TRANSACTIONS

OF THE

Institution of Engineers and Shipbuilders

IN SCOTLAND

(INCORPORATED).

VOLUME XLIII.

FORTY-THIRD SESSION, 1899-1900.

EDITED BY THE SECRETARY.

GLASGOW:
PUBLISHED BY THE INSTITUTION AT
207 BATH STREET.

1900.

Sci 1480.151

MAR 22 1901

LIBRARY.

Engin. Appropr.

PRINTED FOR THE INSTITUTION BY
WILLIAM ASHER, PRINTER AND PUBLISHER,
128 RENFIELD STREET, GLASGOW.

OFFICE-BEARERS.

FORTY-THIRD SESSION, 1899-1900.

President.

ROBERT CAIRD, LL.D., F. R. S. E.

Vice-Presidents.

JAMES GILCHRIST.
PROF. W. H. WATKINSON.
PROF. ARCHIBALD BARR, D.Sc.

Councillors

ARCHIBALD DENNY.
WILLIAM FOULIS.
MATTHEW HOLMES.
JOHN F. M'INTOSH.
MATTHEW PAUL.
WILLIAM BEARDMORE.
A. S. BIGGART.
THOMAS KENNEDY.
HENRY A. MAVOR.
R. T. MOORE.

Finance Committee.

ROBERT CAIRD, *Convener.*
WILLIAM FOULIS.
MATTHEW PAUL.
THOMAS KENNEDY.

Library Committee.

PROF. W. H. WATKINSON, HON. LIB., *Convener.*
HENRY A. MAVOR.
R. T. MOORE.
MATTHEW PAUL.

Honorary Councillors—Past Presidents.

JAMES M. GALE.
HAZELTON R. ROBSON.
JOHN INGLIS, LL.D.
SIR WILLIAM ARROL, LL.D., M.P.
GEORGE RUSSELL.

House Committee.

From Institution.
ROBERT CAIRD, F.R.S.E.
PROF. ARCHIBALD BARR, D.Sc.
A. S. BIGGART.
JAMES GILCHRIST.
HENRY A. MAVOR.
EDWARD H. PARKER, *Secretary.*

From Philosophical Society.
DR F. FERGUS.
JOHN ROBERTSON.
J. F. CAMPBELL.
GILBERT THOMSON.
JOHN MANN, *Treasurer.*

Committee on Papers.

ROBERT CAIRD, F.R.S.E.
PROFESSOR ARCHIBALD BARR.
ARCHIBALD DENNY.
PROFESSOR W. H. WATKINSON

Representatives on the Board of Trade Consultative Committee.

JAMES DENNY.
JAMES HAMILTON.
JAMES WEIR.

Representatives on Lloyd's Technical Committee.

SINCLAIR COUPER.
JAMES GILCHRIST.
FRANK P. PURVIS.
JOHN WARD.

Representative on the Board of Governors of the Glasgow School of Art.

JAMES MOLLISON.

Representative on the Board of Governors of the Glasgow and West of Scotland Technical College.

JOHN WARD.

Honorary Treasurer—JAMES M. GALE City Chambers John Street.

Secretary and Editor of Transactions—EDWARD H. PARKER,
Institution Rooms, 207 Bath Street.

Curator and Librarian—FRANCIS MARTIN, Institution Rooms, 207 Bath Street.

PRESIDENTS OF THE INSTITUTION

Since Foundation in 1857.

1857-59	WILLIAM JOHN MACQUORN RANKINE, C.E., LL.D., F.R.SS.L. & E., Professor of Civil Engineering and Mechanics, Glasgow University.
1859-61	WALTER MONTGOMERIE NEILSON, Hyde Park Locomotive Works, Glasgow.
1861-63	WILLIAM JOHNSTONE, C.E., Resident Engineer, Glasgow & South-Western Railway, Glasgow.
1863-65	JAMES ROBERT NAPIER, Engineer and Shipbuilder, Glasgow.
1865-67	JAMES GRAY LAWRIE, Engineer and Shipbuilder, Glasgow.
1867-69	JAMES MORRIS GALE, C.E., Engineer, Glasgow Corporation Water Works.
1869-70	WILLIAM JOHN MACQUORN RANKINE, C.E., LL.D., F.R.SS.L. & E., Professor of Civil Engineering and Mechanics, Glasgow University.
1870-72	DAVID ROWAN, Marine Engineer, Glasgow.
1872-74	ROBERT DUNCAN, Shipbuilder, Port-Glasgow.
1874-76	HAZELTON ROBSON ROBSON, Marine Engineer, Glasgow.
1876-78	ROBERT BRUCE BELL, Civil Engineer, Glasgow.
1878-80	ROBERT MANSEL, Shipbuilder, Glasgow.
1880-82	JOHN LENNOX KINCAID JAMIESON, Marine Engineer, Glasgow.
1882-84	JAMES REID, Hyde Park Locomotive Works, Glasgow.
1884-86	JAMES THOMSON, LL.D., F.R.S., Professor of Civil Engineering and Mechanics, Glasgow University.
1886-87	WILLIAM DENNY, Shipbuilder, Dumbarton.
1887-89	ALEXANDER CARNEGIE KIRK, LL.D., Marine Engineer, Glasgow.
1889-91	EBENEZER KEMP, Marine Engineer, Glasgow.
1891-93	ROBERT DUNDAS, C.E., Resident Engineer, Southern Division, Caledonian Railway, Glasgow.
1893-95	JOHN INGLIS, LL.D., Engineer and Shipbuilder, Glasgow.
1895-97	Sir WILLIAM ARROL, LL.D., M.P., Engineer and Bridge Builder, Glasgow.
1897-99	GEORGE RUSSELL, Mechanical Engineer, Motherwell.
Elected Apr. 25, 1899.	ROBERT CAIRD, LL.D., F.R.S.E., Shipbuilder, Greenock.

CONTENTS.

PAPERS READ.

PLATES.

PREMIUMS AWARDED

FOR

PAPERS READ DURING SESSION 1898-99.

GOLD MEDAL.

1.—To Professor ARCHIBALD BARR, D.Sc., for his paper on "Comparisons of Similar Structures and Machines."

PREMIUMS OF BOOKS.

2.—To Mr C. A. MATTHEY, for his paper on "The Mechanics of the Centrifugal Machine."

3.—To Mr JAMES WEIR, for his paper on "The Problem of Combustion in Water-tube Boilers and a Means of its Solution." (Read at Sheffield.)

4.—To Professor JOHN OLIVER ARNOLD, for his lecture on "The Internal Architecture of Metals." (Delivered at Sheffield.)

ADVERTISEMENT.

The responsibility of the statements and opinions given in the following Papers and Discussions rests with the individual authors; the Institution, as a body, merely places them on record.

ERRATUM.

Page 105 line 1, *for* "than" *read* "that."

INSTITUTION
OF
ENGINEERS AND SHIPBUILDERS
IN SCOTLAND.
(INCORPORATED.)

FORTY-THIRD SESSION—1899-1900.

PRESIDENTIAL ADDRESS.

By Robert Caird, F.R.S.E.

Delivered 24th October, 1899

Gentlemen,

In acknowledging the great honour this Institution has done me in electing me to the office of President, I confess that there is mingled with a very natural pride a deep sense of responsibility. It is impossible for the most modest of men to repress—even if it were desirable—a feeling of pride in being called upon to succeed the scientists and engineers whose names, borne upon our Presidential List, are writ upon the larger roll of the leading spirits in the profession the development of which is perhaps the most distinctive feature of the century. The list of your Presidents opens with a name which still holds, and ever will hold, a foremost place wherever applied science is studied. The text books of Macquorn Rankine have stood the test of years, and remain unsuperseded to-day, monuments of an indefatigable activity, of a marvellous genius for mechanics, and of a grasp, resourcefulness, and power, in the application of mathematics to practical problems. There is no one to whom the engineer of to-day is under greater obligations than to him. There is no one to whom the Institution owes more.

Since his time the chair has been successively occupied by leading men in the various divisions of engineering—by eminent marine, mechanical, and civil engineers and shipbuilders.

It is needless to recapitulate them ; you have the list before you in the Transactions, and you can very readily see for yourselves how difficult it must be to fill the place of the least of them. You will, however, allow me to say a word or two with reference to my immediate predecessor, Mr Russell. I served with him for four years on the Council, and had the closest possible association with him in the work of the Institution. I could not but be struck with admiration at the minute knowledge he possessed of the history of this Society. It has grown up with him, and he has never ceased to take the liveliest self-sacrificing interest in its welfare. No one knows more of the Institution than Mr Russell, and no one, certainly, has the promotion of its interests more closely at heart. With these qualities, it is not surprising that our period of greatest expansion is coincident with that of his tenure of the chair. I can never sufficiently acknowledge my personal indebtedness to him for the wise counsel he gave without stint, for the good example he set of diligence and urbanity in conducting business, and for the inspiration of his inextinguishable zeal.

We may, I think, congratulate ourselves on the increase in the membership of the Institution as detailed in the Report of the Council, which has just been presented to you. It is not a sensational increase, but it shows a satisfactory response to the efforts the Council has been making to render this Society as representative as possible of the engineering profession in Scotland.

We have under consideration the appointment of a number of members to represent the Institution (each in the district in which he is resident), to advise as to the special requirements of different localities, and to awaken and maintain an interest in our work and aims. It is hoped in this way to keep in touch with engineering centres distant from headquarters, and to create an active and lively *esprit de corps* animating the whole profession. An extension of membership brings us face to face with the question of accommodation. The condition of this lecture hall to-night is a warning that we must, at no distant date, make proper provision for the orderly and convenient assembling of ourselves together. For, if members turn out in such numbers to listen to the platitudes of a President, what will the throng not be when we have a paper on a controversial subject of general interest under discussion? The matter will have the fullest consideration, and we shall be glad to receive any suggestions that members may wish to make on the subject.

The Council, considering that the Exhibition to be held in Glasgow in 1901 will undoubtedly attract a large number of engineers, not only from England and the colonies, but also from the Continent and America, has decided to organise an International Engineering Congress, to meet in the autumn of that year. A Committee has been appointed by the Council to study the whole question, and to make the necessary preliminary arrangements. Some progress has already been made, and negotiations are proceeding with a view to obtain the assistance and co-operation of the greater scientific and technical societies in this country. Every encouragement has been given to the proposal by the leading members and officials of such societies and institutions as have been consulted. The financial support already promised by members of this Institution is such that the Committee has no doubt of being able to organise a Congress well worthy of the occasion which calls it forth, of the professions its discussions will illustrate, and of the great city in which it is to be held. Members will excuse a certain reticence about the proposed arrangements in view of the fact that, the negotiations on which the Committee is engaged being in their initial stages, and many of them only tentative, no good purpose would be served by disclosing the details of them. Indeed, such premature disclosure would probably be productive only of disappointment, for the changes which discussion and the gradual development of ideas will inevitably bring about in the original design and scope of the scheme would naturally tend to confuse the minds of those who might not have had the opportunity of weighing the reasons for them, and so blunt the enthusiasm which it is so desirable to keep keen and serviceable.

It may be well, however, to mention that Lord Kelvin has consented to act as Honorary President of the Congress. I need not say a word in commendation of that selection, except this, that the honour his Lordship does this Institution in giving the Congress we are promoting the authority and sanction of his world-wide name and reputation pledges us, its members, to show the full extent of our appreciation of that honour by the intelligence, vigour, and unanimity with which we throw ourselves into the work of organisation.

Application will be made to the University authorities for permission to hold the meetings of the Congress in the University buildings. It is proposed to have a number of sections, corresponding to the principal divisions in engineering practice, on lines similar to those adopted by the *doyen* of scientific societies in this country—the Institution of Civil Engineers—each section having a chairman and a distinct set of officials. Papers will be read in each of the sections, and, doubtless, apt illustrations of much that will there form the subjects of discussion will be found in the Exhibition buildings. If the promoters and organisers of the Exhibition are successful in the efforts which they are understood to be putting forth to make the engineering exhibits a specially prominent feature, our Congress will be held under almost ideal conditions as to date, site, and surroundings. And so we as an Institution, although we have no official connection with the Exhibition, will have the satisfaction of feeling that we are contributing in no inconsiderable degree to its success.

It is perhaps unfortunate that the addition of the word "Shipbuilders" to our title appears to restrict the term "Engineers," as if in the minds of the founders a shipbuilder were not an engineer in the sense in which they employed the words. The Institution of Civil Engineers, recognising the possibility of misconception, made it unmistakeably clear in their charter that they intended to include in their organisation all engineers other than military, and gave to the term "engineering" a definition so comprehensive that there is practically no application of science to the arts of life which is not covered by it. There is no reason why our charter should not be as wide as theirs, our interest co-extensive with the interests of mathematical, physical, mechanical, and, in great measure, chemical science.

So much has been written recently of the progress of applied science in the numberless fields opened up by our industries during the century that is drawing to a close, and so much will certainly be written and spoken, in the way of formally summarising that progress, by the presidents and chairmen of learned and scientific bodies all over the world, in the interval until a new century dawns, that I may be permitted to spare you a reiteration of its stages. The fact, however, that engineering in its broadest sense has become the most important factor in modern civilisation is abundantly apparent. The discoveries in metallurgy and the improvements in metallurgical processes which have stimulated and rendered possible the enormous advances in the means of communication on land and by sea; the development of electricity and its almost limitless application as a source of energy; the substitution of mechanism, set in motion by controlled natural forces, for manual labour; have brought about most momentous changes in the status, responsibilities, and educational requirements of the engineer. There is no need to magnify our office. We have now established our claim to at least equal social rights and a position of equal dignity with those who practice theology, law, or medicine. Engineering is a learned profession, if there ever was one. And that our claim is not at once and universally conceded is due in great measure to a species of conservatism on the part both of the higher seats of learning and of the public generally, which prevents the recognition of the fact that the ancient antagonism between theory and practice is but "the ghost of a defunct fallacy." Dr Whewell long ago pointed out this fallacy, and his words would perhaps have been more generally pregnant of conviction had not his illustration savoured so strongly of the schools. He said: "The distinction of fact and theory is only relative. Events and phenomena considered as particulars which may be colligated by induction are facts; considered as generalities already obtained by colligation of other facts, they are theories. The same event or phenomenon is a fact or a theory according as it is considered as standing on one side or the other of the inductive bracket."

There will always be minds so constituted as naturally to adopt the one, and other minds so constituted as to adopt the opposing point of view. And so, as Dr Klein remarks, the antagonism between theory and practice will never be dispelled. The philosopher stands midway between the two camps, recognising and teaching the essential unity of the two standpoints. That, too, is the position of the educated engineer. He follows the physicist in his most abstruse investigations, turns the results of his laboratory experiments into the countless channels that feed the arts and industries, and devises the methods and means by which they may be applied for the use and convenience of man. Or, inversely, the difficulties the engineer encounters even in the simplest operations—the limitations he runs up against—suggest the problems that call for analytical treatment, and furnish the data for the research of the physicist and the mathematician.

"Thus it is," says Rankine, "that the commonest objects are by science rendered precious; and, in like manner, the engineer or the mechanic, who plans and works with understanding of the natural laws that regulate the results of his operations, rises to the dignity of a sage."

I should like, with your permission, to address to you a few words on the urgent question of the present state of higher scientific and technical education in the west of Scotland, and our duties and responsibilities as a profession in regard to it. There is no need, in order to convince you of the supreme importance of the subject, to invoke the bugbear of foreign competition. That is a material stimulus which has already produced, and is now in an ever-increasing degree producing, its effect in creating a genuine demand for the means of meeting the encroachments of our rivals with their own weapons. What these weapons are has formed the subject of inquiry by Royal Commissions, and by Commissions appointed again and again by educational authorities throughout the country, and I believe there is a consensus of opinion among the experts who served on those Commissions that our inferiority to our competitors, where such inferiority has been shown to exist, is attributable mainly to the lack of a thoroughgoing scientific and technical training of the designers, supervisors, managers, and directors of industrial enterprise in this country.

There is no question of any inferiority in the field of abstract science. In the very forefront of investigators and natural philosophers are, and have always been, our countrymen; and, great as may be many of the names of foreigners among the pioneers of modern science—names which we treasure with gratitude and reverence—there are none of greater prominence or of greater brilliance than those of men of our own race. In this noble and generous rivalry, as against a La Place, a Carnot, a Mayer, a Clausius, a Helmholtz, we can cite a Newton, a Watt, a Joule, a Rankine, a Kelvin. And you will not readily find names among the most original and fruitful of the thinkers and workers of the Continent and America to bracket with those of Stokes and Rayleigh and Dewar, in those fields of research they have made their own. I can think of no one who combines the power of abstract reasoning with that of the practical application of scientific discoveries to everyday use in anything like the degree exhibited by Lord Kelvin. It is impossible to open a book on electricity and magnetism without being met with evidence of the reach and subtlety of his mathematical methods, his almost inconceivable ingenuity, his versatility, and the stupendous range of his knowledge; while there is scarcely an instrument or an appliance, however apparently insignificant and subsidiary, among the thousands that the evolution of electricity has called into existence, that is not either the direct outcome of his invention or at least of his suggestion. It is not possible now to recite the reasons why Lord Kelvin is held in special reverence by the members of the engineering profession; but I should certainly disappoint your expectation did I not seize the opportunity which presents itself on the occasion of his retiral from the Chair of Natural Philosophy in the University of Glasgow, to express our unbounded admiration of those qualities which have made his occupancy of the Chair so illustrious, and our deep sense of the loss the University sustains in his withdrawal from its councils and staff. This loss is graciously tempered by his decision to remain among us, and we hope to see that venerable and familiar figure which we look upon not only with profound respect, but with warm affection, going in and out among us for many a year.

You remember an eloquent forecast by Dr Lodge at the close of a series of lectures on physical science. "The long line," he said, "of isolated ripples of past discovery seem blending into a mighty wave, on the crest of which one begins to discern some oncoming magnificent generalisation."

Would it not be a fitting climax to so great a career were this culminating discovery made and announced to us by Lord Kelvin? Gentlemen, the methods by which genius arrives at and applies its results are inexplicable, and, as no rules can be laid down according to which these methods have been and may be again selected, they are of little assistance to ordinary students. The fact remains that careful inquiry, as I have said, points to a defect in our system of teaching applied science as the cause of our inferiority to other nations in certain branches of industrial enterprise.

I believe we are all convinced of the necessity of putting our leading educational establishments in a position to meet the requirements of the day. The two teaching bodies with which we have chiefly to do are the University and the Glasgow and

West of Scotland Technical College. We have reason to believe that the authorities of the University are keenly alive to the need for an immediate and far-reaching extension of its influence, so as to get into and maintain close touch with the new developments of modern life. The constitution of the Court provides a sufficient representation upon it of what we may call lay interests, and it is to these lay members that we engineers naturally look to have the higher scientific teaching of the University made at once more accessible, better adapted to modern requirements, and, above all, quickened with a progressive spirit.

I should not like to convey, even by inference, an impression that there is any difference of opinion or of tendency on this point as between the Professors and the City Fathers. I believe that the forward movement on the modern side which has already been initiated owes much of its activity to the academic element in the Court. The Principal has lost no opportunity of showing his appreciation of the urgency of the reform, which, besides, has had his vigorous and powerful advocacy; and Prof. Jones, in a memorable address to the Educational Institute of Scotland, a few months ago, threw the weight of his acknowledged authority, and ranged the proselytising power of his personality and the charm of his eloquence, on the same side. Prof. Gray, too, has begun his labours with an unequivocal declaration of the importance he attaches not only to the practical applications of science to the arts, but also to a great extension of experimental research by which the trained forces of the University may be brought close to—nay, may be even incorporated with—" the great laboratories of applied science which we call our workshops." Such a declaration, coming from a man who is a consummate mathematician and an experimental physicist of the first rank, is full of promise and encouragement. But we are inspired with even a greater confidence when we consider the power Prof. Gray displayed at Bangor of realising his conception of the relation in which university teaching stands to industrial practice. His experience has been of such a character as should form an invaluable mediating influence between the two forces it is sought to bring into harmonious interaction.

Far from there being any division between gown and town in the Court, those to whom, as I have said, we look to guide and energise the movement, will have to see to it that they are not out-distanced in the forward march by their colleagues, whose material interests, at anyrate, lie in the maintenance of the *status quo*. In the appeals that have been made from time to time for assistance and support from outside, the University has, I think, lost sight to a certain extent of what has been done in the matter of the new Engineering Laboratory. It is now ten years since Prof. Barr, in his inaugural address, on taking possession of the Chair of Engineering, pointed out how miserably inadequate were the premises and appliances devoted to the purposes of the subjects he had to teach. He lost no time in setting on foot an appeal for funds, and, with the aid of an advisory Committee, succeeded in raising a sum of practically £25,000. The plans of an engineering laboratory, designed to be second to none in this country, have at last been approved by the University Court, and the work of building—or, at anyrate, the preliminary work of excavating foundations—has been begun. It is needless now to inquire what the difficulties were which caused so great a delay in commencing operations; let us rather take what comfort we may from the reflection that, in coming somewhat late into the field, Prof. Barr and his colleagues are in a position to reap the benefit of the experience of those who have forestalled them. The buildings, as designed, have no pretensions to the magnificence or extent of such laboratories as the Prussian State one at Charlottenburg or the M'Donald Laboratory in the M'Gill University at Montreal. But Prof. Barr believes that they are sufficient, and that they are not surpassed by any similar establishment in this country.

I quite understand that financial limitations have prevented certain developments which would have greatly enhanced the educational and general value of such a laboratory As a shipbuilder, I may be allowed a few observations on the apparent exclusion of the subjects of naval architecture proper from this scheme. I am not speaking in any spirit of adverse criticism of the efforts of those who have designed and found the means for the building of this laboratory; rather do I marvel at the apathy of those who, directly interested in shipbuilding and in the economical propulsion of steamships, allowed the occasion to slip of having, in connection with this scheme, a tank for the experimental determination of resistances and of propeller efficiencies. Every shipbuilder and every shipowner is directly interested in the establishment of such a tank. The question has not until recently become urgent, simply because the increase in the speed of ships has been a very gradual one, and the experience at the command of the designer has generally been sufficient to enable him safely to make the modifications necessary to meet slightly altered requirements. It has only been in the case of vessels of unusual type or of unprecedentedly high rates of speed that the need for the determination of nett resistance has been really felt. But this subject has been treated at considerable length, and with his well-known ability and lucidity, by Sir William White, in the course of his address as chairman of the Mechanical Section of the British Association at Dover this year. I feel that his presentation of the question, being made by an acknowledged expert and by *the* leading authority where new types and unusual speeds are concerned, carries so much greater weight than any words of mine could that I shall simply read you the portion of his address dealing with model experiments:—

"To Froude we owe the device and application of the method of model experiment with ships and propellers, by means of which the design of vessels of novel types and unprecedented speeds can now be undertaken with greater confidence than heretofore.

"Looking back on what has been achieved, it is impossible to over-rate the courage and skill displayed by the pioneers of steam navigation, who had at first to face the unknown, and always to depend almost entirely on experience gained with actual ships when they undertook the production of swifter vessels. Their successors of the present day have equal need to make a thorough study of the performances of steamships, both in smooth water and at sea. In many ways they have to face greater difficulties than their predecessors, as ships increase in size and speed. On the other hand, they have the accumulated experience of sixty years to draw upon, the benefit of improved methods of trials of steamships, the advantage of scientific procedure in the record and analysis of such trials, and the assistance of model experiments.

"In this direction, however, I am bound to say that much might be done if experimental establishments capable of dealing with questions of general nature relating to resistance and propulsion were added to the equipment of some of our universities and colleges. Engineering laboratories have been multiplied, but there is as yet no example of a model experimental tank devoted to instruction and research."

We have been told that such a tank would cost, completely equipped, about £20,000; and its annual upkeep and operation would not, I presume, fall short of from £1000 to £1500.

A very complete description of the most modern tank and apparatus—that of the Washington Navy Yard—was published in the *Engineer* of August 4th and 11th, and the announcement made that the tank will be available for testing the models of private shipbuilding firms and of individuals.

In this, America, in her new campaign to regain her position as a maritime power, will have an advantage over us, for *our* Admiralty tank is so constantly engaged on naval work that its resources are not at our disposal, and the only private tank—that of Messrs Denny—has not, so far as I can learn, been thrown open to the experiments of their confrères. This is a matter that claims the attention of Prof. Barr's Advisory Committee, in conjunction with Prof. Biles, as representing shipbuilding and marine engineering in the University.

Apart from buildings and equipment, the inadequacy of the teaching staff of the University on the science side will be at once apparent to you if you compare it with, for instance, that of the Faculty of Applied Science in M'Gill College. That Faculty has nineteen professors and lecturers, besides eight demonstrators, as compared with our two professors and three lecturers and demonstrators. Indeed, if we compare the teaching of medical science with that of engineering, we cannot but be struck with the extreme disproportion in the number of chairs, considering the very analogous character of the educational claims of the two professions. There are about eleven professors in the Faculty of Medicine of our University, and twelve lecturers.

The analogy between medicine and engineering, from an educational point of view, was brought out very clearly by Rankine in his inaugural address to his students in 1856, and it has been frequently referred to since, more especially in Germany, in connection with the development of technical high schools.

It may be objected to the comparison I have made and to the figures I have cited, both with reference to the M'Gill College and to the Medical Faculty here, that the staff of the Glasgow and West of Scotland Technical College on the engineering side should have been brought into the account, because in Canada the Faculty of Applied Science covers the whole ground occupied by the University and Technical College in Glasgow, and on the other hand our University undertakes the whole teaching of medicine down to the minutest specialisations. But, even if that objection were sustained, engineering would still appear to receive very much less than its due share of attention. Besides, it is scarcely fair to compare the ordered settled systematic curriculum of a University with the courses of instruction of such an institution as the Technical College. It is painful and humiliating, in considering the position of that College to have to admit that, from the points of view of accommodation, of appliances, of supply of teachers, it is lamentably behind similar institutions both in this country and abroad; and that notwithstanding the fact that there is probably no College of the kind in the world which can boast a larger attendance roll. The reason is to be sought, not in the constitution of the governing body, which is sufficiently representative of both academical and industrial interests, but rather in the financial conditions under which it is administered. The income available for the purposes of the College is inadequate and precarious, or, at anyrate, so uncertain in amount that it is impossible to make suitable provision for the educational requirements of the hosts of young men who come crowding to its class-rooms. In Germany, the State provides the funds for the installation and equipment of her magnificent technical high schools, while in America and Canada the municipalities support scientific and technical training by liberal subventions, supplemented, in a degree unprecedented in the world's history, by the princely benefactions of prominent and patriotic citizens.

In Scotland we are dependent upon doles, in the form of grants in aid, which come to us through tortuous channels, intermittently, and liable to diversion and interception. It is high time that here in Glasgow, as in Manchester, the maintenance of the Technical College should be assumed by the Corporation. And there are evidences that our civic rulers have awakened to a sense of their responsibility, and that we may soon hope to see that zeal and prudent activity in the conduct of business which have made the municipal enterprises of Glasgow so conspicuously successful devoted to the great cause of the higher and specialised education of her citizens. The example of Manchester is, perhaps, the best that could be followed, taking account, of course, of the differences in the respective industrial requirements of the two cities. Manchester has on several occasions sent deputations to the Continent and to America to examine and report upon the schools and methods of teaching abroad, and to collect information as to the effect of technical instruction on the development of industries. The last Report, dealing with the schools of Germany and Austria in 1897, is a short document, but a model of what such a Report should be. It brings home to us in the clearest and most convincing way the leading position Germany occupies in the manufacture of chemicals. We read that: "The command of the world's market in colouring matters and pharmaceutical products derived from coal tar, the value of which is estimated at about £10,000,000 sterling, is in the hands of Germany to the extent of three-fourths, 75 per cent. of which is sent abroad." And, further, as more directly affecting our own pursuits: "It is clear that the educational advisers of the various German Governments are of opinion that the same success which has already attended the establishment of numerous and costly chemical laboratories in stimulating German industry, and placing the nation first in the manufacture of chemical colour products, will be repeated through the establishment of like laboratories for the study of technical electricity as applied to the field of chemistry and to engineering."

This is the carefully expressed opinion of thoughtful men, themselves engaged in the direction of industries which have been gravely threatened, and which have suffered severely from foreign competition. It is the opinion of the great majority of engineers in this country that it is only by a more systematic training in scientific and technical subjects, as well as in business methods and in workshop management, that we can hold our own against the vigorous, skilfully directed and amply subsidised attacks of our foreign rivals. No educational scheme has a chance unless it rests upon a certain and secure financial basis. And if the financial responsibility for the Technical College were assumed by the city, her protection, far from checking the flow of private benefactions, would rather attract it, in affording a guarantee of efficient administration. Her concentrated importance and authority, too, would necessarily have great weight with the Legislature in securing a fuller recognition of the claims of higher education to State support.

I believe that this Technical College, as it was the first in time so would soon become the first in efficiency, in importance, and in the far-reaching character of its influence on our national industry, under the fostering care of the Corporation of Glasgow. There is a difficulty—a danger—which will have to be faced. It lies in the co-ordination of the studies of the University and the Technical

College. That is a difficulty which has reached a very acute stage in Germany at the present moment, where the research work in the physical laboratories of some of the greater technical high schools has been pushed so far as to go beyond even the high standard of the universities.

The two institutions must work hand in hand, arranging the methods and extent of the teaching in their respective spheres with a due regard to the great diversity of requirements which an ever-increasing specialisation has introduced into the problem. If they so work together without the exhibition of an offensive superiority on the one hand or of a petty jealousy on the other, but with a single eye to the advancement of science, and the shedding of its beneficent light with a diffusion so ample as to reach even the darkest and remotest corners where the lowest order of humanity labours at the simplest tasks, they will not look in vain for the cordial support—intellectual, moral, and substantial—of the members of this Institution.

VOTE OF THANKS.

Professor A. Barr, D.Sc. (Vice-President), said he had been asked to propose a vote of thanks to the President for his address, which would be a delightful duty if he were able to fitly discharge it. He was sure that every one present had been struck, not only with the admirable manner in which Mr Caird had dealt with the subjects which he had brought under their notice, but also with the singular literary grace with which he had clothed his treatment of topics which were often to them common-place and even dry. Nothing that he might say could add to their appreciation of Mr Caird's address, but he could not refrain from thanking Mr Caird in the name of the University, of the Technical College, and of all who were interested in the higher scientific and technical education in this country, for the help and encouragement his words would give them in a work which had often been uphill and occasionally might have been misunderstood. In Glasgow, he was happy to say, the work had been by no means lacking in support from the leaders of their profession. It was now ten years, as Mr Caird had said, since he (Professor Barr) proposed the erection of an engineering laboratory at the University and the late Professor Jenkins suggested that something should be done towards the adequate equipment of the department of naval architecture. On his side, at least, the proposals had met with most hearty support from the engineers of the city and from many others. It was no fault of the engineers, and he hoped he could say no fault of his own, that it had taken the University authorities so long to break ground for the new engineering buildings upon the site which was selected, or at least proposed, some seven years ago. There had been difficulties to overcome, one of which, at least, might point a lesson to all concerned with the scheming of college buildings—and workshop buildings for that matter. Their predecessors in the University had not foreseen, and had not provided for the great development of science teaching which had characterised the progress of the latter half of the century. They had erected a building which it was not easy to extend. Fortunately, however, there was within the precincts of the University sufficient room for new buildings of an extensive character, and, as Mr Caird had hinted, a strong forward movement had now commenced. He might also acknowledge here, on behalf of the engineers, and on behalf of all who were interested in applied science, the very hearty action which had been taken by their colleagues upon the arts side of the University in promoting this movement. In connection with what Mr Caird had said regarding the position which ought to be accorded to engineering science (in its widest sense) as a University subject, he thought nothing could be more hopeful or gratifying than the fact that those responsible for the older subjects of University education should take a foremost place in advocating the claims of applied science. The time was not far distant, he felt sure, when, not only from the outside, but from the inside of their Universities, engineering would be recognised as one of the leading learned professions.

Prof. A. Barr.

If he was not talking too long he would like to refer, in a word, to another point upon which Mr Caird had laid great stress. He was happy to say that the Technical College and the University did work cordially hand in hand. The University received from the Technical College a considerable number of its best engineering students, and those who had gone through a sufficiently complete curriculum in the Technical College could go up for their degrees at the University after six months' study within its walls. He thought the University could hardly go further in recognising the admirable work which was done in the sister Institution. He was only sorry that the governors of the Technical College did not appear to see that it was advisable that the College should be located in very close proximity to the University, so that duplication of teaching and of teaching appliances might be minimised, and that students might be enabled to attend classes in the two Institutions during the same session. The Technical College must move sooner or later from its present inadequate building, and if it located itself in close proximity to Gilmorehill resources might be husbanded and Glasgow might be provided with a unique organisation for the advancement and diffusion of applied science. Again he would thank Mr Caird for his admirable advocacy of schemes which were so much at his own heart, and he would ask them to accord him a most hearty vote of thanks for the admirable address to which they had listened.

Mr ARCHIBALD DENNY (Member of Council) thought it was not necessary for him to say very much in seconding the motion for the vote of thanks to Mr Caird. He felt that Mr Caird had done the Institution great service, and his method of putting the matter together was only what they would have expected of him. They all felt that he had just exactly expressed their own sentiments, but about ten times better than they could have done it themselves.

LIGHTHOUSE ENGINEERING AT HOME AND ABROAD.

By John A. Purves, D.Sc., F.R.S.E. (Member).

(SEE PLATES I. AND II.)

Read 24th October, 1899.

In choosing such a subject as lighthouse engineering for the opening paper of this Session, I felt that, as our Institution was composed principally of engineers and shipbuilders, the subject of lighthouse engineering was one which would appeal to both sections, to engineers as it is in many ways a unique branch of their profession, and to shipbuilders and shippers generally, on the ground that the efficient lighting of coasts, estuaries, and the like, is a matter which concerns them closely.

In the first place, I shall very briefly sketch the history of lighthouse engineering from the earliest times, in our own and other countries, up to the present time.

The history of lighthouses dates from the earliest days when such shipping as then existed was warned and guided by means of open fires kindled upon projecting headlands or other elevated sites.

The next advance seems to have been made by the Libyans and Cushites, dwellers in lower Egypt, who made use of watch-tower during the day, which were used as beacons by night, open fires being lit upon their summits.

These, however, are largely conjectural, and the first actual lighthouse, of which a written account exists, appears to be that of Sigeum, which was erected by Lesches, author of the "Little Iliad," sometime about the year 744 B.C. Following upon this comes the world-famed Pharos of Alexandria, one of the seven wonders of the world. This lighthouse, which has given the name of Pharology to the science of lighthouse engineering, was, according to Pliny, built by Sostratus, by command of Ptolemy Philadelphus, about the year 284 B.C. According to other writers, the building was square in cross section, consisting of many storeys which diminished in size towards the top. Its height is given as equal to 512 English feet, and the cost has been calculated as equivalent to £195,000 in modern money, and we are told by Josephus that the fires lit upon the summit were visible for a distance of about twenty-nine geographical miles.

With the rise of the Roman Empire, coast illumination progressed rapidly, and lights are mentioned as existing at Ravenna, Puzzoli, Ostia, and elsewhere. The lighthouse at Corunna, in Spain, is perhaps the oldest existing tower now used as such, dating from the days of Trajan, A.D., 98-117. At Dover Castle there are remains of a Roman Tower, built about 53 A.D., which is supposed to have been used as a lighthouse; there is also reason to believe that the Romans established a light upon Flamborough Head, and another on the coast of Flintshire.

The first actual tower which was built with the express and sole object of a lighthouse seems to be the Tower of Corduan, in the Bay of Biscay, which may be taken as the starting point of modern lighthouse engineering. The Lighthouse Tower of Corduan, guarding the mouth of the river Gironde, was designed and executed by Louis de Foix, in the reign of Henry IV. of France, and was completed in the year 1611, having taken twenty-six years to build. The building, which is shown in Fig. 1, is 197 feet in height, and consists of a circular lower storey in which are the light-keeper's apartments, surmounted by successive circular rooms. Communication is had from one apartment to another by means of a spiral staircase. It was modified to suit modern practices in 1854, and again in 1895 certain alterations were made, relating chiefly to the apparatus, which now consists of a fixed light with red and green sectors to indicate the channel. In many ways this tower may still be looked upon as the finest lighthouse in the world, and its form remains practically unaltered even after a lapse of 300 years.

