DESIGN, DEVELOPMENT AND CONSTRUCTION OF A LINEAR OSCILLATING ELECTRIC MACHINE

By M. S. T. Narayanan

(Department of Electrical Engineering, Indian Institute af Science, Bangalore-12)

[Received November 19, 1966]

Abstract

The paper gives a brief description of a new type of " A Linear Electric Motor ", developed and built in the Department of Electrical Engineering. A brief outline af the principles of operation of the motor is given. The use of the motor for some possible applications in Industry is also indicated.

Some test performance results are shown in relevant graphs.

Introduction

The " Linear-Oscillating-Motor " is a new development in the field of " Linear-Electrical-Machines ". The Principles of operation of the motor is based on a paper written by Prof. West and his associates at the University of Essex, England.

Based on this paper and certain other published papers on " Linear Electrical Machines ", a project work was undertaken in the Department of Electrical Engineering, at the Indian Institute of Science, to design and construct a working model of a " Linear-Oscillating-Motor ".

After some preliminary investigations, a suitable design of a working model of such a machine was developed and built successfully in the Department of Electrical Engineering.

The Machine has been subjected to a series of rigorous experimental tests, under no load and loaded conditions of operation and the Machine is found to operate quite satisfactorily to give desired results.

Description of the Machine

The working-model of the Machine is shown in the photograph of Fig. IV. A front view and an end-view drawings of the Machine are shown in Figs. I and II.

The Machine consists of a long straight rectangular laminated iron core of Transformer-silicon-steel, at both ends of which are mounted two Electromagnet-type of field coils, one at each end of the core. A suitably designed

