TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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INSTRUMENT FOR MEASURING ENGINE CLEARANCE VOLUMES.

By

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The following Technical Note on an Instrument for Measuring Engine Clearance Volumes was designed and constructed under the direction of the Automotive Power Plants Section of the Bureau of Standards, and submitted for publication through the Subcommittee on Power Plants for Aircraft of the National Advisory Committee for Aeronautics.

A few years ago, when the gasoline engine with vertical cylinders was the well-nigh universal type, a description of apparatus to measure clearance volume would have aroused little interest. In the highest part of such cylinders there was usually located either a valve or a spark plug through the opening for which liquid could be poured. The volume of liquid required to fill completely the combustion space with the piston at upper dead center served as the clearance measurement. To be sure, it was a rather messy procedure requiring considerable time to remove the liquid when check readings were desired, but otherwise was fairly satisfactory. With the advent of the V type engine, the problem ceased to be simple. Frequently it was almost impossible to make this measurement with the engine mounted for test, as all openings were then below the highest point in the cylinder.

In the summer of 1919, Major Norman of the English Royal Aircraft Establishment at Farnborough suggested making this measurement by a process which consisted essentially of simultaneously changing both a known and an unknown volume of gas by a known amount and then calculating the magnitude of the unknown from the resulting difference in pressure between the two. To Dr. Dickinson, who was in Europe studying aviation development, the idea made instant appeal and on his return to the Bureau of Standards he started the construction of an instrument based on this principle. In the first instrument, Fig. 1, no attempt was made at refinement in constructional details as it was believed that, once the instrument was proved practical, its use would suggest such changes as would make for greater accuracy and convenience of operation. In the development of the present design, Fig. 2, Mr. C. W. Elliot has incorporated many such changes but in all major features the instrument is the same as the original built by Mr. A. R. Long, to whom much of the credit for its success is due.

The principle of the apparatus is shown in Fig. 4. If the volumes A and B are each decreased the same amount by the movement of the pistons, there will be a pressure increase in each cylinder, the greater increase occurring in the smaller volume. The pressure difference will be indicated by the difference in liquid level in the U tube connecting the two cylinders. In practice, Volume a, the clearance volume, is always unknown, while the other, Volume b, can be altered by moving piston c, Fig. 5, in or out of the measuring cylinder and its magnitude read from the scale on the piston stem. This calibrated volume is changed until the movement of the two companion pistons produces the same pressure increase in both cylinders as indicated by the liquid in the U tube remaining level. Both volumes are then equal. The above statements hold true only if both cylinders are air-tight or if both leak at the same rate. Since the engine cylinder is never strictly tight, an adjustable opening is provided to permit an equal rate of leakage from the comparison cylinder. For clearness, the simultaneous volume changes are described as taking place in the clearance and measuring volumes, whereas actually there are auxiliary volumes d_1 and d_2, connected with these in which the actual change is made, so that it is (clearance volume + auxiliary volume d_1) and (measuring volume + auxiliary volume d_2) that are changed. The addition of these auxiliary volumes simplifies the apparatus for making the volume changes and inasmuch as both are equal, does not alter the relations described above.

The actual instrument is shown in diagram in Fig. 6, in section in Fig. 3, and in the photograph, Fig. 2. For producing the changes in volumes the pistons, shown in the schematic drawing, have been replaced by the cylindrical copper bellows, A. Changes in the comparison volume are produced by turning hand wheel C, the motion being transmitted to the piston B through a gear and rack. A vernier and graduated scale on the piston stem permit the direct reading of volumes up to 48 cubic inches in steps of one-tenth of a cubic inch. Should it ever be necessary to measure larger volumes, an auxiliary cylinder can be connected to Tee, D, now closed by a pipe plug. The measurement would then be made as before except that to the reading on the piston stem should be added the volume of the auxiliary cylinder. Tank E is a check volume of 7 cubic inches, used only for calibration purposes. When the tubing is renewed, fitting F is screwed into the tank, screw G loosened, and vernier H adjusted to read exactly 7.

Measuring clearance volumes consists of three distinct steps:

1. Measuring the rate of leakage from the engine cylinder.

2. Making the rate of leakage from the comparison volume equal to that from the engine cylinder.

3. Equalizing the comparison volume with the clearance volume.

In measuring the rate of leakage from the engine cylinder, after having latched cover plate N, needle valve J is opened, leaving the right side of the U tube open to the atmosphere. Lever K is then pulled back until a considerable pressure difference is produced. The leakage rate is estimated by noting the approximate time required for the pressure to decrease a definite amount. Valve L is next opened and J closed, one side of the U tube now being open to the atmosphere and the other connected to the comparison volume. Valve M is then adjusted until the leakage rate is approximately the same as that from the engine cylinder.

In equalizing the volumes, valves J and L are both closed, the left leg of the U tube then being connected to the engine cylinder and the right leg to the measuring cylinder. When changing the volumes by means of lever K, it is most convenient to watch but one leg of the tube. If the left leg be the one chosen and the initial movement of the liquid is downward, it indicates the pressure in the engine cylinder to be the greater and its volume to be the smaller. After relieving the pressure on both sides by raising cover plate N, the volume in the measuring cylinder should be decreased. The cover plate is again lowered and secured tightly with latch O and the process repeated. The correct volume is that with which there is no change in liquid level noted at the first application of the pressure.

