REPORT ON THE LILLE EXPERIMENTS UPON THE COMPARATIVE EFFICIENCY OF ROPES AND BELTS FOR THE TRANSMISSION OF POWER.

Translated by Professor DAVID S. CAPPER.

The idea of making comparative trials of the work absorbed by Ropes and Belts in the Transmission of Power was first suggested to the civil engineering committee of the Société Industrielle du Nord de la France, in connection with a paper by M. V. Dubreuil, read and discussed at their meetings on 25th May and 25th June 1893. For preparing his paper M. Dubreuil wrote to a large number of manufacturers both in France and in other countries, asking their opinion on this subject. The replies he received were uncertain and contradictory, and brought to light a general desire for the matter to be investigated. With this object M. A. Dujardin, a Lille engineer, offered to furnish at his own expense a 200-H.P. steam engine, fitted with both rope and belt fly-wheels of $14\frac{3}{4}$ feet ($4\frac{1}{2}$ metres) diameter,* on which exhaustive experiments could be made. The committee accepted the offer, and appointed a commission of five, afterwards increased to nine, with power to invite the co-operation of those who, though not belonging to the Société Industrielle, were interested in the question. This appeal was successful, and on 5th November 1893 six additional members were elected by a general meeting to represent on the commission those who had responded to the invitation. Thus completed, the commission consisted of the following fifteen members:—Messrs. Bonet, chief engineer of the Steam Boiler Association of the North of France; D. S. Capper,

* This diameter was afterwards altered to the diameters given in Tables 1 and 13. [Translator's note.]

professor of mechanical engineering, King's College, London; Chapuy, engineer, Corps des Mines, Lille; de Cuyper, engineer, managing director of the works of Van den Kerkove, Ghent; V. Dubreuil, engineer and architect, Roubaix, delegate of the Société des Ingénieurs Civils, and of the Association des anciens Elèves de l'Ecole nationale des Arts et Métiers, President of the civil engineering committee and of the commission for the rope and belt trials; A. Dujardin, manufacturing engineer, Lille; Goerich, manager of the Alsatian Engineering Works at Mulhouse and Belfort; Gruson, engineer-in-chief, Corps des Ponts et Chaussées, director of the Industrial Institute of Lille; Colonel Laussedat, director of the Conservatoire des Arts et Métiers, Paris; Olry, engineer-in-chief, Corps des Mines, general delegate of the Council of the Steam Boiler Association of the North of France; Neu, electrical engineer, former pupil of the Polytechnic School, professor at the Industrial Institute of Lille, co-delegate of the Société des Ingénieurs Civils; Schmidt, engineer-in-chief of the Steam Boiler Association of the Somme; Vigneron, mechanical engineer, manager of the cotton mills of Messrs. Wallaert Brothers, Lille; Villain, manufacturing engineer, Lille; Witz, mechanical engineer, doctor of science, professor at the Free Faculty of Science, Lille.

A meeting of the commission was held on 5th February 1894, when the following resolution was passed:—

Firstly, the steam engine shall have a double fly-wheel or two fly-wheels, one for the belt and the other for the ropes.

Secondly, the dynamo, driven direct off the fly-wheel without a counter shaft, shall likewise be provided with two pulleys, one for the belt and the other for the ropes.

Thirdly, the dynamo shall be mounted on adjusting screws, so that the tension of the belt or ropes can be regulated at will.

Fourthly, a cotton belt is to be ordered from M. Lechat of Ghent and Lille; a leather belt from M. Lemaire of Tourcoing; a homogeneous leather belt from M. Domange of Paris; and ropes from Messrs. Saint Brothers of Paris.

The experiments shall be made alternately with ropes and belts, several tests being made each day. The trials being comparative,

and the double fly-wheel allowing alternate runs with ropes and belts, it may be assumed that the mechanical efficiencies of the engine and dynamo will not vary during the experiments, and that it will consequently not be necessary to determine these.

For carrying out this programme M. Dubreuil was assisted by those members of the commission who had had experience in experimental work and were willing to make the observations; and also by those who were willing to lend apparatus at the least cost, so as to reduce to the lowest possible the expenditure on machinery, which would otherwise have cost £6,000 (150,000 francs). The experimental staff consisted of the following experienced observers:—M. Bonet, chief engineer, aided by the staff of the Steam Boiler Association; Messrs. Neu and Paillot, professors at the Industrial Institute and the Faculty of Science at Lille; Messrs. de Loriol, Finet, and Maréchal, electrical engineers representing the Alsatian Company; and M. A. Dujardin, manufacturing engineer, Lille. The Alsatian Company furnished and laid down and took charge of a 200-H.P. dynamo constructed especially for these trials. Messrs. Gabriel and Anguenault of Paris supplied 1,800 incandescent lamps. M. Henneton of Lille fitted up 300 additional lamps. The Industrial Telephone Company of Paris supplied the electric leads, and Messrs. Lazare Weiller and Co. of Paris the main copper conductors. Messrs. Sage and Grillet of Paris sent lamp-frames and accessories. Messrs. de Loriol and Finet supervised the general fitting of all the electrical apparatus. Messrs. Lechat, Lemaire, Domange, and Saint Brothers, supplied the belts and ropes. The Northern Railway lent one of their powerful boilers. Messrs. Dujardin and Co. not only provided the engine, the steam supply, and a site suitable for the erection of the machinery, but also defrayed a number of incidental expenses. To the gratuitous help thus given the success of the experiments must be largely ascribed.