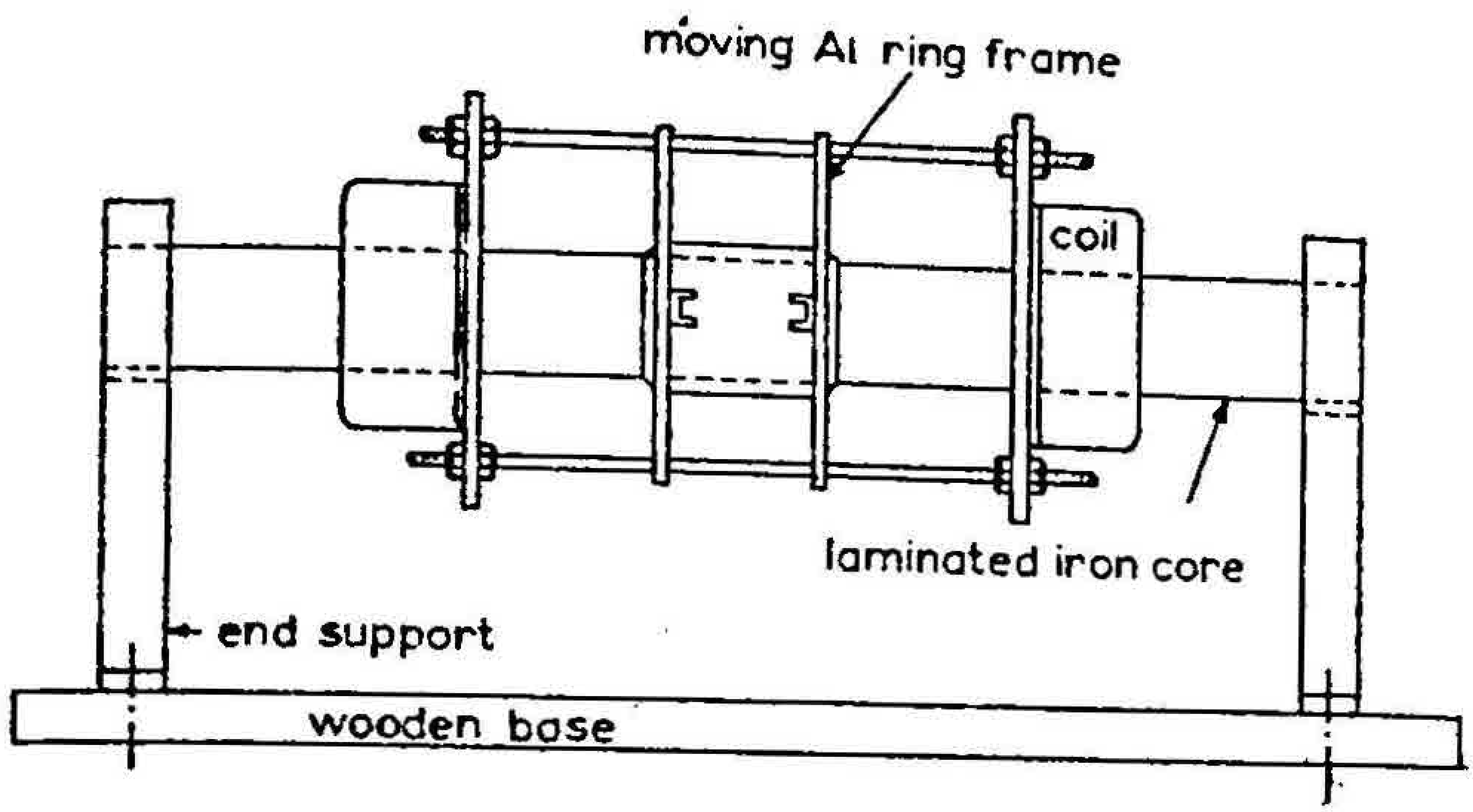

FIG. I
Front view

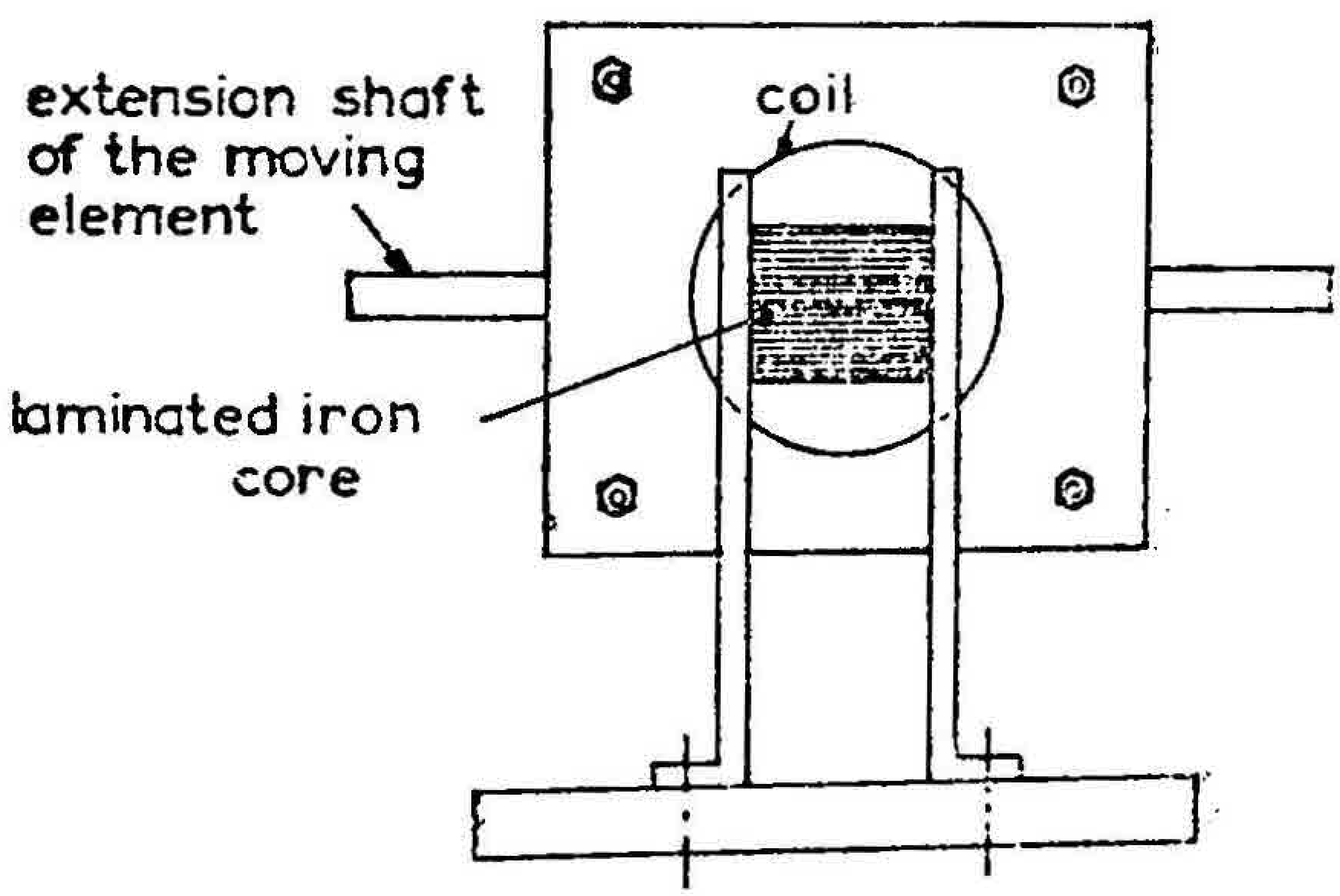

FIG. II
End view

closed aluminium ring, round the core is made to move freely on suitable guides, in between the two field coils. The aluminium ring has a small air gap all round the core. The two field coils are connected in parallel with a capacitor in series with each coil as shown in the circuit diagram of Fig. III.

A single phase 50 cycle A C. supply from 230 volts supply is given to the circuit through an A.C. variac, to obtain the necessary range of voltage variation.

