CONSTRUCTION AND TESTS FOR RESEARCH ON HYDRAULIC TRANSMISSION

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CHAPTERS:

INTRODUCTION

This study of the possibility of a hydraulic transmission was made in the hope that something might be brought to light which would make possible an easier means of speed and motor control in the automobile. The study deals with the basic principles only, but application of these seems likely to reach proportions of great practical value. There is an increasing demand for a more efficient transmission, with the increased traffic problems, and demand for quicker, easier gear control. Women especially would be benefited by such a transmission.

The underlying principle upon which this proposed transmission would operate is one developed by Mr. Forrest R. Jones and is the product of his long experience with gearing design and mechanical problems, coupled with his broad knowledge of subjects pertaining to this line of work. Mr. Jones is the author of several books; among these works on machine design and on gasoline engines. He has patented quite a number of mechanical devices.

SURVEY OF THE FIELD

The experiments along the lines of hydraulic transmission have been few as far as can be determined. Certainly there is a broad field for such a device in present day automobiling.

The French have accomplished more in this field than any one else. There is a transmission of this type installed on a French make automobile which has operated with some degree of success. The principle upon which the French transmission works is as follows: Liquid pumps are arranged radially with the plungers extending toward the outer end of the cylinders. The cylinders revolve and the plungers are in contact with a circular track. When the center around which the cylinders are arranged, and the center of the circular track coincide, there is no plunger action and as the two centers are separated the plunger action increases as the cylinders rotate.

The hydraulic brake now widely used on automobiles points to the approaching demand for a hydraulic transmission. As more experiments are carried on, resulting from the wide use of hydraulic brakes, it is probable that valuable information will be brought to light and speed the development of a practical transmission.

GENERAL THEORY

The theory of the transmission is simple enough from a standpoint of variable speed ratios. A liquid pump supplies liquid under pressure to a liquid motor, thus operating it. The pump and motor, being of the type known as gear pump or gear motor, are positive acting with the exception of a percentage of slip due to clearance or leakage as the "fits" in the pump and motor are "sliding fits". Let us assume that for one revolution of the pump the motor makes one revolution. If the supply line between the pump and motor be equipped with a by-pass valve, the speed ratio may be regulated by the valve. If the pipe line is so arranged as to deliver liquid to either side of the motor the direction of flow of the liquid through the motor may be reversed, reversing the direction of the motor. By closing the supply valve leading to the pump, no liquid is pumped, therefore, there will be no rotation of the motor. A braking effect is obtained by arranging a valve on the exhaust of the motor. When the valve is closed the motor cannot rotate as it is positive acting and the liquid is incompressible.

In an automobile the drive wheels would be turned by the liquid motor, while the auto engine would operate the liquid pump.

The experiments carried out were for the purpose of obtaining some knowledge regarding the possibility of

increasing the torque ratio, as well as the speed ratio.

When a liquid is passing through the system and no liquid is by-passed the speed and torque of the motor practically equals the speed and torque of the pump. When liquid is by-passed the pump does just as much work but the motor drops off and power is wasted through the valve. If the power could be retained and the speed of the motor decreased at the same time adding the power which is wasted through the valve to the torque of the motor, the efficiency would not drop off as the speed ratio changes, and an ideal automobile transmission would be the result.

The torque of a pump or motor is the product of a force and a radius. The radius in the case of pumps and motors of this type is determined by the size of the gears and cannot be changed with out rebuilding the device. Therefore, to vary the torque, the force will have to be varied, as the radius is unchangeable. Moreover, for a given speed the pressure is constant for a liquid. If a vapor could be pumped through the pump and then liquified before going through the motor the speed of the motor would be in a ratio to the pump as the ratio of the volume of the liquid to the vapor. In the present case, to gain the benefit of this principle, the pump would have to have a suction sufficient to vaporize the liquid. The vapor would have to liquefy before it reached the motor, after having passed through the pump, and probably would do so, as the pressure

is very high in this part of the line. This pressure is what actually transmits the power.

