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A Recording System for Flight Test Data

By

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Summary

While the existing type of automatic observer has enabled more and different data to be obtained during flight tests, it incurs a very heavy expenditure of man hours in subsequent "film-reading". This large effort results in considerable delay in terms of elapsed time before the data from a test are available which, as well as slowing down the general tempo of the work, creates difficulties in test planning and progressing.

To obviate these difficulties a new recording system is proposed in which the reading of the record can be mechanised. This system leads naturally to the direct use of computing machines for the subsequent analysis which would further reduce the man hours and elapsed time involved in testing.

The system proposed employs a transmission system from the instruments which enables the instrument readings to be recorded in the binary digital system. This record is subsequently transcribed in an automatic "reader" the output of which may be either in the form of tabulated results, or as punched tape suitable for direct use in a sequence controlled calculator. A prototype transmission unit has been constructed.

/Contents.....

List of Contents

List of Illustrations

1. Introduction

1.1 Until about 1944 the bulk of the data from routine flight tests was recorded manually from direct visual readings of test instruments. The increasing number of instruments involved and the desire to obtain frequent observations led to the adoption of the "automatic observer" in which most of the test instruments could be photographed and the data subsequently extracted from the film.

1.2 The man hours involved in "film reading" has steadily increased until now, both for routine and research testing, it represents a major factor in total labour involved and the time required to make tests. In this report the present system of recording is discussed and proposals made to reduce the labour involved in transcribing and analysing test data.

2. The processes involved in recording and evaluating data

2.1 Except in the case of direct visual observing there are three main processes involved in the recording and evaluation of test data.

(a) obtaining a permanent record of the data at the time of test

(b) transcribing this record into a form suitable for analysis

(c) analysing the data so obtained.

2.2 For convenience we will call these three processes recording, reading and analysing and we may consider first the existing system, based on the "automatic observer", in relation to these headings.

3. The "automatic observer"

3.1 Use of the "automatic observer" relieved the pilot and test observers in the aircraft of much of their work and was of particular merit for single-seat aircraft in leaving the pilot free to concentrate on his flying technique. For all aircraft types it had the advantages of enabling data to be obtained simultaneously and from a larger number of instruments and/or at a higher frequency than was feasible with human observers; in the latter case it permitted unsteady motions to be studied. Under our first heading of "recording" it thus represented a material improvement.

3.2 The process was, however, essentially more laborious than manual recording both in man-hours and overall time and the advantages gained under the first heading were at the expense of introducing the second "reading" process. The increased labour is particularly noticeable for flight tests under steady conditions because whereas a skilled observer viewing an instrument directly can assess accurately the mean value of a quasi-steady instrument reading without tabulating readings at frequent intervals, the tabulation and subsequent arithmetical averaging is necessary with the automatic observer records. From the aspect of elapsed time, the necessity for developing the film, reading it and tabulating results subsequent to flight leads to a delay of 2 days or more between the completion of the flight and the results becoming available. This in turn leads to difficulties in programming tests because an abortive flight may not be apparent until these results are available. A further disadvantage of the automatic observer type of recording is in the instrument calibration procedure involved. Normally parallax errors are involved which necessitates a photographic calibration in situ. This again involves more man-hours and elapsed time than normal calibration and further is inconvenient from the servicing aspect when changes of individual instruments are involved.

3.3 Discussion with other flight test organisations in this and other countries has shown general agreement that the reading of automatic observer films is now a major factor of delay in flight test work and the man-hours involved is a serious deterrent to undertaking much work which would otherwise be possible. In

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our experience the effort involved in film reading can easily occupy 50% or more of the total technical man-hours involved in performance flight testing. A system of recording in which the human element in the reading process can be either eliminated or greatly reduced would therefore be a major advance in flight testing technique and this problem is discussed below.

4. The form of record required

4.1 To eliminate the human element in the reading process, a form of record is required suitable for insertion in an automatic apparatus which will read the records and, if necessary, tabulate results. However once one has reached the stage of mechanised reading it is a comparatively short step to the process of mechanising the analysis using some existing type of calculating machine. Thus tabulation of the "raw" data is not essential in the fully mechanical system. For the work under consideration the high speed electronic type of calculating machine is unnecessary and the electro-mechanical sequence controlled type of calculator described by Petherick[1] is adequate. This machine requires the data to be supplied in the form of punched tapes and for this purpose employs a modified binary-decimal system.

Although we had in mind the Petherick machine for analysis, it seemed undesirable to be committed to a form of recording directly suitable for one particular type of calculating machine, particularly since this was unlikely to give the best solution to the problem of producing a compact and reliable airborne recorder.

We therefore considered that the best form of record for this particular application should be chosen and that one should rely, if necessary, on mechanised readers (on the ground) to transcribe the primary record into a form suitable for direct use in a calculating machine.

4.2 For performance tests a recording accuracy in the order of 1 in 1,000 of the full scale deflection is considered necessary and to achieve this accuracy a digital recording system is preferred.