Next in importance and order of date, is the Eddystone. This lighthouse, which has probably attracted more public interest than any other, marks the Eddystone rocks, lying some fourteen miles off Plymouth.

The first actual attempt to erect a permanent building was made in 1696, by Henry Winstanley, who undertook to establish a lighthouse upon the rocks. The work was commenced in that year, and completed in four years. It consisted, as will be seen from Fig. 2, of a cylindrical lower portion of masonry 16 feet in diameter, above which was the gallery and lantern. The total height of the building was 80 feet, and the light was first exhibited in 1698. A year later, it was deemed advisable to increase the diameter of the building, and to increase the total height to 120 feet. This was completed in 1700, and Fig. 3 is a sketch of the building as thus altered. In November, 1703, the entire structure was washed away, and the unfortunate Winstanley, who then happened to be in the tower, perished amidst the wreck.

In 1706 Mr Rudyerd undertook the erection of a new tower. This consisted in its lower portion of timber work, bolted together and to the rock, and above this were placed stone courses surmounted in turn by a second course of wood-work. Despite the composite nature of this structure, it weathered the storms for forty-six long years, and its final destruction was caused not by water, but by fire. Fig. 4 is a drawing of Rudyerd's Tower.

Following upon Rudyerd's Tower comes the ever memorable Tower of Smeaton. This triumph of engineering skill, Fig. 5, has served as the model from his day till ours of all rock towers. It was begun in 1756, and completed in 1759. The building was entirely of stone, the individual blocks of which averaged one ton in weight. These stones were all dovetailed together from Smeaton's design, which was the first in which dovetailed joints were employed. The total cost of the work amounted to £40,000; the cost per cubic foot of structure being £2 19s 11½d.

In 1877 it became apparent to the Trinity House that, although the tower was still in good preservation, the rock upon which it was built was showing signs of being undermined by the action of the sea, and it, therefore, determined to erect a new lighthouse some 120 feet S.S.E. from the site of the old one. The building was commenced in 1878, and completed in 1882.

From a glance at Fig 6, it will be seen that the new Eddystone offers certain contrasts to other rock towers. The curvilinear outline of the old Eddystone, and of other towers, had the effect of raising the centre of pressure of each impinging wave, and this led Sir James Douglass to design his tower with a cylindrical base carried to 2½ feet above high water; above this, and set some little distince in, is the curvilinear structure, which is really a concave elliptical frustum. The base is 44 feet in diameter and 22 feet high, while the total height of the tower is 173 feet. The tower is solid for 25 feet 6 inches above high water, while the walls, which are 8 feet 6 inches at the bottom, taper to 2 feet 3 inches at the thinnest part of the service room. All the stones, which are of Cornish and Scottish granite, are dovetailed both horizontally and vertically. The lower courses resting upon the rock are sunk to a depth of one foot, and bolted to the rock by Muntz metal bolts. The lantern surmounting the tower is of the helical type, while the optical apparatus which it contains is of the biform group flashing type, giving two groups of two flashes in quick succession. The maximum candle power of this apparatus is about 79,000, the luminary being a six-wick burner. This lighthouse is further provided with fog bells, which are actuated by means of the same mechanism which rotates the apparatus. The total cost of this building was £59,255, equivalent to 18s 2d per cubic foot of building. The work was executed under the personal superintendence of Mr W. T. Douglass, son of the late Sir James Douglass.

The Bell Rock Lighthouse, which marks the dangerous reef of rocks known as the Bell or Inchcape Rock, lies some twelve miles off the coast of Forfarshire, and fully exposed to the waves of the

North Sea. The lighthouse was begun in 1800, and its site is sixteen feet below high-water mark, or just above the level of low-water spring tides. The tower was designed and carried out by Mr Robert Stevenson, who, in a measure, took the Eddystone of Smeaton for his model. He, however, increased the thickness of the walls as compared with the Eddystone, and carried the solid portion to a greater height. This tower is illustrated in Fig. 7, which might be compared with the drawing showing Smeaton's Eddystone. The total cost of the work was £55,619 12s 1d, equivalent to £1 19s per cubic foot of building. It is curious that this very important lighthouse is still only provided with the old parabolic reflectors installed as far back as 1811. The apparatus, which is a revolving one, has four faces, the alternate faces giving red and white flashes respectively. The reflectors used are all 21 inches in aperture, there are five of these to the red flash, and three in the white. The power of the light is only 5000 candles.

Next in order of date I may mention the Skerryvore Lighthouse, off the Argyllshire coast. This beautiful tower, the cone of which is hyperbolic, was designed by the late Mr Allan Stevenson. The work was begun in 1838 and was not completed till 1843. The tower, which is entirely of granite, is shown in Fig. 8. It contains 58,580 cubic feet of masonry, and its total cost amounted to £72,200 11s 6d, equivalent to £1 4s 7¾d per cubic foot of structure. The apparatus used in this tower is an eight-sided first-order, with a power of beam equal to 44,000 candles. The light gives one flash every half minute.

The tower of Les Baleines, Fig. 9, built upon the I'le de Ré on the west coast of France, was completed in 1854. It is a handsome stone structure, octagonal in form, and approximately 166 feet in height. The oil apparatus originally fitted was replaced, in 1882, by an electric light showing groups of four flashes in quick succession, the candle power of the flashes being 900,000.

The La Coubre Lighthouse, illustrated by Fig. 10, is also upon the west coast of France. The tower is cylindrical and of masonry; its height is 172 feet. The building was completed in 1860, and in 1895 a new electric apparatus was installed to replace the old oil one. The apparatus is of the feux-éclairs type, showing groups of two flashes in quick succession, each flash being only ¼ of a second in duration. The power of this light is estimated at 20,000,000 candles.

The Wolf Rock Lighthouse, off Lizard Point, was designed by Mr James Walker and was begun in 1862. Its height is 116½ feet, its diameter at the base 41 feet 8 inches, diminishing to 17 feet at the top. The solid portion is carried up to 39 feet 6 inches. The form of the tower is an elliptic frustum of a cone. The total cost was £62,726, or an equivalent of £1 1s 3d per cubic foot. The apparatus is a first order with 16 sides, alternately red and white. The power of the beams are equalised by the size of the panels employed. The candle power is approximately 16,000. A sketch of the tower is shown in Fig. 11.

The Dhu Heartach Lighthouse is 14 miles from the Island of Mull. The tower, which is shown in Fig. 12, is parabolic in outline, and is entirely constructed of granite, its height being 145 feet. This important lighthouse has a somewhat antiquated form of apparatus, with a total candle power of only 6,000. The cost of the structure was £72,584 9s 7d, or £1 14s 6d per cubic foot.

Roches Douvres, on the north coast of France, is shown in Fig. 13. The tower is a handsome iron structure, 182 feet in height, built in 1869. The apparatus employed has a candle power of 28,800.

Cape San Thomé.—This iron lighthouse, shown in Fig. 14, was constructed by Messrs Barbier & Bénard, of Paris, and erected for the Brazilian Lighthouse Service in 1882. Its total height is 148 feet, and the nature of the building is clearly shown by the drawing.

The Bishop Rock Lighthouse, situated upon the westernmost part of the Scilly Islands, is exposed to the full stretch of the 3000 odd miles of the Atlantic. The site is of historic interest, being the scene of the disaster which fell upon Sir Cloudesley Shovel's squadron in 1703. In 1847 the Trinity House began the erection of an iron open work structure upon the Bishop rocks. The living rooms and lantern were supported upon iron columns, and access was had to them by a ladder up the central support. This structure was completed in 1850, but before it ever came to be inhabited, it suffered the same fate as Winstanley's ill-fated tower, being swept entirely away during the night of the 5th of February. In no way daunted by this mishap, the Trinity House commenced a granite tower upon the rocks, under the direction of Mr N. Douglass, which was completed in 1858. It was soon discovered, however, that even this tower was scarcely able to meet the requirements, and in 1874 it was strengthened by bolting iron ties to the internal wall surfaces and connecting them through the floors; but even this did not prove entirely satisfactory, and in 1881 a complete renovation was determined upon. Fig. 15 shows the altered and finished form of the lighthouse as it now exists. The entire tower up to the service room is encased in an outer covering of granite, the blocks of which are dovetailed together, while the lower courses are further secured together by means of Muntz metal bolts. The original tower was moreover increased in height by the addition of four new rooms, the height being increased from 110 to 140 feet. The optical apparatus is of the largest type, being of the hyper-radiant class, and it is furthermore not a single, but a bi-form apparatus. The tower is, moreover, provided with a gun-cotton explosive fog signal which is attached to the lantern.

The cost of the various lighthouse works erected upon this rock are approximately as follows:—

(1) Cast iron lighthouse, ...	£12,500
(2) Granite lighthouse, ...	34,559
(3) Improved granite lighthouse, ...	64,889
Total, ...	£111,948

The cost of the granite lighthouse, stated at so much per cubic foot of building, amounts to £1 8s 6d.

The most recent of Continental lighthouse towers is Penmarc'h. Although a land and not a rock station, it is well deserving of our attention. The tower, which is shown in Fig. 16, a handsome octagonal structure, built entirely of granite, was only completed in October, 1897. It guards the prominent headland of Penmarc'h (Finistère), and it owes its being largely to the generous bequest of the Marquise de Blocqueville, who left a sum of £12,000 for the erection of a lighthouse to adequately protect the coast. The height of the tower above the ground is 207 feet, while in addition to the tower are the dwelling, dynamo, siren, and engine houses. The luminary in this lighthouse is an electric arc, and the apparatus is of the twin type, where both are mounted side by side upon a revolving table, instead of being superposed, as in the case of the new Eddystone and Bishop Rock lighthouses. The maximum candle power of this apparatus is 30,000,000. The total cost of the tower and buildings amounted to £16,000, while the apparatus with all its electrical generating plant cost £5000, and the siren installation £1200—a total, including carriage and sundries, of £23,200.

Turning from the actual buildings themselves, to what may really be considered the prime factor of all lighthouses, the light-directing apparatus itself, I shall not touch upon the metallic and other purely reflecting lights, but shall at once pass to the dioptric or lens apparatus, which may to all intents and purposes be considered the invention of the great Fresnel. Starting from the fixed light I shall sketch its evolution to the lightning-flash lights of the present day.

The fixed light, shown in elevation and section in Fig. 17, consists essentially of a cylindrical refractor encircling completely the illuminant, and either with or without the provision of top and bottom reflecting prisms. The function of such an apparatus is to parallelise into a horizontal beam, extending all round the horizon, all the light emitted from the burner non-horizontally.

The apparatus, of course, has no effect upon the light in horizontal planes, and this light simply passes through the glass medium and illuminates the horizon all round. The first improvement on this form of apparatus was the flashing light which has practically superseded it. Here there is not a cylindrical belt or refractor, but a change from the circular to the polygonal form.

In the old forms of the flashing system, the panels or sides are many in number and small in size. In this style of apparatus, in order to flash round the whole horizon, the entire apparatus revolves about a vertical axis. Here the light from the burner, falling upon the panels, becomes parallelised, both horizontally and vertically, into a horizontal beam or pencil of light, the axis of the beam passing through the centre of the burner and the centre of the bull's eye. It is seen, therefore, that in this apparatus there is a condensation or strengthening of light both in the vertical and horizontal planes.

The next advance in optical apparatus to be considered is the group-flashing light. Here the panel or panels are broken up into two or more sections, each section giving its particular flash, while the flashes succeed each other at very short intervals. Each broken up panel now represents a group of flashes, whereby a distinctively characteristic light can be obtained.

Having viewed very briefly the fixed light and its function, the flashing light and its function, and lastly the group-flashing light and its function, it will be seen that the polygonal or many-sided form of apparatus is a natural or easy step from the true cylindrical refractor, and that it needs but small reasoning power to see that the fewer the number of sides employed the greater will be the power of the flash. This reasoning naturally led to the reduction of the number of panels, so that instead of the old lights, with their twelve, fourteen, sixteen, or even twenty-four sides, there are employed in the more modern form only, four, six, or eight sides ; the panels in these cases being correspondingly larger, and the emergent beams more powerful. The reduction of the number of sides, however, owing to the slow rotatory movement of the apparatus, produces flashes which are separated by long intervals of dark and which in many ways are unsatisfactory as characteristics. Hence naturally arose the group-flashing system mentioned above, the brilliant conception of Dr. Hopkinson, who divided up the large panels into sections, thus producing two, three, or more flashes in quick succession out of what had been previously one flash. This system, however, necessitates the reduction of the number of panels still further if the power of the flashes are to be great, and this is accordingly done.

The natural and logical outcome of these various developments is to be found in the new system of feux-éclairs. Here the number of panels is reduced to a minimum and, as a consequence, the resultant beam is a maximum. Then the advantage of having flashes of short duration, followed by others in quick succession, had already been proved in the group-flashing system, and this idea was accordingly made a leading feature in the feux-éclairs system.

In the early days of lighthouse illumination, when our coasts were but scantily supplied with lighthouse stations, which were situated at great distances apart, the old fixed lights were all that could be desired, and served their purpose well. As the number of lights increased it was found necessary to furnish some distinction between one light and another, so as to guide the mariner upon his way in safety, and this end was in a large measure accomplished by the introduction of the revolving and occulting lights. The revolving light, as will be seen from a glance at the Admiralty List of Lights, was until very recently the favourite form of apparatus. For this reason the older fixed lights have in a great many instances been altered to occulting or intermittent lights, either by the addition of racks of revolving vertical prisms, or still more commonly by the application of a mechanical *shutter* or *eclipser* which rises and falls over the illuminant. The simple revolving light has, however, not been able to cope with the increased demand for distinctive characteristics now required by the lighthouse service. This difficulty has, however, been met most successfully by Dr. Hopkinson's group-flashing system now so universally adopted in our newer lights.

The group-flashing system, good in so many ways, has one serious disadvantage, which is, that a well marked and distinctive characteristic is obtained at the expense of power of beam. This is necessarily so, as the power of the emergent beam is a direct function of the number of beams employed. The beams are further necessarily weakened, in most cases, by having a larger proportion of reflecting prisms than in the single-flash panel. As an example we may take a four-sided apparatus, each side of which forms groups of two flashes. This apparatus has, therefore, a beam the power of which is approximately equal to that given from an apparatus of eight sides. This disadvantage has to a large measure been overcome in France and elsewhere by the use of the feux-éclairs system.

The desirability of having the lights round our coast distinctly differentiated from one another, so that no possible mistake can be made by the mariner, is obvious to every one, and this end can be attained to, so far as distinctive characteristics go, by an extension of the group-flashing system. The drawbacks of such an extension have, however, just been pointed out, and it is undoubtedly a serious problem and one well deserving of the attention of the lighthouse engineer, how a well marked characteristic can be obtained in conjunction with a light of great and unreduced power.

In order to obviate the loss which is necessarily entailed in a group-flashing apparatus I designed the spindle-eclipser group-flashing mechanism, which may be briefly described as the application of mechanical shutters, eclipsers, or the like, to flashing lights instead of fixed. This at a first glance may seem absurd, but a moment's reflection shows the obvious advantages of the scheme. In the first place, I prefer to use the rapid rotary system of the feux-éclairs, and to employ an apparatus with the minimum number of sides, *i.e.*, *one* supplemented by

180 degrees of mirror. With such an apparatus, provided with an eclipsing device, it is at once seen that practically an endless variety of characteristics can be produced, including the known forms now in use. Suppose a group-flashing light is desired, each group having two flashes, all that is required is to so design the mechanism of the eclipser that it will eclipse the light after two complete all round flashes, remain closed for the length of time desired, and then open just long enough to allow the two flashes to be seen once more, and so on *ad infinitum.*

It may be remarked here that this system makes use of the most powerful form of apparatus which can be designed, and from it is obtainable a series of characteristics which, under the old style, would have necessitated the addition of elaborate group-flashing dioptric arrangements.

The above is a general illustration of the principle. The Casquets might be taken as an example of a group-flashing light in actual existence, to see how it could have been made under the new system. This is a three-sided first-order apparatus, each side of which gives a group of three flashes. The three quick flashes are separated from one another by dark intervals of 18 seconds. It will be clear, from what has been said above, that all that is necessary to produce a similar characteristic is to make the one-panel apparatus revolve at such a rate as will produce three corresponding flashes, after which the mechanism closes the eclipser during a period corresponding to the long dark between the groups, and then raises it again for such a time as will allow for three more flashes being seen, and so on. This system possesses many advantages from an economic point of view. It permits of small apparatus being used, and consequently of small lanterns and accessories. It permits of smaller burners being used, and consequently of less consumption of oil, although this is a small matter. But the great saving consists in this, that as *one* standard form of apparatus would serve every purpose, new designs would not need to be prepared for every new light, and therefore new and expensive dioptric elements would not need to be calculated, moulded, and ground. It may further be remarked that by using such a standard light as, say, a third-order, for the first, second and third class lights our mariners would not be perplexed by the endless and uncertain variations of the power of our lights. All these would have the same intensity of beam, whatever number of flashes they might have; all would have an equal luminous range in clear weather and penetrating power in fog; and all an equal geographical range so far as the power of light is concerned. I may sum up, in a word, the advantages to be derived from this system.

1. Greater characteristic distinctiveness.
2. ,, ,, ,, with no loss of power.
3. Cheapening of first cost.
4. ,, maintenance.
5. Simplification of design and construction.
6. Equality of power and efficiency of all lighthouses.

I have mentioned one panel as being the desirable number to employ when in conjunction with an eclipser, and, indeed, for some time after designing the first spindle-eclipser I saw no possibility of making use of two panels without a confusion of flashes. For the solution of this problem I am indebted to my brother Mr W. T. Purves, of Edinburgh, who demonstrated the possibility of employing two panels instead of only one in conjunction with an eclipser. This form of apparatus is known as a bivalve holophote, and consists of two large panels of lenses each subtending approximately 180 degrees, in the centre of which is the luminary. It is now clear that if these panels be mounted upon mercury-floats, rollers, or other bearings, and caused to revolve, the result will be a simple flashing light which gives two flashes for each complete revolution of the apparatus. It is, however, possible to produce with this bivalve *and* an eclipsing mechanism any characteristic that is required, by the simple revolution of the apparatus. This is accomplished by having the eclipser formed in two halves (the eclipser can either be of the horizontal or vertical type) each half of which, when closed, completely shuts out the light of the lamp from the particular panel on which it would otherwise shine. When both halves have been closed, the apparatus revolves without any light being seen, and it is this complete darkness which forms the long dark interval between the groups of flashes. The short dark interval between the individual flashes of the group is given by the period between the flashes caused by the revolution of the two panels of the apparatus in this case. For example, suppose that a double group-flashing light is desired, this can be effected by causing the apparatus to revolve so that an observer will see the flash of first one panel which I shall call A, and then of the second panel which I shall call B. Now, as the flash from panel B passes over the eye of the observer, the one-half of the eclipser, which I shall call *a*, is closed, so that when the panel A has revolved so as to face the observer no light is seen, and as soon as it occupies this position the panel B, which is now diametrically away from the observer, has its eclipser, which I shall call *b*, closed, so that upon the apparatus still further revolving no light whatsoever is seen, and the time of total eclipse is so arranged as to give the required long dark between the groups of two flashes. In order to give the next group of flashes the respective eclipsers are raised one after the other as in the case of closing.

It is clear that such an apparatus, consisting of two panels, can by means of this arrangement be made to give any number of flashes, as this simply depends upon the number of times that the apparatus is revolved; while the "long dark" can be made of any duration by keeping both eclipsers closed for as long as is desired. The advantage of such an apparatus is that the flashes of a group follow one another twice as fast as in the single-panel spindle-eclipser.

I have now pointed out how it is possible, by means of a single- or double-panelled apparatus and an eclipser, to produce all varieties of characteristics, but in both cases it may be contended by those who are prejudiced, foolishly, I think, against the lightning-flash lights that the duration of flash is too short, and in order to meet this objection I have designed a new form of lens. The inner surface of glass of the refracting portion, is so constructed as to parallelise all light emanating from the focus into a beam whose central ray is parallel to the horizontal axis, while in the reflecting portion of the apparatus, the combined action of the two first operating surfaces, parallelise all focal light in a similar manner to the refracting part. It will be seen that all the focal light of the apparatus has been converted into a cylindrical beam of light.

My object is to produce, without the employment of two distinct optical agents, as has previously been done, a divergence or directing of the emanating beam in the horizontal direction only, without in any way interfering with the vertical condensation. I accomplish this by forming inclined prismatic surfaces upon the outside surface of the annular lens rings, all of which surfaces intersect planes which are horizontal. The outside prismatic surfaces are in fact vertical planes traversing the lens face from top to bottom, so as in no way to affect altitudinally the light which has already been rendered horizontal by the inside face or faces. Indeed, the vertical faces cut upon the outside of our optical agent may be regarded as the equivalent of the straight vertical prisms well known in lighthouse work. With such an arrangement as I have just described, the duration and direction of the flash can be determined at pleasure by properly designing the surfaces which are formed on the outer surface of this lens.

The directing instead of diverging of the emanating beam is also possible by this arrangement, so that the emergent rays which would naturally emerge at right angles therefrom bend round in azimuth and when the apparatus revolves a group of two flashes in close proximity, instead of a simple light, is the result. It is, moreover, clear that in a single panel of 180 degrees, as shown in Fig. 20, it is practicable to make one half of the panel direct light in one direction, while the other half directs it in another, by suitably designing the vertical faces cut upon the outside of each half, and by this method a new means of producing group-flashing lights is found. To push this matter a little further, it is possible to split up the beam from a single panel, by means of the outside vertical faces, into as many flashes as are desired.

A bivalve simple flash holophote is shown in Fig. 18, while Fig. 19 is a front elevation of a spindle-eclipser apparatus, and Fig. 21 is a profile of an inverse equiangular refractor.

I have now dealt with the history and engineering features of some of the more remarkable lighthouse towers, and with the apparatus by means of which the beams of light from the luminary are rendered of service to the mariner; and it only remains for me to review briefly the position here in Scotland with respect to lighthouse matters as compared with other countries.

As regards lighthouse buildings our neighbours can teach us but little—saving economy—with which all important exception I shall deal with later. Round our coast are the illustrious towers of the Bell Rock, Skerryvore, and Dhu Heartach, which owe their existence to the genius and practical ability of the elder Stevensons, while in addition to these rock towers we have many of the finest land stations in existence. It might, however, have been a wiser policy if, instead of erecting such monumental structures as are to be seen around our coasts, *that* rigid economy had been adopted which has marked from the very outset the lighthouse engineering of our neighbours the French.

The following table, compiled as long ago as 1880 by M. Allard, of the French Lighthouse Service, shows all too clearly the vast difference in cost that there is between British lighthouses and those of France, and it must be remembered that economy in first cost, means that more lighthouses can be built and dangerous places upon our still ill-lighted coasts rendered safe to navigation:—

FRENCH.

Name.	Total Cost.	Cost per Cubic Foot.
Cape la Hague,	£15,428	£0 5 2·25
Bréhat,	21,268	0 6 5·40
Haut Banc	13,240	0 13 0·82
D'Oloune,	18,240	0 12 4·75
La Banch,	15,568	0 6 2·65
La Croix,	5,800	0 9 3·92
Grand Jardine,	10,196	0 7 0·89
Pieres Noires,	14,200	0 8 6·12
Four de Brest,	12,000	0 7 3·60
Average	£13,993 6 8	£0 8 4·7

BRITISH.

Name.	Total Cost.	Cost per Cubic Foot.
Eddystone,	£40,000 0 0	£2 19 11½
Bell Rock,	55,619 12 1	1 19 0
Skerryvore,	72,200 11 6	1 4 7¾
Bishop,	34,559 18 9	0 19 7½
Smalls,	50,125 11 8	1 1 7¼
Hanois,	25,296 0 0	1 0 7¼
Wolf,	62,726 0 0	1 1 3
Dhu Heartach,	72,584 9 7	1 14 6
Longships,	43,869 8 11	0 18 5
New Eddystone,	59,255 0 0	0 18 2
Average,	£51,623 13 3	£1 7 9·3

The following general statement gives annual expenditure in Scotland and France upon new works during the last seven years:—

	Scotland.	France.
	Expenditure on New Works.	Expenditure on New Works.
1892	£22,477	£22,000
1893	43,422	do.
1894	21,897	do.
1895	16,579	do.
1896	17,561	do.
1897	30,466	do.
1898	35,509	do.

It may be seen from the above table that our average yearly expenditure on new works during the last seven years amounts to £26,831, whereas that of France has remained constant at £22,000. It must next be seen whether with this much higher average expenditure the results attained in this country have been correspondingly greater. For the sake of such an investigation I have divided up the lighthouses of both countries into nine classes:—

1st	above	100,000 candle power.			
2nd	between	40,000	and	100,000	candle power.
3rd	,,	22,000	,,	40,000	,,
4th	,,	10,000	,,	22,000	,,
5th	,,	5,000	,,	10,000	,,
6th	,,	1,000	,,	5,000	,,
7th	,,	500	,,	1,000	,,
8th	,,	100	,,	500	,,
9th	below	100 candle power.			

Since 1892 no light of over 100,000 candle power has been installed in Scotland, while in France no fewer than ten lights of a total candle power of 102,810,000 have either been altered to their present power or newly installed. In the second class of lights, those between 40,000 and 100,000, the number of lights in Scotland and France is equal, and in this case the total candle power of the Scottish lights is superior to that of the French, the Scottish being 206,000 and the French only 173,000. In class 3, where the lights are between 22,000 and 40,000, the French have either newly installed or altered 31 lights to our 3 since 1892, their total candle power amounting to 156,000 as against our 90,000. In class 4, which includes all lights between 10,000 and 22,000, the French have either freshly installed or altered 7 lights to our 2, the respective total candle powers being in France 97,000 and in Scotland 34,000. In class 5, where the lights are between 5,000 and 10,000, Scotland has added no new light, while France has either newly erected, or brought up to this standard of efficiency, 6. In the sixth class, between 1,000 and 5,000 candle power, France's total is 10 lights to 3 for Scotland. In class 7, France has to be credited with 12 lights all installed or altered since 1894, while Scotland has neither installed or altered any lights of this size since 1892. In class 8, where the lights are between 100 and 500, there are 12 lights in the French lists as against 5 in the Scottish, while in the last and smallest class France can claim 50 lights as against Scotland's 20.

The above statement embodies a comparison of the lights installed since 1892. The following table gives a summary of the total number of lights in the first four classes, without restriction as to date:—

Class.	Candle Power.	France.	Scotland.
I.	above 100,000 ...	39 ...	1
II.	between 40,000 and 100,000 ...	22 ...	11
III.	„ 22,000 „ 40,000 ...	17 ...	6
IV.	„ 10,000 „ 22,000 ...	10 ...	3

To follow this line a little further, let us look at the lights installed in France since November 1896.

Name.	Candle Power
(1) Cap Matifou,	10,000
(2) Ile de Sein,	300,000
(3) Groix,	300,000
(4) Eckmühl,	30,000,000
(5) Cayeux,	6,000
(6) Armen,	300,000
(7) Ville-és-Martin,	600
(8) L'Ailly,	600,000
(9) L'Hé Vierge,	700,000
(10) Pointe des Chats,	2,500
(11) Penfret,	10,000
(12) Cap Gris Nez,	35,000,000
(13) La Carche,	35,000,000
(14) Planier,	35,000,000
(15) Entrée Nord de Marseille,	10,000
(16) La Horaine,	600

No new thing in the way of optics, acoustics, or mechancial contrivance has been hastily or rashly set aside, and the result has been that the French Lighthouse Service of the present day is able to maintain both a constant yearly expenditure on maintenance and new works with an ever increasing number of power of lights. It was in 1890 that the late M. Bourdelles, the distinguished head of the French Lighthouse Service, devised the system of lightning-lights known as the feux-éclairs, and from that day onwards the French Lighthouse system has advanced by leaps and bounds. This system of lighting is universal, with the exception of our own land. The advantages are so obvious as scarcely to require pointing out, but the fact remains, nevertheless, that it is not adopted in our country.

Even the feux-éclairs system cannot, however, compete either as regards cost or efficiency with the spindle-eclipser apparatus which I have described, and in order to bring out clearly the saving that can be effected by the use of this apparatus I have prepared the three following tables wherein will be found the respective costs of the old style of apparatus, which the authorities in Scotland persist in using, compared with those spindle-eclipsing feux-éclairs of equivalent power. See pages 40, 41, and 42.

A glance at the list of lights installed in France since November of 1896 shows the very powerful nature of the apparatus employed, yet it is to be remembered that there are none of them of the expensive and old-fashioned type, such as the hyper-radiant, the employment of which is still persistently used in our service when lights of great power are employed. For example, in the case of Armen, on the west coast of France, the apparatus is of the second order, and the luminary is an incandescent gas light. The gas is formed from mineral oil and is under pressure. The light of this apparatus is equal to 300,000 candle power, and its cost is approximately £2000, while the cost of hyper-radiants of equal candle power amounts approximately to £5600. I have merely mentioned, in passing, the electric light; but, as you are all doubtless aware, Scotland can boast of but one electric light—the Isle of May. France, on the other hand, has 11, England 3, Russia 4, Germany 6, Spain and Portugal 4.

I am at the present time unable to speak of other branches of the Lighthouse Service, such as lightships, fog signals, beacons, buoys, and lighthouse tenders, but these are all subjects of the utmost importance and interest, and if this Institution should at another time still feel an interest in this subject I shall be happy to afford it information on these matters.

In conclusion, I would like to say that viewing, as a whole, our own Lighthouse Service as compared with others, one cannot but be struck by the absence of progress and reform, while it is also clear to everyone who looks carefully into the matter that economies are not practised here which are elsewhere, and that large expenditures are sanctioned without very adequate or satisfactory results.

TABLE I.

COMPARISON OF HYPER-RADIANT APPARATUS WITH SPINDLE-ECLIPSING APPARATUS OF APPROXIMATE POWER.

No.	Description of Apparatus.	Candle Power.	Cost of Glasswork	Cost of Accessories.	Total Cost.	Saving got by use of Spindle-Eclipsers.
1	Hyper-Radiant Apparatus with 4 sides - - - - -	284,528	£3300	£2332	£5332	—
i.	Corresponding to Second-Order Spindle-Eclipser subtending 175°	294,000	690	1637	2327	£3005
2	Hyper-Radiant Apparatus with 6 sides - - - - - -	224,961	3150	2032	5182	—
ii.	Corresponding to Second-Order Spindle-Eclipser subtending 150°	231,200	645	1637	2282	2900
3	Hyper-Radiant Apparatus with 8 sides - - - - - -	165,087	2950	2032	4982	—
iii.	Corresponding to Second-Order Spindle-Eclipser subtending 125°	171,000	600	1452	2052	2930
4	Hyper-Radiant Apparatus with 3 sides, each side giving a group of 2 flashes - - - - - - - -	224,961	3200	2032	5232	—
iv.	Corresponding to Second-Order Spindle-Eclipser subtending 155°	231,200	645	1637	2232	2950
5	Hyper-Radiant Apparatus with 3 sides, each side giving a group of 3 flashes - - - - - - - -	146,744	3500	2032	5532	—
v.	Corresponding to Third-Order Spindle-Eclipser subtending 175°	147,000	410	1080	1470	4042
6	Hyper-Radiant Apparatus with 4 sides, each side giving a group of 2 flashes - - - - - - - -	165,087	3550	2032	5582	—
vi.	Corresponding to Second-Order Spindle-Eclipser subtending 125°	171,000	600	1452	2052	3530
7	Hyper-Radiant Apparatus with 4 sides, each side giving a group of 3 flashes - - - - - - - -	110,058	3500	2032	5532	—
vii.	Corresponding to Third-Order Spindle-Eclipser subtending 160°	128,634	490	1080	1570	3962

TABLE II.

COMPARISON OF FIRST-ORDER APPARATUS WITH SPINDLE-ECLIPSING APPARATUS OF APPROXIMATE POWER.

No.	Description of Apparatus.	Candle Power.	Cost of Glass-work.	Cost of Accessories.	Total Cost.	Saving effected by use of Spindle Eclipser.
1	First-Order Apparatus with 6 sides and 180° of mirror - -	62,606	£825	£1568	£2393	—
i.	Corresponding with Small Third-Order Spindle-Eclipser subtending 150° - - - - - - - -	65,000	290	770	1060	£1333
10	First-Order Apparatus with 6 sides - - - - - -	97,534	1350	1568	2918	—
x.	Corresponding with Third-Order Spindle-Eclipser subtending 140°	103,441	405	1080	1485	1433
11	First-Order Apparatus with 8 sides - - - - - -	79,387	1200	1568	2768	—
xi.	Corresponding with Small Third-Order Spindle-Eclipser subtending 175° - - - - - - - -	83,000	320	770	1090	1678
5	First-Order Apparatus with 3 sides, each side giving a group of 2 flashes - - - - - - - - - -	97,534	1680	1748	3428	—
v.	Corresponding with Third-Order Spindle-Eclipser subtending 140°	103,441	340	1080	1420	2008
6	First-Order Apparatus with 3 sides, each side giving a group of 3 flashes - - - - - - - - - -	70,567	1700	1748	3448	—
vi.	Corresponding with Small Third-Order Spindle-Eclipser subtending 160° - - - - - - - -	72,562	300	770	1070	2378
7	First-Order Apparatus with 4 sides, each side giving a group of 2 flashes - - - - - - - - - -	79,387	1680	1568	3248	—
vii.	Corresponding with Small Third-Order Spindle-Eclipser subtending 175° - - - - - - - -	83,000	320	770	1090	2158
8	First-Order Apparatus with 4 sides, each side giving a group of 3 flashes - - - - - - - - - -	52,925	1750	1568	3318	—
viii.	Corresponding with Small Third-Order Spindle-Eclipser subtending 140° - - - - - - - -	58,352	280	770	1050	2268

TABLE III.

COMPARISON OF SECOND-ORDER APPARATUS WITH SPINDLE-ECLIPSING APPARATUS OF APPROXIMATE POWER.

No.	Description of Apparatus.	Candle Power.	Cost of Glass-work.	Cost of Ac-cessories.	Total Cost.	Saving got by use of Spindle Eclipser.
1	Second-Order Apparatus with 6 sides and 180° of mirror -	44,692	£520	£1160	£1680	—
i.	Corresponding with Small Third-Order Spindle-Eclipser subtending 120° - - - - - - - - - -	45,014	250	770	1020	£660
10	Second-Order Apparatus with 6 sides - - - - - -	70,637	950	1160	2110	—
x.	Corresponding with Small Third-Order Spindle-Eclipser subtending 160° - - - - - - - - - -	72,562	300	770	1070	1040
11	Second-Order Apparatus with 8 sides - - - - - -	56,670	825	1160	1985	—
xi.	Corresponding with Small Third-Order Spindle-Eclipser subtending 140° - - - - - - - - - -	58,352	280	770	1050	935
5	Second-Order Apparatus with 3 sides, each side giving a group of 2 flashes - - - - - - - - -	70,637	1050	1440	2490	—
v.	Corresponding with Small Third-Order Spindle-Eclipser subtending 160° - - - - - - - - - -	72,562	300	770	1070	1420
6	Second-Order Apparatus with 3 sides, each side giving a group of 3 flashes - - - - - - - -	50,373	1100	1440	2540	—
vi.	Corresponding with Small Third-Order Spindle-Eclipser subtending 130° - - - - - - - - - -	51,000	270	770	1040	1500
7	Second-Order Apparatus with 4 sides, each side giving a group of 2 flashes - - - - - - - -	56,670	1075	1440	2515	—
vii.	Corresponding with Small Third-Order Spindle-Eclipser subtending 140° - - - - - - - - - -	58,352	280	770	1050	1465
8	Second-Order Apparatus with 4 sides, each side giving a group of 3 flashes - - - - - - - -	37,780	1125	1440	2565	—
viii.	Corresponding with Fourth-Order Spindle-Eclipser subtending 180°	38,389	160	374	534	2031

The **President** stated that the discussion on this paper would be postponed till the next meeting, but he might be allowed in a very few words to express the thanks of the Institution to Dr Purves for the more than excellent and elaborate paper which he had read on a subject with which they were possibly not so well acquainted as they ought to be, but Dr Purves had put it in such a way that their interest was awakened.

Discussion.

The discussion on this paper took place on 21st November, 1899.

