



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

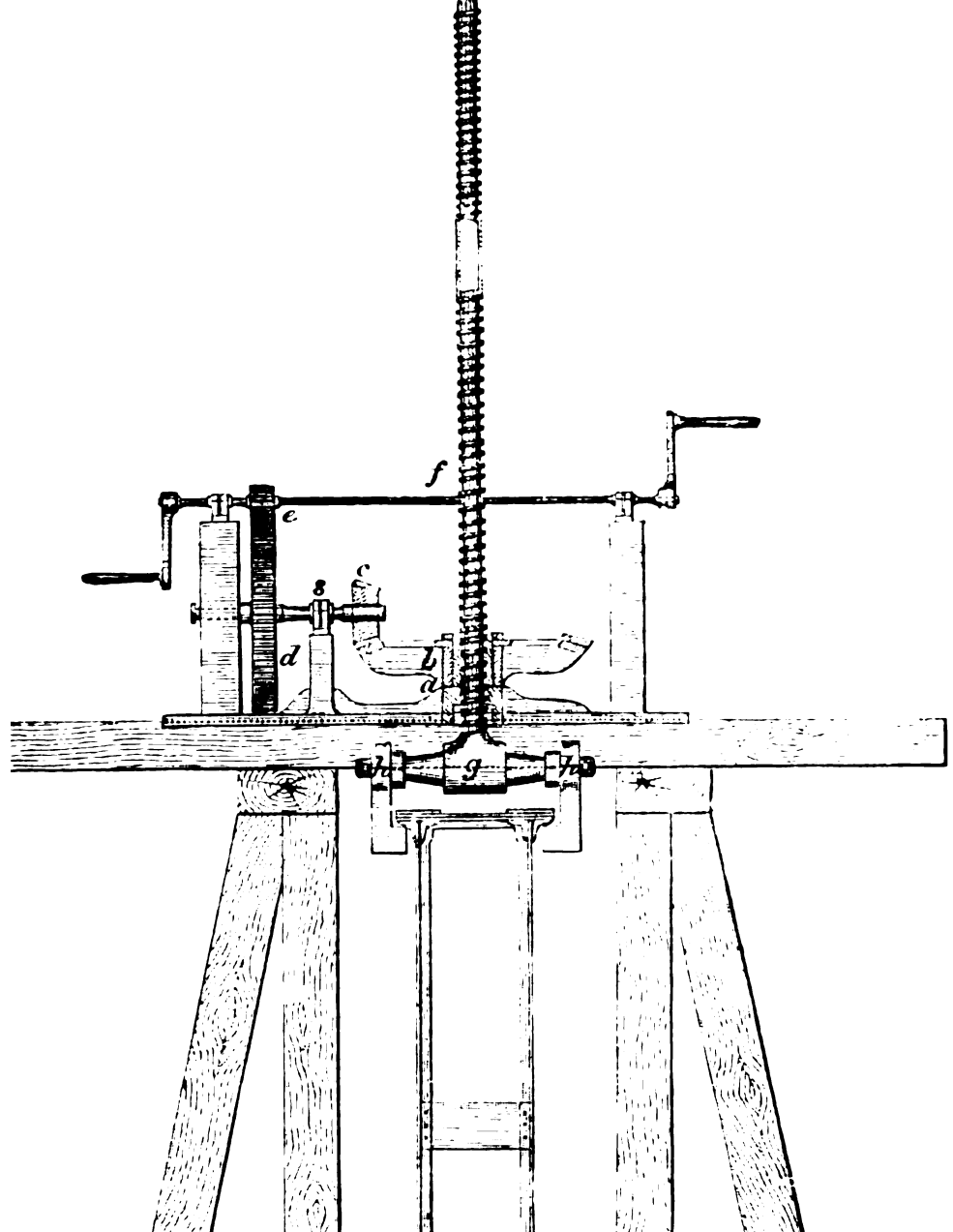
Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>



*Minutes of proceedings of
the Institution of Civil Engineers*

Institution of Civil Engineers (Great Britain)

D. VAN NOSTRAND
PUBLISHER & IMPORTER
Scientific Books,
NEW YORK.

Sci 1480.72

N5

Lawrence Scientific School.

ENGINEERING DEPARTMENT.

No.

SCIENCE CENTER LIBRARY

HARVARD COLLEGE
LIBRARY



MINUTES OF PROCEEDINGS
OF THE
INSTITUTION
OF
CIVIL ENGINEERS;

WITH
ABSTRACTS OF THE DISCUSSIONS.

VOL. XXII.

~~~~~  
SESSION 1862-63.  
~~~~~

EDITED BY
JAMES FORREST, Assoc. Inst. C.E., SECRETARY.

INDEX, PAGE 643.

LONDON:
Published by the Institution,
25, GREAT GEORGE STREET, WESTMINSTER, S.W.
1863.

[The right of Publication and of Translation is reserved.]

JUN 20 1917
TRANSFERRED TO
HARVARD COLLEGE LIBRARY

LONDON: PRINTED BY W. CLOWES AND SONS, STAMFORD STREET AND CHARING CROSS.

ADVERTISEMENT.

THE Institution is not, as a body, responsible for the facts and opinions advanced in the following Papers read, or in the abstracts of the conversations which have occurred at the Meetings during the Session.

CONTENTS.

No. of Paper.	Subjects.	Author of Papers.	Date.	Page.
	Remarks on opening of Session, as to the deaths of Mr. James Walker and Mr. J. E. Errington.	J. R. M'Cleau .	1862 Nov. 11	1
1,071	Railway System of Germany	B. Crawford .	..	2
	Discussion on ditto	..	..	27
1,058	Hownes Gill Viaduct (1 plate)	W. Oudworth .	.. 25	44
	Discussion on ditto	..	..	52
1,051	Use of Timber of the Palmyra Palm, in the Construction of Bridges.	H. Byrne . .	..	58
	Discussion on ditto	..	..	62
	Election of Members	..	Dec. 2	65
1,076	Internal Disturbing Forces of Locomotives (2 plates).	A. W. Makinson	..	65
	Appendix to ditto (8 woodcuts)	..	..	79
	Discussion on ditto (9 woodcuts)	..	.. 9	83
	Annual General Meeting	..	.. 16	111
	Election of Council	..	..	112
	Annual Report.	..	..	113
	Abstract of Receipts and Expenditure	..	..	127
	Premiums Awarded	..	..	130
	Subjects for Premiums	..	..	132
	Original Communications, List of	..	..	139
	Catalogue of Presents	..	..	141

No. of Paper.	Subjects.	Author of Papers.	Date.	Page.
	List of Officers	..	1862 Dec. 16	166
	Election of Members	..	1863 Jan. 13	167
1,079	Railway Telegraphs (12 woodcuts)	W. H. Proece .	..	167
	Discussion on ditto	..	„ 20	193
	Railway Break.	W. G. Creamer .	..	240
	Election of Members	..	Feb. 3	241
1,048	Sleeper Woods, Madras Railway	B. M ^c Master .	..	241
	Discussion on ditto	..	..	255
1,053	Drainage of Dundee (2 woodcuts)	J. Fulton . .	„ 10	262
1,054	Sewerage of Newport (1 plate, 2 woodcuts)	A. Williams .	..	273
	Discussion on Drainage of Towns (1 plate, 7 woodcuts).	..	..	284
1,063	American Timber Bridges (1 plate). . . .	J. R. Mosse .	„ 24	305
	Discussion on ditto	..	..	318
1,088	Dinting and Mottram Viaducts (3 woodcuts)	W. Fairbairn .	..	327
	Discussion on ditto	..	..	334
	Election of Members	..	Mar. 3	336
1,074	Upper Thames (1 plate)	Rev. J. C. Clut- terbuck.	..	336
	Discussion on Upper Thames	..	..	353
	Resolution to adjourn over 10th March . .	..	„ 17	370
1,075	Lydgate and Buckhorn Weston Railway Tunnels (1 plate).	J. G. Fraser .	„ 24	371
	Discussion on ditto (1 woodcut)	..	..	381
1,089	Public Works in Pernambuco	W. M. Peniston	..	385
	Appendix A. Rolling Stock	Ditto	..	406
	„ B. Table of Wages	Ditto	..	407
	„ C. Prices of Materials, &c.	Ditto	..	407
	„ D. Cost of Maintenance of Way	Ditto	..	408

No. of Paper.	Subject.	Author of Paper.	Date.	Page.
	Discussion on Public Works in Pernambuco	..	1863 ..	409
1,082	Structures in the Sea (2 plates)	D. Miller . .	Mar. 31	417
	Discussion on ditto	..	..	439
	Resolution to adjourn over Easter Tuesday.	..	..	450
	Election of Members	..	Apr. 14	451
1,090	Scinde Railway (2 plates)	J. Brunton . .	..	451
	Appendix to ditto	..	..	475
	Discussion on ditto (2 plates)	..	..	480
1,092	Cofferdam and Syphons, Middle Level (3 plates, 2 woodcuts).	J. Hawkshaw .	„ 21	497
	Appendix A. Quantities of Material used in construction.	Ditto . . .	..	509
	„ B. Working of Syphons	Ditto . . .	..	509
1,093	Charing Cross Bridge (3 plates)	H. Hayter . .	„ 28	512
	Appendix to ditto, Experiments on Plate Iron.	Ditto . . .	..	527
	Discussion on ditto (3 woodcuts)	..	..	528
	Election of Members	..	May 5	540
1,091	American Iron Bridges (1 plate, 3 woodcuts)	Z. Colburn . .	..	540
	Discussion on ditto (1 plate)	..	..	557
1,094	London and Dublin Communication	W. Watson . .	„ 12	574
	Appendix to ditto	Ditto . . .	..	595
	Discussion on ditto	..	..	596
	Election of Members	..	„ 19	604
1,095	Duplicate Machines and Engines (2 plates)	J. Fernie . .	..	604
	Discussion on ditto	..	..	612
	President's Conversation	..	..	614
	Appendix: Memoirs	..	..	615
	Notice of decease of H.R.H. the Prince Consort.	..	..	615

No. of Paper.	Subjects.	Author of Papers.	Date.	Page.
	Memoir of Peter Barlow	..	1863 ..	615
	,, James John Berkley	..	..	618
	,, James Cooper	..	..	624
	,, Henry Hind Edwards	..	..	625
	,, John Edward Errington	..	..	626
	,, Joseph Lane Manby	..	..	629
	,, James Walker.	..	..	630
	,, William Weallens.	..	..	633
	,, Major Baddeley, R.A.	..	..	634
	,, Captain Collingwood	..	..	636
	,, Colonel Samuel Colt	..	..	636
	,, Robert Cowen	..	..	638
	,, John Withers	..	..	640
	,, John Brannis Birch	..	..	640
	Index	..	..	643

THE
INSTITUTION
OF
CIVIL ENGINEERS.

SESSION 1862-63.

November 11, 1862.

JOHN ROBINSON M'CLEAN, Vice-President,
in the Chair.

At the commencement of the proceedings, Mr. M'Clean, V.P., in the absence of the President, said it was his duty to notice the loss the Institution had sustained by the death, during the recess, of two of its most eminent Members, Mr. John Edward Errington, Vice-President, and Mr. James Walker, Past-President.

For upwards of thirty years, indeed ever since the introduction of the railway system, Mr. Errington occupied a prominent position as an Engineer; and, in conjunction with Mr. Locke, executed some of the principal railway works in Great Britain. He was, like his partner, Mr. Locke, a strong advocate for economy in the first cost of construction. By his death the profession had lost one of its most distinguished members, the Institution one of its warmest supporters, and many, a sincere friend, who was ever ready to afford advice, especially to his numerous pupils and assistants, whose interests it was his constant endeavour to advance. As many of his pupils were actively engaged in the practice of the profession, and had, through his influence, been enabled already to take good positions, Mr. M'Clean expressed the hope, that they would feel it a duty, no less than a pleasure, incumbent upon them, to communicate plans and descriptions of the works of their eminent masters, so as to keep alive the memory of "Locke and Errington" in the Institution of Civil Engineers. Mr. Errington had proved his attachment to the Institution, and his desire to see it prosper, by bequeathing to it the sum of ONE THOUSAND POUNDS, free of legacy duty, without attaching any condition whatever to the gift.

Mr. Walker was one of the oldest Members of the profession, having been in active practice as an Engineer for upwards of sixty
[1862-63. N.S.]

years. He was also one of the earliest Members of the Institution, having joined it in the year 1823, and, after the death of Mr. Telford, he became its President. For a period of eleven years, during which he so ably conducted its proceedings in that capacity, he was most devoted to its interests, and to his zeal and energy must be greatly attributed the eminent position it held on his retiring from the Chair in 1845. Mr. Walker's name was associated with many of the greatest hydraulic works in England and Scotland, including lighthouses, harbours, bridges, embankments, and drainage. His opinion was much valued by the Elder Brethren of the Trinity House, by the Lords of the Admiralty, and by the Corporation of the City of London; and it must not be forgotten, especially at the present moment, that twenty years ago he laid down lines for embanking each side of the River Thames, which had never been improved. Having had the privilege of being in Mr. Walker's employment for many years prior to 1844, Mr. M'Clean had had an opportunity of knowing his worth, and while expressing gratitude for many personal acts of kindness, must state that it was Mr. Walker's constant endeavour to promote the interests of those engaged under him. Many members of the profession had also been trained in the same school, including Burges, Bidder, Hawkshaw, Borthwick, and Hartley. During his long and useful career, he had secured the admiration and respect of numerous influential friends, as well as the regard of his professional brethren.

Mr. M'Clean had much gratification in announcing, that Mr. Walker having left at Mr. Burges' disposal the twenty-five remaining copies of Telford's "Life and Works," as well as the copyright and the copper-plates, Mr. Burges had, in the most handsome and liberal manner, presented them to the Institution.

No. 1,071.—"The Railway System of Germany."¹ By ROBERT CRAWFORD, Assoc. Inst. C.E.

THERE are few subjects which afford, at the present day, more varied and interesting questions for consideration than the growth and development of railways. Whether viewed with regard to the general influence which they exert on the commerce of nations, or their beneficial effect in promoting the introduction of improvements in machinery and manufactures, they cannot fail to present abundant matter for examination and reflection. Nor can an outline of their progress within fixed territorial limits be without some

¹ The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

value, in furnishing and grouping together the elements of information, which may aid in the formation of correct opinions, as to the advantages and defects of certain systems.

It is in this latter respect that Germany has been selected as the field of investigation for this Paper, since, although in the first instance railways were there adopted with reserve and caution, their construction was afterwards prosecuted with considerable steadiness of purpose, and with but slight fluctuations in the regularity of their progress, except such as arose from political questions, or state policy. In Germany, as in England, tramways formed the germ from which subsequent enterprise developed the vast network of railways now extending throughout the length and breadth of the land, facilitating its commerce, and increasing in no small degree its material prosperity and wealth.

The oldest of these undertakings originated in a fifty years' 'privilege' granted by the Austrian Government, upon the 7th September, 1824, for the construction of a line from Budweiss, in Bohemia, to opposite Linz, on the Danube, a distance of upwards of 80 English miles. In the beginning of the year 1825, this concession was transferred to a Joint-stock Company, formed in Vienna, under the title of "The Imperial Royal First Railway Company of Austria." The works were immediately begun, and about 40 miles finished before the close of 1828. The completion of the remaining portion occupied until the 1st August, 1832, the day of the opening of the line throughout its entire length. About this time a new project was set on foot, and a concession granted to an association of business firms in Vienna, for a line from Linz to Gmünden (42½ miles), which was made over, in 1834, to the Budweiss and Linz Company. The works were begun in the same year, and finished in 1836. This line, although claiming the name of railway, was in reality a tramway, worked by horses. The gauge was 3 feet 7½ inches in the clear. The rails consisted of flat bars of iron, 2½ inches wide by rather more than ½ an inch in thickness, and weighed 14½ lbs. per yard; they were laid on longitudinal timbers, supported and kept in place by cross sleepers, 6 feet 3 inches apart from centre to centre. The maximum gradients were 1 in 20 on the length between Budweiss and Linz, and 1 in 46 between Linz and Gmünden. The junction of the northern and southern sections was effected by means of a short line, on which occur gradients of 1 in 15 and 1 in 28, passing over the Danube on the timber bridge between Linz and the north shore of the river, which answers for the purposes of ordinary traffic as well as for those of the tramway. The cost of the Budweiss, Linz and Gmünden line was about £4,877 per mile. In 1854, small locomotive engines were adopted for the working of a portion of the southern section, and this system was extended in

the following year to the entire length between Linz and Gmünden. The gauge remained the same, but the permanent way was altered on the inclines and sharp curves; the original flat bars and longitudinal timbers having been replaced by small solid rails of the contractors, or broad-based pattern, laid on transverse sleepers. Still more recently, the whole of this undertaking has been incorporated with that of the "Empress Elisabeth Western Railway of Austria," from Vienna to Passau and Salzburg; and it is contemplated, eventually, to convert both the branches to Budweiss and Gmünden into ordinary railways, with the regular normal gauge of 4 feet 8½ inches.

Returning from the digression occasioned by tracing down to a recent period the salient points in the history of what was not only the first line in Austria, but in all Germany, the enterprise which next attracts attention is that of a proposal for connecting Prague with Pilsen, by means similar to those already described. The works were begun in 1828, and a portion of the line was opened in 1830. The original project was never completed, and a length of 34½ miles of tramway, the extent to which it was carried into execution, after changing ownership twice, was finally made over to a Colliery Company for local purposes.

These preliminary remarks bring down the subject to the most important and decisive period in its history, occasioned by the proposal to adopt steam as a motive power instead of horse labour; a proposition carried into effect for the first time in Germany in the case of a railway 4 miles in length from Nürnberg to Fürth, which was opened for public traffic on the 7th December, 1835. The works on this line were unimportant, and presented no engineering difficulties whatever, occupying only nine months in their construction. The cost was £4,745 per mile. The rails, which were for a single way, were laid for about three-fourths of the distance on stone blocks, and the remainder on timber sleepers, which were subsequently replaced by stone supports. The maximum gradient was 1 in 250.

Thus Germany, possessing, at the close of the year 1835, upwards of 108 miles of tramways, had up to the same time only 4 miles of railway, properly so called.

The five years following in regular succession from this date served to introduce railways into all parts of the country, and to give them a fair start. It appears that upon the 31st December, 1840, five years after the completion of the first line, there were twelve railways in Germany, either wholly or in part finished, and yielding a total length opened, equivalent to 377 miles. These, arranged according to the priority of opening of any part of them, assume the following order; it being premised, that those lines worked by steam power are alone referred to:—

1st	Railway in Germany was that from Nürnberg to Fürth, opened	7th Dec. 1835.
2nd,	" Leipzig to Dresden, a portion of which was opened	24th Apr. 1837.
3rd,	" Vienna to Oderberg "	23rd Nov. 1837.
4th,	" Berlin to Potsdam "	22nd Sept. 1838.
5th,	" Düsseldorf to Elberfeld "	15th Oct. 1838.
6th,	" Brunswick to Wolfenbüttel "	1st Dec. 1838.
7th,	" Magdeburg to Leipzig "	29th June 1839.
8th,	" Cologne to the Belgian frontier "	2nd Aug. 1839.
9th,	" Munich to Augsburg "	1st Sept. 1839.
10th,	" Frankfort-on-Maine to Wiesbaden "	26th Sept. 1839.
11th,	" Berlin to Anhalt "	1st Sept. 1840.
12th,	" Mannheim to Heidelberg "	12th Sept. 1840.

Such was the position of railways at the close of the year 1840, after which they became so numerous and varied that it would be impossible, keeping in view the object of this Paper, to follow them any further in detail. It is sufficient for the present purpose to review in general terms their progress from time to time, from their first adoption down to the present day, as exhibited in the following statement, showing the extent opened at different fixed periods:—

There were 4 miles of Railway in Germany opened up to the close of 1835.

"	377	"	"	"	1840.
"	1,817	"	"	"	1845.
"	4,487	"	"	"	1850.
"	5,750	"	"	"	1855.
"	8,512	"	"	"	1860.
"	8,866	"	"	"	1861.

The local distribution of this latter quantity and the cost per mile are as follows:—

In Prussia there were about . . .	8,417 miles constructed at an	£.
average cost per mile of		15,200
In the German provinces of Austria	1,706	22,700
" Bavaria	1,172	13,670
" Hanover	450	13,100
" Saxony	435	18,350
" Baden	260	16,500
" Württemberg	260	14,500
" the other German States	1,166	14,890

Total 8,866 miles constructed,
at an average cost of about £16,400 per mile.

Nearly one-fourth of the entire length is provided with two lines of rails.

About 38 per cent. of the existing lines are Government property.

" 10½ " are the property of Companies, but worked by Government.
" 51½ " are the property of, and are worked by private, or Joint Stock Companies.

Many railways which were originally constructed by State means have been sold, or rented to Joint Stock Companies, and the reverse of this has in some instances taken place. Hence it becomes

necessary to return to an examination of the manner in which they were at first carried out, in order to estimate the extent to which Government resources participated in these undertakings. In this respect it appears, that

39½	per cent. of the entire length were constructed by the different States.
24½	“ by Companies under a guarantee of interest, or a Government subvention.
35½	“ “ at their own cost and risk.

That is to say, Government aid has been granted directly, or indirectly, to nearly two-thirds of the entire system. These 8,866 miles of railway comprise sixty-two different undertakings as at present constituted, under as many separate organisations, and are managed by nineteen Government departments, and forty-three boards of Directors, or some substitute, whose control however is not confined to Germany proper, but extends to adjoining territories, over an aggregate length of 10,830 miles of line.

Not long after the introduction of railways into Germany, it became apparent, that their management would be far from sufficiently perfect to meet the continually increasing requirements of commerce, except some common plan of action could be agreed upon, which would bring all the railways in the country into one large association, for regulating, to a certain extent, their relations with each other, according to general rules, somewhat after the manner of the German political Confederation. For this purpose a conference was held at Cologne, in June, 1847, which resulted in the formation of a society under the title of “The Association of German Railway Directions,” which now embraces the whole of the lines already referred to, with very trivial and unimportant exceptions. Each railway subscribes a fixed sum towards the general management fund, together with a variable amount depending upon its length, and is represented at the meetings of the Association and in the debates, in proportion to its importance. Yearly general meetings are held, at a time and place mutually agreed upon, and when considered expedient, special meetings are also called. At all of these, such matters as relate to the interests of the Association are discussed and settled. A code of laws has been drawn up, and agreed to, by the Engineers and managing directors present at these meetings, which is revised and enlarged from time to time, according to the requirements. These rules express the decided opinion of the associated body, upon all the points which are usually involved in the construction and working of railways, and are adopted by all concerned, as the standard source of guidance and instruction in such matters. It may here be proper, before passing on to the consideration of the engineering points involved in the present subject, to state that Germany

at the close of the year 1861, had, in addition to railways, about 143 miles of tramways, constructed at an average cost of £3,200 per mile.

The battle of the gauges can scarcely be said to have been fought in Germany, or, if so, it was conducted with almost all the energy on one side; as, early in the movement, the gauge of 4 feet 8½ inches came off victorious, and the line from Mannheim to Heidelberg, which represented the opposing interest, having been laid to a medium width of 5 feet 3 inches between the rails, after struggling along for some time in its unsocial loneliness, was obliged to yield under the pressure of public opinion and the inconvenience arising from a break of gauge, and was altered to the ordinary width of 4 feet 8½ inches, which is now the universal gauge of the country.¹ The width between the ways on a double line of railway is usually fixed at 2 metres between the centres of the rails, or 6 feet 4½ inches in the clear. At stations, this allowance is generally greatly increased.

With regard to curves and gradients the rules laid down are,—First, The radius of curvature shall, if possible, not be less than 3,600 feet on level land, nor than 2,000 feet in hilly districts, except in particular instances, when it may be necessary to reduce it to 1,200 feet. This latter is to form, as a general rule, the minimum rate of curve on railways in mountainous countries, to be diminished in exceptional cases, where necessary, to 600 feet, but never less.

Secondly, The general scale of maximum gradients admissible on railways is, 1 in 200 in level districts, 1 in 100 among hills, and 1 in 40 on mountain lines.

As examples of sharp curves upon works already executed may be noticed :—One of 570 feet, and another of 590 feet radius on the Baden State Railways; two curves of 618 feet radius on the railway from Magdeburg to Wittenberg, and a similar minimum radius on the railway from Breslau to Schweidnitz; one of 560 feet and several of 622 feet radius occurring on the passage of the Alps, on the line from Vienna to Trieste; the viaduct approach to the Cologne bridge, on the left bank of the Rhine, is on a curve of 618 feet radius; a curve of 780 feet radius on the line between Passau and the Austrian frontier, and of 824 feet as the minimum radius of curvature on the Main Weser Railway from Frankfort-on-Maine to Hesse Cassel; besides numerous other curves of importance on existing lines.

The increased power of locomotive engines has introduced into practice a severer character of ruling gradients than was formerly contemplated. On main lines, when practicable, 1 in 100 is now

¹ To this must be mentioned as an exception the branch from Lambach to Gmünden, 16 miles in length, already described.

generally adopted as the maximum rate of inclination. In many instances, where the districts traversed are very level, the gradients are much easier than this ; but on the other hand, Germany has ample proofs of having approached the limits recognised at present as suitable for the working of locomotives, in gradients of the steepest description, which are not confined to one State, or locality, but are to be found in both north and south. As an illustration of this statement it will suffice to instance some of the most important cases :—Between the stations of Erkrath and Hochdahl, on the railway from Düsseldorf to Elberfeld, there occurs a continuous incline of 1 in 30 for a distance of 8,038 feet, or upwards of $1\frac{1}{2}$ mile. This was originally worked by stationary engines and a long endless rope. In 1841 the plan was altered, and the trains in opposite directions arranged so as always to meet at this point, and the weight of the descending train was made use of in helping to draw the other up, by means of a rope attached to both trains, and passed round rollers at the top of the incline. The difficulties arising from the necessity for the meeting of trains brought about another modification in the system of working, which is that now in use. A pilot engine is always ready with steam up to assist the ascending trains, which it does by acting as a counterpoise attached to the upper portion of the rope, in the same capacity as was formerly fulfilled by the descending train. This latter now always passes down without being attached to the rope, and under the control of powerful breaks, and by these means the inconvenience to the traffic, from being compelled to depend upon meeting trains, has been removed. The Aix-la-Chapelle incline of 1 in 38, for a length of 6,844 feet, stands next on the list. It begins immediately on leaving the station, and rises westwards towards the Belgian frontier. It, also, was intended to be worked by stationary engines ; but a tank engine, with three pairs of coupled wheels of small diameter, now answers the purpose, by pushing the train from behind, up to the station at the level on the summit, where an ordinary engine is in waiting to take the train on. Several gradients of 1 in 40 and 1 in 45 were adopted on the Semmering Railway, of which a particular account has already been brought before the Institution.¹ An incline of 1 in 40, for a distance of 17,680 feet, or upwards of $3\frac{1}{4}$ miles, upon the Bavarian State Railway, from Augsburg to Hof, serves to surmount the watershed between the rivers Maine and Saale, near the village of Neuenmarkt. The short Schneeberg branch line in Saxony has gradients of 1 in 40, and the total ascent which it makes averages at the rate of 1 in 48. The passage of the Swabian Alps, between Geislingen and Amstetten, on the Würtemberg State Railway,

¹ Vide "Minutes of Proceedings Inst. C.E.," vol. xv., p. 349.—"On Steep Gradients of Railways, &c.," by C. R. Drysdale, in which an account is given of this line, and of the mode of working it.

from Stuttgart to Ulm, is accomplished by means of an incline of 1 in 45, 16,720 feet long, or $3\frac{1}{2}$ miles. There is a gradient of 1 in 45, for a length of about 1,800 feet, at Viennenburg, on the Brunswick State Railway, from Wolfenbittel to Harzburg. On the railway from Bamberg to Asschafenburg, there is a gradient of 1 in 50, extending over $4\frac{3}{4}$ miles. The same rate of inclination occurs on the line from Breslau to Schweidnitz, and also between Eisenach and Coburg, near the former place, on the Werra Railway; the length of the gradient being 3 miles.

The Semmering Railway, already alluded to, is one of the most remarkable instances of a combination of heavy gradients with sharp curves. This line, which is in reality but a section of the Southern Railway of Austria, from Vienna to Trieste, extends from the station of Gloggnitz to that of Mürzzuschlag, a distance of 25.44 miles, or more exactly 134,300 feet. In considering the nature of the gradients, it may be divided into three sections as follows:—

1st from Gloggnitz to Payerbach	20,815 feet.
2nd „ Payerbach to the Semmering summit	64,083 „
3rd „ The summit to Mürzzuschlag	49,452 „
Total	134,300 „

In going southwards the rise is gradual until Payerbach is reached, the maximum inclination being 1 in 100. From thence, until attaining the summit level, which gives its name to the pass, the gradients and curves are of the heaviest and sharpest character, in order to overcome the various natural obstacles in the way. On this middle section several gradients of 1 in 40, one of them, the longest on the line, being 11,618 feet, or $2\frac{1}{2}$ miles, and curves of 622 feet radius occur. From the summit to Mürzzuschlag station the descent is rapid and steep, the heaviest rate being 1 in 41.4. The difference of level between Gloggnitz and the summit is 1,506 feet; the height of the latter being 2,937 feet above the sea-level; and the fall from thence to Mürzzuschlag on the south side is $714\frac{1}{2}$ feet. The nature of the inclines, and their effect upon the working of the line, will be best understood by referring to the following tabular statement:—

LIST OF GRADIENTS.

From 1 in 40 to 1 in 50	61 per cent. of the entire length.
„ 1 in 51 to 1 in 70	9 „ „
„ 1 in 71 to 1 in 100	8 „ „
„ 1 in 101 to 1 in 120	15 „ „
„ 1 in 121 to 1 in 500	6 „ „
Level	1
	<hr/>
	100 „ „

The curves under 1,000 feet radius are,

1 Curve of 560 feet radius.			
29	"	622	"
1	"	746	"
2	"	871	"
1	"	902	"
34	"	933	"

The proportion of straight line and curves stands thus,—

Curve of 560	feet radius	04	per cent. of the entire length.
" 622	"	15½	"
" 623 to 1244	"	26	"
" 1245 to 1867	"	6	"
" over 1867	"	2	"
Straight lines		50	"
		100	

Several of the curves of 622 feet radius occur upon inclines of 1 in 45.

There are fifteen tunnels on this work, of the aggregate length of 14,867 feet. The longest is that through the summit, called the Semmering, which is 4,695 feet. The next, in point of length, is one of 2,280 feet.

The viaducts, of which there are sixteen, are built of masonry and brickwork, and are principally composed of semicircular arches, varying in span from about 25 feet to 65½ feet. The longest of these works is 614 feet, and the four which attain to the greatest height, from 119 to 150 feet, consist of two rows of arches, one above the other; the lower of which tends to strengthen the piers and add stability to the structure. Many of the viaducts are placed on curves of 622 feet and 933 feet radius, and on gradients of 1 in 45.

The permanent way consists of flat-based rails, weighing 76½ lbs. per yard, resting on cross-sleepers, laid 3 feet 1½ inch apart from centre to centre, which in their turn are supported by longitudinal timbers, into which they are let, and held firmly in place by small angular iron brackets. The rails are 4½ inches in depth, have a similar width of base, with a head 2½ inches broad, and a thickness of ½ inch for the central web; their usual length being 18 feet 8 inches. The joints are made fast by fish plates, with four screw-bolts in the usual manner; underneath are placed wrought-iron chair-plates, to prevent the working of the ends of the rails into the sleepers. A similar plate, but of smaller dimensions, is interposed between the base of the rail and the timber at each of the intermediate bearings. The joint sleepers are 12½ inches wide, by 6½ inches thick, and the intermediate sleepers are 9 inches by 6½ inches. The ballast consists of a lower course of angular broken stone of large dimensions, laid with the

hand, on which rest smaller broken stone and gravel. Its depth at the centre of the gauge, measured from the surface of the 'boxing,' which reaches to within 2 inches of the rail level, is 2 feet 4 inches, and the width to which it extends outside the rails is 4 feet 6 inches on embankments, and 3 feet 9 inches in cuttings.

The engines used for working the line are of a peculiar description, the result of a prize offered by the Government, for the best locomotive to take a given load up the inclines, with a fixed minimum velocity. The engine and tender are in one, and rest upon five pairs of wheels; the three leading pairs are coupled together, and attached to axles fixed at right angles to the axis of the boiler. The other two axles are placed, one in front of the fire-box, and the other under the tender, and are attached to a movable carriage, or frame, which admits of the wheels suiting themselves to the nature of the sharp curves to be traversed. The following statement shows the comparison between the passenger and goods engines on this line, and their principal average dimensions :—

	Passenger Engine.		Goods Engine.			
	Ft.	In.	Ft.	In.	Ft.	In.
Diameter of Driving-wheels (3 pairs coupled)	4	3	3	4 to 3	6	
Ditto of uncoupled wheels (2 pairs)	3	1	3	4 to 3	6	
Ditto of Cylinder	1	6½	1	7 to 1	7½	
Length of Stroke of Piston	2	0		2 ft. 0 in.		
Diameter of Boiler (mean)	4	3		4	3	
Length of ditto	15	6		15	6	
Number of Tubes 2 inches diameter	No. 191		No. 191			
Average Heating Surface, in square feet	1,694		1,694			
Maximum pressure of Steam in Boiler, per square inch	100 lbs.		100 lbs.			
Thickness of Iron Plates in Boiler	½ in.		½ in.			
Distance apart of centres of extreme coupled wheels	ft. 8	in. 11½	ft. 7	in. 6		
Ditto, ditto, uncoupled, about	8	0	8	0		
Total length of Engine from buffer to buffer	37	11	ft. 34	in. 9 to 35	ft. 35	in. 10
Total weight of Engine on 5 pairs of wheels (empty)	44 tons.		48 to 50 tons.			
Adhesive weight of Engine on 3 pairs of coupled wheels, loaded with an average supply of water, &c.	39 tons.		38 to 41 tons.			

The cost of one such engine was about £3,500.

The experience derived from the working of this line goes to show, that one of the goods engines can ascend the inclines of 1 in 40 at the rate of 9½ miles per hour, taking with it a train whose gross weight varies from about 100 tons to 165 tons, according to the state of the rails and the weather at the time. The normal rate of speed fixed is as follows :—

	Ascending.	Descending.
For Express Trains . . .	14½ miles per hour	16½ miles per hour.
„ Ordinary Passenger ditto	11½ „	14½ „
„ Military Transport and Goods Trains . . .	9½ „	9½ „

In case of a train being late, any one of the foregoing speeds may be increased, if necessary, by $4\frac{1}{10}$ miles per hour. The maximum number of trains which have passed over the line in one day occurred during the Italian war, and amounted to seventy-two, counting both ways. The ordinary average daily number of trains is twenty-seven, with from seven to eight carriages in each train. The actual works of construction on the Semmering Railway were begun towards the close of the year 1848, and the line was opened for public traffic on the 17th July, 1854. Previous to this, however, during the year 1853, rails were laid throughout the entire length of the line, and goods were transported over it by means of locomotives. The line, which is laid with a double way throughout, cost £98,270 per mile.

Passing on to the next point for consideration, that of earthworks, it appears to be a general, although not a universal, plan, in the case of all main lines, to prepare the earthworks and masonry for a double way from the first, but not to lay the second line of rails, until the success of the undertaking makes itself apparent, and the requirements of the traffic demand the additional way. Some of the heaviest earthworks executed have been:—An embankment on the Southern State Railway of Bavaria, from Augsburg to Lindau, its greatest height being 172 feet, width at formation $33\frac{1}{2}$ feet, and length 1,675 feet, requiring upwards of 2,900,000 cubic yards of material to make it up. On the same line also occur embankments of great importance, two of which are respectively 84 feet and 72 feet high. On the railway from Augsburg to Ulm, there is a cutting 2,390 feet long, and reaching to a depth of 90 feet; also an embankment 53 feet high, and 5,755 feet in length. Between Elberfeld and Dortmund occurs an excavation 86 feet deep, and upwards of $1\frac{1}{2}$ mile long; and on the same line there is an embankment 120 feet in height, with a length of 1,600 feet. Embankments from 75 feet to 130 feet high are to be found on the Westphalian railways. On the Bavarian State line, from Bamberg to Aschaffenburg, there is an embankment 100 feet in height at the highest point, and 1,743 feet long; besides two cuttings measuring in depth, the one 84 feet, and the other 71 feet, their respective lengths being 3,254 feet and 2,297 feet.

With regard to tunnels, the first executed in Germany was one 1,678 feet long, on the Leipzig and Dresden Railway. Besides

the summit tunnel, 4,695 feet in length, on the Semmering Railway, already mentioned, there are many others worthy of notice, among which some of the most important are :—

A Tunnel 5,359 feet long at Königsdorf between Cologne and the Belgian frontier.			
"	4,419	"	" Heiligenberg between Ludwigshafen and Bexbach.
"	3,600	"	" on the Saarbrück, Trier and Luxemburg Railway.
"	3,235	"	" Railway from Gerstungen to Carlshafen.

and a tunnel 3,037 feet long through the Schwarzkopf between Bamberg and Aschaffenburg.

This brings the subject to one of the most interesting of its subdivisions, that of viaducts and bridges, which it is proposed to treat under two separate headings,—First, Bridges composed altogether of masonry, and, secondly, Iron Bridges. There are instances of large timber bridges, such as those over the branches of the Danube, at Vienna, on the “Emperor Ferdinand’s Northern Railway,” and that over the Elbe, at Magdeburg, whose superstructure only is of wood ; but as these are cases of works executed in past years, and it being now laid down as a maxim by German Engineers, that timber is not to be used in railway bridges, it becomes unnecessary to devote space to the consideration of such works. To explain more fully these somewhat anticipatory remarks, it may be well to introduce here, the views of the Associated Railway Directors on bridge building, as expressed in their code of rules. These are—I. For bridges, arches of stone, or good bricks, are preferable to every other description of structure, except in cases which require very oblique bridges. II. Timber bridges are inadmissible. III. When iron bridges are made use of, the portion of the superstructure which sustains the roadway shall consist of either wrought, or rolled iron. Thus cast-iron bridges, as well as timber ones, are removed from the field of investigation. The former by negation, and the latter by direct condemnation.

Germany abounds in fine examples of stone viaducts and bridges of imposing dimensions and extent. It will be sufficient to adduce a few instances in addition to those already casually noticed, as occurring on the Semmering Railway. At the head of these stands the viaduct over the Goeltzsch Valley, on the railway from Leipzig to Hof. It consists of one central span of 93 feet, twenty-three spans of 46 feet in the clear, four spans of 39 feet, and two spans of 21 feet, one on each side of the large span through what may be called the abutment piers. Its greatest height is 255 feet, and extreme length 1,882 feet. The 93 feet opening has two arches one above the other, and on either side of it rise four rows of arches decreasing to one row at the ends. These additional arches are for the purpose of strengthening and supporting the

piers, which carry the upper or main arches. All those in the upper tier are semicircular in form, as is also the lower arch of the central span, while the others are segmental.

There is also another fine viaduct over the Elser Valley, on the same railway. It is formed of six semicircular arches of 93 feet span in the clear, three openings of 20 feet, and one of 15 feet. Two of the lesser openings have four tiers of arches in height, and occur on both sides of the arch which spans the deepest part of the valley. Two of the 93 feet widths are strengthened by a lower row of semicircular arches, and two others by means of connecting walls. This viaduct is, at its greatest height, 223 feet above the stream, and is 914 feet long.

The Neisse Viaduct on the branch railway from Kohlfurth to Görlitz, in Prussia, consists of one row of semicircular arches, thirty in number, of which three spans have a clear width of 73 feet 1 inch, three of 61 feet 9 inches, five of 41 feet 2 inches, and eighteen of 30 feet 10 $\frac{3}{4}$ inches. Its greatest height is 123 feet above low water, and its length, inclusive of abutments, 1,550 feet. This viaduct carries a double line of railway, and occupied about three years and a half in its construction, having been begun during the spring of 1844, and finished in the autumn of 1847. The masonry composing it amounted to 1,173,200 cubic feet.

The result of a series of experiments, for the purpose of ascertaining the best description of concrete to be placed round the foundations of the river piers, gave the proportions most suitable for yielding a quick setting, hard concrete, at

22	per cent. of cement
22	" " of sand
56	" " of small broken stone (2 inches diameter)
<hr/>	
100	

A stone bridge over the Elbe, on the Junction Railway, at Dresden, is well worthy of notice. It consists of twelve basket-handle arches of 93 feet span each. The width of the roadway is 50 feet, one half of which is applied to the purposes of an ordinary road, and the other half to those of the railway. Its height is 37 feet above the river at summer level. One approach to this bridge is formed by a viaduct of forty-four arches of lesser span.

A bridge over the Roeder, on the railway from Dresden to Görlitz, consists of one arch 148 feet 8 inches wide.

As a sample of an ordinary river bridge of handsome, although not very extensive, proportions, may be mentioned that over the Neckar, on the railway from Frankfort-on-Maine to Heidelberg. It is divided into seven equal spans of 88 feet 7 inches each, and carries a double line of permanent way at about 35 feet above the

ordinary water level. Its building occupied from 1844 to 1848. The form of the arch is segmental, with a versed sine equal to one-eighth of the span. The thickness of the piers at the springing is 10 feet 4 inches, or between one-eighth and one-ninth of the span. That of the abutments is 39 feet 4 inches. The width of the bridge between the outside faces of the masonry is 31 feet 6 inches, and the depth of the key-stone is 3 feet 11½ inches (1·2 metre). Comparing this latter quantity with the results to be derived from the different rules of eminent French authorities on bridge building, it appears that the depth of the key in the case of the Neckar bridge is somewhat over the minimum thickness required, both by Desjardin's formula and by that of Gauthey. On the other hand, it is so out of proportion with the huge thickness obtained from the method of Perronet, as to prove the total unsuitness of this system for calculating cases similar to the one in question. Thus—

By Desjardin's formula for an arc of a circle = 40°,

$$E = 0\cdot02 r + 0\cdot30 \text{ metre,}$$

where E = the thickness of the key, and r = the radius of curvature of the intrados in metres, which in the present instance is approximately 42 metres. Supplying this value, the expression becomes

$$E = 0\cdot02 \times 42 + 0\cdot30 \text{ metre} = 1\cdot14 \text{ metre.}$$

By Gauthey's rule for spans of 16–32 metres

$$D = \frac{1}{24} S$$

where D = the depth of the key, and S the span in metres, and S being 27 metres,

$$D = \frac{27}{24} = 1\cdot125 \text{ metre;}$$

whereas in testing the matter by the method of Perronet it stands

$$E = \frac{1}{24} D + 0\cdot325 \text{ metre} - \frac{1}{144} D,$$

in which E = the depth of the key, D = the span, in the case of semicircular arches, but in segmental or elliptical ones, D = double the radius of the intrados at the crown. Reducing this equation to a simpler form, it becomes

$$E = \frac{5}{144} D + 0\cdot325 \text{ metre,}$$

and supplying for D its value, 84 metres,

$$E = \frac{5}{144} \times 84 + 0\cdot325 \text{ metre} = 3\cdot241 \text{ metres,}$$

or nearly three times as great as the thickness required by Gauthey's rule.

By comparing the practical example with the three calculated results, the following is obtained :—

		metre.
The Neckar bridge, as actually built, has a depth of key	=	1·200
Ditto, according to Desjardin's formula, requires ditto	=	1·140
Ditto, ditto, Gauthey's ditto, ditto	=	1·125
Ditto, ditto, Perronet's ditto, ditto	=	3·241

In the case of wrought-iron bridges the arrangement most usually adopted, when the spans are wide, is that of a lattice construction, in some one of its various modifications.

One of the earliest examples of importance is that of the bridge over the river Kinzig, at Offenburg, on the Baden State Railway. It is built for a double line of railway, with two projecting foot-paths on the outside, and consists of three main girders, one on each side, and one in the centre between the ways. There is but one span, its width being 206 feet 8 inches in the clear. The depth of the girders is 20 feet 7 inches, and they rest 13 feet 3 inches on each abutment. The top and bottom cross sectional areas of all three girders are the same, consisting of three thicknesses of iron laid one over the other, and forming together a plate $1\frac{7}{8}$ inch thick and 13 inches wide; in addition to which there are four angle irons $4\frac{3}{4}$ inches by $4\frac{3}{4}$ inches by $\frac{1}{2}$ inch to $\frac{3}{4}$ inch thick, and one vertical bar, $5\frac{9}{16}$ inches by $\frac{1}{2}$ inch, on the outside, running along the centre of the horizontal plates which form the top and bottom portions of the girder, to which it is attached by two of the angle irons, the other two serving to join the flanges to the bars which form the central web. This latter is composed of lattice-work, which, in the case of the two outside girders, is formed with two sets of bars, $4\frac{1}{2}$ inches by $1\frac{3}{8}$ inch, crossing each other at right angles, and inclined to the top and bottom at an angle of 45° , the distances of the crossings apart being 1 foot $5\frac{1}{8}$ inches between the centres of the rivets measured along the bars. The central rib of the middle girder, between the ways, is stronger than that of the outside ones, inasmuch as it consists of three sets of bars, two of which are $\frac{5}{8}$ inch thick and one $1\frac{5}{16}$ inch, all having the same width as the other lattice bars. Along the whole length of each central rib there are two horizontal rows, formed of double rails of the bridge pattern, one on the inside and the other on the outside, and riveted to the lattice work. These rows occur at distances of 3 feet $11\frac{1}{4}$ inches and 7 feet $2\frac{1}{2}$ inches respectively below the top and above the bottom of the girders. The roadway inside and the projecting foot-paths are supported by transverse trusses, at intervals of 6 feet 3 inches apart, formed of ordinary flat-based rails, and the entire bridge is connected above and below by a system of cross and diagonal braces. The clear width between the outside and

the central girders is 12 feet 8 inches. The abutments are surmounted by handsome ashlar portals in red sandstone. The weight of cast iron in the bed plates is 23 tons, and of wrought iron about 322 tons, distributed thus:—

Weight of central girder.	= about	92 Tons.
Ditto, two side girders (together)	"	148 "
Ditto, cross girders and lower braces	"	55 "
Ditto, upper connecting bars	"	20 "
Ditto, handrail for footpaths	"	7 "
Total wrought iron in bridge		322 Tons.

From this short description it appears, that the arrangement of the material is not a judicious one, considering the nature of the strains arising from the weight of the bridge itself and any superimposed load, since,—I. the dimensions of the ironwork are uniform throughout the length of the span.—II. Although a stronger lattice construction is adopted in the case of the central girder, still its top and bottom sections are of similar dimensions to the outside ones; and—III. the cross sectional area of the iron has not been properly proportioned to its different powers to resist compression and extension, where these forces act.

Passing on from the consideration of the first of these undertakings on an extensive scale, the largest work of the kind yet executed in Germany naturally presents itself. This is the bridge on the Eastern Railway of Prussia, over the river Vistula, at Dirschau, consisting of six spans, each 397 feet 5½ inches in the clear. The depth of the girders is 38 feet 9½ inches and the height of their underside, above the ordinary water level, is 34 feet.

The arrangement is for a single line of railway, but the width is 20 feet 7½ inches in the clear, and the rails are laid along the centre, so that sufficient space is left on each side for ordinary traffic, to which the bridge is open except on the approach of trains. In addition to this, pathways for foot-passengers are suspended on cantilevers on both sides. The ironwork of each two spans is distinct in itself, being fixed on the pier at its centre, and moving on rollers at both ends. The system on which the iron work is constructed is that of two girders, one on either side of the roadway, held together above and below by a series of diagonal and transverse braces, in both the vertical and the horizontal planes. The girder top consists of four horizontal tiers of boiler-plate 2 feet 6½ inches wide, placed one above the other, at distances of 2 feet apart, and made fast to a central vertical web, by means of angle irons; and similar angle irons are riveted below each of these horizontal plates along their outside edges. The bottom section consists of an ordinary boiler-plate girder 4 feet 1¼ inch deep, with two flanges 4 feet 6 inches wide; the bottom of which has two thicknesses of plates, and angle irons along the

[1862-63. N.S.] C

outside edges, while the top consists of a single plate. The solid top and bottom sections of the girders are connected by means of a lattice frame, consisting of two rows of bars inclined at 45° to the horizontal, and crossing each other at right angles, at distances of 1 foot $6\frac{1}{4}$ inches between the rivets, measured along the bars. This is again strengthened by double angle irons $5\frac{1}{2}$ inches by $4\frac{1}{2}$ inches, and $1\frac{1}{2}$ inch by $\frac{1}{2}$ inch thick respectively, arranged vertically, one inside and the other outside, and riveted to the lattice at horizontal distances of 6 feet $2\frac{1}{8}$ inches apart. At these points also are attached the cross-girders, of lattice construction, which support the roadway at a height of 6 feet $2\frac{1}{8}$ inches above the underside of bridge. The thickness of the boiler plates in the top and bottom sections is about $\frac{1}{2}$ inch at the centre of the span. The lattice bars vary from a width of $4\frac{1}{8}$ inches at the centre to $5\frac{1}{8}$ inches at the sides, and are $\frac{1}{2}$ inch thick at the centre of the span, increasing to $\frac{7}{8}$ inch at the moveable end, which rests on rollers, and to 1 inch on the piers where the girders are fixed. Over all bearings the vertical angle irons are only half the normal distance apart, and the ends of the girders are further stiffened by solid plates. At the bearings furnished with rollers—that is to say, both abutments and piers Nos. 2 and 4—the breadth and depth of the top and the bottom sections of the girders remain the same as at the centre of openings; whereas in the case of piers Nos. 1, 3 and 5, where the bearings rest immoveably, the top is increased to 4 feet 4 inches in width, and all its horizontal plates are laid in double thicknesses of iron, while the bottom section, although retaining its regular width, is strengthened by doubling its depth by means of two corbels attached to the lower flange, the furthest of which projects about 40 feet from the face of the masonry and the other 8 feet 6 inches. The whole of the material in the superstructure was carefully proportioned to the nature of the strains to which it would be exposed. The foundations for the piers were prepared by driving a number of bearing piles into the sand, at the rate of one to every $18\frac{1}{2}$ square feet. The whole space was enclosed by a row of sheet-piling timbers 12 inches square, driven close together and reaching to a height of upwards of 10 feet above the tops of the bearing-piles. The area thus formed, being filled up level with the tops of the surrounding piles with concrete, furnished a bed 10 feet in thickness on which the masonry rests. The foundations of the abutments were treated somewhat similarly to those of the piers, but they are not so deep.

The projections of the piers both up and down stream present sharp vertical arrises, or nearly so, from the water edge to the underside of the roadway. The facework masonry consists principally of basalt, with a small proportion of granite ashlar up to above ordinary water level. Above this hard sandstone is used,

but only in the body of the piers. In the cutwaters the basalt masonry is continued for their full height. The blocks immediately under the ends of the girders are also of basalt. The backing and filling in is formed of hard burned bricks, and partly with ashlar, where greater strength is required, the whole being laid in hydraulic mortar. The piers are 32 feet 11 inches wide at the underside of the girders and 82 feet long in the direction of the stream. On each of the piers rise two circular towers, one on either side of the roadway, whose battlements reach to nearly 43 feet above the top of the girders. The abutments are surmounted by massive rectangular towers and a handsome connecting portal. The towers are all built with yellowish-white bricks, ornamented glazed ones of a purple colour being used in some of the mouldings. The copings and principal dressings are of gray sandstone.

The general effect produced by this bridge, when seen from a distance, is very fine. The great depth of the girders reduced to some extent, however, the impression which would otherwise arise from the magnitude of the spans, apparently diminishing them to much within their real limits.

There is one point in which the Author thinks the ornamenting of this beautiful bridge is deficient. That is the crowded state of the relief over the pointed arch of the Dirschau portal, in which the field is far too small for the subject, and the upper moulding is brought down so close to the head of the principal figure, as to give the appearance of the design having been originally intended for a totally different position to the one it now occupies.

About 10 miles nearer to Königsberg than Dirschau, and also on the Eastern Railway of Prussia, occurs the Marienburg Bridge, over the Nogat, which is in reality another arm of the river Vistula. The bridge consists of two spans of 321 feet $3\frac{1}{4}$ inches each, and two segmental arches in masonry of 53 feet $6\frac{1}{2}$ inches in width, one at either end of the bridge. The roadway is for a single way, with a footpath on both sides, and is arranged for ordinary traffic similarly to the Dirschau Bridge. The distribution of the iron in the superstructure is, however, altogether different. The Nogat Bridge may be described as a compound, the whole forming one girder, or tube, about 25 feet in depth, of which the top and bottom are composed of ordinary boiler plates, and the sides of lattice-work, similar in principle to that already described. The cross girders which support the rails are of lattice work 24 $\frac{3}{4}$ inches in depth, and are placed at distances of 6 feet $2\frac{1}{8}$ inches apart. At these same intervals, attached to the upper portion of the vertical L irons, within 6 inches of the top plates, are transverse bars, something in form like the letter Z, stretching from the lattice on one side of the roadway to that on the other.

These ribs, as well as the keelsons below, are more securely made fast to the vertical rods by gusset pieces, which tend to stiffen the bridge laterally. In the space, 6 inches, thus left between the cross ties and the covering plates, six iron bars, also Z shaped, run longitudinally for the whole length of the girder, giving the top the appearance of a cellular form of construction in cross section.

As regards the nature of the foundations and the character of the masonry, they are similar to those at Dirschau. The towers on the central pier are, however, rectangular in form, instead of round as in the latter case.

Both bridges have arrangements for mounting cannon, and other military precautions, at their ends.

The next example selected is that of the bridge over the Rhine at Cologne. It consists of four river spans each $322\frac{3}{10}$ feet in the clear, and two equal land openings of 64 feet $10\frac{3}{4}$ inches in width over the wharf and street on the left bank of the river. Two distinct bridges, one 24 feet $8\frac{1}{2}$ inches in the clear carrying a double line of railway, and the other 27 feet $9\frac{1}{2}$ inches inside width, for the purposes of ordinary traffic, are placed parallel to each other, and close together on the same piers; that on the down stream side being used by the railway. The depth of the girders for the four large spans is 27 feet $9\frac{1}{2}$ inches, and they are formed in two separate lengths each extending across two openings. The clear height above low water is 50 feet.

The railway bridge is formed of lattice girders, double on each side. The cross section of the top of one side is that of two T's placed one after the other, and close together, thus TT, and the bottom has a similar form, but reversed. The lattice frames which connect them are 2 feet apart, and are tied together and stiffened by diagonal braces, placed vertically at every 5 feet $1\frac{3}{4}$ inch. At the same intervals there are vertical angle irons, to strengthen the lattice, and keelsons to carry the roadway. Transverse angle irons and diagonal bars above are attached at every second one of these points. The lattice bars cross each other at distances of 2 feet $6\frac{1}{8}$ inches apart measured diagonally. They are about $3\frac{1}{8}$ inches by $\frac{1}{2}$ inch at the centre of spans, increasing to $4\frac{3}{8}$ inches by $\frac{3}{4}$ inch, at the ends resting on rollers, and to $5\frac{1}{8}$ inches by $1\frac{3}{16}$ inch at the fixed bearings.

The principle of construction of the bridge for ordinary traffic is similar to that for the railway, with the exception that the top and bottom sections are in shape that of a single T, and the sides consist of a single lattice instead of double frames. Every second vertical rod is also composed of two angle irons, instead of one, laid together so as somewhat to resemble the letter E. The total weight of iron in both bridges is about 4,600 tons.

The foundations were formed of concrete, laid on the solid

natural bed of gravel, which approaches close to the surface in the neighbourhood of Cologne. The ashlar masonry consists of basalt and sandstone, the former being used in the facework up to the underside of the girders, and where the greatest strength is required. The piers terminate in sharp upright cutwaters; their form on the down stream side being similar to the upper. Their thickness is 20 feet 7 inches at the level of the girders. The ornamental portion of the design only includes towers, which are rectangular in shape, on the centre pier, and on both abutments.

The approach to the bridge from the Central Railway Station in Cologne is effected by means of a viaduct of segmental arches, in brickwork, upon a sharp curve, whose radius, as already mentioned, is 618 feet.

The next case to be alluded to is that of the bridge across the Rhine, at Kehl, close to Strasburg. In cross section this bridge is somewhat similar to the Kinzig one, comprising two lines of rails with a lattice girder on either side and one in the middle, all connected together, and two footpaths supported on the out-sides. The main portion of the bridge is that to which the lattice system is applied, and consists of three spans of 184 feet $8\frac{3}{4}$ inches each. In addition to this there are two swing bridges of 210 feet diameter, with solid wrought-iron plate sides, and opening a clear width of 85 feet 3 inches on each side of the river for military purposes rather than those of navigation. The depth of the girders for the three principal spans is 19 feet $10\frac{1}{2}$ inches, and the clear roadway in each case is 13 feet 9 inches. The lattice bars are inclined at an angle of 45° to the horizontal, and form a net work, the open spaces of which measure about 3 feet diagonally. They are secured at their crossings by two rivets. The top and bottom sections of all three girders are in form that of the letter T; but they, as well as all other parts, are carefully arranged, so as to insure uniform strength for the bridge throughout, in proportion to the effect produced upon it by a load. The keelsons occur at intervals of $3\frac{1}{2}$ feet, and are in direct contact with the rails, which are riveted to them. The lattice work is stiffened by vertical angle irons, fixed double on both sides, at distances of 9 feet $6\frac{1}{2}$ inches. The iron work in the whole of the three openings is in one length, and is tied together above and below by a system of transverse and diagonal rods. The entire weight of the wrought iron in the superstructure is 984 tons, or at the rate of 328 tons per span of 184 feet $8\frac{3}{4}$ inches for a double line of railway. All the piers are surmounted by handsome Gothic ornamental work in cast iron. Great difficulty was experienced with the foundations of the bridge, owing to the nature of the stratum of shifting sand which underlies the bed of the river at this point. They were eventually

sunk to a depth of about 66 feet below the lowest water, by means of wrought iron cylinders, in which the masonry was built and undermined; the method adopted being that of compressed air. The operation of sinking the foundations progressed at the rate of about 20 inches per day of twenty-four hours.

In addition to these two bridges there is another now in process of erection over the Rhine, at Mayence, which is expected to be completed during the autumn of the present year. It consists of the following spans :—

					Feet.	In.
4	River openings of	331	feet	8½	inches	each
6	Flood	109	"	11	"	"
2	"	82	"	0	"	"
20	"	49	"	2½	"	"
<hr/>						
32 spans in all, yielding a clear waterway of						3,134 5½
lineal measure.						

The total distance between the abutments is 3,372½ feet, and the heights of the underside of the girders above low water is to be 45½ feet. The foundations are, like those of the Cologne Bridge, formed of concrete. The face masonry consists of red sandstone and ashlar, formed from the granite boulders found in the neighbourhood. The ironwork in the superstructure, which is for a single way, is very similarly arranged to that in the Saltash Bridge, modified in some particulars as to the cross section, and the form in which the material is applied, according to what is known in Germany as the system of Professor Pauli, of Munich, which gives a rectangular top to the beam instead of an oval one. As a good example of Herr Pauli's system may be mentioned the bridge over the Isar, at Grosshesselohe, on the railway from Munich to Salzburg. It has four spans,—two of 191½ feet, and two of 95½ feet, at a height of 101½ feet above low water.

The Eastern Railway of Bavaria has also some fine lattice bridges, such as that over the Danube at Regensburg, having five river spans of 153 feet 2½ inches each, with iron superstructure for single way, and fifteen flood openings of segmental arches in masonry each 47 feet 10½ inches wide, of which three are on the left and twelve on the right bank of the river. The height of the underside of the girders is about 33 feet above low water. The bridge was finished in 1859, and the weight of the ironwork in the five openings is 563 tons, or 112½ tons per span. On the same railway, at the town of Passau, there is a bridge over the river Inn, with one span of 296 feet 10 inches measured on the skew, the angle between the axis of the railway and the direction of the stream being 71°; adjoining this opening there are six stone arches, five of 47 feet in width on the left bank of the river, and one of 38 feet 3½ inches on the right. The level of the rails is

about 46 feet above low water, and the weight of iron in the bridge is 347 tons, for a single line of rails.

These few examples are sufficient for the purpose of illustrating the progress made in Germany in the construction of iron bridges on a large scale, and complete this portion of the subject under consideration.

Directing attention to the next branch, that of the permanent way, it appears that about seven-eighths of the rails in use are of the broad base or contractors' pattern; the remaining one-eighth being composed chiefly of chair rails, with a small proportion of the bridge-shaped ones. Fishplates, made fast with four screw-bolts, are now almost universally adopted, for connecting the ends of the rails, and the joints are always supported by a sleeper, generally 12 inches by 6 inches, a wrought-iron chair-plate being interposed between the rail and the timber. The modern English system, of leaving the joint free without any sleeper under it, has hitherto met with but little favour from German Engineers. A trial of this arrangement has, however, lately been made, on a short length of the railway from Frankfort-on-Maine to Heidelberg, and the result has been so satisfactory, that it is intended to lay the entire permanent way of the new line about to be constructed from Gustavsburg (opposite Mayence) to Frankfort, on this plan.

With regard to the size of rails, the rule laid down is that they shall not be less than $4\frac{1}{2}$ inches in height by $2\frac{1}{4}$ inches in width of head, and that their surface shall be curved to a radius of from 5 inches to 7 inches. The general weight of rails now adopted varies from about 66 lbs. to 76 lbs. per yard, both these limits being passed in a higher and lower direction according to local requirements.

