TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 281

A COMPARISON OF PROPELLER AND CENTRIFUGAL FANS FOR CIRCULATING THE AIR IN A WIND TUNNEL

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Summary

The tests described in this paper afford a direct comparison of the efficiency and smoothness of flow obtained with propeller fan and multiblade centrifugal fan drives in the same wind tunnel. The propeller fan was found to be superior to the centrifugal fan in that the efficiency was about twice as great, and the flow much smoother.

T e s t s

While aircraft propeller type fans are used in most wind tunnels for circulating the air, in some cases multiblade centrifugal fans are employed. The tests herein described give a direct comparison, as regards efficiency and smoothness of flow produced, between a propeller and a centrifugal type fan in the same wind tunnel.

The N.A.C.A. six-inch wind tunnel at the Langley Memorial Aeronautical Laboratory was used for the tests. As originally built, the air in this tunnel was circulated by means of a Sturtevant multivane centrifugal fan, design 3, size 2, direct connected to a variable speed compound wound, direct current motor. The tunnel is of the open jet, single return passage type, having guide vanes at the corners and a honeycomb at the large square section of the entrance cone. It is shown diagrammatically in Figure 1. The cross sections of the air jet and exit cone are circular, but those of the return passage are rectangular.

The energy ratio, or the ratio of the kinetic energy of the air passing through the throat per unit time to the electric input power, was obtained for the tunnel with the centrifugal fan at air speeds of 50, 75, and 100 M.P.H. The electric input to the motor was measured by means of a standard voltmeter and ammeter on the armature and series field line, and another pair of smaller instruments on the shunt field line. The air speed at the throat was obtained from the pressure difference between the large square section of the entrance cone and the experiment chamber, as measured by means of an N.A.C.A. micro-manometer and a calibrated static pressure plate.

After the energy ratio had been determined, a record was made of the dynamic pressure over a short period of time as obtained from a Prandtl type Pitot-static tube and an N.A.C.A. photographically recording manometer, the fluctuations of the dynamic pressure being an indication of the relative smoothness of flow.

After the above tests had been made the tunnel was modified by replacing the centrifugal fan by a corner section having guide vanes and putting a four-blade propeller fan in the exit cone as diagramed in Figure 2. The propeller, which is one foot in diameter, is shown in Figure 3. It is mounted on a shaft supported by two deep groove ball bearings, one of which takes the thrust. The propeller shaft is connected, by means of pulleys and a special high speed fabric belt, to the same motor which formerly ran the centrifugal fan, the diameter of the driving pulley being five times that of the driven pulley. Except for the corner section replacing the centrifugal fan the tunnel was not changed. It is shown in Figure 5 as arranged for the propeller fan. The energy ratio was then obtained for the tunnel driven by the propeller fan, and a record of the smoothness of the air flow made, in the same manner as for the centrifugal fan installation.

In order to obtain the efficiency of the drive to the propeller fan, the power absorbed by the propeller was measured for one condition of air speed and R.P.M. (93 M.P.H. and 6500 R.P.M.) by means of a Prony brake. The exit cone was taken off as far as the propeller, the propeller removed, and a five-inch water-cooled steel brake drum put in its place. By means of a strap, the proper braking force was applied to hold the speed of the shaft to 6500 R.P.M. with the same electrical input to the motor as for an air speed of 93 M.P.H. The torque force was measured on a Toledo scale.

R e s u l t s

The results of the energy ratio tests are shown in Table I and Figure 4. The efficiency of the tunnel with the propeller fan drive is much the greater of the two at all speeds. The curves of Figure 4, however, do not show the true relative efficiencies of the drives. The centrifugal fan rotor was mounted directly on the motor shaft, while the propeller fan was mounted on a special shaft with two extra bearings and a belt drive, which absorbed a certain amount of power. Also, with the centrifugal fan the motor was loaded to its rated power at high speed, whereas with the propeller fan it was comparatively lightly loaded and therefore less efficient.