A valve at A (Figure 1) would regulate the vapor passing through the pump. When open sufficiently to supply the suction of the pump, no vapor would be formed and the liquid would be pumped, making the speed ratio one to one as the ratio of volumes is one to one. (Volumes of liquid at A and at B, Figure 1)

Referring to Figure 2, the proposed design of Mr. F. R. Jones, it may be seen that by regulating the plunger valve A the amount of liquid entering the pump is controlled. The valve B is operated by a back-pressure, caused by the motor operating from external force, as would be the case when an automobile installation was operated by the motion of the wheels in coasting down hill. The back-pressure operates the piston, closing the pump supply and opening the port E to thereservoir. The four-pass valve C, when turned ninety degrees from the position shown, reverses the motor. This valve may be adjusted to permit a portion of the supplied liquid to be by-passed through E, regulating the speed. The valve at E acts as a brake since it restricts the passage of the exhaust liquid from the motor.

The liquid which would be most adaptable to this type of transmission probably would have to be mixed from a viscous liquid and a light liquid in order to obtain the proper density, the proper one being one which would seal the "sliding fits" and at the same time be light enough to vaporize.

APPARATUS AND METHOD

The source of power was a one-sixth horse power, alternating current motor, with a speed of eighteen hundred revolutions per minute. The pump was the usual two-gear pump. The gears had fifteen teeth of twelve ~~diametrical~~ pitch. The outside diameters were one and forty-one hundredths inches and the tooth height was eighteen hundreths of an inch. A three-hundred pound per square inch pressure gauge was used and the liquid was contained in a half-pint, air-tight container connected in the motor-pump circuit, as illustrated in the diagram at C, Figure 1.

The device illustrated in a plan view in Figure 1 and shown in the photograph, was constructed. A series of liquids, varying in density and viscosity, were used as a medium of transmitting the power. The line B, Figure 1, is the high pressure line and the power is transmitted through this high pressure which is indicated on the pressure gauge. (Figure 1) By closing the valve at A partially, the pump does not receive the total volume of liquid it will pump at eighteen hundred revolutions per minute, and a partial vacuum is created, causing the liquid to vaporize. If the valve in line B is closed, the flow of liquid exhausting is restricted, and the pressure increases proportionally. By properly regulating both of these valves while the motor is in operation, a determination of the resultant pressures may be made. If the proper vaporization takes place, the

line at A, Figure 1, will drop in temperature as a result of the heat absorbing effect of vaporization. This was the case in some of the lighter-liquid tests, and is explained under "Tests".

TESTS

A serious defect in the pump is brought out by these tests and is known as "slip". This is due to leakage through the gears, housing, and bearings, as well as around the drive shaft.

If V_o is the theoretical volume the pump should deliver, and V is the volume actually delivered, then

$$\text{Slip} = \frac{V_o - V}{V_o}$$

No exact measurement of this was undertaken, although its effect was very marked. The slip when using light liquids such as ether, carbon-tetrachloride and alcohol was considerable as the liquids were not viscous enough to seal the sliding fits. Oils show no appreciable slip under pressures as high as three hundred pounds per square inch. At this pressure the one-sixth horse power motor becomes stalled when using liquids which do not afford sufficient slip to allow the motor to run, maintaining the pressure.

Ether is a liquid which will vaporize at ordinary temperatures and condense at normal temperatures under slight pressure. When under test, and the valve at A, Figure 1, closed nearly shut, the pipe at a cooled off showing that vaporization was taking place, the supply of liquid being insufficient in volume to supply the demand of the pump running at eighteen hundred revolutions per minute. When

CONCLUSION

Further development of gear pumps and gear motors seems necessary before a practical installation of a hydraulic transmission can be made. The efficiency of the gear motor is comparatively low due to the equalizing effect of the liquid as it enters the gear motor. The pressure is distributed on both sides of the axes of both gears. The torque which tends to rotate the motor is the product of the pressure and the difference between the radius of the gear at the addendum circle and the radius of the dedendum circle. If the pressure could be applied upon only one side of the axis of the gears, then the torque would be increased very materially. The defects in manufacture are not so great but what some results could be obtained with a gear pump.

The possibilities of such an installation are not very great. Much development will have to be made on gear-pumps and gear motors. The results point to a more efficient system than was used in this experiment, since with viscous liquids this one was efficient to some degree. The torque change could not be definitely determined due to the low pressure at which the lighter liquids would permit slip, but obviously such a device, if valuable, is so only in a primitive way. The field promises quite a scope for development as it is simple in fundamental principle.

the valve in line B, Figure 1, was closed down the pressure climbed until the back pressure was great enough to slip enough liquid to allow the pump to run at that speed. The pressure was very low, and means were taken to try to minimize the slip that more accurate results could be determined. A packing box was constructed as is shown at D, Figure 1, This packing box greatly helped matters and ether would not slip under a pressure of forty pounds per square inch. The other liquids stood pressures ranging higher, approximately in a ratio as their densities or viscosities. With heavy oil, the motor was stalled by closing the valve in line B, Figure 1.