The following Table of the dimensions and weights of some of the principal broad base, or contractors', rails in use on various lines will afford interesting information on the subject:—

—	Weight per Yard.	Width of Head.	Width of Base.	Thickness of Cen- tral Web.	Height of Rail.
	lbs.	inches.	inches.	inch.	inches.
Dortmund and Soeste Railway.	66	$2\frac{1}{4}$	3.86	0.55	4.65
Louise of Hesse ditto	68.25	$2\frac{1}{4}$	3.85	0.65	4.70
Frankfort-on-Maine to Cassel ditto	70	$2\frac{1}{4}$	3.95	0.65	5.00
Ditto to Heidelberg ditto	70	$2\frac{1}{4}$	3.95	0.65	5.00
Vienna to Salzburg ditto	70.68	$2\frac{1}{4}$	4.20	0.60	4.90
Frankfort-on-Maine to Wiesbaden do.	72.57	$2\frac{1}{4}$	4	0.70	4.93
Hanoverian State Railways	72	$2\frac{1}{4}$	4	0.75	4.50
Bavarian ditto ditto	73.98	$2\frac{1}{4}$	3.95	0.75	4.55
Prussian ditto ditto	74.75	$2\frac{1}{4}$	4	0.55	5.15
Baden ditto ditto	75.93	$2\frac{1}{4}$	4.40	0.80	4.70
Semmering ditto ditto	76.66	$2\frac{1}{4}$	4.54	0.90	4.54

The almost universal system of supports is that of cross-sleepers. They are generally of oak, when it can be procured at a reasonable price. Different descriptions of larch and fir are often used, after being prepared by some chemical process to resist the tendency to decay. Various are the means adopted for this purpose, but the one which is now most favourably received is that of forcing a solution of sulphate of copper through the pores of the timber to be prepared. The most simple arrangement for carrying out this method is a tank erected on a wooden frame about 30 feet high, into which the solution is pumped from the tub in which it is mixed below. From the tank a main distributing-pipe descends, until reaching within a couple of feet of the ground, when it diverges into two horizontal branches, with a series of small feeders about every 3 feet at right angles to the mains, and 10 inches or 12 inches long. On these are tied flexible gutta-percha tubes 6 feet in length, furnished at the ends with brass nozzles, and having screw clamps attached to them, by which the supply can be cut off from each separate feeder, without interfering with the others. The timber to be prepared must be round, with the bark on, generally in lengths of, say, two sleepers. It is laid horizontally, on a rough supporting frame, and sawed across the middle, through about nine-tenths of its thickness. A wedge is then carefully driven under the middle of the stem to raise it up from the frame. This opens the saw-cut above, and admits of its being caulked round the outside edge with oakum. The wedge is next removed, and the cut closes up to a certain extent on the caulking, leaving a vacant space inside between its two faces. Into this a slanting hole is bored from above, and the nose of the flexible tube inserted. The clamping-screw is then loosened, and the solution allowed to flow into the centre of the tree, and acting by the hydraulic pressure from the high-level tank, it makes its way through the pores, forcing the sap out before it. When the wood has become thoroughly saturated, it is ascertained by applying litmus paper to the end of the stem. The clamping-screw is then made fast and the piece of timber removed, to make way for another. The most advantageous number of stems to prepare at the same time with one apparatus is about fifty, a similar number being always ready to supply vacancies as they occur. For success with this method, it is necessary that the timber should be cut down when the sap is in it, and prepared while green, as otherwise it occupies too much time. Also, that the bark should be whole, to prevent leakage, and that the stems should be in duplicate lengths, so as to admit of their being prepared from the centre. The average time of preparing a log 18 feet or 20 feet long, under favourable circumstances, is about twenty-four hours.

Square stone blocks are used to a considerable extent, as

supports for the rails, on the Taunus Railway, but this is only on the old permanent way, as they are not made use of on the new line of rails now being laid down by this Company.

In noticing ballast on German railways, there is a system frequently to be met with which can scarcely be passed over without comment: that is, the filling up of the space outside the ballast to the level of the top of the sleepers with common earth, drains being cut through it at intervals, from the ballast to the outside slope, and filled up with broken stone. These drains, although at first answering tolerably well the purposes for which they are intended, after awhile become choked with the mud which is washed into them by heavy rains, and the free escape of water from the ballast is prevented. Add to this the mixing of the earth with the ballast, which is almost inevitable during repairs, and it becomes evident that the system has great drawbacks.

The stations on German railways are, as a rule, large and commodious, and in many cases display much architectural taste. They are generally close together.

The frequent absence of any description of fencing is also a marked feature on many German railways, the necessity for such a protection being done away with, inasmuch as cattle, except in some districts, are never allowed to stray at large without being attended by a herdsman. This latter arrangement is rendered imperative by the minute subdivision of land, which prevents the practicability of enclosing each separate property.

The quantity and description of rolling stock in use on different railways in northern and southern Germany varies greatly. The passenger carriages have principally six wheels, but there are many lines on which four-wheeled vehicles are adopted. On the Würtemberg State Railways, the long eight-wheeled carriages on the American system are in use. As nearly as can be estimated, the quantity of rolling stock at the close of the year 1861 stood thus:—

Locomotive Engines	per English mile	0·414
Passenger Carriages (averaging 41·81 seats each)	"	0·807
Goods ditto (average load 6·91 tons)	"	7·040

Before any engine is permitted to be used, its boiler must be tested with hydraulic pressure to at least once and a half the maximum steam pressure which it is intended to sustain, and a similar test must be applied after the engine has run 46,109 miles, and subsequently repeated every time an additional 36,887 miles has been made, or whenever important repairs are required should this be sooner. In no case, however, must the intervals between such testings exceed three years. On all such occasions the weighting of the safety-valves is also proved.

With regard to the proper proportion of breaks to any train, the rule laid down fixes the minimum number according to the following scale :—

				For Passenger Trains.	For Goods Trains.
For lines with a maximum gradient of 1 in 500				$\frac{1}{2}$ of the entire number of wheels to have breaks.	$\frac{1}{3}$ of the entire number of wheels to have breaks.
"	"	"	1 in 300	$\frac{1}{2}$ ditto.	$\frac{1}{3}$ ditto.
"	"	"	1 in 200	$\frac{1}{2}$ ditto.	$\frac{1}{3}$ ditto.
"	"	"	1 in 100	$\frac{1}{2}$ ditto.	$\frac{1}{3}$ ditto.
"	"	"	1 in 60	$\frac{1}{2}$ ditto.	$\frac{1}{3}$ ditto.
"	"	"	1 in 40	$\frac{1}{2}$ ditto.	$\frac{1}{3}$ ditto.

When the rate of gradient exceeds 1 in 300, it is ordered that the last carriage shall be supplied with breaks, and another rule in regard to the arranging of trains is, that between the engine and first passenger carriage there shall always intervene at least one carriage which does not contain passengers. It might have been well, when laying down such rules, to have gone still further, and ordered that the last carriage in every train, whether on a line with heavy or light gradients, should have breaks attached to it, and should not contain passengers. Where there are so few trains daily, and large quantities of small parcels and light goods requiring speedy transit, an arrangement of the kind might easily be carried out.

The rate of speed varies very much on different railways. For express trains it is usually from 27 miles to 35 miles an hour, exclusive of stoppages; the maximum velocity attained by trains while in motion being from 30 miles to 37 miles, and in some rare instances touching 40 miles. Ordinary passenger trains travel at the rate of from 20 miles to 25 miles, and goods trains at from 10 miles to 15 miles per hour, exclusive of stoppages. These comparatively low rates of speed, as might be expected, are most satisfactory in their results upon the wear and tear of both the permanent way and the rolling stock.

[Mr. VIGNOLES

Mr. VIGNOLES said, he did not think the Paper should be designated as treating on the German system of railways, though it contained an interesting description of various railway structures, and there were a number of points which, when studied in detail, would be useful and instructive. Nothing was related, however, of which there were not good examples, long previously existing in this country, and of a character which, if examined, would, he believed, be found more interesting to the engineer. Many of the works which had been described he knew perfectly well; and while he gave due credit to the engineers of Germany for what they had done, he was obliged, in his own mind, to compare them with similar works executed here and elsewhere. The German system of construction was, in general, no more than adopting, in a greater or less degree, the plans which had been found successful in this country, with such modifications as the circumstances required; but their works would not as a rule bear comparison with similar ones in the United Kingdom. For instance, the viaducts built from the designs of Mr. J. Miller (M. Inst. C.E.), upon the Glasgow and Dumfries Railway, were still unequalled in Europe, for boldness of conception and excellence of workmanship, and instead of following the old Roman fashion, of building tier upon tier of arches, as was the practice on the continent, there was only one tier of arches, each pier being carried up to its full height without lateral support. With regard to the Dirschau and the Marienberg Bridges, it was unnecessary to analyse the principles upon which they had been designed, because even from the descriptions given by the engineers of those bridges, and from the diagrams published with respect to those works, it might easily be shown that their mathematical construction was faulty, there being a want of due proportion between the several parts. He had watched the progress of these works during their construction, and had ascertained that their cost had certainly not been less than £45 per ton. It must be understood that this was not said by way of depreciation, because he thought, considering the struggles that had taken place in Germany, the results were most creditable.

He was exceedingly diffident in speaking on this subject, for he had so much to do in Germany many years ago, at the time of the introduction of railways, that it was impossible to allude to that period without saying more of himself than was becoming. When, thirty years ago, he laid out the railway from Brunswick to the foot of the Hartz Mountains, then almost the first after the Nuremberg and Fürth line, he introduced that particular form of rail, of which the Author had properly stated that seven-eighths of those in use on German lines consisted, which was known in this country as the contractor's rail, but was still better known in America and on the continent as the Vignoles' rail: it was a

system which he studied very much, before finally recommending and adopting it. It was properly called the contractor's rail, because the contractors were the first persons who had the courage to use it, in the face of authorities who would not at that period recognise it. At the same time he also strongly advocated the introduction, as many of his friends knew, of the system of fishing the joints of rails, which was first adopted in Germany.

The great principles, which he thought ought to have been insisted upon, as characterizing the German system of railways, were the simplification of the permanent way, and the perfection of their statistics. All the Companies were compelled, as in France, to give positive returns, under specific heads, of every detail of expenditure, and as these were published annually the Companies were brought into a wholesome competition, for the reduction of the working expenses to a minimum. Each Company was held up "in terrorem" to the others, so that all were interested in the reduction of their respective expenses. A recent inquiry showed, that the expenses per train mile on two-thirds of all the German railways were within a fraction of each other. But notwithstanding this, he believed it was capable of proof that the average expenses per train mile were less in the United Kingdom than in Germany. Still he thought it would be a wholesome regulation if Railway Companies in this country were compelled to give that information, in the same way as farmers were asked to contribute agricultural statistics. If those returns were furnished, it would be possible to trace every item of expenditure to its source, so that it would readily be seen where economy might be effected. It had been stated that the average cost of the German railways, one-fourth only having two lines of way, was £16,400 per mile; that would amount to about £14,000 per mile of single line. Now when the cost of land, the Parliamentary and legal expenses, and a vast number of other items which had unfortunately swelled the expenditure in this country were taken into account, he thought that the average cost of the lines in this country did not very much exceed that amount, particularly when of later date, those items of construction which did not fall upon the continental lines being of course eliminated.

The principle of railway legislation in Germany, as on the continent generally, was this:—The Government granted a concession for a railway from the town of A to the town of B, and sometimes provision was made, that it should run by way of the intermediate towns C and D, but all the details were left to be decided during the progress of the works. The evidence of individuals, in respect to the direction the line should go, was not taken, but the line being granted from point to point, the details were decided on the spot, where they could best be settled; and although it some-

times gave rise to considerable delay and annoyance, it saved vast sums of money. The same might be said as to the land. There was more trouble, perhaps, in getting land on the continent, but then it was obtained at the mere agricultural or mere town value.

There were a number of matters to be considered in making a comparison between the cost of lines in Great Britain and on the continent. As a rule, neither the engineers nor the labourers were so well paid on the continent, and there were various contingencies besides; so that he really thought—and it was a question he had studied for many years—when all these were taken into consideration, if the quantity of work done and its cost were contrasted, that the expenditure was not greater in Great Britain than it was, in the end, on the continent. And he would lay it down as a positive fact, that in no part of the world could work be done so cheaply as in the United Kingdom, whether measurement or weight of material were taken as the standard of comparison.

With respect to inclines, on the line between Nuremberg and Hof, on the route eastward to Leipsic, there were about 7 miles of 1 in 45, with curves of 400 yards radius, worked by locomotives. The last returns of the Semmering Railway in Austria showed that the working expenses exceeded the receipts; so great was the cost of working over 22 miles, with gradients of 1 in 40 and 1 in 45, and curves of 10 chains radius. The railway itself had been constructed at a cost of nearly £100,000 per mile, and he might mention that the bricks for the viaducts were brought from Vienna, so that the expense was enormous. However advantageous the line might be politically, and perhaps in other respects, to the Austrian Government, commercially the speculation was a most unprofitable one.

In mentioning the railway between Cologne and Liège, the Author had not noticed the way in which the passage had been effected between the two countries. The principal works were in Belgium between Liège and Verviers, and up to the Prussian frontier. They were constructed at an early period in the history of railways, and abounded in rapid curves, and comprised an extraordinary series of tunnels and viaducts; and altogether formed one of the most remarkable examples of engineering on the continent.

He had laid out the Würtemberg State Railways, and he knew they had been executed according to his recommendations; but most of the rolling stock was founded upon the American fashion, and he thought had not turned out satisfactorily. In determining the gauge for the railways in Würtemberg, Mr. Vignoles was called on to decide, whether the Bavarian gauge of 4 feet 8½ inches English, or the Baden gauge of nearly 6 feet, should be adopted. Though himself a warm advocate for a wider gauge, he felt compelled, under the then existing circumstances, to declare

in favour of the narrow gauge. It was then too late to adopt the wider gauge ; and the Baden Railways being isolated from the lines of Germany on the east, France on the west, and Switzerland on the south, were, as the Author had remarked, compelled to alter their gauge, and change the under-frames of their rolling stock.

The Taunus Railways had latterly been relaid, in consequence of the failure of the rails. These were originally double-headed, and when worn they were turned ; but a few months afterwards they broke, as might have been expected, at a short distance from the point of support : and he saw hundreds of tons of those rails which had been broken, lying in stack. Since then a different kind of rail upon sleepers had been adopted.

Mr. T. E. HARRISON said, in his opinion the Paper contained much useful information, and although it was possible some of the Members might be acquainted with the railway system in Germany, yet the younger members, who had not had the same opportunities, could not fail to profit by it. It was stated that the average cost per mile of the whole of the railways in Germany amounted to £16,400. If this was contrasted with the cost of railways in England, undoubtedly it showed very favourably ; but there were many causes which operated in favour of the German system, in respect of cost of construction. In the first place, they were exempt from Parliamentary expenses, which was a heavy item in this country ; then, an exorbitant price was not paid for the land. Besides, the railways, when made, were not subject to the same competition as in England ; and until lately,—for he believed a change had taken place in the views of Parliamentary Committees,—the whole basis on which railways seemed to be considered by those Committees was, that competition was a desirable thing. In Germany the lines, for many hundreds of miles in some districts, ran almost upon the surface,—while other portions were made through a country of the most difficult character,—yet on an average the cost per mile was low, and being without competition, he thought there could be no doubt that the railways there were destined to pay a remunerative interest to the shareholders. He observed also, that the Government had contributed aid, either directly or indirectly, to nearly two-thirds of the entire system. In England, that was a state of things with which they were totally unacquainted. True, in India the Government were contributing towards the completion of nearly the whole of the railways ; but the lines in India would not be liable to the same competition as in England : because the Government being the guarantors, they would take care that competition should not exist. With regard to the Society formed in 1847, under the title of ‘The Association of Government Railway Directions,’ it appeared that part of its

duties was to lay down rules for the government both of the railways and of those who had the management of them. Thus, the radius of the curves, and the maximum gradients admissible under particular circumstances, were prescribed; but after all these rules resolved themselves into the simple question,—what was the best gradient, or curve, which, having reference to the nature of the country, could be obtained? A rigid rule providing against a steeper gradient or sharper curve than a particular amount was simply impossible, inasmuch as what might be good in one state of things, where there was a large amount of traffic, would possibly entail expenses which would not be justifiable, in a case of a small amount of traffic. The question of statistics was referred to, and it appeared to be considered by some engineers in this country, that it would be a wholesome regulation, if Railway Companies in Great Britain were compelled to give detailed information as to the cost of working the lines, and that such statistics would lead to a reduction of expenditure. Now Mr. Harrison held, as regarded the management of railways, that there was no point which was of more importance to the Companies than having perfect statistics of working cost. Having been much engaged in the practical working of railways, he had felt the general advantage of that plan; but when it was urged that it would be desirable if Railway Companies were compelled to make those returns—he presumed to Government—he believed the results would not be such as had been anticipated. In so far as the statistics prepared by the Railway Companies themselves were concerned, they were invaluable; because not only the officers of the Company but also the Directors were enabled to see from time to time what expenses were incurred; and by weekly or fortnightly returns being laid before the Board of Directors, which was the case with the Company with which he was connected, showing in a tabular form the cost of each individual part of the system for a series of years, any excess of expenditure in any department could be at once detected. But then there was this difficulty—the cost even of one large system of railway could not be compared with another, without these details being accompanied by a great number of facts which bore upon that cost. For instance, on portions of the system he was more immediately connected with, the cost of maintenance of way was, in some cases, four times as much as it was on others. The working expenditure per mile reached nearly 80 per cent. on some portions of the line, whilst on other portions the cost did not exceed a minimum of about 40 per cent. Therefore, for the North-Eastern Railway Company to compare its expenditure with that of the London and North-Western Railway Company, for instance, would be to contrast two things which were totally dissimilar; and unless all the circumstances involved in the expenditure were taken

into account, such a comparison would not only be useless, but would be calculated to mislead. He had seen statements, prepared with great ability, from figures exactly of the same data, of the results of the working of one Company as compared with another, the deductions from which were, to his own knowledge, exactly the reverse of the facts. He held that however valuable such statistics might be to the Companies themselves, the advantages were confined to their own particular system.

Allusion had been made, in the Paper, to the Semmering Railway. He had passed over that line, which was the work entirely of foreign engineers, and he would say that he knew no engineering work that would better repay the time and trouble of an inspection. It had been stated that, on the Southern State Railway of Bavaria, there was an embankment 172 feet in height, containing 3,000,000 cubic yards. The details of that embankment, as to the conditions under which it was carried out, were not furnished, but it was certain that in no part of England was there an embankment of that height. It appeared from the rules of the Association to which he had previously referred that the use of cast iron was completely ignored. Now he thought there were many cases in which cast iron was exceedingly useful for bridges; and though that material might be open to some objections, yet when employed in the form of segments, of which there were many admirable examples on railways in England, he could not agree in the conclusion which had been arrived at by the German engineers. The details had been given of a number of bridges of great spans, some exceeding 370 feet, which had been executed in Germany. He would suggest that it would be very useful if the Author would furnish some data from which an estimate could be formed of the cost of those bridges—either per ton of metal or per lineal foot; and in the case of tunnels the cost per yard; as it would be interesting to compare the cost of these large works with the cost of similar works in this country. The viaducts on the Semmering Railway were constructed with intermediate arches in their height. There were numberless examples of high viaducts throughout this kingdom—and those upon the Glasgow and Dumfries Railway had already been referred to; but in many parts of Lancashire, there were viaducts more than 100 feet in height, and he had built viaducts more than 150 feet in height, without a thought of introducing intermediate arches. Comparing the general designs of these viaducts, it appeared to him that those on the Semmering Railway contained more material than had been introduced into viaducts in England. Looking upon the Paper as a carefully prepared record of what had been done in a foreign country, entirely by foreign engineers, he regarded this communication as a valuable

one; and he repeated that any one who visited those works would be amply repaid for his trouble.

Captain MOORSOM remarked, with reference to the small cost of the German lines of railway, that it appeared they were laid down generally with the earthworks and bridges to receive double tracks eventually, but almost invariably waiting for the double track till the traffic should justify it. He thought a useful lesson might be taken in that respect in this country. He had only a few weeks ago perused a report from one of the Government Inspectors, in which it was noted as a matter of unfavourable character, that land had not been purchased sufficient to lay down a double track on a railway branch where only four trains each way were run during twenty-four hours. The fact was erroneously reported by the Inspector, but still it showed one of the impediments thrown in the way of economy in this country, as compared with the German system. He was at a loss to understand why 'The Association of Government Railway Directions' in Germany should limit the radius of curves to 3,600 feet on level ground, 2,000 feet for hilly country, and never less than 600 feet. He was prepared to say, that curves of 300 feet radius might in some instances be desirable. Not that in England such were frequently found, but he should not hesitate to adopt a curve of 300 feet radius, if necessitated by the circumstances under which he was obliged to lay out a railway, as he believed it would be possible to work round such a curve, to the satisfaction of the locomotive superintendent, at a speed of 20 miles or 30 miles an hour. Some years ago, he laid down a curve upon a radius of 7 chains, or between 400 and 500 feet, which remained to this day on one of the great lines of the kingdom. The trains were calculated to travel on that curve at 25 miles an hour; but when the line went out of his hands, the Directors issued instructions not to exceed 15 miles an hour round that curve, by which instructions of course all the calculations for 25 miles were falsified. With respect to the limitation of gradients to 1 in 200 in level districts, 1 in 100 among hills, and 1 in 40 on mountain lines, he remarked that the character of gradients must be guided by what the country would admit, as some countries seemed to be laid out for a certain class of gradient. Thus, in the West of England, the land was laid out for 1 in 60, and if 1 in 70, or 1 in 80, were attempted, serious difficulties would be encountered. In other parts the ground was suitable for gradients of 1 in 100. Therefore, as the country seemed itself to design the gradient on which the railway should be laid out, to limit these gradients by the dictum of book, or tables, appeared exceedingly undesirable.

The speed of the trains on these German lines appeared to be lower than was necessary. On the Semmering Railway the speed

[1832-63. N.S.]

v

of the express trains was limited to 14 miles an hour in ascending, and to 16½ miles in descending, gradients of 1 in 40. He was satisfied that speed might be doubled with safety, from his experience in the working of the Lickey incline, of 1 in 37, on the Birmingham and Gloucester Railway, since the year 1839. The goods train at 9½ miles an hour might do very well, as high speeds were not required for goods, and it was expensive to have high speed for goods trains on heavy gradients. In descending such gradients, it was quite possible, with ordinary breaks, always to have the train under command, when travelling at a much higher speed; and the only limitation in descending upon heavy inclines was that which enabled the train to be held 'in hand.' When a train was obtaining the mastery, running ahead in fact, it was readily perceived, and there was a certain stage of progression which might be denominated the ultimate speed which a train attained, after the breaks had been got to a proper bearing; and this speed would not decrease, or increase, unless a greasy part of the line, or the falling of dews, intervened to give more sliding way. The late Mr. Robert Stephenson used always to complain of the cost of going up those heavy inclines; but Captain Moorsom believed, that the cost of working up the Lickey incline, at 28 miles an hour, was practically no more than going up at the rate of 15 miles. From the year 1840 to 1845 the speed on that incline was 15 miles an hour with passenger trains of seven or eight carriages, at a certain cost per train mile, which he did not remember, but it was per engine about £700 per annum. From 1845 to about 1855, a material improvement took place, as regarded the traffic, which increased so much as to require ten or twelve carriages, instead of an average of seven or eight, and heavier engines were used. The result was that, from 1845 to 1855, the trains of twelve carriages used to run up that incline at 28 miles or 30 miles an hour at no more practical cost than they ran in 1845 at the rate of 15 miles an hour. He referred to the accounts in verification of the correctness of this statement. He thought that embankments of 170 feet in height were dangerous to execute. He was laying out a line for the next session with 82 feet of cutting rather than have an embankment of 42 feet. The London clay or lias would slip at less heights than that, and he knew of no soil that could be trusted to the height of 172 feet. He had an embankment of 84 feet in the gritstone, but not higher than that. With respect to the bridge over the Rhine, at Cologne, to which allusion had been made, he thought it worthy of mention, that a member of this Institution furnished the design for which the Prussian Government gave the prize over sixty-one competitors of all nations. That design was for a lattice bridge of peculiar character, and very large spans. He was not certain whether the

design had been carried out in all its details, but he was told that a lattice bridge had been constructed there. He mentioned this circumstance, as reflecting credit upon the Institution, that one of its members should carry off the prize as to Engineering Construction thus largely competed for, while the prize for Architectural Design was awarded to an Architect of Berlin. He quite agreed that the general contour of the Paper was useful, and that they were indebted to the Author for the statistics he had given.

Mr. J. SCOTT RUSSELL said, it had happened that during the last fourteen years he had passed over many of the German railways, and he had been struck by several points which appeared to distinguish them from the railways of this country. In the first place it seemed to him that the Germans, almost first among the continental nations, set to work to ascertain what, in the British system, was best suited for their practice; and nothing surprised him more, than to see how rapidly anything successfully introduced into this country was, not copied there, but adapted to suit German circumstances and the peculiarities of the German mind. He had often asked himself the question, what could be the reason that the German engineers so quickly took to making railways, and he found but one cause, and that only accounted for it up to a certain point. He observed that, so far back as the year 1848, the German governments had taken to the belief, that a special education for engineers of all classes—mechanical and civil—was one of the first duties of a government. At that time, when young English engineers were picking up knowledge in the best way they could, there were regular colleges for the training of skilled workmen, and the education of civil engineers, in most of the great cities of Germany. By these means a set of thoroughly educated young men was prepared, ready to acquire practical knowledge, and to turn it to account in a short period of time. Many of these men were sent to England, to take advantage of the earlier practical experience in engineering works gained here, and they proved to be most apt pupils. One result of this was rather remarkable. Sooner, he thought, than any other country the Germans took to making locomotive engines. The English types were at first implicitly copied, but when once that was accomplished, and engines had been fairly constructed, the German engineers took to making designs for themselves, and departed more and more from the established patterns; so that now the engines on most of the principal lines were made exclusively in Germany, and in some cases at a less cost than in this country. It was still more remarkable that German engineers were now tendering against the British in many foreign markets; and it was even said, that one firm, that of Borsig, of Berlin, had recently successfully competed in England. From the manufactory he had named many beautiful and admirably

constructed locomotive engines were sent out, and they were far from being copies. In another case he knew that a German house had taken a large iron bridge contract from the best English houses.

Another circumstance which attracted his notice was, as it could not fail to do that of any engineer—the character of the earthworks. Immense trouble was evidently taken, the works were executed with great nicety and skill, and the result was, there were few slips. He believed that might be partly owing to the fact, that many of the early earthworks in Germany were designed by military engineers, who bestowed more care and attention upon earthworks than railway engineers. With regard to the gradients, he quite agreed in the view already expressed, that it was pure pedantry to attempt to dictate the gradients on any class of lines. The country and the circumstances must determine what these should be. Great mistakes had been made on some German railways from the adoption of theoretical gradients for a long line of country, where, in order to preserve—say a gradient of 1 in 200—many miles of moderate cutting had been incurred, which might readily have been avoided, if the contour of the ground had been more closely followed. It was true, the curves were generally of much longer radius than in this country, but that also was due to the character of ground passed over. Germany was, in general, well suited to the construction of railways, because there were long tracts of level land; and it was easy to concentrate the gradients upon that place where any auxiliary power that might be wanted could be obtained. Great judgment had been shown in the early adoption of a cheap permanent way, including the fish-joint, which, he might remark, it was somewhat astonishing was only first used on the great lines in this country, about ten or twelve years ago, after the Germans had adopted it almost throughout their entire railway system. The waggon-stock was peculiar. It consisted of long square boxes, or warchouses, placed upon two lauries, on four wheels; and was perfectly watertight, instead of being composed of open trucks, covered with tarpaulin. It was said that the goods were carried with great care, and were delivered in admirable condition.

In the first-class carriages, seats for four passengers abreast had been all along provided. Whether that was a convenience, or not, to individual passengers was a question; but the plan was coming into use in this country. In regard to the first cost of the German railways, he did not think there was much merit in that. The country itself was not of a nature to demand expensive works; and to compare the two countries—so different as the great level corn-fields of Germany to the hilly undulating garden of England—would give no useful information. It was no doubt true, that

•

many expenses necessarily incurred here were not repeated there ; but it was entirely a question of country ; and he regretted that the papers had not entered more fully into details on this subject, because it would have been useful to know what the great bridges and the earthworks had cost in the two countries respectively. In regard to management and economy of working, he thought there was much to be explained. In the first place, on the German lines less accommodation was given than on the English. The trains were very heavy, but they were run seldom, and at slow speeds, comparatively, and in that respect offered little public convenience as compared with the metropolitan lines. Therefore their economy of making did not go for much. It must also be remembered that the stations were far apart, and therefore there was not the loss in stopping and in starting which was incurred on more frequented lines. Then again, in regard to the earnings of the lines, there was another element besides first cost. It was this—he did not remember to have heard it stated what the comparative fares were ; but a friend of his, who had a large trade in minerals, had made inquiries in this country as to the cost of the carriage of goods, minerals, and heavy traffic, when he found that the current rates on German railways were two or three times greater than on railways in England. That was another cause why the earnings should be higher, without there being any superiority over English railways. If the accommodation was less, the speed slower, and a higher sum was charged for the transport of goods, it was plain these were elements which would cause larger dividends to be realised on comparatively smaller capital. These were a few of the main circumstances which he thought distinguished German railways, and he believed would go to show, that though German railways had great merit, yet it must not be considered that all these apparent advantages were really advantages to the country through which the railways passed, and whose interests those railways were intended to serve. The Institution was under great obligations to the Author of the Paper, and the young engineers of England could not do better, than ascertain what their professional brethren were doing in other countries ; for, as far as he was able to judge, although English engineers were at present superior to the engineers of all the countries of Europe, he had the impression that the engineers of other countries, especially on the continent, were making more rapid progress.

Mr. MALLET said, he had had a good deal of experience, while a mechanical engineer and contractor, of the methods employed in this country and abroad in the construction of railways. Last year he had travelled over many German railways, and upon some lines not commonly visited by Englishmen. For his part he felt unbounded admiration of German engineers, and he was satisfied

that, as regarded sound technical education, the comparison between the English engineer and the German was much in favour of the latter, and increasingly so. Such an expression of opinion would probably be unpopular, but if true, it was nevertheless wholesome to be heard. As an illustration of the general truth of the opinion, as to the imperfect character of engineering education in England, he would ask any one who had visited the Western Annexe of the International Exhibition of 1862, which amongst the steam engines there shown displayed most mind and knowledge of principle, and the best advance towards theoretic perfection. Not certainly any of the English ones, but two of American origin, one improved and carried out by Germans. With respect to originality of construction manifested in the German railways, no doubt the earliest lines in that country were suggested by the successful creation of the railway system in England. They were, he believed, not designed by military engineers, but by officers from the Bergampt (School of Mines), the first ideas of railways being taken from those of their great projector, George Stephenson; but the works were carried out in their own way from the commencement, and with striking originality in structural detail. So far from having copied English engineers, the latter had in several respects copied them. The lattice bridge in iron was in fact introduced from Germany. One of the earliest German iron lattice bridges was that across the Elbe at Magdeburg, the wooden lattice having been long previously known and adopted in America. Sir John Macneill, who was the first to employ iron lattice bridges in this country, took his earliest examples, in Ireland, from this and other early German bridges. Mr. Mallet would venture to say that he believed, in the end, the lattice bridge, in iron, in one form or another, would supersede all others for railway uses.

He had recently been over a new line of German railway, the Deutz and Giessen, which ran along the valleys of the Lahn and Sieg, through, in great part, a very uneven country, one very unlike the level plain of Central Germany, so commonly supposed to form the basis of all German lines. This line comprised a vast amount of heavy earthworks, and over bridges, and extensive lattice viaducts repeatedly crossing the Lahn, a large navigable river, and it passed through a country more difficult than any he had seen in England. In one place, for 14 miles in length in one stretch, the gradient was 1 in 40, and nowhere less than 1 in 80; almost all this was in rock cutting and side embankment, and the line was obliged to take curves in the form, in some places, of the letter U. That line, he understood, had been made nevertheless at an expense of about £12,000 per mile. The bridges over the Lahn were on the lattice principle, and were beautiful examples of structural skill, and in some points novel. One cha-

racteristic of the German railways was well worthy of imitation; that was the care taken to prevent accidents, which seemed to be to a great extent neglected in this country. Some years ago a brother of their member Mr. Siemens, himself a German engineer by education, proposed a mode of telegraphing along all the lines, by which each train, as it started, telegraphed its approach to the station immediately in advance. That system was adopted on every line, he believed, and the result was an almost entire immunity from accidents on German lines. It was not correct to suppose, that the freedom from accidents on the German lines arose from their running few trains, or that these invariably travelled at a slow rate. In Westphalia, the grand centre of German industry, on the trunk lines, as many trains ran as on some of the English lines, and the speed of the express trains was 40 miles an hour, while the average speed of ordinary trains was 4 German, or nearly 21 English miles per hour. Repeated efforts had been made to get the same system introduced here, but the attempt had been nugatory except in one or two instances. This inertness to improve in England might be illustrated by a smaller matter. Nearly all the railways in Germany had their axles lubricated with liquid oil, instead of solid grease, the imperfect material in universal use here; one loth, or ounce of oil, serving to grease an ordinary axle for a month. About fifteen years ago, he introduced a mode of oiling the axles of railway wheels which, although independently invented by him, turned out afterwards to be identical with that in use in Germany on certain lines. He endeavoured to get the method tried on some English lines, but was met by the statement, that however good it might be, grease was so generally employed that no change would be made.¹ In Germany there was an admirable system at work for the technical education of engineers and others engaged in skilled and scientific employments with which there was nothing to compare in this country, and it would be well to study it and to adopt it as far as possible, otherwise this nation would, in this respect, assuredly fall into the rear.

In illustration of the rapid expansion of German industry, Mr. Mallet then directed attention to a map, annually produced by the 'Oberbergamt,' which exhibited, graphically, the progress and distribution, year by year, of the coal industry of Prussia. It showed the tons of coal raised, used and exported, from each of the great coal basins—the Westphalian, the Saarbrücken, the Silesian, &c.—and also the imports and distribution in Germany of coal from England. This was at once an indi-

¹ An attempt is now (September, 1865) being made to try oil as a lubricant on some passenger carriages on the London and North Western Railway.—R. M.

cation of the perfect way in which Germany treated every question, and an illustration of the enormous progress of German industry and railway traffic. The Westphalian basin alone contained more coal than the whole of Great Britain. A comparison of that map, over a few consecutive years, would show, how steadily British coal exports were decreasing all over the continent, and the product of German coal increasing. Germany had now got an abundance of coal, and everything needful for industrial success along with it. It was in itself the source to her of direct wealth, and the creator of every other form of riches. If then technical education in this country was not made to keep pace with that of Germany, the British would not long maintain that relative manufacturing pre-eminence which they had hitherto held amongst the nations of the earth. He regarded the growing prominence of Germany in the industrial arts as mainly owing to the more perfect education of all its technical classes. The great movement in education dated in Prussia from the year 1813, when Germany shook off the despotism of Napoleon. Education, in its primary rudiments, was compulsory on all; so that no one could stand between the child of Prussia, and that fundamental knowledge that should fit it, in whatsoever station, to become an honour, and not a disgrace, to the fatherland. Moreover, the gymnasia, and the universities were better fitted for technical education than in Great Britain, where, as an organized system, there did not exist, between the elementary schools (more particularly for the middle and wage classes) and the universities, any efficient system of technical education at all. There was thus a great gap, filled only by a few isolated institutions, such as the Museum of Practical Geology, &c. The superiority in result of the German system was not badly indicated, by comparing the 'Taschenbuecher,' or pocket-books of data, in use in that country, with those found here. The German books were prepared by men of thorough and exact information, and were obviously addressed to persons who had already received the fundamentals of a sound general education, and hence were prepared to accept and apply scientific and technical data in an exact and technical form. Similar books in this country were addressed to men, who were yet supposed not to have the elementary knowledge of well-educated schoolboys; and as such books were in demand, it was plain that English artisans, &c., really had not on the whole that amount of preliminary knowledge.

Mr. SHEILDS said, that in the north and north-east of Germany, everything in the way of railway works was so plain and simple, and so like what it was in any easy district of country at home, that there was not much to remark upon. The expenditure upon the railways had been small from a variety of reasons, one

being that the population supplied an excellent industrious class of workmen, and the work did not appear to be hurried so much as was the case in this country. There was a less amount of work to be done, and being carried out more slowly, large bodies of workmen were not collected together, by which the price of labour was raised to an artificial height. The German navy was paid about 1s. 6d. per day, and did a large amount of work, so that he believed throughout Prussia the cost of the earthwork did not exceed 8d. or 9d. per cubic yard. It was to be remarked, that but little contractors' plant was employed, the embankments being executed mostly from side cuttings, with barrow runs of much greater lengths than in this country, even up to 300 yards. This might account, in a great degree, for the excellence of the earthwork to which allusion had been made. The stations in Germany had been spoken of as being excellent; and he was surprised that the Author had not noticed especially the station at Breslau, which was perhaps one of the finest in Europe, as regarded architectural effect. In his opinion, the German lattice bridges should not be taken as models of the best design and construction. The lattices were composed of flat bars, which were inherently weak in themselves, and which, however they might be supported at intervals, by vertical bracings, to keep the top and bottom flanges apart, were imperfect constructions. It was, he thought, far better to give the lattice bars the necessary rigidity in themselves, than to make them inherently weak, and supply what was deficient in them by additional construction. He had made such girders some years ago, when it was the customary practice, but he found their deflection to be very great; in consequence, he had since adopted the system of employing angle irons for the lattice braces, whether in tension or compression, or of using plate girders, which undoubtedly formed a good strong bridge. The rolling stock was of excellent construction, and the passenger carriages most commodious; but the trains were few in number, and in most cases several hours apart. Under such circumstances, he did not think that so much credit as had been claimed for them was due for their freedom from accidents. In fact, no fair comparison could be made in this respect between the German and the English systems; and he believed that if the trains ran as frequently on German lines as on those in England, it would be found that as great, if not a greater number of accidents would take place on the former than on the latter.

Mr. COCKBURN CURTIS said, notwithstanding the remarks which had been made, he did not feel any apprehension, that English engineers would be surpassed in professional ability, or practical attainments by their German, or other continental brethren. Such a result certainly would not be owing to any fault in their pre-

sent mode of education ; but if it ever unhappily did take place, he considered it would be more likely to be occasioned by the substitution of a theoretical system of training, for the practical apprenticeship, and the test of public confidence, in existing works, which had hitherto been the credentials of the English engineer. It must be remembered, that the qualifications required in an efficient engineer were more of a practical than of a theoretical character, and that the great object in educating a youth for the profession was to strengthen his thinking and working powers, by habits of self-reliance and by the acquisition of such an amount of scientific and practical knowledge as would be readily available in cases of emergency. He contended that no amount of theoretical knowledge, however easily it might be insinuated into the mind by treatises and compendiums, could compensate for the ready aptitude, and difficulty-overcoming power, which was attained by that continuous labour which simultaneously connected scientific knowledge with actual experience. Mr. Curtis had never been in Germany, but his personal experience in other continental countries, where similar institutions and systems had been adopted for the education of engineers, induced him to believe, that any advance that might have been made in the efficiency of the German engineers was rather to be attributed to the national development of a healthful spirit of speculation and enterprise, and the consequent necessity which had arisen for emerging from the previous state of crude and pedantic theory, of which instances had been given and commented upon in the course of the discussion ; and upon the whole he considered that while the evils of the English system of engineering education were probably overrated, on the other hand, it would be impossible to overrate the evils that might arise from transplanting the German, or any other continental system of educating engineers into this country.

Mr. C. H. GREGORY said, he was afraid the effect of some of the observations which had been made might be of a depressing character, as regarded the capabilities and prospects of English engineers. He observed, however, that the map which Mr. Mallet had alluded to showed, that notwithstanding the great advantages arising from the Prussians having coal-mines close at hand, still English coal found its way into that market, and competed with the coal of the country, in spite of the expenses of transport. With regard to the alleged advantages of special education, without venturing to depreciate that which was a valuable aid to the labour of all classes, and very useful in assisting the engineer, and the practical man, to the best way of attaining his object, yet he submitted that undue importance should not be attached to theoretical education, to the neglect of that practical experience and training which the engineer should always bring to bear upon

his profession. The history of engineering in this country showed that the works which reflected the highest honour upon the profession had been carried out, to a great extent, by men who had not any large amount of special theoretical education, but who, being possessed of great natural powers, were enabled to take advantage of the national resources and peculiarities in such a way as to command for English engineers universal respect. He thought that this result would not have been attained, if they had relied upon a technical theoretical education, and systematized rules, cut and dried by others, instead of their own energy and originality of mind and action.

Mr. MALLET was far from wishing to disparage the achievements of those who had been the great fathers of English engineering; but he would ask, how much greater would those achievements have been if these undoubtedly great men, the Brindleys and the Stephenson of engineering history, in place of having to employ their grand intellects in hammering out imperfectly, and as best they could, the information they needed, had had that educational training that would have placed at their command, in orderly array, the accumulated stores of knowledge of all mankind in all time past, and the power that such confers?

Mr. CRAWFORD observed, through the Secretary, in reference to a remark that the works between Verviers and Liège, on the line from Cologne to the Prussian frontier, had not been described in the Paper, that that railway was in Belgium, and being beyond the Prussian frontier, was not within the limits treated of in the Paper. The principal works of interest on the railway from Cologne to the Prussian frontier, namely, the incline at Aix-la-Chapelle and the large tunnel, one of the first constructed in Germany, were alluded to.

November 18, 1862.

JOHN FOWLER, Vice-President,
in the Chair.

THE Discussion upon the Paper No. 1,071, on "The Railway System of Germany," by Mr. R. CRAWFORD, was continued throughout the evening to the exclusion of any other subject.

November 25, 1862.

JOHN ROBINSON MCLEAN, Vice-President,
in the Chair.

No. 1,058.—“The Hownes Gill Viaduct, on the Stockton and Darlington Railway.” By WILLIAM CUDWORTH, M. Inst. C.E.

THE Stockton and Darlington Railway has been no exception to the system of gradual extension, which appears to be so commonly the policy, or the necessity of railway management. Its length, at the time of its opening in 1825, was 25 miles. It has now spread out, by numerous ramifications, to 183 miles. The branch upon which the Hownes Gill Viaduct has been erected was formerly the western part of the Stanhope and Tyne Railway. After the dissolution of that Company the part referred to came into the hands of the Stockton and Darlington Railway Company, in the year 1844. On account of the mountainous character of the country traversed by this branch, which has a summit level of about 1,450 feet above the sea, the adoption of steep gradients, worked by stationary engines and ropes, though diversified with occasional intermediate lengths comparatively level, was unavoidable; but it was carried to a greater extent than would be consonant with modern ideas. Thus, Hownes Gill, a dry ravine 800 feet wide and 160 feet in depth, situated near the Consett Ironworks of the Derwent Iron Company, in the north-western part of the county of Durham, was crossed by a descent and ascent corresponding with the contour of the Gill; the gradient on the west side being 1 in $2\frac{1}{2}$, and that on the east side 1 in 3. A small traffic, conveyed in chaldron waggons, was for some years taken over these gradients with little difficulty, although encumbered with what subsequently proved to be a needless contrivance, for preserving the waggons in a horizontal position. This consisted of cradles, or carriages, one for each incline, having front and hind wheels of unequal diameter, upon which the waggons travelled side foremost. Only one waggon could be passed across in each run, and delay and expense were incurred, by each having during its transit to be turned upon four turntables. It was, however, arranged that both inclines should be in operation at once, by which means the gravitation of the descending waggon aided the engine in drawing up the ascending one.

Soon after the connection of this branch with the Stockton and

Darlington Railway, the increased traffic was objectionably retarded at the Gill, and greater facility of transit became imperative. This was obtained by the simple removal of the cradles and turntables, and by allowing the waggons to travel upon their own wheels, when three could be linked together in a train, and passed across in less time than was previously occupied by one. This alteration was satisfactory, and the Gill was worked well for a time; but a large accession of traffic, consequent upon the discovery of the Cleveland ironstone, and its purchase by the Derwent Iron Company, at length demanded further accommodation. The trains were necessarily limited to three waggons, to avoid putting undue strain upon the couplings, and various methods of obviating this restriction were considered; but nothing less than the erection of a high level viaduct seemed to offer a satisfactory solution. The idea of a viaduct had been a favourite one with the Directors of the Stockton and Darlington Railway Company from the first; but for some years the traffic was insufficient to warrant the necessary outlay. As early as the year 1844, with the view of ascertaining the probable cost, the Directors issued advertisements offering premiums for the two best designs of viaducts, to be accompanied with estimates of cost. This met with a ready response, but the estimates attached to the premium drawings exceeded £17,000. When, in 1853, the subject became more pressing, the remembrance of the premium experiment was sufficiently encouraging to induce the Directors to repeat it. Upon this occasion their attention, and that of their engineer-in-chief, Mr. John Dixon (M. Inst. C.E.), was attracted by a design sent in by Mr. John Anderson, then of Edinburgh, now of Middlesbro'-on-Tees, contractor, and prepared by Mr. Thomas Bouch (M. Inst. C.E.), as it was accompanied by a tender to erect the viaduct, and to uphold it for twelve months after completion, for the sum of £11,697 if built of common brick, or of £13,237 if built of fire-brick. The design represented twelve arches each of 50 feet span. Although the ability of Mr. Anderson was well known to the Directors, and although they had also great confidence in Mr. Bouch, it was thought desirable to consult the late Mr. Robert Stephenson, M.P., as to the sufficiency of the design. In the interview which Mr. Dixon had with Mr. Stephenson, when Mr. G. P. Bidder (Past-President Inst. C.E.) was present and gave his advice, a general approval of the plan was expressed, with some limitations and recommendations, as the proportions of the viaduct were considered to be such as to leave no margin for inferior material, or workmanship.

Nearly three years elapsed before further action took place. At length, in 1856, Mr. Anderson's offer was accepted, to erect the viaduct in fire-brick, set in hydraulic mortar, the arches to be in

cement, for the sum of £14,100. As the premium drawing, with the modifications suggested by Mr. Stephenson and Mr. Bidder, was the basis of this contract, the sum required to be readjusted, when the circumstances of the foundation, site, &c., had been considered. In December, 1856, a revised contract was entered into, referring to a duly matured working drawing and specification. Mr. Anderson then undertook to erect the viaduct in eighteen months, and to uphold it for twelve months after completion, for the sum of £14,614. To avoid interfering with the traffic over the inclined planes, a deviation of the line was an obvious necessity. The piers in the slopes of the Gill found a firm foundation on the shales and stone of the coal measures. The only difficulty was the occurrence of abandoned iron-stone drifts, the entrances to which were concealed by a thick cover of débris. A careful probing of the doubtful foundations, with boring-rods, was therefore resorted to. Some of the drifts were entered and explored, and eventually both the abutments were sunk through the strata in which the mines occurred. In the bottom of the Gill there was a thick bed of heterogeneous material, consisting of the débris of the slopes, into which a bore-hole was put down for 30 feet, without indicating a change of stratum. Although this bed was by no means of a soft nature, it was not deemed firm enough to sustain the great weight of the structure with ordinary foundations. At the suggestion of Mr. Stephenson, the bases of the three central piers were extended, by the application of inverts, until the weight scarcely exceeded 1 ton per superficial foot. The choice of fire-brick, in preference to common brick, was made with the view of having the best material, the common bricks of the neighbourhood being inferior both in strength and regularity of shape. Large quantities of fire-bricks are made at the collieries in the district, for the linings of the coke ovens and of the iron furnaces of Cleveland.

The extreme length of the viaduct (Plate 1) is 730 feet, and its greatest height, from the bottom of the inverts to the level of the railway, is 162 feet, or from the surface of the ground about 150 feet. There are twelve semicircular brick arches, each 50 feet span, 14 feet in length, and 2 feet 6 inches in thickness, set in Portland cement. The inverted arches in the foundations, four in number, have a versed sine of about 14 feet, and are 38 feet in length, and 3 feet in thickness. The brickwork in these, as well as in the piers, and in the whole of the viaduct, with the exception of the arches, was set in hydraulic mortar. The height of the five loftiest piers, measured from the springing of the inverts to the springing of the arches, ranges from 114 feet to 110 feet; that of the six remaining piers diminishes rapidly towards each end. Their length is 14 feet at the top, and 38 feet at the bottom, in the case

of the high ones, the latter dimension corresponding with that of the invert. The piers down to within about 15 feet of the invert are stayed with buttresses, which are transverse to the line of the viaduct. At this point they are only 17 feet 6 inches in length, but below this level the buttresses merge into the piers, when they together present a rectangular horizontal section 38 feet in length. The buttresses are 3 feet thick at the top and 5 feet thick at the bottom; their projection from the piers being increased by offsets at intervals of about 35 feet. The piers, although light in their proportions, are reduced by recesses 7 feet 3 inches wide, and averaging 3 feet 9 inches deep, in each side, so that the horizontal section of the pier and buttresses is in the form of a double cross, the brickwork left in the middle being only 2 feet thick. These recesses are not continuous throughout the pier, but are divided into three compartments, the solid parts between affording facility for the introduction of two bond courses of stone, the continuation of which through the buttresses forms a finish and protection to the offsets. The amount of brickwork abstracted from one pier by the adoption of the recesses is 142 cubic yards, or about $14\frac{1}{2}$ per cent. of the contents of a solid pier without recesses.

Between the spandril walls, which are of brick 3 feet thick, two internal parallel walls of stone 2 feet thick were introduced, to sustain a platform of flagging 6 inches thick, upon which the 'way-beams' and ballast are carried. The arches between these walls are kept dry by a layer of puddled clay, which conveys the water to discharging-pipes over the piers in the usual manner. The way-beams are of Memel fir, 12 inches by 12 inches. They were at first fixed to the flagging with bolts secured to the internal walls; but it was soon found that there was an objectionable rigidity in the permanent way, indicated by the working of the ballast and the occasional fracture of a joint chair, and accompanied by an unpleasant amount of vibration. These evils were remedied by simply removing the nuts from the locking-down bolts, lifting the way-beams 6 inches, and interposing that thickness of the common coke ballast of the district, between the way-beams and the flagging. The external walls were covered with a simple projecting string course, 3 feet 6 inches by 1 foot 9 inches, and upon this was fixed a substantial cast-iron railing, forming the parapet. The choice of iron was more than a mere question of taste, it effected a considerable saving of brickwork; for if a brick or a stone parapet had been adopted, the upper part of the viaduct, including the arches, must have been about 16 feet wide, instead of 14 feet.

The fire-bricks, which were of excellent quality, were obtained chiefly from Pease's West Fire-brick Works, near Crook, about 14 miles from the viaduct, but having railway communication with

it. They were $9\frac{3}{4}$ inches by $4\frac{3}{4}$ inches by 3 inches in size, weighed 9 lbs. 11 oz. each, and cost the contractor 26s. 6d. per thousand at the works, which the railway dues increased to 31s. 2d. per thousand at the viaduct. The number used was 2,655,000. The greatest care was taken to insure the adhesion of the mortar and the solidity of the work, the bricks being freed from dust, well wetted, and set with a mallet. The internal work was as good and solid as the external portion; and in the arches, which were constructed in half-brick rings, whenever the coincidence of two courses admitted of it, radiating bond bricks, moulded for the purpose, were introduced. It is gratifying to be able to state, that not a single crack can be discovered in the whole of the structure.

The scaffolding used in the erection of the viaduct was of a very light character (Plate I.). It proved, however, to be sufficiently strong, and the work was completed without accident. The erection of the scaffolding was considerably facilitated by the hoisting tackle being made to traverse a stout wire rope stretched across the Gill, and firmly fixed at each side to the roots of trees. When the arches were about to be turned, the piers were stayed with two parallel wire ropes, $1\frac{1}{4}$ inch in diameter, stretched from end to end of the viaduct, and firmly fixed to the abutments and large springing stones of the arches. The first brick was laid on the 24th of February, 1857, and the first train passed over the viaduct on the 1st of July, 1858. The cost of the structure, which was increased by the additional depth of the foundations, a much heavier parapet than was originally specified, and other contingencies, amounted to £15,756. This may be analysed as follows, the prices affixed being those given in the contractor's schedule:—

			£.	s.	d.
Excavation	7,254 cubic yards, at 1s. 9d.		634	14	6
Brickwork in inverts	999 " 20s.		999	0	0
Brickwork in piers, spandrels, &c.	6,796 " 19s.		6,456	4	0
Brickwork in arches, set in cement.	1,371 " 22s.		1,508	2	0
Ashlar masonry in foundations	4,558 cubic feet, at 1s. 6d.		841	17	0
Ashlar masonry in piers	30,977 " 1s. 9d.		2,710	9	9
Broken stone in foundation of west abutment	96 cubic yards, at 5s.		24	0	0
Rubble masonry in backing of arches and internal longitudinal walls	1,083 " 9s. 6d.		514	8	6
Flagging, 6 inches thick	795 square yards, at 6s.		238	10	0
Cast-iron parapet railing			688	10	9
Scaffolding, centres, and contractor's contingencies			1,581	0	4
Examining foundations, draining, etc			59	3	2
Total			£15,756	0	0

Regarding the viaduct as an unpierced solid, its contents would amount to 61,910 cubic yards, and its cost would be 5s. 1d. per cubic yard.

The question of the relative cost of brick and iron viaducts having engaged the attention of the Author, he will proceed to state the result of his inquiry. In his capacity of Engineer to the Stockton and Darlington Railway Company, he has under his care, besides the Hownes Gill brick structure, two iron viaducts, recently erected by Mr. Bouch, on the South Durham and Lancashire Union Railway.

These iron viaducts consist of three lines of trellis girders, resting upon skeleton piers, each of which consists of six cast-iron columns 12 inches in diameter, jointed at intervals of 15 feet, and braced together by horizontal cast-iron struts, and by vertical and horizontal diagonal tie-bars of wrought iron. The clear spans between the piers are in all cases 48 feet.¹

The Beelah viaduct is 1,000 feet in length and 197 feet in extreme height. The Deepdale viaduct is not so large, and more nearly resembles the Hownes Gill in its proportions, being 740 feet in length, and about 160 feet in extreme height. If applied to the Hownes Gill valley, it would only need the removal of one tier of columns in three of the piers to adapt it to that site. The cost of the Deepdale viaduct being £20,266, and that of the Hownes Gill viaduct £15,756, the first impression would be in favour of the brick structure. But further investigation would considerably modify this conclusion. The brick viaduct has only width for a single line of railway; the iron one was constructed to carry two lines. Considerable expense has been incurred upon the foundations of both structures, but in dissimilar ways; and it would be mere hasty assumption to treat the outlay upon one as a fair offset to that upon the other. It was thought that the best way of making a comparison would be by calculating, from the data already obtained, what would be the cost of the Hownes Gill viaduct if it were widened 11 feet, so as to carry a double line of railway, and then by computing what would be the cost of an iron structure, like the Deepdale, if erected across Hownes Gill, omitting the invert in the former case, and adjusting the spread of the bases of both viaducts, so as to sustain a weight of $2\frac{1}{2}$ tons per superficial foot, including the greatest moving load. The prices of the brickwork and of the masonry in both erections were taken from Mr. Anderson's schedule; those of the timber and ironwork were the prices actually paid to Messrs. Gilkes, Wilson, and Co., of Middlesbro', the contractors for the South Durham and Lancashire viaducts, minus a deduction of 10s. per ton, the cost of cartage over country roads, which was not incurred upon the material for Hownes Gill. With this adjustment, the price of

¹ A description of these viaducts, with drawings, is published in Mr. Humber's work on "Iron Bridge Construction." 2 vols. 4to. London, 1861.

[1862-63. N.S.]

the cast-iron work was £9 2s. 6d. per ton, that of the wrought-iron work £22 7s. 6d. per ton, and that of the timber 2s. 0½d. per cubic foot, including erection and 32 miles of railway carriage. It was found that the cost of the viaducts calculated in this way, the details of which are given in the Appendix, would be £20,681 for the brick structure, and £16,249 for the iron one, giving a difference of £4,432 in favour of the latter. It is probable, however, that the interest on this sum, say £222 per annum, would be absorbed in the periodical examination and painting of the iron structure, and the depreciation of its perishable timber platform; and it may be assumed, that at the place referred to, a brick viaduct would be, ultimately at least, as cheap as an iron one. If the comparison were made between viaducts designed to carry a single line of railway, it is believed that the balance would be more evidently in favour of a brick one. Although the Author strongly prefers brick or stone, he by no means regards iron viaducts as ineligible under all circumstances. The Beelah and the Deepdale viaducts have stood remarkably well, no loosening of the bolts or cotters from vibration having been observed, while their steadiness during the passage of the trains is such as to inspire confidence. Much of this firmness is to be attributed to the excellent workmanship and the perfect fitting of the parts, for which great credit is due to the enterprising contractors.

The material to be used in the construction of any viaduct must depend upon local and other considerations, among which the absence of expensive carriage, and the facility afforded for expeditious erection, are not the least important. In situations which do not yield suitable building materials, and where there are no cheap means of conveyance, as by railway or by water, from a distance, the small relative mass of an iron viaduct would be a strong argument in its favour; for the whole weight of such a structure, including its foundations of masonry, would be less than one-fifth of that of a brick one. This might also lead to the selection of iron in cases of doubtful foundations. If, in the viaducts which have been compared, the material of every description had to be conveyed 20 miles at a cost of say 9d. per ton per mile, there would be an increase of cost of £17,719 or 85 per cent., entailed upon the brick structure, but of only £3,464, or 21 per cent., upon the iron one. The possible absence of scaffolding is also worth something, for the Deepdale and the Beelah viaducts were erected in a masterly way without its aid, and with such expedition in the case of the latter, that after the masonry foundations were laid, the fifteen iron piers with their girders were erected in less than five months. The South Durham and Lancashire Railway passes through a mountainous country, where stone is the only building material. Structures in masonry are

notoriously slow of execution, and there is no doubt, that if this kind of work had been adopted in the Deepdale and the Beelah viaducts, the completion of the line would have been retarded two or three years. It was important, too, that the Deepdale viaduct should be completed long before the opening of the line, as nearly 200,000 cubic yards of earth had to be removed from a cutting to form an embankment on the opposite side of the valley. Under these circumstances it is submitted that Mr. Bouch exercised sound judgment in selecting iron as the material for these viaducts.

The Paper is accompanied by two drawings from which Plate 1 has been compiled.

APPENDIX.

ESTIMATE of the COST of a BRICK VIADUCT, for TWO LINES of WAY over HOWNES GILL, without INVERTS.

		£	s.	d.	£	s.	d.
Excavation	10,068 cubic yards at	0	1	9	880	19	0
Brickwork in piers	9,730 "	0	19	0	9,243	10	0
Ditto in arches	2,388 "	1	2	0	2,626	16	0
Ashlar in footings	18,366 cubic feet	0	1	6	1,875	4	0
Ditto in piers	36,052 "	0	1	9	3,154	11	0
Bubble in internal longitudinal walls, &c.	1,971 cubic yards	0	9	6	936	4	6
Flagging to carry roadway	1,615 square yards	0	6	0	484	10	0
Iron railing	477½ yards	1	8	10	688	17	11
Bolts	1,730 lbs.	0	0	4½	32	8	9
Scaffolding					1,200	0	0
Draining foundations, &c.					58	0	0
					£20,681	1	2

ESTIMATE of the COST of an IRON VIADUCT over HOWNES GILL, similar in design to that at DEEPPDALE.

		£	s.	d.	£	s.	d.
Excavation	6,160 cubic yards at	0	1	9	539	0	0
Ashlar in footings	21,523 cubic feet	0	1	6	1,614	4	6
Ditto in string course of abutments, &c.	1,186 "	0	1	9	103	15	6
Rubble in retaining walls to protect metal columns	199 cubic yards	0	9	6	94	10	6
Brickwork in abutments	1,317 "	0	19	0	1,251	2	0
Cast iron	603·1 tons	9	2	6	5,503	5	9
Wrought iron	275·75 "	22	7	6	6,169	18	1
Brass slides and moveable bearings	2cwt. 2qr. 12lbs.	0	2	0	29	4	0
Wrought-iron stays, bolts and nuts for handrailing					17	9	1
Timber in transverse beams and planking	8,891 cubic feet	0	2	1	926	2	11
					£16,248	12	4

[Mr. CUDWORTH
E 2

Mr. CUDWORTH said, he had but little to add to the Paper, in which, although condensed as much as possible, it did not occur to him that anything material had been omitted. He was glad to have had the opportunity of bringing under the notice of the Institution, a viaduct in which economy of materials had been much studied, and in which this appeared to him to have been carried almost as far as was consistent with due regard to safety. He had brought into comparison with this viaduct one constructed of iron; and as both structures were designed by the same Engineer, it might be inferred that similar ideas, as to economy of materials and of fitness, prevailed in both cases.

Mr. G. P. BIDDER, Past-President, said, every Engineer must be guided in the selection of the particular material, or mode of construction, by the locality, the facility of obtaining different materials, and the purposes which the work was intended to serve. No doubt viaducts, like all other works, were now constructed at less cost than was the case in the early days of railways, when the stereotyped price of a viaduct was 6s. 8d. per cubic yard. It appeared from the Paper, that the Hownes Gill Viaduct had cost 5s. 1d. per cubic yard. This was a reduction of nearly 20 per cent.; but he did not think that was more than had been effected upon other works, as the result of better appliances, and the application of larger capital. The admirable spirit in which this Paper was written was highly commendable; and if it had been prepared by Mr. Bouch himself, the comparison between the different works could not have been more fairly stated. This evinced such a desire to elicit real truth, that the Author was deserving of great praise. With regard to the use of either iron, or wood, or brick for structures of this description, the decision must entirely rest upon the judgment of the Engineer. There were circumstances in which timber structures were obliged to be erected, as ancillary to other designs. In Norway, viaducts of 90 feet and 100 feet in height had been constructed of that material, in the readiest manner, and with great economy, where they were afterwards to be replaced by embankments. It would appear from the statement of the Author, that under the particular conditions with which Mr. Bouch had to deal, iron was the most suitable material for those works, which were simple, substantial, and free from undue motion; and looking at the cost, it showed that economy of material had been carefully considered. The Paper brought out facts of great practical value, and gave data for the construction of extensive viaducts. This information could not fail to be useful to Engineers, when they were called upon to design works of this description.