A fair comparison can be made for a speed of 93 M.P.H. with the aid of the data from the Prony brake test. This showed that for an air speed of 93 M.P.H. and a propeller speed of 6500 R.P.M., the electric input was 1.53 HP. while only .923 brake HP. was delivered to the propeller. Thus the combined electrical and mechanical efficiency of the drive to the propeller was 60.3 per cent. Now if the propeller fan had been driven directly by means of a motor of the proper power, an efficiency of approximately 80 per cent would have been obtained. This gives an energy ratio for the tunnel of

$$\frac{1.051 \times .80}{.603} = 1.40,$$

and since the energy ratio with the centrifugal fan is .67 at

93 M.P.H. (from Figure 4), the direct drive propeller fan installation is 2.1 times as efficient as the centrifugal.

The photographic records of the dynamic pressure in the air jet are shown in Figure 6 for both drives. From the records, each of which covers a period of about four seconds at 100 M.P.H., it is apparent that the flow is much smoother with the propeller fan. In fact, the records indicate that while the dynamic pressure varies a maximum of 1.5 per cent from the mean with the propeller fan, with the centrifugal fan this variation is 7.1 per cent, or between four and five times as great.

Evidently a smooth flow cannot be obtained by merely having a large number of blades in the fan or a large number of impulses per unit time. The centrifugal fan has 60 blades and gives more than three times as many impulses per unit time as the propeller fan, yet the flow is much smoother with the latter. The explanation seems to be that the guide vanes in the corner of the propeller installation turn the air more smoothly than the centrifugal fan, the casing of which forms the corner. Excessive turbulence in changing the direction of the air would also help to explain the lower efficiency of the centrifugal fan installation.

C o n c l u s i o n s

1. For the tunnel used in these tests the propeller fan installation including a corner with guide vanes is approximately twice as efficient as the centrifugal fan.

2. The air flow is much smoother with the propeller fan installation than with the centrifugal fan.

Langley Field, Va.,

January 24, 1928.

TABLE I.

Energy Ratio Test Data

	Air speed M.P.H.	Shunt field amperes	Shunt field volts	Armature amperes	Armature volts	Electric input power ft.lb. per sec.	Air energy per sec. ft.lb. per sec.	Energy ratio	
Centrifugal Fan Installation	50	1.04	10.0	4.0	83.2	257	119.4	.465	Temp. = 20°C.
	75	.77	30.0	8.0	105.0	630	402.5	.639	Bar. pressure = 30.53 in. Hg
	100	.38	43.0	20.5	94.0	1434	955.0	.666	ρ = .00239 lb.sec.^{2}ft.$^{-4}$
Propeller Fan Installation	50	1.36	1.0	2.5	93.0	172	117.0	.681	Temp. = 21°C.
	75	.93	17.6	5.0	107.0	406	395.5	.974	Bar. pressure = 30.10 in. Hg
	100	.57	55.0	11.4	103.0	890	936.0	1.052	ρ = .00234 lb.sec.^{2}ft.$^{-4}$