Two factors must be considered when choosing the scale of notation to be adopted for the digital counter; firstly the efficiency of the scale as defined by the number of digital positions required to specify a given number and secondly the simplicity of the mechanism needed to represent the scale. From both aspects the binary, or scale of 2, notation is the best; as compared with the usual decimal notation a considerable simplification is effected. For instance to record numbers up to 1,000 in the decimal system, would require 30 digital positions (3 scales of 10) while in the binary notation only 20 positions (10 scales of 2) are necessary. From the second aspect, any mechanism having simply an "ON" and an "OFF" position can be used to represent the scale of two. It is thus eminently suitable for recording by, for instance, punched tape, light spots on film or magnetised wire; in any such scheme the reading of records may be mechanised.

We may now consider the system needed to produce such records.

5. The recording system

5.1 General. In the system envisaged the indicating units for the various parameters would normally comprise the movements from existing type instruments, the output of which may be typified by the rotation of a shaft through 360°. The main problem is to transmit, in binary notation, the instrument indication to the recording unit.

5.2 Binary transmitter. It is required to present the instrument reading represented by a given rotation in the binary digital notation. This may be done by a simple type of commutator which is illustrated diagrammatically in Fig. 1. For simplicity a 5 channel counter is shown, which gives a count by 1/32nds.

The segments drawn represent contacts and for any position (A, B etc.) of a brush assembly, electrical circuits are made which, as shown in the table of Fig. 1, represent the angular displacement in binary notation.

Two problems arise here:-

(a) the majority of instruments have inadequate output torque to drive the necessary mechanism

(b) to avoid incorrect readings there must be no uneven overlapping of the brushes between "on" and "off" segments of the commutator.

The first aspect demands some form of servo drive: if this is in the form of an impulse motor with movement increments equal to the smallest commutator segments a particular solution to the second problem is also obtained.

Using this type of commutator a schematic diagram of a complete transmitter unit is shown in Fig. 2. Shaft "A" is rotated by the instrument mechanism, for instance an altimeter capsule, and the movement of the pointer B is followed by means of a reversible impulse servo-motor C to which is connected the binary counter D. The motor is driven from a master impulse generator which supplies all transmitters. At any instant therefore the position of the counter corresponds to that of the instrument pointer and the appropriate output channels are energised to represent the instrument reading in binary notation. The arrangement of the reversible ratchet gear employed in the impulse motor is shown in Fig. 3.

There are practical difficulties in making a small counter with 10 channels, because of the small segments involved in the first channel. It is therefore preferable to use two 5 channel units with the secondary counter triggered by the rotation of the first to obtain the required 1 in 1,000 counting accuracy.

Photographs of an actual 5 channel unit (less relay) are shown in Fig. 4 and the size of this pilot model is $1\frac{1}{2}$" x $1\frac{1}{2}$" x $1\frac{1}{4}$". It is still under development and is illustrated here to demonstrate a practical application of the scheme envisaged.

For connection of a full 10 channel unit to the recorder a 13 core cable is required. Since only one circuit (for the impulse motor) is required to carry any appreciable current, the cable would be of modest size.

5.3 Recorder. Various types of recording are under consideration but a possible optical system is illustrated, by way of example, in Fig. 5. This employs a bank of signal units of the type used in the French Hussenot-Beaudoin recorder; a unit is provided for each channel and consists of a small solenoid operated tilting mirror which, when energised, reflects light from a single source onto the record film. By suitable masking a record in the form illustrated in Fig. 6 is obtained. This system is attractive in that suitable signal units are available, and it would be sufficiently fast in operation, but the fact that subsequent processing of the record is necessary is a disadvantage.

Punched tape recording would eliminate the need for processing but it is not considered suitable because of mechanical complication. An alternative system to eliminate processing is the use of multiple contracts on teledeltos paper; this would, in addition, dispense with moving parts and would probably give the simplest and most compact form of recorder. In general it is felt that some such form of "visible spot" recording will be the best solution for an airborne recorder.

6. The automatic reader

6.1 With the "visible spot" type of record discussed above the reading unit could consist of a photo-electric cell arranged to scan the channels of each instrument reading in turn. Since a positive indication in any channel has a unique numerical significance, the signals from the reading head could be used to set up a printing head and in this way a printed tabulation of the raw experimental data obtained. If the mechanisation process were ended at this point it would be necessary for "scale" corrections to be applied and the remaining analysis completed manually; this may be adequate in certain cases. However, as already noted, it is a comparatively short step from this stage to the complete mechanisation of

/the....

the process. Although tabulation of the raw data may sometimes be needed and would be a convenient interim stage resulting in an appreciable saving in man-hours, our conception is that the reading unit should also transcribe the data from the aircraft record into a form suitable for use in an automatic computor. No detail development of this unit has yet been made.