It will frequently be found that with the volumes well equalized, after the pressure has been maintained for a second or two, the deflection of the liquid in the U tube will increase, showing that the leakage rates have not been perfectly balanced. A few trials will readily convince the operator that it is the initial movement that should be considered in adjusting the comparison volume and that extreme care in balancing leakage is unnecessary. The explanation will be evident from a consideration of the effect of a difference as large as 10% in the leakage rate from the two volumes. For this purpose, let the rate be assumed as .03 cubic inches per second, a rather high value for the small pressure increase produced with this instrument. With the above assumption, a measurement taken at the end of one second will be in error by the difference in the amounts that have leaked from the two volumes, namely, .03 - .9 (.03) = .003 cubic inches. The sensitivity of the instrument, however, is about 1%, a difference between the comparison volume and the measured volume of this amount being required to produce a readable deflection on the manometer. The .003 cubic inch error will therefore be too small to be noticed in measuring volumes of the magnitude of engine clearance spaces. The initial manometer deflection observed can therefore be attributed entirely to the difference in the magnitude of the two volumes.

In using this apparatus, care must be taken to prevent temperature changes in either volume as a change of 3 degrees C will change the deflection a noticeable amount and hence vitiate the result. Obviously, such measurements should never be attempted immediately after operating the engine, before it has cooled to normal temperature.

To attempt precise measurements of a clearance volume without first carefully setting the piston at dead center would be utter folly. Markings on flywheel or propeller hub make this a matter of comparative ease in the majority of cases. In the absence of such markings, the clearance measuring apparatus may be connected as was done for measuring leakage with valve J open and L closed. This merely enables the U tube on the instrument to be used to measure the difference between the pressure in the cylinder and the atmosphere. Moving the piston toward upper dead center produces pressure; moving it away, suction. In the Liberty "12" one degree motion of the crank from dead center can be detected with this instrument.

In every branch of internal combustion engineering there is an insistent demand for greater economy in operation and there is at present a decided trend toward increased compression ratios as a means of meeting this demand. With the higher compression ratio the margin between normal operation and preignition is reduced and the manufacturer must exercise greater care in maintaining clearance volumes within close limits. To accomplish this, suitable measuring apparatus will be required and it is in accordance with a policy of anticipating the needs of the industry that the instrument described above has been prepared.

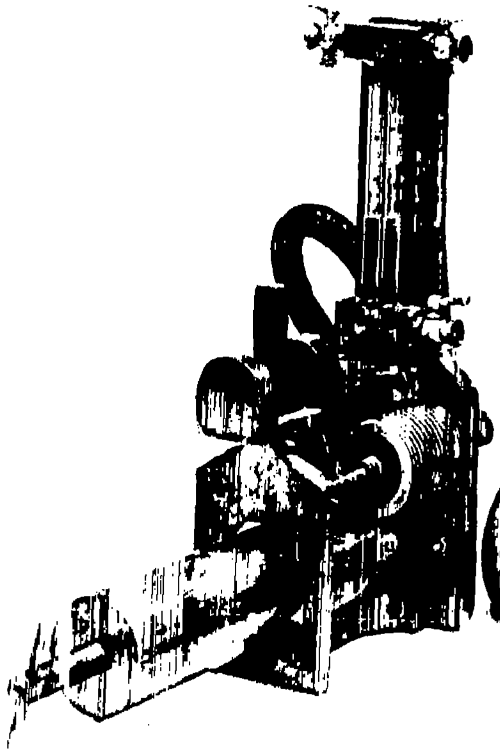

FIGURE 1.

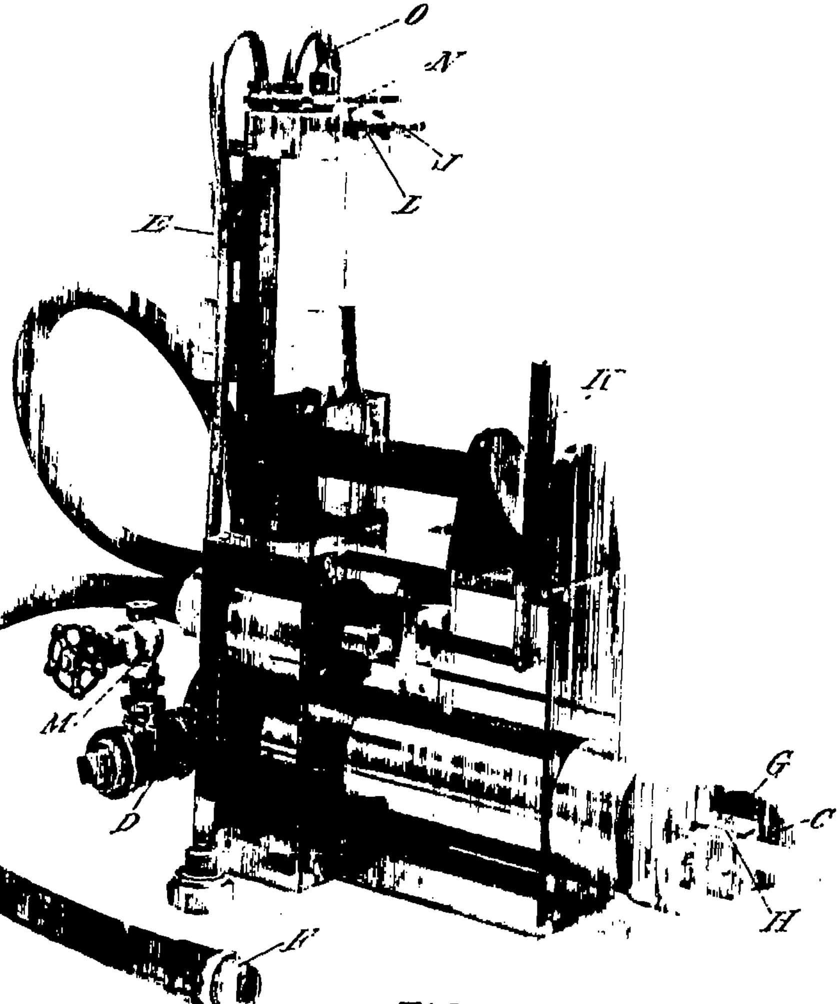

FIGURE 2.