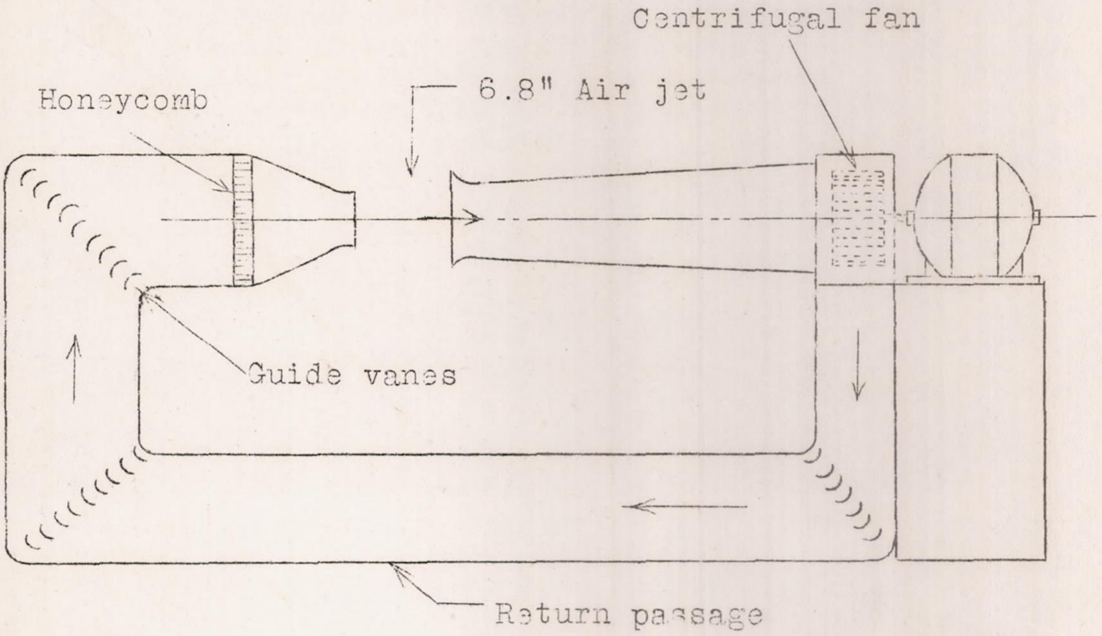


Fig.1 Six Inch Wind Tunnel With Centrifugal Fan

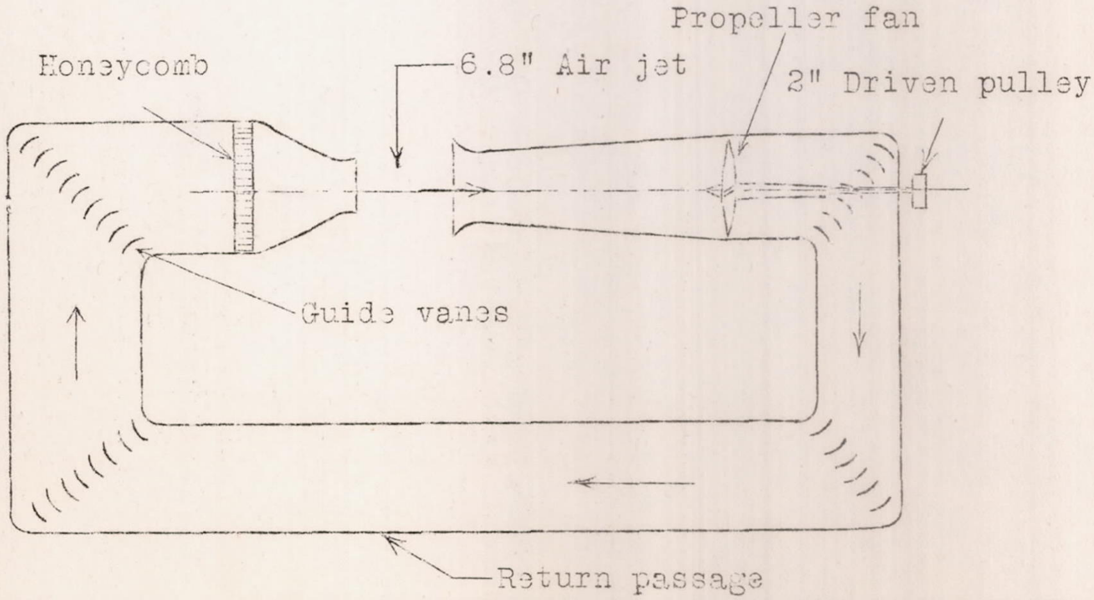
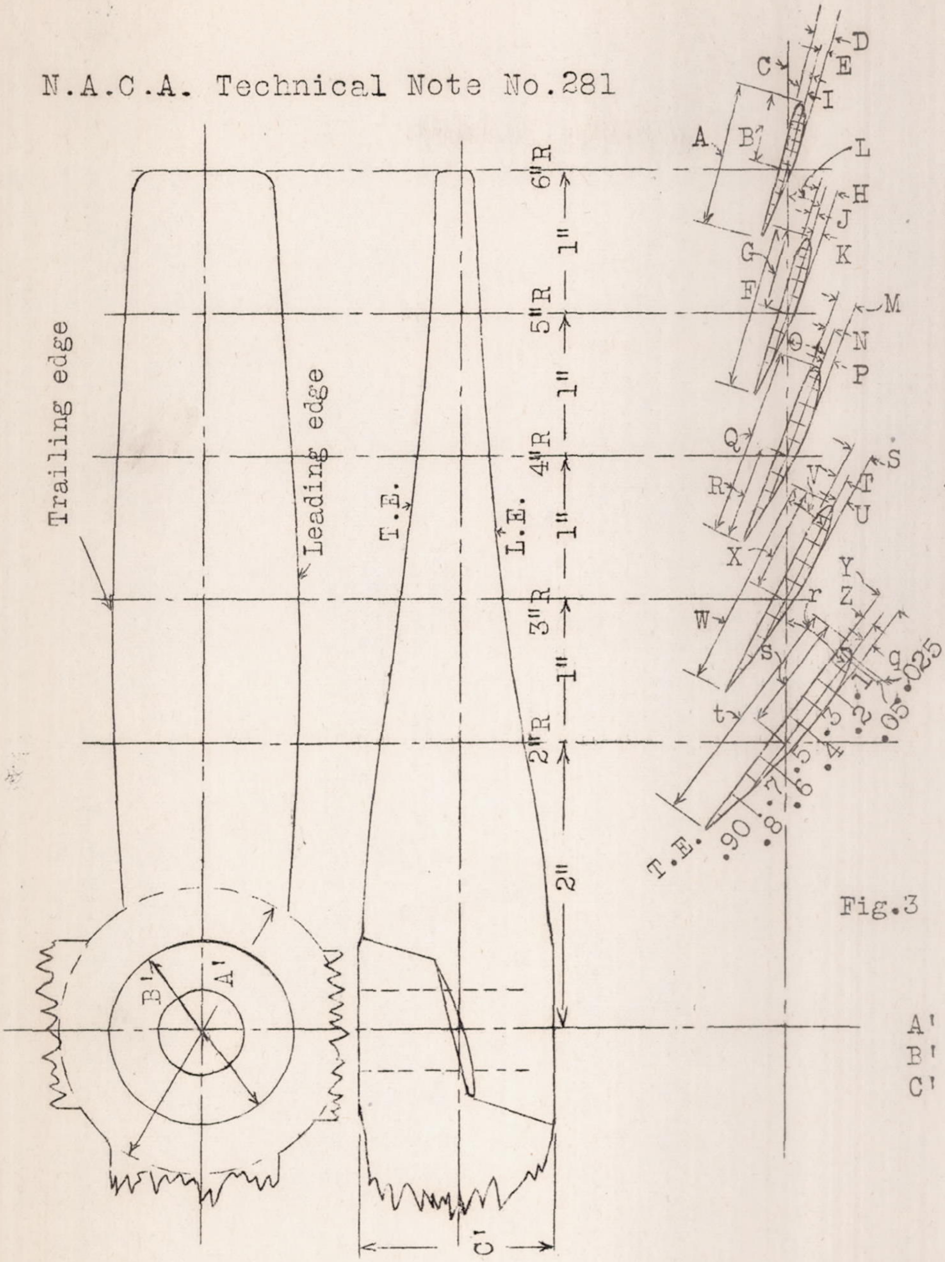


Fig.2 Six Inch Wind Tunnel With Propeller Fan



A 1.00"	O 21°		
B .50"	P .065"		
C 14°	Q 1.33"		
D .10"	R .665"		
E .05"	S .15"		
F 1.15"	T .075"		
G .575"	U .075"		
H .12"	V 27.2°		
I .05"	W 1.50"		
J .06"	X .75"		
K .06"	Y .17"		
L 16.85°	Z .085"		
M .13"	q .085"		
N .065"	r 37.2°		
	s .825"		
	t 1.65"		

Fig.3 Four blade propeller fan.