Mr. BOUCH said, the subject had been dealt with in so fair and comprehensive a manner, as to leave but little room for remark.



With regard to the comparison which had been made between the Hownes Gill viaduct and the iron structure, he thought that there were no points of analogy between the two works. He quite agreed that the brick structure described in the Paper was a proper one in that particular situation; but in the other case the circumstances were so changed, that neither brick nor stone could have been used. The Hownes Gill viaduct was designed for a railway which had already been many years in operation. There were thus facilities for the conveyance of the materials, which were procured in the district, on the most favourable terms, as the viaduct was to be built for the owners of the railway. Therefore, if he had again to design that bridge, he should adhere to the plan that had been adopted. But in the case of the two iron viaducts on the South Durham and Lancashire line, the circumstances were entirely different. At Deepdale, there was a cutting of 200,000 cubic yards, which could not be commenced till the viaduct was completed, as the whole of the material had to be carried across the valley, to form an embankment on the other side; while at Beelah, there was a cutting containing 50,000 cubic yards of rock, which also had to be taken across the bridge, and could not on that account be commenced until the viaduct was built. Those were circumstances which weighed with him, in estimating time as money, and as railways must be treated as commercial enterprises, the delay of a few years in their construction might be sufficient to condemn an undertaking. It was therefore necessary, without reference to cost, to adopt some form of structure which should enable the line to be completed within a reasonable time. Although in the immediate vicinity of both works there was a vast quantity of stone, yet it was only on one side of the Gills, for on the other side, especially at Beelah, he scarcely knew any district in which stone was so scarce. In point of fact, looking at the quantity of stone required for the foundations of the Beelah viaduct, it cost nearly as much as the whole of the ironwork. On the South Durham line, there were a great number of viaducts, many upwards of 100 feet in height, which were built of rubble, after the plan first adopted by Mr. Hawkshaw. Those were the cheapest on the line, and he had built two viaducts upon that plan in Scotland, 80 feet in height, at a cost of £20 per lineal yard for a single line. In all cases he had used stone, where time allowed him to do so, and the material was at hand. In other cases, he had adopted stone piers, with trussed iron girders; but then the iron was merely used to save time, bearing out the remark, that in works of this description no fixed rule could be laid down. He might mention that the sixteen openings of the Beelah bridge were completed in four months, or at the rate of one span per week, including the erection of the piers. In

some instances the difficulties with regard to the foundations were the greatest he had ever encountered. The Westmoreland Gills, as they were termed, were nothing more than great cracks in the mountains. There might be rock at the sides of the Gill, giving the appearance of great solidity; but as soon as it was disturbed, it was found to be only débris from the sides, easily set in motion, and with considerable tendency to slip. In fact, there was one large slip close to the viaduct, which carried away a cottage and a smithy, and for a time placed the viaduct in jeopardy. As an instance of the difficulties of the foundations, he stated that, after the railway had been for some months in operation, it was found that one of the columns of the piers, instead of resting upon the masonry foundation to which it was bolted, had the masonry hanging to it. Although express and heavy mineral trains had been running over the line perhaps for months before this condition was discovered, still the work had withstood this test. It was speedily remedied, and he had no fear that it would occur again. It was but fair to the contractors to add, both as regarded the Hownes Gill viaduct, and the Deepdale and the Beelah iron viaducts, that as examples of good workmanship he believed they could not be surpassed.

Mr. SHEILDS thought the comparison between the cost of a brick viaduct and of an iron one was hardly fairly put. In his opinion, in almost all cases, except under extraordinary circumstances, an iron viaduct of the dimensions referred to, could be erected more economically than one of masonry. He did not mean to say that either in durability, or in solidity, an iron viaduct was superior to one of masonry, provided the foundations were good; as a more rigid structure could be formed of masonry than of iron girders, which always involved a greater amount of deflection and vibration, and probably therefore of comparative instability; but for various commercial and practical considerations, he thought iron was generally superior to masonry for this class of structures. For instance, in the comparison made by the Author, the brick structure in question was estimated to cost £20,681, whereas it was calculated that an iron one could be erected in a similar situation for £16,249, or with a saving of one-fifth. Moreover, in considering the prices on which these estimates were founded, it must be noticed that the bricks were obtained on favourable terms, both as regarded first cost and delivery, whilst the ironwork was taken at £22 10s. per ton, which, in the present day, was certainly a high rate. Under these circumstances, he believed the saving in first cost by the use of iron would be considerably more than had been stated. The fact that large quantities of bridge ironwork were sent to India, Spain, Russia, and the most distant parts of the world, even where masonry work was cheap,

was an argument in favour of the superior advantages of iron structures for large bridges, as it was reasonable to suppose that cost was an important element in these cases.

Mr. BIDDER could not allow the observation to pass unnoticed, that the large extent to which ironwork was sent to India and other places was a proof of its superiority to masonry. That was a mistake; and indeed it might just as well be said, that iron girders were used in the Charing Cross Bridge, because they were cheaper than brickwork, whereas it was well known that that plan of construction was adopted, in order to avoid increasing the height of the railway. Ironwork was sent to India, not on account of its economy over brickwork, but to serve a particular object—in other words, to keep down the level of the railway over the rivers where brickwork could not be applied without raising the railway to an undue height.

Mr. SHEILDS said he had referred to cases in his own practice, where the cost was calculated, and where iron was selected solely for the purposes of economy. There was more scope for economically designing a large viaduct in iron than in masonry; as the spans could be made much wider in the former material. Of course the greater the openings, the fewer would be the piers, and vice versa; and when the piers were of great height, it was important to diminish their number by enlarging the spans; which could be done more easily and cheaply with iron girders than with arches of masonry. Keeping this in view, it would be seen, that when the cost of a pier, and the weight of ironwork for girders of various-sized openings, were known beforehand, it would be easy, by a trial and error process, to arrive at a minimum of cost for the piers and girders together forming the whole bridge, and he repeated that his own experience had proved to him that ironwork, except under peculiar circumstances, could be erected at a cheaper cost than masonry, in a viaduct such as that referred to in the Paper.

Professor POLE said, that having sent out large quantities of material for Indian railways, he could state that one great reason for the large use of iron upon works of construction in that country, was the saving of time. On the greater part of the East Indian line, for example, brickwork was the natural material of the country; both bricks and labour were very cheap, and the work could be well executed by the native workmen at a cost much lower than in Europe. But there was found to be a limit to the quantity of bricks which could be made in a given time, and as the nature of the country required bridges and flood-works of enormous extent, it soon became evident that if all these were to be constructed of brickwork, the completion of the line must be delayed to an almost indefinite period. For this reason, it was the interest of the com-

pany to send out large quantities of ironwork, at an expense much greater than need have been incurred, if the normal material of the country could have been used.

Mr. W. H. BARLOW concurred in the remark, that no rule could be laid down, as to the material of which viaducts should be constructed. He was at present constructing a line of railway upon which there were several viaducts of considerable extent; and in all ordinary cases he had found simple rubble to be the cheapest and the best. But for skew bridges, and under some other circumstances, iron could be used with advantage. He did not think that, at present, either iron or stone could be said to be the cheaper material for viaducts; the choice must be governed by the locality.

Mr. JOHN FOWLER, V.P., said, it was difficult usefully to compare ironwork with masonry, unless all the circumstances were stated in great detail. He had seen the Hownes Gill viaduct, and could pronounce it to be a most substantial work. The dimensions were of the ordinary kind, the material was good, and the foundations were carried down according to the nature of the ground. There was, however, one peculiarity upon which further information was desirable; that was the remarkable spread of the piers, by means of the buttresses. This was carried to a greater extent than he had ever known in a viaduct of similar dimensions. The piers had been extended, laterally, to nearly three times their length at the springing of the arches. He should be glad to know whether the object was to give greater base to the foundations (which he presumed must be the case), and for architectural effect, or whether it had been done with reference to the vertical stability of the piers, which he could scarcely think necessary. The buttresses were certainly not, *primâ facie*, a necessity for the stability of the work, or for its appearance, and they must have involved considerable additional expense. As to recesses, or openings, in piers, the question, whether desirable or otherwise, must always depend upon the nature and value of the materials used.

Mr. J. SCOTT RUSSELL said, in the bridge aqueduct of Roquefavour,¹ on the line of the canal of Marseilles, there was the peculiarity of the buttresses spreading very much at right angles to the centre line; but the piers were perfectly parallel and vertical on their inner faces. In the Hownes Gill viaduct there was an increase in the dimensions both ways, which required to be accounted for.

Mr. BOUCH remarked, that the lateral spread of the piers was to secure a greater area for the foundations. As the piers were only 12 feet in length at the springing of the arches, and the height of

¹ *Vide Minutes of Proceedings Inst. C.E., vol. xiv., p. 190.*

the loftiest ranged from 110 feet to 114 feet, he thought buttresses were necessary to give steadiness to the structure. As a proof that this view was agreed in by other Engineers, it was only necessary to refer to the fact, that inverts had been added to the original design, in order to give a larger base.

Mr. CUDWORTH said, with regard to the remark, that the comparison between the two constructions was not a fair one, he had furnished data from which every one might form their own conclusions, and thus be enabled to judge how far he had been justified in the observations he had made.

No. 1,051.—“On the Use of the Timber of the Palmyra Palm in the Construction of Bridges.” By HENRY BYRNE, M. Inst. C.E.

THE well-known fact, that all trees of the palm tribe contain a mass of pithy fibre in the centre of the stem, (the woody and useful portion being thus reduced to the condition of a mere pipe or tube,) would seem to preclude the possibility of employing such timber in a structure pretending to any degree of permanence, and in which beams are a prominent feature, and framing a matter of necessity. But there are extensive districts in Southern India and in Ceylon, and doubtless in other tropical regions, where no other description of timber grows in any quantity, and where consequently bridges, jetties, &c., must either be constructed with such imperfect material, or dispensed with, if the cost of square timber, and still more of stone or brick, be an object of serious consideration.

The tract of country at the northern extremity of Ceylon, known as the Jaffna peninsula, a district of the province of which the Author had charge till recently, as Resident or Assistant Civil Engineer, is thus circumstanced : Intersected in various directions by tidal inlets, its wants as to means of communication, and especially of bridges across these inlets, (which are of considerable width, and fordable only by foot-passengers and not always without risk,) far exceeded the pecuniary means that could immediately be devoted to it out of the colonial treasury, when the Author took charge of the province. These wants could only be met gradually, by adopting the least expensive plans, consistent with efficiency, that could be devised. Obviously, then, timber piled bridges, of the most simple form, were the best adapted to all the circumstances ; and the only question to be decided was, what description of timber should be used. The Jaffna district, embracing an area of about 400 square miles, does not produce, in any quantity, such timber as admits of being squared, and the little that there is, can only be procured in short lengths, and of small scantling fit, merely, in fact, for verandah-posts, wall-plates, door-frames, and similar purposes ; while imported timber of large dimensions is as costly as it is in England. But, on the other hand, it abounds with cocoa-nuts and Palmyra palms, the first of which is seldom to be found straight for any considerable length, and is in all other respects inferior as a material for building to the Palmyra. This latter timber was accordingly selected, as the only fitting material which the circumstances admitted of being used.

This palm, known to botanists as the *Borassus flabelliformis*, grows to a height of about 60 feet, of which, however, the lower half only contains sufficient woody fibre to render it useful. It grows perfectly straight, and is of nearly uniform thickness, about 10 inches, from a few feet above the ground. In good specimens the woody portion of the tree, at a height of about 30 feet, is from 3 inches to 4 inches thick, or one-third of the whole diameter of the stem; while at the base there is little or no pith, but the timber is somewhat less hard and compact than higher up, where the interior is of a more decidedly pithy character. The specific gravity of the best portion of the stem is, on an average, 1.055, and its power of resistance to a transverse strain is, as compared with teak, as 9 to 8. A well-grown tree will yield a pile of 30 feet in length, requiring only to be stripped of its outer integument, sometimes, but erroneously, called the bark, and pointed to fit it for use. So compact is the woody fibre, that the Author has never had occasion to ring the top of a pile, in order to secure it from splitting in the process of driving, while the nature of the ground is such as to render shoes unnecessary.

For roadway bearers, the most efficient plan is to split the tree in half, and, after removing the pith, to join the two halves together by wooden keys, at intervals of about 4 feet, and when fixing them to place them on edge. Such beams would be 8 inches deep, and about 6 inches or 7 inches in lateral thickness; too small a scantling certainly to sustain a heavy weight, unless supported at short intervals; but five lines of such bearers, under a roadway 15 feet wide, supported at intervals of 10 feet, are sufficient for the heaviest turnpike road traffic, including the largest elephant waggons. For planking, the trees are usually split into three, yielding planks 6 inches wide, and from $2\frac{1}{2}$ to 3 inches thick. In every case, the roadway bearers were supported directly by piles. The plan of strutting them from the piles, or of supporting them by iron tension-rods, in order to afford wide bays, is objectionable. The first because it would involve either the weakening of the piles, by notching them to receive the struts, or the use of iron bolts and straps, which corrode very rapidly in that climate, and injure the timber in contact with them; and the second, because the safety of the structure would depend solely upon the iron, and become a source of constant anxiety, from the perishable nature of that material. Besides it is not necessary, in any case, to provide bays of greater width than will suffice for the passage under the bridge of a fisherman's canoe, or catamaran, while the additional cost of piling, at such short intervals as 10 feet, is not worth considering.

It may be objected that the roadway platform is not adequately connected with the piling, and that its security is left dependent

on its dead weight. But this is found to be quite sufficient in most cases, for the piles are not liable to disturbance by the shock of heavy boats and barges coming in contact with them, and the roadway bearers are generally at too high a level to be reached by floating bodies during floods. In one case only, where such a bridge was constructed across the mouth of an inlet exposed to a heavy surf, was it necessary to strap the roadway bearers down to the piles.

The inexpediency of employing iron in the construction of these bridges, where it was possible to avoid it, has been already referred to; and accordingly, as a rule, it has only been used for spiking the planking to the roadway bearers. There is no objection to its use in this way, for it is sufficiently protected from damp by the concrete usually laid over the planking.

As to the durability of such bridges, it is only necessary to state, that the first the Author constructed has stood for sixteen years without requiring any repairs, beyond the occasional renewal of handrail bars, when wantonly destroyed. It is now in perfect order, except a few of the piles, which were originally of an inferior quality of timber. In the most favourable situation it is believed the average duration of a Palmyra timber bridge may be reckoned at twenty-five years, and even then a large proportion of the material would be found fit for use in the reconstruction of it. The piles are the most liable to decay, perhaps in consequence of their containing so much pith. The natives make a point of removing the pith from all Palmyra timber before storing it up, in the form of rafters and planks for sale, alleging as a reason, that the decay to which the pith is liable is readily communicated to the hard woody fibre. There is probably some justice in this, and it might be worth while, in the case of piles containing much pith, to bore out the centre and fill it with some composition, of which tar or pitch should form a chief ingredient. But a little experience in selection, and a knowledge of the localities which produced the best trees, soon enabled the Author to procure piles containing little or no pith, and he has occasionally met with trees which contained absolutely none for about 20 feet of their length. This timber seemed to be proof against the attacks of the teredo, and even inferior specimens remained perfectly sound below the water-line, while above it a coating of tar was all that was needed to prevent splitting from exposure to the sun.

The following statement of the actual cost of 20 lineal feet of a bridge constructed wholly with Palmyra timber, 300 feet in length between the abutments, and 15 feet wide between the handrails, may be taken as a fair average, though some of these bridges have cost from 15 to 20 per cent. less.

	£.	s.	d.
6 piles at 5s. each	1	10	0
2 transverse bearers, 21 feet, at 6s.	0	12	0
5 longitudinal roadway bearers, 20 feet, at 6s.	1	10	0
45 roadway planks, 15 feet, at 1s. 6d.	8	7	6
100 running feet of handrail bars and posts, at 1d. per foot	0	8	4
36 lbs. iron spikes, at 4½d.	0	13	6
Construction of 20 feet of bridge, at 7s. 6d. per foot lineal	7	10	0
Contingencies	1	0	0
Total	£16	11	4

or 16s. 6d. per running foot.

The practical value of such apparently unpromising material as Palmyra timber, in a district unprovided with bridges, and too poor in money and all other resources to afford the luxury of scientific display, or to admit of the slightest indulgence on the part of an engineer in what has been called the pride of construction, will be manifest on a comparison between the cost of such bridges as the Author was thus forced to build, and of such as he might have been tempted to build had square timber been at hand. In the interior and southern parts of the Jaffna province, where the forests abound with fine timber, and the Palmyra is unknown, or at any of the chief sea-coast stations, where square timber is readily procurable and Palmyra despised, except for roofing purposes, the cost per running foot of a piled bridge of the dimensions stated would not be less than £6, or nearly eight times greater than that of one constructed of Palmyra; so that in the district referred to, instead of an aggregate length of about 2,000 feet of bridges which have been built within the last few years, not 300 feet could have been built for the sum actually expended; if indeed the supposed necessity for using squared timber would not, from its great cost, have precluded the attempt to improve the means of communication through the country, or led at least to its indefinite postponement.

The Paper is accompanied by a Drawing, showing the mode of construction adopted, and by a Model with specimens of the timber employed.

[Mr. JOHN BETHELL.

Mr. JOHN BETHELL remarked, that this timber, from the specimen exhibited, presented an extraordinary appearance. When he first saw it, he fancied it was a piece of creosoted wood. It would be observed that there was a dark substance in the grain, like regular streaks of creosote, such as would appear in young wood which had been subjected to that process; whilst in the heart wood there was nothing of the kind; and it was a question in his mind, whether this palm was not impregnated with some natural bitumen, or resin, which had been drawn up from the earth, and travelled with the sap into the younger layers. In the green heart timber of *Demerara*, which, in many cases, acted like creosoted wood in resisting the attacks of the worm, the pores were infused with a sort of resinous bitumen, and the wood itself burnt like a torch. He believed that if the Palmyra palm were analysed, it would be found to be of a similar character, and he had no doubt that it was more inflammable than ordinary woods. It was the practice of Engineers to require that sleepers should consist entirely of heart wood, and that the young wood should be cut off, and then such sleepers were sent to be creosoted; but he invariably declined to undertake it, because it was quite impossible that heart wood could be properly creosoted. If Engineers considered heart wood uncreosoted was more valuable than young wood charged with creosote, well and good. Any one, however, who knew the way in which a tree grew, was aware that the external pores remained open, whilst the internal pores were choked up, by the deposit of ligneous matter on the descent of the sap, so that the pores could not afterwards be charged with any artificial bituminous matter. Of the specimens of Scotch fir sleepers creosoted, which were laid on the Great Eastern Railway in 1841, 80 per cent. were still doing duty in the permanent way. On examining one specimen it was found that, while the outer portion which showed the dark colour of the creosoting was perfectly sound and hard, the interior portion or heart of the wood had begun to decay. The rot had commenced in the heart wood, because it had not taken the oil. So in the case of the specimen of the palm now exhibited, the heart wood was decayed already, and might be picked away with the finger, whilst the outer portion was sound and hard.

Mr. J. SCOTT RUSSELL remarked, that there were two kinds of trees of totally different and opposite natures in their growth; one class taking their young wood from the inside, and another class taking young wood from the outside. These were called by botanists, in the one case endogenous and in the other exogenous. The specimen of wood of the Palmyra palm tribe was no doubt of the endogenous class. The former kind had its hard wood in the centre and the soft wood on the outside; while the other had its hard and old wood on the outside, and the young wood gradually

filled up the inside, until it became perfectly solid at the centre, when it was in its highest degree of maturity. He believed that would explain the apparent contradiction between the two kinds of timber, and their relative density at the skin and the heart.

Mr. C. H. GREGORY, V.P., said, the Author had directed attention to the convenience of employing native timber for works of economical construction in the island of Ceylon. In many countries there were other reasons to induce the use of native unprepared woods, in preference to timber imported from Europe, and prepared by the processes in common use to prevent decay. English Engineers had found the advantage of these preparations, especially of creosoting when properly applied, with the soft pine woods used in this country. He had known cases where creosoted timber lasted for so long a period, that it became fairly worn out mechanically, without showing any signs of decay. In tropical climates the circumstances were different, and his experience led him to know, that there were climates where carefully prepared soft European timber would not stand. On the Pernambuco Railway sleepers of pine timber creosoted were used for a considerable time; but in a few years they had become seriously deteriorated by decay. He had examined into the cause of failure, and as far as the most reliable evidence went, he came to the conclusion, that the wood had been well and properly prepared, the process having been conducted by highly-respectable houses, under the most careful and trustworthy inspectors, and he could only suppose, that the creosote had been drawn out of the wood by tropical heat and moisture. He had, therefore, adopted sleepers of native woods; and in Brazil, Ceylon, and other tropical countries, there were woods which, when carefully selected, would withstand all variations of climate, as well as the ravages of the white ant, the dangers from which he believed were not so great as was generally supposed in sleepers, as it was found that the white ant did not attack timber which was frequently shaken.

Mr. POLE said, he was scarcely prepared for the statement in the Paper, that the transverse strength of this palm-wood was greater than that of teak, which was one of the strongest woods known. He did not think this could really be so; but he conceived the impression might have arisen from the fact that, in these endogenous woods, the strongest and best part of the fibre was on the outside, and was therefore in the most favourable position for transverse strength, when an experiment was tried on a whole tree.

Mr. DOYNE said, he had met the Author in Ceylon, and could bear testimony to the great value of the works carried out by the Department with which Mr. Byrne was connected, which had resulted in that island being better provided with roads than

almost any other colony under the British Crown. Great judgment had been displayed in the erection of simple and economical works. The facilities and the amount of money at command were not large, and the greater credit was therefore due to the Department for the works that had been carried out, more particularly in the providing of good roads. The tree which had been referred to grew like the cocoa-nut and all other palms. It was virtually a shell containing pith, like the alder tree of this country. That portion which had been alluded to as being decayed was pith, and might be cut out without lessening the strength of the tube. The bamboo was used to a great extent in Ceylon, and though not more than about 4 inches in diameter, with a tube only $\frac{1}{2}$ an inch thick, it was surprising the weight it would carry; the hardness of its texture being such as to resemble horn rather than wood.

December 2, 1862.

JOHN ROBINSON M'CLEAN, Vice-President,
in the Chair.

The following candidates were balloted for and duly elected :—
GEORGE BRUNTON, CHARLES DEAN, WILLOUGHBY CHARLES
FURNIVALL, JOHN EDWARD HARTLEY, THOMAS LOVELL, MARTIN
SAMUELSON, JOSEPH FRANK STRONG, and JOHN TAYLOR, as Mem-
bers; JOHN BROWN, THOMAS GAUL BROWNING, CHRISTOPHER
JOSEPH CATO, AUGUSTO TEIXEIRA COIMBRA, WILLIAM HENRY
CUTLER, JOHN FERNIE, MAJOR JOHN CHARLES HARRIS, B.E.,
FRANCIS ADOLPHUS SMART, and JOHN WADDINGTON, as Associates.

No. 1,076.—“On some of the Internal Disturbing Forces of Locomotive Engines.”¹ By ALEXANDER WOODLANDS MAKINSON, M. Inst. C.E.

GREAT and successful efforts have been made of late years to improve the permanent way of railways. In any case of accident arising from an engine leaving the rails, the state of the permanent way first engages attention; and the occurrence of numerous accidents of this nature, and the consequent public inquiry and criticism, have stimulated engineers to effect great improvements in the permanent way. Notwithstanding, however, the high state of perfection to which it has been brought, engineers of eminence have denounced high speed on railways as dangerous, to the extent even of justifying, or demanding, Government interference for its prohibition. The Author ventures to hope, that he may further the progress of engineering practice, by an attempt, not to divert the attention of engineers from the efficient maintenance of the permanent way, but to direct it more to the construction of the locomotives using that way.

In the great problem then, of the safe transit of passengers at the high speeds called for on trunk lines, have the locomotive engineers done their part, by putting on the permanent way, engines without any internal disturbing forces tending to make them leave the rails? May not a modern locomotive engine be accurately described, as an engine intended to move only in a forward

¹ The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

[1862-63. N.S.]

direction, but which, from the imperfect arrangement of its parts, is subject continually to erratic and transverse movements from forces generated within itself, and expended destructively on the permanent way; so that it is, when in motion, continually striving to escape from the rails, and is not so much the passive recipient of blows, originating in the imperfections of the permanent way, as it is, in a far greater degree, the ceaseless active agent in inflicting blows on the permanent way, these blows, of course, in their reaction, recoiling on itself? To answer these questions, the Author has endeavoured, by the diagrams shown on Plates 2 and 3, to exhibit graphically the different forces acting on the locomotive when in motion: or neglecting only such as tend to give a disturbing motion vertically.

It will assist in appreciating the disturbing and objectionable action of these forces, if the consideration of them be premised, by a short statement of the forces which are essentially required in the locomotive. A locomotive engine is intended to move, and exert a tractive force, in a direction parallel to the rails on which it moves: and as, at a given speed, and on a given gradient, (other accidental circumstances, as wind, state of rails, &c., being the same) the resistance is constant, and (except on curves) equal on both rails,—the tractive force, or resultant tractive force of the engine, ought to be exerted in the central longitudinal section of the engine: *i. e.* midway between the rails; otherwise it will, in conjunction with the resistance of the train, which does act in the central longitudinal section of the engine, produce, or tend to produce, in the engine, a motion of rotation, transverse to the direction of its intended motion. Moreover, since the resistance is constant in amount, the tractive force ought as far as possible, to be constant, or liable only to trifling fluctuations, so as to reduce the strain on the working parts of the engine to the minimum.

Returning to the diagrams, in assigning numerical values to the forces under consideration, it was requisite to take some one engine as a type of the modern locomotive: for this purpose, the 'Great Britain' locomotive of the Great Western Railway has been selected, of which indicator diagrams are given in Mr. D. K. Clark's "Railway Machinery." In this engine the length of stroke of the piston is 24 inches, and the diameter of the driving wheels is 8 feet.

Diagram No. 1, Plate 2, from which all the other diagrams are constructed, shows three indicator diagrams taken from this locomotive, at the velocities of 26, 35, and 52 miles per hour respectively. The base, or horizontal line, is the length of the cylinder, 24 inches. The effective steam pressures per square inch of piston, shown by the vertical lines, are given at every inch of the stroke.

Diagram No. 2 shows the effective steam pressures when reduced to the path of the crank pin. The formula showing the ratio between the steam pressure in the cylinder and the equivalent pressure at the crank pin is given in the Appendix No. 1. The effective steam pressures, shown on Diagram No. 2, bear a constant ratio to the tractive force exerted at the rails, and therefore show the variation in the amount of tractive force developed in each cylinder, throughout both the forward and the backward strokes. It is here necessary to remark, that in this Paper, by the forward stroke is meant the stroke of the piston made in the direction of the motion of the train; and by the back stroke that made in the opposite direction to the motion of the train.

But the steam pressures, although the only forces applied to the locomotive, and applied with the object of producing motion in one straightforward direction only, are not the only forces operating on it when in motion; nor are these steam pressures effective only to produce motion in one direction. Other forces are developed, by the *vis inertię*, and the varying velocity of some of the parts of the engine, relatively to the main body, or mass of the engine. These forces are fully recognized, and have been happily named "disturbing forces:" the definition of a disturbing force being—a force which impresses, or tends to impress, on the engine some other motion on a horizontal plane, than that simply progressive, straightforward, and equable motion along the rails, which alone is required. These disturbing forces may be divided into two classes:—First, those which are generated by the revolving parts of the engine, as the crank, crank-pin, and half the weight of the connecting-rod; and secondly, those which are generated by the reciprocating masses, as the piston, piston-rod, cross-head, and half the weight of the connecting-rod, &c. In the Appendix, No. 2, an investigation and formula are given to determine the amount of the first class of these disturbing forces—those arising from the revolving appendages of the locomotive. This examination shows their equality with the horizontal component of the centrifugal force; but as it is understood by the Author that, in the practice of the best locomotive engine-makers, the proper counterbalance for these, the revolving appendages, are now always applied, so as to entirely destroy the disturbing effects produced by them, they will, after this mention of their existence, be no longer referred to in this Paper. But the other class of disturbing forces—those generated by the relatively varying velocity of the reciprocating appendages—are not, as the Author believes, met by any counterbalance, but remain as a feature, and as disturbing forces, in by far the largest proportion of the locomotives now running. The Appendix, No. 3, contains an investigation and formula for the amount of this disturbing force.

Diagram No. 3 exhibits graphically the amount of the pressures generated, referred to the square inch of the piston, in the case of the 'Great Britain' locomotive, in which engine the weight of the reciprocating parts on each crank is taken at 495 lbs. The pressures are referred to the path of the crank-pin, and are given at every inch in that path, both for the backward and the forward strokes, at the velocities of 26, 35, and 52 miles per hour respectively.

It is now proposed to examine, somewhat in detail, the nature and origin of these forces. If the piston be supposed to be on the point of commencing the forward stroke, it is then, relatively to the engine, at a state of rest; and has the same absolute velocity V as the engine. Let W represent the weight of the piston, piston-rod, and one half of the connecting-rod; then U , the accumulated work residing in the reciprocating appendages, when the piston is just commencing its forward stroke, $= \frac{1}{2} \frac{W}{g} V^2$, by the well-known

formula. But as the piston advances in its stroke, its absolute velocity V_1 becomes greater than V , and continues to increase until the crank arm is vertical, or nearly so; and the amount of work accumulated, or stored up, in the reciprocating parts goes on increasing. During the first half of the front stroke therefore, the reciprocating appendages increase their store of accumulated work; such increase of accumulated work absorbed by them, has been abstracted from the store, or total amount of accumulated work in the mass of the engine; and the effect of such increased accumulation of work in the piston, during the first half of the forward stroke, on the main body, or mass, of the engine, is such as would be produced by a resistance to the train. During the latter part of the forward stroke, the velocity of the piston diminishes; the work stored up in it therefore diminishes, and to the extent of such diminution, becomes available for, and is expended in, the traction of the train; so that for the second half of the forward stroke the effect of the disturbing forces is to develop pressures assisting the motion of the train. The same may be said during the former half of the back stroke; during which the absolute velocity V , of the piston, &c., keeps diminishing, until it acquires its minimum value at, or near the mid-stroke. During the latter half of the back stroke, the velocity of the piston, &c., again begins to increase; it again becomes an absorbent of work—to such an extent diminishes the work available for the traction of the train, and produces on the body of the engine the same effect as a resistance to the train. Thus, the *vis inertiae* of the reciprocating parts, and their varying velocity relatively to the body of the engine, makes them distributors of force, sometimes absorbing, and sometimes yielding it up; and giving rise coinci-

dently to pressures against, or in favour of the motion of the train ; now deducting from, and now adding to, the available tractive force of the engine. If the circular path of the crank-pin around the axle be divided vertically, by a straight line through its centre, then the crank-arm will approximately coincide with this line, when in its position of greatest, as also when in its position of least velocity ; and while the crank-pin moves through 180° —from its position of greatest to its position of least velocity—the reciprocating appendages develop pressures in favour of the motion of the train ; and while the crank-pin moves through 180° —from its position of least, to its position of greatest velocity—the reciprocating appendages develop resistances to the motion of the train. Referring to Diagram No. 3, it will be seen that, in the ‘Great Britain’ locomotive, at the velocity of 26 miles per hour, the *vis inertiae* of the reciprocating parts throws a pressure, referred to the path of the crank-pin, against the motion of the train, of 16 lbs. per square inch of piston at the commencement of the forward stroke, diminishing to zero, at a little beyond the mid-stroke. From thence the pressure becomes one assisting the motion of the train, increasing to 26 lbs. per square inch of piston at the end of the forward stroke. The back stroke commences with a positive pressure, or a pressure assisting the motion of the train, of 26 lbs. per square inch of piston, and terminates with a negative pressure, or a resistance to the train, of 16 lbs. per square inch. Similarly, at the velocity of 35 miles per hour, the forward stroke begins with a negative pressure of 33 lbs. per square inch of piston, and terminates with a positive pressure of 45 lbs. per square inch. The back stroke commences with this positive pressure of 45 lbs. per square inch, and terminates with a negative pressure of 33 lbs. per square inch. At the velocity of 52 miles per hour, the pressures of *vis inertiae* become far greater in amount per square inch of piston than the steam pressure. Thus, the forward stroke commences with a negative pressure of 70 lbs. per square inch of piston, and terminates with a positive pressure of 99 lbs. per square inch ; the greatest steam pressure during that stroke being, as shown on Diagram No. 2, only 57 lbs. per square inch. The backward stroke commences with a positive pressure of 99 lbs. per square inch of piston, and terminates with a negative pressure of 70 lbs. per square inch. In general terms, it will be seen that, at every velocity, the pressures generated by the *vis inertiae* of the reciprocating parts are the greatest at the end of the stroke, and vanish at, or near, the mid-stroke. The pressure during the second half of the forward stroke, and the first half of the back stroke assisting the motion of the train ; and during the second half of the back stroke, and the first half of the forward stroke, opposing the motion of the train. Of course, at every

velocity, and in both the forward and the backward strokes, the work done in favour of the motion of the train is exactly equal to the work done against it. The *vis inertiae* and relatively varying velocity of the reciprocating parts are competent, not to create, but merely to distribute, work.

Diagram No. 4 is formed from Diagrams Nos. 2 and 3, by adding together the steam pressures and the coincident pressures arising from *vis inertiae*. It shows the variation in the tractive force, developed throughout one stroke of either piston. Comparing Diagram No. 4 with Diagram No. 2, it will be seen that the variation in the tractive force of the engine is much greater than would be supposed, if the steam pressures alone were considered. At the velocities of 35 and 52 miles per hour, it will be seen that in the first half of the forward stroke, as well as in the second half of the back stroke, there is really as much or more work done against, as in favour of the motion of the train; so that all the tractive force required for the traction of the train, through one entire revolution of the driving-wheel, is given out during that half of the revolution which is made coincidently with the second half of the forward stroke, and the first half of the back stroke of the piston; being that half revolution made while the piston moves from its position of greatest to its position of least velocity. During the other half revolution of the driving-wheel, or that made while the piston moves from its position of least to its position of greatest velocity, the work done by the steam in the cylinder is barely equal to the work absorbed by the piston in acquiring that increase of velocity; so that no work during that half revolution is available for the traction of the train.

If there were only one cylinder in the modern locomotive, or if both the cranks were similarly placed on the axle, the consideration of the forces acting on the locomotive might here cease. But as modern locomotives are constructed with two cylinders, with cranks at right angles to one another, the three Diagrams No. 5 are required, to exhibit graphically the total tractive force exerted at any moment by the engine. It is evident how these Diagrams are constructed from Diagram No. 4. The one piston being always in advance of the other 90° , or one quarter the path described by the crank-pin, during one turn of the driving-wheel, or 18.8 inches, it is only necessary to add together every two pressures on Diagram No. 4 which are that distance apart, to get the total tractive force of the engine, at every point throughout one entire revolution of the crank-pin. Diagrams No. 5 then show, the variation in the amount of the entire tractive force of the engine (estimated at the crank-pin) throughout one entire revolution of the driving-wheel, at the several velocities of 26, 35, and 52 miles per hour respectively. The datum line in these Diagrams,

is equal to the length of the crank circle, or four times 18·8 inches. The vertical lines above the datum show the amount of tractive force exerted by the engine at every inch of the crank circle. The upper horizontal line is the line of mean pressure, and coincides therefore with the constant resistance to the motion of the train. The wave line is the line of tractive force, and where this lies on the upper side of the line of mean pressure, or of resistance, the space between shows the work done over and above what is required to balance the work of the resistances, and which therefore accumulates. Where the dark wave line crosses and passes below the datum line, as it does in Diagram No. 5, velocity 52 miles per hour, it indicates that no tractive force is there developed in the engine; but that a positive resistance to the motion of the train is then created in the cylinder. It will be seen, that at all the velocities—26, 35, and 52 miles per hour—it is in the second quarter of the path of the crank-pin, or that quarter in which both pistons are decreasing in their absolute velocity V —the one piston making the second half of the forward stroke, and the other piston the first half of the back stroke—that the greatest accumulation of work takes place; and that in the fourth quarter of the path of the crank-pin, or where both pistons are increasing their absolute velocity V —the one making the second half of the back stroke, and the other the first half of the forward stroke—that the least amount of work is developed; or, as happens at the velocity of 52 miles per hour, that an absolute resistance to the train is developed. The Diagrams No. 5, now under consideration, show the tendency of the *vis inertiae* of the reciprocating parts to produce a fore-and-aft motion, as it has been termed, of the engine and train; or, more accurately speaking, a varying velocity of the engine and of the train, throughout each revolution of the driving-wheel; as also, a relatively varying velocity of both. During that part of the revolution, where the Diagrams No. 5 show accumulated work, the engine and train increase their velocity. From the point where the tractive force equals the mean steam pressure, to the point where it becomes zero, or vanishes, the engine and train decrease in velocity. But up to this latter point the coupling-bars between the engine and tender remain 'taut' on their pins, though subject to oscillation with the coupling-spring, from the varying amount of the tractive force exerted by the engine. During that part of the revolution where the tractive force (if it may then be so called) becomes negative, the engine, being then subjected to a resistance developed within itself, will be overtaken by the train, and will be 'buffed' forward by the tender, the coupling-bars being then loose on their pins. When the tractive force again becomes positive, the engine will, as it were, run away from the train, till the coupling-bars again bear 'taut' on their pins; the train, however,

still decreasing in velocity till the tractive force is equal to the mean pressure of steam. The same cycle of changes then again commences.

If the history of the locomotive is referred to, it will be found that the early experimenters, Murdoch, Trevithick, and others, constructed their engines with a single cylinder only. The use of two cylinders, with cranks at right angles, was first introduced, in 1811, by Blenkinsop; the presumed advantages being first, certainty of starting, and secondly, uniformity of motion. At the speeds then, and for twenty years after, contemplated on railways, both these important objects were no doubt best secured in the double-cylinder engine. But since that time, the necessities of railway travelling in respect of speed, and the power of engines, have greatly altered. With the aid of the diagrams the Author believes he may clearly establish, that for locomotive engines of the present day, the double-cylinder engine, as generally constructed, has, in respect of the second advantage claimed for it, uniformity of motion, hardly any superiority over the single-cylinder engine, as it may be constructed, even at what may be termed the minimum speed of 26 miles per hour; while at all greater speeds than that, the double-cylinder engine is in respect of uniformity of motion, decidedly inferior to the single-cylinder engine.

Before, however, proceeding to make this comparison, it is proposed to complete the examination of the disturbing forces at work in the modern locomotive. Hitherto, only the disturbing effect of these forces, in their tendency to produce a fore and aft motion, has been considered. But their most prejudicial effect is in their tendency to produce a sinuous motion, primarily in the engine, and thence communicated to the train—a tendency to move transversely to the rails, first to the right hand, and then to the left. In considering this tendency to produce sinuous motion, it will be necessary to include the steam-pressures in the cylinders, among the disturbing forces. Both the classes of disturbing forces hitherto alluded to—those arising from the revolving and reciprocating parts—are entirely independent of the action of the steam in the cylinders. Their magnitude is determined by the velocity of the engine and the proportions of its parts; and these being the same, remain unaltered whether the engine is running with steam on or steam off. But in the modern locomotive, with two cylinders, and cranks at right angles to each other, the very action of the steam which propels the train may fairly be classed among the disturbing forces of the engine. Its tendency is exactly the same in character as that of either class of the disturbing forces before alluded to. It is only by studying the action of the steam-pressure in its character as a disturbing force—firstly alone, and then as combined, or in its joint action with the other disturbing

forces—that the merits or demerits of the modern two-cylinder locomotive engine, with regard to its stability on the rails, its action on the permanent way, its essential resistances, and the wear and tear of parts, can be properly appreciated.

Diagram No. 6, Plate 3, has been prepared to illustrate the disturbing action of the steam in the double-cylinder engine. It has been assumed that the two cylinders are at the distance apart of 5 feet, or one over each rail. The two horizontal lines are supposed to represent the rails, and from each rail as a datum line is marked off, at right angles to it, the pressure exerted by the steam on the crank-pin over that rail at every point travelled over during one revolution of the crank-pin. The diagram thus shows separately the two simultaneous steam-pressures exerted, referred as in the other diagrams, to the path of the crank-pin. The centre of pressure of each pair of simultaneous steam-pressures has been found, and is marked on the diagram by a small black circle. The line joining these centres of pressure, it will be seen, crosses over from one rail to the other, in each quarter of the path of the crank-pin. Only at that point where the line intersects a line midway between the rails, does the resultant steam-pressure, therefore, act in the same straight line as the resultant of the resistances to the train. At any other point these two resultant pressures are parallel, and at a certain distance or leverage from each other. Such a couple of forces tends to produce a motion of rotation transversely to the rail. As the leverage is first on one side of the centre of resistance, and then on the other, so the motion of rotation tended to be produced alternates first to the right and then to the left; and is, in short, sinuous motion. This tendency to sinuous motion in the double-cylinder engine, produced by the steam-pressures, would exist, however perfectly the revolving and the reciprocating parts of the engine were balanced.

Diagrams No. 7 are similarly prepared, to show the tendency to sinuous motion produced by all the disturbing forces. The same assumption is made, as to the distance apart of the cylinders, as in the last diagram. From each rail as a datum line is set off, at right angles to it, the total tractive force developed in the cylinder over it, at every point in the path of the crank-pin. Hence the diagram shows, on every transverse line, the separate pressures acting as tractive force simultaneously developed in the two cylinders, and referred, as in all the other diagrams, to the path of the crank-pin. The shaded part on the diagram indicates, that at that part of the revolution the tractive forces developed, if indeed they may still retain that name, are negative in their character—act, in short, as resistances. It will be seen, that at some points the two pressures acting simultaneously on the engine over the two lines of rail, are acting in opposite directions; so that while one

side of the engine is being propelled forward in the direction of the motion of the train, by a positive pressure, the other side of the engine is simultaneously retarded by a negative pressure. This of course produces the sinuous motion in its greatest development. The amount of the pressure thus caused, and tending to throw first one rail and then the other outward has been estimated at the various points in the distance travelled over, in one entire revolution of the driving-wheel, and are exhibited graphically in Diagrams No. 8. The necessary assumptions as to the proportions of the engine are as follows: Distance apart of the cylinders 5 feet, as before; diameter of cylinder 16 inches; distance of the driving-axle, in which the centre of rotation is supposed to be, from the leading axle, where the disturbing force is measured, 6 feet. The amounts of these pressures, tending to drive the leading wheels outward against the rails, are given in pounds. Although the proportions of the engine, taken as the type of modern locomotive, are most favourable for steadiness of motion, yet it will be seen, that the maximum outward pressures of even this engine are considerable. Thus, at a velocity of 26 miles per hour, the maximum pressure is 2,868 lbs., and at 52 miles per hour, 3,942 lbs., or 26 cwt. and 36 cwt. respectively. So markedly have these outward pressures told upon one part of the permanent way, the fastenings of the chairs, that the Government inspectors have lately condemned the use of wooden trenails, and have pronounced iron to be the only fit material to withstand the shocks to which the chair-fastenings are liable.

The wear of the flanges of the leading wheels of locomotives is another evidence of the injurious effects of these outward pressures. Such wear of the flanges shows the wheels of the leading axle to be running always on unequal diameters, whence results sledging, of which the burnished state of the rails furnishes independent evidence. It is to be expected that great waste of power is thus incurred. It is well understood, that the resistance of a train exposed to a side wind is increased something like 15 per cent., and it is conceivable, that the oscillatory motion of the two-cylinder engine will generate alternately on either rail, a resistance similar in nature to that produced constantly on the same side of the engine by a side wind. The continual jarring and vibration of the carriages, which make railway travelling so unpleasant to all, and as medical men assert, decidedly unhealthy in the case of invalids and persons of delicate health, have their rise mainly in the sinuous motion now under consideration, and the sledging and shocks thereby caused. Whoever has travelled on the atmospheric railway, and remembers the gliding, the delightful smoothness, and the steadiness of the motion, will recognize what railway travelling might be, if the sinuous motion and tendency were anni-

hilated. The several cases which have occurred of engines leaving the rails on different lines, on the Great Northern, the North Staffordshire, the South Eastern, the South Wales, and lately on the London, Chatham, and Dover line, had one circumstance in common, high speed of travelling. That, and the absence of sufficient explanation by reason of any defect in the permanent way, point out as their originating cause, the sinuous motion inherent in an unbalanced double-cylinder engine.

What, then, is the practical remedy for the evils here glanced at? The Author ventures to submit, for the opinion and discussion of the members, that the remedy lies in the return, at all events for passenger traffic, to the single-cylinder engine. It will perhaps be conceded, that a locomotive worked by a single cylinder, placed exactly in its mid-section, would not give rise to sinuous motion, and the grave evils attendant thereon. But the objections made, and taken as conclusive, against the single-cylinder engine are, as stated before—a less uniform exertion of tractive force than the double-cylinder engine, and the impossibility of starting at certain parts of the stroke of the piston. Although the great majority of the locomotives now worked in this country are not balanced, so far as concerns their reciprocating parts, yet the necessity for doing so has been pointed out both by French and English writers; and a mode of doing it suggested, by weights applied to the wheels. Without discussing the question, whether this is the best way of balancing these parts, let it be supposed that a single-cylinder engine is thus fully counterbalanced. The disturbing forces of inertia will thus be annihilated, and the tractive power per square inch developed by such a balanced single-cylinder engine will be represented accurately by Diagram No. 2, Plate 2, which is a diagram of the steam pressures referred to the path of the crank-pin. This Diagram shows that the accumulated work per square inch of piston during one stroke of the piston, is at 26 miles per hour 39 units in the forward stroke, and 43 units in the back stroke. But as the supposed single-cylinder engine must have a cylinder equal in area to both those of the two-cylinder engine, it is necessary, in order to make Diagram No. 2 a correct diagram of the total tractive force, to double all the pressures marked on it, and thus 78 and 86 units will represent the accumulated work during the forward and the back strokes of the supposed single-cylinder engine; these amounts measuring its greatest departure from uniformity of motion, at a velocity of 26 miles per hour. Now it might be shown, how insignificant this amount of accumulated work is, compared with the total amount of accumulated work in even a small train moving at that velocity; a locomotive at speed forming in fact a fly-wheel of more controlling power than in any case is thought requisite. But it is preferred to make the direct

comparison, which the Diagrams provide for. Thus, referring to Diagrams No. 5, it will be seen that the accumulated work, or measure of departure from uniform motion, in each revolution of the driving-wheel, in the double-cylinder engine of ordinary construction, is—at 26 miles per hour 71 units, at 35 miles per hour 124 units, and at 52 miles per hour 240 units. Then referring to Diagram No. 2, and bearing in mind that, for the purposes of comparison, all the amounts there given must be doubled, it will be seen, that in the balanced single-cylinder engine, the accumulated work is—at 26 miles per hour 86 units, at 35 miles per hour 48 units, and at 52 miles per hour 70 units. So that the uniformity of motion of the single-cylinder engine, compared with that of the ordinary double-cylinder engine, would be at 26 miles per hour less in the ratio of 71 to 86, at 35 miles per hour greater in the ratio of 124 to 48, and at 52 miles per hour greater in the ratio of 240 to 70.

With respect to certainty of starting, it must be conceded that the double-cylinder engine has the advantage over the single cylinder; but the Author hopes to show, that the superiority in this respect is very slight. As the resistance of a train increases rapidly with its velocity, it is evident that a locomotive engine can never be required to exert at starting its full average tractive force. The proportion, however, of this which it may be required to exert at starting will vary with circumstances of load, gradient, &c.; and the only way of making the comparison, with respect to certainty of starting, between the double-cylinder engine and the single-cylinder engine, is, to determine what tractive power the double-cylinder engine is capable of exerting at starting, when starting with its pistons in the most unfavourable position. Suppose, then, the double-cylinder engine, having, when working in full gear, an admission of steam through three-quarters of the stroke, and the steam released at 90 per cent. of the stroke; and suppose the engine to be standing in such a position, that the piston in one cylinder, making the backward stroke, may be at 90 per cent. of its stroke, or a little more advanced; the steam behind this piston is then cut off from the steam-chest, but open to the exhaust. While the engine is standing, this cylinder of steam will be exhausted, and on the starting of the engine will be altogether useless for the creation of tractive power, which can only then be supplied by the other cylinder. If it be supposed that the length of the stroke is 24 inches, and the connecting-rod six times the length of the crank, it will be found that when the piston in the backward stroke is within 10 per cent. of its stroke from the end, the crank-arm is $39\frac{3}{4}^{\circ}$ from the horizontal. The other crank, 90° in advance, is therefore $50\frac{1}{4}^{\circ}$ from the horizontal, and its piston has advanced $3\frac{3}{4}$ inches on the forward stroke. The pressure

exerted on the piston, when referred to the path of the crank-pin, varies (neglecting the influence of the connecting-rod) as the sine of the angle of the crank with the horizontal. If P be the pressure of steam in the cylinder per square inch of piston, A the area of the cylinder, and n the ratio of the diameter of the driving-wheel to the stroke of the piston, the total tractive force which the double-cylinder engine can exert, when starting from its most unfavourable position, = $\frac{P A \sin 50\frac{1}{2}}{n} = .77 \frac{P A}{n}$. The area of

the single cylinder will be $2 A$; and the engine will therefore exert an equal tractive power at starting with the double-cylinder engine, when the sine of the angle with the horizontal of its crank-arm equal $.375$, which is the sine of 22.3° ; or when its piston has advanced about $\frac{7}{8}$ of an inch on its stroke. The dead part of the stroke of a single-cylinder locomotive would therefore be passed, when its piston has advanced $\frac{7}{8}$ of an inch in its stroke, at which time it would be exerting a tractive force of $\frac{.375 \times P \times 2 A}{n}$. If

the pressure of the steam be equal to 100 lbs. per square inch, and the area, $2 A$, of the cylinder be equal to the area of two cylinders of 18 inches diameter, or 520 square inches, the required starting tractive force would be $\frac{.375 \times 100 \times 520}{4} = 4,875$ lbs., which

may therefore be taken as the maximum resistance to a passenger train at starting. If, now, the single-cylinder engine be supposed to be starting from its most unfavourable position—that is the position in which the piston would be at the end of the stroke—it is evident that before its crank-arm could be made to describe the angle 22° , or its piston be advanced $\frac{7}{8}$ of an inch in the stroke, there must, by some means or other, be overcome a resistance of

4,875 lbs., through a distance $\frac{22}{180} \times 4 \times 3.1416 = 1\frac{1}{2}$ foot, or a

total work overcome of $4,875 \times 1\frac{1}{2} = 7,312$ units. Of the work thus required to be done, before the engine could exert the requisite tractive power unaided to start the train, a certain portion

represented by $520 \times 100 \times \frac{7}{12} = 3,791$ units would be supplied

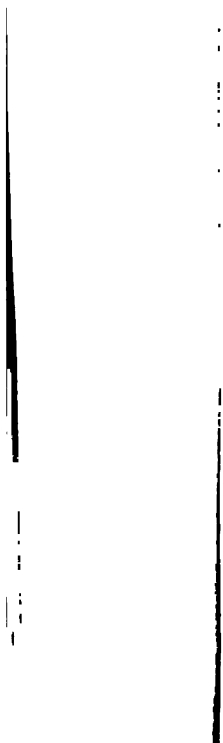
by the steam in the cylinder; so that only $7,312 - 3,791$, or 3,521 units of work would be required from some external source. Thus, then, to give a single-cylinder engine the same certainty of starting as a double-cylinder engine, all that is required is to put into the hands of the driver, a means of applying to the circumference of the driving-wheel of the engine a maximum pressure of 4,875 lbs., and to exert a certain power, or work, represented by 3,500 lbs. lifted through 1 foot; which quantity of work is gene-

rally estimated as the work of one man for one minute, working from six to eight hours per day. This does not appear to be a very difficult mechanical problem.

In conclusion, the Author condenses the foregoing Paper, in venturing to submit for the consideration of the members,—that a single-cylinder engine would be free from all sinuous motion; that at 26 miles per hour, it would have, when counterbalanced, about the same, and at higher speeds, far less fore-and-aft motion than the ordinary two-cylinder engine; that by supplying the driver with the means of applying about as much power as is expended in putting the breaks on hard, the single-cylinder engine would have equal certainty of starting with the two-cylinder engine; that the use of single-cylinder engines for passenger traffic would, by reducing or annihilating the oscillation and vibration of the carriages, render railway travelling less unpleasant; that it would reduce the cost of locomotive power, and the expense of maintenance of permanent way; and that it would lengthen the life of the rails, and lessen the dead weight of the engine, and the wear and tear of its parts.

The Paper is accompanied by a series of Diagrams, from which Plates 2 and 3 have been compiled.

OF THE

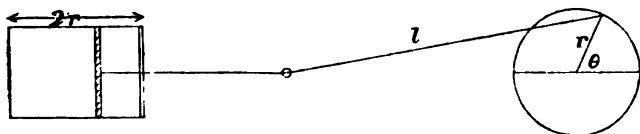


APPENDIX.

No. 1.

FORMULA SHOWING THE RELATION BETWEEN THE PRESSURE ON THE PISTON, AS OBSERVED BY THE INDICATOR, AND THE EQUIVALENT PRESSURE AT THE CRANK PIN.

Fig. 1.



Let P , be the pressure on each square inch of piston.

P_1 , the equivalent pressure at the crank pin.

r , the radius of the crank circle.

l , the length of the connecting rod.

θ , the angle which the crank arm makes with the horizontal.

Then, while the crank pin has moved through $r\theta$, the piston has moved :—

$$r - r \cos. \theta \mp (l - \sqrt{l^2 - r^2 \sin. 2\theta}) \left\{ \begin{array}{l} \text{for the forward} \\ \text{for the backward} \end{array} \right\} \text{stroke.}$$

Now, let the angle θ be increased by the infinitely small increment $\delta\theta$; then while the crank pin moves through $r\delta\theta$, the piston will move through the differential of :—

$$r - r \cos. \theta \mp (l - \sqrt{l^2 - r^2 \sin. 2\theta}) = \left(r \sin. \theta \mp \frac{r^2 \sin. \theta \cos. \theta}{\sqrt{l^2 - r^2 \sin. 2\theta}} \right) \delta\theta$$

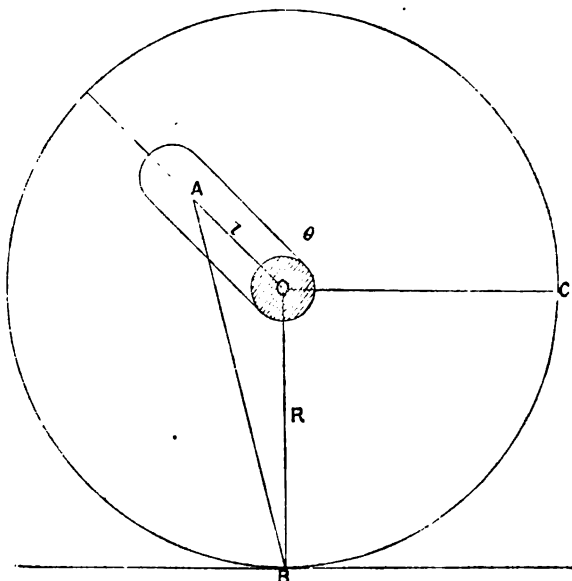
$$\text{therefore, } P \times \left(r \sin. \theta \mp \frac{r^2 \sin. \theta \cos. \theta}{\sqrt{l^2 - r^2 \sin. 2\theta}} \right) \delta\theta = P_1 r \delta\theta;$$

$$\text{and, } P_1 = P \left(\sin. \theta - \frac{r \sin. \theta \cos. \theta}{\sqrt{l^2 - r^2 \sin. 2\theta}} \right) \text{ for the forward stroke of the piston,}$$

$$= P \left(\sin. \theta + \frac{r \sin. \theta \cos. \theta}{\sqrt{l^2 - r^2 \sin. 2\theta}} \right) \text{ for the backward stroke of the piston.}$$

No. 2.

DISTURBING FORCE GENERATED BY THE UNBALANCED REVOLVING MASSES.



Let A be the centre of gravity of the unbalanced part of the crank, and let I be its moment of inertia about A : and I_1 its moment of inertia about B.

Let l be the distance of A from the centre of the axle.

θ = the angle A O C.

R = the radius of the driving wheel.

Then, the moment of inertia I_1 of the crank about B (1)

$$= I + \{ (l \cos. \theta)^2 + (R + l \sin. \theta)^2 \} M$$

$$= I + (R^2 + l^2 + 2l R \sin. \theta) M,$$

where M is equal to the volume of the crank.

Let V be the velocity of the train : then $\frac{V}{R}$ is the angular velocity of the centre of gravity A about B. Then U the accumulated work in the crank . . . (2)

$$= \frac{1}{2} \frac{V^2}{R^2} \left(\frac{u}{g} \right) \{ I + R^2 + l^2 + 2l R \sin. \theta \} M.$$

$$\text{Let } \theta \text{ become } \theta + \delta \theta, \text{ then } d. U = \frac{V^2}{R^2} \frac{u}{g} M l R \cos. \theta \delta \theta$$

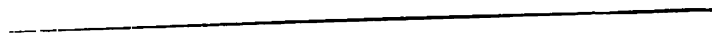
$$= \frac{l}{R^2} \frac{V^2}{g} \frac{W}{\cos. \theta} R \delta \theta$$

But $\frac{l}{R^2} \frac{V^2}{g} \frac{W}{\cos. \theta}$ is the centrifugal force C of the crank, whose weight is W

¹ Vide "Moseley's Mechanics," page 82.

² Ibid. page 75.

E



having its centre of gravity at the distance l from the centre of the wheel :

Therefore, $dU = C \cos. \theta R \delta \theta$;

While U thus becomes $U + d \cdot U$, the train moves through the distance $R \delta \theta$; and the increase or diminution of the accumulated work U in the crank, as it describes the small angle $\delta \theta$, has the same effect on the train as a pressure $P = C \cos. \theta$ acting against, or in favour of the motion of the train. This equality of P to the horizontal component of the centrifugal force is noticed in Mr. D. K. Clark's *Railway Machinery*, page 168.

No. 3.

TO FIND THE PRESSURES, REFERRED TO THE CRANK PIN, GENERATED BY THE VIS-INERTIA AND VARYING VELOCITY OF THE RECIPROCATING PARTS OF A LOCOMOTIVE IN MOTION.

Let r = the radius of the crank.

πr = the radius of the driving wheel.

L = the length of the connecting rod.

θ = the angle the crank makes with the horizontal.

V = the velocity in feet per second of the train.

V_1 = ditto, ditto, of the piston, not relative, but absolute velocity.

First, for the forward stroke of the piston, or that made in the direction of the motion of the train. While the axle of the driving wheel moves through $\pi r \theta$, the piston moves through

$$\pi r \theta + r \text{ ver. sin. } \theta - (L - \sqrt{L^2 - r^2 \sin^2 \theta})$$

Now let the angle θ be increased by an infinitely small quantity $\delta \theta$; coincidently with this increase, the axle moves through $\pi r \delta \theta$, and the piston through the differential :—

$$d \cdot (\pi r \theta + r \text{ ver. sin. } \theta - (L - \sqrt{L^2 - r^2 \sin^2 \theta})) \delta \theta \\ = \left(\pi r + r \sin. \theta - \frac{r^2 \sin. \theta \cos. \theta}{\sqrt{L^2 - r^2 \sin^2 \theta}} \right) \delta \theta$$

The velocities V and V_1 of the axle and of the piston respectively are to one another as the spaces they travel through in the same time :—

$$\frac{V_1}{V} = \left(\pi r + r \sin. \theta - \frac{r^2 \sin. \theta \cos. \theta}{\sqrt{L^2 - r^2 \sin^2 \theta}} \right) \delta \theta$$

Therefore,

$$\text{or } V_1 = \left(I + \frac{\sin. \theta}{n} - \frac{r \sin. \theta \cos. \theta}{n \sqrt{L^2 - r^2 \sin^2 \theta}} \right) V.$$

Now let U represent the work accumulated in the reciprocating parts of the engine, the weight of which is represented by W . By a well-known formula :—

$$U = \frac{1}{2} \frac{W}{g} V_1^2$$

V_1 has been shown to be a function of θ . Let then θ be increased by the infinitely small quantity $\delta \theta$; coincidently with this increase, the crank pin has moved through a distance $r \delta \theta$, and the accumulated work in the reciprocating parts has been increased by the differential $d \cdot U =$

$$d \cdot \left(\frac{1}{2} \frac{W}{g} V_1^2 \right) = \frac{W}{g} V_1 d \cdot V_1$$

But

$$V_1 = \left(I + \frac{\sin. \theta}{n} - \frac{r \sin. \theta \cos. \theta}{n \sqrt{L^2 - r^2 \sin^2 \theta}} \right) V \text{ and—}$$

$$d \cdot V_1 = \left(\frac{\cos. \theta}{n} - \frac{r (\cos. 2\theta - \sin. 2\theta)}{n \sqrt{L^2 - r^2 \sin^2 \theta}} + \frac{r^2 \sin. 2\theta \cos. 2\theta}{n \sqrt{(L^2 - r^2 \sin^2 \theta)^3}} \right) V \delta \theta$$

[1862-63. N.S.]

