

Fig. 7.

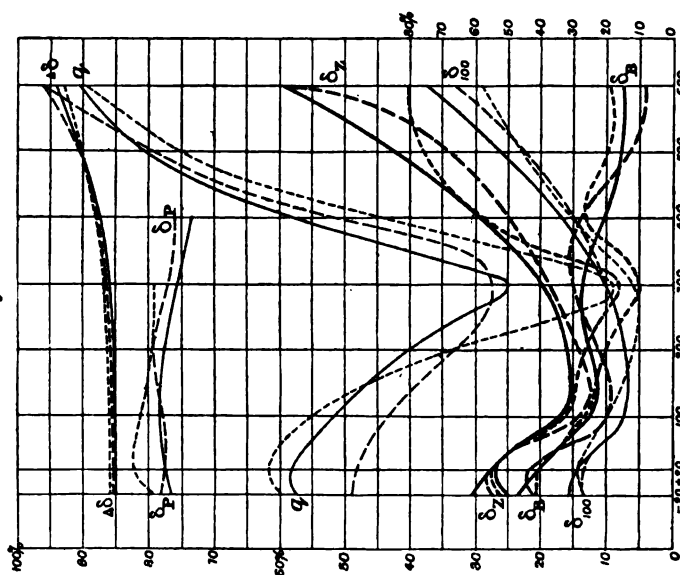
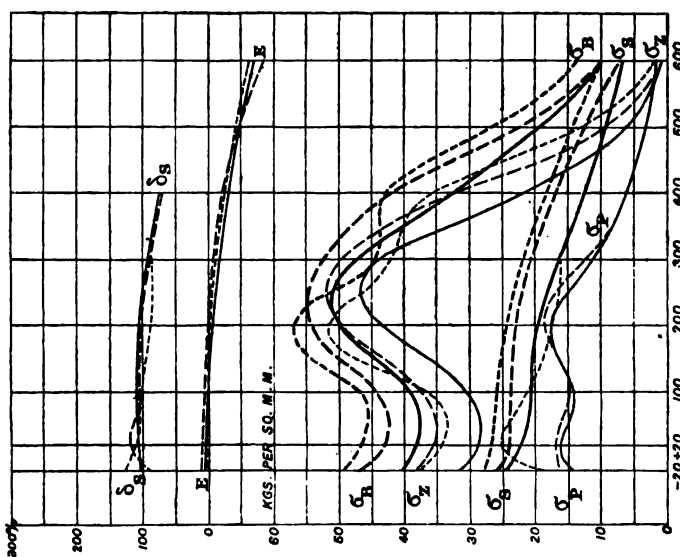


Fig. 6.



I and II were supplied by the Hoerde Company, quality III by the Union Company.

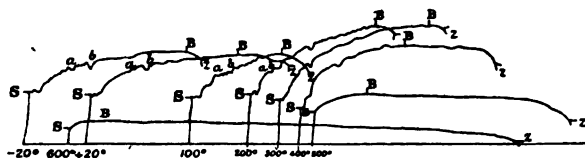
In general the last of these (III) exhibits the same characteristics in regard to the values of σ_s and σ_z as the other two, but deviates noticeably from the latter at 300°. The elongation δ_s increases between -20° and +20°, and then, for the "Hoerde" material, decreases and reaches a minimum at about 130°. From this point the curves rise again up to between 280° to 330° and then fall. For the "Union" material (III) the minimum value of δ_s is attained only at 300°, and the curve afterwards rises, a maximum occurring at 400°. Similar differences are also to be observed in the character of the curves for δ_z .

The following Table, compiled from the mean observed values, gives the ratios in per cent. of δ_s to δ_z for various temperatures:—

Quality of Material.	Ratio for							
	-20°	+20°	100°	200°	300°	400°	500°	600°
I . .	78	76	76	79	73	36	20	[28]
II . .	75	79	68	76	81	58	19	8
III . .	78	72	81	74	59	48	26	15

In Fig. 8 the stress diagrams for material of quality II are reproduced. The limit of stretch, in each diagram, is denoted by

Fig. 8.



STRESS DIAGRAMS FOR QUALITY II AND TEMPERATURES -20° TO 600°.

S, the point of maximum stress by B, the point of fracture by Z. At 400° the material has assumed the character of the soft metals, zinc for instance. The irregularities at the points a and b occurred when the flow extended to the shoulders of the test-piece, beyond the actual test-length.

The variations in the contraction of area are extraordinarily great. For all three qualities of material the smallest value of q , the reduction of area, occurs at 300°.

The stress at the limit of proportionality increases with rising temperature between -20° and $+20^{\circ}$, reaching a maximum about $+20^{\circ}$, it then falls slightly to 100° , and at 200° attains a second higher maximum, subsequently falling rapidly. The elongation at the limit of proportionality δ_p is subject to no appreciable alterations. For the stresses usual at ordinary temperatures the engineer may therefore reckon, in steel heated even up to 200° , on elongations proportional to the load and on sufficient safety. It would, however, scarcely be safe to draw conclusions from the results of these experiments as to the admissible working stress for temperatures over 200° , or for frequent changes of temperature ranging from 150° to 350° . Reliable values in such cases could only be arrived at by repeated tests, continued for long periods (*Dauerversuche*), with the metal in a heated state.

The question of the safety of iron structures may be influenced by the peculiar behaviour of the material at 300° . At this temperature the strength is greater, but the reduction of area and elongation less than in a cold state. Fracture occurs suddenly without previous contraction, the metal exhibiting a certain brittleness, which also finds expression in the appearance of the fractured surface. On this account it is questionable whether at 300° steel is capable of resisting repeated shocks.

The original is accompanied by facsimiles of photographs of the test-pieces after fracture, arranged in groups according to the temperatures at which they were tested. From these a tendency is evident for the fracture to occur at a particular part of the piece for each temperature. This is probably due to want of uniformity in the heating of the piece, causing it to yield in the coldest or hottest part, according to the effect of heat at the different temperatures.

At each temperature the character of the fracture has also a distinctive form.

(*Paper No. 2527.*)

“Authorities on the Steam-Jacket : Facts and Current Opinions.”

By Professor R. H. THURSTON.¹

Abstracted by BRYAN DONKIN, JUN., M. Inst. C.E.

IN this Paper the Author summarizes the opinions entertained, and experimental data furnished by leading scientific engineers respecting the use and advantages of the steam-jacket. He begins by quoting a phrase of Mr. G. A. Hirn, “that the effects of the steam-jacket have been alternately vaunted and denied, but the public have never yet been put in possession of the actual facts.” Such, even at the present day, is for the most part the state of knowledge upon the subject.

Knowing the differences of opinion which exist as to the value of the steam-jacket, and its relative efficiency under different circumstances in ordinary practice, it has been deemed desirable to examine and summarize the views of some of those who have studied the subject. Much uncertainty still prevails as to the effect of the jacket, and it is an open question whether it is of any practical utility at all. Under these circumstances there can be no better method of clearing up doubtful points than that here adopted by the Author. To bring together the opinions of so many authorities must lead to a certain unanimity of judgment, and this, as will be seen, is in favour of retaining the jacket as a means of increasing the economy and efficiency of the steam-engine. A correct theory, when it is obtained, will show that the jacket may be either a decided advantage, an unimportant appendage, or have a deleterious effect upon the working of the steam-engine.

The Author does not here profess to give his own views on the subject of the steam-jacket. They had been already laid before the public in a paper on “The Philosophy of the Multiple-Cylinder

¹ The original Paper was presented to the American Society of Mechanical Engineers in November 1890.

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Engine," presented to the American Society of Mechanical Engineers, November 1889. In it he says that steam-jacketing is a common partial remedy for waste, and may be made to produce the effect of superheating, that is, to secure drier steam in the engine. High-speed engines derive less advantage from it than those of low-speed ones, and the economy is not so marked in compound as in single-cylinder engines. The saving effected is about 20 per cent., and a similar gain may be obtained by superheating. In compound engines the Author considered it advisable to jacket the whole series of cylinders, since "to omit the jacket from any increases the aggregate loss of heat in the whole engine." The greater the piston-speeds, the less the necessity for the jacket, and it is not unfrequently omitted from marine engines, which attain a speed of 1,000 feet a minute, while slow-moving pumping engines must be jacketed to work economically. The actual numerical value of the economy obtained by the jacket can only be determined by collating the numerous experiments made by independent observers.

The steam-jacket was invented by James Watt, and patented in 1769. His attention was drawn to the waste of heat in the engines he had already made, which he attributed to the introduction of the steam into a chilled cylinder, and he laid down the obvious principle, still valid after 120 years, that it is necessary to keep the cylinder always as hot as the steam which enters it. This he proposed to do either by covering it with a non-conducting material, or by surrounding it with a heated body, such as steam. From that day to this, therefore, the steam-jacket has been more or less a necessary adjunct of economical engines. The phenomenon of cylinder-condensation was certainly known to Watt. Although he does not appear to have fully understood the theory of the steam-jacket, he always employed it, for he found that when he tried to lay it aside, the consumption of fuel was much greater. It was only in later years that its use was discontinued by engineers who did not understand that the type of engine, and the quality of the steam, often diminished, and sometimes wholly annulled, the advantage of the steam-jacket.

The first of modern writers to draw attention to Watt's jacket was Combes. In the *Comptes Rendus* of the French Académie des Sciences, 1843, he says that the object of the jacket is to maintain the temperature of the steam, and to prevent condensation during expansion, and that it gave an economy of about 36 per cent. In 1844 Mr. Gill found that even where the steam is dry, and no loss by radiation takes place, a loss of heat

caused by the sudden evaporation of the steam, in other words, cylinder-condensation ensues. This theory was verified by Mr. Farcot, a French engineer, who, as early as 1848, built compound engines with both cylinders jacketed.

But the honour of establishing the theory of the steam-jacket on a firm experimental basis unquestionably belongs to Hirn. He introduced a new method of gauging the heat of an engine, and his researches materially contributed to the elucidation of the subject. In every trial he measured the quantity of water entering the boiler and there turned into steam, the quantity of steam in the cylinder, and the heat transferred to the metal from the steam, and returned to the steam too late to transform it into mechanical energy. He found that the economy produced by the steam-jacket was $23\frac{1}{2}$ per cent. This was obtained not by actual diminution of the quantity of fuel and steam consumed, but by augmenting the amount of work done by the engine. From this he deduced the principle that the influence of the steam-jacket consisted in preventing the partial condensation of the steam during expansion, and the resulting loss of pressure. The quantity of heat consumed by the engine must alone be taken as the true measure of its efficiency. If the theoretical value of the engine be calculated without reckoning the waste found in actual practice an error of 30 to 60 per cent. may arise, and this will be increased if the waste produced by heat taken up by the exhaust-steam be neglected. Hirn found that the walls of a single-cylinder engine give up the same amount of heat to the steam with as without a jacket, but in the former case the heat is yielded during expansion, costs nothing, and adds to the work done, while without a jacket this heat is passed into the condenser without doing any work, because it evaporates the condensed water after the exhaust-valve has opened. This has been confirmed by subsequent experiments. But whatever the result obtained with compound engines, the value of the jacket with single-cylinder engines is incontestible. Hirn's able coadjutor Hallauer considered that this type of engine can with the aid of the jacket be made as efficient as the compound. But both Hallauer and Hirn thought that the advantages gained by superheating the steam were still greater than those of a jacket. With a compound engine a gain of 20 per cent. was obtained by using superheated steam to 410° Fahrenheit; with a single-cylinder engine with steam superheated to 437° Fahrenheit, an economy of 31 per cent.; and when the temperature of the steam was raised to 473° Fahrenheit a gain of 47 per

cent. was noted. Superheating gives an advantage to a single cylinder over a compound Woolf engine of nearly 14½ per cent., both working without a jacket.

Superheating, however, has not found much favour with engineers because of the wear and tear to the engine. John Penn appears to be the only authority who recommended it; he was of the opinion that to superheat the steam before it enters the cylinder is preferable to the use of a steam-jacket, and believed it to be possible in large marine engines thus to secure dry steam throughout the stroke.

As early as 1858 Professor Rankine recognized that the principal effect of the jacket invented by Watt is "to prevent the liquefaction of steam in the cylinder." This condensation, however, he attributed only to the quantity of steam condensed during the expansion in the preceding stroke, which was very small. Still he thought it possible, by the use of a jacket or superheated steam, greatly to diminish the loss of efficiency arising from the conducting-power of the cylinder. He deprecated the absence of a jacket, and declared that the practice of marine engineers proved that it was useless, if not wasteful, to employ the high rates of expansion suited to compound engines, if the jacket were abandoned. The use of the steam-jacket was also advocated by Mr. Cowper, Mr. L. E. Fletcher, and by Mr. Labouchère. The latter considered that the economy resulting from it ranged from 20 to 25 per cent. In a series of experiments reported to the "Vereine deutscher Ingenieure" by Mr. Hirn, it was found that a condensing non-jacketed engine, when expanding ten times, demanded 74 per cent. in excess of the theoretical quantity of steam required; when cut off at one-fifth 62 per cent.; and with three expansions 55 per cent. excess. The addition of a jacket reduced these losses to 64, 54, and 48 per cent. respectively. Increased piston-speed produced the same effect as a jacket; an engine running at a speed of 3 feet per second showed a loss of 96 per cent., with 7 feet speed the loss was 70 per cent.

The first of later writers to describe the way in which heat is wasted in an engine is Mr. D. K. Clark. Writing in 1850 he maintained that to prevent condensation in steam worked expansively, the cylinder must be kept at the initial temperature of the steam. Even with a steam-jacket, however, this condensation is not wholly avoided; the use of superheated steam was probably more effectual. In a single-cylinder engine he considered the gain with a jacket was about 15 per cent., and from 10 to 12 per cent. in the compound engine. The advantage obtained with a

jacket in the single-cylinder engine is due to the fact that the range of pressure and temperature is more in it than in each separate cylinder of the compound engine, between which it is distributed. Another advantage was obtained by having long-stroke cylinders, on account of the proportionally larger surface of the covers and pistons exposed to the action of the steam in short-stroke cylinders.

These opinions were confirmed by Mr. Isherwood. His experiments showed that the steam-jacket is of real advantage, but varied in the degree of economy it confers. Where no expansion is used, and the cylinder is large, there is practically no gain. The greater the expansion and initial pressure, and the less the speed, the higher the efficiency with the jacket, but where condensation is prevented by superheating, it has no effect. Small engines give an economy of 20, and large of 8 or 9 per cent., but the steam used in the jacket must be brought direct from the boiler.

Ledieu does not wholly endorse these views. He thinks the steam-jacket should be applied to all the cylinders of a compound engine, and that with compounding, superheating and a jacket, it might sometimes be possible to attain an economy of 40 per cent., but special care must be bestowed on the construction of the jacketed cylinder. It is not advisable to make the cylinder and jacket in one piece throughout, nor to allow the boiler steam to pass from the jacket into the cylinder, since it has already been cooled. The ordinary economy of a steam-jacket he fixes at 15 to 25 per cent. unless the heat in the jacket is insufficient to prevent cylinder-waste, when it becomes harmful instead of beneficial.

The effect of the jacket upon the quantity of fuel used was shown in experiments by Messrs. Farey and Donkin. In a compound engine the fuel per indicated HP. per hour was 2·6 lbs. with, and 3·8 lbs. without, jackets; and in another, the water rate per indicated HP. per hour was 24½ lbs. with, and 39½ lbs. without, the jackets. In a marine compound engine built by Messrs. Napier, the number of revolutions fell from 63 to 58 per minute when the jackets were shut off.

Turnbull thinks the steam-jacket more effectual and economical when applied to compound than to single-cylinder engines, on account of the greater range of temperature in the latter, while Professor Trowbridge says the gain is greater if the large cylinder of a compound engine be jacketed than if a jacket be applied to the cylinder of a single engine. Mr. Emery fixes the saving at

11.78 per cent. in the latter example, and in the former at 11.72 per cent., and his opinion of the value of the jacket is confirmed by Mr. G. Holmes. Mr. Cornut, the French engineer, puts the gain at from 15 to 20 per cent., and he found that shutting off the jackets produced a sensible reduction of initial pressure. Professor Cotterill enunciates the useful rule that great caution is necessary in drawing conclusions from any special set of experiments on the influence of the steam-jacket. Its employment is strenuously defended by Mr. R. Sennett.

Longridge gives an instance in which on an economical compound engine he obtained slightly better results without than with jackets.

Loss from leakage appears to be one of the objections to their use, even where it is admitted that the jackets prevent condensation during admission, and reduce waste. This difficulty, however, can be overcome. The economy obtained with the jacket appears to be especially marked when it is applied to Woolf engines with two cylinders, though Mr. Lee, an American engineer deprecates its use.

A series of valuable experiments were made by Mr. Delafond at Creusot in 1883 upon a Corliss engine. It was found that the greatest economy was obtained with the jacket at equal ratios of expansion with higher steam-pressures, while the less the expansion with equal pressure, the less the economy due to the jacket. A gain of 15 to 20 per cent. was reported in these experiments. The proportion existing between expansion and the economy due to the jacket was clearly exhibited in Mr. Borodin's valuable series of trials, where the gain was 12 per cent. with $3\frac{1}{2}$ expansions, and 16 per cent. with about five expansions. In one case the gain to the engine was 14 per cent. owing to a decrease of 8 per cent. in initial condensation; but notwithstanding these figures, Mr. Borodin was not on the whole favourable to the employment of steam-jackets for locomotive engines, unless they are properly constructed and thoroughly drained. He found that a jacket was in some cases positively injurious, and was always of less value with a compound than a single-cylinder engine. Owing to defective handling, the gain attested when the engine was under cover was lost when on the road.

Messrs. Crampton, Walker, and Wylie all consider the steam-jacket of advantage, and the latter thinks it essential to attain maximum efficiency. From motives of economy it is frequently discarded; and there is no doubt that cylinder-waste takes place

in spite of the jacket, especially in the high-pressure cylinder of a compound engine. Professor Ewing thinks the jacket useful with slow-running engines when well drained, increasing their efficiency 20 to 25 per cent., but of small benefit in high-speed engines. In a single-cylinder pumping-engine running at 20 revolutions per minute, Mr. Mair-Rumley reported that the steam used was 22 lbs. per I.H.P. per hour with a jacket, and $26\frac{1}{2}$ lbs. without. In the latter case the cylinder-condensation was from 25 to 37 per cent. more. Professor Dyer, when reviewing Mr. Willans' experiments, pointed out that the use of the steam-jacket was no longer so imperative as formerly, since the steam was maintained at a more even temperature by the successive cylinders of a compound engine. The ideal function of a jacket was simply, he considered, to prevent condensation, but unfortunately it also acted as a boiler. In the compound engine it generated steam in the low-pressure cylinder, which, instead of doing work, passed immediately to the condenser; and it was better this steam should be sent on in the form of water. The sub-division of expansion into successive steps economized the steam better. The use of a steam-jacket also violated a fundamental law of heat-engines, namely, that they should receive their heat at the maximum, and give it out at the minimum temperature, instead of at an intermediate temperature. Professor Dyer is, however, willing to allow that a steam-jacket is of advantage where the ratio of expansion is large; but he thinks super-heating a better method of reducing waste.

Professor Schröter, of Munich, gives particulars of a set of experiments conducted by him on a triple-condensing Sulzer engine, jacketed throughout. The boiler-pressure was 150 lbs., ratio of expansion 24, and the quantity of steam per I.H.P. per hour 15.2 lbs. Remarkable results were also obtained by Professor Reynolds¹ at the Whitworth Laboratory, Manchester, with three independent cylinders combined in a triple-engine. In this very economical engine the loss by shutting off the jackets was about 18 per cent.

Professor Dwelshauvers-Dery, of Liège, subjected these figures to analysis, and found that the cylinder-jackets afforded a net gain of 17 per cent., due to their action in promoting efficiency of working, apart from the thermodynamic efficiency. The famous experiments of Hirn showed, according to Mr. Dwelshauvers-Dery, a gain of 25 per cent. caused by super-heating; but to super-heat the steam of a cylinder already jacketed did not, he

¹ Minutes of Proceedings Inst. C.E., vol. xcix. p. 152.

thought, add to any appreciable extent to its efficiency. Such were also the views entertained by Hirn himself, who, only a few weeks before his death, declared that "the use of super-heated steam absolutely dispenses with the need of a jacket." A manufacturer of Roubaix, however, found that with super-heated steam in the jacket the speed was increased nearly 10 per cent.

Mr. Mallet, a French engineer, says that the utility of the jacket is so much the more as the difference of temperature is greater between the walls of the cylinder and the initial steam. He thinks the jacket most advantageous on a single-cylinder engine, while Professor Unwin would apply it in all cases and to all cylinders, provided ordinary steam be used; "but the advantages may diminish to an amount not worth the interest on extra cost."

Two American engineers, Worthington and Edwin Reynolds, advocate the use of the jacket. In some of Mr. Reynolds's experiments on a compound engine at 12 revolutions per minute he obtained an economy of 33 per cent. with jackets. Driving the engine up to 56 revolutions, the gain fell to 9 per cent. Pumping engines, when tested, showed a decided saving with the jackets; and Mr. Reynolds's experience leads him to conclude that a marked advantage is obtained where the larger cylinder is jacketed with boiler-steam over jacketing with steam of lower pressure. Two or three manufacturing firms, among them the Westinghouse Co., think the economy obtained with the jacket hardly compensates for the cost of construction. Mr. Leavitt considers the jacket advantageous for every kind of cylinder. Mr. Hill concurs, if proper conditions be maintained, and summarizes his views as follows:—

1. The steam-jacket is best adapted to low speeds and high expansive-engines.
2. For high pressures, with wide range of expansion and temperature, it is desirable to have a jacket.
3. The higher the ratio of expansion, the greater need for the jacket.
4. With super-heated steam it is comparatively valueless.
5. With compound or triple-engines the high-pressure cylinder, if little expansion be used, should not be jacketed.

Professor Schröter deduces the following conclusions from his experiments:—

1. The value of the jacket may vary within wide limits, or become negative.
2. The shorter the cut-off, the greater the gain with a jacket.

3. The use of higher pressure in the jacket than in the cylinder is of advantage. The greater the difference the better.

4. The high-pressure cylinder may be leftunjacketed without much loss; the others should always be jacketed.

The following Table (pp. 234-237) gives a list of the experiments cited by Professor Thurston.

STEAM-JACKET EXPERIMENTS

Number.	Type of Engine.	Dimensions.						Pressure of Steam.	Ratio of Expansion.
		Diameters.			Strokes of				
		First Cylinder.	Second Cylinder.	Third Cylinder.	First Cylinder.	Second Cylinder.	Third Cylinder.		
I.	{Single-cylinder.}	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Lbs.	..
II.	{Non - condensing.}	2	..	..	8	..	..	115	..
III.	..	7 $\frac{1}{16}$	..	..	26 $\frac{1}{2}$	..	..	45	1-2.7
IV.	..	..	..	..	..	..	..	..	8 and 21
V.	..	..	..	..	..	..	..	..	10
VI.	..	34.1	..	..	30	..	..	68.5	3.5-4.4
VII.	..	16.54	..	..	23.62	..	..	50-78	3.3-5.4
VIII.	..	21.65	..	..	43.31	..	..	50-110	1-7.1
IX.	{Single-cylinder.}	..	..	..	..	..	..	53	6
X.	Condensing.	15.35	..	..	31.5	..	..	50-58	20
XI.	..	5.25	..	..	10	..	..	38-56	5.3
XII.	..	90	..	..	117	..	..	12	1.7
XIII.	..	70	..	..	110	..	..	36	4
XIV.	..	7 $\frac{1}{16}$	..	..	26 $\frac{1}{2}$	..	..	45	1.8
XV.	..	20 $\frac{1}{16}$	..	..	41 $\frac{1}{2}$	..	..	80	10
XVI.	..	26	..	..	30	..	..	17	3.4
XVII.	..	25	..	..	24	..	..	78	5 $\frac{1}{2}$
XVIII.	..	34.1	..	..	30	..	..	13-71	1.5-7.8
XIX.	..	24	..	..	48	..	..	67-68	5.7-12.4
XX.	..	30	..	..	42	..	..	30-60	3.1-4.7
XXI.	..	39.37	..	..	70.87	..	..	60-62	13-15
XXII.	..	32	..	..	66	..	..	42	3.8-4.3
XXIII.	..	21.65	..	..	43.31	..	..	36-110	1-14

QUOTED BY PROFESSOR THURSTON.

L.H.P.	Revolutions per Minute.	Gain per cent. due to Jackets.	Authority.	Date.	Parts Jacketed.	Type of Engine, &c.
120	..	8-10	{Thomas & Laurens.}	1846	..	..
..	203	23	McKay.	1859	..	..
4·5-10·6	45-51	11-21·5	Donkin.	1874	{Body and bot- tom end jack- eted only.}	Beam-engine.
79-136	..	13·8-19·5	Cornut.	1874	..	..
..	..	19	"	1874	..	..
170-212	46·7-53·2	10·3	{Loring and Emery.}	1875	{Body and both ends jacketed.}	{Steamship 'Gal- lotin.' Locomotive; summary of twelve experi- ments. Summary of twenty-two ex- periments.}
40-59	92-102	7½-22·4	Borodine.	1881-83	..	..
108-237	60-64	1·0-22	Delafond.	1883	{Body only jack- eted.}	..
..	..	30-32	{Thomas & Laurens.}	1842	..	..
6-7	..	27·5-41·7	Combes.	1843	..	..
0·93-1·13	60-61	31·2	Isherwood.	1860	{Body, both ends and valve- chest jacketed. Body only jack- eted.}	..
352-361	7·9-8·1	2·7	"	1860	{Body only jack- eted.}	Pumping-engine.
153-161	12	12·9	Donkin.	1870	{Body only jack- eted.}	Pumping-engine.
7·7-9·3	37-40	19·4	"	1870	{Body and bot- tom end jack- eted.}	Beam-engine.
56-83	55	23·7	Hirn.	1873	..	Beam-engine.
39-42	37-40	31·3-32·4	Rennie.	1873	..	Beam-engine.
89-116	47-54	11·8	Emery.	1874	..	{Steamship 'Bache.'}
87-348	40-69	6·1-16·3	"	1874	{Body and both ends jacketed. Body and both ends jacketed. Body and both ends jacketed. Body only jack- eted.}	{Steamship 'Gal- lotin.'}
81-158	49-50½	21·5-30·3	W. Meunier.	1878	..	..
170-192	53	15·5	Fletcher.	1877	..	..
166-174	27	17·1	Faroot.	1879	{Body only jack- eted.}	Pumping-engine.
124	20½	14·6	Mair.	1882	{Body and bot- tom end jack- eted.}	Pumping-engine.
69-212	58-62	½-26·6	Delafond.	1883	{Body only jack- eted.}	Summary of forty-six ex- periments.

STEAM-JACKET EXPERIMENTS

Number.	Type of Engine.	Dimensions.						Pressure of Steam.	Ratio of Expansion.
		Diameters.			Strokes of				
		First Cylin-der.	Second Cylin-der.	Third Cylin-der.	First Cylin-der.	Second Cylin-der.	Third Cylin-der.		
XXIV.	Compound.	16½	29½	..	49½	66¾	..	56	4·3
XXV.	Condensing.	7⅞	14	..	26½	36	..	41	5·5
XXVI.	„	13⅜	24	..	39½	54	..	41	11-14
XXVIA.	„	13⅜	24	..	39½	54	..	41	12
XXVII.	„	7⅞	14	..	26½	36	..	45	10·3
XXVIII.	„	20⅞	31½	..	51½	70½	..	60	13
XXIX.	„	16	25	..	24	24	..	80	7
XXX.	„	6	10	..	12	12	..	42	4·45-10·78
XXX.	„	6	10	..	12	12	..	42	5·38-16
XXX.	„	6	10	..	12	12	..	42	5-13
XXXI.	„	22	34	..	43	66	..	45	9½-16
XXXII.	„	24½	38	..	41	66	..	73	7·8-9·6
XXXIII.	„	19	25	..	24	24	..	80	7
XXXIV.	„	6	10	..	12	12	..	40-96	8-11
XXXV.	{ Triple-con- densing. }	5	8	12	10	10	15	190	15-26

QUOTED BY PROFESSOR THURSTON.—continued.

I.H.P.	Revolutions per Minute.	Gain per cent. due to Jackets.	Authority.	Date.	Parts Jacketed.	Type of Engine, &c.
{ Brake HP. 78-102 }	23½	23½	Hirn.	1855	{ Body and bot- tom jacketed. }	Beam-engine.
17-20	36	28·6	Donkin.	1859	{ Body and bot- tom ends jack- eted. }	"
28-46	32½	31·2	"	1868	{ Body and bot- tom ends jack- eted. }	"
37	32½	13·7	"	1868	{ Only 4 lbs. pres- sure steam in jackets. }	"
10-17	37-44	38·6	"	1870	{ Body and bot- tom ends jack- eted. }	"
119	25	4·5	Lhoest.	1873	{ Low - pressure cylinder only jacketed. }	"
77-99	48-53	11·7	Emery.	1874	..	{ Steamship 'Beache.' }
6·7-10·5	98	25·5	Donkin.	1881	{ Bodies only jacketed; steam in h.p. jacket only. }	{ Horizontal engine. }
7-12	98	29	"	1881	{ Bodies only jacketed; steam in l.p. jacket only. }	"
7-13	98	34	"	1881	{ Bodies only jacketed; steam in both jackets. }	"
75½	18-19½	35	Mair.	1881	{ Bodies and both ends jacketed. }	Pumping-engine.
268	34	8·7	"	1881	{ Bodies only jacketed. }	..
157-168	55	15·4	{ Donkin and Kennedy. }	1887	{ Bodies only jacketed. }	Pumping-engine.
7-13	75-101	4·4-38·2	Kennedy.	1888	..	{ Summary of twenty-one ex- periments. }
73	230-322	17-18	Reynolds.	1890	{ Jacketing very complete. }	Vertical-engine.

(*Paper No. 2503.*)

“On the Sewerage and Sewage Disposal Works of the Borough of Dudley.”

By EDWARD DIMMACK MARTEN, M.A., Assoc. M. Inst. C.E.

THE difficulty of dealing with the sewage of the populous district which overlies the celebrated South Staffordshire ten-yard seam is enhanced by mining-operations. Wherever this coal is worked the surface is more or less affected, and subsides or is “drawn,” sometimes gradually, but sometimes with such suddenness as to endanger life. Water-pipes of the ordinary description are frequently fractured by these movements, which often cause considerable leakage at the joints. So much is this the case that the Author’s father, Mr. Henry John Marten, M. Inst. C.E., many years ago found it necessary to design a special socket to obviate the difficulty. Some of the canals which intersect the district are now carried upon embankments, 20 feet in height, over ground which, within the memory of man, was on a level with their banks. It will readily be understood that these subsidences, which are of every-day occurrence in the Black Country, seriously interfere with the work of the sanitary engineer.

The difficulties are not so formidable in the towns themselves as in the districts which surround them, since in most cases the value of the surface-rights in towns, and the necessity of affording vertical and lateral supports to buildings, make any mining operations thereunder impracticable, and it is generally, but not always, found possible to construct and work a system of internal sewerage. It is mainly in connection with outfall and intercepting sewers laid outside town limits that the troubles accruing from mining-operations are experienced.

Whilst, moreover, the mining in this district is a standing cause of leaky sewers, it is at the same time emphatically a reason why they should be watertight. The South Staffordshire Mines Drainage Commissioners have spent large sums of money in draining the coalfield and in constructing works to prevent water finding its way into the mines, and they very properly watch with

a jealous eye any action which may possibly add to their pumping-expenses. All sewers constructed outside the actual town district have to be laid in a thick bed of puddled clay, and sometimes are required also to be of cast-iron.

Sewage-farming within the mining-area would be attended with great difficulty, as even if a sufficiency of surface land could be acquired without the vast expense of purchasing the minerals below, anything in the shape of irrigation would be open to suspicion, as likely to send water into the mines, and would probably be opposed by the Mines Drainage authorities on that ground. Precipitation, aided by artificial filtration, is practically the only process available for the central towns of this district, unless the sewage can be conveyed by some means over the intervening mining ground on to the non-mining *terra firma* which surrounds it. Precipitation, however, is also attended with considerable difficulties, because to enable the necessary works to be constructed, the first requirement is suitable land, the mines and minerals underlying which must be purchased. This adds considerably to the cost, and further difficulties are often experienced on account of the operations of adjoining mine-owners, which have a tendency to "draw" the site and the structures erected upon it.

The municipal borough of Dudley has a population of about 46,000, the town itself containing about 30,000 inhabitants, while the remaining 16,000 are scattered among the mining villages which lie within the borough boundaries. It is situated upon a ridge running nearly north and south, and forming a portion of the watershed of England, the natural drainage of the town being partly into the Severn basin, and partly into the Trent basin. Some of the houses stand at an elevation of over 800 feet above sea-level; and the lowest part of the ridge, where it passes through the town, is 660 feet above sea-level. The districts to be drained lie on each side of the main hill, extending as far down as 590 feet above sea-level, so that it is only possible to deal with the whole sewage of the town at any one point, by means of long lines of intercepting sewers connected by a tunnel about $\frac{1}{2}$ mile in length through the ridge. To these difficulties, arising from the conformation of the ground on which the town is built, were added those arising from mining-operations around it.

In 1876 the Corporation purchased an estate known as the Russell's Hall estate, 70 acres in extent, closely adjoining the western side of the town, and lying at a sufficiently low level to deal with the whole of the sewage from both sides of the ridge.

It was proposed to bring the sewage to this land by means of intercepting sewers traversing both flanks of the hill upon which the town is built, and connected by a tunnel, and to deal with it there by means of a combination of filter-beds and irrigation. The estate consisted entirely of mining-ground, and the scheme was consequently opposed, both by the South Staffordshire Mines Drainage Commissioners, and by the late Earl of Dudley, who was by far the largest ratepayer in the borough, and who was advised that the diversion, as proposed by the Corporation, of storm-water as well as sewage on the land, would injuriously affect his mines in the neighbourhood, and the streams passing through his estates, besides being unnecessarily costly and likely to create a nuisance. Mr. H. J. Marten was consulted, and with the concurrence of Mr. George Taylor, the agent for the surface of the Dudley and Himley estates, prepared an alternative scheme which was laid before the Town Council in a Report, on July 25, 1876. This scheme, after a delay occasioned by the necessity of obtaining an Act of Parliament—certain portions of the Earl's settled estates being affected by the covenants entered into with the Corporation—was carried out by Mr. H. J. Marten, assisted by the Author, during a period extending from June 25, 1879, to July 30, 1884.

The town has been entirely re-sewered on the separate system, and upon the most modern principles. The gradients are in most cases so steep that practically no artificial flushing is required, and from the same cause a few ventilators carried up the sides of the houses in the higher parts of the town are sufficient, with the aid of the ventilating covers of the manholes, to keep the sewers free from noxious gases. The branch sewers are all stoneware, and the joints are made with tarred yarn and cement. Manholes are placed at every change of line or gradient. Only one case of stoppage has occurred since the system has been in operation; and on an investigation being made as to the cause, it was discovered that a butcher was in the habit of discharging hot fat into the sewer. This was put a stop to, and it has always worked well since. The houses have, to a large extent, been disconnected from the old drains, which are intended to be used henceforth exclusively for surface-water, which they convey to the streams and brooks, eleven in number, forming the natural outlets from the town. Only such storm-water as it is impossible to exclude is allowed to enter the new sewers. The old drains, as is usually the case, were found to be of immense size compared with the work they were constructed to perform, and to have

been put in without any attempt at system, and the capital outlay which they represent would probably, if properly applied, have sufficed to put down three or four complete modern systems of internal sewerage for the town.

The sewage, collected as above described, gravitates to an intercepting-sewer along each side of the ridge upon which the town is built. These intercepting-sewers, whose flattest gradient is 5 feet per mile, converge upon the Russell's Hall Estate, the northern one being for the last $\frac{1}{2}$ mile in a tunnel which is in some places more than 100 feet below the surface of the ground. The hill through which this tunnel passes has been formed by an upheaval of the Upper Silurian Limestones, which here form an anticlinal, from the summit of which the coal measures have been denuded. No trouble, consequently, was experienced from mining operations in driving the tunnel, though the intercepting-sewers themselves suffered greatly from this cause. They had to be laid almost entirely in a thick bed of puddled clay, and as near the surface of the ground as possible, which added seriously to their length, as it was necessary to follow the contour of the land. To show the difficulties which have to be contended with in a mining country, the Author may mention that during the construction of the works, he found one morning that some 30 yards of the new sewer had disappeared bodily into the workings below, leaving nothing to be seen except a deep hole resembling the crater of a volcano. This accident rendered necessary a somewhat costly deviation from the line originally selected.

At Russell's Hall Estate, the liquid is first sent through rough strainers formed of broken blast-furnace cinders, and capable of removing the heavier solid matters; it is then passed into a small reservoir or storm-water catch-pound, formed partly by excavation and partly by embankment, and capable of holding about 2,500,000 gallons. This storm-water catch-pound is situated upon the upper part of the Russell's Hall Estate, and the level of its top water-line is 544 feet above Ordnance Datum. There is a considerable fall between this and the River Smestow, $4\frac{1}{2}$ miles to the westward, the bed of which is 344 feet lower. Still going westward, the country rises rapidly for the next mile beyond the river to the summit of a range known as the Black Hills, which is 426 feet above Ordnance Datum. From this point there is a gradual fall westward for some miles. The sewage, collected as above described into the storm-water catch-pound, is delivered by gravitation through a 13-inch cast-iron main, acting as an "inverted siphon," across the valley of the River Smestow, on to the summit of the

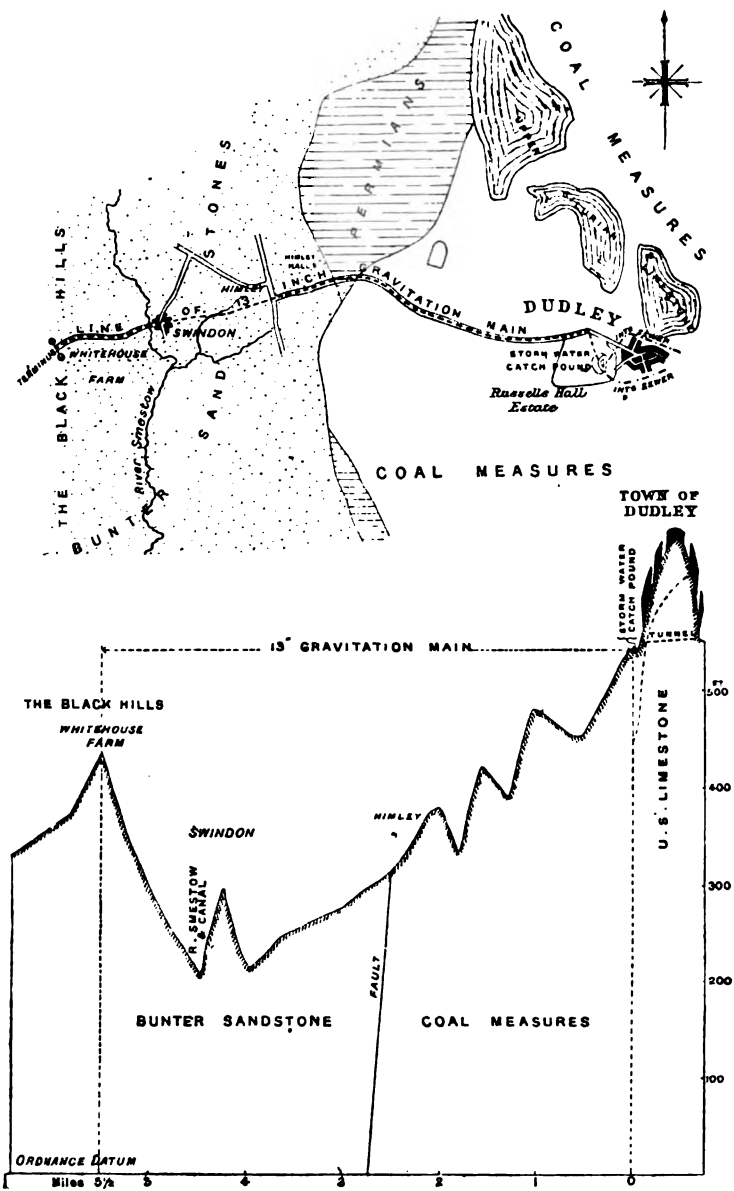
Black Hills above referred to, near the Whitehouse Farm, in the centre of a considerable area of land belonging to the Earl of Dudley. This 13-inch main is $5\frac{1}{2}$ miles in length, and the *average* fall between the catch-pound and the point of delivery at Whitehouse Farm is about $21\frac{1}{2}$ feet per mile. It will be observed from the plan and section, *Figs. 1 and 2*, p. 243, that the pipe follows all the irregularities of the land along which it is laid, with rising gradients in the steeper parts, ranging from 1 in 10 to 1 in 21, the total rise from the bottom of the valley to the Whitehouse Farm being 210 feet in a length of $\frac{3}{4}$ mile.

There is an overflow weir at the top-water level in the catch-pound, but the Author is informed that the accumulated sewage has never risen so high, even during storms. In ordinary times it passes directly from the sewers into the 13-inch main without rising up in the catch-pound, and although consequently it undergoes no previous "settling," and the only treatment it receives is from the rough strainers above referred to, the scouring power is such that the main is always free from silt. Indeed, when first the works were put into operation, large stones and other *débris* left in the pipes during the construction were forced through the main by the current and discharged at Black Hills, although in some parts the gradients up which they were rolled were as steep as 1 in $10\frac{1}{2}$ to 1 in $8\frac{1}{2}$.

Means are provided at all depressions of scouring out any deposits which may form, and air-valves are fixed at every summit. In constructing these, care was taken to prevent the possibility of the ball-seats becoming at any time choked with sewage. This was effected by means of a separate connecting-pipe between the bottom of the ball-seat and the main air-valve branch. In all other respects the fittings were the same as for an ordinary water-main. For the first $2\frac{1}{2}$ miles the 13-inch main traverses the mining district to the west of Dudley, but near Himley Hall, one of the seats of the Earl of Dudley, the main fault is crossed, and for the remaining 3 miles of its course it is entirely over the Soft Red Rocks and Conglomerates of the Bunter Series of the New Red Sandstone, which also extend beyond it for 2 miles to the west of the terminus, and for many miles to the north and south.

Throughout the last 3 miles, the main lies entirely upon the property of the Earl of Dudley. It is provided, at convenient intervals, with lateral branches leading to circular brick reception-tanks placed in elevated situations on various parts of the estate. On each of these a sluice-cock is fixed so that sewage may be

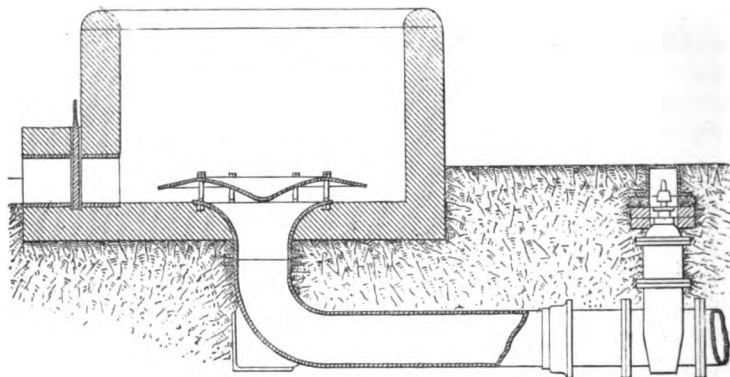
Figs. 1 and 2.



run into the tank when desired. In order that it may not be discharged high into the air by the pressure in the main, a wrought-iron shield or spreader is fixed over the inflow, so that the liquid impinges against it, and is spread quietly over the floor of the reception-well. Openings leading in several directions and guarded by sluice-boards are provided in the tank, and through these the sewage passes to carriers in any direction (*Fig. 3*). This ramification of distributing-pipes is available over a tract of country (including certain lands to the west of the terminus at the Black Hills) some 4 or 5 miles in length, and having an average breadth of 2 miles, or between 5,000 and 6,000 acres in area.

Although this land is available, and is amply provided with

Fig. 3.



Scale $\frac{1}{4}$ -inch = 1 foot.

SECTION SHOWING THE SPREADER IN THE DISTRIBUTING WELL.

the means for the distribution of the sewage, by far the larger proportion of it serves for the present merely as a reserve, and the most interesting operations are to be observed on a comparatively small area in the neighbourhood of the terminus at Black Hills. Here the sewage is applied intermittently to three farms, with an aggregate of 722 acres, under the control of the Earl of Dudley's principal land agent, Mr. George Taylor. Unlike the greater part of the available land (which is upon the Upper Soft Red Rocks of the Bunter Series, and which is tolerably fertile), these three farms are upon the Conglomerate, and the soil is poor and sandy, so that prior to the construction of the works of

the Dudley Corporation this land was a bye-word in the neighbourhood for sterility. At first the supply of sewage, as might naturally have been expected, was limited; but as from year to year it has increased, the fertility of the farms has developed in a more than corresponding degree. So much is this the case that the Earl (whose leading condition on offering the Corporation the facilities they enjoy, was that he should be entitled to the whole of the sewage from the town) is now threatening legal proceedings against them for their alleged neglect to compel the householders to connect with the new system.

This bargain is perhaps unique in the history of sewage disposal. The Earl of Dudley takes the sewage from the Corporation without either paying for it or receiving any payment for doing so. He relieves the Corporation, by an ample indemnity, of all further responsibility in connection with it, by an agreement which has been ratified by special Act of Parliament. Thus the town of Dudley is rid for ever and entirely of its "sewage question," whilst that portion of the Earl's estates under treatment is considerably improving in value. The bargain has been satisfactory to both the parties to it.

A point upon which sanitary engineers will desire information is as to the nature of the effluent from these farms. Mr. Taylor, on being asked, replied, "We have never seen an effluent. The soil absorbs it all," and it is impossible to detect, either in the River Smestow or any other neighbouring brook course, a trace of the proximity of sewage-farming operations. The district is sparsely inhabited, but it has never been suggested that there is any contamination of the few local wells.

Although it could not be expected that a system such as this should have been in operation for the past six or seven years without occasional allegations that a nuisance was being created, it has generally been possible to show the complainant wherein his error lay. On one occasion an excellent imitation of the ideal sewage smell was produced in the village of Swindon, which is adjacent to the land under treatment, by the practice of cooling the ashes from a small local ironworks by pouring water upon them. It was not until this practice was discontinued—when the smell at once ceased—that the inhabitants were satisfied upon the point. It is now generally conceded that the sewage works, whilst greatly enhancing the prosperity of the agricultural community, produce no more nuisance than the manuring of land usual in rural districts.

No precipitation is required. The matter held in suspension,

which has been described as the bane of the ordinary sewage-farmer, and which clogs the pores of ordinary soil, is found, when applied in the intermittent and sparing manner adopted in this case, to mix admirably with the sandy soil, the nature of which it is gradually changing. The essential feature of the scheme is that the land available is practically of unlimited area as compared with the volume of the sewage. Finally, there are no working expenses. The Corporation men clean out the strainers at Russell's Hall once a week, and by way of precaution a turn-cock is sent along the line of the 13-inch main once a month to open and oil every valve. In every other respect the system is self-acting.

The total cost of the works, including the internal sewers, the intercepting-sewers, the storm-water catch-pound, and the $5\frac{1}{2}$ miles of 13-inch gravitation main, was about £44,000, but the purchase of Russell's Hall estate, way-leaves for intercepting-sewers, and other extraneous expenses, brought the total up to about £55,000. The cost of the 13-inch main and the necessary valves for scouring purposes, &c. (but exclusive of the distributing fittings), was 16s. 2d. per yard, laid complete. No way-leave had to be paid. The storm-water catch-pound, with the necessary ironwork, brickwork, &c., cost 16s. $1\frac{1}{4}$ d. per 1,000 gallons capacity, or, including a high unclimbable iron fence which was ultimately found to be necessary, 17s. 11d. per 1,000 gallons. The intercepting and internal sewers, including all man-holes, junctions and other necessary adjuncts, but exclusive of way-leaves, cost £30,422 5s. 3d., or £1 0s. 3d. per head of the population served by the sewers. The above figures are based on the final certificates. They do not include engineering or clerk of works, for which, and one or two other small matters, about $7\frac{1}{2}$ per cent. should be added.

In connection with the question of way-leaves, a somewhat curious case arose. Lord Dudley, in his original agreement, gave a way-leave for the $5\frac{1}{2}$ miles of 13-inch cast-iron outfall pipe to the Black Hills, but none for intercepting or other sewers. During the progress of the works it became necessary to carry the intercepting-sewers through his lordship's land, which for more than a mile was mining ground, and his trustees were advised that they had no option but to press for full compensation. The matter was referred to an arbitrator, and it was contended, on behalf of Lord Dudley's trustees, that under the Public Health Act, 1875, the Corporation must acquire and pay for the minerals necessary to afford vertical and lateral support to the sewer; that

to afford such vertical and lateral support considerable areas would require to be left unworked, which would vary in width according to the depth and inclination of the strata, but which in some cases might be as much as 80 yards wide, and that in the then existing state of the law, the way-leave for the construction of the sewers would deprive his lordship's trustees of the right to get minerals over a large area of land, for which they claimed as compensation upwards of £22,800. This claim created great consternation, not only on account of its magnitude, but because it was to a certain extent a new one and was sure to become a test case, and if upheld the Corporation would probably have to face a total outlay for compensation for way-leave of upwards of £50,000. The arbitrator awarded a surface value of £1,011, and submitted certain alternatives dealing with the mining question for the decision of the Court, which could only, even if given against them, entail a further expenditure of £3,000 upon the Corporation. The state of the law upon the question, however, was found to be so involved and unsatisfactory, that an amendment to the Public Health Act, 1875, was passed by Parliament in August, 1883 (46 & 47 Vict. chap. 37) giving public bodies the same facilities for taking sewers over mining ground as are enjoyed by railway companies.

In conclusion, it may be remarked that the Corporation of Dudley claim—and with some reason—that they have a sewerage system which is practically perfect. They enjoy all the advantages of the possession and user of a sewage-farm without any of its liabilities; they are burdened with no perpetual charge in the shape of working expenses; they have an entirely modern system of internal and outfall sewerage which gives complete satisfaction, and they get all this for the moderate expenditure upon works of under 30s. a head of the population. Moreover, the only other interest affected (that of the Earl of Dudley) has largely benefited by the operations. That Dudley has succeeded in wiping off what may be termed the adverse balance resulting from mining-difficulties, and from the physical conformation of the town, and in replacing it by the exceedingly substantial asset which has been described, should be an encouragement to municipalities where the sewage question is still unsolved. At the same time it must be admitted that this state of things resulted from three circumstances, all exceptional, namely:—

1st. That there was a practically unlimited tract of land eminently suited for the reception of sewage within a few miles of the town.

2nd. That the level of this land was such as to allow of the sewage passing on to any part of it by gravitation.

3rd. That the owner was willing to take the sewage and deal with it thereon upon the terms which have been described.

The Paper is accompanied by drawings, from which the *Figs.* in the text have been prepared.

(*Paper No. 2513.*)

"Petroleum-Storage Installations at Avonmouth and at Cardiff."

By R. PICKWELL, Assoc. M. Inst. C.E.

SCARCELY any industry in this country has grown with such remarkable rapidity as that of the import of petroleum. In 1859 it amounted to 2,000,000 gallons, and the official returns for 1889 show that in that year it exceeded 102,000,000 gallons. This enormous increase has called forth improved methods of conveying the oil and storing it. The old method of bringing it to England in barrels was successfully superseded about the year 1886, by the use of specially built steamers, provided with oil-tanks and powerful pumps. Owing to the presence in some cases of large proportions of naphtha, serious explosions have occurred, and legislative measures have been passed for the protection of the public. No oil that flashes at less than 73° on the Abel instrument is considered safe. Dr. (now Sir) Lyon Playfair, in evidence before a Parliamentary Committee, stated that he would not use oil that flashed under 120°, but would prefer 130°.

Although this substance was known to the ancients over 2,000 years ago, it has only within the last thirty years become an important article of commerce.

It is found over a wide field, including India, Persia, Peru, Java, the shores of the Caspian, the United States, Canada and South America. The chief supply at present is obtained from Pennsylvania and the Caspian Sea. The increase of the shipments from Russia is very remarkable; in 1883, 500 barrels were sent to this country, whilst in 1890 the supply was 787,529 barrels, or about 32,288,689 gallons per annum. During the same time the consignments from the United States increased from 53,000,000 gallons to 54,489,164 gallons per annum.

In this Paper it is proposed to give a description of two petroleum-storage installations, one erected at Avonmouth jointly by Mr. C. M. Jacobs, M. Inst. C.E., and the Author's firm; the other

coming under his professional notice, both of which are provided with improved machinery and arrangements that may be of interest to the Institution.

AVONMOUTH INSTALLATION.

These works were erected for the Bristol, West of England, and South Wales Petroleum and Storage Association. In the storage of so inflammable and dangerous a commodity as petroleum great care is required in the selection of a site which shall afford facilities for easy communication with the steamers and vessels bringing the oil, and at the same time be as isolated from the neighbouring property as possible, in order to avoid such disastrous occurrences as the fires at Antwerp and Rouen. The site selected for these works (see Fig. 1, Plate 7) is situated on the banks of the Avon, about half a mile from the head of the Avonmouth Dock, being outside the ancient banks of the river, on what is known as the Outstays. It possesses on two sides deep water accommodation for barges or vessels, and on a third, railway connection with the main line from Avonmouth to Bristol. The site is leased from the Bristol Docks Corporation, and contains from 4 to 5 acres.