Method of carrying out the Experiments.—In carrying out the experiments it was assumed that, given a constant resistance, and power applied in overcoming it, any variations in the power will be due to the particular efficiency of the transmitting medium—ropes

or belts—which alone can modify the result. In conformity with this principle, the resistance was provided by a sufficient number of incandescent lamps to maintain the output in watts constant; while the revolutions of the engine and dynamo were recorded, the speed of the latter being kept constant throughout the whole of the trials, and indicator diagrams were taken at the exact moment when the load was normal.

Constancy of Load.—As constancy of load was of the utmost importance, special care was taken throughout the whole duration of the experiments that the difference of potential at the terminals of the lamp circuit, and the current through the lamps, should be constant: in other words, that the number of watts absorbed by the lamps should be the same in every case. The difference of potential and the current were measured in M. Dujardin's office, at such a distance from the dynamo and lamps that all disturbing influences were almost entirely got rid of. The instruments were lent from the physical laboratories of the Faculty of Science and of the Industrial Institute.

Difference of Potential.—To measure this a torsion voltmeter by Siemens and Halske was used; it was carefully calibrated, and could be read with ease to one-third or one-fourth of a volt.

Current.—The determination of the current in ampères would have presented greater difficulty; but as it was not necessary to know its exact value, but only to ensure that it should be constant, the following method was adopted. At two points on the main circuit, about a yard apart, two fine leads were attached, and led to the terminals of a highly sensitive Wiedemann and d'Arsonval galvanometer. The readings were taken by Poggendorf's reflecting method, which proved too sensitive. It was therefore found necessary to reduce the sensitiveness of the galvanometer, in order to keep the image upon the scale. The current, and with it the direction in which the spot of light moved along the scale, could be reversed by a commutator, so as to correct any possible variations of the zero point owing to alteration of the magnetic field. The difference between the two readings on the opposite sides of the zero point would remain constant for a constant

current. The recorded measurements were not commenced until a sufficient time had elapsed for the temperature of the conductor to become steady. The difference of potential and also the current intensity were measured every ten minutes. Any variation in the potential was corrected by altering the main stop-valve of the engine, and thus changing the speed; and a final adjustment was obtained by regulating the field. If, when the potential had been brought back to its normal value, a variation of current was observed, lamps were switched on or off until equilibrium was restored. Indicator diagrams were then taken. It was thus ensured that during the whole duration of the trials the lamps absorbed always the same number of watts.

Date of Trials.—The experiments were carried out on the 7th, 8th, and 9th of August 1894; and not only the members of the commission, but all who desired to attend, were admitted to them. On 9th August the commission met again, and drew up the following record.

Tuesday 7th August.—The morning was spent in preliminary trials for accustoming the observers to their duties, so as to avoid all risk of hitch in the subsequent runs. The newness of the machinery would probably have led to inconsistencies, if the experiments had been run without previous trial. During these preliminary trials it was found that the electrical instruments, which had been placed in an erecting shop, were affected by the shifting of iron forgings in their vicinity; and it was found necessary to remove them into M. Dujardin's office.

The observers were stationed as follows. The boiler was fired by a stoker of the Northern Railway, who received orders to keep the pressure constant at 96 lbs. per square inch ($6\frac{3}{4}$ kgs.). The steam engine was in charge of the engineers to the Steam Boiler Association, who also took the indicator diagrams, under the direction of M. Bonet. Messrs. de Loriol, Finet, and Maréchal took charge of the dynamo. The engine and dynamo counters were observed by the engineers to the Boiler Association and M. Dujardin. The lamps were superintended by the Alsatian Company, and the electrical

measuring instruments by Messrs. Neu and Paillot. The whole of the observations were under the general supervision of M. Dubreuil.

With a view to uniformity the procedure on all the trials was as follows. (1) A thirty minutes' run without load. (2) Another thirty minutes' preliminary run under full load. (3) Ten minutes allowed for final adjustments. (4) The actual trial, lasting 140 minutes, with fifteen sets of indicator diagrams taken at intervals of ten minutes. (5) Indicator diagrams taken after the load had been removed. (6) The driving ropes or belt taken off and weighed.

Trial 1.—In the afternoon of Tuesday, trial 1 was made with ropes. No account was taken of the first portion of the run, when the voltage* rose to 104. The trial was resumed at 94 volts. The trial began at 3.40 and ended at 6.0 p.m. During its progress the engine counter missed several times. During the run Messrs. Neu and Paillot found the voltage quite steady.

Trials 2 *and* 3, *Wednesday* 8*th August.*—In the morning, trial 2 was made with M. Lechat's cotton belt: the start was at 7.50; full load was put on at 8.20; and the duration of the trial was from 9.10 to 11.30 a.m. In the afternoon, trial 3 was made with M. Lemaire's leather belt: starting at 3.10, full load was put on at 3.40; and the trial was from 4.30 to 6.50 p.m.