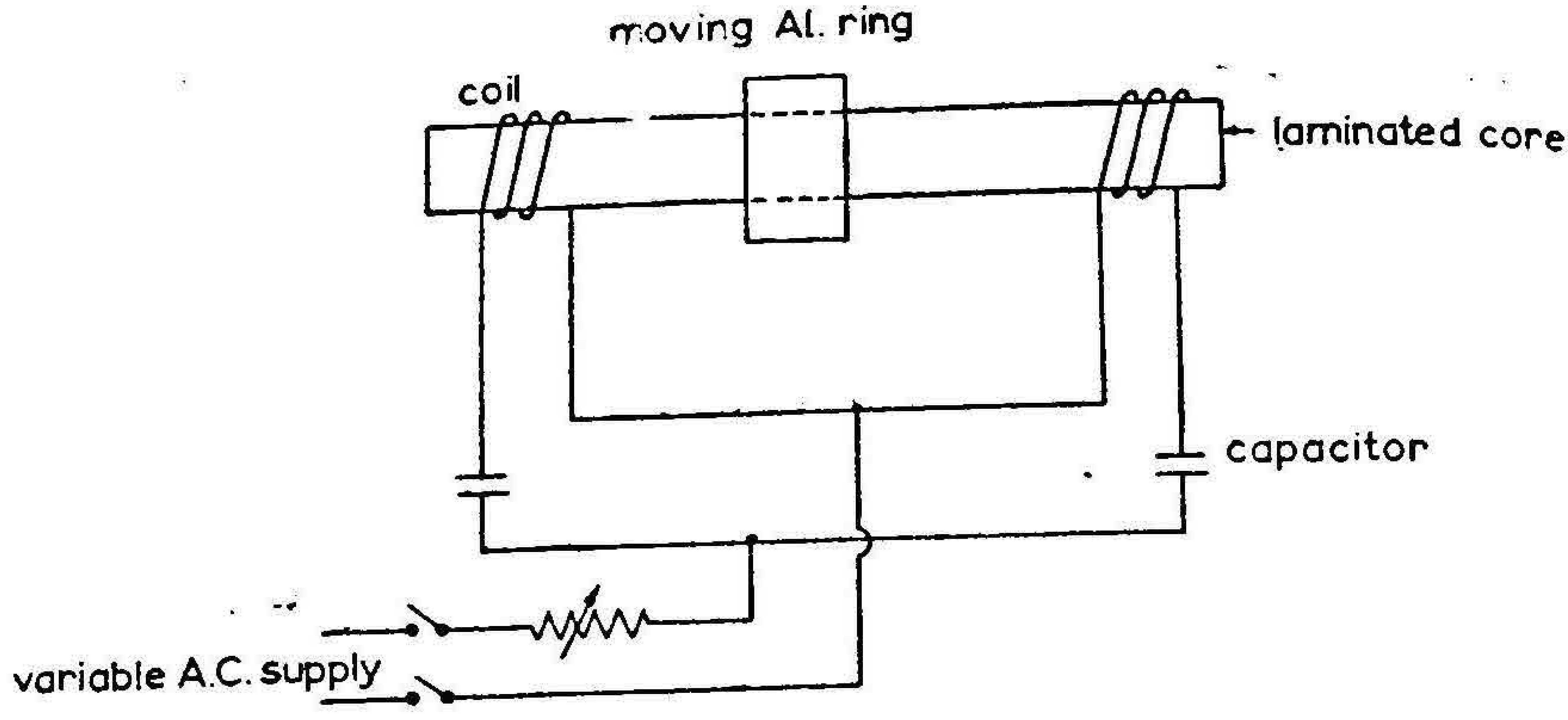

FIG. III

Circuit diagram
A Linear Oscillating Motor

PRINCIPLES OF OPERATION

Consider first only one of the field coils at one end of the core energised without the capacitors in series, and the aluminium ring situated near this coil. Currents will be induced in the ring due to the linkage of the flux created in the core material by the energised coil. The magnetic polarities between the ring and coil face will be such as to repel the ring to the other end of the core. If now the coil at the other end of the core is also energised the ring will again be repelled back to the other remote end of the core. The ring will thus be subjected to a sort of mechanical oscillations in between the two coils. When both the coils are simultaneously energised, —since the coils are connected in parallel, the forces acting on the ring will be simultaneously equal and opposite at every instant and the oscillations will damp-down after a while and the ring will take a position at the neutral zone, in the centre of the core length and remain stationary, acted upon by two equal and opposite forces.

Therefore if the oscillations are to be sustained a "time-lag" has to be created in the forces acting on the ring, from the two coils at the opposite ends of the core.

The forces acting on the ring at any instant of its travel between the two coils depend on the magnitude of the flux pulsations in the core, which in turn depends upon the magnitude of the exciting current. These forces should not be equal and opposite at the same instant, if the oscillations are to be maintained. When the two coils are energised, the distribution of the flux along the core between the two coils may be assumed to decrease from a maximum at the face of the coils to a minimum at the centre of the core, so that the linkage of fluxes in the ring is varying during the length of its travel between the two cores. Also the non-linear-saturation characteristics of the iron-core-inductor, gives rise to a variable-inductance in the circuit as the ring traverses between one coil to another.

As previously indicated in order to sustain the oscillations, it is necessary to give a time-lag to the forces acting on the ring; that is when the ring is kicked from one coil to the other coil at the other end of the core, the flux linkages with the ring due to the first coil will be decreasing, from a maximum near this coil, to a low value when the ring reaches the other coil. If the force from the other coil increases to a maximum at the instant the ring approaches this coil and the force from the other coil decreases, the ring would again be kicked back to the first coil and the oscillations will thus be sustained continuously.

This "time-lag" in the forces acting on the ring is accomplished by including in the circuit, capacitors of suitable value in series with each coil and connecting the circuit in parallel as shown in Fig. III.

The circuit then is an RLC circuit, with an inductor and a capacitor in series with it, having a net effective reactance of the value.

$$X_e = \omega L - 1/\omega C$$

When a voltage is applied to this circuit, the ring will begin to oscillate in between the two field coils, the oscillations being maintained by the time lag provided by suitable capacitors in series. The frequency of oscillations will then depend on the time lag obtained through the introduction of the capacitors and making the circuit nearly resonant, the condition of resonance being governed by the ratio of L to R of the coil. The choice of the capicitor is governed by the nearly resonant criterion of the LCR Circuit. The moving ring need not be insulated and is therefore air-cooled.

Application of the Motor

The Design set-up and the mechanical features of the construction of the Machine are entirely our own.

The Machine is entirely a new development in the field of "Linear-Electrical-Motors," and offers many useful applications in Industry, where-ever oscillatory or vibratory motions are required directly without the necessity of converting rotational motion to a reciprocating motion. The Machine will find special applications in some types of high speed bobbin winding and possibly in the movement of the shuttles in Textiles and for applications in many types of reciprocating motion; with suitable modifications in the mechanical shaft attachments, the motor will find ready use.