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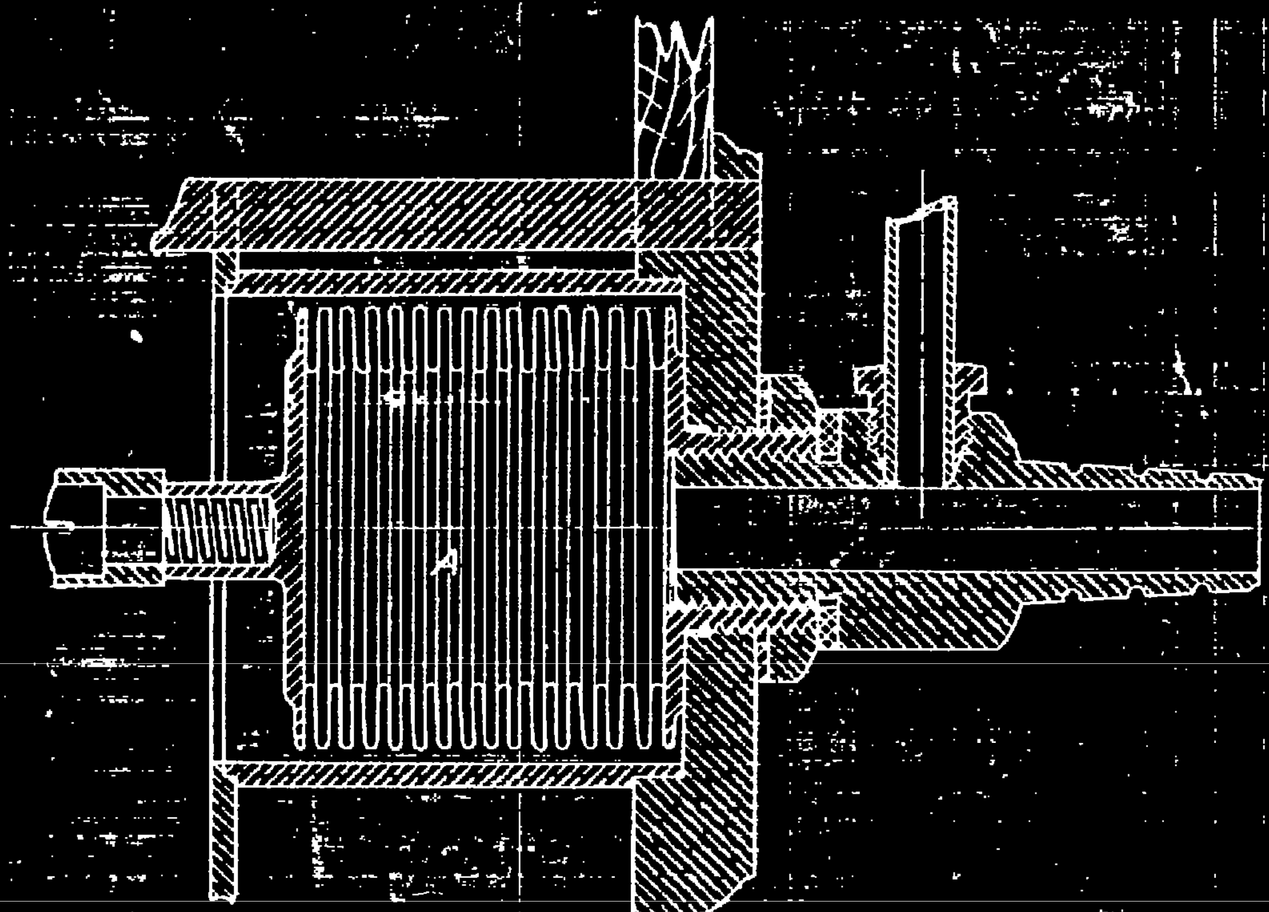
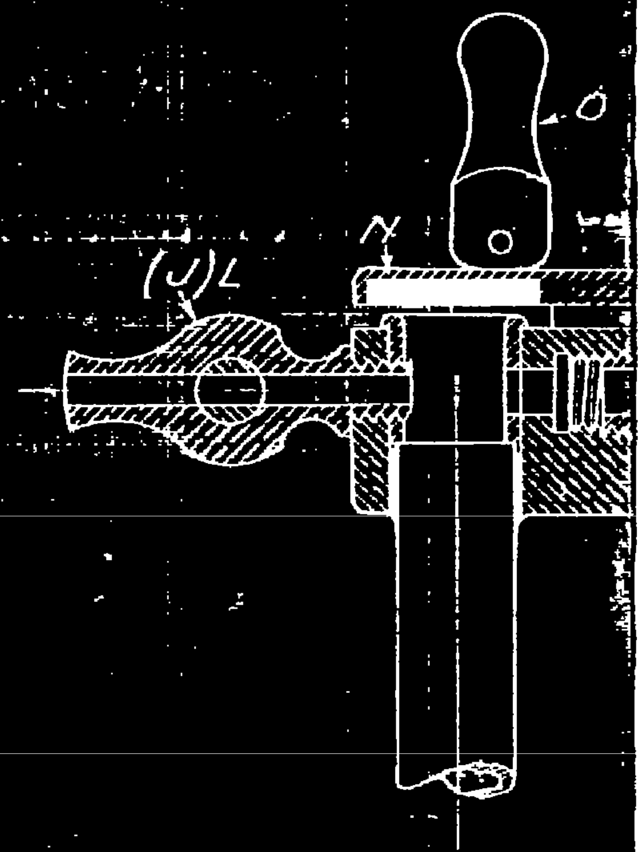
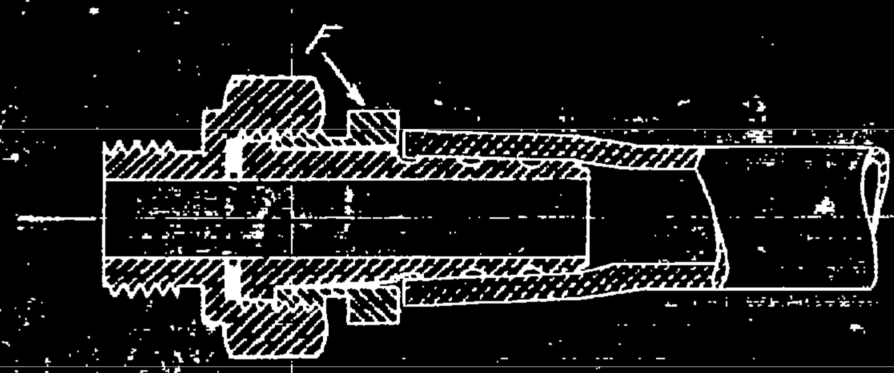


