DESIGN OF LOW FREQUENCY FATIGUE TESTING MACHINES

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Introduction

Loads applied to an airplane are not of the shock or impact type due to the inherently elastic nature of the aircraft structure. Hence we have in the case of aircraft structures, fatigue of low frequencies.

The fatigue testing machines available in the market are of high frequency type. It may be possible in some cases to reduce the frequency to the desired level by introducing reduction gears, but in such cases there is a tendency for a beat frequency to develop and this overstresses the specimen.

For investigating the effects of fatigue above the proportional limit on aircraft materials, a low frequency fatigue testing machine of the hydraulic type was built by Lt.-Commander Bull and Lt.-Commander Mastin at the Daniel Guggenheim Aeronautical Laboratory, California Institute of Technology, during 1946-47.[1] One of the authors had the experience of working with the equipment and it was found not entirely trouble free ; the hydraulic system was complicated and there were leaks now and then.[2] Hence to eliminate this trouble two fatigue testing machines have been designed and built. They are comparatively sturdy and are expected to be more trouble free.

Type A (Figs. 1 and 3) is a low frequency fatigue testing machine designed to produce compressive as well as tensile stresses in the specimen whereas in type B, only tensile stresses at a low frequency are produced.

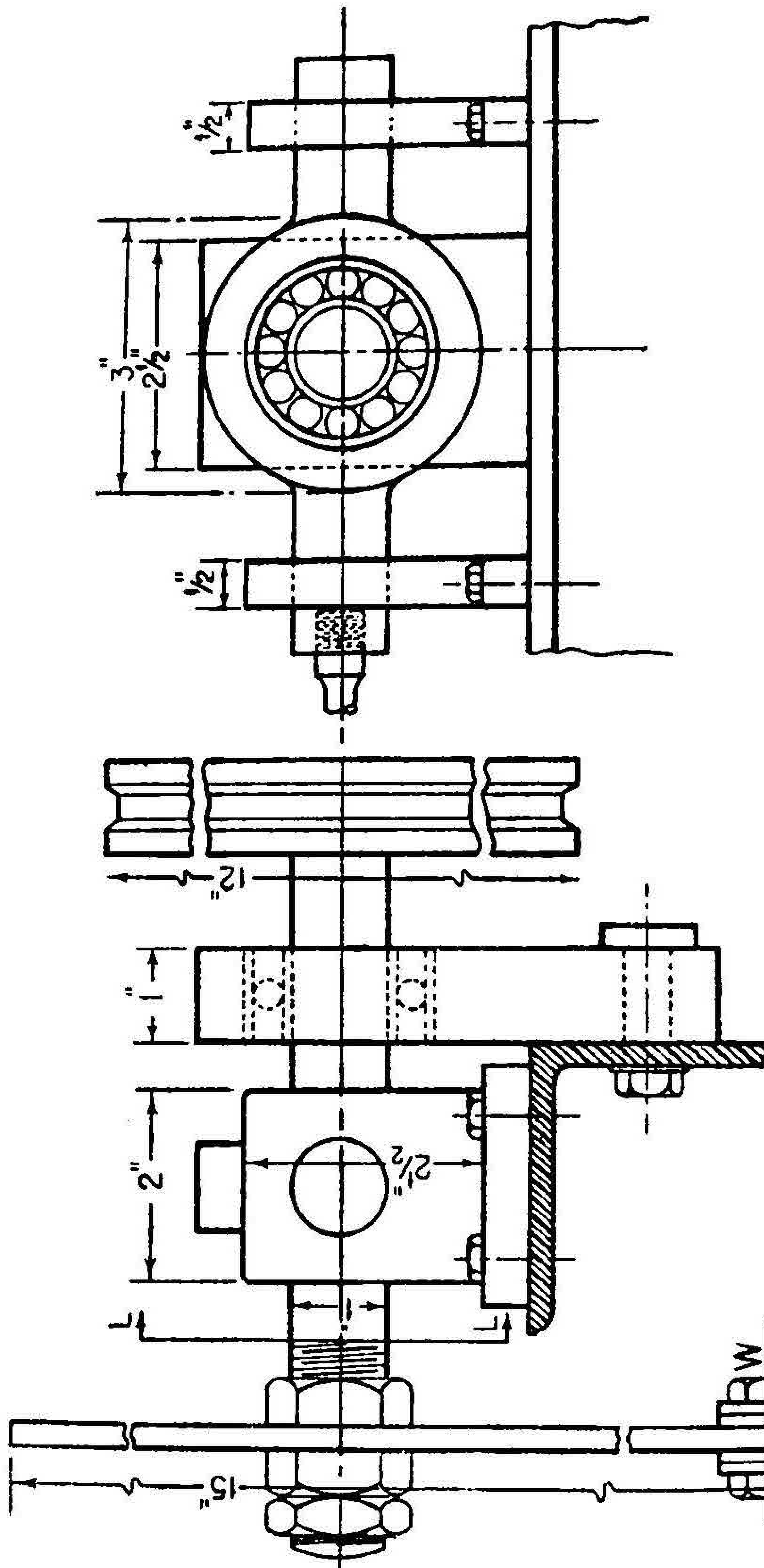

Fig. 3. Type 'A'—Low Frequency Fatigue Testing Machine for Tension and Compression.

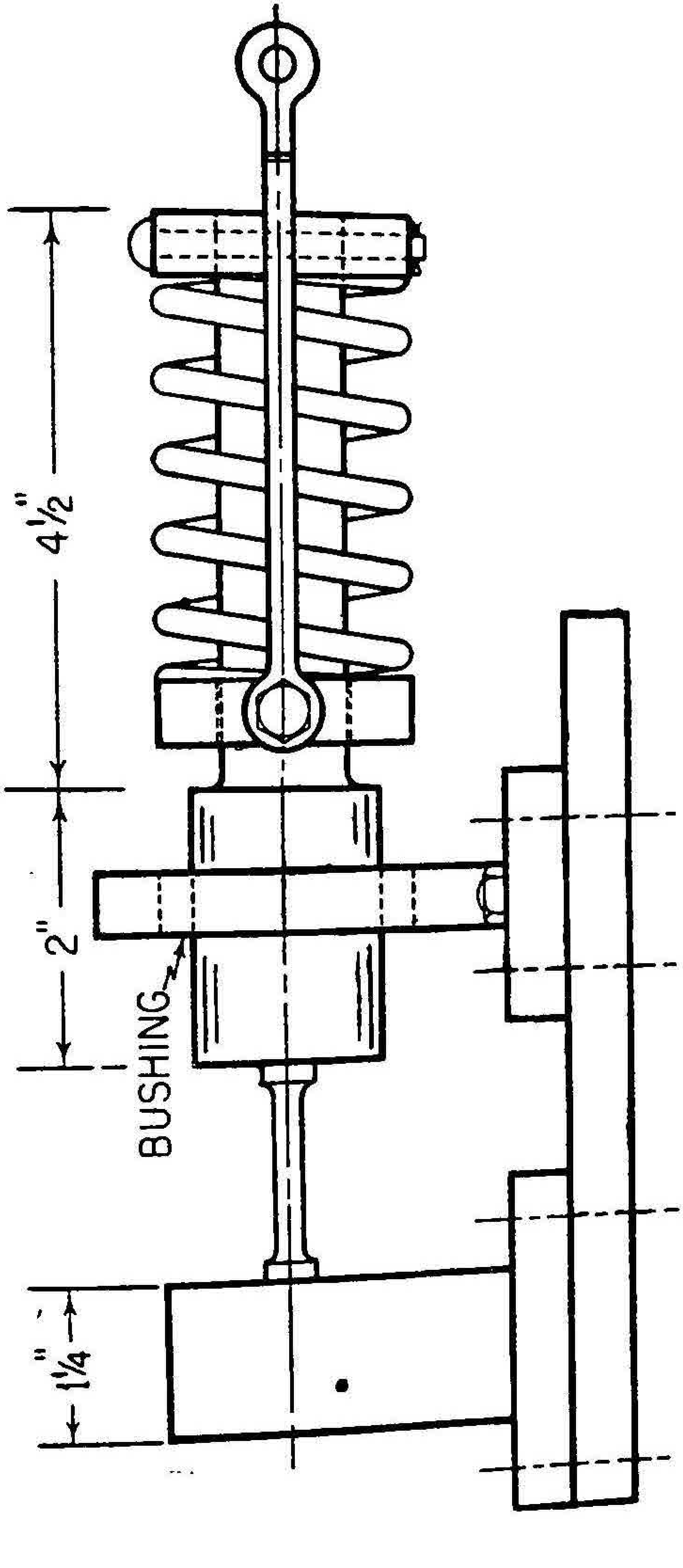

Fig. 4. Type 'B'—Low Frequency Fatigue Testing Machine for Tension

In the past decade several interesting and new features on the fatigue properties of aluminium alloys have been found. Considerable amount of work remains to be done in this field as there are a number of factors which have to be taken into account in arriving at results which can be useful to the aircraft industry.

