

**NATIONAL BUREAU OF STANDARDS REPORT**

3665

PROPERTIES OF CONCRETE IN FLEXURE  
AT HIGH RATES OF LOADING  
(Progress Report)

by

D. Watstein and T. W. Reichard

Report to  
Bureau of Yards and Docks  
Department of the Navy



**U. S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS**

U. S. DEPARTMENT OF COMMERCE

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NATIONAL BUREAU OF STANDARDS

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● Office of Basic Instrumentation

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# NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT

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To

Bureau of Yards and Docks  
Department of the Navy



**U. S. DEPARTMENT OF COMMERCE**  
**NATIONAL BUREAU OF STANDARDS**

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# PROPERTIES OF CONCRETE IN FLEXURE

## AT HIGH RATES OF LOADING

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### Abstract

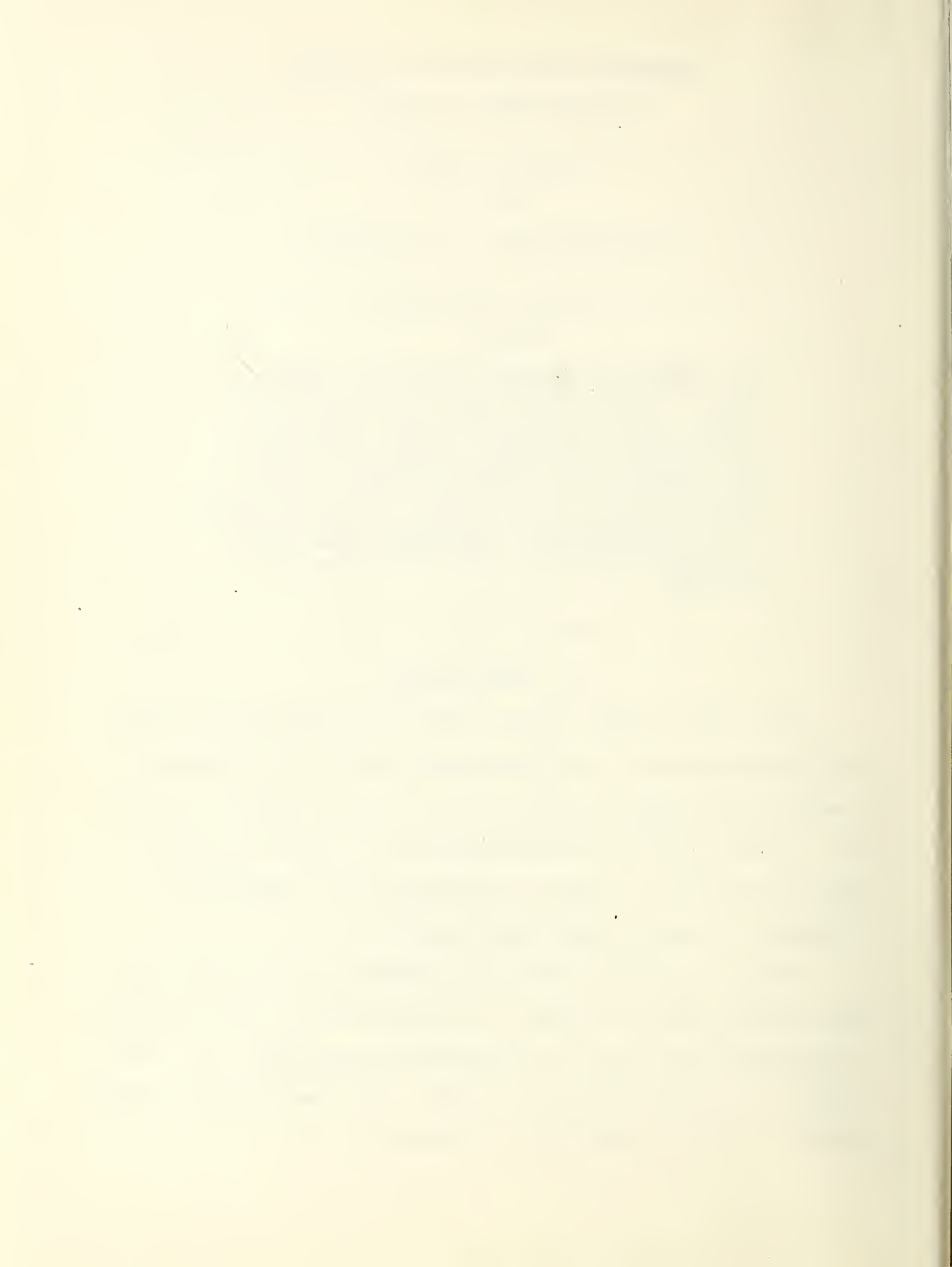
Two methods of applying impulsive loads to flexural concrete specimens were investigated. One of these utilized a drop-hammer machine and an attempt was made to produce a triangular load pulse by means of suitable buffers. The second method of producing the required load pulse utilized a spring loaded device, whose energy was transferred to the specimen in a prescribed time. Exploratory tests of a third method are in progress.