G

$$\text{therefore, } d \cdot U = \frac{W V^2}{r g} \left(\frac{I + \sin. \theta}{n} - \frac{r \sin. \theta \cos. \theta}{n \sqrt{L^2 - r^2 \sin. 2\theta}} \right) \times \\ \left(\frac{\cos. \theta}{n} - \frac{r (\cos. 2\theta - \sin. 2\theta)}{n \sqrt{L^2 - r^2 \sin. 2\theta}} + \frac{r^2 \sin. 2\theta \cos. 2\theta}{n \sqrt{(L^2 - r^2 \sin. 2\theta)^3}} \right) r \delta \theta.$$

Now this increase of work $d \cdot U$, accumulated in the reciprocating parts of the engine, while the crank pin moves through $r \delta \theta$, has been for the moment abstracted from the moving, or effective force of the engine: or should $d \cdot U$ be negative, it represents the work yielded up by the reciprocating parts to aid the moving forces on the engine. In either case, the moving forces of the engine are diminished, or increased, by a pressure P , which, estimated at the crank pin

$$= \frac{d \cdot U}{r \delta \theta}, \text{ or}$$

$$P = \frac{W V^2}{r g} \left(I + \frac{\sin. \theta}{n} - \frac{r \sin. \theta \cos. \theta}{n \sqrt{L^2 - r^2 \sin. 2\theta}} \right) \times \\ \left(\frac{\cos. \theta}{n} - \frac{r (\cos. 2\theta - \sin. 2\theta)}{n \sqrt{L^2 - r^2 \sin. 2\theta}} + \frac{r^2 \sin. 2\theta \cos. 2\theta}{n \sqrt{(L^2 - r^2 \sin. 2\theta)^3}} \right)$$

Similarly for the back stroke $V_1 = \left(I - \frac{\sin. \theta}{n} - \frac{r \sin. \theta \cos. \theta}{n \sqrt{L^2 - r^2 \sin. 2\theta}} \right)$, and

$$P = \frac{W V^2}{r g} \left(I - \frac{\sin. \theta}{n} - \frac{r \sin. \theta \cos. \theta}{n \sqrt{L^2 - r^2 \sin. 2\theta}} \right) \times \\ \left(- \frac{\cos. \theta}{n} - \frac{r (\cos. 2\theta - \sin. 2\theta)}{n \sqrt{L^2 - r^2 \sin. 2\theta}} + \frac{r^2 \sin. 2\theta \cos. 2\theta}{n \sqrt{(L^2 - r^2 \sin. 2\theta)^3}} \right)$$

Mr. M'CLEAN inquired what mode was proposed for overcoming the mechanical difficulty of starting the train with a single-cylinder engine.

Mr. MAKINSON replied, that he had devised a means of doing this ; but he had not prepared either a model or a drawing of it, as he had proposed in the Paper merely to define the limits of the pressures and forces necessary for the starting of the engine, and so prepare and clear the way for the mechanical solution of the problem. The plan which had occurred to him as a feasible one was as follows :—Two parallel friction discs, having their working faces inclined to each other, capable of being thrown in and out of gear, were pressed upon and gripped between them the two sides of the tyre of the driving-wheel. Pressure applied by the driver to a hand-wheel, and multiplied by proper gearing, turned the friction discs, and with them the driving-wheel.

Mr. KITSON thought the members were indebted to the Author, for his elaborate demonstrations of the disturbing forces which, in his opinion, operated upon the locomotive engine ; but as a practical man, Mr. Kitson was not disposed to admit, generally, the correctness of all the data. In the first place, it was difficult to apply theory to the working of the locomotive engine ; and he could hardly understand how it was possible to apply all the tests that would be necessary, to enable such carefully tabulated results to be prepared. The chief reason for the introduction of the double-cylinder locomotive was the practical difficulty of starting a train with a single-cylinder engine, a difficulty which he at present regarded as insurmountable, and which was of itself sufficient to cause the idea of a single-cylinder locomotive to be at once dismissed. Another difficulty seemed to have been overlooked by the Author,—that was, that the centre of gravity would have to be raised so high, with a cylinder in the centre, as to create a serious objection, which would counterbalance any presumed advantage of a single-cylinder engine. Nor was he disposed to admit, that the locomotive engine deserved all the blame attributed to it for the lateral motion of the train, as he thought that defects in the permanent way had a great deal more to do with it. With a light locomotive engine it was possible that many of these forces might have a serious effect, in increasing the unsteady motion ; but with locomotives of the present weight, the influence of the cylinders upon the large mass was much less than he was prepared to expect, as was shown by the results now submitted. The tendency to produce an oscillating motion by the engine was to a great extent neutralised by its weight, and was not communicated from the engine to the train ; but was principally owing to the difficulty of keeping the road in perfect order. Although great pains had been taken in demon-

strating, theoretically, some of the results, yet practically he considered the object sought would not be obtained by the reintroduction of the single-cylinder engine.

Mr. T. E. HARRISON said, the point suggested, of equalizing the motion of the engine by having a single-cylinder, was tried in another way by the late Mr. Robert Stephenson. An engine was built by him with three cylinders, a large one in the centre and two smaller ones at the sides, and was tested for many years on the North-Eastern Railway. The main object was to avoid the lateral motion. He had constantly ridden upon that engine, and having been in the habit of riding upon other descriptions of engines at the highest velocities, he confessed he had never found any advantage in that respect in the engine to which he alluded over other well-balanced engines. There was no doubt a great difference in the balancing of engines; and one class, known as the Rocking Horse of Kent, with outside cylinders, badly balanced, had caused more accidents from running off the line than any other engines with which he was acquainted. Much depended upon the state of the permanent way, and that could not always be kept in perfect order, subject as it was to variations in the temperature, to changes in the weather, and to other influences. Two things required special attention; first, the permanent way should be maintained in as good order as possible, and in the next place, the balancing of the engine should be rigidly enforced; and here he would remark, that whatever might be professed, he believed engines were not sufficiently put through the test of the weighing machine. When turned out of the factory, the engines were put upon the machine, and the springs were properly adjusted; but when an engine was tested, which had been at work some time, it was often found that, for some reason or other, it was not properly balanced. That was a question simply as regarded the adjustment of the springs, but in the design of the engine he believed sufficient attention was not always paid to the balancing. He had noticed a great difference in engines in respect of their motion, and it undoubtedly was a difficult question, but he could not agree, that by the plan suggested, of using one cylinder only, the steadiness of the engine would be improved; because in the three-cylinder engine to which he had referred, the necessity of raising the boiler, to get in the middle cylinder, caused the centre of gravity to be so high, that all the expected advantage in steadiness was lost, and if a single cylinder was employed the difficulty would be increased.

Mr. MAKINSON said, in reply to questions, that in Diagram No. 6, the tendency to produce sinuous motion was that due to the pressure of the steam only, without any allowance being made for the momentum of the parts; and that throughout the series of

diagrams, the pressure of steam per square inch of piston, referred to the path of the crank pin, was given.

Mr. F. J. BRAMWELL said, the opinion appeared to be entertained, that in this Paper theory and practice were at variance with each other. Now he believed it was a truism, that theory and practice could never be at variance, when the theory itself was perfect and sufficient, *i. e.* worked out so as to embrace all points, and when the practice had been carefully observed and properly reported. In this case there could be but little doubt, that the practice had been carefully reported, for observations had been made by too many men of experience to leave that in dispute. If, therefore, there were in this instance discord between theory and practice, it must arise from inaccuracy in the theory, and not from imperfect appreciation of the practice. He would briefly state what he considered the inaccuracies were in the present Paper. The disturbing forces had been divided by the Author into two classes,—those which arose from the pressure of the steam in the cylinder propelling the engine,—and those which arose from the momentum of certain parts,—and it would be convenient to keep to that classification. With regard to the former, and assuming the parts to be without weight and without momentum, he understood the Author put forward this position, that there were working pressures on the piston, divided by the ratio of the crank to the radius of the wheel, acting alternately on the two sides of the engine, and that these tended to produce sinuous motion. This, in Mr. Bramwell's view of the case, was an error; for when two wheels were keyed fast upon a shaft, of such strength as not to yield appreciably under torsion, there could be no difference of pressure (of this kind) between the two sides of the engine; and that was true, wholly irrespective of the number of cylinders, or the places where they were put. In order to show this he would refer to diagrams, Figs. 1, 2, and 3 (p. 86), for the elementary character of which he apologised. He had supposed, for convenience, as the Author had done, that the cylinder, one wheel, and the bearing were infinitely thin, so that they might all be considered as lying in one plane, and therefore there would be no occasion to take into account the places where the pressures bore upon the shaft. Fig. 1 assumed a wheel 6 feet diameter, and a crank 1 foot in length, and that the piston in its forward stroke pressed with a force of 3 tons. The black arrows indicated the pressures due to the piston, and the dotted arrows the opposite pressures, or those due to the cylinder cover. It was clear if there were a pressure of 3 tons driving the piston to the right, the tendency to drive the crank shaft to the right was as 4 : 3, as the crank and the radius of the wheel together would be a length of 4, while the radius of the wheel would be only 3. But that was in part counteracted by the pres-

sure of 3 tons tending to drive the cylinder and framing to the left hand, leaving a balance of 1 ton for the propelling pressure of the engine, or the pressure on the piston divided by the multiple that the radius of the driving-wheel was of the crank.

Fig. 1.

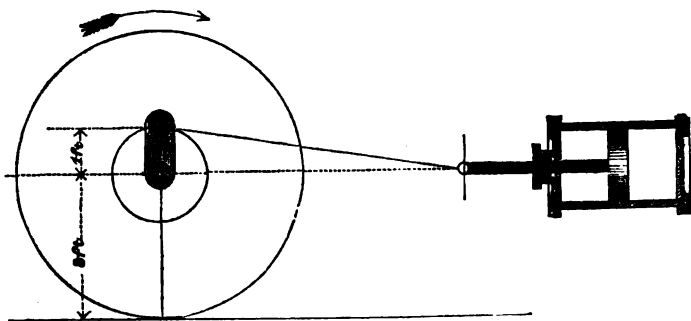


Fig. 2.

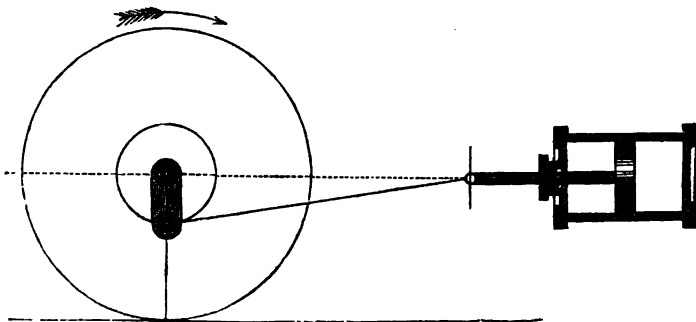
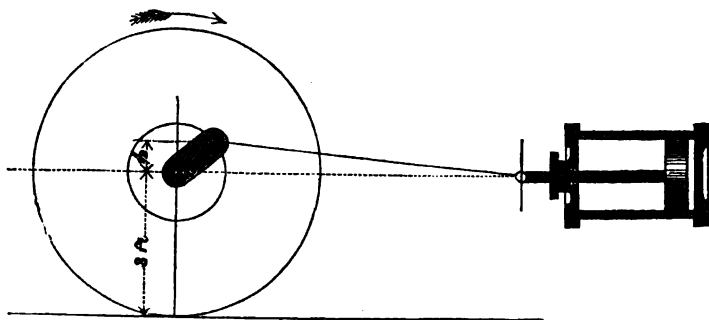


Fig. 3.



In Fig. 2 the piston was shown making the backward stroke. In this case the crank pin, instead of being above, was below the

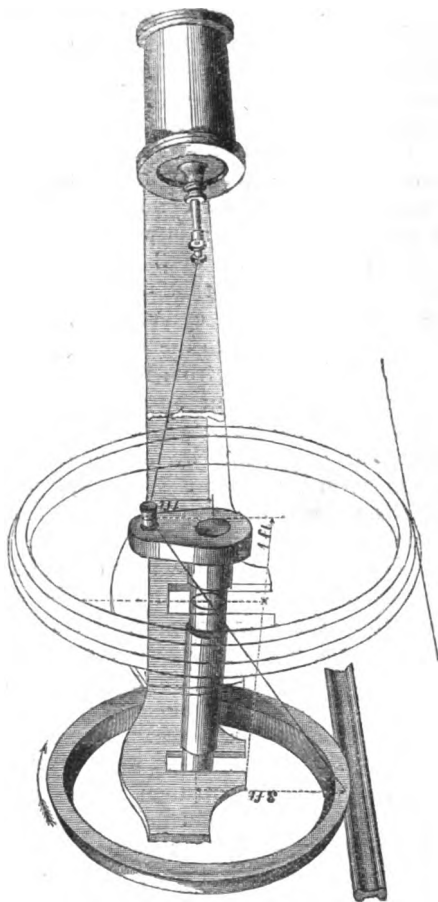
shaft. Therefore 3 tons pressure on the piston produced only 2 tons pressure upon the crank shaft; but 3 tons on the cylinder-cover produced 3 tons upon the frame and shaft, and the difference between 2 and 3, was the 1 ton for the driving pressure. In Fig. 3, the piston was shown as making its forward stroke with the crank at 30° from the horizontal. Following out the reasoning used when alluding to Fig. 1, it would be seen that the pressure now tending to propel the engine was only $\frac{1}{2}$ ton; therefore it was clear the unbalanced pressure upon a bearing at any time was that due to the force driving the engine by that particular bearing, and that it could be nothing else.

Having, he thought, established that point, he would refer to a diagram (Fig. 4, p. 88), which, in order to test the principle, was illustrative of an extreme case; an engine, being assumed with one (the shaded) wheel only, and one cylinder, the piston being supposed to be in the act of making a forward stroke. The result of that would be to put a pressure of 3 tons upon the crank pin to the right,¹ driving the crank in that direction, but it would be reduced by the pressure from the cylinder-cover. Taking an imaginary line from the crank pin to the driving-wheel, and another through the centre of the shaft from the bearing to the centre of the wheel, then as the piston put on a pressure of 4 tons in the right-hand direction, at the point where these two lines crossed, this was balanced at that point by an equal pressure obtained from the cylinder-cover acting in the left-hand direction; and it would be seen, by tracing the two imaginary lines to the parts where they touched the driving-wheel, that the piston-pressure resulted in an effort to turn the wheel upon the rail, with a pressure to the left-hand of 1 ton (which might be called the abutment pressure), while the cylinder-cover put a pressure of 1 ton to the right-hand on the bearing close to the wheel, which was, in truth, the driving-pressure. Such an arrangement of one wheel would no doubt tend to produce sinuous motion, with a force proportioned to the distance of that wheel from the centre of gravity of the engine. But if the other wheel were taken into consideration, as being fixed on the shaft, then it would be seen that an engine which was capable of producing 1 ton of tractive force, must distribute it over the two bearings, and that there would therefore be $\frac{1}{2}$ ton on each bearing; though the engine were driven by one cylinder, it was manifest it could not put a pressure

¹ Mr. Bramwell wished to correct an error in the diagram (Fig. 4), viz.—the bearing on the right hand, instead of being drawn close to the crank, was shown away from it, and it had been put in such a position that unhappily the imaginary line indicating the transmission of the force from the crank-pin to the point where the driving-wheel touched the rail, appeared to cross it. He would request the meeting therefore to dismiss from their minds the position of the bearing, and suppose it to be in the plane of the cylinder.

upon one side of that engine, which was not equalled by that on the other side at the same moment. He trusted that he had made it apparent, that there could not possibly arise any sinuous motion from the driving pressures. If not true, then he would ask what would happen. Take the case of a paddle-steamer,

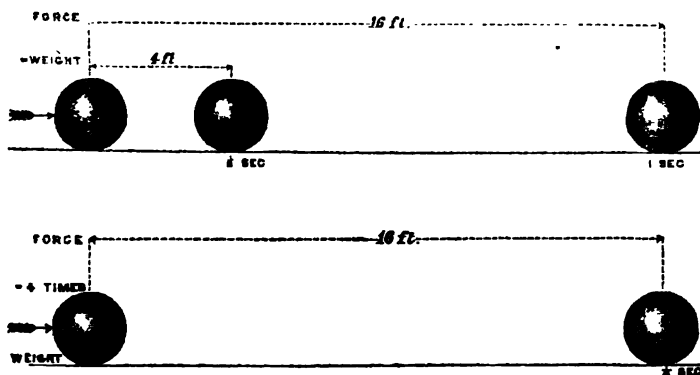
Fig. 4.



with a pair of wheels, and, as had occurred in his own practice, with the driving-engine on one side. Now, if the position of the cylinder in relation to the wheels it worked, whether those of a locomotive, or the paddles of a steam-boat, had anything to do

with the amount of the driving-pressure on either side, that vessel ought to have carried helm on the side nearest to which the engine was. Again, in the case of a screw not fully immersed, and therefore producing a sideway pressure upon the bearing, such pressure ought to be greater, or less, according as the engines were placed aft, or nearly midships. Now Engineers knew, that no such result could happen in the case of the paddle-wheel, or of the screw, and he trusted his observations would lead to the conviction, that it was equally impossible for it to happen in the case of a locomotive. With respect to the disturbances arising from the momentum of the parts, no doubt there was such disturbance, but he could not help thinking that the Author had given it an undue importance, and that he had been led to do so by a neglect of this fact, that though the force of the parts in motion increased as the speed got higher, the times through which they acted decreased. The space through which these forces were capable of moving an engine must be equal for all speeds. Referring to another elementary diagram (Fig. 5), in the upper portion a ball was shown, which was assumed

Fig. 5.



as being moved towards the right by a force equal to its own weight; therefore at the end of a second of time it would have moved through 16 feet, and in half a second it would have moved through 4 feet. In the lower part of the diagram a ball was shown which was assumed to be impelled by a force of four times its own weight. The result would be, that in half a second it would be moved four times as far as the 4 feet motion of the other ball, or 16 feet.

The consideration of this diagram (Fig. 5) showed, that if there were two forces, one of which was four times as great as the

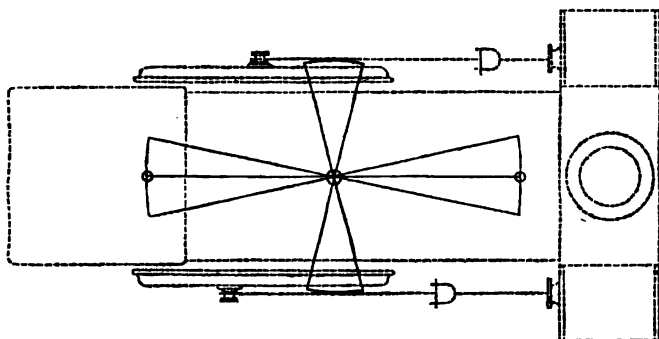
other, but acted for only half its time, this greater force would produce the same amount of motion as the first force. He did not say, however, the terminal velocities of the balls would be the same in the two cases, as no doubt, in the instances cited, the ball impelled by the greater force through the same distance would have a terminal velocity equal to twice that of the other. Applying these considerations to the question under discussion, if a locomotive had a velocity of one mile an hour, the force due to the momentum of the parts might be called 'one,' and the time during which it acted also 'one.' If the velocity were increased to 2 miles, the force would be increased as the square of the velocity (or 4), but it would only act for half the time. Similarly, if the velocity were increased to 10 miles, the force would be increased 100 times, but would only act for a tenth part of the time. Thus it would be seen, that whatever the speed of the engine, the distance through which the forces moved it must be the same for all velocities. The next point to which he wished to direct attention was the distance which the forces alluded to by the Author ought to move such an engine as he had described. Assuming, as the Author had done, the weights of the moving parts belonging to each cylinder to be 492 lbs., or in round numbers 500 lbs., and that 300 revolutions per minute were made, giving 63 miles per hour, or sufficient to fulfil all the conditions of a railway, then 500 lbs. and 300 revolutions per minute, at a radius of 1 foot, which was the length of the crank of the engine under consideration, gave, in round numbers, a maximum alternately of momentum and inertia of about thirty times the 500 lbs.

Therefore, each set of moving parts would give a pressure of 15,000 lbs. at the velocity he had stated. He thought it was in accordance with the Author's diagram to say, that the forces could not be taken as being of more value than was equal to their maximum through two-thirds of the whole revolution; and as 300 revolutions per minute had been assumed, which gave $\frac{1}{3}$ th of a second for a revolution, it followed that the force of the moving part—viz., the 15,000 lbs.—could only act through $\frac{2}{3}$ of $\frac{1}{3}$ second, or $\frac{2}{9}$ ths of a second. But it must be borne in mind, that even of this time, short as it was, only the latter half could be employed in producing motion, because it was clear the first half must be occupied by destroying the motion left by the immediately preceding impulse in a contrary direction, and that, therefore, in effect $\frac{1}{9}$ th of a second was the time during which the momentum of the parts would operate to produce motion.

Having ascertained the time, the next point for consideration was the distance of the force from the centre line of the engine, for which purpose the weight of the engine must be taken into

account, and a position be fixed for the centre of gyration of that weight. Diagram Fig. 6 was prepared to illustrate these points. He had assumed the centre of the cylinder, *i. e.*, the centre of the moving parts, to be 3 feet from the centre line of

Fig. 6.



the engine ; that the engine weighed 60,000 lbs., or from 27 tons to 28 tons ; that the weight was uniformly distributed over a length of about only 16 feet, giving the centre of gyration at 4 feet 6 inches on each side of the centre of the length. These proportions would reduce the 15,000 lbs. force of the moving parts to 10,000 lbs. when applied in the centre of gyration ; and as this 10,000 lbs. would be equal to only $\frac{1}{6}$ th of the whole weight of the engine, the effect would clearly be to move the engine only $\frac{1}{6}$ th part of the distance through which it would be moved by the action of gravity operating for the same time. As this force would act for the $\frac{1}{15}$ th of a second, and as the distances moved through were as the squares of the times, it would follow that the space in this instance would be only

$$\frac{1}{6} \text{ of } \sqrt{\frac{1}{15}} = \frac{1}{6} \text{ of } \frac{1}{225} = \frac{1}{1350},$$

and the $\frac{1}{1350}$ th part of 16 feet, through which a body would fall in a second of time, was equal to about $\frac{1}{100}$ ths of an inch. That being so, he trusted he had shown, that with a locomotive, the crank shaft of which was making 300 revolutions a minute, with a crank 1 foot in length, the moving parts of each engine weighing 500 lbs., and the weight of the locomotive being from 27 tons to 28 tons, there would be an amount of motion equal to only $\frac{1}{100}$ ths of an inch ; and it must be remembered, that while this would be the extent of each motion, the number of such motions, as they occurred at each revolution of the crank shaft, could not increase for a given distance travelled over, although from the

greater number of revolutions per minute when the velocity was high, there would be a greater number of movements in a given time.

If these conclusions were correct, he thought it must be admitted, that the disturbance from the momentum of the parts was not so great as the Author imagined, and that the corrections proposed would make theory accord with practice. But even if these disturbances were so grave, then Mr. Bramwell would not seek a remedy by the construction of single-cylinder engines, to which there were great practical objections, while there were many better contrivances. There was the plan introduced by Mr. Bodmer, as early as the year 1834, of having two pistons in one cylinder, with the piston-rods issuing at opposite ends of the cylinder, and provided with suitable connecting-rods to the crank shaft. In 1841 Mr. Bodmer modified this plan, by having the two piston-rods to issue at one end of the cylinder, the one rod being made hollow to allow of the passage of the other. An engine of that kind he saw at work many years ago. Further, there was the 'Duplex' engine in the International Exhibition of 1862; also drawings by French Engineers, who proposed to employ four cylinders, two for giving a forward, and the others an aft motion. To his mind any one of these plans was superior to that which had been proposed by the Author. Supposing, however, a single-cylinder engine were to be used, he believed it would not be impossible to scheme an implement to enable the driver to start the engine. He had introduced into some heavy reciprocating machinery, a starting screw, which worked the machine up to the time when it was in a position to move without such assistance, and then this starting screw was simply thrown out of gear, by the mere act of the machine; but he hoped no one would ever be called upon to devise a similar plan to be employed upon locomotive engines.

Mr. J. SCOTT RUSSELL said, although he had pursued a somewhat different mode of investigation to that adopted by Mr. Bramwell, yet it was curious that he should have arrived at almost identical conclusions, but for another size of engine; that was to say, taking the forces exactly as the Author had done, he found the total lateral translation in the mass of an engine by those forces would be in one case $\frac{1}{3}$ th of an inch, and in another $\frac{1}{10}$ th of an inch. He considered the valuable part of this Paper was the careful analysis which had been made of the forces as actually measured from the diagrams of Mr. D. K. Clark's observations, and the manner in which the various effects were recorded; all of which must be regarded as tending to eliminate the effects produced by the momentum of the parts. At all events, as he understood the matter, the diagrams truly represented the resolved transverse forces tending to displace the engine, horizontally, off the rails;

and to those, therefore, as the results of an investigation, which he had every reason to believe had been carefully carried out, he would apply himself. As far as he had followed this investigation, the practical effect of these disturbing forces would be this:— That if the engine wheels had no flanges, and the engine was going forward at the velocities stated, on a perfectly smooth surface, it would perform this vibratory oscillation, first on one side and then on the other. That being so, and taking the analyses, as given by the Author, of the times during which those forces acted at a speed of 35 miles an hour, he observed that each of those was acting during about $\frac{1}{16}$ ths of a revolution, and as at this velocity a revolution was made twice in a second, it followed that each of the diagrams represented forces acting during the $\frac{1}{8}$ th part of a second. The effect of that, compared with the effect of gravity, gave 3 inches as the total displacement which would take place, supposing those forces to act during an instant of time. In the next place, those forces were, as nearly as he could make it, the $\frac{1}{16}$ th part of the mass which they moved; and it followed therefore that the lateral translation produced by the force in one of the diagrams was $\frac{1}{8}$ th part of an inch to the right or to the left, as a maximum when the force was uniform. Taking the diagram as composed of two straight lines, one-half this amount, or the $\frac{1}{16}$ th part of an inch, would represent the horizontal translation on either side. It appeared to him, that the inference to be drawn from this inquiry, as regarded the light to be thrown by theory upon a practical question, was that it was most desirable a theoretical investigation of this kind should have put in a visible form a series of tendencies, which were very small, but which certainly existed, and that every practical man should know those tendencies, and where they lay. The Author had, in his opinion, done good service in bringing forward the subject so plainly and so clearly, for when it was known where a bad tendency existed, however slight it might be, practical precautions could be taken to prevent its increasing and to diminish it. But it seemed to him that the subject should have been carried further, so as to embrace the measure of the effects of those tendencies; for it was not worth the trouble of inventing cures for tendencies, until the strict and rigid measures of the effects which those tendencies produced had been ascertained. If the Author would do this, before the Paper was printed, for the actual engine of which he had all the measures, then the communication would be more complete, and by that means he believed theory and practice would be thoroughly reconciled. In the early days of railways comparatively little attention was paid to the perfect balancing of the revolving and reciprocating masses in the locomotive engine; but now that this was done, railway travellers were not conscious of those serious jolts in every

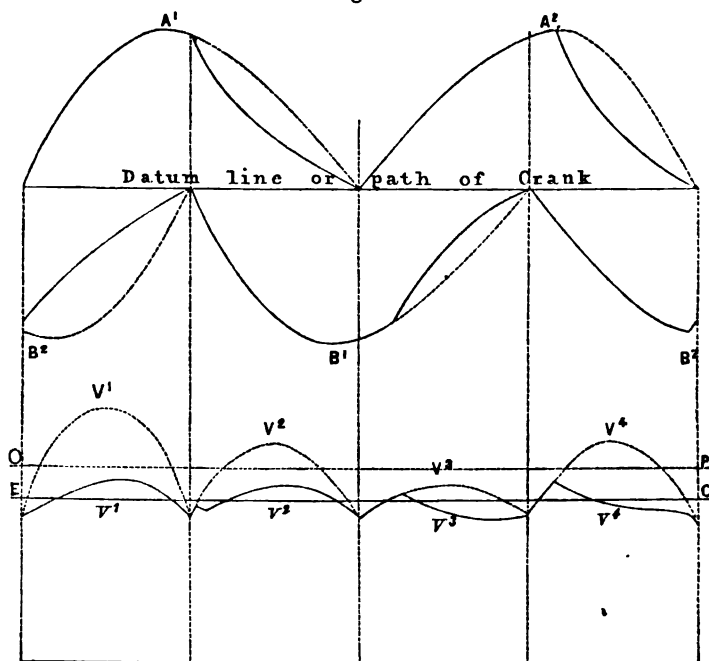
revolution, which the appearance of the diagrams would lead them to apprehend. The Paper gave rise to one valuable suggestion, the importance of allowing considerable play between the flanges of the engine and the rails. These should not fit each other too closely; and it appeared that, in a good engine, a lateral free play of more than $\frac{1}{4}$ th of an inch on each side of the centre line did take place, and considerably more must be allowed. It was much more comfortable to stand on the foot-plate of an engine when going round a curve, than when running on a perfectly straight line, as in the latter case there was a series of oscillations, and all the road did on the curve was to guide that side, and prevent the engine going towards the other side. It was important that attempts should not be made to remedy small evil tendencies, by serious and formidable measures. He thought, if Mr. Bramwell and he were right in their measures of the horizontal translation, that this amount of oscillation should not lead to the conversion of the double-cylinder engine into a single-cylinder engine, with all the mechanical inconveniences which attached to the latter. He was sure that no engine-driver, who had limped home with only one cylinder at work, or who had one or two inclines to surmount, would wish to 'improve' the double-cylinder engine by making it a single-cylinder engine. He was glad that justice had been done to Mr. Bodmer's plan of balancing the engine. He had noticed substantially the same plan as Mr. Bodmer's in an Austrian engine in the International Exhibition of 1862, yet if it turned out that the measures of the effects given were near the truth, he thought no one would recommend a considerable deviation from the established form, to get rid of tendencies, the measure of whose effects was really so small.

Mr. COWPER could not agree that there was any necessity for having resort to a kind of Cyclops engine with one cylinder, in order to remedy the defects mentioned, in the balancing of locomotive engines. Indeed it hardly seemed to require an argument to prove, that it was unwise so to construct an engine, as to produce the greatest possible amount of snatching at the drag chains, or irregularity in the tractive power; to say nothing of putting a crank with twice the ordinary strain upon it, in the centre of the axle, where it was weakest, and where in fact there was no room for it to go round under the boiler. The result of concentrating the whole power in one cylinder would be, that in place of a somewhat distributed rotative force, there would be two portions of each revolution during which the engine would not even have power enough to drive itself, and must therefore be propelled by the pressure of the train behind. This would be a great evil; but a still more formidable objection would arise from the power being excessive at two other portions of each revolution, nearly twice what it

ever was, with an ordinary engine having two cylinders. Practical locomotive engineers knew that the weight on the driving wheels had to be adjusted so as to give sufficient adhesion to the rails; and that often this weight was quite as much as it could be made with safety. Now if one cylinder only were used, nearly double this weight would have to be applied. In ordinary heavy engines, and particularly those for luggage trains, it was generally absolutely necessary to couple at least two pairs of wheels, in order to obtain sufficient adhesion; and with a single-cylinder engine, of the same power, it would be impossible to get the extra adhesion required to make the wheels 'hold' the rails. It was unnecessary further to allude to the starting of the train, as that was so great and self-evident a difficulty, that any proposition for a single-cylinder engine was incomplete, without the means being defined by which the engine was to be started. With regard to the plus and minus pressure caused by the momentum of those parts of an engine which moved horizontally, in a straight line, backwards and forwards, he was well aware that it was a matter worthy of serious consideration; for although it had received some attention, much more was required, in the way of direct trials of improvements, and alterations in the weights and position of the parts, before the best result could be attained. He had designed, many years ago, an arrangement for balancing a quick-working machine, moving a weight by means of a crank. A second crank was placed precisely opposite to the first, to move another similar weight, so that the machine was completely balanced. Mr. Heaton, of Birmingham, had proposed the same plan for a locomotive, and had constructed guides under the foot-plate of an engine, on the London and Birmingham Railway, and placed an outside crank on the axle to work a dummy weight in the guides, so as exactly to imitate the piston, &c., the cranks being opposite. This made the engine run very steadily indeed, and was so far successful, though the complication was of course objected to. Recently the doffers of carding engines had been balanced with second cranks and dummy weights, with great advantage to their quick and smooth working. With regard to the effect produced by the reciprocating parts of an engine when left unbalanced, he could not agree that the $\frac{1}{4}$ th of an inch was practically anything like the real measure of the sinuous motion of most engines; indeed, from his own observation, he felt convinced that the motion was much more like 2 inches, at the ends of the frame, even with a good road, and more if the road were bad. Nor did he think that a small measure of motion expressed the evil in its true form, as it was, or might be at any instant that the flange was in contact with the rail, a question of the amount of force that was exerted against the rail, tending to bend the rail or break the chair. He believed for this reason that

high speeds were far more dangerous, when the ballast was frozen hard, than when the road was in an ordinary condition. The plus and minus pressure under ordinary circumstances was upwards of 8,000 lbs. for each cylinder. With respect to the uniformity of the rotative power, irrespective of the plus and minus pressure, it would be seen from the diagrams, that one cylinder with full steam was the most irregular, next came two cylinders at right angles with full steam, whilst the most uniform rotative power was obtained by using two cylinders, and cutting off the steam at a little before, and a little after half-stroke. The advantage of cutting off steam at half-stroke had been first pointed out, in 1849, by the Author of a Paper read at the Society of Arts. Fig. 7 showed the variation

Fig. 7.



in the rotative power obtained by using full steam throughout the stroke in two cylinders, having cranks at right angles, and also the variation when cutting off at certain definite points. The full lines A^1 , A^2 , represented the rotative power obtained from the two strokes of one cylinder, as developed on the path of the crank, whilst the full lines B^1 , B^2 , represented the power obtained from the other cylinder, also developed on the path of the crank, when using full steam in both cylinders. The dotted lines V^1 , V^2 , V^3 , V^4 , showed

the combined rotative power of the two cylinders, and a variation from the average line OP of 31 per cent. It should be stated that, if expansion were carried to any extent in each of the cylinders separately, this variation would be much greater. The full lines A¹, A², and B¹, B², showed the rotative power when cutting off at the points indicated, and the lines v¹, v², v³, v⁴, showed the combined rotative power of the two cylinders, working as just stated, giving a variation from the average line EC of only 14 per cent., which in practice amounted to perfect uniformity in effect. The length of the connecting rod had been taken into account in Fig. 7. It should also be noticed, that when using full steam, the variations in power were not only large, but long continued; for instance, in the first quarter of the revolution, the power was greatly in excess of the average, whereas in the third quarter it was greatly below the average. When cutting off at the particular points before noticed, each quarter had nearly the same power.

In conclusion, he would beg once more to urge locomotive engine builders, in common with marine engineers, to use steam-jackets both to the cylinders and the cylinder covers, as he felt it was an improvement that had been far too long neglected. He was bound, however, to say, that some marine engineers were now beginning to appreciate steam-jacketing, though the Government neglected it still.

Mr. PHIPPS said, with regard to the supposed advantage of one cylinder over two cylinders, he was willing to concede, that as all the reciprocating parts would be situated in the middle of the single-cylinder engine, it would be free from the sinuous motion, which in the double-cylinder engine was occasioned by the resistance to the change of velocity in those parts, acting on the mass of the engine, with a determinate leverage. As regarded tractive power, however, he could not agree that there would be anything like the same equality of pull in the single-cylinder as in the double-cylinder engine. If the tractive power of the two classes of engines were examined, simply with relation to the pressure of steam on the pistons, and the effective leverages of the cranks, it was easy to show, that whilst the maximum and minimum rotatory power of the double-cylinder engine varied in each quarter revolution nearly in the proportion of 14 to 10, in the single-cylinder the variation was as much as 20 to 0. That was, for the double-cylinder, the area of each being 6, when the cranks were at A and C (Fig. 8, page 98), if the power were taken as 10, at B and D, it would be as 14 nearly; while for the single cylinder, whose area was 2, when the crank was at A, the power would be as 0, whilst at B it would be as 20. As, however, the Author in his Paper stated, that in estimating the rotatory power of the engine, it was necessary to incorporate with the pressure of steam on the pistons, the effect of the inertia of the

reciprocating parts, it could be shown that, in the cases illustrated by these figures, the inertia was totally inoperative, and therefore that the proportionate variation of power remained unaltered. For example, whenever the cranks were at any of the positions A, C, E,

Fig. 8.

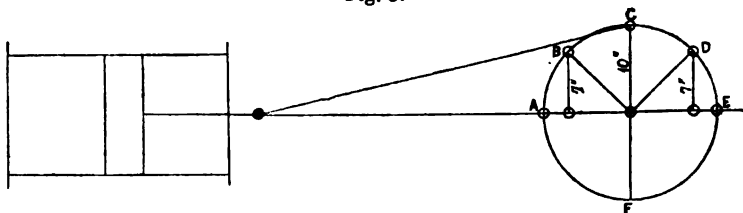
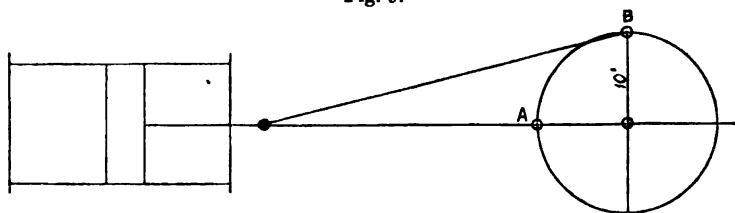


Fig. 9.



or F (Fig. 8), the reciprocating parts attached to them were undergoing neither acceleration nor retardation, and could not therefore be either absorbing power from the steam, or giving out power. Also when the cranks were at B and D (Fig. 8), the parts attached to B were being accelerated, precisely in the same degree that those at D were retarded, and hence the original power of the steam was not interfered with. These results were calculated on the supposition of full steam being used throughout the stroke. If cut off at half-stroke, the friction connected with the crank at D (Fig. 8) would only have upon it $\frac{3}{8}$ ths of the pressure on the other piston connected with B, whence the total rotative power would then be as 11.08 in the position of B and D, compared with 10, as before, when at A and C.

Mr. SINCLAIR said, he had had considerable experience in the practical working of the locomotive engine, and was surprised to hear that the sinuosities of its motion had been reduced, by calculation, to $\frac{1}{4}$ th or $\frac{1}{10}$ th of an inch. In all his experiments with these machines, he had never found one whose irregularity of motion was not much greater than anything which had yet been stated in the course of this discussion. He believed it had been the universal practice to apply weights to the wheels, for the purpose of balancing the irregularity of motion, and that by that means the irregularity had been reduced to a minimum: but he had never met with one whose minimum amount of irregularity was not greater than had

been mentioned. These balance weights might be applied until the irregularity was reduced to a minimum, but beyond a certain amount the more the weight was increased the greater would become the motion. He had always entertained the belief, that irregularity was due to the varying position of the several reciprocating parts of the engine; that beyond a certain point it was next to impossible to alleviate it; and that however perfectly the engines might be designed, so long as there were two cylinders, a certain amount of sinuosity or oscillation must result; but that the measure of it, according to his experience, was considerably greater than had been pointed out. Then, unfortunately, any defect in the original design was aggravated as the engine got out of order, and whenever the way upon which it travelled was not in a good state; and neither could be assumed to be so perfect, under all circumstances, as to prevent this increased injurious effect taking place. He believed that if a single-cylinder engine could be got to go at all, it would neutralize, to a great extent, these sinuosities and irregularities. He had for many years had that notion; and a long time ago he took an engine, which had become deteriorated by long use as a ballast engine, and which, at a slow speed of 15 miles an hour, was very uncomfortable to travel upon, and although he did not actually convert it into a single-cylinder engine, yet the two cranks were placed in the same direction, so that for all practical purposes it was a single-cylinder engine. That engine—when it could be got to go—that was when the difficulty of getting over the centre was overcome—travelled 60 miles or 70 miles an hour with perfect steadiness. Therefore he was led to think, if that inconvenience could be overcome, a simple and a steady engine might be obtained. Although he had applied himself assiduously to the subject, he regretted to say that both his ingenuity and patience had been at fault, for he had not yet been able so to arrange such an engine as to give facility for starting or reversing, without which it was of course useless for practical purposes.

Mr. GRAVATT remembered that twenty-five years ago, when driving wheels of 10 feet in diameter were in use, he investigated this question. The result then arrived at was, that if there were no torsion, there would be no sinuosity. The whole thing depended upon the torsion of the crank shaft. If the shaft was indefinitely stiff, and the wheels were all going at the same speed, there could be no sinuosity.

Mr. KERSHAW thought there could be no question, that an action of a side character took place in an engine, but not to so dangerous an extent as the diagrams indicated. The speed at which the whole of the parts ran had a tendency, he believed, to counteract any evil effect, and there was no reason to apprehend danger from diagrams of the nature of those exhibited. The single-cylinder

engine appeared to be considered as wholly impracticable, therefore it was not necessary to enter upon that question.

Mr. MOLESWORTH said, the theory of the disturbing forces had been so fully gone into, that there was little left to add upon that point. Although agreeing, to a certain extent, with the remarks which had been made on that subject, he yet held the opinion that, practically, the measure of motion very greatly exceeded what was indicated by the theory which had been propounded. He ascribed the discrepancy between theory and practice to the fact, that the theory was based upon the supposition that the wheels were without flanges, whereas, in his opinion, the flange was a very important element in the question. When the direction of the course of an engine at a high velocity was suddenly altered by any disturbing force, the momentum of the engine brought the flanges into violent contact with the rails, and the elasticity of the rails caused the engine to rebound, or rather glance off, against the opposite rails. When the rebound happened to be simultaneous with a disturbing force acting in the same direction, the maximum oscillation was caused; but the rebound was in some degree neutralized, when the disturbing force acted simultaneously in the opposite direction. In support of this view it was adduced, that the oscillations of an engine were not coincident with its pulsations, as they would be in the theoretical case of an engine without flanges; but that they were very irregular, sometimes extending over a period of eight or ten pulsations.

A single-cylinder engine he considered to be impracticable. Even if means could be devised for starting the train under ordinary circumstances, that was not the only difficulty; as it would be much increased in frosty weather, a drawback which could only be fully appreciated by one who had driven an engine, and had experienced the difficulty of starting a heavy train in slippery weather. He presumed that the apparatus for starting would be worked by hand, and thrown into gear so as to move the engine off its dead centre; after which it would be thrown out of gear, and the steam would carry on the stroke. When the rails were slippery, the wheels, if moved off their dead centre, would rotate a few times without biting, and would probably stop on one of the dead centres again, as the steam would have the least power at those points to make the wheel rotate; the hand apparatus would then have to be thrown into gear again, and the engine worked off its dead centre, probably with the same result as before.

Mr. VIGNOLES said it appeared to him, that the object the Author had in view was to ascertain how far the engine itself was at fault, and how far blame might be laid upon the permanent way. It had been satisfactorily demonstrated theoretically and

practically, that the sinuous motion of the engine was but small, and that it was not so injurious as had been supposed; and he believed in the earlier experiments upon railways, it had been proved that, where the railway was in perfect order, the flange of the locomotive might be almost dispensed with. Therefore the remedy for the evils described must be found in the perfection of the permanent way. When the subject was first broached, he thought too much blame had been thrown upon the deficiencies of the permanent way, and too little assigned to the locomotive engine: but he now considered that, when the problem was the revolution of the engine upon a theoretically perfect line, and as the maximum amount of sinuosity was only one-fifth of an inch, if an accident arose, it must be from other causes than defects in the construction of a well-balanced modern locomotive, and that safety must be sought in the perfection of the road. So small a lateral deviation as the one-fifth of an inch might sometimes arise from the imperfection of a chair, and he would ask, why should chairs be used at all, since the most perfect way was also the simplest, and chairs were merely a complication and only uselessly increased the number of parts? Defects in the way comprised the want of perfect gauge, of perfect gradient, and of perfect smoothness of the whole of the parts. The perfection of gauge was of course insured by the transverse sleepers to keep the rails in place; the perfection of the vertical position of the rails by attention to the ballasting and by packing; while as regarded smoothness, the junction of the rails, by means of fish plates, enabled one even continuous line to be obtained, which was so important to the easy action of the engine travelling over it.

Mr. G. W. HEMANS, without controverting the scientific inquiry into the action of the disturbing forces in the locomotive, and the measure of their results, would record his opinion, for what it was worth, that these sinuous movements were very serious. He had had occasion to observe the movements of engines on one line in particular, where a great proportion of the stock consisted of inside-cylinder engines, there being only six engines with outside cylinders, and he found that the sinuous motion with outside cylinders was greater than with inside cylinders,—so much so indeed as to be dangerous,—and the result of the investigation showed the movement to be much more than the one-fifth of an inch indicated as the limit in theory. He believed this irregularity arose from imperfection in the machinery; that there was a movement in the axles of the engine, which did actually bend and suffer some amount of torsion, which in outside-cylinder engines with light axles might be serious. If, as he thought was the case, outside-cylinder engines had more sinuous motion than those with inside cylinders, it was clear that the sinuous motion must arise from a

want of proper balancing. The adoption of a single-cylinder engine, which was the remedy proposed by the Author, was not, in his opinion, one which would cure the defect, or remove one present source of safety. When an engine with two cylinders was partially disabled, it could be brought home with one cylinder working; whereas the single cylinder would take away that important chance of safety, and on that account would be objectionable.

Mr. G. P. BIDDER,—Past President,—thought it desirable to come back to the essence of the Paper, which undertook theoretically to point out the sources of danger in engines, and to suggest a practical remedy; and here he would remark, that the observations, on which the investigation was based, were, in his opinion, as unpractical as the remedy proposed for overcoming the evils that had been described. The Author alluded to the fact, that the side pressure, arising from the position of the cranks, was a source of great increase of resistance; and confirmed that position, by reference to the effects of a very strong side wind upon the train. Now it had been satisfactorily established, that the resistance of a strong side wind was not due to side pressure, but to end pressure; and that strong side winds became diagonal, when combined with the speed of the train, and would thus be distributed partially over the ends of all the carriages; whilst a direct end wind operated on the end of one carriage only. It frequently happened, especially in regard to railways, that remedies designed to overcome one evil, themselves introduced other sources of danger. The Author had suggested a single-cylinder engine; but that, he thought, had already been satisfactorily disposed of as a most unpractical idea. If it were desired to get rid of this sinuous action, or tendency to sinuous action, it could be done with two cylinders, by putting both the cranks in the same position, instead of at right angles to each other; and that would be a more practical method than the one proposed. This had been accomplished by the late Mr. Robert Stephenson, in a three-cylinder engine, having one large cylinder in the middle and two smaller ones at the sides. That engine worked with remarkable steadiness, but it was costly, and that, together with the complication of the parts, prevented its adoption. In 1836 Mr. Weallens, of Newcastle-on-Tyne, brought out an engine with four cylinders; and it was a curious fact that there was an engine upon that plan in the late International Exhibition of 1862. But although by the use of a single-cylinder engine, or a double-cylinder engine with the cranks moving together, the sinuosity might be avoided, another element of danger was introduced, inasmuch as there must be a varying pressure between the back and the forward motion of the engine, which would produce a jolting action that

was likely to give rise to accidents from the breaking of the connections of the train. Therefore, practically, all these suggestions failed, and he thought they would hardly have occurred to any one conversant with, or experienced in, the working of railways. He concurred in a great measure in the remarks which had been made, as to the extent to which the oscillation of the engine was occasioned by the varying operations of the steam in the cylinders. But there was this fault in the deductions, that the whole mass of the engine had been taken into account. If that were done, there could not be a side motion without causing the wheels to grind literally upon the rails; and as the friction was one-sixth of the weight, it would be found, if the whole mass of the engine was taken, that the pressures given by the Author could produce no sinuous action at all. But the fact was, that part of the mass of the engine should be taken which was upon the springs, and this was much less than the whole; therefore the motion communicated to this portion of the bulk of the engine would be in excess of the results arrived at by Mr. Bramwell and Mr. Scott Russell. But even then the amount of oscillation which was known to exist would not be reached; and so long as there were wheels and cranks, and engines were put on railways with curves, so certainly would the element of oscillation be introduced. With a perfect road, and an engine perfectly adjusted, it was not in the power of man to place that engine perfectly straight upon that railway, and then, at once, the element of oscillation came into play. Besides, an engine that was put on the road perfect on one day would not be so on the following one. The eye failed to detect those defects in a railway which occasioned oscillation; and not only the eye, but no instruments could do it. Neither could those errors in the construction of the engine which occasioned oscillation be detected. If any one of the wheels were out of truth the one-hundredth part of an inch, that might occasion serious oscillation. There were no means of investigating the extent to which these defects prevailed, because they might be acting either together or in opposition to each other, and thus aid or retard the oscillation, or the tendency to oscillation, which the backward and forward pressure of the steam in the cylinder must occasion to the boiler and other parts connected with it. Therefore it was found in practice, that engines, more or less imperfect, ran at high velocity for a long period without accident; whilst a new engine, or, what was better, one which had run a few journeys, might be put upon as perfect a piece of road as man could make, and an accident might forthwith ensue. The investigation of this subject, so as to embrace all the elements which tended to affect the action of the engine, demanded very high mathematical powers, combined with great daily experience in the working of railways. If that

combination could be brought about, data would be afforded of great practical value to locomotive managers, and to those who were so much, and so painfully, interested in the results of railway accidents.

Mr. REYNOLDS thought one point had been overlooked in considering these disturbing forces, and that that was the only one of practical importance, because, though it must be admitted that many imperfect engines were running, still the ordinary knowledge of engineers, if properly applied, was sufficient to enable them to neutralize the evils arising from the sources of disturbance which had been discussed. The effect of the inertia of the pistons, &c., was well known; but he could not conceive how the combined action of the two sets of parts making strokes alternating with each other in the usual way, and having, therefore, in the course of each revolution, four periods of acceleration and of retardation at (neglecting the influence of length of connecting rod) equal intervals, could possibly produce diagrams like those shown in Plate 2, Diagrams No. 5. It surely must be more like that exhibited in Fig. 7, page 34. It was only fair to say, that in Mr. D. K. Clark's treatise the question of sinuous motion arising from the inertia of the moving parts had been carefully, and as it appeared to him, accurately gone into. The effect of such inertia could be, and in practice frequently was, completely neutralized by balance weights in the wheels. It was true that if there was sufficient balance in the wheel to counteract the horizontal action of the piston, &c., a new tendency was introduced, which, however, at the speeds attained in practice, did not practically affect the motion of the engine. He meant that as the balancing weight must be greater than that necessary to counteract the centrifugal force of the revolving parts, a greater pressure was caused upon the rail at one period than another, and thereby a slight inequality in the wear of the wheel tires was in practice produced; but as the amount of unequal pressure was not sufficient to lift the wheel from the rail, the horizontal action of the balance weights alone came into operation, so far as regarded the motion of the engine. As had been previously stated, he believed the amount of displacement of engines was generally much greater than had been calculated by some of the speakers; but he thought it might be accounted for, by considering that the engine had as much tendency to turn itself round the driving axle, as to turn the axle in its bearings. If this tendency was uniform, it would merely amount to a transference of weight from the leading to the driving and trailing axles, and if it was centralized, as in Mr. Robert Stephenson's three-cylinder engine, it would not induce, or affect, lateral motion, but in practice the action took place alternately at opposite corners of the engine, and the amount of the tendency

might be taken for the present purpose to be represented by the upward pressure of the slide blocks upon the slide bars. The "White Horse of Kent" had been referred to. A number of engines of this class, which had come under his observation, had 15 inch cylinders, 2 feet stroke, and 6 feet driving wheels, and the connecting rods were about $5\frac{1}{2}$ times the length of the crank. Speaking from memory, the usual weight was about 21 tons, disposed thus:—leading wheels $5\frac{1}{2}$ tons, driving wheels 9 tons, and trailing wheels $6\frac{1}{2}$ tons. Hence, if the engine had 100 lbs. per square inch on the pistons, the total pressure on each piston would be 17,600 lbs., and this divided by $5\frac{1}{2}$ would give something like $1\frac{1}{2}$ ton lift on the slide bars; and as the whole weight on the rails at the leading wheels was only $5\frac{1}{2}$ tons, of which the wheels and axle would weigh more than $\frac{1}{2}$ ton, leaving only 5 tons, or $2\frac{1}{2}$ tons upon each leading spring, and as these springs were only 4 feet between centres, whilst the slide bars were 6 feet 1 inch between centres, it was easy to understand how considerable motion might be produced. He once had occasion to make a number of small engines, with 14 inch cylinders, 18 inches stroke, and 4 feet wheels, only 6 feet between the extreme centres. The leading wheels were coupled to the drivers, by return rods inside the connecting rods, and the distance between the centres of the cylinders was 6 feet $4\frac{1}{2}$ inches. The connecting rods were 8 times the length of the crank, and though there was not the usual rigid coupling between the engine and tender, yet (the wheels being carefully balanced) these engines were practically steady when lightly loaded, at any speed which the length of line at his command admitted. But when heavily loaded, or working up severe inclines, the way in which they, as it were, worked their shoulders was very conspicuous. It was clear that this action would be more considerable in proportion as the cylinders were farther from the centre of the engine. In modern inside-cylinder engines, with the ordinary loads, it was not generally visible, except in the case of goods engines, which were generally well loaded, and had the additional disadvantage of inclined cylinders, which concentrated the action referred to in one of the strokes, instead of dividing it equally between the two; and no balance weights could modify the effect of this tendency. Even in the duplex arrangement, where the balance, so far as the parts in motion were concerned, was practically perfect, he believed that, when heavily loaded, the action to which he had directed attention would be traceable, in spite of the excellent disposition of the weight upon the wheels. He thought the operation of balance weights was in some cases less satisfactory than it might be, because they were very commonly wrongly placed. He had seen some few inside-cylinder engines correctly balanced, having upon each wheel two balance weights;

the amount due to each set of parts (crank, piston, &c.) being divided between the two wheels in amounts varying inversely with the distance from the crank. Thus there would be a large and a small weight upon each wheel, and the same effect was sometimes obtained by the use of a single weight in each wheel of such amount, and in such intermediate position, as would be equivalent to the two weights described; but he never yet saw an outside-cylinder engine correctly balanced. It was clear that a single weight in each wheel, radially opposite the crank, could not be right, unless the planes of motion of the piston, &c., and of the wheel coincided, and it also seemed to him that for inside-cylinder engines, the position of single weights in each wheel must be at an angle with each other smaller than a right angle; and the amount of such weight would be somewhat less than would be required if the weight revolved and the piston moved in the same plane. For outside-cylinder engines the two weights must be at an angle greater than a right angle, and the amount must be greater than that due to the action of the piston and balance weight in the same plane.

Mr. W. NAYLOR could only agree with the Author as to the bare fact that there were sinuous and oscillatory motions in locomotive engines, but he differed entirely as to the cause. He was prepared to show, that sinuous and oscillatory motions took place in all railway vehicles, as well as in locomotive engines, and that it always must do so. He was well aware that this motion might be greater in one class of vehicle than in another, and that one class was more destructive to the permanent way than another which had more oscillation, and he could give many instances of parts of trains running off the line, when the engine and tender had not done so.

Mr. C. B. LANE observed, through the Secretary, that some of the results of the disturbing forces at which the Author had arrived, would be much greater in a broad gauge than in a narrow gauge engine; for the unbalanced reciprocating portions of the engine referred to in the Paper, which were estimated to weigh 495 lbs., and to the action of which was ascribed that sinuous motion of the locomotive on the rails that tended to burst the road, must, in the case of the broad gauge, as contrasted with the narrow gauge, act at the extremities of levers in the ratio to each other of 7 feet to 4.66 feet, and therefore produce a much greater amount of deleterious action in the former case than in the latter. As many of the points relating to the question of gauge had turned more upon commercial or financial considerations, it appeared important to notice this mechanical one.

Mr. MAKINSON, in reply upon the discussion, said Mr. Bramwell appeared to hold the opinion, that the steam pressures in the cylinders had no tendency to produce sinuous motion in the engine.

He thought the contrary was proved, simply by reference to the well-known proposition in dynamics, that in order that a body might move with a motion of translation only, the resultant of its impressed forces must act through its centre of gravity. With regard to the remark, that any oscillation in the engine, produced by the internal disturbing forces, would be the same at all velocities, two erroneous assumptions were made, when it was taken for granted that the time allowed for the oscillation varied inversely with the velocity of the engine, and that the disturbing force varied directly as the velocity. Now the Diagrams No. 8 (Plate 3), showed that at the velocity of 26 miles per hour, there was a tendency in the engine to make two oscillations in each revolution of the driving wheel, and that at the velocity of 52 miles per hour there was a tendency to one oscillation only in each revolution; so that the time allowed for an oscillation was the same whether the train was moving at 26 or at 52 miles per hour. The pressures shown in the diagrams, as tending to produce oscillation, were opposed by the friction of the wheel on the rail. The difference of these two pressures was the moving force producing transverse motion; and whether this friction were assumed at $\frac{1}{4}$ th or only $\frac{1}{10}$ th of the insistent load on the wheel, it would be seen from the diagrams, that the moving force increased somewhat more rapidly than the velocity. He must contend that the diagrams were quite sufficient to prove the incorrectness of Mr. Bramwell's conclusion; and although they had a special and not a general character, they were at all events suggestive of the conclusion, that engines travelling at high speed acquired a dangerous amplitude of oscillation.

Mr. Scott Russell, while accepting the accuracy of the numerical values assigned to the forces tending to give lateral motion or oscillation to the engine, regretted that attention had only been directed to those tendencies, and suggested that the Paper would have been more complete, if a measure had been given of the amount of the lateral motion. Mr. Russell had himself undertaken to supply this deficiency, and gave as the result of his calculation, that the lateral movement would be between $\frac{1}{10}$ th and $\frac{1}{4}$ th of an inch. Considering this as insignificant, and, in fact, hardly worth eliminating, the conclusion was arrived at by Mr. Russell, that the remedy, the single-cylinder engine, for so slight an evil, was worse than the disease. Had a three-cylinder engine, like that constructed by Mr. Stephenson some years ago, or a four-cylinder engine, like the 'duplex' in the late International Exhibition of 1862, been proposed, then Mr. Makinson could have recognized more force in the conclusion; but, so far from any complexity being introduced, the single-cylinder engine would be simpler in construction, and have fewer working parts than the present engine. He had wished to avoid the attempt to determine, theo-

varying amounts of tractive power represented changes such as would be produced by the train descending about one inch, and again rising one inch, in every 25 feet of its advance. And at 52 miles per hour, the same variations were equivalent to a descent, and then an ascent of the train, in every 25 feet of its advance, of nearly 2 inches.

Some admissions had been made by Mr. Bidder which were valuable to the cause advocated in the Paper, inasmuch as he had stated, as the result of his great experience of two-cylinder locomotives, that violent oscillations did sometimes occur when least expected, as when the engine was travelling on a straight road, and that road an excellent road; thus fully confirming the opinion, that great causes of oscillation existed essentially in the ordinary two-cylinder locomotive, so that at high speeds great oscillation would occur, however perfect the road on which it travelled.

He thought he had established, if not a certainty, at least the probability, that were the permanent way mathematically perfect, locomotive engines of the ordinary construction would create lateral and oscillatory movements of a grave character at high speeds, and also results similar to those produced by numerous small depressions in the level of the rails.

December 9, 1862.

CHARLES HUTTON GREGORY, Vice-President,
in the Chair.

The discussion upon the Paper No. 1,076, "On some of the Internal Disturbing Forces of Locomotive Engines," by Mr. A. W. MAKINSON, was continued throughout the evening, to the exclusion of any other subject.

ANNUAL GENERAL MEETING.

December 16, 1862.

JOHN FOWLER, M.P., Vice-President,
in the Chair.

MESSRS. T. M. SMITH, HARRISON HAYTER, and W. HALL, were requested to act as Scrutineers of the Ballot, for the election of the President, Vice-Presidents, and other Members and Associates of Council.

The list of the attendances of the Members of Council for the past year was read, and the Ballot was commenced; the balloting-papers being sent for examination, at intervals of fifteen minutes, in order to expedite the labours of the Scrutineers.

The Annual Report of the Council, on the proceedings of the Institution during the past year, was read.

Resolved,—That the Report of the Council be received and approved; and that it be referred to the Council, to be printed and circulated with the Minutes of Proceedings, in the usual manner.

Resolved,—That the thanks of the Institution are due, and are presented to Messrs. Stileman and Bramwell, for the readiness with which they undertook the office of Auditors of Accounts, and for the clear statement they have laid before the Meeting; and that Messrs. Bramwell and John V. N. Bazalgette be requested to undertake the office of Auditors for the ensuing year.

The Telford and Watt Medals, the Stephenson and Miller Prizes in money, and the Council and Manby Premiums of Books, which had been awarded, were presented.

Resolved,—That the thanks of the Institution are justly due, and are presented to the Vice-Presidents and other Members of the Council, for their co-operation with the President, their constant attendance at the Meetings, and their zeal on behalf of the Institution.

Mr. Gregory, Vice-President, returned thanks.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Hawkshaw, President, for his strenuous efforts in

the interests of the Institution, for his extraordinary attention to the duties of his office, and for the urbanity he has at all times displayed in the Chair.

Mr. Fowler, Vice-President, returned thanks, in the unavoidable absence of the President.

Resolved unanimously,—That the cordial thanks of the Meeting be given to Mr. Charles Manby, the Honorary Secretary, and to Mr. James Forrest, the Secretary, for their constant zeal and devotion to the interests of the Institution, the ability displayed by them in the execution of their duties, and their attention to the individual wishes of the Members.

Mr. Manby and Mr. Forrest severally returned thanks.

The Ballot having been open more than an hour, the Scrutineers, after examining the papers, announced that the following gentlemen were duly elected to fill the several offices in the Council for the ensuing year:—

President.

JOHN HAWKSHAW, F.R.S.

Vice-Presidents.

John Fowler.

Charles Hutton Gregory.

John Robinson M'Clean.

John Scott Russell, F.R.S.

OTHER MEMBERS OF COUNCIL.

Members.