Type 'A'

A circular disc with an eccentric mass is rotated at about 100 R.P.M. by means of an electric motor. The centrifugal forces developed by the rotating mass produce tensile and compressive stresses in the specimen.

The details are shown in Fig. 1. Here A is a disc keyed to the shaft B and carrying an eccentric weight W. The shaft is run by an electric motor by means of a belt drive. Since the shaft B passes through the part C, the centrifugal forces produced by the rotating eccentric weight W are transmitted to the specimen as tension and compression alternately through the part D. The specimen is screwed on one side to D and on the other to a fixed block E. Fig. 3 gives some of the important dimensions of the fatigue testing machine.

Calculations:

Diameter of the specimen at test section	$= \frac{1}{8}$ in.
Therefore the area of cross-section	$= 0.0123$ sq. in.
Diameter of the disc	$\doteq 15$ in.
Distance of weight W from the disc centre	$= 6$ in.

If N denotes the R.P.M. of the rotating disc the centrifugal force is given by

$$\frac{W}{g} \times \left(2\pi \times \frac{N}{60}\right)^2 \times 6 \text{ lb. or } 0.1702 \times 10^{-3}\, WN^2 \text{ lb.}$$

If σ is the maximum stress required on the specimen,

$$0.0123\sigma = 0.1702 \times 10^{-3}\, WN^2$$

$$\sigma = \frac{0.1702 \times 10^{-3}\, WN^2}{0.0123} \text{ psi}$$

$$= 13.84 \times 10^{-3}\, WN^2 \text{ psi}$$

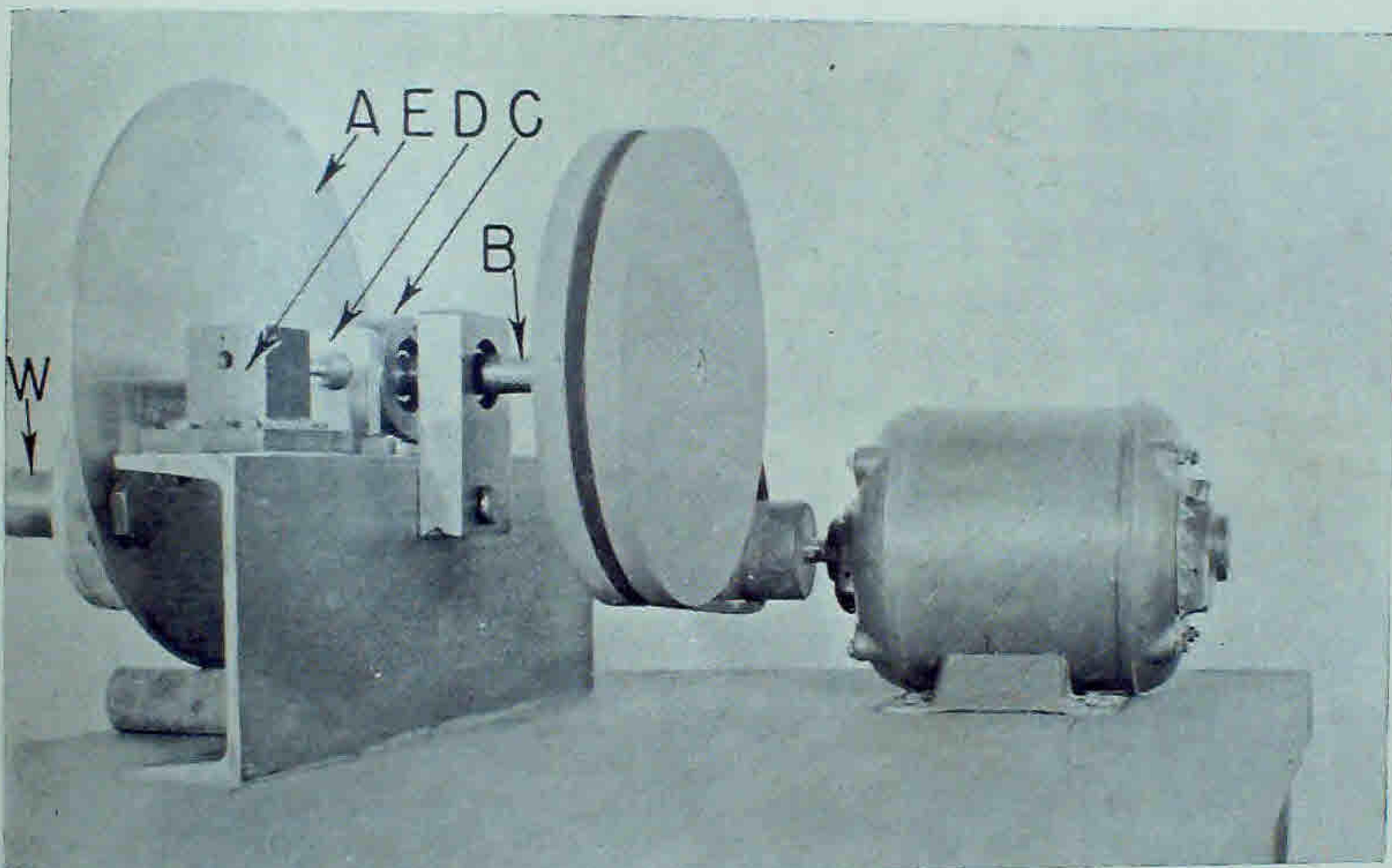

FIG. I. Type 'A'—Low Frequency Fatigue Testing Machine for Tension and Compression.

Hence for tests at any particular frequency or particular value of N, we can vary W to give us the desired maximum stress.

Type 'B'

An eccentric drive is attached to an electric motor and this is used to produce tensile stresses only on the specimen. As the elongation of the specimen during test is very small, a helical spring is used to provide the necessary movement to the eccentric.