Mr **James Mollison** (Member) said this was a subject which he had been more or less interested in for many years, and he had listened with pleasure to Dr Purves, who had given a very able and clear description of the principal lighthouses round our coasts, the names of which were familiar to all, and to many they formed objects of interest as well as beacons of safety. Not only had Dr Purves traced the history of these lighthouses, but he had put in tabulated form their original costs, and compared them with those of the corresponding lighthouses erected by the French. They must have been struck, not so much with the comparison as to the first cost, which might be accounted for in many ways, but the greater cost of maintenance of the Scottish lighthouses, and the low efficiency in illuminating power as referred to on page 38 of Dr Purves's paper. On that page Dr Purves said: "It was in 1890 that the late M. Bourdelles, the distinguished head of the French Lighthouse Service, devised the system of lightning-lights known as the feux-éclairs, and from that day onwards the French lighthouse system has advanced by leaps and bounds. This system of lighting is universal, with the exception of our own land. The advantages are so obvious as scarcely to require pointing out, but the fact remains, nevertheless, that it is not adopted in our country." The want of efficiency and progress on this side of the Channel would appear to be a very serious matter, as borne out again by Dr Purves in his concluding remarks where he said: "It is also

Mr James Mollison.

clear to everyone who will look carefully into the matter that economies are not practised here which are elsewhere, and that large expenditures are sanctioned without very adequte or satisfactory results." He (Mr Mollison) thought it was quite within the province of this Institution to review the policy which was responsible for this state of matters, and it would have been well if some of the shipowning members of the Institution had been invited to attend that evening to discuss this paper, some of whom were well versed in lighthouse administration. It had been a long standing grievance with the shipowning interests of this country that, although they paid the light dues, they had little or no voice in the expenditure. At present, the Northern Lighthouse Board, as constituted, consisted of twenty-five members, of whom there were the Solicitor-General and the Lord Advocate, thirteen Sheriffs of Counties adjacent to the coast, the Lord Provosts of Edinburgh and Glasgow with their Chief Magistrates, and the municipal heads of six other towns. Those who took an interest in this matter would have observed lately, from some of the papers, that it was the Sheriffs of Counties who, generally, with the Lord Provost of Edinburgh and the Provost of Leith, attended the meetings and administered the lighthouse revenue. They should give credit to these worthy legal gentleman for doing the very best they could, but it was obvious that, by themselves, they lacked the knowledge and experience in nautical affairs which should form an essential feature in the qualification and fitness of at least some of the members of the Board. As reform appeared to be the order of the day, the time might not be far distant when this Institution, which was not behind in matters of this kind, might have an opportunity, through popularly elected representatives, of taking part in the affairs of that important Board. The addition of practical business men would greatly fortify and strengthen the position of the present Board, particularly when it came to adjudicate on the position of a contemplated lighthouse, the merits of a foghorn, or other mechanical apparatus, as well as the allocation of the revenue derived from the dues which hitherto had been

Mr James Mollison.

a great bone of contention. When such a reform came about, Dr Purves' indictment would, no doubt, disappear, and great good result, not only with regard to the better lighting of our coasts, but also to greater efficiency in plant and machinery, at less expenditure.

Correspondence.

Professor **Archibald Barr**, D.Sc. (Member)—The paper which Dr Purves had submitted would, no doubt, have been heard or read with much interest by many members of the Institution, and he thought that some, at least, of the members would feel with him that they would like to have a more definite indication of the points of novelty in the author's systems, and the relation they bore to the systems hitherto in use, as the details of lighthouse equipment were, for the most part, outwith the ken of engineers in general. He was specially interested in the beautiful and ingenious optical appliances described in the paper, but he did not feel able to discuss these, from lack of sufficient knowledge of the details of the systems now in use and in the absence from the paper itself of sufficient indications of the extent of the departures from previous practice. He could not agree with the statement on page 28, that in the early days, when lights were far apart, " the old fixed lights were all that could be desired." It was well-known that even the most highly trained eye could not distinguish between a powerful light at a great distance and a feeble light near at hand, in the absence of land marks that would indicate the nature of the source. Conditions were easily attainable—and were of not infrequent occurence—under which the flicker of a candle could not be distinguished from the light of a fixed star. Lord Kelvin dealt with that matter in a lecture which some of the members would remember hearing in 1881, and which was published in his "Popular Lectures and Addresses," Vol. III. Navigation. When on board of one of the cruisers, during the naval manœuvres some years ago, he had an interesting illustration of the difficulty of judging the distance even of lights of known character. Certain other cruisers

Prof. A. Barr.

had instructions to keep one mile astern during some scouting operations. The ship had drawn ahead and had been slowed down to let the others recover their stations. After some time the captain—an officer of much experience—judging that the lights were now not more than one mile astern, was about to give the order to increase speed, but the range finder being appealed to, it gave the distance as exactly two miles. In that case the lights were of known capacity. The difficulty of judging the distance of a light of unknown character and intensity was of course much greater, and indeed the effects on one's eye might be absolutely identical in the case of two lights differing enormously in power and in distance, so that differentiation was impossible. No blame therefore was attachable to a mariner who mistook a fixed light in a distant lighthouse for a near mast-head light, or *vice versa*, as frequently happened when nothing else was visible, and more especially when the light was right ahead so that even if near its bearing did not change. There was, therefore, great need for distinguishing characteristics in lights independently of the need to differentiate between the several lights on one coast. It was satisfactory to known that lighthouse engineers were now giving so much attention to the means by which lights might be caused to reveal their identities, and that the old fixed lights were being rapidly converted into flashing or occulting lights. Further, the advantages of cycles of short period seemed now to be more fully recognised. This also was in accord with the views so forcibly advocated by Lord Kelvin at various times many years ago; views founded not only on his knowledge of the physical and physiological principles involved in the identification of lights but upon extensive sea experience. He said extensive experience, for though it could not be claimed for his lordship that he had spent as many hours at sea as the master of a coasting tramp, still he was a skilled navigator, and it should not be forgotten that experience was to be measured, not only in terms of the number of the opportunities for observation, but with reference to the capacity of the observer to take full use of the opportunities as

Prof. A. Barr.

they arose, and to draw just conclusions from what he saw. He would venture to express the expectation—it might arise from lack of knowledge of some of the conditions—that Lord Kelvin's recommendations, in regard to the use of short intervals of darkness and longer periods of light, would yet be more fully adopted by those in authority, even though this might involve the use of lamps of somewhat higher candle power, than were required for flashing lights.

Mr Robert T. Napier (Member)—He had found some difficulty in understanding from the paper the mode of action of the feux-éclair system, and would be glad if the author in his reply would kindly add a short description of this system, and also show wherein it differed from his own. With respect to the candle powers given of French lighthouses—the 35,000,000 candle power of Cap Gris Nez for instance: Had these been actually arrived at photometrically? On the matter of cost of construction, he thought that British practice was to build a lighthouse on the best available site, irrespective of difficulty and cost; whereas, the French selected sites where economy could be practised. He questioned if a French engineer, being given the Eddystone or Bishop's rock on which to build, could have produced a satisfacfactory job at anything like the cost of even the most expensive of the French towers named. He looked forward to Dr Purves, on a future occasion, giving to the Institution a like interesting paper on sound signals.

Dr J. A. Purves, in reply, said he entirely agreed with Prof. Barr's remarks on fixed lights and the great advantage which they possessed. The fixed lights as they existed round the coast were not adequate or would not be adequate in the present state of matters. If they had one fixed light within five miles of another no person could distinguish between the one and the other, but when they had only five or six lights altogether it was pretty well-known which light they were passing, by knowing the port they had left and the port to which they were making. The rapid

Dr J. A. Purves.

departure from the fixed lights was a proof that they were not fit to cope with the requirements of the day; they were being rapidly superseded by flashing lights. Mr Napier desired to know the difference between the feux-éclair system and that of his own. He would point out that whereas the lightning-flash lights were made to give groups of flashes by means of the arrangement of their dioptric elements, the system he had devised produced groups of flashes by a mechanical contrivance which eclipsed the light periodically. All the candle powers of the French lights were derived from actual photometric experiments, unlike those of our own country which were arrived at by a more or less uncertain method of calculation. The French lighthouses, which he had quoted as examples, so far as cost went, were nearly all old towers, and most of them fully exposed to the storms from the Atlantic, and despite these facts, they were still in a perfectly efficient and sound condition notwithstanding the smallness of first cost. He regretted the doubt expressed by Mr Napier as to the ability of French engineers to execute as satisfactory work as could be accomplished at home; such insular prejudices, he hoped, were almost extinct by this time. He was obliged to Mr Mollison for his remarks concerning the Northern Lighthouse Board, but felt that it was not his province to deal with that matter although he had it very much at heart. He was entirely in sympathy with those shipping associations, chambers of commerce, and shipbuilders, who for a good many years had done the utmost to alter the constitution of that anomalous Board; and he only hoped that the time was not far away when it would not be ruled by the purely legal element which had no knowledge of a technical kind beyond what was acquired at Board meetings and conversations with scientific advisers of the Board. It was a highly desirable thing that the Board should, in its major part at least, be constituted of shipowners and shipbuilders who had a direct interest in the management and in the affairs of shipping. It was really only such persons who were able to judge of the best sites for lighthouses, the arrangement for steam tenders, and matters dealing with buoys, etc., and until the Lighthouse Board was reconstituted the best results could never be realised. Recently, repairs had been carried out at enormous cost, and fresh steamers had been built, and he had no doubt that some of the shipowners knew that the expense had been very great. He had not the least hesitation in saying that had the Board been composed of shipowners and shipbuilders the expense would have been minimised.

The President said he agreed with Prof. Barr that they would have been still better pleased with the paper if it had been less descriptive and more technical. With regard to Mr Mollison's remarks, the constitution of the Northern Lighthouse Board had always been to him a very strange one, and he thought the anomaly would be remedied to a great extent if an Institution such as theirs were given a representation on the Board. On the motion of the president, Dr Purves was awarded a vote of thanks for his paper.

A RECORD OF EXPERIMENTS ON FLOW OF WATER OVER BELL-MOUTHED PIPES.

By JOHN BARR (Member).

(SEE PLATES III., IV. AND IV$_A$.)

Read 21st November, 1899.

As the formula given for the discharge of water over bell-mouthed pipes has, under certain conditions, been found to be unreliable, the following experiments were undertaken to get at accurate deliveries under the experimental conditions shown by illustration on Plate III., with the object of applying the results to deliveries by telescopic bell-mouthed overflows of filtered water in filter draw-off wells, Fig. 1.

It will be observed that the deliveries are not those given from *still water*, as such a condition was not practicable in the circumstances. The size of the box in which the bell-mouth was placed in the experiments approximates closely to that obtaining with filter outlet wells. For the larger deliveries, say about 900 gallons per minute, the approach velocity of water through the opening at the bottom on the left-hand side of the inlet to box in which the bell-mouth was placed is equal to about 2 feet per second, probably a somewhat greater velocity than is likely to obtain for a filter outlet tube. For smaller quantities, however, it is about what is found in regular practice.

DIMENSIONS OF BELL-MOUTHED TUBES.

The cast-iron bell-mouthed pipes were made (from 2 inches to 12 inches diameter inclusive) as shown in Fig. 2. The extreme diameter of bell-mouth A, in Fig. 2, is 2½ times the diameter of the pipe in the case of the 2-inch size; in sizes up to 9 inches in diameter it is fully greater than twice the diameter of the pipe. In the 10-inch, 11-inch, and 12-inch sizes the extreme diameter is exactly double the size of the pipe. The depth B varies from 2½ times the diameter of the pipe in the 2-inch size, to the same depth as the diameter in the 12-inch size. The radius of curve C varies from 7 inches in the smallest size to 12 inches in the largest.

The bell-mouthed lip was turned true and rounded off in the lathe, and the diameter given for the overflow edge is the extreme top of the rounded part of the lip marked A*, in Fig. 2.

ARRANGEMENT OF MEASURING TANK, ETC.

The bell-mouthed pipe to be experimented upon was placed in the right-hand end compartment of a wooden tank provided with baffle plates to render the water as still, and free from waves as possible, Fig. 3. This tank was provided with a false bottom as shown, the whole resting on the top of cast-iron measuring tanks. An adjustable gauge-board was placed opposite the bell-mouth pipe. In addition to this a hook-gauge was employed, and the level of the overflow at the front side of the box was carefully adjusted to correspond with the level shown by the gauge-board and by the hook-gauge. The supply of water was discharged by a pipe from an overhead cistern into the left-hand end of the wooden tank; the supply valve being adjusted by hand, so that the level of the water flowing over the bell-mouth pipe was kept uniform. When all was ready, and the level of the water flowing over the bell-mouth pipe properly adjusted, the water being in the meantime allowed to flow to waste through the overflow casing in front; at a given signal, the flap-door was suddenly pulled up, thus allowing the water to drop into the cast-iron measuring tanks below; and, at the same time, cutting off the overflow. The contents of the measuring tanks was 485 gallons, and whenever the quantity was reached, the time was noted by a stop watch. Thirty-nine experiments were recorded. All of them were repeated; generally three or four times. The results of the experiments agreed very closely, the average being noted as the correct delivery.

BOX'S RULE.

The rule given by Thomas Box in his "Practical Hydraulics" for overflows to tanks, etc., is stated as under.

"The rules and table for weirs apply also with approximate correctness to an overflow pipe to a tank, which may be considered as a circular weir whose length is equal to the circumference of the trumpet-mouth." The rule is given thus:—

$$G = D \times \sqrt{D} \times d \times 8{\cdot}4.$$

Where
G = Gallons discharged per minute.
D = Depth of water over the lip (measured from still water) in inches.
d = The diameter of the trumpet-mouth in inches.

It is to be noted that Mr Box is careful to say that the delivery is thus ascertained only with "approximate correctness.'

TABLE OF DELIVERIES

The actual deliveries in gallons per minute are given in the annexed table and, alongside, the calculated deliveries are given according to Box's Formula.

It will be observed that for overflows of 1 or 2 inches diameter the discharge given by Box's Rule is too low, while for overflows of 3 or 4 inches diameter it is too high.

In the case of 2, 3, and 4-inch bell-mouths with an overflow equal in depth to 2, 3, or 4 inches, it was evident that the pipe or throat of the bell-mouth was unable to take away the water supplied over the lip. These discharges are printed in italics in the Table. In other words, a 2- or 3-inch bell-mouth pipe should never have more than a 1-inch depth of overflow to carry away, while a 4-inch bell-mouth should never have more than a 2-inch overflow, and a 5-inch bell-mouth a 3-inch overflow.

Diameter of Pipe.	Diameter of Bell-mouth Pipe. A	Perimeter of Inlet. A	Delivery in gallons per min. for head in inches.				Delivery in gallons per min. for head in inches, per Box's Rule.			
			1″	2″	3″	4″	1″	2″	3″	4″
2″	4½″	14	47·3	*50*	*52·3*	*54·6*	37	*107*	*196*	*300*
3″	6⅛″	19	73	*113*	*125*	*130*	50	*142*	*262*	*403*
4″	8″	25	91	208	*235*	*240*	67	190	*349*	*537*
5″	9⅞″	31	116	271	371	*430*	84	237	436	*673*
6″	11½″	36	125	330	484	640	96	273	502	773
7″	13⅜″	42	144	393	590	864	116	320	590	910
8″	15¼″	48	161	420	620		130	368	676	
9″	17¼″	54	185	457	657		144	404	743	
10″	18¾″	60	205	480	703		160	453	832	
11″	20¾″	66	230	540	840		176	498	915	
12″	23″	72	260	610	910		192	544	999	

For overflows of *1 inch* in depth $G = D \times \sqrt{D \times d} \times 11$ is approximately correct. For greater depths this formula does not hold good.

Curves of deliveries of various sizes of bell-mouths are shown in Fig. 4.

Discussion.

The discussion on this paper took place on 19th December, 1899.

Mr J. D. Cormack, B.Sc., (Member) remarked that Mr Barr had done two things; he had given them some data for the flow of water over the bell-mouthed pipes experimented with, and at the same time he had pointed out how very far from the truth were the formulæ

Mr J. D. Cormack.

which they sometimes met with, expecially in connection with hydraulics. The problems in hydraulics were, perhaps, the most interesting and at the same time the most difficult of all the problems of engineering theory and engineering practice. The formula which Mr Barr criticised was founded on several assumptions which were not complied with in the case of the bell-mouthed pipes he used. It was founded on the formula which was employed for the flow of water over long rectangular sharp-edged notches. In that case, if the end contractions were neglected, the results would be given approximately by Box's formula :—

$$G = 2{\cdot}67\ l\ D^{\frac{3}{2}},$$

where G = gallons discharged per minute,
l = length of notch in inches,
D = depth in inches of bottom edge from still water surface.

To take account of the contraction in the stream due to the curvature of the stream lines flowing round the edges, some alteration had to be made in the form of the formula. This was done in, and the flow was very nearly given by, Francis' formula, which in this case was:—

$$G = 2{\cdot}49\ (l - 0{\cdot}2D)\ D^{\frac{3}{2}},$$

the part 0·2D represented the effect of the sides in diminishing the effective length. Box's formula always gave a larger flow than Francis'. It neglected, the end contractions, and it represented a co-efficient of discharge of ·665 instead of ·62 as in Francis' formula. If the flow were guided so that there were no end contractions, Francis' formula became :—$G = 2{\cdot}49\ l\ D^{\frac{3}{2}}$. In the case of water flowing over the very sharp edge of a pipe they could consider the stream as equivalent to the stream from a notch of length equal to the perimeter and free from end contractions, and it might be expected that a formula of the form above would give the flow approximately. It could not, however, give it accurately, as the flow was radial and not quite similar for different heads. In this case by Box's formula—

$$G = 2{\cdot}67 \times \pi d \times D^{\frac{3}{2}} = 8{\cdot}4\, d\, D^{\frac{3}{2}}.$$

Now Box applied this formula to, and Mr Barr had been experimenting on, a very different case. The flow was not over a sharp edge, but over a rounded corner, and the shape of the edge had a very great influence on the flow. The rounded edge might be looked upon either as a guide leading the stream over a sharp edge at the level of the top, the head being measured from the top; or, it might be looked upon as an obstruction which might diminish the flow over a sharp edge placed at O, Fig. 5. For example, in flowing freely over a sharp edge, Fig. 6, the bottom stream line had a curvature somewhat as shown. The sectioned part could be filled in without disturbing the flow, but the head was measured from the level of the sharp edge E and not from the top T. In addition to this, account had to be taken of the backward flow of the water from region B, Fig. 5, and also the effect of the shape of the bell-mouth at M. These considerations showed that it was not to be expected that Mr Barr's experimental results should agree with Box's formula. He had plotted out Mr Barr's results as in Figs. 7 and 8. Fig. 7 showed that for the same head the flow was nearly proportional to the perimeter for orifices whose pipes had diameters more than double the head. With the orifices used by Mr Barr, when the head was about half the diameter of the pipe, the pipe ran full bore, and when that was the case the law of flow was entirely different. Fig. 8 showed the relation between the logarithms of the heads and the logarithms of the corresponding deliveries for some of the orifices used. If the flow was proportional to the $\frac{3}{2}$ power of the head these curves would be straight lines parallel to the dotted line. This method of plotting was extremely useful in such a case as this, where between two variables x and y a relation was expected of the form $y = ax^n$. It permitted one to find the values of a and n, which gave the closest approximation to the experimental results, and it

Mr J. D. Cormack.

also gave at a glance the percentage error. Fig. 8 showed how at small heads the tangents to the curves were more nearly parallel to the dotted line than at large heads, and for the larger pipes the curves were more nearly straight lines.

Professor Barr—Had Mr Cormack taken the heads down to the beginning of the curve, or, as Mr Barr had taken them?

Mr Cormack—He had taken them as Mr Barr had done. The point to which Dr Barr referred was one he would like to allude to briefly. From Fig. 7 he had extrapolated and obtained the delivery for an orifice 100 inches in perimeter under different heads. He plotted the logarithms of these deliveries and the logarithm of (the head + ½ inch) the ½ inch being added to allow for the half-thickness of the lip, the thickness of which had not been given by Mr Barr in his paper, though it seemed to range between ½ inch and 1 inch for the small and large orifices. This plotting gave nearly a straight line, and from it was obtained the formula:—

$$G = 6.2 \ H^{\frac{3}{2}} \ d,$$

G, as before, being the delivery in gallons per minute,
H, the head in inches above the top + ½ inch; and
d, the greatest diameter of the bell-mouth.

The greatest deviation of the experimental results from the formula, within the limits between which it was applicable, was about 10 per cent. A closer agreement could not be expected, and the formula could at best only be looked upon as an empirical formula expressing roughly Mr Barr's results. No one formula could accurately express the results. Flows over a sharp-edged notch without end contractions were similar for different heads, but if the edge was thick or rouuded, the flows could not be similar. Nor were the bell-mouths similar. If they had been similar in every respect, the flow for corresponding heads would have been proportional to the $\frac{5}{2}$ power of the linear dimensions. He wished to express his interest in Mr Barr's paper, and his appreciation of its usefulness.

Prof. A. Barr, D.Sc. (Member) observed that, in connection with what Mr Cormack had said with regard to the interest that there was in hydraulic questions generally, he found something of a fascination to himself in flowing water. There was one particular element of interest attachable to experiments upon hydraulics, which was, that only in a very few of the simplest cases could quantitative results be obtained at all by calculation on true dynamical principles. An interesting example was the very beautiful and extraordinarily simple analysis that Mr Froude gave for the case that Mr Cormack referred to—that of a thin re-entrant pipe where he (Mr Froude) proved by the very simplest dynamical reasoning that, neglecting friction, the area of the section of the jet, where it came to be sensibly parallel, was exactly one-half the area of the external section of the tube.* The investigation of the motion of water under such conditions as those to which the paper referred, was far beyond any human mathematics. He was sorry that Mr Barr had not made the orifices on which he experimented, or, at least, a few of them, of similar forms—that was to say with the same curves but on different scales, and with the thicknesses proportional to the diameters—as then he would have had a series of experiments on one particular form of orifice, whereas, it was on a variety of different orifices he had experimented, and the orifices differed very considerably in the important point of the thickness of lips which Mr Cormack had made quite clear as having a peculiar bearing on the subject. Mr Barr remarked on the fact that certain of the results he had tabulated referred to a different case from the others, inasmuch as that in them the pipe was running full bore. Seeing that many people were too much in the habit of looking at a paper like this, and taking the results without reading the qualifying remarks that were made by the writer, he would suggest that Mr Barr should draw a heavy line marking those results as being outside the special subject to which the paper referred. It would be observed that as

---

* Proceedings of the Philosophical Society of Glasgow, February, 1876.

Prof. A. Barr.

soon as the pipe began to run full bore the results would depend greatly upon the length of fall pipe attached to the nozzle, and other conditions as to the freedom of exit of the water. He had looked into the question as to how far Mr Barr's results agreed with the two entirely different formulæ that would be applicable to the cases of partial and full-bore flow from the discharge end of the nozzle, and the results of that inquiry threw at least some light on the accuracy with which Mr Barr's observations had been made, so far as his apparatus permitted of accuracy. He had plotted Mr Barr's results for the 4-inch and 7-inch pipes on the accompanying diagram, Fig. 10, and he had added two curves, one calculated from what might be called the notch-board formula as given by Box, and the other showing the discharge from a bell-mouthed pipe under heads equal to the height of the still water surface above the exit end of the nozzle. It would be seen that Mr Barr's results, especially for the 4-inch pipe, followed approximately the portions of these curves which were applicable to the conditions of the experiment. He thought that the tank from which the flow was taken was much too small to secure very consistent results, for the larger nozzles at least, and more especially so since the water was admitted at one end of the box, and must, therefore, have had a considerable velocity of flow towards one side of the bell-mouth.

Correspondence.

MR W. H. RIDDLESWORTH, B.Sc.—Mr Barr's "Record of experiments on flow of water over bell-mouthed pipes" was full of interest, and the departure of the results from the theoretical discharge, as quoted by the author, at once challenged inquiry. Further, the rejection of several experiments on account of the "pipe or throat of the bell-mouth" being unable to take away the water supplied over the lip, raised the question of the limiting ratios of head and height and diameters of bell-mouth. First, plotting the results of the experiments on a base line representing diameters of lip of bell-mouth, it would be seen at once that the majority of the results for any one head lay (approximately) upon a straight line passing through the origin—showing that the discharge varied as the diameter of the lip of the bell-mouth; that was, as the length of the discharging edge. The obvious exceptions, namely, those results which lay much below the line, were reserved for treatment later on. Taking the results which conformed to the above variation of discharge with diameter, the following approximate equations held good—

$$\begin{aligned} &\text{Head } 1'', & G_1 &= 11{\cdot}12\text{D}. \\ &\quad ,, \quad 2'', & G_2 &= 26{\cdot}9\text{D}. \\ &\quad ,, \quad 3'', & G_3 &= 39{\cdot}6\text{D}. \\ &\quad ,, \quad 4'', & G_4 &= 64{\cdot}7\text{D}. \end{aligned}$$

where G = gallons per minute, and
D = diameter of lip of bell-mouth in inches.

It should be noted that the result for the 4″ head was derived from a single experiment, and was therefore not to be implicitly relied upon. By plotting the logarithmic homologues of the above expressions for discharge and head, the following empirical equation was obtained—

$$G = 11{\cdot}35\, h^{1{\cdot}19}\text{D}.$$

where h = head, in inches above the lip of the bell-mouth,
G and D as before.

This equation gave approximately the discharge in all the cases included in the experiments, excluding, of course, the cases which "choked." Regarding the lip of the bell-mouth as the crest of a weir, circular in plan, the expression for discharge ought to be

$$G = 375\, c\, \pi \frac{\text{D}}{12}\, \frac{h}{12}\, k \sqrt{2g\, \frac{h}{12}},$$

c being a co-efficient of contraction (chiefly) depending

Mr W. H. Riddlesworth.

on the ratio of depth of flow over the lip to head from still water.

k being a co-efficient of velocity and for a rectangular weir = $\frac{2}{3}$. (The present was only a special case of rectangular weir).

Inserting this value of k, and retaining for the present the co-efficient c, then

$$G = 12{\cdot}54\ c\ D\ h^{\frac{3}{2}}.$$

The values of c from the experiments were—

Head	c
1″	·887
2″	·760
3″	·608
4″	·643

The increase of the co-efficient at 4-inch head was exceptional, and, as only one experiment was available at that head, it ought to be rejected. The values of c for heads up to 3 inches might be expressed as $c = 1 - {\cdot}125\ h$, giving as a general expression for the flow

$$G = 12{\cdot}54\ (1 - {\cdot}125\ h)\ D\ h^{\frac{3}{2}},$$

which was applicable to heads up to 3 inches, beyond which the experiments were no guide. The co-officient which one would expect on theoretical grounds was that appropriate to a broad crested weir, as that was more like the actual case than the sharp-edged notch. The co-efficient for this was ·577, and the experiments seemed to lead to the conclusion that, for slightly greater heads than had been used, that co-efficient would be obtained. The greater value of the co-efficient actually obtained might, perperhaps, be explained as the result of the convergence of the streams to the lip over which they flowed. It was known that converging wing boards to an ordinary weir caused a very considerable increase in the quantity discharged, and in this case the convergence was very marked, and the resultant effect correspondingly great. The choking phenomenon might be investigated in the following manner. The discharge (full bore) through a bell-mouthed orifice was—

$$G = 375\frac{\pi}{4}\left.\overline{\frac{d}{12}}\right|^{2} \cdot 95\sqrt{2g\frac{H}{12}}$$

$$= 4{\cdot}48\, d^2\, H^{\frac{1}{2}}$$

where d = diameter of orifice, in inches.
H = head above orifice, in inches.

Choking was about to occur when the discharge over the lip was just equal to the discharge through the throat, the head being counted in each case from the same still water level. Hence choking took place when

$$12{\cdot}54\, c\, D\, h^{\frac{3}{2}} = 4{\cdot}48\, d^2\, H^{\frac{1}{2}}$$

$$\text{or } c\, D\, h^{\frac{3}{2}} = {\cdot}357\, d^2\, H^{\frac{1}{2}}$$

an expression which connected the four principal dimensions involved. The following was an example of the application of this expression to find the minimum height of bell-mouth—

Taking $d = 4$
$D = 8$
$h = 2''$
$c = {\cdot}75$

in the equation

$$c D h^{\frac{3}{2}} = {\cdot}357\, d^2\, H^{\frac{1}{2}}$$

$$\text{then } {\cdot}75 \times 8 \times 2^{\frac{3}{2}} = {\cdot}357 \times 4^2\, H^{\frac{1}{2}}$$

$$\text{or } \sqrt{H} = 2{\cdot}11\sqrt{2},$$

$$\therefore\ H = 8{\cdot}9 \text{ inches.}$$

The minimum height of bell-mouth = 8·9 − 2 = 6·9 inches. Therefore, with an actual height of about 8 inches, choking was

Mr W. H. Biddlesworth.

just avoided. The same case might serve to illustrate the use of the formulæ obtained for the discharge over the lip.

$$\begin{aligned}(1)\ \text{Taking } G &= 12{\cdot}54\,(1 - {\cdot}125\,h)\,D\,h^{\frac{3}{2}}\\ &= 12{\cdot}54 \times {\cdot}75 \times 8 \times 2\sqrt{2}\\ &= 212{\cdot}5\end{aligned}$$

a close approximation to that actually obtained.

$$\begin{aligned}(2)\ \text{Taking } G &= 11{\cdot}35\,h^{1{\cdot}19}\,D\\ &= 207{\cdot}4\end{aligned}$$

A closer approximation to the experimental result. This did not of necessity imply that formula (2) was the more reliable of the two, but that the average which it represented happened to very nearly fit the case tested.

The expression

$$c\,D\,h^{\frac{3}{2}} = {\cdot}357\,d^2\,H^{\frac{1}{2}}$$

embodied the laws of similarity of bell-mouths. By similarity was meant that in any one series of bell-mouths "choking" would happen with the same head in all cases. If the head and height were constant, then

$$D \propto d^2$$

If $D = n\,d$, then

$$\frac{c}{n}\,h^{\frac{3}{2}} = {\cdot}357\,d\,H^{\frac{1}{2}}$$

Whence, knowing the approximate constant for any particular head, the ratio of diameter and height of bell-mouth could readily be obtained. It might be further noticed that the expression already obtained might be used to give the minimum size of the bell-mouth at any point of its curved outline, by finding the size at that section which would ensure that choking could not take place.

Mr John Barr.

Mr John Barr said he was afraid that it was almost impossible to reply at length just then to the very learned remarks they had heard from Mr Cormack and Prof. Barr, but he thought that Prof. Barr's suggestion to put a heavy line below the figures in italics in the table was a very good one. The hole in the compartment underneath was about twice the width of the hole in the diaphragm plate. He desired to explain that the bell-mouthed pipes used in the experiments were made from standard patterns. A great many of these were in daily use in waterworks all over the country; and what he aimed at was to get some reliable data of actual discharges from these forms of overflow under conditions somewhat similar to those that obtained in actual practice. Indeed, the question had been asked him by civil engineers whether any experiments concerning these discharges had ever been carried out, as they were sure that the existing formula was considerably misleading. It would, undoubtedly, have been preferable had the bell-mouths all been similar in curve; but he had to deal with existing conditions; and, to be of use for existing overflows made to these patterns, he had, perforce, to take them as they were. He was glad to know from Prof. Barr that a goodly proportion of the space in the New Technical Department of the University was intended to be devoted to hydraulic experiments, which would be carried out with greater facilities at command, and with greater skill than was possible in the hurry and bustle of an engineering establishment, where the only time usually available for such work was after ordinary working hours were past. The manner in which Mr Riddlesworth had investigated the results of experiments was extremely interesting and useful, and he was much indebted to him for going into the matter so thoroughly. Mr Riddlesworth was quite right in treating the discharge with a 4-inch depth of overflow as a somewhat doubtful quantity, as the velocity was really too great and the surface of the water too rough to get a proper result. He was gratified that the discussion had been gone into in such a scientific manner, as it was, he dared say, quite as valuable as the paper itself.

The President.

The PRESIDENT said they would all agree with him that they had heard, not only a very excellent paper from Mr Barr, but a very interesting discussion. He had much pleasure in moving a very hearty vote of thanks to Mr Barr for his paper.

The motion was carried by acclamation.

THE MEANS ADOPTED FOR MODERATING THE ROLLING OF SHIPS.

By W. J. Luke (Member).

(SEE PLATE V.)

Read 21st November, 1899.

The writer, having been requested by the Secretary to contribute to the proceedings of this Institution, the present subject has been chosen, not for the purpose of advancing any new theories, but simply to place on record in the Transactions a brief account of the work that has been done, and the experiments made in this direction during the past thirty years. The fact that nearly all the published information on the subject has reference to warships, is a sufficient reason for almost exclusive reference to vessels of that type.

BILGE KEELS.

There is no doubt that the wooden sailing ships in the British and other navies, as well also as merchant vessels in the first half of the century, were constructed without bilge keels. The deep keels with which many of these ships were fitted in order to give them the sailing qualities required, no doubt acted in the direction of quelling rolling motion. The only notable exception to the above general statement is that of the ill-fated "Atalanta." It will be remembered that for the purpose of training ordinary seamen and boys the Admiralty had been accustomed to keep a frigate in commission, in addition to the brigs attached to the various stationary training ships. H.M.S. "Eurydice," the ship detailed for the duty mentioned, was capsized in a squall on Sunday, March 24th, 1878, off Ventnor, with a loss of about 300 hands, only two surviving of the whole ship's company. The Admiralty thereupon selected H.M.S. "Juno" to replace the lost vessel, and she was brought forward and renamed "Atalanta."

Her principal dimensions were:—Length 131 ft., and breadth 40 ft. 9 in., with a draught of water of 17 ft. 4 in. She was commissioned in September, 1878, and made two voyages, after which, in consequence of the report as to her heavy rolling, she was fitted with bilge keels, Fig. 1. These fittings proved to be less successful than was anticipated. While of course they moderated the rolling of the ship, she still rolled heavily enough to frequently lift them out of water, and the shocks brought about caused straining of the fastenings and consequent leakage through bolt holes. This, added to the discomfort of the tremor and noise, caused the bilge keels to be removed. The "Atalanta" was in no sense an abnormal type of warship; her great metacentric height we now know must have conduced to her heavy rolling; but this heavy rolling was by no means unusual in wooden men of war as will be seen by a perusal of Fincham's History of Naval Architecture, or other works of similar character. Of course, had the bilge keels been originally incorporated in the structure of the ship, the straining which occurred would no doubt have been prevented, but this type of ship, it is clear, was ill adapted for the application of bilge keels, and the sailors of fifty years ago evidently led lives of much greater discomfort than seafaring people are prepared to accept nowadays.

Although not germane to the subject under discussion, the subsequent history of the "Atalanta" may be given. She made one voyage after the bilge keels were removed. She left Bermuda for the British Isles on 1st February, 1880. The North Atlantic was at that time visited by storms of exceptional violence which caused the loss of a very large number of merchant vessels, and nothing has since been seen or heard of the "Atalanta."*

It may be remarked that sails are a valuable means of moderating rolling motion; for a full discussion of this point, reference should be made to Sir William White's paper on "The rolling of sailing ships." †

---

* Report of the "Atalanta" Committee.

† Trans. of the Institution of Naval Architects, 1881.

The French claim to have used bilge keels at the commencement of the present century, but it is probable that they were looked upon primarily as lee boards, and until quite late in the present century it was a commonly received opinion that their utility in moderating rolling was very doubtful[*]

From the earliest days of ironclad ships in the naval service bilge keels have been fitted.

Figs. 1, 2, 3, 4, 5, 6, and 7, illustrate various vessels with these adjuncts shown in position. As the scale of the illustrations is very small, the linear dimensions of the keels have been exaggerated in some cases for the sake of clearness.

In the section of H.M.S. "Devastation," shown in Fig 2, it will be observed that, in addition to the bilge keels fitted, the ship was designed with the armour overhanging the bottom to the extent of about 2 feet. On service, it was found however, that this feature was a source of annoyance to those on board, due to the noise and shock of the alternate immersion and emersion of the armour shelf, and the corner has consequently been eased off as indicated. In other cases it will be noticed that two bilge keels were fitted on each side.