The first contract, which was let in July, 1889, was for the construction of a sea-bank, which was thrown up all round the site to a height of 6 or 7 feet, with the double object of shutting out the high spring-tides, and of confining the petroleum in case of the accidental bursting of a storage tank. As will be seen by the cross sections, Figs. 2, the banks generally were formed with a two to one batter on the river side, and a one and a half to one batter on the back, with a 4-foot top. The seat of the bank had the turf first pared off, and was then dug up one spade deep, after which the earthwork was barrowed up and put together by chopping and ramming in the usual way. After waiting for several months any settlement was made up, the batters trimmed off, and the bank sodded over. A cess-ditch was formed at the back of the outer bank for the purpose of drainage, and provided with a small outfall clough at A, Fig. 1, details of which are shown on Figs. 3, 4 and 5. The site was then thoroughly drained into the cess-ditch, by laying lines of 3-inch agricultural drain-pipes, 2 to 3 feet deep, every 30 feet, the trenches being filled with broken stone; and the whole of the surface was subsequently covered with ballast and ashes.

At point B on the plan, a deep-water jetty was erected on the foreshore of the Avon, constructed of pitch-pine piles, ranging from 30 to 60 feet long, with timber walings, struttings, and deck, as shown in Figs. 6 and 7, where barges or vessels lie for either discharging or taking in cargo.

TANK FOUNDATIONS.

The petroleum is stored in bulk in large circular iron tanks, two of which contain 2,000 tons each, and the others 1,000 tons each, and it was important that a firm foundation should be secured for them. Trial borings showed the ground to consist of about 6 feet of brown clay on the top, with 30 feet of very soft black warp below (Fig. 8). It was found that piling would be too expensive, and ultimately the Author designed the following plan, which was adopted.

After taking off the soil, a timber and concrete raft, about 5 feet larger in diameter than the tanks, was constructed; a layer of concrete, 18 inches thick, was first spread over the whole area, and upon this 12-inch by 6-inch timbers were laid across as shown, and another 18 inches of concrete put over the whole, thus forming a circular raft 3 feet thick and 68 feet in diameter for the large tanks, and 52 feet in diameter for the smaller ones (Fig. 14, Plate 7). These foundations have answered the purpose satisfactorily, and are similar to those used for the large grain warehouses at Avonmouth Dock. A gutter was formed all round the base of the tanks for collecting any leakage which might come from them. Sidings were laid from the main line of railway into the works as shown in Fig. 1, Plate 7.

The installation comprises three departments:—The storage tanks, the cooperage department, and the filling or barreling-off department.

It was desired to separate these as much as possible, keeping the tanks as well as the filling-house away from the cooperage and boiler-house to lessen the danger of fire. To maintain economical connection between these three departments, the installation is designed to work by the gravitation of both full and empty barrels from one department to another; for instance, the cooperage is connected with the filling-house by means of "barrel-runs," upon which the empty barrels, as they are turned out from the cooperage, run down to the filling-house and storing platform; empties also pass down similar runs from the jetty into the works for either storage or repairs; barrels already

filled run from the filling-house down to the end of the jetty ready for shipment. The gradient used is 15 to 16 inches in 100 feet, which is found to be just sufficient to cause the barrels to move without any tendency to run away. The runs are carried on light trestles (see Figs. 9), and consist of timbers $5\frac{1}{2}$ inches by 3 inches, fixed at about 2 feet 2 inches gauge by bolts. They are made in portable lengths of from 12 to 14 feet, and are put up where required. On reference to the general plan it will be seen that the coopeage floor is fixed at about 2 feet above the filling-house floor, and the filling-house floor a similar height above the jetty; the other runs have a similar gradient. The barrels are put on to them one after another, and close together, and as each one is taken off at the low end, the whole line moves forward one barrel. This method of dealing with them is important as regards the economical working of the installation.

STORAGE-DEPARTMENT.

A line of 6-inch wrought-iron screw-jointed filling-pipes is laid from the dock to the tanks along the surface of the ground, and is fixed upon strong wooden carriages to keep it in position. At the dock end is a stand-pipe similar to an ordinary water-main stand-pipe, or suitable bends are provided, which can be readily connected with a flexible hose-pipe from the steamer. At the other end of this main filling-pipe a branch with screw valves is taken off to each tank.

The tanks are circular and constructed of boiler-plates riveted together with lap-joints as in an ordinary gas-holder, the large ones being 64 feet in diameter and 30 feet high, the smaller ones 47 feet in diameter and 26 feet high. The bottom is made of $\frac{3}{8}$ -inch plates, with 4 inches by 4 inches by $\frac{1}{2}$ -inch angle-irons. The sides are formed of seven tiers of plates of uniform width, the first and second being $\frac{5}{8}$ inch thick, the third and fourth $\frac{3}{4}$ inch thick, the fifth $\frac{5}{8}$ inch thick, and the sixth and seventh $\frac{1}{2}$ inch full. The tops are of $\frac{1}{2}$ -inch plates, supported on angle-iron frames and principals (Fig. 10). They rise 6 feet in the middle, forming a dome, and have four raised man-holes 24 inches in diameter, provided with hinged covers which can be locked. The attachment of the side and bottom plating to the angle-iron at the base is by a double row of rivets, as is also the case with the vertical seams of the sides, but all other longitudinal seams are single-riveted. The edges of the plates both in the bottom

and in the sides are planed, and the work generally is equal to the best boiler work. All joints are made iron to iron, and caulked inside and out. Each tank is provided with a disk or false bottom, $\frac{3}{8}$ inch thick and 66 feet in diameter, which rests upon a bed of thin boards and sand, interposed between it and the foundation, in order that the tank may take an even bed (Fig. 14, Plate 7).

The smaller tanks, 47 feet in diameter, are made in the same manner, except that the thickness of the sides is slightly reduced. They were constructed under a guarantee for tightness, and after erection were tested by filling with water. Each is fitted with a 4-inch emptying and a 6-inch filling-pipe, with screw-valves, and furnished with a joint so that the orifice of each can be lifted up clear to the crown of the tanks by a hauling chain which passes over rollers at the top, and is brought down to the level of the ground outside, where it is worked by a small winding-gear. The orifices can thus be maintained at about the surface of the oil so as to avoid the possibility of drawing off any water that may have accidentally got into the tank, and which being heavier than oil would sink to the bottom, and also the vibration and ebullition which would occur in filling against a head of pressure. Each tank is provided with an external glass gauge from top to bottom, in lengths of about 4 feet, fitted with brass cocks, and each tube over-lapping the other so as to show the height of the oil in the tank. A light iron ladder on the outside gives access to the roof, and another is fixed from one of the man-holes to the bottom inside.

The contract was given to Messrs. Lysaght & Co. of Bristol, and the cost was about £4,000. The tanks are painted preferably white outside, and are provided with a ventilator at the top.

The operation of filling is as follows:—When a petroleum vessel arrives in port she is moored at the proper berth; her petroleum-pumps are then connected with the pipe on the quay, the valve of any particular tank required to be filled is opened, and the pumping commenced. As soon as the oil has been pumped out of the ship the valve at the stand-pipe is closed. At this stage of the proceedings the whole line of the feed-pipe from the quay to the storage tank will be full of oil. To facilitate the extraction of this the feed-pipe has a slight fall at each end to a point near the filling-house, where a small Worthington pump is attached, and the contents of the pipe are transferred into a small tank in the filling-house.

COOPERAGE-DEPARTMENT.

This consists mainly, as shown on Figs. 11, 12 and 13, of a two-storied brick building about 100 feet by 38 feet, in which the work of cooperage generally is carried on. At one end is erected the boiler-house, in which is a Cornish boiler, 26 feet by 6 feet 6 inches diameter, with the usual tanks and donkey-pumps. Adjoining the end of the boiler-house is the steaming-house, where the barrels are first steamed and then dried. At the south end of the cooperage the empty barrels are stored in the yard, from which they are taken to be cleaned and repaired prior to being sent to the filling-house. The details of the plant are as follows :—

At the end of the boiler-house, Figs. 14 and 15, Plate 8, there is a large air-heating chamber filled with a coil of small pipes supplied with steam from the boiler. This chamber is connected with the blower by the pipe A A, which enters it at the bottom and passes out at the top and down to the ground by the pipes B B B, and is connected with the main air-pipe laid underground along the side of the steaming- and drying-house. Three branches are taken from this main air-pipe at C C C, leading into the three underground pipes D D D, from which are taken short branches E E E E of 1-inch pipe, about 2 feet apart, and spaced so as to exactly fit the bung-holes of the barrels, which are placed over them in three nests of eight barrels each. The main and branch air-pipes are fitted with valves at G G G, for the purpose of shutting off either the whole or any one of the nests. Similarly steam is taken from the boiler through the pipe H into the main steam-pipe O, from which it passes into the branches P P P, leading into the branches C C C of the air-pipes. A set of barrels is taken from the empty stock and rolled on to wooden carriages with the bung-holes over the branches E E E. The main steam-valve Q and the branch valves are opened, and the steam passes along C, D and E into all the barrels for ten to fifteen minutes. It is then shut off at Q, and the main hot-air valve F and its branch valves opened, the blower set to work, so as to drive hot air through the same branches C, D, E, until the barrels are perfectly dry, after which they are rolled into the cooperage for any necessary repairs. A large steam-jacketed glue-kettle is arranged as shown in Figs. 12 and 13, Plate 7. The repaired barrels receive a charge of hot glue, and are rolled along carriages over zinc-lined troughs, laid below the floor-level, and stored over them with the bung-hole down. The surplus glue is pumped

back to the glue-kettle (Fig. 12). After this the barrels are lifted on to the floor above by the elevator D (Fig. 12), which is worked by a small separate engine; there they receive a coat of paint, and are then ready for sending down the run to the filling-house. The painting is done with large flat brushes, with such expedition that a skilled man is said to be able to paint fifteen hundred barrels per day.

The boiler and steaming and drying plant were supplied by the Uskside Engineering Company, Newport, Mon.

FILLING- OR BARRELING-OFF DEPARTMENT.

This department is situated at a point near the jetty (see general plan, Fig. 1, Plate 7), and consists of a simple brick building about 46 feet by 32 feet (Figs. 16, 17, 18 and 19, Plate 8). The main floor, which is of wood, is about 6 feet above the ground, and has a 10-foot platform all round, communicating with a long platform at a lower level, about 150 feet by 30 feet. This long platform is at the level of the floor of the railway trucks, and is used for taking empties or loading up full barrels to be sent by rail. In the centre of the filling-house are two rectangular wrought-iron tanks about 12 feet by 4 feet by 4 feet, raised about 3 feet above the floor, and provided on each side with a number of 1-inch filling pipes, about 2 feet apart (Fig. 16). From the main storage-tanks to the filling-house tanks a 4-inch screw-jointed pipe is laid similar to the 6-inch main already described (Fig. 17). The arrangement of branches under the filling-house, from the 4-inch and 6-inch pipes, is as follows:—The 4-inch branch A leads from the main emptying-pipe into the two small tanks; the 4-inch branch B is carried round to the pump, and by C to pipe A; another branch D is carried from the 6-inch pipe into branch C; the main-pipe draining-branch E is carried from the point F to the pump. All these branches are fitted with screw-valves as shown at *a, b, c, d, e, f, g, h, i* (Fig. 17).

Oil in the ordinary way flows by gravitation from one of the large storage-tanks by the 4-inch pipe, and along A into the two small barreling tanks, until they are filled, the valves *e, f, g, h* being closed and the rest worked as required.

When the oil in the large storing-tank has been lowered so that it ceases to flow by gravitation, it is raised by pumping, and passes along B to the pump, and thence through C and A, into the barreling tanks, the valves *a, b, f, h* being closed, and *c, d, e, g* opened. When the main filling-pipe is being emptied, as already

described, the valves *h, e, c, d* are opened and *a, b, f, g* closed, and the remaining oil pumped along *E C* and *A* into the barreling tanks.

As it may sometimes be necessary for repairs to take the oil out of one storage tank and put it into another, a branch *D* is laid from the 6-inch filling pipe No. 1 to *C*, and the transfer of oil from one tank to another takes place by gravitation from the tank through the 4-inch emptying pipe No. 2, along *B*, to the pump, and thence along *C* and *D* into pipe No. 1 passing on to the other tank, as if it was being pumped from a vessel; in this case valves *g* and *f* are opened and valves *a, b, c, d, e, h* and *i* are closed. It will be seen that this arrangement of pipes gives the foreman at the filling-house complete control over the direction taken. A Worthington pump is used with a cylinder 8 inches in diameter and about 10 inches stroke.

A little above the floor-level, and running the entire length of the barreling tanks, two iron waste-troughs are fixed. The process of barreling is as follows:—Empties are rolled up off the long platform into the filling-house and put on these troughs close together, as shown in Figs. 16 and 18, with the nozzles from the tanks dipping into the bung holes. When filled they are rolled down the barrel-run to the jetty, or if required to go away by rail, to the siding. To prevent barrels from being over-filled, an American automatic filler, ingeniously arranged with a pneumatic sliding piston and spring shut-off, which can be so set as to regulate the speed of filling, is attached to the nozzles of the tank by a flexible tube. The pneumatic piston rises with the oil, and when the barrel is filled, the spring shut-off is released and the supply stopped.

The tank steamers for conveying petroleum to England range from 2,000 up to 4,000 tons carrying capacity. The engines and boilers are usually aft, the petroleum hold occupying almost the whole of the remaining portion of the ship. The hold is divided along the centre as well as across by several bulkheads (Figs. 20 and 21). By the kindness of the builders, Sir W. G. Armstrong, Mitchell and Co., the Author has been able to give a drawing of one of these ships, which was constructed according to the design of Mr. Swan. It will be seen on reference to the cross-section, Fig. 21, that the petroleum hold is made considerably narrower above the level of the water-line, the object of this arrangement being to ensure that the main part of the hold should be perfectly full, the narrow part at the top giving ample facilities for the expansion of the oil. If the petroleum were contained in one

hold of the ordinary shape, not perfectly full, the stability of the vessel would be seriously affected. A pump is provided capable of discharging from 100 to 120 tons an hour, the suction-pipe of which has a branch fixed to each of the separate holds.

CARDIFF INSTALLATION.

This installation has just been erected by the South Wales Public Wharf, Warehouse and Transit Company, Limited, Cardiff, and is situated on a stretch of land on the banks of the Ely, and about one mile from the Bute Docks, Cardiff (Fig. 22, Plate 8). The River Ely is a small tributary running into the Bristol Channel, and joins the mouth of the River Taff in what is known as the West Muds, opposite the Port of Cardiff. The Public Wharf Company have erected upon this tongue of land extensive wharves and warehouses, which are fitted in the most complete manner with hydraulic cranes, grain-warehouses, cellars, &c. The site possesses several hundred yards of deep-water frontage to the Ely, and good railway communication.

The petroleum installation is situated at the southern end of the site. It is enclosed by an embankment of earthwork similar to that at Avonmouth.

STORAGE DEPARTMENT.

From the wharf, at the point A on the plan (Fig. 22), a cast-iron 7-inch filling-pipe is laid to the storage department with branches to the five tanks, three of which hold nearly 1,300 tons each, and the two others about 1,000 tons each.

The branches from the main filling-pipe are of copper, and are bent up in a saddle-back form to allow for expansion. The tanks are in all respects similar to those at Avonmouth, and are fitted with gauge-glasses and jointed internal feed-pipes, &c. They stand upon a concrete foundation about 3 feet thick, resting on gravel. The surface of the foundations in their vicinity is finished with a cement-rendered floor, proper facilities being provided for collecting any leakage of oil. The emptying pipe is of cast-iron, 4 inches in diameter, and is laid from the bottom of the tanks to the filling-house (Fig. 22, Plate 8). An auxiliary feed-pipe is being laid with branches into the tanks, and a portable oil-pump made by the East Ferry Engineering Company, capable of delivering 120 tons per hour, will be connected with it so as to supplement the ship's pumps and discharge the vessel in half the time. After

discharging, the ships receive their coal-supply without changing their berths. A new wharf is being constructed in a more convenient position.

COOPERAGE-DEPARTMENT.

The general arrangement of this department is shown in Fig. 22, Plate 8. It consists of a shed of corrugated iron, at the end of which is placed the boiler-house, and is fitted with a steaming and drying apparatus at C, glue-kettle and troughs at D, and a painting and branding house at E.

The empty barrels are stored in the yard at F, whence they are taken to the steaming and drying department, repaired, glued, and sent forward to the painting department. Barrel-runs are freely used, and are for the most part of a portable description.

BARRELING-OFF DEPARTMENT.

This is situated at the end of the long painting floor, which is elevated to about the level of the bottom of the railway trucks, and is arranged similarly to the one already described at Avonmouth. Two men can fill and bung 1,200 barrels per day.

Under the present system of distribution by barrels great loss is incurred, not only in filling and in carriage, but also from the large waste of space between the barrels when loaded, the expense on the returned empties, and the necessary repairs and cooperage. To avoid this loss this company have adopted the use of 10-ton tanks, mounted on railway trucks, which are filled and consigned direct to the dealers, carriage being paid only on the net weight of the oil. The dealer can either retain the tank in his siding until emptied, or he can have his own small storage tank into which the oil is discharged, the portable tank being consigned back to the depot. It is probable that this system of distribution will shortly become general.

The Author expresses his thanks to Mr. Robert Johnston for supplying him with information concerning the Cardiff installation.

The Paper is accompanied by six tracings, from which Plates 7 and 8 have been prepared.

(Paper No. 2506.)

“A Method of Calculating the Area of a very Irregular Cross-Section of a Railway Cutting without the necessity of Plotting.”

By F. H. BREAKELL.

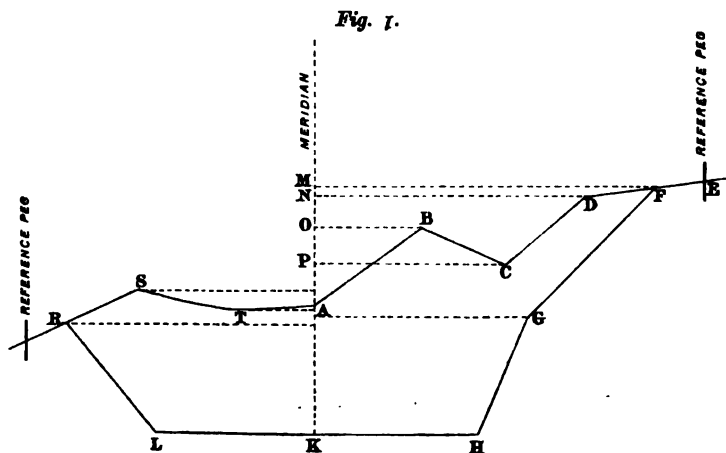
THE operation of levelling is performed in the ordinary way by booking the “sights” at every important change in the inclination of the natural surface, commencing at a peg well beyond the edge of the proposed excavation, and proceeding across to a corresponding one on the other side. These “reference pegs,” as they may, for convenience sake, be called, serve as permanent marks by means of which the exact centre of the work may be ascertained at any stage of its progress. After the cutting has been taken out, the levels are read over the excavated surface from “edge to edge of cutting,” but in an opposite direction to the natural surface levels, the reading at the terminal or “foresight” reference peg being entered as a “backsight,” because it is necessary that the sights should appear consecutively round the figure showing the limits of the cross-section. The reason for this will appear more clearly further on.

The zero of the distances (which are distinguished by opposite signs, according as they are right or left) must be on the same vertical line or “meridian” for both sides of the cutting, whether in natural surface or excavation levels, and this vertical line may be supposed to pass through the centre, or indeed any other point; but for the sake of convenience it should intersect the base of the cutting in preference to either of the slopes.

After the levels have been entered as stated it will be found that there are more natural-surface levels than are required—for instance, the reading at the reference pegs, and possibly others. These will be easily found by inspection, as those natural-surface levels which have a greater distance reading than that of the “edge of cutting” in the excavation levels are, of course, unnecessary, and must be struck out before commencing the calculations. In the specimen page of a Level-Book which accompanies this Paper (page 261)—such cases are indicated by the figures being printed in italics—

thus it will be seen that the edge of cutting F on the right side is at 34.80 feet from the centre or meridian, whilst the sight immediately above it—that of the reference peg E—is at 40 feet, and must be crossed through. The sight at D is evidently inside the cutting, its distance being less than that of the “edge,” and it must therefore be left intact; but the difference of level (rise 1-10) between D and F must be obtained from the reduced levels and noted accordingly. The superfluous levels on the left side are eliminated in the same manner. It is well before going any further to total up the rises and falls, and if the results are equal the alterations have been correctly performed.

The levels and distances having been recorded as directed in columns Nos. 1 to 7 inclusive (which are the same as in the ordi-



nary Level-Book), the “double longitudes” are next calculated by adding each distance to the one immediately preceding, the results being placed in column 8. In commencing, the first sight inside the cutting (S), has to be added to that of the “edge” (R), which is entered in its proper place at the end of the excavation levels.

The following explanation may not be considered out of place, as the “double longitude” method is rarely dealt with in works on engineering. Assuming the vertical line before mentioned to be a “meridian,” the distances OB, PC, ND, see *Fig.*, &c., are the “longitudes” of the points BCD, &c., with respect to it, and the sum of the “longitudes” of any two consecutive points is equal to double that of the centre of the line of which these two points are the extremities; hence the term “double longitude.”

Specimen Page of Level-Book.

1	2	3	4	5	6	7	8	9	10	11	Remarks.
B.S.	Int.	F.S.	Rise.	Fall.	Red. level.	Distance.	Double Longitude.	Multiplics.	Producta. +	Producta. -	Left Nat. Sur. Ref. peg.
18.80	..	..	..	..	15.80	- 30.00	..	..	..	..	Left Nat. Sur. Ref. peg.
..	13.10	..	3.55	..	21.50	- 19.00	- 44.8	+ 3.5	..	- 157.2	" (S)
..	14.90	..	..	1.80	19.70	- 9.30	- 28.3	- 1.8	+ 50.9	..	" (T)
..	14.60	..	0.30	..	20.00	+ 0.00	- 9.3	+ 0.3	..	- 2.8	Centre " (A)
..	6.80	..	7.80	..	27.80	+ 10.70	+ 10.7	+ 7.8	+ 88.5	..	Right " (B)
..	10.30	..	..	3.50	24.30	+ 19.50	+ 30.2	- 3.5	..	- 105.7	" (C)
..	3.60	..	6.70	..	31.00	+ 28.00	+ 47.5	+ 6.7	+ 318.3	..	" (D)
4.80	..	1.60	2.00	..	33.00	+ 40.00	..	..	..	..	" Ref. peg. (E)
1.20	..	5.70	1.10	0.90	32.10	+ 34.80	+ 62.8	+ 1.10	+ 69.1	..	" Excav. Edge (F) of cutting.
2.20	..	14.60	..	13.40	18.70	+ 21.80	+ 56.6	- 13.4	..	- 758.2	" (G)
..	14.30	..	..	12.10	6.60	+ 16.70	+ 38.5	- 12.1	..	- 465.9	" (H)
..	14.30	..	..	0.00	6.60	+ 0.00	+ 16.7	..	..	..	Centre " (K)
..	14.30	..	..	0.00	6.60	- 16.70	- 16.7	..	..	..	Left " (L)
..	..	2.95	11.85	..	17.95	- 25.80	- 42.5	+ 11.4	..	- 484.5	" of cutting.
..	..	..	30.80	30.80	..	202.30	404.6	..	+ 521.8	- 1874.3	
..	..	..	..	..	..	..	..	..	..	+ 521.8	
									2 - 1452.5	- 726.2 = Area of cross-section.	

The correctness of the "double longitudes" is proved by adding up the figures in the columns 7 and 8, not noticing the signs, and if the total of the "double longitude" column (8) is double the total of the distance column (7), the results are correct. In column 9 are placed the plus and minus multipliers, which are simply the rises and falls. In column 10 are placed the plus, and in column 11 the minus products which are obtained by multiplying the "double longitudes" by the rises and falls or plus and minus multipliers.

PART OF CROSS-SECTION TO RIGHT OF "MERIDIAN."

Sums of pairs of distances. $\times$ Falls. = Areas.

$$\left. \begin{array}{l} (MF + AG) \times MA = \text{Twice the area of figures} \\ (AG + KH) \times AK = \text{ " " " } \\ (OB + PC) \times OP = \text{ " " " } \end{array} \right\} \begin{array}{l} \text{MFGA} \\ \text{AGKH} \\ \text{OBCP} \end{array} = 2(\text{MFGHK} + \text{OBCP}).$$

Rises.

$$\left. \begin{array}{l} (\text{OB}) \times \text{AO} = \text{Twice the area of figures ABO} \\ (\text{PC} + \text{ND}) \times \text{PN} = \text{ " " (OBCDN} + \text{OBPC)} \\ (\text{ND} + \text{MF}) \times \text{NM} = \text{ " " " NDFM} \end{array} \right\} = 2 (\text{ABCD} + \text{OBOP}).$$

**Subtracting the less from the greater the result is 2 (ABCFGHK)
= twice the area of the cross-sections.**

(Paper No. 2528.)

“Oil-Gas Tire-Setting Apparatus in the Grand Trunk Railway Company’s Works at Montreal.”

By FREDERIC LUMB WANKLYN, Assoc. M. Inst. C.E.

(Abstract.)

THE object of this Paper is to describe an apparatus for producing oil-gas from refined petroleum having a flashing-point of 95° Fahrenheit; and for burning this gas with heated compressed air for the purpose of expanding railway tires before placing them upon, or removing them from, locomotive or wagon wheels.

The apparatus is the invention of Mr. T. W. Gentry, and has been erected under the supervision of the Author, at the workshops of the Grand Trunk Railway, in Montreal. It consists essentially of four cast-iron cylindrical vessels, 11½ inches diameter, 3 feet long, and 1½ inch thick, built into an ordinary coke- or coal-heated furnace. Three of these vessels, having been brought to a red-heat, are used for vaporizing the oil, and the fourth for heating the air, which is supplied at a pressure of 30 to 40 lbs. per square inch from a reservoir, fed by a standard 8-inch Westinghouse air-pump.

The oil is stored underground, outside the building, and is lifted by means of a 2½-inch hand-pump into a small tank in communication with the compressed air, by which it is forced through a pipe ¾ inch in diameter, to an injector or regulator. Here it is blown into fine spray by means of a jet of cold air, and is carried forward in a pipe of the same diameter into the three hot vessels or retorts in succession. It is then conducted in the form of a rich smoky gas through about 25 feet of 1½-inch wrought-iron pipe to the setting-house, where it joins the heated air, with which it passes through a short pipe to the perforated hoop-shaped tubes encircling the tires, and is there ignited.

A complete set of regulating valves controls the admission of oil and air to the retorts, beyond which point no obstruction should be placed, so that all possibility of accumulated pressure may be avoided.

The tire-setting shop is separated from the fire-proof building

in which the oil-gas is produced. It is polygonal in plan, and the entire floor is covered by a 5-ton rotary bridge-crane, having a span of 22 feet, and a lift of 14 feet. The wheels and tires are placed in position by this crane, the oil-gas and air mixture being brought through flexible pipes to the ring-burners.

At a trial of the complete apparatus in December 1890, two and a half hours were occupied in heating and setting three pairs of tires, 6 feet $1\frac{1}{8}$ inch, 3 feet 7 inches, and 3 feet 1 inch diameter respectively, and from $3\frac{1}{8}$ inches to $2\frac{9}{16}$ inches thick, including one hour taken to heat the retorts. In this operation 5.78 gallons of oil, worth in Canada 6d. per gallon, were vaporized. The work was accomplished by three men, whose wages amounted to 3s. $7\frac{1}{2}$ d., bringing up the total cost of fuel and labour to 8s.

Two sets of apparatus have been successfully worked at Montreal for twelve months, the cost of maintenance being nil.

The advantages claimed for this method of tire-setting are, cleanliness, economy, and absence from risk of fires. The chances of failure or accident are not greater than when ordinary illuminating or coal-gas is used. The apparatus is easily controlled, and the generation of gas started or stopped by opening or closing the oil-valve placed between the small oil-tank and the injector.

The original was accompanied by three blue prints.

(Students' Paper No. 276.)

"The Counter-balancing of Locomotive Engines."¹

By EDMUND LEWIN HILL, Stud. Inst. C.E.

HISTORY OF BALANCING.

THE discovery that for a wheel to run smoothly it must be balanced, or, in other words, must have its centre of gravity coincide with its centre of motion, is without doubt of prehistoric date, though the reasons for this necessity and the rules which arise from them have only been properly understood and acted upon for a comparatively short time. One of the earliest instances of balancing was the method formerly adopted with respect to water-wheels. These used to be made of wood, and if they were allowed to stop for any length of time, the part above water would dry while that below would remain wet, so that the wheel on starting again would run in a succession of jerks, being heavier on one side than on the other. To obviate this it was usual to keep the wheel moving very slowly instead of stopping it altogether.

Mr. Heaton² was probably the first to counterbalance the disturbing force on a locomotive engine by a weight in the wheel. In 1831 he and his brothers made a common road steam-carriage, and found that at a speed of 160 revolutions a minute the shaking was so violent that they could not keep their seats. Mr. Heaton described his plan in a letter to the "*Mechanics' Magazine*," April 8th, 1842,³ as follows:—"Being aware that this motion could only be produced by some portions of our machinery being out of balance, we placed a compensating weight opposite each crank, and found we attained greater speed with no greater consumption of fuel, and the machine travelled perfectly steadily at any speed and free from any symptoms of rocking or shaking." This was only taking into consideration the revolving weights. It was a long while before a practical method of balancing the reciprocating weights of locomotives was pro-

¹ This communication was read and discussed at a meeting of the Students on the 30th of January, 1891.

² *Engineer*, 30 January, 1880, p. 77.

³ *Mechanics' Magazine*, 8 April, 1842, p. 279.

posed, though the necessity of doing so was seen by many engineers. At an early date the Stephenson had tried on the Liverpool and Manchester Railway to minimize the action of the reciprocating parts by diminishing the length of stroke and increasing the diameter of the cylinder, but this method was given up because the engine used too much steam.¹

Mr. Bodmer² in 1834 proposed to entirely destroy the action of the reciprocating parts by having two pistons working in one cylinder with the piston-rods issuing at opposite ends and connected to a double crank, and in 1841 he modified this plan by making the two piston-rods work one inside the other from the same end of the cylinder.³ He built some of these engines for the South Eastern Railway, and one was stationed at New Cross in 1845.⁴ Mr. Weallens in 1836 brought out a four-cylinder engine with the same object.⁵

In 1837 Mr. Braithwaite, of the Eastern Counties Railway, Mr. Richard Roberts, of Sharp, Roberts and Co., and Mr. Rogers and Mr. Griggs in America, began to balance the revolving parts of locomotives by a weight in the wheel.⁶

Mr. Heaton, who had been experimenting on the subject, made in 1838 a model of the wheels and crank-shaft of a locomotive to show the effects of unbalanced moving-parts, and submitted it to the Resident Engineer at Birmingham of the London and Birmingham Railway. The Company's engine "Brockhall," which was being repaired at the time, was ordered to have balance-weights applied to it under Mr. Heaton's supervision, and the result being satisfactory, all the company's engines were balanced in the same way.⁷ In 1842 Mr. M'Connell began to use Mr. Heaton's plan on the Birmingham and Gloucester Railway,⁸ and in the same year Dr. Melson read a Paper on balancing, probably the first written on the subject, before the Birmingham Philosophical Institute.⁹

In February 1843 Mr. Crampton, in a letter to the *Railway Times*, pointed out that one of the causes of unsteadiness in

¹ Minutes of Proceedings Inst. C.E., vol. viii. p. 260.

² *Ibid.*, vol. xxii. p. 92.

³ *Ibid.*

⁴ Report of the Gauge Commissioners—Carriages, Question 4,293.

⁵ Minutes of Proceedings Inst. C.E., vol. xxii. p. 102.

⁶ "Locomotive Engineering." By Colburn, p. 51.

⁷ *Engineer*, 30 January, 1880, p. 77.

⁸ "Railway Machinery." By D. K. Clark, p. 165.

⁹ *Mechanics' Magazine*, 9 April, 1842, p. 276.

engines was that the reciprocating parts were unbalanced, but he did not suggest any method by which this could be remedied. Mr. Fernihough was the first to propose and carry out the balancing of the reciprocating parts by a weight in the wheel. This he did in his engines on the Eastern Counties Railway in 1845, and he described his plan before the Gauge Commissioners in that year.¹ In 1847 Mr. Heaton brought forward a device for effecting the same purpose, which consisted of a double crank with one connecting-rod attached to the piston-rod and another to a dummy weight working in slides under the foot-plate by the side of the fire-box. This plan was used for some years on the London and Birmingham Railway.² In 1838 Mr. E. A. Cowper had proposed to balance a quick-working rubber-cutter in exactly the same way by a dummy weight. This, however, was never carried out, because of the expense.³

In 1847 Mr. Haswell, Locomotive Superintendent of the Austrian State Railways, also brought out an engine similar in idea to Bodmer's, but with two cylinders on each side, one on the top of the other, working on to double cranks.⁴ This engine, which was named "Duplex," was still in use in 1873.

Mr. Nollau, Locomotive Superintendent of the Holstein Railway, was the first to go thoroughly into the theory of balancing. In 1847 he conducted elaborate experiments on the subject, the results of which are embodied in an article by him in Mr. Couche's work on "Permanent Way Rolling Stock."⁵

Nollau was followed in 1848 by Le Chatelier, who wrote a treatise on the question,⁶ and Mr. D. K. Clark in 1852 published an account of his investigations, together with the rules deduced from their results, which have since been almost universally employed.⁷

Since then the disturbing forces of locomotives have always been balanced in the wheels, and though many other methods of balancing have been invented they have never been adopted in practice. Among them may be mentioned Mr. Resal's plan in 1853 of applying a dummy weight on the prolongation of the connecting-

¹ Report of the Gauge Commissioners. Question 4,294.

² *Engineer*, 30 January, 1880, p. 77.

³ Minutes of Proceedings Inst. C.E., vol. xxii. p. 95.

⁴ "Modern Mechanical Engineering." By R. Scott Burn. p. 191.

⁵ "Permanent Way Rolling Stock." By C. Couche. Vol. ii. notes p. 783.

⁶ "Railway Machinery." By D. K. Clark, p. 177.

⁷ "Recent Practice in the Locomotive Engine." By Clark and Colburn, p. 45*.

rod;¹ Mr. Makinson's single-cylinder engine in 1862;² a four-cylinder double-crank engine, built about 1880 by Mr. Shaw, an American engineer;³ and another by the same maker in 1882 with oscillating cylinders placed between the driving-wheels with two pistons in each cylinder connected direct to the crank-pins;⁴ and, lastly, Mr. Crampton's four-cylinder tank-engine with two pairs of single driving-wheels, the front pair of which are actuated by the two right-hand cylinders and the back pair by those at the left side, each set of cylinders working on to a double crank.⁵

THEORY.

The moving parts of a locomotive which cause disturbance may be divided into two classes, revolving and reciprocating, the former comprising the cranks and side-rods, and the latter consisting of the piston, piston-rod, and cross-head. The connecting-rod cannot properly be classed under either of these heads, since the small end, which moves in a straight line, is reciprocating; the big end, which describes a circle, is revolving, while all the intermediate points describe ovals of various magnitudes. It is usual to consider part of the rod as reciprocating and part as revolving, and in the relative proportions taken there is a wide difference in practice.

The revolving parts as they move round develop centrifugal force, the horizontal component of which throws a stress on the engine longitudinally, and causes recoil backwards and forwards.

At the same time the vertical component tends to reduce the adhesion between the wheels and rails, and to cause slip on the top half-stroke, and pounds the wheels against the rails on the bottom half-stroke. This vertical force, by acting first on one side of the engine and then on the other, produces also a rolling movement from side to side.

To the fore-and-aft motion, caused by the horizontal component of the centrifugal force of the revolving parts, must be added that due to the momentum of the reciprocating parts. These have to be brought to rest at the end of each stroke, and the steam-pressure required for starting them again acts with equal and opposite effect on the cylinder-head, imparting, when at the front

¹ "Permanent Way Rolling Stock." By C. Couche. Vol. ii. p. 349.

² Minutes of Proceedings Inst. C.E., vol. xxii. p. 75.

³ Transactions of the American Society of Mechanical Engineers, vol. ii. p. 277.

⁴ *Railroad Gazette*. 17 February, 1882, p. 99.

⁵ Société des Ingénieurs Civils, Paris, 5 March, 1886.

dead centre, a forward movement to the engine.¹ This force decreases until the piston reaches its position of maximum velocity, when acceleration ends and retardation begins, and continues to increase until the piston arrives at the end of the stroke. During this retardation the pressure which was absorbed in producing the acceleration is given out again, and imparts a backward movement to the engine. Thus the horizontal component of the centrifugal force of the revolving parts, together with the varying pressure caused by the acceleration and retardation of the reciprocating parts, causes a movement of the engine alternately backwards and forwards.

These two forces do not always act together. Owing to the obliquity of the connecting-rod the reciprocating parts arrive at their position of greatest velocity before half-stroke, at which point the disturbance caused by them changes in direction—on the bottom part of the stroke from forwards to backwards, while that of the revolving parts is still acting forwards. On the top half-stroke the contrary effect occurs, the momentum of the revolving parts beginning to act forwards, while that of the reciprocating parts is still directed backwards. This force, which alternately gives the engine a forward and a backward movement, causes also a sinuous movement by acting first on one side and then on the other.

The obliquity of the connecting-rod produces also pressure on the slide-bars, varying from nothing at the dead-centres to a maximum at half-stroke. This pressure under ordinary conditions acts upwards during forward running, and inasmuch as one piston is at half-stroke when the other is near the dead-centre, it produces a rolling motion from side to side round a longitudinal axis. At the same time it also causes an up-and-down movement of the whole engine round the driving-axle—"galloping"—and the galloping and rolling together produce an "elbowing" motion.

Since the only practical way of balancing an engine is by a weight in the wheel, it remains to be determined how nearly perfect equilibrium can be attained by this method. If the connecting-rod were of infinite length the disturbing force would increase or decrease with the cosine of the crank-angle, and its equation would be

$$\text{Disturbing force} = m r \omega^2 \cos \theta$$

(m being the mass of the moving parts, r the radius, and ω the angular velocity of the crank). At the dead-centre, $\cos \theta = 1$,

¹ See Appendix IV.

and the disturbing force is then $= m\omega^2$, that is to say, the centrifugal force. If then a mass whose centrifugal force equalled $m\omega^2$ were placed opposite the crank the engine would be perfectly balanced as to its fore-and-aft motion. But the effect of the finite length of the connecting-rod is that the disturbing force varies with the expression

$$\cos \theta + \frac{n^2(\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}},$$

where n is the ratio of the length of the connecting-rod to that of the crank. This formula is given by Mr. Imray in his Paper on "High-Speed Motors."¹ Now, since the horizontal component of the centrifugal force of the balance-weight varies with $\cos \theta$, there is a continual discrepancy between it and the disturbing force. The horizontal disturbances being far more injurious to the stability of the engine than those in a vertical direction, the Author proposes to determine how nearly it is possible to eliminate them.

The problem has been worked out for a 7-foot single-wheel express engine, the particulars of which are :—

Radius of crank	12 inches
Centres of cylinders	24 "
" wheels.	60 "
Radius of balance-weight	33 "
Weight of piston and appendages	350 lbs.
" crank-blades and pin.	430 "

The weight of the connecting-rod is 400 lbs., and it is assumed that the big end and half the length of the rod, which together weigh 250 lbs., are revolving with the crank, and that the small end and half the length of the rod, which together weigh 150 lbs., are reciprocating with the piston. This gives a total reciprocating weight of 500 lbs., and a total revolving weight of 680 lbs. The connecting-rod is 6 feet 6 inches long, and the crank being 12 inches the ratio of the two is as 6.5 to 1. The engine is in all cases assumed to be travelling at 60 miles per hour, at which speed a 7-foot wheel makes 240 revolutions a minute.

The disturbing influence of the reciprocating parts will be first considered. These weigh 500 lbs. At the dead-centre the crank, connecting-rod, and piston-rod, are all in one straight line, and this weight of 500 lbs. may be assumed to be acting as if fixed to

¹ Minutes of Proceedings Inst. C.E., vol. lxxxiii. p. 121.

the crank-pin. The centrifugal force of it at the given speed is found to be 9,807 lbs., and the curves in *Figs. 1-6* represent the disturbing forces during 1 revolution.

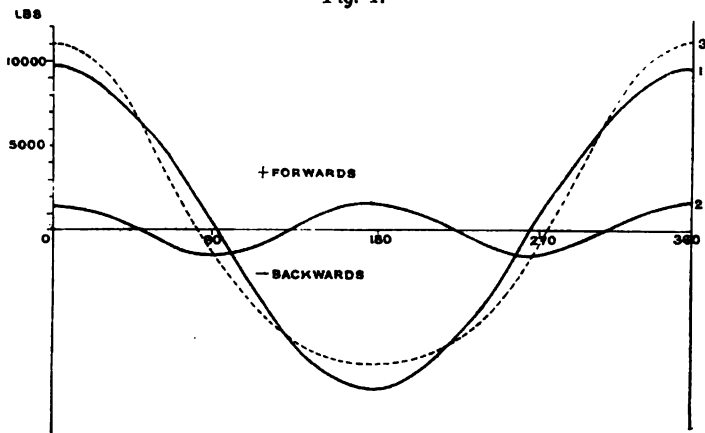
In order to show the effect produced by the obliquity of the connecting-rod, it has been assumed in the first place to be of infinite length, and the corresponding result is given in *Fig. 1*, curve No. 1.

Curve No. 2 represents the expression

$$\frac{n^2 (\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}},$$

which is the second term in Mr. Imray's formula for a connecting-rod of finite length, and shows how the disturbing force is

Fig. 1.



modified by the obliquity of the connecting-rod. Curve 3 is the sum of these two, that is to say, the graphic representation of the complete formula. It will be seen that the extra disturbance, caused by the finite length of the connecting-rod, is too great to be neglected.

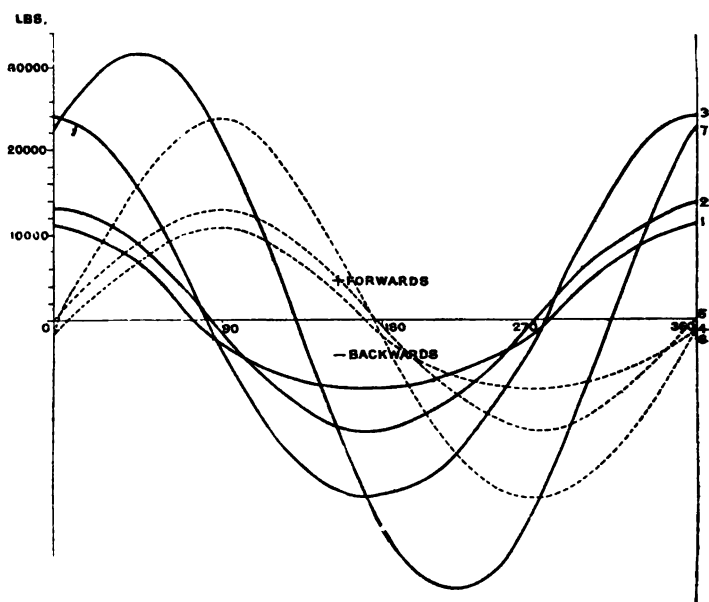
It has been already stated that in the example selected, the centrifugal force of the reciprocating parts, assumed to be concentrated at the crank-pin, is 9,807 lbs. Now, the disturbing influence of the reciprocating parts, for successive crank-angles, is equal to this centrifugal force multiplied by the corresponding values of the expression

$$\cos \theta + \frac{n^2 (\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}}.$$

For instance, the disturbing force at the front dead-centre is 9,807 lbs. $\times$ 1.1538 = 11,315 lbs. Working out in a similar way the values for the other crank-angles, the data were obtained, from which curve 1, *Fig. 2*, representing the disturbing influence of the reciprocating parts for one revolution, was prepared.

To this has to be added the disturbing force caused by the revolving parts. These weigh 680 lbs., and their centrifugal force is 13,357 lbs. The horizontal component of this force produces a longitudinal disturbance, which varies with $\cos \theta$,

Fig. 2.



and is represented by curve 2, *Fig. 2*. Curve 3 shows the total disturbing force of the revolving and reciprocating parts combined.

Hitherto only one crank has been dealt with. To get the total disturbing force on the engine it is necessary to combine the effects of the moving parts on both sides. In *Fig. 2* the dotted line, curve 4, is that of the disturbing force of the reciprocating, and curve 5 that of the revolving parts of the other crank, 90° behind. Curve 6, *Fig. 2*, is the resultant of these two, and finally the thicker black curve, No. 7, obtained by combining

curves Nos. 3 and 6, is that of the total longitudinal disturbing force due to both sides of the engine.

SINUOUS FORCE.

So far only those forces have been considered which act backwards and forwards, and it is necessary now to examine the equally destructive disturbances which are directed sideways and give the engine a sinuous motion. Le Chatelier first pointed out that the force on each crank is not confined to its own wheel, but is exerted on both according to their respective distances from its line of action. The disturbing force of the revolving and reciprocating parts acting at one crank tends to turn the axle about its centre of gravity, and that at the other crank produces a similar effect on the opposite side of it. When the right-hand crank is on its front dead-centre there is a force of 24,672 lbs. on it directed forwards, and pushing the head of the engine to the left, and a force of 1,601 lbs. on the left-hand crank, acting backwards, and pulling the locomotive round in the same direction. Taking moments round the centre of the axle, the leverage being in each case 1 foot, there is found to be a total force of 26,273 lbs., turning the head of the engine to the left.

The algebraic sum of the turning forces of the two cranks during 1 revolution of the axle is given graphically in curve 1, *Fig. 3*, which represents the resultant sinuous force on the engine, and shows the necessity of so arranging the balance, if possible, that it shall counteract this turning force as well as the fore-and-aft disturbance.

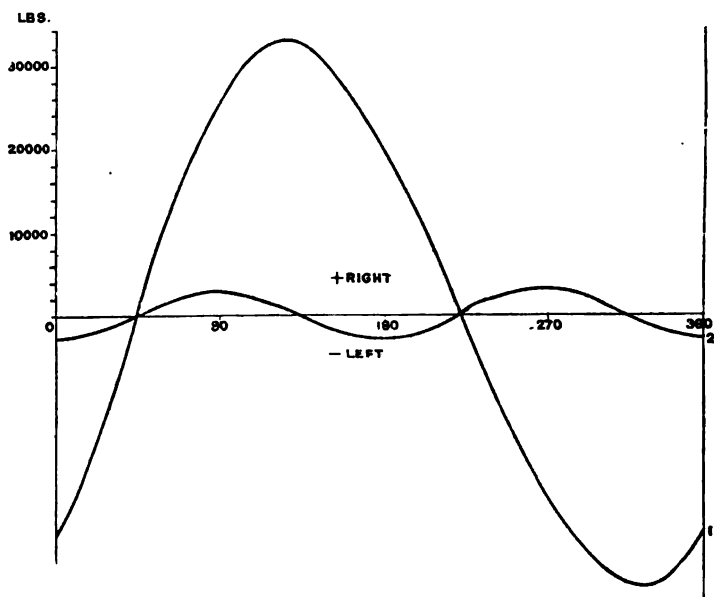
It will be seen at once that an engine cannot be balanced, both as to its horizontal and vertical disturbances. If horizontal equilibrium is aimed at it must be got by a balance-weight, which, while counteracting the disturbance of the reciprocating parts by its horizontal action, will develop also a superfluous vertical force, thus causing a new disturbance. If, on the other hand, vertical equilibrium is required, the reciprocating parts must remain unbalanced.

As in the Author's opinion the horizontal disturbances are far more harmful than the vertical, the latter, which cause pounding, rolling, and galloping, will be omitted for the present until the method of counteracting the former has been dealt with.

Mr. D. K. Clark has fully explained this in his work on "*Railway Machinery*," and the rules which he there gives have been almost universally adopted.

Since the weight of the moving parts, which has been assumed to be concentrated at the crank-pin, is not in the plane of revolution of the balance-weight, a couple will be left at each crank after its balance has been adjusted. The effect of these two couples will be to cause a sinuous motion of the engine about the centre of the crank axle, which must be got rid of by making the sum of the moments about the centre of the axle

Fig. 3.



of the two balance-weights and of the two cranks equal to zero.

This can be done by dividing each balance-weight into two parts and putting one in each wheel, so that, for example, the balance-weight of the left-hand crank is placed part upon the left-hand wheel and part upon the right-hand wheel.

It will be seen that, when the other side has been treated in a similar way, there will be two weights, a large one and a small one, in each wheel. By supposing these to move towards each other through a space inversely proportional to their masses, a position may obviously be found at which a single balance-weight may be placed so as to have the same effect as the pair. The

weight of this is found by extracting the square root of the sum of the squares of the two weights. The formulas are

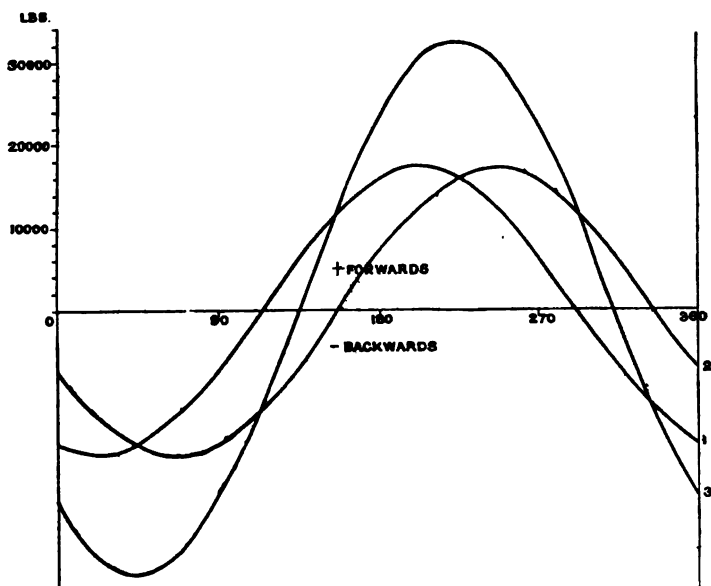
$$\mu, \text{ the large weight} = \frac{p}{2r} \cdot \frac{a+b}{a} \cdot M \quad (1)$$

$$\mu', \text{ the small weight} = \frac{p}{2r} \cdot \frac{a-b}{a} \cdot M \quad (2)$$

$$m, \text{ the resultant weight} = \sqrt{\mu^2 + \mu'^2} \cdot \quad (3)^1$$

To find the inclination of the balance-weights the smaller must

Fig. 4.



be divided by the larger; the result will be the tangent of the angle, which each balance makes with its own crank, diverging from it towards the other crank. As horizontal equilibrium is aimed at, the whole of the parts which cause disturbance must be balanced.

The application of these formulas to the engine under consideration, the disturbing parts of which weigh 1,180 lbs., gives 300 lbs. for the large weight, 128 lbs. for the small weight, and 326 lbs.

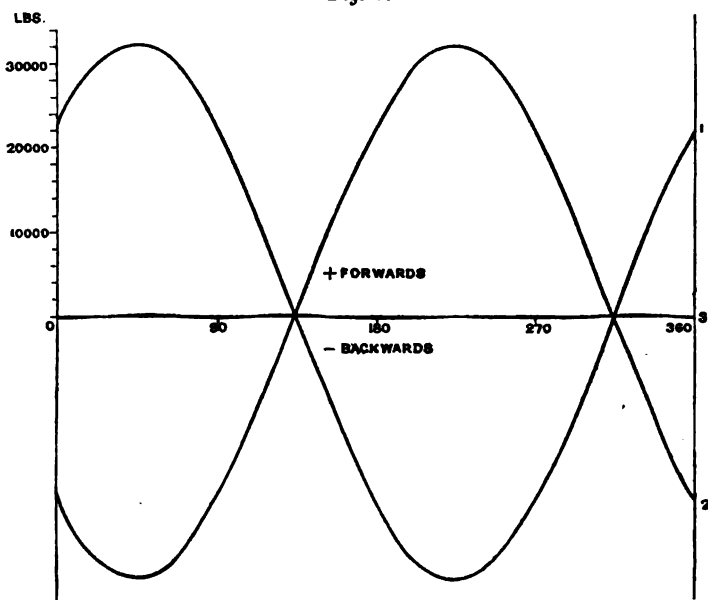
¹ See Appendix, p. 282.

for the resultant weight, the centre of gravity of which is 33 inches from the centre of the wheel.

The angle, which each balance makes with its own crank, is found to be 23° (see *Fig. 9*, Appendix). The weight of the balance being 326 lbs., its centrifugal force equals 17,647 lbs. Now, the horizontal component of this force is the part which balances the fore-and-aft motion, and is equal to the centrifugal force multiplied by the cosine of the angle, which the balance-weight makes with the centre line of the engine.

Working this out for successive crank-angles, the Author

Fig. 5.



obtained curve 1, *Fig. 4*, as the expression of the horizontal component of the centrifugal force of the right-hand, and curve 2 as that of the left-hand balance-weight. Curve 3 shows the total horizontal force of the two balance-weights combined.