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### 1. INTRODUCTION

The object of the current study sponsored by the Bureau of Yards and Docks is to investigate the effect of dynamic loading on the physical properties of plain concrete in flexure. This project is a continuation of a previous study in which the effect of rate of straining on the compressive strength of concrete was investigated.

The work in the current investigation has been confined thus far to the development of a device suitable for applying a load pulse of controlled duration and magnitude. The load pulse was to be triangular in shape, with the rise time being about 0.1 of total duration of the pulse.



Two methods of producing the required load pulse are described. One of these utilizes a drop-hammer machine and the other a spring loaded device. It is planned to explore a third method of producing a dynamic load before undertaking a systematic study of properties of concrete.

## 2. DESCRIPTION OF TEST SPECIMENS

The preliminary tests in which various loading devices and techniques were evaluated were made with plain concrete beams 4- by 9-in. in cross-section and 44-in. long. The beams were tested on 24-, 30- and 36-in. spans.

The static compressive strength of the concrete, as determined with 6- by 12-in. cylinders, averaged about 7500 psi. It has been planned to use two different mixes of concrete in this investigation. The two mixes, classified as "weak" and "strong" concretes, were to have compressive strengths of about 2500 and 6500 psi, respectively.

## 3. METHOD OF TESTING

### 3.1 Drop-Hammer Machine

The drop-hammer used in a previous investigation<sup>1/</sup> produced a load pulse in tests of concrete cylinders whose shape

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<sup>1/</sup> Effect of straining rate on the compressive strength and elastic properties of concrete, Journal of the American Concrete Institute, April 1953.





was determined by the elastic properties of the buffer interposed between the drop-hammer and the test specimen. In the first phase of the investigation it was decided to utilize the existing impact machine to obtain a triangular load pulse by means of suitable buffers. It was hoped that a material could be found which would be sufficiently inelastic to dissipate the energy of the drop-hammer and thus produce a load pulse having the required triangular shape.

Various materials including modeling clay and sand were tried with varying degrees of success. A fine dry sand in a piston type buffer gave the most promising results as shown by the approximately triangular load pulse in figure 1b. The use of the sand buffer was discontinued, however, since the duration of impact produced with it was too short and the magnitude of the peak value of the force could not be controlled with adequate accuracy.

The device used in conjunction with the sand buffer to limit the peak value of the applied load consisted of an attachment which interrupted the travel of the hammer at a prescribed instant and served to produce a relatively long decay period in the load pulse.

### 3.2 Spring Loaded Impact Machine

This device was developed in an effort to improve control over the duration and magnitude of the load pulse. The device is illustrated in figures 2 and 3. It consists basically of



a steel coil spring which is compressed by the hydraulic ram of a 50,000 lb capacity testing machine. The compressed spring bears against the hydraulic ram at its upper end, while its lower end bears on an auxiliary crosshead where it is locked by a trigger mechanism. When the trigger is released, the loading shaft which supports the spring is shot down against the test specimen. The test specimen supported by the lower crosshead of the machine is brought up to bear against the shaft just prior to release of the trigger. It will be noted that a dynamometer and a suitable buffer are interposed between the test beam and the loading shaft.

The trigger mechanism is illustrated in figure 4. It consists essentially of a pair of 1-in. steel bearing balls spring loaded into a groove cut in the loading shaft. The groove in the shaft was sufficiently deep to permit nearly half of the steel balls to interlock with the shaft. In this manner, a slight pressure on the balls was sufficient to lock the shaft in position while it carried a large load. A simple lever system was used to relieve the pressure on the steel balls and release the loading shaft.

Some needed changes in the design of the device became apparent as the work progressed, but the basic ideas of this device have been proven sound. The device, as used now, is