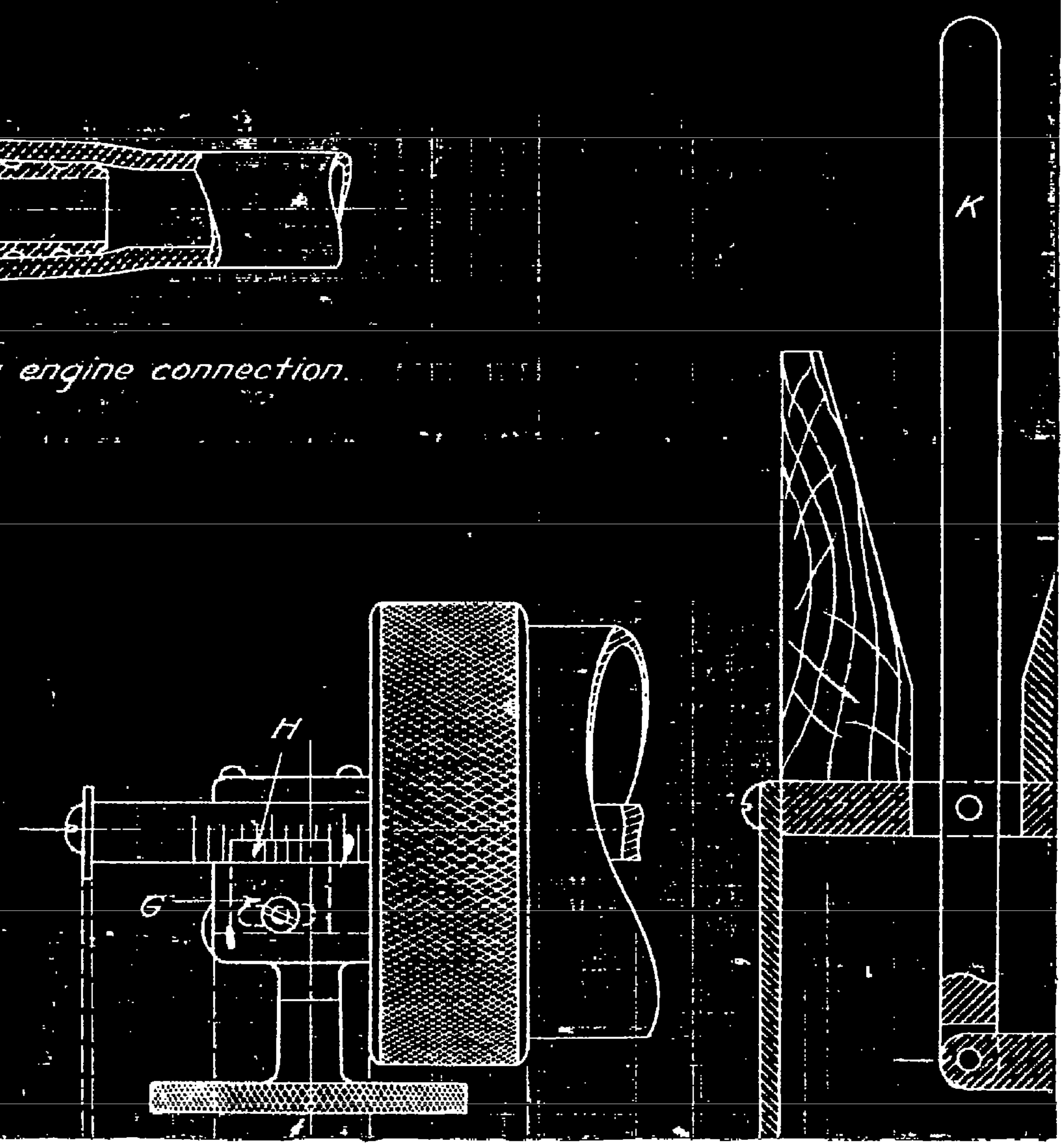
Section thru bellows (A).