The result of the investigation is given in *Fig. 5*, in which curve No. 1 is identical with curve No. 7, *Fig. 2*, and represents the total longitudinal disturbing force, and curve No. 2 is the same as curve No. 3 of *Fig. 4*. It will be seen that the resultant, curve No. 3, *Fig. 5*, is so nearly a straight line that it can only be indicated by a slight thickening of the zero line, and the following

Table is therefore given to show that the engine is almost perfectly balanced as regards its longitudinal movements. Decimal places have been neglected in the working.

+ *Forwards.* — *Backwards.*

Right Hand Crank.	Total Disturbing Force.	Total Balancing Force.	Resultant Disturbing Force.
	Lbs.	Lbs.	Lbs.
0	+ 23,071	— 23,117	— 46
18	+ 29,146	— 29,152	— 6
36	+ 32,398	— 32,311	+ 87
54	+ 32,398	— 32,311	+ 87
72	+ 29,146	— 29,152	— 6
90	+ 23,071	— 23,117	— 46
108	+ 14,832	— 14,858	— 26
126	+ 5,161	— 5,117	+ 44
144	— 5,077	+ 5,117	+ 40
162	— 14,907	+ 14,858	— 49
180	— 23,257	+ 23,117	— 140
198	— 29,221	+ 29,152	— 69
216	— 32,314	+ 32,311	— 3
234	— 32,314	+ 32,311	— 3
252	— 29,221	+ 29,152	— 69
270	— 23,257	+ 23,117	— 140
288	— 14,907	+ 14,858	— 49
306	— 5,077	+ 5,117	+ 40
324	+ 5,161	— 5,117	+ 44
342	+ 14,832	— 14,858	— 26
360	+ 23,071	— 23,117	— 46

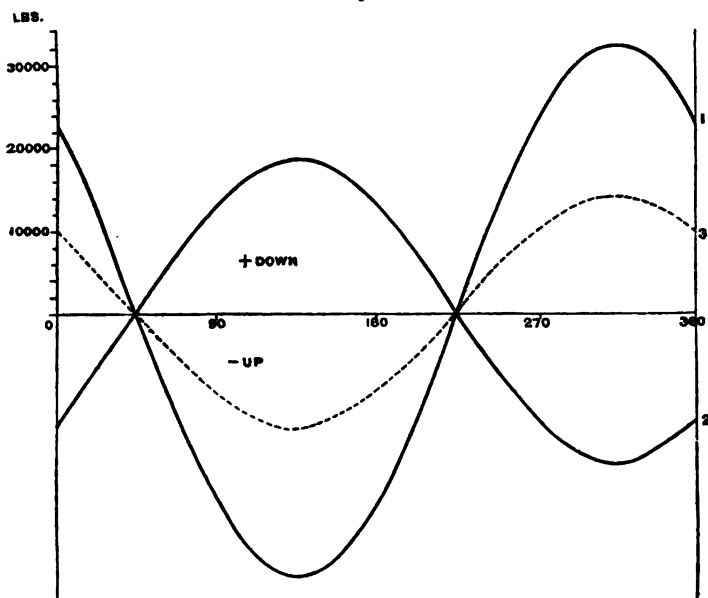
SINUOUS MOTION.

It remains to be seen whether the engine is also balanced as to sinuous motion. When the right-hand crank is on its front dead-centre, the force of the corresponding balance-weight is pulling the head of the engine to the right; those of the left-hand crank and left-hand balance-weight are pulling it to the left, and the force of the right-hand crank is pushing it to the left. For lateral equilibrium, the sum of the moments of all these forces round the centre of the axle should vanish. Working this out for successive crank-angles, curve 2, *Fig. 3*, is found to represent the resultant sinuous force on the engine, and shows that while the longitudinal disturbing force is practically destroyed, the sinuous disturbing force is very much reduced.¹

¹ See Appendix, p. 285.

VERTICAL FORCES.

In order to balance the reciprocating parts, which produce only horizontal disturbances, a weight has been added, which has both horizontal and vertical action. There results from this a superfluous vertical action. Taking the total vertical force of each balance-weight, which is equal to its centrifugal force multiplied by the sine of the angle which the crank makes at any moment with the centre line of the engine, and combining the action of the two, a curve is obtained which is represented by curve No. 1, *Fig. 6*.

Fig. 6.

But part of this vertical action is neutralized by that of the revolving parts, which equals their centrifugal force multiplied by the sine of the crank-angle. Working out these values and combining the action of both cranks, the Author has obtained curve No. 2, *Fig. 6*. Curve No. 3 is the resultant of curves Nos. 1 and 2, and shows the excess vertical action at the axle.

This, however, is not the only force which tends to give the engine an up-and-down movement. The obliquity of the connecting-rod causes a pressure on the slide-bars, which acts upwards during forward running, and which equals the total

pressure on the crosshead, multiplied by the tangent of the angle which the connecting-rod makes with the axis of the cylinder. To get the total pressure on the crosshead, it is necessary to take the steam-pressure on the piston, and add to, or subtract from, it the additional pressure caused by the retardation or acceleration of the reciprocating parts. Since this disturbing force is not a constant quantity, but varies with the steam-pressure, the cut-off, and the speed of the engine, it has been thought useless to show its effect in modifying the vertical disturbances on *Fig. 6*. The excess vertical force of the two balances, together with this vertical action on the slide-bars, through being greatest first on one side and then on the other, causes a rolling motion of the engine from side to side. At the same time the upward pressure on the slide-bars, continually changing in magnitude, imparts a galloping movement to the locomotive, round the axle of the driving-wheels.

Hitherto the engine has been considered as running with steam on. But whether it is on or off does not alter the fore-and-aft disturbance. It does, however, affect the sinuous motion, since when the steam is shut off, the piston, instead of being moved by it, is alternately pushed and pulled by the crank. Thus the disturbing forces are made to act at the axle instead of at the cylinders, and have consequently more power over the mass of the engine. This explains the fact that engines run more steadily with steam on at high speeds. From the fact that the crank-axle is moving the piston instead of being moved by it, when steam is shut off, it follows that the pressures on the slide-bars, caused by the acceleration and retardation of the reciprocating parts, also change their direction from upwards to downwards, and this modifies the rolling and galloping of the engine.

In this Paper it has throughout been assumed that the horizontal forces are the most injurious to the stability of the locomotive. Some engineers in America consider the vertical disturbances to be the most harmful, principally on account of their effect on the rails and bridges, and balance their engines accordingly by not taking into account the action of the reciprocating parts.¹

In England the majority of the locomotive superintendents aim at the mean between excessive vertical action on the one hand, and horizontal on the other, by only balancing part of the disturbance caused by the reciprocating parts.

¹ Transactions of the American Society of Mechanical Engineers, vol. ii. p. 274; American Institute of Mining Engineers, vol. ix. p. 375; *Railway Engineer*, July 1890, p. 174; November 1889, p. 339.

The Author's reason for regarding the horizontal disturbances as the most destructive is that, whereas the vertical forces act on and are taken up by the springs, the horizontal disturbances act through the axle, axle-boxes and horns, and are thence transmitted to every part of the engine and its connections with the tender and train. He believes that by balancing them as far as possible, the saving in coal, and the reduction of wear and tear, would more than compensate for the increased cost of turning up the tires which would be made necessary by the excess vertical action. No doubt this would not be the case in America, where the weight of the moving parts frequently exceeds 2,000 lbs., and it would be quite impossible to fully balance the longitudinal disturbances, with due regard to the safe running of the engine.

In conclusion, the Author desires to express his thanks to the Locomotive Superintendents of all the principal railways who have given him every information as to the rules they use for balancing their engines, and to Mr. C. G. Crump, of the Record Office, for checking much of his mathematical working.

The Paper is accompanied by two tracings from which *Figs. 1 to 9* have been prepared.

APPENDIXES.

APPENDIX I.

THEORY OF THE METHOD OF BALANCING AN INSIDE-CYLINDER SINGLE ENGINE.

A A' is an axle, of which O is the centre.

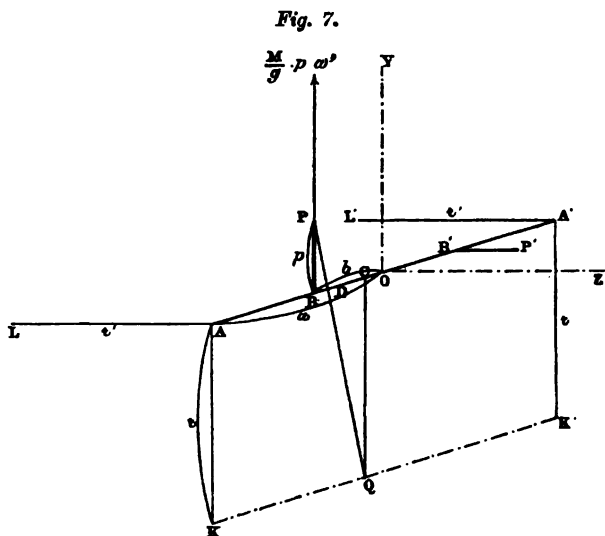
B P = p , and B' P' = p' , are the two cranks.

B O = b = distance from the centre of the engine to the centre of the cylinder.

A O = a = distance from the centre of the engine to the centre of the wheel.

A K = r = distance from the centre of the axle to the centre of gravity of the balance-weight.

Let a weight of M lbs., fixed to P, represent that of the moving parts referred to the crank-pin.



The force on the crank BP affects each wheel in proportion to its distance from the line of action, and must be met, in order to neutralize its effect on the engine, by other weights opposite it, one in each wheel, viz., at K and K'.

In like manner two weights must be placed opposite the other crank B' P', one at L and the other at L'.

Let ω be the angular velocity of the axle. Now the weight at P is M lbs., and therefore the centrifugal force at B is $\frac{M p \omega^2}{g}$ acting along BP. Let μ and μ' be the weights to be placed at K and K'. Then the centrifugal forces

due to these are similarly: $\frac{\mu r \omega^2}{g}$, and $\frac{\mu' r \omega^2}{g}$ acting along A K and A K'.

The first condition which must be satisfied is that these forces must be in equilibrium, i.e., the sum of their moments round O must vanish.

$$\begin{aligned} \text{Thus: } \frac{\mu r \omega^2}{g} \cdot a - \frac{\mu' r \omega^2}{g} \cdot a - \frac{M p \omega^2}{g} \cdot b &= 0; \\ \text{i.e. } \mu r a - \mu' r a - M p b &= 0; \\ \text{or } \mu - \mu' &= M \cdot \frac{b p}{a r} \dots \dots \dots (1.) \end{aligned}$$

Again, the centre of gravity of these weights must be on A A'. Now the centre of gravity of μ and μ' lies somewhere along K K', say, at Q.

Let Q C be drawn perpendicular to A A', and let P Q be joined, cutting A A' in D. Now the force acting at P is M, and that at Q is $\mu + \mu'$. But the centre of gravity must be at D, and this will be the case if $M : \mu + \mu' :: D Q : P D$. But $D Q : P D :: r : p$, so that—

$$\frac{M}{\mu + \mu'} = \frac{r}{p} \text{ or } \mu + \mu' = M \cdot \frac{p}{r} \dots \dots \dots (2.)$$

$$\text{But } \mu - \mu' = M \cdot \frac{b p}{a r} \dots \dots \dots (1.)$$

$$\text{therefore } 2 \mu = M \cdot \frac{p}{r} \left(1 + \frac{b}{a} \right);$$

$$\text{and } \mu = M \cdot \frac{p}{2 r} \left(\frac{a + b}{a} \right) \dots \dots \dots \text{I};$$

$$\text{and } \mu' = M \cdot \frac{p}{2 r} \left(\frac{a - b}{a} \right) \dots \dots \dots \text{II.}$$

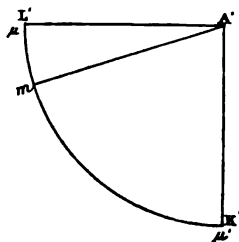
Now it is clear that there will be a weight μ' acting at K', and another μ acting at K, and similarly for the other crank μ' at L, at μ at L'. But μ and μ' may be replaced by a weight m which will have the same effect

$$\text{if } m = \sqrt{\mu^2 + \mu'^2} \dots \dots \dots \text{III,}$$

$$\text{and if } \frac{\mu'}{\mu} = \tan \theta \dots \dots \dots \text{IV,}$$

where θ is the angle which μ makes with its own crank, diverging from it towards the off crank (Fig. 8).

Fig. 8.



When this is done for both sides of the engine, each balance-weight will diverge from its own crank towards the other, so that the angle between the two will be less than 90° .

Balance-Weights for the Engine under Consideration.

	Lbs.
Weight of the revolving parts referred to the crank-pin . .	= 680
Weight of the reciprocating parts referred to the crank-pin .	= 500
Total weight	<u>= 1,180</u>

Dimensions. (See page 281.)

	Inches.
a	= 30
b	= 12
p	= 12
r	= 33

By equation I $\mu = 1,180 \cdot \frac{12}{66} \cdot \frac{30 + 12}{30} = 300.36$ lbs.

" " II $\mu' = 1,180 \cdot \frac{12}{66} \cdot \frac{30 - 12}{30} = 128.72$ "

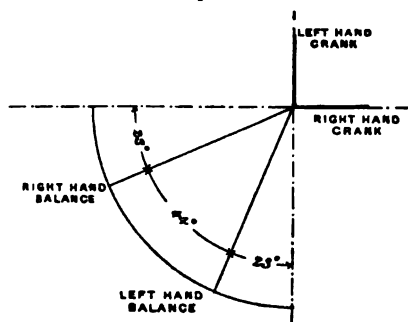
" " III $m = \sqrt{300.36^2 + 128.72^2} = 326.7$ "

Inclination of Balance.

By equation IV $\frac{128.72}{300.36} = 0.429 = \text{tangent } \theta,$
 $\theta = 23^\circ$ approximately.

Thus the balance is placed at an angle of 23° with the near crank, diverging from it towards the off crank. The two weights are situated as in *Fig. 9*.

Fig. 9.



For an outside-cylinder engine the same rule may be used, but in this case the angle which the two balance-weights make with each other is greater than a right angle. For a coupled engine the disturbing parts may first be balanced as if they were not coupled; then the same may be done with the side rods, and the one result subtracted from the other.

N.B.—This only holds good when the outside cranks are opposite the inside cranks. When the two cranks are on the same side of the axle, the side-rods have to be balanced.

APPENDIX II.

It has been shown in this Paper, in the section relating to the history of balancing, that many plans have been invented of having two cylinders on each side of the engine, and at the same end, the action of one of which should neutralize that of the other.

An important point seems to have been overlooked, viz., the effect produced by the finite length of the connecting-rod. If both connecting-rods were infinitely long, and the cranks 180° apart, the action on the one would counter-act that on the other, as the disturbances caused by each would be the same at every point, whereas one would be positive while the other was negative. The separate effect of each would be represented by curve No. 1, *Fig. 1*.

But on taking into account the extra disturbances shown on curve No. 2, *Fig. 1*, which are those caused by the finite length of the connecting-rod, it will be seen that, instead of being neutralized, they are doubled, since the disturbances caused by each crank are the same at every point, and with the same signs also. This objection only applies to those engines like Haswells, where the cylinders are on the same side of the axle.

The following Table shows the effect of placing two cylinders side by side with cranks 180° apart:

Infinite Connecting-rod. Values of $\cos \theta$				Finite Connecting-rod, ratio 6.5 : 1. Values of $\frac{n^2 (\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}}$		
Crank Angle.	First Crank.	Second Crank.	Resultant.	First Crank.	Second Crank.	Resultant.
0	+1.000	-1.000	0	+0.1538	+0.1538	+0.3076
18	+0.951	-0.951	0	+0.1245	+0.1245	+0.249
36	+0.809	-0.809	0	+0.0485	+0.0485	+0.097
54	+0.588	-0.588	0	-0.0445	-0.0445	-0.089
72	+0.309	-0.309	0	-0.1281	-0.1281	-0.2562
90	0.000	0.000	0	-0.1633	-0.1633	-0.3266

As regards lateral movements, it will be observed that the disturbance due to the obliquity of the connecting-rod disappears, while that caused by the centrifugal force $\times \cos \theta$ is doubled. But as the cylinder centres will be very close together, and therefore nearly equidistant from the centre of the axle, these disturbances will not be at all large.

It is often claimed that an engine with three cranks, 120° apart, will be perfectly balanced. This would be the case, longitudinally, if the connecting-rods were of infinite length. But taking successive values of the complete formula

$$\cos \theta + \frac{n^2 (\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}}$$

for each crank, and combining the three, it will be found that the longitudinal disturbances, though not entirely destroyed, are much reduced, while on the other hand the sinuous disturbances are very bad indeed.

APPENDIX III.

It will be noticed that while the longitudinal disturbances are almost entirely destroyed by this method of balancing, the transverse disturbances are not reduced in a corresponding degree. This is due to the finite length of the connecting-rod. The movements caused by the revolving parts are completely neutralized, but those due to the reciprocating parts, which are equal to their centrifugal force multiplied by the corresponding value of:—

$$\left\{ \cos \theta + \frac{n^2 (\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}} \right\}$$

are left partly unbalanced.

If the connecting-rod were of infinite length, the disturbance would equal the centrifugal force $\times \cos \theta$. Hence the centrifugal force $\times$ the value of the second term of the above expression gives the extra disturbance caused by the finite length of the connecting-rod. This cannot be counteracted by a balance-weight, the compensating force of which necessarily varies with $\cos \theta$.

Thus the disturbing force left over is, for one cylinder:—

$$\text{W. R. } N^2 0.00034 \times \frac{n^2 (\cos^2 \theta - \sin^2 \theta) + \sin^4 \theta}{(n^2 - \sin^2 \theta)^{\frac{3}{2}}}$$

and for the other cylinder, whose crank is 90° behind:—

$$\text{W. R. } N^2 0.00034 \times \frac{n^2 (\sin^2 \theta - \cos^2 \theta) + \cos^4 \theta}{(n^2 - \cos^2 \theta)^{\frac{3}{2}}}$$

Working out these values for successive crank-angles, and combining those due to both cylinders, it is found that with one crank 90° behind the other, the longitudinal disturbance is nearly destroyed, but at the same time a couple is left which increases the transverse disturbances.

Right-Hand Crank Angle.	Value for R. H. Crank.	Value for L. H. Crank.	Resultant Longitudinal.	Resultant Sinuous.
0°	+0.1538	-0.1633	-0.0095	0.3171 Left.
18°	+0.1249	-0.1255	-0.0006	0.2504 „
36°	+0.0485	-0.0445	+0.004	0.093 „
54°	-0.0445	+0.0485	+0.004	0.093 Right.
72°	-0.1255	+0.1249	-0.0006	0.2504 „
90°	-0.1633	+0.1538	-0.0095	0.3171 „

These resultant longitudinal values, multiplied by the centrifugal force of the reciprocating parts, give the disturbance that is left after the engine has been balanced by the preceding method.

With regard to lateral equilibrium, it will be seen from the last column of the above Table that a couple is formed; for example, when the right-hand crank angle = 0° , there is a force = 9,807 lbs. $\times$ 0.1538 pushing the head of the engine to the left, and a force = 9,807 lbs. $\times$ 0.1633 pulling it also in the same direction.

The leverage of the couple is 1 foot, as the centres of the cylinders are two feet apart.

Hence the total force at this point is 9,807 lbs. $\times$ 0.3171, turning the head of the engine to the left (*vide* curve 2, *Fig. 3*). The product of the centrifugal force of the reciprocating parts, and the successive values of this couple, gives the unbalanced sinuous force on the engine.

APPENDIX IV.

THE EFFECT OF THE STEAM ON THE DISTURBANCES OF A LOCOMOTIVE.

Mr. Robert Stephenson, in his evidence before the Gauge Commissioners in 1845,¹ being asked whether he did not think that outside cylinders caused more disturbance than inside cylinders, through the alternate action of the piston, replied :—

“It is exceedingly difficult to say; I cannot make up my mind about it. If you consider the action of the cylinder, it is perfectly rigid metal—engine and cylinder together. Now when the steam presses upon the piston, it is at the same time pressing against the lid of the cylinder; the action and re-action must be equal. Therefore, I do not believe that it is the steam that causes the irregular action, but I believe it to be the mere weight of the pistons themselves; and therefore, if we could continue to balance the pistons by the weight upon the wheel, we should get rid of that very much.”

The opinion that an engine can be balanced by means of a suitable amount of compression, is still held by some. The following considerations, taken in conjunction with those quoted above, seem conclusive against it. The disturbances are caused by two things—the weight of the moving parts, and their speed. The weight is a constant quantity. Hence, in order to lessen the amount of the disturbance, the compression in the cylinder would have to be such, that it would reduce the velocity of the moving parts, and, therefore, of the driving-wheel, and would thus introduce an irregularity in the speed of the train which is the very thing that it is desirable to avoid. The due regulation of the compression of steam in the cylinders is equally important with the balancing; but the object of it is, in the Author's opinion, entirely different, namely, to equalize the effort on the crank-pin. He has therefore omitted the consideration of it from the Paper, as being really a separate branch of the subject.

¹ Report of the Gauge Commissioners. Carriages. Questions Nos. 246-7.

OBITUARY.

GRANVILLE GEORGE LEVESON-GOWER, second Earl Granville, was born on the 11th of May, 1815. It is unnecessary in this place to enlarge on his political career as a leading member of successive Liberal Administrations since 1841. It will suffice to record that he was an *attaché* of the British Embassy in Paris during part of 1835 and 1836, and in the latter year was elected Member of Parliament for Morpeth, a seat which he soon afterwards exchanged for Lichfield. He was Under-Secretary for Foreign Affairs in 1840-1. In 1846 he was called to the House of Lords on the death of his father, the first Earl. From 1846 to 1848 he held the office of Master of the Buckhounds; from 1848 to 1851, that of Vice-President of the Board of Trade. In 1851-52 he was Secretary of State for Foreign Affairs; in 1852-54, 1855-58, and 1859-66, President of the Council; in 1868-70 he was Secretary for the Colonies; from 1870 to 1874, and from 1880 to 1885 he was again Foreign Secretary, and for six months in 1886 again Colonial Secretary. He was also an Elder Brother of the Trinity House, Chancellor of the University of London, and from 1865 to the time of his death, Lord Warden of the Cinque Ports.

Lord Granville's association with this Institution began in the year 1885, when he first attended the Annual Dinner, being invited officially as a member of the Government of the day. He afterwards accepted the Council's invitation on no less than eight occasions, being present in 1867, 1869, 1870, 1874, 1878, 1884, 1886, and 1890. At all of these banquets he manifested his goodwill to Engineers by making speeches couched in the most appreciative strain. It mostly happened that he had to return thanks for the Government, a function which he fulfilled with all the gracefulness and tact for which he was renowned, taking care that in a non-political assembly there should be no note of gratulation likely to offend those of opposite opinions to his own. Occasionally he spoke for the Upper House, notably in 1890. It happened that Lord Rosebery, being of senior creation, was deputed to return thanks for the House of Lords, but he flatly refused to do so in the presence of the older peer. Lord

Granville, thus called upon, made, on the spur of the moment, one of his happiest efforts. With singular felicity, he disclaimed disinterestedness in his praise of engineers on the score of his association with them as an individual whose business it was to dig out coal and ironstone, and to make iron and steel for their consumption. At previous dinners he had claimed fellowship with the exponents of engineering science, and in 1881 it was thought well to mark the sense entertained by the Institution of his Lordship's genial overtures by nominating him as an honorary member. His certificate bears date the 6th of December, 1881, and after reciting his titles and honours, details his having filled the office of Vice-President of the Royal Commission for the Great Exhibition of 1851, his Chancellorship of the London University, his Chairmanship of the Commissioners of the Exhibition of 1862, and lastly, his interest in the production of iron, and his great and varied accomplishments, as qualifying him to be elected. It is needless to say of so courteous a gentleman as Lord Granville that he gracefully accepted the honour, and duly fulfilled the prescribed formalities attendant on his election. Owing to his Staffordshire estates largely producing coal and ironstone, which latter was worked up in his own furnaces, Lord Granville was intimately connected with the iron-making industry of the country, which no doubt disposed him to take an active interest in the objects for which this Institution was established. In any case, he occupied a unique position among its Honorary Members, and one that is not likely to be easily refilled.

Lord Granville died on the 31st of March, 1891, in his seventy-sixth year.

STEPHEN BALLARD was born on the 5th of April, 1804, at Malvern Link. His father, Mr. Phillip Ballard, was a solicitor. After the usual term of schooling, which in that day was not of a wide range, his tastes led him to the congenial occupation of a nurseryman, and for some years he was with Messrs. Lee and Kennedy, of Hammersmith. Leaving this calling, he determined to learn building, and apprenticed himself for three years to Mr. Lucy, of Cheltenham, who afterwards worked for Mr. Ballard when the latter had become a large employer of labour. He then became, through the influence of Mr. Biddulph, the grandfather of Mr. M.

Biddulph, M.P., manager, and afterwards engineer, of the Hereford and Gloucester Canal, and carried out the extensions of the same between Ledbury and Hereford. On the completion of that work Mr. Ballard was appointed Resident Engineer by Messrs. Walker & Burges of the Middle Level Main Drain. This work was carried out under his supervision from the Ouse to the junction with the sixteen-foot river at Upwell. It was when this was on the point of completion that he was introduced to Mr. Brassey, whom he met accidentally at the Cambridge railway station. Mr. Brassey, who had contracted for the making of the Great Northern Railway between London and Peterborough, was returning to London from a visit of inspection to the country through which the line was to pass—a portion of the land being a “quaking bog.” On consulting one of his trusted agents as to this difficulty, the agent said, “Ask Mr. Ballard; he has had considerable experience in the Fens.” Mr. Ballard became Mr. Brassey’s principal agent for carrying out the works of the Huntingdon district, extending from Biggleswade to Peterborough, upon which section occurred by far the most difficult part of the line, the railway traversing the Fen country. The method adopted by him was to build up gradually a kind of solid raft, formed of alternate layers of faggots and peat sods, the effect being to displace the water, but to leave the solid parts behind. Great stress was laid by Mr. Ballard on the necessity, in all such cases, of proceeding slowly, adding the weight little by little, so as to allow the water time to escape.

In 1851 he went to India to inspect the country for a line of railway; but his stay was confined to a few months, the climate not agreeing with him. In 1852, in conjunction with Mr. Brassey, Mr. Ballard undertook the construction of two sections of the Dutch Rhenish Railway between Utrecht and Rotterdam and between Arnheim and the Prussian frontier. A great portion of the line—between Utrecht and Rotterdam—was over peat similar to that of the Fen district of the Great Northern Railway, and was successfully executed by Mr. Ballard in the manner there adopted.

His next work was the Worcester and Hereford Railway. His efforts to promote this undertaking exhibited him in an unusual light. In the early days of railways, the companies had to contend with the greed of landowners, and fabulous sums were often demanded for land of little value. When Mr. Ballard was applied to for a part of his land, which was required for the line, his answer was, “Take it at your own price”; and to those who

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feared that his generosity might be to their pecuniary disadvantage, he declared that so sure was he of the benefit that would ultimately accrue to all by its construction, that he would not hesitate to make a present of his land rather than that the project should not be carried out.

The Ashchurch and Evesham Railway next engaged Mr. Ballard's labour, in 1862, and in 1864 the Evesham and Redditch line, both of which made heavy demands on his strength and patience without corresponding profit. But it was a principle with Mr. Ballard first to discharge his obligations, not allowing the risk of loss to interfere with his sense of honour. His last undertaking was the extension of the Midland Railway from Bedford to London, which was commenced in 1865.

Perhaps no employer was ever regarded with more real respect and affection by his workmen. They felt that their master was a friend in whom they could place implicit trust. Numbers of the old employees would from time to time call at Mr. Ballard's house, The Winnings, some in less prosperous circumstances than aforetime, but many who had attained positions of ease and comfort by their industry and sobriety. They never called without receiving a hearty greeting, and thoughtful help when help was needed. A pleasing incident illustrative of this reciprocity of kindly feeling transpired only recently. Mr. Ballard took with him to Holland, in 1852, a number of workmen. One of them was offered a permanent situation on the completion of the railway, which he accepted. After the lapse of thirty-eight years the man made a journey from Holland to Colwall to see his old master. This is but a solitary instance of the cementing influence which a generous and true-hearted employer exercised on material not the most easily wrought upon.

He purchased and settled on the appropriately-named Winnings estate about forty years ago, erecting his own and several other handsome residences upon it. His model farm buildings have been copied in many places. The village and neighbourhood of Colwall has undergone a variety of improvements through Mr. Ballard's instrumentality. Ten years ago he built a Workmen's Hall and Temperance Hotel, and he has carried on a successful vinegar manufactory. The "Jubilee Drive," which is a fine road along the upper side of the Malvern Hill, a welcome alternative to the old highway at the base of it, will long be associated with his memory. He was not only the prime mover in this enterprise and the largest subscriber, but gave a considerable portion of the land, and superintended the whole of the work.

One incident, characteristic of his nature, may be mentioned here. It became necessary to banish a number of starlings, which had fixed their nests about the mansion, at The Winnings. Mr. Ballard built a bird-house for them in the grounds, and so suitably did it meet their tastes that they removed to it of their own accord.

Four Papers from his pen have appeared in the Minutes of Proceedings,¹ and not many weeks before his death he brought out a second edition of his pamphlet on "Cheap Railways," in which he advocated the construction of light lines in many places where the ordinary heavy system would not be profitable. This idea is bearing good fruit in Ireland. He was a geologist, and was very fond of botany, and a horticultural show has been regularly held on one of his meadows. At the model farm-buildings he presided every autumn over one of the most enjoyable "harvest homes" that could be conceived. In consequence of his serious illness, last autumn passed by without the usual festivities.

He died on the 14th of November, 1890, in the eighty-seventh year of his age. According to his expressed desire, he was interred in a steined grave made on the top of a high mound formed with the soil from the boring of the Malvern railway tunnel. This tump is about 300 yards from The Winnings residence, and approached by a road known as "Ballard's Drive," leading to the Malvern Hills. A few yards from the grave is the third ventilating shaft of the railway tunnel. It is almost exactly in the centre of the estate, near to the field in which the flower shows have taken place, and in view of handsome plantations of trees, in the culture of which Mr. Ballard took such delight.

Mr. Ballard was elected an Associate of the Institution on the 14th of March, 1837, and was transferred to the class of Member on the 17th of February, 1846.

JOHN GEORGE THORNTON CODDINGTON, second son of the Rev. Henry Coddington, Vicar of Ware, Herts, late Fellow of Trinity College, Cambridge, was born on the 29th of June, 1841, at the Vicarage, Ware. He was educated at Charterhouse School, and also received private tuition. He went as pupil to Sir John Macneill in 1858, and in 1860 was sent to Londonderry to lay out and superintend the construction of the Lough Swilly Railway. Subsequently he prepared Parliamentary and

¹ Minutes of Proceedings Inst. C.E., vol. i. (1839), pp. 31, 52, vol. i. (1838), p. 47; vol. x., p. 352.

contract plans of the Buncrana Branch, and took the soundings for a pier in Lough Swilly. He remained as Resident Engineer under Sir John Macneill till 1865, when all these works were completed and opened for traffic. In 1866 and 1867 he was employed making surveys and setting out railways in England and Ireland.

Early in 1868 Mr. Coddington proceeded to India under a five years' covenant with the Government. He was posted to the Irrigation Department of the North Western Provinces, and in this branch he served till his resignation in 1879. After a short period of secretariat duty he held charge of the Survey for the Fatehgarh Branch of the Lower Ganges Canal. This work involved about 1,000 miles of levelling over a country where there was little to guide the eye, and where at the same time an error in location would have serious consequences. The resulting project was distinguished for extreme accuracy in levelling and comprehensive location and scope. On the commencement of the construction of the Lower Ganges Canal, in 1872, Mr. Coddington was placed in charge of the Third or Bhongaon Division of it as Executive Engineer. This appointment he held for about four years, during which time the alignment of the canal, nearly the whole of the extensive excavations and collection of material, and the construction of four large bridges—two of them on the skew—were carried out under his superintendence. Here Mr. Coddington received the acknowledgments of the Government for his success. He was distinguished for love of accuracy, completeness, and economy, and by his zeal for obtaining only the highest class of materials and workmanship.

After a period of furlough he rejoined the Lower Ganges Canal in 1878, this time as Executive Engineer of the second or Kharganj Division. Just then a famine and epidemic of fever supervened on the failure of the monsoon rains of 1877, and there was great anxiety for the pushing on of the canal distributaries, both as relief works and for giving a supply of water to the land. Into his duties Mr. Coddington entered with characteristic devotion, and under his superintendence 55 miles of the distributary irrigating channels of the Fatehgarh branch were lined out and prepared ready to receive the water between June and December, 1878. For this work he received the special thanks of Government; but the anxiety and worry were too much for his health. His friends prevailed on him to retire in 1879, the Government giving him a handsome bonus and a pension.

After some time spent in travelling in Germany and Italy,

having regained his health, he went in 1883 to Ireland to make plans and surveys, &c., for light railways, and in November, 1885, was elected Engineer-in-Chief of the Suck Drainage Board, in which employment he continued to the end of his life. The Suck Drainage dragged on for years without useful result for money expended, until Mr. Coddington put new life and sound engineering into the project.

Mr. Coddington died on the 11th of March, 1891. He was elected a Member of the Institution on the 1st of May, 1877. Many of his brother officers in India regret the genial host, the accomplished musician, and the kindly companion, who has passed away.

ROBERT JOSEPH HUTTON was born in Dublin on the 22nd of April, 1842. He was educated at Portora Endowed School near Enniskillen, then perhaps the chief school in Ireland. In the summer of 1858 he entered Trinity College, Dublin, where he obtained a mathematical scholarship in 1861. He graduated at Michaelmas, 1862, receiving the First Gold Medal for Mathematics, in which he was bracketed equal with the late Lord Chancellor Naish, and the First Silver Medal in Experimental and Natural Science. For the next four years he served a pupilage under Messrs. B. and E. Blyth, of Edinburgh. During the summer of 1868 he was employed as Assistant Engineer by Mr. James Barton, on the Carlingford Bar Works. From May, 1869, to March, 1872, he was on the Dundalk and Greenore Railway as Resident Engineer during its construction, also for Mr. Barton. From March, 1872, to 1873, he was employed by the Irish North-Western Railway Company as Engineer of the northern half of the line from Enniskillen to Londonderry and Bundoran, a length of about 100 miles.

From 1873 to 1874 he had charge as Resident Engineer of the doubling of the Whitehaven line, Furness Railway, and of the Arnside branch for Mr. F. C. Stileman. From 1874 to 1878 he was engaged as Assistant Engineer on the loop-line of the Cape Government Railways under Mr. W. G. Brounger, and was also at the same time Resident Engineer of the Orange River Bridges for Mr. James Fforde. After his return from the Cape he was induced to put his money into a large brick works near Cork, of which he took the superintendence. Owing to the depressed condition of affairs in Ireland at the time, he lost all, and had to begin again

as a Resident Engineer under Mr. Barton on the Cloghen Valley Railway. On the completion of that line he went to the Argentine Republic, where he was engaged on various railways as contractor's engineer.

He died on the 11th of September, 1890, suddenly, of hæmorrhage of the brain, at a hotel in Tigre, about 3 miles from Buenos Ayres.

Those who knew him best bear testimony to the sincerity and simplicity of his character: truthful and candid in disposition, and with a high sense of duty, he was intolerant of anything approaching what he considered hypocrisy, and some of the difficulties of his career are perhaps to be ascribed to his inability to bend his mind to take the views of others. He was elected an Associate of the Institution on the 1st of April, 1873, and was transferred to the class of Member on the 11th of May, 1880.

ALEXANDER MACNAB was born at Belleville, Ontario, on the 18th of March, 1837—a memorable year in Canada, owing to the outbreak of the Canadian rebellion, in which his father, Captain James Macnab, was killed in the performance of his duty to the loyalist cause.

Mr. Macnab began his professional career in 1853, and was engaged for two years in the construction of the Hamilton and Toronto Railway under Mr. Marcus Smith. He then joined the engineering staff of the Great Western Railway of Canada, at that time in course of construction, and now forming part of the Grand Trunk, and was connected with this line for five years under Mr. George Lowe Reid. In 1861 he received from the Imperial Government the appointment of Surveyor of Public Works in the Island of Granada, West Indies, but was compelled to resign after a few months on account of ill health.

In 1865 he assumed the office of Chief Engineer to the Government of the Province of Nova Scotia, having charge of the construction and maintenance of the railways built by that Government. In 1872 he received the additional appointment of Chief Engineer of the Maintenance of Way Department of the Intercolonial Railway, about 750 miles in length, connecting the maritime provinces with Canada; and this position he held until, in 1878, he came to England for the benefit of his health. On his return to Canada he undertook the management, engineering

and otherwise, of the Prince Edward Island Railway, which, however, after two years, proved too great a strain, and he was obliged again to take a rest for the sake of his health.

For the next ten years he lived in England, and in May, 1887, became Chief Engineer to the late Mr. T. A. Walker, in connection with the heavy contracts that gentleman then had on hand, consisting of the Barry Dock and Railways, the Buenos Ayres Harbour Works, the Preston Docks, and the Manchester Ship Canal. Early in 1888 he went out to Buenos Ayres to inspect the Harbour Works, but during the last two years his attention was chiefly confined to the Manchester Ship Canal; and it was while engaged on this contract that he was taken ill at Manchester, and after lingering nearly six weeks, died on the 4th of January, 1891.

Mr. Macnab was endowed with a most amiable disposition and attractive manner, and was beloved by all with whom he had relations, either social or professional. His character was a noble one, and his zeal and faithfulness to the interests entrusted to his care won for him the esteem and confidence of all who had to do with him.

He was elected a Member of the Institution on the 3rd of December, 1878.

WILLIAM RUSS, came of an old Hampshire family, which has been settled in the neighbourhood of Winchester for many generations. He was in 1848 a pupil to Mr. Sharp, Gas Engineer, of Winchester and Southampton. He then went to Australia, and in 1851 and 1852 was on the staff for the survey of Crown lands, roads, and bridges in the Colony of Victoria. He afterwards acted for several years as Resident Engineer of the South Essex Waterworks, in the employment of Messrs. Easton & Amos. He then entered into partnership with Mr. Charles Minns, in conjunction with whom he carried out the sewerage and drainage and water supply of a number of towns, amongst which may be mentioned Romford, Ware, Brentwood, Sawbridgeworth, Enfield, Andover, Swindon, Shirehampton, Westbury-on-Trym, Stoke Bishop, Portishead, Basingstoke, Newport (Isle of Wight), Richmond (Surrey), and Petersham.

He was also extensively engaged in the reclamation of land from the sea in Essex, Norfolk, and Hampshire. He designed a scheme for bringing sea-water from Shoreham to London, for

which an Act was obtained in 1881, and was also engaged in the designing of the Mid Kent Water-works and the Guernsey Water-works. In common with his brother, Mr. Percy Russ, he paid great attention to the subject of fish-culture, and wrote several reports on the cultivation of oysters.

He was well known and respected at the offices of the Local Government Board, with the officials of which he was constantly in communication in connection with inquiries in relation to various sanitary works.

Mr. Russ was an enthusiastic Volunteer, and besides holding a commission in the Guernsey Militia, belonged in succession to the 1st Hants Volunteers and the 3rd Essex Rifles, from which latter corps he retired with the rank of Major. He is regretted by a large circle of friends, to whom he had endeared himself by his geniality of disposition, his kindliness of heart, and the sterling integrity of his character.

He died, in his 63rd year, after an illness of only a few days, on the 13th of February, 1891. He was elected a Member of the Institution on the 3rd of December, 1878.

MICHAEL SCOTT was born in Glasgow on the 4th August, 1818. He was educated at Fisher's Academy, and afterwards attended the lectures of Professors Graham, Wilson, and Gregory, at Anderson's College, Glasgow, where he distinguished himself for his regular attendance. He studied architectural and mechanical drawing with great interest, and became an excellent draughtsman. He soon evinced a taste for mechanical engineering and was anxious to learn the practice of it, and although the project was opposed by some members of his family, his mother wisely determined to encourage her son in his natural talents, and he was articulated as a regular working apprentice. The firm to which he was first apprenticed appears to have given up business shortly afterwards, but he served a regular period of pupilage under Mr. Starke (Glasgow) as Mechanical Engineer, then on the Ayr Railway, and afterwards under Messrs. Caird & Co., Greenock, as a Marine Engineer.

During his apprentice days a threatened attack by his shop-mates was prevented by the gate-keeper, a former shipmate in the Royal Navy of a servant of his father. Having only served three years, by the rules of the Trade Union he was not allowed to act

as a journeyman, although the works manager had employed him in this capacity and given him the full wages. "Hey lad, hast thou lines?" asked the gate-keeper. "No," he replied. "Thou must up anchor and off," and he closed the gates against the excited workmen whilst Scott made good his retreat. An extract from his diary on his railway experience in those days is interesting. "Called at 5 A.M., started with break-down gang; engine had gone off the rails at a bridge, knocking over 20 feet of parapet, and was as near as possible over into river; returned to terminus. One o'clock message, another train off the line, gang sent—I remained; five o'clock, no news, another train past due, at last it arrived, had also been off the line; six o'clock train late, started with an engine to see what was wrong. Driver let fire low, steam down, stopped, expecting to be run into every minute; broke down a fence to burn and got steam up just in time to escape."

Referring to the Glasgow Post Office of those days he says, "It was a miserable little place, situated a little way up an alley branching off the main street. There was a little old man dressed in knee breeches, who had a little wheelbarrow, and suspended from his neck by a leathern strap was a large old-fashioned watch, the back resting on his breast, and the face exposed so that all could see the time. There was only one mail from the south in the day, and it was often late; when the coach arrived the little letter-bags were placed in the old man's wheelbarrow, the watch showing the time, and away he scuttled up the alley to the post office, the watch proving he had not loitered on the way."

At one time whilst engaged in the manufacture of engines, a trial was to be made, and the stoker had, unnoticed, hung the great weight intended as a balance for the damper upon the extreme end of the safety-valve lever. Addressing men near him he ordered two to remove the weight, and on their refusal, Scott undertook it himself, and succeeded in pushing it in a little distance; the lever instantly tipping up caused the weight to slide further inwards, thus relieving the pressure of the boiler. Mr. Scott said he lived a lifetime in those few moments.

Whilst studying shipbuilding and marine engineering, in order to gain maritime experience he took employment as an Assistant Engineer on one of the steamers between Glasgow and Liverpool in 1843. After his seafaring life terminated he moved south, where his headquarters continued ever after.

Soon after this an Assistant Engineer was wanted for the Bootle Water-works near Liverpool, and Mr. Scott applied for and obtained the appointment. In 1846 he became Engineer-in-Chief

to the Company, and successfully completed the undertaking. When the Water-works were purchased by the Corporation of Liverpool in 1847, Mr. Scott was unanimously appointed Resident Engineer, and held that office till the end of 1849, when he proceeded to London and began business on his own account as a Civil Engineer. One of his first engagements was the superintendence as Resident Engineer of the construction of extensive harbour works at Goole, which he had designed. In 1851 he was consulted by the Corporation of Swansea in connection with the water-supply for that town, and the Bill authorizing the works recommended in his report received the Royal Assent on the 30th June, 1852. About this time he invented an apparatus for laying large masses of concrete under water, everything being done by divers.¹

From 1856 to 1860 he was engaged as contractor under Mr. James Abernethy, in the construction of the Port of Blyth breakwater. On the 7th December, 1858, Mr. Scott read a Paper before the Institution describing this work, for which he was awarded a Telford medal.² In a supplementary Paper on the same subject read on May 22, 1860, he remarks that it had been exposed for four winters without injury. In connection with these works he read Papers before the Institution of Mechanical Engineers on a steam pile-driving machine, which was also available as a steam crab and a dredging machine. Whilst at Blyth he arranged a system of profit sharing, which worked satisfactorily, and is interesting as being one of the earliest instances of a profit-sharing concern in England. He described this system anonymously in 1866 in a pamphlet entitled: "On the relations between masters and men." In 1865 Mr. Scott was engaged in the construction of another breakwater at St. Ives in Cornwall; but the undertaking had to be abandoned as those locally interested in it were unable to obtain the capital required to complete it. In his capacity of Consulting Engineer he designed some important buildings constructed at Bombay, including the Victoria and Albert Museum there.

Having formed a high opinion of the Siemens open-hearth process of steel manufacture, he called upon some enterprising capitalists in Glasgow with a view to its being introduced as an

¹ Report of the Commissioners on Harbours of Refuge. Vol. i. Folios 295, 298. London, 1858.

² Minutes of Proceedings Inst. C.E. vol. xviii. p. 42.

industry into Scotland. In this he was successful and a Limited Liability Company was formed, of which he was appointed interim Secretary and General Manager. The works, which were built at Hallside, near Cambuslang in Lanarkshire, were erected on plans supplied by the late Sir William Siemens, and were carried out under Scott's directions in a perfect manner, but unfortunately for the immediate prospects of financial success, before they were ready to commence operations the prices of steel had begun to fall, and Mr. Scott was advised to refuse to accept contracts on a falling market. As he had already purchased stocks of pig-iron and ore at the inflated prices, the prospects of successful manufacture were very small, and it resulted in his resigning his position; this resignation was a great blow to him, but he felt, as did also his friends, that the fault was not his, but due to untoward circumstances. It may be added that the Steel Company of Scotland has now for years been a successful concern.

Mr. Scott was also concerned in other enterprises with which his name has not been directly connected. On the 8th July, 1858, a scheme of Dr. Siemens and Mr. Scott for the purification of the Thames appeared in the *Times* newspaper, similar to the one described by Mr. Scott in a letter dated 9th March, 1868, addressed to the Chief Magistrate of Glasgow, as applicable to the Clyde. It was proposed that at every tide a column of comparatively pure water should be so interposed as to prevent the reflux of the impure water with the returning tide and thus twice in twenty-four hours the sewage would be forced out to sea.

In 1860 a Committee of the House of Commons had under consideration the purification of the water of the Serpentine by filtration. Mr. Scott drew up a memorandum on the subject in which he stated that the chief stimulating cause of vegetation in water exposed to daylight was carbonic acid, either free or combined with certain bases in the form of salts, and proposed its removal by applying Dr. Clarke's process for softening water. On his recommendation, caustic lime was added to the water in the upper reach of the Serpentine with the result that it became and continued quite clear for some time.

He took great interest in matters connected with Naval Warfare and Defence, and read Papers on these and cognate subjects before the Royal United Service Institution, the Institution of Naval Architects, the British Association and elsewhere. In a speech at the meeting of the Royal United Service Institution of the 21st of May, 1862, he showed that for a given bore of gun, whatever the

weight and velocity of the shot, provided they varied so as to keep the strain on the gun unaltered, the destructive power of the shot always remained the same. In his Paper on Projectiles before the same Institution, he described the accomplishment of what had previously been held to be impossible, viz., the firing from a smooth-bore gun of elongated projectiles which did not revolve, and which did not turn over during flight. He brought forward a plan for the defence of Spithead, in which he proposed to place two powerful forts in a position to bar the channels between the forts and shore, and provided means for impeding the passage of an enemy's vessels through the deep-water channel.

Mr. Scott commenced his professional career as a Marine Engineer, and a great portion of the 2nd volume of his "Occasional Papers" is devoted to Naval Architecture. He claimed to have originated and first made known the Inflexible type of ship. In the Inventions Exhibition he placed outline drawings of war-ships of types originated by him, of which the first plan was communicated officially to the Admiralty on 25th August, 1870, and the second was explained to the Chief Constructor in May 1871. The first plan included a central armoured citadel the full breadth of the ship, an armoured deck under water; the cellular system arranged so that fuel could be stowed in it, high freeboard, and guns protected by armour; in the second plan the armoured under-water deck was sloped downwards, so as to save weight, prevent the ship being raked in a sea-way, and strengthen the ram stem. He also proposed to place the turrets abreast, in order to obtain fire in the line of the keel both fore and aft from all the large guns in both turrets simultaneously, and to provide sail power without the disadvantages of rigging. Subsequently the "Inflexible" and other vessels were built, embodying several of these improvements. Mr. Scott's claim to have originated this type of ship was acknowledged by several Admiralty authorities, and Mr. Merrifield wrote to him: "I have always considered that you had priority in all that distinguishes the Inflexible type apart from a question about the unpublished sketches of Mr. Reed just before he left the Admiralty." The Admiralty, however, have not considered that Mr. Scott had any claim to compensation.

Those who knew Mr. Scott best will agree that the main reason why his professional career was not a marked success, was that his interests were so multifarious that he did not draw that distinct line between business and pleasure, which is necessary to ensure success. He was a very fair musician, and more than an average art critic; in his more prosperous days his house, which was

replete with treasures of Art, was the rendezvous of its votaries. He was of a most kindly and amiable disposition, and was constantly engaged in works of benevolence done without ostentation. In his declining years, which he spent in Tunbridge Wells, he took great interest in local charitable institutions, especially those having reference to children. For some years previous to his death he was in delicate health and had practically retired from professional life. He died at Tunbridge Wells on the 13th of September 1890. He was elected an Associate of the Institution on the 1st of February 1848, and was transferred to the class of Member on the 26th of April, 1853.

JOHN LUM STOTHERT was born on the 29th of June, 1829, at Bath. His father was Mr. Henry Stothert, then proprietor of the old Newark Foundry at Bath. He received his education at private schools, and in 1845 was apprenticed to the firm of Stothert and Slaughter, at their locomotive works in Bristol, where, under Mr. Slaughter's somewhat strict but admirable rule, he acquired a thorough mastery of handicraft, and laid the foundation of that sound practical knowledge for which he was distinguished in after life.

In 1844 Mr. Stothert's father took into partnership his then managing engineer, Mr. Rayno, and also Mr. R. Pitt, who had served his apprenticeship at the works in Bath, the firm becoming Stothert, Rayno, and Pitt. Eight years afterwards Mr. Henry Stothert withdrew from active participation in the business, and transferred his share to his son, and on the retirement of Mr. Rayno in 1855, through ill-health, the firm became Stothert and Pitt, and the business was carried on under that title by the two partners for the succeeding thirty years. During this long period of hard and active labour Mr. Stothert earned a prominent position amongst mechanical engineers by the soundness of his designs and the careful manner in which they were carried out, so that in general engineering, and especially in the department of lifting-machinery, the reputation of the firm became second to none.

The part Mr. Stothert took in the introduction of machinery for making and dealing with artificial blocks of concrete for the construction of breakwaters and harbours is in too recent recollection to require detailed description here, but it may be said that in this particular branch his experience was without parallel.

About the year 1883 his health, which up to that time had been apparently strong, showed signs of giving way, and his partner, Mr. R. Pitt, broke down a few months afterwards. This led to the formation of the present private company, Stothert and Pitt, Limited, of which Mr. Stothert remained chairman until his death, and was always ready with his counsel and experience although he retired from the active management.

Mr. Stothert was also for a time chairman of the Avonside Engine Company, Limited, the successors of the firm with whom he was brought up. He was a leading director of the Bath and Bristol Gas Companies, and also of other local companies, his energetic disposition never permitting him to be long without doing some useful work. Those who visited Bath during the British Association meeting in 1888, and who were in any way behind the scenes, will remember how admirably he filled the position of local secretary.

Mr. Stothert's favourite relaxation was found in his small but extremely well-fitted observatory, where he occupied himself with practical astronomy, of which he was very fond. He had also a well-furnished private workshop. His health had been in a very unsatisfactory condition for some years, and he died somewhat suddenly, from heart disease, on March 5th, 1891, amid the general regret of a large circle of friends. His character and abilities were such that most of those who commenced his acquaintance by formal business relations remained for years his personal friends. As an engineer he possessed the true instinct of "mechanical fitness," and an adaptability of resource which enabled him to deal successfully with problems outside the range even of his large experience. His early training in the best traditions of the old millwright school gave him a love for honest work which made him regard scamping with utter abhorrence, and contributed not a little to the confidence with which his friends looked forward to the completion of whatever he took in hand.

Mr. Stothert was a Freemason, and held high office. He was a member of the Grand Lodge, and in this connection actively participated in the charitable work of the society.

He was elected a Member of the Institution on the 4th of March, 1879.

THOMAS WARING was born in 1825 at Wheatley Hall, Wooley, in the West Riding. After serving a regular period of pupilage as an Engineering Surveyor, he entered the office of Messrs. T. L. Gooch and F. M. Young, and was employed by them on the construction of the Leeds and Bradford and Extension Railways. This engagement having come to a close when all the works were completed, Mr. Waring became Contractor's Engineer under Mr. Young. He carried out contracts on the Leeds Waterworks extensions under Mr. J. W. Leather; on the London and North-Western Railway branches under Mr. Woodhouse; on the Furness Railway, and Ulverston and Lancashire Railway under Messrs. M'Clean and Stileman. He was also engaged on some arbitrations at Sunderland Docks and other places. In the autumn of 1854 Mr. Waring became Resident Engineer upon the Cardiff Sewage Works under Mr. Hawkshaw, and the office of Surveyor to the Local Board of Health of Cardiff falling vacant in the following year, that appointment was also offered to Mr. Waring. The carrying out of the Sewerage Works was not effected without some difficulty; the severe weather in 1855, together with financial difficulties, and the necessity of opposing a scheme which would have compelled the drainage of all Butetown into the packet slip, delayed the final completion, which was not effected till 1857. The beneficial effect of it, however, was speedily apparent in the improved health of the town. No sooner was the first sewage scheme finished than a material extension was required, which was successfully accomplished under Mr. Waring's directions. In a short time the length of the sewers had to be doubled in consequence of the rapid growth of the town. Many new streets were built, and the whole of the old ones re-made, and there are few public institutions in Cardiff which have not benefited in some way by Mr. Waring's exertions. The large expenditure of money in the erection of cottage dwellings for workmen, on land liberally granted by Lord Bute at a low rent, was in a great measure due to his influence. For several years he was Surveyor to the Canton and Roath Boards of Health, and Chief Engineer to the Cardiff Rural Authority. He acted as Engineer to the Borough of Aberavon, and laid out their system of sewerage and water supply. He took an active interest in municipal affairs, and in 1886 was elected Alderman.