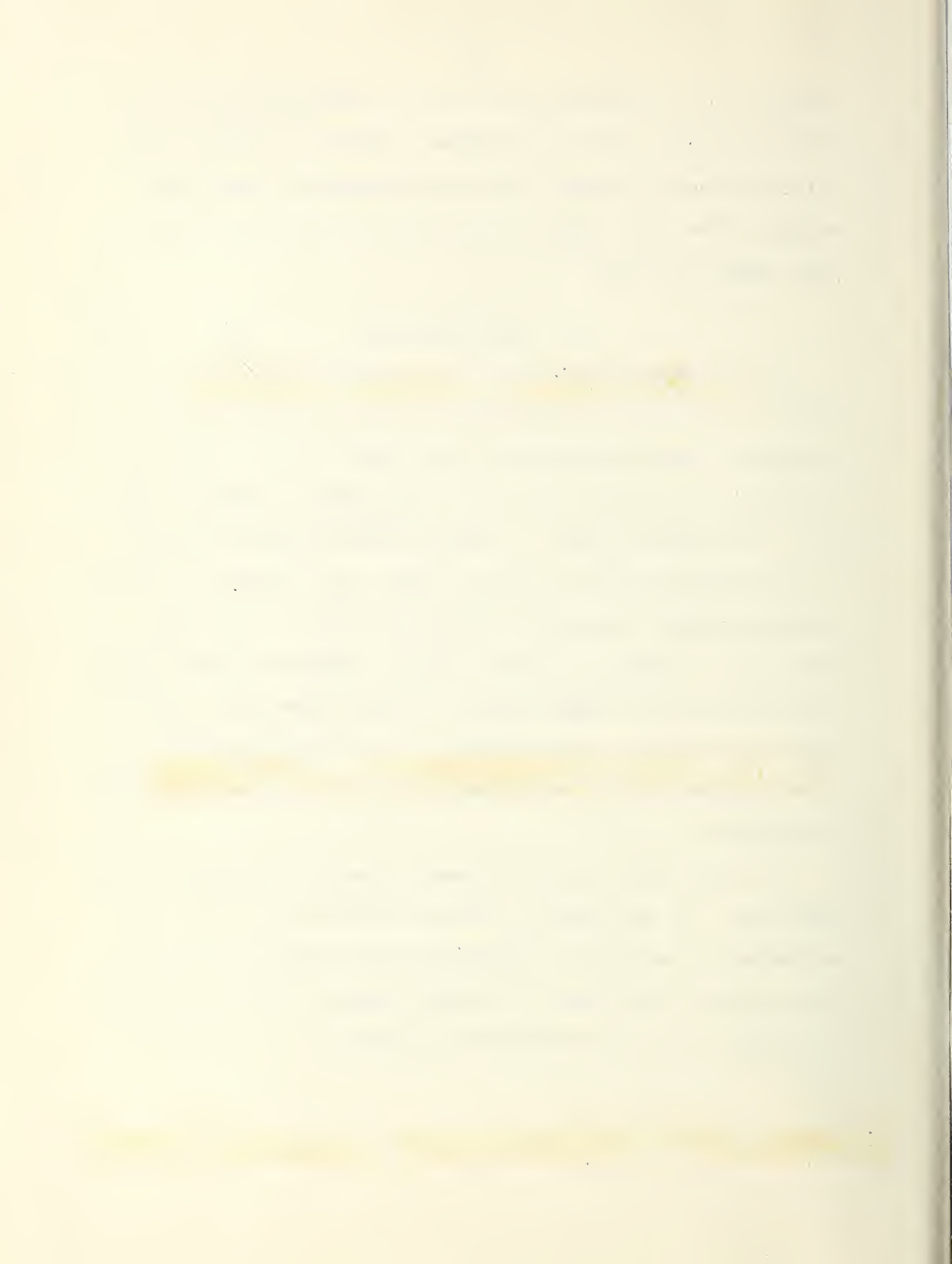


designed for a maximum load of 5000 lb which is sufficient for the flexure tests in progress. Figure 1a shows a typical test record obtained from the dynamometer using this machine. The rise time is about 0.004 sec and the decay time about 0.016 sec.

#### 4. INSTRUMENTATION

The instrumentation used in recording the applied loads and strains in the concrete beams was essentially the same as used previously in the "hard" impact tests of compressive strength made in the drop-hammer machine. (See Ref. 1 in Introduction). Slight modifications were made in the preamplifiers to improve their low frequency response and an automatic six-step calibrator (Figure 5) was constructed. A highly filtered, voltage regulated power supply was tried out as a gage circuit voltage source, but due to rapid line voltage fluctuations the idea was abandoned. A block diagram of the instruments as used at present is shown in figure 6.

At the present time a change in instrumentation is contemplated. An amplifying system reliable down to d.c. is necessary to accurately amplify the long decay portion of the required load pulse. A system using a carrier frequency of at least 10 kc is the probable answer.



