and, at the same instant, readings from the brake were obtained. A comparison of the power indicated by the diagrams and that shown by the brake gave a difference which measured the friction of the engine. During the trial, the engine, when working at its rated power, consumed, according to the indications of the diagrams, 28.2 pounds of steam per horse-power per hour, or, probably, between 35 and 38 pounds, allowing for the loss by cylinder condensation, not accounted for on the indicator card, a very excellent performance for an engine of but 35 horse-power. The action of the governor was extraordinarily perfect. The engine was adjusted to make 230 revolutions per minute under 90 pounds steam pressure. The observers reported that it made the same number of turns whether loaded or unloaded, an evident impossibility with a governor of this class, in which only approximate isochronism can be attained. The writer, to settle the question, counted the revolutions, minute by minute, with a hand-speed counter, and made it 230 revolutions with the whole rated load on the engine (35 to 40 horse-power), and 231 when entirely unloaded, the brake-strap being loosened until it could be shaken about on the pulley, by the hand, with perfect ease. This was repeated until no question could longer exist in regard to the matter. The variation with variable steam pressure was greater.

The following are the data obtained from the brake and indicator readings:

Number of Card.	Revolut'ns.	Steam Pressure.	Brake H. P.	Indicator H. P.	Diff.	Friction per cent.
1	232	50	4.06	7.41	3.35	45
2	229	65	4.98	7.58	2.60	34
3	230	63	6.00	10.00	4.00	40
4	230	69	7.00	10.27	3.20	32
5	230	73	8.10	11.75	3.65	32
6	230	77	9.00	12.70	3.70	29
7	230	75	10.00	14.02	4.02	28
8	230	80	11.00	14.78	5.78	25.5
9	230	80	12.00	15.17	3.17	21
10	230	85	13.00	15.96	2.96	18.5
11	230	75	14.00	16.86	2.86	17
12	230	70	15.00	17.80	2.80	15.75
13	231	72	20.1	22.07	2.06	9
14	230	75	25.00	28.31	3.36	11.75
15	229	60	29.55	33.04	3.16	9.5
16	229	58	34.86	37.20	2.34	6.3
17	229	70	39.85	43.04	3.19	7.4
18	230	85	45.00	47.79	2.75	5.8
19	230	90	50.00	52.60	2.60	4.9
20	230	85	55.00	57.54	2.54	4.4

This engine was 8 inches in diameter of cylinder, 14 inches stroke of piston, having a rod 44 inches long between centers, a balanced valve with stroke of 2 to 4 inches, according to position of governor and eccentric, a fly-wheel 50 inches in diameter, weighing 2,300 pounds, the steam and exhaust-pipes having diameters of 2½ and 4 inches, respectively, and the whole machine weighing 2½ tons. The space occupied by the engine was 9 feet 4 inches in length, by 4 feet 8 inches in width, and 3 feet 10 inches in height.

Examining the above table of powers, it is seen that the difference between indicated and dynamometric power, the friction of the engine, varies somewhat, with varying steam pressures and varying total power; but in such manner as to indicate the controlling cause to be irregular in action, and possibly to some extent due to errors of observation and to accident. The maximum is four horse-power, the minimum about two horse-power. The usual difference is about three and the variations are irregularly distributed throughout the whole range of experiments. It is evident at a glance that the law of De Pambour does not hold, and that it is as nearly correct to say that the friction of engine is constant as otherwise. The column of friction, as given in percentages of the total power, exhibits the same fact. There is continual, though somewhat irregular, reduction of the percentage of friction, throughout the range from the lowest to the highest power, and very nearly inversely as the power exerted. This is best shown by the curve given in the accompanying plate (Fig. 23), in which a smooth line has been drawn to represent as nearly as possible the mean of all observations. It is evidently more nearly correct to assert that the friction of a non-condensing engine of this class is constant, and independent of the total power developed, than to accept the rule of De Pambour. The power for which the engine is proportioned is 35 to 40 horse-power. At this power, the friction of engine is but about 6 per cent. of the total, or less than one-half that assumed by De Pambour, and accepted as correct by Rankine, for engines generally, and presumably for locomotives especially. The result is exceedingly gratifying, and seems to the writer extraordinary for so small an engine.

The repetition of the experiment upon an engine of another make, having a cylinder 9 inches in diameter and a stroke of piston of 12 inches, which would naturally give

METHOD OF ATTACHING THE INDICATORS.

Fig 16