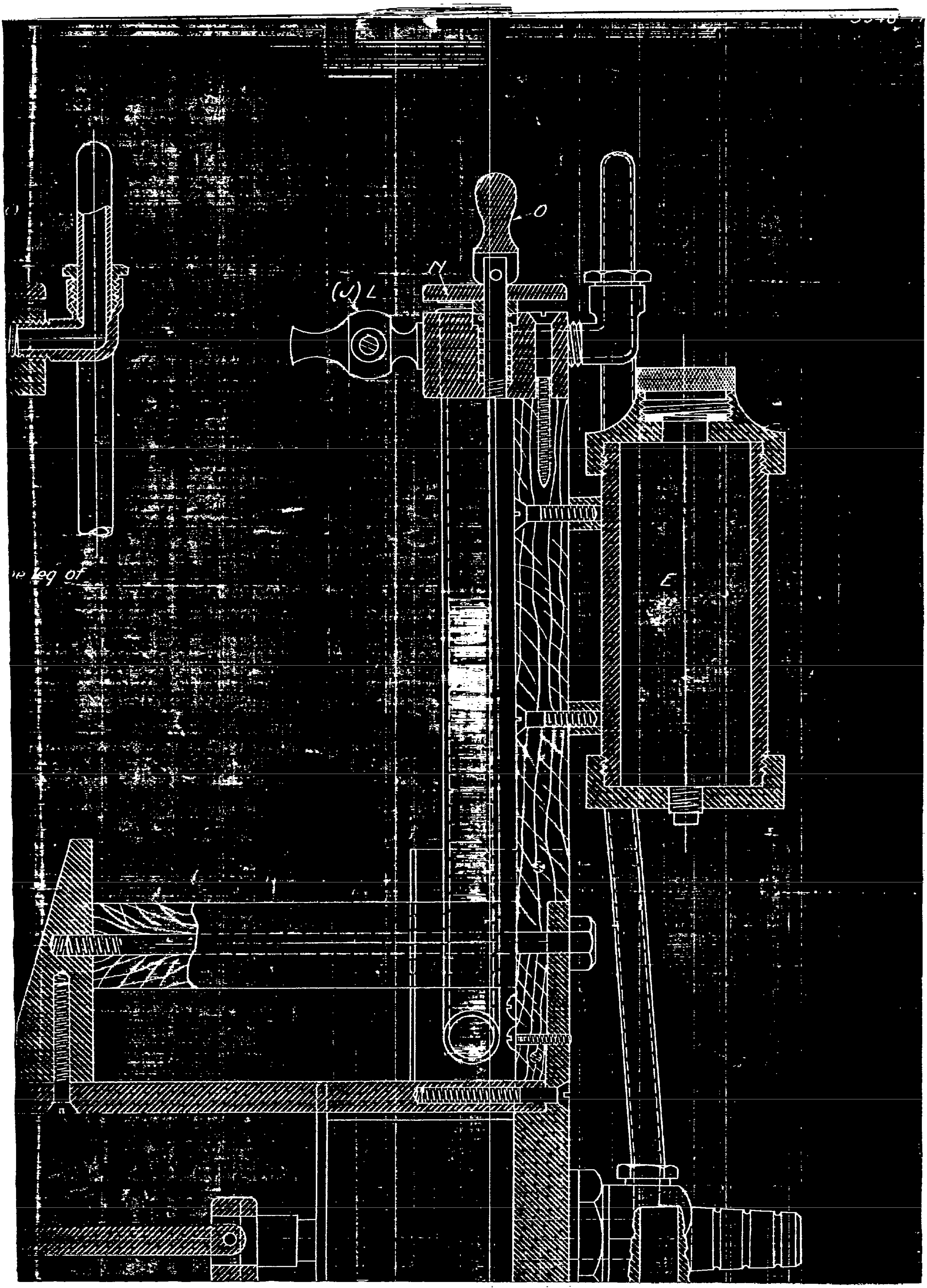


Section thru top of one U-tube.



Section thru engine connection.