TESTS

Liquid	Pressure (lbs per sq. in)	R. P. M.
Ether	40	1750
Alcohol	60	1700
Carbon tetrachloride	50	1750
Heavy Oil	300	Stalled

Above tests were made after the slip of the pump had been reduced to a minimum

FIGURES

Figure 1 is a plan view of the apparatus.

Figure 2 is a blue print of the original design by Mr. Forrest R. Jones

Figure 3 is a photograph of the device as described and shown in plan view in Figure 1.

APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval, the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

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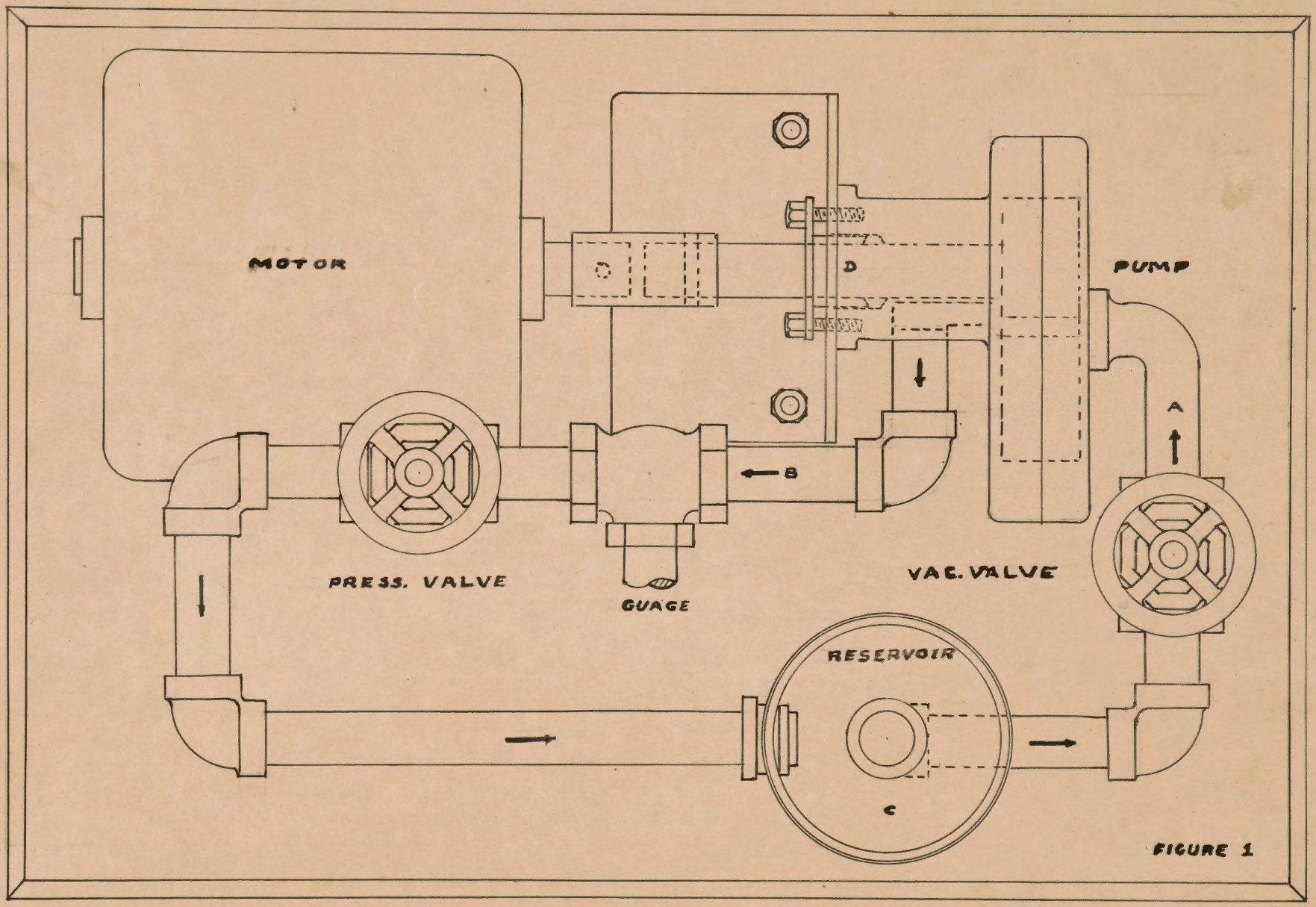