On the morning of 7th September, 1870, H.M.S. "Captain" was capsized off Cape Finisterre: following the court martial of the survivors, the Admiralty appointed a committee of enquiry into the designs for warships then in progress. The late Mr Froude, a member of the committee, made a series of experiments with a model of the "Devastation," in which the utility of bilge keels was fully demonstrated. The trials were made both in still water and among waves, and as the experiments are at least as exhaustive as any which have come under the writer's notice, and as the report is not generally accessible, Mr Froude's own account of his experiments is here reproduced.[†]

---

[*] Shipbuilding by Rankine and others, p. 65, Naval Science, Vol. IV. p. 225; and Report of the Committee on Designs.

[†] Parliamentary Paper. C. 477, 1872.

William Froude, Esq., F.R.S., a member of the Committee, examined.

Q. 3275. (*Sir W. Thomson.*) You have made investigations, I believe, regarding bilge pieces, both theoretically and experimentally, and you have some experimental investigations in progress?

A. Yes; with a large model of the "Devastation" which has been made at Portsmouth, which I have tried oscillating in still water with variously arranged and proportioned bilge pieces, to note how the oscillations are extinguished under each separate condition.

The model is constructed on a scale of $\frac{1}{3}$rd of an inch to a foot, or $\frac{1}{36}$ the dimension of the ship herself.

It was loaded to the load draught of the ship, or 9,090 tons, with the weights carefully placed so as to give to the model, as loaded, a position of centre of gravity corresponding exactly with that calculated for the ship herself, and spread or winged out from the centre in order to correspond in effect with the distribution of the weights in the ship herself, so that, on the whole, the dynamical conditions of the model, as loaded, should correctly represent those of the ship I have also tried the same model in a seaway under similar conditions, so as to observe how far the limitation of the rolling in a seaway corresponds with the rapidity, and time of extinction, of oscillations in still water. Here is a drawing (*producing the same*) showing various bilge pieces, with which the model was tried, viz.:—

(1.) With no bilge pieces.

(2.) With a single bilge piece on each side, projecting 21 inches to scale, and representing that which it has been proposed to apply to the ship.

(3.) With a single bilge piece on each side, projecting 3 feet to scale.

(4.) With a pair of bilge pieces on each side, each projecting 3 feet to scale.

(5.) With a single bilge piece on each side, projecting 6 feet to scale.

Under each of these conditions, the model was "hove down" in still water to certain angles, and then released; and the number of oscillations made by her was counted until the range was so reduced by friction, etc., that the motion was no longer discernible, the last oscillation counted being, by my estimate, about one degree. The period of oscillation was also noted. The initial angles selected in each case were:—

(1.) That which brought the edge of the freeboard to the water level, or 8½°.

(2.) That which brought the top edge of the breastwork to the water level, or 24½°.

The results given are the "means" of many observations, the differences being small except when occasionally disturbance was created by the wind. The results thus vitiated are excluded.

CONDITIONS.	No. of Double Rolls with 8½° Initial Angle.	Period of Double Roll.	No. of Double Rolls with 24½° Initial Angle.	Period of Double Roll.
(1.) No bilge piece	31½	1·77″	29	1·78″
(2.) Single 21-inch bilge piece each side ...	12½	1·90	8½	1·90
(3.) Single 3-feet bilge piece each side ...	8	1·90	6¾	1·90
(4.) Pair of 3-feet bilge pieces each side ...	5¾	1·95 1·90	5½	2·00 1·85
(5.) Single 6-feet bilge piece each side ...	4	2·00 1·98	3½	2·00 1·75

As well as could be observed, whenever the 24½° initial angle was tried, the first single roll appeared to occupy rather over one second or a little more than the average for the succeeding rolls.

On examining the table, it will be observed that under each condition, the series initiated with the 24½° inclination was extinguished in fewer rolls than that initiated with the 8½°; and this is at first sight paradoxical, as it would seem that since the former angle includes the latter, the series initiated by it ought to have exhibited more, instead of fewer oscillations.

The fact was however indisputable, and I have observed the same circumstance in other similar experiments.

In those cases the result was apparently due to some counteracting water surface oscillation, which the first roll of the large range appeared to have initiated; indeed, in the experiments now reported, it was not possible to note whether any such counteracting oscillation was established or not, since the surface of the water in the dock was too much disturbed by wind to exhibit it, probably however it did exist, and perhaps the water discharged off the deck when rising from the deeper angles, may have contributed sensibly to the result.

The deck may thus have in part performed the function of a bilge piece, and if that be borne in mind, it was noteworthy that even without bilge pieces, the first roll from the 24½° inclination extinguished nearly the whole of the range between the 24½° and the 8½°.

The model was subsequently tried in a seaway, with corresponding variations in bilge piece conditions.

It is unfortunately impossible to command exactly waves of a character and period calculated to give to such a trial its maximum value; and in fact when the trial was made, the waves were relatively to the model steeper and more violent, as well as longer in period, than any which in any sea whatever the ship herself could have to encounter.

The most formidable, that is to say the most effective, were those which occasionally followed four or five in partly regular succession. Their height from hollow to crest was then from 15 to 18 inches, with an exceptional ridge of about 2 feet; heights which, when measured by the scale of the model, are equivalent to waves of from 45 to 54 feet, and occasionally over 70 if encountered by the ship herself. Their period from crest to crest being from 2·1″ to 2·25″, the metacentric period of the model being 1·7″ or 1·8″, while her period might probably be 2·1″ to 2·2″ (as a sort of average) for rolls of large range, so that it was a most trying sea to her.

The model was kept pretty regularly broadside to the sea by help of men manœuvring her from a boat some way to leeward of her, with long light strings which were always relaxed while we made observations of angle; ourselves keeping a position, in the steam launch, end on to the model.

The angles were noted by three separate observers, each holding one leg of a 2-foot rule tangent to the horizon, while the other leg was set parallel to the extreme angle of deviation from the vertical made by a mast on the model.

The angles agreed very fairly, as noted by the three observers, and those which I mention are the "means" of the observations.

The trials were four in number:

(1.) With a 6-foot bilge piece on mid-turn of each bilge.
(2.) With a 3-foot bilge piece on mid-turn of each bilge.

(The trial with the 21-inch bilge piece of the ship as designed, was omitted, to save time, and because we supposed it would not differ very largely in effect from that of the 3-foot.)

(3.) With two 3-feet bilge pieces on each side, one a little above, the other a little below the mid-turn of the bilge.

(4.) Without any bilge pieces.

(1.) Model with single 6-feet bilge piece each side,

Gave 3¼° as the maximum angle as noted; but we had not become quite skilled in the method of observation, and though I felt pretty confident of the result, yet eventually we all were inclined to say it would be safer to say 5° as the maximum, judging by mere ocular comparison (made "memoriter" afterwards) with subsequent observations; this extreme was however very rarely attained; for the most part 1° or 2° was the maximum.

(2.) Model with single 3-feet bilge piece each side,

Gave 13½° as the maximum, with many rolls of 8°, 9°, 10° and 11°.

In both the above cases, the weather rolls were rather the greater, but the absolute amount of difference was not noted.

(3.) Model with two 3-feet bilge pieces each side,

Gave maximum lee lurch ... ... 18° to 20°
maximum weather roll to match ... 9° or 10°
Often 10° to 15° lee lurch, with 5°, 6°, and 7° weather rolls.

Here it will be observed the character of the result was reversed, the lee lurch being conspicuously the greater.

Probably the excess of the lee lurch was due to the elevated position of the upper bilge pieces, which gave great lateral extension of "couple" to be operated on by the wave stratification near the surface; and as, in consequence of the fresh breeze blowing, this was considerably steeper on the lee sides of the waves (especially near the crest), than on the weather sides, there must have been a considerable disturbing and effective "couple," tending to produce preponderating lee lurch.

(4.) Model without any bilge pieces,

Gave repeated rolls up to 20° and 21°; and in the first big waves that came, and this very soon, the model *turned right over*, on a weather roll.

The weather roll was plainly the greater of the two; she sluggishly fell over to meet the advancing wave, and was over-run by it. Her deck immersion, regarded as a bilge piece, did not avail her, or possibly it helped to submerge her, as it must have hindered her from raising her side to meet the advancing wave slope.

. . . .

I was considerably disappointed in the result of the two 3-feet bilge pieces on each side; for in still water rolling, their retarding effect was greatly superior to that of the single 3-foot bilge piece. Possibly the failure in the sea way was due to the fact that the greater period of the wave necessarily instituted that kind of roll which is most in conformity with the surface "up and down" displacement of the water, and thus converted the upper bilge pieces at regularly recurring periods into auxiliary instruments of disturbing impulse, and to some extent neutralized their total effect. Had the period of the waves been the shorter of the two, so that the motions of the upper bilge pieces would be brought by the altered character of rolling into conflict with the disturbances of the surface, it is possible that a superior instead of an inferior result would have ensued.

Mr Froude may be described as a prince amongst experimentalists in the subject of naval architecture, and it would be presumptuous on the part of the writer to add anything in qualification of the results recounted above. If it be objected that these results are merely model experiments, it may be stated that in the "Report of the Committee of Inquiry into the design of the 'Inflexible,'"* comparisons are made between the results obtained from these experiments on the "Devastation's model, and experiments made in rolling the actual ship; the results are practically coincident, the slight difference shown being in favour of the ship as regards extinctive qualities.

An interesting series of experiments with bilge keels were carried out by French experimenters, in the early seventies, on a small copper sheathed tug, the "Elorn." The conclusions reached were, that bilge keels reduced the amplitude of oscillation to a far less extent than might at first sight have been anticipated; this conclusion agrees with the opinion held by M. Dupuy de Lôme, the celebrated French director of naval construction. The French experimenters pointed out the disagreement between their results and those obtained by Mr Froude on the model of the "Devastation." The latter, as we have seen, established the existence of a considerable reduction, although the bilge keels employed by him were of relative dimensions less than those fitted

---

* Parliamentary Paper, C 1917, 1878.

to the "Elorn." They think that the difference of dimensions might partly account for this; and that the period of the oscillations of the "Elorn" being very small might be a reason for the different effect of the bilge keels in the two cases. This was a question that, in their opinion, could only be solved by further experiments.

Mr Froude also carried out some comparative experiments on rolling with the "Greyhound" and the sister ship "Perseus." The results bore out the general conclusions he had formed from the results obtained with the model of the "Devastation.*" The "Greyhound," a vessel 172 feet in length, and 1160 tons displacement, had been fitted with one bilge keel on each side, 100 feet in length and 3 feet 6 inches deep, in connection with the towing experiments made on this ship. The "Greyhound" and "Perseus" were taken into Plymouth Sound on various occasions in rough weather, having previously been brought to the same draught and metacentric height. The general result was that the "Greyhound" rolled to about half the angles reached by the "Perseus"; the latter having no bilge keels. The test was sufficiently severe, as the latter vessel once rolled to an angle of 23° from the vertical.

From the time of these experiments until the period of the Naval Defence Act, 1889, bilge keels were fitted to all or nearly all the ships of the Navy. It was considered the better policy to omit them in the battleships built under the provisions of that Act. Subsequent experience with these vessels at sea, however, led to the keels being fitted, the steadiness of the ships being thereby greatly improved. On one of the vessels, H.M.S. "Revenge," a series of experiments were carried out, comparing the behaviour of the ship in smooth water before and after the keels were fitted.† The results on the actual ship may be summarised as follows: — Starting from an inclination of 12° to the vertical in smooth water, it required about 18 single swings

---

* Trans. Institution of Naval Architects, 1874.

† Trans. Institution of Naval Architects, 1895.

from one side to the other to reduce the maximum angle of inclination to 6°, and about 45 swings to reduce the angle of inclination from 6° to 2° when without bilge keels. When bilge keels 200 feet long and 3 feet deep were fitted, the reduction from 6° inclination to 2° inclination was effected in 8 swings only. It was found also, in confirmation of the experimental results obtained many years previously, that the period of oscillation was sensibly lengthened. As illustrating the comparative difficulty of setting up rolling in the "Revenge" after bilge keels were fitted, it may be stated that the vessel could be easily rolled to angles of 13° or 14° from the vertical by suitably timed trainings of the heavy guns before the keels were fitted, but afterwards it was difficult to roll the vessel to 8°, with the guns as before and with nearly 400 men running across the decks in addition. Trials were made by rolling the ship when the latter possessed headway, and the results showed that the extinctive effects of the bilge keels were sensibly increased under these conditions.

Here it may be stated that similar trials had been made by the French, about twenty years previously, on a small vessel named "Navette." As in the "Revenge," the results proved that an increase in extinctive effect was produced as the speed of the vessel increased.

As a fitting complement to the experiments made on the "Revenge," reference may be made to a similar set of observations carried out on the U.S. battleship "Oregon." For much the same reasons that had led the British authorities to construct their largest vessels without bilge keels, three of the U.S. battleships were similarly built. Experience demonstrated that these vessels would roll without much apparent provocation, and they were thereupon fitted with bilge keels as had been the case with the ships of our own Navy.* The writer of the paper referred to remarks that, "the rolling of these ships was probably ex-

---

* "Trans. American Society of Naval Architects and Engineers," 1898.

aggerated;" the present writer is of opinion that the same may be said in regard to the British vessels. To return, however, to the "Oregon," she was fitted with keels about 208 feet long and of varying width, the maximum being 34 inches, and the minimum 14 inches. The total surface of one was 830 square feet. Starting from an inclination of 6° from the vertical, it took 60 swings to reduce the roll to an inclination of 2° to the vertical before the bilge keels were fitted, and only 10 swings after they had been added. The period also was lengthened. These experiments, in conjunction with those cited above, are entirely conclusive, and should dispose once for all of any doubts which may exist as to the utility of these appendages in checking rolling.

As regards their effect on speed, we have it on the authority of the late Mr Froude that their resistance to motion ahead was less than might have been expected, and on the authority of Sir William White that "the practical test of actual service proves that there is no sensible reduction in speed for given power, or material increase in coal expenditure for a given speed at a given draught, and with the bottom in similar condition." It is to be remarked, however, that this refers to vessels whose average speeds on actual service may be described as moderate, or even low; but the writer has heard of one or two cases in which the average speed of large fast ships of the mercantile marine has been materially reduced with keels relatively small. Further information on this point from any one who can speak authoritatively on the matter will no doubt be welcomed by the Institution.

Experiments on the "Revenge" established that bilge keels have had a beneficial effect on her manœuvring power, and have improved her steadiness in steering. The tactical diameter has been reduced from about five times the water-line length to a little more than four times the same length, both screws turning ahead. So far as it is prudent to generalise from a few facts, it may be anticipated that bilge keels will not prejudice the steering qualities of any ship to which they may be fitted, but, on the contrary, may be expected to improve them.

With the present information on the subject it is questionable whether any good result would arise from an attempt to estimate quantitatively the effect of the adoption of bilge keels upon any given type of vessel. It is to be hoped, as foreshadowed by Sir William White, that Mr R. E. Froude will, in the not distant future, be able to throw light on what is at present a very obscure matter.

When Mr W. Froude was engaged on his researches on resistance to rolling, he experimented on the resistance of a plane area oscillating at some depth below the surface of the water in which it was immersed. He arrived at the conclusion that the resistance was about 1·6 lbs. per square foot for an average velocity of 1 foot per second,* as compared with the resistance of 1·12 lbs. per square foot for a plane area moving normally to itself, and with a uniform velocity of 1 foot per second. The resistance was assumed to vary as the square of the mean velocity of oscillation. So far, experiments have shown that this result is altogether inapplicable to cases in which the oscillating plane is in contact and moving with a large body, such as is a bilge keel attached to the hull of a ship. In this case, assuming the law of the square of the velocity to obtain, the figure 1·6 lbs. per square foot given above, very greatly underestimates the forces of resistance in operation; in fact, the co-efficient is found to vary in different types of ships and for different angles of swing from 6 lbs. to about 16 lbs. per square foot. The larger side pressure thus induced should therefore be amply met by having the keels sufficiently stiff and well fastened. It is at least just to the late Mr Froude to say that, in his account of the experiment with the oscillating plane, he states that it was so deeply submerged as not to give rise to any surface disturbance, and that he was quite alive to the fact that surface disturbance played an important part in resistance to oscillation.

Coming to the question of size and construction of bilge keels, Figs. 8, 9, 10, and 11 illustrate a few typical cases in modern practice. A large warship usually has keels extending over from

* Naval Science, 1874, p. 330.

40 to 50 per cent. of the vessel's length and projecting about 3 feet beyond the bilge. In special cases the width is reduced at the fullest part of the bilge, but this is only to avoid difficulties in docking. In an unsheathed ship they are formed of two plates, each about ⅜-inch thick, set so as to form a V-shaped section, Fig. 9. The enclosed space is filled in with light wood. The angles connecting the plates to the shell are in some cases riveted, and in others screw bolted. The latter method is intended to minimise any danger which might arise if the bilge keel were carried away by accident. The bolts are screwed through the shell, and nutted on the inside. Accidents, however, are rare, and as the bilge keels are fitted in wake of cellular bottoms, this method errs, if at all, on the side of caution.

In smaller vessels the bilge keels may be reduced in width to two feet, or even less, and as the cellular structure is usually less extensive as the size of ship diminishes, the last mentioned method of securing may perhaps be the preferable one. In all cases the space between the plates, forming one of the keels, at their connection to the bottom, is about one-half the depth of the keel.

Turning now to ships which are sheathed with wood, the general dimensions adopted for bilge keels are the same as in unsheathed ships. The latest method of construction, is to fit a stout central plate, well secured to the bottom with double angles, and supported at intervals with plate and angle chocks, Fig. 8. The planking adjacent to the central plate is made a little thicker than the general planking of the bottom, and forms the base for the keel, which is then built up in wood to a shape approximating to a V, although the outer edge, it is clear, cannot be quite so sharply defined as in the previous cases mentioned. The whole is coppered, the copper on the outer edge of the keel being 60-oz., and the remainder of the same weight as the copper on the bottom of the ship. In the case of the wood-sheathed ship, as in the case of the ship which is unsheathed, the fastenings securing the steel work of the keel to the hull are in some cases hammered rivets, and in other cases screwed.

In the case of merchant vessels, the writer's information is somewhat restricted, but, so far as he is aware, where bilge keels are fitted, they are generally composed either of a bulb-plate riveted between a pair of angles secured to the shell with hammered rivets, or a bulb-plate secured to a large T-bar on the shell. It is understood that they rarely exceed 18 inches in depth. Longitudinally they extend along the straight portions of the bilge for about the half-length amidships. The methods are illustrated in Figs. 10 and 11.

As a possible explanation of the great difference in the transverse dimensions of bilge keels fitted on large warships and mercantile vessels respectively, it may be noted that, the much greater metacentric heights in the former class compared with those in the latter cause the warships to be quicker rollers than the merchantmen, and this despite the fact that the relative inertias have a contrary tendency; hence, it might well be expected that, size for size, the merchant steamer would prove, on the whole, steadier than the man-of-war, and the necessity for bilge keels, therefore, would not be so much felt. Further, the greater fulness of the section of the merchant ship makes it necessary to keep down the size of projections from the bilge.

The web of the keel (or the central surface of a V-shaped keel) is kept in a plane which intersects the vertical central plane of the ship, in a line parallel to the mean water surface on service. An endeavour is made to keep the keel at what we may call an average normal to the shell surface, and this leads generally in warships to the keel standing, at the midship section, with the bevelling shown on Fig. 5, and generally in an opposite way at the extremities.

INTERNAL MOVING WEIGHTS.

So far as the writer is aware, there are only two other methods of moderating rolling motion which have met with any success. In each of these, the action of a moving internal weight has been made use of.

First, we may briefly notice the use of water chambers, which are fully described in two papers by Mr Watts in the Transactions of the Institution of Naval Architects for 1883 and 1885. The method was discovered during the investigations made in connection with the design of the "Inflexible," when it was found that in the large model then made, its resistance to rolling was greatly increased by perforation of the bulkheads and sides at the extremities, representing the actual ship as she might have been after a hotly contested action. The enormous resistance to motion offered by the water when passing to and fro through the imitation shot holes, made rolling by hand in a tank an almost impracticable operation, although when the model was intact she could easily be rolled to considerable angles. These considerations led to spaces being set apart in several men-of-war building, and in the stage of design at this time (1878-1880), in order that loose water might be admitted for moderating rolling as occasion required. The effect of comparatively insignificant quantities of water (not in general exceeding 1 per cent. of the displacement of the ship), and, when adjusted to suitable depth, was well marked, especially at small angles. The rolling chambers were in all cases of sufficient capacity to allow the admitted water great freedom of movement.

The battleships in which this method was adopted had considerable metacentric heights, and were, therefore, comparatively lively in their rolling movements. In later battleships the metacentric heights adopted are less in amount; the ships are larger, and therefore tend to be slower in movement. Added to these facts, the noise of the water breaking violently against the sides and decks in its motion to and fro was objectionable; and last, but not least, the sentiment of the Navy seemed opposed to having loose water on board, even in small quantities. For all these reasons, this method of quelling rolling motion has gone out of use.

In the comparative experiments made in the "Edinburgh," and detailed in Mr Watts' 1885 paper, mentioned above, it appears that, up to angles of 12° with the vertical, the water chamber was more advantageous than 2 feet additional width of bilge keels would have been; for larger angles of oscillation the additional width of bilge keels would have been preferable. These figures are cited to show what a powerful means of quelling rolling may be found in the use of water chambers, and with the advantage, too, that it has its greatest comparative effect at small angles of roll, and therefore tends the more readily to damp down any tendency to oscillation before the motion has had time to grow to any serious or uncomfortable extent.

The remaining method of checking rolling which will be noticed has been applied, it is believed, in only one case—by Mr John I. Thornycroft — in the screw yacht "Cecille." It consists in moving a weight across the ship in a way analogous to that in which the water moves in the method previously described. In the "Cecille" the movements of the weight were controlled by hydraulic power, which in turn was set in action by the movements of a short period pendulum.*

In conclusion, it may be said that the subject of quelling rolling will always be of interest, and anyone who can invent a method whereby the way of a ship in the sea is made absolutely steady, not only as regards rolling, but also with respect to pitching and 'scending and heaving, will be hailed as a benefactor to mankind.

The sources of the information on the subject are noted in the body of the paper, and I have nothing further to do than to acknowledge my indebtedness to Mr John Black, of the Clydebank staff of Messrs Brown & Co., for his assistance in this compilation.

Discussion.

The discussion on this paper took place on 19th December, 1899.

Mr Archibald Denny (Member) said Mr Luke in his paper had given a very full history of what had been done, and he would like to add some experience of his own firm. In the year 1893 they, Messrs Wm. Denny & Bros., were building a vessel for which an extremely high speed had been guaranteed, and they were naturally anxious

---

* Trans. Institution of Naval Architects, 1892.

to make as sure of that speed as possible, and to do everything to reduce the resistance of the vessel. The specification called for bilge keels of considerable length. It occurred to him, that perhaps by slightly increasing the breadth and reducing the length, and otherwise altering the form of the bilge keels, the resistance might be lessened without diminishing control over the rolling, and a model of the vessel with different bilge keels was therefore tried in the experimental tank. According to the contract the ship was to be fitted with bilge keels 12 inches deep and 90 feet long, but the result of experiments showed that less resistance would result with bilge keels 15 inches deep at the middle, 60 feet long, and very much tapered towards the ends; these were made of the Admiralty form Fig. 9. An apparatus was rigged up for recording the rolling of the model, and Figs. 13, 14, and 15 represented the extinction diagrams for the different conditions under which the model was tried.

Fig. 13.—Model without bilge keels or shaft webs; extinction starting from 9° = 25 per cent. at seventh single swing.

Fig. 14.—Model with bilge keels, corresponding to 90 feet long by 12 inches deep throughout for the ship, and with shaft webs; extinction starting from 8½° = 49½ per cent. at seventh single swing.

Fig. 15.—Model with bilge keels, corresponding to 60 feet long by 18 inches deep at the middle of the length for the ship, and with shaft webs; extinction starting from 8° = 49 per cent. at seventh single swing.

The effect, roughly, was that both for the 90-feet and 60-feet keels the reduction of angle after seven swings was 49 per cent., and without keels it was only 25 per cent. Incidentally he might say that the resistance of a bilge keel properly fitted had usually been considered as that due to its surface. If a plain plate were assumed, then the surface would practically be twice the depth of the plate

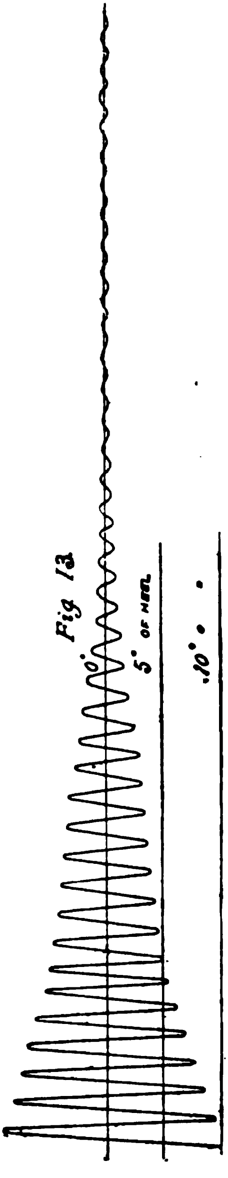


Fig 13

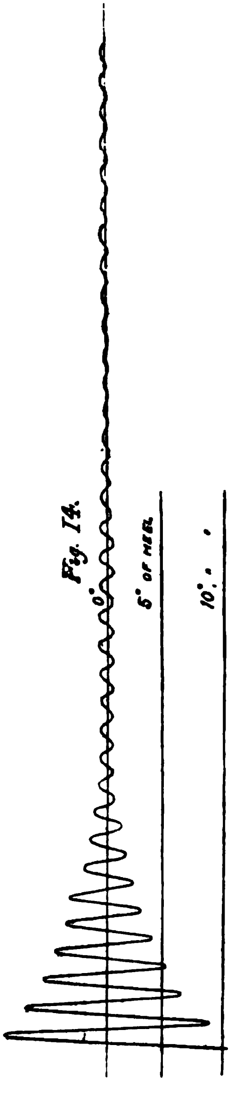


Fig. 14.

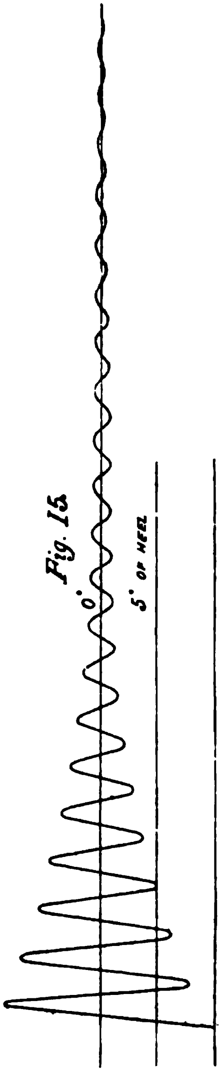


Fig. 15

multiplied by its length. The Admiralty type had of course much more side surface, but it should not be forgotten that while that was true, the surface at the base of the triangle had to be deducted. It would be observed in Fig. 14 that oscillation reappeared after having practically disappeared altogether. That arose from the wave caused by the first oscillation reflecting back from the side of the tank. Generally speaking it was found that the rolling period was independent of the bilge keel fitted, at any rate within the limits tried. They also incidenally proved the well-known rule that, if one increased the inertia or radius of gyration of the vessel, the period would also be increased; and this was done by winging or concentrating weights. As the registering apparatus was on shore, to control the model somewhat in its rolling it was assumed that the axis of rotation would be about the centre of gravity. A long horizontal rod was fixed inside the model, the rod passing through the centre of gravity, and two loose fitting vertical jaws were slipped over the rod; this gave, he thought, a sufficient freedom for practical purposes. In regard to the effect of bilge keels on speed, his firm had subsequently an opportunity, on another vessel, of obtaining accurate data as to this. Those who wished further information concerning the exact circumstances would find it in his paper read before the *Engineering Congress, 1897, entitled, "Practical applications of model experiments to marine merchant ship design." The experiments were not undertaken initially for the purpose of finding out the actual effect of bilge keels on a trial result, but the necessary information was acquired incidentally, because the idea was, that part of the apparent undue resistance was owing to the fact that the bilge keels were not only of considerable length, but, on account of the smallness of the draught, they were not placed in the usual normal position to the bilge. The vessel was placed in dry dock and the bilge keels first reduced in length and then removed altogether. No doubt this removal did decrease the resistance, but the effect

---

* Proceedings Inst. of Civil Engineers, Vol. CXXX., p. 205, ; Engineering. Vol. LXIII., p. 713.

Mr Archibald Denny.

was so small that it was not appreciable as a result of trials on the measured mile. A little consideration would show that results of resistance trials on bilge keels in the tank could not be directly comparable with those on the full sized ship; eddy-making was not a comparable resistance from model to ship, and eddy-making along the skin of the ship depended upon the actual size and speed, and was not scaleable from the model to the ship. Experiments in the tank, however, showed that the bilge keels might be placed very much out of the usual normal position without appreciably affecting the resistance of the vessel. As to the effect of bilge keels on speed at sea, his feeling was that they could not but be beneficial. The resistance of a vessel in his opinion must be increased by movement at sea, which movement was undoubtedly lessened by bilge keels. So convinced from actual experience was one large Company for whom his firm built, that it had fitted bilge keels to those vessels of its enormous fleet which were originally built without them, and with most beneficial results upon performances at sea. It was not often that a naval architect got the opportunity of studying rolling on a long voyage at sea. He had lately had this advantage in a large vessel belonging to an important Company, in a voyage between Colombo and Australia. Running down to Albany the South-East Trades were encountered, the vessel pitched a little, but the rolling was very slight. He, however, succeeded in getting her rolling period, which immediately after leaving Colombo was about 17 seconds; the wind and sea was not dead ahead but on one bow, and the vessel was wonderfully steady, and he formed the opinion that there was practically not a roll in her. Just before they arrived at Albany, the period had increased to 20 seconds for a double roll, due no doubt to a consumption of coal altering the metacentric height and radius of gyration. Running from Albany to Adelaide they had a rude awakening in regard to rolling; although the sea was not heavy for that part of the world, the vessel rolled heavily, he meant in regard to the angle of roll, but the motion was easy and the period increasing. From Adelaide to Melbourne they experienced

Mr Archibald Denny.

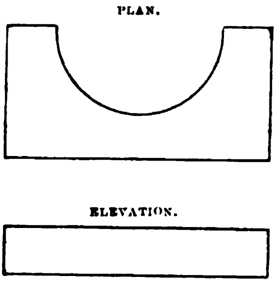
bad weather, the ship pitched and rolled very much, and the period was quite 21 seconds. That vessel had no bilge keels. He thought the Company would have done well to have fitted them even supposing it did not improve the vessel, which he was sure, however, it would. The travelling public, while intensely ignorant about ship matters, had a decided idea that bilge keels prevented rolling, and nothing would satisfy them but to know that they were fitted. The Colonial travelling public was an extreme example of this attitude of mind, their own countrymen being good seconds. That vessel having proceeded to Melbourne went to Hobart and began her loading for home, taking in fruit. He was not aware of her exact condition of loading, but presumed she was largely in water-ballast. A friend of his, whom he had carefully instructed how to take the period of the rolls., made the passage in the ship from Hobart to Melbourne, and he wrote to him saying—"We had a good deal of east and south-east winds up the Tasmanian East Coast, and the vessel rolled as never I knew a vessel roll. We made a complete roll in from 13 to 15 seconds, and fetched an angle of 33°. She chucked the captain from one side of the bridge to the other." These observations showed that here was a vessel whose loading might at different times vary so much that, at one time she would have a period of from 13 to 15 seconds and at another from 20 to 21 seconds. The latter showed that her metacentric height was probably very small; but so long as a vessel had a high side, as all these passenger vessels had, a small metacentric height was the best. In the case of the vessel running up the Tasmanian coast, he did not doubt she would have been much better had the water-ballast been so arranged that her metacentric height was small. In any case she would have been improved with bilge keels.

Prof. J. H. **Biles** (Member) remarked that he usually took, in the course of a year, about 15 or 16 hours to discuss this subject, and then only began it, and if he was longer in discussing this paper, they would know that he had begun his course of lectures. The subject was full of interest, and contained a great deal that

Prof. J. H. Biles.

might be very well discussed in the Institution. The particular item which he wanted to say a little about was that of a vessel rolling with a water chamber on board. Some years ago he had occasion to consider the desirability of fitting a rolling chamber in one of the large Atlantic liners, and, with the view of making an experiment on a somewhat smaller scale, a tank was fitted on board a comparatively small ship, about 360 feet long by 45 feet beam, and this vessel was tested at sea with the tank on board. The tank was not an ordinary rolling chamber of rectangular form, but one of the character shown in plan and elevation in Fig. 16, in which, for a given amount of water, a much larger transference of the water could be had than with the rectangular form. The neck of the bottle, so to speak, was much narrower, the water was held back longer, and it lagged behind more. This tank was tried, and, generally speaking, the results demonstrated that for small angles there was about 40 per cent. reduction of roll. That was a general deduction for small angles up to 10° of a full swing, when the chamber was half filled with water, or to a depth of about 3 feet 6 inches. These observations were made by Mr Archer, a member of the Institution, who was sent across the Atlantic to take them. Later on, the captain of the ship reported that on subsequent trials, with large angles of heel, it appeared rather doubtful whether the rolling chamber reduced the angle. He had a suspicion—he could not

Fig. 16.



say it was more—that sometimes it increased the angle of roll. He was perfectly sure, however, that the rolling chamber reduced the roll for small angles. The rolling chamber was fitted into the Atlantic ship, and she went to sea with it; unfortunately, however, it was never filled with water, but with cargo instead, and finally the bulkhead was removed, and the space used for cargo. He supposed the reason for doing so was that it was considered her rolling could not be improved. For those who had not seen the effect of rolling chambers in reducing rolling, he had placed on the table an apparatus which he had devised to determine the best form of rolling chamber, and after a considerable number of experiments the form shown in Fig. 16 was found to be the best. The apparatus might be taken to represent the motion of a ship in rolling, and if it was found how long it took to fall off a certain number of degrees in oscillation, some measure was obtained of the extinctive effect on anything that was rolling. When there was no loose water in the chamber, the only resistance was that of the air and friction, and it took some considerable time to reduce the rolling appreciably. Counting five complete rolls, starting at 20° from the vertical, then in the first case, without any water chamber, there were 2° of a falling off in five oscillations. With the rectangular form of rolling chamber the falling off was 8° in five oscillations, and with the other form of tank the oscillation was reduced to about 15° in the same number of oscillations. If the apparatus were made to more nearly resemble the motion of a ship, the extinctive effect was much increased. This was quite as marked if the apparatus was suspended from the roof and allowed to swing. The oscillation of the whole of the apparatus from about its point of suspension in the roof represented the oscillation due to a wave, and they got the oscillation of the ship in the wave by the motion about its point of support, and the extinctive effect was quite as marked as it was in the former case. He never himself believed in any observations at sea upon ships that were not made by batten instruments. The so-called batten

Prof. J. H. Biles.

observations consisted of sighting the horizon, and by this means keeping the sight permanently level, and measuring the oscillation of the ship by measuring the inclination of the sight to the ship. Observations with a pendulum suspended in different parts of a ship were misleading. The captain often had a pendulum on the bridge, and he recorded the inclinations of the pendulum as being inclinations of the ship. From experiments with different pendulums in the apparatus, it was shown that, for the same amount of rolling, one pendulum would make a complete revolution of 360°, while another, in spite of the rolling, would record no inclination. With respect to another practical question—the reduction of speed due to having bilge keels—two ships that he knew a little about had lately been fitted with bilge keels. The first one was about 500 feet long, and was fitted with bilge keels 200 feet in length, and it was thought that the speed of the ship was reduced thereby. It was very difficult, however, on an average of a few voyages to determine the actual facts, because, when a certain speed was acquired, one was not sure that the weather or the power was the same at different times. Another was a sister ship in which shorter bilge keels were fitted, and no appreciable difference was found in the two; in each case, it was said, there was about a quarter of a knot loss of speed due to fitting the bilge keels. He was not quite sure that the loss of speed really took place, because he had heard of cases where the speed had been improved, and he did not know whether it was not due to the kind of weather that the ship encountered. If a vessel rolled very much in a sea-way, rolling might very appreciably decrease the speed, but if she was in weather where she was pitching, then, on account of the angle that the bilge keel sometimes presented to the forward motion of the vessel, due to the oblique angle at which she moved through the water, he was disposed to think that in cases of that kind probably the resistance was increased. At any rate, he gave them the facts for these two ships, and he had heard of other high-speed Atlantic ships of large size in which the speed had been appreciably reduced by fitting bilge keels.

