYSTEM

the M02 each time mark was offset along the film from corresponding points on the light-spot traces from the pendulums. This made correlations between records tedious, for example, between different parts of a building. For the M02A, however, time marks are aligned with corresponding light spots to within 1/50 sec, giving a greater facility in the use of the records.

An improvement has also been made in the running time of the instrument. Whereas previously the film ran for 45 seconds after triggering, which resulted in a waste of film during trial runs in the field and short duration earthquakes, and particularly aftershocks, the new instrument continues to record until the ground motion has decreased below the triggering threshold for 18-24 seconds. This will reduce the chance of consuming the available film during brief earthquakes, for example foreshocks, and hence missing the main shock, and will also ensure that no significant motion is lost during a large earthquake of long duration. This should allow the length of time between servicings to be increased and lessen the need to give the instruments immediate attention after a series of earthquake events. In the M02 an electro-mechanical counter viewed through the case indicated the number of triggerings, but in the new instrument the amount of film used is indicated by pressing a pushbutton to illuminate an LED display showing the number of seconds the film drive has been running.

Film Type -

Unperforated 35 mm film, of a high speed type, is normally employed in the M02A. This is specially imported by DSIR. In the event of its non-availability the normal type of high speed 35 mm perforated film can be used although the perforations could cause some loss of the records for extreme values of acceleration.

Calibration -

As the accelerometer system for the M02A is identical to that for the M02, calibration is unchanged as previously described[5]. Static calibration is performed at the Physics and Engineering Laboratory on each block sub-assembly containing the three accelerometers and reference mirror, by mounting in the M02 calibrating device which allows the block to be accurately and rapidly placed into each of eight calibration orientations. The sensitivities and error angles obtained, together with the cross-axis characteristics, are used for the correction of earthquake accelerograms following their digitisation.

PRODUCTION OF THE M02A:

Production of the M02 type of accelerograph has been suspended by the makers, Victoria Engineering Ltd of Lower Hutt, and an initial batch of ten M02A instruments is being produced. Of these instruments, five will be located in the base-isolated William Clayton Building in Wellington, and a further two on the Maui A gas platform and the associated shore base at Oaonui.

In addition, parts to update the existing 120 M02s in the New Zealand network will be manufactured and the work carried out as time and labour permit, possibly by outside contract, or otherwise internally at PEL at the rate of 20-30 instruments per year, as they are brought back from sites for servicing.

The procedure for the delivery of exported models will be as for the M02. Because of the delicate nature of the pendulum suspensions, these are usually clamped in position with packing for transportation, or the mounting blocks containing the suspensions are delivered by courier. The damping oil is introduced following receipt of the instrument as once the oil is in position the instrument must not be tipped more than about 45° to the horizontal as otherwise oil may contaminate the mirrors. In this event they must be cleaned repeatedly by flushing the blocks with solvent.

Amendments to the Installation and Operating Manual for the M02 are in hand to cover the modifications which have been made and these will be made available with the new instruments.

UTILISATION OF THE M02A:

Our investigations indicate that, because the calibration checks (linearity, sensing-direction errors, and cross-axis errors) carried out on the M02 instrument are more complete than those performed on comparable instruments overseas, more accurate results can be obtained on the M02 as compared with other mechanical-optical type instruments. Because the 150 M02 instruments in the field can readily be converted to M02As this type of instrument is likely to form the basis of the New Zealand Strong-Motion Recorder Network for some time to come, particularly as the cost, for an instrument is not likely to exceed NZ$3,000 in 1980.

A digital accelerograph manufactured in New Zealand by Solid State Equipment of Lower Hutt, which employs geophone sensors and a tape memory, is now available and is being calibrated at the Laboratory for use in the Bowen Street Bridge, Wellington, on a research project funded by the National Roads Board. The cost, for the measurement of six components of acceleration, is NZ$7,000. When this instrument has been evaluated in the field, a comparison can then be drawn with the M02A and a decision made on the best type of instrument for future purchases for the NZ Recorder Network.

One obvious advantage of the digital equipment is that the process of digitising a film record is eliminated. On the other hand, film records have the advantage that the strength of the ground motion can be assessed by a single viewing of the film without the necessity of unscrambling the record on a tape by electronic means.