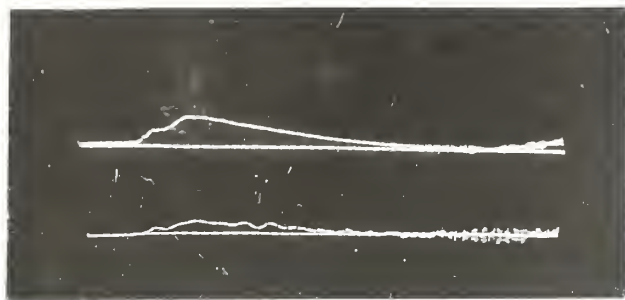


Fig. 1a TEST DATA FROM SPRING LOADED MACHINE



Fig. 1b LOAD PULSE FROM DROP HAMMER USING SAND BUFFER

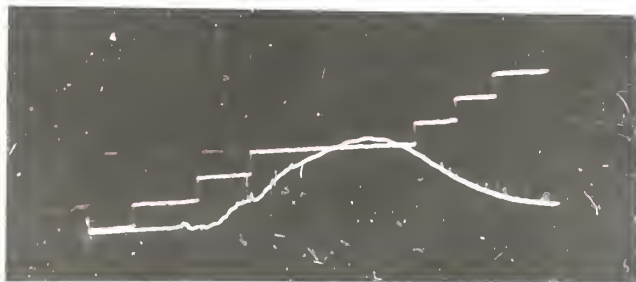
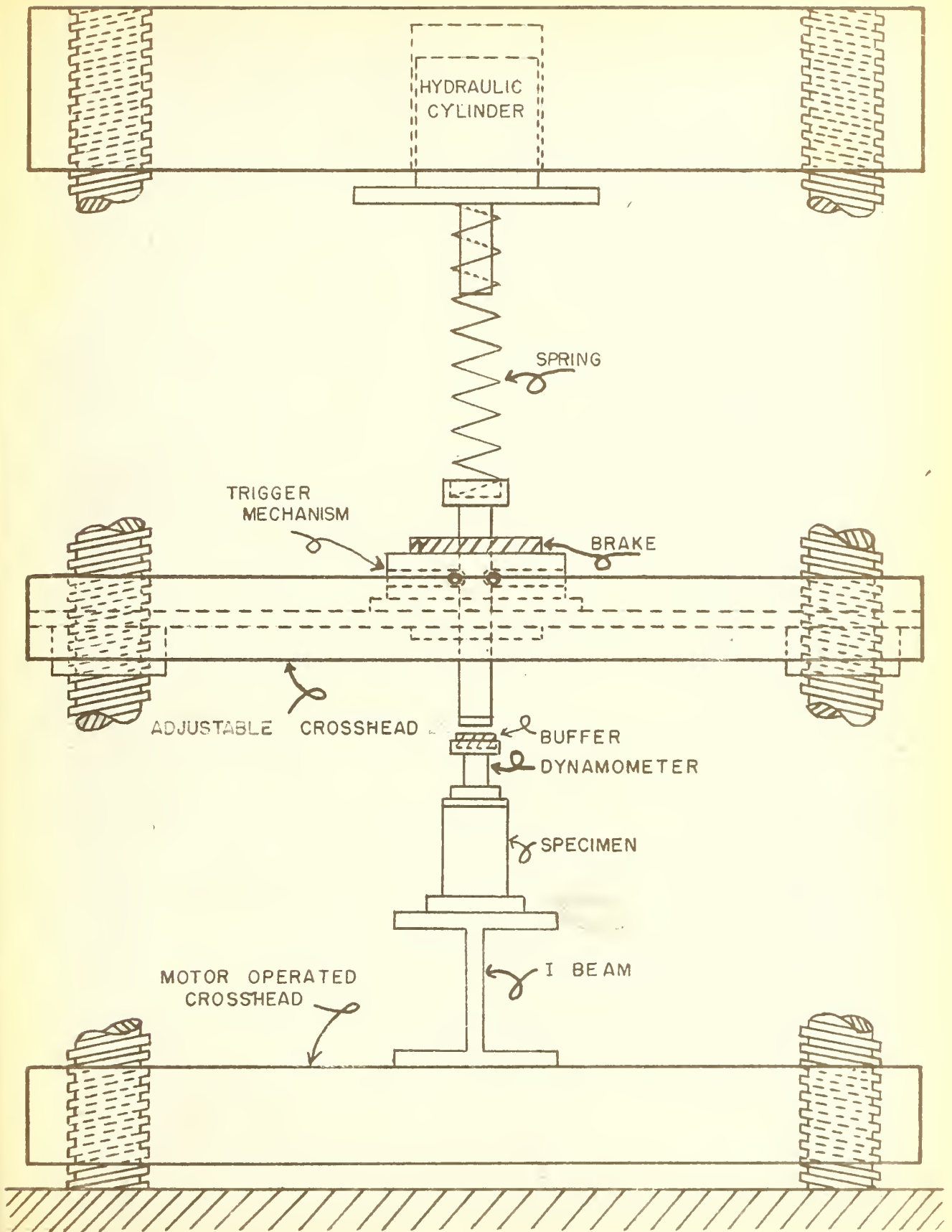