7. Instrument scales and errors

7.1 Whatever scaling system is adopted for test instruments there are normally errors present for which corrections must be applied on the evidence of laboratory calibrations. With the system of recording described above the working range of an instrument, as defined by the rotation of an output shaft, is divided into a known number of equal parts without reference to the scaling for some particular units of measurement. This has had the advantage that the data have been, numerically, presented over the same range of magnitudes and it has not been necessary to define magnitudes in the recording as would have been necessary had a presentation in particular units been attempted. Before, or during analysis it is thus, in general, necessary to apply both a scale function conversion and an error correction for minor deviations from the smooth function.

7.2 It would be possible to obtain a "true" output from the transmitter by suitable arrangement of the servo following mechanism*, but this is not likely to be economical for flight test work where frequent recalibration of instruments is necessary. It is therefore proposed to correct for scaling either during reading or analysis. With either method it is necessary to prepare a tabulated function of "true" to "indicated" values and this can be done directly from the calibration process, in the same form as the aircraft data record.

If the corrections were applied during analysis a relatively simple type of reader could be used which would transcribe the calibration records into the punched tape form demanded by the calculating machine, in the same way as with the aircraft data record.

For correction during the reading process a more complex type of reader would be required. The instrument indication would be "read" and the corresponding reading (or range) sought in the "indicated" tabulation of the calibration record; the corresponding "true" value would then be despatched to the output.

Although more development work is involved there are a number of advantages in the second method. With the Petherick calculating machine the number of tabulated calibration functions which can be accommodated would normally not exceed 14 for analysis of performance tests. This could lead to difficulty with results from multi-engined aircraft and further it would be uneconomical to occupy the machine with a large volume of simple calculations if these can be handled otherwise. From the users aspect also it is an advantage to be able to obtain tabulations of true values at an early stage and in a number of cases use of a calculating machine for the analysis may not be warrented; in such cases it is still desirable to avoid the manual labour of applying instrument corrections and tabulating true values.

8. Calculating machine

8.1 Although this report is concerned with the recording, and not the analysis of test data we may, for the sake of completeness, briefly examine this latter aspect. With a machine of the Petherick type[1], the observed data is fed in on punched tapes and, by means of a control tape, the sequence of operations in the machine automatically controlled to analyse the data and finally tabulate it in the required form. An example of a typical calculation sequence for performance tests is given in Fig. 7. With the recording system here envisaged, tapes giving the "recorded" or "true" values would be obtained from the reading unit depending on the method of dealing with instrument scale corrections as

/discussed....

* For instance by "following" the instrument pointer with a disc having a spiral contact, the shape of the spiral being arranged to give "true readings" i.e. incorporating both the scale and instrument error functions.

discussed in para. 7 above. The tapes for the tabulated functions $\Delta P_P : P_D$ and $\Delta P_S : P_D$, representing the pitot and static pressure error corrections respectively, would be prepared manually. In the pressure error calculation sequence the nomenclature of ref. 2 has been used and for simplicity calculation of the effect of compressibility on pressure error has been omitted.

9. Discussion

9.1 In the automatic recording and reading system which has been described, there are three main component groups:-

(i) transmitter units

(ii) recorder

(iii) reader

9.2 At the present time development has proceeded to the stage where a working transmitter is available. The small size achieved in the pilot model suggests that the application of this transmission to existing types of instrument movement will be feasible and convenient in practice; a compact transmitter is of particular importance, of course, in sealed instruments such as altimeters where it must be incorporated within the sealed case. It will be appreciated that by adopting this type of transmission a remotely recording system has thereby been achieved. This is of particular merit for pressure instruments since it obviates the necessity for long pipe runs which are frequently difficult to install and undesirable in that lags may be caused. Instead, each pressure instrument may be installed at any convenient position close to the point of measurement and connected to the recorder by its cable. With the unit type of construction employed for the binary counter one is not limited, of course, to the 10 channel system which has been described; for special applications further counters may be added.

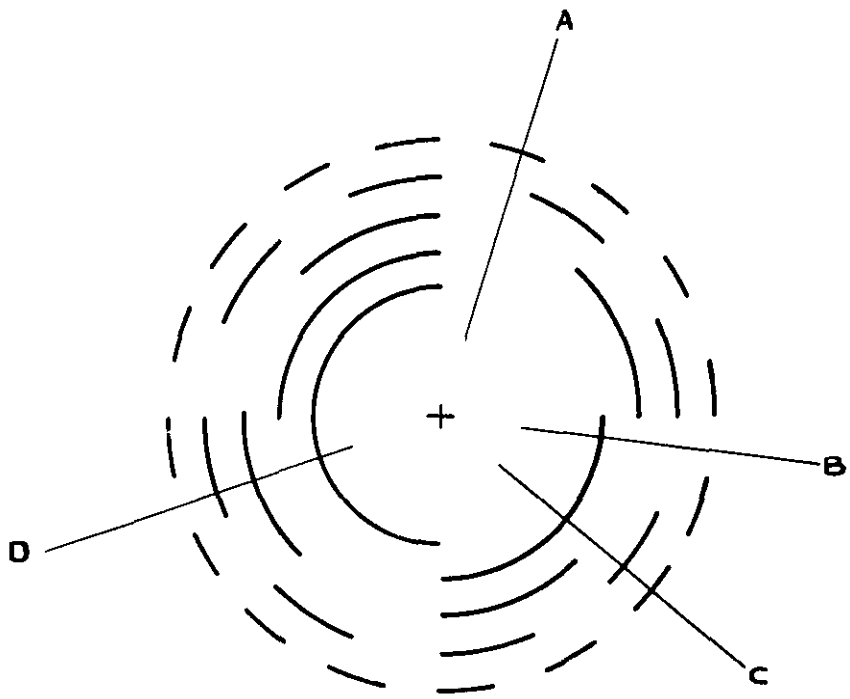
9.3 In the development of a suitable recorder no particular difficulties are foreseen. Since it does not have to contain the instrument mechanisms it would, for a given number of parameters, be considerably smaller than the exisitng type of "automatic observer". This feature is particularly attractive for fighter aircraft where the problem of stowing large box-like apparatus is already acute.