Trials 4 *and* 5, *Thursday* 9*th August.*—In the morning, trial 4 was made with M. Domange's leather belt: starting at 7.50, full load was put on at 8.20; and the trial lasted from 9.10 to 11.30 a.m. In the afternoon, trial 5 was made with ropes, starting at 2.0; full load was put on at 2.30, and the trial lasted from 3.8 to 5.30 p.m.; the voltage was as steady during this trial as during the first rope trial.

After the trials a meeting of the commission was held on Thursday afternoon 9th August, M. Dubreuil, President, in the chair. Present: Messrs. Dujardin, Chapuy, Neu, Vigneron, Villain, Bonet, Capper, de Loriol, and Finet, as members of the commission;

* Although the potential difference is stated as "voltage," it was really measured in arbitrary units, whose exact relation to the volt was not determined and was unnecessary for the purpose in view. [Translator's note.]

Messrs. Lemarchand, delegate of the Industrial Society of Rouen, Paillot, and Dubrule, by invitation; and M. Letombe, assistant secretary. The president communicated the foregoing account of the arrangements that had been carried out during the three days' trial, which received the approval of the members present. At the request of M. Dubreuil, M. Bonet on behalf of the Boiler Association undertook to work out the indicator diagrams, and report the results to the commission in tabular form and in the order of the experiments. The president invited all the observers to report the observations on which they had been engaged; and asked Messrs. Lemarchand and Capper also to communicate their opinions.

Results.—In accordance with the request of the commission, the Boiler Association has worked out the indicator diagrams, of which a set of four was taken every ten minutes; and has prepared the accompanying detailed Tables 1–12, pages 608–619. A general summary is given in Table 13, page 620, from which the ultimate results can be gathered at a glance.

Summary.—Neglecting the first trial, which was rendered untrustworthy through the failure of the engine counter and the newness of all the apparatus, Table 13 shows that, with a constant resistance, the power expended in the several modes of transmission was as follows:—

Ropes,	gross power 158·54 I.H.P.	with a slip of	0·33 per cent.
Cotton Belt (Lechat)	159·67 I.H.P.	„ „ „	0·78 per cent.
Leather Belt (Lemaire)	158·84 I.H.P.	„ „ „	0·96 per cent.
„ „ (Domange)	160·23 I.H.P.	„ „ „	0·78 per cent.

The diameters of the pulleys were measured at the surface and line of contact. Stated in percentage value, and allowing for the variations in the mean load as given in line 18 of Table 13, the results were as follows:—

Ropes,	gross power 100·00	. slip	0·100
Cotton Belt (Lechat)	„ „ 100·87	. „	0·237
Leather Belt (Lemaire)	„ „ 100·37	. „	0·292
„ „ (Domange)	„ „ 101·07	. „	0·237

General Remarks.— During the trials with ropes the tension gear was not used; but it was employed more or less throughout the belt trials, under the control of the belt makers, who regulated it as they pleased while running. Table 13, page 620, shows that the linear speed of the belts and ropes and their tension per square inch of cross section were very nearly the same. Thus the linear speeds at the surface of contact with the pulley, and the corresponding tensions, were as follows:—

Ropes		ran at	66·9	ft.	per sec.	under	156·4	lbs.	per	sq. in.
Cotton Belt	(Lechat)	67·2	„	„	„	„	177·3	„	„	„
Leather Belt	(Lemaire)	67·1	„	„	„	„	134·4	„	„	„
„	„ (Domange)	67·3	„	„	„	„	156·1	„	„	„

The needle of the volt-meter was practically steady with the ropes, while with the belts it oscillated through one or two divisions. Though sufficient at times to render the reading difficult, the oscillation did not cause any fluctuation in the light. As it coincided exactly with the passage of the belt joint over the pulley, it proves the importance of making good joints. Owing to the necessity of limiting the number of experiments, the commission were unable to try all the forms of belt offered to them. They therefore limited themselves to those which have been in practical use for at least fifteen to twenty years. They regret however that M. Domange was accidentally prevented from sending for trial the "homogeneous belt" which was at first offered by his representative. The rim of the belt fly-wheel was made of Messrs. Van den Kerkove's form, for a belt of $17\frac{3}{4}$ inches width, as shown in Fig. 4, Plate 151. The rim of the grooved fly-wheel was made according to the plan usually adopted by Messrs. V. Dubreuil and A. Dujardin for rope gearing; it was grooved for five ropes of $1\frac{3}{4}$ inch diameter, as shown in Fig. 1. These drawings give all the necessary details, and Fig. 3 shows the method adopted for determining the depth of the ropes in the grooves and the diameter of the circle of contact, after the trials and before the ropes were removed. No mishap of any sort occurred during any of the trials. The dynamo, although

new from the manufactory at Belfort, ran without trouble or hitch of any kind. Not a lamp was fused or damaged. The boiler was admirably tended by the stoker from the Northern Railway. The engine and the whole of the machinery ran perfectly.

The experiments show that, in the transmission of power, ropes and belts when well arranged absorb almost the same amount of power. In presenting this report the President of the commission desires to express his gratitude to his distinguished colleagues, to whose energy and experience the success of these trials is due. In conclusion he begs the President of the Société to unite with him in conveying to all his most cordial thanks, and to add the thanks of the administrative council to those of the civil engineering committee and of the members of the Société Industrielle du Nord de la France.