Mr. Waring was a ready speaker, eminently practical, and always listened to, on account of his great experience, with attention. He was a Member of the Council of the University College

of South Wales and Monmouthshire. He died on the 24th of April, 1891.

He was elected a Member of the Institution on the 1st of April, 1862.

ROBERT WATSON was born at Dartington, near Totnes, Devonshire, on the 21st of November, 1822. He was educated first at local schools, and subsequently at the Exeter Diocesan College. He then became articled pupil to the late Mr. Henry Symons, of Plymouth, and was connected with the construction of the South Devon Railway, and was also engaged, under the late Mr. Wm. Froude, on the Plymouth and Tavistock and the North Devon Railways. Between 1849 and 1851 he spent a year with an architect in London, and a year with a mechanical engineer, during which time he was connected with the erection of the Hanwell and the Warwick Lunatic Asylums. In 1852 he joined the staff of Messrs. Locke and Errington, with whom he was engaged on the Shrewsbury and Aberystwith and the Direct Portsmouth lines.

In November, 1854, he proceeded to Victoria, and on his arrival in Melbourne, almost immediately joined Mr. Darbyshire, Engineer of Construction, then District Surveyor under Government at Williamstown. There was at that time no Railway Department. The surveys were under the control of the Surveyor-General, Captain (now Sir Andrew) Clarke, and Mr. G. C. Darbyshire. His first work was to lay out the main road from Melbourne to Ballarat, with instructions to examine the country, having in view railway construction at some future time. The levels over this road were the first taken far into the country. The datum was an assumed low-water mark in Hobson's Bay, and the levels for the whole railway system of the colony have been reduced to it. On the completion of this preliminary work, the railway surveys were commenced, and Mr. Watson at once occupied a prominent position in connection with them. The Geelong and Ballarat Railway, the direct Ballarat line, the Echuca line, the North-Eastern and branches, the Gippsland line and branches, many of the lines to the Western District—in fact, all the principal railways of the colony—were surveyed under his direction, and it is a somewhat remarkable fact that the line from Bacchus Marsh to Ballan, now under construction, follows literally the route marked by him about thirty years ago, notably in the

difficult part immediately after leaving Bacchus Marsh, where there is an abrupt ascent of 300 feet in a distance of less than a mile. Mr. Watson, as Resident Engineer, superintended the construction of the Geelong and Ballarat Railway, the Sandhurst and Echuca, the North-Eastern and branches, the Gippsland and branches, and many others.

Having carried out these works in a satisfactory manner, he was granted twelve months' leave of absence on account of ill health, and visited Europe, accompanied by his wife, who unfortunately died in England. On the expiration of his leave he returned to Melbourne and resumed work in the Railway Department. In 1878, when political emergency deprived the Government of the services of Mr. Thomas Higinbotham, Mr. Watson became Engineer-in-Chief. In 1880 a new Ministry expressed a wish to redress what had been regarded as a great injustice and wrong, by re-instating Mr. Thomas Higinbotham as Engineer-in-Chief. Mr. Watson was offered the position of Senior Resident Engineer, without any alteration in the salary he had been receiving, and his position was to be only temporary, as changes were contemplated which would make it possible for him to resume the office of Engineer-in-Chief. However, he elected to retire, and Mr. Higinbotham was re-instated. Shortly after other changes took place, and Mr. Watson was asked whether or not, in the event of Mr. Higinbotham's resigning, he would be willing to resume the position of Engineer-in-Chief. These overtures he unhesitatingly rejected as unjust and unfair towards Mr. Higinbotham.

Mr. Watson then went on a difficult expedition for the Queensland Government. He explored the country from the East Coast to the Gulf of Carpentaria, with a view to the construction of a railway, and received the highest praise for the manner in which he carried out the enterprise.

Unhappily, Mr. Higinbotham died suddenly, a few months after his re-instatement, and another Engineer-in-Chief was appointed in his place. Mr. Watson was asked in 1882 to return to his former position, which he held up to the time of his death.

To Mr. Watson is due the credit of introducing cheaply constructed railways, and timber bridges, altogether lighter and less costly than those employed in English practice. He died on the 7th of April, 1891, at the Melbourne Club, of Bright's disease and congestion of the lungs. He was elected a Member of the Institution on the 1st of December, 1868.

ROBERT STODART WYLD, Jun., was born on the 12th of March, 1855, at Queensferry, close to where the great bridge now spans the estuary of the Forth. His father had been trained as a Writer to the Signet; but giving up the practice of the law, had settled at Queensferry, of which for many years he was the much respected Provost. Robert Wyld received his education at the Academy and University of Edinburgh. Having made choice of engineering as his profession, he served a pupillage of five years, from 1872 to 1877, under Messrs. J. and A. Leslie, whose extensive practice gave him an early experience in many kinds of engineering operations. During this time he attended the engineering classes of the late Professor Fleeming Jenkin, and that of geology and mineralogy under Professor A. Geikie. On the completion of his articles he was appointed by Messrs. Leslie as Resident Engineer at the waterworks then being constructed for supplying the town and district of New Cumnock. After some months he was transferred to Midlothian, and placed in charge of a section, 13 miles long, of the pipe-line conveying a new water-supply to the City of Edinburgh from the Moorfoot Hills, with all the reservoirs, bridges, and other works connected with it.

At the beginning of 1879 he was appointed Resident Engineer on the Scarborough Harbour Improvement Works, which consisted of the deepening of two harbours, widening and extending a pier, underbuilding old quay-walls, and other operations. This undertaking occupied him for two years, and in January, 1881, he returned to Scotland to superintend for Messrs. Leslie the construction of the Acreknowe Reservoir on the Hawick Waterworks. A few months later, namely, in October, 1881, he was selected to take charge of an important section of the Vyrnwy Waterworks, of the Liverpool Corporation. The portion of this great engineering undertaking more especially under his supervision consisted of 35 miles of the main aqueduct, including all the special works connected therewith. From the nature of the ground these were of a multifarious kind, and calculated to fully tax the resources of an engineer. They included reservoirs and tanks, with earthen embankments as well as with concrete and brickwork walls. filters, clear-water tank, valve-houses, cottages, new roads, bridges, culverts, crossings over rivers, canals, and railways, and three tunnels, having an aggregate length of about 4 miles. The cost of that portion of the great work with which he was connected exceeded £300,000. On the eve of its completion he

was struck down by illness. A chill caught in March developed into rheumatic fever, which closed his career, on the 17th of April, 1891.

Mr. Wyld was remarkable for a singular gentleness and modesty, combined with a straightforward frankness, which gained him the respect and goodwill of all who came into close personal contact with him. His energy and enthusiasm in the discharge of his duties were unflagging. His professional skill and fertility of resource marked him out as one who, had he lived, would doubtless have gained a high place among the hydraulic-engineers of this country.

He made a short communication on "The Laying of Large Mains" to the Liverpool Engineering Society, which has been published.¹ He interested himself in the remarkable deposits of shell-bearing gravels cut through at high levels above the sea during the construction of the Liverpool Waterworks, and it was hoped that he might be induced to bring his observations before the Geological Society. But this and many bright anticipations for his future have been abruptly shattered by his premature death.

Mr. Wyld was elected an Associate Member of the Institution on the 4th of May, 1880, and was transferred to the class of Member on the 23rd of February, 1888; he became a Fellow of the Geological Society in 1890.

ARTHUR JOSEPH EDWIN ARCH was born at Brockley Hill, on the 4th of August, 1862. After receiving his education at Dulwich College and at King's College School, he was for several years engaged under a firm of London surveyors. Meanwhile he was studying at the City of London College under Mr. Henry Adams, and in April, 1885, passed the qualifying examination for the Professional Associateship of the Surveyors' Institution. In August, 1885, he joined the staff of the Rio Tinto Mines, under Mr. James Osborne. At Rio Tinto he was engaged in surveying various parts of the works and surrounding villages, gaining the good opinion of his superior officers. "He displayed the

¹ Transactions of the Liverpool Engineering Society, vol. x. p. 20.

"greatest care in the different works, and the information obtained "was thoroughly reliable, and the plans very neatly executed. He "always showed great devotion to the work he had in hand." In August, 1887, he left Spain to proceed to Tientsin, China, as Assistant Engineer in the construction of the China Railway. He had shortly before passed the qualifying examination for the Fellowship of the Surveyors' Institution. In China he was employed on the construction of the line from Tientsin to Tongku. He also made surveys for the extension line to Siku, showing himself a capable and intelligent officer. In December, 1888, he left Tientsin to take up the appointment of Resident Superintendent of the Punjom and Sunghie Dua Samartan mines in the Malay Peninsula. His services were afterwards engaged to examine and report on various mining concessions in the Sultanate of Johore. In October, 1889, he was appointed to superintend the operations carried on by the Malay Peninsula Prospecting Company. While holding this appointment Mr. Arch prepared a valuable sketch map of Pahang concessions. In the course of this task he was compelled to undertake many adventurous journeys in unfrequented parts, on one occasion losing valuable memoranda and observations through the swamping of rafts in a Pahang river. In all his duties he gave every satisfaction to the Directors. At Christmas, 1890, he returned to England from the East, and early in 1891 left for Brazil, having received an appointment under the firm of Messrs. Brunlees and McKerrow, on the Brazilian Imperial Railway Extension. He met an untimely death by drowning in the Rio Paraguassu, near Bahia, on the 23rd of March, 1891.

Mr. Arch was characterised by a keen devotion to his work and an indomitable perseverance. He was possessed of a firm self-reliance, to which he owed in a large measure the success he had obtained. His early death cut short a career of much promise.

He was elected an Associate Member on the 10th of April, 1888.

JOHN BOURDEAUX was born in London on the 13th of August, 1834. At the age of fifteen he entered the service of the Electric Telegraph Company, with whom he stayed until 1859, when he received an appointment in the instrument department of the

London offices of the Submarine Telegraph Company, and remained there until 1862, when he was transferred to Dover, and had charge of that and the Folkestone stations. Some few years after this, he was appointed Assistant Engineer under Mr. France, who retired from the Company's service in 1870, and Mr. Bourdeaux succeeded him as Engineer. Up to this time the cables, which were owned and worked by the Company, had been repaired by various tugs fitted with the necessary gear at Dover; but as time advanced, the work increased so much, that in 1871 it became necessary, in order that it might be more expeditiously effected, to have a steamer for the purpose, and eventually, under the direction of Mr. Bourdeaux, the paddle steamer "The Lady Carmichael" was built, and with it and other means the work was carried on much more satisfactorily than hitherto. He remained as Engineer to the Company until the transfer to the Post Office in 1889, and it was at this time that his health began to fail, owing, in the first place, no doubt, to anxiety during the valuation and purchase of the property, including the cables, which had been repaired so many times by him. He entered the service of the Post Office in the same capacity as he had previously held under the Company; but, owing to his shattered health, was never at any time really able to undertake his full duties. In January, 1890, he was confined to his house, and after a lingering illness, died on the 2nd of July of the same year. He was elected a Town Councillor of Dover, but at the expiration of his first term of office, finding he could not give sufficient time to his municipal duties, he did not stand again. When the Bell telephone was first introduced, Mr. Bourdeaux made many interesting experiments, at first with a single overhead line, which he had previously erected for the Town Council, from the police station to the water-works, and afterwards through some of the cables belonging to the Submarine Company between England and France.

He was elected an Associate Member on the 4th of March, 1879.

JOHN DIXON was born on the 2nd of January, 1835. He was the eldest son of the late Jeremiah Dixon, of Newcastle-on-Tyne, who came of a well-known Quaker family of coal-owners at Cockfield, in the county of Durham, some of whom were distinguished as engineers and scientists even in the last century. His uncle,

the late John Dixon, was the first Chief Engineer of the Stockton and Darlington Railway, and was associated with George Stephenson in making the original surveys for that work. John Dixon, the subject of this notice, received his education at Dr. Bruce's school in Newcastle, and became, in January, 1851, an articled pupil of the late Robert Stephenson. Soon after the completion of his articles, he was appointed Engineer and Manager at the Bishopwearmouth Ironworks of the Consett Iron Company; but in 1864, after a brief adventure in iron manufacture at Bedlington, he removed to London, where he began a successful career as engineer and contractor, which was continued till his death. In this capacity he carried out many important works in various parts of the world, commencing with the landing-stages on the Thames Embankment, piers at Southport and at Douglas, Isle of Man, and the large iron piers and wharves at Huelva in Spain, for the Rio Tinto Company. A bridge over the Nile at Cairo was his next work, followed by extensive drainage and sanitary works at Rio Janeiro, and piers in Mexico and Pará on the Amazon.

In 1875, in connection with Mr. Richard Rapier, he got the concession for, and made, the first railway in China, from Shanghai to Woosung. It was very successful and popular among the natives for a time, but, owing to the prejudices of the ruling Mandarins, was bought by the Chinese Government and taken up in October, 1877;¹ not, however, before thousands of the people had had practical experience of its utility. Mr. Dixon's discovery of an unexpected supply of fresh water in the rock of Gibraltar was due to his geological knowledge, and brought him into high repute with the military authorities and the War Department, who purchased his concession. His next enterprises were in Portugal, where he constructed the Custom House piers at Lisbon, and a 60-mile line of railway, for which he was awarded by King Luis I. an Order of Merit. Bridges at Waterford in Ireland, and docks and harbour extensions at Port Talbot, in Wales, occupied him for some time, and almost his last important undertaking was the rebuilding of Hammersmith suspension bridge over the Thames, for the Metropolitan Board of Works.

But the work of all others which brought him most repute,

¹ See Minutes of Proceedings Inst. C.E., vol. lix. pp. 274, and vol. ciii. p. 278. Also the History of the Shanghai and Woosung Railway, by G. J. Morrison, in the library of the Institution (in MS.).

both for the public spirit and the ingenuity displayed in it, was the initiation and carrying out of the transport from Alexandria to London of the famous Cleopatra's Needle, now on the Thames Embankment, which bears his name on the bronze tablet of its pedestal. In this enterprise he was supported by the late Sir Erasmus Wilson, F.R.S., to the extent of £10,000, but, owing to the unfortunate salvage claims, he was a financial loser to almost the same amount—a fact which has never been sufficiently known and appreciated. In 1888 he was induced to visit the colonies in South Africa, in the hope of benefiting by the change, but, broken down in health, he never thoroughly rallied after his return, and died on the 28th of January, 1891, at the comparatively early age of fifty-six.

Mr. Dixon's personal qualifications were those which go to the making of a great contractor. Original in conception as regards the practical carrying out of works, and guarded by his engineering training against mistakes of a theoretical nature, he faced difficulties with a light heart and found them but a stimulant to greater efforts. He tendered for the construction of the Forth Bridge, and was quite prepared to undertake that work single-handed, but the directors did not deem it prudent to entrust it to any one man. His enthusiasm was contagious, and the hesitations and doubts of engineers and financiers were often swept away by his vigorous and cheery eloquence. He was an accomplished amateur artist, and his water-colour drawings, mostly sea-pieces, were frequently hung in various exhibitions in London. His loss will be deeply felt by a large circle of friends, who esteemed highly his great abilities, his indomitable enterprise and genial personal qualities, which will secure him a high position among Newcastle worthies. He was some years ago accorded by the University of Durham the honorary degree of M.A.

Mr. Dixon was a Lieutenant of the City of London. He was elected an Associate-Member on the 7th of December, 1869.

CHARLES HILTON HINGESTON was born in London on the 14th of May, 1858. He was a pupil of Mr. F. E. Duckham, and was engaged as his assistant on railway and other extension works at Millwall Docks, until August, 1882, when he was appointed Resident Engineer with sole charge of the submarine operations

of the Stonehouse Pool Improvements for the London and South Western Railway. Upon the completion of those works in 1888, he was sent to Tasmania by the Long Reach Dredging and Tin Mining Syndicate, to take the management of their interests, and superintend the erection of their machinery. In May, 1890, he was appointed Colonial Engineer of the British settlement on the Gambia, with his headquarters at Bathurst. On the 22nd of the following September, he accompanied the Administrator to Albreda, and while there contracted malarial fever. The return to Bathurst was made as speedily as possible, but Mr. Hingeston died on the 1st of October. He was elected an Associate-Member of the Institution on the 4th of March, 1884.

JORGEN DANIEL LARSEN was born on the 26th of September, 1833, and was educated at the Polytechnic School at Copenhagen, with the object of following the profession of a Civil Engineer.

From 1856 to 1859, he was engaged on the Newcastle and Maitland Railway, New South Wales, as Contractor's Resident Engineer, and was employed from 1860 to 1862 in the Roads and Bridges Department in the Northern District of New South Wales, as a Government Assistant Engineer. He then spent some time in the United States for the purpose of studying the systems of Street Tramways. From 1866 to 1868, he was Engineer to the North of Europe Land and Mining Company, for whom he designed and carried out works. From 1869 to 1873, he was Resident Engineer to the London Tramways Company, and laid out and superintended the construction of all its lines. He also acted in the same capacity for the Pimlico, Peckham, and Greenwich Tramways Companies; and had charge of the construction of the tramways in Cardiff, Belfast, and Plymouth. He was Consulting Engineer for the tramways in Madrid; and from 1874 to 1879, was Engineer for those in Paris, both on the north and south sides of the river. In the middle of 1879, he proceeded to Johannesburg, where he was engaged for a short time in reporting on coal farms, &c. From 1881 to 1884 he was Resident Engineer on, and superintended the construction of, the Calcutta tramways for Mr. Hopkins. After visiting Melbourne to examine and report on the tramways in that city, he became engineer to the newly formed Johannesburg Tramway Company, and made all the necessary surveys and plans, prepared specifications for plant and rolling-stock, and super-

intended the construction of some 3 or 4 miles of tramway, together with the necessary buildings, &c. This was completed in the face of much opposition and difficulty, and is now being worked successfully. The anxiety and strain had told visibly upon Mr. Larsen for some time, and in the month of March he had a paralytic seizure which terminated in his death on April the 20th.

Mr. Larsen was much respected, and the success of the Johannesburg tramways was in a great measure due to his experience and tact, as owing to the opposition they met with, and the nature of the route, the work was rendered one of real difficulty.

Mr. Larsen was by birth a Dane, but had become a naturalized British subject. He was elected an Associate Member of the Institution on the 1st of February, 1881.

JOSEPH MUSGRAVE was born on the 10th of March, 1812. He was apprenticed to Messrs. Rothwell, Hick, and Rothwell, of the Union Foundry, Bolton, and when Mr. Hick left that firm and built the present Soho Ironworks, Mr. Musgrave went with him, in a responsible situation. In 1838 was appointed Resident Engineer on the North Union Railway. He designed a skew bridge for the Lancaster and Preston Railway, consisting of a series of arches side by side, receding at the buttress or spring of the arch.

The Globe Ironworks, with which Mr. Musgrave's name is mainly associated, were founded early this century by his father, the late John Musgrave, who had up to that time been engaged in a responsible position at the Soho Ironworks, then belonging to Messrs. Benjamin Hick & Son. In its initial stage the Globe Foundry was of comparatively small dimensions; but thanks to the earnestness of purpose, and the ingenuity and ability displayed by the head of the concern, aided materially in subsequent years by his sons, Messrs. Joseph, Jonathan, John, and James Musgrave, the firm gradually extended its operations until at the present time; the works cover a tract of ground, extending from Kay Street into Waterloo Street, and constitute one of the largest engineering and millwright establishments in the country. About a quarter of a century ago Messrs. Musgrave and Sons took up the cotton-spinning business, beginning with the erection of the No. 1 Atlas Mill, fronting Chorley Old Road, Halliwell, which was first put in operation about March, 1864; and the venture proving successful, fresh mills were added, the last extension to the spinning depart-

ment being in 1887, when a sixth factory, for about one hundred thousand mule spindles, was constructed, which has been popularly called the "Jubilee Mill." Since then, the firm has also embarked in the manufacture of cotton cloth. Including the employees at the Globe Ironworks and those engaged in their spinning and weaving concerns, the firm have now in their service nearly three thousand workpeople of all ages. Mr. John Musgrave, sen., died on the 19th of December, 1864, at the age of eighty years; and since then Mr. Joseph Musgrave acted as head of the establishment.

In the question of local railway-improvements, Mr. Musgrave greatly interested himself at various periods. He was mainly instrumental in inducing the Lancashire and Yorkshire Railway Company to carry out the work of establishing and extending the Halliwell goods station many years ago, an addition which has proved of great benefit to the eastern and northern extremities of the borough. One of his latest efforts in the direction of railway development was his project for the extension of the London and North-Western line by carrying it over the central part of the town, from the present terminus in Great Moor Street to a suggested new site in Church Street, Little Bolton, a distance of about 900 yards. Mr. Musgrave had plans prepared showing the route of this contemplated addition, together with other particulars; and he brought the matter before the Bolton Chamber of Commerce in November, 1887. The project was heartily approved by the Chamber, and strong representations were made to the Railway Directors to induce them to carry out the work, but they declined to accede to the suggestion.

Mr. Musgrave was for twelve years a member of the Halliwell Local Board, during three of which he was Chairman. When the incorporation of Halliwell with the borough was first suggested, he was strongly against the proposal, but afterwards seeing that the township must benefit from the change, he supported the project heartily, and gave evidence in favour of it before the Committee of the House of Commons.

He was made Justice of the Peace in 1867, and in the exercise of this function showed much discrimination and thoughtfulness. In 1874 he was returned unopposed, as a councillor for the East Ward (in which the Globe Ironworks are situated); and in 1877, when that portion of the township of Halliwell which was within the Parliamentary borough became incorporated within the Municipal borough, Mr. Musgrave was chosen as one of the Aldermen for the new ward. The department in which he took

most interest was the Water-works, for the development of which he, along with the other members of the Corporate Committee, had worked very hard. The last important Water-works undertaking which was inaugurated under the auspices of this Committee (of which he had been Chairman for several years up to his decease) was the new High Rid Reservoir, at Heaton, which is well advanced towards completion. It is calculated to hold about 100,000 gallons. As President of the Bolton and District Incorporated Chamber of Commerce, Mr. Musgrave—who held the office from the formation of the Chamber in 1887 up to his decease—achieved much valuable work on behalf of the trading community.

He was elected Mayor of Bolton in 1880. His name has been associated for many years with the Bolton Infirmary and Dispensary, to which he contributed liberally. He died on the 12th of January, 1891. Mr. Musgrave was elected an Associate Member on the 2nd of February, 1869.

ERNEST SPON was born on the 1st of August, 1849. He was regularly educated as a Civil Engineer for upwards of three years, from 1869 to 1872, in the office of the late Mr. Oliver Byrne, and subsequently spent eighteen months at the works of Mr. Thomas Don, millwright, of Reigate. He then entered into partnership with Mr. G. G. André, as Consulting Mechanical Engineer, being also largely employed in sinking wells. In 1879 he commenced practising on his own account; and in 1881 received the appointment of Engineer to the Explosives Company, for whom he designed and superintended the construction of new works at Pembrey, near Cardiff. The works of the Smokeless Powder Company, at Barwick, of which he was the manager, were designed by him. He was also Engineer to the Pembrey Old Harbour Board. His death, which occurred on the 28th of November, 1890, was totally unexpected. Two days previously he had started for Aberdare in order to carry out some important blasting experiments in a mine belonging to Mr. G. Brogden. At eleven o'clock on the date named the manager of the mine came to accompany him to the scene of the experiments, and it was then discovered that his bedroom door was

locked on the inside. The police were called, and the door burst open, when Mr. Spon was found lying in bed with his right arm over his chest, apparently in a peaceful sleep; and Dr. Rhys, who was sent for, pronounced him dead. From the medical evidence at the inquest, it was evident that the cause of death was syncope, resulting from a sudden severe chill.

Mr. Spon was in many respects a remarkable man; he was deeply read, a good linguist, and a brilliant conversationalist. As an expert in explosives he occupied a high position. As an author he is best known by his popular and valuable book "Workshop Receipts." He also wrote the "Modern System of Well Sinking," partly edited "The Dictionary of Engineering," was editor of several colonial engineering papers, and contributed largely to the scientific journals. He was a great lover of natural history, and delighted in music and literature. For over twenty years he had been connected with the volunteers, and held the post of Lieutenant of the 1st City of London Artillery Volunteers. His father belonged to an old French family, and his uncles, Messrs. E. and F. N. Spon, are the well-known publishers. For many years the deceased had been a Freemason.

Mr. Spon was elected an Associate Member on the 2nd of May, 1882.

RICHARD MORELAND, the eldest son of John Moreland, a builder of chimney-shafts of 18, Old Street, St. Luke's, London, was born in Wilderness Row, Clerkenwell, on the 16th of February, 1805. After receiving an ordinary school education, he was apprenticed at the age of fourteen to Mr. Thomas Cooper, of 149, Old Street, London, for a term of seven years. In June, 1828, he started in business on his own account as a millwright in a neighbouring workshop in Teanby's Buildings, Old Street.

Mr. Moreland was of a very practical turn of mind; he was ingenious in designing work and accurate and rapid in the execution of it, and was looked upon by his fellow-workmen as a leading man. He took the opportunity of attending such evening classes as were then in existence for general improvement on those things which pertained to his business.

The millwrights of that period were a most intelligent and useful body of men. The greater part of their knowledge was

derived from experience. They were equally handy at the anvil, the vice, the pattern makers' and carpenters' bench, and were masters in erecting work. When engaged away from the works they were then thrown completely on their own resources as regarded the carrying out of the work—the art of working from detail drawings not being then invented.

In March, 1831, he entered into partnership with Mr. Thomas Cooper, and the firm soon became celebrated for their mill gearing, which had lately superseded the old wooden lantern-wheels and pinions. They executed tread-wheel machinery for the various prisons, with grinding-apparatus, mustard- and drug-mills, &c., and had all the principal London and country breweries and distilleries on their books.

In 1832 Barclay's brewery was burnt down, from an explosion of malt dust in an elevator, and Messrs. Cooper and Moreland were called in to reinstate it. Mr. Moreland made the designs, working night and day, and executed the work in six months from the date of the fire.

In 1834 Mr. Cooper died, and Mr. Moreland purchased the business of his executors for £10,000, bringing into it his father, uncle, and brother-in-law, the two former as sleeping partners, and the latter as office-manager and book-keeper. The appliances of the workshop were crude and primitive up to about 1850. There were only half a dozen lathes of a very old type, and the turning was done exclusively with hand tools. For long work a bar of iron with a groove in it was fixed parallel to the axis of the lathe, and one edge of the tool, which was in the form of a T, rested in the groove while the other cut the metal. The boring was effected principally with boring bars, the feed being given with a leading screw.

The modern workshop-tools—introduced by Whitworth and other makers about the year 1840—were sparingly purchased, and it was not till 1856 that the necessity of adopting them was recognized. The traditions of the workshop were antagonistic to them. None of the wheels or couplings were bored to fit on the shafts or spindles. Key-ways were all cut with a chisel, and the shafts made with key-beds, so that under the circumstances the workmen were independent of machine tools.

In 1857 his son, Richard Moreland, became a member of the firm, the name of which was changed on the death of his brother-in-law to Richard Moreland & Son. Mr. Moreland retired from business altogether in 1886.

He took an active interest in charitable work. About 1852 the

affairs of the Finsbury Dispensary, which had been established in the neighbourhood since 1780, were in a critical condition, and it was feared that it would have to be closed. This institution provided medical relief and attendance to the working classes in Clerkenwell and St. Luke's and the neighbourhood. Mr. Moreland at this juncture took the matter in hand, and, through his exertions and liberality, sufficient money was collected to put it in working condition. He held the office of honorary secretary for forty years, and a testimonial, in the shape of his portrait painted by Mr. John Pettie, R.A., was presented to him by the subscribers in the year 1886. He was a member of the Hospital Sunday Fund since its commencement.

He was appointed by Her Majesty's Commissioners for the Great Exhibition of 1851 one of the Local Commissioners for engineering and machinery. He was elected an Associate on March 8th, 1836. He died on the 18th March, 1891, of cystitis, after an illness of three months, in his eighty-seventh year.

Captain GEORGE CHARLES PARKER was born at Havant, Hampshire, on the 19th of February, 1836. His father was a captain in the Royal Marines, and his three brothers served in the Royal Navy. After receiving his education at the New Cross Royal Naval School, he was appointed on the 3rd of April, 1853, as a midshipman in the Indian Navy, in which he served until its abolition on the 30th of April, 1863, when he was retired as a lieutenant, and transferred to the Indian Marine, in which, in 1883, he was granted the title of captain.

While in the Indian Navy, Captain Parker saw much service in the two China wars of 1856-7, and 1860. He was in the Naval Brigade during the Indian Mutiny of 1857-58, and was mentioned in despatches. He took part in the expedition against the Wagheers in 1859, in which, at the assault and capture of Beyt, he was wounded, and his sword-hilt smashed by a bullet. The gallantry and coolness with which he commanded the "Zenobia's" field-piece party, and worked his gun under a heavy and destructive fire, were specially mentioned in despatches, which also spoke favourably of his services in the Naval Brigade at the siege and occupation of Dwarka, in the same expedition. He

received the China war medal (with clasp for Pekin), and the Indian Mutiny medal.

Soon after his transfer to the Indian Marine in 1863, Captain Parker was appointed Port Officer and Superintendent of the Government timber depot at Carwar, when he surveyed the harbour, and received the thanks of the Hydrographer of the Admiralty for the chart which he prepared. He was also thanked by the Conservator of Forests for his able management of the timber depot.

He took fifteen months' sick leave to England in 1868-9, and was transferred in August, 1873, to the charge of the rising port of Karáchi as Master Attendant (afterwards called Port Officer). He entered upon this office at a time when the improvements of the harbour (on the plans of the late Mr. James Walker), which had been for several years in progress, had reached a stage at which his professional skill and zeal proved of great advantage to the Government and to the trade of the port, in fully utilizing the advantages so far gained for navigation, and in supporting the engineering proposals for the continuance and further development of the works. The growing importance of the place, which resulted from these undertakings, led to the establishment in 1880 of a Harbour Board, which in 1887 merged into the present Port Trust, and in the arrangements and working of both Captain Parker bore a prominent and most laborious part, not only as executive officer, but as member and vice-chairman of the respective boards. He also rendered valuable service, which was duly acknowledged by Government, in aiding the transport of troops and baggage animals, via Karáchi, in connection with the Afghan and Soudan wars, and in the fitting out and despatch of troops for the Malta Expedition in 1878, during one of the short periods in which he acted as Port Officer at Bombay. Latterly, also, he raised and formed the Karáchi Brigade of Naval Volunteers, in which H.R.H. the Duke of Connaught took much interest, during his inspection of the Karáchi defences in 1890.

He received the thanks of Government for his personal exertions and prompt measures in saving life and property in wrecks at or near Karáchi on four different occasions. All these labours, with heavy responsibility, in a trying climate, told on Captain Parker's health, and he reluctantly took sick-leave in October, 1890; but unhappily did not live to reach England, his death having occurred at sea on the 15th of November, 1890.

The Karáchi Port Trust Board placed on record their high appreciation of Captain Parker's services and advice, their deep

regret for his loss, and sympathy with his wife and children, in a resolution dated 20th November, 1890, in which reference was also made to the feelings of all those who had been associated in work with him, or had served under him. Captain Parker was careful of the welfare of his subordinates, not merely as a matter of official duty, but as one who took a warm interest in the education of their children, and in their social gatherings and amusements.

In private life his sociable character will be long held in kind remembrance by a large circle of friends, who heartily sympathize with his family for the loss of one who may be truly characterized as a brave and skilful sailor, an able administrator, and a kindly and honourable man.

Captain Parker was elected an Associate on 2nd of December, 1884. He was a Fellow of the Royal Geographical and Royal Astronomical Societies, and a Member of the Royal Asiatic Society.

JOHN ALEXANDER RADCLIFFE was born at Salisbury on the 26th of February, 1823, being the fifth surviving son of the Rev. George Radcliffe, D.D., Prebendary of Sarum, who was well known in the south-west of England during the early part of this century as the headmaster of one of the largest of those private schools which have now almost entirely disappeared, but which then rivalled the leading public schools as centres of classical education. He inherited from his father an intensity of energy, which lasted throughout his life. Firmness of will, combined with great tact in dealing with men, a strong capacity for, and love of work, united to an almost instinctive perception of the main points at issue in any matter, were some of his characteristics; and these, added to great kindness of heart, integrity, and an honest devotion to the best interests of his clients, gained for him, to an unusual degree, their confidence and esteem.

Having received an excellent classical education in his father's school, Mr. Radcliffe, after being articled to a solicitor in Salisbury, proceeded to London for further training, and entered the office of Mr. Warry, a lawyer of some repute, in New Inn. His ability was soon recognized, and he had not been there long before he had the conduct given him of a *cause célèbre*, in which a well-

known nobleman was interested, and which led to a journey over a great part of the Continent in search of evidence in days when railways were unknown. Shortly after his successful handling of this case, Mr. Radcliffe started business on his own account in Delahay Street, where, in conjunction with Mr. Edwards and other partners, he laid the foundation of a large and important practice. The era of railway making had then begun, and his firm soon got the charge of a large railway business, principally relating to lines in the west of England and Ireland. Here he was necessarily brought into close contact with the leading civil engineers of the time, and the connection thus formed continued uninterruptedly throughout the rest of his professional career. He was frequently associated with them as legal assessor in important arbitrations, and his advice was constantly sought with reference to the drafting of awards. He acted as solicitor for the Institution on many occasions, notably in the case when the Commissioners of Inland Revenue sought, unsuccessfully, to make the Institution liable for Corporation duty.

Mr. Radcliffe had frequent occasion to travel abroad under circumstances unusually favourable for acquiring information. Early in life he had been commissioned to visit America and report on its railway system. He had been to Egypt to advise upon large irrigation works; to Spain with reference to water-works. As director of the West Flanders Railway, he had represented the Board at more than one railway conference. He had some acquaintance with Italy, Switzerland, and Germany. Being thus a man of varied experience, brought into close intercourse with some of the most eminent persons of the day, with a retentive memory, and considerable conversational powers, he was a welcome guest wherever he went, while his warmth of heart and uprightness of character won him many firm friends, who will miss his wise advice and ready sympathy.

Mr. Radcliffe died on the 27th of January, 1891, leaving a widow and seven children surviving him. He was elected an Associate on the 7th of February, 1888.

THOMAS WRIGHT was born in 1812, and was educated at Leeds. After serving an apprenticeship of seven years as a Mechanical Engineer under Mr. Goldthorpe, of Leeds, he became for three years foreman to Messrs. Hattersley and Son, of Bradford, after which he was, for a short time, in the establishment of Messrs. Joseph Whitworth and Co., of Manchester, and subsequently in that of Messrs. Sharp and Roberts, with whom he remained eighteen months. He then entered the locomotive department of the London and South Western Railway, where he stayed for about four years. He was next employed for five years in the office of Mr. Joseph Locke, being engaged during part of that time on the construction of the Barcelona and Mataro Railway, of which he afterwards became the Locomotive Engineer and Carriage Superintendent.

About 1851 Mr. Wright commenced business on his own account as a railway engineer. In 1856 he was appointed, on the recommendation of Sir Charles Hartley, agent in England of the European Commission of the Danube, for the selection and purchase of machinery and goods of all kinds required for the construction of the river-works from Galatz to the sea. The duties of this office he continued to discharge up to within a few months of his death, to the entire satisfaction of the Commission and its Resident Engineer.

It is interesting to note that as early as 1851 a scheme was brought forward by Mr. Wright for the establishment of a "Metropolitan Streets Tramway Company," the object of which was "to collect, condense, and systematize, as well as to cheapen, the transit of passengers, parcels, and goods through the streets of London and its environs." He proposed to "insert two lines of rails into and flush with the surface of the cart road," and stated, as a part of his scheme, that "the ground occupied by these rails after the trams shall have passed will be common to every other kind of vehicle as at present." The gauge was to be 4 feet 8½ inches, so that the wagons used on it could run on ordinary railways. The carriages were to be of the same width as an ordinary omnibus, but the wheels were to be placed underneath in lieu of at the sides, and he considered that three such vehicles carrying a hundred and twenty passengers could be propelled by one pair of horses. The fare for a single journey was to be 3d., but "intermediate distances of a mile" would be charged at 1d.

only, while for 6d. the passenger might change from one car to another till he arrived at his journey's end. A system of parcels delivery between the waiting-rooms provided for the passengers was also contemplated.

Another of Mr. Wright's proposals has been already realized, namely, that of the "Artillery Train." This idea was advocated by him in 1864, when he pointed out the great services which such a train might render in military operations, and showed how the difficulties arising from the concussion of firing and the recoil of the guns might be met.

For the last two years Mr. Wright had suffered from bad health, and the inclemency of the weather during the winter of 1890-91 brought on an illness which proved fatal. He died of bronchitis on the 20th of February, 1891, aged 79. In character he was remarkably straightforward and unpretending, and by his strict integrity and business-like qualities earned the confidence and esteem of all who knew him. Mr. Wright was elected an Associate of the Institution on the 5th of April, 1853.

* * The following deaths, in addition to some of those included in the foregoing notices, have been made known since the 10th of March, 1891 :—

Members.

ANDERSON, HENRY JOHN CARD; <i>died</i> 25 March, 1891; <i>aged</i> 56.	PERKINS, LOFTUS; <i>died</i> 27 April, 1891; <i>aged</i> 56.
BAZALGETTE, Sir JOSEPH WILLIAM, C.B., <i>Past-President</i> ; <i>born</i> March, 1819; <i>died</i> 15 March, 1891.	RENNIE, WILLIAM COUPAR; <i>born</i> 3 December, 1843; <i>died</i> 5 April, 1891.
FISHER, GEORGE; <i>died</i> 3 May, 1891; <i>aged</i> 81.	RICHARDSON, ROBERT; <i>died</i> 21 March, 1891; <i>aged</i> 79.
HARDCASTLE, WILLIAM JOHN, <i>Bey</i> ; <i>died</i> 1 December, 1890; <i>aged</i> 61.	RIDDELL, ROBERT; <i>died</i> 16 May, 1891.
HAWKSHAW, Sir JOHN, F.R.S., <i>Past-President</i> ; <i>born</i> 1811; <i>died</i> 2 June, 1891.	SLAUGHTER, EDWARD; <i>died</i> 13 May, 1891; <i>aged</i> 75. (<i>Syncope following pneumonia.</i>)
MARLEY, JOHN; <i>born</i> 11 November, 1823; <i>died</i> 4 April, 1891. (<i>Paralytic seizure.</i>)	WALKER, BENJAMIN; <i>died</i> 14 April, 1891; <i>aged</i> 70. (<i>Congestion of the lungs.</i>)

Associate Members.

ATCHISON, ARTHUR TURNOUR, M.A.;		born 5 November, 1857; died 19
died 21 April, 1891; aged 43.		March, 1891.
MONTRESOR, CHARLES EDWARD CAGE;		

Associate.

JACKSON, JOHN; born 3 February, 1834; died 14 February, 1891.

Information respecting the life and works of any of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 5 June, 1891.

SECT. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS
AND PERIODICALS.*The Celluloid Slide-rule.* By — CAVILLE.

(Zeitschrift fuer Vermessungswesen, vol. xx., 1891, p. 119.)

The Author has had in constant use for two years a 10-inch slide-rule of the Gravét type made of celluloid by a German firm. With a view to ascertain the degree of accuracy attainable with this rule after two years' wear, he has made the following series of tests, in which the actual results were of course calculated and entered in the table after the slide-rule results had been noted :—

No.	Slide-rule Result.	Actual Result a.	Error δ.	$\frac{100\delta}{a}$	$\left[\frac{100\delta}{a}\right]$
				per cent.	
1	$2.78 \times 8.64 = 24.02$	24.02	..	..	..
2	$9.31 \times 1.24 = 11.53$	11.54	-0.01	0.09	0.0081
3	$2.56 \times 8.27 = 21.14$	21.17	-0.03	0.14	0.0196
4	$1.23 \times 2.43 = 2.99$	2.99	..	..	..
5	$9.01 \times 6.75 = 60.75$	60.72	+0.03	0.05	0.0025
6	$8.04 \times 7.94 = 63.8$	63.81	-0.04	0.06	0.0036
7	$9.95 \times 6.41 = 63.8$	64.05	-0.25	0.39	0.1521
8	$1.52 \times 20.5 = 31.2$	31.16	+0.04	0.13	0.0169
9	$7.18 \times 16.4 = 117.8$	117.75	+0.05	0.04	0.0016
10	$3.65 \times 11.3 = 41.3$	41.25	+0.05	0.12	0.0144

Thus, for this series, the error $m = +\sqrt{\frac{0.2188}{10}} = 0.15$ per cent., or approximately 1 in 650.

In the following series the calculations consist of combined multiplications and divisions, involution and evolution :—

No.	Slide-rule Result.	a.	δ.	$\frac{100\delta}{a}$	$\left[\frac{100\delta}{a}\right]^2$
				per cent.	
1	$\frac{6.5 \times 3.74}{2} = 12.15$	12.16	- 0.01	0.082	0.0067
2	$8520 \div 6.35 = 1342.0$	1341.73	+ 0.27	0.020	0.0004
3	$725 + 12.35 = 58.69$	58.70	- 0.01	0.017	0.0003
4	$735^2 = 54.01$	54.02	- 0.01	0.019	0.0004
5	$735^3 = 397.0$	397.05	- 0.05	0.013	0.0002
6	$\sqrt{1654} = 40.65$	40.67	- 0.02	0.049	0.0024
7	$\sqrt{754} = 27.49$	27.46	+ 0.03	0.109	0.0119
8	$\sqrt[3]{684} = 8.82$	8.81	+ 0.01	0.113	0.0128
9	$\sqrt[3]{216} = 6.00$	6.00	..	..	..
10	$\frac{4.35 \times 7.89 \times 18.5}{17.4 \times 12.5} = 2.92$	2.92	..	..	..

Thus, for this series, the error $m = +\sqrt{\frac{0.0351}{10}} = 0.06$ per cent., or approximately 1 in 1,700.

Three similar series gave 0.05, 0.07, and 0.06 per cent. respectively. The average error may therefore be taken at 1 in 1,500. The greater degree of accuracy obtained in the second series may be due to the fact that the intermediate result may be fixed with greater accuracy with the cursor than it can be read with the eye. Possibly, too, by combining several operations errors are neutralized.

B. H. B.

*Periodical Movements of the Ground as Indicated by Spirit-Levels.*¹ By P. PLANTAMOUR.

(Archives des Sciences Physiques et Naturelles, Geneva, vol. xxiv., 1890, p. 441.)

The Author recounts his twelfth (and last) year's level-observations, in which he restored to its original position and direction the spirit-level, which previous to October 1886 had been oriented south-north, and which for the last three years had been placed nearer the centre of the house, and oriented east-west, in order to compare its readings with the other spirit-level similarly oriented, but placed near the outer wall of the house. He found its indications similar in all respects to those of the first eight years; i.e., that the oscillatory ground-movements have less

¹ Minutes of Proceedings Inst. C.E., vol. liv. p. 286; vol. lx. p. 342; vol. lxiv. p. 343; vol. lxviii. p. 321; vol. lxiii. p. 324; vol. lxxv. p. 326; vol. lxxix. p. 375.

amplitude in this direction than in that of east-west, and that the south end in addition experiences other movements than those produced by the temperature and acting in an *opposite* direction, the cause of which is still an enigma.

The inclination of the east end has diminished 1.44 second of arc, and the mean inclination for the year 2.14 seconds, as compared with the preceding year. The east end reached its lowest point (-124.85 seconds) on 6th March, 1890, the minimum of the south end (-2.24 seconds) occurring also on the same day, while the lowest reading of the mean temperature occurred on 2nd March, or four days earlier. The highest mean temperature for the twenty-four hours was taken on 26th June, whilst the maximum rise of the east end (-99.18 seconds) occurred on 18th August, fifty-three days after, and that of the south end ($+3.98$ seconds) on 29th May, twenty-eight days in advance of, the maximum temperature. These anomalies have existed in the previous years, and are not easy to explain; but, generally speaking, the ground-movements coincide with those of the temperature.

After twelve years' patient investigation the Author insists that the regularity and accuracy of the indications of the ground-movements by the spirit-levels cannot be questioned, although definite conclusions as to the causes which produce these movements cannot yet be deduced. The anomalies in the level-readings prove that one or more factors, besides the temperature, must influence these ground-movements. He concludes by expressing the hope that these level observations will be continued at Geneva and elsewhere, until definite conclusions can be deduced therefrom.

E. H. C.

Shaft-Surveying at the Przibram Mines.

(Oesterreichische Zeitschrift fuer Berg- und Huettenwesen, 1890, p. 301.)

The government mine-surveying department publishes a full account, illustrated by means of two drawings, of the survey of the Kaiser Franz-Josef shaft at Przibram—probably the most complicated and difficult mine-survey ever executed. In 1875 the Adalbert shaft attained a perpendicular depth of 1,000 metres (3,280 feet). The same horizon, the thirtieth level, was reached by the Maria shaft in 1879, the depth from the surface being 1,010 metres (3,313 feet). In order to facilitate the haulage from this enormous depth, it was decided in 1879 to sink a third shaft to this level. The shaft selected was the Franz-Josef, which at that time had reached the seventeenth level, a depth of 421 metres (1,380 feet) from the surface. In order to accelerate the construction of the shaft, it was arranged to work at several levels by sinking and rising. The work was conducted at the following levels:—

						Feet.
Between the 17th and the 23rd, with a rock-thickness of . . .						755
" 23rd "	25th,	" "	" "	" "	" "	249
" 25th "	28th,	" "	" "	" "	" "	500
" 28th "	30th,	" "	" "	" "	" "	360

The total thickness of rock to be driven through thus amounted to 1,864 feet. Before the shaft could be begun, it was necessary to drive cross-cuts of various lengths at the twenty-third, twenty-fifth, twenty-eighth, and thirtieth levels. Besides these, a cross-cut had also to be made at the twenty-sixth level. The success of the project was obviously dependent on the accuracy of the determination of the shaft axis at the different levels, and the survey consequently had to be extended over a large area of the Maria-Adalbert mine. A survey had first to be made at the twelfth level, where the three shafts (Maria, Adalbert, and Franz Josef) were already connected, in order to accurately determine the triangle formed by them. The well-known problem of connecting the surveys at different levels by means of two perpendicular shafts was then repeated five times. The following are the results of the determination of the shaft triangle at the twelfth level, the instrument used being a mining theodolite with two verniers reading to one minute:—

Sides of the Triangle.		Angles opposite.			
		Metres.			
a. Maria-Adalbert . . .	561,091	α. At Franz . . .	°	'	"
b. Maria-Franz . . .	340,091	β. At Adalbert . . .	90	34	58
c. Adalbert-Franz . . .	442,828	γ. At Maria . . .	37	18	28
			52	6	34

The total length of levels traversed amounted to 1,120 metres (3,673 feet), the number of stations being forty-four. When the boring was effected (January, 1883), the survey at the twenty-third level gave the following results:—

Sides.		Angles.			
		Metres.			
a ₁	561,045	a ₁	°	'	"
b ₁	340,054	β ₁	90	35	40
c ₁	442,740	γ ₁	37	18	21
			52	5	59

The length traversed amounted to 1,960 metres (6,430 feet) with seventy stations. Corrections being made for instrumental and other errors, the following mean results were taken:—

Sides.		Angles.			
		Metres.			
a ₁₁	561,055	a ₁₁	°	'	"
b ₁₁	340,064	β ₁₁	90	35	17
c ₁₁	442,773	γ ₁₁	37	18	25
			52	6	18

and with these data, the shaft was continued by sinking from the twenty-third and rising from the twenty-fifth level. The shaft

was made of full dimensions, $19\frac{3}{4}$ by $6\frac{1}{2}$ feet, and on holing the sides exactly coincided. A check survey at the twenty-fifth level gave the following results:—

		Metres.			
a_2	.	.	.	.	a_2
b_2	.	.	.	.	β_2
c_2	.	.	.	.	γ_2
		560,990			90 36 41
		339,793			37 16 37
		442,762			52 6 42

In order to obtain these results, a traverse of 2,200 metres (7,217 feet) with ninety-two stations was necessary. The variation of these results from those obtained at other levels is due to the difficulty of rendering so long a plumb-line perfectly stationary. Lastly, for fixing the shaft-axis at the twenty-eighth and thirtieth levels, the arithmetical mean of the three previous surveys, at the twelfth, twenty-third and twenty-fifth levels, was taken, the sides and angles being—

		Metres.			
a_m	.	.	.	.	a_m
b_m	.	.	.	.	β_m
c_m	.	.	.	.	γ_m
		561,042			90 35 45
		339,979			37 17 49
		442,777			52 6 26

The holing was effected in December, 1889, after the axis had been determined at the twenty-eighth level by a traverse of 1,110 metres (3,640 feet) with forty-four stations, and at the thirtieth level by a traverse of 1,520 metres (4,987 feet) with fifty-two stations. The coincidence was so exact that not the slightest change in the masonry or timbering was necessary.

In order to give an idea of the magnitude of this survey, it may be noted that all the operations were repeated, and that for the construction of the cross-cut at the twenty-sixth level, a further traverse of 1,020 metres (3,345 feet) with forty stations was required. The total distance traversed amounted to 11 miles, with 684 stations.

B. H. B.

Tunnel-Surveying on the Croton Aqueduct. By F. W. WATKINS.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 17.)

With the aid of eight plates, the Author describes the methods of surveying for shaft- and tunnel-work adopted in Division No. 6 of the Croton aqueduct tunnel, which extends from a point near the northern boundary of New York city to the Harlem river, a distance of 24,140 feet. The tunnel was driven from six shafts; the distance between them, and the depth from the surface being as follows:—

Shaft.	From Surface to Invert.	From Top of Curbing to Invert.	Distance between Shafts.
No.	Feet.	Feet.	Feet.
19	56·83	57·00	..
20	128·87	138·82	3,116
21	115·21	135·51	5,426
22	94·11	104·65	6,925
23	78·21	86·17	3,940
24	189·96	205·07	4,280

In the alignment there were three changes of direction; whilst the grades changed very considerably. The shafts were placed longitudinally with the axis of the tunnel, and on one side of the centre line, so that the wires should not interfere with the cages in the shaft. It was found that the centre-line wires were very difficult to distinguish, as the cross-hair of the telescope and the two plummet-lines appeared so nearly alike. The Author was therefore induced to devise an illuminated slit apparatus to replace the wires at the bottom of the tunnel. This instrument consists of two vertical strips of brass, 3 inches in height, attached to separate horizontal bars, moving in guides, and provided with a tangent-screw motion, by which one or both could be moved right or left, and the vertical aperture between them made as small as desired. One of these instruments was screwed to a plank-bracket close behind each plummet-wire, and so placed that the farther one could be seen through the theodolite in line just above the other. When these slits were adjusted so as to be directly behind the plummet-wires, the latter were removed, and lights placed behind the slits. In this way two fixed and illuminated points were substituted for the wires.

For test-alignment work, a point was selected in each heading some 150 feet from the shaft. Holes were then bored in the roof to a depth of 8 inches, and wooden plugs inserted. Into these flat spikes of iron, 9 inches long, were driven. To these spikes a horizontal brass plate was bolted, with a zero mark cut on its lower edge. A movable vernier-bar was then hung under the brass plate, so that the distances east or west of the zero mark of a new test-line could be read off. The Author records a number of alignment-tests made in this way, the results showing that the accuracy of the surveys was very remarkable. In order to reach the plugs in the roof for hanging lines in a circular tunnel, ordinary ladders were not available, and consequently tripod ladders were devised which would stand alone.

For taking cross-sections for measuring the areas and quantities of excavation, the Author devised an instrument consisting of a circular disk or protractor, 3 feet in diameter, attached to a vertical iron rod capable of moving up and down in a socket, regulated by a thumb-screw. It was supported by a tripod with extensible legs, made of wrought-iron gas-pipe. The disk was set in the plane of the axis, and its centre made to coincide with that of the

circular tunnel. Cross-sections were then taken, the measurements showing at once where any trimming was necessary. This instrument worked well, but was rather heavy. A lighter form was devised by Mr. A. Craven, who used a wooden tripod, a shifting top, a ball-and-socket joint, and levelling screws. A vertical brass tube slides through the socket, and carries at its top a wooden graduated disk, 18 inches in diameter. An arm revolving on a central socket traverses the face of the disk, and a wooden measuring rod, 14 feet in length, is placed on this rest in front of the disk, and slid out to touch the surface of the tunnel, the end of the rest at the same time indicating the angle from the vertical. In order to ensure the cross-section being taken at right angles to the axis of the tunnel, the disk is provided with a small sighting-tube, perpendicular to its face. The areas of the cross-sections are either calculated from the field-notes, or measured with the polar planimeter. In the Croton aqueduct-tunnel sections were taken every 10 feet over 30 miles of tunnel.