9.4 The development of the reading unit is a larger undertaking. No detailed discussion is feasible at this time since only consideration in principle has so far been given to this unit.

References

1.	Petherick	The R.A.E. sequence controlled calculator. R.A.E. Tech. Note M.S.1. A.R.C. 12,917
2.	Weaver	The calibration of airspeed and altimeter systems. Report No. A.& A.E.E./Res/244. A.R.C. 12,564.

FIG. I.

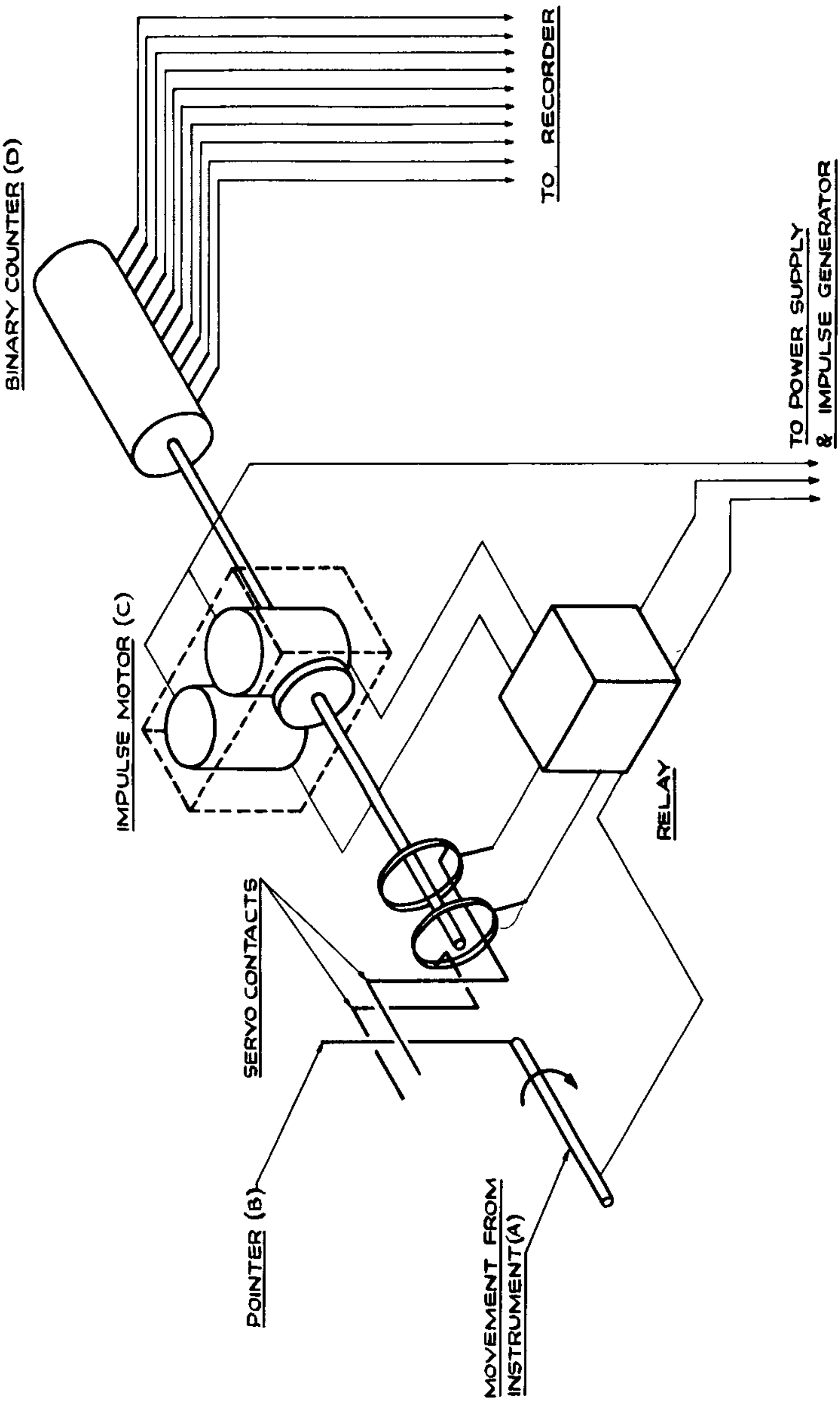


DIAGRAMMATIC ARRANGEMENT OF COMMUTATOR

POSITION	READINGS					DECIMAL EQUIVALENT
A	x					1
B				x		8
C	x	x		x		11
D		x	x		x	22
DECIMAL SIGNIFICANCE	1	2	4	8	16	

5 CHANNEL BINARY DIGITAL COUNTER.

FIG. 2.