Sir W.G. Armstrong, C.B., F.R.S.

Nathaniel Beardmore.

Joseph Cubitt.

Thomas Elliot Harrison.

Thomas Hawksley.

George Willoughby Hemans.

John Murray.

George Robert Stephenson.

Charles Vignoles, F.R.S.

Joseph Whitworth, F.R.S.

Associates.

John Towlerton Leather.

Frederick Marrable.

Resolved,—That the thanks of the Meeting be given to Messrs. Smith, Hayter, and Hall, the Scrutineers, for the promptitude and efficiency with which they have performed the duties of their office, and that the ballot-papers be destroyed.

ANNUAL REPORT.

 SESSION 1862-63.

THE term of office of the present Council being about to expire, it becomes their duty to present a Report to the general body upon the state of the Institution, and particularly upon the proceedings of the past year; and they hope to show, that its interests have been satisfactorily advanced since the conduct of its affairs was committed to them.

The actual business of the Institution will alone be dealt with in this Report. Commencing, then, with what must ever be considered to stand first in order of importance—the Ordinary General Meetings—it may be stated, that the principal Papers read during the past Session were:—"The Hooghly and the Mutla," by J. A. Longridge, (M. Inst. C.E.); "On Measuring Distances by the Telescope," by W. B. Bray, (M. Inst. C.E.); "On the Discharge from Under-drainage, and its effect on the Arterial Channels and Outfalls of the Country," by J. Bailey Denton, (M. Inst. C.E.); "On the Form and Materials for Iron-Plated Ships, and the points requiring attention in their Construction," by J. D'A. Samuda, (M. Inst. C.E.); "Description of the Loch Ken Viaduct, Portpatrick Railway," by E. L. J. Blyth, (M. Inst. C.E.); "Description of the Centre Pier of the Saltash Bridge on the Cornwall Railway, and of the means employed for its Construction," by R. P. Brereton, (M. Inst. C.E.); "Description of the Delta of the Danube, and of the Works, recently executed, at the Sulina Mouth," by Sir C. A. Hartley, (M. Inst. C.E.); "Description of Works at the Ports of Swansea, Blyth, and Silloth," by J. Abernethy, (M. Inst. C.E.); "Railway Accidents, their Causes and means of Prevention," by J. Brunlees, (M. Inst. C.E.); "Railway Accidents, showing the bearing which existing legislation has upon them," by Captain Douglas Galton, R.E., (Assoc. Inst. C.E.); "On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea," by J. Paton, (M. Inst. C.E.); "On Reclaiming Land from Seas and Estuaries," by J. Oldham, (M. Inst. C.E.); "On Reclaiming Land from Seas and Estuaries," by J. H. Müller, (of the Hague); "The Malta and Alexandria Submarine Tele-

[1862-63. N.S.]

graph Cable," by H. C. Forde, (M. Inst. C.E.); and "On the Electrical Tests employed during the construction of the Malta and Alexandria Telegraph, and on insulating and protecting Submarine Cables," by C. W. Siemens, (M. Inst. C.E.)

A brief epitome of some of these will bring to your recollection the amount of useful information thus collected, the variety of the subjects treated, and the animated discussions which arose on several of the Engineering topics of the day.

In his "Description of the Delta of the Danube, and of the Works, recently executed, at the Sulina Mouth," Sir Charles Augustus Hartley, the Chief Engineer of the European Commission of the Danube, first gave an account of the chief characteristics of the river through its delta, and then of the three principal channels, or branches, with their numerous outlets, by which it reached the sea. It was stated, that great diversity of opinion existed as to the relative merits of these several branches, or mouths, and their capability for improvement. Eventually, after considerable discussion, it was resolved to improve the bar channel of the Sulina, by guiding piers of a temporary character, in order to afford the speediest relief to the navigation in the cheapest manner; but it was agreed at the time, that this decision should not prejudice the choice of the mouth to be selected for permanent treatment. A detailed description of the works, and of their mode of execution, then followed, from which it appeared that the length of the north pier was 4,631 feet, and of the south pier 3,000 feet. They were built in a depth of water varying from 6 to 20 feet, at a cost of about £80,000; a sum which did not exceed the amount paid in one year for lightening vessels over the bar. The changes which had taken place at the Sulina mouth, consequent on the projection of the piers, were then noticed. At the time when the works were commenced, the depth over the bar was only 9 feet, whereas after their completion, when the whole force of the river current was concentrated directly on the bar, there never was a less depth than $16\frac{1}{2}$ feet, and it frequently amounted to $17\frac{1}{2}$ feet, over a navigable width of 500 feet. These works, as well as being of political importance, possessed great engineering interest, and had been completed up to their present stage most successfully.

In the Paper "On Reclaiming Land from Seas and Estuaries," by Mr. John Müller (of the Hague), it was stated that, the reclamation of large areas was the least expensive in the end, and that the object should be to enclose the largest area, with the shortest length of bank, and the smallest average cross section. These points were regulated by the direction and situation of the sea banks; and the conditions to be observed in determining these preliminaries were then noticed. The defences of the slopes of the works alluded to consisted of clay and grass flags, wood, and

stone. A minute description was given of the protection by fascine work, as well as of the stone defences, as commonly constructed by the Dutch. It was observed, that creeks should be crossed, if possible, at right angles, and at the same level; and in Holland, the plan adopted in closing them was, to raise the bottom uniformly to the level of low water, by means of cradles, the construction and mode of applying which were minutely detailed, and the precautions to be adopted were strongly enforced.

Mr. Paton, in his Paper "On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea," spoke of the vast extent of land enclosed by these dykes, as being probably greater than any similarly protected in other parts of the world. An account was then given of the principal storm floods which had occurred on the Danish coasts, and of the changes and variations to which these coasts had been subjected, during a period of two thousand years. The construction of the dykes, the materials employed, the mode of formation, and the various plans of protection, were then treated of in detail. Numerous examples were adduced of the advantage of projecting arches, or groynes, especially in exposed localities. The Author further urged that no other engineering works were of greater importance than reclamations from the sea; and as it was believed there were still 600,000 acres of land in Great Britain and Ireland, worth from £20 to £60 per acre, which might yet be reclaimed, besides similar tracts in other countries; hence he contended that the magnitude of the results could scarcely be overrated.

Mr. Oldham, in his Paper on the same subject, first alluded to the system of 'warping,' as commonly practised on the Trent, the Ouse, and the Don, and then explained the phenomena of tidal deposits and accretions in the formation of new land. In practical operations on the River Humber, it was stated that a year or two before embanking, endeavours were made to secure a thoroughly uniform surface on the land to be enclosed. In illustration, the works of the last embankment, for enclosing 700 acres of new accretion, at Small Island in the Humber, were described. After this land had been reclaimed about three years, there was a spontaneous growth of white clover, and the tenants admitted that they frequently obtained six imperial quarters of grain per acre; whilst flax was produced in large quantities and of fine quality, as well as potatoes, turnips, mangold-wurzel, and other root crops.

In the "Description of Works at the Ports of Swansea, Blyth, and Silloth," Mr. Abernethy gave an account of the past and present engineering history of those ports, as well as of the works connected with them.

With regard to Swansea, it was stated, that the effect of the piers, completed in the year 1800, from the designs of Captain Huddart, F.R.S., had been to lower the bar and to drive it out to sea. The Reports submitted by Mr. Telford, in 1827, and by Mr. Jesse Hartley, in 1831-32, were then alluded to; and the Author remarked that, in his opinion, it was fortunate the works for the 'canalisation' of the river, as suggested by Mr. Hartley, had not been carried out. In 1845, under the direction of Mr. Rendel, the construction of an entrance, with a double cill, was proceeded with, as a preliminary step to the conversion either of the river, or of the town reach, into a float; but of this work the masonry alone was executed. When the Author was first consulted, in 1849, he proposed the formation of a dock on the site of the town reach, or old bed of the river, and he subsequently carried out several works, including a lock and float, and a half-tide basin, besides straightening the lower portion of the river, and deepening both it and the new cut by dredging. By these means the depth of the entrance channel had been increased 4 feet, since 1850. But the most important work, connected with the port, was the range of floating dock accommodation called the South Dock, which had been formed on the foreshore of the sea, beyond high-water mark. These works comprised a trumpet-mouth entrance basin, to an outer, or half-tide dock, with a single pair of gates, 70 feet in width, between them, and of an inner dock, connected with the outer dock by a lock, divided by intermediate gates; the total cost amounted to £169,073. Details were then given of the manner in which the works had been executed, and of the materials of which they had been constructed.

The successful application of hydraulic power for working the ordinary hand gear, for opening and closing the gates at the float lock, and at the lock at Newport, led to the adoption of the same plan at the new dock entrance at Swansea; as, in case of any accident happening to the hydraulic machinery, the usual means remained available. The time employed in opening, or in closing the gates, was about two minutes and a half. The same system was also employed for opening and shutting the bridges and sluices, for working the capstans, for discharging ballast, and for loading coal, as well as for the shipping and discharging of general cargoes. It was found that about 1,000 tons of coal per day could be shipped by each machine, at a cost for hydraulic power alone of about one farthing per ton.

At Blyth, the result of the construction of an eastern break-water and of a western half-tide training wall was said to have been to increase the velocity of the outgoing current to 5 knots per hour, by which the bar at the entrance was entirely removed,

and a depth at low water of from 8 to 9 feet, or 4 feet more than before, was maintained throughout the channel.

It was stated, that the general design of the works at Silloth, on the Solway Frith, was due to Mr. John B. Hartley, but their execution had been intrusted to Mr. Abernethy. They comprised a pier, or jetty, on the seaward side of the dock entrance, a channel parallel with the jetty, an embankment on the foreshore, enclosing the entrance to the dock, and the dock itself. These works indicated that great care must be exercised, in projecting solid moles from the foreshore of an estuary, on a sandy coast, as an entrance to a port. The entrance gates, cranes, and coal-hoists were all worked by Sir William Armstrong's hydraulic machinery; but the coal-hoists were exceptional, and deserved special notice, as involving the question of the relative capabilities and advantages of a high, or a low level system for loading coal.

The value of this communication was much enhanced, by the complete series of drawings illustrating it.

Mr. Bailey Denton's Paper "On the Discharge from Under-drainage, and its effect on the Arterial Channels and Outfalls of the Country," contained deductions from a series of experiments made at Hinxworth, to ascertain the relative fall of rain on the surface, and the discharge of water from the under-drains. The general results of under-drainage, on the arterial water-supply and outfalls, seemed, to the Author, to be—first, to render the surface more capable of absorbing the rain that fell upon it;—secondly, to lower the discharge of the upper surface springs in a slight degree; and thirdly, to withdraw from the power of evaporation, all the water which the under-drains discharged.

The Paper on "The Hooghly and the Mutla," by Mr. Longridge, contained, first, a statement of the commercial importance of the Port of Calcutta; secondly, a brief account of the present mode of transport of the traffic to the port, and the modification of it by works now in progress; thirdly, a sketch of the physical features of the two outlets—the Hooghly and the Mutla; and fourthly, remarks on the past and present state of those rivers, as navigable channels, together with a consideration of remedial measures. The Author urged the establishment of a new port at the head of the Mutla, which was an arm of the sea, rather than a river, as it was believed it would lead to a saving of two days in the time of the postal and passenger service between this country and Calcutta; for whereas, in general, a ship drawing 24 feet could only get to sea from Calcutta by the aid of steam, and, under the most favourable circumstances, in from three to four days, or during the south-west monsoon in five days, a similar vessel could at all times get to sea from the head of the Mutla, in from eight to ten hours.

It was urged by Mr. Samuda, in his Paper "On the Form and Materials for Iron-Plated Ships, and the Points requiring attention in their Construction," that four indispensable conditions must be kept in view: first, a superiority in speed over the best timber-built frigates afloat; secondly, complete protection over their entire length; thirdly, armour capable of rapid replacement, or repair; and fourthly, armour entering into the construction of the ship, so as to add to the strength of the fabric. He examined how far these conditions had been attained in the ships already launched, or being built; and next proceeded to describe an arrangement by which a perfect ship, without armour, was first made, then a complete armour case was attached through five longitudinal ribs, or bars of rolled iron, riveted outside the framework, but under the ordinary skin plates, without interfering with the joints, or fastenings of the ordinary skin of the vessel. The edges of the armour plates were brought close together, and the vertical butt joints of each plate were made to break joint with the skin plates. This important subject was not by any means exhausted by the arguments either in the Paper, or in the discussion upon it.

"Railway Accidents" formed the subject of two Papers; one by Mr. Brunlees, in which the causes of accidents were mostly treated of; and the other by Captain Douglas Galton, who devoted himself, principally, to showing the bearing which existing legislation has upon them.

Mr. Brunlees took as the basis of his Paper, the Reports of the Inspecting Officers of the Board of Trade, for the seven years from 1854 to 1860. During this period 540 accidents had occurred, of which 11 per cent. was attributed to the permanent way, 7 per cent. to the rolling stock, and 76 per cent. to the management, including insufficient means for securing safety, leaving only 6 per cent. as not ascertained. The causes of the accidents were then referred to in detail; but the Author stated, that as they were sufficiently apparent, he would not attempt, by theory, to establish rules for their prevention.

Captain Galton submitted the same series of accidents to another analysis; taking, first, those which could not be guarded against, and secondly, those which were within the control of the managing, or working staff; and including in the first class, accidents arising from engines and carriages leaving the rails, or from fractures of machinery, and in the second class, collisions of every description. It appeared to him that a large proportion of the so-called accidents were due to preventable causes, and that out of 319 collisions, only 16 were attributable to purely accidental causes, whilst 183 were assigned to the negligence of inferior servants, and 120 to the manner in which the traffic was con-

ducted, and which ought not, therefore, to have occurred. The greater comparative safety of foreign railways was traced to differences in the conditions of the traffic and of the management, as well as in the habits of the people. Captain Galton calculated, from the sum paid by British Railway Companies for compensation, that an insurance of one twenty-fourth part of a farthing per passenger per mile would, on the average of all lines, cover the cost of Railway Accidents. The existing law, affecting Railway Companies as carriers, was then alluded to; and it was urged that freedom from accidents was not to be obtained by Government interference, but by an effective and responsible internal management, which would enforce the greatest punctuality and care in working the traffic, and would maintain the strictest discipline amongst the servants employed.

These Papers, although very interesting, still leave the subject of Railway Accidents to be treated from a purely engineering point of view, and it is hoped that this branch of the question will soon be further discussed.

In Mr. Forde's Paper on "The Malta and Alexandria Submarine Telegraph Cable," an account was given of the manufacture of the cable, and of the reasons which led to the adoption of a particular form and size. Originally intended to be employed between Falmouth and Gibraltar, and then proposed to be used to join Rangoon and Singapore, the cable was ultimately laid between Malta and Alexandria. The operation of paying out, and the mechanism by which it was effected, were minutely described; and it was observed that as the cable was submerged, its electrical condition invariably improved; the rate of working was about five words per minute through a length of 1,100 knots.

Mr. Siemens in his Paper "On the Electrical Tests employed during the construction of the Malta and Alexandria Telegraph, and on insulating and protecting Submarine Cables," stated that, in the course of the manufacture of the cable, the chief object was to obtain throughout strictly comparative results. For this purpose a standard measure of resistance was adopted,—as suggested by Dr. Werner Siemens—and the results were given in tables, as well as exhibited graphically in diagrams. They showed a decided improvement in the insulation, after submersion. Although the line was divided into three electrical circuits, messages were transmitted mechanically and instantaneously, at the intermediate station, by a system of double relay, or translation. Attention was then directed to the insulating covering of cables, and the relative merits of india-rubber and of gutta-percha, as well as of compounds of the two, were commented upon; their absorption of water, and the insulating and inductive capacities of wires covered with these different substances, being made the subject of experiment. The outer

covering of cables was also taken into consideration, and a sheathing was proposed, which confirmed the application, under the influence of great pressure, of from three to six strips of copper, or other metal, secured spirally round the cable, and made to overlap each other for nearly half their breadth; the pressure applied being sufficient to crush, or socket the one metal down, where it was covered by the other.

The following Telford and Watt Medals, Stephenson and Miller Prizes in money, and Council and Manby Premiums of Books, have been awarded to the Authors of some of these communications:—

1. A Telford Medal, the Manby Premium, in Books, and a Stephenson Prize of Twenty-five Guineas, to Sir Charles Augustus Hartley, M. Inst. C.E., for his "Description of the Delta of the Danube, and of the Works, recently executed, at the Sulina Mouth."
2. A Telford Medal, and a Miller Prize of Fifteen Guineas, to John Henry Muller (of the Hague), for his Paper "On Reclaiming Land from Seas and Estuaries."
3. A Telford Medal, and a Miller Prize of Fifteen Guineas, to John Paton, M. Inst. C.E., for his Paper "On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea."
4. A Telford Medal, to James Abernethy, M. Inst. C.E., for his "Description and Illustrations of the Works at the Ports of Swansea, Blyth, and Silloth."
5. A Telford Medal, to John Bailey Denton, M. Inst. C.E., for his Paper "On the Discharge from Under-drainage, and its effect on the Arterial Channels and Outfalls of the Country."
6. A Watt Medal, to Joseph D'Aguilar Samuda, M. Inst. C.E., for his Paper "On the Form and Materials for Iron-Plated Ships, and the Points requiring attention in their Construction."
7. A Council Premium of Books, to Jas. Brunlees, M. Inst. C.E., for his Paper on "Railway Accidents—their causes and means of prevention."
8. A Council Premium of Books, to Capt. Douglas Galton, R.E., F.R.S., Assoc. Inst. C.E., for his Paper on "Railway Accidents, showing the bearing which existing legislation has upon them."
9. A Council Premium of Books, to Henry Charles Forde, M. Inst. C.E., for his Paper on "The Malta and Alexandria Submarine Telegraph Cable."

10. A Council Premium of Books, to Charles William Siemens, F.R.S., M. Inst. C.E., for his Paper "On the Electrical Tests employed during the construction of the Malta and Alexandria Telegraph, and on insulating and protecting Submarine Cables."
11. A Council Premium of Books, to James Atkinson Longridge, M. Inst. C.E., for his Paper on "The Hooghly and the Mutla."
12. A Council Premium of Books, to James Oldham, M. Inst. C.E., for his Paper "On Reclaiming Land from Seas and Estuaries."

It will be observed that, for the first time, premiums in money have been awarded; and it will be for the in-coming Council to consider how far the increased value of the premiums, by in some degree offering remuneration for the time devoted to the study of the subjects, will induce the presentation of complete and well-composed Papers for reading at the Meetings.

Since the date of the last Report, Vol. xix. of the Minutes of Proceedings, containing 700 pages, has been issued. Vol. xx., consisting of nearly 600 pages, is complete, and will be forwarded to the Members in a short time. Considerable progress has also been made with volume xxi. for the last Session. The publication of these volumes has been retarded by the non-receipt of information required and corrections requested,—more especially with respect to the Memoirs of deceased Members. It has indeed been necessary at last to omit some memoirs, as the relatives and friends have, notwithstanding repeated requests, neglected to furnish any particulars. It is under consideration, whether it may not be advantageous in future to publish the Memoirs as an Appendix to the volume, rather than allow them to occasion delay in the publication of the Minutes of Proceedings.

During the past session, the custom of assembling the Members at dinner was revived, and advantage was taken of the presence in London, on the occasion of the International Exhibition, of many foreigners of scientific reputation, to invite them as guests. The dinner was so successful, that it is suggested to repeat it annually; and it may be fairly anticipated, that as the Members increase in number, so will the Annual Dinner be looked forward to as another general meeting of a more social character.

The Institution was also able to be very useful to many foreign engineers and scientific men who visited this country; and communications have been established which will be mutually beneficial, and will render the mere title of Member of this Institution, the best passport for all Engineers when travelling in foreign countries.

The tabular statement of the transfers, elections, deceases, and resignations of Members of all classes, during the years 1860-61 and 1861-62, (taking into consideration the names which have been erased from the Register), appears thus:—

—	Honorary Members.	Members.	Associates.	Graduates.	Annual Increase.
1860-61.					
Transferred to Members . . .	..	..	2	..	69 - 54 = 15
Elections	..	24	45	..	
Deceases	2	9	12	..	54
Resignations	..	2	7	1	
Erased from Register	..	1	18	2	
1861-62.					
Transferred to Members . . .	..	..	7	..	73 - 18 = 55
Elections	..	35	37	..	
Restored to the List	..	1	..	..	18
Deceases	2	7	6	1	
Resignations	..	..	2	..	
Members of all Classes on the Books, November 30, 1862 . }	20	405	565	10	= 1000

As the total number of Members of all classes on the 30th of November 1857 was 835, it appears that there has been an increase of nearly 20 per cent. in the last five years, of which about 6½ per cent. occurred in the past twelve months.

If the Honorary Members and Graduates are omitted from the calculation, the annual increase of Members and Associates stands thus:—

YEARS.	Members Elected.	Associates Elected.	Total Elected.	Deceases, Resignations, and Erasures.	Effective Increase.
1857	12	57	69	23	46
1858	11	25	36	13	23
1859	16	41	57	20	37
1860	23	39	62	25	37
1861	24	45	69	49	20
1862	35	37	72	15	57

The following Associates having tendered their resignations, have been permitted to retire from the Institution:—Messrs William Southcote Inman and Francis Cranmer Penrose.

The deceases during the past year have been H. R. H. The Prince Consort, and Peter Barlow, Honorary Members; James John Berkley, James Cooper, Henry Hind Edwards, John Edward

Errington, Joseph Lane Manby, James Walker, and William Weallens, Members; Major John Fraser Lodington Baddeley, R.A., Captain Carlton Thomas Collingwood, Colonel Samuel Colt (U. S.), Robert Cowen, John Evans, and John Withers, Associates; and John Brannis Birch, Graduate.

The Memoirs of our late friends will be found in the Appendix to this Report.

In this list there will be observed the names of two Members well known in this Institution—Mr. J. E. Errington, Vice-President, and Mr. James Walker, Past-President.

Mr. Errington had long occupied a distinguished position in the profession. In conjunction with his partner, the late Mr. Joseph Locke, he had been actively and successfully engaged, during the last thirty years, in the execution of important works, and had materially contributed to the extension of that vast network of railways now covering the United Kingdom, which is one of the distinguishing features of the present age. Mr. Errington has been taken from among us, just at the period when we might have looked forward to his having more leisure, which would have enabled him to impart to the Institution the results of his varied practice, as he had promised to do, when he occupied the position of Vice-President. It is hoped that among his pupils, there are several young Engineers who, mindful of his constant desire to advance their position, will lay before the meetings, plans and descriptions of the works upon which they have been engaged under him, and thus, while benefiting the Institution, they will evince their gratitude to the memory of him who had always their well-being in view.

Mr. Errington demonstrated his anxiety for the advancement and prosperity of this Institution, by bequeathing to it the sum of One Thousand Pounds, free of legacy duty, for the general purposes of the Society.

Mr. Walker was one of the oldest Members of the profession, having been in active practice as an Engineer for upwards of sixty years. He was also one of the earliest Members of the Institution, having joined it in the year 1823, and, after the death of Mr. Telford, he became its President. For a period of eleven years, during which he so ably conducted its proceedings in that capacity, he was most devoted to its interests, and to his zeal and energy must be greatly attributed the eminent position it held, on his retiring from the chair in 1845. Mr. Walker's name was associated with many engineering works in England and Scotland, including light-houses, harbours, bridges, embankments, and drainage. His opinion was much valued by the Elder Brethren of the Trinity House, by the Lords of the Admiralty, and by the Corporation of the City of London, and it must not be forgotten,

especially at the present moment, that twenty years ago he laid down lines for embanking each side of the River Thames, which have never been improved. Many Members of the profession, including Messrs. Burges, Bidder, Hawkshaw, M'Clellan, Borthwick, and Hartley, were engaged with and under Mr. Walker, and to the experience they gained on his works may be partly ascribed the eminence they have attained.

Mr. Walker left at Mr. Burges' disposal the twenty-five remaining copies of Telford's "Life and Works," as well as the copyright and the copper-plates, and the Council have much pleasure in announcing that Mr. Burges has, in the most handsome and liberal manner, presented them to the Institution for the purpose of being used as Premiums.

The amount of arrears of subscriptions for 1862, due November 30th is:—

	£.	s.	d.	£.	s.	d.
From Members of all classes, residing abroad	56	3	6			
From Members of all classes, residing in the United Kingdom	219	19	6	276	3	0
<hr/>						
The amount of arrears for the years 1860 and 1861, was—						
From Members of all classes, residing abroad	40	8	6			
From Members of all classes, residing in the United Kingdom	110	5	0	150	13	6
<hr/>						
Total				£426	16	6
<hr/>						

Although there is an increase in the amount of arrears, as compared with the previous year, notwithstanding every effort having been made to obtain payment of the sums due, yet the financial position of the Institution, as shown by the Abstract of Receipts and Expenditure appended to this Report, is most satisfactory. The total amount received under the head of "Subscriptions and Fees" does not quite equal the return of the previous year, partly owing to one Member only having paid a life-composition, but mainly from the non-payment of arrears, for the current subscriptions have exceeded those of the previous year by from 7 to 8 per cent. The receipts from other subsidiary sources remain about the same. During the last twelve months, there has been a considerable increase in the income arising from the dividends upon the several stocks held by the Institution. With regard to the expenditure, the establishment charges are somewhat higher. And a very large sum, upwards of £1,000, has been paid on account of Minutes of Proceedings. Still, however, the total disbursements have been less than the receipts from subscriptions and fees alone, without including the other sources of revenue.

The executors of the late Mr. Joseph Miller have transferred

into the name of the Corporation of the Institution of Civil Engineers £2,133. 6s. 8d. Reduced Three per Cent. Annuities, representing the sum of £2,000—the dividends upon which were directed to be paid to Mr. John Miller during his life,—which was bequeathed “to be applied for the general use and benefit of the Institution, in such manner as the managing body for the time being may think proper.”

It may be remembered that, at the date of the last Annual Report, there was on deposit at the Union Bank a sum of £1,221. 19s. As there was no immediate prospect of this money being required for the current expenses, and as the rate of interest then obtained at the Bank was low, it was thought that the time had arrived when a further investment could be safely made. Accordingly this amount, together with £322. 4s. 5d. withdrawn from the general account at the banker's, was invested in the purchase, at par, of £1,500 Great Northern Railway Company, Four per cent. Debenture Stock. Subsequently, £1,000 of this stock has been assigned as representing the Errington Bequest. It having been found that there was a considerable balance of dividends arising from the Telford Fund, which had not as yet been expended in Annual Premiums, in accordance with the directions of the testator, it was deemed advisable to consult the Honorary Solicitor of the Institution on the subject. Acting on the recommendation of Sir Roundell Palmer, Her Majesty's Solicitor-General, this balance, amounting to £1,669. 8s. 6d. has been invested in the purchase of £1,775. 19s. 8d. Reduced Three per Cent. Consolidated Annuities.

The Funds now under the charge of the Institution, in addition to a balance in the hands of the Treasurer of £456. 8s. 2d. and of an amount on deposit on account of the Building Fund of £447. 7s., are as follows:—

I. GENERAL FUNDS.

	£.	s.	d.	£.	s.	d.	
1. Stephenson Bequest, North Eastern Railway Company Four per Cent. Debenture Stock	2,000	0	0				
2. Miller Bequest, Reduced Three per Cent. Consolidated Annuities	2,133	6	8				
3. Errington Bequest, Great Northern Railway Company Four per Cent. Debenture Stock	1,000	0	0				
4. Institution Investments, Norfolk Railway Company Four per Cent. Debenture Stock	£2,000						
" Great Northern Railway Company, Four per Cent. Debenture Stock	£1,000						
	—	3,000	0	0			
		<u>3,000</u>	<u>0</u>	<u>0</u>	8,133	6	8

Together yielding an annual income, at the present time, of £292. 12s.

II. TRUST FUNDS.

	£.	s.	d.	£.	s.	d.
1. Telford Fund,—“given in trust, the Interest to be expended in Annual Premiums, under the direction of the Council,”—Three per Cent. Consols	2,551	15	10			
“ “ Three per Cent. Annuities	2,342	17	1			
				4,894	12	11
“ “ Balance of Dividends, not yet expended in “ Annual Premiums, standing in Three per Cent. Consols				1,775	19	8
2. Manby Donation,—“to form a fund for an Annual Premium, or Premiums, for Papers read at the Meetings,”—Norfolk Railway Company Five per Cent. Preference Stock.				200	0	0
3. Miller Fund,—“for providing Premiums, or Prizes, for the Students of the said Institution, upon the principle of the Telford Fund,”—Lancashire and Yorkshire Four per Cent. Debenture Stock	£2,000					
“ “ Norfolk Railway Company Four per Cent. Debenture Stock	£1,100					
				3,100	0	0
Total				£9,970	12	7

The Telford Fund produced in the last financial year £141. 6s. 8d.—irrespective of the balance of dividends not yet expended in Annual Premiums—the Manby donation realised in the same period £9. 12s. 6d. and the Miller Fund £119. 6s. 11d.

It will be for the succeeding Council to consider in what manner these several funds, especially the conditional trusts, can be best applied, in furthering the object of the Incorporation, which is stated in the Charter to be “for the general advancement of Mechanical Science, and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a Civil Engineer.”

In preparing the balloting list it was necessary, owing to the decease of Mr. Errington, to nominate another gentleman to fill the vacant office among the Vice-Presidents. Mr. John Scott Russell, the senior Member of Council, has been selected. The nine remaining Members of the Council are all eligible and are submitted for re-election; and, in accordance with the Bye Laws, the names of three other Members, Messrs. Abernethy, W. H. Barlow, and N. Beardmore, all of whom have consented to serve, have been added to the list.

The two Associate Members of Council retire annually. The names of four gentlemen have to be inserted in the list for your consideration, and on this occasion Messrs. J. T. Leather, F. Marrable, C. Waring, and Colonel Sale, have consented to be put in nomination.

The Council believe that the past Session may be looked upon with satisfaction, for the increase in the number of the Members, and for the nature of its general proceedings; and they regard the present success and well-being of the Institution, as the best guarantees for its future and long-continued usefulness.

ABSTRACT *of* RECEIPTS *and* EXPENDITURE.

ABSTRACT of RECEIPTS and EXPENDITURE

RECEIPTS.					
<i>Dr.</i>		£.	s.	d.	£. s. d.
To Deposit at Union Bank		1,000	0	0	
— Balance of Petty Cash, Nov. 1, 1861, in the hands of the Secretary			10	19	2
— Balance in the hands of the Treasurer		668	9	3	
					1,679 8 5
— Subscriptions and Fees :—					
Arrears		151	4	0	
Current		2,382	19	6	
Subscription, 1863 (in advance)			2	12	6
Fees		223	13	0	
Life		26	5	0	
					2,786 14 0
— Publication Fund					44 2 0
— Council Premium Fund					45 0 0
— Publications :— Sale of Transactions					73 4 4
— Telford Fund :—					
Dividends—1 year, on £2,551. 15s. 10d, Three per Cent. Reduced Consols		73	13	8	
Ditto, on £2,342. 17s. 1d., Three per Cent. Reduced Annuities		67	13	0	
					141 6 8
— Manby Premium :—					
Dividends—1 year, on £200, Norfolk Railway Company, Five per Cent. Preference Stock					9 12 6
— Stephenson Bequest :—					
Dividends—1 year, on £2,000, North Eastern Railway Company, Four per Cent. Debenture Stock		77	0	0	
Balance of Deposit Account, after purchase of the above Stock		23	16	4	
					100 16 4
— Miller Fund :—					
Dividends—1 year, on £2,000, Lancashire and Yorkshire Railway Company, Four per Cent. Debenture Stock		76	19	11	
Ditto, on £1,100, Norfolk Railway Company, Four per Cent. Debenture Stock		42	7	0	
Balance of Deposit Account, after purchase of the above Stocks		18	5	0	
					137 11 11
— Miller Bequest :—					
Balance of $\frac{1}{4}$ -year's Dividends on £2,133. 6s. 8d., Reduced Three per Cent. Annuities		23	1	3	
$\frac{1}{4}$ -year's Dividends on £2,133. 6s. 8d., Reduced Three per Cent. Annuities		80	16	0	
					53 17 3
— Institution Investments :—					
Deposit Interest— $\frac{1}{4}$ year on £1,221. 19s.		18	2	7	
Dividends—1 year on £2,000, Norfolk Railway Company, Four per Cent. Debenture Stock		77	10	0	
Ditto, 126 days on £1,500, Great Northern Railway Company, Four per Cent. Debenture Stock		19	12	5	
					114 15 0
— Errington Bequest					1,000 0 0
					<u>£6,186 8 5</u>

from the 1ST DEC., 1861, to the 30TH NOV., 1862.

PAYMENTS.				£.	s.	d.	£.	s.	d.
Cr.									
By House, Great George Street:—									
Rent				360	10	2			
Rates and Taxes				48	6	9			
Insurance				18	19	9			
							425	16	8
— Salaries							475	0	0
— Clerks, Messengers, and Housekeeper							247	2	0
— Wages of Old Messenger, while in Hospital—57 weeks							57	0	0
— Postage and Parcels:—									
Postage				29	2	5			
Parcels				1	0	0			
							30	2	5
— Stationery, Engraving, Printing Cards, Circulars, &c.							60	4	0
— Coals, Candles, Oil, and Gas:—									
Coals				11	0	0			
Candles				0	7	0			
Oil.				3	14	3			
Gas				20	10	1			
							35	11	4
— Tea and Coffee							84	8	0
— Library:—									
Books				90	18	1			
Periodicals				19	1	8			
							109	19	9
— Publication, Minutes of Proceedings							1,001	18	2
— Telford Premiums							6	6	0
— Council Premiums							24	1	6
— Manby Premium							10	10	8
— Diplomas							14	8	10
— Manuscripts, Original Papers, and Drawings							4	6	0
— Winding and Repairing Clocks							4	6	0
— Annual Dinner							92	3	8
— Incidental Expenses:—									
Gratuities and Christmas Gifts				1	16	0			
Donation, St. George's Hospital				10	10	0			
Occasional Assistance				4	11	6			
Assistance at Meetings				10	19	6			
Beating Carpets				3	13	6			
Household Utensils, Repairs, and Expenses				40	14	2			
							72	4	8
							£2,705	9	8
— Great Northern Railway Company Debenture Stock:—									
From Deposit at Union Bank				1,000	0	0			
„ Current Account				322	4	5			
							1,322	4	5
— Telford Fund, Balance of Dividends, not yet expended in Annual Premiums							1,669	8	6
— Balance of Petty Cash, Dec. 1, 1862, in the hands of the Secretary							32	17	8
— Balance in the hands of the Treasurer							456	8	2
							£6,186	8	5

Examined and Compared the above Account with the Vouchers and the Cash Book, and find this Account to be correct, leaving a Balance in the hands of the Treasurer of Four Hundred and Fifty-six Pounds, Eight Shillings, and Two Pence.—November 30, 1862.

(Signed) F. C. STILEMAN, } Auditors.
F. J. BRAMWELL, }
JAMES FORREST, Secretary.

December 13th, 1862.
[1862-63. N.S.]

K

PREMIUMS AWARDED.

SESSION 1861-62.

THE COUNCIL of the Institution of Civil Engineers have awarded the following Premiums :—

1. A Telford Medal, the Manby Premium, in Books, and a Stephenson Prize of Twenty-five Guineas, to Sir Charles Augustus Hartley, M. Inst. C.E., for his "Description of the Delta of the Danube, and of the Works, recently executed, at the Sulina Mouth."
2. A Telford Medal, and a Miller Prize of Fifteen Guineas, to John Henry Müller (of the Hague), for his Paper "On Reclaiming Land from Seas and Estuaries."
3. A Telford Medal, and a Miller Prize of Fifteen Guineas, to John Paton, M. Inst. C.E., for his Paper "On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea."
4. A Telford Medal, to James Abernethy, M. Inst. C.E., for his "Description and Illustrations of the Works at the Ports of Swansea, Blyth, and Silloth."
5. A Telford Medal, to John Bailey Denton, M. Inst. C.E., for his Paper "On the Discharge from Under-drainage, and its effect on the Arterial Channels and Outfalls of the Country."
6. A Watt Medal, to Joseph D'Aguilar Samuda, M. Inst. C.E., for his Paper "On the Form and Materials for Iron-Plated Ships, and the Points requiring attention in their Construction."
7. A Council Premium of Books, to James Brunlees, M. Inst. C.E., for his Paper on "Railway Accidents—their causes and means of prevention."
8. A Council Premium of Books, to Captain Douglas Galton, R.E., F.R.S., Assoc. Inst. C.E., for his Paper on "Railway Accidents, showing the bearing which existing legislation has upon them."
9. A Council Premium of Books, to Henry Charles Forde, M. Inst. C.E., for his Paper on "The Malta and Alexandria Submarine Telegraph Cable."

10. A Council Premium of Books, to Charles William Siemens, F.R.S., M. Inst. C.E., for his Paper "On the Electrical Tests employed during the construction of the Malta and Alexandria Telegraph, and on insulating and protecting Submarine Cables."
11. A Council Premium of Books, to James Atkinson Longridge, M. Inst. C.E., for his Paper on "The Hooghly and the Mutla."
12. A Council Premium of Books, to James Oldham, M. Inst. C.E., for his Paper "On Reclaiming Land from Seas and Estuaries."

SUBJECTS FOR PREMIUMS.

SESSION 1862-63.

THE COUNCIL invite communications on the following, as well as other Subjects, for Premiums :—

For a limited number of Papers of distinguished merit, pecuniary awards will be made, not exceeding in each case Twenty-five Guineas, in addition to the Honorary Premiums. The subjects numbered 14, 18, 28, and 41, have been selected as those upon which, it is hoped, such communications may be received during the ensuing Session. But Papers on other subjects, if of adequate merit, will be taken into consideration in the adjudication of the pecuniary awards.

1. On the Decay of Materials in Tropical Climates, and the methods employed for arresting and preventing it.
2. On the Manufacture of Bricks by machinery, and their comparison with hand-made bricks.
3. On the Methods of constructing Foundations, for large Structures, in deep water, and on the various systems of Driving Piles.
4. On the Construction of Suspension Bridges, with rigid platforms, and the plans of Anchoring the Stay-chains.
5. On the various modes adopted for moving Earth in Tunnels, Cuttings, or Embankments, with the cost.
6. On the Mechanical Methods of Boring and of Sinking large Shafts, of introducing the Tubing and the impervious lining, and of traversing running sand, and other difficult strata.
7. On the Results of Contrivances for facilitating the Driving of Tunnels, or Drifts in Rock.
8. On Locomotive Engines for ascending Steep Inclines, especially when in combination with sharp curves, on Railways.
9. On the Construction of Railway Carriages and Waggon, with a view to the reduction of the gross weight of Passenger and Goods Trains; also of Railway Wheels, Axles, Bearings, Axle Boxes, and Breaks, and of Bearing, Traction, and Buffer Springs; treating particularly, their ascertained duration and their relative friction.

10. On the Working Expenses of Railways, and the influence of the original design and construction.
11. On the Application of the Electric Telegraph to Railway Train Signalling.
12. On the Results of a series of Observations on the Flow of Water from the Ground, in any large district; with accurately-recorded Rain-Gauge Registries, in the same locality, for a period of not less than twelve months.
13. On the Construction of Catchwater Reservoirs in Mountain Districts, for the Supply of Towns, or for Manufacturing purposes.
14. Accounts of existing Waterworks; including the Source of Supply, a description of the different modes of collecting and filtering, the Distribution throughout the Streets of Towns, and the general practical results. (Twenty-five Guineas.)
15. On the Drainage and Sewerage of Large Towns; exemplified by accounts of the systems at present pursued, with regard to the level and position of the outfall, the form, dimensions and material of the sewers, the prevention of emanations from them, the arrangements for connecting the house drains with the public sewers, and the disposal of the sewage, whether in a liquid form, as irrigation, or in a solid form after deodorisation.
16. On the Results of the Employment of Steam Power on Canals, and of other measures for the Improvement of Canals as a means of conveyance for heavy traffic.
17. A History of the successive changes of any Fresh Water Channel,—accompanied by plans and longitudinal and cross sections,—including a description of the drainage area, and the results of a series of consecutive gaugings, with tables of rainfall for a period of not less than twelve months, as well as notices of any works which may have been executed upon it, and of the effects of the works,—such as those relating to Land Drainage—Irrigation—Navigation—Compensation Reservoirs—Permanent and Moveable Dams—&c.
18. A History of any Tidal River, or Estuary,—accompanied by plans and longitudinal and cross sections,—including notices of any works which may have been executed upon it, of the relative effect of Tidal and Fresh Water, and of the effect of Enclosures from the Tidal Area upon the general régime, of Sluicing where applied to the improvement of the entrance or the removal of a Bar, and of Groynes or Parallel Training Walls. Also, of Dredging, with a description of the Machinery employed, and the cost of raising and depositing the material. (Twenty-five Guineas.)

19. On the Results of a Series of Tidal Observations, illustrative of the modifications which the tidal wave undergoes in its passage up and down a tidal river or estuary.
20. On the Construction of Tidal or other Dams, in a constant or variable depth of water.
21. A History of any Harbour, including the reasons for selecting the site, the mode of construction adopted, and the subsidiary works for the convenience of shipping, and for commercial purposes, with the cost, &c.
22. A History of any Refuge Harbour, including the reasons for selecting the site, the mode of construction adopted, its cost, and the time employed in its execution.
23. A History of any Dock, on the course of a Tidal Stream, in communication with Railways and with Inland Navigation, including the reasons for the selection of the site, the mode of construction adopted, the position of the entrance with reference to the direction of the stream, the cost, &c.
24. Descriptions of the various kinds of Machinery in use in the principal Shipping Ports, for the Shipment of Coal; noticing particularly, those in which the greatest expedition is combined with the least amount of breakage of the coal; and also accounts of the means of unshipping and measuring, or weighing the Coal, on its arrival in Port.
25. On the arrangement and construction of Floating Landing-Stages, for passenger and other traffic, with existing examples.
26. On the different systems of Swing, Lifting, and other opening Bridges, with existing examples.
27. On the Construction of Lighthouses; their Machinery and Lighting Apparatus; with notices of the Methods in use for distinguishing the different Lights.
28. On the Results of the use of Tubular Boilers, and of Steam at an increased pressure, for Marine Engines, noticing particularly, the difference in weight and in speed, in proportion to the Horse Power and the Tonnage. (Twenty-five Guineas.)
29. On the relative advantages of the Principle of Expansion, as applied in the Single long-stroke Cylinder Engine, in the Double Cylinder Engine, and in the Three Cylinder Engine; and on the adaptation of the two latter to marine purposes.
30. On the Causes of the alleged Failure in Economising Fuel, in working Steam expansively, and the probable conditions for insuring success.
31. On the Results of the use of Superheated Steam and of Surface Condensation.

32. On the Measure of Resistance to Steam Vessels at high Velocities.
33. On Boiler Inspection as practised in this country and on the Continent, with remarks as to the comparative merits of the two systems.
34. On the construction of, and the comparative duty performed by, modern Pumping Engines for raising Water, for the Supply of Towns, or for the Drainage of Mines; noticing in the latter case, the depth and length of the underground workings, the height of the surface above the sea, the geological formation, the contiguity of streams, &c.
35. On the Results of the use of Pumps of different kinds, for lifting large quantities of water to a limited height, for the purposes of Drainage, or of Irrigation.
36. On Turbines and other Water Motors of a similar character; their construction and performance, and comparison with Water-wheels.
37. On the means of Utilising the products of the Distillation of Coal, so as to reduce the price of Coke; with descriptions of the Ovens, and of the best processes used in Great Britain and on the Continent, in the manufacture of Coke.
38. On the present systems of Smelting Iron Ores, and on the Conversion of Cast Iron into the malleable state, and of the Manufacture of Iron generally, comprising the distribution and management of Iron Works.
39. The Chemical Analysis, and the application to economic purposes, of the Gases generated in Iron Blast Furnaces.
40. On the Manufacture of Iron for Rails and Wheel Tyres, having special reference to the increased capability of resisting lamination and abrasion; and accounts of the Machinery required for rolling heavy Rails, Shafts, and Bars of Iron of large sectional area.
41. On the manufacture of large Masses of Iron for the purposes of Warfare, as Armour Plates, &c. (Twenty-five Guineas.)
42. On the Construction of Rifled and Breech-loading Artillery; and on the Initial Velocity, Range and Penetration of Rifled Projectiles, and the influence of Atmospheric Resistance.
43. On the use of Steel Bars and Plates in Enginework and Machinery, for Boilers and for Ship Building.
44. On Machinery adapted for the Better Separation of the various Substances found in Combination with Metallic Productions.
45. On the Substitution of Machinery for Manual Labour in Mining Operations; and on Hydraulic Machinery in Mines.

46. On the Precautions to be adopted for guarding against Accidents by Fire-damp and After-damp in Mines.
47. On the Improvements which may be effected in the Buildings, Machinery, and Apparatus for producing Sugar from the Cane in the Plantations and Sugarworks of the British Colonies, and the comparison with Beet Root, with regard to quantity, quality, and economy of manufacture.
48. The uses of Vulcanised, or Mineralised Caoutchouc; the means of increasing its durability, and the modes of causing its adhesion to metal.
49. On the Application of Photography to Engineering.
50. Memoirs and accounts of the Works and Inventions of any of the following Engineers:—Sir Hugh Middleton, Arthur Woolf, Jonathan Hornblower, Richard Trevithick, William Murdoch (of Soho), Alexander Nimmo, and John Rennie.

Original Papers, Reports, or Designs, of these, or other eminent individuals, are particularly valuable for the Library of the Institution.

The competition for Premiums is not confined to Members, or Associates of the Institution, but is equally open to all persons, whether Natives or Foreigners.

The Council will not consider themselves bound to award any Premium, should the Communication not be of adequate merit; but they will award more than one Premium, should there be several Communications on the same subject deserving this mark of distinction.

The Communications must be forwarded, on or before the 1st of February, 1863, to the house of the Institution, No. 25, Great George Street, Westminster, S.W., where copies of this Paper, and any further information may be obtained.

CHARLES MANBY, *Honorary Secretary.*
JAMES FORREST, *Secretary.*

25, Great George Street, Westminster, S.W.,
October, 1862.

NOTICE.

It has frequently occurred, that in Papers which have been considered deserving of being read and published, and have even had Premiums awarded to them, the Authors may have advanced somewhat doubtful theories, or may have arrived at conclusions at variance with received opinions. The Council would, therefore, emphatically repeat, that the Institution must not, as a body, be considered responsible for the facts and opinions ad-

vanced in the Papers, or in the consequent Discussions ; and it must be understood, that such Papers may have Medals and Premiums awarded to them, on account of the Science, Talent, or Industry displayed in the consideration of the subject, and for the good which may be expected to result from the discussion and the inquiry ; but that such notice, or award, must not be considered as any expression of opinion, on the part of the Institution, of the correctness of any of the views entertained by the Authors of the Papers.

EXTRACTS FROM THE MINUTES OF COUNCIL, FEB. 23rd, 1835.

“The principal Subjects for which Premiums will be given are:—

- “1st. Descriptions, accompanied by Plans and explanatory Drawings, of any work in Civil Engineering, as far as absolutely executed, and which shall contain authentic details of the progress of the work. (Smeaton’s Account of the Edystone Lighthouse may be taken as an example.)
 - “2ndly. Models, or Drawings, with descriptions of useful Engines and Machines ; Plans of Harbours, Bridges, Roads, Rivers, Canals, Mines, &c. ; Surveys and Sections of Districts of Country.
 - “3rdly. Practical Essays on subjects connected with Civil Engineering, such as Geology, Mineralogy, Chemistry, Physics, Mechanic Arts, Statistics, Agriculture, &c. ; together with Models, Drawings, or Descriptions of any new and useful Apparatus, or Instruments applicable to the purposes of Engineering, or Surveying.”
-

EXCERPT BYE-LAWS, SECTION XIV., CLAUSE 3.

“Every Paper, Map, Plan, Drawing, or Model presented to the Institution shall be considered the property thereof, unless there shall have been some previous arrangement to the contrary, and the Council may publish the same, in any way and at any time they may think proper. But should the Council refuse, or delay the publication of such Paper, beyond a reasonable time, the Author thereof shall have a right to copy the same, and to publish it as he may think fit, having previously given notice, in writing, to the Secretary of his intention. No person shall publish, or give his consent for the publication of any communication presented and belonging to the Institution, without the previous consent of the Council.”

INSTRUCTIONS FOR PREPARING COMMUNICATIONS.

The Communications should be written in the impersonal pronoun, and be legibly transcribed on foolscap paper, about thirteen inches by eight inches, the lines being three-quarters of an inch apart, on the one side only, leaving a margin of one inch and a-half in width on the left side, in order that the sheets may be bound.

The Drawings should be on mounted paper, and with as many details as may be necessary to illustrate the subject. Enlarged Diagrams, to such a scale that they may be clearly visible, when suspended on the walls of the Theatre of the Institution, at the time of reading the communication, should be sent for the illustration of any particular portions.

Papers which have been read at the Meetings of other Scientific Societies, or have been published in any form, cannot be read at a Meeting of the Institution, nor be admitted to competition for the Premiums.

ORIGINAL COMMUNICATIONS,
DRAWINGS, PRESENTS, &c.,

RECEIVED BETWEEN JUNE 30th, 1861, AND JUNE 29th, 1862.

ORIGINAL COMMUNICATIONS.

AUTHORS.

- Abernethy, J. No. 1,052.—Description of Works at the Ports of Swansea, Blyth, and Silloth. With a series of Drawings.
- Bothams, J. C. No. 1,056.—Account of the Waterworks of the City of Salisbury. With one Plan.
- Bray, W. B. No. 1,045.—On Measuring Distances by the Telescope.
- Brereton, R. P. No. 1,062.—Description of the Centre Pier of the Saltash Bridge on the Cornwall Railway, and of the means employed for its construction. With a series of Diagrams.
- Brunlees, J. No. 1,059.—Railway Accidents—their causes and means of prevention.
- Byrne, H. No. 1,051.—On the Use of the Timber of the Palmyra Palm, in the Construction of Bridges. With one Drawing, a model and specimens.
- Crawford, R. No. 1,071.—The Railway System of Germany.
- Cudworth, W. No. 1,058.—The Hownes Gill Viaduct, on the Stockton and Darlington Railway. With two Drawings.
- Denton, J. B. No. 1,046.—On the Discharge from Under-drainage, and its effect on the Arterial Channels and Outfalls of the Country. With a series of Diagrams.
- Forde, H. C. No. 1,070.—The Malta and Alexandria Submarine Telegraph Cable. With a series of Diagrams.
- Fulton, J. No. 1,053.—Description of the Drainage of the Borough of Dundee. With three Drawings.
- Galton, Capt. D., R.E., F.R.S. No. 1,067.—Railway Accidents—showing the bearing which existing legislation has upon them.
- Hartley, C. A. No. 1,061. Description of the Delta of the Danube, and of the works, recently executed, at the Sulina Mouth. With a series of Diagrams.

- Justen, J. No. 1,050.—Observations on the Action of the Tides within Tidal Estuaries.
- Landale, J. J. No. 1,060.—The Precautions to be adopted for guarding against accidents from Fire and After-damp in Mines.
- Longridge, J. A. No. 1,047.—The Hooghly and the Mutla. With a series of Diagrams.
- McMaster, B. No. 1,048.—On the Woods used for Sleepers on the Madras Railway.
- Morshead, W. Jun. No. 1,043.—On the Duty of the Cornish Pumping Engine. With two Diagrams.
- Mosse, J. R. No. 1,063. American Timber Bridges. With three Drawings.
- Muller, J. H. No. 1,066.—On Reclaiming Land from Seas and Estuaries. With a series of Diagrams.
- Oldham, J. No. 1,055.—On Reclaiming Land from Seas and Estuaries. With two Drawings.
- Paton, J. No. 1,065.—On the Sea Dykes of Schleswig and Holstein, and on Reclaiming Land from the Sea. With a series of Diagrams.
- Sadasewjee, H. No. 1,069.—On the Drainage of Bombay.
- Samuda, J. D'A. No. 1,049.—On the Form and Materials for Iron-Plated Ships, and the points requiring attention in their construction. With one Diagram.
- Siemens, C. W. No. 1,072.—On the Electrical Tests employed during the construction of the Malta and Alexandria Telegraph, and on Insulating and Protecting Submarine Cables. With a series of Diagrams.
- Williams, A. No. 1,054.—Description of the Sewerage and Drainage Works, at Newport, Monmouthshire. With a series of Diagrams.
-

CATALOGUE OF PRESENTS.

BOOKS.

- | DONORS. | TITLE OF WORK. |
|---|---|
| Académie Royale des Sciences, des Lettres et des Beaux Arts, de Belgique. | Annuaire. 1851, 1854, 5, 6, 7, 8, 1860, 61, and 62. Sm. 8vo. Plates. Bruxelles, 1852-62. |
| ----- | Bulletins. Tomes 18, 19, 20 Part I., 22 Part II., and 23. 8vo. Bruxelles, 1851-56. |
| ----- | 2 ^{me} série. Tomes 1-12. 8vo. Bruxelles. 1857-61. |
| ----- | Annexe aux Bulletins. 1853-4. 8vo. Bruxelles, 1854. |
| ----- | Mémoires Couronnés. Vols. XXV. and XXX. 4to. Plates. Bruxelles, 1851-3, 1858-61. |
| ----- | Mémoires Couronnés et autres Mémoires. Vols. IX. to XII. 8vo. Plates. Bruxelles, 1859-60. |
| ----- | Nouveaux Mémoires. Vols. XXVI.-XXXIII. 4to. Plates. Bruxelles, 1851-61. |
| Airy, G. B. | Report of the Astronomer Royal to the Board of Visitors of the Royal Observatory, Greenwich. Tract. 4to. Greenwich, 1862. |
| Akademie der Wissenschaften. | Abhandlungen der Mathemat-Physikalischen Classe der Königlich Bayerischen. Neunter Band. 4to. Plates. München, 1861. |
| ----- | Sitzungsberichte. 1861.—I. Heft 2-5. 1861.—II. Heft 1-3. 8vo. Plates. München, 1861. |
| ----- | Verzeichniss der Mitglieder der Kon. Bay. 4to. München, 1860. |
| Anonymous. | Croydon Sewage v. London Sewage. Tract. 8vo. No place, 1862. |
| ----- | Notes on Art, British Sculptors, Sculpture, and our Public Monuments. Tract. 8vo. London, 1861. |
| ----- | The Armstrong Guns. Letter from Sir W. G. Armstrong to the 'Times,' dated 25 November 1861. 8vo. London, 1861. |
| ----- | The Great Triennial Handel Festival, at the Crystal Palace in 1862. Tract. 8vo. Plates and Cut. London, 1862. |
| ----- | The Royal Engineer Department: its Work and the Estimates. By Argus. Tract. 8vo. London, 1862. |

- | DONORS. | TITLE OF WORK. |
|------------------------------------|--|
| Ansted, Prof. D. T. | On the Decay and Preservation of Building Materials. By Prof. D. T. Ansted. Tract. 8vo. London, no date. |
| Architecten-und Ingenieur-Vereins. | Zeitschrift. Band VIII. Heft 1 and 2. 4to. Plates and Cuts. Hannover, 1862. |
| Architectural Publication Society. | The Dictionary of Architecture. Part XII. Felin to Fyvol. Folio. Plates. London, 1862. |
| Art Union of London. | Report of the Council, for the year 1861, with List of Members. 8vo. London, 1861. |
| Ayris, J. | Ure's Dictionary of Arts, Manufactures, and Mines, containing a clear exposition of their principles and practice. Edited by R. Hunt. 3 Vols. 8vo. Cuts. London, 1861. |
| Bakewell, F. C. | Considerations respecting the Figure of the Earth, in relation to the action of Centrifugal force and to the attempts to determine the ellipticity of the Globe by Pendulum Observations. By F. C. Bakewell. Tract. 8vo. Cuts. London, 1862. |
| Baude, Baron. | Exposition Universelle à Londres en 1862. Empire Français. Notice sur les Modèles, Cartes et Dessins relatif aux travaux publics réunis par les soins du Ministère de l'Agriculture, Commerce et des Travaux Publics. 8vo. Paris, 1862. |
| Bazalgette, J. W. | Metropolitan Board of Works. Report on Tenders for the Supply of Perchloride of Iron, and on Drs. Odling and Letheby's observations on its use as a deodorising agent. By Drs. Miller, Hofmann, and Frankland, 8vo. London, 1860. |
| ————— | Report on Communication from Dr. Letheby, with reference to the quantity of Arsenic in Perchloride of Iron. By Drs. Hofmann and Frankland. Tract. 8vo. London, 1860. |
| ————— | the use of Lime as a Disinfectant of Sewage; and on the necessity for, and advantages to be obtained from the use of Perchloride of Iron. By Drs. Miller, Hofmann, and Frankland. Tract. 8vo. London, 1860. |
| ————— | the Deodorization of Sewage. By Dr. Hofmann and Dr. Frankland. Tract. 8vo. London, 1859. |
| Beamish, R. | Memoir of the Life of Sir Marc Isambard Brunel. By R. Beamish. 8vo. Plates. London, 1862. |
| Beardmore, N. | Manual of Hydrology: Containing—I. Hydraulic and other Tables. II. Rivers, flow of Water, |

DONORS.

TITLE OF WORK.

- Springs, Wells, and Percolation. III. Tides, Estuaries, and Tidal Rivers. IV. Rainfall and Evaporation. By N. Beardmore. 8vo. Plates. London, 1862.
- Board of Public Examiners. Cape of Good Hope. Report of the Board of Public Examiners in Literature and Science. Tract. 8vo. Cape Town, 1861.
- Bouniceau, M. Note et Expériences sur la Torsion des Bois. Par M. Bouniceau. Tract. 8vo. No place or date.
- Boxer, Lt.-Col., R.A. Remarks on Permanent Forts and Moveable Floating Batteries as means of Defence against the Bombardment of our Arsenals and Dockyards by an Enemy's Ships. By Lt.-Col. E. M. Boxer. Tract. 8vo. No place, 1862.
- Remarks on the system of Ordnance calculated to prove the most efficient against Iron-Clad Ships and Batteries. By Lt.-Col. Boxer, R.A. Tract. 8vo. Woolwich, 1862.
- Remarks on the system proposed by the Royal Commissioners for the Defence of the Country. By Lt.-Col. Boxer. Tract. 8vo. Woolwich, 1862.
- Bowley, B. R. The Exhibition of 1862; How are the Working Classes throughout the Kingdom to get to it? 8vo. No place, 1861.
- British Government, through Major-Gen. Sabine. Observations made at the Magnetical and Meteorological Observatory at St. Helena, with discussions of the Observations at St. Helena, the Cape of Good Hope, the Falkland Islands, Carlton Fort in North America, and Pekin. Vol. II., 1844-49. Under the superintendence of Major-Gen. E. Sabine, R.A. 4to. Plates. London, 1860.
- Observations on days of unusual Magnetic Disturbance, made at the British Colonial Magnetic Observatories, under the Departments of the Ordnance and Admiralty. 1842-44. Printed under the superintendence of Lt.-Col. E. Sabine, R.A. Vol. I., Part II. 4to. London, 1851.
- Observations made at the Magnetical and Meteorological Observatory at Hobarton, in Van Diemen Island. Printed under the superintendence of Lt.-Col. E. Sabine, R.A. Vols. II. and III. 4to. London, 1852-3.
- Ditto at Toronto in Canada. Vols. II. and III. 1843-48. Printed under the superintendence of Lt.-Col. E. Sabine, R.A. 4to. London, 1853-7.
- Ditto at the Cape of Good Hope. Magnetical Ob-

DONORS.

TITLE OF WORK.

- servations 1841-46. Printed under the superintendence of Lt.-Col. E. Sabine, R.A. Vol. I. 4to. London, 1851.
- Broise and Thieffry, MM. Album Encyclopédique des Chemins de Fer. By MM. Broise and Thieffry. 1^{re} an, 9 liv. Folio. Plates. Paris, 1861.
- Brooks, W. A. On the Defence of Portsmouth and the adjacent Anchorage. By W. A. Brooks. Tract. 8vo. Map. No place or date.
[From the "Journal of the Royal United Service Institution," vol. vi.]
- Brown, J. On Cast Iron Tubbing, used in sinking Shafts. By J. Brown. Tract. 8vo. Plates. Birmingham, 1861.
[Excerpt Minutes of Proceedings Inst. Mechanical Engineers, August 1, 1861.]
- Buffon, N. de. Hydraulique Agricole applications. Des Canaux d'Irrigation de l'Italie Septentrionale, envisagés sous les divers points de vue de la Science Hydraulique, de la Production Agricole, et de la Legislation. Par N. de Buffon. 2^{nde} édition. 8vo. 4to Atlas of Plates. Paris, 1861.
- Burnell, G. R. Elementorum Architecturæ Militaris. By N. Goldmanni. 3 Vols. 12mo. Plates. Leyden, 1643.
- I quattri Primi Libri d'Architettura. By Pietro C. Senesi. Folio. Plates. Vinegior, 1554.
- Natural and Political Observations mentioned in a following Index, and made upon the Bills of Mortality. By Captain John Graunt. 8vo. London, 1676.
- Navigation Improv'd : Or, the Art of Rowing Ships of all Rates, in Calms, with a more easy, swift, and steady Motion than Oars can. Also a description of the Engine that performs it. By T. Savery. 8vo. London, 1698.
- The Art of Dialling by a New, Easie, and most Speedy Way. Shewing how to describe the hour Lines upon all sorts of Plains howsoever, or in what Latitude soever situated. By W. Leybourn. 8vo. Plate. London, 1675.
- Campbell, Lt.-Col. T. H. On the Construction of Gun Carriages. 8vo. Plates. No place or date.
- Notes on the Construction of Iron-Clad Ships of War. By Major T. Hay Campbell. Tract. 8vo. No place or date.
- On Iron Shields for Ships of War, &c., &c. By Lieut.-Col. T. Hay Campbell. Tract. 8vo. Plates. Bangalore, 1861.