The details are shown in Fig. 3. The specimen B is fixed on one side to the block A and on the other side to a movable rod, which passes through a bushing in block D. The spring is mounted on the movable rod and is held by the pin E. As the motor rotates, the throw of the eccentric induces compression on the spring through two rods C, C. This results in tensile stresses being produced on the specimen. Knowing the spring constant and the deformation of the spring, the force on the specimen can be calculated.

Calculations.—The diameter of the coil wire of the spring is calculated on the basis of the ultimate strength of the test specimen.

Diameter of the specimen at test section $= \frac{1}{8}$ in.

Therefore the area of cross-section $= 0.0123$ sq. in.

With an ultimate stress of 66,000 psi., the maximum stress on the specimen $= 66{,}000 \times 0.0123 = 811$ lb.

With a strain of 0.2 in./in at the ultimate stress, the extension on the gauge length $= 0.2 \times 1.5 = 0.3$ in.

Assuming a load of 1,000 lb. for spring calculations, we have

shear stress $= \dfrac{1{,}000}{\frac{\pi d^2}{4}}$, where d is the diameter of the coil wire. Equating this to the allowable shear stress of of 10,000 psi., we have $d^2 = \dfrac{4}{10\pi}$ or $d = 0.356$ in.

If n = number of coils

P = load on the spring = 1,000 lb.

R = mean radius of the coils of the spring

G = modulus of rigidity of the material of the spring and assuming the maximum compression of the spring as 1″,

$$\text{we have } \frac{64n\,PR^3}{Gd^4} = 1$$

or

$$nR^3 = \frac{Gd^4}{64P} = \frac{12 \times 10^6 \times (0.356)^4}{64 \times 1000} = 3.0$$

With $n = 6$, $R^3 = 0.5$. Hence R = 0.79″.

Hence a spring of a mean diameter of 1.5 in., coil wire diameter of 0.35 in. and a free length of 3 in. has been selected.

The design of the fatigue testing machine for compression and tension (Type A) is due to the second author, whereas the fatigue machine for tension (Type B) has been designed by the first author.