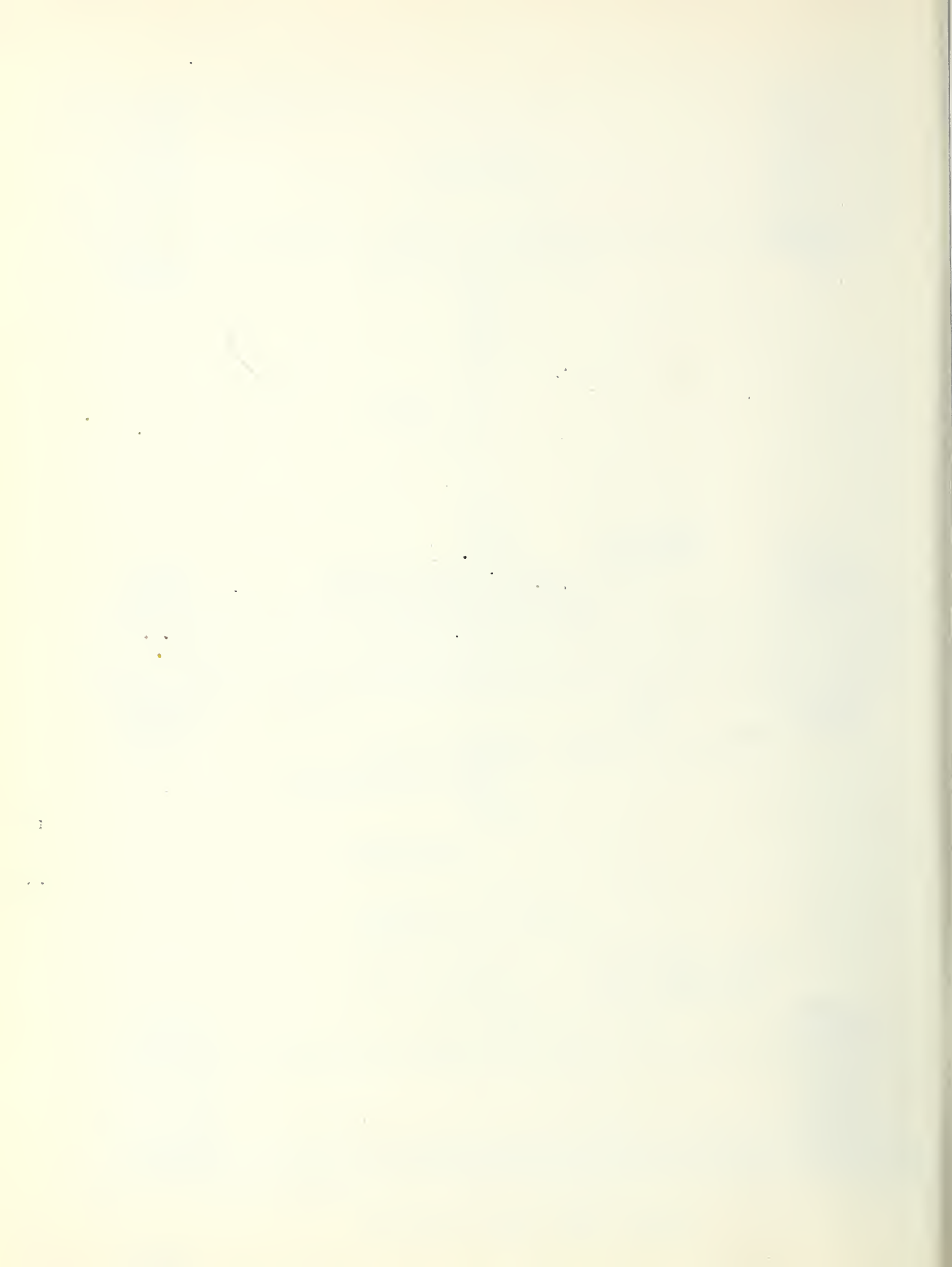
Fig. 1c SIX STEP CALIBRATION SIGNAL SUPER-IMPOSED ON LOAD PULSE