B. H. B

The Construction of Roadways across Peat-Bogs.

By A. SCHACHT.

(Zeitschrift des Architekten- und Ingenieur-Vereins zu Hannover, 1890, p. 749.)

As the instances of high-roads crossing peat-bogs or mosses are not very numerous, the records of the methods adopted in their construction are few. In most cases the surface of the underlying solid ground is above the level of the water-ways of the district, and this is illustrated by a diagram, showing a section of the natural formation along the course of the Hunte-Ems canal, between the River Hunte, in the Weser basin, and the River Vehne, in the Ems basin. The length shown on the section is 6 miles long; the ordinary level of the water in the Hunte is about 15·75 feet above datum, and the level of the immediately adjacent land is about 23·30 feet above datum. The ground is there of a solid nature, and the section shows the surfaces of this and of the overlying peat, the latter being shown by two contours, representing its surface in 1846 and again, after being drained, in 1887. The solid ground falls gradually, until about 1½ mile from the Hunte, to a level of 19·70 above datum, and thence rises to the summit at 4 miles, where it is 46·60 above datum, and falls thence to the Vehne.

The moss commences at about two-thirds of a mile from the Hunte, and continues to and across the Vehne, its greatest thickness being at a point about 2 miles from the Hunte, and where it was originally 29 feet 6 inches deep.

Its thickness at the summit was 8 feet 3 inches (2·5 metres), and at the Vehne 6 feet 6 inches (2 metres); the latter stream-bed, being entirely in the peat, is in the summer usually dry.

The above instance having been quoted as an example of the mosses of Northern Germany, the Author deals with the question of the construction of roadways laid upon the surface of the moss.

An undrained moss consists of about 90 per cent. of water, and 10 per cent. of vegetable matter, and consequently while in that condition quite incapable of sustaining a roadway. By gradual drainage, however, the fluid mass is condensed into a more or less dense peat, but it is of great importance that this should not be attempted to be effected at too rapid a rate, as there is a liability of the escaping water carrying off with it the particles of vegetable matter, causing the sides of the ditches to collapse, and the production of fissures on the surface of the moss which, becoming filled with water, and ice in winter, extend more and more.

The drainage of the strip of moss along the site of the intended roadway should be effected by side-drains, carried gradually down, and into the solid underlying ground; and if this can be done, it is probable that the moss by conversion into peat will be reduced by about one-third of its total thickness. It is recommended that in making the drains, the sides, instead of being sloped, should be cut in a series of steps or benches, each of about 3 feet 3 inches deep, and 3 feet 3 inches broad, down to the requisite level, so as to expose as large a surface as possible to the influence of wind and sun, and thereby produce a comparatively hard skin of dry peat, and consequently lessen the destructive action of frost.

Supposing it be required to make a roadway of 10 metres (32 feet 9 inches) broad across a moss of 6 metres (20 feet) in thickness, it is recommended that, to begin with, a surface of 1 foot 8 inches to 2 feet 6 inches broad and deep should be cut parallel with the centre-line of the roadway, and at a distance of from 36 to 46 feet on each side of the axis, depending upon the width of the moss (viz., from 6 feet 6 inches to 16 feet 6 inches) which it is intended to leave between the edge of the roadway and the side drain. At right-angles to these and across the roadway, similar drains should be cut about 32 feet 9 inches apart, extending laterally across and beyond the side-drains, and from 130 to 160 feet long. The excavation from these drains should not, however, be deposited near their edges, or slips will probably occur, but laid on the roadway site, as it will have to be used for refilling the cross-drains later on. This work having been executed in the first summer, during the next season all drains can be deepened to the extent of a further 1 foot 8 inches or 3 feet 3 inches, and the sides, in the case of the longitudinal drains, widened 1 foot 8 inches ($\frac{1}{2}$ metre) or more. In the third year all the drains can be further deepened in like manner, care however being taken to keep the transverse drains crossing the road site as narrow as possible.

A matter of the greatest importance is to prevent the formation of fissures longitudinally on the site of the roadway, transverse

fissures being of but little importance. The foregoing forms only the preliminary process of drainage, and it must depend upon the nature of the moss as to whether four, five or more years will suffice for bringing it into a condition sufficiently solid to allow of the forming of the roadway, composed of sand, etc., topped with metalling.

The Author refers to the remains of Roman causeways which are discovered occasionally at a depth of from 3 to 6 feet below the surface of some of the mosses in North-West Germany. They are formed of longitudinals of rough-hewn timber, overlaid by transverse timbers of lighter scantling.

D. G.

On Componential Trusses. By H. B. SEAMAN.

(Transactions of the American Society of Civil Engineers, Dec., 1890, p. 277.)

This paper describes a pair of compound trusses constructed to carry the stringers of a travelling-crane which was to convey heavy blocks of marble across the tracks of the Baltimore and Ohio Railroad.

The span to be bridged was 100 feet, and the various elevations of the railroad and of the buildings to be served by the traveller were such, that, combined with the existing traveller, it was not possible to employ a girder more than 2 feet 5½ inches in depth. The shape of the traveller, extending 12 inches beyond the rail, was prohibitive of the use of a deep truss outside the stringer because of the lateral moment produced. The design finally adopted was a pair of compound trusses of triangular cross-section, consisting of three chords, one vertical web-system, one inclined web-system, and a horizontal web-system; the vertical web-system being outside.

The final span was reduced to 87 feet 7 inches. The truss-depth from out to out of the chords vertically was 8 feet, giving a ratio of $\frac{\text{span}}{\text{depth}}$ of close upon 11. The horizontal componential truss was

4 feet between centres of chords, and the inner lower chord, which was common to the vertical and horizontal web-systems, was also the box-girder, which carried the rails of the traveller, and, including a 6-inch wooden stringer, only measured 2 feet 4½ inches from base of rail to clearance beneath.

Each 61-foot box-girder of 2 feet depth, as employed when the tracks to be crossed had not been widened, weighed 28,000 pounds, or 460 pounds per foot, so heavy a weight being due to a desire to reduce deflection.

The new componential trusses of 87 feet 7 inches weigh 34,000 pounds each, or 390 pounds per foot only.

The weights taken for calculation were a live load of 30,000 pounds on two wheels 6 feet apart; a dead load of 400 pounds per foot.

Panel load, outer chord	750 lbs.
„ stringer chord	1,750 „
„ top chord	1,050 „

There are thus two separate end support reactions; that under the outer or vertical web-system passing directly to the vertical system, whilst the reaction beneath the inner lower chord or stringer passes partially by the inclined web-system and partially by the horizontal system, which takes of course the strains arising from the horizontal component of the stress in the end oblique strut.

The stresses in all members are tabulated, and the Paper is accompanied by six lithographed plates.

The trusses have continued to give satisfaction since their erection, though many adverse opinions were volunteered. The first lead to which they were subjected was one of 14 tons (28,000 pounds), carried close to one of the trusses, and which, with the weight of the traveller itself, was probably fully equal to that for which the trusses were designed.

W. H. B.

The Malleco Viaduct, Chili. By H. MAMY.

(Le Génie Civil, vol. xviii., 1891, p. 277, 1 Plate, 9 Cuts.)

The Author introduces his description by stating that the total length of railways in Chili in the year 1889 was 1,740 miles, of which 750 miles belonged to the Government and 990 miles to private companies.

Since that date the Government has encouraged emigration to Araucania, and for this purpose is now constructing a line of railway 310 miles long, which passes through the south of Chili, along the valley which separates the Cordilleras of the coast from the Andes proper. This line will be merely a continuation of that which serves the valley running from Santiago to the Bio-Bio river.

The viaduct of Malleco is at the point where the new line begins, and is one of the largest works of its kind in Chili.

The River Malleco itself is only about 20 yards wide, but it runs in a valley with very steep sides, so that a viaduct was necessary in order to cross it. Mr. Aurelio Lastarria, a Chilean engineer, prepared the original plans, and, after tenders had been obtained from Europe, the work was placed in the hands of the Creusot firm in France, who have carried out the whole of the construction.

The viaduct carries a single-track of railway of 5 feet 6 inches

gauge, and its total length is 1,140 feet. The principal girders are supported by masonry abutments at each end, and by four columns of open ironwork, so that the viaduct consists of five equal spans of 228 feet each. The two main girders are placed at a distance of 14·7 feet between centres, and are 23 feet between the covering plates.

The whole of the struts and ties are of a U section. The Author then enters into details as to the dimensions of the different members of the girders, and states that with the double system of staying, both in a horizontal and vertical plane, that the viaduct is well able to withstand deformation from either wind-pressure or a rolling-load. There are two foot-ways between the ends of the sleepers and the sides of the girders, and a hand-rail 5 feet high is carried the whole length. The open ironwork columns which support the viaduct are of different heights; the two nearest to the abutments are 143 feet high, measured from the top of the stone foundation to the summit. One of the other two is 222 feet high, and the second is 248 feet high. These four columns have to support the entire weight of the girders, and also the lateral pressure of the wind. The bases have been therefore firmly anchored into the masonry in a most complete manner. All the capitals of these columns are of the same size, 14·8 feet across the viaduct, and 9·8 feet in a longitudinal direction.

The columns are constructed of four principal pillars which support all the weight, each pillar being composed of eight bars of U section. The diameter of a circle inscribed within the bars is 20 inches, while the circle described about the projections of the bars is 27·25 inches. The central pillar has been made of similar section to the other four pillars, although it does not carry any of the load. Particulars are given of the dimensions of the tie-rods and struts of the pillars. The columns are anchored down to the masonry foundations, and are provided with plates in such a way that the mass of masonry held by the tie-rods is 24·5 feet deep. The tie-rods are made of wrought-iron, and are 6·6 inches diameter for the two high columns, and 5·45 inches diameter for the shorter columns; they are screwed at the ends, and the nuts are tightened up while the rods are heated, in order to prevent loosening caused by vibration. The main girders are fixed to the two central columns, and the expansion of the centre girders caused by a rise of temperature is too small to injuriously affect the columns at such a height above their base, but the weight of the viaduct is carried upon rollers upon the other two columns, and upon the end abutments.

The material used throughout has been mild steel, and the breaking stress required in the test-pieces was 28·5 tons per square inch with an extension of 25 per cent. on a length of 3·94 inches. The test-pieces used had a width of 1·18 inch, and a thickness corresponding to the particular plate tested, and the average results given were a maximum breaking load of 30 tons per square inch with an extension of 28 per cent. upon 3·94 inches.

Tables are given of the maximum bending moments of the five spans with various loads, and also of the shearing loads.

The maximum load is obtained with a locomotive of 46 tons weight carried upon four axles, at a distance of 4·6 feet between centres.

In the calculations for stability of the structure, a maximum wind-pressure of 55 lbs. per square foot has been allowed for when the bridge is unloaded, and of 35 lbs. per square foot when a load is upon it. The members have been so calculated that under the combined action of both wind and load, the stress does not exceed 6·35 tons per square inch.

The masonry work for the viaduct which had been at first placed in the hands of the contractors was begun in 1886, but it proceeded very slowly for the first two years, and it was only in 1888 when the Chilean Government took the work in hand that progress was made. Mr. Aurelio Lastarria was the chief engineer, and after his death Mr. Edward Vigneaux, also a Chilean engineer, took charge of the work.

The tests of the completed viaduct began upon October 11, 1890, and were made conformably to the French law of 1877.

E. R. D.

Hydraulic Apparatus for a Swing-Bridge at Ghent.

By E. BRAUN.

(Le Génie Civil, vol. xviii., 1890, p. 247. 1 Plate.)

A swing-bridge has been built at Ghent for the entrance of the dock-basin. The platform is about 130 feet long, 72 feet being for the approach. The width is 26 feet and the weight 150 tons. A type of hydraulic apparatus is used to work the bridge, which has now been in use four years and given excellent results. It consists of three parts:—

1. The motor itself. 2. The apparatus for transmitting the power from the motor to the platform of the bridge. 3. The controlling gear.

The motor is a Dulait turbine driven by the town water-supply, which is at a pressure of 51 lbs. The axis of the turbine is vertical, and turns only in one direction.

2. The axis carries a friction-cone made of leather disks compressed and cemented together. This cone is placed in the centre of a vee-shaped groove in the rim of a pulley, which can slide sideways upon a key let into the shaft, so that according as one or other side of the groove is driven by the rotary cone, so the bridge is closed or opened. The work is thus done by friction alone, which allows the bridge to be suddenly locked while moving quickly without risk of breaking any gearing. The turbine rotates at 200 to 250 revolutions per minute, while the bridge

makes a quarter turn in seventy-five seconds, so that gearing is employed to obtain the necessary speed. The gear-wheels are keyed upon the same shaft as the pulley with the vee-groove, and drive another shaft which carries a wheel gearing into a circular rack fixed under the platform of the bridge.

3. The controlling-gear consists of two parts; that which governs the admission of the water, and that which controls the direction of movement of the bridge. The admission of water to the turbine is regulated by a sluice-valve which is controlled by a vertical spindle, which carries a grooved pulley, round which a steel-rope is coiled one complete turn; one end of this rope carries counterweights and the other is attached to a piston working in a small cylinder. The position of the piston is controlled by the admission of water under pressure. The gear for controlling the position of the friction-pulley is also worked by a water-cylinder. The water-pipe to the turbine is 5·85 inches diameter, while the pipes to the small cylinders are only 0·78 inch diameter. The controlling-valves and pressure-gauges are all in the cabin of the bridge-keeper. The apparatus can also be worked by hand-power if necessary, and in that case two men are required and the movement of the bridge is slower. The water used for the turbine is 77 gallons for each rotation of the bridge in seventy-five seconds. The price of water at Ghent is 2·3d. per 1,000 gallons, so that each movement of opening and closing the bridge costs 0·35d. The bridge opens about thirty times a day; the expense for water is therefore about 10d. The first cost of the plant was £160, and the cost for maintenance has so far been almost nothing. The water passes through a grating to avoid any chance of solids entering the turbine. The locking-apparatus consists merely of four cams fixed on the ends of the bridge, which are enabled to mount inclined planes owing to the speed of movement; at the end of its course the bridge strikes a spring-stop and is held by a hook. The hook is lifted on commencing a movement, and the springs assist the turbine to start the bridge.

E. R. D.

The Inland Navigation of Spain.

(Anales de la Construcción y de la Industria, Madrid, 1890, pp. 321, 337, 353.)

River-navigation in Spain has been much neglected; it is generally limited to the tidal waters near the coast, and there are only two navigable inland canals, the Canal of Castile and the Imperial Canal of Arragon. The first of these traverses the table-land of Old Castile, 80 miles running N.E. from Valladolid to Alar del Rey at the foot of the Cantabrian mountains, and a branch of about 50 miles running due E. from Dueñas to Rio Seco. It is

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expensively constructed, 50½ feet wide at the surface, 40 feet at the water-level, and 19 feet 6 inches at the bottom; the depth of water is 6 feet 6 inches. The larger half of the works were executed towards the end of the eighteenth century at the cost of the State, but they remained unfinished and neglected until 1831, when they were taken over by a private company which completed them in 1849, under a Royal Concession, with seventy years to run from the latter date.

The traffic consists chiefly of flour, corn, and coal, conveyed in barges of 35 tons burthen drawn by horses; and there are forty-nine locks, at which the average fall of water is 10 feet 10 inches, which also supply water-power to thirty flour-mills and fifteen other factories paying tribute to the Canal Company. Since the opening of the railways from Valladolid to Santander, and from Palencia to Leon, the average annual traffic has decreased from 63,606 tons, during the quinquennial period 1875-1879, to 40,161 tons in 1880-1884, and to 22,324 tons in 1885-1889; and the annual gross receipts have fallen from £5,766 to £4,377 and to £3,037 during the corresponding periods, less than half of which were derived from the navigation-tolls.

The Imperial Canal of Arragon derives its water from the Ebro, and runs parallel to that river from Tudela to Saragossa, a distance of 53 miles, with an extension of about 3 miles below the latter city, and two short branches from Saragossa, together 7½ miles in length, named the Miraflores and the Burgo. Originally built by the State in the sixteenth century as an irrigation canal, without locks, and with an average fall of 1 in 200, it was enlarged between 1770 and 1790, and rendered navigable for vessels of 100 tons drawing 10 feet of water, but the strong current makes the ascent difficult from Saragossa to Tudela. Moreover, a railway has been built running parallel to it which carries off the traffic from the canal, and its waters are now chiefly used for the irrigation of about 70,000 acres of land, and for supplying water-power to sixty-eight mills. For these services the State is satisfied with very low charges, and, although the canal has cost the State altogether £800,000, the net revenue, in 1888 from all sources, did not exceed £1,482.

With the view of rendering the Ebro navigable from Saragossa to the Mediterranean, extensive works of canalization were commenced about forty years ago. It was soon found that this was a very formidable undertaking, and the portion between Saragossa and Escatron had to be abandoned; but after an expenditure of nearly £700,000 the canalization was considered to have been successfully completed from Escatron to the sea. Meanwhile, however, the railways from Saragossa to Barcelona, and from Lerida to Tarragona had been built, and when in 1858, the navigation was formally inaugurated it was found that neither goods nor passengers presented themselves for conveyance. The steamers which had been provided had to be sold, and only a few small coasting vessels, and one small daily steamer ply now at the

mouth of the river below Tortosa. In 1889 this traffic was limited to 3,448 tons.

Seville, on the River Guadalquivir, was a commercial port of great importance at the period when Spain was the chief colonial power in Europe; but during the eighteenth century the river was much neglected. It has many windings, the water is at all times very turbid (sometimes holding 4 per cent. of solid matter), and shallows were formed which greatly interfered with the navigation. The chief bends in the river were at Torno de la Merlina (10,000 metres in length), Torno del Borrego (17,600 metres), and los Jeronimos (18,000 metres), and by cutting straight channels respectively 600 metres, 1,600 metres, and 5,500 metres in length and 100 metres in width across these bends, the distance from Seville to the sea has been reduced by no less than 28 miles, and the minimum depth of water, at low tide, increased from 4 feet to 17 feet. In 1862 vessels of 200 tons could with difficulty reach Seville, whereas now vessels of 2,000 tons load and unload at the quays. When cutting these new channels it was found that retaining-walls built parallel with the stream were frequently carried away by winter floods, but the system having been adopted of projecting at short intervals transverse walls into the stream a little below the water-level, these checked the current and caused such a deposition of the floating solid matter between them that a perfectly sound channel has been formed. The last of these works was completed in 1889. It reduces the distance from Seville to the sea to 54 miles, and has increased the rise of tide by 7 feet 6 inches since 1862. Between July 1st, 1888, and June 30th, 1889, the exports by river amounted to 163,755 tons, and the imports to 155,609 tons. The river is navigable for only a short distance above Seville, and mill-dams which intercept the stream preclude all navigation above Tocina. By a singularly fortunate disposition of some rocks at the mouth of the Guadalquivir, the depth of water on the bar has remained constant from time immemorial.

On the same coast is the tidal estuary which goes by the name of the Huelva river, and is formed by the junction of the Rio Tinto and the Odiel at about 4 miles below Huelva, and 8 miles from the sea. The Rio Tinto Company and the Tharsis Company have built extensive quays on the River Odiel for loading their ores, and so also have the companies owning the railways from Seville and from Zafra. Another private quay has also been built at San Juan del Puerto by the Buitron Mining Company. The exportation, chiefly of copper pyrites, exceeds 1,000,000 tons per annum.

The River Guadiana which, as it nears the sea, becomes the frontier between Spain and Portugal, is navigable for large vessels for 36 miles from the coast. On the Portuguese bank it has double the traffic which there is on the Spanish side, owing to the large shipments of copper pyrites from the well-known mines of Santo Domingo. From Spanish ports about 25,000 tons of pyrites are annually exported in English vessels from the mines of Los Pastos

and Santa Catalina, besides which the coasting trade averages 28,120 tons, and the exclusively river traffic (consisting of fish, building-stone, and flour) amounts to 13,300 tons. Vessels of 1,000 tons reach the wharf of the Los Pastos mines, but the coasting vessels do not usually exceed 60 tons, although the minimum depth of water is 27 feet. No works have been constructed of any kind to improve the conditions of the river and the upper portions of the river are not used for navigation.

The Tagus is the next large river. It crosses Spain and Portugal from east to west, discharging its waters into the Atlantic at Lisbon. During the reign of Philip II. it was sometimes utilized for the conveyance of war materials from Toledo to the frontiers of Portugal, and towing-paths and other minor works were executed under the direction of the notable engineer Antonelli, but these were subsequently neglected and gradually disappeared. In 1855 some similar works were commenced, but it was found that the conditions of the river made any useful navigation impossible. The stream forms a succession of broad open expanses with a fair depth of water alternating with narrow gorges and with rapids (of which there are nineteen between Toledo and Portugal), where the water is only 2 feet deep, and the current runs at the rate of from 5 to 9 miles an hour. At the bridge of Alcantara the waters rise frequently during floods to a height of from 35 to 65 feet, and sometimes even to 100 feet above their usual level, and, moreover, there are several mill-dams, solidly constructed across the stream, which interfere with the free navigation. The population on the banks of the Tagus is scanty, and the river could only be rendered navigable at an enormous expense.

The conditions of the River Douro resemble those of the Tagus, to which its course is approximately parallel, although much further north; its mouth is also in Portugal, at Oporto. In many places straggling rocks interrupt the current, and in others shallows and numerous rapids intercept the navigation, so that the only traffic is conducted in a few boats which convey small quantities of wine to Oporto, and, with great labour, return with sardines and other fish. With the exception of one landing quay at Frejeneda, where the River Agueda runs into the Douro, no works of any kind have been executed to improve the navigation.

The lower part of the River Minho forms the boundary between the Spanish province of Galicia and Portugal. The tide rises to a distance of about 21 miles, and here the river is navigable for fishing-boats averaging 12 tons burthen. Timber is also floated down the river from forests in the interior, but no attempts have been made to better its conditions.

Round the coasts of Galicia, Asturias, and Santander, in the Bay of Biscay, there are a large number of minor rivers which support a limited traffic over a short distance from their mouths, and the Author enumerates and briefly describes the conditions of those of Vigo, Pontevedra, Arosa, Muros, Camariñas, Betanzos, Ares, Ferrol, Cedeira, Santa Marta, Vivero, Foz and Rivadeo in

Gallicia; of those of Navia, San Estevan de Pravia, Aviles, Villaviciosa and Rivadesella in Asturias; and of the Deva, Tina Menor, Santander, Cubas and Limpias in the province of Santander. They are mostly only navigable as far as the tide reaches, but at Vigo and Ferrol they form magnificent harbours, and the Royal Arsenal at Ferrol is the most important in Spain. It was visited by Mr. Pitt before the great war, and he remarked of it that it was worthy of being protected by walls of silver. At Aviles the river expands into an extensive back-water, and there being more than 15 feet of water at low tide over the bar, a splendid harbour might, and perhaps some day will, here be made. A large basin, 137,000 square yards in extent, has recently been constructed, which is chiefly used for embarking coal from the neighbouring mines, and it is probable that further works will soon be undertaken.

The only remaining river which need be mentioned is the Nervion which forms the important harbour of Bilbao. Very extensive works have here been constructed during the last few years in order to develop the trade of the port and the export of iron ore. River-walls which extend from the town to the mouth of the Nervion have narrowed and deepened the channel so that vessels with a draught of 20 feet can now discharge at the quays of the town; and the importance of the trade which has been created in a few years' time is evidenced by the fact that in 1889 the imports amounted to 580,155 and the exports to 3,879,816 tons. 85 per cent. of the latter consisted of iron ore, mostly for the English market, while of the imports 369,047 tons were of coal.

O. C. D. R.

The Protection of River-Banks. By G. VICTOR REYV.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereines, 1890, p. 325.)

This Paper refers to the works undertaken of late years for the safety and protection of the rivers Theiss and Bodrog, in Hungary. On the former river the breaches of the bank are occasionally very considerable, and particularly while the floods are subsiding, for the upper loamy strata, previously saturated by the flood-waters, lose their cohesion and crumble away, while the more sandy strata at the foot are washed out by the low-water current, which also carries the fallen upper strata with it. The nature and design of the works necessary for strengthening the banks depend upon the character of the river and local considerations, and vary as the curves or bends are sharp or gentle in each case, or the banks are straight. Single or isolated spurs, extending far and deep into the river-bed are to be avoided, for though they may be strong enough to resist destruction by floods, they frequently cause damage in other parts of the river. Again, as the breaches of the

banks almost always take place downwards towards the foot, very strong and heavy works are not required at the top of the bank: all that is necessary is to secure them from attack in rear. The works lying below low-water level must be firmly secured in position, and at the points subject to attack the velocity of the current should be reduced so that a silting up may take place. The rivers Theiss and Bodrog are dissimilar in character, and therefore require different treatment. On the Theiss timber is mostly used, in the form of piles, branches of trees, brushwood wattles, &c., because these are cheapest, and only a small quantity of stone is employed as it is difficult to obtain. The works are begun at low-water level by driving in rows of piles till their tops reach that level, and between the piles tree-branches are laid on one another, with their brush ends towards the stream. On these are laid wattles and brushwood, weighted down as uniformly as possible with stones until the lower layer reaches the bed, and thus the work is advanced until low-water level is reached, when the piles are connected by cross-stays, so as to form a compact whole. The part above low-water level is similarly treated, but the work is gradually lighter—that is, less compact—till it reaches the top of the bank, which is then sloped and revetted. Works of this kind have been carried out at six different points on the Theiss river, and are still in good condition. Of these, the following details are given of the works undertaken at Kenezlo and Csermely. After the great floods of 1884, the Theiss at Kenezlo had so scoured away the bank in the sharp curve below a cut in the river as to threaten the embankment behind. The depth of water on the concave bank increased enormously, while the bed on the opposite side was silted up. On the subsidence of the floods, work was commenced by driving in piles from 26 to 30 feet long, with branches of trees laid between, as before mentioned. At the end of three years it was found that the former concave side had silted up, while the current had forced a passage through the sand-banks previously formed on the opposite side. At Csermely the old bed of the river below the cut was not interfered with, and the banks of the cut were not attacked. The flood consequently discharged freely through this cut till it reached the next bend of the river, where a whirlpool or eddy was formed which changed the direction of the current, and led it on to the opposite concave bank. The trees and branches brought down by the flood and deposited on the convex side, contracted the waterway and thus increased the velocity of the stream, and made the bend still greater. The effect of this scour is shown by the fact that in a distance of 130 yards the river-depth was increased from 10 to 59 feet. For the security of the bank, piles from 1 to $1\frac{1}{2}$ foot in diameter, and 33 to 52 feet long, were driven in four rows, $6\frac{1}{2}$ feet apart; and between these, as in the previous example, branches of trees and wattles were laid and weighted with stones. Altogether 620 piles and 1,300 cubic yards of stone were employed. The effect of this work,

as obtained by measurements taken in February 1890, is that the great depth of 59 feet has been reduced to $32\frac{1}{2}$ feet, thus showing that the bed had silted up $26\frac{1}{2}$ feet. Moreover, the obstruction previously caused by the accumulation of trees &c., on the opposite side, was entirely removed by the current. As regards the Bodrog the conditions are different, for the Theiss runs through sandy soil and frequently changes its course rapidly in a remarkably capricious manner, but in the Bodrog the stream moves on slowly and steadily without any perceptible change, as it cannot work through the firm loamy soil confining it; the protecting works have therefore remained unchanged for years. For these works stone is mostly used as the quarries are near at hand, and as it is not necessary to go down deep into the river-bed, shorter piles suffice. There are nine points where such masonry works have been constructed on the Bodrog, and these are still in good condition. The most important are at Szomotor and Szerdahely, where little or no change has taken place during the past eight years. A plate, with plan and cross-sections, showing the works constructed at Kenezlo and Csermely on the Theiss, and at Szomotor and Szerdahely on the Bodrog, accompanies the Paper.

W. H. E.

The Blasting of the Iron Gates (River Danube).

By J. J. VAN DEN WYNGAERT.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, February, 1891, p. 119.)

On September 15, 1890, the first portion of this great work was inaugurated by Mr. Baross, the Hungarian Minister of Commerce, who attended in person to transmit the electric current which caused a most successful explosion. The Author shows that the importance of improving the waterway of the Lower Danube was recognized even by the Romans in the time of Trajan, and the subject has since that period been constantly mooted; but owing to the want of unity among the nations inhabiting either bank of the river, the works have been from various causes delayed or hindered, and it was not until after the Crimean War, at the Congress of Paris, that the subject of the regulation of the Danube was discussed upon a basis likely to lead to a satisfactory conclusion. The Author gives an account of the various schemes which have from time to time been propounded for the improvement of the navigation, and he states that to Mr. Baross belongs the credit of the ultimate decision that has been arrived at, namely, to blast away channels in the rock, and to do without locks; the provision of which latter would have greatly impeded navigation, and would have entailed an expenditure of not less than 85,000,000 gulden

(£7,083,333). The Author states that in the course of the next five years the following quantities of rockwork will have to be removed from the bed of the river:—

	Cubic Metres.
At Stenka	7,000
„ Izlas Tachtalia	121,000
„ Juczsa	32,000
„ The Iron Gate	246,000

In addition to the above the rocks at Greben on the right bank of the stream, with a cubic content of 505,000 cubic metres, have to come away, making up a gross total of 1,360,000 cubic metres of rock to be got rid of. Assuming a uniform specific gravity for all the rock, the total weight of material is estimated at 4,365,000 kilograms (*sic*)¹, or say 436,500 double truck-loads, which would require a period of three years and four and a half months to train away. Details are given of the pile-drivers, steam-dredgers and rock-drills mounted on tripods and on barges employed on the job. The works have been begun at three different places at once. The obstruction caused to the flow of the river by the rocks, which jut out into the stream from the Servian territory for a distance of 420 metres, occasion a whirlpool with a depth estimated at 50 metres. Directly these rocks are passed, the river widens out into a veritable lake, with a width of 2,500 metres. Various improvements of the bed will have to be undertaken here, in regulating the stream, and it is intended to construct a dam with the excavated rock, and to support it with cross dams. The cost of the plant alone for these works is estimated at 2½ millions gulden (£208,333). The Author concludes with a brief statement of the advantages to navigation and commerce of a waterway for large vessels through the heart of Europe, from Holland to the furthest confines of Austria.

G. R. R.

Progress of the Works of Improvement in the Bilbao River.

(Anales de la Construcción y de la Industria, Madrid, 1890, pp. 21, 36 and 52.)

In continuation of previous reports by the chief engineer, Mr. de Churruca,² the *Anales* publishes an account of works subsequently executed at the expense of the local authorities. They consist chiefly in the completion of the river-side embankments. At every 75 metres on the right bank truncated cones have been built in masonry rising to above the highest level of spring-tides, and furnished with stout wrought-iron rings to which vessels in the river can secure their cables. The sea-wall at Portugalete,

¹ Milliers.

² Minutes of Proceedings Inst. C.E., vol. xcvi. p. 431.

890 yards in length, has been completed with a parapet in masonry 10 feet in height, and the same in width, crowned with an ashlar cornice, which on the side of the sea is inclined outwards to throw off the waves which break against the wall. Covered sheds have been built for the receipt of merchandise, and several powerful steam-cranes have been erected. The dredging is now confined to the river-channel, in which it is estimated that 800,000 cubic metres of sand and mud brought down by the river, or driven up by the tide, must be annually removed, at an average cost of 6·7*d.* per cubic metre.

The important outside harbour has been commenced, the contract for the breakwater (1,500 yards in length) and approaches having been taken by Mr. Allard, at the price of £860,000; but the report published in the *Anales* only brings down the account of the states of these works to the 1st July, 1889. They are being executed with a large subvention from the State; the Provincial Deputation contributes £102,800, and the Town Council of Bilbao £42,000, both sums payable in twenty annuities, and extra harbour dues of 2½*d.* per ton are to be levied in aid of the work, which will allow of money being raised by loan. The position of the breakwater was buoyed on the 21st September, 1888, and on the same afternoon the Ministers of Public Works and of Marine inaugurated the works with great solemnity, and launched the first stone (previously blessed by the church) into the sea.

Large quarries have been opened by the contractors on the hill-side adjoining the breakwater, and along the front of them they have built a road, or terrace, 40 feet wide and 450 yards long with lines of rails connected by an embankment 130 yards in length, and a bridge over the Bilbao-Las Arenas Railway, with the shore end of the breakwater at a height of 27 feet above low water. They have also provided three steam-barges, each of 300 tons, upon which the large blocks, which are to form the lower layers of the work, will be conveyed to their destination, and then lowered to their proper site. The foundation and the outer layers are to be built of large artificial blocks, the making of which has been also commenced. Within the breakwater there will be anchorage and shelter for the largest ships, the depth of water being from 40 to 50 feet; and it is noted, with satisfaction, that the ministers, who came from Madrid to inaugurate the harbour works, took the same opportunity also to celebrate the commencement of the construction of the three large armour-clad war-ships which Messrs. Rivas and Sir Charles Palmer are now building in their docks at Bilbao, and of which the formidable armament is also to be supplied from the arsenal they have erected on the spot.

O. C. D. R.

*The Bilbao Arsenal and the Launch of the Cruiser
"Maria-Teresa."*

(Anales de la Construcción y de la Industria, Madrid, 1890, pp. 265-268.)

In October, 1888, Messrs. Rivas and Sir Charles Palmer commenced the construction of the arsenal and dock at Bilbao, at which they have undertaken to build and equip for the Spanish Government, with Spanish materials and workmen, the three powerful iron-clad cruisers, "Maria-Teresa," "Vizcaya," and "Oquendo," the first of which was launched in the presence of the Queen Regent and her ministers on the 30th of August, 1890. The armament of each of these ships is to consist of:—

Two 33-ton guns of 12-inch bore and 35 feet in length; weight of projectile, 704 lbs.; weight of charge, 352 lbs., to pierce an iron plate 20 inches thick at 4,000 metres distance. These will be mounted in turrets at each end of the ship.

Ten 14-centimetre guns, 17 feet long; eight Nordenfeldt rapid-firing guns, bore 5·7 centimetres; eight Hotchkiss revolving guns, bore 3·7 centimetres, two Gatlings, bore 11 millimetres, and eight tubes for projecting torpedos. These are all to be made on the spot, with the exception of the Nordenfeldts and the Gatlings, which are to be supplied from the gun factory at Plasencia.

The buildings composing the establishment are very extensive, and cover a space of 52 acres. The dry dock, 376 feet long by 82 wide, is encircled by piles formed of large cast-iron cylinders, weighted, when driven, with 100 tons, and filled up with scoria and cement. Around it the workshops are built, comprising in separate compartments all the machinery which is required for building war ships. The artillery department is separated from the rest by a short distance. It consists of four galleries 275 feet in length, the two inner ones 50 feet, and the two outer galleries 33 feet in width. Two thousand four hundred men are employed on the works, of whom one hundred and sixty are English and the rest Spanish. The works are lighted by electricity.

The building of the "Maria-Teresa" commenced on the 24th of July, 1889, and she is to be completed and armed by the 1st of December, 1891. The launch on the 30th of August, 1890, was witnessed by an enthusiastic crowd of fifty thousand persons, and it was effected without a single hitch.

O. C. D. R.

The Ports of Italy. By DOMENICO LO GATTO.

(Il Politecnico, 1890, p. 217.)

The ports of Italy, situated upon an almost tideless sea, differ essentially in all features of design and construction from all tidal ports, such as those on the Atlantic or the North Sea. In this respect nature has favoured the latter more than the shores of the Mediterranean. The ports of most world-wide renown, where commerce is most fully developed, are situated on river estuaries where the ebb and flow, in their natural course, or regulated by embankments and docks, ensure and maintain the existence of the navigable water-area by the systematically repeated scour, and assist the progress of vessels entering or leaving the port or floating into dry dock. With comparatively few exceptions, ocean ports are thus situated on estuaries, the river constituting the roadstead or outer port, and the port itself comprising a series of docks. Being sheltered from the direct effect of storms, the action of the waves is in most cases of little importance, and large breakwaters are unnecessary.

In the Mediterranean, where the range of ordinary tides is only 8 to 10 inches—rarely exceeding 12 inches—where violent gales are frequently experienced, and where the bays are mostly but shallow indentations and the rivers discharge through sandy deltas and shifting channels, with currents decreasing in force as they spread towards the sea, and thereby tending continually to silt up the waterway, the estuary port is practically impossible. The only places in Italy that can in any way be considered under this category are the canal ports, which are all of very limited accommodation.

The only currents in the Mediterranean which in any way affect the existence or maintenance of a port—with the exceptions of Venice and Messina—are those occasionally produced by any prevailing wind. The “littoral current” so often referred to is not sufficiently powerful to carry in suspension any but the very finest matter. The velocity of the current does not exceed 3 or 4 miles in 24 hours, and its average distance from the shore is three miles (increased to 6 miles near headlands and to ten or more across bays): while—following the law of river-flow—its velocity decreases both laterally and vertically, so that at a depth of 13 feet no motion whatever is perceptible. The essential agent in the formation of sandbanks and bars is the triturating and upheaving action of the waves upon the shelving shore; and it is therefore mainly with the waves that the designer of an Italian port has to deal.

The usual formation adopted is to construct an “outer port”—where the waves spend their force—and an “inner port” or harbour, with quays, docks, and other necessary structures. Many ancient ports—such as Genoa, Leghorn, Civitavecchia and Naples

—have grown up piecemeal, without systematic design: but generally speaking Italian ports may be classified under three heads, viz.:—

1. Basin-ports or harbours.
2. Dock-ports.
3. Canal-ports.

The majority come under the first category, being formed in natural or artificial basins—small bays being utilized as far as possible, and extended by masonry piers and breakwaters. Most of these harbours have only one entrance, and are protected by two piers; that to leeward (*sottovento*) being generally unimportant, while that to windward (*sopravento*) is extended to cover the furthest point of prevailing winds which would affect the water up to the end of the leeward pier. There are, however, two notable examples of harbours with two mouths, viz., Leghorn and Civitavecchia, as well as Licata, in Sicily. At Salerno and Molfetta and other places the second mouth has been closed, and the same process is required at the other three places named. At the present day, when steamers and tugs have rendered the old wide harbour entrances unnecessary, the most important requirement is tranquillity of water inside the harbour, and for this purpose the old type of exposed port with two entrances may be considered as practically abandoned.

Where there is not sufficient draught of water alongside the quays, or where space has to be especially economised, short piers or double-faced quays (*ponti sporgenti*) are built out at right angles with the shore.

The type of dock-port is at present not frequent in Italy, the most notable examples being Savona and Leghorn.

The canal-ports—which, as stated, are of very limited accommodation, being suitable only for small coasting vessels—are mostly on the Adriatic coast, viz., Magnavacca, Ravenna, Ceroia, Cesenatico, Rimini, Pesaro, Fano, Sinigaglia, and the five ports of the Venetian lagoon: Malamocco, Chioggia, Lido, Sant' Erasmo, and Treporti. The only ports of this kind worth mention on the Tirrenian coast are Fiumicino and Viareggio. The channels at Malamocco and Lido (referred to later) are the only ones available for large vessels. Of the above mentioned ports, three are on artificial canals and the remainder on natural streams. The type of construction is two parallel or slightly divergent piers extending to a sufficient depth of water for the draught of vessels to be provided for. With the small range of tide, however, and sluggish streams, the solid matter brought down is continually silting up the mouths of these ports, and involves incessant dredging. At Pesaro the old channel having become entirely choked up, a new cut has been made. In two cases the scour is assisted by a large reservoir or basin at the inland extremity of the port, viz., at Cesenatico (26 acres) and at Magnavacca—where there is a fine natural catchment basin of 495 acres.

Following this general description of the character of Italian ports, the author proceeds to a succinct description of the more important places.

Savona: Natural bay with two small piers. Consists essentially of two docks, with extensive siding accommodation. Depth of water in outer port and in new dock—26 feet. Chiefly exposed to winds N. and E.

Genoa: The chief port of Italy. A semi-circular bay with important defence works of irregular plan, arising from successive development of the port. Depth of water at quays averages 20' to 23 feet. Length of quays available for large vessels—7,321 yards; ditto for smaller vessels—1,972 yards. When completed, the port will comprise 12,260 yards of quay accommodation. There is a complete system of sidings, connected with three stations; also hydraulic installation comprising forty-two $1\frac{1}{2}$ -ton travelling cranes, and three fixed 10-ton cranes—the water compressed to 50 atmospheres by two 250-HP. engines and four accumulators. There are also steam and hand cranes, and ten pontoon-shears capable of lifting from 20 to 70 tons. The warehouse accommodation is not yet fully developed, but is still in course of construction. The repairing arrangements are also being extended, the large dry docks having a length of 722 feet, breadth 82 feet, and depth 29 feet. Up to the close of 1888 the amount expended on the various works was:

Piers, quays, and other seaworks	£ 1,370,000
Sidings, cranes, gas, &c.	537,500
Custom house, warehouses and buildings	605,300;

about £500,000 being still required, bringing the total expenditure up to about £3,000,000.

Leghorn is a harbour with two entrances and with docks. The anchorage being exposed, a long curved breakwater was constructed some years back. The harbour was formerly very shallow, but the southern end is now excavated to a depth of 29 to 33 feet, decreasing to 23 feet at the northern end. Good repairing accommodation, including dry dock 443 feet long and 24 feet 3 inches deep.

Civitavecchia, near the mouth of the Tiber, dates from the time of Trajan. It is formed by a small bay with two piers, and on the north side a dock constructed in the year 1500. The mouth is protected by a breakwater, giving an entrance at each end. The south channel only is available for large vessels, the northern entrance having only 18 feet of water. There are neither available quays nor repairing accommodation; but in view of the position of the port in relation to Rome it is probable considerable improvements will shortly be carried out.

*Naples*¹: This port comprises two harbours, the military port and the commercial port, together with the outer roadstead. The

¹ Minutes of Proceedings Inst. C.E., vol. cii. p. 360.

depth of water in the latter is from 40 to 100 feet; in the old commercial port 29 feet 6 inches to 16 feet 6 inches, and in the new commercial port, minimum 26 feet.

Brindisi is an entirely natural harbour. The roadstead has been improved by the construction on the northern side of a causeway 1,473 feet in length to the small island of S. Andrea, and the extension of a breakwater 843 feet long from a spur of the same island. The outer port has an area of 536 acres of good anchorage, and there is a further fairly protected roadstead of 650 acres. The port is the principal point for Oriental traffic and passenger service. It is chiefly exposed towards the east.

Bari has a small ancient harbour, facing east, and a large new port on the north side of the town exposed chiefly from N.W. to N.E., with extensive quays and having a depth of water varying from 33 feet to 20 feet.

Ancona: Port entirely artificial, formed by two long piers connected at base by quays. It is exposed to west winds, and the sea is frequently very rough, waves 6 feet high rolling into the harbour. The water is shallow, only one-fifth of the area having a depth of 26 feet, a further two-fifths being 16 feet deep, and the remainder about 10 feet. Few large vessels, therefore, are able to moor near the quays, but considerable excavation is now in progress.

Venice, being protected from the sea by a long belt of land, has no need of defence works, and simply comprises anchorage, quays, and docks. The Canale della Giudecca, with a length of $1\frac{1}{4}$ mile, an average width of 1,000 feet, and a depth of water of 24 feet 6 inches to 28 feet, is the chief roadstead, but there is not much quay accommodation for large vessels to moor close alongside. The dock-basin (*stazione marittima*) has an area of 2,300 feet by 623 feet, with a depth of 26 feet, and is well furnished with sidings and hydraulic cranes. The tidal range at Venice averages 2 feet 3 inches, but with the scirocco the water has risen as high as 4·37 feet above the mean level, while under opposite conditions it has sunk to 4·82 feet. The duration of ebb tide is considerably less than that of the flow, and the velocity, therefore, much greater. No very reliable data are yet available on the subject, and there is considerable variation in the tide, but the approximate average velocity is nearly 5 feet per minute. The present channel through the lagoon to Malamocco, a distance of eight miles, has a width varying from 150 feet to 330 feet, and an average depth of 28 feet: but as the distance from Venice to the sea by this way is very inconvenient, extensive works are now being carried on at Lido.¹ These works will also absorb the ports at Sant' Erasmo and Treporti into one channel, 3,280 feet in width, the depth of which is expected to become 28 feet by natural scour, and extending out to sea between piers 11,320 and 9,350 feet in length respectively.

Messina (Sicily): An entirely natural port, formed by a deep

¹ Minutes of Proceedings Inst. C.E., vol. c. p. 189.

circular indentation of the coast with a narrow opening towards the north, and having a depth of 130 feet to 200 feet. At present, however, there is not a great length of quays in sufficient depth for large vessels. The tidal effects are very irregular and peculiar, owing to the position of the port on the strait of the same name, connecting two distinct parts of the Mediterranean. Low tide in one corresponds nearly with high tide in the other, and the effect at Messina depends chiefly upon the wind, which causes one tide or the other to prevail. The ebb tide lasts only $1\frac{1}{2}$ to 2 hours, sometimes even less; the flow, therefore, generally 10 to $10\frac{1}{2}$ hours, while the range varies from only 2 inches to 13 inches.

Catania: A much exposed port, in the gulf of the same name. It is enclosed by one pier, 3,600 feet in length, and has a depth of water varying from 26 feet to 50 feet. The port accommodation is not yet much developed.

Palermo is entirely artificial; average depth, 23 feet. Formed by two piers enclosing a long shallow bay.

Trapani: A natural port, with one pier. Exposed partly to south winds. Depth of water, 23 feet to 80 feet; anchorage, 900 yards in length and average 530 yards wide; quays, 766 yards long, with depth 24 feet 6 inches to 16 feet 6 inches, and further length of less depth.

Girgenti (Porto Empedocle): Entirely artificial. Formed by two long curved piers, of which the windward is 3,480 feet long. Depth of water at entrance, 26 feet to 29 feet. No warehouses yet constructed or quays in sufficient depth of water.

Licata: An entirely artificial port, still in course of construction, but badly located, being rapidly silted up by a river close to the harbour mouth. In the course of ten years, the depths of water in various parts of the harbour have been reduced 8 or 10 feet, and in one instance 15 feet. It is now proposed to close that one of the two entrances to the port which is nearest to the river.

Cagliari (Sardinia): An entirely artificial port, not yet by any means completed, and still very much exposed. Average depth of water 24 feet 6 inches; 820 yards of quays with depth of 28 feet, and 380 yards with depth of 13 feet.

The Author remarks, in conclusion, that while much has already been done, since Italy became a united kingdom, in the improvement of the ports, much remains to do to ensure the safety of the harbours and to develop the means of quick handling, storing, and transit of goods. The old harbour mouths are far too wide and exposed for modern requirements, the entrance to the inner port not requiring to exceed 165 feet in width. The development of Italian ports is necessarily limited by the overstrained national finances, but the sum of £2,525,000 is at present allocated to the work by a vote of the Chambers in 1889.

P. W. B.

Notes on the Employment of Water under Pressure in founding the Quay-Walls of the Outer Harbour at Calais.

By M. BAILLY.

(Compte Rendu des Travaux de la Société des Ingénieurs Civils, October, 1890, p. 582.)

In the execution of the new harbour works at Calais, the foundations of the quay-walls for the outer harbour have been sunk by means of water injected under pressure, a method which has been attended with the most satisfactory results as regards economy and rapidity of execution, and which the Author believes to have been here introduced for the first time.

The quay-walls are founded in a very fine and movable sand, easily loosened by water; and, after some preliminary trials, which proved that piles could easily be sunk by a jet of water directed beneath them, the experiment was extended to the sinking of great blocks of masonry built upon a timber curb. The experience gained in these further trials was so far reassuring that the system was then adopted on a large scale for the sinking of the quay foundations and also for the driving of piles and sheeting.

The foundations are carried down to a depth of 8 to 11 metres below the present bottom of the basin, provision being made for the subsequent dredging of the outer harbour to allow vessels of the deepest draught to lie alongside at low water.

The quay is founded upon a series of square wells built of rubble masonry upon a curb or base of strong concrete. The outer surfaces of these square cells are vertical throughout, while the central shaft is octagonal in form and splayed outwards at the base, so that the walls come to a sort of cutting-edge, which, however, has a width of 1 metre, corresponding with the width of the concrete shoe. In general, the wells are 8 metres by 8 metres in outside dimensions, the octagonal shaft being 4 metres in diameter, and the wells are sunk side by side in the line of the quay wall, leaving spaces of 0·4 metre between them. In sinking the series of wells, the first, third, fifth, &c., are first got down, and then the intervening ones, and lastly the intervening spaces of 0·4 metre are excavated by the water-jet and filled with concrete, which dovetails the whole series together by filling two pairs of grooves, which had been formed in the sides of the contiguous masonry wells.

The process of sinking one of these wells is as follows:—The masonry cell is first built *in situ* to a height of 4 metres, and the well is sunk by injecting water under the cutting-edge by means of wrought-iron pipes carried down through the central shaft, and splayed outwards so as to direct the jet upon the sand beneath the cutting-edge. Thus loosened, the sand is brought up by a centrifugal pump, whose suction-pipe descends in the centre of the

shaft, and draws sand and water from the bottom of the conical cavity, which is gradually formed by the disengagement of the sand around its sides. The pumping-machinery for the sinking of the wells is mounted on wheeled trucks, which run upon a line parallel to the line of wells. For the water-jets, four Tangye pumps are employed, and are supplied with steam from two small vertical boilers, while the centrifugal pump is driven by a separate portable engine and boiler. The wrought-iron pipes, by which the water-jets are delivered, are twelve in number, and are divided into four groups, the three pipes of each group being connected with one of the Tangye pumps by flexible rubber tubes. The jets are so directed around the cutting-edge as to excavate the sand regularly and to correct any tendency of the well to deviate from the vertical in sinking, and in general the deviations are almost insensible.

Some difficulty was at first experienced in the working of the centrifugal pump, owing to the settlement of the sand in suspension in the suction-pipe, which tended to choke the valve at the foot of the pipe whenever the pumping was temporarily stopped. This was remedied, however, by attaching to the valve-box one of the wrought-iron pipes through which a jet of water was at such times delivered into the valve-box just above the valve, and by means of the circulation of a continuous stream of water the deposit of the sand was prevented.

On the average the sinking of a well to a depth of 4 to $4\frac{1}{2}$ metres was accomplished in twelve to fourteen hours, which is equivalent to about 20 cubic metres of excavation per hour.

When the well had been sunk to a depth of 4 metres, bringing its top to the level of the ground, the masonry was carried up for a further height of 4 metres, and the operation of sinking was then resumed.

In a bed of clay the operation is more difficult and much more tedious; but the system was successfully employed to sink through beds of about 1 metre in thickness. It was also applied to the sinking of wells of smaller dimensions, $4\frac{1}{2}$ metres by $4\frac{1}{2}$ metres and 4 metres by 4 metres. In these cases the rate of sinking in sand was much faster, and it became more difficult to prevent the well from deviating from its true position.

T. C. F.

On the Prevailing Winds and Silting-Action in Sea and Lagoon at Venice. By DAVIDE BOCCI.

(Annali della Società degli Ingegneri e degli Architetti italiani, 1890, pp. 119, 203.)

The Author premises that his observations are founded especially on studies on the Brenta, Bacchiglione, Gorzone, Sile, and other rivers of this part of Italy. The first portion of the memoir comprises a summary of general considerations and hydraulic formulas. The second portion refers to winds and currents.

On the Venetian coast the N.E. wind prevails for six months in the year, and this is also the quarter of the most violent gales. The prevailing winds produce not only waves but temporary currents; and although the littoral current passes sluggishly along the coast at a distance of 2 or 3 miles, its effect is often locally diverted by the wind, as well as by mingling with flood waters from the Po delta. During the prevalence of N.E. winds the water level in the lagoon from Brondolo to Le Tresse—the inlet of the land drainage—is frequently raised. This is very apparent at the sluices at Brondolo, where, when the gates are open, the water flows from the river to the lagoon except when strong N.E. winds reverse the current. The force and direction of the prevailing wind in times of river-flood materially affect the extent of solid matter deposited on the shore. Carrying much heavier matter in suspension, the river-current impinging on the littoral current, when the latter is sufficiently backed by a N.E. wind, is checked and deflected. The silting naturally takes place firstly on the leeward side; but the relative and varying force of the two currents constantly affects and determines the direction and depth of the channel. At Chioggia, where the current from the lagoon counterbalances that from the Brenta, the shore-line remains practically unchanged; but from this point to Ca Manfrin and Fosson the land is extending at varying rates, attaining at the latter point its maximum average advance of 43 feet per annum. The advance is apparently proceeding now at a more rapid rate than formerly. The deltas of the Po, the Adige, and the Brenta and Bacchiglione are all closely adjacent and almost coterminous; in fact, the silting action of the former may be said to absorb the effect of the smaller rivers, and certainly no improvement of these can be permanently effective without regulation of the channels of the Po. The varying direction of the coast line with respect to the prevailing wind is obviously a material point in studying the progress of marine silting. From the mouth of the Piave to Punta della Maistra, a distance of 50 miles, the Venetian shore forms a semi-ellipse, the northern portion of which, from the Piave to Lido, lies nearly parallel with the prevailing winds; the middle portion, from Lido to Chioggia, at an approximate angle of 45°; while along the southern end the same wind blows straight towards shore. Under the effect of this wind the maximum

deposits of suspended matter naturally strike this portion of the coast, and it is precisely along this southern end of the Venetian shore that the rivers have their outlets. The Brenta and Bacchiglione now discharge their waters by one united channel into the open sea,¹ after undergoing many alterations. The Author relates very fully the history of the former and the opinions of hydraulic experts in past times as to the effect of the outlet of the river into the lagoon. In the earliest historical times the Brenta discharged its waters into the lagoon at Venice; but so seriously did the alluvial deposits threaten the existence of the port that at various times from the 14th century onwards it was diverted successively to the lagoon of Malamocco, to Chioggia, to Brondolo, and finally, about 1565, to the open sea. About fifty years ago it was decided to connect the river once more with the lagoon near Chioggia; but the recent improvement works above referred to have restored the outlet to the sea. Flowing into the lagoon through a network of channels, continually shifting and silting up, the river current, freed from the greater part of its alluvial matter by the time it reached the main outlet from the lagoon to the sea, materially assisted the scour and improved the main channel; but at the latter stage, when the alluvial matter had reached to within a short distance of this outlet, the beneficial effect was reversed, and the current becoming more sluggish began to silt up the main channel also. But for this deposit, the tendency of the tidal scour would be to constantly deepen the lagoon. In early times the port of San Nicolo del Lido was available for the largest vessels of the Venetian fleet, but in spite of all efforts the channel gradually silted up to such an extent that in 1540 it was too shallow for even a gondola. After the exclusion of the Brenta from the lagoons the scour gradually increased the channel again to its former depth.²

P. W. B.

The Railways of Mexico.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 285.)