V. DUBREUIL, Engineer,
President of the Civil Engineering Committee
and of the Commission for these trials.

This report is approved by Messrs. Bonet, Capper, Chapuy, de Cuyper,* Dujardin, Gœrich, Gruson, Laussedat, Olry, Neu, Schmidt, Vigneron, Villain, and Witz.

---

* In line 13 of Table 13, page 620, giving the slip, M. de Cuyper considers that the thickness of the belt should have been taken into account in calculating the diameters of contact: the slip of the belts would then have compared more favourably with that of the ropes.

TABLE 1.

Engine, Fly-wheels, Pulleys.

Horizontal Compound Engine.	High-pressure Cylinder.	Low-pressure Cylinder.
Diameter of piston . . .	16·34 inches	29·53 inches
Diameter of piston-rod . .	2·95 inches	2·95 inches
Cross section of piston-rod .	6·85 square ins.	6·85 square ins.
Effective area of piston { front	202·81 square ins.	677·92 square ins.
Effective area of piston { back	209·66 square ins.	684·77 square ins.
Length of stroke	31·497 inches = 2·625 feet.	
Diameter of Fly-wheel for Ropes . .	196·30 „ = 16·358 „	
„ „ „ „ Belt . . .	196·58 „ = 16·382 „	
Diameter of Pulley for Ropes . .	58·86 „ = 4·905 „	
„ „ „ „ Belt . . .	59·06 „ = 4·922 „	
Breadth of Fly-wheel and Pulley for Ropes	13·08 „	
„ „ „ „ „ „ Belt	18·48 „	
Distance between centres of Fly-wheel and Pulley . . .	30·184 feet.	

TABLE 2.

Values of Coefficient K,

for converting Mean Effective Pressure M *into Indicated Horse-Power;*
I.H.P. = K × M.

Cylinders	HIGH-pressure. Front.	HIGH-pressure. Back.	LOW-pressure. Front.	LOW-pressure. Back.	Revolutions per minute.
Indicator Spring, lbs. per square inch per inch compression: nominal	45·19	45·19	12·05	12·05	
Indicator Spring, lbs. per square inch per inch compression: actual	43·81	43·03	11·74	11·83	
Piston area in square inches × stroke in feet ÷ 33,000	0·01613	0·01668	0·05397	0·05446	
K = revolutions per minute × piston area × stroke ÷ 33,000	K	K	K	K	Revs.
	1·255	1·298	4·195	4·238	77·84
	1·275	1·317	4·261	4·303	79·03
	1·275	1·318	4·259	4·305	79·08
	1·278	1·321	4·272	4·314	79·23
	1·265	1·308	4·228	4·272	78·46

TABLE 3.—*Trial with Ropes.* 7 *August* 1894.

Revolutions of Engine and Dynamo.

Time p.m.	ENGINE. Reading of Counter.	ENGINE. Revolutions Difference.	ENGINE. Revolutions Per minute.	DYNAMO.* Reading of Counter.	DYNAMO.* Revolutions Difference.	DYNAMO.* Revolutions Per minute.
H. M.	No.	Revs.	Revs.	No.	Revs.	Revs.
3 42	13,595			8,730		
		1,078	77·00		1,218	261·00
3 56	14,673			9,948		
		691	76·77		782	260·66
4 5	15,364			10,730		
		782	78·20		870	261·00
4 15	16,146			11,600		
		1,018	78·32		1,132	261·23
4 28	17,164			12,732		
		775	77·50		869	260·70
4 38	17,939			13,601		
		697	77·44		783	261·00
4 47	18,636			14,384		
		848	77·09		958	261·27
4 58	19,484			15,342		
		860	78·18		958	261·27
5 9	20,344			16,300		
		1,092	78·00		1,219	261·22
5 23	21,436			17,519		
†		1,096	78·30		1,216	260·57
5 37	22,532			18,735		
		775	77·50		868	260·40
5 47	23,317			19,603		
		865	78·64		955	260·45
5 58	24,182			20,558		
	Mean §		77·84	Mean §		260·91

* The Dynamo Counter was geared to run at one-third the speed of the dynamo.

† Up to 5.23 the Engine Counter missed several times. From 5.37 to 5.58 it ran without failure.

§ The mean is obtained by dividing the total number of revolutions by the total duration of the trial.

TABLE 4.—*Trial with Ropes.* 7 *August* 1894.

Mean Pressure and Horse-Power from Indicator Diagrams.

Mean pressure of steam at engine 88·65 lbs. per square inch.