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References

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2. "*Repeated Loads above the Proportional Limit on 24ST Aluminium Alloy*", by C. V. Joga Rao—Thesis in partial fulfilment of the Degree of Aeronautical Engineer, Guggenheim Aeronautical Laboratory, California Institute of Technology (Galcit), 1948.

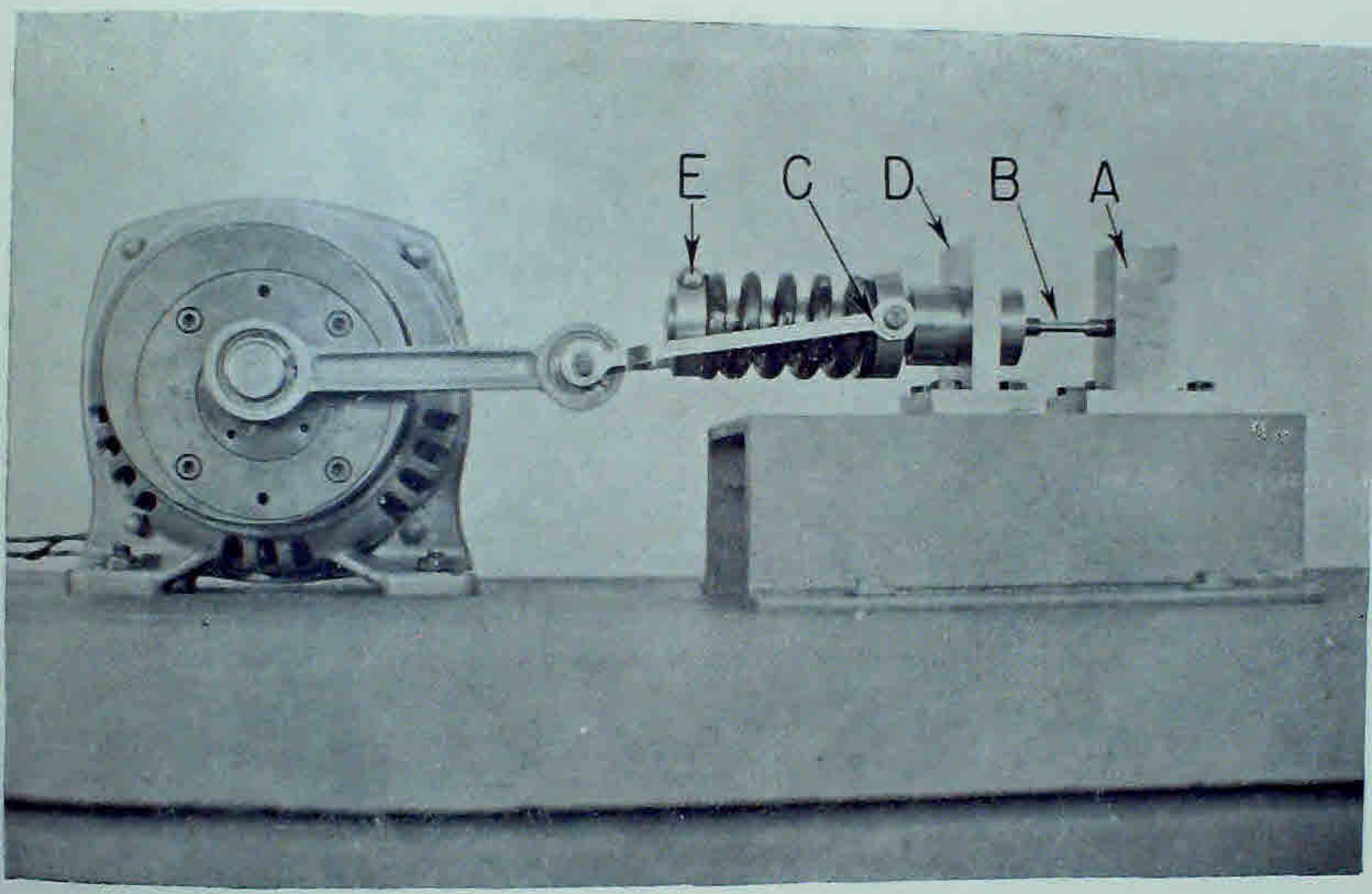

FIG. II. Type 'B'—Low Frequency Fatigue Testing Machine for Tension.