In Vol. xxii. of the American Society's Transactions a Paper was published on the railways of Mexico, by Mr. W. Barclay Parsons, in the course of which it was stated that gradients of 4 per cent. (1 in 25) occur on the Mexican Central Branch from Tampico, to Aguas Calientes. Mr. Max E. Schmidt, M. Am. Soc. C.E., corrected this in the discussion. The ruling gradients are 1·5 per cent. (1 in 66·6) except on the two mountain divisions of 27 miles and 5 miles respectively, where the maximum inclines are 3 per

¹ Minutes of Proceedings Inst. C.E., vol. xcix. p. 429.

² *Ibid.*, vol. c. p. 189.

cent. (1 in 33·3), and all the gradients are compensated for curves in conformity with a Table which is now printed. On the other hand, it was stated in the Paper that 4 per cent. (1 in 25) is the maximum incline on the railway from Vera Cruz to Mexico ("the Mexican Railway"), whereas this is correct only as far as the tangents are concerned, for the absence of all compensation on the curves virtually increases the maximum to nearly 5 per cent. Mr. Schmidt proceeded to comment unfavourably on the latter railway company having recently placed Fairlie engines, weighing over 90 tons, to run upon these steep inclines. In his opinion it would have been preferable to have added a centre rack-rail on the heavy gradients of the mountain divisions, and to have substituted Abt engines which at 63 tons service-weight develop a tractive power of 27,500 pounds, for the ponderous weight of the Fairlie engines is against them under the best of circumstances. An Abt engine, he said, on a track supplemented by a third rail, would haul 280 tons of gross train-load on 4 per cent. non-compensated gradients, and at a speed of 10 miles per hour.

Mr. Barclay Parsons accepted the correction as to the gradients on the Tampico branch of the Mexican Central, but did not think it by any means clear that the introduction of Abt engines on 4 per cent. gradients would be economical. As chief engineer of a system of lumber railways which he is constructing in the Allegheny Mountains of Northern Pennsylvania, he uses gradients frequently of $3\frac{1}{2}$ per cent., and at times up to and over 4 per cent. The power he uses is a Shay engine,¹ with three vertical cylinders driving a horizontal shaft which is geared to all the wheels, tender included. This shaft is jointed so that the longest rigid wheel-base is 56 inches. Such an engine uses the whole weight for adhesion, and at a ratio of $\frac{1}{4}$ with a weight of 60 tons would develop 30,000 pounds of tractive power.

O. C. D. R.

Railways in Construction in Spain.

(Anales de la Construcción y de la Industria, Madrid, 1890, pp. 220, 246, 254.)

The works on the railway from Murcia to Granada are being continued with great activity, and locomotives already run over some portion of the line at the Lorca end. The tunnel under the pass at Hijate has been commenced, and the passage of the gorges near the station at Gor, which involves some important viaducts, one of which consists of several spans exceeding 100 yards in length, is advancing towards completion. Between Gor and Granada the nature of the ground involves many difficult and expensive works, among which are tunnels at Guadix, Las Animas, and between

¹ Minutes of Proceedings Inst. C.E., vol. cii. p. 386.

Moreda and Iznalloz, and also the bridge over the river Fardes, which is a noteworthy work owing to its length.

The direction of the railway from Linares to the Port of Almeria has been materially modified, and its length thereby reduced from 192 to 150 miles. Starting from Linares, the new line reaches the river Guadalquivir at Torre Blasco Pedro, then continues up that river to Baeza and Ubeda; it then bears off to the south, crossing the rivers Bedmar and Jandulilla, and a few miles further on the rivers Salado and Guadiana, which last it follows for several miles. At kilometre 89 it reaches Chilla, and at kilometre 100 the station of Manzano. From this point it runs due south, past the Baths of Alicún de Ortega into the province of Granada, and for a distance of about 14 miles runs parallel with the line from Murcia to Granada. Guadix is reached at kilometre 140 ($87\frac{1}{2}$ miles from Linares), Huejena at kilometre 160, Benahadux at kilometre 228, and finally Almeria at kilometre 240.

On the railway from Jativa to Alcoy the works were being rapidly proceeded with. The most important are the bridges over the rivers Albaida, Las Estacas, Molinar, Torralva, Rafalgani, Mallols, Algar and Bufali. Those over the Albaida and Las Estacas have been completed, and the others are far advanced. The tunnels Nos. 2, 6, 7 and 8, had been completed, and No. 1 would be so shortly. The railway was expected to be opened to traffic in the course of the year.

O. C. D. R.

Construction and Maintenance of Track.

By J. A. HALL, M. Am. Soc. C.E.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 330.)

This Paper contains an account of the points which demand attention in connection with the subject of railway track. Thus, while laying down practical rules for the preservation of a good road-bed, the writer gives suggestions and advice respecting the drainage of wet cuttings, the location of culverts under embankments, &c. When selecting timber for sleepers, he would prefer white oak, post oak, or chestnut oak, or, if pine must be used, a good long-leaf pine will last two or three years longer than ordinary pine; and above all, pine which has been bled for the resin should be carefully avoided, as it rots all over, and will often on the outside have the appearance of being sound while so rotten within as not to be able to hold a spike. Hewn sleepers will last one-third longer than sawn, but they should be of uniform thickness. They should be cut when the sap is down—preferably from the middle of December to the middle of February—and be

allowed to season under shelter for at least one year before being laid down. Creasoting is the only satisfactory chemical process, and only open-grained and seasoned wood can be successfully treated.

"Servis" tie-plates, curved safety-spikes, bolts with nut-locks, rail-braces for sharp curves, level crossings, barbed wire fences, switches and frogs, surface cattle guards across the whole width of the line, and the "Fisher" bridge-joint are among the special appliances recommended and shown in the text by illustrations. With regard to the shape of rails, he enumerates, illustrates, and unhesitatingly endorses the recommendations of the rail-section of the American Society of Civil Engineers. The square-jointed rail gives more or less of an opening for the wheels to drop into, while the "mitered" rail, with angles of from 45 to 60 degrees, obviates this to a great extent, but on the other hand offers less springiness to the sledge-hammer blows of the passing wheel, and the writer explains at some length the reasons for his opinion that no absolutely satisfactory joint has yet been found. Great care should be taken so to handle the rails as not to bend or kink them. As a general rule when locating a railway, he says, "Follow that route which affords the easiest possible gradients for the longest possible distances, and then pass over the intervening distances with such gradients as are found necessary." Much unnecessary expense would be saved in railway construction by employing the very best engineers that can be obtained, and they should be well equipped and have plenty of time to do their work. A great mistake is made by the employment of incompetent engineers, and money spent in engineering is always money well spent; the location of a line should never be hurried.

Advice is given as to the selection and packing of ballast, the proper way of laying the curves, the maintenance of the track, the renewal of sleepers, precautions against rain and snow, &c., and the Paper concludes with some practical suggestions for the encouragement of efficient inspection and of a high standard of excellence in the performance of first-class work by all classes of workers, from the chief engineer to the lowest grade of labourer.

O. C. D. R.

The Manitou and Pike's Peak Railway. By F. H. HASTINGS.

(Scientific American, New York, January 24, 1891, p. 47.)

On the summit of Pike's Peak in the Rocky Mountains, at an elevation of 14,115 feet above the level of the sea, the United States Government has established an Observatory at a distance of about 9 miles from the Station of Manitou, on the Pacific Railway, which is at 7,552 feet lower level.

A railway to connect these two points has now been constructed

and was opened to traffic in October, 1890, although it is only intended to run regular trains during the summer season. In order to overcome the steep gradient, which averages 1 in 6½ (16 per cent.) throughout the whole distance, a rack-rail is laid in the centre between two tee-rails (weighing 40 lbs. to the yard), and the road is worked on the Abt cog-wheel system. The rack-rail consists of two continuous Bessemer steel rails made up of parallel bars, set 1½ inch apart, each containing seventeen teeth, or cogs, in their length of 80 inches, and held in position by means of die-forged steel chairs, secured to the sleepers by wood-screws. The parallel bars vary in weight from 21 to 31½ pounds per foot, the heavier bars being used on the steeper portions of the incline.

In order to prevent the track from sliding downwards on the passing of the trains a very thorough system of anchorage has been adopted, one hundred and forty-six anchors being used varying in distance one from another according to the steepness of the incline, from 200 to 600 feet. Some of these consist of steel straps, secured at the lower end to the chairs, and at the upper end to a strong pin 2 feet long and 2½ inches in diameter, which is leaded into the solid rock under the road; but where there is no rock available, a steel bar is fixed to the lower side of the cross sleeper, and held in its place by means of a piece of stout oak timber, which is carried downward at a steeper incline than that of the road until it thrusts against rock, or against another block of oak timber.

Each engine is of 200 HP., weighs 26 tons, and is capable of drawing or pushing two carriages up the incline. In descending, the cylinders of the engine are used as air-compressors, a stream of water being kept running into them continually to keep them from heating. By controlling this compressed air, the speed of the train is regulated. The engines are built to stand level on a 16 per cent. incline; there are three sets of double pinion brakes on each engine; the two back sets furnish most of the power for ascending, while the forward set are principally used to apply brake power. The two front sets of pinions have a peculiar steam-brake connection which locks them instantly, and the back pinion has a hand brake connection which is capable of stopping the whole train in a few seconds' time on the heaviest incline.

The carriages are handsomely fitted with the sides and ends as far as possible of glass so as to allow of the scenery being observed. The seats are constructed so as to be level when on the 16 per cent. incline. The trip from Manitou to the summit occupies an hour and forty-five minutes, the trip down half-an-hour less. The maximum speed is 8 miles, the minimum 3 miles an hour. The cost of constructing the entire road was about £100,000.

O. C. D. R.

Railway from Reichenhall to Berchtesgaden.

By GUSTAV EBERMAYER.

(Zeitschrift des Architekten und Ingenieur-Vereins zu Hannover, 1890, p. 381.)

This line was opened for traffic in the autumn of 1889, and was constructed as regards details in accordance with the practice followed generally throughout Bavaria for local railways. The district passed through is one which, on account of the mountain scenery and of the saline baths at Berchtesgaden, attracts each season a large number of tourists, and it is probable that the line would have been made much earlier had not the question of the large outlay required proved a barrier.

In 1867 there was a project for connecting Berchtesgaden with the main railway system by following the valley high road, by the Salzach to Salzburg, but the consequent entry into Austrian territory, and the Customs complications which would have arisen therefrom, led to its abandonment in favour of the only alternative route, viz., by making a connection with Reichenhall, the course of the latter, however, being through a very mountainous district. The amount then estimated to be required for its construction was £402,850, or about £32,410 per mile, the length being about 12·43 miles. This amount was, however, deemed so considerable, that the idea was abandoned and not revived until nearly twenty years later. Various projects of about the year 1884 are described by the Author, but it was not until 1886 that the line as constructed was definitely decided upon. The question of gauge and also of the use of a rack rail upon the steepest portions occupied considerable attention, but eventually the normal gauge of 4 feet 8½ inches was adopted, and laid in the ordinary manner as an adhesion railway.

A very detailed account is given of the construction of the line, which is about 11½ miles long. The minimum radius adopted was 590 feet, but this is only at one or two exceptional points, the minimum elsewhere being 656 feet, and the least length of straight between the reverse curves is 98 feet. The longitudinal section, of which a diagram accompanies the Paper, shows by a dotted line the grades originally contemplated, when it was proposed to use a rack rail, and by full lines the grades of the line as constructed. It is divided into three main inclines, viz., a length of 1·05 mile, between Reichenhall and Kirchberg of, for the most part, 1 in 100; a length of 3·54 miles, from Kirchberg to Hallthurm of 1 in 25; with the exception of a short piece of level for the station of Gmain and a short length of 1 in 28·57, and a length of 7·15 miles between Hallthurm and Berchtesgaden, with a ruling gradient of 1 in 50. The geological formation of the district is described. The rocks near the Reichenhall end are principally of mountain limestone, and at the Tristramberg of clay, so insecure as to necessitate a tunnel of 54½ yards long, in place of open cutting; cross-section

diagrams are given of the formation in cutting and embankment. The amount of excavation was 307,380 cubic yards, of which a sixth part was rock. The course of the line in relation to the public highway and steamways is described throughout; in many places the stream being diverted to give room for the railway. For the bridges the use of ashlar was as far as possible avoided, and either carefully set rubble adopted for their construction or Portland cement concrete, the latter also being used for the bed-stones of the girder bridges, and for the voussoirs of arches up to 13 feet in span. Descriptions and diagrams are given of the principal bridges, but there are none of much importance, as the spans in no case exceed 40 feet.

The ballast required for the permanent way was on an average 1·196 cubic yard per lineal yard, and cost 1s. 8d. per cubic yard. On the steepest incline, viz., between 1·73 and 7·35 kilometres, or a length of $3\frac{1}{2}$ miles, iron cross-sleepers were used and steel rails. The weight per lineal yard of permanent way, including the iron sleepers, was $257\frac{1}{2}$ lbs., and the cost of the ready laid track was 18s. 3d. per lineal yard. On the rest of the line timber sleepers were used, the cost thereby being reduced to 13s. $8\frac{1}{2}$ d. per lineal yard. The elevation of the outer rail of the curves was calculated for a speed of $12\frac{1}{2}$ miles per hour, but in actual practice the speed during the descent of the inclines is from $6\frac{1}{2}$ to $7\frac{1}{2}$ miles per hour, and is forbidden to exceed $9\frac{1}{2}$ miles per hour.

The locomotives are fitted with automatic speed indicators, and as an additional check upon the incline between Kirchberg and Hallthurm there are electrical contact makers affixed to the rails at every 546 yards, which are connected by wires with a registering clock at the Reichenhall station, so that the speed at which the trains are run on the incline can be ascertained at any time. Descriptions and diagrams are given of the various station-yard arrangements and of the buildings. There are on the new railway, commencing from the junction with the main line at Reichenhall, stations or stopping places at Kirchberg, Gmain, Hallthurm (the summit), Bischofswiese, Gmundbruecke and Berchtesgaden, the latter terminal station being the most important as regards the buildings and general arrangements.

Of the foregoing Gmain and Gmundbruecke are mere stopping points. The cost of the buildings and station arrangements was as follows, viz.:—

At Kirchberg	£ 1,105
„ Hallthurm	140
„ Bischofswiese	800
„ Berchtesgaden	5,745

Electrical communication between the stations is by telephone only, as is usual on all the Bavarian local lines.

As regards the rolling stock there are in service at the present time three tender-locomotives, with three pairs of coupled wheels and one pair of bogie wheels, each weighing 43 tons; there are

ten passenger carriages of second and third class; two full-glazed, "prospect" saloon cars for tourist traffic in the summer season, three goods-wagons and two service wagons for postal service, &c. The Westinghouse brake is used. The total cost of the rolling-stock was about £10,000. The cost of each locomotive was £1,700, "prospect" car £450, passenger carriage £270, service-wagon £225, and goods-wagon £200.

The construction of the line, which is 11·68 miles (18·81 kilometres) in length, between the centres of the end stations at Reichenhall and Berchtesgaden, or altogether about 11 $\frac{3}{4}$ miles (19 kilometres), was commenced in July 1887, and it was in a sufficiently advanced condition to be opened (provisionally at first) for traffic on October 25th, 1888.

The various items of construction and their cost are given, the total amount being £72,000, or about £6,114 per mile.

D. G.

Landquart and Davos Narrow-Gauge Railway. By — JOHNER.

(Schweizerische Bauzeitung, 1890, p. 51.)

As early as 1874, when Davos-Platz was beginning to gain a reputation as a sanatorium, a normal gauge line was projected to connect it with the main line, by way of the Prättigau, the maximum grade being not steeper than 1 in 25 and the curves of not less than 9 chains radius. The estimated cost for this project, however, amounted to £500,000, or about twice the sum upon which the probable traffic would suffice to yield a fair return, whereupon the idea for the time being was abandoned.

The increasing need for some better means of communication with Davos-Platz, and also the possibility of a rival line being constructed *via* Chur Thuisis and Filisur, whereby the traffic would be permanently diverted from the Prättigau Valley, led to the granting in 1886 by the local authorities of Davos and the latter district of a subvention for a narrow-gauge line, the terms of which were a grant of £20,000 cash, the expropriation of the requisite land, the assignment of the necessary sand, gravel and stone, and the provision of the timber required in the construction of the railway. The studies were commenced in the autumn of 1887. The general course of the line from its junction with the main line at Landquart, and after leaving the valley of the St. Gall Rhine, is through the Klus gorge, following the Prättigau valley as far as Klosters, where it turns into the Stuetzalpbach valley to Davos Culm Pass, and thence, following the left shore of the Davos Lake, reaches its termination at Davos-Platz. The height above sea-level of the line at Landquart is about 1,722 feet; at the Davos-Culm summit, it is 5,358 feet, and at Davos-Platz about 5,052 feet. It was originally proposed to adopt a rack rail

line, with a grade of 1 in 10, between Klosters and the summit, but after a careful enquiry it was decided to make the railway an adhesive one throughout, the requisite extra length for the less steep grade being gained by zigzags along the mountain slopes opposite Klosters. The distance from the commencement to the summit is about $27\frac{1}{2}$ miles, and to the terminus at Davos-Platz about $31\frac{1}{2}$ miles, the maximum grade being 1 in 23·7, which extends over a continuous length of $5\frac{1}{2}$ miles. The geological formation of the district is described, and also the course of the line, which was such as to necessitate heavy works. The snow throughout the winter does not often exceed $2\frac{1}{2}$ feet in depth, but in laying out the line this snow-fall was kept in view, and cuttings consequently avoided wherever possible. The gauge originally contemplated was 2 feet $5\frac{1}{2}$ inches, but that actually adopted was 3 feet $3\frac{1}{2}$ inches (1 metre), with curves of a minimum radius of 328 feet and intervening straights of at least 98 feet 6 inches in length.

The estimated expense of the line was as follows, viz. :—

Provision of capital	£ 16,000
Engineering and superintendence	9,600
Land	9,200
Earthwork, retaining-walls, tunnels, bridges, works, river-works, and ballast	138,040 ¹
Permanent way	40,840
Station buildings, &c.	13,360
Mechanical appliances—viz., cranes, &c.? } (<i>Mechanische Ausrüstung</i>)	3,720
Gates, fencing, and signals	4,600
Items in connection with working of traffic	1,080
Rolling-stock	24,000
Interest during construction	14,000
Sundries	5,560
	<hr/> £280,000

The traffic it was estimated would amount to £28,000 annually. The actual works were commenced in the summer of 1888; the first section was opened in 1889, and the entire length in July 1890.

A number of cross-section diagrams are given showing the line where passing through the glacial moraine, rock, &c.; also of the protective stone-work where the line abuts upon stream-courses, and of the dry walling supporting the formation, in place of the natural slope, upon steep mountain slopes; cross sections are also given of the masonry retaining-walls and of the two forms of tunnels where piercing the moraine and the rock, which latter have a clear internal width of 11 feet 10 inches at rail-level, and a height of 15 feet 1 inch from the rail to the soffit. Sketches are also given of the principal bridges.

¹ In construction, this combination of items, included under the head of "Unterbau," amounted to £158,980 (3,974,500 francs).

The permanent way is formed by steel rails of the Vignoles type, spiked to oak cross sleepers 2 feet $7\frac{1}{2}$ inches apart. The weight of the rails is $47\frac{1}{2}$ lbs. per yard, the depth being $4\frac{1}{2}$ inches and breadth of head 2 inches, rolled in 32-foot 10-inch lengths, and the road is laid on a 1 foot 4 inches thickness of ballast.

Diagrams are given of the type of station buildings (chalet order) and of the station yards arrangement; also of the rolling-stock, including plans, sections and elevations of locomotives, carriages and wagons. Full particulars are given of the locomotives which have outside cylinders and three pairs of coupled wheels, with a wheel-base of 8 feet $2\frac{1}{2}$ inches exclusive of a single-pair bogie, and a weight of 23 tons when empty and 29 tons when in running order.

The traffic receipts are given for each month since the line was opened, up to July 1890.

D. G.

The Ventilation of Tunnels. By N. W. EAYRS, M. Am. Soc. C.E.

(Transactions of the American Society of Civil Engineers, vol. xxiii. 1890, p. 288 (2 plates).)

This Paper deals with the methods of ventilation adopted on railways in the United States, and particularly describes those employed on the Hoosac tunnel, which is ventilated entirely by a natural current of air through a central shaft, and on the St. Louis tunnel, which is ventilated mechanically by means of a central fan, with both of which the writer was connected as engineer. Some reference is also made to the conditions of ventilation of some of the principal European tunnels.

The Hoosac tunnel is about $4\frac{3}{4}$ miles long and perfectly straight from end to end. The two extremities are at the same elevation of 769 feet above the sea-level, but from each end to the central shaft there is a rising gradient of 26.4 feet to the mile (1 in 200). The shaft is elliptical in shape, 27 feet $\times$ 15 feet and 1,028 feet deep from the ground surface to the floor of the tunnel. When this was first opened for traffic with only a single line of rails, timber shields were placed at the foot of the shaft to protect the passing trains from the danger of stones becoming dislodged from the sides and falling on the line, but when in 1882 the increased traffic required a second line of rails to be laid, and it became necessary to protect that also, the ventilation of the tunnel would have been seriously affected by the use of additional shields, and the plan was adopted of closing the tunnel at the bottom of the shaft and building two spiral ventilating galleries 15 feet in diameter, starting at right-angles to the line of railway from opposite points in the tunnel each 42 feet from the centre, and winding up to a height of 70 feet before entering the main shaft. The combined

area of the two galleries being larger than that of the shaft, they maintained the ventilation of the tunnel as it was before, and neither the abrupt turn at right-angles from the line of the tunnel nor the spiral form of the rising tubes have proved any obstacle to the air-current, fifteen minutes sufficing under ordinary circumstances to clear the tunnel and renew the air from the two extremities to the shaft. The maximum number of trains passing daily through the tunnel in 1889, with an average of thirty cars, was sixty-five, which is very near the limit which can be safely run under present conditions, and the time is fast approaching when recourse must be had to artificial ventilation unless some other motor is used than the ordinary locomotive.

The St. Louis tunnel is constructed beneath the city of St. Louis, and forms the connection between the bridge over the Mississippi river and the Union Depot at Twelfth Street and Poplar Street in the midst of the city. It is 4,095 feet in length, the two main portions running nearly at right angles to each other and connected by a curve 740 feet in length approximately in the centre of the tunnel, where the ventilating fan is placed. The steepest gradient is 1 in 75. It is really a double tunnel, for a central wall, with openings at every 25 feet, separates the two lines of rails throughout, excepting at the fan and at the Custom House. Originally air-holes through the roof were left in several places, which it was expected would suffice to keep the tunnel free from smoke and foul air, but this proved a mistake, and, moreover, loud complaints were made because of the issue of smoke into the streets, and after many experimental tests all those openings were closed and a central fan and ventilating stack were adopted.

The stack is of boiler iron, 130 feet high, 37 feet in diameter at the base and 15 feet at the top. The fan, which is 15 feet in diameter and 9 feet wide, consists of a pair of steel cones placed butt to butt and riveted together. These cones carry sixteen blades, 3 feet wide, driven by an engine of 190 HP. at a speed varying from 70 revolutions per minute when the passenger traffic is light to 110 revolutions when it is heaviest. At 110 revolutions the tunnel is cleared of smoke in four and a half minutes from the time of the locomotive passing the fan when going east, and in three and a half minutes when going west, and it has been estimated that the total amount of air requiring to be removed on the passage of each train is 2,750,000 cubic feet. The writer, however, believes that this estimate is excessive, and judges from the tests made by himself that at 110 revolutions per minute the volume of air driven up the shaft does not exceed 240,000 feet per minute. The ventilation of the St. Louis tunnel has been considered fairly good up to within two or three years, but in certain states of the atmosphere the smoke moves very sluggishly, and the air in a portion of the tunnel is very foul whenever there is a strong westerly wind. During the year 1888 an average of one hundred and sixty-seven trains passed daily through the tunnel, so that the average

interval between the trains was about eight and a half minutes, but by June 1890 the traffic had so increased that there were several hours in the day during which one train passed every four minutes; so that increased means of ventilation will soon become indispensable.

In Europe the subject of tunnel ventilation received a great deal of attention at the opening of the Mont Cenis and of the St. Gothard tunnels, but so far natural ventilation has been found sufficient on railways traversing the Alps. The difference of elevation at the two ends of the St. Gothard tunnel is 120 feet, and the corresponding difference in barometrical pressure is always sufficient to produce a definite current from the northern or lower end to the higher southern end, when the temperature is about the same at the two extremities. Moreover the traffic through the Alpine tunnels is comparatively light.

Reference is also made to the mechanical ventilation of tunnels in England, the system in use at the Mersey railway being fully described.¹

In the writer's opinion the hope of successful ventilation lies in the possibility of keeping smoke and gas out of tunnels rather than in removing the vitiated atmosphere, and he thinks that where the gradients are light the best solution of the problem may be looked for from the application of electricity as the motive power.

O. C. D. R.

Compound Locomotives.

(Mémoires de la Société des Ingénieurs Civils, October 1890, p. 315.)

A lengthy discussion arose on communications made by Mr. Mallet, Mr. Durand, and Mr. Lencauchez, on the compound principle of steam-expansion, and its application to locomotives. Mr. Pulin remarked that there appeared to be but one *raison d'être* in compound locomotives—the complete utilization of the expansive action of steam; and but one advantage—economy of fuel, although in many cases it is difficult to appraise it, and should be considered as the indication rather than the measure of the economy of steam. Though the question of complication is related to that of cost of maintenance, Mr. Pulin instances the compound locomotives No. 701 on the Northern Railway of France,² having four cylinders, with four valves. In this engine only seven valves have been worn out in the course of a mileage run of 119,000 miles, whilst in the ordinary locomotives on the same service twice as many valves have been worn out. When No. 701 was repaired in 1888 the working parts were found to be but little worn. The

¹ Minutes of Proceedings Inst. C.E., vol. lxxvi, p. 40.

² *Ibid.*, vol. xcix, p. 474.

mechanism had worked well. During the three years in which the engine has been at work it has not been interrupted by any cause attributable to the compound system. This system permits of augmentation of expansive working in locomotives, even while considerable percentages of admission are practised, and the working of the expansion-link near the middle is avoided, without neutralizing the benefit of long admissions by abnormal condensation. It appears to be sufficiently established that the employment of high pressures is not the only cause of economy realized by compound locomotives.

Mr. Polonceau maintained that it had not yet been proved that, given a compound locomotive, it was not possible to construct a non-compound locomotive to draw the same train at the same velocity, and not consuming more fuel. "I shall always," he said, "prefer the non-compound locomotive, which has the great advantage of its great simplicity, by which it conforms to the dictum of Watt: 'In everything, and above all in machinery, seek for simplicity.'" Mr. Polonceau read two communications received from Mr. F. W. Webb and Mr. Cleminson, the first in favour of, the second adverse to, compound locomotives, showing that elsewhere, as well as in France, opinion was divided. Incidentally, Mr. Webb stated that he had much simplified, in applying automatic reversing-gear to the second or low-pressure cylinder, abandoning the Joy gear. Mr. Polonceau noticed the difficulty of making comparative experiments on locomotives. One engine-driver might make a difference of 15 or 20 per cent. in fuel consumed in comparison with another.

Mr. Mallet maintained that compound locomotives had passed out of the experimental stage. He could instance several places where twenty-five or thirty such engines had been ordered at once. Comparative trials were not so difficult to make as was usually supposed. The remarkable experiments of Mr. Borodin led to the final adoption of the compound locomotive not only on the railways of South-west Russia, but on all the Russian railways, for which compound locomotives exclusively were now constructed. Many other trials had been made. On the Eastern Railway of Switzerland an engine of the Bourbonnais type had always, for more than two years, on the various sections of the railway, shown very notable economy. The Jura-Simplon Railway Company ordered a number of locomotives, some compound, some ordinary, alike in all respects except in the cylinders. Not only did the average working of the compound engines show an important economy on the average of the ordinary engines, but the compound, which showed the greatest consumption, used notably less fuel than the ordinary engine using the least. It might be taken for granted that if there were now from 1,000 to 1,200 compound locomotives, it was because the system had manifested real advantages.

Mr. Lencauchez declared that in theory the compound system could not show any economy; and he quoted instances of comparative trials in support of this assertion. "Certain engineers,"

he said, "think that the compound system is preferable; others equally competent think the contrary." He referred to a locomotive (No. 76, on the Orleans Railway) fitted with Corliss valves (cylindrical) which had been at work, thus fitted, for two years, with steam of 10 atmospheres. The valves were in good order, and they were of "indefinite durability."

Mr. Pulin pointed out that, with a high degree of expansive working in ordinary locomotives, an important extent of condensation of steam took place which did not appear to take place in the compound engine, in which an expansion of from five to six volumes corresponded to the best practical utilization of the steam.

Mr. Du Bousquet believed that the chief element of the economy that might be expected arose from the augmented degree of expansion rendered available by the augmented pressure in the boiler, and that, as the rate of expansion depended only upon the ratio of the final to the initial volume, it could be realized in one cylinder as well as in two; and he commended the experiments of Mr. Polonceau towards a settlement of this question.

In this connection Mr. Polonceau referred to the priming of water in mixture with the steam from the boiler, as a difficulty influencing the results. Priming, he maintained, varied from 30 per cent. to 50 per cent. in locomotives; and therefore all results were false.

Mr. Collet was of opinion that the advantage derived from the compounding of locomotives was that the "very bad" distribution effected with the expansion-link for high degrees of expansion in one cylinder was obviated by the distribution of the work of expansion in two cylinders.

D. K. C.

Contribution to the History of Compound Locomotives.

By E. BRUECKMANN.

(Organ fuer die Fortschritte des Eisenbahnwesens, Wiesbaden, vol. xxvii. 1890.)

The rapid but steady development of the compound locomotive renders it desirable to note some important points in the history of this development, which may be conveniently divided into two periods: the first period from the earliest ideas and experiments down to the year 1876, when Anatole Mallet made his valuable series of researches with compound locomotives on the Bayonne and Biarritz railways; the second period from the year 1876 down to the present time.

The International Railway Congress, held in Paris in September 1889, recommended that experiments with compound locomotives should be instituted, on account of the importance of the subject, especially for those countries where fuel is scarce, thus showing that they did not consider the compound locomotive to be thoroughly established, but to be still in the experimental stage.

The development of the compound locomotive, during the second period, can be followed in detail from the technical journals, but it is quite otherwise with the development during the first period; only scattered notes can be collected from the above source, and also from reports of the railway companies.

The earliest known example of a compound locomotive seems to have been that of James Nicholson, an engine-fitter in the Eastern Counties Railway works at Norwich, in either 1846 or 1847. His idea was to make more use of the expansion of the steam than was usually the case in locomotives. In his arrangement, the pistons of the two cylinders were coupled in the usual way to cranks, and at right angles to each other. The boiler steam was admitted into one of the cylinders (No. 1) for nearly half-stroke, and when the piston of No. 1 cylinder had travelled quite up to half-stroke, the steam was admitted by a special arrangement of valves from the first cylinder into the second cylinder; the admission of steam in the second cylinder only amounted to one-twentieth of the stroke; the communication between the two cylinders then ceased, and the expansion continued in both cylinders, independently of

Fig. 1.

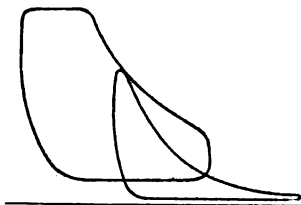
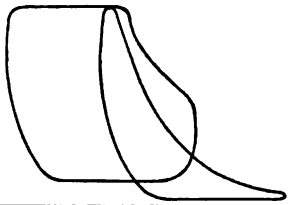


Fig. 2.



each other. Mr. Nicholson claimed that by his arrangement the exhaust steam from only one cylinder was made use of in the blast-pipe to force the draught, whilst in the second cylinder the greatest possible use was made of the steam by very complete expansion. Mr. Nicholson communicated his idea to Mr. J. Hunter, the Locomotive Engineer of the Eastern Counties Railway Company, in 1848, and then went to the Stratford works of the same company, and in course of time a goods locomotive from his designs was built. This engine ran regularly between Stratford and Norwich for many months. Mr. J. Hunter died soon after his interview with Mr. Nicholson, but his successor, Mr. Samuel, pursued the subject with success, and in October 1850 took out a patent for a compound express locomotive. A report on this was given before the Institution of Mechanical Engineers; the title of the patent was for "Continuous Expansion Engines." The question arises, Can engines, with such a distribution of steam as in Mr. Nicholson's arrangement, be truly considered as "compound engines"? Two answers may be given to this question, as may be seen from the two diagrams showing the steam admission and expansion, *Fig. 1* and *Fig. 2*. If the admission of steam in

the first cylinder is for *less* than half-stroke (see *Fig. 1*), then, as the second cylinder takes its supply of steam from the first during the period of expansion, the engine may be considered as truly a compound engine. But if, as in *Fig. 2*, the admission of steam in the first cylinder is for more than half-stroke, then both cylinders take the supply of steam from the boiler, and the engine cannot truly be considered as a compound engine.

Further research into the history of these early compound engines has not been successful, and the above gives, speaking generally, all that is known with certainty.

About the year 1860 a compound locomotive was proposed by Mr. E. Kemp, of the Glasgow and South-Western Railway, at Kilmarnock, from the designs of his brother, Mr. W. Kemp, of Gourlay & Co., Dundee. In this engine the cylinders were arranged with a high and low pressure on each side of the engine. Each high-pressure cylinder was divided into two single-acting cylinders with a common plunger, and between them a low-pressure cylinder, with piston fixed on the plunger, so that they together formed a tandem system, one for each side of the engine. A specially-designed double channel-valve served to effect a correct distribution of steam, giving boiler steam to the high-pressure cylinders, and exhaust-steam from them to the annular piston of the low-pressure cylinders. Mr. Kemp laid this design before Mr. B. Conner, of the Caledonian Railway, but apparently without result; eventually he took out a patent for the above arrangement of cylinders, and it has been used for marine engines.

After these early examples, the history of the compound locomotive becomes much easier to follow.

The Author proceeds to give descriptions of some of the examples of later types, with critical remarks, and the Paper is very completely illustrated, with three large plates showing the arrangements of all the early types, down to the compound locomotive by Mr. A. Mallet, of the Northern Railway of France, in 1875.

H. H. P. P.

Tugging-Strength of Railway-Couplings. By A. PULIN.

(Revue générale des Chemins de fer, September 1890, p. 135.)

On the Northern Railway of France, a falling weight of 535 kilograms, or 1,180 lbs., was employed for testing the tensional resistance of carriage screw-couplings to tugs or sudden stress, such as they are subjected to in the ordinary course of work. The height of each fall was measured, as well as the total elongation of the coupling after each fall. The trials were conducted in two ways: by commencing with a minimum height of fall, which was augmented at each fall; or by adopting a constant average fall. Table I shows the results of trials of a coupling:—

TABLE I.

Number of Trial.	Height of Fall.	Total Elongation.
No.	Inches.	Millimetres or Inches.
1	7·9	3
2	11·8	5
3	15·8	8
4	19·7	11
5	23·6	14
6	27·6	20
7	31·5	26
8	35·5	31
9	39·4	40
10	43·3	..

At the tenth stroke, the screw was broken across at the junction with the plain portion which carried the counterweight.

Such trials by tug or shock may supply very useful indications of the quality of the materials employed in the manufacture of couplings, and of the relative strength of the pieces of which they are composed.

D. K. C.

On Ropeways, with Notes on the Plomosas Line.

By B. MCINTYRE.

(Transactions of the Technical Society of the Pacific Coast, San Francisco, 1890, p. 113.)

The Author remarks that the system of transporting materials by means of wire ropeways has been thoroughly tested, the results proving that a well-constructed ropeway is as sure in its operation as an ordinary railway. It is specially adapted for the Pacific coast, where there are many valuable mining properties undeveloped on account of the ore being of too low a grade to be profitably worked on the spot by steam-power. By grinding these ores in a mill by water-power, which in many cases may be found within a few miles distance, these may often become valuable properties, and it is only a question of some means for transporting the ore, or, in some cases where water-power is not available, of providing fuel from some wooded district within reach. The Plomosas ropeway was constructed by the Author for the latter object, the upper terminal being placed 2 miles from the mines in a position where quantities of wood and charcoal were available such as would supply the mill for five years without going outside of a radius of half-a-mile from the terminal. A survey was made, from which a plate accompanying

2 B 2

the paper has been prepared, showing the profile of the ground. The spans between the guide-posts vary from 104 feet to 1,066 feet, and the total distance about 10,115 feet, the greatest difference in level being 3,575 feet, between the upper and lower terminals. Hewn timber only being available, most of the frames were constructed of it, round timber being but little used. The frames of the upper terminal, the details of which are given in Plate 2, were built of timber 8 inches square. The run of the carriage for taking up the slack of the rope was restricted to 54 feet, the counter-weight gear was at the lower terminal only, and the slack of the rope was taken up when the splices were renewed from time to time. At first the intermediate posts were single, but afterwards X frames were substituted in many places. The Author remarks that during three and a half years he had no occasion to tighten up any of the frame-bolts. A four-post tower was built for the counter-weight gear 24 feet high, the weight box being 5 feet square and 3 feet deep. The transport of the rope was a serious difficulty; it was transported in ten lengths, each 2,250 feet long, each length made up into seven coils with an intermediate length of 10 feet, and each coil loaded on the back of a mule; the whole train consisting of seventy mules in all, with three men to each seven mules. An accident (described in detail in the paper) caused some delay and the death of three mules. The rope used was $1\frac{3}{8}$ inch diameter steel plough-rope, made at the California wire-works of special steel from Germany, and gave a tensile strength of 300,000 lbs. A detailed description is also given of the way in which the rope was played out. The rope needs care and attention, and after trying Swedish tar mixed with boiled linseed oil, it was found that black West Virginia oil fed on to the rope by automatic lubricators was the most satisfactory, about three gallons per month being used. The cost of the work is given as follows:—

	£	s.	d.
Cost of construction of upper terminal	39	10	0
" " lower "	44	10	0
" " intermediate terminal	300	0	0
Sundries, stretching rope, etc.	52	0	0
Total cost of construction	436	0	0
Cost of ropeway material	3,168	0	0
Opening roads, etc.	373	0	0
Total for ropeway in working order	3,977	0	0

The comparative cost of wood delivered at the mill before and after the ropeway was made is as follows:—

	£
5,100 cords of wood delivered at mill before ropeway	12,670
5,900 cords delivered by ropeway	3,392
Saving	9,278

Other expenses saved are given in detail.

The Author states that six years' experience has given him opportunities of studying the wear and tear of ropeways, and he finds that the slipping of the clips on the rope is one of the most fruitful sources of wear. He gives two woodcuts showing a clip devised to remedy the evil. The Paper is further illustrated by six plates showing the arrangement of the upper and lower terminals and other details.

H. H. P. P.

The Thermo-Siphon for Heating Railway-Carriages.

(Revue générale des Chemins de fer, September, 1890, p. 131.)

The thermo-siphon in use on the State Railways of France for warming the passenger carriages was designed by Mr. Gallet of Tours, to the instructions of Mr. Parent. The system consists of two multitubular boilers fixed beneath the frame of each carriage, one at each end, distributing hot water in multitubular structures, one in each compartment, placed transversely under the feet of the passengers. Each boiler has a central fire-box heated by peat charcoal contained in a basket, which can be put in place through a side doorway, the door of which can be securely fastened by a spring latch. Air is supplied to the furnace from below, through circular openings fitted with adjustable conical plugs, by means of which the supply may be regulated.

The foot-warmer in each compartment consists of a shallow chamber at each end, and an intermediate stratum of steel tubes, 10 millimetres, or 0·4 inch, in diameter inside, $\frac{1}{8}$ inch thick, fifteen in number. The hot water from the boiler rises into one of the chambers, passes through the tubes to the other chamber, and then back to the boiler, by natural circulation. A small cistern holds a reserve of water. The peat-charcoal fire burns slowly on the two movable grates on which it is placed red-hot, and is sufficient for eighteen hours' work consecutively. The products of combustion pass off at a temperature not exceeding 170°.

The weights and prices of the apparatus are as follows:—

	Weight.	Price.
	Lbs.	£.
1st class	1,430	56
2nd „	1,485	60
3rd „	1,540	64

D. K. C.

Filtering-Establishments for Municipal Water-Supplies.

By DR. FRÄNKEL and C. PIEFKE.

(Deutsche Vierteljahrsschrift fuer oeffentliche Gesundheitspflege, 1891.
p. 38.)

The Sixteenth Meeting of the German Public Health Society was held at Brunswick in September 1890.

The discussion was founded upon a series of theses placed before the meeting, which were as follows:—

I. All surface water must, before being used for drinking purposes, be freed from any possible sources of infection.

II. For this purpose, in all cases in which large volumes of water have to be dealt with, filtration through sand may be deemed to be the most practicable and perfect process under existing circumstances.

III. The sand-filter is not, as it has been generally assumed to be, thoroughly efficacious under all circumstances. Sand-filters are by no means capable of extracting all germs, but when intelligently worked it is possible by their means to confine the number of germs within very moderate limits.

IV. The following are the conditions for satisfactory working:—

(a) Good raw material (unfiltered water) so far as possible free from pollution.

(b) Moderate filtering speed.

(c) Regularity in the working of the filter.

(d) The rejection of the water supplied at the beginning of each filtering period.

Speaking upon these axioms Dr. Fränkel drew attention to the differing sources from which water was obtained, as surface-water, spring-water, &c. The grave consequences arising from various pollutions in water were pointed out, and the importance which has been given to bacteriological investigations by the germ theory of diseases, which for the first time afforded a clear insight into the nature of the organisms of infection. The knowledge of these germs rendered it imperative that at the outset all micro-organisms should be removed. In order to accomplish this effectually it would be necessary, in theory, to convert the water into an absolutely sterile fluid. The various means of doing this are enumerated, viz., by chemical treatment, the employment of heat, and by mechanical operations. The germs are small floating bodies, which may be entangled in the meshes of a filter and thus removed. Where large volumes of water have to be dealt with, this last process is the only one really practicable, and to James Simpson is due the credit of having devised in 1839 a method of clarifying water upon a manufacturing scale. Recent experiments have shown that, however carefully it may be used, the sand-filter is not absolutely "germ-tight." It depends largely for its impermeability upon a thin stratum of impurities and micro-

organisms entangled in its upper layers or deposited as a net-work upon its surface, and for this reason, until a considerable volume of water has been passed through the filter, leading to the formation of this preservative layer of organic matter, the water yielded is liable to contain many germs. This net-work, however, greatly retards the passage of the polluted liquid, and in the course of time opposes such obstacles to the action of the filter that the bed becomes worked dead, and filtration has to be discontinued in order that the filtering substance may be cleansed. The Author discussed, at some length, the conditions under which the filter-bed can be used successfully for the extraction of bacteria, and it is pointed out that the number of micro-organisms in the original liquid is of very slight importance, as it becomes possible to reduce that number in a good filter-bed to from fifty to two hundred germs per cubic centimetre, whether the original number in a like volume of water was a thousand or one hundred thousand germs. Attention was called to the very sensitive nature of a filter-bed when in working order, to the derangements caused by slight changes in the pressure or the working speed, and to the dangers attending the use of the water which first passes through a new bed, and which is always very rich in germs washed off the sand, &c.

As a natural consequence of these observations, the Author maintained that the unreliability of the filter points to the necessity of adopting in all cases, where it became possible to do so, an underground supply, obtained from deep wells or springs, and he believes that waters of this kind will ultimately have an important part to play.

Mr. Piefke, in continuing the debate, pointed out that advantage must be taken of the light which scientific knowledge was now shedding upon the subject of filtration, more especially when it involved the re-modelling of the plant or the amelioration of the processes. One of the matters of extreme importance was to render the speed of filtration independent of the fluctuations in the daily rate of consumption, which varies very considerably, as was shown by a graphic diagram. For this purpose the provision of a compensation-reservoir became a matter of urgency, and the mode of calculating the capacity of this reservoir was explained. Attention was directed to the superior quality of the water yielded by covered filter-beds to that obtained from open filter-basins, and the relative cost of construction of each was considered. Diagrams and tables are given to show the comparative purity of water from open and that from covered filters at different seasons, and the great advantage of freedom from ice in the winter-time, in the case of covered beds, is insisted upon.

In the subsequent discussion it was pointed out that the theses embody most of the conditions laid down in the Metropolis Water Act, 1852. Other speakers called attention to the various methods of freeing water from iron, to the results obtained at Kiel, and to the difficulty of obtaining conclusive evidence from experiments

conducted with filters of a small size. The congress ultimately declined to pass a formal vote upon the theses.

G. R. R.

The Water-Supply of Modern Rome. By E. HIEKE, of Milan.

(Gesundheits-Ingenieur, Jan. 1, 1891, pp. 14 *et seq.*)

Before dealing with the modern system of supply and distribution in Rome, the Author describes the arrangements by which in ancient times the water was brought into the city and was made available for the use of the inhabitants. During the first four centuries of its existence Rome possessed no public water-supply, but the citizens resorted to springs. As the population gradually became more dense, the public supply was augmented until 500 litres per head per diem, or according to some historians 1,000 litres of water per head daily, were available. To give an idea of what was implied by these figures, the Author states that the population of Rome in the year 725 after its foundation, B.C. 32, was one million, three hundred and thirty-six thousand, six hundred and eighty souls, or including the residents in the suburbs, who were also supplied from the aqueducts, a total of six millions of inhabitants. Much water was used in the public baths, which at the time of Rome's greatest prosperity, amounted to twenty-two warm and eight hundred and fifty-six cold baths, apart from eight hundred and eighty private baths. Some of the former were on a colossal scale; thus the baths of Diocletian would accommodate three thousand two hundred bathers at one time. Water-closets were in use, both in ancient Rome itself and in other rich provincial towns. According to Professor Spataro, the basins were sometimes formed of solid gold.

The first aqueduct was completed B.C. 312, and subsequently the number rose according to Frontinus to nine, according to Procopius to fourteen, or as P. Victor relates to twenty-four. The names and estimated yields of the chief aqueducts are given. The collecting reservoirs, into which the water was conducted, were called "castelli." Of these there were not less than two hundred and forty-seven in various parts of ancient Rome.

The supply was regulated by so-called "moduli," or the volume of water passing in a given time, at a known speed, through a pipe of a fixed section. The pipes used were of bronze; they were termed "calices," and, according to Frontinus, were 12 inches in length. These "moduli" of supply were not always of one fixed standard, and the various changes in unit are discussed. The water was conveyed from the castelli into the houses by means of lead or clay pipes, and the regulation of this distribution was entrusted to the official in charge of each reservoir, the "castellarius." After the fall of Rome the aqueducts were

destroyed, and the population sank in A.D. 1377 to seventeen thousand souls. Pope Adrian I. began the restoration of the ancient aqueducts, and in the fourteenth century the city was again supplied by the Aqua Vergine and the Aqua Felice. Pope Paul V. restored the Trajan aqueduct, renamed the Aqua Paola, the water of which is, however, not potable, and till the close of the sixth decade of the present century these three aqueducts supplied Rome, with a population at that time numbering two hundred and forty thousand inhabitants.

All ancient Authors were unanimous in praising the water of the Marcian aqueduct, and it occurred to Professor Camina that this supply might be restored. He died, however, before his project was completed, and Mr. Moraldi, an architect, subsequently worked out similar ideas, until at last an English company was incorporated for the purpose of recovering this supply; the so-called Società dell' Aqua Pia-Antica-Marcia. Before the works could be commenced it was necessary to ascertain the district from which the ancient supply had been obtained, and the data for this problem were very scanty, all traces of the aqueduct itself having vanished. The Author, on the basis of the testimony of the various ancient documents, on the known cost of execution, the price of slave labour, and the length of the structure, as described by ancient writers, gives the facts by which the vicinity of Lake St. Lucia in the Apennines, 43 kilometres, as the crow flies, from Rome, was finally indicated as the probable source. Mr. Campbell was thereupon instructed to examine the springs near the lake, and he found remains of ancient masonry in the so-called second "siren" (spring), which left little doubt that the water was formerly obtained from that spot. This siren is a group of seven springs, which were collected and brought into one reservoir. The conduit from thence to the city is 53·649 kilometres in length (33·3 miles). The water is first conveyed to an ancient reservoir at Tivoli, partly in masonry channels, partly in tunnels through the rocks. From Tivoli to Rome, a length of 26·84 kilometres (16·68 miles), the water passes under pressure through a cast-iron main, 600 millimetres in diameter (23·62 inches). This main has a total fall of 108 metres, and the water flows through it with a velocity of 1·3 metre per second. The whole time required for the passage of the water from its source to the city is from eight to ten hours. This water-system was inaugurated in the presence of Pope Pius IX., on September 10th, 1870, just ten days before the Italian army breached the walls of Rome close to the works. The four aqueducts, which now supply Rome, yield a daily volume of 232,400 cubic metres (about fifty-one million gallons), an amount relatively much in excess of the supply of any other modern city.

Details are given of the methods adopted by the company of measuring the supply, as also illustrations of the special taps with glass slide-valves that are employed. The unit of measurement is the "uncia," equivalent to 1 litre of water delivered in 4·27 seconds,

together with subdivisions of the same as low as the one-fortieth part, but the oncia of Marcian water differs from the oncia of the Aqua Vergine. The former represents a supply of 20,217 litres in twenty-four hours, and the latter a total of 40,434 litres per diem. The price of the water to householders is from six centessimi to fifteen centessimi per 1,000 litres (3·26*d.* to 8·15*d.* per one thousand gallons), but reductions are made for quantity, and traders pay 7 centessimi. The mode of house storage is explained by reference to diagrams. Chemical analyses and temperature observations on the water follow. In consequence of its composition the water causes considerable incrustations of calcic carbonate in pipes and cisterns.

G. R. R.

The Water-Supply of Hohenelbe. By — SCHMIED.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereins, 1890, p. 393.)

The town of Hohenelbe, in Bohemia, is situated at the foot of the range of mountains called the Riesen Gebirge, and the springs which furnish the supply of water are about $3\frac{1}{2}$ miles distant from the town. The quality of the water on analysis was found to be excellent, and the measured yield was 132,000 gallons daily—quite sufficient therefore for the present wants of a town containing 6000 inhabitants; but in case of further demand, other springs, some above and some below those under notice, could be drawn upon. The amount of water to be supplied is taken at $15\frac{1}{2}$ gallons per head per diem for a population of 10,000, the main therefore had to discharge 155,000 gallons a day. Taking the interior diameter of the pipe at $3\frac{1}{2}$ inches, the necessary head of pressure would be 403 feet, but as the difference of level between the water-surface of the highest spring and that of the main reservoir was 479 feet, this made the pressure too great for the lowest points of the main; consequently a shaft or well was interpolated in order to reduce the pressure at these points to $10\frac{1}{2}$ atmospheres, the pipes being tested to bear nearly double that pressure without injury. In crossing the Elbe a trench was dug 6 feet deep, in which the flanged pipes were laid, and the whole was then filled in with concrete up to $2\frac{1}{2}$ feet above the top of the pipe. It is stated that a few hours after this had been done a fresh flood occurred, which on its subsidence, exposed some parts of the pipe, and it was found that the concrete packing had already hardened. A distributing reservoir (which serves to regulate the fluctuations in the demand for water at different periods of the day) was built at a level of from 130 to 200 feet above the streets of the town, and this holds 55,000 gallons. It was blasted out of the clay slate-rock, and required the removal of 845 cubic yards of material. The walls are built

of hard quartz schist, and are covered with a $\frac{1}{2}$ -inch coating of cement. This reservoir is arched over, and on the top is a layer of earth $3\frac{1}{4}$ feet thick.

The whole network of pipes and branches is 9,537 yards long; the greatest diameter of pipe is 5 inches, the least $1\frac{1}{2}$ inch. There are fifty hydrants, and at present 110 house-service pipes.

W. H. E.

The New Filter-Beds of St. Petersburg compared with those of Warsaw. By EMIL SOKAL.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereins, 1890, p. 385.)