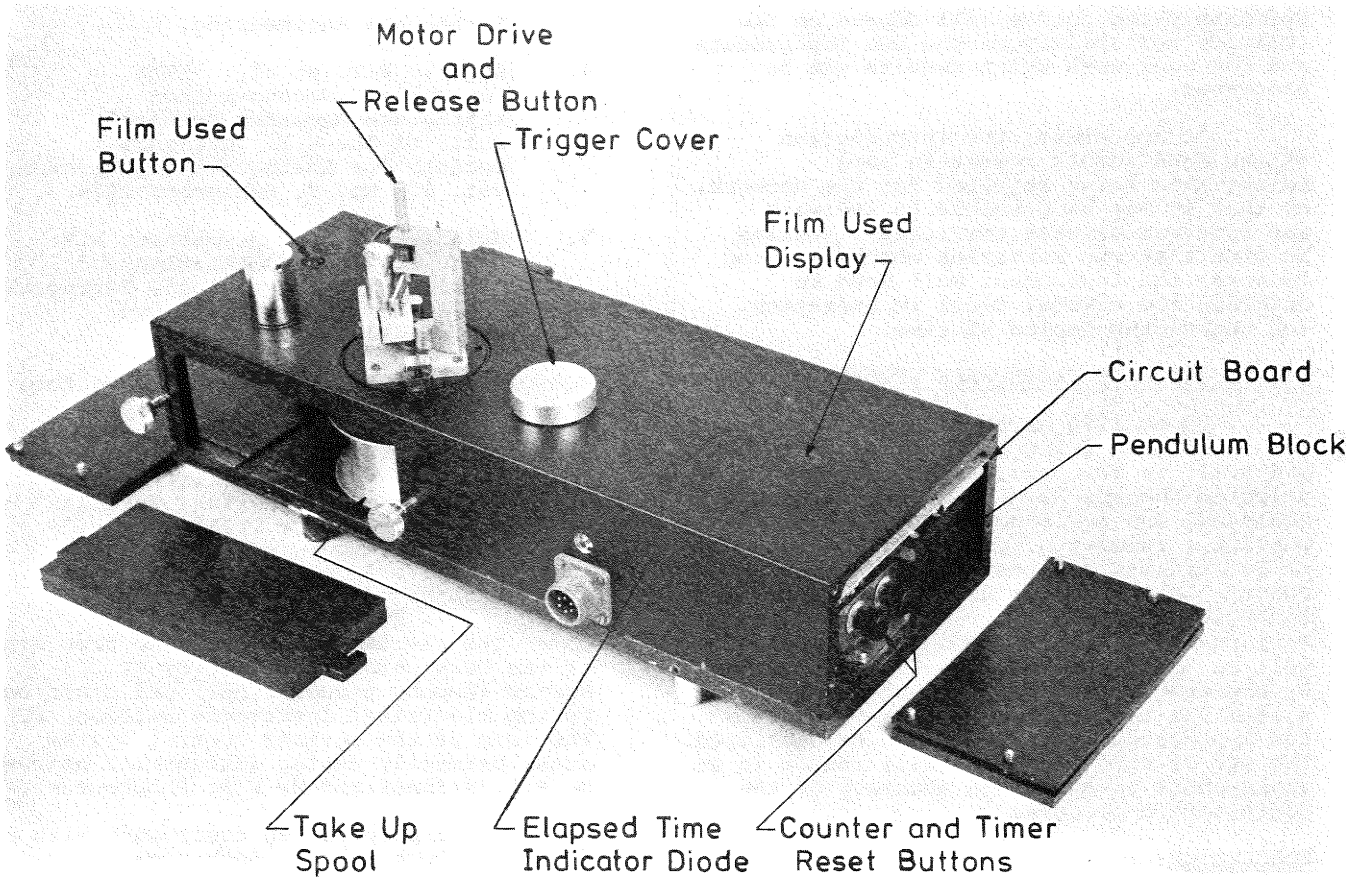

Fig. 3. M02A WITH COVERS REMOVED

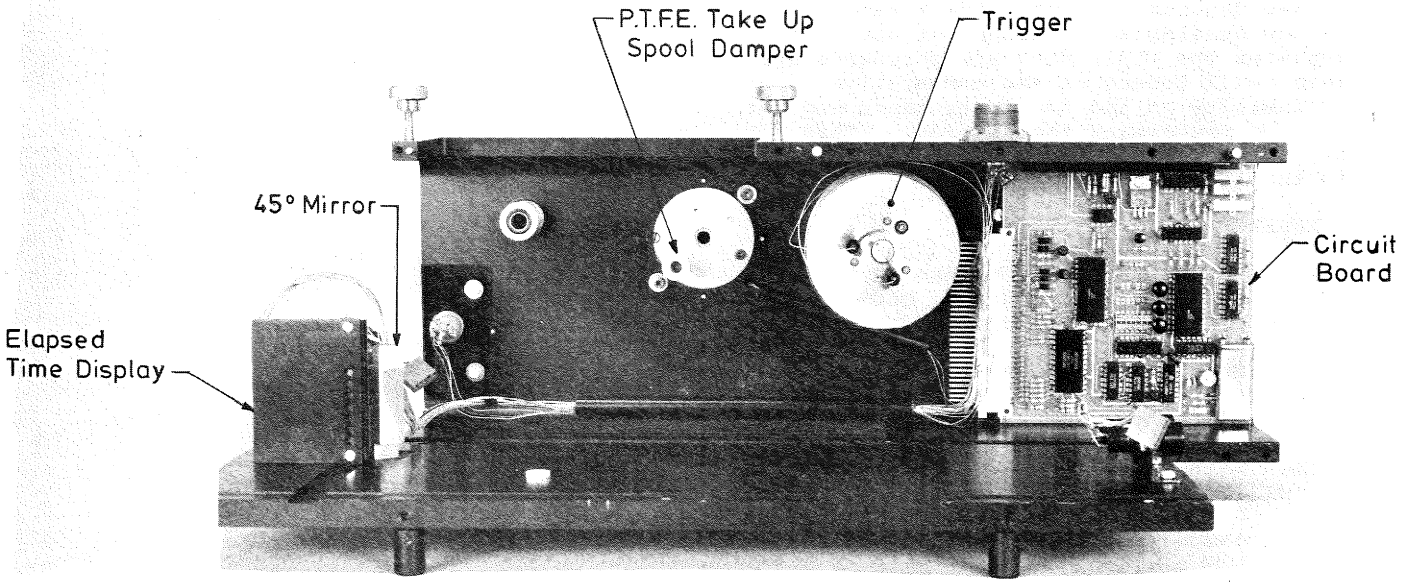

Fig. 4. M02A VIEWED FROM UNDERNEATH WITH BASE REMOVED

Ultimately the choice will depend on the relative reliability of the two instruments and the ease with which results can be processed.

At any event, the introduction of the M02A should result in less maintenance being required for the network, so that it may be possible to increase the interval between servicings, bearing in mind that the batteries which are used to power the instrument will need to maintain the crystal clock in operation for the chosen period of time.

DIGITISATION OF EARTHQUAKE RECORDS:

Up to 1980 earthquake records have been digitised using a digitiser designed and built in the Laboratory. Nineteen selected records have been digitised and analysed, and it is hoped shortly to publish a summary of the records obtained so far, including acceleration response spectra in the manner used for the Milford Earthquake of 1976[6]. A new Hewlett-Packard digitiser has been purchased and will be on-line with a LSI-11 computer by the end of 1980 when a projection system for the film records is complete and appropriate software has been developed. The use of this equipment will result in an improvement in speed and accuracy of the digitisation process.

CONCLUSION:

In its redesigned form the M02A will be an accurate and reliable accelerograph. Because of the existing investment in about 120 of the M02 type of instrument in the New Zealand Strong-Motion Earthquake Recorder Network, which will be upgraded to the M02A, the new instrument is likely to form the basis of the network for some time to come. It may be possible to increase the interval between servicings as a result of the introduction of the modified instrument.

A digital accelerograph manufactured in New Zealand and employing a tape memory is now available. Whether or not this replaces the M02A, when new purchases are made, will depend on the comparative reliability of the two instruments and the ease of processing the records. This can only be established after a period of trial in the field.

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ACKNOWLEDGEMENTS:

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The concept of an instrument with a built-in clock and the mechanical redevelopment, including prototype production, were due to Mr R.T. Hefford.