A' 2"D
B' 1.25"D
C' 1.375"

Station	L.E.	.025	.05	.10	.20	.30	.40	.50	.60	.70	.80	.90	T.E.	
Upper camber	.03	.05	.07	.08	.10	.10	.10	.09	.08	.06	.05	.03	.01	6"R
Lower camber	.03	.01	.01	0	0	0	0	0	0	0	0	0	0	
Upper camber	.03	.06	.08	.10	.12	.12	.12	.11	.09	.08	.06	.04	.01	5"R
Lower camber	.03	.01	.01	0	0	0	0	0	0	0	0	0	0	
Upper camber	.04	.07	.09	.11	.13	.13	.13	.12	.10	.08	.06	.04	.01	4"R
Lower camber	.04	.01	.01	0	0	0	0	0	0	0	0	0	0	
Upper camber	.04	.08	.10	.12	.15	.15	.15	.14	.12	.10	.07	.05	..01	3"R
Lower camber	.04	.01	.01	0	0	0	0	0	0	0	0	0	0	
Upper camber	.05	.09	.11	.14	.16	.17	.16	.15	.13	.11	.08	.05	.01	2"R
Lower camber	.05	.02	.01	0	0	0	0	0	0	0	0	0	0	

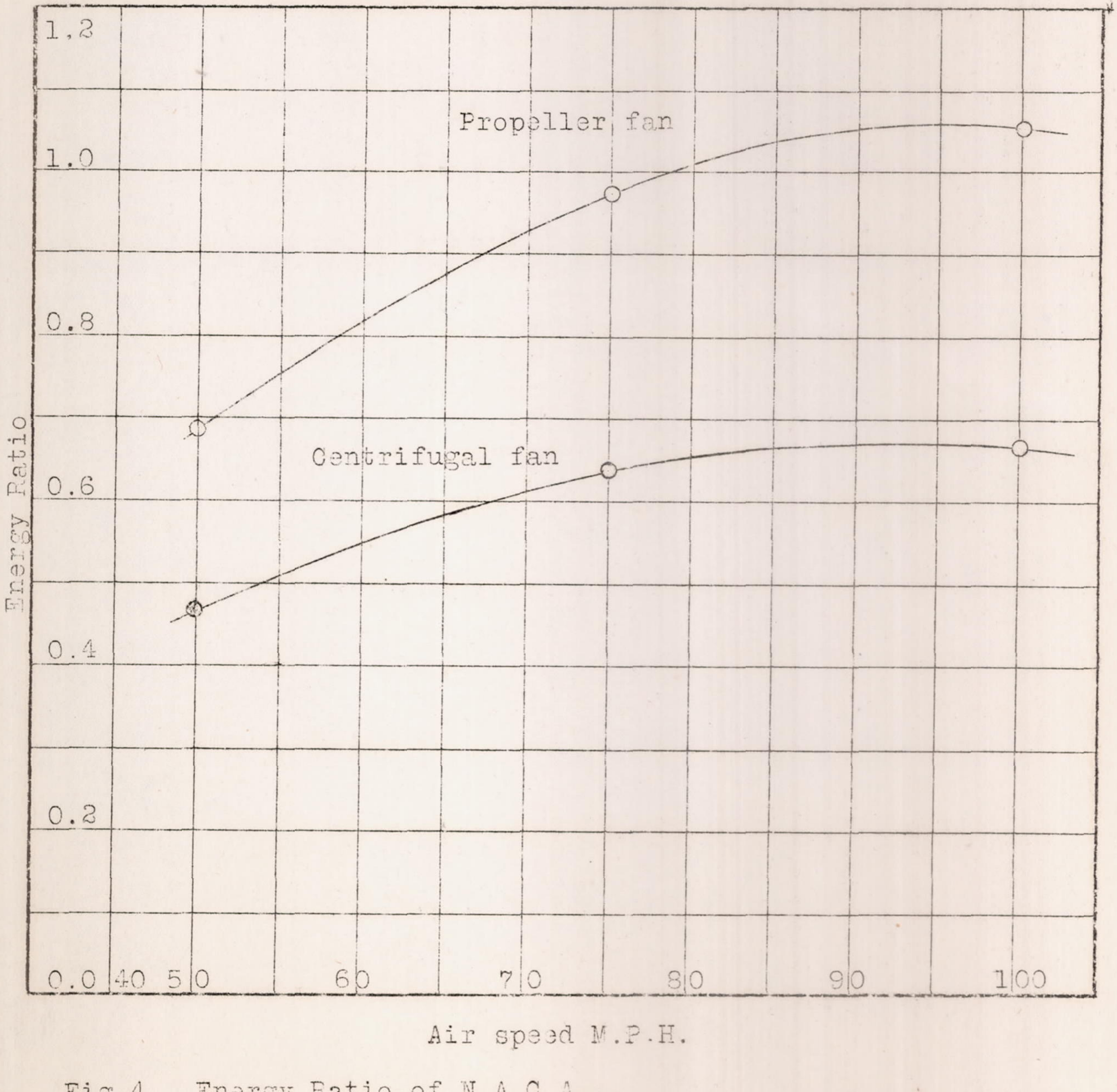


Fig.4 Energy Ratio of N.A.C.A.
Six Inch Wind Tunnel With Propeller Fan and With Centrifugal Fan.