The St. Petersburg filter-beds were completed in 1889, and consist of two groups of seven and four beds each, with a total filtering area of nearly 6 acres. Warsaw at present has two groups of filter-beds, covering an area of nearly $6\frac{1}{2}$ acres, but this is only one-sixth of the total area to be provided. The St. Petersburg scheme is the property of a Company, and has been laid out with the utmost economy with a view to large profits, but the Warsaw works are the property of the City, which aims at possessing the finest water-supply scheme in Europe. The former supplies $32\frac{1}{2}$ million gallons daily for a population of 930,000, or 35 gallons per head per diem, while the latter in its present incomplete state supplies 10 gallons per head daily to a population of 500,000. The St. Petersburg works have 165 miles of delivery pipes, the Warsaw works $69\frac{1}{2}$ miles. The cost of water in the former is about 1d. per 100 gallons, and in the latter from $1\frac{1}{2}$ d. to $2\frac{1}{2}$ d. per 100 gallons, according to the size of the houses supplied and the status of the occupiers. Barracks and military buildings are supplied at half-price, and hospitals gratis. The Petersburg scheme returns a clear profit of £75,000 yearly, but the profits of the Warsaw scheme are expended by the municipality in the extension of the sewers.

In St. Petersburg the pumping and filtering-stations are close together; in Warsaw they are nearly 2 miles apart. As regards economy of working, Petersburg is the more favourably situated, as in Warsaw the water from the Vistula has to be lifted nearly 120 feet before reaching the filter-beds, but as regards cost of construction, the Warsaw beds at £3 7s. per square yard of filtering-surface compare most favourably with the Petersburg filters at £8 8s. per square yard, this great difference, it is stated, being due to the difficulty of the foundations, owing to the unfavourable condition of the soil of St. Petersburg. The Warsaw works have been in operation since 1886, and supply excellent water, the pressure between the filter-beds and the settling reservoir or clear-water basin being automatically regulated by a contrivance invented by Mr. Lindley, the chief engineer, which answers perfectly.

As regards the St. Petersburg works, it is stated that, though early to judge of their ultimate success, both official and private reports speak of faulty construction, but it is thought that this may be remedied without difficulty. A plan of the Petersburg groups of filters, showing the clear-water basins, and the feed-pipes from the Neva to the filter-beds, accompanies the Paper.

W. H. E.

The Deep Boring at Lucknow. By R. D. OLDHAM, Assoc. R.S.M.

(Records of the Geological Survey of India, 1890, p. 261.)

An experiment of great scientific importance has lately been carried out by the Municipality of Lucknow in putting down a bore-hole to a depth of 1,300 feet in search of an artesian water-supply. As a source of water-supply the boring is a failure, but as an experiment it has been conspicuously successful. It has shown that at a depth of 1,200 feet there is water under sufficient pressure to flow to the surface. It is probable that the succeeding water-bearing strata, which would be struck by a deeper well, would yield water at higher pressure, and in any case an abundant supply of pure water can be obtained by pumping. The Author publishes in full a section of the boring received from the President of the Municipal Board, and from this concludes that the bore-hole has nearly reached the base of the alluvium, the total thickness of which is probably less than 2,000 feet. The single bore-hole put down is insufficient to decide whether the head of water comes from the northern or from the southern margin of the plains. There is a greater effective head to the north, but a more tortuous passage for the underground water. To the south the effective head is less, but if the base of the alluvium has been nearly reached, there is a more direct passage for the water, and consequently less loss of head by friction. No decision has yet been arrived at with reference to making a second boring. A deeper trial is certainly warranted.

B. H. B.

Stand-Pipe at Malden, Massachusetts. By R. S. LEA.

(Transactions of the Canadian Society of Civil Engineers, January to June, 1890, p. 75.)

Malden is one of the numerous suburban towns of Boston, Mass., having a population of 20,000. The town has been extending up the slope of the hill, demanding high-service, for the supply of which a stand-pipe or tank of wrought-iron was constructed on the

top of Wales Mountain. The stand-pipe was more suitable than an ordinary reservoir, as the hill consisted of granite rock. It is 75 feet in diameter, 35 feet high, and the bottom of it stands 200 feet above the level of the city datum. The bottom is constructed of $\frac{5}{8}$ -inch plates, 10 feet long, 6 feet wide, riveted together with a single row of $\frac{3}{4}$ -inch rivets, pitched at $3\frac{1}{4}$ -inch centres. The plates at the periphery are of softer material than the others, to allow the formation of a 5-inch flange all round, to which the first row of side-plates are riveted. The bottom and first side-row of plates thus united were constructed at about 3 feet above the side, and were lowered into position on the foundation. This was prepared by laying a 4-inch stratum of Portland cement-mortar—1 of cement and 2 of sand. The material was put in dry, the moisture from the foundation and bottom being considered sufficient to set it. The bottom was lowered by means of screw-jacks.

The first or lowest course is connected to the flanged bottom-plates with a triple row of $\frac{1}{8}$ -inch rivets at $2\frac{1}{2}$ inches of pitch. The first and second courses are $\frac{3}{4}$ -inch plates, 6 feet by 10 feet; the vertical seams being triple-riveted with 5-inch lap, and the horizontal seams double-riveted with $3\frac{3}{4}$ -inch lap. The third and fourth courses are of $\frac{1}{2}$ -inch plates, 6 feet by 10 feet, and all the seams are double-riveted. The two topmost courses are of $\frac{5}{16}$ -inch plates, $5\frac{1}{2}$ feet by 10 feet, single-riveted, with $2\frac{3}{4}$ inches of lap. All the seams were caulked. In one of the lower side-plates, an oval manhole, 24 inches by 18 inches, is formed, with an iron cover on a seat of india-rubber.

At a height of 28 feet from the bottom, the stand-pipe is encircled by a balcony, supported by angle-bar brackets riveted to the tank, reached by a staircase.

The stand-pipe is covered by a slate roof having twelve sides supported by 12 iron trusses tied together at the centre by 1-inch iron rods. Between the trusses, the roof is supported by five rafters of channel-bar and angle-bar, across which, at $10\frac{1}{2}$ -inch centres, are placed the purlins, which are of tee-iron, 1 inch by $1\frac{1}{2}$ inch, weighing 6 lbs. per yard. The roof was required, by specification, to sustain the following vertical loads:—On the purlins, 45 lbs. per sloping square foot of roof-surface; on the rafters, 50 lbs. per square foot; on the trusses, 56 lbs. The tensional stress was not to exceed 12,000 lbs. per square inch; and the compressive stress, 10,000 lbs. The roof is surmounted by a galvanized-iron ventilator or cupola.

The inside of the stand-pipe received three coats of black asphalt varnish; and the outside three coats of white lead and linseed-oil.

The stand-pipe has a capacity of 1,180,000 gallons (American), and when it is full, the water-level stands 235 feet above the city datum.

The foundation cost \$1,500, or £312 10s.; the roof, \$5,000, or £1,041 10s.; the stairs, \$500, or £104. The total cost of the

structure complete, including the foundation, was \$22,440, or £4,675. It was built under the direction and according to the specifications of Mr. M. Tidd, of Boston.

D. K. C.

The Pollution of the Isar when the River is at the Lowest Level.

By PROF. VON PETTENKOFER.

(Deutsche Bauzeitung, Feb. 18, 1891, p. 81.)

In continuation of investigations carried out by Dr. v. Widenmayer into the pollution of the Isar and its tributaries between Munich and Freising, the Author undertook to examine into the state of the river as respects sewage pollution at the time when the water was at the lowest possible level. These conditions were obtained after the long drought during the present winter, when the Isar had been frozen over for many weeks continuously, and when it had become so shallow that every part of it was accessible. On January 21st, 1891, three samples of river-water were taken below Munich near to the bridge at Freising, and at the same time a sample was obtained above the town at Thalkirchen. All the samples were identical in appearance, the water was clear and colourless, and was quite devoid of taste and smell. The chemical analysis was restricted to the estimation of the residue on evaporation, which most clearly indicates the contents in fecal matters, while the amount of organic substances present was obtained by treatment with permanganate of potash. Each part of oxygen required involves, it may be assumed, the destruction of twenty parts of organic substances extant in the water. The following were the results of the analyses expressed in milligrams per litre:—

Derivation of Sample.	Residue on Evaporation.	Oxygen Required.
Thalkirchen	243·2	1·37
Freising right bank . .	248·0	1·56
„ left bank . .	256·8	1·66
„ above bridge .	252·4	1·71

The figures obtained by Dr. v. Widenmayer for the river during the highest summer-level and also for mean water-level will be seen from the following Table. The results are, as before, set forth in milligrams per litre.

Freising.		Residue on Evaporation.	Oxygen Required.
Flood time	{ June 28, 1890 .	194	2·16
	{ July 22, „	190	2·52
	August 2, „	206	2·15
	Mean . . .	197	2·28

The comparison between these results is very surprising, for it will be evident that during the summer floods, while the solid residue is smaller than in the winter, the amount of oxygen needed is much in excess of that required during the winter time, when the relative proportion of the excretal matter to the volume of river-water is vastly larger. The fecal polluting substances may be assumed to be equal in quantity both in summer and winter, and it would consequently be anticipated that when the river is at its lowest during the winter months, the amount of impurities present therein would greatly exceed the pollution of the river in the summer time, when the volume is much swollen, and when the proportion of river-water to sewage is so much larger. According to the gangings of Boecking, the discharge of the Isar is as follows :—

	per second.
At lowest level	50 cubic metres.
At mean „	189 „ „
At highest „	359 „ „

The Author considers that the solid residue is mainly derived from mineral matters contained in the water furnished by springs, the relative volume of this water being much larger in the winter, when there is no rainfall, than it is in the summer, when the river is swollen with melted snow. He states also that the amount of fecal matters now discharged into the Isar produces little permanent pollution, and that it would be possible to adopt a water-carriage system for Munich, without the provision of depositing tanks and filter-beds. It is a fact, indeed, that the water is much more free from pollution when the river is low than it is when it is in flood. The salt used to thaw the tram-lines may, it is pointed out, give rise to much of the dissolved chlorine found in the river-water in the winter time. The Author shows that the two hundred and eighty thousand inhabitants of Munich could only raise the organic substances present in one litre of Isar water, at the abnormally low level of a discharge of only 40 cubic metres per second, by 7 milligrams. This amount would involve the use of 0·35 milligram of oxygen to neutralize it; whereas the organic matters present in the summer flood-water require, on an average, 2·28 milligrams of oxygen per litre, or over six times as much. In a similar way it

is shown that the solid residue can have nothing to do with excremental pollution, and the Author asserts that he retreats from his previously expressed opinion that the sewage of Munich would have an injurious effect on the Isar, and he believes that no evil results will ensue from the discharge of the raw sewage into the river. He undertakes on a future occasion to prove that the bacteriological investigations do not support the theories of the adversaries of the water-carriage system.

G. R. R.

A Lead Pipe pierced by the Larva of a Wood-wasp (Sirex gigas).

By K. HARTMANN.

(Gesundheits-Ingenieur, January 15, 1891, p. 49.)

By reference to illustrations, the injury is shown which was inflicted upon a lead pipe by an insect that was actually found with its head in the hole pierced by it. A workman employed by the firm of Naruhn and Petsch was called in to repair a defective pipe which had been injured on a previous occasion, as was reported, by a "nail-hole" occurring in a soldered joint. This time the worm causing the mischief was found *in situ*. The hole on the exterior of the pipe was of a rounded form, 7 millimetres long by 4 millimetres wide, and the penetration was through the entire thickness of the metal. By quotations from various publications it is shown that, though of rare occurrence, well authenticated instances of similar injuries by insects are on record.

G. R. R.

The Cleansing of Sewers. By EMIL SOKAL.

(Wochenschrift des oesterr. Ingenieur- und Architekten-Vereins, 1890, p. 333.)

This Paper contains a description of a contrivance invented by the Author for the purpose of clearing the sludge in the Warsaw sewers, where the fall is too slight to admit of its being removed by the ordinary means of flushing. Recently some 25 miles of new drains have been laid in Warsaw, but out of about 900 houses in the neighbourhood only 250 drain into them, the remainder are connected with the old drains of the city, which receive also the rubbish from the houses and the street sweepings, and occasionally are so blocked with deposit as to resist the ordinary flushing power, and manual labour has to be resorted to.

The fall of the new sewers is generally sufficient to keep the bottom clean by flushing only, but there are two or three places

where the fall is less than 1 in 1,000 and therefore require special arrangements. Warsaw also had a network of old wood and brick drains nearly three parts full of mud and deposit, which led straight to the River Vistula by the shortest cut. The new main sewer runs parallel to that river and is frequently crossed by these old drains. Connections with the new sewer were made at these crossing points, and although this arrangement undoubtedly improved the sanitary condition of the low-lying part of the city near the Vistula (for the points of discharge of the old drains into the river were closed, and the new sewer discharged at a point five miles lower down the river), at the same time it seriously affected the discharge of the new sewer.

At certain intervals dependent on the fall, flushing-gates are built in the sewer, similar to those constructed by Mr. Lindley in Frankfort and by Mr. Gordon in Stuttgart and Munich, and on the whole this arrangement answers its purpose completely, but in some places as before mentioned deposits are met with which resist the flushing power and necessitate removal by hand.

With a view to do away with this manual labour, the Author in 1889 (after an examination of the methods adopted under similar conditions in Munich, Zurich, Lausanne and Berlin), prepared the following simple contrivance. A wooden templet or mould fitted to the profile of the sewer, rests on a batten $1\frac{1}{2}$ inch thick, which is pointed at the end for the purpose of penetrating and loosening the sludge. The flushing sluice above the portion of the sewer to be cleaned is closed, and water allowed to accumulate. About 6 or 10 feet lower down the templet with pointed scraper is set up: the sluice is now opened and the scraper, which is under the control of a workman, moves on and clears the deposit. If this be very solid and hard, a small shutter in the templet is opened and water sufficient to thin it is admitted, or the scraper may be used more than once at the desired spot.

W. H. E.

The Cohen Furnace. By G. LEROUX.

(Mémoires de la Société des Ingénieurs Civils, Paris, September 1890, p. 462.)

The Cohen system of furnace comprises an inclined grate, at an angle of about 45° , an auxiliary foot grate for receiving clinker and ash, and a preliminary short grid at the upper end of the inclined grate, surmounted by a hopper, which is charged with the fuel to be delivered into the furnace. The uppermost grate receives the fuel from the hopper, and it can be moved with a rocking movement for the purpose of moving down the fuel, and regulating the feed. The bars of the foot-grate are in close contact for a part of their length, in order to prevent the passage of air at that place.

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At the level of the uppermost grate the upper part of the furnace is formed with a massive lintel of fire-brick, in front of which air is admitted for the combustion of the distilled gases, through an opening at each side. Air is also admitted for the same purpose from the front through the uppermost grate. A separate supply of air is admitted under the main grate through the fire-doors.

The special features of the Cohen furnace may be noted as : 1. The movability of the uppermost grate, whereby the rate of feed may be adjusted. 2. The power of regulating the production of steam. 3. The distinct supplies of air for the two phases of combustion of the distilled gases at the upper part, and the solid coke on the main grate.

The lengths of the grates are constant. The areas are varied by varying the width. The lengths are as follows:—

	Metre.	or	Inches.
Upper grate	0·25		9·85
Main "	1·00		39·40
Foot "	0·25		9·85
	<u>1·50</u>	<u>"</u>	<u>59·10</u>

For a width of 1 metre, the total grate-area is therefore $1\frac{1}{2}$ square metre, or 16·14 square feet.

A Cohen furnace at work at the Central Electric Station, Palais Royal, Paris, was tested with semi-bituminous coal, mostly small, for a period of six days consecutively. For each 24 hours the average quantity of coal consumed was 6,908 lbs., or 288 lbs. per hour, or 12·81 lbs. per hour per square foot of grate.

The total coal consumed per day by this and the ordinary furnaces together was 1,188 lbs.; but before the installation of the Cohen furnace a total of 1,351 lbs. was consumed, showing an economy of 163 lbs. per day by the introduction of the Cohen furnace.

On the premises of Messrs. Sordes, Huillard & Co., with logwood chips, containing 55 per cent. of moisture consumed in a Cohen furnace, 1·53 lb. of water was evaporated per lb. of fuel. In another trial with chestnut wood, containing 64 per cent. of moisture, supplemented by 5·19 per cent. of coal, 1·20 lb. of water was evaporated per lb. of fuel.

The communication is accompanied by an illustrative plate.

D. K. C.

The Moal Steam-Boiler. By J. FARCOT.

(Bulletin de la Société d'Encouragement, Paris, 1891, p. 22.)

This boiler, the invention of Mr. F. Le Moal, is designed for producing a considerable quantity of high-pressure steam, from a small extent of heating surface, with a limited weight and of minimum bulk. It is a flat, rectangular, shallow chamber, placed vertically; closed at the top and bottom with plates of semi-circular section riveted to the sides, and at the ends with two flat covers bolted on, and readily removable. The chamber is traversed horizontally by short flue-tubes placed very near together, by which the water is thoroughly divided for the reception of heat. A steam-reservoir is placed above the boiler, connected to it by three neckings riveted to the upper semicircular plate of the boiler. The plate is not cut out but only perforated, to act as a strainer to prevent priming into the reservoir, as well as to retain the strength of the piece. The boiler is built into a rectangular brick seating above the fire-grate. The burning gases rise on both sides of the boiler, and are partially diverted by a partition at one side through one-half of the flue-tubes to the other side of the boiler, whence they rejoin the gases there. The whole of the gases pass through the other half of the tubes, thence they pass by downward draught to the chimney.

A boiler of this class was submitted for trial in September, 1890. The heating-surface was 118 square feet. The fire-grate was about 3 feet square, making 9 square feet of grate, or over one-twelfth of the heating-surface. In the course of five hours' trial, a pressure of from 10 to 11 atmospheres was maintained, and 860 lbs. of briquettes was consumed, at the rate of 172 lbs. per hour, or 19.1 lbs. per square foot of grate; making about 4 per cent. of ash. Water was evaporated at the rate of 884 lbs. per hour, or 5.14 lbs. per lb. of fuel.

The weight of the apparatus is about 2,420 lbs., and it has a volume of about 20 cubic feet. For higher powers, two or more such chambers are ranged in the same furnace.

D. K. C.

Results of Comparative Trials made in the United States on Water-Tube Boilers. By Chief Engineer C. H. LORING.

(Journal of the American Society of Naval Engineers, 1890, p. 580.)

Three experiments on the evaporative power of the Thornycroft and Ward types of water-tube boiler are given, and the method of conducting the trials described. The feed-water was measured by

a Worthington water-meter carefully standardized by tests at different speeds; the record being continuous, it was possible to take the data of water-consumption at the same time as the coal and other measurements, every fifteen minutes.

The fuel used was Pocahontas coal of good average quality, that used in the trial of the Ward boiler being slightly the better; the analysis of the coal is not given.

	Ward.	Thornycroft.
Grate surface, square feet	53	38
Heating surface, square feet	2,473	2,451
Ratio of H.S. to G.S.	46·67	64·5
Weight of empty boiler in tons	11·84	9
Weight of boiler in steaming condition in tons	13·85	11
Duration of trial in hours	12	11·5
Air-pressure in inches of water	2	3
Feed-temperature	50·4	58
Steam-pressure above atmosphere	160	250
Coal per hour per square foot of grate	55·05	40·23
Refuse per cent.	4·84	7·53
Moisture per cent.	12·48	3·89
Apparent evaporation from temperature of feed at temperature of steam per pound of coal . . . }	6·60	7·53
Same from and at 212°	8·04	9·19
Actual evaporation from temperature of feed at temperature of steam per pound of coal . . . }	6·00	7·23
Same from and at 212°	7·31	8·84
Actual evaporation from and at 212° per hour per square foot of H.S. . . . }	8·62	5·51
I.H.P. per 100 square feet of H.S. on basis of 20 lbs. of water per hour from and at 212° . . . }	43·10	27·55
I.H.P. per ton of boiler and water on same basis . . .	76·98	61·38

The following abstract gives the result of trials of the Thornycroft boiler at different rates of combustion:—

Air-pressure in inches of water	0·0	0·5	3·0	4·0
Duration of test in hours	2·5	11·5	11·5	1·0
Temperature of feed	52°	58·5°	58°	52°
Steam-pressure above atmosphere	250	250	250	250
Coal per hour per square foot of grate-surface	7·58	24·12	40·23	66·32
Refuse per cent.	6·11	8·04	7·53	6·27
Moisture per cent.	8·09	2·11	3·89	6·68
Apparent evaporation from temperature of feed at temperature of steam per pound of coal . . . }	10·55	8·13	7·53	5·69
Same from and at 212°	12·95	9·93	9·19	6·98
Actual evaporation from temperature of feed at temperature of steam per pound of coal . . . }	9·69	7·96	7·23	5·30
Same from and at 212°	11·90	9·72	8·84	6·51

The Thornycroft boiler experimented upon was one of those

on the United States torpedo-boat "Cushing" built by Herreshoff; the stokers were ordinary navy firemen with little or no previous experience in the use of forced draught.

S. W. B.

Experiments on a Pair of Compound Steam Pumping-Engines at the Copenhagen Waterworks.—By F. OILGAARD.¹

At the Copenhagen Waterworks there are a considerable number of compound condensing pumping-engines of the beam type. The following experiments were made on a pair of engines of this type, coupled together on the same crank-shaft, and working four water-pumps, two from each beam. Each of them consists of high and low-pressure cylinders, the walls of which are jacketed with steam, but not the top covers. The dimensions of the engine are as follows:—

	Diameters.		Strokes.	
	Inches.	Feet.	Inches.	
High-pressure cylinder	19	3	8·6	
Low-pressure "	31	5	6	
Main water-pumps	20	4	7·3	

Two Cornish boilers furnished the steam used during the trials, which was supposed to contain 5 per cent. of priming water; the feed-water was measured into these boilers by a Kennedy water-meter. The water-pumps gave an efficiency of 98 per cent. of their contents.

The subjoined Table gives details of two sets of experiments, one with steam in the jackets, and one without. In those made without steam in the jackets it was not possible to run the engines faster. The jacket-water was carefully measured. When the jackets were on, the pressure in the jacket of the high-pressure cylinder was 40 lbs., in that of the low-pressure cylinder 37 lbs. For each lb. of steam condensed in the jackets, about 5 lbs. of steam were economized in the cylinders. It will be seen that there is a considerable gain in economy due to the jackets. The quantity of steam condensed in the high-pressure cylinder during admission was calculated at 28 per cent. of the total. The total expansion in both cylinders was about 10. It was reckoned that about 5 per cent. of the total heat was withdrawn from the walls of the cylinder, and carried off to waste into the condenser. The Table gives the chief points of interest in these experiments.

The Author is of opinion that it is important to jacket not only the high-, but the low-pressure cylinder with boiler-steam. He considers that these experiments prove the powerful influence

¹ The Danish original is in the library Inst. C.E.

exercised by the metal walls of the cylinder, as already strenuously maintained by Hirn, whose theories and experiments here receive full confirmation. The action of the jackets he summarizes as follows: When the jacket does not work, the walls withdraw heat from the steam during expansion in the low-pressure cylinder; when the jackets are used, they impart it. The heat thus taken away from the steam is wasted during the exhaust stroke. The quantity of heat which passes from the jacket into the steam is small, but it exerts a very favourable influence owing to the fact that the walls, which act as a reservoir to store up and impart this heat, yield it to the steam at the right time, that is, during expansion. If no jackets are used the heat given up by the walls to the steam escapes to waste into the condenser. The temperature of the steam-jacket should therefore be maintained as high as possible.

TABLE OF EXPERIMENTAL RESULTS WITH AND WITHOUT STEAM IN JACKETS.

	With Steam in Jackets.	Without Steam in Jackets.
Number of revolutions per minute	24	19
Mean boiler-pressure lbs.	53	54·3
Mean temperature of feed-water	72° Fahr.	74° Fahr.
Consumption of dry steam per I.H.P. per hour of water raised (jackets included) lbs.	22·7	28·5
Lbs. of steam (with 5 per cent. water) per lb. of Newcastle coal lbs.	7·57	7·48
Consumption of coal per I.H.P. per hour of water raised lbs.	6·3	8·0
I.H.P. for each engine	81·1	65·7
Efficiency of engine (proportion between work done in water raised and indicated work) per cent.	85·22	83·45
Consumption of dry steam per I.H.P. per hour (jackets included) lbs.	19·3	23·8
Work due to the high-pressure cylinder in per- centage of total	52½	60
Work due to the low-pressure cylinder in per- centage of total	47½	40
Proportion of consumption of steam in the jackets to total per cent.	6·25	..
Condensation of steam in the cylinder during admission per cent.	28	40·4

In the original Paper an outline drawing of the engine, and copies of the indicator diagrams are given.

B. D.

By Passed Assistant Engineer A. B. CANAGA, U.S. Navy.

The Author finds graphically the path of the centre of gravity of the connecting-rod, and its velocity at all parts of the path. The tendency of the rod to fly off at a tangent to its path is ever changing in amount, since the radius of curvature of the orbit and the velocity of motion along it are not constant.

Having found the mean radius of curvature, and the mean velocity of the centre of gravity, a diagram is constructed from which the weight of the counter-balance necessary to counteract the part of the centrifugal action of the connecting-rod which comes upon the crank-pin, can be determined.

Diagrams so made for an engine 6 inches in diameter, and 12 inches stroke, show that two-thirds of the weight of the rod acting on the crank-pin is to be balanced by a counter-weight, and the Author thinks that this will generally be found to be more nearly what is required than half the weight of rod, as recommended by some text-books.

S W. B

(Transactions of the American Society of Mechanical Engineers, 1890, p. 1028.)

Experiments made for the purpose of determining the effective areas of screws are described, and the results are said to confirm the statement in Rankine's "Shipbuilding," p. 89, that, "The effective area is the sectional area of the stream of water laid hold of by the propeller, and is generally if not always greater than the actual area in a ratio which, in good ordinary examples is 1.2 or thereabouts, and is sometimes as high as 1.4."

The ratio of the effective-to the actual disk-area of the screws experimented upon was found to be as follows:—

Tug-boat with ordinary true-pitch screw	1.42
" " screw having blades projecting backwards	0.57
Ferry-boat "Bergen" with) at speed of 12.09 miles per hour	1.53
ordinary true-pitch screw) " " 13.4 " "	1.48
Steamer "Homer Ramsdell" with ordinary true-pitch screw	1.20

The low ratio in the case of the screw with blades thrown backwards is considered to be partly due to the fact that the blades

were exceptionally thick, and 25 per cent. less in area than those of the screw it replaced.

The dimensions of the screws and data from which the above results are derived are :—

	Bergen.	Tug-boat.		Homer Ramsdell.
		Ordinary screw.	Special screw.	
Diameter of screw in feet	8	8.5	8.5	11.1
Pitch	8.9	12.0	14.0	15.8
Velocity of the boat through the water in statute miles per hour	12.09 13.40	11.77	11.32	16.02
Velocity of slip in statute miles per hour	2.18 2.88	1.73	4.5	2.00
Total indicated horse-power	435.4 684.7	342.6	329.5	1063
Estimated effective horse-power	267.1 420.1	210.2	202.1	652

The effective horse-power is taken as equal to 0.613 I.H.P.

S. W. B.

A Pneumatic Accumulator for Hydraulic Machinery.

(Stahl und Eisen, vol. xi. 1891, p. 132.)

This arrangement, invented by Messrs. Prött and Seelhoff, in which the ordinary dead weight loading of the accumulator plunger is replaced by an air-buffer or compressor, is intended to prevent the danger due to the shock, at the change of stroke of heavily loaded accumulators when working at high speeds, and also to do away with the necessity of air-vessels on the pressure-mains, in which case the drawing over of air with the driving water is prevented, and a high hydraulic pressure may be produced by a much lower one of air.

As represented in the figures accompanying the description, the accumulator consists essentially of an air-cylinder and plunger placed above a water-cylinder and plunger, which are firmly connected by a framing of three vertical columns. The area of the upper plunger is ten times that of the lower one, so that when there is a pressure of 50 atmospheres in the air-vessel with the plunger at the bottom of the stroke, the pressure in the hydraulic cylinder will be 500 atmospheres when the plunger is lifted by water from the driving pumps. This pressure will of course go on increasing from the diminution of the space for the enclosed air as the piston rises, and conversely the pressure will diminish as the plunger falls, and water is drawn from the main by the machines at work. When this variation of pressure is not desired it may in some degree be prevented by making the body of the plunger hollow,

and using it as a reservoir, or the working cylinder may be connected with a series of air-reservoirs by a pipe passing through the top cover. In an accumulator built for the Bochum Steel Works six of these reservoirs, 28 inches in diameter and 13 feet high, are used, the air-plunger being 30 inches in diameter. These were calculated to give a difference of about 10 per cent. between the beginning and end of the stroke, but in reality the inequality is considerably less, and in very rapid work the pressure at the end of the stroke is even a little in excess of that at the beginning, a result due to the work done to the mass of the plunger. Fewer reservoirs will therefore suffice, and four are now considered to be a more convenient number. In some instances, however, a comparatively rapid rise or fall in working pressure may be desirable, and in such cases the air-vessels may be dispensed with, or a valve may be placed on the communicating pipe which opens when the pressures exceed the required maximum, and closes automatically when the plunger is at the top of the stroke. An arrangement whereby the end pressure is about half that at the beginning of the stroke is found to be a most convenient one.

The air in the cylinder being a constant quantity, moving only between it and the reservoirs, does not require renewal except in case of leakage through the packed joints of the plunger. This is prevented by keeping a layer of fluid, preferably oil, in the bottom of the cylinder which prevents the air from coming in contact with the packing. A further source of leakage, namely, though the body of the cast steel plunger is similarly prevented by a watertight wrought-iron lining, enclosing a small annular space which is filled up by the oil, and so keeps the air out of contact with the steel casting, which, however good it may be will always be somewhat permeable when pressures of 50 atmospheres and upwards are used. For very high pressures the wrought-iron air-cylinder may be protected by a similar oil casing against leakage, or fluid carbonic acid may be used instead of air. In the latter case glycerine must be substituted for oil as a hydraulic packing.

For cranes and other machines, where a comparatively low working pressure is sufficient, both air- and water-plungers may be made of the same diameter, so that no increase of pressure is obtained and the construction is somewhat simplified.

The largest accumulator of this kind constructed up to the present time, was started in July 1890 at the Bochum Steel Works, where it replaced one with a dead-weight load. The working pressure is 500 atmospheres. A similar one has since been constructed for the same company's branch establishment at Savona in Italy. A smaller one has also been at work for about a year and a half at the Wissem Steel Works, and two others of the kind represented in the accompanying plate are in construction, the larger one being intended to work a forging press, and the smaller one a lifting plant.

H. B.

On the Effect of Preservative Agents on Mine-Timber.

(Comptes-Rendus Mensuels de la Société de l'Industrie minière, November, 1890, p. 223.)

At Saint-Eloy in Auvergne, experiments on the effect of antiseptic agents on the duration of timber underground, have been carried on since 1879, upon the following description of timber:—

1. Oak from the Allier	35 years old.
2. " " Nièvre	27 "
3. Fir " Allier	22 "
4. Pine " "	20 "
5. Birch " "	5½ inches diameter.
6. Beech " "	" "
7. Poplar " "	" "

Method of treatment.—A stem of each description of wood was sawn into fifty-two disks, each $\frac{1}{4}$ -inch thick, the first and last of which were preserved in their natural condition above ground in the open air, but protected from damp, the remaining fifty were placed in a kind of cage in a damp level underground where the prevailing temperature was about 75° Fahrenheit. Two disks in each ten were left unprotected, while the remainder were subjected to treatment by the following substances:—

1. Sulphate of iron. } The strength of the solutions varied from 100 to 450 grams of the salt to 1 litre of water, and the
2. Sulphate of copper. } period of immersion from one hour to four days.
3. Chloride of zinc. }
4. Creasote, of the impure commercial kind immersed for similar periods.
5. Painted with three coats of the following oil colours: Pure white lead, white lead and yellow ochre, white lead and emerald green, red lead, white lead and lamp black, white lead and prussian blue.
6. Tar mineral and vegetable, immersion for five minutes.

After preparation, the samples were kept in the office at the surface for fifty days before exposing them underground, and they were subsequently examined at five different periods—namely, six months, one and a half year, two and a half years, three and a half years, and eight and a half years, the amount of alteration being laid down on a diagram which accompanies the Paper (Plate XXXIV.) From this it appears that the unprotected specimens were almost all destroyed in a comparatively short time—two and a half years to three and a half years—the observed order of durability being as follows:—

No. 1. Beech.	No. 5. Birch.
" 2. Oak No. 1.	" 6. Fir.
" 3. Poplar.	" 7. Pine.
" 4. Oak No. 2.	

The preservative effects of the different substances employed is given in the following table, which represents the increase in the duration of the protected specimens in terms of that of the unprotected ones, the latter being taken as unity.

—	Oak.	Oak.	Fir.	Pine.	Beech.	Birch.	Poplar.
	No. 1.	No. 2.					
Tar	28·7	24·6	263·5	87·5	105·4	26·2	150·5
Chloride of zinc	10·5	9·2	50·0	26·3	18·6	52·5	34·7
Oil Paint	6·1	10·2	31·7	54·5	25·0	12·1	2·5
Sulphate of copper	42·1	26·4	12·0	8·0	1·8	2·5	15·5
Sulphate of iron	18·0	12·5	12·1	4·2	4·7	3·5	2·9
Creasote	1·7	0·9	2·5	4·4	0·6	3·3	1·3

H. B.

The Darjiling Coal-field between the Lisu and Ramthi Rivers.

By P. N. BOSE, B.Sc.

(Records of the Geological Survey of India, vol. xxiii. 1890, p. 237.)

The Author describes, with the aid of a map, the economic geology of the Darjiling coal field. Though observed by Sir Joseph Hooker in 1849, this coal was neglected until 1873, when the completion of the Northern Bengal State Railway gave it a new importance. In that year Mr. F. R. Mallet reported against the workability of the deposit. The district has now been re-examined by the Author, and the discovery of thick seams of coking coal appeared so promising that it was considered advisable to ascertain their extent by excavations. All the rocks in the district have been greatly disturbed, and the crushing effect is specially noticeable in the shales and coal. The Author describes the various coal seams, giving a tabular summary of the principal ones, twenty-five in number, not less than 5 feet in thickness, omitting those which have been too highly altered by contact with igneous rock to be of value. With regard to quality, the coal may be classed under three heads:—

- A. Cakes strongly. Ash less than 16 per cent.
 B. Cakes strongly. Ash between 16 and 22 per cent.
 C. Does not cake. Ash between 22 and 33 per cent.

The average percentage of ash in coal of class A is 12·23, and that of fixed carbon 61·44. The Darjiling coal (average of eight assays of classes A and B) may be compared with the Raniganj coal (average of thirty-one assays) as follows:—

	Moisture and Volatile Matter.	Fixed Carbon.	Ash.
Darjiling	59·56	22·94	17·43
Raniganj	53·20	30·63	16·17

The utilization of the Darjiling coal depending largely upon its coking properties, practical tests were made in three kilns erected for the purpose. The coke produced was of good quality, containing but 0.62 per cent. of sulphur. The fact that so many of the outcrops have yielded good coke is the most hopeful feature about this coal-field. With regard to the quantity of coal available the Author confines his calculations to the central portion of the explored area. In this area of 97 acres, there is 5,592,645 tons of good coal almost immediately available. In this calculation, all coal with more than 22 per cent. of ash is neglected, the limit of workable depth is taken at 1000 feet, and the Author restricts himself to seams he has actually traced. For the whole area explored, which measures about 1 square mile, a fair estimate of the amount available is 20,000,000 tons, or 30,000,000 tons of coal if class C is also taken into account.

At the present time the difficulties of transport are considerable. The coal-field is advantageously situated with reference to mineral resources; important deposits of iron ore, of copper ore, of arsenic, and of tufaceous limestone occurring in the vicinity. Labour is scarce, as the district is scantily populated, and if the coal were to be worked, Nepalese labourers would have to be obtained. The cost of extraction of the coal would be less than in the Raniganj and Giridih districts, as, owing to its crushed condition, the coal can easily be dug out with picks. Extensive timbering would, however, probably be required. On account of its high dip, the coal has been brought to the surface, and consequently it will not be necessary to sink shafts through unproductive rocks.

B. H. B.

The Coal Seam of the Dore Ravine, Hazara.

By C. S. MIDDLEMISS, B.A.

(Records of the Geological Survey of India, 1890, p. 267.)

The Author gives two sections of this coal-seam, which has been erroneously described by the engineers in charge of the mines, as lying with the adjacent limestones in the form of an anticlinal arch cut through by river action. The order of the strata on the left side of the section is, however, not the same as on the right side. As a matter of fact, it is inverted. The difficulties implied by such a structure are fatal to the development of the coal-field. In working the coal on the north side of the river, the engineer must be prepared for the continuous increase in the dip of the bed, until within 300 feet from the surface it assumes an angle of 80°; whilst on the south side it will pass the vertical until it rests at 80°, dipping in the same direction as the coal on the north side. These circumstances will necessitate expensive working. The Author is, however, confident that large quantities of serviceable coal may be extracted from the outcrops.

B. H. B.

Experiments with Boiler-Plate Materials made at the Royal Technical College, Berlin. By — RUDELOFF, Chief-Assistant.

(Mittheilungen aus den koeniglichen technischen Versuchsanstalten zu Berlin, 1890, p. 289, 5 tables, 2 plates.)

PART II.¹

The specimens were cut from plates of welding iron, Thomas iron and Siemens-Martin iron, in the condition in which they were delivered, i.e., unannealed and tested in a Werder machine with the following mean results:—

I.—WITH GRAIN.

Material.	Modulus of Elasticity.	Limit of Elasticity.	Breaking Stress.	Elongation on		Reduction of Area.
				3·93 Ins.	1·96 Ins.	
Welding-iron .	Lbs. per Sq. In. 29,300,000	Tons per Sq. In. 14·50	Tons per Sq. In. 22·8	Per cent. 27·9	Per cent. 33·5	Per cent. 42·2
Thomas iron .	29,200,000	18·90	26·1	28·0	34·6	52·7
Siemens - Martin } iron	29,100,000	13·75	22·2	32·7	40·9	58·0
Siemens - Martin } iron	29,400,000	12·90	21·6	32·6	41·0	57·7

II.—ACROSS GRAIN.

Material.	Modulus of Elasticity.	Limit of Elasticity.	Breaking Stress.	Elongation on		Reduction of Area.
				3·93 Ins.	1·96 Ins.	
Welding-iron .	Lbs. per Sq. In. 29,400,000	Tons per Sq. In. 15·8	Tons per Sq. In. 21·6	Per cent. 17·2	Per cent. 19·9	Per cent. 24·7
Thomas iron .	29,200,000	18·1	25·7	25·8	33·8	49·2
Siemens - Martin } iron	28,900,000	13·6	22·3	28·2	37·7	53·9
Siemens - Martin } iron	29,000,000	13·25	21·8	30·7	39·2	57·2

The chemical tests are given in full, but do not show the same uniformity as the mechanical tests.

¹ Minutes of Proceedings Inst. C.E., vol. cii. p. 75.

The Author next carried out experiments to ascertain the effect of annealing and tempering the various materials with the following results.

The annealing makes very little difference, but the differences due to hardening are more noticeable. This difference, however, cannot be due to irregularity in hardening as the same effect is noticeable both with and across the grain. Comparing the means of the annealed specimens it is found that the breaking stress is lowered in pieces tested with the grain by 7 per cent. and across the grain by 5 per cent., while the extension was increased in both, but not uniformly.

Effect of hardening is most marked in the case of the Siemens-Martin iron, where the breaking stress is increased by 71 per cent. and the extension decreased by 55 per cent. For the Thomas iron the values are 54 per cent. and 45 per cent. respectively, and for the welding iron 34 per cent. and 45 per cent.

The fractures are minutely described and well illustrated by photographs.

In the punching tests in the annealed, hardened, red-hot and blue-hot conditions the welding-iron is less tough than the Thomas iron. All tests showed the injurious effect of working at a blue heat and hardening. In annealed and red-hot conditions all the specimens were bent double without fracture, whereas this was not the case with the blue-hot and hardened specimens.

The hot bending tests were carried out as follows: Specimens 1.57 inch and 2.36 inches broad 6 inches long were nicked in the centre with a chisel to a depth of about 0.07 inch, warmed over a charcoal fire and put into a lead bath. Right temperature was ascertained by the colour of the specimen, and then specimens were broken with a sledge-hammer as quickly as possible, and arranged in six groups, according to the fractures, without reference to the test numbers. The angles at fractures were not taken, but the Thomas iron bent very considerably less than the Siemens-Martin iron.

The cold bending tests were carried out by nicking one side with a chisel to the depth of about 0.07 inch, and then bending the specimens in a press until fracture occurred, in order to show the nature of the material by the fracture. Twenty-four specimens were broken with and across the grain, and arranged in eleven groups according to the fractures without reference to the test numbers. Photographs of fractures are appended to the Paper. The Thomas iron shows by a long way the smallest angle before fracture. In the red-hot tests there is a considerable falling off in the angle in the case of the Siemens-Martin iron, i.e., from 117° to 72° with the grain, and from 127° to 80° across the grain.

The Author then sums up in the following general conclusions:—

(1) In spite of the small percentage of phosphorus in the Siemens-Martin iron, the breaking stress was the same for annealed and unannealed conditions, whilst the effect in materials rich in carbon was more marked. According to the punching tests the

materials with high percentage of carbon and low percentage of phosphorus seem to be the toughest.

(2) The Thomas iron with approximately the same chemical composition as the Siemens-Martin iron, both being rich in carbon, shows in the annealed and unannealed condition a higher breaking stress and lower extension.

After hardening the effect on the breaking stress is the same for all materials.

(3) The effect of hardening according to the tension tests is least noticeable in the Thomas iron, and according to the punching tests it is more marked in the Thomas iron than in the Siemens-Martin iron.

(4) According to the hammer tests the working at a blue-heat has an injurious effect on all the materials, and according to the bending tests the Thomas iron is most influenced.

(5) From the above it appears that the Thomas iron ought not to be prohibited, as is the case, for use in boiler construction.

L. S. R.

Experiments on the Effect of Pickling and Rusting on the Strength of Iron. By A. LEDEBUR.

(Mittheilungen aus den Koeniglichen technischen Versuchsanstalten zu Berlin, 1890. Supplement I.)

These experiments have been undertaken in order to obtain further information concerning the brittleness imparted to iron by the action of acid in pickling and by atmospheric rusting, which had been previously announced by the Author and other investigators, and to determine whether dangerous deterioration was likely to ensue from such causes. The former experiments having mostly been made with wires it was considered most desirable to extend them to objects of larger section, such as rails, joists, and bars. That has accordingly been done with the following articles:—

1. Steel rails, the Prussian state line section from Krupp's.
2. Wrought-iron joists, $9\frac{1}{2} \times 3\frac{1}{2}$ inches, from Koenigshutte.
3. Wrought-iron round bars, 0.8 inth diameter, from Lanch-hammer.
4. Steel round bars, 0.8 inch diameter, from Peine.
- 5a. Wrought-iron wire, 2.2 millimetres diameter, from Felten and Guilleaume.
- 5b. Steel wire, 2.2 millimetres diameter, from Felten and Guilleaume.

These were treated in the following manner:—

- I. In the condition as delivered.
- II. After exposure for the purpose of rusting.

- III. Zincked (galvanized) and tested at once.
 IV. Galvanized and exposed for a time.
 V. Pickled in acid and immediately tested.
 VI. Pickled and kept for a time in a dry place.

The pickling was done with sulphuric acid diluted with water in the proportion of 1:100, and the metal was protected from direct attack by covering one end with melted zinc, the time of immersion being seventeen hours. In a few instances, in order to render the effect more visible, stronger acid 1:50 and a period of forty-one hours was used. The alteration due to rusting by two months' exposure was, except in a few instances, scarcely appreciable, and a continuance of the experiments for a longer period was likely to have led to a partial destruction of the material and to erroneous conclusions from the result.

The samples were tested transversely in tension and compression, and under a falling weight, three experiments being made on the same sample for each of the six conditions, and the tabulated results given at length fill twenty-four pages. The general conclusions given in the introductory report are as follows:—

1. *Bending tests with wrought-iron joists.*—The elastic properties, amount of bending, and limit of proportionality are substantially the same for all the conditions tested, the flexure for given loads being almost identical when the average results are compared. The maximum loads carried show differences, being highest in the natural conditions and lowest when freshly pickled. Rusting also produces a diminution in strength, which is more apparent in the galvanized than the ungalvanized pieces. In the few instances where the specimens were broken by the tests, the diminution in strength is very decided in the pickled and perceptible in the rusted specimens. The figures for these are:—

Conditions.	I.	II.	IV.	V.	VI.
—	Tons.	Tons.	Tons.	Tons.	Tons.
Breaking-strain	35	33·9	32·7	29·6	30

Bending-tests with steel rails.—The length between the supports was 1 metre; none of the specimens were broken. The average values from the results show that neither elastic nor ultimate strength are affected by any of the methods of treatment; the rusted specimens, whether galvanized or not, giving rather the highest figures. This may possibly be due to the chemical composition, which is as follows:—

Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.	Copper.
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
0·25	0·21	0·47	0·10	0·06	0·08

A very marked difference was observed in the behaviour of the pickled specimens, those of wrought-iron, even after immersion for several hours in lime-water to remove all traces of free acid, gave

off a strong smelling gas, probably a hydro-carbon compound, for several hours, while those of steel were perfectly odourless. This seems to show that acid sets up chemical changes in wrought-iron that it is not competent to produce in steel.

Tensile-tests with round steel and iron bars.—Neither ultimate nor elastic limit was sensibly altered by any method of treatment under the conditions of the experiments; but it is considered that differences might have been produced had the action been longer continued.

Tensile- and bending-tests on wires.—The strength of ungalvanized wire, both of iron and steel, is diminished by rusting. Galvanizing diminishes the absolute tenacity, but increases the proportion of elongation. The elastic limit and ultimate tensile strength observed for the different conditions were:—

—	I.	II.	III.	IV.	V.	VI.
<i>Iron.</i>						
Elastic (kilograms per millimetre) .	51·9	42·5	45·1	50·2	..	..
Ultimate (kilograms per millimetre) .	55·0	50·6	52·4	52·6	55·8	57·1
Elongation (per cent.)	4	3·3	15·1	13·5	5·5	5·0
Bends	12	10	11	9	7	11
<i>Steel.</i>						
Elastic	109·1	107·7	103·9	103·9	109·1	114·3
Ultimate	121·1	117·7	116·3	117·3	121·7	121·0
Elongation	8·7	7·5	18·0	16·5	9·0	9·0
Bends	13	9	12	12	11	12

These results indicate that the diminution of flexibility in pickled and rusted wire is less than that obtained in previous experiments. This, however, is mainly due to the circumstances that in the latter the acid used was stronger, or the action if weak was allowed to continue for a much longer time.

Compression-tests with iron and steel.—These were applied to test-pieces 30 and 50 millimetres high. No very sensible differences due to treatment were observed, the diminution of height for successive equal increments of weight being about the same. The ultimate strength was not determined owing to the bending of the test-pieces and the limit of power in the machine, which was 100 tons. Under the impact of a weight, viz., 56·7 kilograms falling 1 metre, freshly pickled wrought-iron was bent about 10 per cent. more by the same number of blows than when in the state received from the works. This effect was obtained with the steel specimens. A supplementary series of bending and falling weight-tests was made upon bars about 48 millimetres square of steel of the following composition:—

Carbon. Per cent.	Silicon. Per cent.	Manganese. Per cent.	Phosphorus. Per cent.	Sulphur. Per cent.
0·51	0·75	1·42	0·09	0·094

both in the natural condition and after pickling with acid 1:50 for forty-one hours. There was no difference in the elastic limits under steady loading, but by impact the pickled specimens bent more readily after the fourth blow than the unprepared ones. The breaking-strain under either condition was sensibly diminished from 142.7 kilograms to 126.8 kilograms under steady load, and from 1643.5 net kilograms to 895.6 net kilograms total energy of blow to produce fracture by the falling weight. The diminution is not, however, as large as that observed by previous experiments, where the breaking strain was reduced from 169.5 kilograms to 102.5 kilograms by pickling. The latter results were, however, obtained with bars of smaller section—22 millimetres as against 48, and remained in the acid for nine days. The steel treated on the present occasion was also exceptionally rich in silicon, which no doubt added to its resisting power.

As regards chemical composition the susceptibility of iron to become brittle by pickling and rusting is least in cast-iron and silicon steel, and highest in wrought-iron, and, according to Bädcker, in high-carbon steel. Combined carbon appears to increase the action and silicon to diminish it. The influence of manganese in either direction has not as yet been determined.

H. B.

Test of Ores from Schemnitz and Altai at the Alsó Kapnik-bánya Smelting-Works. By KARL LASKE.

(Berg- und Huettenmaennische Zeitung, 1891, p. 33.)

To supplement the description of the Alsó Kapnik smelting-works, published 1889 and 1890,¹ the Author now gives the results of two trial lots of ore treated by the Bittansky process.

In consequence of the previous Papers on this subject containing such authentic proofs of the economy of this method numerous applications from home and foreign mines (including distant countries such as Transvaal and Australia) have been received for treatment of their ores. This has been permitted, and representatives are invited to study the operations. The results given below have been verified by actual sales of the metals extracted to the mint and other quarters. The following gentlemen were present during the whole of the process: Mr. V. Laske, Mr. E. von Bittansky, Mr. A. Maly, Mr. N. von Koksharof, and the manager and officials of the works.

I. TEST OF ORES FROM ALTAI.

The ores consist of iron and copper pyrites, zincblende, galena, quartz, and gauque, carrying small quantities of gold and silver.

¹ Berg- und Huettenmaennische Zeitung, 1889, pp. 413, and 1890, pp. 203.

The proportion of zincblende varies from 45·28 per cent., and in consequence smelting would not be an economical treatment for this ore, even if fuel were abundant and cheap in the neighbourhood of the mines, which it is not. The Bittansky process is therefore very suitable, with the exception perhaps that the zinc is not recovered, a previous hand-picking or dressing is advised to avoid this loss. The ore arrived in three parcels; the combined weight was 4 tons 1 cwt. 2 qrs. 26 lbs., consisting of 60 per cent. leaching material (metallic sulphides), and 39 per cent. of sulphide of zinc, and containing 1·89 lbs. of copper, 20·3 lbs. of lead 3 dwts. 7 grs. of silver bullion, and 1 dwt. 7 grs. of gold.

After mixing the ore was subjected to a preliminary roasting in a reverberatory furnace, as it contained too great a quantity of sulphides to enable a direct chlorinizing roasting in the Bode furnace (50 per cent. being the limit this furnace can cope with efficiently). This preliminary roasting completed, the patent process was gone through in the usual manner, with the result that 92·4 per cent. of the silver, 89 per cent. of the gold, 36 per cent. of the lead, and 100 per cent. of the copper contained in the ore was extracted.

The cost for roasting and leaching was 1s. 7d., that of smelting and refining the products 11·6d. per cwt.; total cost 2s. 6·6d. per cwt. In the year 1889 the cost of treatment of this class of ore was 3s. 4d. per cwt.

II. TESTING OF SCHEMNITZ ORES.

The ores were delivered in three parcels, viz :—

I. Silver slimes containing 21 per cent. of leaching material, 4·9 per cent. of sulphide of zinc, and 6 dwts. 12 grs. of silver bullion, and 1 dwt. of gold to the cwt. of ore.

II. Silver slimes containing 30 per cent. of leaching material, 5·1 per cent. of sulphide of zinc, and 4 dwts. of silver bullion, and 1 dwt. 8 grs. of gold to the cwt. of ore.

III. Silver ores containing no leaching material, 4·9 per cent. sulphide of zinc, 6 dwts. 8 grs. of silver bullion, and 6·8 grs. of gold to the cwt. of ore.

The whole consignment weighed 88 tons 14 cwt., and contained, on the average, 11 per cent. of leaching material, 4·9 per cent. sulphide of zinc, and 6 dwts. 8 grs. of silver bullion, and 12½ grs. of gold to the cwt. of ore.

In order to ensure the most perfect method for conducting the chlorinizing roasting, preliminary tests were made on small parcels of the ore, both in the Bode furnace and reverberatory furnace, the best and cheapest result was obtained in the reverberatory furnace with 9 per cent. of leaching material. The bulk test was therefore accordingly conducted with the excellent result, that the total loss of silver amounted to only 1·85 per cent., and that of gold to 24·17 per cent., while 125 lbs. of copper and 720 lbs. of lead were also extracted, which metals had not been taken into

account in the valuation of the ore on account of the insignificant quantity in which they existed. The cost (not counting the expenses of management) were for roasting and chlorinizing 11·88d., for leaching 6·96d., and for smelting and refining the products 9·36d. per cwt., or a total cost of 2s. 4·2d. per cwt.; to this must be added the value of the copper and lead, giving an equivalent of an additional 2·2d. per cwt.

The cost of treatment of these ores at Schemnitz is 6s. 3d. per cwt. There is, therefore, 2s. 4·2d. - 2·2d. + 1s. 2d. for management = 3s. 4d. against 6s. 3d., or a saving of 2s. 11d. per cwt.

H. L. L.

The New Chimney-Stack at the Halsbrueckner Works, Freiberg.

By O. HUEPPNER.