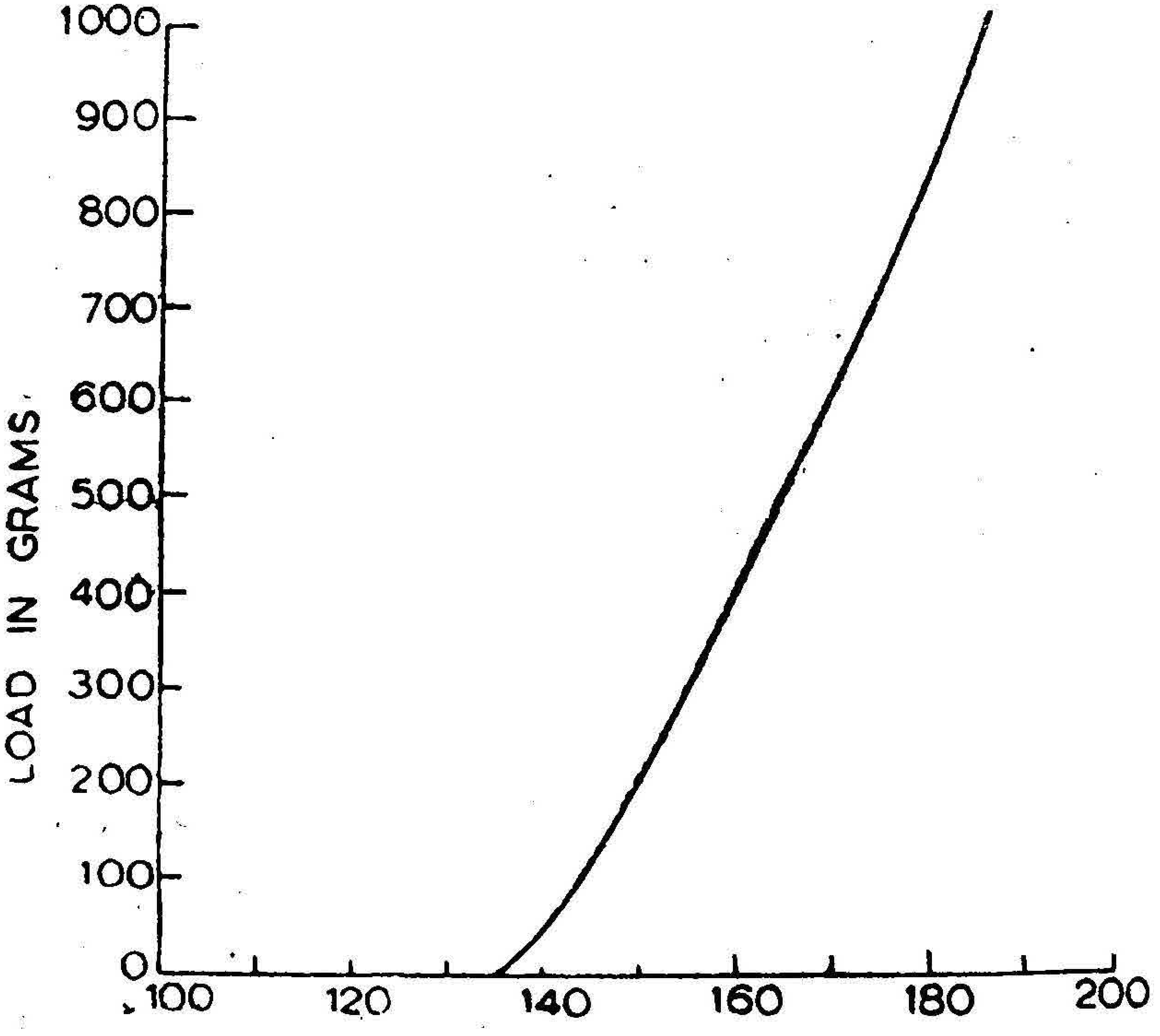

FIG. V
Minimum volts input to start sustained