Time p.m.	HIGH-PRESSURE Cylinder.				LOW-PRESSURE Cylinder.				Total Indicated Horse-Power.
	Front end.		Back end.		Front end.		Back end.		
	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	
H. M.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	I.H.P.
3 40	29·6	37·16	32·1	41·69	9·9	41·64	10·2	43·48	163·97
3 50	29·3	36·86	32·0	41·56	9·7	40·72	10·4	44·01	163·15
4 0	27·8	34·86	30·2	39·25	9·5	40·02	10·0	42·41	156·54
4 10	29·5	36·88	31·3	40·68	9·8	41·30	10·1	43·01	161·87
4 20	27·4	34·39	29·6	38·46	9·6	40·33	10·0	42·59	155·77
4 30	28·8	36·16	31·3	40·59	9·8	41·12	10·2	43·13	161·00
4 40	29·4	36·95	29·9	38·79	9·5	39·90	9·9	41·82	157·46
4 50	29·3	36·77	30·5	39·59	9·4	39·44	9·8	41·47	157·27
5 0	31·1	39·07	29·7	38·57	9·3	38·97	9·5	40·40	157·01
5 10	29·9	37·50	29·9	38·88	9·1	38·10	9·5	40·28	154·76
5 20	27·7	34·76	33·1	43·01	9·6	40·13	10·0	42·23	16·130
5 32	30·9	38·81	31·6	41·03	9·3	38·86	9·8	41·59	160·29
5 43	30·0	37·68	31·5	40·90	9·8	41·07	10·2	43·24	162·89
5 56	27·6	34·69	31·7	41·21	9·8	41·19	10·0	42·41	159·50
6 0	29·7	37·25	30·8	40·02	9·6	40·13	10·0	42·41	159·81
Means	29·21	36·65	31·01	40·28	9·58	40·18	9·97	42·29	159·42

TABLE 5.—*Trial with Cotton Belt (Lechat).* 8 *August* 1894.
Revolutions of Engine and Dynamo.

Time a.m.	ENGINE. Reading of Counter.	Revolutions Difference.	Revolutions Per minute.	DYNAMO.* Reading of Counter.	Revolutions Difference.	Revolutions Per minute.
H. M.	No.	Revs.	Revs.	No.	Revs.	Revs.
9 0	5,226			28,165		
		1,184	78·93		1,305	261·00
9 15	6,410			29,470		
		1,412	78·45		1,554	259·00
9 33	7,822			31,024		
†		897	79·74		987	263·20*a*
9 43	8,719			32,011		
		957	79·75		1,052	263·00
9 55	9,676			33,063		
‡		687	78·52		757	259·54*b*
10 3	10,363			33,820		
		874	79·09		962	262·38
10 14	11,237			34,782		
		1,347	79·24		1,483	261·70
10 31	12,584			36,265		
		1,186	79·06		1,306	261·20
10 46	13,770			37,571		
		1,263	78·94		1,390	260·64
11 2	15,033			38,961		
		1,181	78·73		1,301	260·20
11 17	16,214			40,262		
		949	79·08		1,044	261·00
11 29	17,163			41,306		
	Mean §		79·05	Mean §		261·08

* The Dynamo Counter was geared to run at one-third the speed of the dynamo.

† From 9.33 to 9.43 the actual interval was more than ten minutes, as the watch which was used for timing stopped for about 1¼ minute.

‡ From 9.55 to 10.3 another watch was used, which was not exactly in agreement with the first. About ¾ minute must be added for this.

§ The mean speed for the trial must be reckoned on the 131 minutes from 9.0 a.m. to 9.33; from 9.43 to 9.55; and from 10.3 to 11.29. The total revolutions counted in the whole table were actually accomplished in 151 minutes instead of 149.

a including the additional 1¼ minute. *b* including the additional ¾ minute.

TABLE 6.—*Trial with Cotton Belt (Lechat).* 8 *August* 1894.

Mean Pressure and Horse-Power from Indicator Diagrams.

Mean pressure of steam at engine 89·42 lbs. per square inch.

Time a.m.	HIGH-PRESSURE Cylinder.				LOW-PRESSURE Cylinder.				Total Indicated Horse-Power.
	Front end.		Back end.		Front end.		Back end.		
	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per. sq. in.	Indicated Horse-Power.	
H. M.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	I.H.P.
9 10	28·0	35·66	31·3	41·31	9·3	39·46	9·9	42·70	159·13
9 20	29·1	37·07	31·1	40·99	9·1	38·87	9·8	42·22	159·15
9 30	29·1	37·07	31·7	41·85	9·1	38·98	9·9	42·82	160·72
9 40	27·4	34·96	30·9	40·68	9·5	40·64	9·6	41·46	157·74
9 50	27·9	35·55	31·6	41·70	9·4	40·16	9·5	41·02	158·43
10 0	29·3	37·33	30·7	40·52	9·3	39·81	9·8	42·34	160·00
10 10	29·4	37·47	32·7	43·13	8·9	37·80	9·4	40·54	158·94
10 20	30·2	38·52	32·0	42·14	9·2	39·22	9·5	40·77	160·65
10 30	31·3	39·91	33·9	44·74	9·0	38·28	9·3	40·11	163·04
10 40	30·6	38·96	34·8	45·81	8·8	37·45	9·3	40·05	162·27
10 50	30·9	39·45	32·7	43·13	8·7	37·10	9·0	38·79	158·47
11 0	30·8	39·32	33·6	44·25	9·0	38·28	9·1	38·97	160·82
11 10	29·2	37·20	32·7	43·08	9·1	38·63	9·3	39·93	158·84
11 20	29·3	37·40	31·3	41·26	9·1	38·98	9·4	40·29	157·93
11 30	30·0	38·30	32·2	42·39	8·9	38·16	9·3	40·15	159·00
Means	29·50	37·61	32·21	42·47	9·09	38·79	9·47	40·81	159·67

TABLE 7.—*Trial with Leather Belt (Lemaire).* 8 *August* 1894.
Revolutions of Engine and Dynamo.