(Oesterreichische Zeitschrift fuer Berg- und Huettenwesen, vol. xxxix., 1891, p. 96.)¹

The new chimney at the Halsbrueckner smelting works, which was completed at the end of October 1889, and brought into use about six months later, is intended to carry away the deleterious gases from the calcining and blast furnaces and discharge them into the atmosphere at such a height above the ground to prevent any nuisance to the surrounding habitations, for which purpose a height of about 100 metres (324 feet) above the highest ground in the neighbourhood was determined to be sufficient. The selected site is on a hill overlooking the Mulde valley about 12 metres before the summit, and distant about 450 metres from the works, with which it is connected by a flue following the rise of the ground. The total height is 140 metres, the top being 200 metres above the level of the lower part of the works. The leading dimensions of the chimney, which is of circular section, are:—

Total height	140 metres
Height of base	9 "
Diameter of stack at top (inside) . .	2·5 "
" " at base " . .	5·25 "
Thickness of stack-wall at top . .	0·25 "
" " at base . .	1·50 "
Average thickness throughout . .	0·837 "
Bearing surface at base	31·8 square metres
Outside batter of stack	1 in 50
Bottom breadth of rectangular base .	10 metres
" " foundation pillar .	12 "

In the determination of the thickness of the walling the following data were assumed:—Wind pressure, 150 kilograms per

¹ This is an abstract of a longer illustrated description in "Jahrbuch fuer das Berg- und Huettenwesen im Koenigreiche Sachsen, 1890."

square metre effective upon one half of the complete surface projection; coefficient of stability, 4·3; and weight of the finished brickwork 2,000 kilograms per cubic metre. The corresponding pressures under the maximum wind effect are:—

	Kilos. per Square Centimetre.
On the stack and base	17
„ foundation	9
„ ground, solid rock	5·1

While the maximum pressures due to the load at rest are:—

	Kilos. per Square Centimetre.
On the bottom of the stack	11·3
„ „ base	6
„ „ ground	3·8

In order to keep the maximum loading within the limit adopted, 17 kilograms per square centimetre, it has been necessary to make the lower part of the stack up to within 94·3 metres of the top thicker than is required on the mere consideration of stability alone.

The total height of the stack is 131 metres, which is divided into twenty-six annular sections, each diminishing in thickness upwards by 5 centimetres in each section. The sections are of varying height, the thickness at the top of each one in ascending order from the base being as follows:—

Metres.	Metre.	Metres.	Metre.
At 3·1	1·50	At 68·9	0·85
„ 6·2	1·45	„ 81·5	0·80
„ 9·3	1·40	„ 89·8	0·75
„ 12·4	1·35	„ 94·1	0·70
„ 15·5	1·30	„ 98·4	0·65
„ 18·6	1·25	„ 102·7	0·60
„ 21·7	1·20	„ 106·7	0·55
„ 24·8	1·15	„ 110·7	0·50
„ 27·9	1·10	„ 114·7	0·45
„ 31·0	1·05	„ 118·7	0·40
„ 34·3	1·00	„ 122·7	0·35
„ 37·8	0·95	„ 126·7	0·30
„ 56·8	0·90	„ 131·0	0·25

The material used is a hard-burnt pressed brick from Ilse, near Sentenberg, having a mean specific gravity of 2·05, and a resistance to crushing of more than 400 kilograms per square centimetre, the absorptive capacity measured by the increase of weight by immersion in weak acid or water is from 4·5 to 4·8 per cent. The excellent character of this brick allowed the reduction of the upper section to the small dimension of 25 centimetres in accordance with the precedent of the Mechernich stack of 135 metres.

The standard composition adopted for the mortar was one part of cement, nine of Bohemian hydraulic lime, and twenty of

Dresden building sand, ail by volume. In the upper length of 90 metres the proportion of cement was doubled in order to hasten the work, and the last course at the top was increased to four parts. The entire outer surface of the stack was pointed with mortar made of equal parts of sand and cement.

In order to prevent the penetration of the brickwork by the chimney gases, the facing of the inside rings were tarred on one face by immersing them at one end for four hours in boiling tar, which was done at the works immediately after drawing them from the kiln. The inside pointing was done with a mixture of four parts of Dresden sand to one of infusorial earth boiled in tar and worked on hot.

The brickwork is further protected by iron rings of 70 by 12 millimetres section, put together in four segments whose distance from each other is taken at two-thirds of the diameter of the stack at the corresponding level, and that which has the effect of bringing them closer together as the height increases. The cap of the chimney is of cast-iron U section built up in sixteen segments, which enclose the top of the stack. The butt edges of the segments are provided with projecting lugs, which support cast-iron cappings covering the joints. By this arrangement the iron cap is made entirely independent of the brickwork, and is free to expand and contract without reference to the latter. Climbing irons are provided both inside and outside. The inner ones are in double series opposite to each other, and were used for supporting the bearers of the lift pulleys during the building. The outside irons are supplemented by safety staples placed 54 centimetres apart, which not only serve for protection in climbing, but as a support for the back while resting. Two 10-millimetre copper lightning-conductors are carried down the outside, each having its own copper earth-plate of 2 square metres surface at a distance of 90 metres from the bottom of the chimney. One of them is buried in damp ground, while the other is placed in a cistern through which a current of water is constantly flowing. At the top both are connected by an iron ring to the cast-iron cap, and one of them is further in conductive connection with each of the iron outside rings of the stack.

The work was carried out by contract by Mr. H. R. Heincke, of Chemnitz, the first course of the foundation having been laid on the 28th September, 1888. The rock, a compact gneiss, was dressed up by hand and levelled by a bed of concrete 10 centimetres thick, upon which the brickwork was begun. The foundation pillar and half the height of the base block, 650 metres, were finished in fifty-two days, the drying of the brickwork being accelerated by artificial drainages. In the spring of 1889 the work was resumed in April, and on the 4th of May the building of the stack was begun without the use of external scaffolding, a steam-lift with a portable engine being used as the height increased. The number of bricklayers at work was at first eight, afterwards six, and finally four, as the section diminished. In fine weather the work

was carried on at night with the aid of electric light, and in spite of several interruptions by rain and storms the work was finished by the placing of the cap on the 28th of October, 1890. In the construction, in addition to the iron armature, which weighs $15\frac{1}{2}$ tons, five hundred and forty truck-loads of 10 tons each of building materials were delivered. The total cost was about £6,500.

H. B.

A Method of treating Complex Silver Ores containing Zinc.

By W. WEST.

(Engineering and Mining Journal, New York, vol. li., 1891, p. 321.)

At Thomasville, in North Carolina, the Author, in 1889-90, treated several hundred tons of argentiferous lead ores containing blende and pyrites, by the following method:—

The ore was crushed, to pass a forty-mesh screen, and if containing more than 21 per cent. of zinc, pyrites was added to reduce it to that proportion. It was then roasted, and the sulphur gases, after being drawn through a coil of pipes cooled with water, were forced by a Root's blower through a charge of the roasted ore, placed in a tank with a false bottom, a jet of steam at low pressure being injected simultaneously with the sulphur dioxide gas. The result is the change of the zinc oxide to sulphite, and ultimately to sulphate, which may then be readily extracted by washing with water. It rarely happened that more than two-thirds of the zinc, 14 out of 21 per cent., was removed by the first washing, and a repetition of the operation was necessary by which the whole of the zinc oxidized in roasting was removed.

The roasting was done in a muffle-furnace of 5 tons capacity, and four tanks, 10 feet square and 40 inches deep, were required for the gassing process, which was continued for thirty-six to forty hours.

The extraction of the zinc sulphate was done in a second series of vats, as the action of the gas caused the charge to pack so closely that it was impossible to subject it to a second gassing until it had been opened out again. The residue of the extraction containing the lead and precious metals was dried upon a floor heated by the gases of the roasting furnace, and was then ready for the lead smelters.

The zinc in the sulphate solution was recovered by precipitating it as hydrated oxide with ammonia supplied in the form of gas from a still, and when washed, dried and heated, gave zinc oxide in a saleable form. The final solution was then returned to the still, and the ammonium sulphate was decomposed with caustic lime. The loss of ammonia was a little more than 3 per cent. of the weight of the zinc recovered.

The average returns obtained from the process were the full assay value of the gold and silver, 80 per cent. of the lead, and 70 per cent. of the zinc as oxide.

H. B.

Zinc-Ore Mining in Sweden.

(Oesterreichische Zeitschrift fuer Berg- und Huettengewesen, vol. xxxix, 1891, p. 106.)

The position of Sweden as a zinc-producing country is mainly due to the work of the Vielle Montagne Company, who shortly before 1860 purchased the Ämmeberg ore-deposits, and built large dressing-floors and a railway to navigable water for the export of the product. These mines are still the principal contributors to the total produce of the country—72 per cent. in 1889, the next place being held by the neighbouring Låggesta mines, which, after lying idle for several years, were reopened in 1887, and in 1889 produced nearly one-fifth of the quantity raised at Ämmeberg. The yield for the three years, 1887 to 1889, inclusive, was as follows:—

	1887.	1888.	1889.
	Tons.	Tons.	Tons.
Ämmeberg .	41679·5	42195·4	43009·0
Låggesta . .	561·0	3966·6	7784·0
Langfallsgruben	1789·7	1058·2	2760·4
Dannemora. .	1102·3	1567·7	2116·0
Rylshytte . .	..	730·3	1865·3
Kafveltorp . .	776·7	444·6	824·5
Sundry mines .	332·1	9·1	1021·8
	46241·3	49971·9	59381·0

As regards the yield of the ore of the total output of 126,883 tons at Ämmeberg during the years under review, 22,415 tons, or about 18 per cent., was lump blende, which required no dressing but only crushing and roasting. The remainder of the output, 82 per cent., or 102,922 tons, was mixed ore stuff, which by dressing gave 43,529 tons of smelting ore, or 1 ton of the latter to 2·37 tons of the former. In the same period 64,410 tons of ore were roasted, giving 59,504 tons of calcined ore for export. In the dressing-operations 5,533 tons of lead ore were saved as an accessory product, or about $4\frac{1}{2}$ per cent. of the weight of the zinc-ore treated.

H. B.

Stein's Concentrator. By C. BLOEMEKE.

(Berg- und Huettenmaennische Zeitung, 1891, p. 69.)

This is an invention of Mr. Stein, of Freiberg, and has been perfected and adapted to practical purposes by Mr. Bilharz.¹ It was first used at the new central dressing-works of the Himmelfahrt mines, near Freiberg. This machine differs from the older constructions described by Rittinger by its shaking revolving motion, and, unlike the newer American inventions, i.e., Frue vanner, Triumph Concentrator, &c., is adapted to separate and deliver from four to five grades of concentrates, or different products.

The apparatus, of which the Author gives a drawing, consists of a wooden frame, in which rollers are fixed, over and through which an endless rubber belt revolves. This belt is not inclined longitudinally, as with the Frue vanners and kindred machines, but slopes towards the side; lengthways it is horizontal. It is fed from the top right-hand corner (the belt revolves from right to left), and discharges over the whole length of the lower edge or side. Adjusting-screws are fitted, to enable the belt being inclined to the angle most suited for the material it has to treat. To ensure an even surface, and to avoid adhesion of the rubber to the rollers, narrow troughs, continuously filled with water, are fitted under the belt, which form a cushion, over which it glides. To prevent the belt from running askew on the rollers, small wooden pivots are fixed to the underside, which correspond and fit into slots on the rollers. A percussion motion is effected by an eccentric, thrusting the frame, with belt, &c., forward, while a spring reacts backwards, knocking the apparatus against a buffer. The number of percussions per minute are one hundred and fifty. The speed at which the belt travels is about $2\frac{1}{2}$ inches a second.

The pulp, being fed on to the belt at the upper corner, moves forward with it. The effect of the percussion is to speedily separate the particles contained in the pulp, which adhere to the rubber coating and are carried towards a perforated jet-pipe, placed diagonally across the table, from the left-hand lower corner to the right-hand upper edge, where the feed is charged. The jets of water play on and towards the advancing particles, and wash them according to their specific gravity, over the lower edge of the inclined belt. A receiving launder, divided into compartments to suit the circumstances, is placed immediately under the discharging side of the table. For greater convenience and facility of adjustment, sheet-iron boxes can be substituted for the launder.

The diagonal position of the jet-pipe naturally causes a loss of working surface on the belt, but this has been found to be unavoidable.

¹ Die Oesterreichische Zeitschrift, No. 19, 1890.

The usual length of belting is 8 feet $2\frac{1}{2}$ $\times$ 2 feet $5\frac{1}{2}$ wide. At Freiberg these machines yield the following different products:—

- (1) Tailings.
- (2) Iron pyrites and zinblendes.
- (3) Pure iron pyrites.
- (4) Arsenical pyrites and galena.
- (5) Pure galena.

The discharge-surface of the different products on the lower side of the belt varies, of course, with the class of material treated; the average has been found to be as under:—

- | | |
|--|---------------------------------|
| (1) Tailings, 2 feet $7\frac{1}{2}$ inches. | |
| (2) First intermediate product, 1 foot $7\frac{3}{4}$ inches | } 8 feet $2\frac{1}{2}$ inches. |
| (3) Second " " 1 " $7\frac{3}{4}$ " | |
| (4) Pure galena . . . 2 " $1\frac{1}{4}$ " | |

Among the principal places where these machines are in use, the Author mentions Ramsbeck, in Westphalia; Werlau, on the Rhein; Laurium, in Greece, and Muhlenbach, by Ehrenbreitstein.

The end, or final product of the Stein Concentrator, is in every case pure; the intermediate ones, which generally consist of galena and zinblendes, are re-treated on the same machines, when a perfect separation of the two minerals is effected.

The Author says this concentrator is one of the most perfect in existence for treating high-grade slimes. From a qualitative point of view, it does better work than any other known machine; its capacity, however, is not so great as the Linkenbach, or the revolving buddle. The Rittinger table is inferior to it, both in efficiency and capacity. At Freiberg the excess of work of this machine over the Rittinger table has been found to be 4.4 lbs. per minute.

From a labour-saving point of view it is economical, one man being able to attend to three or four machines with ease.

Experiments on galena and zinblendes slimes, with Frue vanners and kindred machines, have not given satisfactory results, and the Author considers the Stein Concentrator superior to these, apart from the facts that its first cost is less, it requires less power, it is more economical to keep in repair, and requires less foundation.

One disadvantage is that the belt is liable to pucker, if not of sufficient thickness; the Author recommends $\frac{1}{8}$ inch as the correct thickness.

For the treatment of large bodies of low-grade ores, the Author advises a combination of two or three of these machines with a Linkenbach buddle, which latter will partially dress the pulp and pass the intermediate products on to Stein's Concentrator for final separation.

H. L. L.

A New Gold-Coloured Alloy. By T. HELD.

(Dingler's Polytechnische Journal, vol. 279, 1891, p. 119.)

The Author has invented an alloy of copper and antimony in the proportion of 100 to 6 which is made by melting the copper, and when at the right heat adding the antimony; and when both are melted and intimately mixed, fluxing the mass in the crucible, with an addition of wood-ashes, magnesium and carbonate of lime, which has the effect of removing porosity and increasing the density of the metal when cast. The alloy can be rolled, forged, and soldered in the same manner as gold, which it very closely resembles when polished, the gold colour being unchanged, even after long exposure to ammonia and acid vapours in the atmosphere. It is also much stronger than gold. The cost of the alloy in the ingot is about 1s. per pound.

H. B.

The Influence of Hardening upon the Electrical Resistance of Steel. By H. LE CHATELIER.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxii., 1891, p. 40.)

Hardening of steel has been of course practised for ages, but the principles upon which the practice is based are still not well understood. The question is difficult, and the mere fact that the chemical composition, temperature, etc., of the material are known does not lead to an accurate perception of what occurs. For example, if a bar be cut into small portions, and these brought close together, the electrical conductivity and density are the same as in the original bar while the tenacity is zero. Without going to such an extreme case it may be said that all bodies are formed of aggregates of crystals, of which the form, size and polarity may vary infinitely. The internal changes appear in the grain of the fracture, and modify the properties of the material to a considerable extent.

The hardening of steel modifies both its chemical composition and its internal structure. These two results should be examined separately. Mr. Osmond used the variation in the condition of the contained carbon to designate the chemical state of the metal.

The Author believes it possible to arrive at more precise results by investigating the electrical resistance of the material.

Tests were made upon wires 0·0078 inch diameter, and 3·94 inches long. The following Table gives the resistance of the

metal in ohms reduced to the standard size of 39·37 inches in length and 0·0039 inch diameter, as well as the percentage of contained carbon.

Ohms, resistance	0·190	0·250	0·27	0·22
Percentage of carbon . . .	0·085	0·485	0·67	0·83

The influence of the initial temperature of heating is important. The increase in the electrical resistance of the hardened metal only begins at a certain well-defined temperature; it is sudden, and does not increase with a further rise of temperature.

The exact point at which this occurs varies slightly, according to whether the temperature is rising or falling, from the known fact of the inertia of the molecular changes, such as overheating, over-melting, over-saturation. The following Table gives the mean of the temperatures of the hardening with a rise and with a fall of temperature, as well as the resistance expressed as a function of its initial value previous to hardening:

Temperature, Fahrenheit . .	1,282°	1,373°	1,337°	1,355°
Resistance in ohms	1·13	1·18	1·55	1·60

In these tests uncertainty as to strength occurred at the same time as the increase of the electrical resistance. The temperature of hardening of steel is thus that of the transformation of carbon (1,346°). These results confirm the theories of hardening obtained by Mr. Osmond upon this most important point, that the positive hardening, that is, the hardening accompanied with weakness of the material, has the effect of preserving, at the ordinary temperature, the molecular condition of carburetted iron which is only normally stable above 1,346°. On the contrary, these results weaken his theories upon the secondary point that hardening would retain part of the iron in the β state, that is, in the molecular state stable above 1,560°. If this were so, hardening should give different results, according as slaking took place above or below 1,560°, which is not the case. Besides this, the magnetic conditions should be changed by hardening; but ferro-nickel and manganese steel, in which the existence of iron in the β state seems certain, are not at all magnetic when cold, while iron and ordinary steel are so when heated above 1,560°.

These tests prove that in mild steels hardening, although not producing weakness, yet hinders the transformation of carbon quite as completely as in hard steels.

Annealing Steel.—When steel is heated its electrical resistance decreases by a quantity which increases according as the temperature is higher, and the heating is more prolonged. There appears to be for each temperature a limit to this decrease which would be only attained after the lapse of an infinite time, but for all practical purposes the greater part of the annealing takes place in a very short time. The following Table gives the resistance of steel

No. 3 slaked off in water at 50°, and then annealed for a minute at increasing temperatures.

Temperatures . . .	50°	250°	400°	590°	725°	840°	1,020°
Resistances in ohms .	1.55	1.47	1.29	1.15	1.10	1.07	1.04

The Effect of Temperature of the Slaking-trough.—The results obtained in slaking steel in baths at an increasing temperature have been, so far as electrical resistance is concerned, similar to those obtained by slaking off at a low temperature, and then reheating to the temperature of the slaking-trough. In considering the change of resistance during the hardening, it must be remembered that the temperature of the specimen and of the fluid is quickly equalized with wires of 0.0078 inch diameter. Then the condition of the wire remains constant for a period varying from some seconds to several minutes, according to the temperature and to the quality of the steel, and the metal is completely hardened. Then the process of re-heating begins quickly and continues at a rate which falls rapidly. The phenomenon is similar to the freezing of water, the temperature of which has been lowered below the normal freezing point by a rapid cooling. The same retardation in the transformation is not noticeable in the ordinary method of annealing by re-heating.

The results collected in the following Table were obtained by slaking steel heated to a temperature between 1,272° and 1,652° in baths at variable temperatures, retaining it in the bath for one minute and then allowing it to cool down in the air.

	Ohms Resistance.			
	1.13	1.18	1.55	1.60
Cold water, mercury, and a freezing mixture	1.13	1.18	1.55	1.60
Boiling water	1.06	1.09	{1.09 1.55}	1.09
Nitrates of the alkalis, at 480°	1.08	1.15	1.55	1.40
" " 660°	1.02	1.07	{1.02 1.55}	1.17
" " 840°	1.02	1.01	1.01	1.03

Steel No. 3 gave in certain cases discordant results from the fact of the retardation in the annealing referred to above, and which varied from one test to another. The effect of slaking in boiling water is almost nothing, cooling takes place so slowly as to allow of the production of recalcrescence.

This first series of tests demonstrates the fact that by measuring the electric resistance of the metal, the state of the contained carbon may be ascertained and also to some extent the part of it which is transformed in steel which has been hardened. This method will be used by the Author in further research into the mechanical properties of steel.

E. R. D.

On the Electrical Resistance of Metals. By H. LE CHATELIER.

(Comptes Rendus de l'Académie des Sciences, Paris, vol. cxi., 1890, p. 454.)

This is a sequel to the Author's Paper on the "Influence of hardening upon the electrical resistance of steel," and is an application of the same method to a new series of metals and alloys.

Those metals which show no molecular changes before fusing have electrical resistances which vary directly with the temperature plus a constant, as is illustrated by the following examples.

RESISTANCE IN OHMS OF WIRES 0·0039 INCH DIAMETER.

Pt	0·140 + 0·000180 ($t + 32^\circ$)
Pt + 10 per cent. Rh	0·335 + 0·000195 ($t + 32^\circ$)
Cu	0·032 + 0·000055 ($t + 32^\circ$)
Cu + 10 per cent. Sn	0·150 + 0·000060 ($t + 32^\circ$)
Cu + 20 per cent. Ni	0·420 + 0·000060 ($t + 32^\circ$)
Ag	0·023 + 0·000058 ($t + 32^\circ$)

where t stands for the temperature in degrees Fahrenheit.

It will be seen that copper, silver and their alloys, have a coefficient for temperature almost identical and approximately 0·000060; while the coefficient for platinum and its alloys is three times as great.

Silver has an interesting peculiarity, for when heated in oxygen its curve for electrical resistance remained quite straight, its mechanical properties were not changed, and its melting point was found to be $1,733^\circ$, which is almost identical with that of $1,750^\circ$ given by Mr. Violle. When, on the other hand, it was heated in hydrogen all its properties were changed from the temperature of $1,200^\circ$, its resistance increased more rapidly than when in oxygen, and the metal after cooling showed great loss of strength; wires of 0·001 inch diameter could not be bent without breaking, and the melting point was lowered to $1,680^\circ$. The metal takes on a dull appearance similar to that of palladium obtained by deposition from its hydrate. These facts prove that silver at a red heat occludes hydrogen. The Author states that he believes that the quantity of hydrogen occluded is too small to form a definite chemical compound, and that the metal does not retain a measurable quantity of it after cooling.

A large number of the metals show like iron sudden molecular changes which occur at well-defined temperatures.

The electrical resistances then show at those temperatures sudden variations in their law of increase, but their absolute value does not change on passing a point where these changes occur, as is the case at the melting point. The Author then gives curves demonstrating these phenomena. The best result was obtained with an alloy of a composition, Cu 70, Ni 18, Fe 11. The temperatures

at which molecular changes occur in some of the specimens are as follows :—

Zinc	680°
Brass, with 38 per cent. of zinc	1,330°
Alloy Cu, Fe, Ni	1,270°

The Author has found by direct experiment that in brass the molecular change is accompanied by a considerable absorption of latent heat. Some alloys show progressive molecular changes which call to mind those observable in the chemical equilibrium of saline solutions such as those of the salts of chromium and of chloride of copper, &c. The transformation is not instantaneous, but takes place as a rule within a limited range of temperature, as may be seen with aluminium bronze, containing a small percentage of silicon where the change takes place between 1,020° and 1,200°. The metal should be hardened above the latter temperature. German-silver and the alloys of copper and nickel show this peculiarity to a marked extent; when these alloys are heated their resistance decreases considerably from 570° to 930°, and in order to observe the result a specimen must be taken which has been annealed and cooled very slowly. In the case of German silver, in order to avoid almost complete hardening it is necessary to allow several hours for the cooling down from 930° to 570°. The presence of small quantities of foreign matter seems also to hinder the transformation; the amount of the change seems also to vary considerably with different specimens, and may be entirely absent, as is the case with the specimen of copper containing 20 per cent. of nickel, the resistance of which was given above. The following figures relate to three specimens chosen out of a dozen which were tested :—

	Temperatures.						
	32°	390°	570°	750°	930°	1,290°	1,650°
Cu 50 . .	0·465	0·480	0·505	0·520	0·518	0·530	0·552
Ni 24 . .	0·495	0·513	0·527	0·525	0·518	0·530	0·552
Zn 25 . .	0·514	0·527	0·537	0·525	0·518	0·530	0·552
Cu 66 . .	0·285	0·308	0·320	0·330	0·338	0·352	0·390
Ni 11 . .							
Zn 22 . .							
Cu 81 . .	0·485	0·497	0·500	0·492	0·475	0·473	0·492
Ni 18 . .							

The first of these alloys gave the best marked transformation. The three series of readings were taken during the heating of specimens which had been cooled at different rates, and which were therefore hardened to different degrees.

These tests show the cause of the well-known effect that standard resistance coils of German silver do not remain constant for an

indefinite time, and why their resistance increases. This effect arises from the fact that the wires employed are always partially hardened and gradually become annealed spontaneously from the effect of slight variations in temperature, of mechanical forces, or of the lapse of time. A similar spontaneous annealing is observable with hardened steel wires, which shows itself by a change of the resistance in an opposite direction.

The Author gives in the last Table the results obtained with specimens of alloys of iron and nickel. Some of them show different resistances in heating, and in cooling, that is to say, the changes produced by raising the temperature are not immediately reversible; the changes are only observable on the return when the temperature is at about the same as that of the surrounding air.

Percentage of Nickel.	—	Temperatures.						Transformation Points.
		32°	390°	750°	1,110°	1,470°	1,830°	
5	Rising .	0.36	0.45	0.59	0.90	1.38	1.50	1,250
	Falling .	0.36	0.54	0.77	1.35	1.45	1.50	1,530
25	Rising .	0.98	1.15	1.30	1.42	1.51	1.55	Nil.
	Falling .	0.98	0.81	1.10	1.42	1.51	1.55	1,020
35	(Rising and falling .)	0.59	0.84	1.04	1.10	1.13	1.18	750
50	(Rising and falling .)	0.46	0.80	1.14	1.28	1.32	1.36	860

It will be seen that at temperatures above that of transformation iron, nickel and their alloys exhibit a law of change for the electrical resistance which is similar to that of platinum and its alloys, while at lower temperatures, on the contrary, the law of change is infinitely more rapid.

E. R. D.

On the Changes in Resistance of Bodies under Different Electrical Conditions. By E. BRANLY.

(Comptes Rendus de l'Académie des Sciences, Paris, 1891, vol. cxii., p. 90.)

The Author read a Paper before the French Academy of Sciences upon the changes in conduction of bodies under varying electrical conditions. In a certain number of tests he used as a conductor a very thin plate of copper coated in certain cases with a little tin and stretched upon a rectangular plate of unpolished glass or of ebonite of about 2.75 inches in length, and 0.78 inch in width. The resistance of this sheet of copper, which was polished with a burnisher varied from a few ohms up to several millions for the

same weight of metal. The electrical circuit was made by means of two narrow strips of copper parallel to the short sides of the rectangular plate, and forming good contact with it by means of screws. When the two copper strips were raised the plate was cut out of the circuit. The Author also used as conductors fine metallic filings of iron, aluminium, antimony, cadmium, bismuth, &c., which he sometimes mixed with insulating liquids. The filings were placed in a tube of glass or ebonite, and were held between two metal plates. When the electrical circuit, consisting of a Daniell cell, a galvanometer of high resistance, and the metallic conductor, consisting of the ebonite plate, and the sheet of copper, or of the tube containing the filings, was completed, only a very small current flowed; but there was a sudden diminution of the resistance which was proved by a large deviation of the galvanometer needle when one or more electric discharges were produced in the neighbourhood of the circuit. In order to produce these discharges a small Wimshurst influence machine may be used, with or without a condenser, or a Ruhmkorff coil. The action of the electrical discharge diminishes as the distance increases; but the Author observed it easily, and without taking any special precautions, at a distance of several yards. By using a Wheatstone bridge, he observed this action at a distance of 20 yards, although the machine producing the sparks was working in a room separated from the galvanometer and the bridge by three large apartments, and the noise of the sparks was not audible. The changes of resistance were considerable with the conductors described. They varied, for instance, from several millions of ohms to 2000, or even to 100, from 150,000 to 500 ohms, from 50 to 35, and so on. The diminution of resistance was not momentary, and sometimes it was found to remain for twenty-four hours. Another method of making the test was, by connecting the electrodes of a capillary electrometer to the two poles of a Daniell cell with a sulphate of cadmium solution. The displacement of mercury which takes place when the cell is short-circuited, only takes place very slowly when an ebonite plate, covered with a sheet of copper of high resistance, is inserted between one of the poles of the cell, and the corresponding electrode of the electrometer; but when sparks are produced by a machine, the mercury is rapidly thrown into the capillary tube owing to the sudden diminution in the resistance of the plate. An examination of the conditions necessary to produce these results leads to the following data:—

1. The circuit need not be closed to produce the result.

After testing some plates, and having found them to be of high resistance, the Author lifted the copper contact strips and thus insulated the plates completely during the time when the sparks passed; when the strips had been replaced, and the circuit closed through the Daniell cell and the galvanometer, it was seen that the effect had been produced although the diminution of resistance is more marked if the plate, while on open circuit, is still fastened to the conductors.

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2. The passage of an induced current in the body produces a similar effect to that of a spark at a distance. The Author then describes some of the apparatus used.

3. An induction-coil with two equal lengths of wire was used, a current is sent through the primary while the secondary forms part of a circuit containing the tube with filings and a galvanometer. Before closing the circuit a test is made to see that the current at make and break gives the same deviation on the galvanometer. The filings are then placed in the secondary circuit, and the primary opened and closed at regular intervals. The following Table shows how the two induced currents caused the resistance of the filings to vary:—

Zinc filings	1st closing,	1	1st opening,	18
"	2nd	64	2nd	100
"	3rd	146	3rd	140
Aluminium filings	1st	1	1st	5
"	2nd	40	2nd	47
"	3rd	59	3rd	81

These deviations were obtained with an induction coil without core. The results obtained with a core were almost identical.

4. When working with continuous currents the passage of a strong current lowers the resistance of the body for feeble currents. A circuit was used consisting of a battery, the body to be tested, and a galvanometer; the electromotive force of the battery used was 1 volt at first, then 100 volts, and then again 1 volt. The deviations of the galvanometer-needle for the currents produced by the electromotive force of 1 volt before and after the passage of the current produced by 100 volts, was as follows:—

	Before Passage.	After Passage.
1st plate of ebonite coated with copper	16	100
2nd " " "	0	15
Iron filings	1	500

Summing up, the Author states that in all these tests the use of ebonite plates covered with copper or mixtures of copper and tin was less satisfactory than the use of filings; with the plates he was unable to obtain the initial resistance of the body after the action of the spark or of the current, while with the tubes and filings the resistance could be brought back to its normal value by striking a few sharp blows on the support of the tube.

E. R. D.

A Simple Method of Dynamo-Design. By THORBURN REID.

(Electrical Engineer, New York, vol. xi., 1891, pp. 134, 160.)

The Author discusses first the formulas given by Kapp, and objects to them because in bringing in the constants required for

the practical evolution of the design, the form of the equation is changed from the simple relation between the "magneto-motive" force, and the magnetic resistance of the three component parts of the magnetic circuit (magnets, armature and air-space) into one in which this ratio is lost, and the engineer consequently works without a sufficiently intelligent grasp as to effect of each portion of his design.

The method advocated is as follows:—The saturation-curve of the cast- and wrought-iron employed in the manufacture is first obtained, either by furnishing samples to an electrical laboratory or by the engineer himself; and here the remark is made, that the iron from any given manufacturer is sufficiently constant in its magnetic qualities to allow of one set of curves being adopted for that. These curves, with that for air (for copper is stated to be practically the same), being plotted to a suitable scale, and in the units adopted for the mechanical execution of the design, serve to determine the number of ampere turns required for exciting the magnetic field; a specimen set of such curves is inserted in the Paper. Given, then, the length and cross-section of each of the three component parts of the magnetic circuit, and assuming a leakage coefficient for the magnetic lines (dependent on the form of the magnet, and for a horse-shoe usually about 1.3), the total number of lines per unit of area required to produce the electro-motive force are given, and entering the curves with this quantity, the whole process of determining the number of ampere turns required for each portion of the magnetic circuit is fully detailed. This method is applied to the calculation of these quantities for an Edison-Hopkinson machine, of which details were published in the London *Electrician* for 1886, p. 39, and the difference between the actual values and the calculated is only three per cent.

F. J.

Accumulators in Central Stations. By HERMANN MUELLER.

(*Elektrotechnische Zeitschrift*, 1891, p. 2.)

In this article the Author describes in detail and illustrates by diagrams various methods for using accumulators in connection with direct current dynamos in Central Electric-Light Stations. The first station equipped according to the Author's method was Barmen in 1887. The battery is placed in parallel with the dynamo, and is provided with a charging and a discharging switch so that by suitably manipulating these switches the dynamo current can be utilized partly for charging the battery and partly for direct lighting as long as the demand for current is small. At maximum demand the dynamo current is supplemented by the battery current. The Author next describes a modification of his method arranged for the three-wire system with two batteries and

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two dynamos, and finally another modification with only one dynamo (or group of dynamos coupled parallel) and two sets of batteries feeding a three-wire net-work. Special switches are employed by means of which the pressure at the station end of the feeders can be independently regulated in order to keep the pressure at the feeding points uniform throughout the district.

G. K.

Efficiency of the Transformer.

By CALVIN HUMPHREY and W. H. POWELL.

(Transactions of the American Institute of Electrical Engineers, 1890, p. 311.)

The Authors describe experiments made on a forty-light transformer, the method adopted being similar to that which was used by Prof. Ryan and Mr. Merritt in their investigation of a ten-light transformer submitted to the Institute in December of the previous year. The instantaneous values of current and electromotive force were obtained by a commutating device fixed to the spindle of the alternator. This consisted of a wooden disk with a contact pin at the periphery revolving with the shaft, and a second wooden disk, having a contact brush which could be set in different positions so as to collect the electromotive force existing at any instant. The electromotive force was measured on a quadrant electrometer to which a condenser was connected. Current measurements were made by the same apparatus by determining the potential difference between two points of a non-inductive resistance. The Authors give numerous diagrams showing the actual shape of current and electromotive force curves, and a diagram showing an efficiency curve computed from these curves. The efficiency at normal load is 96.2 per cent., and the "all-day efficiency" is 90 per cent.

G. K.

The Cost of Electric Street-Mains. By Dr. GUSTAV RASCH.

(Elektrotechnische Zeitschrift, 1890, p. 658.)

The Author bases his calculation on the formula: cost of cable = $aV + bL$, in which a and b are constants depending upon the price of copper, and the price and quality of the insulating material, whilst V represents the volume of the cable, and L its length. By means of this formula he obtains approximate estimates for the various arrangements of feeders and mains which may be adopted in any given case of distribution, the mains being calculated for an equal maximum drop in pressure, and the feeders for equal energy loss. Comparing first the three-wire with the

two-wire system, he finds that the total volume of copper in the former is 60 per cent. of the latter, whilst the length is 150 per cent. This refers to the mains, whilst in the feeders the volume is 27·6 per cent. of an equivalent two-wire feeder and the length 150 per cent., there being three wires instead of two. The differential current in the middle wire is assumed not to exceed 10 per cent. of the total current. For the four-wire system the Author finds the following figures of comparison with an equivalent two-wire system. Mains: volume, 46·6 per cent.; length, 200 per cent. Feeders: volume, 16 per cent.; length, 200 per cent. Similarly for the five-wire system. Mains: volume, 40 per cent.; length, 250 per cent. Feeders: volume, 9·4 per cent.; length, 250 per cent. A practical example is given to explain the application of these figures. The Author assumes that the feeders and mains for a certain area of distribution have been formed on the two-wire system. The question to be solved is how far can the total cost be reduced by adopting a multiple-wire system. The figures for the two-wire system are:—

Volume of mains, 1,500,000 cubic centimetres; length, 5,000 metres.
 „ feeders, 1,600,000 „ „ „ 10,000 „

The cost of the various systems is then found to be as follows:—

System.	Two.	Three.	Four.	Five wires.
Cost in £	5,775	3,695	3,685	3,935

In conclusion the Author points out that his method does not pretend to be more than a rough approximation to be used in working out preliminary estimates.

G. K.

The Verona Electric-Light Station. By WALTER MENG.

(Elektrotechnische Zeitschrift, 1891, p. 25.)

This station has been at work since last September, and, although unimportant as regards total capacity, the Author considers it interesting enough for description on account of certain details. The boilers and engines are of Italian make, the dynamos of German make. The engines are vertical compound tandem engines developing each 85 HP. at 265 revolutions per minute; each engine drives by belts two dynamos which feed a three-wire net-work. The belt speed is 4,500 feet per minute, or considerably more than customary, but the Author states that no difficulty has arisen from the high belt-speed. The distributing system is overhead, and the streets being too narrow to admit of the erection of posts, the wires are carried by iron brackets fastened to the houses at a height between the first- and second-floor windows.

The average length of each feeder is 4,000 feet and the average current in each feeder is 350 amperes. The wires are naked, and no stouter wire than 275 mils diameter has been used, as it was found impossible to properly strain heavier wire. The total length of net-work is about 26,000 feet and the total length of single wire erected is 380,000 feet. All junctions are made by means of fuse boxes. The cost of the street-mains amounted to 30s. per 16 candle-power lamp.

G. K.

Comparative Tests of an Electric Motor and a Steam-Locomotive.

By LINCOLN MOSS.

(Transactions of the American Society of Civil Engineers, vol. xxiii., 1890, p. 193.)

The tests described in this paper were made on the Manhattan Elevated Railway, New York, in February, 1889, on a section of road 1·76 mile long. The trial trains were made up of the electric or steam locomotive and empty cars, each weighing 29,500 lbs. At first two cars were attached, then three, and finally four. The generating-station for the electric service contained a steam-engine capable of developing 400 I. HP. and four 50 HP. dynamos; but the Author does not state the current or voltage. The positive conductor along the railway consisted of $\frac{5}{8}$ in. diameter, copper rods, bolted to the wooden guard timbers by insulated clamps. The insulation resistance is not given. The return circuit was through the rails. The motor was connected by steel spur-wheels with the rear axle, and the latter was geared with the front axle by coupling rods. The wheels were 48 in. diameter, and the maximum pull exerted by the electro-motor at the moment of starting was 4,500 lbs. The weight of the locomotive exceeded 10 tons. A Shaw hydraulic dynamometer was used to determine the pull on the draw-bar.

Diagrams are given, showing the profile of the line and the HP. exerted on the train, and indicated in the engine at the same moment. Indicator-cards were taken throughout the run at intervals of 16 seconds, and the nett HP. transmitted to the train was determined from the observed speed and pull on the draw-bar. The indicated power averaged 176·8 I. HP., and the average nett train-power 26·7 HP., making the average efficiency 15 per cent. Speed about 10 miles per hour. When a steam-locomotive was used, the average indicated power was 25·92 I. HP., and the average net train-HP. was 21·95 HP., making the efficiency 85 per cent. The speed was slightly lower.

The Author concludes the paper by a comparison of the working expenses of the two cases, and finds that electric propulsion, at the moderate speed of 9 or 10 miles per hour would cost 2·38, and at 15 miles per hour four times as much as haulage by steam-locomotives.

G. K.

The Heating of Naked Copper Wires by a Current.

By U. BARBIERI.

(Elektrotechnische Zeitschrift, 1891, p. 30.)

The Author gives an account of experiments carried out in the Munich Electrical Laboratory to determine the coefficient in the temperature formula c^2/r^3 (c being the current and r the radius of the wire) for copper wires of 20, 40, 60 and 80 mils diameter. A piece of the wire to be tested was firmly attached to the wall of the room at one of its ends, and the other end was led over a pulley and strained with a suspended weight of about one-tenth the breaking stress. A mirror fastened to the pulley in conjunction with a scale and telescope permitted an exact determination of the elongation of the wire when heated by a current, and the temperature was calculated from the observed elongation. The Author finds that the coefficient depends on the size of the wire and also to a certain extent on the current, but taking averages as regards the latter variations the following Table gives the coefficient for the different wires.

Diameter of wire in mils	20	40	60	80
Coefficient	0.018	0.024	0.030	0.036

The highest temperature reached in these experiments corresponded to a rise of 200° Centigrade over the temperature of the room.

G. K.

The Electrical Resistance of Gases in the Magnetic Field.

By A. WITZ.

(Journal de Physique, 1891, vol. x. p. 68.)

If a tube provided with suitable terminals and filled with a gas be placed in a magnetic field, the potential between its terminals, when excited by a Ruhmkorff coil, increases with the intensity of the field. The term resistance, as applied to such a tube, is hardly correct, as there is no fixed relation, as in ordinary conductors, between current and electromotive force, and the Author therefore gives in each series of experiments the value of electromotive force and current observed, the former by a spark micrometer, and the latter by a special galvanometer. The portion of the tube subjected to the magnetic field, is of considerable influence on this effect, but this again varies with the nature of the gas. Thus for air the maximum occurs opposite the negative pole, and is greater there than at the positive pole ;

while for bromine, chlorine, etc., it is just the opposite. If the line of magnetic force traverses the tube parallel to the length, the effect is almost nil. The effect also varies considerably with the pressure of the gas, thus at a pressure of three atmospheres the alteration in resistance is very small, while at a pressure of about $\frac{1}{100}$ of an atmosphere the resistance increased tenfold, showing that the magnetic field acts on the electric stream and not on the spark. The effect is ascribed to the change in the capacity, which modifies the state of vibration of the gaseous particles.

F. J.

The Petroleum and Inflammable Gas of the Trenton Limestone in Ohio and Indiana. By EDWARD ORTON.

(Eighth Annual Report U.S. Geological Survey, Part II., 1890, p. 483.)

In certain districts of Ohio and Indiana the Trenton limestone has been recently found to be one of the most important sources of petroleum and gas in the United States. The principal centres of development are, in Ohio, at Findlay, about 45 miles south of Toledo on Lake Erie, Lima, and Saint Mary's, near the western boundary of the State, and in Indiana, a district about 60 miles by 40 of an area of about 1,800 square miles, the centre of which is about 60 miles N.W. of Indianapolis. In both States the geological conditions are similar, the gas-field being limited to a high-lying area of the Trenton limestone which is nearly flat, forming a subterranean terrace about 300 to 350 feet below the sea-level, covering the districts in which the same limestone is at greater depth, being unproductive for gas though sometimes producing oil. The surface, which has a maximum elevation of about 400 feet above Lake Erie at a distance of 60 or 80 miles from it, is deeply covered with drift deposits, and the drainage being sluggish, swampy and marshy areas abound. The district was in early times known as the Black Swamp. At Findlay, where the gas has been most largely developed, about twenty wells were active in 1885, but of variable yield, some of the smaller ones falling below 200,000 cubic feet a day, while at the other end of the scale the Karg well, when measured in May, 1885, delivered from a 4-inch pipe a little more than 12,000,000 cubic feet per day, the volume being computed at 50° Fahrenheit. Similar measures made on five other wells showed a daily production from 1,159,000 to 3,318,000 from 2-inch pipes. The depth of the wells varies from about 1,000 to 1,100 feet from the surface, and the maximum or rock pressure when the gas is shut within the well is from 300 to 400 lbs. per square inch, or only about half of that observed in the great gas-wells of Pennsylvania, where from 750 to 950 lbs. has been observed. The open pressure, or that registered on a gauge held on the current of

escaping gas from a pipe of any size, is considerably less. The highest pressure noted in the casing pipe, $5\frac{1}{2}$ inch diameter, of any Ohio well is $6\frac{1}{2}$ lbs. per square inch; but this is rapidly increased when the area of the well is contracted. A well that gives 6 lbs. in the casing shows $20\frac{1}{2}$ lbs. when the gas is made to escape through a 4-inch pipe. The methods of determining the volume of gas escaping from a high-pressure well are due to Professor S. W. Robinson, who undertook his investigations for the Ohio Geological Survey, and worked them out upon the great wells of Findlay, and especially on the strongest of all, namely the Karg well. These methods are very simple and easy of application, the strongest of gas-wells, provided the gas is dry, can be measured by a single observation that need not occupy more than a few seconds. The appliance adopted where the pressure is moderate is the Pitot tube, the pressure being read in inches of water or mercury, and the velocity in feet per second found by the expression—

$$v = 83 \cdot 1 \sqrt{h},$$

h being the height of the water column in inches. The daily discharge is—

$$V = 86400 v a,$$

a being the area of the delivery-pipe in superficial feet.

In the larger wells a steam-gauge is used to read the pressure, and the velocity is computed by the formula for adiabatic flow where a gas flows from a receiver into a space outside with a relatively large fall of pressure. The mathematical discussion of the problem is given at length in Vol. vi. of the "Reports of the Geological Survey of Ohio," but not reproduced in the present Report. The numerical results are however exhibited in tables, in which the volumes are given for wells from 11·6 inches diameter for pressures from 0·1 inch of water to 60 lbs. per square inch. Where the flow is less than 1,000,000 cubic feet per day the velocity may be directly determined by an anemometer.

The gas from the different wells is remarkably uniform in composition in both States, the analysis varying between the following limits—

—	Minimum Per cent.	Maximum Per cent.
Hydrogen.	1·2	2·35
Marsh gas	92·67	94·16
Olefiant gas	0·15	0·49
Carbonic oxide	0·41	0·73
Carbonic acid	0·20	0·30
Oxygen	0·30	0·40
Nitrogen	2·80	3·82
Sulphuretted hydrogen .	0·15	0·21

Although employed both for lighting and heating, the chief value of this gas is for the latter purpose. Theoretically about 31,000 cubic feet are equal in calorific power to 1 ton of Pittsburg coal, but practically less than half this amount of gas will do the work done by 1 ton of coal. The chief drawback is in the sulphur compounds contained, which renders the gas offensive when diffused. This, however, is not an uncompensated disadvantage, as even the smallest leakage is immediately disclosed by the smell, and thus dangerous accumulations may to some extent be guarded against. The chief use is, however, in raising steam and in heating for iron and steel manufacture. At the Briggs Tool-works in Findlay the gas was first used for welding iron and steel in June, 1886, doubt having been previously felt as to the practicability of this application owing to the sulphur contained in the gas, but it has proved thoroughly adequate to the service.

A more important application of the gas is, however, in the manufacture of glass, for which it is so completely adapted that a great advantage is given to localities where it can be commanded. The principal seats of glass manufacture in Ohio are at Wheeling and Bellaire, and large sums have been expended in the search for gas near those places but without result. It is therefore either brought by pipe-lines to the works, or the latter are bodily transferred to the gas-fields. The first glass-works in Findlay was built by a Bellaire firm in 1886, and the fuel bill for the same scale of operations, which would have been £60 per month in the old location, was reduced to £40 per annum. Since that date six other glass-works, as well as three rolling mills, have been established.

In the Indiana gas-fields the conditions observed are similar to those prevailing in the Findlay district, the upper surface of the productive gas-rock lying from 65 feet above to 90 feet below the sea-level, or from 875 to 975 feet below the surface of the ground. When the rock is more than 100 feet below the sea-level the bore-holes almost invariably yield salt water. The essential condition for gas-production is that the rock should be porous, and this is only realized in those districts where the Trenton limestone, which is over the greater part of its area, is compact, and nearly pure carbonate of lime is converted into a dolomite, the change being accompanied by the development of a crystalline structure with large interstitial spaces. In the most productive wells the proportion of carbonate of magnesia in the rock varies from 37 to 43 per cent., and that of carbonate of lime from 52 to 56 per cent., while in the dry wells the former constituent is sometimes as little as 1 per cent., or even entirely absent, the well being a nearly pure limestone. In this cellular rock the gas and oil accumulates in the higher parts of the slightly undulating surface of the rock, these lighter substances being imprisoned by the pressure of salt-water in the lower portions of the bed. It is noticeable that this brine contains

a much larger proportion of calcium and magnesium chlorides than sea-water, and therefore that it represents an ancient bittern, or mother liquor remaining after the separation of salt by atmospheric evaporation.

A large number of wells have been drilled in the field in Indiana, the most important one being at Fairmont, which yielded 11,500,000 cubic feet in June, 1887; several others yielded from 1,000,000 to 5,000,000, and at a few points larger ones from 5,000,000 to 11,000,000 feet have been struck. The supply has been far in excess of any considerable demand, as the district is mainly an agricultural one, and the discoveries have led to sharp competition between the localities, most of the towns offering land for building free of charge, and also free fuel for the purpose of attracting population, and, in the words of the Author, a vandal-like waste has characterized the early exploitation of most of the subdivisions of the field. Numerous industries, including especially glass manufactories and rolling-mills, are, however, being brought into the more promising of the towns, and a rapid and substantial growth is going forward in many of them.

*The Lima Oil-field.*¹—This district, which the Author considers to be second only in productive power to the great Russian oil-field on the Caspian, is situated midway between the Indiana and Ohio gas-fields. As far as proved at present it consists of a tract 8 or 10 miles long and from 2 or 3 miles broad. The surface elevation averages from 850 to 900 feet, and the productive area is limited to a flat-lying terrace of Trenton limestone, between 375 and 390 feet below the sea-level, the dead-line, where only salt-water is found, being at 400 feet. The field is a very productive one, in fact the output has been restricted owing to a difficulty in disposing of the product; the highest daily yield is not far from 14,000 barrels. In July, 1887, the price obtained was only 15 cents ($7\frac{1}{2}d.$) per barrel of 40 gallons. In the North Baltimore field single wells have yielded as much as 5,000 gallons per day, while nearly one half of the wells in operation at that period gave 100 barrels or more.

The Trenton limestone oil is of dark colour, rather low in specific gravity, 0.31 to 0.42, and containing some sulphur compounds which make it rather offensive and difficult to refine. These drawbacks make it unsuited for competition with the purer oils from Pennsylvania as an illuminating material; but it is well suited for fuel. Four barrels of oil are considered equal in heating power to 1 ton of bituminous coal, and at the present price (15 cents. per barrel) it could scarcely be displaced by natural gas. An enormous stock of power vastly greater than that of the natural gas-fields is made available in the Trenton limestone oils.

H. B.

¹ The Lima oil is used as boiler fuel at the works of the Illinois Steel Company at South Chicago, whence it is conveyed by a pipe line 208 miles in length.—H.B.

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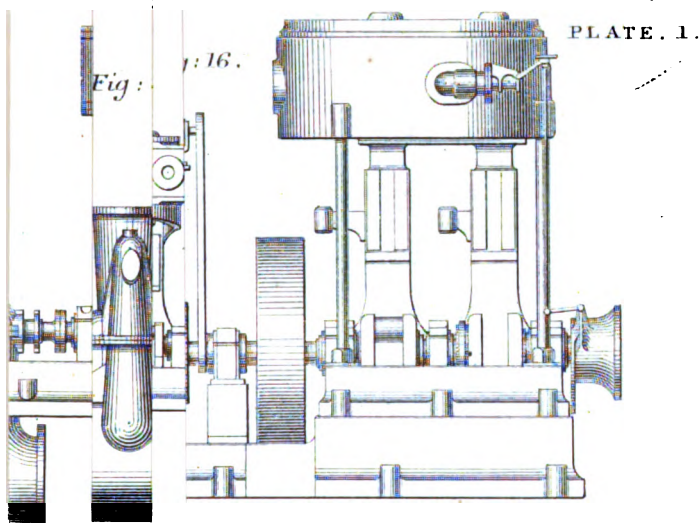


PLATE . 1 .

Fig:

16.

DYNAMO ENGINE .

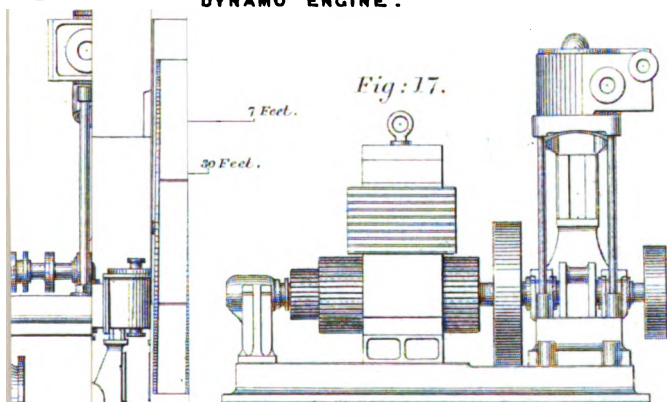


Fig: 17.

7 Feet.

30 Feet.

ORDINARY PASSENGERS AND CARGO STEAMER
DYNAMO ENGINE .

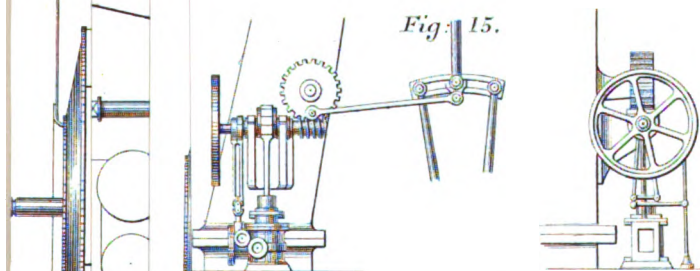


Fig: 15.

ROUNABOUT REVERSING ENGINE .

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