- | DONORS. | TITLE OF WORK. |
|--|--|
| Canadian Institute. | The Canadian Journal of Industry, Science and Art. New Series. Nos. 34, 35, 36, 37, 38. 8vo. Cuts. Toronto, 1861-62. |
| Cavalli, G. | Aperçu sur les Canons Rayés se chargeant par la Bouche et par la Culasse et sur les Perfectionnements à apporter à l'Art de la Guerre en 1861. Par. J. Cavalli. 4to. Plates. Turin, 1862. |
| ———— | Memoria su varii perfezionamenti Militari. Di G. Cavalli. 4to. Plates. Torino, 1856. |
| ———— | Memoria sul delineamento equilibrato degli archi in muratura e in armatura. Di G. Cavalli. 4to. Plates. Torino, 1859. |
| Chadwick, D. | On the Social and Educational Statistics of Manchester and Salford. By D. Chadwick. Tract. 8vo. Manchester, 1862. |
| Clark, L. | Experimental Investigation of the Laws which govern the propagation of the Electric Current in long Submarine Telegraph Cables. By L. Clark. Folio. Plate and Cuts. London, 1861. |
| Committee on the Decay of the Stone of the New Palace at Westminster. | Report. Folio. London, 1861. |
| Corlett, H. L. | Rails and Railways. By H. L. Corlett. Tract. 8vo. Plate. No place or date. |
| | [From the "Practical Mechanics' Journal," April 1, 1860.] |
| Corporation of London. | Catalogue of the Library of the. Supplement. 8vo. London, 1861. |
| Corps of Royal Engineers. | Papers on subjects connected with the Duties of the Corps. New series. Vol. X. 8vo. Plates. Woolwich, 1861. |
| Cotton, C. P. | Manual of Railway Engineering in Ireland. With Appendices, including the Irish Tramway Acts. By C. P. Cotton. 8vo. Plates and cuts. Dublin, 1861. |
| Daly, César. | Lectures sur les Fusées de Guerre. By Major-Gen. Konstantinoff. 8vo. Plates and cuts. Paris, 1861. |
| Délesse, M. | Rapport de MM. Délesse, Beaulieu et Yvert, nommés experts par le Conseil de Préfecture de la Seine, au sujet de l'Inondation Souterraine qui s'est produite dans les quartiers nords de Paris en 1856. 4to. Plates. Neuilly, 1861. |
| Department of Public Works, Melbourne, through W. W. Wardell, (Assoc. Inst. C. E.) | Artesian Wells. C. — No. 41a. Plans. Folio. Tract. Melbourne, 1856-7. |
| ———— | Board of Science. First and Second Annual Reports. Nos. 45 and 48. Folio. Melbourne, 1858-59, and 1859-60. |

[1862-63. N.S.]

L

- | DONORS. | TITLE OF WORK. |
|--|--|
| Department of Public Works, Melbourne. | Building Stone. |
| ————— | No. 14. Folio. Melbourne, 1858. |
| ————— | Central Road Board. A General Statement of Works carried on by the, to 1st of October, 1854. A.—No. 17a. Tract. Folio. Melbourne, 1854. |
| ————— | Additional Statement of Works carried on by the. A.—No. 17a*. Tract. Folio. Melbourne, 1854. |
| ————— | Return of Appropriations and Expenditure on the Mount Alexander and Branch Roads on the Gold Fields. A.—No. 31. Tract. Folio. Melbourne, 1855. |
| ————— | Return of Moneys paid into the Treasury, derivable from Punts and Tolls, to 31st December, 1854, together with the estimated amount derivable from the same for the year, 1855. A.—No. 58. Tract. Folio. Melbourne, 1854-5. |
| ————— | Ditto, ditto, from 1st January to 31st December, 1855. A.—No. 93. Tract. Folio. Melbourne, 1855-6. |
| ————— | Return of Works and Expenditure in 1853. A.—No. 56a. Tract. Folio. Melbourne, 1853-4. |
| ————— | Ditto, for the half year ending 30th June, 1855. No. 28a. Tract. Folio. Melbourne, 1855. |
| ————— | Ditto, for the year ending 31st December, 1855. A.—No. 119a. Tract. Folio. Melbourne, 1855-56. |
| ————— | Return of Works on Roads and Bridges, from 1st January to 30th June, 1854; and of the Expenditure of the same, from 1st January to 30th September, 1854. A.—No. 23a. Tract. Folio. Melbourne, 1854. |
| ————— | Return showing the amount and nature of work performed under the Central Road Board, from its formation to 31st December, 1855. A.—No. 121. Tract. Folio. Melbourne, 1855-56. |
| ————— | Statement of the amount and nature of the work performed, and cost of same, under vote of £300,000, from 1st January to 30th June, 1853; together with a further statement of the Expenditure upon these Works from 30th June to 31st August. A.—No. 12a. Tract. Folio. Melbourne, 1853. |
| ————— | Coal Field. Report on the Carboniferous Strata and Coal Seams situated on the Coast between Western Port Bay and Anderson's Inlet, eight miles east of Cape |

DONORS.	TITLE OF WORK.
	Patterson, in Bass's Straits. A.—No. 39. Tract. Folio. Melbourne, 1853-4.
Department of Public Works, Melbourne.	Correspondence Relative to the Establishment of Electro-Telegraphic Communication between the Australian Colonies. No. 32a. Folio. Melbourne, 1856.
————	Electric Telegraph between England and Australia by way of India. No. 12. Tract. Folio. Melbourne, 1858.
————	Report of the Superintendent of the Electric Telegraph, of the proceedings in connection with the establishment of lines of Electric Telegraph, to 31st December, 1856. No. 46a. Folio. Melbourne, 1856-7.
————	Ditto, of the General Superintendent upon the advancement and present condition of the Department for the half year ending 30th June, 1857. No. 72a. Tract. Folio. Melbourne, 1856-7.
————	Half-yearly Report of the General Superintendent of Electric Telegraph, relative to the advancement and present condition of the Department up to 30th June, 1858. No. 30. Folio. Melbourne, 1858-9.
————	Ditto, up to the 31st December, 1858, No. 42. Folio. Melbourne. No date.
————	Ditto, up to 31st December, 1859. No. 39. Folio. Melbourne, 1859-60.
————	Ditto, up to the 31st December, 1860. No. 35. Folio. Plates. Melbourne, 1860-61.
————	Expenditure upon Roads within five miles of the Post Office, Melbourne, from 1st January, 1853, to 31st December, 1854. A.—No. 61. Folio. Melbourne, 1854-5.
————	First Report of the Mineralogical Surveyor. Report on the Geology and Mineralogy of Mount Alexander and the adjacent country lying between the Rivers Loddon and Campaspe. C.—No. 12. Tract. Folio. Plate. Melbourne, 1853.
————	Geological Survey. A.—No. 33. Folio. Melbourne, 1860-61.
————	Report of the Geological Surveyor on the Geological Structure of the Colony of Victoria, the Basin of the River Yarra, and part of the Northern, North Eastern, and Eastern Drainage of Western Port Bay. A.—No. 108a. Folio. Plans and Sections. Melbourne, 1855-56.

DONORS.	TITLE OF WORK.
Department of Public Works, Melbourne.	Geological Surveyor's Report. A.—No. 21a. Folio. Plans and Sections. Melbourne, 1854.
—————	Geological Surveyor. Report of Progress of Survey, from date of commencement. No. 29a. Tract. Folio. Melbourne, 1856.
—————	Internal Communication. Report of the Commissioners appointed to inquire into the best mode of providing for the Internal Communication of the Colony. A.—No. 4. Folio. Melbourne, 1854.
—————	Land Sales Returns. C.—No. 7. Tract. Folio. Melbourne, 1858.
—————	Meteorological Reports. Meteorological Report and Diagrams of Barometric Pressure, &c., for the eight months ending 31st January, 1856. A.—No. 115a. Folio. Melbourne, 1856.
—————	Second and Third ditto, ditto. Nos. 58a and 3. Folio. Plates. Melbourne, 1856-7 and 1858.
—————	Mining Resources of the Colony of Victoria. Report of the Commissioners appointed by H. E. the Officer administering the Government, to inquire into the Mining Resources of the Colony. No. 21a. Folio. Melbourne, 1856.
—————	Ditto, Second Progress Report of the Commissioners, &c. No. 84. Tract. Folio. Melbourne, 1856-7.
—————	Mining Surveyors' Reports. Furnished by the Mining Surveyors of Victoria to the Board of Science. Nos. 9 to 32. 8vo. Melbourne, 1860-61.
—————	New Lunatic Asylum. Report on the proposed New Lunatic Asylum. No. 38a. Tract. Folio. Map. Melbourne, 1856-7.
—————	Public Buildings. A Return of the Actual Amount Expended from the Various Votes for Public Buildings, from the 1st January to the 30th October, 1851, inclusive, showing also the Amount Voted for each particular Building. Tract. Folio. No place, 1851.
—————	Ditto, ditto, from the 31st October to the 31st December, 1851, inclusive, showing also the Amount Voted for each Building. Tract. Folio. Melbourne, 1852.
—————	Report of the Royal Commission appointed to inquire into the best Method of Removing the Sludge from the Gold Fields; together with Proceedings of the Commission, Minutes of Evidence, and Appendices. No. 7. Folio. Plates. Melbourne, 1859.
—————	Report of the Royal Commission on Harbour Improve-

DONORS.

TITLE OF WORK.

- ments, and a River and Harbour Trust to H. E. Sir Henry Barkly, K.C.B. No. 5. Folio. Melbourne, 1860.
- Department of Public Works, Melbourne. Report on the Murray River District, in reference to its Geology, Soil, Prospective Resources, Proposed Means of Inter-communication, etc. By C. Hodgkinson. No. 16. Tract. Folio. Melbourne, 1856.
- Reservoirs. A.—No. 32. Tract. Folio. Melbourne, 1860-61.
- Results of the Magnetical, Nautical, and Meteorological Observations made and collected at the Flagstaff Observatory, Melbourne, and at Various Stations in the Colony of Victoria. March, 1858, to February, 1859. No. 32. Folio. Melbourne, 1859-60.
- Roads and Bridges. C.—No. 24a. Folio. Melbourne, 1856-7.
- Ditto. C.—No. 4. Folio. Melbourne, 1860-61.
- Ditto, and Sydney Road. Tract. Folio. Melbourne, 1851.
- Sewerage and Water Commission. Report. No. 10. Folio. Melbourne, 1856.
- Statistical Notes on the Progress of Victoria, from the Foundation of the Colony, (1835-60.) By W. A. Archer. 4to. Melbourne. No date.
- Ditto, ditto, First Series. Part II. By W. A. Archer. 4to. Melbourne. No date.
- Submarine Telegraphic Connection between Cape Otway and Tasmania. Second Report of the General Superintendent of the Electric Telegraph, relative to the Survey for laying down the Cable between Cape Otway and Tasmania. No. 27. Tract. Folio. Melbourne, 1858-59.
- Supply of Water to Geelong. Report of Chairman of Geelong Water Company together with Reports of Chemical Investigation and Analyses of Waters in the vicinity of Geelong. No. 78a. Folio. Map. Melbourne, 1856-7.
- Telegraph Stations. A Return of the Actual Working Expenses and Revenue derived from every Telegraph Station in Victoria, during the year 1859. C.—No. 5. Tract. Folio. Melbourne. 1859-60.
- The Statistical Register of Victoria, from the Foundation of the Colony; with an Astronomical Calendar for 1855. Edited by W. H. Archer. 8vo. Melbourne, 1854.

- | DONORS. | TITLE OF WORK. |
|---------------------|--|
| Douglas, J. N. | A Treatise on Electricity, in Theory and Practice. By A. de la Rive. 3 Vols. 8vo. Cuts. London, 1853-58. |
| East India Company. | Annals of Indian Administration. Vol. VI. Part I. 8vo. Serampore, 1862. |
| ————— | A Classified Catalogue of the Raw Produce exhibited at the Madras Exhibition of 1857, to which is added a few remarks on the best methods of exhibiting Raw Produce. By Lieut. Henry P. Hawkes. 8vo. Cuts. Madras, 1857. |
| ————— | Catalogue of the Museum of the Agra College, at the close of 1854. 8vo. Agra, 1855. |
| ————— | Code of Regulations for the Public Works Department under the local governments of Bengal, the North Western Provinces, and the Punjab; and for the minor administrations under the direct control of the Government of India. 8vo. Calcutta. 1858. |
| ————— | Correspondence on the subject of the Geological Map of India. Compiled by Prof. Greenough. 8vo. Madras, 1857. |
| ————— | Cyclopædia of India, and of Eastern and Southern Asia, Commercial, Industrial and Scientific; Products of the Mineral and Animal Kingdoms, useful Arts and Manufactures. Edited by E. Balfour. 8vo. Cuts. Madras, 1857. |
| ————— | First and Second Annual Reports of the Great Indian Peninsula Railway Company, for the years 1854-55, 1855-56. 8vo. Map. Bombay, 1857. |
| ————— | Government Central Museum, Madras, Catalogue. Mollusca of Southern and Eastern Asia, containing— Part I. Madras Shells. Part II. Shells from Asia generally. Part III. Shells presented by W. Theobald, Esq. By E. Balfour. Tract. 8vo. Madras, 1858. |
| ————— | Kurrachee Harbour. Second Report of James Walker, LL.D., F.R.S., L. and E., dated 28th October, 1858; and Report of the Survey of 1857-8, by W. Parkes, addressed to Mr. Walker. 8vo. Map. Westminster, 1858. |
| ————— | Letter from Colonel A. Cotton to H. Forbes, March 5, 1858. "Memorandum on the Ports of Malabar, &c., the proposed Neilgherry Tanks, and the project for a Canal or light Railway from Trichinopoly to Negapatam as called for by the Honorable Court." Tract. Folio. No place. 1858. |
| ————— | Memorandum of Colonel A. Cotton, on the Bombay |

- | DONORS. | TITLE OF WORK. |
|---------------------|---|
| | Minutes of the Members of Council on a Railway from Beikul Harbour to Hyderabad, prepared in obedience to orders of the Madras Government, 13th September, 1858. Folio. No place or date. |
| East India Company. | Memoirs of the Geological Survey of India. Vol. III., Part I. Published under the direction of T. Oldham, LL.D. Royal 8vo. Plates. Calcutta, 1861. |
| ————— | Memoirs of the Geological Survey of India. Palæontologia Indica. I. The Fossil Cephalopoda of the Cretaceous Rocks of Southern India, (Belemnitidæ-Nautilidæ.) By H. F. Blandford. 4to. Plates. Calcutta, 1861. |
| ————— | II. 1.—“The Fossil Flora of the Rajmahal Series, Rajmahal Hills, Bengal.” By T. Oldham, and J. Morris. 4to. Plates. Calcutta, 1862. |
| ————— | N. W. Coast of Borneo. Observations on the Physical and Political Geography of the Districts lying between Gaya Bay and the Tampasuk River. With a Map. Tract. Folio. London. 1859. |
| ————— | Proceedings of the Madras Government, Public Department, from 5th to 21st October, 1859. Tract. Folio. Madras, 1859. |
| ————— | Report of the Committee on the Drainage of Calcutta, 1857. 8vo. Plates. Calcutta, 1857. |
| ————— | Reports on the Districts of Midnapore [including Hijelee] and Cuttack. By H. Ricketts. 8vo. Maps. Calcutta, 1858. |
| ————— | Report on the Engineering operations at the Siege of Lucknow, in March, 1858. By the Chief Engineer, now Brigadier General Sir R. Napier, K.C.B. Folio. Maps, 1859. |
| ————— | Reports on the Government Central Museum, Madras, By Surgeon E. Balfour. 8vo. Madras, 1853. |
| ————— | Reports of the Juries of the Madras Exhibition of 1855. Royal 8vo. Madras, 1856. |
| ————— | Report on two Brick-making Machines sent out to India in 1851, as called for in the Honble. Court's Military Dispatch No. 171, dated the 29th June, 1858, para. 6. With a few Remarks on Brick-making by Machinery generally, with special reference to its successful working in India. By R. S. Sterling. 8vo. Cuts. Alipoor, 1858. |
| ————— | Statement showing the number of miles of Roads or Navigable Canals opened for Traffic in each Presidency |

DONORS.

TITLE OF WORK.

- and administration, under the Government of India since the year 1848. Folio. Calcutta, 1859.
- East India Company. Mr. D. Smith's Report of the Sigrowlee and Kurhurbaree Coal Fields. Tract. 8vo. Calcutta, 1857.
- List of Members, Officers, &c., with the Report of the Visitors for the year 1860. 8vo. London, 1861.
- Ecole des Mines. Annales des Mines. 5^{ème} série. Tomes XIX. and XX. 8vo. Plates. Paris, 1861.
- Ferrel, W. through the Smithsonian Institution. The Motions of Fluids and Solids, relative to the Earth's surface; comprising applications to the Winds and the Currents of the Ocean. By W. Ferrel. 4to. Cuts. New York and London, 1860.
- Finch, E. Description of E. Finch's proposed improvements in the Metropolis. Tract. 8vo. Plate. London, 1861.
- FitzRoy, Rear-Admiral. Station instructions for Meteorological Telegraphy. 8vo. Cuts. London, 1862.
- Fletcher, L. E. Association for the Prevention of Steam Boiler Explosions. Report of the Committee of Management, to be presented to the subscribers at the Seventh Annual Meeting. 8vo. Map. Manchester, 1862.
- Förster, C. F. L. Allgemeine Bauzeitung mit Abbildungen. Von C. F. L. Förster. Heft 1-3. 4to. Folio Atlas of Plates. Wien, 1862.
- Franklin Institute. Journal. Vol. XLII., and Vol. XLIII., Nos. 1-5. 8vo. Cuts. Philadelphia, 1861-2.
- Galton, Captain D. Correspondence respecting the establishment of Telegraphic Communications in the Mediterranean and with India. Folio. Map. London. No date.
- General Report of the Commissioners appointed for improving; the Sanitary condition of Barracks and Hospitals. Folio. Cuts. London, 1861.
- Geological Society of Dublin. Journal, Vol. IX. Part I., 1860-61. 8vo. Plates. Dublin, 1861.
- Geological Society of London. Quarterly Journal. Vol. XVII., Nos. 67, 68. Vol. XVIII., Nos. 69, 70. 8vo. Plates and Cuts. London, 1861.
- Gibbs, J. Cotton Cultivation in its various details, the Barrage of Great Rivers, and instructions for Irrigating, Embanking, Draining, and Tilling Land in tropical and other countries possessing high thermometric temperatures, especially adapted to the improvements of the Cultural Soils of India. By J. Gibbs. 8vo. Plates. London, 1862.

- | DONORS. | TITLE OF WORK. |
|--|---|
| Gilbart, J. W. | Lectures on the History and Principles of Ancient Commerce. By J. W. Gilbart. 8vo. Portrait. London, 1853. |
| ———— | The Prize Essay on the application of recent inventions collected at the Great Exhibition of 1851, to the purposes of practical Banking. By Granville Sharp. 8vo. Portrait. London, 1852. |
| Gordon, A. | Lighthouses and Beacons of the British Colonies ; what is required for them, and for their administration. In two letters addressed to the Right Hon. T. Milner Gibson, M.P. By A. Gordon. Tract. 8vo. Cuts. London, 1861. |
| Grantham, R. B. | An Act to amend the Law relating to the Drainage of Land for Agricultural purposes. Folio. London, 1861. |
| Hamilton, Rear-Admiral W. A. B. | Report of the Commissioners appointed to inquire into the condition and management of lights, buoys, and beacons, together with a letter from Rear-Admiral W. A. B. Hamilton, and Appendix and Index. Folio. Plates. London, 1861. |
| Harris, Sir W. Snow. | National Defences ; The great question of the Day. By Sir W. Snow Harris. Tract. 8vo. Plates. London, 1862. |
| Haughton, the Rev. S. | Account of Experiments made to determine the velocities of Rifle Bullets commonly used, By the Rev. Samuel Haughton. Tract. 8vo. Dublin. 1862. |
| Herschel, Sir J. F. W., Bart. | Considérations sur les Lois qui président à l'accomplissement des Phénomènes Naturels rapportées à l'attraction Newtonienne et basées sur la synthèse des actions moléculaires exposée dans les mémoires publiés jusqu'ici. Par M. Séguin, aîné. 8vo. Cuts. Paris, 1861. |
| ———— | A Manual of Scientific Inquiry, prepared for the use of H.M. Navy : and adapted for Travellers in general. Edited by Sir J. F. W. Herschel, Bart. 8vo. Maps and Cuts. London, 1849. |
| H. E., the Minister for Trade, through B. Hebler. | Statistische Nachrichten von den Preussischen Eisenbahnen, Bearbeitet auf Anordnung Sr. Excellenz des Herrn Ministers für Handel, Gewerbe und öffentliche Arbeiten von dem technischen Eisenbahn-Büreau des Ministeriums. Bands V. to VIII. Folio. Plates. Berlin, 1858-61. |
| H. M. Government, through the Director General of the Geological Survey. | Report on the Geology of Cornwall, Devon, |

- | DONORS. | TITLE OF WORK. |
|-------------------|--|
| | and West Somerset. By H. T. de la Beche. 8vo. Plates. London, 1839. |
| H. M. Government. | Records of the School of Mines, and of Science, applied to the Arts. Vol. I., Part III. On the Mines of Wicklow and Wexford. By W. W. Smyth. 8vo. Plates and Cuts. London, 1853. |
| ————— | Vol. I., Part IV. Statistics of the Produce of Copper, Tin, Lead, and Silver from the Mines of the United Kingdom, with the exports and imports of these Metals, from 1848 to 1852 inclusive. By R. Hunt. 8vo. London, 1853. |
| ————— | Memoirs of the Geological Survey of the United Kingdom. Figures and Descriptions illustrative of British Organic Remains. Decades. I. to IX. 8vo. Plates and Cuts. London, 1849-58. |
| ————— | Monograph. I. 8vo. With 4to. Atlas of Plates. Cuts. London, 1859-61. |
| ————— | Memoirs of the Geological Survey of Great Britain, and of the Museum of Practical Geology. The Iron Ores of Great Britain. Parts I., II. and III. 8vo. Plates and Cuts. London, 1856-61. |
| ————— | The Geology of the Country around Cheltenham. (Sheet 44.) By Edward Hull. 8vo. Plates and Cuts. London, 1857. |
| ————— | of parts of Wiltshire and Gloucestershire. Sheet 34. By A. C. Ramsay, W. T. Aveline and E. Hull. 8vo. Cuts. London, 1858. |
| ————— | The South Staffordshire Coal-field. By J. Beete Jukes. Second Edition. 8vo. Plates and Cuts. London, 1859. |
| ————— | The Geology of the Country around Woodstock, Oxfordshire. (Sheet No. 45, S. W.) By E. Hull. 8vo. Cuts. London, 1859. |
| ————— | of the Warwickshire Coal-field and the Permian Rocks and Trias of the surrounding District. By H. H. Howell. 8vo. Plates and Cuts. London, 1859. |
| ————— | of the country around Prescott, Lancashire. (Description of quarter sheet 80, N. W. and corresponding 6 in. Maps. Nos. 107 and 108.) By E. Hull. Tract. 8vo. Cuts. London, 1860. |
| ————— | of part of Leicestershire. (Description of quarter sheet No. 63, S. E.) By W. T. Aveline and H. H. Howell. Tract. 8vo. London, 1860. |
| ————— | of part of Northamptonshire (Description |

- | DONORS. | TITLE OF WORK. |
|---------------------------------|---|
| | of quarter sheet, No. 53, S. E.) By W. T. Aveline and R. Trench. Tract. 8vo. London, 1860. |
| H. M. Government. | The Geology of the Leicestershire Coal-field and of the country around Ashby-de-la-Zouch. By E. Hull. 8vo. Plates and Cuts. London, 1860. |
| ————— | ————— of Parts of Oxfordshire and Berkshire. (Sheet 13). By E. Hull and W. Whitaker. 8vo. Plate and Cuts. London, 1861. |
| ————— | ————— of Parts of Northamptonshire and Warwickshire. (Sheet 53, N. E.) By W. T. Aveline. Tract. 8vo. London 1861. |
| ————— | ————— of the Country around Wigan, and Description of Geological Map, 89, S. W., and of the corresponding 6 in. Sheets, 84, 85, 92, 93, 100, 101. Lancashire. By E. Hull. 8vo. Cuts. London, 1860. |
| ————— | ————— around Nottingham. (Quarter sheet 71, N. E.) By W. T. Aveline. 8vo. London, 1861. |
| ————— | ————— of parts of Nottinghamshire, Yorkshire, and Derbyshire. (Quarter sheet, No. 82, N. E.) By W. T. Aveline. 8vo. Cuts. London, 1861. |
| ————— | ————— of the neighbourhood of Edinburgh. (Map 32.) By H. H. Howell and A. Geikie. 8vo. Plates and Cuts. London, 1861. |
| ————— | Report of the Geology of Trinidad, or Part I. of the West Indian Survey. By G. P. Wall and J. G. Sawkins. 8vo. Plates and Cuts. London, 1860. |
| ————— | Memoirs of the Geological Survey of Great Britain and of the Museum of Practical Geology. Mining Records. Mineral Statistics of the United Kingdom of Great Britain and Ireland for 1853, 1854, 1855, 1856, 1858, part II. and 1860. By Robt. Hunt. 8vo. London, 1855-61. |
| Houlston, Wm. | The Circle discerned from the Square, and its area gauged in terms of a triangle common to both. By Wm. Houlston. Tract. 4to. Plate. London, 1862. |
| Hübbe, H., through C. Vignoles. | I. Ueber die Eigenschaften und das Verhalten des Schlicks. II. Von der Beschaffenheit und dem Verhalten des Sandes. III. Von der Bewegung des Wassers im Sande. Folio. Plates. |
| | [Besonderer Abdruck aus der "Zeitschrift für Bauwesen." Jahr. xi., Berlin, 1861.] |
| Huffam, — | Report of J. B. Hartley, Esq., with reference to a proposed Extension of the Dock Accommodation of the Port of Hull. Tract. Folio. Plan. Hull, 1843. |

- | DONORS. | TITLE OF WORK. |
|--|--|
| Institution of Engineers in Scotland. | Transactions. Vol. IV. Fourth Session, 1860-61. 8vo. Plates. Glasgow, 1861. |
| Institution of Mechanical Engineers. | Proceedings. 31st January, May 2nd, July 31st, August 1st. Nov. 7th, 1861, Jan. 30, 1862. 8vo. Plates. Birmingham, 1861-62. |
| Institution of Naval Architects. | Transactions. Vol. II. 4to. Plates and Cuts. London, 1861. |
| I. R. Istituto Lombardo di Scienze, Lettere ed Arti. | Atti. Vol. II. Fasc. 1-14. 4to. Plates. Milano, 1860-61. |
| ———— | Memorie. Vol. VIII. Fasc. 1-5. 4to. Milano, 1860-61. |
| Jackson, F. | Plan of the Town and County of the Town of Nottingham. By F. Jackson. 8vo. Folded Map. Nottingham, 1861. |
| James, Col. Sir H., R.E. | Abstracts from the Meteorological Observations taken at the Stations of the Royal Engineers, in the years 1853 to 1859. By Colonel Sir Henry James, R.E. 4to. London, 1862. |
| ———— | Ordnance Survey. Abstracts of the Principal Lines of Spirit Levelling in Scotland. By Colonel Sir Henry James, R.E. 4to. With Index. Atlas of Plates and Map. London, 1861. |
| Koninklijk Instituut van Ingenieurs. | Verhandelingen van het, 1860-61. Nos. 1-3, 1861-62. Nos. 1 and 2. 4to. Plates. 'sGravenhage, 1861-62. |
| ———— | Uittreksels uit vreemde Tijdschriften voor, de Leden van het. 1860-61, Nos. 1 and 2, 1861-62, Nos. 1 and 2. 4to. Plates. 'sGravenhage, 1861-62. |
| Lawrie, J. G. | On the Operation of Air-Engines. By J. G. Lawrie. 8vo. Plate. Glasgow, 1861. |
| | [Excerpt Minutes of Proceedings Inst. Engineers in Scotland, May 1, 1861.] |
| Lees, J. | Report on the Project of a Dock for St. Helena. Tract. 8vo. St. Helena, 1860. |
| Longman & Co. | The Elements of Mechanism designed for Students of Applied Mechanics. By T. M. Goodeve. 8vo. Cuts. London, 1860. |
| McClean, J. R. | Thames Embankment Commission, 1861. Report of the Commissioners appointed to Inquire into plans for Embanking the River Thames within the Metropolis. With Plan and Appendices. Folio. London, 1861. |
| Mallet, J. W. | On the Chemical and Meteorological Conditions, involved in the successful Cultivation of Cotton. By J. W. Mallet. 8vo. London, 1861. |
| | [From the "Proceedings of the Royal Society of London."] |

DONORS.

TITLE OF WORK.

- Mallet, R. Account of Experiments made at Holyhead (N. Wales) upon the Transit-Velocity of Waves through the local rock formations. By Robert Mallet. 8vo. No place or date.

[From the "Proceedings of the Royal Society of London," June 20, 1861.]

- On Muzzle Swivelling and Hydraulic Gun Mounting. By R. Mallet. Tract. 8vo. Cuts. Glasgow. No date.

[From the "Practical Mechanics' Journal."]

- On the protection of the Bottoms of Iron Ships from concussions and from foulings. By John Grantham, with remarks, by Robert Mallet. 8vo. Cuts. No place or date.

[From the "Journal of the Royal United Service Institution."]

- Medhurst, T. A New Method of conveying letters and goods with great certainty and rapidity by Air. By George Medhurst. 8vo. Plates. London, 1810.

- Mercantile Marine Association. On the Opportunities of advancing Science, enjoyed by the Mercantile Marine. By C. Collingwood. Tract. 8vo. Liverpool, 1862.

- Mesnil-Marigny, J. Du. The Free Trade Question, its solution. By J. Du Mesnil-Marigny. 8vo. Paris, 1861.

- Morin, Général A. Rapport de la Commission sur le Chauffage et la Ventilation du Théâtre-Lyrique et du Théâtre du Cirque Impérial. 4to. Plates and Cuts. Paris, 1861.

- Morton, F. F. Morton's System of Permanent Way Fencing, Iron Telegraph Poles, &c. Folio. Plates. Liverpool, 1861.

- Murray, A. Navy (Dockyard Economy). Minutes of Evidence taken before the Committee of Inquiry on the Economy of H.M. Dockyards; with an Appendix. Folio. London, 1859.

- The Theory and Practice of Ship Building. By Andrew Murray. With portions of the Treatise on Naval Architecture, by A. F. B. Creuze. Steam Ships by Robert Murray. 4to. Plates and Cuts. Edinburgh, 1861.

- Observatory of Cambridge, through the Rev. Prof. Challis. Astronomical Observations made at the Observatory. By G. B. Airy. Vols. I.-VIII. For the years 1828 to 1835. 4to. Cuts. Cambridge, 1829-1836.

- Owen, D. D., through the Smithsonian Institute. First and Second Report of a Geological Reconnoissance of the Middle and Southern Counties of Arkansas, made

- | DONORS. | TITLE OF WORK. |
|---------------------------------------|---|
| | during the years 1857-58, 1859-60. By David D. Owen. 8vo. Plates and Cuts. Little Rock, 1858; Philadelphia, 1860. |
| Parlby, Colonel S. | Endeavours to improve the construction of the War Rocket. By Colonel S. Parlby. Tract. 8vo. London, 1862. |
| Permanent Way Co. | Description of Dr. Boucherie's Patent Process for Preserving Timber from Decay. 8vo. Plate. London, 1858. |
| Plocq, A., through M. Carlier. | Cinq Rôles des Ecluses du Port de Dunkerque dans la Navigation Maritime. Folio. Dunkerque. 1859. |
| ———— | Mémoire sur l'Exécution d'un Pont tournant à deux Volées en tole. Par A. Plocq. 8vo. Plates. Paris, 1859. |
| ———— | Port de Dunkerque. Sept plans par courbes de niveau du Port d'échouage, de l'Avant-post, du Chénel et de la Passe extérieure en 1851-61. Folio. 1861. |
| ———— | Plan d'Ensemble avec l'enceinte de la Ville et le tracé des zones de servitudes militaires. 1862. Folio. Lith. Lille, 1862. |
| Post Master General. | Eighth Report of the Post Master General, on the Post Office. 8vo. London, 1862. |
| Price, G. through R. Stephenson, M.P. | A Treatise on Fire and Thief-proof Depositories and Locks and Keys. By G. Price. 8vo. Plates and Cuts. London, 1856. |
| ———— | A Treatise on Gunpowder-proof Locks, Gunpowder-proof lock-chambers, Drill-proof safes, &c. By G. Price. 8vo. Cuts. London, 1860. |
| Public Library of the City of Boston. | The Eighth and Ninth Annual Reports of the Trustees. Tracts. 8vo. Boston, 1860-61. |
| ———— | Index to the Catalogue of a portion of the, arranged in the Lower Hall. Royal 8vo. Boston, 1858. |
| ———— | Ditto, ditto, in the Upper Hall. Royal 8vo. Boston, 1861. |
| Rankine, W. J. M. | A Manual of Civil Engineering. By W. J. M. Rankine. 8vo. Cuts. London, 1862. |
| Rawlinson, R. | West Ham Local Board of Health. Report on the Completion of the Public Sewerage Works for the District of West Ham, in the County of Essex. By R. Rawlinson. 8vo. London, 1862. |
| Rickards, J. L. | Encyclopédie Technologique. Dictionnaire des Arts et Manufactures, de l'Agriculture, des Mines, etc. 2 Vols. 2 ^{ème} édition. 8vo. Cuts. Paris. No date. |

DONORS.

TITLE OF WORK.

- Rigby, W. through J. Dinnen. Dictionnaire de Marine à Voiles et à Vapeur. Par MM. le Baron Bonnefoux et Paris. 2^{me} édition. 8vo. Plates. Paris. No date.
- Robertson, G. On the Concrete used in the late Extension of the London Docks. By G. Robertson. Tract. 8vo. No place or date.
- [Read before the Royal Scottish Society of Arts, Dec. 10, 1860.]
- Robinson, M. R. Klimatologische Beiträge. Von H. W. Dove Erster Theil. 8vo. Plates. Berlin, 1857.
- Meteorologische Untersuchungen. Von H. W. Dove. 8vo. Plates. Berlin, 1837.
- Royal Artillery Institution. Minutes of Proceedings. Vols. I. and II. Vol. III., No. 1. 8vo. Plates and Cuts. Woolwich, 1858-62.
- Occasional Papers. Vol. I. and Vol. II., Nos. 1-5. 8vo. Plates and Cuts. Woolwich, 1859-60.
- Royal Astronomical Society. Memoirs. Vol. XXX. Session, 1859-60. 4to. Plates. London, 1861.
- Royal Cornwall Polytechnic Society. Annual Reports, 6th, 15th, 16th, 18th, 19th, 22nd, 23rd, and 28th. 8vo. Plates and Cuts. Falmouth, 1838-60.
- Royal Dublin Society. Journal. Nos. 20-23. 8vo. Plates. Dublin, 1861.
- Royal Geographical Society of London. Proceedings. Vol. V. Nos. 3, 4, 5. Vols. VI. Nos. 1-2. 8vo. London, 1861-62.
- Royal Institute of British Architects. Papers read at the Meetings. Session, 1860-61. 4to. Plates. London, 1861.
- List of Members, Report of Council, &c. 4to. London, 1861.
- Royal Institution of Great Britain. Notices of the Meetings. Parts I. and II. 8vo. London, 1851-2.
- Ditto. Part XI. 1860-61. 8vo. London, 1861.
- Royal Scottish Society of Arts. Transactions. Vol. V., Part II. Vol. VI., Part I. 8vo. Plates and Cuts. Edinburgh, 1861.
- Royal Society of Edinburgh. Proceedings. Vol. IV. No. 53. Session 1860-61. 8vo. Cuts. Edinburgh, 1861.
- Royal Society of London. Proceedings. Vol. XI. Nos. 44-9, 8vo. London, 1861-2.
- Transactions, for the year 1861. Vol. CLI. 4to. Plates. London, 1861-62.

- | DONORS. | TITLE OF WORK. |
|-----------------------------------|---|
| Royal United Service Institution. | Journal. Vol. IV. No. 16.
Vol. V. No. 20. 8vo. Plates and Cuts. London, 1861. |
| Russell, J. Scott. | The Fleet of the Future in 1862 ; or, England without a Fleet. By J. Scott Russell. 8vo. 2nd edition. London, 1862. |
| Sabatini, D. | Grand Canal Maritime à travers le Duché de Slesvig, unissant la Mer du Nord à la Mer Baltique, Projet de Domenico Sabatini de Naples. Tract. Folio. Naples et Elsenieur, 1859. |
| Scott, Commander. | Naval Ordnance. By Commander Scott, R.N. Tract. 8vo. Plates. No place or date.
[From the "Journal of the Royal United Service Institution."] |
| ————— | The Progress of Ordnance Abroad, compared with that of Ordnance at Home. 8vo. Plates. London, 1862.
[From the "Journal of the Royal United Service Institution," vol. vi.] |
| Scott, Capt. H., R.E. | Limes and Cements : their nature and properties. By Captain Scott, R.E. Tract. 8vo. No place. 1861. |
| Scott, M. | On Projectiles and Guns. By Michael Scott. Tract. 8vo. Cuts. London, 1862. |
| Siemens, C. W. | Outline of the Principles and Practice, involved in dealing with the electrical conditions of Submarine Electric Telegraphs. By W. and C. W. Siemens. Tract. 4to. Cuts. London. No Date.
[Read before the British Association, Section A. Oxford, July 3, 1860.] |
| ————— | Regenerative Gas Furnaces. By C. W. and F. Siemens. Tract. 8vo. Plate. Glasgow. No date. |
| Smithsonian Institution. | Annual Report of the Board of Regents, showing the Operations, Expenditures, and Condition of the Institution for the year 1859. 8vo. Cuts. Washington, 1860. |
| Smyth, S. R. | A Short Treatise on the Construction of Steam Boilers, and a description of Smyth's Patent Corrugated Retort Boiler, applicable for Land, Marine, Locomotive, and Circulation Engines. By S. R. Smyth. 8vo. Plate. London, 1861. |
| Société des Ingénieurs Civils. | Mémoires et Compte-Rendu des Travaux. Jan., Fév. et Mars, 1862. 8vo. Plates. Paris, 1862. |

- | DONORS. | TITLE OF WORK. |
|--------------------------------|--|
| Sowerby, W. | Selections from the Records of the Government of India, (Public Works Dep.) No. 26. Report on the Government Ironworks at Kumaon, with Plans, Specifications, and Estimates for establishing Ironworks in Kumaon, and remarks on the Iron Deposits of the Himalayas. By W. Sowerby. 8vo. Plates. No place, 1859. |
| Stanford, E. | Recollections of A. N. Welby Pugin, and his Father Augustus Pugin; with notices of their Works. By B. Ferrey. 8vo. Plates and Cuts. London, 1861. |
| Statistical Society of London. | Journal. Vol. XXIV. 8vo. London, 1861. |
| Stephenson, H. P. | Encyclopædia Britannica, or Dictionary of Arts, Sciences and General Literature. Eighth Edition. Vols. I.-XXI. Index. 4to. Plates. Edinburgh, 1860. |
| Stevens, E. A. | The Stevens Battery. Memorial to Congress. Merits of the Battery as unanimously admitted by the Board of Examiners. 4to. Cuts. No place or date. |
| Stevenson, D. | Biographical Sketch of the late Robt. Stevenson. By A. Stevenson. 4to. Portrait and Plate. Edinburgh, 1861. |
| ———— | Notice of the Ravages of the 'Limnoria Terebrans' on Creosoted Timber. By D. Stevenson. Tract. 8vo. Edinburgh, 1862. |
| | [From the "Proceedings of the Royal Society of Edinburgh," vol. iv.] |
| Stewart, W. | Calculations of an Inflexible Iron Bridge, a Beam Bridge, 600 feet span, uniting the arched and the suspension systems; and a Landing Stage, on the River Mersey at Liverpool. By W. Stewart. Tract. 4to. Liverpool, 1861. |
| ———— | Causes of the Explosion of Steam Engine Boilers explained, and means suggested for its prevention. By W. Stewart. Tract. 8vo. 2nd Edition, 1849. |
| ———— | Exposition Universelle de 1855. Mémoire raisonné sur les Ponts Suspendus et Observations Comparatives entre le fer en barre et le fil de fer appliqués à la Construction de ces Ponts, avec une notice sur quelques Ponts de l'antiquité. Par W. Stewart. Tract. 4to. Paris. 1855. |
| ———— | Machine pour Travailler et Polir avec une extrême précision les Verres d'Optique pour Télescopes de toute grandeur. Par W. Stewart. Tract. 4to. Paris, 1855. |
- [1862-63. N.S.]

- | DONORS. | TITLE OF WORK. |
|---------------|--|
| Storer, F. H. | On the Alloys of Copper and Zinc. By F. H. Storer. 4to. Cuts. Cambridge, U. S. A., 1860. |

[From the "Memoirs of the American Academy," New Series, vol. viii.]

- On the impurities of Commercial Zinc, with special reference to the residue insoluble in Dilute Acids, to Sulphur, and to Arsenic. By C. W. Elliot and F. H. Storer. 4to. Cambridge, 1860.

[From the "Memoirs of the American Academy of Arts and Sciences," New Series, vol. viii.]

- Symons, G. J. British Rainfall. On the Distribution of Rain over the British Isles, during the years 1860 and 1861, as observed at about 500 Stations in Great Britain and Ireland. Compiled by G. J. Symons. Tract. 8vo. London, 1862.

- Tennant, Prof. Diamonds. By W. Pole. With a note on the Imperial State Crown and its Jewels. By Prof. Tennant. 8vo. Cuts. London, 1861.

[Reprinted from the "Transactions of the London and Middlesex Archæological Society," vol. i.]

- Thomas, J. L. Notes on the Mines of Rio Tinto, Province of Huelva, Spain. By J. L. Thomas. Tract. 8vo. London, 1861.

- Timbs, J. The Year Book of Facts in Science and Art. By J. Timbs. 8vo. Plate and Cut. London, 1862.

- Treadwell, D. On the Construction of Improved Ordnance. By D. Treadwell. Tract. 8vo. Cambridge, U. S. A., 1862.

- Wallich, Dr. Notes on the presence of Animal Life at vast depths in the Sea; with observations on the nature of the Sea Bed, as bearing on Submarine Telegraphy. By G. Wallich. Tract. 8vo. London, 1860.

- Weale, J. The Rudiments of Civil Engineering, for the use of Beginners, and for those who are in Practice. By H. Law and G. R. Burnell. New Edition. 8vo. Plates and Cuts. London, 1862.

- Webb, E. B. On Iron Breakwaters and Piers. By E. B. Webb. Tract. 4to. Cuts. London, 1862.

- Whewell, Prof. Essay towards a first approximation to a Map of Cotidal Lines. By the Rev. Prof. Whewell. 4to. Plates. London, 1833.

[From the "Philosophical Transactions."]

- Researches on the Tides. 4th series. On the Em-

DONORS.

TITLE OF WORK.

- pirical Laws of the Tides in the Port of Liverpool. By the Rev. Prof. Whewell. Tract. 4to. London, 1836.
[From the "Philosophical Transactions," Part I. for 1836.]
- Whewell, Prof. Researches on the Tides. 6th series. On the Results of an extensive system of Tide Observations made on the Coasts of Europe and America in June 1835. By the Rev. Prof. Whewell. 4to. Plates. London, 1836.
[From the "Philosophical Transactions," Part II. for 1836.]
- Additional Note to the Eleventh series of Researches on the Tides. By the Rev. Prof. Whewell. Tract. 4to. London, 1840.
[From the "Philosophical Transactions," Part I. for 1840.]
- Researches on the Tides. 12th series. On the Laws of the Rise and Fall of the Sea's Surface during each Tide. By the Rev. Prof. Whewell. 4to. London, 1840.
[From the "Philosophical Transactions," Part II. for 1840.]
- 13th series. On the Tides of the Pacific and on the Diurnal Inequality. By the Rev. Prof. Whewell. 4to. Cuts. London, 1848.
[From the "Philosophical Transactions," Part I. for 1848.]
- 14th series. On the results of continued Tide Observations at several places on the British Coasts. By the Rev. Prof. Whewell. Tract. 4to. Cuts. London, 1850.
[From the "Philosophical Transactions," Part I. for 1850.]
- Woodcroft, B. Alphabetical Index of Patentees of Inventions, from March 2, 1617, (14 James I.) to October 1, 1852. (16 Victoriæ). By B. Woodcroft. 4to. London, 1854.
- and Applicants for Patents of Invention, from 1st October, 1852, to 31st December, 1853. By B. Woodcroft. 4to. London, 1857.
- Ditto, for the years 1854-60. By B. Woodcroft. 4to. London, 1855-61.
- Titles of Patents of Invention, chronologically arranged, from March 2, 1617, (14 James I.) to October 1, 1852, (16 Victoriæ). 2 Vols. By B. Woodcroft. 4to. London, 1854.
- Subject Matter Index (made from Titles only) of Patents of Invention, from March 2, 1617, (14 James I.) to October 1, 1852. (16 Victoriæ). 2 Vols. By B. Woodcroft. 4to. London, 1857.

DONORS.	TITLE OF WORK.
Woodcroft, B.	Subject Matter Index of Patents applied for, and Patents Granted, from 1st October to 31st December 1852. By B. Woodcroft. 4to. London, 1861.
-----	Alphabetical and Chronological Index of Patents applied for, and Patents granted, from 1st October, 1852 to 31st December, 1853. By B. Woodcroft. 4to. London, 1860.
-----	Subject Matter, ditto, ditto. For the year 1853. By B. Woodcroft. 4to. London, 1861.
-----	Alphabetical, Chronological, and Subject Matter Indices of Patents applied for and Patents granted, for the years 1854-1860. By B. Woodcroft. 4to. London, 1855-61.
	[There is no subject matter Index for 1860.]
-----	Abridgments of the Specifications, relating to Drain Tiles and Pipes. 8vo. London, 1857.
-----	Manure, 8vo. London, 1857.
-----	Preservation of Food. 8vo. London, 1857.
-----	Sewing and Embroidery. 8vo. London. 1857.
-----	Marine Propulsion. 3 parts. 8vo. London, 1857-8.
-----	Manufacture of Iron and Steel. 3 Parts. 8vo. London, 1857-8.
-----	Aids to Locomotion. 8vo. London, 1858.
-----	Steam Culture. 8vo. London, 1858.
-----	Watches, Clocks, and other Timekeepers. 8vo. London, 1858.
-----	Bleaching, Dyeing, and Printing Calico and other Fabrics and Yarns. 8vo. London, 1859.
-----	Electricity and Magnetism, their generation and applications. 8vo. London, 1859.
-----	Firearms and other Weapons, Ammunition and Accoutrements. 8vo. London, 1859.
-----	India Rubber (Caoutchouc), and Gutta Percha; including Air, Fire, and Water Proofing. 8vo. London, 1859.
-----	the Manufacture of Paper, Pasteboard, and Papier Mâché. 2 parts. 8vo. London, 1859.
-----	Printing. 8vo. London, 1859.
-----	the Production and applications of Gas (excepting Gas Engines). 8vo. London, 1860.
-----	Metals and Alloys (excepting Iron and Steel.) 8vo. London, 1861.

DONORS.	TITLE OF WORK.
Woodcroft, B.	Abridgments of the Specifications, relating to Photography. 8vo. London, 1861.
Wyatt, M. D.	On the present aspect of the Fine and Decorative Arts in Italy, with special reference to the recent Exhibition in Florence. By M. D. Wyatt. Tract. Royal 8vo. London, 1862.

MISCELLANEOUS.

Pearce, J. G. Cubical Specimens of Coal, Iron-stone, Limestone and Cold Blast Cast Iron.

[OFFICERS.]

OFFICERS.—1862-63.

COUNCIL.

PRESIDENT.

JOHN HAWKSHAW, F.R.S.

VICE-PRESIDENTS.

JOHN FOWLER.		JOHN ROBINSON M'CLEAN.
CHARLES HUTTON GREGORY.		JOHN SCOTT RUSSELL, F.R.S.

MEMBERS.

SIR W.G. ARMSTRONG, C.B., F.R.S.		GEO. WILLOUGHBY HEMANS.
NATHANIEL BEARDMORE.		JOHN MURRAY.
JOSEPH CUBITT.		GEORGE ROB. STEPHENSON.
THOMAS ELLIOT HARRISON.		JOSEPH WHITWORTH, F.R.S.
THOMAS HAWKSLEY.		CHARLES VIGNOLES, F.R.S.

ASSOCIATES.

JOHN TOWLERTON LEATHER. | FREDERICK MARRABLE.

AUDITORS.

FREDERICK JOSEPH BRAMWELL | JOHN V. N. BAZALGETTE.

TREASURER.

EDWARD MARJORIBANKS.

HONORARY SECRETARY.

CHARLES MANBY, F.R.S.

SECRETARY.

JAMES FORREST.

HONORARY COUNCILLORS.

PAST-PRESIDENTS.

SIR JOHN RENNIE, F.R.S.		JAMES SIMPSON, F.G.S.
JOSHUA FIELD, F.R.S.		GEORGE PARKER BIDDER.

HONORARY COUNSEL.

CHARLES F. F. WORDSWORTH. |

HONORARY SOLICITOR.

WILLIAM TOOKE, F.R.S.

HONORARY ARCHITECT.

THOMAS HENRY WYATT, F.R.I.B.A.

January 13, 1863.

JOHN HAWKSHAW, President,
in the Chair.

The following Candidates were balloted for and duly elected:—
JOHN WATTS BRASSINGTON, JONATHAN SPARROW CROWLEY,
EDWARD GOTTO, and GEORGE WILSON, as Associates.

No. 1,079.—“On Railway Telegraphs, and the Application of
Electricity to the Signalling and Working of Trains.”¹ By
WILLIAM HENRY PREECE, Assoc. Inst. C.E.

IN the two Papers on “Railway Accidents” by Mr. Brunlees (M. Inst. C.E.) and by Captain Galton (Assoc. Inst. C.E.), read at the Institution during the last session, it was deduced from statistical tables, that the great majority of accidents were attributable to preventible causes, and that of these, 27 per cent. were due to the absence of the Electric Telegraph. No description was however given of, nor was any opinion expressed upon, the various methods and mechanical arrangements in use on different lines for supplying this desideratum. The present Paper is intended to furnish this information, and in it to examine the several systems of telegraphic signalling instruments, hitherto adopted in working trains through long tunnels, over steep inclines, at junctions, on single lines, and in other exceptional cases, with particular reference to their liability of error and imperfect construction.

It has been asserted that the Authors previously referred to should have given a list of those accidents which were ascribable to the presence of the Electric Telegraph, as well as of those consequent upon its absence; for it is argued that, while in some instances it may have prevented accidents, yet in other cases it actually produced them. Several examples could be cited, where accidents have resulted from errors, or mistakes in the transmission of messages, or from misunderstanding and mismanagement in the working of the telegraph. Some Railway Companies have from such causes even abandoned its use, after it has once been fixed. The Clayton Tunnel accident would, in all probability,

¹ The discussion upon this Paper extended over portions of four evenings, but an abstract of the whole is given consecutively.

not have occurred, if there had not been a telegraph at that particular spot. This, however, cannot be considered as any argument against its employment in such localities. It might as well be contended that because a distant signal failed, distant signals should be abandoned. The accident in question was not owing to the existence of the telegraph, but to the inefficient regulations adopted in working it. It is only a proof of an incomplete and inadequate system. An accident involving the death of a passenger produces intense sensation. The strictest inquiry is made into every detail. The telegraph, the staff, the rolling stock, the permanent way, are all in their turn severely criticised, and often censured. But the innumerable hair-breadth escapes, where such disasters have been avoided, flow silently by, unheeded and unknown.

Many illustrations could be adduced of accidents prevented by the use of the telegraph, affording indisputable evidence of its utility when well-regulated. Captain Tyler, in his Report on the Clayton Tunnel accident, says:—

“On the Great Northern Railway, the leading axle of the engine gave way, as the Scotch express train was entering the Tottenham Tunnel on its way to London, on the 27th July 1860, while the train was travelling at a speed of perhaps 60 miles an hour. The engine swerved first to the right, to the down line of rails, and then, after throwing off its left leading wheel, back again to the up line, on which it had been travelling; and it pulled up, in 400 yards or so, with its train across both lines of rails. None of the passengers were hurt, and no one suffered but the fireman, whose thumb and finger were crushed between the hand rail of the engine and the side of the tunnel, as he held on to the former; and it was to the circumstance that the engine thus grazed, and received support from the wall of the tunnel, that the fortunate escape of the passengers was under Providence due. But it was in the neighbourhood of this tunnel that the two Scotch express trains, when they were in time, usually passed each other, the one being due to reach King's Cross at 9.30 p.m., the other to leave it at 9.50 p.m. Happily, the down train was somewhat delayed in starting, by the number of people who presented themselves to travel by it, and the tunnel was comprised in a section of line worked by telegraph. The signalman south of the tunnel received notice from the signalman north of the tunnel of the up train having passed him; and he was made aware of its having entered the tunnel shortly afterwards by hearing a bell ring outside of his hut, connected with a signal north of the tunnel, similar to that at the south end of the Clayton tunnel to which I have had occasion to refer. He observed that it was longer than usual in coming to him, and heard a good deal of whistling from the engine. He found that his telegraph would not work to the northward, and he received notice of the approach of the down train. He therefore took upon himself the responsibility of keeping up his signals against that train, under the apprehension that there might be something wrong in the tunnel; and he thus prevented what might have been a most serious accident, as may be

¹ Vide ‘Reports of the Inspecting Officers of the Railway Department, &c., upon certain Accidents which have occurred upon Railways during the year 1861.’ Folio. Lond., 1862. Page 93.

imagined, when I add, that eight hours were afterwards occupied in clearing the down line before the train for the north could proceed on its journey."

On the other hand, Captain Tyler, in the same Report, says :¹—

"On the Great Northern Railway, on the 14th December 1853, three trains were passing through the Stoke Tunnel, half a mile long, between Corby and Great Ponton. The gradient was a descending one of 1 in 180, and the trains left Corby, which is eight miles to the south of Grantham, at 12.30, 12.35, and 12.45, respectively. The driver of the second of these trains slackened speed very properly, in order to avoid collision with the first; but in endeavouring to prevent one accident he occasioned another, for the third train caught up the second train, and came into collision with it, when it had proceeded about two-thirds through the tunnel, and the guard of the second,—a coal train, was seriously injured.

"In my report of the 3rd January 1854, upon that accident, I was led to state prematurely that I was happy to learn that the tunnel was about to be worked by telegraph, no train being permitted to enter at one end of it until the preceding train had passed out at the other end. This was not adopted sufficiently soon for the exigencies of the case; for within three months afterwards another collision occurred, under precisely similar circumstances, on the 7th March, 1854. Three other trains left Corby for Grantham at 9.36, 9.45, and 10 A.M. The driver of the second train was proceeding cautiously through the tunnel, at a speed of about 14 miles an hour, that he might not run against the first train, and he also was caught up by the third train. After the second collision the tunnel was supplied with a telegraph."

Experience has therefore proved, that there are localities where the adoption of the telegraph for signalling trains is essential. The Author would refer to such places as the Victoria Station, Pimlico; the New Street Station, Birmingham; the Lickey Incline; and the Box, Kilsby, and Stoke Tunnels. But it must not be inferred that, because telegraphs are sanctioned and are used in similar situations, the Author advocates the general and indiscriminate application of the Electric Telegraph, as a primary power, in the working of railways. On the contrary, he does not hesitate to affirm, that the greatest caution should be exercised in its introduction. It should never be employed until its use is imperatively demanded, for the most perfect telegraph is liable to occasional accident and interruption. It is, at the best, like many mechanical arrangements, an uncertain agent. Its defects and probabilities of failure have apparently been reduced to a minimum, but still, implicit reliance cannot always be placed upon its efficiency.

The chief advantage of the Electric Telegraph lies in its secondary, or auxiliary character. In this capacity it is an invaluable agent in the hands of a traffic manager, and no railway should be without it, while upon single lines it is absolutely essential. It hastens the transaction of business, instils order and

¹ *Vide Ibid.* Page 91.

regularity into the running of the trains, and produces punctuality, which is the greatest element of safety in the working of a railway. In moments of emergency, when trains break down and accidents arise, despatch is everything, and the importance of the telegraph is then evident. It fortunately happens that accidents which affect trains very rarely injure the telegraph, and being chiefly required in such urgent cases, it is generally available, and its services are correctly appreciated. But accidents are comparatively few and far between, and a well-regulated telegraph is frequently allowed to fall into disuse. Railway Directors, after a serious accident, are liberal enough in their allowances for telegraphs, and other elements of safety; but long immunity from accident lessens their vigilance, economy prevails, the staff is reduced, and the system again becomes loose and irregular.

The maintenance of an efficient telegraph is undoubtedly costly. Its debits are only too visible—its credits are unknown. But how trifling is its cost when compared with that of a single accident! Its erection is cheaper than that of the fencing of the line. To quote the words of Captain Huish, as reported by Mr. Edwin Clark,¹ "If only one collision of a Passenger Train, with its sickening accompaniments of suffering, to say nothing of its heavy expense, were prevented by a free use of the Telegraph, the immunity would be cheaply attained, and the cost of the improvement be amply compensated."

The question has frequently been mooted, as to the advantage of dividing lines into sections, and of maintaining trains a certain distance apart, in place of separating them by intervals of time, as at present. The Author does not propose to discuss this broad question. He will only allude to it incidentally, and leave it for subsequent discussion. It is one more suited for the Railway Manager than the Telegraph Engineer.

Mr. Cooke, the original introducer of the Electric Telegraph into practical use for commercial operations, was also the first to point out its adaptability for railway purposes. He published an interesting pamphlet in 1842, called "Telegraphic Railways," in which he suggested the principle of working which has been more or less followed in every system that has been subsequently introduced; most of the railway signalling telegraphs being merely mechanical improvements upon Mr. Cooke's idea. He conceived

¹ Vide "Letter to Captain Huish, as to proposed improvements in the Electric Telegraph system, for the service of the London and North-Western Railway Company. By Edwin Clark. March 1854." 8vo. Lond. Page 12.

² Vide "Telegraphic Railways; or, the single way recommended by safety, economy, and efficiency, under the safeguard and control of the Electric Telegraph. By W. F. Cooke." 8vo. Plates. Lond. 1842.

a line of railway divided into sections, each of which should be governed by its own telegraph, and into which no second train should be allowed to enter, until the first had been signalled clear of it. Thus trains, in place of being maintained at a certain presumed safe distance apart by intervals of time, would be kept secure by being divided by an interval of space, which is pronounced by many to be a more satisfactory principle than that almost universally adopted. It is argued, that where fast express and slow goods trains are travelling over the same line, now through a thick fog, now up a wet incline, it is nearly impracticable to maintain that rigid interval of time which is essential to prevent collision; but when two trains, however rapidly, or slowly they may be running, are invariably kept apart by an interval of two, three, or four miles, such accidents are impossible. This Mr. Cooke essayed to obtain by what has since been termed the 'block' system.

The line being divided into sections, each having its own telegraph, every instrument should declare upon its face, whether there was a train upon that length, or not. The needle instrument which he employed (Fig. 1) had two signals—the one to the left signifying 'line clear,' and the one to the right 'line blocked,' or 'train on line.' Whenever a train entered the length A B (Fig. 2), the man at A would signal 'train on line' to the man at B, which would be acknowledged by him, and be maintained, or 'blocked over' until it arrived at B, when B would remove the block, and signal 'line clear.' The man at A would keep his danger signal on until 'line clear' was signalled, and no second train would be admitted until the

Fig. 1.

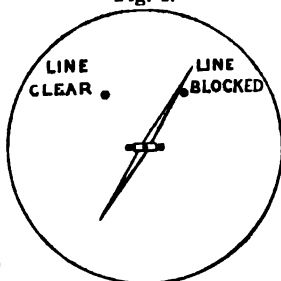
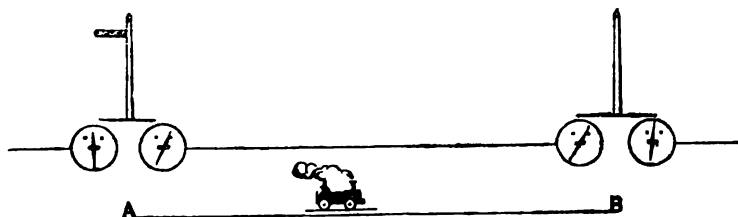


Fig. 2.



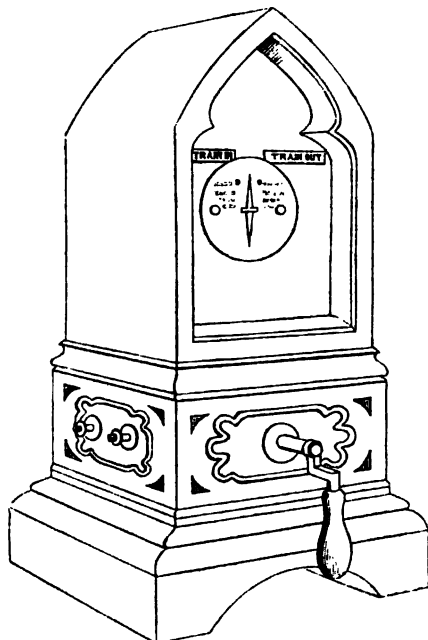
first was out of that length. When 'line clear' was given, he would acknowledge that information, and take down his danger signal. The out-door signal at A would, therefore, be a repre-

sentation of the instrument at B, and become practically a distant signal worked by B; and this, in the Author's opinion, is the principle upon which all telegraphic railway signals should be constructed. It is impossible by mechanical means to work distant signals much beyond 1,000 yards, but by this plan the distance can be increased ad infinitum. It is evident that, whether the telegraph be general, and the line divided into sections, or whether it be local, and only applicable to a tunnel, or an incline, the principle is the same.