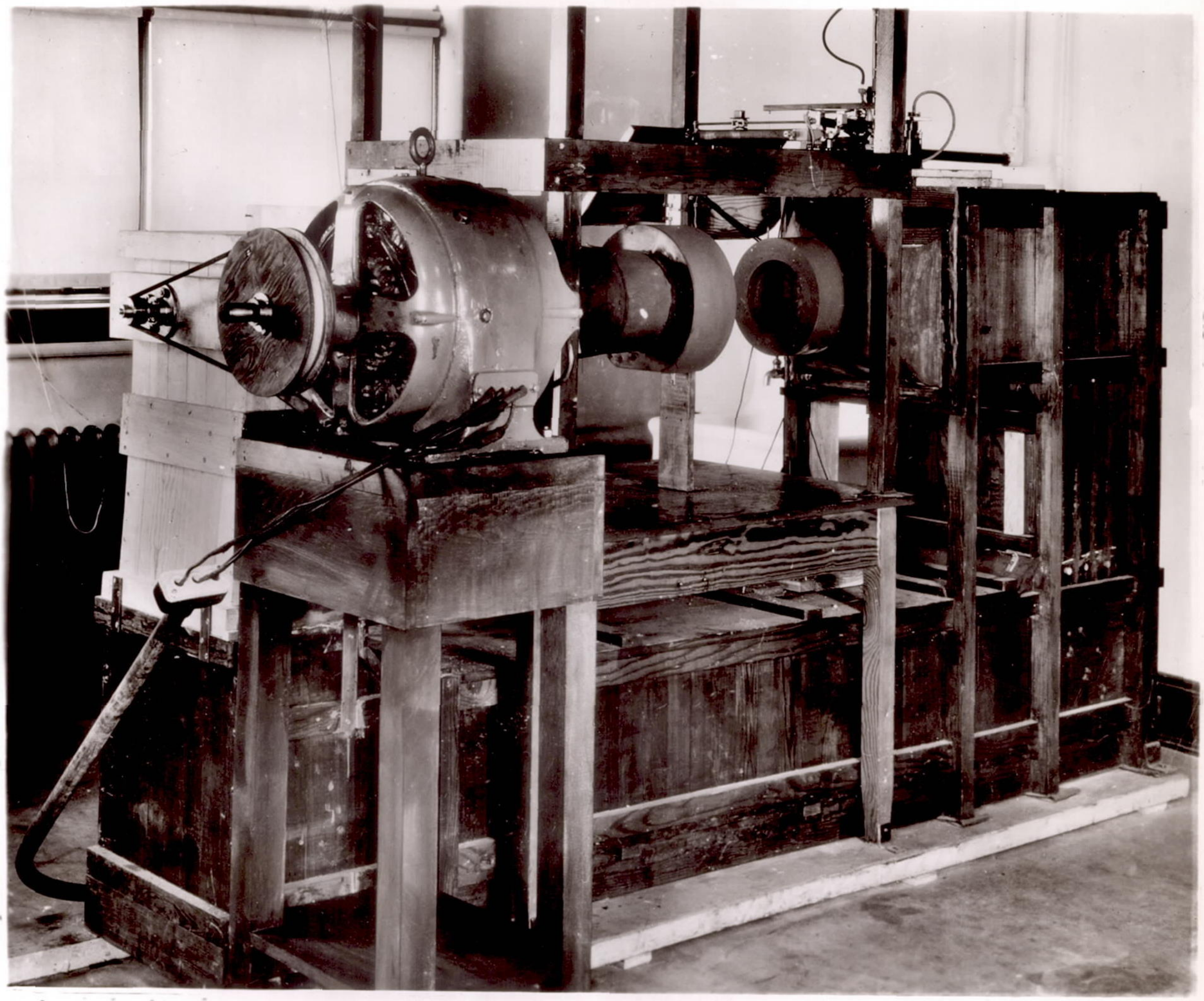


Fig. 5. N.A.C.A. six inch wind tunnel with propeller fan drive.