SPRING LOADED IMPACT MACHINE



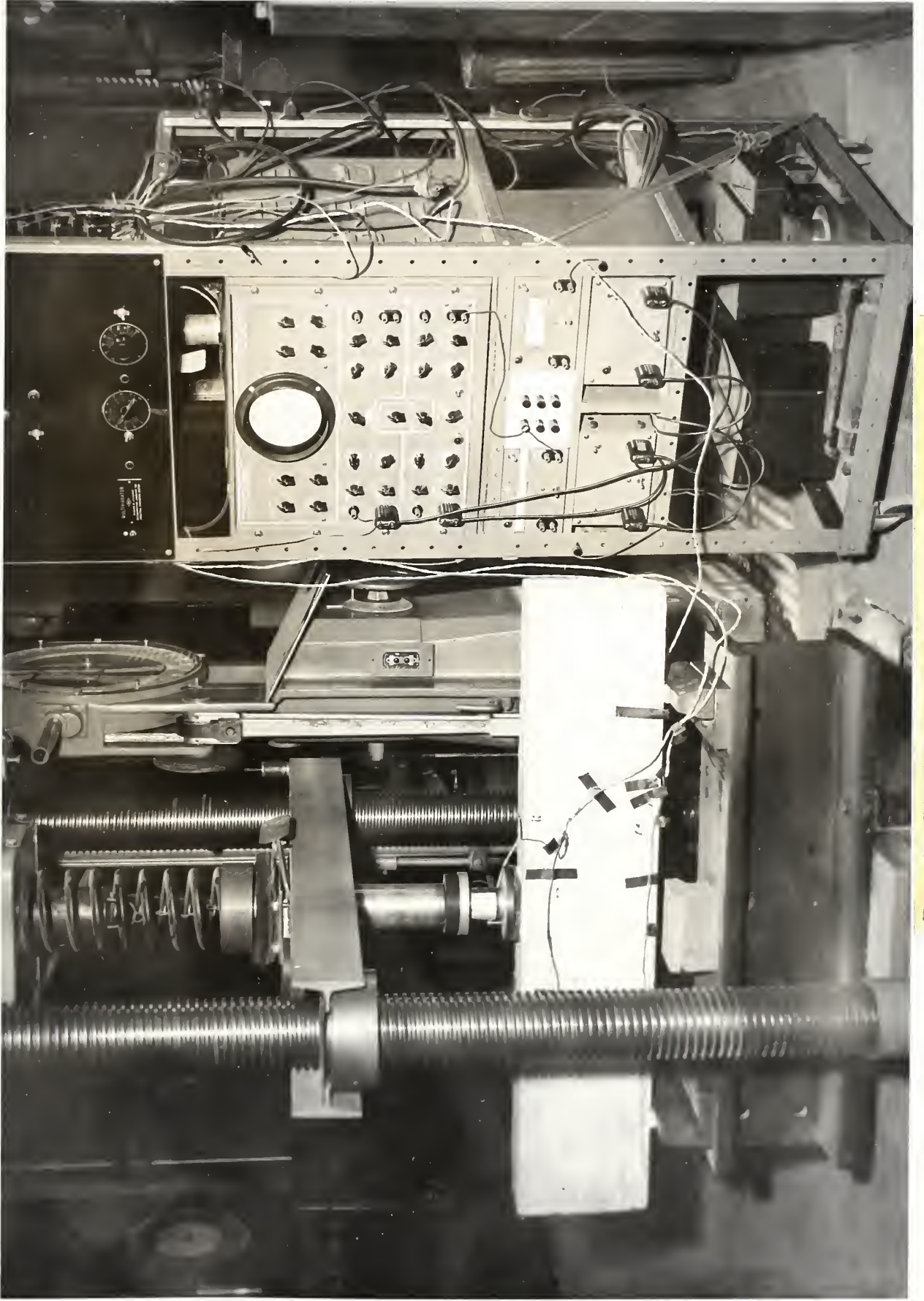
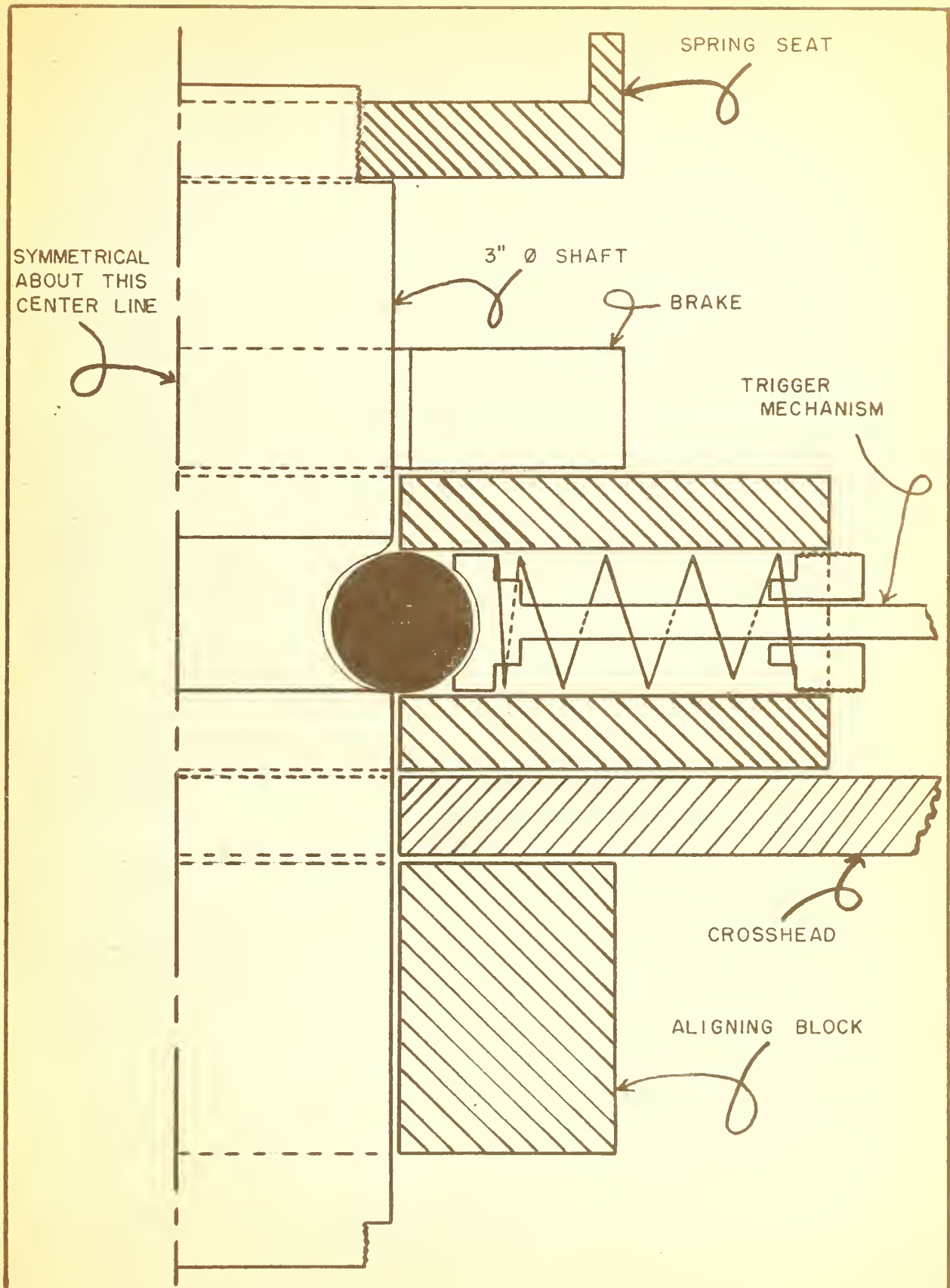