oscillations

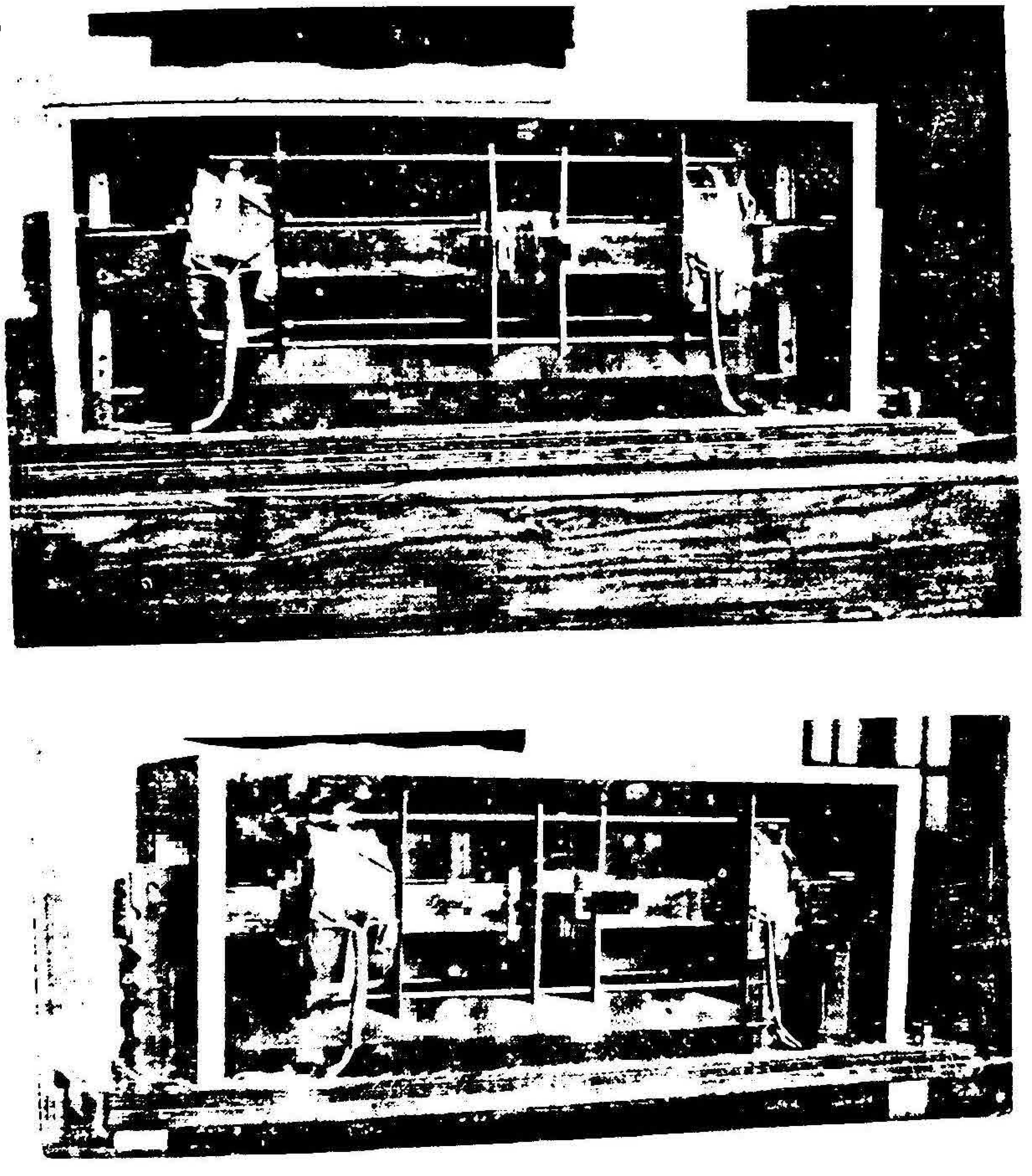

FIG. IV

A linear ocisllating machine