FIGURE 1

Reversible Hydraulic Drive
Speed and Torque both Variable
for substantially constant power
by Forrest R. Jones.

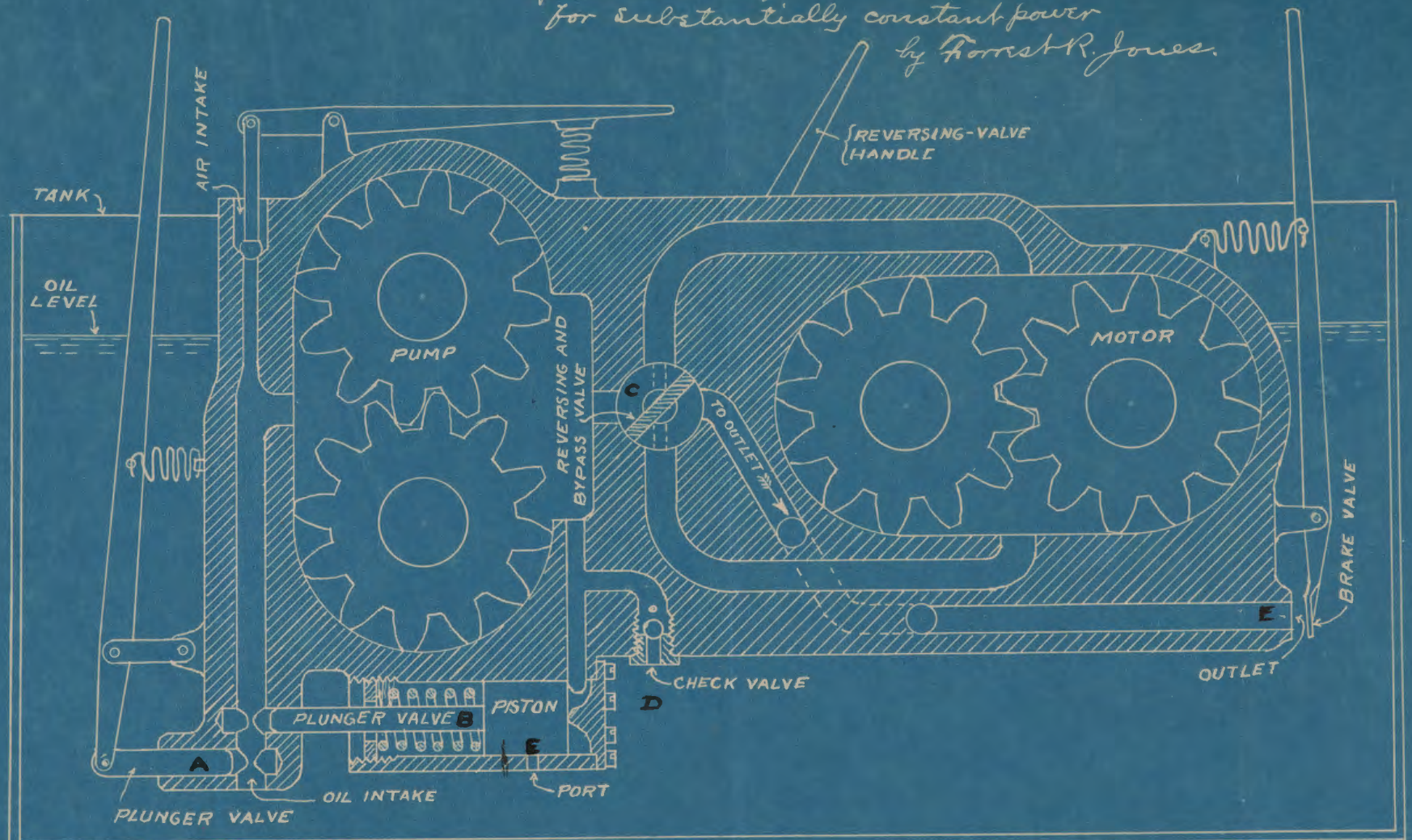
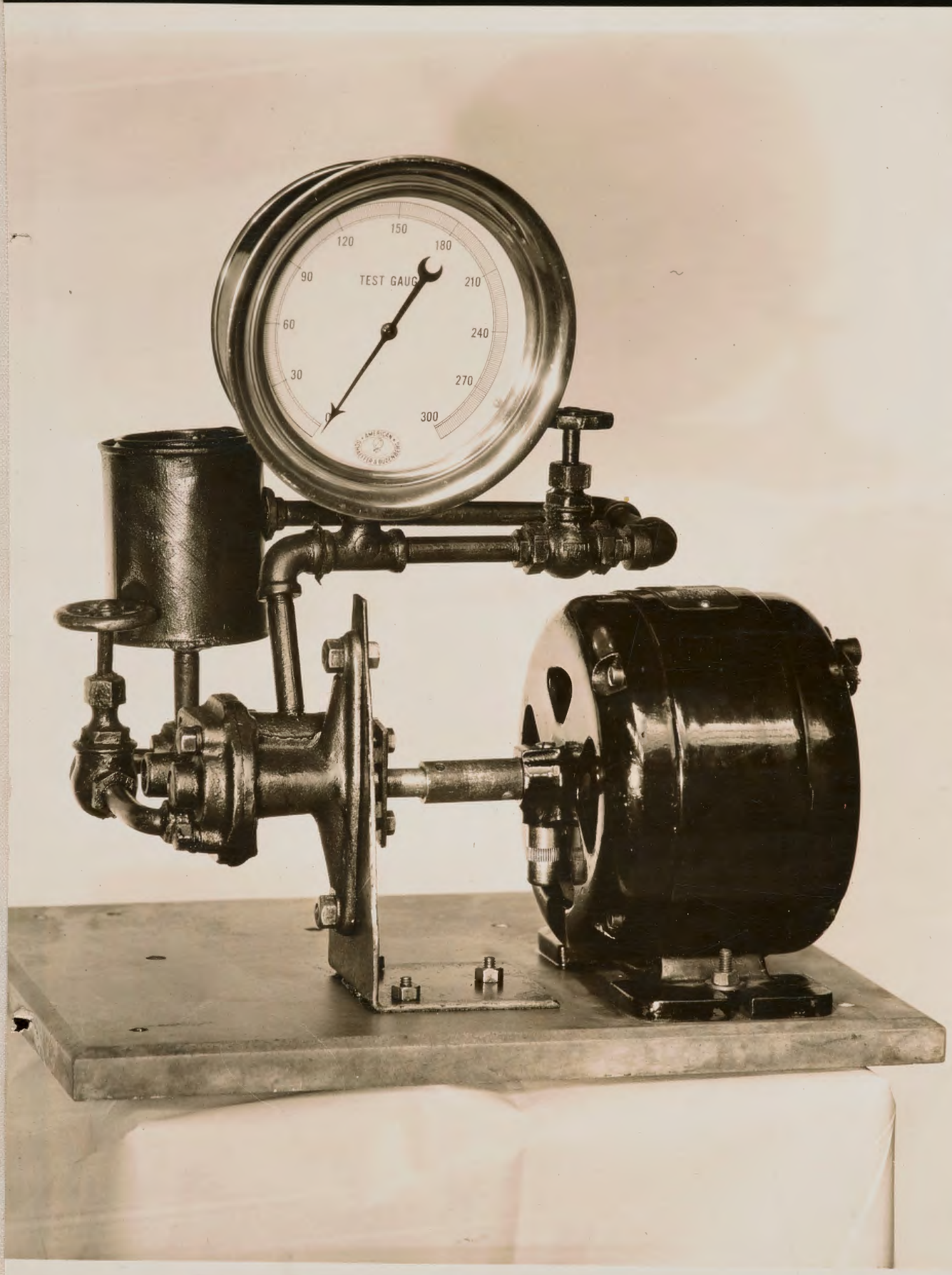


FIGURE 2


150
120
180
90
TEST GAUG
210
60
240
30
270
0
300