ARRANGEMENT OF TRANSMITTER. (DIAGRAMMATIC.)

REVERSIBLE RATCHET SYSTEM.

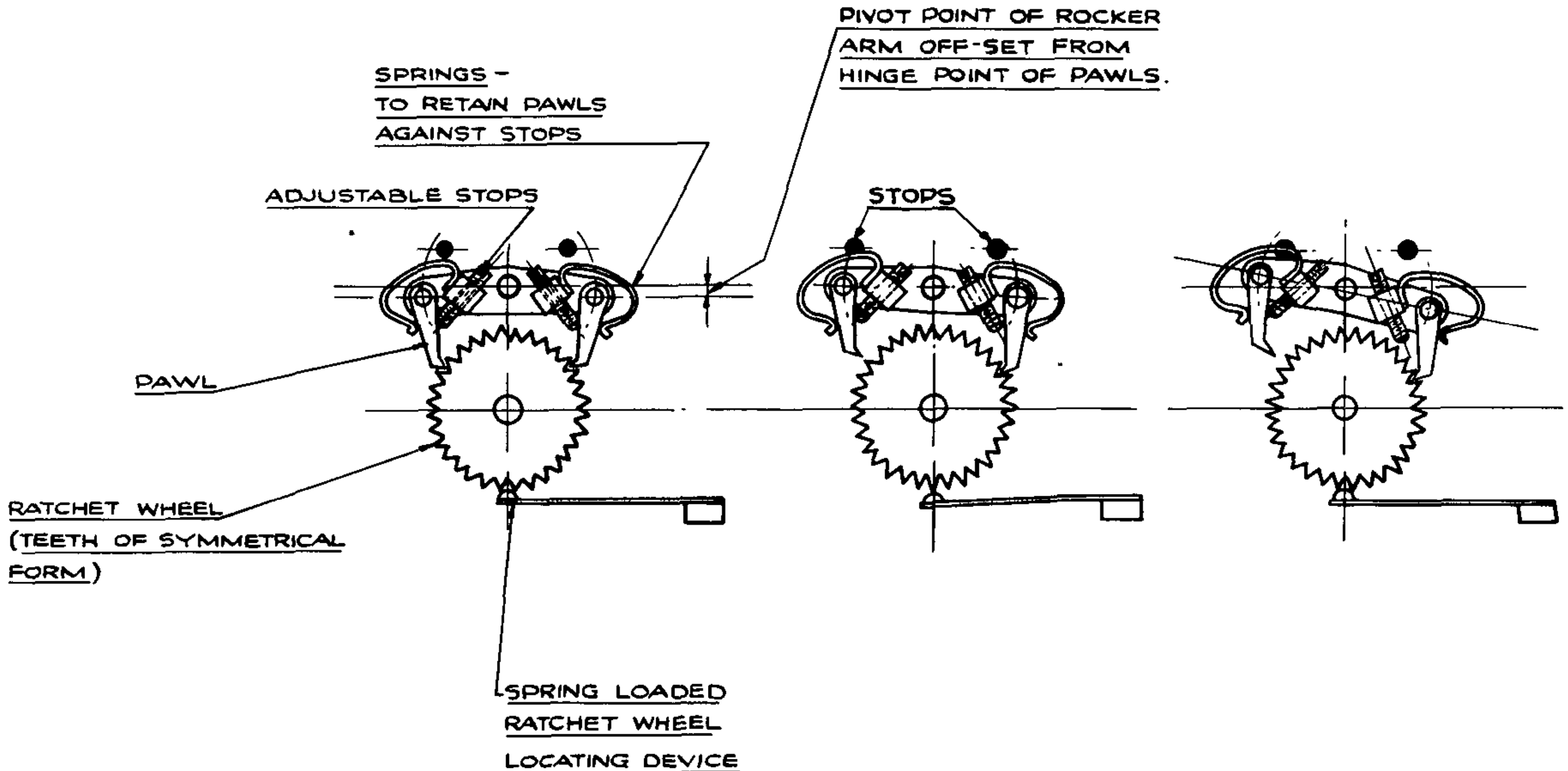


FIG.3.