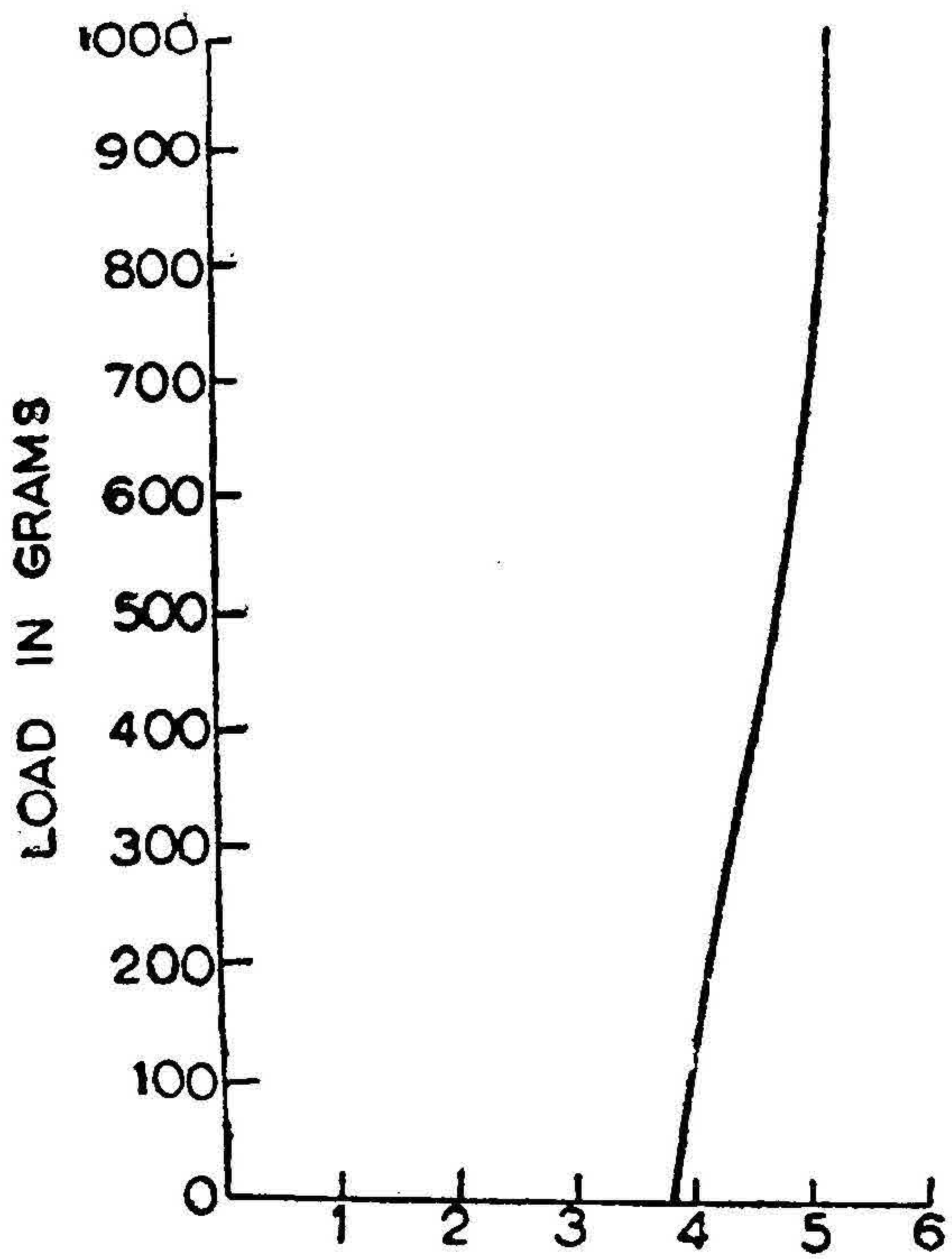

FIG. VII
Minimum exciting current Amps.