Time p.m.	ENGINE. Reading of Counter.	ENGINE. Revolutions Difference.	ENGINE. Revolutions Per minute.	DYNAMO.* Reading of Counter.	DYNAMO.* Revolutions Difference.	DYNAMO.* Revolutions Per minute.
H. M.	No.	Revs.	Revs.	No.	Revs.	Revs.
4 26	24,438			49,239		
		1,504	79·16		1,653	261·00
4 45	25,942			50,892		
		1,497	78·78		1,645	259·75
5 4	27,439			52,537		
		1,356	79·76		1,491	263·10
5 21	28,795			54,028		
		945	78·75		1,039	259·75
5 33	29,740			55,067		
		1,501	79·00		1,649	260·37
5 52	31,241			56,716		
		1,186	79·07		1,303	260·60
6 7	32,427			58,019		
		1,418	78·77		1,560	260·00
6 25	33,845			59,579		
		863	78·45		959	261·52
6 36	34,718			60,538		
		949	79·08		1,042	260·50
6 48	35,667			61,580		
	Mean §		79·08	Mean §		260·72

* The Dynamo Counter was geared to run at one-third the speed of the ynamo.

§ The mean is obtained by dividing the total number of revolutions by the)tal duration of the trial.

TABLE 8.—*Trial with Leather Belt (Lemaire).* 8 *August* 1894.

Mean Pressure and Horse-Power from Indicator Diagrams.

Mean pressure of steam at engine 88·61 lbs. per square inch.

Time p.m.	HIGH-PRESSURE Cylinder.				LOW-PRESSURE Cylinder.				Total Indicated Horse-Power.
	Front end.		Back end.		Front end.		Back end.		
	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	
H. M.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	I.H.P.
4 30	29·1	37·08	27·9	36·85	9·0	38·59	10·0	43·09	155·61
4 40	29·1	37·08	27·9	36·76	9·6	40·78	10·2	43·92	158·54
4 50	28·8	36·69	28·8	37·99	9·2	39·18	10·2	43·92	157·78
5 0	29·0	36·95	28·6	37·71	9·5	40·43	10·2	43·92	159·01
5 13	29·2	37·23	27·3	36·04	9·2	39·36	9·8	42·36	154·99
5 19	28·9	36·82	27·4	36·18	9·4	40·07	9·9	42·73	155·80
5 30	29·0	37·03	29·2	38·51	9·4	40·07	9·9	42·73	158·34
5 40	29·8	38·02	30·0	39·58	9·4	39·95	10·1	43·33	160·88
5 50	29·1	37·08	28·3	37·38	9·4	40·07	10·0	42·97	157·50
6 0	29·5	37·66	28·7	37·78	9·2	39·36	9·8	42·36	157·16
6 10	27·5	35·10	29·3	38·60	9·4	39·95	10·1	43·33	156·98
6 20	28·1	35·85	31·4	41·39	9·8	41·96	10·5	45·20	164·40
6 30	27·9	35·64	30·6	40·33	9·8	41·61	10·3	44·28	161·86
6 40	27·6	35·24	29·5	38·86	9·7	41·37	10·2	43·82	159·29
6 50	28·7	36·56	30·5	40·20	9·9	42·32	10·5	45·38	164·46
Means	28·75	36·66	29·03	38·28	9·46	40·33	10·11	43·55	158·84

TABLE 9.—*Trial with Leather Belt (Domange).* 9 *August* 1894.
Revolutions of Engine and Dynamo.

Time a.m.	ENGINE. Reading of Counter.	ENGINE. Revolutions Difference.	ENGINE. Revolutions Per minute.	DYNAMO.* Reading of Counter.	DYNAMO.* Revolutions Difference.	DYNAMO.* Revolutions Per minute.
H. M.	No.	Revs.	Revs.	No.	Revs.	Revs.
9 8	5,346			5,904		
		1,890	78·75		2,080	260·00
9 32	7,236			7,984		
		1,199	79·93		1,319	263·80
9 47	8,435			9,303		
		2,069	79·58		2,278	262·80
10 13	10,504			11,581		
		1,494	78·63		1,645	259·73
10 32	11,998			13,226		
		943	78·58		1,039	259·75
10 44	12,941			14,265		
		1,586	79·30		1,745	261·70
11 4	14,527			16,010		
		1,911	79·62		2,108	263·50
11 28	16,438			18,118		
	Mean §		79·23	Mean §		261·73

* The Dynamo Counter was geared to run at one-third the speed of the dynamo.

§ The mean is obtained by dividing the total number of revolutions by the total duration of the trial.

TABLE 10.—*Trial with Leather Belt (Domange). 9 August* 1894.

Mean Pressure and Horse-Power from Indicator Diagrams.

Mean pressure of steam at engine 88·78 lbs. per square inch.