Mr Frank P. Purvis.

Mr Frank P. Purvis (Member) considered Mr Luke's paper was a very welcome one to the Transactions. He had evidently gone over the literature on the subject very sedulously, especially that connected with bilge keels, and had drawn his conclusions very carefully. It took some of them back in memory over a good many years, himself to some rather uncomfortable hours spent on board the "Perseus" during the very trials to which Mr Luke referred. The effect of bilge keels on the "Devastation" Mr Luke had brought out very clearly in Mr Froude's own words; the comparison between "Greyhound" and "Perseus," tried in the same seas within hailing distance of one another, one without bilge keels and the other with, but otherwise practically identical, he had carefully drawn and shown that in Mr Froude's words "with bilge keels at work the 'Greyhound' rolled just one half what the 'Perseus' rolled." In the case of the "Revenge" he had stated the effect of the bilge keels in a way perhaps not too intelligible to the man in the street. This was a pity, because both Sir William White and Mr R. E. Froude had put the matter pretty pithily. Mr R. E. Froude said, "I must confess myself that when I heard of the result of the trials of the 'Repulse' and 'Royal Sovereign,' which were made simultaneously in the same sea, the 'Repulse' having bilge keels and the 'Royal Sovereign' having none, and that the 'Repulse' had rolled to only about half the angle of the 'Royal Sovereign,' I . . . . . , . . . the difference in the rolling produced by the bilge keels in that case was that the rolling was reduced by half." . . . . Sir William White went further than Mr R. E. Froude, and speaking of the comparison of the "Revenge," with and without bilge keels, from the result of a careful analytic examination said, "the addition of bilge keels, therefore, roughly speaking, would reduce the swing to one-third of its former amount." Mr Luke had made a reference, on page 76, to the late Mr Froude's work, which struck one as being rather inappreciative; he referred to the words "it is at least just to the late Mr Froude to say that he was quite alive to the fact that surface disturbance played an

Mr Frank P. Purvis.

important part in resistance to oscillation." Why, Mr Luke just before making this remark was quoting from a paper of Mr Froude's which opened as follows:—"I have argued . . . that when a ship is rolling in still water, or in a seaway, she inevitably throws off at each roll a wave which travels off at the surface of the water," and later, in the same paper, continued, "the effect which I have thus attributed to wave genesis is denied, and the arguments by which it is deduced are controverted warmly but courteously by M. Bertin." The most that Mr Luke was entitled to say was that, Mr Froude had not related the effect of bilge keels and surface disturbance so fully as had since been brought out by the trials of the "Revenge." One could have wished that Mr Luke's somewhat obscure reference on page 75 had been clearer —the reference, he meant, in which, speaking of the effect of bilge keels on speed, he said, "the writer has heard of one or two cases in which the average speed of large fast ships of the mercantile marine has been materially reduced with keels relatively small." Mr Denny had touched upon that point, and from such public data as they possessed, notably the "Revenge," one might well doubt the fact of such reduction of speed, even in still water. He was perfectly at one with Mr Denny in thinking that in waves the checking of rolling motion by the action of bilge keels was probably in many cases accompanied by an actual increase of speed. On page 78 Mr Luke gave what one might describe as the Admiralty method of fitting a bilge keel so that it would be truly in a diagonal plane. That appeared to be a very virtuous thing to do, but in view of the fact that by no stretch of the imagination could such a diagonal plane be supposed to contain a series of stream lines, and that such a series of stream lines would probably cross and recross this plane, it did not appear that too much attention need be paid to the method. He thought, at any rate, one would be quite safe in making the keel normal to the shell surface at all points, without attempting to strike the average normal spoken of by Mr Luke; the advantage obtained as a piece of construction was obvious to any one who had had the work to carry out. Mr

Mr Frank P. Purvis.

Luke had, he was afraid—although quite innocently—raised a question of priority. He (Mr Purvis) had taken the liberty of sending a copy of Mr Luke's paper to Mr Watts, with the view of asking him some questions relating to the "Perseus" and "Greyhound" which he had himself forgotten. In replying, Mr Watts tackled the question of rolling chambers, and said that "the use of free water in chambers across the ship for reducing the rolling was proposed by me early in the design of the 'Inflexible' before the principal features of the design were definitely fixed . . . The model experiments, to which Mr Luke refers, came some time afterwards." And again, in a further letter, "the statement that this mode of quelling rolling motion was discovered in the model experiments made with the 'Inflexible' is quite untrue. If you will glance at my papers, and the discussions upon them, read at the Institution of Naval Architects, in 1883 and 1885, you will see that my contention that the water chamber was proposed early in the design of the 'Inflexible,' and long before the model experiments referred to were thought of, is made and fully sustained." He had to thank Mr Luke very much for his very valuable contribution.

Mr J. R. Jack (Member) thought the principal points in Mr Luke's excellent paper had been very fully dealt with, but there were one or twô practical points to which he would draw attention. One related to the attachment of the bilge keel to the hull in Fig. 11. That method was sometimes insisted on by owners' representatives, because it gave an excellent connection with the shell, but for that very reason it was objectionable. A merchant ship was different from a warship in several respects, especially in having the bilge keel outside the ballast tank, and as the merchant ship had grown a great deal quicker than the accommodation in rivers and docks, she was liable to have the bilge fin damaged if not torn completely off. Provision should always be made to prevent that contingency causing the hull to leak. With the double angles it was almost impossible to break the bilge keel away without perforating the shell and causing flooding. He thought

Mr J. R. Jack.

the arrangement in Fig 10 was very much superior. The T-bar should be riveted to the shell with closely spaced rivets, say 4½ diameters apart, in order to make it water-tight. There was a great liability to corrosion between the T-bar and the shell, unless it was made water-tight. The connection between the flange of the T-bar and the bulb-plate should be made as small as possible, and the rivets not reeled as shown in the diagram, but straight in row, so that there would be perfect freedom for the rivets to give way in the event of the bilge keel taking the ground. At the same time, the connection should be strong enough not to be torn away by the pressure of the water. Spacing the rivets 7 diameters apart had given very satisfactory results. With regard to the direction in which bilge keels was applied in warships, he agreed with Mr Denny in preferring to have them fitted normal to the hull. The bevelled work was certainly difficult and expensive, and liable not to be thoroughly good, especially when covered up with wood. The resistance of the bilge keel was a doubtful quantity; even if fitted with the slight twist necessary to keep it normal to the hull it would give very little increased resistance, and he did not think that it would be appreciable in practice.

Mr W. T. Courtier-Dutton (Member), said he had intended to make a few remarks regarding the anti-rolling chamber to which Professor Biles had referred, as he had been concerned in the construction of the vessels in which those chambers were fitted; but, as Professor Biles had treated that matter in a more thorough and satisfactory manner than he could do, there was no necessity for him to say anything further about it. In looking at the diagrams, it occurred to him that he would like to emphasise, from a practical point of view, the remarks of the last speaker. Concerning the sketches of the forms of bilge keels in Figs. 10 and 11, he was very strongly of opinion that Fig. 10 was much preferable. He considered that the attachment to the shell should be intact, and to that extent independent of the plate or fin. He thought the bilge fin should be made as light as possible, and the attachment to the shell by the bar as weak as possible—that was to say, only riveted sufficiently close to ensure that it could successfully resist the pressure of the water, and nothing more, so that in the case of the vessel going aground and the fin taking the ground first, it might tear away at once without interfering with the shell connection. For this reason, he thought the form of fitting the bilge keel between two angles was very objectionable, as the least disturbance to this part of the vessel, by striking a quay wall, would at once loosen the connection with the shell and set up leakage. No doubt the form of bilge keel adopted by the Admiralty was excellent and very efficient, and the best at present devised, but they could hardly look for its adoption in merchant ships. It would be very much like associating a cart horse with a phaeton. The Admiralty had got the nation at their back, and they could do what they liked in that respect.

Mr H. C. Sadler, B.Sc., desired to refer to a point with respect to rolling chambers in connection with the large merchant vessels that were being built at the present day. Most of these steamers had a superabundance of stability in the light condition, and also in the ballast condition, and that was to a certain extent overcome by fitting a deep tank usually up to the height of the 'tween decks. No doubt, sooner or later, 'tween deck tanks would be generally adopted, and if they were to be fitted at all in a vessel, they might be made to serve the double purpose of reducing rolling by decreasing the stability and acting as a water chamber, as had been seen in the experiments that night. There would be no practical difficulty in the way of constructing such tanks; in fact, there had been some discussion on the subject already, and he thought it only needed one or two people to make a move in order to ensure the general adoption of 'tween deck tanks. The rolling tank was, if anything, more suitable for a merchant ship than a warship. In the case of a warship, there was plenty of room to fit a large bilge keel, and at the same time the roll was of a comparatively short period; and, if it were assumed that the resistance varied as the surface of the keel and as the square of the

Mr H. C. Sadler.

angle of velocity, then the effect of a bilge keel in a warship would be much greater than could possibly obtain in a merchant ship, owing to the smaller bilge keel that it was possible to fit, and also to the much longer period of roll. There was one point that Mr Luke mentioned at the end of his paper concerning pitching, and he noticed that none of the other speakers had referred to it in any way; but, it seemed to him that such a keel as a pitching keel, if he might so call it, might be fitted at the fore end of fine-ended ships, especially to those which pitched badly. In the case of vessels with twin screws, the stern was bossed out, and that formed a preventive to pitching, but there was no corresponding arrangement at the fore end. Sometimes, in war vessels, a broad fin was carried out to give lateral stiffness to the ram, but he was not aware of it being done in other cases. He did not know that that was a very practical suggestion, but such an arrangement would help to reduce pitching, and could be so arranged as to act as a stiffener to the bow without causing any serious extra resistance.

Mr John Thom (Member), with reference to the history of bilge keels, said he did not know if it was new to the members or not, but he had read that there was a model of a lightship having bilge keels, built in 1795, in the Trinity House Museum. Bilge keels, as Mr Luke had pointed out, might be fitted for other purposes than to prevent rolling; they might be fitted for the sake of keeping the boat upright when aground. He would be glad if Mr Luke would give them some information with respect to the difference of the extinctive effect of a bilge keel on a ship when she was going and when she was stationary. He knew that a law had been proved that if a propeller advanced at a certain rate in knots with a certain power, and if the same propeller was made to advance at double the rate, double the power would be obtained, with the same area of propeller. It might be said that there was no comparison between a bilge keel and a propeller, but there was. The one was a propeller, and the other a retarder, and the power in each depended on the amount of water it passed

Mr John Thom.

through. He did not say that the law would be exactly the same for bilge keels as for propellers, but there would be a certain formula applicable to the former.

Correspondence.

Mr W. Hök—The paper being historical rather than controversial, criticism would be out of place, and he would give instead his own experience for what it was worth. In the first instance all his remarks would refer to merchant steamers. In the yard where he had the honour to be employed, bilge keels were recommended to be fitted to all vessels, and they nearly always carried their point, except in a few isolated cases where the prejudice of the owners was too strong to overcome. The keels they fitted varied from 10 to 16 inches in depth, and consisted either of a bulb-plate (when the depth of keel was limited to 12 inches or thereabout) fitted between double angles, or, when there was no restriction, of either a bulb-plate or a plain plate riveted with a single row of rivets to a 6 × 4-inch T-bar. They always tried to persuade shipowners to make the bilge keels as deep as possible, and when a depth exceeding 12 inches was agreed to, they fitted, in ordinary cases, a plain plate about $\frac{10}{20}$-inch thick. This they had done in several instances with excellent results. The bilge keels were made reasonably short, varying from $\frac{1}{3}$ to $\frac{45}{100}$ of the length of the vessel, the former in the case of very fine vessels, and the latter in full vessels. The bilge keels were made short in fine vessels because they were of comparatively little value except in the wide part of the ship; and anybody adding bilge keels to the end sections of a body plan of a vessel, and imagining her rolling, would at once perceive that long bilge keels were a mistake. He thought there was unanimity with regard to the construction of bilge keels among shipbuilders, but, so far, he did not know of any recognised rule for the most advantageous position. In all merchant steamers of full midship-section, there was, of course, only one place for them, that was on the round of bilge. Away from the midship position they were

Mr W. Hök.

carried straight as long as there was parallel middle body, but at the ends where the parallel middle body ceased, and in fine vessels where it did not exist, he believed there was considerable divergence of practice among builders both with respect to position and as regarded line of bilge keel. Then, firstly, in vessels of very fine midship-section they always placed the bilge keels as far away from the centre line as possible, because the nearer the bilge keels were to the centre line the smaller was their effect. Of course, the bilge keels should not be placed so high up the side that they repeatedly rolled out of the water under ordinary circumstances, and they should not project beyond the greatest breadth of vessel. But the midship position being fixed the question arose, which was the best fore and aft line of bilge keel to offer least resistance to propulsion. He believed that here again great divergence of opinion was prevalent. They always carried the bilge keels fore and aft along a horizontal section parallel with the load water-line in the case of yachts and vessels of fixed trim, and parallel with the keel in the case of cargo steamers with varying trim. To make his meaning clear, assuming that the intersection of bilge keel with the side of the ship at the middle of length happened to be 2 feet above the keel, they drew on the ship's lines a water-line (that was a horizontal section) at a distance of 2 feet above the keel; and that was the line of the bilge keel. Hence, it followed that in very full vessels the bilge keels were straight in way of the middle body as long as the water-line was straight, but at the ends where the water-line diverged towards the centre plane the bilge keels did so too. In full vessels, where they made the bilge keels from ·4 to ·45 of the length of the vessel, the line was straight except at the extreme ends of the bilge keels; but in fine vessels, where there was no parallel middle body, the bilge keels ran their whole length in concave curves with reference to the centre plane. Of course, in order to clear seams in the shell, the above rule could not always be strictly adhered to. Their practice varied somewhat from ordinary practice, he believed; but that was one systematic way of doing it, and it had not been found inferior to any other in result. To mention a recent case, a friend of his had fitted, with excellent results, a small steam yacht with bilge keels 18 inches deep, consisting of a T-bar in conjunction with a plain plate, of the concave form described above, as far away from the centre line as possible, but still within the limit of extreme breadth and for about $\frac{1}{3}$ of the length of the vessel. He trusted his remarks would be of interest to the Institution, and if they induced those builders who had a systematic way of fitting bilge keels to divulge their system they would serve a useful purpose.

Mr C. F. MUNDAY—The history of the subject had been very fully given in the paper, but some interesting experiments carried out in Italy deserved mention in a retrospect of this kind. The experiments were described in the *Rivista Marittima* for March 1895, and he would briefly summarise the most important results obtained. They were performed with a model $\frac{1}{30}$th full size of the "Andrea Doria," the principal dimensions of the ship being ;—

Length between perpendiculars, ...	328 feet.
Breadth extreme, ...	65 ,,
Mean draught, ...	26½ ,,
Displacement, ...	10,600 tons.
Transverse G.M., ...	3·15 feet.
Period of natural oscillation, ...	7·52 seconds.

The model, which was of paraffin wax, was adjusted to proportional G.M. by an inclining experiment, and to period by winging weights. The experiments were conducted without bilge keels, and with bilge keels representing those fitted to the ship; viz., 202 feet long and about 3 feet deep, at a mean distance from the centre of gravity of ship of 35½ feet. Further experiments were made with bilge keels 4·4 feet deep, but the subsequent particulars were for the keels 3 feet deep. Time was taken by electric chronograph, and the amplitude by automatic oscillograph. It was found

Mr C. F. Munday.

that the number of oscillations necessary to reduce the arc from 5·8° to 1° was 35·8 without the keels and 19·3 with them; and the period was practically unaltered, although the deeper keels lengthened it about 3 per cent. The pressure in pounds per square foot, at a velocity of 1 foot per second, could be deduced from the experiments and it worked out to 6·7 for an angle of 3° to the vertical, which confirmed the experience quoted by Mr Luke. The model was also towed at various speeds to ascertain its resistance, and the results showed that, to propel the vessel at 16 knots without bilge keels 4365 effective horse power was necessary, but with the keels the same power gave only 15·65 knots; or, to put the statement in another way, 12 per cent. more power was required for 16 knots, and 18 per cent. more for 10 knots. This large increase was not in accord with experience in H.M. Service. He thought everyone would endorse what Mr Luke said, in the last paragraph but one of his paper, as to the boon an effective steadying device would prove, and in those remarks Mr Luke's friends would detect a peculiar pathos.

Mr HECTOR MACCOLL (Member)—In a coasting steamer with flat plate keel, built about fourteen years since, rolling was such as to be unbearable, and bilge keels were fitted, although at that time their utility was questioned by many; the vessel was at once converted into a comfortable sea-boat with no reduction in speed. In several 10-knot coasting steamers with ordinary keels, to which his firm had fitted bilge keels, their sea-going and steering qualities had been greatly improved, with no reduction of speed; the same might also be said of two 14-knot cross channel passenger steamers. The type of bilge keel adopted in mercantile vessels of ordinary size was that of a steel bulb, double riveted to a steel T, as shown by Mr Luke in Fig. 10.

Mr C. A. MATTHEY (Member)—Mr Luke's able paper interested not only shipbuilders, but all students of physics, and indeed everyone who travelled by sea. There was one view of the subject which Mr Luke did not appear to have touched on, namely, the effect of the form of the ship herself on her rolling propensities, apart from that of such extraneous adjuncts as bilge-keels. The late Mr Froude found that in a certain ship of 1100 tons displacement, with a metacentric height of 3·12 feet, starting with a heel of 6° and reaching 5·65° on the opposite side, thus losing ·35 of a degree in the single swing, there were 4700 foot-pounds of energy lost in the single swing. Of this amount he could only account for 820 foot-pounds by surface-friction and keel-resistance, and came to the conclusion that the balance disappeared in the formation of a broadside wave. If, then, nearly five-sixths of the energy were thus dissipated without the assistance of bilge-keels, might not a study of this broadside-wave-producing function lead to forms of ships that would not require bilge-keels? It could not be doubted that it varied in different ships. In the ill-fated "Atalanta," for instance, with her extreme rise of floor and tumble-home, the section in the neighbourhood of the water-line was nearly cylindrical, and the function in question was probably feeble. Surely every ship constructor in his heart grudged the extra surface-friction introduced by the bilge-keels, although the stereotyped report after their addition to a bad roller was, that they made "hardly any difference" in the speed. The quantity of energy that disappeared in this wave-making in certain forms was truly surprising, and for some time escaped even the acute observation of Mr Froude. There was no reason, however, to believe that the maximum effect had been produced in this direction, and he ventured to think that shipbuilders might with advantage direct their attention to the subject, with a view to increasing this effect. There could be no doubt that bilge-keels always reduced rolling in smooth water; in a seaway, however, the dynamic conditions were very complex, and it was by no means clear that they were invariably advantageous. Thus it was known that while a broad shallow ship conformed approximately to the wave-slope, in fact rolled away from an approaching wave, a very deep narrow ship of small stability rolled towards the wave. Under these latter conditions it was conceivable that

Mr C. A. Matthey.

a bilge keel placed low down might increase the weather roll, by giving the water a hold on the vessel. Perhaps some such consideration might reconcile the conflicting results of the British and French trials. On page 71 of the paper they saw that Mr Froude explained the preponderance of the lee over the weather lurch by the elevated position of the keels. It would seem that until more was known of this difficult subject, the only rational way to fit these keels was to make a model of the ship, with a corresponding centre of gravity and radius of gyration, and note the effect of different keels in water whose disturbances corresponded to those likely to be encountered by the ship. This would involve some expense, but it might be worth it in the case of large passenger ships with a bad character for rolling, and which were avoided by travellers on that account.

Mr B. C. LAWS (Member)—Mr Luke's paper was somewhat disappointing, inasmuch as it contained chiefly the summary of the record of results hitherto obtained by rolling ships and models mechanically, without advancing any ideas which the author doubtless held as to the means that might be adopted to prevent rolling. The mention of the "Captain" and "Atalanta" reminded one of the cause from which the introduction of bilge keels—at least in the Government service—mainly arose, but not until the fairly exhaustive experiments with the "Greyhound" were these appendages extensively used in Government vessels. In the battleships constructed under the Naval Defence Act bilge keels were not fitted, and it would be interesting to know the reasons which led the designers of these vessels to omit such powers of resistance to rolling. The dynamical distribution of the weights which made up the entire vessel in the sea-going condition —in so far as it affected the relative position of centre of gravity and metacentre, as well as the radius of gyration about a longitudinal axis through the C.G.—was the factor governing the rolling motion. Whether the dynamical condition of these vessels was designed to be better than that of their predecessors of similar type, and especially what were the points of difference, it would be very interesting to members of the Institution and naval architects generally to know. Whatever modifications might have been made, these ships were found to be exceedingly heavy rollers; they were, therefore, subsequently fitted with bilge keels. In the mercantile marine bilge keels were apparently only adopted after the benefits derivable from their use were proved to ship-owners by the results obtained in vessels of the Royal Navy. One of the largest Shipowning Companies in Great Britain had not, until the last two years, adopted the use of bilge keels. One of the vessels belonging to this Company, which, on her maiden voyage had proved very dangerous, due to the heavy rolling set up, was docked and fitted with bilge keels on her return home. In this case, as in others of heavy rolling, large metacentric height was a governing factor, but, doubtless, too, the inertia of the weights—and especially that of the cargo—due to the position of the latter, also played a very important part, irrespective of the metacentric height resulting therefrom. It was from these two causes that a great deal of the trouble in the much criticised ocean tramp—when in the ballast condition—arose. Under the ordinary distribution of water-ballast there resulted a large value of G.M., and due to its remote position from the axis of rotation, also such a change in the value of the radius of gyration as generally together produced heavy and uncomfortable rolling as soon as the vessel met with even moderate weather. Methods by which the rolling of this type of vessel might be diminished had, in a few cases, been proposed and put into practice, but none yet seemed to reach the perfect state one wished to see. Two methods had been used, one by constructing deep side tanks, and the other by constructing isolated hold spaces to be utilised for carrying water when the vessel had to proceed to sea in the ballast condition. In each case the evil of large value of G.M. had been overcome by the consequent increase of height of C.G. above keel; and generally such a modification in the value of the radius of gyration was produced as to show that the second position of the water-ballast was the better of the two. The concentration of such a great weight in

Mr B. C. Laws.

the hold space had, however, a prejudicial effect on the structure of the vessel, which tended not only to strain it locally when the vessel had no motion, but more so in the case of pitching and rolling. A better effect would doubtless result by the construction of central vertical tanks extending through to the holds, so that the weight of the contained water might be distributed fore and aft. As stated by the author, vessels of the Royal Navy experienced very little or practically no diminution of speed due to the resistance offered by bilge keels. In the mercantile marine loss of speed had resulted under certain conditions. This might be explained by the fact that war vessels were designed to experience practically no change of trim when on service, and the bilge keels—being situated in a plane whose intersection with the middle line longitudinal plane was parallel to the water plane—offered in consequence a minimum of resistance to motion of the vessel. In merchant ships where—due to the variation of the cargo carried, as well as the position of the bunkers not generally being amidships—the trim was always varying, the intersecting line of the plane of the bilge keels mentioned above was more or less inclined to the horizontal. Consequently, in addition to the usual frictional resistance, there was also a head resistance, which necessarily affected the speed. To minimise this as far as possible, the usual plan was to place the bilge keels in a plane whose line of intersection with the middle line vertical plane of the ship was parallel to the mean water plane on service.

Mr Luke, in reply, said he was surprised that his small contribution to the Transactions of the Institution had excited such an amount of interest, and he was much obliged to the gentlemen who had come forward and given their experience, and also to Prof. Biles for the very interesting experiments that he had shown them that evening. There was very little which called for comment on his part; the only two gentlemen whose remarks he must notice were Mr Purvis and Mr Thom. Mr Purvis very truly said in the latter portion of his criticism that he thought he (Mr Luke) must have introduced the subject of priority of invention of water chambers inadvertently or innocently. He had put in the paper what he had always been given to understand was an official version of their introduction. Mr Purvis had been good enough to call his attention to Mr Watt's letter, and he had referred to the Transactions of the Institution of Naval Architects in which Mr Watt had claimed to be the real inventor of water chambers, but it was a point that of his own knowledge he knew nothing whatever. He was but a very small apprentice in Portsmouth Dockyard when the "Inflexible" experiments were made; he remembered seeing the model, but as for any notion of water chambers or fittings of that character he had none at that time. He must repeat that he was very sorry to think that he had introduced this subject of the invention seeing that there was some slight dispute about the matter. Then Mr Purvis expressed the opinion that he was not sufficiently appreciative of Mr Froude.

Mr Purvis—No, only with regard to those quotations.

Mr Luke—It might be an obscurity on his part in preparing the paper, but if Mr Purvis read his paper again, he would see on page 76 that what he had intended to refer to was simply the experiments which Mr Froude had made from which he was led to infer, for his purpose at the time, that 1·6 lb. per square foot was a fair pressure to take—the unit pressure—on the surface of the bilge keel. Mr Froude made experiments with an oscillating plane, and obtained 1·6 lb. per sq. foot pressure for an average velocity of one foot per second; subsequent experiments, alluded to lower down on the same page, brought out the figure from 6 to 16 lbs.; and he thought it was only just to Mr Froude to say that he indicated that he had some suspicion that the surface disturbance might modify the 1·6 figure. Mr Froude's whole contention in the paper on Naval Science was that surface disturbance in general, bilge keels or not, had a marked influence on the rolling of ships. His (Mr Luke's) remarks were only intended to have reference to the figure for unit pressure.

Mr Thom—Was that 16 taken off the ship when steady?

Mr Luke.

Mr Luke—He believed it was off the ship without headway. With regard to the effect on speed, they had two different statements. Mr Denny seemed to think that there was nothing in the question of speed, while Prof. Biles had information of a different character. He had, he supposed, the same information as Prof. Biles possessed; which was to the effect that certainly in some large fast passenger ships there was an appreciable falling off in speed after the fitting of bilge keels. The gentleman who so informed him—although he did not give him permission to mention his name or the Company with which he was connected—told him that he had been in friendly communication with an official of a rival line, and the experience in that case was precisely the same, namely, that over a number of voyages, with keels which were not relatively large, a distinct falling off of speed was noticeable. He asked for further information on this point in the paper, and all he could say was he was sorry that other gentlemen, besides Prof. Biles and Mr Denny, had not further enlightened him upon that point. With regard to the position of bilge keels, Mr Purvis said that he did not think there was any reason why the diagonal planes should be followed. Neither did he; but if, as Mr Purvis said, the stream line sometimes fell in and sometimes outside of a diagonal line, what other position would he choose? He did not think the paper showed that he personally had any preference. He was merely reporting to the Institution what he knew had been done, and there he must leave it to any gentleman who had the work of fitting bilge keels, to do differently if he was so minded. Mr Thom referred to a ship going ahead, but if he again read the paper, he would see on page 74 the following remarks:—"Trials were made by rolling the ship when the latter possessed headway, and the results showed that the extinctive effects of the bilge keels were sensibly increased under these conditions. Here it might be stated that similar trials had been made by the French, about twenty years previously, on a small vessel named the 'Navette.' As in the 'Revenge' the results proved than an increase in extinctive effect was produced as the speed of the vessel was increased." Mr Munday had drawn attention to some Italian experiments on a model of the "Andrea Doria." From these experiments, the Italians had come to the conclusion that, within the range of speed experimented on, the bilge keels added perceptibly to the resistance,and consequently must have somewhat detracted from the speed. In the case which Prof. Biles mentioned, he supposed it amounted to about 2 per cent. reduction of speed, and, therefore, that also implied a considerable percentage of increased resistance. Mr Matthey suggested that the form of any given ship necessarily had an influence on her rolling propensities, and no doubt that was the case. It was a point which he had often reflected on, but about which he could not form any conclusions satisfactory to himself. Certain vessels with rounded sections—as, for example, the "Sultan"—had reputations for steadiness, whereas others like the "Royal Sovereign" had exactly the opposite reputations, the reasons for these peculiarities he was utterly unable to fathom. He was very much obliged to the meeting for the interest they had taken in the subject.

The President, in closing the discussion, said the experience of his firm with regard to the resistance due to bilge keels was that they had never been able to find any sensible difference between a vessel fitted with them and one not. Of course, the extinctive effect of bilge keels on rolling was very great. For some years back his firm had been fitting a large number of yachts with bilge keels, and they had always given satisfaction in diminishing rolling, and he never found that any resultant diminution of speed had been discovered. It rather raised a little apprehension in his mind to hear what he had heard from Mr Luke and Prof. Biles, because for some years back he had been making little or no allowance, except what he would make for the increased frictional resistance due to the surface of the bilge keels. He asked the members to give a very hearty vote of thanks to Mr Luke for his excellent paper. Mr Luke was one of their

The President.

youngest members in date of membership, but, notwithstanding that he had been very much engaged since he came to the Clyde, he had found time to give them a paper which would, he thought, prove a feature in this year's transactions, and it was particularly gratifying that the members of this Institution had recognised the excellence of the paper, and had discussed it in the way in which they had done.

The vote of thanks was heartily accorded.

ON PILE-DRIVING MACHINES

By Mr F. J. Rowan (Member).

(SEE PLATES VI. AND VII.)

Read 23rd January, 1900.

The subject of pile-driving possesses much interest from a historical, and even from an antiquarian, point of view; its origin being shrouded in the mists of antiquity, as it is associated with that of the inhabitants of the lake dwellings and crannogs of a bye-gone age. The people and the dwellings have perished, but the piles on which the houses were founded still remain in several places as silent witnesses of early engineering skill. The subject also connects us with the existence of many engineering structures of historical interest. In fact, a recent writer on the subject has claimed that pile-driving is the most ancient of all engineering work. Whether this is so or not I cannot say, but I am inclined to think that metal working has a more ancient origin. I do not, however, purpose dealing in this paper with historical matters, except in so far as they are presented to us in a short survey of various machines which have been introduced for driving piles.

Another branch of the general subject of pile-driving, which I must pass over, is that of the piles themselves and their uses, although many most interesting points are connected with the various ramifications of this branch. Questions of form, of size, and of material, come into consideration in the first place, according as the piles are to be used; (*a*) as bearing piles, for foundations, or for consolidating ground; (*b*) as mooring piles, for mooring posts, or beacons; (*c*) as sheeting piles, for coffer-dams, or facings for wharves; or (*d*) for other purposes, such as fender piles, abutment piles, &c.; and secondly, according to the nature of the solid or liquid substances in which they are to be placed.

For a lucid and interesting treatise on these points I cannot do better than refer to the instructive paper on "Piles and Pile-Driving," recently read to the Institution of Junior Engineers by Mr H. Cartwright Reid, civil engineer, attached to H.M. Dockyard, Chatham; whilst the mathematical side of the subject can be studied in the papers, on the "Theory of Pile-Driving," by Messrs Michael Scott and A. J. Robertson (in Proc. Inst. Mech. Engineers, 1857, page 12), and on "Formulas for Pile-Driving," by Mr C. H. Haswell (in Min. Proc. Inst. C.E., Vol. cxv., p. 315), apart, of course, from the text books on Civil Engineering.

I have no intention, in this paper, of entering upon the thorny ground of formulæ* or calculations, especially because the conditions are so varying, that each pile needs practically separate treatment; but I borrow from Mr Reid a rough set of diagrams, Fig. 1, which show graphically, "with," as he says, "no attempt at mathematical accuracy," the various latent forces making up the resistance of a pile to sinking, under ordinary conditions, and when driven in a homogeneous soil. "The set of the pile with a uniform fall of the monkey is represented by *e*. The dotted line, *b*, shows the elasticity due to vibration of the unsupported length of pile above ground; *f* exhibits the sum of the energy absorbed, and *g* the force producing motion in the pile, which, with the set *h*, gives the total effective energy. The rectangle of *i* shows the total energy developed by the falling monkey."

"An absolutely correct formula," says Mr Reid, "would have to take into account all the causes denoted in these diagrams, which are practically interminable for general use, as the most important elements, namely the resistance of the ground to displacement, and the passage of the pile through it are not deducible except by experiment, and vary with almost every pile.

---

* See Appendix for a selection of some of the formulæ which have been proposed, as published by Mr C. H. Haswell and Mr H. C. Reid.

Empirical formulæ, therefore, which depend upon the amount of work put into the pile in driving it, find most favour, and probably give the nearest value to the resisting power of the pile."

It seems to be a general opinion that a heavy monkey with short fall and frequent blows provides the best conditions for rapid driving with least destruction of the pile. "Falls above 5 feet," it is said, "do not result in proportionately more power; *i.e.*, two blows of 5 feet fall give as much power as one of 10 feet, whilst, owing to friction of the air, leaders, etc., no increase of power beyond that resulting from a 40-feet drop is possible." The value of a rapid succession of blows is not so generally conceded, but it seems to have the weight of evidence in its favour. "The longer the interval between the blows," Mr Reid remarks, "the less the pile sinks per blow. This is generally accepted as correct, though it has been advanced that the opposite is the case, because time is required for the material displaced by the point of the pile to disperse and adjust itself to the increased pressure brought upon it. It is evident, on the other hand, that the value of friction of quiescence is considerably more than the friction of motion, and the closer the approach to continuous motion the better. Each blow causes a certain vibration in the pile, separating it from the surrounding ground, and, if the blows follow quickly, there is not time for the ground to settle close to the pile, though, no doubt, when the pile is free to vibrate, it absorbs a larger portion of the blow in itself than when rigid. From these observations it will readily be seen that a pile left for a few hours will give a higher resistance than it will immediately after the cessation of driving, and all experiments prove that this is so, the increase due to quiescence being often from 5 to 20 or more times. This effect is more pronounced in soft or wet ground, and less so in dry or coarse gravel and sand."

In some exceptional circumstances, piles are screwed, and not driven by concussion into the ground, but I leave the consideration of these aside, and confine myself to the machines operating by concussion. For the same reason I pass over interesting apparatus which is used when piles are sunk principally by means of the action of a jet of water. It is evident that this method can apply only in sand and muddy or friable soils.

A proposal has also been made to employ atmospheric pressure for sinking piles, and an apparatus (called the Potts' pile-driving machine) on this principle has been mentioned, but I have not met with satisfactory accounts of its performance or descriptions of the apparatus. The idea was to exhaust the air from the interior of the piles, which were made hollow for this purpose, and to utilise atmospheric pressure for driving them in this condition. It is said that piles were driven in this manner successfully in situations where any other method might have been attended with difficulties.

(1) The oldest pile-driving mechanism was in all probability wrought by manual labour, and possessed some of the features of an ordinary ringing engine. Mr Reid has presented Fig. 2 as a suggestion of the prehistoric form of ringing engine employed in the construction of the ancient crannogs and lake dwellings. In its historical form, the ringing engine possesses two vertical guides or leaders, fastened top and bottom, and carrying at their top a pulley or sheave over which the rope for hoisting the monkey works. One end of the rope is fastened to a cast iron monkey weighing usually from 2 to 3 cwts., and on the other side of the pulley the rope branches off into six spliced ends, one for each man taking part in the work. The monkey rests on the top of the pile when their arms are stretched out. Pulling all together, the monkey rises to the height represented by the length of their reach, and, when all simultaneously let loose the rope, the monkey falls. Working briskly, from 15 to 16 blows a minute can be struck, and, as each man cannot lift more than 40 to 50 lbs. at that speed, the maximum weight of monkey is limited by the number of men employed. It is found, however, that a better result is obtained with three or four men than with six, as they more readily adjust themselves to a fresh position, which is necessary after each blow.

(2) Mechanical improvements upon such an arrangement were too obvious to remain long in abeyance, and consequently the piling engine worked by means of a manual crab-winch, Fig. 3, soon came in. A slip-hook was used, freed by a lever worked by a rope from below, the hook being pulled down to the monkey after each blow, when, of course, either the winch was reversed or the drum was thrown out of gear and allowed to unwind the lifting rope or chain. By the use of such arrangements the weight of monkey could be increased, but the rapidity of blows must be decreased.

