TECHNICAL NOTES.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

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DESIGN OF RECORDING WIND TUNNEL BALANCES.

By

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Aerodynamical Laboratory, N. A. C. A.,
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The following description of the design of a recording wind tunnel balance was prepared at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics, as the use of such a balance will greatly increase the efficiency of operation of a wind tunnel by increasing the capacity of the wind tunnel with a decrease in personnel.

Wind tunnel tests may be divided into two classes: commercial testing, where great accuracy is not important, but where rapidity of testing a more or less standard type of model is essential, and scientific work where the tests are of various kinds and accuracy is more important than speed. A balance for the first class of work need not be universal, but it should have a means for recording lift, drag and pitching moment, preferably plotting them continuously against angle of incidence. The second class of work demands a balance capable of supporting conveniently any type of model, and should hold them rigidly even at high speeds. All three moments and three forces on the model should if possible be recorded simultaneously and plotted either against angle of incidence or angle of yaw. It might seem that such an elaborate recording mechanism would be too great an expense, but when it is realized that it would save the time of three men, and would at least double the capacity of the tunnel there will be no doubt of its advantage.

The qualities desired in a scientific balance may be summerized as follows:

1. It should weigh all forces and moments simultaneously.
2. It should allow an incidence change through 360°.
3. It should allow the use of any type of spindle or wire support.
4. It should allow a yaw of ± 20°.
5. Forces and moments should be continuously recorded against angle of incidence .
6. Models should be easy to install and adjust.
7. Computations should be reduced to a minimum.
8. The weighing mechanism should be simple and positive.
9. The balance should be stiff enough to use at high speeds.
10. The balance should be simple and inexpensive to construct.

In order to choose the type of balance best suited for scientific work, the characteristics of the most successful balances will be considered.

The N.P.L. type of balance (Fig. 1) allows a ready adjustment of the angle of incidence, and the lift drag and moment readings are conveniently read. Its greatest disadvantages are the difficulty of supporting thin ended wings, or any model at high speed, and as moments and not forces are read, spindle corrections are difficult to make. It is also impossible to simultaneously read all forces and moments.

The wire balance as used at Göttingen (Fig. 2) has the advantage of being inexpensive and simple, but it does not allow large angular changes, and it is not universal.

The new Washington Navy Yard balance, working on the parallelogram principle, is the highest development in wind tunnel balances at the present time, and although it is self-balancing, it is not recording. The range of the angle of incidence is from $+ 90^\circ$ to -90° with the usual set-up, and $\pm$ 360 by a special set-up.

After a careful study of the preceding types of balances had been made, it was decided that the most satisfactory arrangement would be a rigid ring completely surrounding the tunnel or wind stream, so that the model could be supported from it by wires or any arrangement of spindles. The forces and moments acting on this ring can then be recorded by suitable weighing apparatus.

A diagrammatic sketch for a balance of this type is shown in Fig. 3. The weight of the balance is supported on a long torsion wire, with a mercury or water float to carry most of the load, and the lift on the model is measured by a simple lever. The drag and pitching moment are measured by two arms connected to ball bearings at the upper and lower side of the ring. The difference of the weighings give the moment and their sum the drag. In the same way the cross-wind force and rolling moment are measured on two similar arms at right angles to the air stream. The yawing moment is measured at the bottom of the balance through a flexible joint. All weighing arms have corresponding counter weight arms to keep the systems in tension, and as the movement of the arms is restricted to a very small amount, the problem of stability does not arise.

The methods available for recording the forces on the arms consist of the following:

1. A motor driven sliding weight, in the manner of a testing machine. This method requires the mounting of the recording drum on the balance arm, thus making it impossible to record the sum or difference of two weighings which, as will be shown later, is quite essential.

2. A spring or Toledo type of balance has been suggested but the deflection required is much too large, as the arm should not have a movement of more than a few thousandths of an inch, or there will be interference between the different weighings, and the stability would have a serious effect.