Time a.m.	HIGH-PRESSURE Cylinder.				LOW-PRESSURE Cylinder.				Total Indicated Horse-Power.
	Front end.		Back end.		Front end.		Back end.		
	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	
H. M.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	I.H.P.
9 10	29·3	37·43	30·7	40·53	9·4	40·03	9·6	41·48	159·47
9 20	29·9	38·23	32·0	42·30	9·4	40·15	9·7	41·84	162·52
9 30	30·4	38·89	32·2	42·57	8·9	38·13	9·7	42·08	161·67
9 40	29·2	37·37	31·4	41·50	8·6	36·83	9·4	40·39	156·09
9 50	30·7	39·28	30·6	40·43	8·6	36·59	9·4	40·52	156·82
10 0	31·0	39·68	29·7	39·30	8·9	38·01	9·5	41·12	158·11
10 10	30·0	38·34	31·7	41·83	8·8	37·77	9·7	41·84	159·78
10 20	30·9	39·50	31·6	41·77	9·0	38·48	9·9	42·56	162·31
10 30	30·7	39·28	32·2	42·52	8·9	37·89	9·7	41·84	161·53
10 40	30·3	38·69	32·2	42·57	8·8	37·60	9·4	40·72	159·58
10 50	31·0	39·65	32·6	43·04	8·7	37·30	9·6	41·36	161·35
11 0	33·3	42·52	32·2	42·57	8·6	36·95	9·4	40·52	162·56
11 10	32·0	40·87	30·1	39·75	8·6	36·71	9·4	40·76	158·09
11 20	33·2	42·05	30·9	40·83	8·4	35·88	9·4	40·39	159·15
11 30	34·9	44·57	32·1	42·44	8·7	37·18	9·3	40·28	164·47
Means	31·12	39·76	31·48	41·59	8·82	37·70	9·54	41·18	160·23

TABLE 11.—*Trial with Ropes.* 9 *August* 1894.

Revolutions of Engine and Dynamo.

Time p.m.	ENGINE. Reading of Counter.	ENGINE. Revolutions Difference.	ENGINE. Revolutions Per minute.	DYNAMO.* Reading of Counter.	DYNAMO.* Revolutions Difference.	DYNAMO.* Revolutions Per minute.
H. M.	No.	Revs.	Revs.	No.	Revs.	Revs.
3 3	22,707			25,172		
		1,013	77·93			
3 16	23,720			——	1,476	260·00
		318	79·50			
3 20	24,038			26,648		
		1,023	78·70		1,133	261·45
3 33	25,061			27,781		
		865	78·64		957	261·00
3 44	25,926			28,738		
		1,414	78·55		1,567	261·16
4 2	27,340			30,305		
		1,016	78·15		1,126	259·85
4 15	28,356			31,431		
		1,333	78·42		1,478	260·82
4 32	29,689			32,909		
		1,021	78·54		1,131	261·00
4 45	30,710			34,040		
		1,334	78·47		1,478	260·82
5 2	32,044			35,518		
		1,255	78·44		1,390	260·63
5 18	33,299			36,908		
		1,177	78·48		1,303	260·60
5 33	34,476			38,211		
	Mean §		78·46	Mean §		260·78

* The Dynamo Counter was geared to run at one-third the speed of the dynamo.

§ The mean is obtained by dividing the total number of revolutions by the total duration of the trial.

TABLE 12.—*Trial with Ropes.* 9 *August* 1894.

Mean Pressure and Horse-Power from Indicator Diagrams.

Mean pressure of steam at engine 89·46 lbs. per square inch.

Time p.m.	HIGH-PRESSURE Cylinder.				LOW-PRESSURE Cylinder.				Total Indicated Horse-Power.
	Front end.		Back end.		Front end.		Back end.		
	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	Mean Pressure per sq. in.	Indicated Horse-Power.	
H. M.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	Lbs.	I.H.P.	I.H.P.
3 8	29·7	37·59	29·6	38·70	9·5	40·11	10·3	44·54	160·94
3 20	29·8	37·68	30·5	39·94	9·4	39·76	10·1	43·94	161·32
3 30	29·4	37·20	28·2	36·97	9·2	39·05	10·1	42·99	156·21
3 40	30·2	38·24	29·4	38·43	9·3	39·52	9·9	42·99	159·18
3 50	29·6	37·41	29·5	38·61	9·2	38·76	10·0	42·51	157·29
4 0	31·0	39·20	30·1	39·45	9·0	38·23	9·9	42·87	159·75
4 10	30·8	39·03	29·1	38·03	9·1	38·59	9·6	42·15	157·80
4 20	30·6	38·77	30·0	39·23	8·9	37·76	9·4	41·08	156·84
4 30	31·0	39·24	29·4	38·43	8·9	37·76	9·4	40·36	155·79
4 40	31·0	39·20	30·1	39·37	8·8	37·20	9·5	40·36	156·22
4 50	31·1	39·43	29·9	39·18	8·5	36·06	9·6	40·60	155·27
5 0	31·2	39·55	30·5	39·90	9·0	38·11	9·9	41·04	158·60
5 10	32·5	41·19	30·7	40·23	8·9	37·53	9·8	42·15	161·10
5 20	31·5	39·82	31·3	41·01	9·1	38·46	9·7	41·79	161·08
5 30	32·4	40·96	31·6	41·36	8·8	37·06	9·7	41·44	160·82
Means	30·79	38·97	29·99	39·25	9·04	38·26	9·84	42·05	158·54

TABLE 13.—*Summary of Trials with Ropes and Belts.*

Rope Fly-wheel 16·358 feet diameter, and Pulley 4·905 feet diameter, grooved for five Ropes of 1¾ inch diameter.
Belt Fly-wheel 16·382 feet diameter, and Pulley 4·922 feet diameter, for Belt of 17¾ inches width.