(3) Consequently the next step was to apply steam power to this arrangement of apparatus, as that could readily be done, see Fig. 4, so as to obtain increased speed of working, but whether this improvement emanated from Britain or America I am unable to say. The arrangement shown in Fig. 4 is however commonly called the American "piler." It has usually a special form of slip-hook. In a modification of this steam pile-driving apparatus, which is sometimes used in this country, a steam crane, usually mounted on a truck or bogie, is employed, with the end of the jib projecting over the top of the leaders or guides for the monkey. In this case, the rest of the framing is dispensed with.

(4) Fully forty years ago a more direct application of steam to the striking mechanism was made in Nasmyth's pile-driver, by which the speed of pile-driving was greatly increased. This was an adaptation of Nasmyth's steam-hammer to the special work mentioned, and it formed an effective, though rather cumbrous, apparatus for driving single piles. Where, as in the illustrations, Figs. 5 and 6, several piles were to be driven singly on the same line, although at different angles, it was possible to arrange the framing so that the hammer case could be hoisted up and moved into a new position—or placed at an angle—by means of a rack and pinion or screw gearing.

In the construction of the river wall at the Tyne Docks (constructed in the years 1855 to 1858), this apparatus was so arranged that it formed its own roadway, no temporary piles being driven to support it. "The framework of the pile engine itself projected so far beyond the wheels that as soon as one set of main piles was driven, a temporary sill was placed upon them, the engine worked itself backwards and forwards, lifted its own road into its place, and then advanced to proceed with the next set of piles."* It is recorded that in driving by this machine the whole length of the pier, extending to 1800 feet, at the Tyne Docks, only 12 pile hoops were used, and only one was broken. The weight of the ram or hammer-block was 1½ tons, and the fall was fixed at 3 feet.

(5) Following the Nasmyth machine, an interesting steam pile-driver, also of the steam-hammer type, was introduced by Mr Robert Morrison of Newcastle-on-Tyne.† This was a modification of the Morrison steam-hammer, and was designed in order to obtain greater rapidity in the work of pile-driving than was possible with manual labour. It is shown in Figs. 7 and 8, of which Fig. 7 represents a side elevation, with the steam cylinder in section, and Fig. 8 a front elevation of the complete pile-driver. Fig. 8 also shows an enlarged section of the steam cylinder and striking mechanism.

A is the movable platform on which the framing C and the boiler X stand: BB are the wheels upon which the platform moves. D is the steam cylinder, and K is the hammer-bar or piston-rod. On the top of the frame are pulleys E for raising and lowering the steam cylinder, and F for raising and placing the piles in position. G shows the pile, rounded at the top, with a shoulder to carry the collar H, which supports four columns I, and on the top of these the steam cylinder is fixed. In this way the whole weight of the cylinder, piston, &c., rests on the pile and descends along with it; an invariable distance between the cylinder and the pile head being also thus maintained, as is necessary with all the steam-hammer machines, to prevent the piston striking the cylinder ends. For working the steam slide-valve very simple

---

* "On the Tyne Docks at South Shields," by Mr Thos. Elliot Harrison, Min. Proc. Inst. C.E., Vol. xviii., p. 490.

† Proc. Inst. Mech. Engineers, Nov. 1856, p. 287.

means are employed. The valve works in the valve-box L, the valve-rod carrying a volute spring fastened to it just above the valve-casing. This spring in normal position holds the valve open, allowing steam to reach the under side of the piston. A projecting catch at the bottom end of the hammer-bar engages the spanner T, pressing against it as the hammer rises, and thus forcing the valve-rod down against the pressure of the spring. When the valve reaches the position closing the admission port, and opening the exhaust port, the catch U slips into a notch at the top of the valve-rod, and holds the valve in this position until the blow is struck, when, by the concussion, the kicker V releases the catch U, and allows the volute spring to raise the valve to its former position. Although this self-acting gearing was fitted in the first of the machines which was used in the Dock Works of the River Tyne Commissioners at Hay Hole, near Newcastle, it was subsequently decided to have the gearing in all other machines worked by hand, as experience with steam-hammers showed that 80 blows per minute could be given by hand-worked gear with better control of the valve.

The hammer-bar weighed 35 cwts., had a clear fall of 3 feet 6 inches, and showed itself capable of driving a 14-inch square pile 35 feet in 12 minutes, in difficult ground; whilst 21 piles per day were driven, including getting up the piles, pointing and preparing to drive them.

(6). About the same date as that to which we have been referring; viz., in 1856 or 1857, Messrs Michael Scott, of London, and Andrew J. Robertson, of Blyth-upon-Tyne,* brought forward a very ingenious arrangement of steam machinery designed to drive two face piles 8 feet apart and one land tie pile 15 feet in rear of the face piles without change of position, the main piles being driven simultaneously by alternate blows from two monkeys operated by the same crab-winch. By this method the time previously occupied in pulling the slip-hook down to the fallen mon-

---

* Proc. Inst. Mech. Engineers, 1857, p. 18.

key for a fresh grip is usefully employed in raising the second ram, and thus an approach to continuous working is made.

Robertson and Scott's arrangement is shown in Figs. 9, 10, and 11; Fig. 9 being a side elevation and Fig. 10 a front elevation. Fig. 11 shows the driving gear and clutches of the two winding drums on an enlarged scale.

By an ingenious device the leaders A are made adjustable to any angle at which the main piles might have to be driven, the leaders having hinges B to the frame D, to which also the ties C are attached, this frame D being capable of movement, forward or backward, on the platform E by means of the wheels F and wedges G. The leading frame L at the back of the platform is for the land tie piles, and is not adjustable. A steam boiler and engine are shown at M working the two drums N, each connected by a chain and slip-hook S to a ram or monkey O. One of the drums having been put in gear by the clutch P, the lever weight Q is shifted into the second position shown in dotted lines. While the strain of hoisting the ram is on, the friction due to that strain prevents the weight Q from disengaging the clutch which is in gear, but as soon as the ram is released, Q acts by throwing out the one clutch and throwing in the other, the winding being thus transferred to the other drum. Brakes are shown at T to control the drums when thrown out of gear. When the slip-hook is drawn down to be re-attached to the ram which has fallen, the lever Q is moved into position ready for another reversal of the clutches when the second monkey reaches the top. In this way the engine is run continuously in one direction, and the time is fully occupied in hoisting weight. In consequence of the rapidity of working, a spring buffer U had to be provided to take the shock of sudden engagement with the weight off the framing.

The weight of the ram O was 1½ tons, the engine having been of 4 horse power, and the fall anything from 3 to 14 feet. The speed of working, though less per minute than that of the Nasmyth machine, was said to be equal to it per day, whilst the cost of the machine was given at £450, as against £1800 for a Nasmyth's.

(7). The Lacour steam pile-driver, Figs. 12 and 13, is said to be the best steam-monkey now in the market. It is another adaptation of the steam-hammer to pile-driving, and will be readily recognised in this district from its resemblance to the forerunner of such plans which was introduced by Mr Condie, *i.e.*, that of a moving-cylinder hammer, as contrasted with Nasmyth's plan of a hammer-block at the end of a small piston-rod, or the Rigby-Morrison plan of a heavy piston-rod hammer-bar.

In applying the moving-cylinder hammer to pile-driving, however, it is necessary to project the piston-rod through the bottom end of the cylinder, and allow the end of the projection to rest on, or be fastened to, the head of the pile. By this arrangement the weight of the hammer rests constantly on the pile, taking the strain altogether off the leading frame, with advantage to the driving in certain soils. The drop of the hammer is limited to the length of the cylinder, which is usually about eight feet, and a full blow with that drop can be given every two seconds. Blows with a shorter drop can be given very quickly. The steam is led to the cylinder by a flexible pipe from an 8 H.P. boiler working at 80 lbs. pressure per square inch, and the admission and exhaust are regulated by a three-way cock, the exhaust steam escaping into the air above the cylinder cover.

One consequence of the necessary projecting piston-rod is that the blow of the cylinder is delivered only on the portion of the pile head which surrounds this rod, and not on the whole surface of the head of the pile. This of course increases the liability of the timber to damage, and there is a further cause of detriment (which is not, however, limited to this one among the steam-hammer pile-drivers); viz., that the condensed steam from the cylinder can run down to the head of the pile, where it acts in softening the wood, thereby increasing the tendency to "brooming" and reducing the effectiveness of the blows. Moreover, all the steam-hammer pile-drivers are open to the objection that each cylinder can be employed on only one pile at a time, so that sheeting piles can only be driven singly.

(8). Still another improvement in the steam pile-driver has been introduced in the shape of an endless chain for lifting the ram, the object being, of course, to enable the hoisting engine to be run continuously in one direction and to minimise the time lost in stopping or reversing to lower the slip-hook or catch to the fallen monkey. The earliest form of this machine was no doubt Bunce's pile-driver, Fig. 14, and since its day several forms of the endless chain pile-driver have been introduced, the modifications being practically limited to different methods of attaching the chain to the ram. A well-considered form of this kind of machine was described by Mr Peter B. Eassie, of Gloucester, in October, 1867.* Figs. 15, 16, and 17, show elevations of pile-drivers on this system, driving raking and upright piles, where the machine has the ordinary form of fixed leading frame; and also elevations of a "telescopic" pile-driver for driving piles below the level of the rails on which the machine runs or of the gantry on which it is carried. This latter form is of value in running out piers in deep water or in driving piles in trenches. Figs. 16 and 17 show the nature of the work done by the first pile-driver of this kind which was adopted by the Admiralty for driving piles in trenches in the extension works at Chatham. In this case the sides of the trenches, being of soft clay and other unstable material, required to be supported by horizontal struts T, over which the pile-driver had to pass clear in traversing the trench longitudinally. U is a traverser mounted on wheels running on rails laid on the gantries S S for longitudinal traverse of the trench, whilst the cross traverse is accomplished by means of the wheels under the platform P of the pile-driver. The telescopic arrangement consists of a long frame X X which is called a "needle," sliding freely between pieces of T-iron fastened on each side of the leaders B of the pile-driver. This frame is raised and lowered by the chains Y, one at each side of it, worked from the drum of a steam-crab, and it serves as a guide for the

---

* Proc. Inst. Mech. Engineers, 1867, p. 255.

ram and follower in place of the leaders themselves. The lower end of the needle may be fastened to the head of the pile as in Fig. 17, or the needle may rest on the bottom of the trench as in Fig 16. The leaders and side stays of the pile-driver being hinged, they can be adjusted for driving raking piles with the needle as in Fig. 17.

The main interest in this class of machines centres in the ram and attachments for the chain. These are shown in Fig. 18. A is the ram which slides freely between the leaders B, and weighs from 15 to 30 cwts. The clamping bolts G G, have, at the back, eyes through which the lifting chain C passes. The steel hook H, for lifting the ram, is jointed on the top of a rod fastened with springs J J to the ram, at its centre of gravity. India-rubber springs have been found to be the best, as the space through which the lifting rod has to yield, when the chain is driven at its greatest speed, amounts sometimes to two inches. The lifting chain C, after passing through the eye-bolts G, is brought forward to the front of the leaders, and into the line of the centre of gravity of the ram, by means of a "follower" F, which is a light iron frame carrying a roller and sliding freely between the leaders B. The follower rests on the top of the ram during its ascent, until the lifting hook H is disengaged from the chain by the striker-off K, when it follows the ram downwards sufficiently slow to allow the ram to settle after its rebound on first striking the head of the pile. The striker-off displays ingenuity in its construction, and altogether the details of this machine reflect great credit upon their designer.

For comparison with other endless chain machines, however, it is the attachment of the chain to the ram that possesses the greatest importance. Fig 19 enables us to see how that part of the apparatus is arranged in two other machines, the one on the left being Sissons and White's machine, which is also shown in elevation in Fig. 20. It will be noticed that in both of these designs, in Fig. 19, the attachment of the ram A to the chain C is at the back of the leaders B, the ram being released either by the catch D being withdrawn in the one case, or by the chain being thrown outwards and off the catch by means of an inclined stop, in the other case. Although the effect of the blow, when once the ram is released, is the same in all these cases, yet it is evident that the two latter methods of attachment must cause more friction in the process of lifting the ram than that of Mr Eassie's does, in consequence of the ram being tilted against the leaders. Mr Eassie announced that by experiment the friction due to such ilting action had been found to amount to nearly one-fourth of the whole weight of the ram.

(9). Although under normal conditions it operates more by a graduated pressure than by a sudden and violent blow on the head of the pile, yet the gunpowder pile-driver, originally introduced, about 30 years ago, by Mr Thomas Shaw of the U.S.A., possesses too much interest to allow of its being passed over without mention. It was first described in this country in *Engineering* of August 1869, pages 79 and 92, but an improved form was exhibited at the Philadelphia Exhibition of 1876, and was used for driving the foundation piles of the dry dock in Messrs Cramp and Son's shipbuilding yard. (A description of that improved form will be found in *Engineering*, Vol. xxi., 1876, pages 408-410). These improvements, and some later ones, are due to Lieut. F. C. Prindle, at one time U.S. Superintendent and Engineer of the Navy Yard at League Island, Philadelphia. In its original form it was rather a crude contrivance, but, as improved by Lieut. Prindle, it developed into a highly efficient pile-driver. Figs. 21 and 22 show an elevation and sections of the main working parts in which interest centres, the upper Fig. 22 being a vertical section of these parts, and the lower one a horizontal section on the line C D through the weight N. M is the mortar of cast steel which is elliptical in section, and weighs from 1,500 lbs. upwards, and on its lower surface it has a recess embracing the head of the pile on which it rests. The cylindrical opening in the upper part, in which the charge in the shape of a cartridge or cake of powder is placed, is bored to make a good fit for the piston P, which has steel piston-rings. The piston-rod is fastened to the underside of the weight N, which is of cast iron, and has also a cylindircal opening bored in its upper part. A piston O is made to fit into this opening, and is suspended from the cast iron cross-piece T which forms the head of the framing. On the back of the weight N is a smoothly planed flat surface at F, on which a brake is fitted, controlled by levers L, and worked from the platform by a lever brought down to the carriage. The brake is employed for stopping the weight on its recoil and for holding it in position ready for a drop. The parallel jointed levers, L, which hold the brake to the rubbing surface, are hinged on supports carried on the angle-iron braces of the main beam. This beam is formed by the angle-irons G, which serve as the guides or leaders, stiffened by transverse angle-irons K placed at intervals along its entire length, these braces being connected at the back by a T-iron H running vertically along the whole length of the beam. The beam is stayed by angle-irons running to the carriage, one at each side, and by a channel-iron J, which is jointed at R, and is also attached to the carriage. The weight N (the weight of which should be in the proportion of 2200 lbs. to a mortar of 1760 lbs.) is suspended above the mortar at a height giving at least 39 inches distance between the piston P and the mortar. A charge being placed in the mortar, the weight is allowed to fall, when the air enclosed by the piston is compressed from 20 to 25 atmospheres, and is by this process heated sufficiently to ignite the charge. The pressure also helps to start the downward movement of the pile, and the expansion of the gases due to the ignition of the charge completes the driving pressure on the pile. The descent of the pile continues until the resistance due to the friction and compression of the ground balances the driving force, and here the recoil takes place, forcing the weight upwards. Should it not be stopped by the brake, the air enclosed by the top piston O forms an elastic buffer which brings it to rest without shock. It is said that each cycle of operations takes four or five seconds and can be repeated for ten or fifteen rounds, after which the mortar should be allowed to cool, both on account of the risk of premature firing of a fresh charge and also to prevent expansion of the mortar destroying the fit between it and the piston.

In works carried out at Dresden it was found that the comparative cost of steam-driven pile-drivers (where three such machines were worked from one central engine), gunpowder pile-drivers, and hand-driven pile-drivers were ;—

For the three steam-piling engines combined, ...	1·0
,, gunpowder pile-driver, ...	2·4
,, hand-driven machines, ...	6·78

In these works a nitro-glycerine compound was used as the explosive in the gunpowder pile-driver, but that is not the kind of explosive best fitted for the work, the nature of the operation showing that a comparatively slow-burning powder would be the most suitable. From its peculiar construction, however, it follows that the weight of the gunpowder machine must be considerable, and this in many instances would be an objection to its use. It is not so heavy as the Nasmyth machine for a practically similar weight of mortar and monkey, the weight of Nasmyth's machine having been 24 tons as against 10 tons for the gunpowder machine. Morrison's machine weighed from 6 to 7 tons, Robertson & Scott's, as illustrated, weighed 12 tons; but it is apparent that a machine to work a single monkey need not be so heavy.

The figures of both cost and speed of driving piles vary so much under different circumstances and with different machines that it is scarcely possible to fix upon a fair average. An attempt to ascertain comparative costs of driving by different kinds of machines was made by M. E. Hacquard, engineer-in-chief to the city of Dresden, who published, in 1877, a long article on this subject in the "Annuaire de la Société des Anciens Elèves des Ecoles Nationales d'Arts et Métiers," a translation of which appeared in *Engineering*, Vol. xxiii., pp. 393, 414, 433. There is some reason to believe, however, that the circumstances under which that comparison was made were not altogether satisfactory, although much may be learned from that article.

Amongst other papers giving accounts of pile-driving work on the Continent are those by Prof. L. Lewicki, referring to work carried out on the Duna in Russia, published in the "Civilingenieure," xxi., Part 1, 1875, pp. 21-44, and by Herr Weber, on pile-driving apparatus used at Dresden, published in the "Protokolle des Sachsischen Ingenieure Vereins," 6th Dec., 1874, pp. 20-24. Short abstracts of these will be found in the Min. Proc. Inst. C.E., Vol. xl. p. 316, and xli. p. 257.

(10) It is apparent that the ideal pile-driving machine should possess lightness, in as far as that quality is compatible with the necessary strength for the work, and durability under its conditions. This facilitates the manipulation of the machine and its removal from point to point in works, where the sinking of special piles to carry the machine, or the construction of other support than the permanent piles afford, would be an unwelcome addition to the cost. In works of very large extent it may be advisable to erect substantial gantries on which a traverser may run carrying a pile-driver moving across it, so that a large area may be commanded. But even in this case quickness and ease in moving the machine from pile to pile will best be secured by making the machine as light as possible consistent with its general efficiency. Some years ago it was proposed to work pile-drivers by means of air under pressure, as by such a system the notable advantage would be secured of having all the steam boilers and engines centrally placed on *terra firma*, whilst the compressed air could be conveyed by flexible pipes to the machines, with less waste than the leakage and condensation of steam in the ordinary machines represented. Such an advantage should be within the reach of the ideal machine, combined with the utmost economy in use of the power developed at the generating station. This machine must also have a sufficiently long range of fall, and a ready means of increasing or diminishing the length of drop that is used, along with the maximum continuance of rapid blows. Added to all

these qualities the ideal machine should be the least expensive of all the machines in first cost. There can be no doubt that it is only by an application of electricity to this special work that one can hope to obtain such a desired combination of qualities, and in concluding this paper, I have the pleasure of submitting to you the design of an electrical pile-driver, which, I believe, is the first of its species, Fig. 23. In this machine I have adopted a means of lifting and releasing the weight which has long been successfully used in the American drop-hammer. The weight is attached to a flat board of wood, or its equivalent, and is lifted by the friction grip of two smooth flat-faced pulleys, or rollers, placed above the point to which the weight is lifted. One of these pulleys has its shaft or spindle bushed in brasses of eccentric form, and these eccentric bushes are connected by a lever, by means of which they can be moved round in either direction in their bearings in the framing of the driving mechanism. The effect of such movement is to cause the one of the two rollers or pulleys either to approach the other or to recede from it, in one case tightening their grip on anything that is between them, and in the other releasing it, without stopping or reversing the movement of the pulleys. An electro-motor drives these rollers either through worm gearing, or not, as desired, and the movement of the lever controlling the eccentric bushes is effected at the top of the stroke by the ram striking against a projection on the lever rod and lifting it, thus throwing the rollers apart. As soon as the ram has fallen, the lever is moved back by hand and the rollers instantly take a fresh grip.

This arrangement enables me to use the electro-motor in the best way; viz., constantly running it in the same direction of rotation at a uniform speed, and to combine the greatest range of fall of ram with the most rapid method of repeating the blows. Not a moment need be lost between the fall of the ram and the commencement of the lifting movement, as it is possible to have instantaneous engagement of the lifting gear on the blow being struck

The size of ram or monkey may be varied in this machine, so that either single piles or several piles together for sheeting piles may be driven. I have shown the ordinary form of leading frame in this illustration, but it is apparent that hinged framing can be used to adapt the machine for driving raking piles, and leaders can be extended below the level of the carriage rails for driving at a low level, as in other machines.

By using another small electro-motor for the crab-winch, I have the lightest possible arrangement of machinery for carrying out the work without manual labour. The electric current which is thus transmuted into driving power is also available for the most perfect means of throwing light upon the work when that is wanted. And, finally, in economy of transmission and utilisation of force, it is now beyond question that the electrical system is superior to all others. The electrical pile-driver will weigh less, cost less, and work more cheaply than, and as efficiently as, any other machine which has been introduced.

APPENDIX.

SOME PILE-DRIVING FORMULÆ.

F = Factor of Safety.
W and w = Weight of Monkey in lbs. or tons (1·25 ton) 2800 lbs.
H and h = Fall of Monkey in feet or inches, 72 inches (6 feet).
S and s = Set of Pile in feet or inches, ½-inch or ·041 feet.
P and p = Weight of Pile in lbs. or tons (0·80 ton) 1800 lbs.
a = Sectional Area of Pile 12 inches × 12 inches.
E = Modulus of Elasticity 1,000,000 lbs.
l = Length of Pile 480 inches (40 feet).

Capital letters W and P refer to weights in tons; H and S to distances in ft.
Small ,, w ,, p ,, ,, ,, lbs.; h ,, s ,, ,, ins.

Authority.	Formula.	Factor of Safety Recommended.	Safe Load on 40 feet Pile.
Major Sanders	$\frac{w\,h}{s}$	⅓ to ⅛	60 tons to 22½ tons.
"Engineering News," (New York.)	$\frac{2\,w\,h}{s+1}$	Nil	14·4 tons.
Trautwine	$\frac{5\,w^3\,\sqrt{h}}{s+0{\cdot}083}$	½ to $\frac{1}{12}$	45·35 to 7·56 tons
Weisbach	$\frac{w^2 \times h \times s}{(w \times p)}$	⅛ to $\frac{1}{10}$	69·8 to 41·3 tons
Rankine	$\sqrt{\frac{4\,\mathrm{E}\,a\,w\,h}{l}+\frac{4\,\mathrm{E}^2\,a^2\,s^2}{l^2}}-\frac{2\,\mathrm{E}\,a\,s}{l}$	½ to $\frac{1}{10}$	29·5 to 5·9 tons. 38·5 to 7·7 for 20 ft. pile.
Nyström	$\frac{w^3\,h}{s\,(w+p)^2}$	⅛	11.3 tons
Stevelly	$w \times \left(\frac{w}{w+p}\right) \times \frac{h}{s}$	⅛ to $\frac{1}{10}$	18·25 to 10·29 tons
Brix & Becker	$\frac{4\,w^2\,h\,p}{s\,(w+p)^2}$	¼ to ⅙	42·85 to 28·56 tons

From Paper on "Piles and Pile Driving," by H. Cartwright Reid, Society of Junior Engineers, London, April 1899. See also C. H. Haswell, Min. Proc. Inst. C.E., Vol. cxv., p. 315.

Discussion.

The discussion on this paper took place on 20th February, 1900.

Mr C. C. Lindsay (Member) observed that Mr Rowan had given a very interesting description of some pile-driving machines, but, unfortunately, no reference was made to modern practice. The machines illustrated were not used anywhere, as far as he was aware. They were very elaborate, but not practical, and on that account, probably, they were not in use. Mr Rowan had given illustrations of an electric pile-driving machine which he had designed. He (Mr Lindsay) had not the slightest doubt that electricity, in the near future, might be used for pile-driving machinery with advantage and economy, but he did not think that Mr Rowan, as far as his illustrations and designs went, had solved the problem. The motor was an elaborate machine, and certainly would require repair occasionally, but it was situated where it could not be easily got at. The connection between the driving rollers and the ram was most peculiar, and if it was formed either of flat timber, steel, or iron, when at its greatest height, the machine would be unmanageable. He could scarcely imagine that pile-driving could be done with it when even only a light wind was blowing. He regretted that Mr Rowan had not shown some modern pile-driver. He (Mr Lindsay) had used the pile-driver shown in Fig. 24 for thirty years, and it had been in common use for the last ten or twelve years. It was simplicity itself, and could be driven even by the aborigines, which Mr Rowan had shown on Fig. 2. The platform was from 10 to 12 feet wide, and on it was fixed a single-cylinder engine actuating the upper shaft, on which was fixed a pinion geared into a spur wheel attached to the chain drum, which was loose on the lower shaft. The chain drum was put in and out of gear by a clutch, and the man in charge was usually a labourer. In the illustration, Fig. 24, the monkey and ram was at about its highest point, and the chain merely drew the monkey and ram to the top. The ram was let go by pulling a rope attached to the monkey lever, and the weighted monkey followed immediately by releasing the clutch. This machine was

Mr C. C. Lindsay.

light, strong, and of moderate cost; it was economical and rapid in execution; and an intelligent labourer could fit it up. He might say it was the "survival of the fittest."

Mr A. S. Biggart—Perhaps Mr Lindsay would explain where the boiler was put, and how it was shifted from place to place.

Mr Lindsay—For simplicity's sake, he had not referred to the boiler, because the author had omitted it in his pile-driver, though required—except in very exceptional cases where electric power would be available. The boiler could be placed either on the platform of the pile-driver or off it, with a jointed steam-pipe connection. While he put forward this steam pile-driver, he did so merely to show modern practice all over the world, and he had not the slightest doubt that Mr Rowan, if he worked in the direction of simplicity and economy, would produce an electrical pile-driver which might surpass "the survival of the fittest."

Mr A. S. Biggart (Member) remarked that probably one of the future applications of electricity would be to pile-driving machines. To be able to do away with the steam boiler on pile-drivers was a decided advantage. All who knew the difficulties attending the use of steam boilers on outside work would at once appreciate the benefit of being able to work without one. If power could be acquired by simply leading a wire from the town's electrical supply, a great advantage would be obtained. So far as the mechanical application was concerned, he did not see why a motor should not be applied to a winch and at the same time retain the simplicity of the arrangement by substituting such a device for the engine in Fig. 24.

Mr W. M'Whirter (Member) thought if Mr Lindsay were to take away his steam engine and boiler and set down a motor, and gear it in the same manner as Mr Biggart had suggested, it would simplify this simple apparatus, Fig. 24, and probably it would then be "the survival of the fittest."

Mr E. George Tidd (Member) said the gist of Mr Rowan's paper was at the end. He would like to know whether Mr Rowan had ever tried to make his electric pile-driver work automatically. He

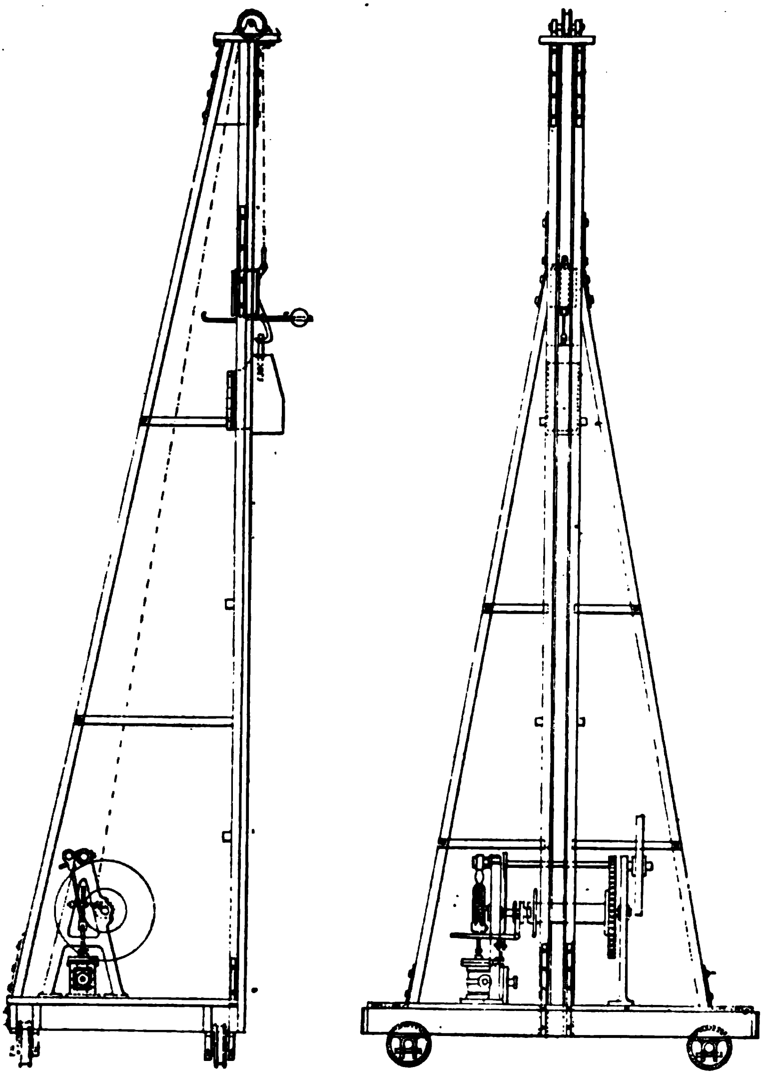


Fig. 24.

Mr E. George Tidd.

noticed that the monkey was automatically released, but Mr Rowan said that "as soon as the ram had fallen the lever is moved back by hand, and the rollers instantly take a fresh grip." Now it seemed to him that it would be a simple matter to arrange a trigger to actuate the rollers by direct mechanical means, or seeing that electrical power was available it might perhaps be more conveniently done by that means. He did not know if the monkey had any appreciable rebound in practice, but if it had and the automatic arrangement could be adjusted so that the rollers gripped during the rebound, it would greatly tend to reduce jarring action on the motor.

Mr James Waddell (Member), whose experience of pile-driving extended over 30 years, said Mr Lindsay had described graphically what he (Mr Waddell) considered the best machine under ordinary circumstances. The great trouble that most people had was not with the machine but with the pile; it would not drive in a straight direction. In Figure 23, Mr Rowan showed a four bay pile, and the band with which the ram was raised seemed to him to be fixed rigidly to the ram. It was quite evident that if the bay of four piles, say 4 feet broad, came upon an obstruction at one side only it might get driven an inch or so off the horizontal. One inch on 4 feet multiplied by the height of the band, if it was 24 feet, would give 6 inches as the amount the band would be off the plumb. In that case the pile would require to be re-cut to get it to the level. The difficulty could be overcome, he believed, by putting on a ring and making the band at the ram flexible, or the band might be put the reverse way from what Mr Rowan had shown in Fig. 23. It would not then interfere with the pulleys at the top by getting off the level at the bottom. The most serious objection he had to the machine illustrated by Fig. 23 was the effect that the law of gravitation would have on it. The machine was not balanced, but Mr Lindsay's was beautifully balanced. Many years ago he saw a machine more stable than Mr Rowan's topple into the Clyde, near Messrs Barclay, Curle & Company's old yard. As represented by Fig. 23, the machine appeared to be situated on a quay wall. The ram shown in the figure, to drive anything like four piles would require to be 4½ to 5 tons weight. Right vertically above that weight was the electric gearing. It was quite evident to him that the machine was overweighted in front of the foremost wheels, and he believed that unless Mr Rowan added weight at the back, or put in a winch, or something else, it would not live to drive a pile; it would topple over.

Prof. A. Jamieson (Member) remarked, in connection with the adaptability of electric motors for working pile-driving plant, that he would explain by a sketch on the black-board a very simple and direct method of applying electricity to such a purpose, which had heen devised and tried on a small scale by one of his students. It consisted of a vertical series of solenoids connected to a source of electrical energy by leading wires and a multiple terminal switch, so arranged that each successive solenoid (beginning with the lowest one and ending with the highest) was brought into circuit. The electro-magnetic action on the central soft iron bar attached to the monkey was such as to elevate it to the top of its stroke. Then, by reversing the switch, the bar was not only pulled downwards by the current, but it also fell by the effect of gravity. Or, by simply turning off the current whenever the iron rod had got to its uppermost position, gravity alone would pull it down, but would not give such a smart blow as when aided by the electric pull due to the current. The student proposed to work the switch automatically by a connection to the monkey bar, but owing to the disturbances which this apparatus created in the laboratory he did not get the length of testing its efficiency, which would not be high.

Mr W. B. Sayers (Member) said that however interesting the sketch of Prof. Jamieson's might be from a scientific point of view, it was absolutely hopeless from a practical point of view. It was well-known that with such an arrangement the energy would be mainly consumed in heating the coils, and that a small proportion only would be expended in lifting the monkey.

Mr Rowan.

Mr ROWAN, in reply, said he must thank the gentlemen who had taken part in the discussion for the interesting remarks they had made. Not the least interesting of these were the remarks of Mr Lindsay, with which, however, he could not altogether agree. In the first place, the pile-driver which Mr Lindsay had shown was not different in its essential features from several of those illustrated. Within the compass of the illustrations in the plates of the transactions, one could not introduce nicely finished drawings like Mr Lindsay's. The elements of the machine which Mr Lindsay had shown were precisely those of a very old machine. That was to say, a steam winch operating on the monkey by means of a chain and a slip-hook which had to descend after the falling monkey at each stroke, thus losing time unnecessarily between the blows. Nobody suggested that it was impossible to work successfully and, to a certain extent, economically with such machines, because they had been used, if not from time immemorial, at any rate for many years. He did not quite see how a machine that had been in use for 30 years was one of most recent date. A more modern arrangement was one in which the upright leaders alone were used and the weight lifted by a travelling steam crane, which was, however, not applicable in all kinds of work. Where piles were driven alongside of solid ground, it was possible to have a travelling steam crane to do the work instead of a travelling platform with a boiler, steam engine and winch, and other appurtenances on it. Mr Lindsay's illustration, moreover, represented a steam winch which was intended to lift a heavy monkey without a supply of the necessary energy. There must be a boiler, and it was all very well to say that it could be put on the solid ground and could be connected by means of flexible pipes to a steam engine on a travelling platform, but the range of movement in that case must be extremely small, or the boiler itself must be on wheels. Referring to electrical arrangements, Mr Biggart suggested that it would be a simpler method to apply the motor direct to the winch for hoisting the weight by means of a chain and slip-hook. There was no doubt

Mr Rowan.

of that, but his (Mr Rowan's) idea was to avoid the delay which necessarily took place between the blows when they had to make the slip-hook follow the falling weight to take a fresh grip. His main object had been to increase the rapidity with which the blows were given. He believed that that was one very great recommendation in favour of direct steam hammer pile-drivers, such as the Lacour, which, by means of a series of rapidly given blows, were able to do the work at a greater speed than was possible with a machine in which a heavier weight was used, but where there was an interval more or less great between the blows. With regard to automatic re-clutching after the monkey had fallen, there was one difficulty in the way of its accomplishment. He had devised an arrangement for automatic re-clutching, but one had to allow for the fact that while the position of the lifting mechanism was to a certain extent fixed, at any rate for the period of one blow, the effect of a blow was to sink the pile and to alter the distance, more or less, between the top and the bottom of the stroke at every blow. Of course, the lifting mechanism was made to follow the pile in its downward movement by means of a winch and chain carried over a pulley at the top of the lifting frame, and that led him to a remark of Mr Waddell's about the balance of weight. Although it was shown on a very small scale it was intended to have a winch at the back corner of the framing, which was to be used for the purpose just named, so that the weight was not altogether on the front of the platform. There was this to be observed, that the weights of electrical machinery were very much less in proportion to the power which was derived from them than in the case of steam machinery. The weight of the motor necessary to lift the heaviest monkey which would be necessary for driving piles did not exceed 5 cwts. That was not a very serious weight even when suspended a good way up in a framing of the kind shown, which was pretty well spread out at the bottom on the moving platform. If one of Mr Lindsay's steam winches had to be suspended to hoist the weight from the top of the leading frame, that would be a serious matter. The

Mr Rowan.

presence of the lifting and lowering arrangement also met Mr Lindsay's objection about the position of the motor, which could always be lowered on to the platform when necessary. As to the use of solenoids, he was glad Mr Sayers had pointed out what was a fact, that they were a very expensive kind of apparatus for the purpose of obtaining power. The idea, which was produced in Professor Jamieson's electrical laboratory, was not quite new. As far back as 1882 or 1883, an electrical smithy hammer was successfully made and exhibited by a Frenchman, M. Despretz, whose name was well-known in connection with early experiments in the distribution of electrical energy over long distances in France and Switzerland. He had a series of about 80 coil connections in a length of one metre. A very simple arrangement like the one indicated by Prof. Jamieson would not work at all, or only to the extent of a few inches; to get anything like a proper stroke, the coils would require to be multiplied to a very alarming extent, because the amount of travel obtained from a single coil would be very small. In the small hammer of M. Despretz, there were eighty sections in the coil for a travel of three feet. Besides that, the switch arrangement had to be of such a character that these sections were put into circuit successively one after the other, the preceding one being cut out when the next went in, otherwise a dead-lock in the movement would result. The effect of the blow from the hammer, which was a plain cylindrical rod, was very much greater than what was due to its weight. He believed that a current of 43 ampères was used. The hammer itself weighed 23 kilogrammes, or about 51 lbs., and the effect of the blow with that current was equal to three times that weight, so that it made a very successful hammer on a small scale. But when the stroke necessary for driving a 40-feet pile was considered, he thought they had not yet arrived at the perfection of working by means of solenoids which would enable them to tackle a job like that in such a direct way.