This complete system of Mr. Cooke's has been much overlooked. It was established in 1844, on the Eastern Counties line, between Norwich and Yarmouth. But each station contained as many needles as there were stations (five in all) on the line, and thus the position and the progress of every train could be perceived at any moment. It was abandoned for a less elaborate system, in consequence of the expenditure entailed in the maintenance of so many wires and instruments.

Most railway companies, in working their long tunnels, &c., employ simply a single-needle speaking instrument, which by a momentary deflection on one side, or the other, gives the information of the entry, or exit of a train. Figure 3 shows the instru-

Fig. 3.



; Single-needle Instrument.

ment most generally employed;—one beat to the right signifies 'train out,' one to the left 'train in.' It is used indiscriminately for both the up and the down lines.

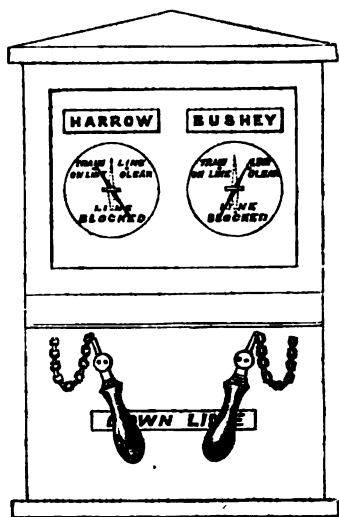
When a train enters a tunnel, the signalman, at the end from which it proceeds, telegraphs to the man at the opposite end 'train in'; and when it arrives at that end, the man there signals back 'train out.' The danger signal is raised while the train remains in the tunnel, and a second one is not allowed to enter until the first has been signalled out. This is a simple but faulty system. It is that which was used at the Clayton Tunnel, and perhaps nine-tenths of the tunnels possessing telegraphs are worked on this principle. Economy probably led to its adoption; but it is to be hoped that another such accident as that which happened on the Brighton line will not ensue, to point out to Railway Companies the danger of using such an indifferent system, when much more perfect arrangements are at their disposal. Even as recently as June last, an accident occurred on the London, Chatham, and Dover line, at the Chatham Tunnel, from the use of a somewhat similar plan.

It might be considered, that the simple information of the presence of a train in a tunnel was sufficient to enable a signalman to work his signals, and to prevent the entrance of a second train upon the same set of rails. But when two or three trains are approaching upon different lines at the same time, it is almost impossible for a signalman to retain in his mind the information conveyed by the momentary movement of a slight delicate needle. Perhaps another train enters the tunnel at the other end, and is signalled at the same time. It arrives, is signalled out, and another is signalled in before the first is out. The signalman gets confused, he has recourse to conversation, and admits a second train while the first is still in the tunnel. An accident occurs, with all its sickening horrors and lamentable results. This cheap and inefficient telegraph is then discarded, and a more improved system adopted. But other companies retain the old system until another accident teaches them the same dearly-bought experience. The excuse is, that it has always answered its purpose, and has hitherto done its duty well. The Clayton Tunnel telegraph worked satisfactorily for ten years, but it failed at last.

The needle system was considerably improved by Mr. Edwin Clark (M. Inst. C.E.) upon the London and North-Western line. He perfected the original scheme of Mr. Cooke. Each set of rails has its own independent telegraph for regulating the out-door semaphore, which thus becomes a distant signal worked by telegraph. Mr. Cooke's double-needle instrument is employed, in which a deflection on one side signifies 'train on line', and on

the other 'line clear'; but it is also made to indicate the occurrence of an accident, and that the line is impassable. A bell or alarum upon an independent wire is used to attract attention. Constant currents of electricity are maintained on the wires by pegging the handles over, as shown in Fig. 4, so as to keep one

Fig. 4.



London and North-Western System.

or other of the signals 'train on line,' or 'line clear,' constantly visible; but if the current is cut off, the needle becomes vertical, and produces a third signal. This third signal signifies 'line blocked and impassable,' that an accident has occurred, or that the telegraph is out of order. It is produced either by an accident to the wires, or by severing a small wire, that descends every alternate pole on the line, within reach of the guard or driver of the broken-down train. Thus when a break-down takes place, instant warning of danger is given to the stations on both sides of the disabled train. This is an ingenious contrivance, but it is questionable whether there be any advantage in its adoption.

Captain Tyler recommends it in his Report on the Clayton Tunnel accident; but it is believed that the London and North-Western Company have abandoned it in their recent extensions. The non-arrival of the train, and the absence of the proper signal at the proper time, acquaint both the signalmen that something is wrong. The rupturing of this wire only gives them the information a little earlier. The guards, who are allowed to cut the wires, either forget, or omit to reconnect them, and in practice the telegraph is rendered useless until the proper man is sent to repair the mischief. Moreover, these disconnecting points cause many interruptions to the working of the circuit, and their original construction is costly. Everything offering the slightest probability of accident to an electrical circuit should be carefully avoided, particularly when it forms part of such a guardian of safety as a signalling telegraph. The London and North-Western Railway, between London and Rugby, is divided into sections, averaging a little more than two miles in length. This is sufficiently close to avoid the necessity of these dangerous disconnecting wires.

It must be observed, that in working this system on the London

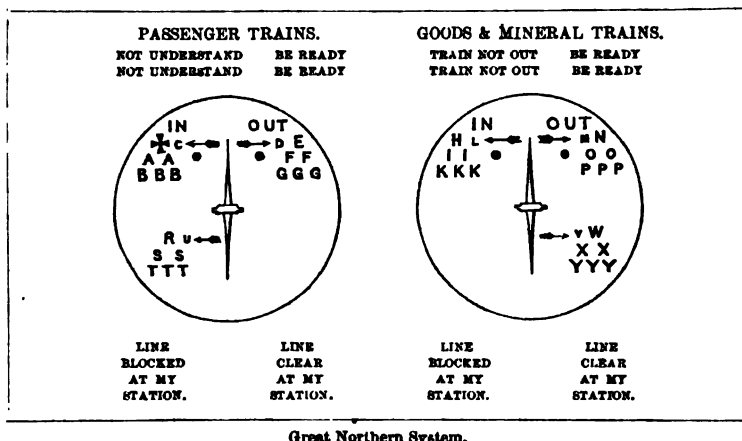
and North-Western Railway, that Company do not strictly adhere to what is termed the 'block' system. They allow two, three, and sometimes four trains to be on the same length at the same time, excepting in the case of tunnels. The signal 'train on line' is simply received as a cautionary signal. The vertical needle alone is accepted as the danger signal. This adulterated form of the 'block' system is not sufficient under all circumstances to prevent collision. An accident which occurred near Wolverton on the 22nd February last will demonstrate this in a most striking manner. A goods train passed Hanslope signal hut, and was duly telegraphed to Wolverton; 'line blocked' was given, and the semaphore was raised to 'danger.' A cattle train immediately followed; and, seeing by the semaphore that a train was on the line before him, the engine-driver slackened speed. A coal train succeeded, the line being still blocked, and received a similar caution. When the second train was close to Wolverton, the third train ran into it, killed one man, injured several, and produced considerable damage. The second train was running too slow, the third too fast.

There are evidently great and serious objections to the working of railways upon the space, or 'block,' in preference to the time system. The London and North-Western, the Great Northern, and other Railway Companies have been compelled to abandon it. The telegraph becomes simply the medium of warning and caution, excepting in the case of long tunnels and steep inclines. It enables all slow trains, or trains behind their time to hasten on, because they are made acquainted with clear lengths before them; while all fast trains, or trains before their time, are informed that there is a train in front of them, and are delayed without being actually stopped. The system in use on the London and North-Western line is undoubtedly a wise precaution against accident, but it is by no means a certain element of safety from collision. Were it strictly carried out, as originally contemplated, it would undoubtedly be so. The Company believe that the line cannot be worked if a distance of two miles is invariably maintained between the trains; but if two miles is impossible, why not adopt a shorter length? And if that be not practicable, then a third set of rails is imperative.

A somewhat similar, but much inferior, system is adopted on the Great Northern Railway. The two needles in each direction are used promiscuously for the up and the down lines. Fig. 5 (page 12) will indicate the signals used. Those on the left-hand needle refer to passenger trains; those on the right hand to engines, and goods, cattle, and ballast trains. One beat to the left on either needle signifies 'train in,' one to the right 'train out.' The signals 'line blocked,' and 'line clear,' are given by holding both needles over

momentarily to those words. No permanent signals are adopted. Every signal is however registered in a record book, so that mistakes and errors in the nature of the signals sent are carefully obviated. An additional warning-signal is also transmitted to the station at the end of the section in advance of that upon which the train is running, to signify that a train may be expected and attention maintained. This is done by pointing the proper needle twice to the right.

Fig. 5.

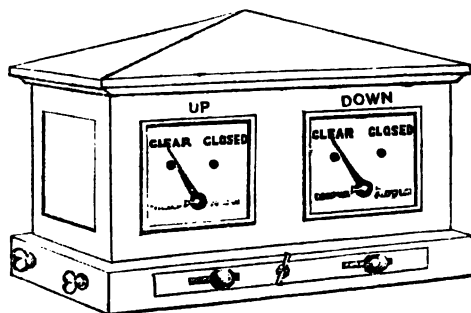


The instrument employed on the London and North-Western, the Great Northern, and indeed, that most generally used for railway signalling purposes, is the needle telegraph. Its signals, except in the case of the 'block' system, are transitory, and therefore dependent upon the memory. They are liable to be reversed by the action of lightning, and 'line clear' may sometimes represent 'train on line,' and 'train in' may mean 'train out.' It is moreover capable of being used as a medium of conversation, which is by some considered objectionable in a telegraph employed solely for the regulation of trains. If it is required for conversational purposes, which, in the Author's opinion, is a questionable practice, although recommended by the Government Inspectors, a separate wire should be erected for that object; but that employed to regulate the distant signals should never be used for anything else. The Clayton Tunnel accident is a remarkable instance of the danger of conversing upon the signalling telegraph. Confusion arose, and the accident ensued. The same confusion might have arisen if a separate wire had been employed. On the other hand, speaking telegraphs are unquestionably of service

at times. An instance of their value was shown on the London and North-Western line in June 1860. The driver of a goods train stopped at Wolverton, and told the signalman there he was afraid something was wrong with the line near Roade. A message was instantly sent to Hanslope, from thence to Ashton bank, and from there to Roade. The line was examined, a rail was found to be displaced, and the mail train was stopped just in time to save, probably, a disastrous accident. All this was effected in ten minutes. It may be added, that the men were self-instructed in the knowledge of telegraphing, as the use of this instrument for speaking purposes was not contemplated; indeed, it was forbidden. In a system like that on the London and North-Western line, the Author would prefer a separate speaking telegraph connecting several signal boxes in one circuit, and totally distinct from the signalling instruments.

The objections to the needle telegraph, as regards its transitory signals, its liability to reversal and demagnetisation by lightning, and its convenience for conversational purposes, are partially avoided in Mr. Bartholomew's and Mr. Tyer's (Assoc. Inst. C.E.) systems. Mr. Bartholomew's (Fig. 6) is employed on the London, Brighton,

Fig. 6.



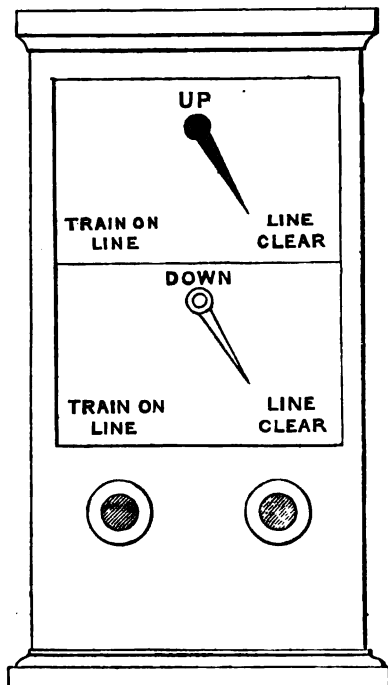
Mr. Bartholomew's System.

and South Coast Railway; Mr. Tyer's (Fig. 7, page 178) on the North London, South-Eastern, and several other lines. Every instrument has an indicator for each set of rails, with two signals, the one signifying, 'line clear,' the other 'train on line.' Tyer's instrument has separate indicators for those signals which are sent and for those which are received. The signalman can see by the upper indicator the last signal received at his station, and by the lower one the last signal transmitted. The indications of both these instruments are constant, and can, therefore, as in Mr. Clark's, be referred to at any moment. This constant deflection is maintained in Bartholomew's, by gravity—in Tyer's, by
[1862-63. N.S.]

N

permanent magnetism. In Tyer's instrument the signal at one station can only be altered and maintained by the man at the distant station. In Bartholomew's this property is wanting. Tyer's system has been highly eulogised by the Board of Trade. Both are supplied with bells, or gongs, so that attention is always attracted by sound to the transmission of any signal. In Bartholomew's the down line bell is of a different note to that of the

Fig. 7.



Mr. Tyer's System.

up line. In Tyer's a gong is used for the one and a bell for the other. A code of signals is adopted, by which a varying number of beats on the bell conveys certain information. Thus:—

Acknowledgment . . .	1 beat
Passenger Train . . .	2 "
Goods do. . .	3 "
Express, or Engine . . .	4 "
Obstruction on Line . . .	5 "
Testing Signal . . .	6 "

Both instruments are worked on precisely the same plan as the

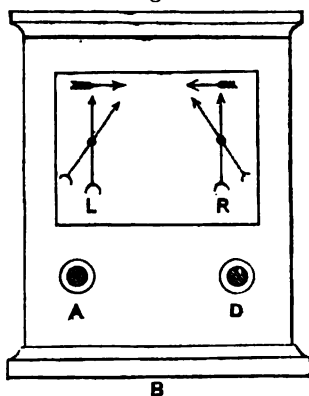
block system, viz: as though they were distant signals. No train is allowed to enter a length unless the index shows 'line clear.' If clear it is signalled on the bell, is allowed to proceed, and the index is thrown over against the admission of any succeeding train.

On other lines systems are at work which differ in some respects from those already described. On the South-Eastern Railway Mr. C. V. Walker has established a system of signalling by bells alone, with a code somewhat similar to that adopted by Mr. Tyer. He dispenses entirely with any index, and depends solely upon the information conveyed by the sound of the bell. It is used principally to give warning of the approach of trains; and not, as in the 'block' system, to regulate the signals. Every train is signalled 'out,' and 'in.' The bells are so connected, that they can be sounded from any point of the line, and thus information of an accident is at once transmitted to the stations on each side. It must be stated in justice to Mr. Walker, that his system was perfect, and in use, long before the introduction of either Mr. Tyer's, or Mr. Bartholomew's, and if the indicating apparatus be removed from them, Mr. Walker's plan remains.

In France a method of signalling (Fig. 8) is employed, which does not differ essentially from the 'block' system previously described. It is the invention of M. Regnault of the Western Railway. Bells are not used. The needles have only one deflection, in the direction shown. The vertical position indicates 'line clear,' when deflected 'train on line.' The needle L denotes a train departing from A; R, one arriving from B. L is called the 'repeating' and R the 'indicating' needle. When a train proceeds from A to B, the man at A presses the key D, which transmits a current to B, and deflects the needle L as shown.

The needle remains deflected, as in Tyer's instrument, by the action of a permanent magnet. It also, by an ingenious contrivance, brings the battery into play at B, and sends a current back to A, which constantly deflects the needle L; thus blocking the needle over by a self-acting arrangement, and not by hand as in Clark's. The current flows until the arrival of the train at B, when the needle at B is restored to its normal position by the pressure of the key A, the current being removed, and the needle at A restored to 'line clear.' This instrument has many defects which render it inferior to those in use in England. The plan of

Fig. 8.



Regnault's System, Western Railway of France.

blocking over by self-adjusting mechanism is highly objectionable, besides which, the signals are completely under the control of either man. In the English 'block' systems, the signal at one station can only be altered by the man at the other; but in this instrument 'train on line,' and 'line clear,' can easily be substituted without the possibility of detection. The French use also, on some lines, an instrument fixed permanently, at distances of about two miles apart, by which an alarm is sounded at each station on both sides when accidents occur. They are called '*appareils de demande de secours*.'

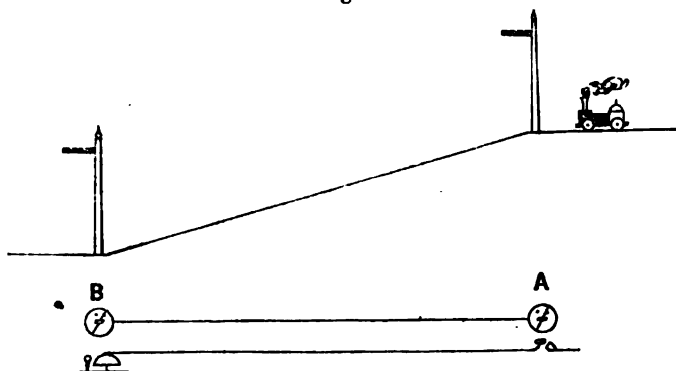
In Germany, where the trains are few and far between, and where level crossings are numerous, bells are fixed along the line at short intervals. All the bells between two stations are rung simultaneously on the departure of every train from one station to another. They act simply as a warning to gatekeepers, signalmen, and platelayers. Such a plan is evidently impracticable in England.

It must be observed that in all these systems, the two signals, denoting such different meanings—the one the element of safety, the other the source of danger,—are not sufficiently distinct in their opposite indications. On the line, the semaphore arm, at one time elevated, and at another depressed, is unmistakeable in either position. So with a disc, at one time visible, at the next moment obscured, no error can occur. But a thin index, in a dark, dismal hut, with only a slight movement from one side to the other, whether it be momentary, or permanent in its deflection, is not decided enough to avoid misconstruction, when examined hastily. In electric, as in out-door signals, nothing should be left in doubt, or to chance. The two opposite signals should be perfectly distinct. It cannot be said to be so in any one of the instruments that have been described. Mr. Highton, in 1854, endeavoured to obviate this in an instrument which is exhibited, and Mr. Spagnoletti, of the Great Western line, has recently introduced the same method on the Metropolitan Railway. It is a modification of the needle instrument, and is used on the 'block' principle. The front of the dial has a slot about one inch and a half long by one inch wide, which allows one of the signals to be visible. The signals consist of bold printed words—the one 'line clear,' the other 'train on line.' The former is printed on a white, the latter on a red ground. They are so attached to the needle, that when it is deflected to the right, 'line clear' is shown, and when to the left 'train on line.' When no current flows neither is fully visible. Although this is to some extent an improvement upon existing needle instruments, yet it removes none of the objections to that system. The needle is still subject to

reversal. One instrument may show 'line clear,' whilst that with which it is in correspondence is signalling 'train on line.' It requires considerable power to work it, and is on that account liable to be deranged.

It must also be remarked, that the signals of all these systems are so dissimilar to those used out of doors, that the signalmen have to master and comprehend two different and distinct methods of signalling—the one, line signals, to regulate the trains,—the other electric signals, to regulate those of the line. This with uneducated men, is always a matter of difficulty, and generally results in confusion in moments of danger, when clearness of mind and confidence are essential. There is no reason why electric signals should not correspond precisely to outdoor signals. An electric signalling instrument is for all practical purposes a distant signal worked by electricity. The bell corresponds to the whistle of the engine, the instrument to the distant signal. In Fig. 9, which represents a steep incline, down which no train

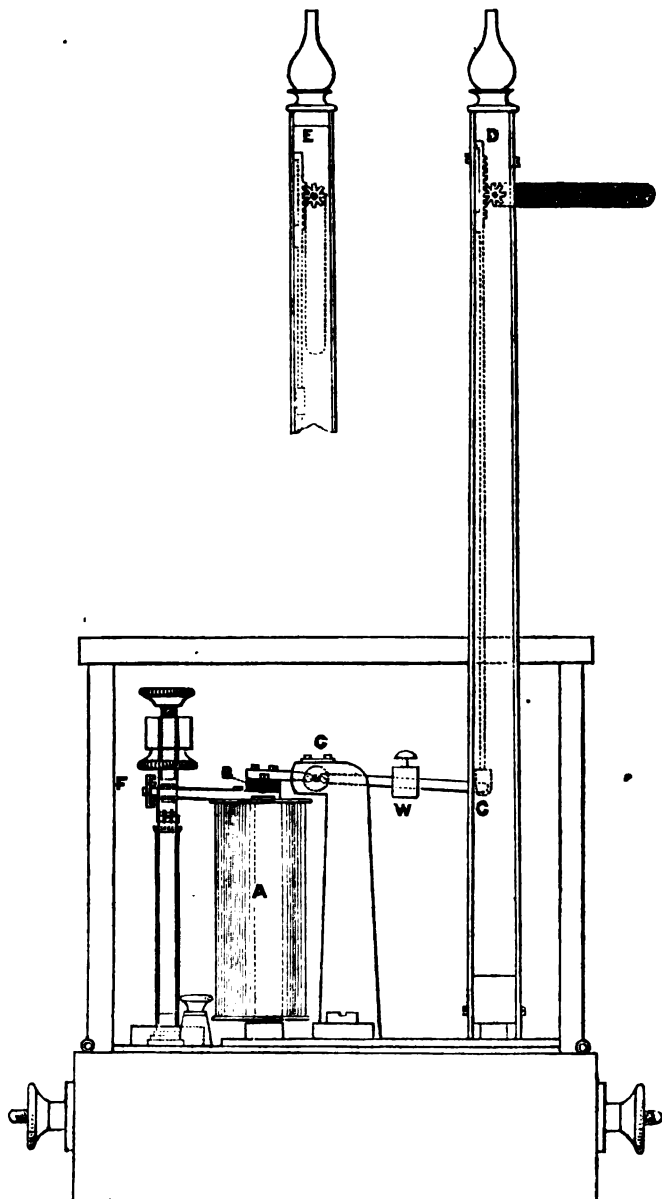
Fig. 9.



must go until the first train is signalled clear, the telegraph instrument is always set at 'line blocked,' until it is asked to be taken off by the bell from A. It can only be altered by the man at B. It is therefore a distant signal worked by B. A makes his outdoor signals correspond precisely with those of his instrument; and thus, though A and B may be miles apart, the signals at A are practically under the control of B, and become distant signals worked by him.

Now, instead of having a needle instrument like Clark's, or an indicating instrument like Tyer's or Regnault's, the Author employs a system which consists of an exact counterpart, on a small scale, of the signals used on the line, and the instrument for which is worked precisely in a similar manner. If a semaphore be used

Fig. 10.



Mr. Preece's System.

on the line, he employs a miniature semaphore, whose arm is raised and lowered by electrical agency. If a disc, then he has a disc, whose half revolutions are effected by the same power. Whatever signal be adopted on the line the same is represented indoors. Bold unmistakeable signals are thus obtained, whose opposite meanings cannot be misread, and confusion is avoided, not only by their distinctness but by their assimilation to those of the line; whilst confidence is assured by their perfect comprehension by the signalmen, and by their inability to cause misunderstanding. The electric signals are worked on precisely the same plan, and nearly by the same means as the outdoor signals—electric force only being substituted for mechanical power.

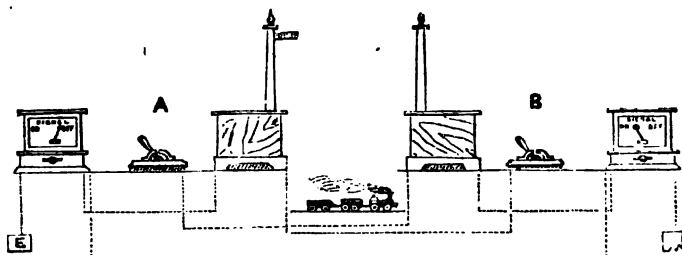
Fig. 10 explains the construction of the semaphore. The electro-magnet A, when traversed by an electric current, attracts the armature B. This armature is attached to a lever B C, centered at G, and connected with the rod C D. The movement of this rod, produced by the attraction of the armature B, respectively lowers or raises the semaphore arm E, by means of the rack and pinion movement D. The ascent of the rod is effected by the action of the electric current; its descent, and therefore the elevation of the arm, is maintained by the weight W. Thus, every current of electricity transmitted through the electro-magnet lowers the semaphore arm E, and this arm can be kept in a depressed position as long as a current flows. By a simple alteration of the rack and pinion movement, the attraction of the armature can raise instead of lower the semaphore. But the other construction is preferred, as in the event of any accident, the danger signal is at once exhibited. When at rest the signal is at danger, and it is only when a current is flowing that the 'all-right' signal can be shown. The weight W is adjustable, so that the instrument can be worked with the most delicate currents, and the danger signal is as easily lowered at a hundred miles as at one mile. It also registers its own signals by means of the contact piece at F. Whenever the armature is attracted, the piece F is brought into contact with A, another current is transmitted on the wire, which rings a bell and indicates that the signal is on, or off, as the case may be. This is also shown by an index on the bell. (Fig. 11, page 184.) The 'all-right' signal being maintained by a constant current, should an accident arise either to the train, or to the wire, the danger signal is immediately shown.

In every respect this system is worked like either of the 'block' systems, excepting that in place of having an indicator pointing to 'line clear' or 'line blocked,' an 'all-right' or 'danger' signal is shown, corresponding to the signals used out of doors. It may be remarked that the machinery is of the most simple character,

almost incapable of derangement, and, if deranged, reparable by an uneducated pointsman. The signals are unmistakeable; indeed it seems evident, that if a system of signalling is found sufficient to work the trains by manual power, that same system must be equally efficient when manipulated by electrical agency.

The manner in which a tunnel, or a section of line would be worked is seen in Fig. 11. A train has just proceeded from A

Fig. 11.



to B. A signals 'train in' on the bell. B replies by raising the semaphore at A, and he maintains it in that position until the train arrives, when he lowers it again. A raises his outdoor semaphore, at the same time making it correspond exactly with his indoor instrument. While the semaphore is raised no second train can be admitted. The index on the bell at B shows the condition of the semaphore at A, so that the signalman has a perfect knowledge of what he is doing. It will be perceived that this is worked precisely as if it were a distant signal. The bell, like the whistle of the engine, gives warning of the approach of a train; the key, like the lever handle, raises the signal; the indicator, like a signal within view, shows that it has acted properly. Everything is within the control of the signalman. If an accident occurs, either to a train, or by the breaking of the wires, the danger signal is shown at once on both sides; everything is stopped and security is obtained.

This instrument has been in use since March last, in working the trains on the London and South-Western Railway, on the incline between the Queen Street and the St. David's Stations, Exeter. It has never once failed. The outdoor signals, on the contrary, have received frequent attention, and the speaking needle telegraph between the same points has been demagnetised and disordered on more than one occasion. It is now in use at several other points, and affords great satisfaction.

The different systems which have been described may here be advantageously compared and their relative superiority discussed.

It will be sufficient for the purpose to confine this to the London and North-Western, Mr. Tyer's, and the London and South-Western systems. Every other is a modification of one of these.

Mr. Edwin Clark (M. Inst. C.E.), in an interesting report, addressed to the London and North-Western Railway Company upon improvements in their telegraphic system, remarked:—

“The following conditions should, I think, be insisted upon in any application of a Telegraph to Railway purposes:—

“1st. The machinery employed must be of the most simple and evident description, not liable to derangement, and easily repaired.

“2nd. The Signals must be simple and few, and so distinctive that no mistakes can occur.

“3rd. No dependence must be necessarily placed on the memory of the person in charge, and the Signals should be permanent and not temporary, or liable to misconstruction or neglect from the absence of the attendant.

“Lastly, and more particularly, no accident should be actually caused by the derangement of the apparatus, or the absence of the Signal-man, but such absence or derangement should merely cause the delay of a Train.”

In the first place, the needle instrument is unquestionably of the simplest and most evident description, but it is liable to derangement. Lightning, the great enemy of telegraphs, soon puts it ‘hors de combat;’ and though it is without difficulty remagnetised, still in the hands of rough men its delicate pivots and weak axles are easily injured.

Tyer's instrument is very simple in construction; but being kept under lock and key, no derangement can be remedied by the man in charge, and a new instrument, or the proper man, must arrive before it is again serviceable. If one needle of Clark's instrument breaks down, there is another to continue the work; but if Tyer's fails, as it is only worked on one wire, no resource is left but the ordinary time-tables. A system worked on one wire, on the score of economy, may be desirable, but on that of efficiency, it is disadvantageous. Moreover, Tyer's instrument is affected by atmospheric electricity—a flash of lightning may make it give a false signal. When ‘train on line’ should be shown, it may indicate ‘line clear.’ It can also be demagnetised and rendered useless. If a wire breaks, or an accident occurs, nothing is shown on Tyer's instrument, but Clark's needles at once give their warning sign. For these reasons the Author considers the needle instrument superior to Tyer's. As regards the semaphore, the construction is more complicated than that of either of the others; but it is so evident, so little liable to derangement, and

¹ *Vide* “Letter to Captain Huish, &c.” Page 17.

so easily repaired, that it may certainly maintain its place by the side of the needle instrument.

Secondly, as respects the signals being simple and few, and so distinctive that no mistake can occur, it is hardly necessary to refer to this particular characteristic of the semaphore.

Thirdly, in neither instrument is any dependence placed upon the memory of the person in charge. The signals are permanent, and not temporary. This permanence is maintained in the semaphore and needle instruments by continuous currents, which are liable at any moment to be interrupted by an accident to the wires, or by the break-down of a train. These two instruments therefore fulfil, in the highest degree, Mr. Clark's last and important condition—that "no accident should be actually caused by the derangement of the apparatus, or the absence of the signalman, but that such absence or derangement should merely cause the delay of a train." By the use of continuous currents instant information is at once transmitted to both ends of the line of any accident to the train, or to the wires, an advantage which Tyer's instrument does not possess, and which alone, independent of its construction, places it below either the semaphore or the needle in point of efficiency. Any system worked by momentary currents upon a single wire must fail to meet this most important condition, and no experienced telegraphist would recommend to any Railway Company, the adoption of a system which is based upon such an erroneous principle. Where permanent currents are employed, it is impossible to transmit false signals; but where momentary currents are used, such false signals are not only possible but frequent. On the North Kent line, where Mr. Tyer's instrument is in use, more than one accident has occurred from this cause. There is not any record of such accidents where permanent currents are employed.

Signor Vincenzi, an officer in the Italian army, had an ingenious contrivance in the International Exhibition, whereby trains in motion might receive and send signals of their approach to stations and trains on the same section of line. Similar self-acting mechanical arrangements have often been suggested, and numerous patents have been taken out, for engines to receive and send signals—for trains to communicate with each other, and to act upon signals—for signals to register themselves on engines and at stations; and, indeed, for every conceivable purpose of giving information and obtaining assistance. But as Mr. Edwin Clark, in the report previously alluded to, very properly observes,¹

¹ *Vide* Ibid. Page 6.

"All the arrangements that have been thus proposed have emanated with a good motive from very ingenious individuals, but they have invariably been from persons who have had no practical experience in the difficulties and intricacies of an actual Telegraph." The Author is not aware of any such single self-acting arrangement having been carried into effect, and been proved to be practically useful.

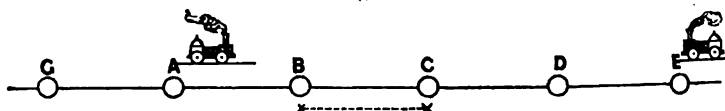
The application of the telegraph to the working of single lines is a subject which demands great attention from railway managers. Where more than one engine is employed, the use of the telegraph is rendered compulsory by the Board of Trade. There are two ways in which this may be done ; either in a primary manner, to rule and regulate the signals of the various stations on the line, by one of the signalling systems previously described, or in a secondary manner, to give notice of the delay of trains, to hurry on one train, to stop another, to alter the authorized passing places, and to prevent the unpunctuality of one train from affecting all the rest. Some single lines are worked on the blocked needle principle, and others with Tyer's instrument. Some are worked on the 'train staff' and 'ticket' system, many by the time-tables alone, the passing places of trains in such cases being altered by some authorized officer by means of the telegraph. The 'train staff' is a sort of truncheon, made of different sizes, forms, and colours ; sometimes supplied to the guard, sometimes placed in a socket on the engine, or tender. Each section of line has one apportioned to it, different and distinct from every other. No train is allowed to travel over that section without its staff. "During the operation of ballasting, or when an accident happens, the 'staff' is supreme. It must be sent for an assisting engine, or must accompany the ballast engine ; and no officer or person in authority can send forward an engine or train during its absence ; but the most hurried director, or the most impatient manager must, as well as a third-class passenger, await its return."¹ With such systems in use collisions are almost impossible. The 'staff' has to be obeyed, or time-tables adhered to, and accidents become unknown.

If punctuality is obtained, everything goes well. But delays arise from many different causes, and the delay of one train throws all the rest into irregularity. The telegraph now becomes available to restore order. Two trains (Fig. 12, page 188) are appointed to meet at B. That coming from A is punctual, that from E is late. It is found that the former can be sent on to C before, or by the time the latter arrives there. C is therefore made the crossing point in place of B, but several precautions have to be

¹ *Vide* "The Quarterly Review," 1862. Vol. 111, page 17.

adopted in carrying this into effect. There must be no mistake in the instructions given. The station-masters, guards, and drivers must all have explicit orders, and the superintendent must know that they have these instructions correctly.

Fig. 12.



On the Shrewsbury and Hereford Railway, a collision with loss of life occurred, in a case of this sort, from the insertion of the word "at" in the copy of a telegram, and from the general want of explicitness in the wording of the message itself. On a railway in the north of Scotland the superintendent was himself killed in a collision caused by his own irregular orders. Everything depends upon the correctness of the message.

On the London and South-Western Railway the system employed is as follows:—Each single line is divided into districts of about fifty miles in length. Over each district there is a superintendent, who has the control of the traffic upon that length. Every train on its departure from certain fixed stations is telegraphed to the superintendent, who thus knows precisely how the trains are running. If a case occurs, as shown in Fig. 12, he takes his measures accordingly.

1st. A message is sent to C, ordering the stoppage of the up train until the arrival of the down train at that station.

2nd. This is repeated in slightly different language by the station-master at C.

3rd. Another message is sent to B, to send on the down train to C, and to pass the up train there.

4th. This is also repeated in a similar manner to the previous message.

5th. The engine-driver of the down train, if an express, is warned at his last stopping station that he will have to stop at C.

Written orders are given to the driver, with a copy of the message itself. No error, or misunderstanding can arise, except from the wilful disregard of clear and explicit instructions: nothing is left to chance. A regular form is adopted for wording these messages, and different-coloured message-papers are used for the various orders issued. Those respecting the stopping of trains are coloured red; those relating to the forwarding on of trains are green. It will be seen that each alteration of a passing place involves four separate messages—in the case of an express-train five—each message being repeated to insure correctness. It

is found in practice, that all this is accomplished in a period averaging five minutes. The greatest care is taken that everything shall be written down. Indeed a message should never be sent by telegraph unless it has been first recorded on a proper form; and it should always be preceded by its proper prefix, denoting its nature and importance.

On the London, Chatham, and Dover Railway, in January 1862, an express train was thrown off the rails near the Rainham station, and considerable damage sustained, though fortunately no lives were lost. This accident might have been avoided if the station-master at Sittingbourne, who had been informed of the fact of there being something wrong by the driver of a previous goods train, had taken the precaution to write down a message, and have it sent with the danger prefix. As it was, he simply told the clerk to warn Rainham of there being something wrong. Another station, seeing conversation going on, broke in with another message, produced delay, and the accident occurred. Most of the delays, and irregularities on railway circuits arise from this simple circumstance. On commercial circuits conversation is strictly prohibited. Everything that is sent, or received, is carefully written down. If Railway Companies carried out the same rule, they would soon reap the benefit in greater despatch of business, prompter attention, and fewer errors. It should also be added, that no message of importance should ever be transmitted by telegraph, without its repetition being demanded, nor should such message be acted upon without such repetition being sent. This is the only safe method to avoid inconvenience from errors, which constantly occur from innumerable causes, even with the best-regulated telegraphs.

On the West Midland, the Shrewsbury and Hereford, and on several other single lines in the west of England, the blocked needle system is carried out. There are two wires—one being used for the 'block,' and the other for speaking purposes. Bells are dispensed with. Explicit instructions are given, so that no train can start until the line is known to be clear; and immediately a train enters a station, the needle is deflected over to 'line blocked.' Record books are carefully kept.

Record books, or slates, in which the times of starting and passing of all trains are entered in ruled columns, are essential elements of attention and regularity. Captain Tyler says,¹—"A man is obviously less likely to commit an irregularity of any sort in duties of this description, when he is himself compelled to make a permanent record of it, liable at any time to be brought against him, open to observation on periodical, or irregular inspections,

¹ Vide "Reports of the Inspecting Officers, &c." 1862. Page 90.

and checked by other records made by responsible officers within a short distance, and perhaps on both sides, of him." Such record books should invariably accompany signalling telegraphs. Few lines now omit to avail themselves of their use. They are, however, scarcely necessary, where the electric signals are worked purely as distant line signals.

In America, where nearly all the railroads are single lines, the traffic is almost entirely worked by telegraph. The system employed is the same as that used on the London and South-Western Railway. Prescott says :¹—"Engineers and conductors now actually feel safer and more secure while moving under telegraphic orders than when following their printed instructions; although, at the time the system was inaugurated, it was not a little amusing to the operators to witness the alarm manifested by these same men at this innovation upon their old-fogyish views."

There is no question that, if properly worked, single lines would be sufficient to meet a great portion of the requirements of the railway service of this country where double lines at present exist. Mr. Minot, the chief superintendent of one of the best-managed railways in America, the New York and Erie line, says :²—"A single-track railroad may be rendered more safe and efficient by a proper use of the telegraph than a double-track railroad without its aid; as the double-track can only obviate collisions which occur between trains moving in opposite directions, while the telegraph may be used effectually in preventing them either from trains moving in an opposite or the same direction." Vast sums of money have been uselessly spent in the construction of double lines in this country, where single lines would meet all the traffic. Parliament has compelled the London and South-Western Railway to double their line from Southampton to Dorchester. A single line would be ample for the traffic of that district. But single lines, until recently, have never been properly worked by telegraph. The telegraph was not understood. No reliable signalling apparatus had been introduced, and delays arose. The public remonstrated, and shareholders' capital has been recklessly expended. With a reliable signalling apparatus to regulate the signals—with a well-managed speaking telegraph to regulate the trains—safety is assured, regularity obtained, and single lines become as secure and rapid as double lines.

Even on double lines the telegraph, properly applied, becomes a great element of safety. As a secondary power, it is invaluable. But railway managers are, to a great extent, prejudiced against

¹ Vide "History, Theory, and Practice, of the Electric Telegraph. By G. B. Prescott." 8vo. Boston (U.S.), 1860. Page 235.

² Vide Ibid. Page 236.

its adoption. They do not use it, because they do not, or will not understand it.

On most railways the telegraph is held in the lowest estimation. Its construction is the very last thing thought of—its convenience is never consulted. Railway managers order a telegraph, and think little more about it. The signals, the switches, the porters' rooms, and the urinals, are all carefully considered; but the telegraph—the most important element of safety—is often neglected to the last moment. It is assumed that it can be fixed anywhere, and that any vacant spot in the parcel, or booking office is sufficient for its purpose. Light is essential to insure attention to its call. Air is imperative to secure the health of the attendant. Indeed special offices should always be constructed at all stations. It is a mistake to combine telegraphing with other occupations. A booking clerk may be attending to passengers when he is urgently wanted at the instrument. A parcels' porter may be absent, when a danger telegram is required to be sent. Constant attention, which is imperative in a well-regulated telegraph, can only be obtained by having a special telegraph-clerk situated in a convenient office, free from interruption, and undisturbed by the ordinary business. The instrument is frequently left in the hands of persons incapable of using it; and it is no uncommon thing to find it placed under the charge of those who, though capable of working it, are, from a superabundance of other employment, unable to give it that strict attention so necessary to make it a valuable and reliable agent.

Captain Tyler says:¹—"Want of a proper system of working and using the telegraph, combined with the employment of unreliable servants, or of servants with too much of other work to attend to, that has in like manner led to accidents in other cases,—that has induced mistakes on the part of the men which would not otherwise have been made,—that has afforded an excuse for not employing it,—and that has prejudiced railway managers against it, in a way materially to hinder its adoption and retard its progress; while the want of a really efficient code of regulations, ready to be applied, and in which confidence can be placed, has also partly contributed to the same result."

There is no doubt that, indiscriminately used, the telegraph becomes a positive source of danger. Still, carefully applied, it may be made the greatest element of safety. There are localities and occasions where it becomes essential and imperative; and if railway managers will only examine and study its construction and principles, they will find it a power in their hands to produce

¹ *Vide* "Reports of the Inspecting Officers, &c." 1862. Page 92.

order and punctuality, security and speed; and, as a necessary consequence, prosperity, and immunity from those dreadful disasters which have startled the public, proved such a serious loss to shareholders, and thrown so many happy families into misery, mourning, and grief.

The Paper is illustrated by a series of diagrams, from which the woodcuts, (Figs. 1 to 12) have been compiled.

[Mr. PREECE

Mr. PREECE said, in writing this Paper, he had two objects in view—first, to bring before the Institution and the railway world the system of signalling that had been introduced on the London and South-Western Railway; and secondly, to place upon record an account of the various applications of electricity to the signalling and working of trains. The Minutes of Proceedings already contained two communications on the Electric Telegraph,¹ several on Submarine Cables,² and one on Electro-Magnetism as a Motive Power;³ but there was no description of the manner in which electricity had been applied to railway purposes. This he had endeavoured to supply in the present Paper, and he trusted to some extent successfully. The necessity for an opportunity of discussing this subject, and of learning what was being done in this department on different lines, would be apparent, when he mentioned that the practice of the principal Railway Companies did not agree upon this point, no two lines having their termini in London following the same system. For instance, the Great Eastern had a system of their own, based upon the needle instrument; the Great Northern one which was only understood, he thought, by themselves; the London and North-Western used Mr. Clark's plan; whilst the Great Western employed various contrivances, but were now introducing the invention of Mr. Spagnoletti. On the London and South-Western Mr. Preece's system was in operation. The London and Brighton presented the curious anomaly of working one end of their line upon one method, and the other upon a different plan. On the South-Eastern main line bell-signals were adopted; while on one of the branches, the North Kent, Mr. Tyer's instrument was in use. Similarly, the Reports of the Inspecting Officers of the Board of Trade upon Railway Accidents were at variance; for in one report, Captain Tyler, R.E., (Assoc. Inst. C.E.,) recommended to the London and Brighton Company the use of Mr. Tyer's instrument, and in another he advocated the needle system. Colonel Yolland, R.E., was invariably in favour of the needle system. Again, he thought, that if the London and North-Western Company were acquainted with the methods in use on other lines, the tunnel at New Street, Birmingham, would not continue to be worked by a system which required eight wires, whilst the London, Chatham, and Dover Company only employed one wire.

The sources from which he had been able to derive the materials for his Paper were very limited. The only published account, with which he was acquainted, of any system of telegraphic sig-

¹ *Vide* Minutes of Proceedings Inst. C.E., vol. xi., pp. 299-388.

² *Ibid.* vol. xvi., pp. 188-225; vol. xvii., pp. 221-385; vol. xx., pp. 26-105; and vol. xxi., pp.

³ *Ibid.* vol. xvi., pp. 386-421.

[1862-63. N.S.]

nalling was that given in the careful and elaborate report of Mr. Edwin Clark to the London and North-Western Railway Company.¹ No treatise upon telegraphy contained any detailed statement of what had been accomplished in this special department. He had been obliged, therefore, to resort to the reports—often long and tedious—of the Government Inspectors upon Railway Accidents; and in this way he had waded through upwards of two hundred of those reports, until he was wearied with the same tale of instructions disregarded, precautions neglected, and experience ignored.

In dealing with this subject, he had endeavoured to be impartial. Having an invention of his own, he was, however, naturally inclined to regard it with some affection; but he was sure those gentlemen whose processes had been alluded to, would do him the justice to say, that he had not failed to describe them as accurately as was possible under the circumstances. It might appear somewhat invidious to have selected Mr. Tyer's instrument, and to have brought it into rather unenviable juxtaposition with the needle system and his own. But that was only taken as the best example of a series which he believed to be founded upon a wrong basis,—he meant those methods which were dependent upon one wire and upon momentary currents. In a Paper which was written more for the purpose of provoking discussion than for careful examination, he had been necessarily limited in the description of the various appliances met with on railways. Thus, he had not entered into any particulars about bells; because if he had gone into that subject, a long account would have been required, which would probably not have been generally understood. There were two kinds of bells,—one termed the direct-action bell, the other the alarum. The latter was placed in the box of a pointsman, who had to leave to attend to the points, as the continuous ringing called his attention to the signals. The single-stroke bell was fixed in a box which the signalman never quitted. He had taken an objection to all kinds of self-acting mechanical arrangements, but he excepted the case where distant signals registered themselves. On the London and North-Western line Mr. Whitaker made the distant signal register itself upon the needle. Mr. Preece adopted a similar plan, only in place of the needle, he let the signal repeat itself on a similar signal, but upon a smaller scale.

As regarded the several points to which the discussion might be directed, he would remark that the question which telegraphists were anxious to have settled was, whether lines should be worked by an interval of space, or by an interval of time. The Government

¹ Vide "Letter to Captain Huish, &c."

Inspectors recommended the former ; the managers of the principal railways said it could not be done, and that reliance must be placed on the interval of time. As a telegraphist, he did not see why the 'space' system should not be adopted ; still he should like to hear the reasons which had induced the London and North-Western Company to modify the original 'block' system. Allusion had been made to the system of signalling on the London and South-Western for working single lines. Of all that he had seen he considered it was the best. It originated with Mr. Williams, on the Yeovil and Exeter line, and was elaborated by Mr. Scott. It was well worthy of attention ; because, up to this time, railway managers had not felt confidence in single lines, from the fact of there being no reliable system of signalling at their command.

The remarks he had made in bringing forward this system would no doubt lead to considerable difference of opinion. The semaphore arrangement had cost him much time and trouble ; and he naturally thought it better suited, than any other, to meet all the requirements of railway working. At the same time he must say, the telegraphist looked with some regard upon the needle,—having been brought to understand it, he knew what it meant—and personally he had such confidence in the needle, that he would just as soon use it as the semaphore. But a railway man looked upon the semaphore in the same way as the telegraphist did upon the needle ;—he knew what it meant, and not understanding telegraphy, he naturally preferred those signalling instruments which corresponded to the out-door signals, with which he was thoroughly familiar. The London and North-Western Railway could hardly have a more perfect plan than that of Mr. Edwin Clark's, for their particular system of working two, three, and four trains in each division. But for tunnels and inclines he was inclined to think the semaphore was superior. It sometimes happened, that there was a tendency on the part of those whose schemes were not approved to consider themselves aggrieved. He hoped he had succeeded in getting through the subject without raising any great degree of feeling. He had endeavoured to avoid mentioning any circumstances, or expressing any opinions, without substantiating them by the narration of well-authenticated facts. Where this was not done, he hoped his long experience would be received as a guarantee for the honesty and truth of his statements. All were apt to make the best that was possible of their own inventions, and that had undoubtedly been his endeavour on the present occasion ; but in such a place personal feeling and personal interest ought to be subordinate to that higher object—the advancement and the perfection of that railway system which was the mainstay of this country.

Mr. EDWARD TYER said that he rose with extreme diffidence to open the discussion. He felt that justice had not been done to the system with which his name was associated, and he likewise thought other systems had been ignored, or had been passed over in a slight manner. His original intention was to have allowed the matter to pass unnoticed; but there were occasions when silence might be misconstrued, and he considered it a duty, both to the Members of the Institution and to himself, to lay before them, in as few words as possible, a full description of the instruments he had introduced, and to endeavour to answer the objections which had been raised.

He would record his thanks and meed of praise to Mr. Preece for the able and intelligent manner in which the Paper had been prepared. It was, however, an example of the great facility with which fault could be found when there was a disposition to do so; still the Paper was valuable, inasmuch as it filled a vacant niche in the archives of the Institution. Beyond that, he could not say much in its favour, as the majority of railway men and civil engineers had had this subject continually brought under their notice, and he believed every instrument had been more, or less submitted to their scrutiny.

Having been engaged for the last ten years in the practical development of his system, which he must be permitted to say, was one of the most efficient, it was natural he should pay great attention to the various topics introduced by the Author; and he confessed that he failed to discover anything new, either in the Paper itself, or in the particular instruments brought forward: indeed the greater portion of the Paper, as most of the Telegraph Engineers present were aware, had already appeared in print. Its object was now stated to be, to show to railway managers what had been done on other lines; but, from the manner in which the subject had been treated, the principal motive appeared to be to make known what had been done upon a portion of the South-Western Railway.

The system in operation on the South-Eastern Railway, which originated with Mr. C. V. Walker, whose labours in this field of inquiry were so well known, had only been cursorily alluded to. As Mr. Walker would doubtless supply this omission, Mr. Tyer would merely remark, that it comprised upwards of three hundred separate sets of bells, beautifully arranged, having various advantages, and being perfectly efficient for all lines where the traffic was not excessive. On the North Kent and the Mid Kent Railways, where the trains were very numerous, it was not found adequate for the requirements of the traffic: and there Mr. Tyer's instruments had been in constant use for the last seven, or eight years.

Mr. Preece had introduced, as a novelty, an instrument which, unfortunately for him, belonged to Mr. Walker, who, in 1854, brought out an instrument exactly coinciding with it, viz., a semaphore signal assimilating with the out-door signal, a persistent current causing the semaphore to be raised or lowered. Mr. Walker's Semaphore Electric Telegraph for train signals was originally described, thus:—"The shape, or configuration, of this electric telegraph is such as to correspond with the ordinary railway semaphores. It consists, as far as my design is concerned, of a model semaphore signal post, with a moveable arm or arms. The instruments are connected between two stations in pairs, and the arms are moved by electric currents acting in any of the usual ways. The handle is on the same side with the arm, and the arrangement is such that the arm and handle shall move in unison. When the handle is put up the arm rises, and the 'danger' signal is made; when the handle is put down the arm falls, and the 'all-right' signal is made. The object of giving this outward form to an Electric Telegraph for train-signalling is, that the signal shown on the train-signalling Electric Telegraph shall be the same to the eye, and have the same meaning as that shown on the common signal post; the meaning of which is so well known to all persons employed on railways, and which cannot be misunderstood." Mr. Tyer therefore claimed for Mr. Walker, the credit of having first assimilated the signals of electrical signalling instruments to the line signals of railways. Models of this instrument were shown at the International Exhibition at Paris, in 1855, where it attracted considerable attention.¹

At the same time Mr. Tyer exhibited a pair of disc signals, coinciding in many points with the French system of using discs. Not only could signals be transmitted between station and station, by discs revolving through a quarter of a circle, but similar signals could be given to the driver of the train, while on his journey, so that he might be made aware, before arriving at the next station, what signals to expect. Experiments were carried out on this system, on a large scale, on the Paris and Strasburg line, and an Imperial Commission was appointed to inquire into the matter. But as it involved the expense of fitting up all the stations and engines with this particular apparatus, it was not then brought into general use. Other Companies, however, availed themselves of it, and at the present time there were about one

¹ The labels then fixed on the instruments were—

"9. Sémaphore-électrique monté, pour signaler un convoi qui va partir."

"10. Sémaphore-électrique monté, pour signaler un convoi qui va arriver."

The price of the pair was given as 6*l*.

hundred and fifty sets of these instruments at work on the Continent.

Before attempting to reply to the various objections raised to his instruments, it would be expedient to explain the system itself and the manner in which it worked. The dial of each instrument was divided into two parts,—the upper portion referring to the up line, the lower portion to the down line. Each instrument had two indicators,—one red, the other black. The former always showed the last signal sent: the latter that last received, and this was unalterable by the man in charge. When either indicator pointed to the right hand, it showed 'line clear.' Bells and gongs were attached, relating respectively to up and down trains. One peculiar feature, which had not been introduced in other instruments until this arrangement was brought forward, was, that no signalman ever sounded his own bell, or gong; therefore, whenever he heard these sound, he knew it must be the station in advance replying to his own signal, and thus no mistake could possibly occur. In order to call another station, and to describe the particular train which was about to leave, it was only necessary to press in one of the piston rods attached to the front of the instrument, by which a current of electricity was transmitted to the station in advance, and the gong, or bell was rung, as the case might be. Two beats on the gong were employed for a down passenger train, three for a mineral train, and one as an acknowledgment that the signal had been duly received. Supposing a down train had left station A for station B, the signalman at A called B, by pressing in one of the piston rods twice. The signalman at B immediately knew that a train had left A; he then pressed in the left hand piston rod, which caused his red indicator to pass over to 'train on line,' and made the index at A coincide with it. A could not alter the needle on his instrument; and his instructions were to keep the ordinary semaphore raised, till, on the train arriving at B, the needle was released, by the signalman at B, which A acknowledged by one beat in reply. The same took place with up trains, in a reverse direction. But supposing that there was an obstruction at B, or shunting was going on, then the code consisted of five beats on the bell, or gong, with this important distinction, that instead of being acknowledged once, as in ordinary cases, it was replied to five times. The man at B caused the needle to go to 'down train on line,' and completed the signal by giving four blows on the bell. The man at A knowing the line was obstructed at B, replied to that signal by five beats on the gong. Thus there was a perfect record of every signal sent and received, and at any time of the day, or night, a signalman could, by the indicator, tell the station in advance, or in the rear, what signals he had last sent, or had last received.

Having described the nature and mode of operation, he would endeavour to dispel any illusions which might have been created, by the objections which had been raised.

First, with respect to the effects of atmospheric electricity, it had been stated, that his instruments could "be demagnetised and rendered useless."¹ Would any one conversant with this subject say, what electric telegraph was not liable at times to be demagnetised and rendered useless? Bringing these three conditions together,—a line wire, a pair of Mr. Preece's instruments attached, and then discharge the contents of a lightning cloud through them,—the result would be, that the whole arrangement would be destroyed; and instead of an uneducated pointsman being able to readjust the instrument, it was most likely that he would shut up his box, and get out of the way as quickly as possible. Mr. Tyer's instruments had been at times deranged by lightning, but he was not aware of a single instance, where atmospheric electricity had caused a false signal to be given. There were two indicators upon each dial. In other arrangements also there were two indicators, or two sets of bells; but in his system there was this peculiarity, that one-half of the needles being out of circuit, the chance of being demagnetised by atmospheric electricity was reduced by one half. It was impossible for the red needles ever to be affected by electricity, as they were out of circuit altogether. With respect to the black needles, when pointing to 'line clear,' if electricity of a positive nature entered it did no harm, as it would simply cause them to remain over to 'line clear;' while if pointing to 'train on line,' and a negative current of electricity entered, it would do no harm, as that was the current requisite to produce the 'train on line' signal. But the question arose, supposing the needle were to turn from 'train on line' to 'line clear,' what would happen? The needle could not be put over from one signal to another without ringing the bell, and before the needle went over, the coil would in all probability be destroyed. If it did go to 'line clear,' the signalman would know that no train was due, none having been previously signalled; he would then refer to the train-book, and if he had any doubt on the subject, he would raise the semaphore and stop the train. If there was no doubt, all the man had to do was to bring the needle to 'line clear,' and then to obtain an acknowledgment, when the signalling would go on as usual. The statement, as to the needles being demagnetised, was incorrect, as that could not possibly take place, for the needles were not permanent magnets, as in most other instruments, but were simple pieces of soft iron, which received their magnetism by induction, from being suspended in close

¹ *Vide ante*, page 185.

proximity to the coil of wire, through which the charge flowed. The permanent magnet was used simply to retain the needle over, and was quite away from the coil, and was not influenced by currents traversing it. Some of his instruments had been injured by lightning, but the charge had been of such a nature and in such volume, that the instruments had been completely destroyed. Two such cases had occurred on the Great North of Scotland Railway, where it had been necessary to provide new instruments; but he never knew an instance of the needles going over from 'train on line' to 'all clear' which would have misled the signalman on duty.

Another objection raised was, that his instruments only required one line wire, whereas in other systems two or three line wires were necessary. Now, in spite of this opinion, he believed one wire to be an element of safety, as well as of economy. If three line wires were employed, and a fracture took place in one of them,—which was not unfrequently the case,—the fractured wire might foul one, or other of the remaining wires. With persistent currents flowing through the fractured wire, or either of the others, false signals might pass into the instruments, and thus lead to confusion and possibly accident. Whereas, with his instruments, in the event of a wire breaking, when a signalman was not able to call the attention of the station in advance, the signal was repeated, and if there was no reply, he was made aware that something was wrong, and he immediately raised the semaphore; because the rule was that no signal was complete, unless it was acknowledged and entered in the book. Therefore, the moment anything happened to the instruments, the semaphore was raised, and information was forwarded to the next station that the telegraph was out of order. Again, with persistent currents there was the liability of the battery getting weaker and weaker, and not indicating the true signal clearly. Now, with his instruments a very low battery power was sufficient to move the needles from right to left. Should it however begin to get weak, still the needles would not be affected; but this state of the battery would be indicated by the fainter ringing of the bells at each station, and the person on duty would thereby be made aware of the fact, of the batteries requiring attention.

The next objection was, that his instruments were always kept under lock and key, and that no repairs could be effected, until the arrival of the superintendent in charge of the line. This was a weak argument; and he found in practice, that unless the instruments were under lock and key, they were liable to be tampered with, and he had no desire that the rough hands of the signalman should be employed in endeavouring to repair the delicate structure of the telegraph instruments. He had known

instances of 'terminals' being undone and wires being broken off, and if, under such circumstances, a signalman should put the wires on to the wrong 'terminals' with persistent currents and needle arrangements, a different signal might be recorded to that which was registered at the opposite station. He strongly recommended, that all 'terminals' and connections should be under lock and key, to avoid any derangement from the signalman attempting to repair, alter, or tamper with, that which he knew nothing about. It was safer to wait for the superintendent, than to allow these things to be done by an ordinary signalman. He remembered on one occasion being sent for, a distance of 200 miles, on account of an instrument he had put up two days before getting, as was imagined, out of order. Upon his arrival, he found that a tin wafer-box had been placed on the top of the bell-case, and had completely closed the circuit, by making contact between the 'terminals.'

Another point raised was, that on lines where his instruments had been placed, accidents had occurred. He believed accidents had also frequently happened where semaphore signals were used. If the trains kept time, and the semaphores were attended to by the drivers, there was not any necessity for electric indicators. But in practice trains did not keep time; and hence electric signalling was a great auxiliary to the efficient working of a railway. Take, for instance, the two accidents which occurred on the South-Eastern line. The first was a slight accident on the Greenwich viaduct, where a train started on the wrong line of rails, and the mistake was only noticed when two trains came in collision. Why that error should be attributed to his instruments he was at a loss to conceive. With reference to another accident, he begged permission to read the following extract from Colonel Yolland's Report:—¹

"The signalman at the Surrey Canal Junction, who had been six years employed at this junction, admits that he did not give the 'line blocked' to the Commercial Dock Station when he lowered the branch line semaphore signal for the cattle train to come out on to the main down line, although it was his duty to do so, in accordance with the Company's regulations, and he therefore gave back a false signal to the Commercial Dock Station, in reply to the telegraphic signal, that the passenger train (8.5) was ready to start, in saying the junction was clear, when the trucks were rolling past his box, part being on the main down line, but the greater portion on the branch down line. And he says in extenuation, that he omitted to give 'line blocked' to the Commercial Dock Station when he lowered the semaphore signal for the cattle train to come out from the branch, because he considered that he could get the line clear before it would be required; again he says, he never did it before for a cattle train, but that he has done it for a light engine that has been standing there. He allows that it is against the Regulations. * * * *

"The Company's mode of working must undoubtedly protect the public

¹ Vide "Reports of the Inspecting Officers, &c., 1862." Page 119.

from ordinary collisions, unless, as in this instance, the regulations for carrying on the traffic are broken, and combined with such infraction of the Regulations that the engine-driver failed to keep a proper look-out."

In that case the blame was put upon the right person, and the indicators being unalterable, he found he could not get out of it, and therefore confessed he had not done his duty. This was another illustration of the advantage of keeping everything under lock and key.

With regard to the needle instruments not having sufficient space between the signals, the Author said¹ :—

"The two signals, denoting such different meanings—the one the element of safety, the other the source of danger,—are not sufficiently distinct in their opposite indications. On the line, the semaphore arm, at one time elevated, and at another depressed, is unmistakeable in either position. So with a disc, at one time visible, at the next moment obscured, no error can occur. But a thin index, in a dark, dismal hut, with only a slight movement from one side to the other, whether it be momentary, or permanent in its deflection, is not decided enough to avoid misconception when examined hastily."

At the present moment there were 50 miles of line fitted with instruments in all respects similar to the semaphore described in the Paper; inasmuch as the indicator moved from the vertical to the horizontal. But they had this important advantage, that while the needle pointed to the signal 'line clear' when in a vertical position, the moment it became horizontal, it not only indicated 'train on line,' but also showed the direction in which the train was advancing. In working his instruments, with one needle red and the other black, the former showed the last signal given, and pointed to the direction in which the train was approaching; but the moment a signal was given to the station in advance, the black needle fell to the horizontal, showing that the train had passed the home station, and was advancing towards the next. When the signalman received that intimation, he brought the red needle back to 'line clear.' Thus with two arms, the lower portions of which were behind a fixed screen, in the same manner as a semaphore, the signalman could not make a mistake. If the indicator was vertical, it meant 'line clear,' if horizontal, 'train on line;' showing in the latter case the direction, either up, or down, in which a train was passing.