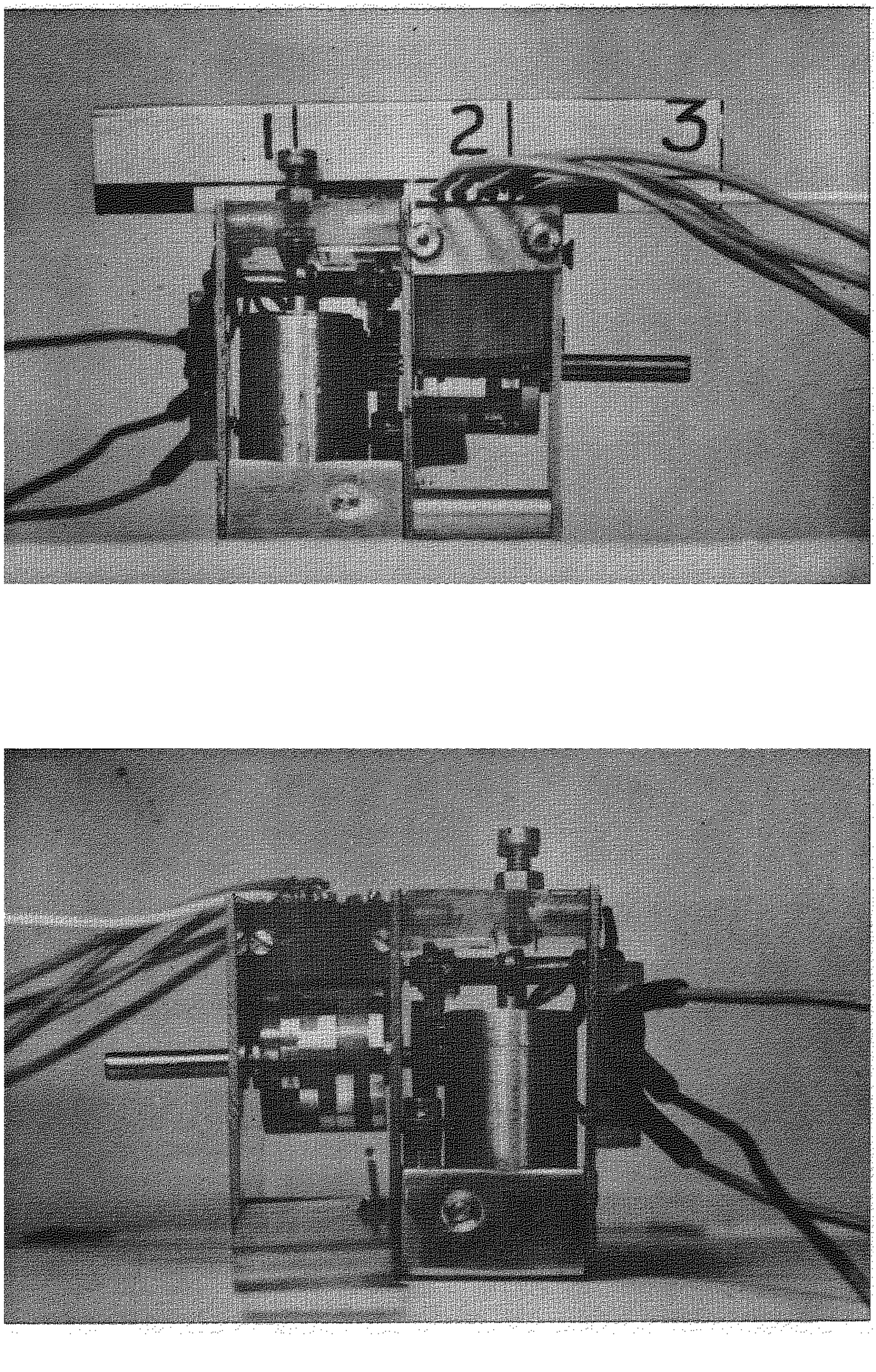


FIG.4.

FIG's 5&6.