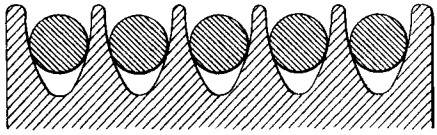
Number of trial		1	2	3	4	5
Ropes or Belt		Ropes.	Belt.	Belt.	Belt.	Ropes.
Material		Manila.	Cotton.	Leather.	Leather.	Manila.
Manufactured by		Saint.	Lechat.	Lemaire.	Domange.	Saint.
Date of trial, August 1894		7th aft.	8th morn.	8th aft.	9th morn.	9th aft.
Duration of trial	minutes	136	151	142	140	150
Indicated Horse-Power	I.H.P.	159·42*	159·67	158·84	160·23	158·54
Mean speed of Engine	revs. per min.	77·84*	79·05	79·08	79·23	78·46
„ „ „ Dynamo	revs. per min.	260·91	261·08	260·72	261·73	260·78
Ratio of Fly-wheel diameter to Pulley diameter at contact		3·335	3·329	3·329	3·329	3·335
C Circumferential speed of Fly-wheel	feet per sec.	66·64	67·75	67·78	67·82	67·16
c „ „ „ Pulley	feet per sec.	66·94	67·23	67·13	67·29	66·93
Slip, $100 \times (C-c) \div C$	per cent.	−0·051	+0·780	+0·961	+0·780	+0·329
Area of cross section of Ropes or Belt	inches	1·6×5	17·72×0·374	17·72×0·492	17·40×0·433	1·6×5
	square inches	=8·00	=6·63	=8·72	=7·54	=8·00
Tension on Ropes or Belt at fly-wheel	lbs. per sq. inch	157·17	176·08	132·98	155·02	155·02
„ „ „ pulley	lbs. per sq. inch	157·17	177·35	134·40	156·16	156·45
Weight of Ropes or Belt	lbs.	418·8	332·8	330·7	293·2	418·8
Mean Potential Difference (see footnote page 604)	volts	94·00	93·88†	93·83‡	94·00	94·00
Relative Power absorbed, taking trial 5 as 100·00		100·58	100·87	100·37	101·07	100·00

* Owing to the failure of the engine counter in trial 1, which perhaps explains the apparently negative slip, the indicated horse-power and speed of engine here given are too low; by counting with a chronometer the values obtained were 160·72 I.H.P. and 78·49 revolutions per minute. The engine and dynamo were new, and had previously run for only two hours since their erection the day before the trial; the mechanical losses would therefore be greater, and this is confirmed by the result of trial 5.

† The last five readings of the voltmeter were 93·66 instead of 94, which gives a mean of 93·88 volts for the fifteen readings.

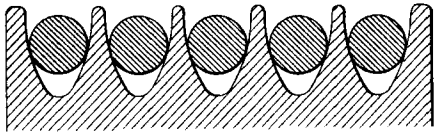
‡ Ten readings out of the fifteen were 93·74 instead of 94, which gives a mean of 93·83 volts. (See footnote page 604.)

Fig. 1. *Rope Fly-wheel.*

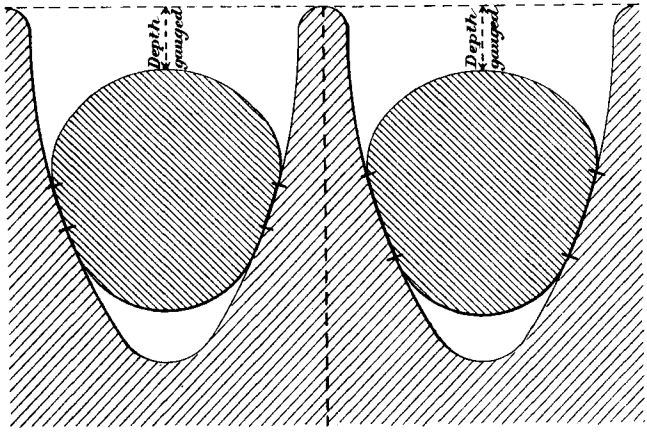


Scale 1/6th

Fig. 2. *Rope Pulley.*

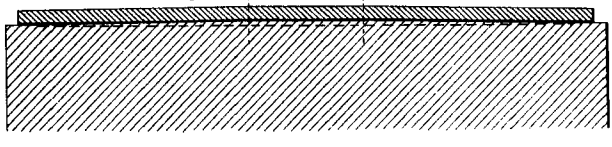


Fly-wheel. Fig. 3. *Pulley.*



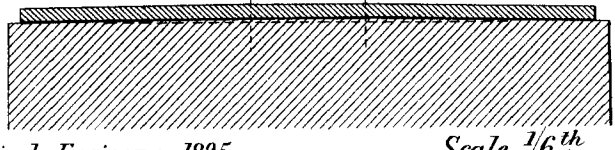
Scale 2/3rds

Fig. 4. *Belt Fly-wheel.*



Scale 1/6th

Fig. 5. *Belt Pulley.*



Mechanical Engineers 1895. *Scale 1/6th*

0 5 10 15 *Inches* 20