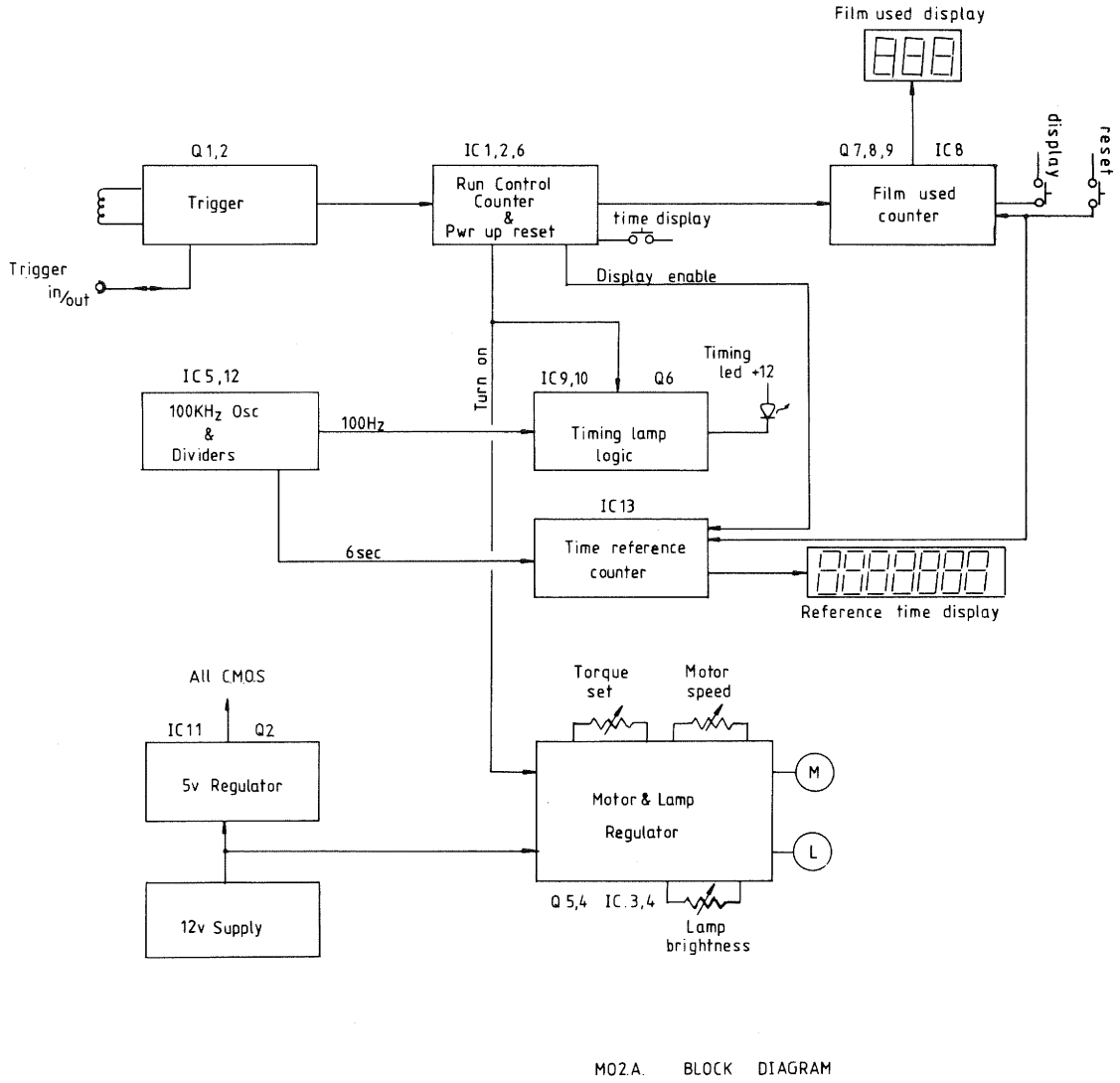

Fig. 5. — Block Electronics Diagram

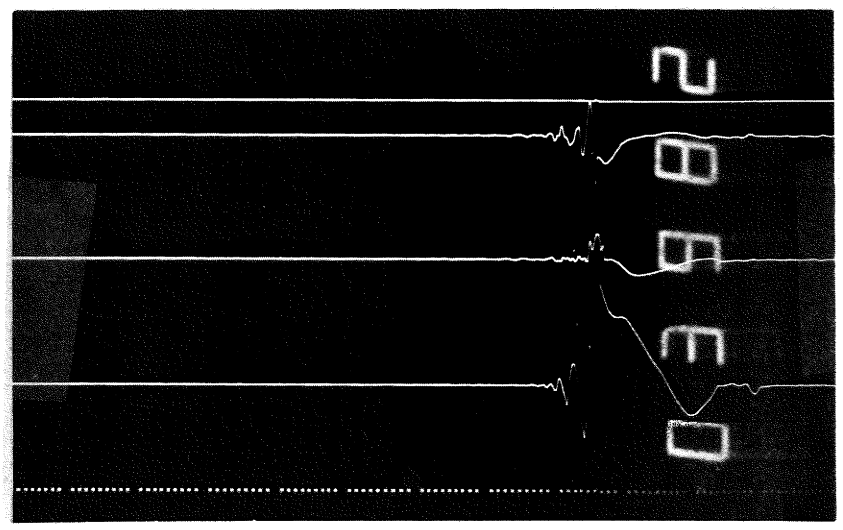

Fig. 6 — Developed film showing time display (right) and (top to bottom) reference trace, vertical accelerometer trace, two horizontal accelerometer traces and 1/50 see time marks (ditto).