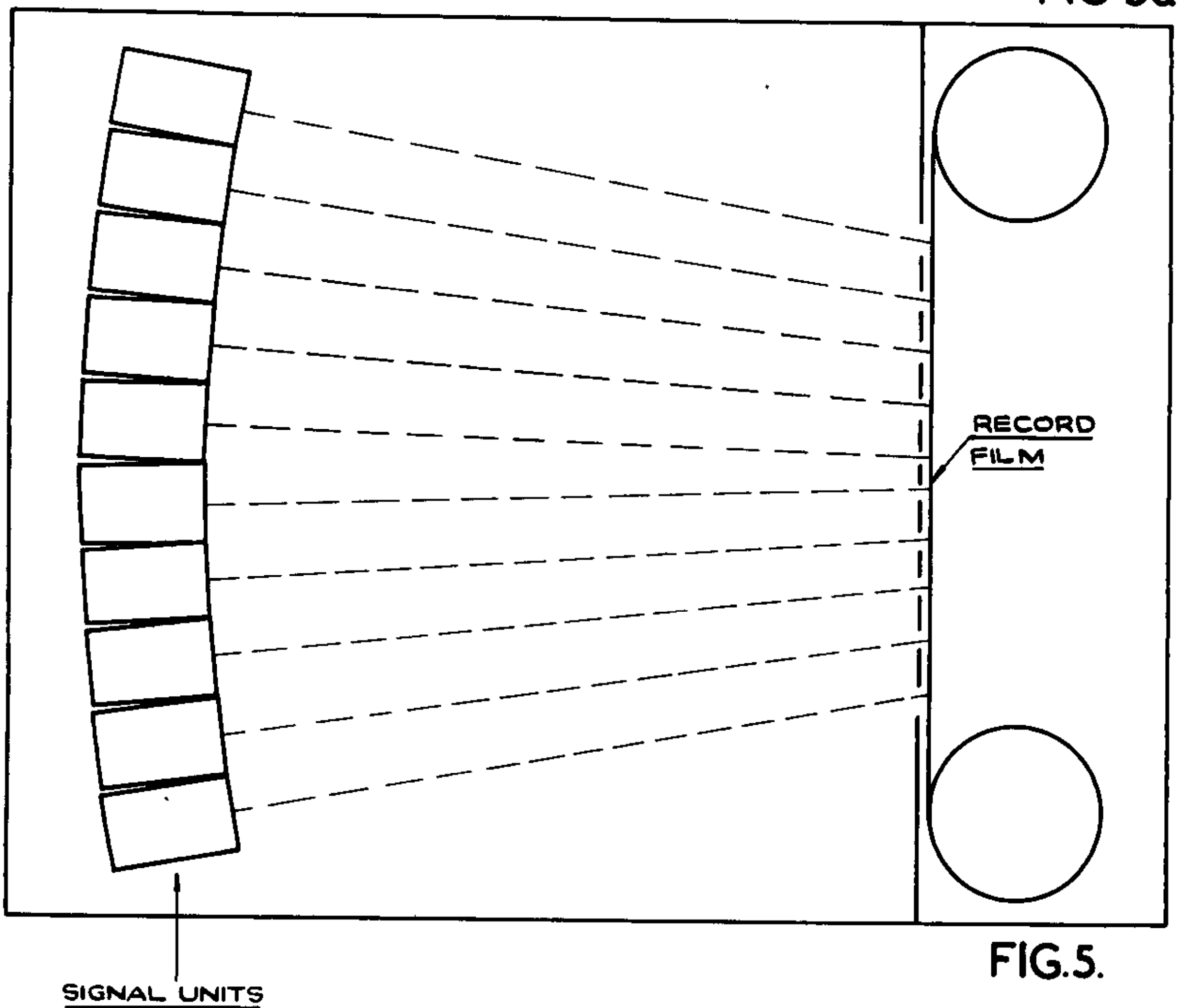


FIG.5.