3. The forces could be recorded by a mercury filled sylphon as shown in Fig. 4. The pressure is recorded by the height of a mercury column, which covers a slit before a moving strip of bromide paper. Let us assume that the maximum pressure to be read is one kilo, with an accuracy of 1 gram. As the height of the mercury could be recorded to 1/10 mm. the total height would be 10 cm. Assuming that the area of the mercury

column could be made as small as 4 sq.mm., the area of the sylphon would be 7.4 sq.cm. and its maximum deflection would be .5mm. While this deflection would not be objectionable on some arms, it would be very much too large in most cases. This method is very simple and positive, but there would be considerable temperature correction which would be objectionable for recording work.

4. A more complicated fluid device is shown in Fig. 5 which will keep the deflection down to a very small value. The force on the arm is simply balanced by the fluid pressure in a sylphon or diaphram. The fluid is pumped through the chamber and its escape is regulated by an electrically controlled valve, operated by contacts on the balance arm, and the pressure in the chamber is recorded in the same way as before. This device would require considerable developing and would be rather expensive to construct.

5. The simplest and most satisfactory device is probably an adjustable chain weight as used in chemical balances, (Fig.6). This is simple, accurate and allows the recording pen to be easily attached. This method has been tested out and it is found that machine-made commercial chain is sufficiently uniform to give good results.

In Fig. 7 is shown a method of using this chain weight on a recording balance. One end of the chain is attached to the balance arm and the other to a slide driven up or down by a screw which is operated by a reversible electric motor. This motor receives its current through the contact points on the balance arm so that it will automatically balance the force. A pen is connected to the slider by a steel tape in order to reduce the motion, and this pen records the force on a drum which is driven synchronously with the model. It is possible to use a heavy enough chain to take care of all ordinary forces, but when runs are made at high speed, it will be necessary to add unit weights, and allow the instrument to rebalance.

As it is very desirable to plot actual forces and moments, the former are obtained by mounting a pen on an equalizing bar so that the sum of the forces are recorded (Fig. 8), and the latter by mounting the drum on one slider and the pen on the other (Fig. 9) so that the difference of the forces are given.

In conclusion, the proposed type of balance will support the model rigidly in a variety of ways, will make a complete test without attention, and will plot the results so that all computations are avoided. While this balance is more expensive to construct than the usual type, it would certainly pay for itself in a short time, by the large volume of work it could turn out and by the reduction in the wind tunnel pay roll.

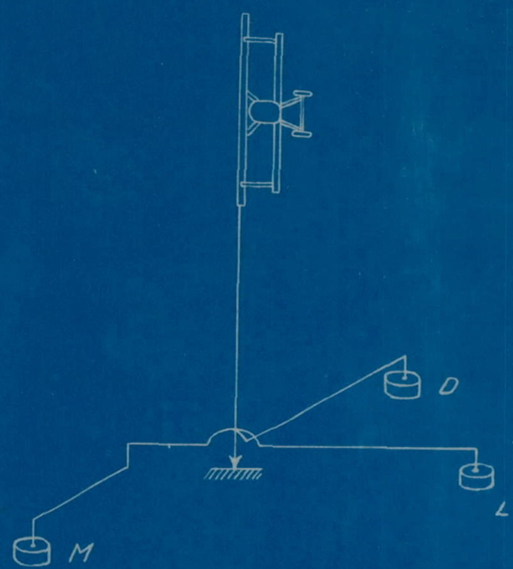


Fig. 1.

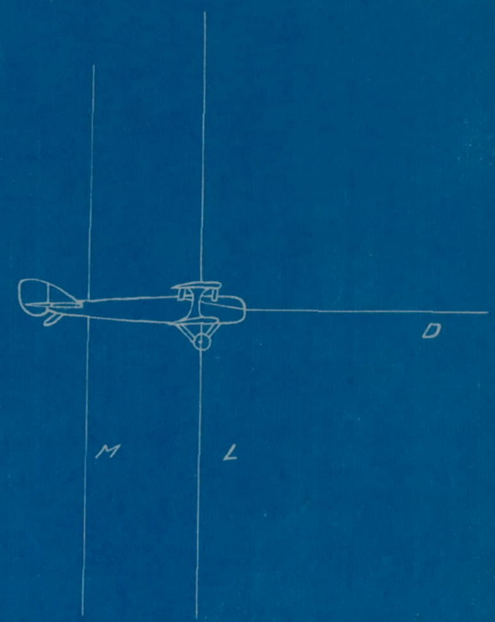


Fig. 2.