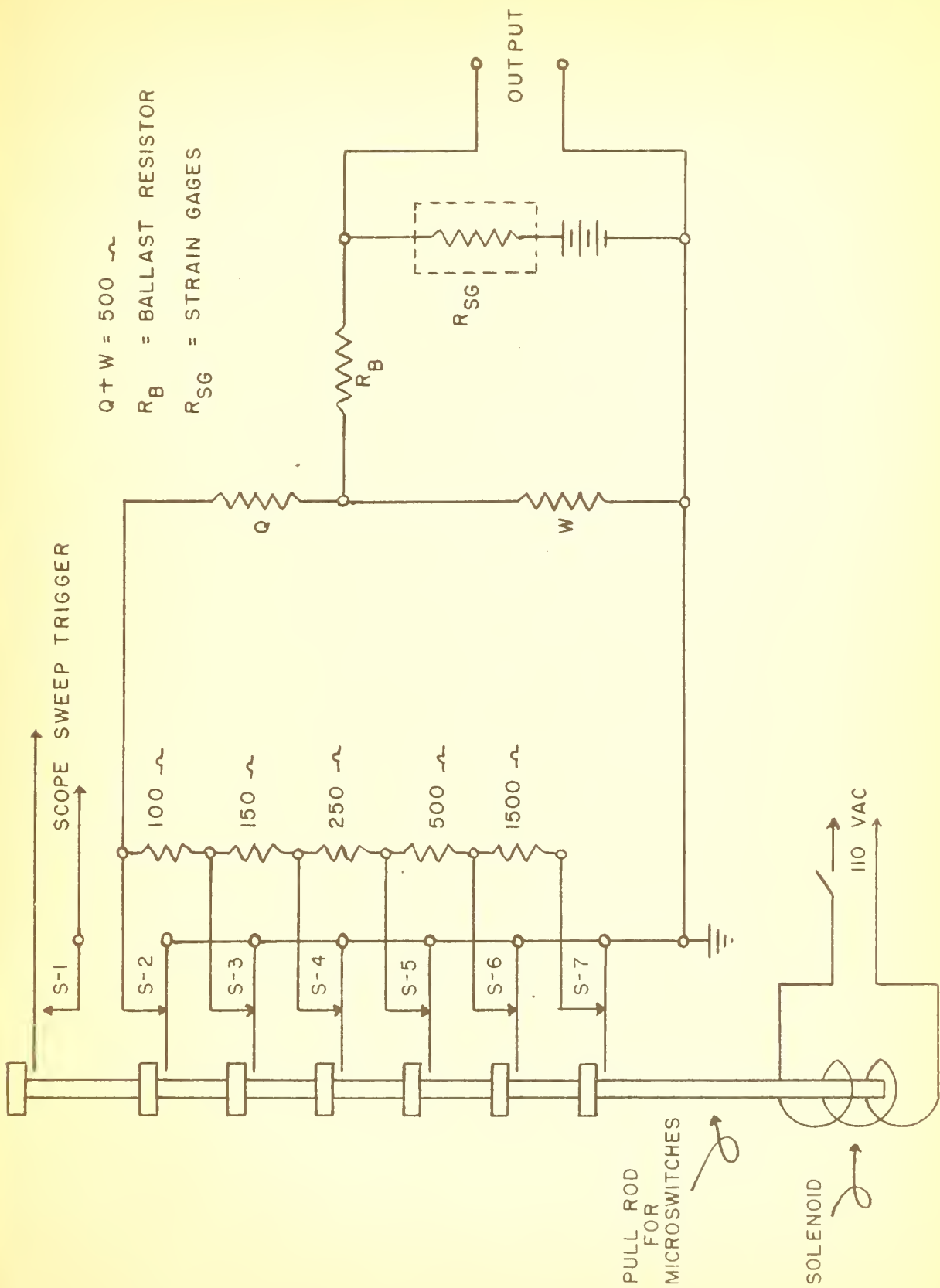
Fig. 3 SPRING LOADED IMPACT TESTING MACHINE