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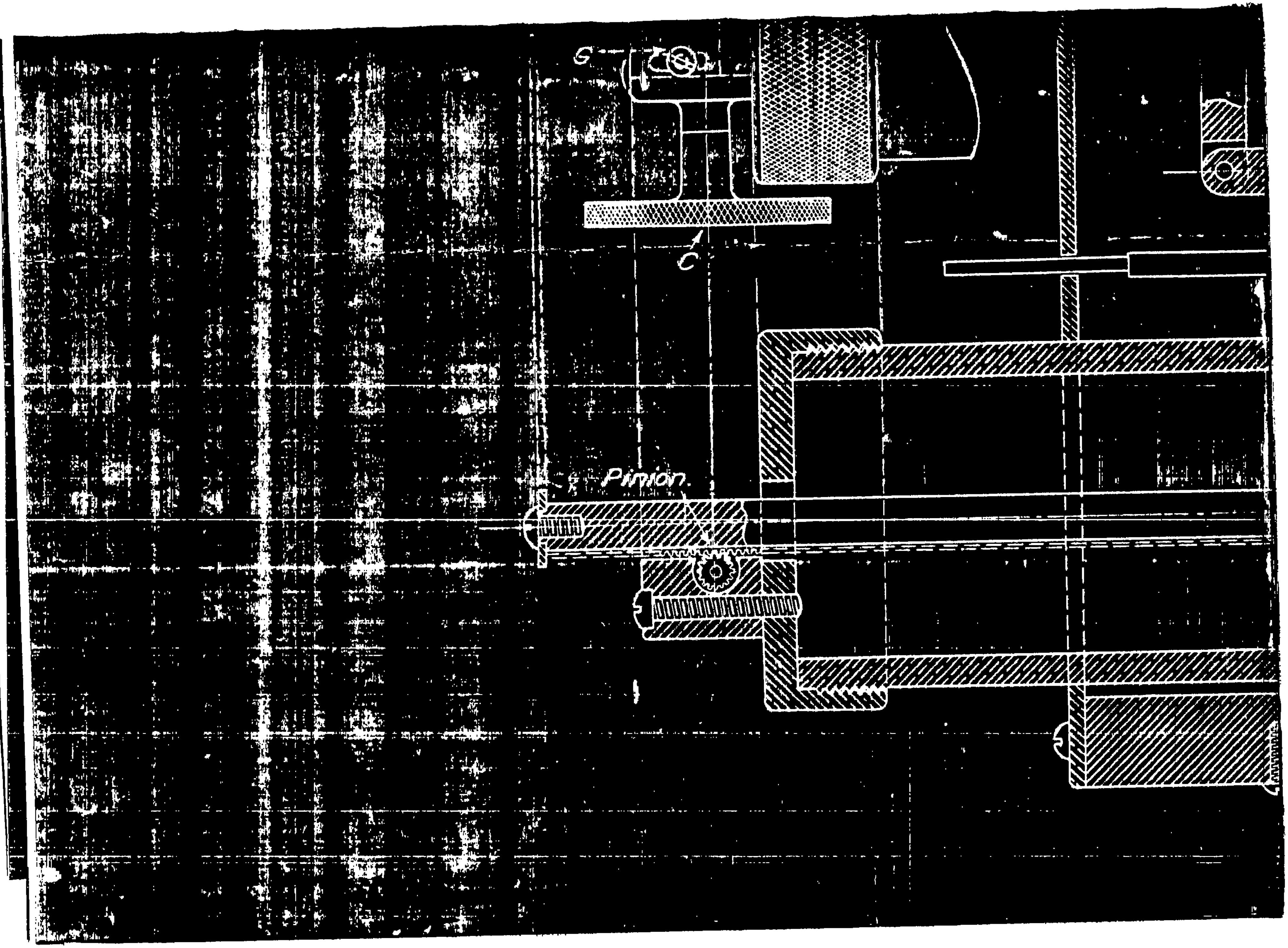
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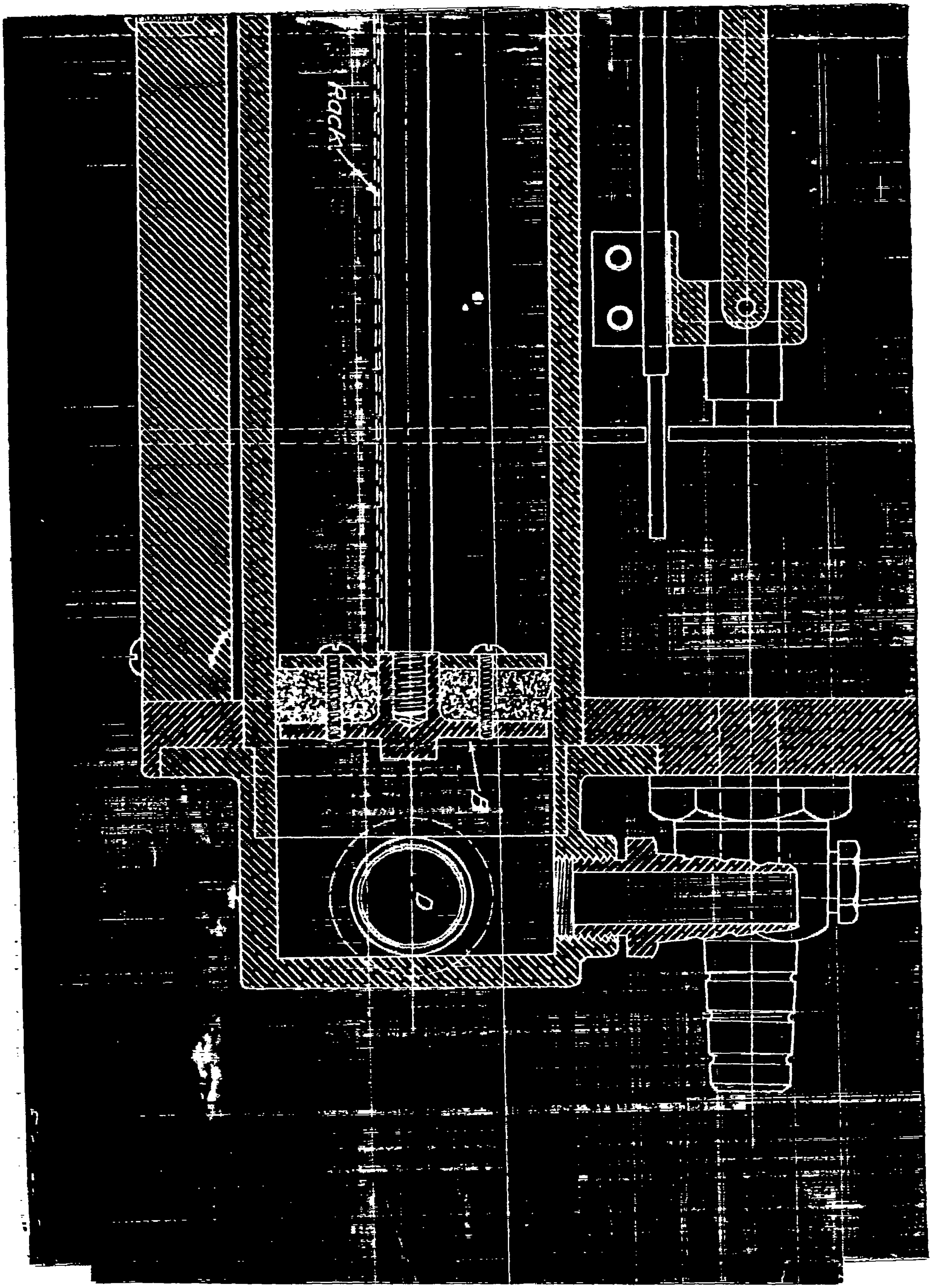