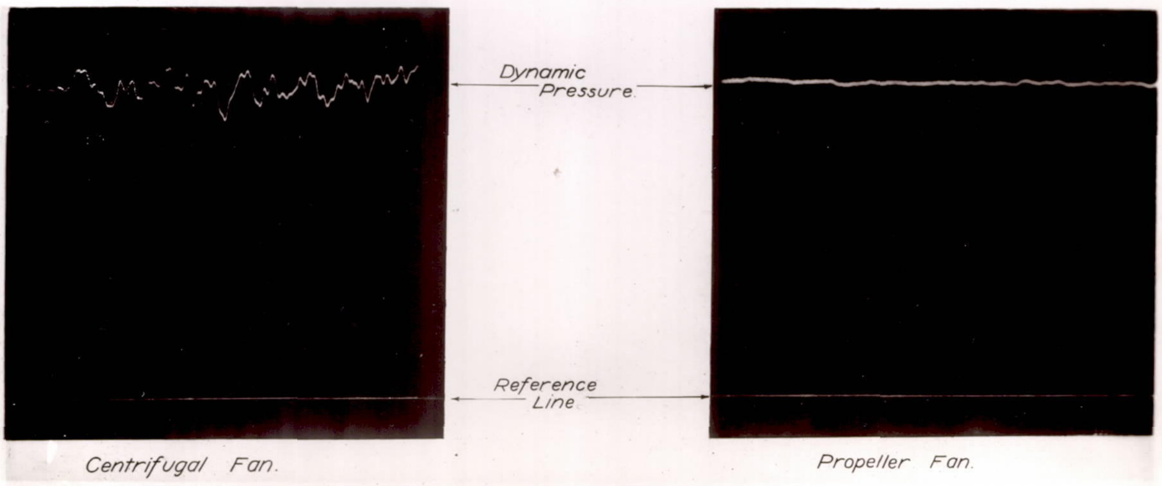


Fig. 6. Photographic recording Manometer records.