special electrical experts by help of suitable arrangments and instruments.

D.-Measurements of Revolutions per Minute.

This was effected by mechanical hand-tachometer with minute intervals, and often by direct counting with acoustic signals of time intervals.

E.-Registration of Speed Variation with Change of Load.

For this there was used the Horn tachograph.

F.—Measurement of Pressure Variation with Change of Load.

This was obtained by means of the instruments above mentioned for measurement of the falls.

Throughout the course of each test the observations were made as far as possible simultaneously, but at the same time independently.

C .-- The Results of the Tests.

The results of the tests I. to IX., inclusive of Francis turbines, are collected in Diagrams I. to V. inclusive; those of the tests Nos. X. to XIII, inclusive in Diagrams VI, and VII., accompany the tables. and finally the ratio Ku = u/c, which is the characteristic speed-coefficient of the turbine. Along the heading of Table III. are also given the efficiencies taken from Tables I. and II.

It is seen from this table that the wheel diameters of Turbines I. to IV. are nearly equal; but the ratios of width to diameter B/D and also the speed-coefficients Ku, are nevertheless different. In respect of this last coefficient, turbine I. is to be classed as "normal dimensioned normal speed;" turbine IV. as "normal dimensioned high speed;" turbine II. as "extra width normal speed;" and turbine III. as "extra width high speed."

In consequence of the equality of the diameters in turbines I. to IV., the results from them are directly comparable, and the comparison yields the following important conclusions:—

In open low-pressure Francis turbines, it is possible, even with extra width high-speed machines, to reach a maximum effective efficiency of 85 per cent. with an opening of the Fink rotary regulation gates corresponding to about 80 per cent. of full load; while with normal speed and divided



H.-Results with Francis Turbines.

(a) Open Arrangement.—Tables I., III., IV. From Table I. it is seen that :—

I. In turbine I. the maximum efficiency is reached at nearly full load; but in the other turbines it is found at between 70 and 80 per cent. of full load.

2. All four turbines have an efficiency of over 85 per cent. at about 80 per cent. of full load.

3. Turbine IV. maintains greater uniformity of efficiency than the other turbines.

4. The simple turbines II. and III. have similar efficiency curves, that of III. showing throughout smaller efficiency than II.

5. Turbine II. has a second maximum efficiency at about 30 per cent. of full load.

On Table III. (above) the data of the designs are given specifying the size of turbine and its rotary speed—that is, the values on which are based the calculations of the fall, the water consumption, the revolutions per minute, and the desired efficiency; also the wheel diameter D, the inlet breadth of wheel B, the ratio B/D, the peripheral speed $u = \pi Dn/60$, the theoretical speed $c = \sqrt{2g}$ H, corresponding to the fall H, inlet passages with axially moved gates still higher maximum efficiencies up to 88 per cent. are attainable.

The appearance of a second efficiency-maximum in turbine II. appears at first difficult of explanation; the cause, however, is masked by influences arising in connection with noload running with varied gate-opening, and the phenomenon proves that in such wheels different stream-line forms may occur—a phenomenon which is also observed in centrifugal pumps.

In the upper row of sections on Table IV. (on the opposite page), the classes of the designs of turbines I. to IV. are shown.

(b) Arrangement with Closed Spiral-Wheel Cases.—The results of the tests of Turbines V. to IX. are set out on the Tables II., III., and IV., along with the important dimensions of the same arranged in tabular and graphic forms. In the lower row of sections on Table IV. their general arrangement and class of design is sketched.

From the diagrams on Table II. it may be seen that also in this arrangement the maximum efficiency is reached between 80 and 90 per cent. of full load; but the values of the efficiency for the same percentage load differ for the different