Rack

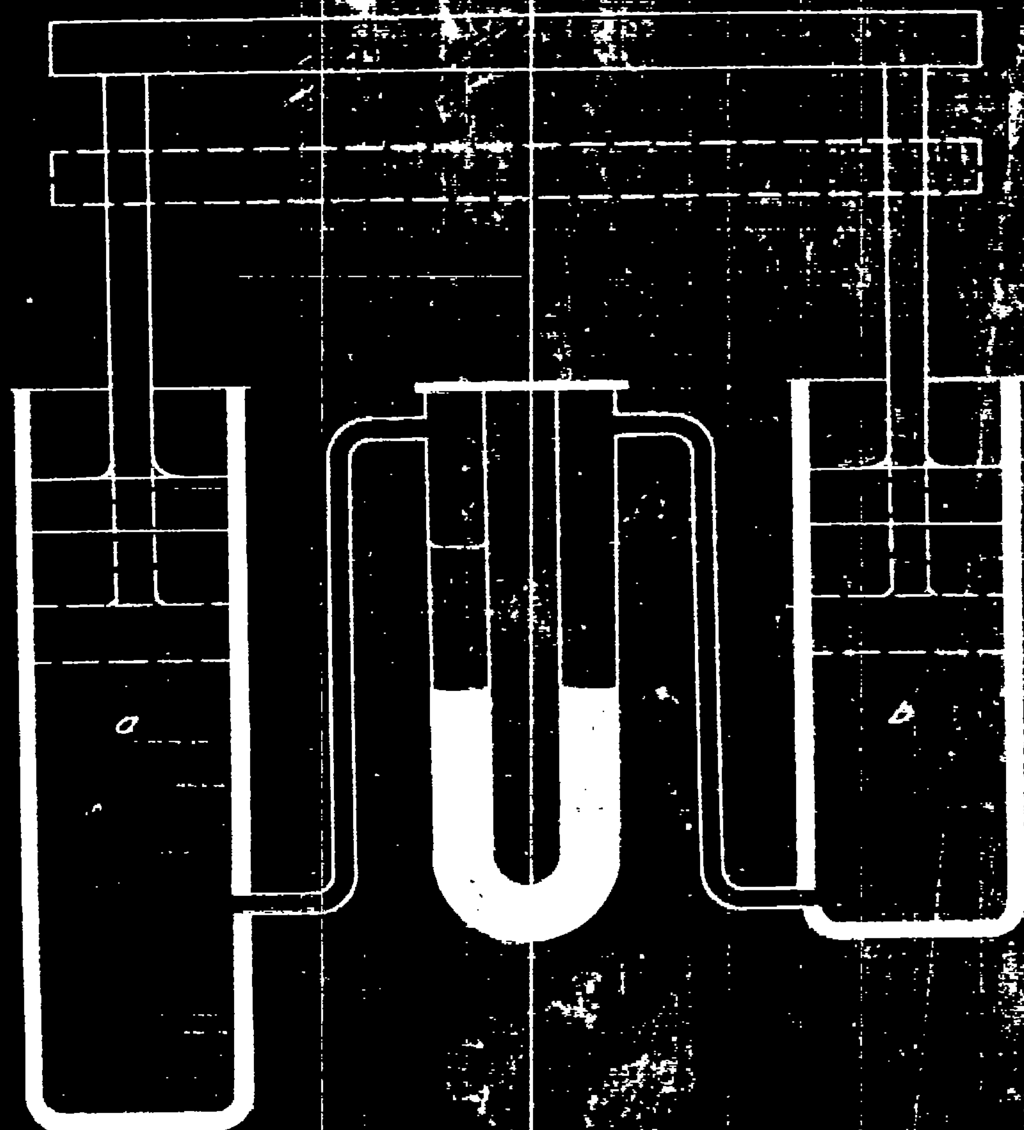

Figure 4.