The Chairman (Prof. W. H. Watkinson) observed that Mr

Prof. W. H. Watkinson.

Rowan's paper on "Pile-Driving Machines" was a very interesting one, and, although the author might not yet have solved the problem of the application of electric motors to this purpose to the entire satisfaction of those using pile-drivers, he had made a great step in advance, and the discussion would probably assist him in the matter. He thoroughly believed with Mr Biggart that the electric motor might be made more suitable for pile-driving than any arrangement depending on a steam engine. The great virtue of electric motors was the flexibility of the connecting wires. By their adoption, the hoisting might be done as efficiently and much more cheaply than by a steam engine and boiler. The electrical hammer described by Prof. Jamieson would be unsuitable for giving the kind of blow required for pile-driving. The blow had to be of a less impulsive nature, otherwise the head of the pile would be destroyed in a few seconds. He was sure they would join heartily in giving a vote of thanks to Mr Rowan for the paper with which he had favoured them.

A vote of thanks was heartily accorded.

THE ELECTRIC WIRING OF BUILDINGS.

By Mr W. A. Chamen (Member).

(SEE PLATE VIII.)

Read 23rd January, 1900.

In presenting this paper to the Institution some apology is needed, as the subject is one which at first sight might be considered uninteresting, and also because there is nothing new in it. There are, however, many electrical engineers connected with this Institution who are daily engaged in this work, as well as several who are engaged upon kindred work on board ship; and, if the paper serves to educe information from those members who are intimately connected with shipbuilding, such information can scarcely fail to be extremely useful, as one of the principal sources of damage to wires; viz., moisture, must of necessity be more frequently present on board ship, and in all probability the precautions which are taken there will prove most interesting and instructive to those more especially engaged in the wiring of buildings.

The greater part of the wiring of buildings *up* to the present time, and perhaps even *at* the present time, is carried out by means of india-rubber insulated wires run in wood casings, and it is well to lay some stress upon this point at the commencement of the paper, as the largest experience obtainable has necessarily been in connection with this system of wiring. It is a system which has much to commend it, and it has undoubtedly done remarkably good service for many years past. It has, however, long been felt by many engineers that it is not the best or soundest mechanical job that can be made, and many different methods have been devised with the object of superseding wood casing.

The objections which are raised against this old established system are:—

(1) That it is extremely unsatisfactory in damp or wet places as the wood casing becomes sodden, and the insulation of the rubber covered wires, although supposed to be permanently waterproof, often breaks down if perpetually subjected to moisture.

(2) That it affords no mechanical protection against nails, screws, saws, chisels, etc., which from time to time of necessity make their appearance in the immediate vicinity of the electric conductors in any building, the operator being usually ignorant of the whereabouts of the electric conductors, and also of the ultimate result of any injury which he may do to them.

(3) That two distinct classes of tradesmen are required for its fitting up; viz., the joiner for fixing the casing and the wireman for laying and jointing the wires.

In enumerating some of the various improved systems which have been invented, the author must be forgiven if he should omit any, as the object of this paper is to refer principally to those systems which are mostly in use rather than to deal historically with the subject.

Of the newer systems the one most frequently met with is perhaps the lead-covered cable system. This is used in various ways—(*a*) in some instances it simply consists of lead tubes into which india-rubber covered wires are drawn; (*b*) of wires insulated with paper or fibre or sometimes with india-rubber, but having the lead sheathing drawn tightly over the insulation so that the lead forms an integral part of the structure of the conductor, each wire having its own insulation and lead sheathing; (*c*) the same as (*b*) except that two wires, positive and negative, are each separately insulated and then laid up together, having one lead covering drawn over the pair; (*d*) also like (*c*) except that the two conductors are concentric with one another and the outer one usually not insulated at all from the lead sheathing.

The first of these (*a*) seems to present but little advantage over the wood casing, except that in damp or wet places, if properly laid, the lead tubing forms a satisfactory protection against moisture. In practice, however, it is frequently found that the joints in the lead tubing are either not soldered at all, or so imperfectly soldered as not to possess any power of excluding moisture. It is obvious that the protection offered by the lead tubing against mechanical injury is not even so good as that offered by the wood casing, and there is the further objection that a nail driven into a lead tube containing conductors with no spacing between them may quite possibly cause a direct short circuit which in the wood casing would not occur.

The next variation (*b*) offers some advantages, inasmuch as it is possible to separate the two conductors so that one nail cannot very well cause a direct short circuit, except in the manner which will be referred to later on. It, however, offers no better mechanical protection to the insulating material than the others, although it possesses the advantage of having no space between the insulation and the lead in which moisture can lie, and that it is much more easy to arrange that no joint shall occur in a damp place. Wires not insulated with india-rubber, however, require special boxes, or other special arrangements or treatment at the ends, for the purpose of preventing the access of moisture to the insulating material, which in most cases is hygroscopic to a considerable extent.

The third variation (*c*) appears only to present the advantage of being less unsightly when used upon the surfaces of walls than two separate wires would be, and that in consequence people may be induced to allow it to be run upon the surface where they would not allow two separate wires. The chances of mechanical injury to wires run upon the surface are obviously less than when they are buried in the plaster and obscured from view, though easily accessible to the point of the nail. This arrangement has, of course, in other respects the advantages of the second variation, and the same disadvantages if the insulating material is hygroscopic.

The fourth variation (*d*) is practically only used for isolated installations, no one as yet having proposed to use wires of the concentric construction in which both conductors are insulated. The fact that the outer conductor is uninsulated is one which presents difficulties, and conflicts with the present Board of Trade regulations if used with public supplies, as the Board of Trade insist on earthing the neutral conductor of the three wire systems most generally in use at one point only; viz., at the generating station. The introduction of concentric systems, in which the outer conductor is uninsulated, into consumers' premises, would probably mean the earthing of the middle wire of the supply system at a great number of points. Whether it is desirable that the Board of Trade rule should be maintained or altered is a question entirely beyond the scope of the present paper, and cannot now be discussed.

A point, therefore, which requires to be borne particularly in mind in using any lead-covered system is, that on a public supply one conductor at any rate is connected to earth, and if the insulation of a wire is injured by nails or in any way so that the wire itself is put in contact with the lead sheathing, that sheathing immediately rises or falls to the same difference of potential from earth as the conductor with which it is in contact. If the contact happens to be on the neutral wire of the system nothing happens, as that wire is at earth potential; but, if the contact should happen to be with a negative or with a positive wire, there is immediately the full available difference of potential between the lead sheathing and any adjoining water or gas pipe, or other conducting material which may be connected with earth. In the concentric system last mentioned, if the outer conductor were insulated from the lead, no serious result could happen through the nail passing through the successive layers of lead and conductors, as it would first of all connect the sheathing with the neutral conductor, doing no harm; and then, if driven further, cause a direct short circuit between the outer and central conductors, which would be purely an internal affair and produce no greater mischief than the immediate blowing of the safety fuses, assuming of course that they were properly arranged in any such system. If, however, the system is not a concentric one, it is clear that the lead sheathing may be raised to such a potential above a neighbouring compo gas pipe that an arc may be established between the two, resulting in burning a small hole in the gas pipe and igniting the gas. Special attention should be given to this point, as it is not merely theoretical but one which does happen in practice.

Before passing from this section it is perhaps as well to point out two remedies of a common-sense kind for the purpose of preventing such accidents. The first is to avoid laying electric conductors near gas pipes at all, and of course also, in the event of the electric conductors being first in the field, to prevent gas-fitters from running their gas pipes close to the electric conductors. In one instance which recently came under the author's notice, a compo gas tube had actually been drawn into place behind some match lining bearing hard upon some electric wires which had been previously fixed there, the result ultimately was a break out of a gas fire which might have had very serious consequences. The other precaution is to connect the lead sheathing in a thoroughly substantial manner with a water pipe, preferably at some point in the lower part of the building near its entrance. Special attention should be drawn to the fact that it is practically useless to make such an earth connection on an iron gas pipe, as it has often been found that the red or white lead used in the screwed joints for keeping them tight has resulted in making a perfect insulation between consecutive lengths of pipe.

In some of the various systems of lead-covered wiring, special joint-boxes are used with the object of making a sound mechanical job of the joints, without relying so much upon the skill and care of the workman. Where, however, these boxes are used without sweated joints between them and the lead sheathing of the wires, they are a source of danger, as the lead sheathing often draws out of them, thus straining the joints and leaving them accessible to moisture. It is said that this can be avoided by preventing any mechanical strain coming upon the lead sheathing that would tend to draw it out, but where buildings are being wired during construction, and before the ceilings, floors, etc., are completed, experience has shown that it is scarcely possible to satisfactorily guard against an accident of this kind.

The next and perhaps most important departure from the wood-casing system is that of running india-rubber covered wires in iron tubing. There are several variations even of this system—(*e*) ordinary iron gas barrel with screwed joints and cast iron junction-boxes; (*f*) ordinary unwelded sheet iron tubes or skelps with cast iron junction-boxes fitted with sockets, the joints, however, not being screwed or fixed in any way; (*g*) welded iron tubes lined with some insulating material, having joint-boxes, bends, and fittings similarly lined throughout. All these variations possess the advantage that they offer a more or less substantial protection against mechanical injury from nails, etc., which neither the wood casing nor the lead sheathing offers. As regards damp places, however, no protection is offered by the thin sheet iron unwelded skelps with the unscrewed or open socket-joints (*f*), and in fact, in any of the alternatives, special precautions require to be taken in making the joints both in the tubes themselves and in the joint-boxes and connections, to exclude moisture; and it is also desirable that a fall should be given to all pipes, and a proper means of exit provided for water which may obtain entrance to them by condensation or in any other way. Probably tubes lined with an insulating material prevent internal condensation entirely, and they also have the advantage that any damage to the insulation of a wire cannot result in a direct contact with the metal pipe. There is no apparent reason why an extremely satisfactory job should not be made of any of these three alternatives, except perhaps the thin unwelded skelps; but experience has proved that trouble arises with (*e*) and (*f*) owing to carelessness in fixing. For instance, the thin sheet iron skelps (*f*) have frequently been found simply threaded upon the wires, and hanging entirely unsupported except by the wires themselves. The tubes have sharp edges, which in these circumstances usually cut through the insulation, and the state of the job is worse than if no protection whatever had been attempted. This system is sometimes even used out of doors, where it must do more harm than good, as obviously moisture cannot be excluded, and it prevents wet or moisture getting away from the wires, as it would do if they were entirely open. The object of all iron-sheathed systems is presumably the prevention of fire from electric causes, even if defects in the insulation of the wire should occur; but cases have arisen in which the tubes have been so thin that an arc set up within them has rapidly burnt the tube away. To be a real protection, therefore, against fire, the tube must be sufficiently thick to avoid being melted away by any arc which may be started and maintained by a current not sufficiently large to blow the protecting fuses on that section. The ordinary gas barrel arrangement (*e*) has much to commend it, but, at the same time, it is capable of being so misused as to give a great amount of trouble. It will no doubt seem unnecessary to call attention to the fact that all ends of tubes should be rounded or bell-mouthed, to prevent the insulation of the wires passing through them from being cut; yet the author has recently experienced a number of earths and faults due to this cause, and also to the fact that cast iron boxes containing switches and fuses had been so defectively arranged that the point of entrance of the tube into the box was not opposite the terminal into which the wire had to be clamped, thus resulting in jambing the wire hard over on to the sharp edge of the tube or hole in the side of the box, and cutting the insulation completely through. These are defects which the author is almost ashamed to speak of as disadvantages in the use of the system in which they have been found. Surely they should rather be called defects due to the carelessness of the British workman, or to some other persons responsible for the way in which the work has been put together.

In considering the iron tube systems, it must again be remembered that, where they are used in conjunction with a Corporation or other public supply, the neutral or middle conductor is earthed, and, in the event of a contact between a positive or negative and the iron tubing, that the iron tubing may at once be raised to a considerable difference of potential above or below that of an adjoining gas pipe; and, in consequence, just the same accident of piercing a compo gas pipe may happen, thereby causing fire through igniting the gas, as when lead sheathing is used for protecting the wires. The remedies against such accidents are the same as before; viz., to keep the electric light pipes clear of the gas pipes, and to endeavour to make a thoroughly good earth connection to a water pipe at some point near the entrance to the building. This, however, is not all that is required, for earthing at one point, unless the metallic continuity throughout the whole system is perfect, is of little avail. It is quite possible to have the various lengths of tube practically insulated from one another, particularly if red lead or white lead is used for jointing.

The author's experience has been, however, that in many cases no joints whatever are made, the end of a tube being simply projected through the side of a cast iron box, sometimes with lock nuts on both sides, but more often with one lock nut missing or with none at all. It would seem quite possible, and not an expensive matter, to design an ordinary gas tube system with joint-boxes and switch- and fuse-boxes, arranged with proper projections cast upon them, which could be drilled and tapped to receive the ends of the gas barrel, and these, if screwed together clean and dry, would probably make sufficently good contact to secure continuity from one end of the systen to the other, and throughout all its branches. With such an arrangement, and with the switch- and fuse -boxes intelligently designed to have the entrances of the wires opposite the terminals, and ample clearance to avoid the possibility of sparking from the fuse terminals to the cast iron case, when fuses may happen to blow from any cause, an electric light installation should be the safest thing imaginable, both with regard to fire and possible extinction of light from faults in the wiring.

The author has had but little experience of the use of tubes with insulating lining, possibly because contractors find them too expensive for ordinary use; but there can be no objection to them as compared with unlined tubes, if they are properly made, although it is not clear that there is any real necessity to go to the extra expense of lining tubes with insulating material It is the usual practice, if not the universal one, to draw rubber insulated wires into iron tubes, and if no injury is caused to the insulation in the act of drawing in, through internal feather edges in the tubes, arising from defective welding, or from sharp edges at tube ends and other defects in joint-boxes, india-rubber covered wires should have a very long life indeed, as they are not subjected to mechanical movement or to alternate conditions of damp and dry which seem to produce breakdowns in all india-rubber covered wires after being in use for a year or two.

Before passing from the question of the system of conductors and the methods of protecting them, some general review of the whole question upon broad lines, together with some suggestions as to the direction in which we may look for improvement, may not be out of place.

The wood casing system is one which lends itself very readily to the protection and hiding up of bad work in the way of defective joints badly insulated, and even of defectively insulated wire, and there is but little doubt that, a dry building might be wired with dry wood casing and with bare or cotton covered wires and still test fairly well and give but little or no trouble, though fire office inspectors would be quite horrified if they knew of the real condition of things. There is but little danger of actual short circuits in wood casing systems except where T branches are taken off, but such places are usually made apparently safe by cutting out the centre fillet of the wood casing, and by putting in between the wires, which cross each other, a sufficient thickness of insulating material, usually of a hygroscopic nature, which, so long as it remains dry, gives no trouble whatever.

While, however, it gives the best protection against actual short circuits of wires, it encourages bad work, and opens up the serious risk of starting electric fires through leakage from bad joints and defectively insulated conductors when subjected, as any place may be at some time or another, to dampness. It has seemed, therefore, desirable to introduce some improved system which would employ men of the gasfitter or plumber type, who could also be wiremen, and at the same time do away with the necessity for joiners. Such improved systems as those which have now been discussed have the disadvantage, if it is to be called a disadvantage, that bad work can scarcely pass unnoticed in them, and even if it does, with the exception of the possibility of firing gas pipes, the only troubles which arise with them are extinctions of the light.

In the interests of safety it is desirable to use some system which shall break down immediately and put out the light without risk of fire, rather than to go on leaking and smouldering away in some hidden corner, with the probability of breaking out into a genuine electric fire at some time or another. Probably it will be thought that this is a good enough theoretical argument, but, that if it is to result in the extinction of the lights at frequent intervals, the remedy is worse than the disease. But surely an analysis of the actual causes of failures and extinctions of light arising from the use of metal sheathed systems, must only prove to any engineer that it is necessary to carry out the work in a reasonable and proper manner, and that, if so carried out, the metal sheathed systems, more especially the iron sheathed ones, possess very great advantages over the old wood casing. It is doubtless to be regretted if we cannot rely upon our workmen to do their work properly, but surely such troubles as have been already referred to cast some reflection upon those who superintend the work. Little has been done in the way of standardising cast iron fuse- and junction-boxes, bends, and connections, &c., for use with wrought iron gas barrels, and apparently nothing with regard to providing workmen with simple tools for rounding out the edges of tubes after cutting them off, and if some one would display a little enterprise after the manner of our American cousins, a most complete, safe, and satisfactory system of iron tubing could be introduced, which at the same time would not be too expensive for general use. It is usually the labour which costs the greater part of the money in fitting up an installation, but if things could be standardised, so as to reduce the amount of time necessary to spend in consumers' houses (to their great annoyance), it might still be possible to carry out the work at an even less cost, though the materials might be a little more expensive.

The author has long hoped for the introduction of a concentric system of conductors, with the outer sheathing of wrought iron tube containing, as an integral part of it, the two conductors with their insulation, the whole of the tube being filled up solid. That is to say, a cable like the concentric lead-covered cables referred to in this paper, but covered with iron instead of lead. The difficulty, however, of jointing with such a system has seemed unsurpassable, and, as it would not be workable to have the conductors made in lengths longer than fifteen to twenty feet, the joints would be of frequent occurrence. The difficulties would be much reduced if the outer conductor could be uninsulated, as the iron tube itself might then be used as a return conductor, leaving only the one wire to be jointed and insulated. The connection between the iron tubes might be made either by long screwed sockets or split sleeves or glands, and in either case secured in place by grub screws; or, by a plain bored length of tube screwed taper on the outside, having saw cuts at each end and nuts to screw down and make it tightly grip the tube ends which it encloses.

It is not proposed in this paper to go into all the details of fuses, switches, lamp-holders, fittings, and all the accessories appertaining to the wiring of a building, but to adhere to the question of wiring systems and general arrangements. The second point, therefore, to be dealt with, is that of the general arrangement of wiring in various buildings. The original conception of wiring was to run a pair of conductors from the point of entrance to the building up through the various floors, taking off branches at each floor and reducing the section of the mains after the tapping of each branch. This system has been generally spoken of as the tree system, presumably from its resemblance to the growth of a tree, the mains, or trunk, being thick and heavy, but getting thinner and thinner as they go upwards and as each branch leaves them. The branches also taper down after each tapping of a smaller branch. This system is a simple one, inasmuch as it makes use of the minimum possible *length of wire*, but it becomes complicated when the question of fuses is considered. Fuses are inserted with the object of preventing the overheating of any wires which may be served with current through them, the fuse itself blowing and cutting off the supply before the current be increased to such an extent as would cause the serious heating of the wire. Theoretically, therefore, it becomes necessary to place fuses at every point where a branch is taken off from a main or from a larger branch. This arrangement, if carried out consistently, results in scattering fuses throughout the building in an indiscriminate manner and in all kinds of awkward places.

To obviate this objection the distribution board system was introduced. In this system, conductors are led from a main distributing board near the point of entrance of the supply to various other distributing boards placed at suitable centres within the building, and from these distributing boards small circuits, supplying only a few lights each, are carried away in all directions, surrounding each centre as required. In this way fuses are fixed, firstly, upon the main distributing board, and secondly, upon each of the local distribution boards, and practically no other fuses are required. This system possesses the great advantage that, if a circuit of lights is extinguished through any petty accident to a lamp-holder or flexible, any one knows at once where to find the fuse, and as distribution boards are generally fixed in some convenient and accessible position, the fuse can be replaced and the light again put on with the least possible delay. The small circuits which branch away from the local distribution boards are not supposed to be reduced in section throughout their entire length, nor on any of their branches, until reaching the fittings to which they carry the supply. If flexibles, having a smaller section of copper than the branches which supply them, are used for pendants or portable lamps, fuses are required in the ceiling roses or in the wall or floor sockets, unless matters can be so proportioned that the current which would be required to burn up the flexible is ample to cause blowing of the fuse at the distribution board, even when none of the lamps on the circuit are lighted. The distribution board system has obviously some very considerable advantages over the older or tree system, but at the same time, if large distribution boards with great numbers of circuits are used, it becomes a matter of some difficulty to get so great a number of small wires away from the distribution board in any convenient manner. In order to avoid unsightliness, what is technically termed "bunching" is resorted to, and while this is not objectionable to a reasonable extent, it may easily become very troublesome if carried too far. If wires, even of the same polarity, are bunched together, an accident may occur which will connect all of them together at a certain point, though at that point they may not be connected to "earth." One of the wires continuing past that point may, however, get connected to "earth," and if it happens not to be a neutral wire, as there are two chances to one it will not be, that wire may then be burnt up, as it is supplied not only through its own fuse, but also through all the fuses which belong to the other wires connected in parallel. Again, if only one wire of a bunch be damaged and an arc be started between it and some "earth," or in case of broken continuity, between the two ends of the wire, then the whole of the wires in the bunch are likely to be damaged by the accident which happened to one of them only, and if the wires so bunched are of mixed polarity the result will be more serious still. It is clear, therefore, that if bunching is to be allowed at all it must be limited. A convenient and fairly safe limit may be set at two wires only when of opposite polarity and in iron or other suitable metal tubing, and four wires only when of the same polarity, either in metal tubing or in wood casing. In each instance the circuits not to carry more than three ampères each at 250 volts.

There is a strong tendency with many people to treat small branch circuits of about three ampères each just as electric bell or telephone wires, after they have left the distribution board, as though the fact of passing through the fuses robbed these small circuits of all power for mischief of any kind. This is a most erroneous idea and must lead to trouble and annoyance, if not indeed to disaster, if habitually put into practice.

It is extremely desirable to have no bunching at all, though there are admittedly cases where some compromise within safe limits must be allowed. The apparent necessity for bunching often arises from assembling too many branch circuits on one distribution board, so that many of the circuits take the same route for some distance from the board. This can usually be remedied by providing more distribution boards and placing them at more frequent intervals. In doing this, however, the question of connection between these boards and the mains requires to be looked into. If the distribution board system is to be maintained from start to finish, it will become necessary to run a considerable number of main branch circuits from the main distribution board to the numerous smaller ones. The same difficulty will arise here, and serious temptation to "bunch" immediately follows. Bunching, however, in the case of these larger circuits should be absolutely prohibited for the simple reason that, do what one will, the amount of current which may pass for destructive purposes must be so much greater than in the instance of the three ampère circuits before referred to. The remedy in such cases is to be found by departing from the distribution board system, so far as the main circuits are concerned, and introducing a common-sense compromise between it and the tree system.

Take the case of a building of four floors in height. Let there be one, or, if the quantity of current requires it, two pairs of mains running up the building from bottom to top. The section of these mains should not be reduced, and, if possible, they should be run perfectly straight and without joints, except where the branches come off. At each floor, let there be one or two branches taken off as the case may require, each branch having its own pair of fuses fixed as close as possible to the main. One or two distribution boards with three ampère circuits can be fixed immediately on each branch, or, if the building is so large that bunching beyond the reasonable limit of four wires of same polarity would require to be resorted to, these branches may be continued along the corridors, and have several distribution boards tapped off, each of them at convenient intervals—the section of the branch not being reduced throughout its length. Where a building contains a large number of offices occupied by different tenants, each of whom is an independent consumer with a separate meter, &c., it is generally far simpler to discard the distribution board system altogether, except, perhaps, within the offices themselves, and to run a pair of branch mains along each wall of each corridor, taking simple tappings off for each consumer with a pair of fuses outside his wall, accessible only from the corridor, and arranged so that they can form the sealed fuses of the supply authority.

Diagrams, Figs. 1-4, are given showing ways in which the various conditions to be met with in large buildings may conveniently be dealt with. They are often complicated by the fact that the building contains an electric motor for driving a hoist or for some other purpose, which requires to be supplied at 500 volts; and, in consequence, to have its wires run entirely in iron pipes, well earthed, and to conform to various special regulations issued by the Board of Trade.

Another trifling circumstance which sometimes destroys the symmetry of the diagram is the stair and corridor lighting, which may require to be supplied through a separate meter, and, consequently, through separate mains and branches.

These two points, however, are quite easily dealt with, if a little consideration be given them, as the diagrams will show.

Discussion.

The discussion on this paper took place on 20th February, 1900.

Mr Fred Bathurst (Visitor) presumed there would be no difficulty in convincing them that the first cost—the cost of the wiring—was the main consideration in electrical application. Electric wiring, as Mr Chamen dealt with it, referred mainly to electric lighting. In the matter of illumination, electric wiring cost more than gas piping. Gas at present held the field, and held it far more securely than it would do if they were in a position to give electric wiring at the same first cost as gas piping. He went specially into this subject of wiring some years ago, and his idea was to supply an "electric piping" system on all fours with gas piping, in respect to the manner in which it could be put into a house, and its cost; but certain Board of Trade regulations still stood in the way, and these difficulties could only be removed by ventilating them and by full discussion. Mr Chamen had mentioned the various systems of wiring that could be employed, and it was for the members of the Institution to discuss the systems and indicate the requirements of those they would rather adopt. The author pointed out the main objections against wood casing—that it was extremely unsatisfactory in damp positions, and dangerous in wet places. It was a fact also that it afforded no mechanical protection against nails and screws, and when fitting it up two classes of workmen had to be employed; viz., wiremen and joiners. Mr Chamen might have pointed out a little more forcibly that wood casing should only be used on the surface. It was convenient for accessible surface work, but its disadvantages must be evident, especially when put underneath the floor boards or under plaster facings, for not only damp and other troubles attacked it, but nails and screws from outside could injure it. It was mechanically weak as well as electrically unreliable. The fact was that damp or mechanical troubles might cause fire, or, if not fire, at least electrical discontinuity, so that the electric current supply might fail when it was most wanted. The lead-covered systems approached the compo system of gas piping, and if the standard

Mr Fred Bathurst.

practice in gas piping were considered, it would be admitted and fully recognised that *iron* piping was the proper practice to adopt. The lead covering had advantages over wood casing, but it was still mechanically weak, and when put under certain plasters it would in the presence of moisture decay, and in that way cause trouble. Mr Chamen pointed out that "no one as yet has proposed to use wires of the concentric construction in which both conductors are insulated." At Harrogate, this system of using one wire inside the other was being tried. In taking connections from these wires, there was the difficulty of getting at the inner one, which had to be effected by cutting away the outer one and yet keeping both carefully insulated. In regard to the question of "earthing," Mr Chamen pointed out that in any system where iron or lead tubing was used, from the fact that the station was already earthed, it was necessary to connect the metallic coating surrounding the electrical wires to the nearest gas or water pipe. When that was not done, there was a chance of the electric pipes and wires in the house becoming electrically charged and touching the other pipes, and, by electrically sparking on to the gas pipe, so burn a hole in it, by which the escaping gas could set fire to the house. This would be the case where the two rival illuminants were in the same house. Mr Chamen recognised that, for safety, *all* the metallic systems should be electrically connected to the water pipe. At present, however, the Board of Trade rules insisted on earthing the neutral conductor of the three-wire system at one point only. That was at the generating station, and his (Mr Bathurst's) contention was that pressure should be brought on the Board of Trade to have this earthing principle adopted completely. A station was made to earth its electric system at one point by regulation and law, but he had no doubt that Mr Chamen, and other engineers, would recommend that it was proper for every house in which metallic protected electric wiring systems were used to connect permanently to the water pipe. To connect through to the station was not allowed, but it was virtually done daily, only imperfectly, and without gaining

Mr Fred Bathurst.

the advantages possible. If the Board of Trade would countenance such practice completely, the outer metallic piping would be used as a conductor instead of simply as a protector. If it were generally recognised that the metallic return could be used for a double purpose—for the purpose of connecting right through to the earth at the station and to see that it electrically protected the wires (the object they were using it for to-day)—then, without any serious alteration, the cost of wiring could be immediately reduced by one half. Mr Chamen said: "It is perhaps as well to point out a remedy of a commonsense kind for the purpose of preventing the possibility of such accidents. That is to avoid laying electric conductors near gas pipes at all." Most would agree that they had to go into houses where there was gas, and where they must go near gas pipes, and they would require some better suggestion than that. It seemed to him that this earthing principle, as at present arranged, was more or less absurb. They carried it out to some extent, but it was not officially recognised that they were doing so. They were certainly not doing it in the way which would reduce the cost of wiring and labour. No doubt, Mr Chamen admitted, there was a general movement in favour of iron piping, the main reason being the desire to find a proper mechanical method of protecting the two insulated wires. Of course the piping brought its own troubles. In cutting a pipe, a "burr" would likely be left on the inside edges, which would destroy the insulation on the wires as they were being drawn in. Cheapness was the first object, and a "close" or "open" joint conduit was now being used, but that had a difficulty of its own, and it could not be set or bent properly. The seams opened, and they could not get the complete protection that was looked for. That system was coming in very largely, but he ventured to think it was only a transitory stage until right principles were reached. He maintained that insulated iron piping was the only perfect form of electric piping that could be adopted, but the question was how to do it. In consequence of the earthing regulation not being allowed, two insulated wires had to be placed into the pipe.

Mr Fred Bathurst.

If earthing was adopted generally, then with a pipe having an insulated lining only one bare copper wire would be required. The bare copper wire formed the positive, and the pipe formed the negative or return conductor. There were ample facilities for getting supplies of bare copper wire, and the contractor would only find it necessary to buy insulated pipes and keep a stock of bare wire for his workmen, who could not damage its electrical qualities in the same way as they damaged the expensive insulated wires to-day. If the cost of wiring were reduced, and the wiring done well and satisfactorily from the first, those in Glasgow would enjoy and extend the many and various applications of electricity.

Mr H. A. Mavor (Member) hoped he might not seem ungracious if he set himself in strong opposition to Mr Chamen's position in the paper. He referred principally to the point on page 137 where Mr Chamen said that the Board of Trade rules were beyond the scope of this discussion. While he believed very strongly that Mr Chamen thoroughly understood this whole question, and had brought this paper before the Institution with an excellent object in view, namely, to stem the tide of bad workmanship, he thought, on principle, that this was a matter which Mr Chamen (in his official capacity), and the Board of Trade, ought to have nothing whatever to do with, because their interference in this was bringing about the same disastrous results as it had brought about in other directions. Mr Bathurst rightly pointed out the absurdity of the regulations of the Board of Trade to the effect that conductors on the lighting system must be earthed only at the station. He would like to illustrate what that meant. At Port-Dundas, the Glasgow Corporation were arranging two electric stations, one for the lighting system and the other for the tramways. The Board of Trade regulations were absolutely incompatible. There was nothing to prevent the power station from supplying lights everywhere over its system with earthed connections at all points of the distribution, and without breach of the Board of Trade regulations. Further, there was nothing to prevent the lighting station from connecting its mains to the

Mr H. A. Mavor.

tramway system which was earthed at every point, and yet a householder who took his lights from the same system was not allowed to make an earthed connection at his house. Mr Chamen's paper, to his mind, constituted one of the strongest arguments which could be adduced for the introduction of earthed connections all over the lighting system. It was clearly shown that the only way to secure safety and satisfactory working was to protect the wiring inside a continuously earthed metallic sheathing. To do this with double wiring inside, the sheathing was, in his opinion, unnecessarily costly, while the use of a concentric system in which the continuously earthed metallic sheathing formed the return conductor, was the only way to satisfactorily meet the two essential requirements of safety and moderate cost. He felt strongly on the subject, because his company, as electrical engineers, had refused for some years past to carry out wiring installations in connection with Corporation stations, because of its opinion that the ordinary methods of wiring for connections to the Corporation supply were not satisfactory either mechanically or economically. The Admiralty system of wiring with two conductors, each enclosed in a separate earthed metallic sheathing, made a satisfactory double insulated system, but was exceedingly costly. Mr Chamen had very rightly pointed out that the risks of short circuit, that was to say accidental contact between the conductors, were small as compared to the risks of discontinuity of the circuit, and it was this which tended to make the enclosing of two conductors in a metallic sheathing a difficult and expensive or dangerous proceeding, because, it was difficult to ensure that the proper electrical connection would be made and maintained throughout the metallic sheathing through which normally no current was allowed to pass. An accidental contact between one of the conductors and the metallic sheathing would be almost certain to give trouble if there were any break in the continuity of the sheathing. He accepted the whole of Mr Chamen's arguments and all his conclusions, but he objected to hold himself bound to the present Board of

Mr H. A. Mavor.

Trade regulations. In Mr Chamen's official position he could not, of course, go past the Board of Trade, but there was nothing to prevent a discussion of the matter on technical and scientific grounds, and on these grounds he had to urge that the Board of Trade be called upon to stop their interference at the door of his private house. He thought it was an extraordinary state of matters that he, an electrical engineer, was not allowed to wire his house in a safe and mechanical manner, because the Board of Trade objected to earthing the conductors on the lighting circuits, whereas, everyone who understood the subject admitted that it was a right and safe thing to do from the point of view of the consumer. All owed a debt of gratitude to Mr Ferranti who was the first to point out to the Government authorities that it was impossible to safely conduct high tension currents of electricity, without thoroughly earthing one of the conductors and enclosing the live conductor in the earthed conductor. Eight or nine years ago, his company had to wire an explosives factory for electric light. The proper method of wiring the buildings by means of concentric earthed conductors was adopted, in direct contravention of the Fire Office rules and the Board of Trade regulations; and, after a careful inspection of the whole of the work, the Home Office had the wisdom to pass this installation as being perfectly satisfactory. This installation had never given any trouble. Following up this experience, his company had put in many thousands of lights into cotton mills and elsewhere. In one special case there were thirteen fire offices on the risk. After the installation was completed, the usual schedule of questions was sent to the company for answer. Its reply to the question — "Was the installation in accordance with the insurance regulations?" was "No." To the question—"In what respect does it depart from these regulations?" The answer was, "In every essential particular." The fire companies then refused to pass the risk, and sent a special inspector representing them all to examine the installation. This inspector reported that it was one of the safest installations he had seen.

Mr H. A. Mavor.