In conclusion he must observe, that although the Institution might be the proper arena for discussing the relative merits of the constructive details of train-signalling instruments, railway engineers and railway managers would not decide so important a question merely from hearing what inventors, or patentees had to say about their own instruments. The proper evidence of effi-

¹ *Vide ante*, page 180.

ciency was to be obtained from the persons in charge of the several instruments, and from the managers who had the supervision of them; and in his own case, Mr. Tyer felt convinced the unanimous verdict would be, that during the ten years the instruments he had described had been in operation, they had worked well, and that experience had proved his system of signalling to be one of the most efficient, simple, and economical yet brought under the notice of the railway world.

Mr. C. V. WALKER said, as the extensive system of telegraph signalling in operation on the South-Eastern railway had been only slightly mentioned in the Paper, he deemed it incumbent upon him to make a few remarks, so that the Members of the Institution and the telegraph world generally might be made better acquainted with it. In doing this, he should, unavoidably, have occasion to refer to it in plain terms, as his own system. It was his own, inasmuch as he originated it, and it had been perfected under his care; he therefore felt a strong interest in it. It was not, however, the subject of a patent, so that he had no pecuniary interest in it.

From the remarks made by a previous speaker, it would have been gathered, that 'sound upon bells' was the basis of the system of train-signalling he was about to describe; without this, a leading feature would be gone. It would be right to place this matter historically correct before the Institution, in order that the origin of the bell-signal system, for which 'Honourable Mention' had been awarded at the International Exhibition, 1862, might remain on record. In the autumn of the year 1851, a want was communicated to him by the then Manager of the South-Eastern line. In his reply, of which the following was a copy, Mr. Walker described the system proposed to be introduced; and he had not since seen any reason to alter his opinion of its efficiency for train-signalling.

-
" SOUTH-EASTERN RAILWAY.

" MY DEAR SIR,

*"Electric Telegraph.
Tunbridge, Oct. 29th, 1851.*

" In respect to the signalman at the Spa Road indicating the character of the up trains to the switchman at the entrance of the South-Eastern and Brighton terminus at London, and to the latter having power to order either train to be stopped at the Spa Road,

" The distance is 820 yards. It would require two¹ wires, which could easily be erected.

" I should construct two bells of a totally different character to those used for the telegraph, and should use a different kind of battery.²

¹ The second wire was not found to be necessary, the viaduct-earth being sufficiently good.

² This was the graphite battery (since platinized), for which a prize medal was awarded at the Great Exhibition, 1851.

One blow on the bell would indicate a Croydon train, two a Brighton, and three a South-Eastern. I would so construct the apparatus, that it could be relied upon. The expense would be very little, and it could not easily be deranged.

"Yours very truly,

"(Signed)

CHARLES V. WALKER,

"To CAPTAIN BARLOW,
"Superintendent."

"Engineer and Superintendent
of Telegraphs."

That letter described the foundation of the bell-system as now in operation throughout the South-Eastern Railway. The first pair of bells were fixed and used January 22-31, 1852. The specification of Mr. Tyer's first patent was dated July 20th of the same year. At the present time, the South-Eastern line was protected in every possible manner by bells of the kind described; there were three hundred and thirty bells in operation,—some being connected merely in pairs, some with intermediate bells, and in other ways. Of these, eighty-four were provided with counting indexes, which indicated the number of blows sounded, and the remainder were plain. The total length of the South-Eastern line, thus protected, was 275 miles; and 11 other miles of the line were furnished with Mr. Tyer's instruments. Signal-bells were in course of erection¹ on the Caterham branch of nearly 5 miles in length. The Angerstein branch of half a mile, which was without bells, was not used for passenger traffic. The Whitstable branch of 6 miles was provided with a pair of telegraph instruments, which were little used for speaking purposes, but served for signalling trains. From Ash to Shalford, upwards of 8 miles, belonging to the South-Western Railway Company, but over which South-Eastern trains ran, electric signalling was not employed.

With respect to the cost of the telegraph signal-bell system, and the amount that had been expended by the South-Eastern Company upon it, in order to promote the safety of the traffic, he might state that the total cost on the 275 miles had been nearly £3,650, or at the rate of £13. 5s. 3d. per mile, including wires, bells, and batteries complete. There was at the rate of one bell and a fifth for every mile, or one bell to every 1,466 yards; and the total cost on each 1,466 yards was £11. 0s. 11d. The average cost per bell, including the 'pecker' or ringing-key, taking the bells one with the other, plain and index, had been £4. 6s. 6d.; and the cost complete, including batteries, had been £5. 10s. 3d. The train signal-bells were in charge of the station-masters and the ordinary signalmen, so that the working expenses were not thereby increased to any appreciable extent. Loud-sounding bells, at least 4 or 5 inches wide across the mouth,

¹ Since these remarks were made, the Caterham branch has been fitted with bells.—C. V. W. Feb. 2, 1863.

were employed. The principle to which he had referred in his letter to Captain Barlow was, to wind the coils with No. 16 or No. 18 wire gauge, which was at that time an unusual size for an actual working telegraph instrument. The hammer which was attached to the keeper of the electro-magnet was the only moveable part of the bell apparatus. The signals were given by the number of blows struck; the code for all ordinary purposes, called in practice 'the General Code,' being one blow for an up train out, two blows for a down train out, and three blows for a train in. For blocking the line, the bell signal was five blows; clearing the line after a block, three blows, or the in signal given and taken twice. One fundamental and essential condition was, that every signal made by one man should be correctly repeated by the other man. If A made a signal to B, and the repetition was not given, it was an indication either of misunderstanding, or of something being wrong. No signal was allowed to be complete, until it was recognized by the return of the same number of blows that had been sent.

Independently of the above application, which was the simple and ordinary process of train-signalling from station to station, these bells were used in many ways and in a great variety of places; in fact, they were almost universally applicable. At the London platform, bells were the effective instruments for supplying a certain want. It now and then occurred that a South-Eastern tidal-train and a Brighton train were due to start from the respective London platforms at about the same time. Should the South-Eastern tidal-train be unable to start to the minute, the inspector on duty had access to a 'pecker,' which enabled him to strike a certain number of blows, three, on a bell in the box of the signalman who had the control of the entrance to both stations. This was an intimation that the South-Eastern train was not quite ready, and that the Brighton train might be allowed to go out.—Again, at every level crossing, without exception, on the South-Eastern line, bells were placed in circuit in the gate-house, to be heard, but not to be answered. In this way indication was given that a train was approaching, either from A or from B, according to the number of blows; and the gate-keeper, hearing the sound of the bell, was made aware when the gates must be closed, till the approaching train had passed. In cases where the gate-house was close to a station, the bell was so connected that every signal, sent to the station to which the gate belonged, from the station either to the right, or to the left, was heard at the gate-house.—Then again, on the London Viaduct, there were two up lines to protect, and three different kinds of up trains to be distinguished. Between London and Redhill, one blow was given on the bells for a South-Eastern train, and two blows for a

Brighton train. On the Bricklayers' Arms branch, a still greater distinction had to be made. There were four kinds of up trains and two kinds of down trains; and blows on the bells were arranged to meet these various circumstances. It was not desirable that bells should be required to express so many different things; but on that branch it was impossible to avoid it. The up distinctions were, South-Eastern Engines, Empties, and Goods, and Brighton Goods; the down, North Kent and main line.—Again, at Hastings, Canterbury, and Paddock Wood, moving trains were indicated to the porters, by a bell placed on the platform of the several stations. The men right and left of the stations did the signalling, a platform bell being placed on a continuation of the wire; so that, all that was taking place at the signal-box, and required to be known by the station-master, was communicated by the bell. If a train was signalled as coming from St. Leonards or Winchelsea, the station-master at the Hastings platform knew what train to expect. At Ashford, there were two junctions, which was another cause of complication, and several different signals had to be given by the bells. They were arranged in different groups, and spoke by the number of blows given. At Beckenham there was another extension of the same kind; and although the signalman was somewhat removed from the station, the station-master heard by a platform-bell the signalling that was going on in the signal-box, and had all the information he required of the various kinds of trains. At Margate the signals sent from Ramsgate were taken at the signalman's box, some distance from the platform, but these were heard also at the station. At Folkestone and Dover there were similar arrangements. Then there were small stations which were closed at night, when the communication with the bells ceased. In such cases the signalling was done by the stations right and left, which were switched into connection before closing. Repairs were now going on in the Bletchingly Tunnel, during which a bell was placed in circuit, in a hut at the tunnel mouth, within hearing of the men; and they were by its means made aware of the approach of a train.

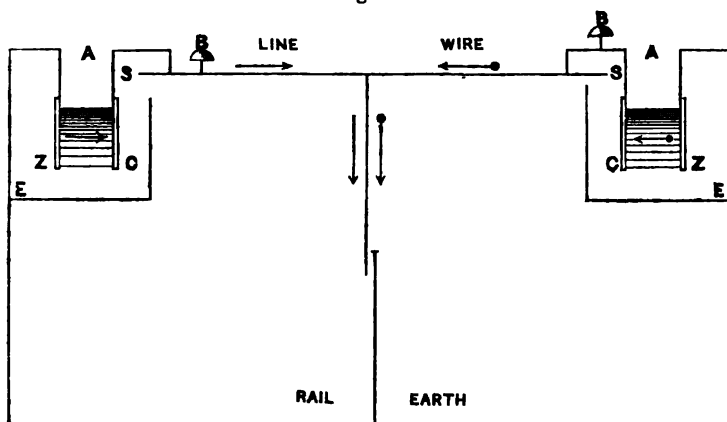
One peculiarity about these instruments was, that they appeared to be the only kind of telegraph instrument that could be actually used, and that had been experimentally and successfully tried, with balanced currents. He communicated to the Royal Society, in 1857,¹ a short notice of the mode of working these bells with balanced currents. He subsequently found that a patent, of which he had not before heard, had been taken out by a Mr. Walker, of Glasgow; on looking to the specification, he could not, however, discover that any instrument had been conceived,

¹ *Vide* "Proceedings of the Royal Society," vol. viii., p. 418.

by which the system could be worked ; nor could he ascertain that any use had been made of the patent. When the bells were arranged with balanced currents, the guard of a train, which might have become disabled between two stations, had merely to fasten a wire to the bell line-wire, and each time he touched the rail with the other end of the wire, the bells at the stations on each side were rung. No batteries or apparatus of any kind had to be carried with the train.

Fig. 13 showed the nature of the arrangements. A A were the two stations ; B B, the respective bells ; Z C, C Z, the station

Fig. 13.



Rheo-electro-static Telegraph.

batteries ; E E, the earth-wire ; S S, the contact-springs of the peckers ; the horizontal arrows, the direction in which the currents tended to move ; but, as the currents were equal, and in opposite directions, the whole of the system was in a Rheo-electro-static state. For ordinary signalling, the pecker-spring at either station was merely depressed into contact with the point beneath ; the battery at that station was thus thrown out of circuit, and the current of the distant battery flowed through the distant bell and rang it. If, on the other hand, the guard in charge of a train required to ring the station-bells on either side, he had only to twist one end of a wire on the line-wire, and with the other end to touch the rail, when the currents from both batteries would flow along that wire, as shown by the vertical arrows, and both bells would be rung ; or contact-springs might be fitted to some of the telegraph poles.

The system of signalling was so efficiently carried out on the South-Eastern line, that such a use of the bells as he had just described was hardly to be looked for. If a train did not arrive within

a few minutes of its time, it was tolerably well known that it had broken down. However, if necessary, nothing more was required for putting all the bells in use into this balanced condition, than to take a couple of wires off their terminals, and to interchange them. Another advantage of the large wires with which these bells were wound, was, that although the gutta-percha covered wires buried in the London Viaduct were perishing,—those on which the bells were at this moment working, giving what was technically known as ‘dead earth,’—still the bells worked very well through these moribund wires. One of the bells, exhibited to the meeting, was plain; and the other had the counting-index, already mentioned, attached to it. That was his idea of a really useful index. The bell-system had been so thoroughly carried out, that in some of the signal boxes there were two, three, and, in rare cases, as many as four bells. The bells differed in tone, and in the position they occupied. Should the noise of an engine blowing off steam, or any other cause, make it uncertain to a signalman how many blows had been struck upon the bells, or which bell sounded, he would find them registered by the index, which pointed to the number on a dial. It was a simple mechanism—a pair of pallets and a scape-wheel on the arbor, which carried the hand of the index to the precise number of blows struck upon the bell.

With regard to the semaphore to which Mr. Tyer had alluded, and which was for making the very signals proposed by Mr. Preece, it was constructed by him merely as an illustration, about eight years ago, and was used at Tunbridge for some months. The pair of instruments now exhibited were alternate. They were shown at the Paris Exposition in 1855. The instrument was of very simple construction, consisting merely of a galvanometer needle, with a semaphore index as an outside needle; and did not differ in principle from Mr. Cooke’s needle, originally used on the Norwich and Yarmouth line, and since employed on the London and North-Western Railway. Instead of an outer needle pointing right, or left to written words, it carried an ivory arm on the top of a semaphore pole to be set up, or let down, and required a persistent current to retain the arm in one of its positions, as Mr. Cooke’s did for both positions; which should be avoided, when practicable.

Of all instruments which had an index Mr. Tyer’s was the simplest and most certain. The manner in which that index was arranged was very ingenious. It was a soft iron needle, hung loosely at the end of the core of the electro-magnetic coil; this was an original and good idea, and such a needle would be less liable to derangement than many others. These needles had worked admirably on the 11 miles of the South-Eastern Railway before referred to. It must be borne in mind, that these indexes

did nothing more than move to the right or to the left; more than this was required, and, as it had been seen, by the bell-system much more was done. The bell-system had been introduced by Mr. Bartholomew on the Brighton line; he had, however, made his bells much smaller, and had added an index with two positions. Mr. Rudall had also adopted the pure bell-system on the London, Chatham, and Dover Railway, employing smaller bells; but Mr. Walker thought it would be more convenient in all respects to adhere to the use of large bells.

The objection he had to an index was this:—His idea of train-signalling was, that a good understanding and communication should be established between two neighbouring stations. In explanation of his views, he had forwarded to the Institution of Civil Engineers, in the year 1856, a Paper on Train-Signalling; but the subject not being then attractive, it was not read. On looking through this a few days ago, he found that there was scarcely a word in it which he would now strike out; and the Paper could as profitably be read now as then. He would merely refer to it in illustration of the principles of train-signalling adopted on the South-Eastern line, and the instruments with which he had brought those principles into practice. The bells now in use were identical in their minute details with those therein described. He read from the Paper four conditions, which appeared to him then, as they did at the present time, to be the basis of all train-signalling. There should, in the first place, be a good speaking understanding between the men at two neighbouring stations, A and B; and the four telegrams which were necessary between them were these—1st. ‘May I send a train?’ given by station A striking one blow to B; 2nd, ‘Yes, you may,’ one blow struck back by B. Nothing could be simpler. The blow was a loud one, distinct in its sound, and readily understood. The third communication would be from B, 3rd. ‘The train you sent is in safe,’ intimated to A by three blows;—to which the fourth message sent back from A; 4th, ‘All right, I understand train is in,’ A repeating B’s three blows. These four signals were booked by each station; the time at which each signal was completed being entered in the proper column, so that a double permanent record was secured. The admirable manner in which these messages were booked was shown in a late Government inquiry. Without unduly boasting, he might state, that no collision had ever occurred on the portions of the South-Eastern line where these bells were in use, which was no bad illustration of how successfully they worked.

One chief reason why he continued to object to semaphores and indexes was, that the second of the above-named four signals was always contradictory, and did not mean what was intended to be

[1862-63. N.S.]

P

conveyed. The first question was, 'May I send a train?' The answer with the combined bell-and-index system would be, 'Yes, you may not;' that was, whilst the bell reply said 'Yes,' the semaphore went up, or the index went over, which meant 'no.' It was true the 'no' was understood to refer to any train that might follow the one in question, although it did not say so; but some day the index might say 'no,' and mean 'no.' In his mind the signal was complete as soon as the men had exchanged signals and had booked them.

Mr. Tyler had stated that his system was used on the North Kent line, because the traffic was so heavy, and Mr. Walker's bell-system was not considered adequate. This was an error. The traffic was greater on the three lines on the west side of the viaduct run over by the South-Eastern, the Brighton, the Croydon and the Crystal Palace trains, where the bells alone were used. For instance, the average number of trains on week-days was one hundred and ninety-six, and in one year seventy-eight thousand six hundred and seventy-six; and on the day of the Foresters' Fête at the Crystal Palace, August 19, 1862, five hundred and thirty-five trains were booked, as having been 'bonâ fide' signalled by one pair of bells; and without that system it would be impossible to work the present traffic on portions of the South-Eastern and the Brighton lines, including the Croydon and the Crystal Palace branches. He had introduced this system in the ordinary performance of his duty to the South-Eastern Company, and he thought there were many other lines where it would be found as useful, and at a very moderate cost.

Before concluding, it was only due to the late Professor Barlow to say, that he was nearly becoming the discoverer of the electric telegraph; but his progress was arrested when he found that a galvanometer wound with a large wire would not work effectively at long distances.

Mr. C. W. EBORALL could fully corroborate Mr. Walker's statement, with regard to the efficiency of the system of telegraph signalling in use upon the South-Eastern Railway. He believed that Company went further than any other in the kingdom, in carrying out what was technically called the 'block' system of telegraph train-signalling; for with the exception of a portion of the South-Western line, between Shalford and Ash, and of 12 miles of the Brighton line, between Redhill and London, that system was completely carried out on all the lines over which the South-Eastern trains ran. He had for many years endeavoured to induce the South-Western Company to adopt the same system, but up to the present time he had failed to do so. Mr. A. Scott (the Traffic Manager of that line) had expressed the opinion, that it was a dangerous system; and Mr. Hawkins, of the Brighton line,

likewise attributed danger to it. But Mr. Eborall was quite satisfied, it was a system which should be legally obligatory upon every Railway Company. He went to the South-Eastern Company prejudiced against the 'block' system; but after a short time he became satisfied that it was the right one to work trains upon a railway, with any degree of safety—especially on lines with trains running at high speeds, and at irregular times, to suit the emergency of the traffic. The tidal trains on the South-Eastern ran at very high speeds, as well as those carrying the Continental mails. He could not agree with the statement as to the great punctuality of the trains on the South-Eastern line, because irregularities sometimes occurred from working in connection with steam-boats; and at the present season of the year, the boats were uncertain in the times of their arrival at Dover and at Folkestone. He would impress upon every one connected with railways, the necessity of looking closely into this matter. It was worthy of attention; because if a proper system, such as he believed that practised on the South-Eastern to be, were adopted, fewer collisions would take place upon railways. With reference to Mr. Tyer's system, it was no doubt a very good one, but he did not think it was better than Mr. Walker's. Both had been adopted on different portions of the South-Eastern line; but Mr. Tyer's was only applied exclusively on 11 miles of that railway, and on that part nothing could be better than the manner in which the trains were signalled by it.

Mr. ARCHIBALD SCOTT said, with reference to the statement that Mr. Eborall, had vainly endeavoured to induce the South-Western Company to adopt the 'block' system of signalling, in working a portion of that line, he was not aware of the suggestion having ever been brought before that Company in such a way that it could be decided upon; and they had certainly not declined to adopt the system on the portion of line alluded to. If it was asked whether he approved of the 'block' system, his answer would be, that he did not as a general rule. Indeed he believed that, upon a main line of railway, its use would be disadvantageous. His experience of the 'block' system was principally gained on a portion of the South-Eastern line, from Wokingham to Reading. The distance between those place was 7 miles, and no train was allowed to leave Wokingham until the preceding train had arrived at Reading. Fifteen minutes were required on an average for that distance, so that a train, under that system, might be detained fifteen minutes at Wokingham, before it was allowed to go on to Reading. He did not consider that upon any ground of public safety such a detention was called for. There might be portions of a railway so crowded with traffic, that the telegraph would become an essential

element of safety; and in such cases the 'block' system might answer very well. But so long as the traffic could be carried on without the necessity for its aid, there was, in his opinion, a positive advantage in ignoring it, and in depending upon the ordinary mode of signalling.

With regard to the different methods adopted by Telegraph Engineers, he could only accord the highest praise to all. He believed the utmost ingenuity had been devoted to the application of the electric telegraph for railway purposes. Mr. Tyer had bestowed great pains upon the development of his system, which was an admirable one. Mr. Walker had adopted another plan, and had exercised his ingenuity with very good results. The same might be said of Mr. Preece, and of the instrument he had brought before the Institution. Mr. Scott hoped these efforts would not be relaxed, and that constant endeavours would continue to be made for perfecting the system of railway telegraphs. At the same time he would caution railway managers, as far as possible, against being wedded to the telegraph, under the impression of thus securing safety. His opinion was that it was a mistake, unless the telegraph was kept within limits. As an auxiliary it was no doubt an admirable agent; but if too much reliance was placed upon it, he believed its tendency would be rather to introduce an element of danger.

Mr. EBORALL explained, that the detention between Wokingham and Reading, which had been alluded to, did not affect the principle—it had been occasioned by the want of an intermediate signal, which was now being fixed; so that the interval of time would not be in future more than seven and a half minutes instead of fifteen minutes.

Mr. GEORGE HAWKINS observed, that the Brighton Company were not opposed to train-signalling by telegraph. He had endeavoured to carry it out on that line, but as an auxiliary only, for in his opinion anything which had a tendency to lessen the caution incumbent upon an engine-driver would increase the danger, rather than diminish it. That was the reason why he had not adopted the electric telegraph so fully as he might otherwise have done. Although on the crowded portions of that line other precautions than the ordinary signals were required and adopted, yet he considered that the 'block' system of working would be impracticable, except with such a larger number of signals and signalmen, as to increase the liability to mistake, and so render the alleged additional safety very questionable. He was able to speak from experience in terms of unqualified praise of Mr. Tyer's system, and he was not aware of a single instance of failure, or where the persons working it had mistaken the signals recorded. He was fully satisfied of the utility of telegraph train-signalling as

an auxiliary, under proper restrictions, but he should be sorry to depend upon it alone, as it might lead to a want of attention to the signals on the part of the engine-drivers.

Captain HUISS, as one of the oldest railway managers in this country, and the first, he believed, who introduced, to any considerable extent, the system of telegraph train-signalling, and also as having, since his retirement from the London and North-Western Railway, taken a somewhat active part in the promotion and extension of the Electric Telegraph, felt deeply interested in this question. The subject, although frequently referred to in the annals of the Institution, had not yet undergone that thorough discussion on the part of railway managers which it deserved. He would not occupy time by noticing in detail the various plans which had been produced; because in his opinion a far wider view should be taken than was involved in the isolated question whether a needle, or a disc, or a repeating signal, or a little semaphore, or a bell was the best mode of effecting the object. In passing, however, he might say he very much distrusted the bell-system. The ear and the eye too were both organs which were apt to be misled—the ear especially. The continual and monotonous repetition of the same thing deadened the effect, and he doubted whether, after hearing five hundred and thirty-five bells ring in one day, it would be easy to distinguish very clearly when the five hundred and thirty-sixth signal was given. The constant repetition of any sound had the effect of confusing the mind; and he believed there was nothing more liable to deceive than attending perpetually to the sound of bells. Even the eye too was liable to error, and the constant motion of the needles had a tendency to produce weariness. Therefore, although he had worked for many years, to a great extent by the aid of the telegraph, he thoroughly concurred with the remarks made in the Paper and in the course of the discussion, that the Electric Telegraph was a dangerous instrument to trust, as the primary agent in the working of a railway. As an auxiliary, telegraph train-signalling was invaluable, and circumstances were continually arising, which temporarily called it into play as the primary and indeed sole agent, and rendered its application indispensable. He remembered on one occasion, while on the London and North-Western Railway, that there were fifty hours' consecutive dense fog; and during the whole of that time the enormous traffic of that railway was carried on exclusively through the agency of the telegraph. One reason of his hesitating to place implicit reliance upon the Electric Telegraph was, because telegraphists themselves were liable to error. In the Electric and International Telegraph Company, with which he was connected, it was found that the best clerk in the establishment made a mistake once in five thousand nine hundred and eighty times. When

the length of public messages was compared with the simple work of signalling trains 'in' and 'out,' the mistakes would doubtless be much fewer in proportion in the working of a railway. Still blunders would unavoidably occur; and as on many lines there were six hundred, or eight hundred trains in a day, they must soon, on the system of averages, arrive at a point when one of those mistakes might involve the most serious results. Highly, therefore, as he appreciated the marvellous facilities and the great power which the possession of the telegraph conferred on railway managers, he agreed in the opinion that the telegraph should not assume a more important position on railways than it deserved.* At the same time he was convinced that Railway Companies had not given that attention to the subject which it undoubtedly deserved; for the telegraph enabled managers to expedite, under extraordinary circumstances, the passage of trains, and to economise time and money, and as auxiliary to and corrective of other signals it was productive of increased safety.

With regard to the London and North-Western line, he knew of no system superior to the very simple one which he left there some years since. The distance of 83 miles between London and Rugby, was divided into lengths of $2\frac{1}{2}$ miles, and at each point there was an instrument with two signals for the 'up' and 'down' lines. The simpler the system could be made, the nearer would comparative safety be attained; and although three blows on the bell for one signal and five blows for another might seem pretty in theory, he was satisfied that it would be better to return to the simple indications of the needle; and it was most desirable to endeavour to enforce uniformity of operation.

Another question arising out of this Paper, was the danger of working single lines by the telegraph alone. He held that a single line, under proper regulations, might be rendered even safer than a double line. Parliament had recently granted running powers to various companies over the lines of other companies: and in the last session that principle was extended, by giving running powers to competing companies over the same single line of railway. He believed this was a wise step, and that the single line might be rendered safer for competing companies to work over than a double line. But then the telegraph must be ignored altogether, as the sole, or even the primary agent of safety. The only way by which a single line could be worked with absolute safety, was by the 'train-staff.' He should like to see it more extensively used, and as he travelled a good deal on a single line belonging to the South-Western Company, he should feel more comfortable if the working was conducted on that plan. The train-staff could scarcely go wrong, whereas in the manipulation of the telegraph one mistake might be fatal. With the train-staff there must be the consen-

taneous mistake of three men to produce a collision; the station-master who had charge of the staff, the guard who received it from the station-master, and the engineman who could not move till the staff was produced. Under that system a dozen companies, although doubtless subject to delay, might work over the same line with absolute immunity from danger, which was after all the main object of every manager. The telegraph alone in such cases was a source of positive danger. Allusion was made in the Paper to an accident on the Hereford line from the omission of the word 'at,' and he knew a very recent instance, in which a family was brought from Switzerland, and an establishment in England broken up, through the omission of the word 'not' in a telegram. He therefore for one must decline to rely exclusively on the telegraph under any circumstances, and as the primary agent he would caution railway managers against its unrestricted adoption.

Mr. FLEEMING JENKIN believed that the point of real importance in this discussion was, what system of signalling should be adopted; and whether if the 'block' system were thought the best, it could be strictly carried out. He regretted that experience did not entitle him to speak on this point; but he would briefly refer to the several instruments by means of which the block system could be conducted.

The Author of the Paper alleged, that Mr. Tyer's instrument could be deranged by atmospheric electricity. On that point Mr. Jenkin agreed with Mr. Tyer's reply in almost every particular; as the instrument was not peculiarly liable to be deranged by atmospheric electricity. The little needle which was deflected was not a permanent magnet, and could not be demagnetised; and therefore, although one wrong signal might be sent by a current of atmospheric electricity, no series of false signals could be transmitted, as might happen if the magnetism of a needle were reversed. The only permanent magnet in connection with the instrument was placed outside the coils, and could not be influenced by those coils. A momentary atmospheric current would, however, produce a permanent alteration in the signal; a fault which did not occur in some other systems. The instrument was also very simple, and only required one wire from station to station; whereas every other system involved the use of at least two wires. Another merit was, that the batteries employed were not permanently closed. The current was not kept constantly flowing through the wires, and consequently the batteries did not deteriorate so rapidly as in those systems in which a permanent current was maintained. One defect of this instrument was, that it did not show immediately any failure that might have occurred in the circuit. If the batteries were out of order, the needle remained where it was placed, and could not be altered; whereas by the system of

Mr. Edwin Clark, on the London and North-Western Railway, in the event of any interruption in the working, the needle became vertical, and the signalman at once knew that something was wrong with the circuit. But Mr. Tyer's instrument had what might be considered a more serious fault, although it was evident that it was not generally so regarded, as several railway managers had declared themselves perfectly satisfied with the instrument. If, for instance, it was wished to move the black needle at the distant station to 'train on line' one button, or piston-rod had to be touched; while, when it was desired to move it back to 'line clear' the other button had to be pressed. In each case the red needle at the home station followed the motion of the distant black needle, and so far nothing could be simpler. But signals had to be sent, when neither needle was required to move, when the gong, or bell only was to be sounded, to call the distant station, that it might send back the permanent signal. Now, to send this call, sometimes one and sometimes the other button had to be pressed, according to the position of the little red pointer. To send one and the same signal two different buttons had to be used at different times, and if the wrong button were chosen, the needles showing the condition of the line would be altered when they ought not to be moved.

Mr. Jenkin then referred to the electrical peculiarities of Mr. Edwin Clark's instrument, about which little had been said in the course of the discussion, except by Captain Huish who had stated, that in practice it had fulfilled its purpose extremely well. It was a needle instrument, and only those who were acquainted with telegraphy could appreciate the advantages which were expressed in those words. These instruments were made of a common magnetised steel needle, balanced on two pivots. There was the least possible amount of friction to restrain the motion of the needle; the action was of the simplest kind, and was scarcely liable to be deranged. The block system was worked by this instrument in the same manner as by Mr. Tyer's. The man at one station called another station by a temporary signal, and the man at the other station made the signal permanent. In that respect the system was the same in both. But if anything went wrong with the electrical circuit, it was at once shown by Mr. Clark's instrument; and it had not the serious defect, that at one time the signal sent by a given handle meant one thing, and at another time it meant another thing. The temporary signal, or call, was given by a temporary movement of the handle, the permanent signal by a permanent alteration in the position of the same handle. The only objection urged against it was, that the needles were liable to have their magnetism reversed. If that happened, the signals sent would be false; but he did not think

that would necessarily lead to accident, or mistake, as a complete signal consisted of a signal sent and an answer received, and unless the two corresponded, which would not be the case if the needle of one instrument had its magnetism reversed, there would not be much risk of error. Moreover, he did not think this was an accident that frequently happened, and if proper precautions were taken, it could never occur. It was quite possible to provide every station with an efficient lightning protector of the most simple description, consisting of one iron plate lying on the top of another, and that would act as an almost perfect protection against the effects of lightning. Further he would say, that rather than use inferior, or more complicated, instruments, he would prefer to put up an extra wire, in connection with the earth, from post to post, along the whole line, and then there would be perfect security against the action of lightning. A momentary atmospheric current of insufficient strength to demagnetise the needle would on this system do no harm; inasmuch as the permanent battery would bring the needle back to its proper place. In Mr. Tyer's instrument, on the contrary, the momentary atmospheric current would produce a permanent effect.

With regard to Mr. Preece's instrument, he would in the first place refer to it as used to give a negative and a positive signal, or, in other words, as an instrument which could be employed as the two others were in working the block system simply. As an instrument, he thought it inferior to the simple needle instrument. There were several hinges, and at each there was a liability to stick. In addition there was a cog-wheel and rack, and the great motion of the semaphore arm, as compared with the small motion of the armature, placed the latter at such a disadvantageous leverage, that the slightest check to the end of the semaphore arm would prevent the motion of the armature, whether moved by the current, or by the weight, unless very powerful currents were had recourse to; and the utmost force caused by the electric current was very feeble. Moreover, the working parts were much exposed to dust and dirt. As regarded the action of atmospheric electricity, only soft iron being used, there was no needle to be demagnetised; but that advantage was counterbalanced by a peculiar property of soft iron. With a soft iron electro-magnet, when an instrument was adjusted to work with a delicate current, if a strong current passed, such as would result from atmospheric electrical action, a certain amount of magnetism would remain in the soft iron, and that would retain the armature down when it ought to let it rise up. On the other hand, if the instrument was set to work with strong currents, the time might come when considerable leakage would take place, and when the current would be too weak to move the armature at all. In needle instruments there was a gradual scale of effects, and the

weakest currents of electricity were sufficient to show something. He therefore preferred the needle instrument. He considered that when a needle was permanently deflected on one side, a signalman was as likely to understand that, as the little arm of the semaphore; but if semaphores were used at all, he preferred that on Mr. Walker's plan, which was a red arm placed on a needle. There was but one pivot, and some of the disadvantages he had referred to, in connection with Mr. Preece's system, disappeared. In Mr. Preece's instrument if anything went wrong with the circuit, the instrument would not show it, and so far it was inferior to Mr. Clark's; but the semaphore arm would point to danger, and in this respect be better than Mr. Tyer's. Mr. Preece had suggested that not only should the call be answered by a permanent signal, but that this answer should be acknowledged by a third signal, and moreover that the receipt of the answer should be acknowledged automatically by the instrument. That arrangement necessitated the use of five wires for a double line, whereas Mr. Clark's only required two, and for Mr. Tyer's only one was necessary. The question of expense might be no great consideration, but a system of automatic contacts ought to be avoided. The force of electricity at disposal was small; the contacts were always points of danger, as the smallest particles of dust were sufficient to cause them to fail. The third automatic signal appeared to him to be a defect rather than an advantage.

With reference to Mr. Walker's instruments, and others which did not leave a permanent visible signal, he thought they threw too great a strain upon the attention of the signalman. In his opinion, Mr. Clark's system, as in operation on the London and North-Western Railway, had fewer practical objections, and was therefore safer, than any other. The using-up of the batteries was of little consequence, and with the exception of requiring protection against lightning, he did not think it stood in need of any improvement. Probably no one rigid system of signals, such as was strictly required for the block system, would meet all the requirements of the railway; and possibly there ought in all cases to be an extra wire between stations, with a bell, or speaking instrument, supplementary to what might be called the block instrument.

Mr. BARTHOLOMEW could not allow the remarks just made to pass unnoticed. Great stress had been laid upon the advantages of the London and North-Western system; now, although it might be a good one, it had this serious defect, in common with all needle instruments, that it could be used for other purposes than train-signalling. He thought no system of mechanism intended for train-signalling should be able to be made available for anything else. One objection urged against Mr. Preece's instru-

ment was, that as there were so many pivots, the chances of derangement were increased. That might be correct; but it must be borne in mind, that the action of the electricity, which had to work upon the short end of the lever, was to show the 'all-clear' signal. If, therefore, anything went wrong, from the battery becoming weak, the semaphore arm was immediately raised to 'danger'; and though this might involve the temporary stoppage of a train, a short detention, under the protection of a back station, was preferable to having a false signal to proceed, whilst there was an obstruction upon the line.

The discussion appeared to embrace two separate questions,—first, as to the peculiar kind of system to be adopted, and secondly, as to the advisability of signalling trains by telegraph. He gathered from some of the observations made by railway managers, who ought to be most competent to judge what was necessary for the protection of the traffic, that the telegraph had better be dispensed with altogether, so far as regarded the signalling of trains. He thought those managers who raised objections against the block system, on the ground of it causing unnecessary detention, lost sight of two points. Usually signal stations coincided with passenger stations; but on the South-Eastern Railway, when the latter were so far apart as to retard the traffic, with such an interval of space between the trains, the distance was subdivided. If the distances between the signal-stations were made to correspond with the maximum amount of traffic likely to arise on any particular section of the line, then this objection to the block system, that it unnecessarily delayed the traffic, would be at once removed. Another point was, that whilst the block system was ignored as an advantage on the open line, its importance was admitted in tunnels, where the greatest caution was required. It was said, that anything which might distract the attention of the engine-driver from his straightforward look-out, must be objectionable; but in a tunnel full of steam, the look-out of the engine-driver was of small value to the safety of a train, which was then solely under the protection of the block system.

He was rather surprised to find that his system, which had been in operation for eight years on the most crowded part of the Brighton line, including the whole of the Crystal Palace traffic, and during five years without his surveillance, should have been overlooked; while Mr. Tyer's instruments, which had only been in use for a few months, on a small portion of the less crowded part of the line, were stated to have answered extremely well on that railway. Both instruments, perhaps, had their own peculiar faults, in common with all others. One great defect in all the systems that had been spoken of, was that arising from the failing of the batteries.

Professor Wheatstone's arrangement of magnetic signals, which he exhibited, coincided with his idea of what train-signalling ought to be. As there was no voltaic battery, there was no diminution of power; and it would be as available twenty years hence, with ordinary care in guarding against rust, &c., as at the present moment. Their power was also far beyond the limit to which any train-signalling instrument was required to work; the instruments now shown being capable of working over 100 miles of railway, whereas they were then speaking of sections of only 5 or 6 miles in length. There was, therefore, a great surplus of power. These instruments had also this advantage, not possessed by any other with which he was acquainted, that whilst they might be arranged so as to give two signals only, either 'train on line,' or 'line clear,' a large number of other signals could likewise be inserted. For instance, on the Edinburgh and Glasgow Railway, between the Cowlairs and the Glasgow stations, there were instruments of this construction, arranged for transmitting fifteen signals, which had given great satisfaction.

It was well known that three signals were given by all station signals—'all clear,' 'danger,' and 'caution.' Now, he should like any one to point out the value of the 'caution' signal as at present employed. He had frequently remarked to those connected with traffic on railways, that it was a dangerous signal in itself. He knew places on lines of railway at which the signals were always either at 'danger,' or at 'caution.' The 'caution' virtually meant in such cases 'all clear,' and the engine-driver, becoming aware of the nature of the supposed impediment which existed on that portion of the line, from the frequency with which he passed the spot, would, in ninety-nine cases out of a hundred, never take the least notice of the 'caution' signal. On the Great Western line, the 'caution' signal was given by a policeman with his hand, and he thought it a good system, as the signal was only given on peculiar occasions, and when really required. But the semaphore with the arm always at 'caution' meant nothing.

Another point, which was deserving of greater attention than it had received, was the advantage of having indexes at level crossings, in connection with the train-signalling apparatus at the adjoining station. This appeared to be adopted in Mr. Walker's system on the South-Eastern line. When the stations were 3 or 4 miles apart, or where the curves would not admit of the crossing-keeper seeing what was coming till the train was close upon him, it was of the utmost consequence, that the man should be aware when anything had left the stations on either side.

When railway managers stated that they did not like the telegraph,—that it was subject to derangement, and might be a source of error,—he did not think it got credit for the accidents that

were avoided through its agency. When an accident took place, the cause was attempted to be discovered, so that the blame might be fixed upon some one, and possibly a child employed to work the signalling apparatus, became the scape-goat. As long, however, as the traffic went on smoothly, no credit was accorded to the telegraph. His own opinion was, that if any derangement occurred in the working of the train-signalling apparatus, it was owing to managers not giving the telegraph its due importance. In fact boys, occasionally mere children, were employed to work this apparatus, sometimes by day and sometimes by night, for twelve hours consecutively, because the pay allowed would not procure the services of men, who could appreciate the importance of the right use of the apparatus under their control. It was like expecting good workmanship from an unskilful workman, simply because he had good tools to work with.

Mr. CULLEY said, he had no system of his own to bring forward, nor even a pet scheme to defend; but for the last seventeen years he had been intrusted, at different times, with the management and maintenance of the Electric Company's telegraphs and of systems of train-signalling, in Scotland, and on almost all the lines of railway in the West, the Midland Counties, and the North-west of England. He had consequently visited a large number of tunnels, and had been able to learn from the signalmen in charge what they had most confidence in. He had found the system of permanent signals preferred to those in which the same wires were used for both lines of rails, and by which trains were simply 'reported' as in or out of a tunnel. It was true that the want of a permanent visible signal was in some measure compensated for, by the entry of each signal in books provided for that purpose; but unless the entry was made at the moment, there was danger that it might be neglected, and the book be made up afterwards. At Springwood, near Huddersfield, there were two tunnels, connected by a short open cutting, in which cutting was a junction with another line—a most difficult point to work. There were three cabins with telegraphs. So much were the men impressed with the necessity of having a permanent signal, that they invented one of their own, consisting of a piece of red rag placed on the instrument when there was a train in the tunnel, and removed when it was reported clear. This red rag was he believed now replaced by a card. Generally speaking he found temporary signals were adopted for the sake of economy: but it was not so in the instance to which he referred, for double-needle instruments were used, and one wire might have been appropriated to the up line and the other to the down line without extra expense. He had heard that the block system was about to be adopted at this place.

Bells to indicate 'line clear,' or 'line blocked,' seemed more objectionable than the system of temporary needle signals; because the eye was more to be depended upon than the ear. He had never had to maintain a bell-system; yet from what he knew of bells, he should be sorry to trust the safety of the line to the accuracy of observation of the number of strokes. He merely ventured this general opinion, as he might be prejudiced in favour of the needle. He had not any experience of the working of Mr. Walker's system, but from what he had heard of it, and from what he knew of the apparatus used, he believed it was the best bell-system that had been introduced.

Mr. Preece had omitted to mention, in his description of the block system, as used at the Clay Cross tunnel and elsewhere, that when the signal 'line clear' was given, on the exit of the train from the length protected by the telegraph, it should be repeated, or acknowledged by the man at the end at which the train had entered. This repetition was the safeguard against error, and against failure from demagnetisation, reversal and accident to the wire, or the apparatus. He was aware that it was not always insisted on, for a few months since he heard of a narrow escape. At the place he referred to, the 'block' was taken off, by simply releasing the needle and allowing it to remain upright. The instrument at the cabin towards which the train was running happened to fail, the needle dropped, but the man very promptly managed to restore the current, although not until the semaphore at the end by which the train entered had been lowered. But if the correct practice had obtained at this tunnel, the sudden failure of the block would not have led to the lowering of the semaphore. It would have been seen that there had been no reversal to 'line clear,' and on trying the instrument, it would have been at once perceived that something was wrong. If the needle were even first reversed by lightning, so as to give a false 'line clear,' and then at once demagnetised, it would be discovered in the act of acknowledging, or of repeating the signal. If demagnetised the needle would not answer the handle at all; if reversed it would move in the contrary direction to the handle. Mr. Edwin Clark's system required permanent currents, and enabled three, instead of two distinct signals to be given. It also allowed of the danger signal being sent from any part of the section. He had no recent experience of Mr. Tyer's system. He had charge of it some years since on the Great North of Scotland and on the Furness Railways. Each system had its own peculiar faults and advantages. It was, in his opinion, most important that the faults should be similar to those of the other telegraphs on the line, so that the man in charge should not have a new set of symptoms to learn. It was an objection to Mr. Tyer's system that its faults

were peculiar to itself, and required a special training; this objection might not be very serious, but it had its weight. Mr. Preece's system could be easily maintained by any ordinary line-man accustomed to alarms. Tunnels were generally difficult of access by the telegraphic superintendents, and few trains could be found which stopped even within 2 or 3 miles. But if a simple apparatus were used, the signalmen themselves could attend to it. They could be trusted to clean the batteries, to magnetise the needles, and to replace a broken wire. It was rarely the case that this class of men could not be trusted so far, whereas a less simple apparatus, however beautiful, or ingenious, could not be left in their hands.

If it were really desirable to assimilate the telegraphic to the ordinary signals, Mr. Preece had most effectually and ingeniously met that requirement. Mr. Culley could not agree with those who condemned the electro-magnet, because it gave no notice, but failed suddenly. It could not be denied, that the needle was superior in this respect, but an intelligent man would not fail to discover symptoms of lessening power, in the gradually decreasing force with which the arm was lowered. The electro-magnet could not of course be demagnetised, or reversed, and even if the current failed to attract the armature, no accident would result from the failure of the current, for Mr. Preece had very properly arranged, that the current should drop the arm instead of raising it. He considered the needle system had an advantage over the electro-magnetic system, and those of Mr. Tyler and of Mr. Bartholomew. He thought the danger from the demagnetising of the needles, had been overrated, and that it might be considerably reduced by using longer needles. When the Electric Telegraph Company first started, needles 6 inches long were used, which only required to be magnetised about once in six months. The needles now employed were only 1 inch long, and they required magnetising very frequently. The advantage of the shorter needles was the greater speed with which they could be worked, and persons accustomed to work the instruments were slow to adopt the longer needle, even where quickness of signalling was not important. He had obtained permission to place longer needles on the Edinburgh and Glasgow Railway, because those instruments being used for trains, and the men not being able to magnetise the needles themselves, it was desirable that the needles should not be liable soon to get out of order; but he had considerable trouble in keeping them on the line, because those of the men who had been telegraph clerks found they could not converse with their accustomed rapidity.

The system of signals at the tunnel on the up side of the New Street Station, Birmingham, had been referred to, as requiring an unnecessarily large number of wires. The Author of that system

would perhaps permit him to give a brief explanation of it. The tunnel was at the foot of a steep incline, leading from the junction of the London, with the Manchester, Derby and Bristol lines. There were points and crossings at the station end of the tunnel, and even in the tunnel itself; and the trains from the different lines had to be shunted to their respective platforms. It was necessary then, that the pointsman should know accurately what train was coming. It was thought undesirable to indicate the trains by beats either of the needle, or of the bell, because a signal if misunderstood might cause a train to be sent on to the wrong line; and it was considered necessary to have a particularly distinct signal. There was first a double-needle instrument, to indicate the description of the train. The movement of the left-hand dial to the right indicated the main line London train, and to the left, the Midland train. The other signals related to the South-Staffordshire line, and to goods trains. When a train reached the ticket platform near the top of the incline, the first step was for the man at the ticket platform to block his indicating needle over to the name of the train coming down; thus asking the man at the other end whether the station was clear, or not, for that particular train. The reply was given on a third dial (showing only the two signals 'line clear' and 'line blocked'), by the pointsman at the switch box blocking his handle over. The signal indicating the description of the coming train was kept on, until it had passed the station points, when the pointsman took off the block, and the man at the ticket platform released the indicating needle. He was informed that, even with these precautions, it had been found necessary to introduce a supplementary pair of wires and dials for the ordinary block system, making five wires in all. Extreme safety was thus gained, and though there were many wires, each had its special use, and had been found in practice to be necessary.

Mr. HEMANS regretted that so many serious difficulties appeared still to exist in the perfection of the telegraph system; because he happened to be connected with several companies in Ireland, where single lines were in use to a great extent. He was rather surprised to hear, from so eminent an authority as Captain Huish, that the 'train-staff' system, as it was generally called, for working single lines, was one which left nothing to be desired. Mr. Hemans had found, from experience, that it was exceedingly defective; so much so that he was satisfied, unless great expense was occurred in doubling the lines, which the traffic on many railways would not justify, that it would be necessary to introduce the bell, or some other telegraph system. The Dundalk and Londonderry Company had a single line of 120 miles, and he had single lines to the extent of 75 miles. He had found, even when running

only four trains per day in each direction, that it was next to impossible to repair defects on the line without working in the middle of the night, owing to the difficulty of getting the 'train-staff' from the passenger trains, for the use of the ballast trains, or even to run extra trains at times of fairs and markets. Under the 'train-staff' system a line might be shut up for hours, when under the telegraph system it might be usefully employed. Supposing a line to be divided into sections of 10 miles: a train would take twenty minutes to travel that distance, and during that time nothing else would be able to pass over that section. Further, there must be the delay of the train coming in the opposite direction, to bring back the 'train-staff' to the starting point. He was convinced that one, or other of these telegraph systems, when perfected, must be adopted, if ever the traffic upon single lines of railway was to be fully developed.

Captain TYLER, R.E., remarked, in reference to the working of single lines, that the train-staff had answered admirably in a great number of cases, both in England and Ireland, and that not a single accident had occurred, from trains meeting one another, where it was employed. On the other hand, where telegraph instruments had been used without a train-staff, there had been a number of accidents under various systems of working, in consequence of mistakes and misunderstanding on the part of the persons in charge of the instruments. Railway traffic was always liable to irregularity, and any system that could not be thoroughly relied on, under this condition, was not fit for adoption. When the time-tables could not be adhered to, it was frequently necessary that the crossing-places of the trains should be altered; and the station-masters then required, either to receive instructions, from a superior officer, and to convey them to others, or to arrange between each other as to those alterations. But station-masters were not always at their posts, and these arrangements were left, during their absence, to the porters, or other subordinate servants. It was in consequence of numerous accidents having taken place on different railways, that he had come to the conclusion, that the electric telegraph was not to be depended upon for the safety of the traffic on single lines. It was an admirable auxiliary for convenience, and no single line ought to be unprovided with it; but for safety he considered the train-staff alone ought to be trusted.

With regard to working double lines by telegraph, there were certain principles which should be observed in all cases; and those instruments ought to be adopted, which would allow of those principles being carried out in the most complete and efficient manner. With two lines of rails, there should be a distinct train-needle (or arm) for each line; and each train-needle should

[1862-63. N.S.]

q

be used solely for saying either 'line clear' or 'line blocked' for the line to which it belonged. There should also be speaking instruments, to enable the men to communicate with each other, and thus to prevent their being tempted to use the train instruments for that purpose. Greater uniformity, than at present prevailed, was very desirable. He knew an instance in which four different systems of telegraph signalling were in charge of one man; and it was extraordinary how, under such circumstances, the traffic could be conducted with safety. When a junction was made between two lines on which different systems obtained, it became difficult to determine which should be adopted at the junction box, or station. Without venturing to express an opinion as to which was the best system, he might be permitted to say, that he thought the needle-instrument had, among others, a great advantage, in always showing when anything went wrong, provided the needles were kept habitually blocked over, either to one side, or to the other. When the needle assumed a vertical position, it was a sure indication that something was out of order; and no instrument ought to be used which did not at once indicate when there was any derangement.

Mr. E. A. COWPER believed no system of signals or telegraphs could ever be of the same importance, as careful and intelligent vigilance on the part of the guards and engine-drivers; and he felt bound to add his testimony to their general watchfulness. Still, if it were possible to increase, so to speak, their powers of hearing, and make them very long-sighted, so as to enable them to know at all times what was on the road two miles a-head, and practically to hear a train start from a station two miles behind, he thought it would be admitted that greater safety would be obtained, particularly having regard to the high speeds now so common, together with the usually deficient break power.

The long-established practice of working railways in Germany by telegraph, had been passed over in a summary manner in the Paper; for the Author had stated little more than that there were a number of bells and but few trains. Now the fact was, there was a considerable traffic on many lines, and although frequently consisting only of a single way, yet there were fewer accidents than on many double roads in this country. The system of signalling was not confined to bells, as one or more of the telegraph wires were devoted to regulate the trains, and generally on a 'block' system, so that a driver knew what was before him, and when a train started from a station behind him.

He might mention, that, in the year 1840, his attention having been called to the difficulty of signalling by a person on the road to the driver of a train, he had attempted, and perhaps with some success, to increase, practically at least, one of the senses of the

driver; and as during a fog sight was of no avail, he had determined to try a definite appeal to hearing. After making several experiments on the Croydon Railway, by permission of Mr. Gregory, (V.P. Inst. C.E.,) then the Resident Engineer of the line, he succeeded in producing the Fog Signal, now so universally known, and he trusted, appreciated. It was only due to Mr. Gregory to say that, possibly but for his assistance, that simple little instrument might not have been introduced, and many lives might thus have been lost, and the traffic at times greatly interrupted.

Mr. ADLEY could not allow the observations of Captain Tyler, with regard to the inefficiency of the telegraph in the working of single lines of railway, to pass unnoticed; inasmuch as in India about 2,000 miles of single lines (or considerably more than all the railways in Ireland put together) were worked by the telegraph, with comparative freedom from accident. During the not inconsiderable period, when he was in charge of the telegraph on the East-Indian Railway not a single accident had been caused by the system, though many had been prevented by it. If the telegraph had been the source of accidents on single lines in England, the failures must have arisen from mismanagement and for want of proper rules, rather than from any inherent defect in the system. Any accidents that had been imputed to the telegraph, as far as he could ascertain, were due more to the eccentricity of genius on the part of the railway officials, than to the system itself, when worked under proper guidance.

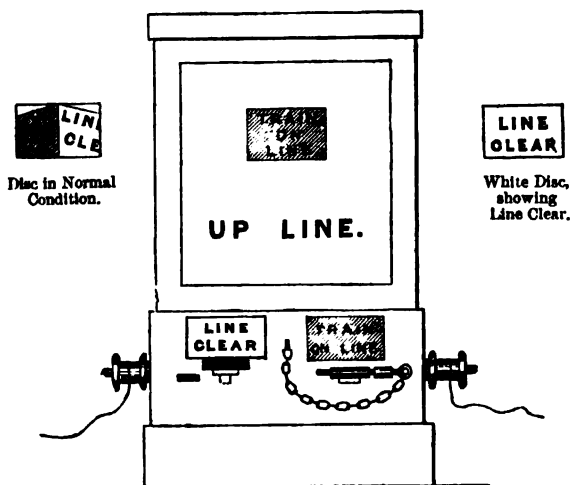
It was stated that 27 per cent. of the accidents in England were due to the want of the telegraph. As all the Indian railways had telegraphs, this percentage might be assumed to be erased from their quota of casualties. It would appear from the Parliamentary returns, that out of 4,225,240 passengers carried in India during the year 1860, none had been killed from causes beyond their own control, while .94 per million only were injured. On comparing this with the English returns, it appeared that out of an annual average of 139,000,000 passengers carried 15 per million were killed, while 3.19 per million were injured. According to the latest returns, however, for the past year, the passengers carried were 173,721,139, while the number killed were .26 per million, and 4.50 per million received injury. It also appeared that one-half of the accidents on the English lines arose from collisions, while on the Indian railways one-seventh only emanated from the same cause. This proved that collisions, which might be looked upon as preventible accidents, to a certain extent, were less frequent in India, and necessarily so, owing to the aid afforded by the telegraph in regulating the traffic.

Mr. Preece had stated that the telegraph was an uncertain agent, because of its mechanical arrangements. In this remark

he could not altogether agree, as he had found it very reliable, amounting almost to a certainty, and the greatest confidence could be placed in it. Moreover, Mr. Preece, in his instrument, had a greater number of mechanical parts, which were so objectionable, and hence increased the liabilities to derangement; for in place of the direct action of a simple needle oscillating on a pivot, there was an indirect motion produced by a combination of levers. There did not seem to be any special advantages in the various instruments which had been exhibited: they were ingenious, and reflected credit on the inventors; but none were so simple, nor so efficacious for train-signalling purposes, as the common needle-instrument adopted by Mr. Edwin Clark.

Mr. T. MARR JOHNSON said, his particular attention had been directed to this subject, in reference to the train-signalling on the Metropolitan Railway. It was his duty as Resident Engineer, to examine most of the systems and instruments that had been referred to, as well as some others, but he did not feel entitled to pronounce upon their merits, as against the opinions of those who had made the matter a constant study. In the case he alluded to, it was considered necessary that, as so much depended upon the signalling, the system as well as the instruments should be simple and easy of comprehension by men of ordinary capacity, and that the instruments should be as little liable to mechanical derangement as possible. The instruments adopted on the Metropolitan Railway were the invention of Mr. Spagnoletti, and they had

Fig. 14.



Mr. Spagnoletti's Instrument, as used on the Metropolitan Railway.
Red Disc, showing Train on Line.

received the unqualified approbation of Mr. Fowler, the Engineer-in-chief of the line. In the normal condition of the instrument, when not in action, or in case of derangement, neither signal was distinctly visible. The line was blocked by pressing the red key, when the disc at both stations immediately showed the red colour, and the words 'train on line.' The colour indicated by the disc was always identical with that of the key upon which the finger was placed. The white disc signal was given for 'line clear.' Either could be seen from any part of the signal-box with a moderate light, and he considered that the marked distinction offered by the broad discs of different colours (red and white) constituted of itself an advantage over the needle signal. In this instrument when the battery became weak, the disc would show a narrow strip of an opposite colour, which increased with the decrease of battery power, and the weakness of the battery was apparent, long before it was of serious importance. The attention of the signalman was called by a bell. Supposing a train had just left A to go to B, the disc at A showing the white colour, B would receive a bell-signal of one stroke from A. At the same time the disc at B would be put over to 'train on line,' but not permanently fixed there. B would then reply by a return stroke of the bell, and by pinning down the red key, which would show a red disc both at A and B, and would indicate that no train was to be allowed to follow until B released it. B would always know by his own disc what colour was being shown at A; thus no effort of memory was required, and no mistake in the signals could be made. The Metropolitan Railway was worked entirely by telegraph; the trains being controlled by station semaphores, moved by the man at the disc instrument. During the three weeks that it had been opened, more than half a million passengers had been conveyed over the line; and on one occasion the passengers amounted to nearly forty thousand within fifteen hours. Some trains were run at intervals of four minutes, some at seven minutes and a half, and others at irregular periods, and no mistake had been made in the working.

Mr. BRAMWELL said, although he had not an intimate knowledge of the minute details of these instruments, nevertheless he believed he was sufficiently acquainted with the subject to appreciate when one instrument came in the guise of another. He could not help thinking, from the opinions which had been expressed, that the instrument of Mr. Edwin Clark was probably the best of all. Now, with reference to the system adopted on the Metropolitan Railway, he was at a loss to understand the distinction between it and Mr. Clark's, except that in Mr. Clark's instrument the needle pointed to the writing, and in Mr. Spagnoletti's the writing was moved by the needle. He thought the latter plan

was objectionable, because in that case the needle was loaded with the surface containing the writing, and, therefore, had to move that surface, as well as itself, while in Mr. Clark's machine, the only matter to be moved was the needle, the writing remaining quiescent.

Mr. NEWMAN said Mr. Clark's signals were erected on the London and North-Western Railway in 1855, under his superintendence, and he had maintained them since that time. He thought the intelligence of the signalmen on railways had been underrated. On the London and North-Western line, they were supplied with magnets, with which they remagnetised the needles when required, and also with sulphate of copper, to recharge the batteries when they got weak. Those duties were performed with the greatest ease, and the instruments worked admirably.

Mr. JENOURE had had some practical experience on railways in the north of England, in Scotland, and in Ireland, as a Supervisor and District Engineer of Telegraphs, but he was not an advocate, or a partisan of any one method. The Author of the Paper urged the importance of having telegraph-signalling rooms wholly distinct. Such an arrangement might be advantageous, when liberal provisions allowed the constant attendance of steady and efficient clerks; but he rather held to an opinion he had formerly expressed, that the various telegraph methods should be generally taught in schools, so that when boys were taken into the service of a Railway Company, they might be able to work any telegraph instrument. He was in favour of the simplest forms of signalling, and held that the acknowledgment of a signal was indispensable, whether such response was by sound, or by a visible indicator. He thought the various alphabetical instruments might be adopted with advantage, because they placed the power of communication in the hands of station-masters, who had not learned the short-hand methods. On the Stockton and Darlington line,¹ the block system was maintained in a somewhat peculiar form, the whole of the mineral traffic being regulated by clockwork alarums. When a train left station A, a key was depressed which rang a bell at station B, and nothing was allowed

¹ Mr. Thomas MacNay, Secretary to the Stockton and Darlington Railway Company, in a letter to the Secretary Inst. C.E., dated January 19th, 1863, relative to the plan adopted in working that line, says—

"All passenger trains are telegraphed by the 'Bell telegraph' from one station to the other; that is, as soon as a train has left a station, the telegraph signal is given to the next station, and that station is to reply, so as to make it known, that the signal has been recognised. Any neglect or omission to reply, is reported to the Superintendent. On any part of our railway which is a single line, we work by the 'staff-system,' and cause a regular message to be sent from one station to the other, stating that the passenger train has left, and the station answers that the message has been received."

to leave B until the train from A arrived there. Traffic might by this method be interrupted accidentally. He had once inadvertently touched a key at station A, which led station B to suppose that an unusual train had left, and the traffic from B to A was stopped, until it could be ascertained that the line was clear. This was an imperfect mode of signalling, because no opportunity was afforded of correcting a mistake. The frequency of trains in other parts of the country did not nearly approach the number on the lines about London, still on many lines the traffic was heavy. The Lancashire and Yorkshire Company's system of telegraph signalling, with Mr. Highton's single-needle instruments, was very complete, so far as regarded the breaking up into short circuits; and it was difficult to imagine how the trains would get on at all without the aid of electricity, for they were frequently behind time. That with care and punctuality a line might be worked without any electrical signals, was shown by the instance of the railway between Glasgow and Paisley, a length of 6 miles 7 furlongs. This line was the joint property of the Caledonian, and the Glasgow and South Western Companies. The former worked all the Greenock traffic over it, and the latter all the traffic to Ardrossan, Ayr, Dumfries, &c. There were two junctions, one tunnel, and one roadside station, between Glasgow and Paisley; both Messrs. Cooke and Wheatstone's, and Mr. Highton's instruments being employed, at Paisley and at the Glasgow terminus for ordinary messages. A year and a half ago he was consulted with reference to the adoption of some system of electrical signalling for trains on that line; but not being satisfied of the thorough efficiency of any mode then in use, the question was deferred. In reply to a recent inquiry, the manager of that line wrote, "We have not any electrical signals in the working of our traffic. In midsummer we had on an average one hundred and eighteen trains within nineteen hours, including up and down traffic. During five hours of the night the line was not occupied. For the greater part of last summer I wrought about one mile of the line as a single way while relaying. This was done under the Red Cap Pilot, and we had comparatively little delay, and no accident." He could bear testimony to the value of electrical signalling as an economical measure, even in its most expensive form, particularly in the case of long tunnels, where the costly use of pilot engines must be resorted to, if the wires failed only for a short time. In these days of ingenuity and diversity of opinion, the uniformity of system, which had been advocated, was scarcely practicable, however desirable it might be; but a wide field was open for labour and for improvement, and he agreed with the Author of the Paper in wishing, that railway authorities would take up the subject more earnestly and zealously than heretofore.