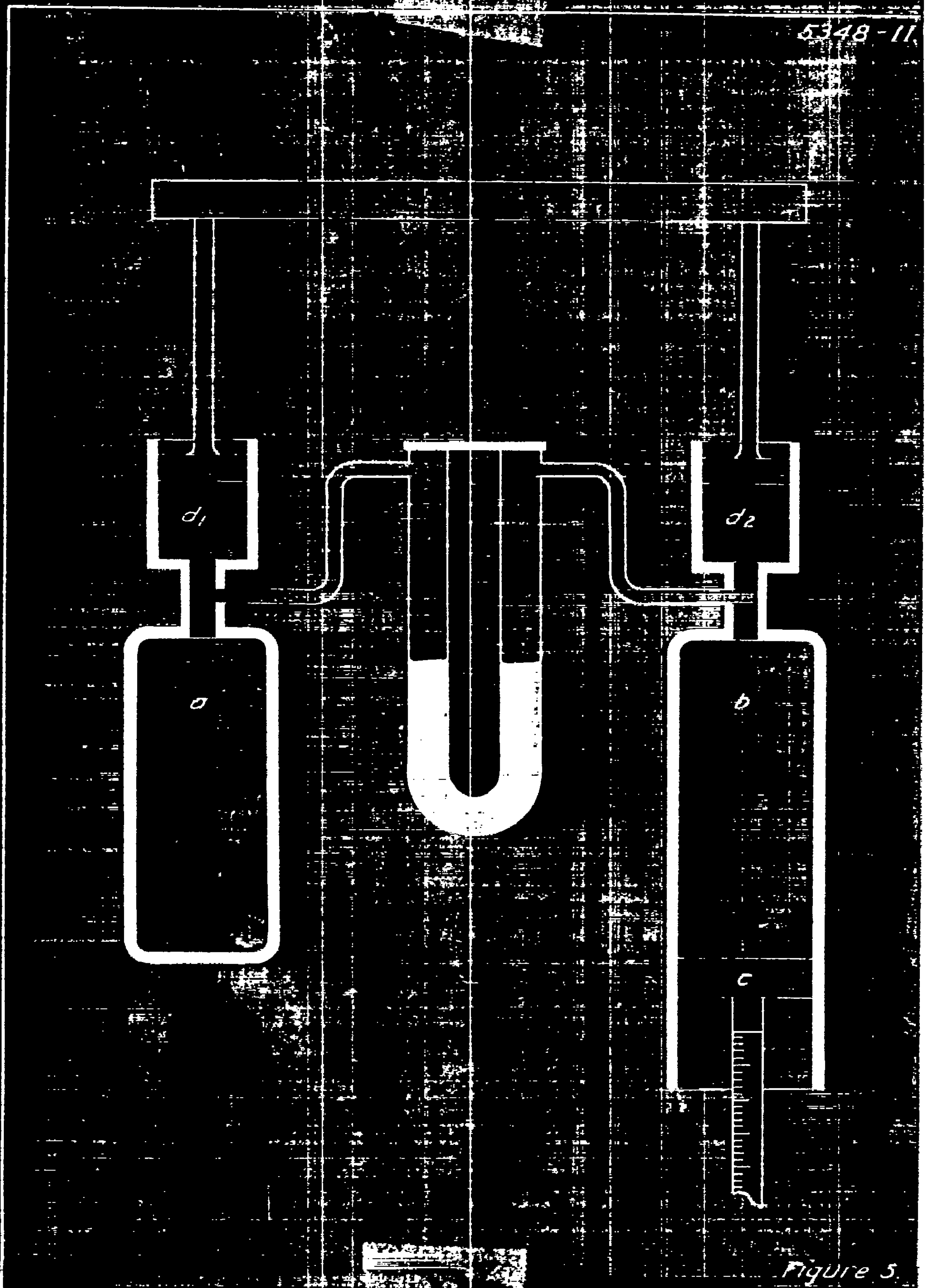

Figure 5.

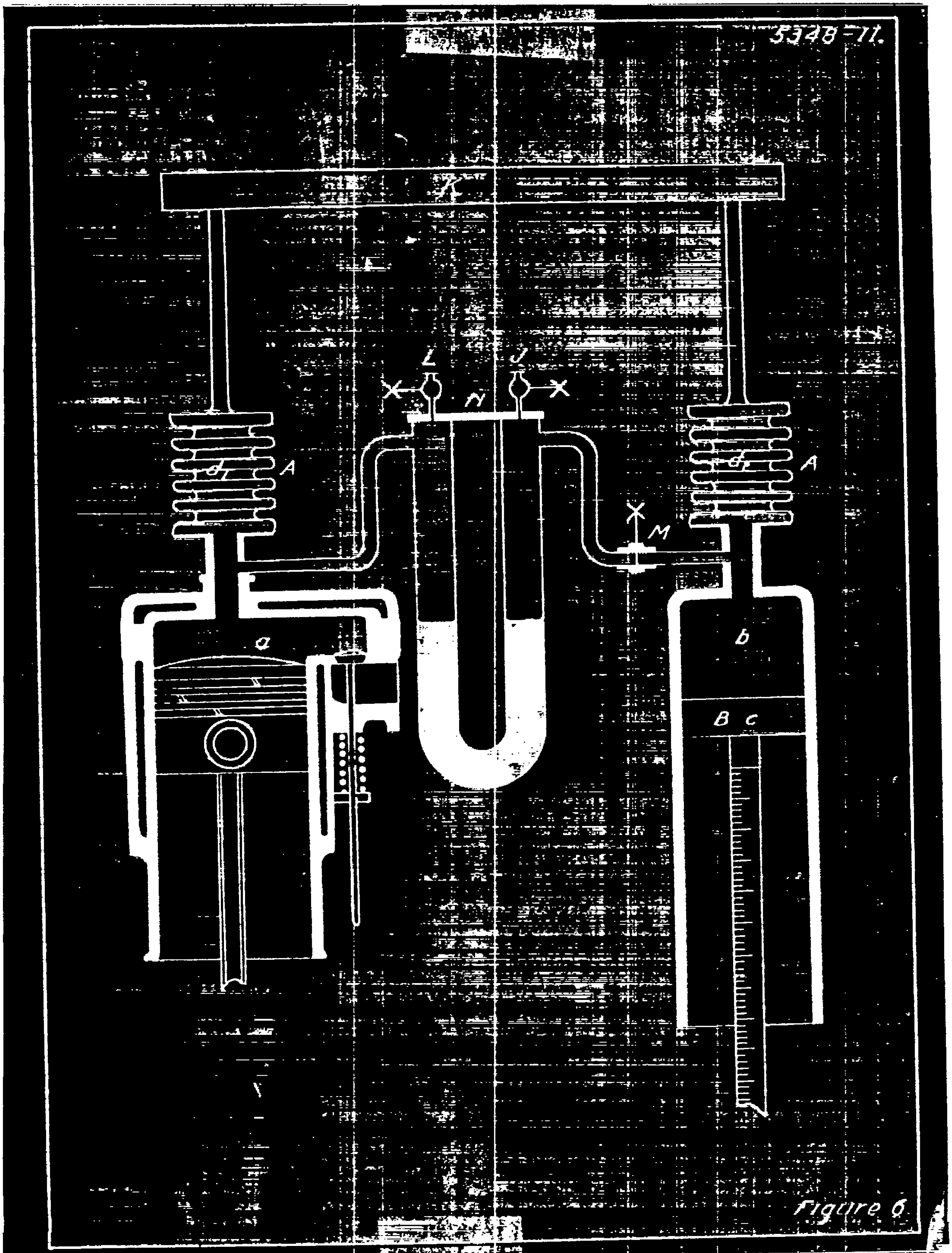

Figure 6.