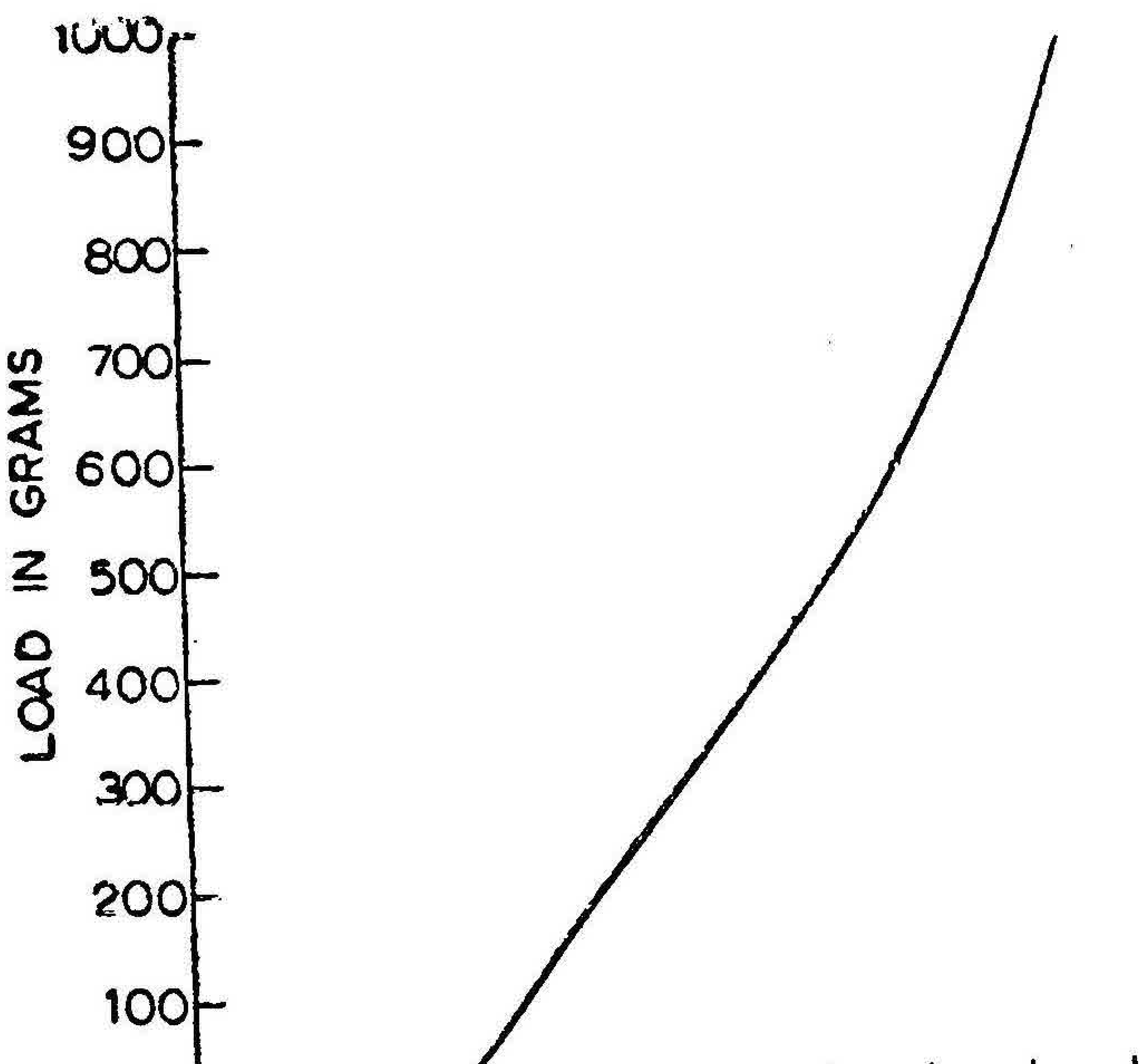

FIG. VI

Minimum watts to start sustained oscillations

The Motor works on a single phase 50 cycle low voltage variable A.C. Supply from a 230 volts mains and may be designed for any low voltage single phase A.C. supply requirements. The efficiency of the Machine cannot be expected to be high in this type of machine but the "Usefulness" of the Machine for all light reciprocating, oscillatory or vibratory motion are indeed remarkable.

The Machine is simple and robust in construction and reliable for carrying out any kind of light oscillatory motion.

It is very sensitive to voltage change and offers useful application wherever a large change in mechanical force and direct linear movement are required, for small changes in the electrical input.

The Machine is built entirely from materials available in the Indian markets and does not need any foreign imported parts.

The low efficiency is mostly due to the Magnetic circuit being, inherently, not a closed one. However, the efficiency is not much of consequence in this type of low power devices.

The efficiency, however, can be much improved with the use of low-hysterisis magnetic materials and reducing the dynamic friction in the movement of the aluminium ring by using friction free mechanical devices in the constructional set-up.

The Machine works quite satisfactorily with an input current of about 3.5 amps at no load and 5 amps at normal full load, at an input voltage range of about 135 volts at no load to about 200 volts at full load and takes about 300 to 600 watts, under normal operating conditions.

The Test performance curves of the machine are shown in Figs. V, VI and VII.

REFERENCES

1. West and Jayawant .. .. *Proc.*, 1962, **109A**, 292.
2. Laithwaite and Lawrenson .. *Ibid*, 1957, **104A**, 93.
3. —— and Nix .. .. *Ibid*, 1960, **107A**, 102.
4. M. G. Say .. .. "Performance and Design of A. C. Machines" Pitman.
5. Clayton and Hancock .. .. Performance and Design of D. C. Machines" Pitman.
6. Kuhlman .. .. "Design of Electrical Apparatus" John Wiley.
7. M. S. T. Narayanan and P. D. Gupta "Investigations in the performance, development and construction of Linear Electrical Machines" Dissertation of a Project Report for M.E. degree in Electrical Engineering, (July 1965), Indian Institute of Science, Bangalore-12.