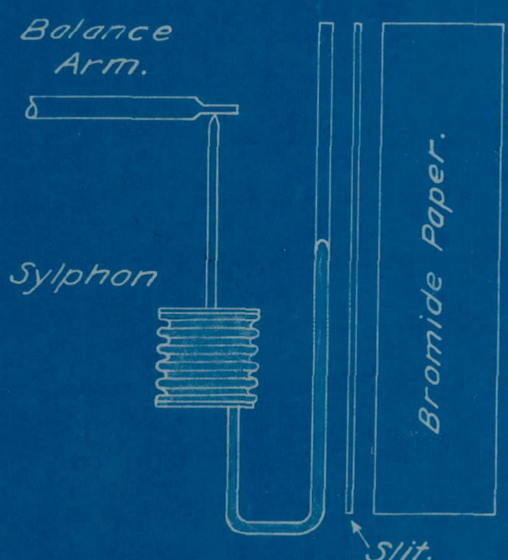


Fig. 4.

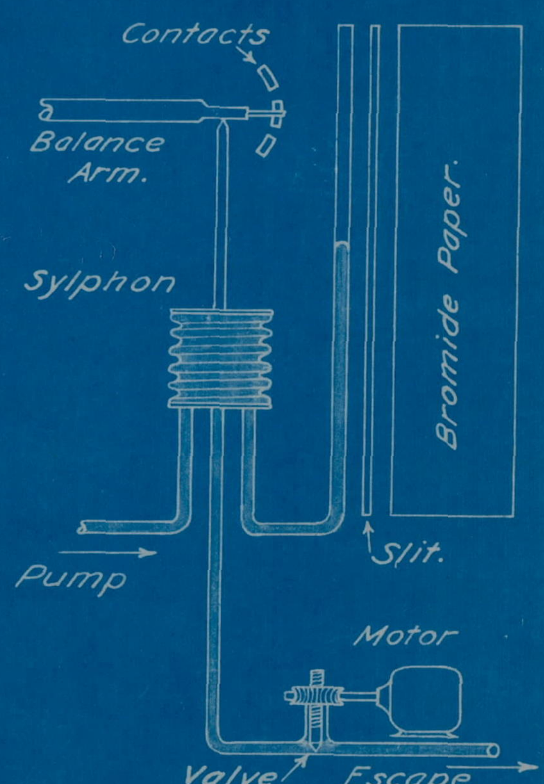
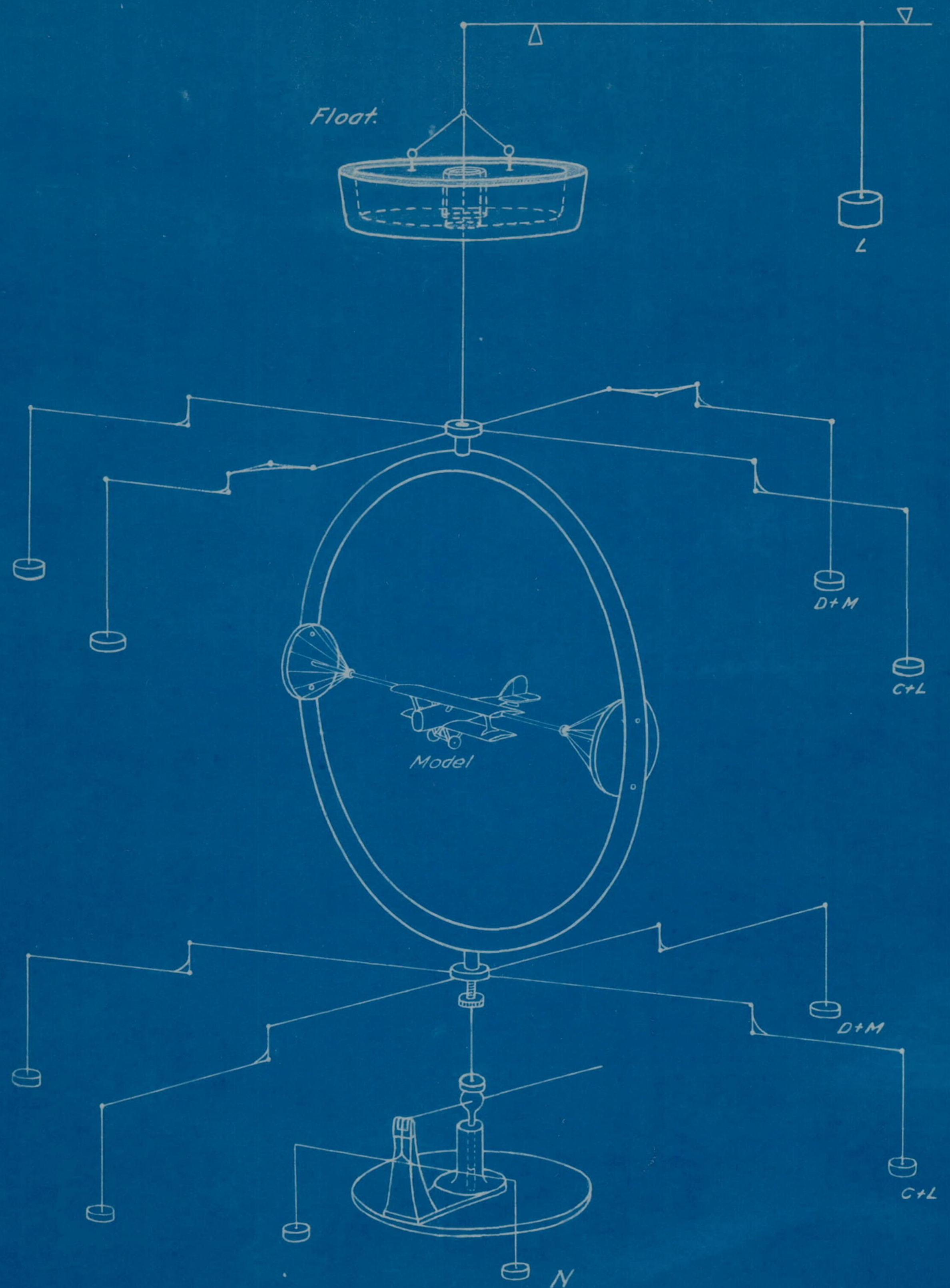