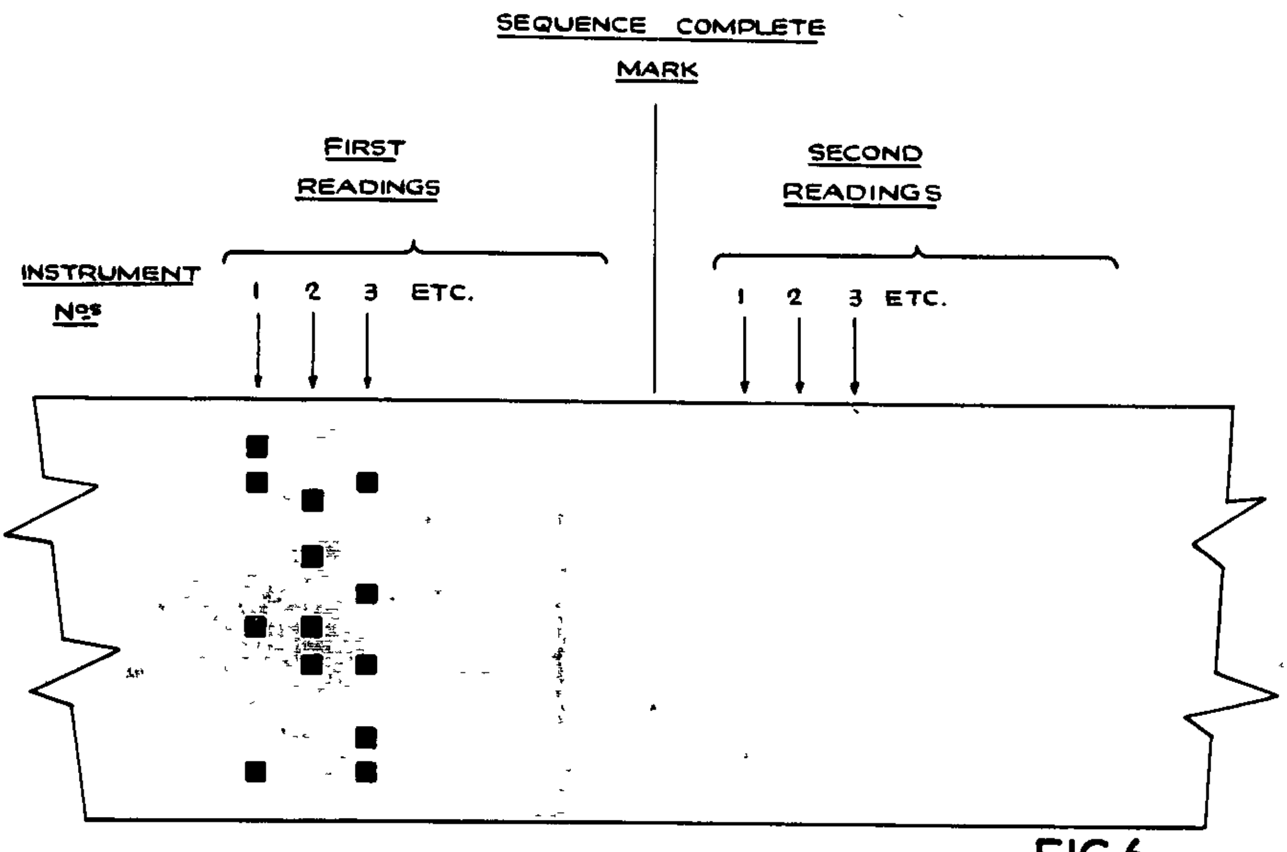
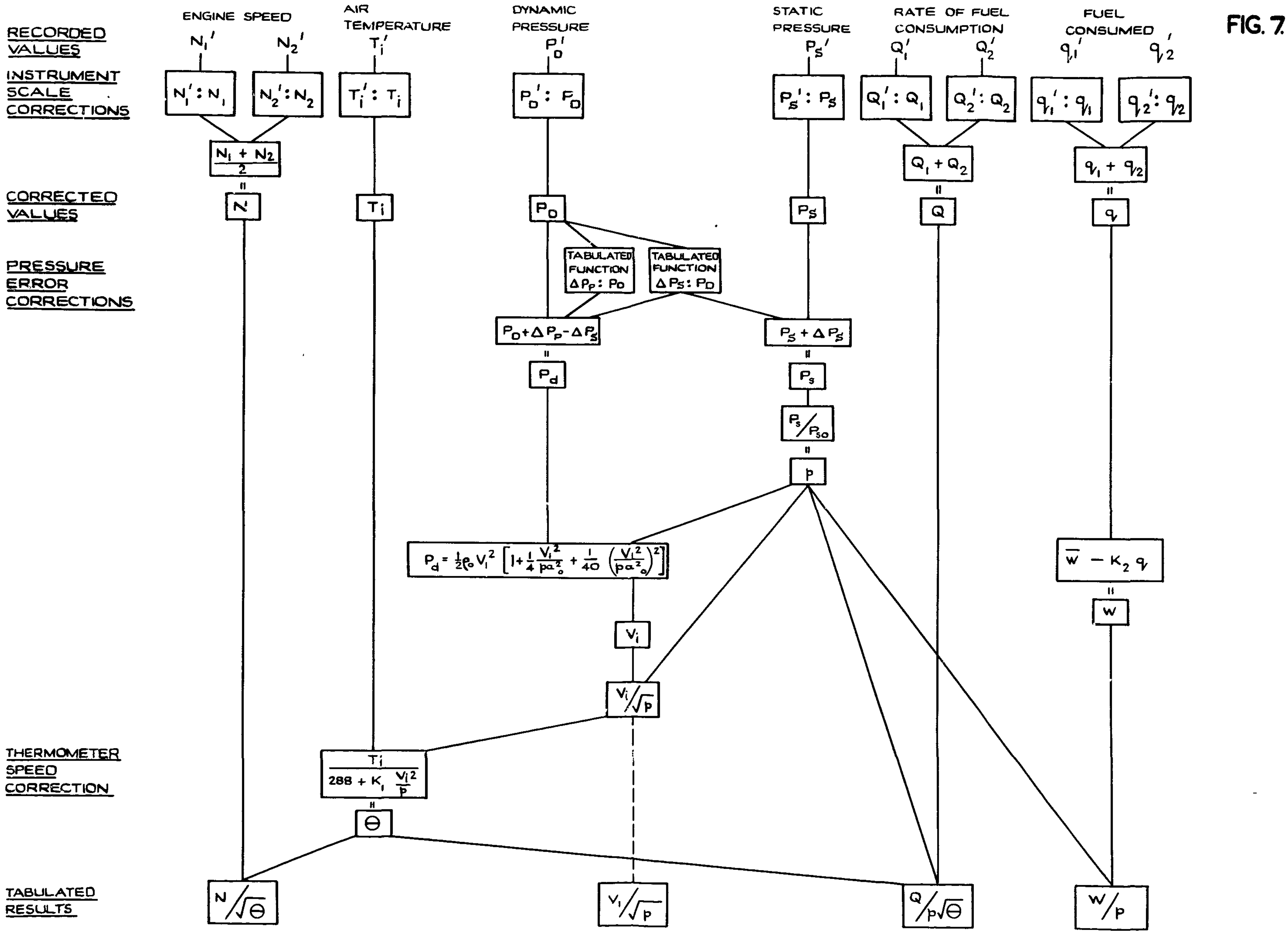


FIG.6.

RECORDER AND RECORD.



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