TRIGGER ASSEMBLY ( $\frac{1}{2}$ ) FOR SPRING LOADED IMPACT MACHINE

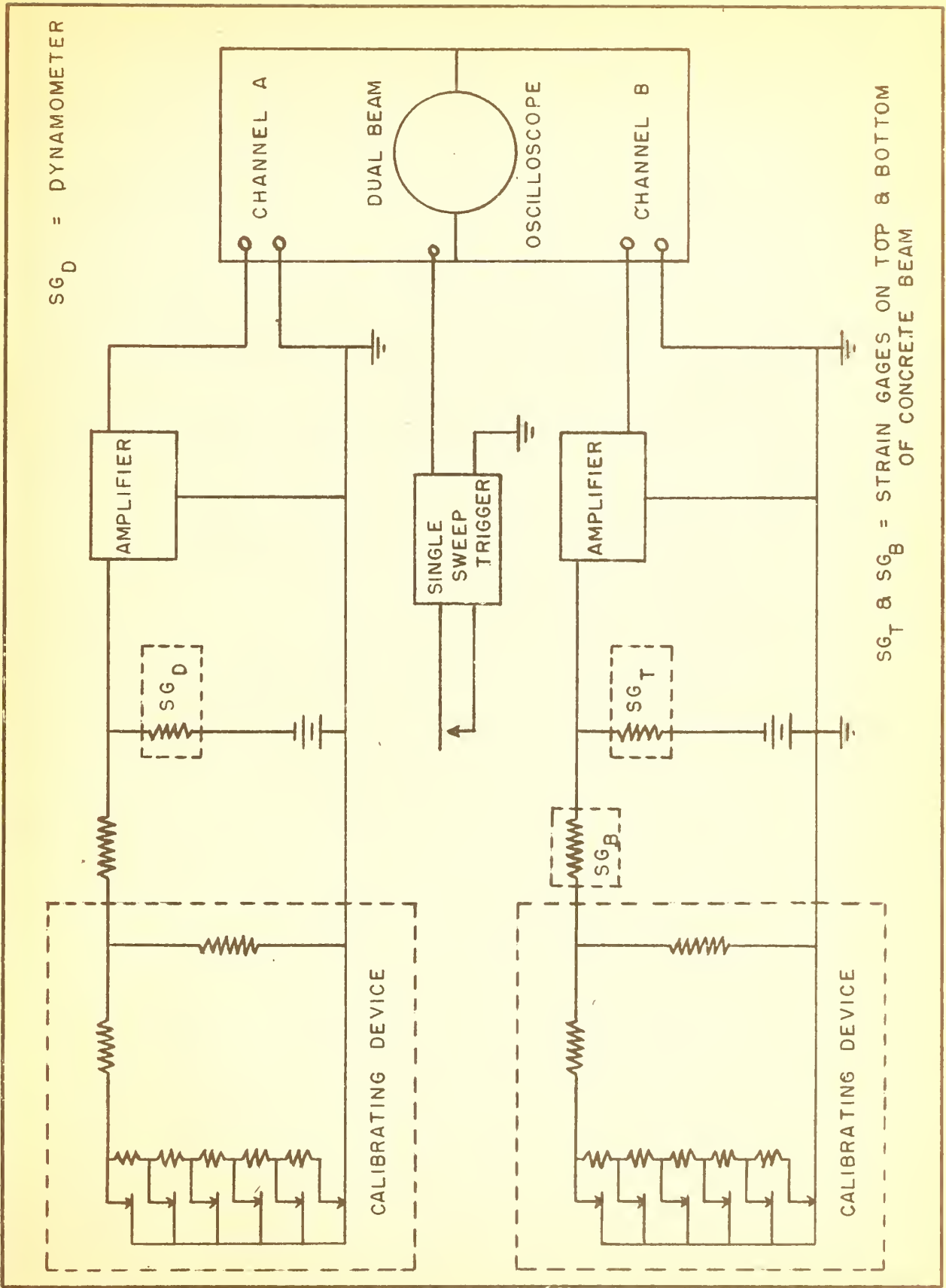




SIX STEP CALIBRATING DEVICE







INSTRUMENTATION FOR FLEXURAL IMPACT TESTS



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