Fig. 5.



Assembly of Balance

Fig. 3.

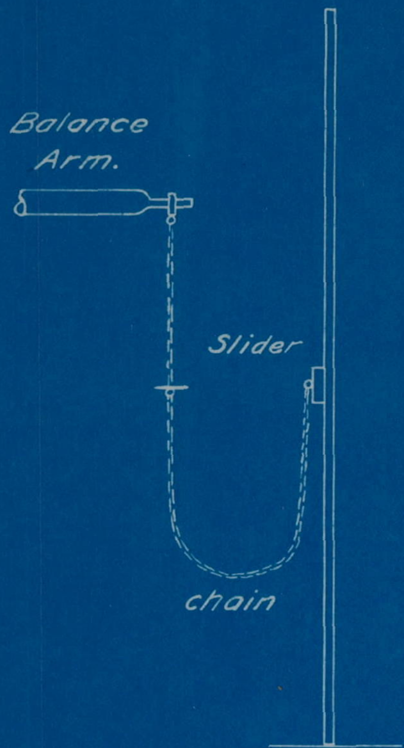


Fig. 6.

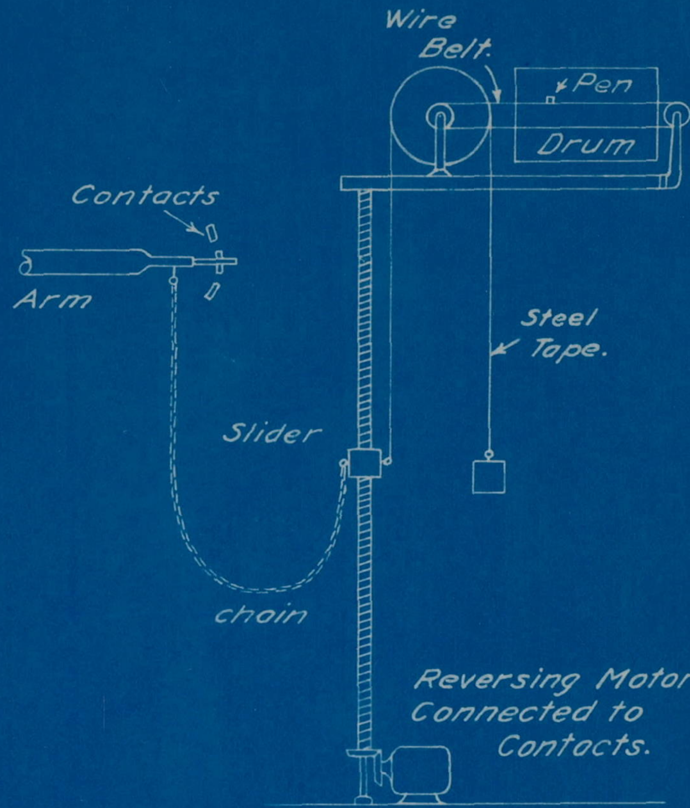


Fig. 7.

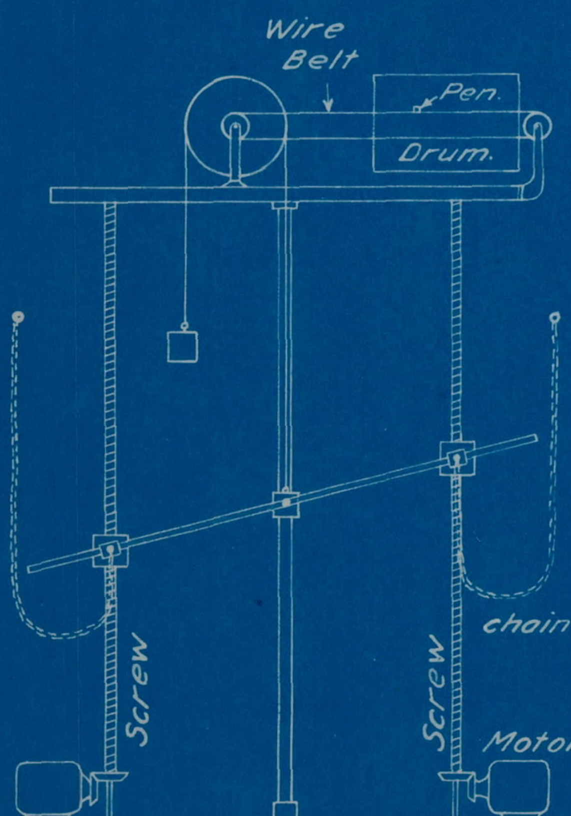


Fig. 8.

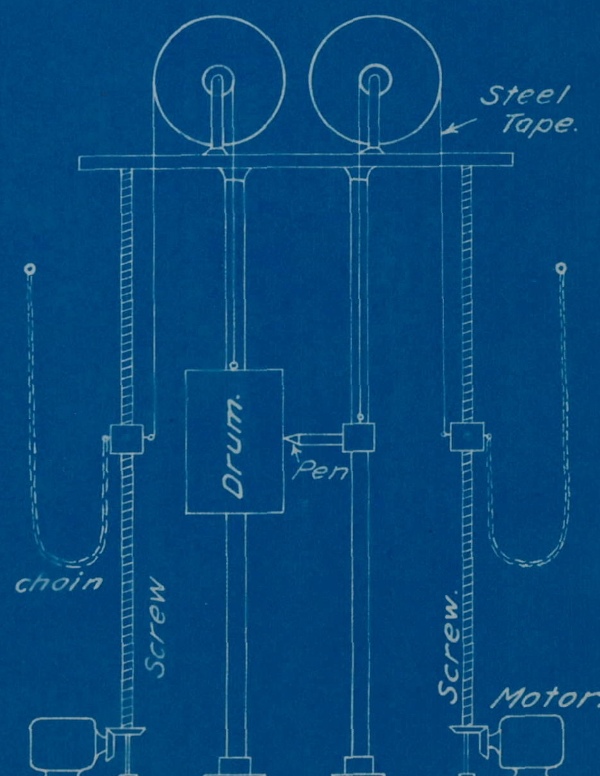


Fig. 9.