The thirteen offices were now on the risk. That being so, he thought they would agree with him that there was a good case for adopting an attitude of opposition to the regulations prohibiting the use of such a system. He would point out that this was not a case of special pleading on behalf of a special method of doing the work, because, it was open to him to do the work as other people did it were it not that he believed that the ordinary methods were positively dangerous as well as unnecessarily expensive, and it was also open to anyone to adopt the proper methods. Mr Chamen was quite aware that he made no suggestion that he was not alive to the truth of what he stated, and he felt that Mr Chamen's position was one in which the best had to be made of a bad job, but he entirely took exception to this attitude being adopted on other than purely official grounds. Mr Bathurst's ingenuous argument in favour of the use of metallic tubing was worthy of respect, but he (Mr Mavor) failed to see wherein the consumer benefited by an arrangement in which he was saved the expense of keeping insulated copper wire in stock by the expedient of keeping insulated tubing in stock. Mr Bathurst's argument that the only satisfactory way of doing the work was to have one conductor continuously insulated and the other not insulated from earth was a right and sound one, but he (Mr Mavor) rather thought that putting the insulation outside the positive conductor was a cheaper and better expedient than putting it inside the negative conductor. There was a point, worthy of consideration, which had not been noticed in Mr Chamen's paper; viz., that the insulation of the negative conductor need not be of the same character as that of the positive conductor. Where buildings were wired with double wiring, and two conductors, each covered with an expensive insulating material, were used, the cost was unnecessarily great. While the positive conductor was maintained at a potential of 250 volts or more, the negative conductor never rose to a potential of 20 or 30 volts above the earth potential, so that even taking the Board of Trade regulations as they stood, the protection to the negative conductor did not require to be of

Mr H. A. Mavor.

the same character as that of the positive; the principal points to be observed being a continuous metallic connection and protection from moisture, whereas, in the case of conductors which carried currents at 250 volts above the earth potential, something in the nature of a really high insulating material was necessary. If the precautions suggested by Mr Chamen were carried out, a safe installation might be made and there need be no fear of fire risks on the part of those who were willing to spend money on this class of work. In fact, the risk of fire from electric conductors had been greatly exaggerated by insurance companies whose interest clearly was to keep their finger on the consumers, by making most of the fire risks. They had succeeded in doing so in this country to a greater extent than anywhere else. All over the European Continent, and in America, the wiring of houses was carried out in a much cheaper and quite as effective a manner at a much lower cost. The use of small porcelain insulators fixed to the building by means of ordinary wood screws, and to which the lightly insulated conductors were suspended, was a much safer method of wiring than the use of continuous wood casings or compo tubing. It was somewhat unsightly in highly decorated rooms, but in the great majority of cases, in his opinion, the method described was quite good enough as far as appearance was concerned, and if carefully carried out it made a perfectly sound job. He pointed out that when Lord Kelvin, who was recognised as something of an authority on such matters, had to arrange an installation of electric lighting not many yards from the meeting room, he carried it out with bare conductors supported on wood insulators at intervals of about six feet apart, the conductors having been left open throughout with no continuous covering whatever on the wires. He held that this was a much safer method than to carry out the installation in strict accordance with fire office rules, which, as was well-known, gave most elaborate and detailed instructions for avoiding practically every expedient which Lord Kelvin saw fit to adopt in this case.

Mr ARCHIBALD DENNY (Member) said that his experience of

Mr Archibald Denny.

electrical work was principally in ships. He sympathised with what Mr Mavor had said with regard to the Board of Trade, and was glad to say that the shipbuilders had succeeded in maintaining their professional independence with the Board of Trade. He was not partial to Government interference with trade. With regard to ship wiring, in most vessels there were not a very great number of lights, and he had found that, as a rule, where the cables were divided up gradually from the main board to auxiliary boards, and from auxiliary boards to the fuse boards, the ordinary vulcanised rubber cable, carefully fitted, was sufficient. His firm used lead-covered wires in all damp places, and lead-covered armoured wires in the engine room. He preferred single wiring to double, but he was aware that it was not approved by everybody. With less wire there was less risk. With double wires there was the chance of either wire going to earth without knowing it at once. Perhaps the concentric system was the best, but expense stood in the way a good deal, and it was not so flexible as the ordinary system used by his firm. Single wiring interfered with compasses on board ship, and in their vicinity double wiring had to be fitted if a continuous current was used. Curiously enough, in the first ship his firm wired, in 1884, an alternating current was used, with a Ferranti ribbon machine. The machine was sold as being sufficient for 150 lamps, but it carried 300, so in that case a good bargain for the money was had. This showed how little was known about electricity in those days. Instead of putting the armature athwartships, it was placed fore and aft, and when the ship rolled there were brilliant fireworks. When the number of wires became great, there was a difficulty in finding room on board ship. At first his firm adopted the tree system, and perhaps some combination of tree and distributing boards, such as Mr Chamen suggested, might be adopted on board ships with advantage. The great difficulty to contend with was moisture. If it was present in a house, it was only to a small extent; on board ship, however, it might obtain to any extent, even to the wire being fully immersed in salt water; but, by using properly

Mr Archibald Denny.

covered wires without joints, except at lamps, switches and boards, lead-covered and armoured in very exposed situations, there was wonderful freedom from accidents. He objected altogether to wires drawn through iron pipes; the pipes were simply water-traps His firm had tried almost all systems, and found faults in them all, but perhaps the concentric system was best for ship work, although it involved a great deal of care and trouble, and was, as he said, not so flexible, nor did it admit so easily of additions.

Mr W. B. SAYERS (Member) thought there was very little in the way of guidance in Mr Chamen's paper. The author had a partiality for all sorts of systems, but he came back to the fact that at present the really safe system was that in which conductors were enclosed in some strong metallic tubing, such as iron or steel. The main point in connection with electric wiring had long appeared to him to be the question of workmanship, and that was very evident from Mr Chamen's paper. Of course a suitable material which did not absorb moisture, and did not corrode or go wrong was essential, and there must be a sufficient space around the fuses, so that if a short current occurred an arc would not be started between the terminals and surrounding metallic work. Sufficient breaks with switches, etc., must also be provided to secure the essential conditions, and almost any of the systems which Mr Chamen had spoken of would no doubt give satisfaction if only the workmanship was perfect. Even to-day, he was sorry to say that the workmanship in electric wiring was far behind the usual standard of workmanship in any other branch of trade. If a piece of gas-fitting done by any ordinary gas-fitter, or a piece of plumbing work were examined, one saw evidence of skill and knowledge on the part of the workman who had done it. This, however, was not the case in a large proportion of electric wiring jobs that came under his notice. He was not altogether in sympathy with Mr Mavor, who said nothing whatever about the difficulty of electrolysis which would arise from the difference of potentiality of conductors that were earthed over a large area. He was inclined to think that the earthed concentric system would be satisfactory

Mr W. B. Sayers.

now that higher pressures and smaller currents for a given amount of lighting and a given amount of electric energy was being used, and also because with the three wire system now almost universally adopted for continuous current distribution, the only current which circulated in the earthed part of the system was the balancing current. The more nearly the circuit was balanced the less current was circulated in the middle wire; it diminished in proportion to the perfection of balancing. He disagreed with Mr Chamen on the question of bunching. Mr Chamen considered that bunching was dangerous, and on page 147 he said: "It is extremely desirable to have no bunching at all, though there are admittedly cases where some compromise within safe limits must be allowed." Instead of calling it bunching he (Mr Sayers) would call it *subdivision*. Mr Chamen preferred large heavy cables running up a building, with branches, to a number of wires grouped in the same tube. He also said: "Do what one will, the amount of current which may pass for destructive purposes must be so much greater than in the instance of the three ampère circuits before referred to." Well, the larger the cable the larger the amount of power present for destructive purposes. Mr Chamen instanced a case which he (Mr Sayers) thought was a very remote contingency indeed. No doubt Mr Chamen knew of one case in which it had happened. It was extremely unlikely that an arc would be set up between two conductors in a tube. If such an arc did occur it would almost certainly get to earth on the tube and break the fuse. Suppose, however, that by some means the wires did get all joined together, which was most unlikely, the next thing that must happen before a disaster could occur was for one of the wires to get to earth at a distance. His contention was that the bunched conductors were very much safer than the large conductor. The large conductor was comparatively stiff and much more likely to get into contact on one edge of the tube than one of the smaller ones. If the smaller conductor did get into contact it was almost certain to have its fuse blown and put out of circuit. Where did the safety of the large conductor come in as compared with the

Mr W. B. Sayers.

number of smaller ones? He agreed there must be some limit, but he thought the limits specified by Mr Chamen were far below what they should be. The author recommended straight runs, but only in one case out of ten could they be obtained. If the conductors were planned in the first instance to have straight runs something would turn up, the architect would have to put in a beam or a buttress, and the tubes and conductors would have to be deflected. With regard to Mr Bathurst's system he should like to ask: What was the character of the insulating material in the tubes? It was quite obvious that the insulating lining must be non-hygroscopic, the casing itself water-tight, and it seemed certain that the insulating envelope would also require to be absolutely water-tight. A system of the kind described with a bare conductor would go rapidly wrong if any water got into it, as the copper would be attacked and the insulation saturated with some salt of copper or iron, or both, and the system would break down.

The discussion on this paper was resumed on 20th March, 1900.

Mr W. M'Whirter (Member) observed that the discussion on Mr Chamen's paper had already brought out a great deal that would interest the members and give them much information. The author referred to the difficulties experienced owing to the peculiar nature of rubber; it was liable to perish, in a manner quite unaccountable to those who were continually using it. He could not offer any reason for that, but he was inclined to think that there must be something in the manufacture of it, for those who could look back to the sixties would remember the cables laid down by Hooper in the Persian Gulf, and other tropical places, which did good service, and after a long period were found to be as good as ever; so that it could not be said that deterioration was all owing to heat, because there the temperature would range up to 100° Fah., and it could not be said that it was due to moisture, because these cables were totally submerged. They were met with a suggestion to use lead-covered wiring, which he believed was a good one. He thought it best to

Mr W. M'Whirter.

keep the wires as much as possible on the surface, and lead-covered wire was certainly better than wires covered externally; but if the plaster was green it very often attacked the lead and gave much trouble. He had had considerable experience of lead covering, with the Callender cable, and others of similar type, and great stress was laid upon the good results that were about to accrue from the use of that cable, and he remembered in several instances—in every instance where he used it—it turned out a failure. The cable was good so long as the lead cover held, but when it gave out the cable simply went to dead earth. Hundreds of thousands of pounds were being sunk in the streets of Glasgow and elsewhere upon cables depending entirely upon the lead covering. Of course the precaution was being taken of spreading the surface with a very thin coating of bitumen. In his opinion that was not sufficient, because it was a well-known fact that lead gave out in the most unaccountable manner in places where no one would suspect it, and he had taken out lengths of cable where the lead had crumbled to pieces. On page 139 Mr Chamen referred to unwelded tubes or skelps. If in that system a joiner could be prevented from putting nails through the tubes it would be a very excellent one. The makers of that system claimed that it was proof against punctures by nails, but he had to come to the conclusion that a joiner could drive a nail through anything up to an $\frac{1}{8}$-inch steel plate, and tubes of about $\frac{1}{16}$-inch thick were of no use in resisting nails. It would take too long to go over all the systems enumerated, but he agreed with Mr Chamen, that all were good in their way, provided that the work in fitting them up was properly carried out. He was much surprised at the doleful manner in which both the author of the paper and the various speakers deplored the skill of the British workman. He had never heard such a dull tale. It was a terrible indictment, but in his opinion the masters and the engineers were alone to blame for the state of things described. They had abandoned the good old system, or they had never given it a trial—the system of apprenticeship—and the result was that any smart fellow who could handle a pair of pliers, or believed that he could

Mr W. M'Whirter.

make a joint, could step in and demand a high rate of wages and yet know next to nothing about what he was doing. He had seen a joint made by one who had no idea as to the care and skill necessary to obtain perfect continuity, in fact he was in gross ignorance of the work entrusted to his care. He tried to bring about an alteration in this state of affairs, and met a number of engineers in Glasgow, and proposed that, as at that time it was impossible to send the men back to work their apprenticeship, they ought to have some method of certification for properly qualified workmen, and he thought this paper showed the growing need for something of the kind. At present an unknown workman, demanding a high wage, might come to him and say that he had been with Mr Mavor, or Mr Chamen, or somebody else, and his word had to be taken; and it was only after he had been sent out to a job it was discovered that he was a useless individual. A remedy for that was certainly within the reach of electrical engineers, and it was possible for them to put it right. The only suggestion that Mr Chamen gave of getting over the difficulty was where he hinted that plumbers and gasfitters should be employed. With such a certificate as that, if Mr Chamen's plumber would only publish his address he was sure his fortune would be made, because plumbers had not been considered ideal tradesmen, and he had never heard any one give them a good name till Mr Chamen posed as their champion. He very strongly agreed with Mr Sayers' idea of bunching. Mr Chamen must have had a scare to make him look at this matter in such a way as he did. In a case of bunching, occurring as it mostly did in small branch circuits, there were usually three wires bunched as the minimum, each carrying a current of three ampères as the maximum; but supposing there were ten wires altogether, and assuming that a fault occurred which would throw the whole current from the ten circuits on to one, if the fuses did not blow as they ought then the total load was only 30 ampères. Such a wire would be able to carry that current for a considerable time. That, Mr Chamen would admit, was a very extreme case; but so long as wires

Mr W. M'Whirter.

of opposite polarity were kept apart, except where enclosed in a metal casing, the question of bunching was not so serious. With reference to the method of sub-mains which Mr Chamen advocated, that was very old, it was before the public ten years ago and had been abandoned, as many fire offices and engineers would not permit of joints upon any consideration. However, he thought Mr Chamen was justified in bringing that point forward, and he had no doubt that the system might be introduced with the best possible results. He would have it strictly laid down that there should be no reduction in the sub-mains, and the conductors should be carried entire to the extreme end, and, wherever branches were led off, there should be fuses as close to the sub-mains as possible. Mr Denny had told them how exceedingly anxious the Board of Trade officials were to keep the shipbuilders right, but he was sure that if any section in this country had cause to bless or ban them it was the electrical engineers. They had had them from the cradle to the present time, and he must say there was no profession in the country that was so well looked after. They had the Board of Trade, and behind it the fire offices, and behind them the municipal engineer, and last, but not least, the consulting engineer. A consulting engineer sent out a specification and intimated that the work was to be carried out in conformity with the rules and regulations of the Board of Trade; the rules and regulations of *all* the fire offices which had any interest in the risk; it must also conform to the requirements of the municipal engineer; and the rules of the Institution of Electrical Engineers for fire risks, excepting so far as these various rules differed from this specification, which must in every part be carefully worked to.

Mr Sam Mavor (Member) considered that no one was better qualified by experience to deal with this subject than Mr Chamen, and he thought they should thank him for the manner in which he had brought it before them. Mr Chamen's method contrasted favourably with the method of some Corporation engineers elsewhere. In Manchester, for example, the Corporation electrical

Mr Sam Mavor.

engineer had taken it upon himself to specify what apparatus should be used in the consumers' houses; and he made up a list of various apparatus and said: "You shall not put into your own house any switch which does not appear in my list or which I do not previously sanction." In doing this he thought the supply engineer was going outside of his province. Imagine for a moment the Corporation gas engineer going into their houses and objecting to the use of a particular type of gas burner. Put in that light the absurdity of it was clear. In so far as a consumer's method of using the current interfered with the continuity of supply to his neighbour, the supply engineer had an undoubted right to interfere. But if they paid for the current through the meter, and used it in such a way as not to interfere with their neighbours, he did not see that the type of internal fittings used should concern the supply engineer in his official capacity. The question of workmanship referred to by Mr M'Whirter was a very difficult one, and the reason was this, that the electric wiring in shops and dwelling houses was not a skilled tradesman's job. It did not require a skilled tradesman to carry it out except for the joiner work. The tradesman got his cables and his switches ready made from the suppliers, and he had only to put them in place, and he (Mr Mavor) contended that any intelligent man who had had six months training was quite competent to make a joint. In house wiring every joint was like another, and it did not require any special skill, but only a little intelligence and handiness. It was not fair to make a youth serve an apprenticeship of five years to such a trade. It was not a skilled trade. The only justification for keeping an apprentice for five years at a very small rate of wages was that he was being taught something. After the first six months as an operative wireman he would learn nothing. Any trade or occupation which could be so easily acquired must have a large number of comparatively incapable men who drifted into it because they were incapable, or had lost the opportunity of learning another trade. He thought all that

Mr Sam Mavor.

pointed clearly to the necessity of stringent inspection during the progress of work, and he felt strongly that this inspection was rather the business of the insurance companies, because they bore the risk of the results of bad workmanship. A good many fires had occurred in Glasgow and elsewhere, and the number would certainly grow. It made one squirm to see, in so many shop windows, 250 volt lamps hanging on flexible conductors twisted round the sharp edges of metal fittings. It was an absolute certainty that fire after fire would occur in those windows, and if the insurance companies did not take the matter up very soon they would be forced by costly experience into some method of inspection or to raising the premiums. In a city like Glasgow, where the interests were so great, it seemed to him that it would be quite feasible for the insurance companies to employ three or four inspectors, and it would pay them, whose duty it would be to go around and make an inspection of the work during its progress, as much of it could not be inspected after completion. The question of standardising was an important one, and it had not had sufficient attention. He did not know that there were more than one or two systems of wiring that laid claim to standardisation. It was claimed for the system with which he had been specially associated, concentric wiring, that it had been reduced to a standard. His firm had many installations, running into thousands of lamps, carried out with only two sizes of conductors, the main and the branch, one size of junction, and so on, and that was a direction in which a great improvement in other systems might be looked for. Standardisation could only come after the system had taken root.

Professor A. JAMIESON (Member) said he was pleased to hear Mr Denny's reference to the very early days of ship lighting, and to learn from him that the wiring, fittings, and electric lighting plant of the S.S's. "Arawa" and "Tainui" (built and fitted out electrically by Messrs William Denny & Bros., of Dumbarton, in 1884) were still intact and serviceable. He acted as consulting electrical engineer for these two steamers, and, in his paper on the "Electric

Prof. A. Jamieson.

Lighting of Steamships," read before the Institution of Civil Engineers in 1884,* complete plans of the plant and positions of the 300 Swan lamps of 20 candle power each, together with insulation and copper resistance tests for these vessels, were given. These were early examples of the single-wire system, using the ships' plates as a return path for the current. Extra care had been taken in fitting the wires, and only the best class of insulating material had been used throughout, so that the insulation resistance of the whole forward system of cables and wires, including the branch and single switches, fuses, &c., but with the lamps left out, reached 30·75 megohms per lamp, and the copper resistance of the longest section on board, from the dynamo to the furthest lamp, was only 0·29 ohm in the case of the "Arawa," just before she left for New Zealand. Similar results were obtained from the "Tainui." The high-class material and workmanship put into these two vessels naturally led him to think of Mr M'Whirter's remarks regarding the present-day wiremen and the causes of slip-shod work; with those remarks he thoroughly agreed. Electric light and power contractors should employ wiremen who had served a sufficient time at their trade, to insure that they would be able to do good sound work in accordance with the rules and regulations laid down by the Institution of Electrical Engineers. These rules had been drawn up most carefully, and had been submitted to the trade. If there was anything wrong with them, let the trade complain, and have them rectified as soon as possible; so that consulting engineers, corporation electrical engineers, fire insurance companies, contractors, and workmen, might, one and all, know exactly what they were expected to demand and supply. He did not agree with Mr Munro that Corporations should lay down rules for the inside wiring of buildings, and also supervise the work as it proceeded. Their province surely went far enough when it included the Corporation meters and all that pertained from the Central Stations to and including these meters, in the same way that the water and the gas

---

* Proc. Inst., C.E., Vol. lxxix., Part 1, 1884.

departments looked after their respective supplies. Did the water and the gas engineers of the city, supply their respective pipes and fittings to Corporation buildings in the same way that Mr Chamen and his staff were at present wiring, fitting, and supplying lamps to Ruchill Hospital and the New Art Galleries? It might very well be asked where the line was to be drawn? He thoroughly sympathised with the Board of Trade rules when they were first drawn up, because, at that time, there was no certainty that electrolysis might not be caused by imperfectly earthed return wires. Now, however, these rules could safely be modified to include the earthed return system as advocated by Mr Henry Mavor, and successfully carried out by his firm, for it was simply a case of the old submarine cable over again, but with a greater need for inspection of the several earth connections.

Mr JAMES DEWAR (Associate) said there had been many questions raised about systems, and, excepting the Simplex tubing system that now existed, he had had more or less experience in all systems which had yet been introduced, and he had come to the conclusion that each and all of them had their advantages and disadvantages; each had defects and each had good qualities. It was the wisest thing possible to avoid danger, and he thought Mr Chamen was right in suggesting that electric conductors should not be laid near gas tubes. For the last 14 or 15 years he had advised architects to make preparations in buildings by leaving ample space for wiring. He did not know whether this had been done in the new Art Galleries, but he knew that it did not matter what class of workmen was employed on the finished building, the best workmen on earth could not make a good job afterwards. In planning buildings there was surely no difficulty in providing plenty of roads for wires. This was done in shipbuilding and the different leads were arranged, and no doubt the system was satisfactory. Mr Chamen hinted at providing workmen with simple tools for rounding out the edges of tubes. He did not know the tool that they could put into the hands of workmen who had to move

Mr James Dewar.

about as electrical workmen had to do; and employers could not provide expensive tools. From practical experience he knew it was one of the most difficult matters for employers to supply the simple tools that were now supplied to workmen. Workmen were exceedingly careless. There was not a simpler tool than a common half-round file, and the master who proposed to supply special tools would need to have a good big banking account. With respect to iron tubing, he had never yet found gas tubing or steam tubing absolutely free from defects and in which he could recommend first-class insulated wire to be put. He had cut lengths of tube into pieces, each about 4 inches in length, to the number of 300 or 400, and in all the four-inch pieces he never found an absolutely clean piece. Mechanical protection for wires was considered a very important thing, but, generally speaking, the interior of the tube was a very much more deadly thing than the exterior. In almost any tube would be found a blister extending 3 or 4 feet, and also hard irregularities like miniature rocks. Every tube maker should be compelled to send a steel rod a little larger than the two wires through every length of tubing. He agreed with Mr Chamen that superintendents of work frequently neglected their duty. That was a matter to which consulting electricians and their officials ought to pay more attention. He did not think they were often enough at the work. With regard to the standardisation of fittings, one of the most grievous errors, from beginning to end, was the smallness of the bayonet socket. If the individual who invented it had made it an $\frac{1}{8}$-inch larger in diameter it would have been a great deal better It was a most extraordinary thing that the same size of wiring might be used throughout till, as Mr Chamen said, the flexible was reached when the wire had to be reduced in section; but, if the bayonet socket were made an $\frac{1}{8}$-inch larger in diameter no reduction in the size of wire need be made. He would strongly recommend the committee formed for the standardisation of fittings to take up this particular item, and make the bayonet socket at least an $\frac{1}{8}$-inch larger in diameter.

Mr James Dewar.

The workman, the consulting engineer, the contractor, and the scientific formula maker were equally to blame for the notorious state in which the electrical trade existed at the present moment. In the wiring of ships in the early "eighties" people had to do the best they could, and all classes of workmen were introduced to carry out the work. Everyone drifted into the electrical trade, tailors, shoemakers, blacksmiths, and labourers of all descriptions. He was not quite in sympathy with Mr Sam Mavor, who assumed that there was no skill needed in connection with electrical wiring —that anybody could do it. If these were his sentiments he would like to see him wire a ship. He would recommend the consulting electrician to simplify matters in his designs; not to put one finish on the top of another; and to consult experienced, skilful, intelligent, and practical men as much as possible. He would advise the scientific formulist to produce a dimensional value, using the common foot-rule, not to haggle over a $\frac{1}{64}$-inch, and he should use the words "full and bare" freely. It was a strange thing that if anything was wanted in the electrical trade one had to go to America for it, and yet the best practice there was based on English theory. To the contracting engineer, assuming that the question of finance was laid aside, and assuming that his abilities and care were represented by 100, he would apportion his work something like this—to wiring he would give 50 per cent. of his time and ability, to sliding contacts he would recommend him to spend 25 per cent. of his time, to earth connections he would recommend him to spend 20 per cent., and to engines, dynamos, switchboard, and all other parts he would give him 5 per cent. So important was the wiring that the whole system of success from beginning to end depended upon it. There was not an installation that ever he had to do with, in which there was not a failure in wiring—and from 1881 to 1891 probably upwards of 100 installations in ships alone came under his observation—and in 99 per cent. he had found a failure in the wiring. He thought all the ships done at that time had been re-wired.

Professor JAMIESON— No, no!

Mr James Dewar.

Mr DEWAR—He did not know many exceptions to that statement.

Mr W. B. SAYERS (Member) remarked that there had been a tendency among engineers who had had the formulating of rules to become scared when accidents involving serious consequences occurred. In many cases there had not been sufficient regard paid to the likelihood of recurrence of the sequence of events which resulted in accident. He referred, particularly at the present moment, to what had been said on the question of mechanical protection and the possibility of damage to lead-covered wires from nails being driven through them. Mr Clark had put this very forcibly in his remarks, and had stated that there were thousands and thousands of soft pipes in use throughout the city carrying gas, and he (Mr Sayers) would like to know the engineer who would prefer to have a gas pipe with a nail in it, and a leak of gas, to an electrical wire damaged in a similar way. The possibility of nails being driven into conductors was really a very remote contingency. Mr Chamen had quite recently formulated a rule that tubes containing electrical conductors were not to be put in contact with gas pipes. If Mr Chamen could insure that this rule would be carried out: Who was to prevent the gasfitter coming afterwards, to fit some gas stove, and placing his pipes in contact with the electrical tubing? He suggested that Mr Chamen's provision, that the tubes be made conducting throughout, either by means of couplings and copper wire, or some other means, was a thoroughly wise and proper one; and that such a provision as an electrical tube might not be laid in contact with a gas pipe was not required. He had fully intended to put a diagram on the board illustrating the point he had brought up at the last meeting with regard to the subdivision of mains—he did not call it bunching—and he hoped to hear Mr Chamen on that point. The subdivision of mains was a very important matter, and would tend to far greater security than the solid heavy conductor, which Mr Chamen recommended, from the bottom to the top of a building.

Mr A. S. Biggart.

Mr A. S. Biggart (Member) observed that the remarks of Mr Sayers reminded him of what had happened in his own works within the last few months. A new building had been lit throughout by electricity, and not long after beginning operations a serious leak of gas took place. On opening up the floors, it was found that a soft gas pipe had been melted and run on the top of the deafening, the reason being that at some other part of the building a nail had been driven into contact with the electric wiring.

Mr Sayers—Although that had been happening time and again, soft covered wires were recognised, and there was no attempt to prevent the use of lead-covered wires.

Mr A. Denny (Member) said Mr M'Whirter had stated that he had great trouble with Callender's lead-covered wire, but in a system under his own control, where the wires were fitted without any lead covering, and simply put into wooden boxes with bitumen, they were as good now as ten years ago, and they were laid in damp earth.

Mr M'Whirter—That had no bearing on the case. Let Mr Denny take away the bitumen and see where he would be.

Correspondence.

Mr E. George Tidd (Member)—In his opening remarks Mr Chamen referred to wiring on board ship. This was a subject that he had devoted a good deal of attention to. He supposed that it might be taken for granted that whatever was good enough for ship work should be good enough for land work (always of course excepting cases where the Board of Trade regulations had to be considered), but the converse of this was by no means the case One point which he had always insisted upon in ship work was an entire absence of joints of any kind in the wires, and while this was possible on a ship with its comparatively short runs and densely clustered lamp-points, it was not possible nor was it necessary on land installations, where the conditions for carrying out the work were so much more favourable. Mr Chamen quoted

Mr E. George Tidd.

three systems which were now commonly in use for land installations; viz., wires in wood casing, wires in lead casing, and wires in iron or steel casing. With regard to the method of laying the wires in wood casing, he could never understand how it was that electrical engineers had put up with it so long. Mr Chamen mentioned the objections to the system it was true, but to his mind he wrongly qualified his objections by referring to "damp places." Were they only to put up a system that was safe only so long as the rain did not come through the roof, or only so long as the pipes did not freeze and burst, or only so long as a pail of water was not upset and allowed to soak through the floor? No. Wood casing should be abolished except when used simply as a cover for ornamental purposes, as there was no doubt that a piece of wood casing, with the fillet between the two wires soddened with water, formed the ideal condition for the outbreak of an electrical fire. With regard to the third system referred to, Mr Chamen had himself sufficiently condemned the use of thin iron skelps. Even when put up in the most workmanlike manner, they could not in the first place be satisfactorily made continuous electrically, if they were so mechanically; in the second place, as Mr Chamen had pointed out, they were not water-tight; and in the third place, they only gave mechanical protection so long as the seam was so placed that it was impossible for nails, etc., to enter it. With regard to the other two types of iron casing named; viz., screwed iron tube either plain or lined, he thought that to a large extent Mr Chamen condemned these himself in his paper. Mr Chamen pointed out very strongly the great dangers that arose when electric leads were enclosed in a metal sheathing every part of which was not thoroughly earthed. Of this point there could not, of course, be any question, and much as he objected to wood casing, he would almost sooner risk an electric fire with this than a gas fire caused electrically by a badly earthed metal sheathing. Mr Chamen also pointed out that reliance for a good earth should not be placed on gas pipes, or in fact on any pipes unless perhaps a water pipe direct off the main supply, on account of the

Mr E. George Tidd.

joints in the pipes not being electrically perfect, and in this he quite agreed with Mr Chamen; but it seemed to him certain that the average British workman would either make his joints in an iron pipe system imperfect electrically, if all right with respect to being water-tight, by the use of red lead, or he might possibly make them sound electrically by screwing the pipes together clean and dry, but they would not then be water-tight. Apart from this: What was the advantage of a pipe or conduit system of running wires? When it was introduced the idea was that it should be a "draw in "system, so arranged that by the use of junction-boxes, etc., it would be possible to draw out and replace any damaged length of wire. Anyone who tried to carry out work with this end in view very quickly found it an utter impossibility in practice, whatever it might be in theory. With regard to the use of a lead sheathing for wires, he could not agree with the remarks that Mr Chamen made under head (*a*); this system, although uselessly expensive, *if properly laid*, presented decided advantages over wood casing. The very fact that Mr Chamen urged against it; viz., that a nail driven through the lead tube would cause a direct short circuit which would not occur with wood casing, he considered to be a great point in favour of this system, as it was very much better to have a dead short circuit that would immediately blow a fuse, than to have a more or less high resistance earth or fault which might be neglected till some damage was done. He did not consider that variation (*b*) possessed any of the advantages of (*c*) or (*d*), but on the other hand—and notwithstanding that all vessels of the Royal Navy were wired on this system—it had several distinct disadvantages which these other two variations had not. These two latter systems had several great advantages in common, but from the public supply point of view (*d*) was little used, although there was, he believed, a system of concentric wiring (called the Safety Concentric System) on the market in which both wires were insulated, but which would, he thought, never come into great use on account of the difficulty of making satisfactory joints. In the case of heavy mains, etc., where the joints were comparatively few, concentric cables with

Mr E. George Tidd.

both conductors insulated were frequently used in conjunction with variation (*c*), or as it was more generally termed, the "twin wiring" system. This system was by far the best electrically, *if properly carried out*, its only weakness being the want of mechanical strength to withstand pointed implements such as nails, for as regarded blows from blunt instruments such as wires might be subject to in works, ample protection was afforded by a covering of galvanized wire. Then with respect to damage from nails, where this was likely to occur the wire could easily be drawn into a length of gas pipe, or even into one of the steel skelps already referred to. Where the wires were more conveniently run on the surface and were not likely to be subject to mechanical injury, they could be perfectly safely laid in wood casing for the sake of appearance. He had previously remarked that the system was good, *if properly carried out*, and in this connection he would point out that for the system to be perfectly satisfactory, no matter whether the insulation was rubber, paper, or any other material, it should be made water-tight by the use of sweated joints throughout; and this was not possible unless a proper system was adopted for the various joints, fittings, etc., in which metal cases were used and suitably arranged for sweating in the wires, so that a workman must of necessity carry out this important part of the joint. It was also an advantage for arrangements to be made so that the insulation of the joint was itself carried out in, if he might so term it, a mechanical manner; by this he meant in such a manner that the workman had not to trouble himself with wrapping the joint with tape, solution, etc. On the other hand, the use of properly prepared pieces of insulating material fitting into the metal cases eliminated, to a very large extent, the danger of careless or incompetent workmen. The first system to be brought to perfection on these lines was the beautifully worked out system so closely connected with the name of Mr Mavor, and anybody who once examined any work carried out on it could not but feel that it was the only proper method to adopt. However, notwithstanding the remarks that Mr Mavor had made concerning the earthing of the

Mr E. George Tidd.

middle wire all over the system, he could not agree with him, neither did he think Mr Mavor would get the Board of Trade to incline to his views, as it could not be got to treat with the lightness that Mr Mavor would like it to do the effect of electrolytic action on gas and water pipes, which was so likely to occur with the procedure that he proposed. In order, therefore, to overcome the insurmountable difficulties of a concentric system with the outer conductor insulated, several systems had been designed with very satisfactory results. In order to further impress the importance that he attached to the system being thoroughly and continuously covered with a metallic sheathing from end to end, he would point out a reason where the use of a hygroscopic material was to be preferred even to rubber, apart from the fact of its admittedly longer life, which was, that with such an insulation as rubber the failure to make proper water-tight joints did not show at once, whereas, with a hygroscopic insulation it tended to show itself more quickly. He did not, however, wish to open a discussion as to the merits of the various kinds of insulation in vogue. On page 143 Mr Chamen made some remarks as to the desirability of using a system that would break down immediately without the risk of a fire, rather than one that would, although keeping the lights going, smoulder away unnoticed till an electrical fire resulted. This statement could not be too forcibly put, and it formed the key note to the whole of the remarks which he (Mr Tidd) had been making. And, in this connection, it should be borne in mind that however carefully fuses were arranged, they were quite powerless to prevent an electrical fire happening through a high resistance fault such as was so common with wood casing, but which was impossible with a concentric or twin wire system. With regard to the general arrangement of circuits in different kinds of buildings, he would refer to two points (1) bunching of wires should be avoided as far as possible, as much for the sake of neatness as anything else, at the same time, when each pair of wires had its own independent earthed metallic sheathing he considered that there was no risk of a fault in one pair affecting the others; (2) Mr Chamen's sugges-

Mr E. George Tidd.

tion that in large blocks of offices the distributing board system should be departed from, was very retrogressive. However large the block of buildings might be, he did not consider this at all necessary, as there was no need to confine the number of distributing boards to one to each floor. Take for instance a block with say forty offices on each floor, at the point where the branch for any floor left the mains one could put a four-circuit fuse board, and run each of the four circuits to a point where a ten-circuit board would be fixed supplying five offices on either side of it. Now a wood moulding about four inches deep could contain five ⅜-inch grooves, with fillets of just sufficient thickness to give mechanical strength to carry the wire, and in each groove a twin wire could be run in a perfectly neat and satisfactory manner.

Mr **George A. Clark** (Member)—There were many points in this paper on which he entirely disagreed with Mr Chamen, and there were some on which Mr Chamen did not seem to agree with himself. Of the various systems enumerated by the author, it occurred to him that there were only two which demanded serious consideration on the part of the electrical engineer; viz.: (1) That in which iron tubes (insulated or not internally) were used, the various lengths being screwed into special junction-boxes, etc., etc.; and (2) A lead covered twin system in which special joint-boxes were employed (he specially made no mention of concentric systems, for though he agreed with Mr Mavor to a very large extent, the system Mr Mavor advocated was not applicable under existing Board of Trade rules). The objections to the first were chiefly as follows: (1) Internal condensation or sweating. This was a very serious defect inherent in *all* non-ventilated systems of iron tubing and one which nothing could obviate. Mr Chamen suggested a remedy, but had given no hint as to the manner in which he would arrange his tubes, so that they might all drain to one point. It seemed to him that whatever draining was done would be into the wall switches, plugs, distribution boards, etc., which were always the lowest points in such a system. (2) Damage to the cables when drawing in. Those members of the Institution who had had any experience

Mr George A. Clark.

of such a system would agree that, even with the greatest care on the part of the workmen, it was almost impossible to draw in even branch cables, let alone heavy mains, without injuring them. (3) Imperfect continuity of the metal sheathing. Mr Chamen pointed out that the use of red or white lead was fatal as far as metallic continuity was concerned—yet the use of such was the general practice of engineers where water- or steam -tight joints were necessary—and it was probable that in a very short time, especially in damp places, the metallic continuity of a series of screwed pipes would become defective. Take for instance the difficulty experienced in obtaining metallic continuity in the return rail of a tramway system. To these serious defects might be added the following, which, if less important from an electrical standpoint, were not to be ignored: (1) It was impossible on such a system to wire an old building without an abnormal amount of cutting away. (2) It was in many cases impossible to conceal the tubes and junction-boxes, when walls were plastered on brick. (3) It was impossible, or next to impossible, to add an additional lamp when the wiring had been completed. (4) Unless very large junction-boxes were used it was impossible to make satisfactory joints. (5) It encouraged bad work; and once the wires were inside the tube they were invisible. A careless workman might joint on lengths to wires he had cut short; or a dishonest contractor might joint on lengths of wire of inferior quality or smaller size, and examination could not be made without extreme difficulty. (6) The first cost was very great. This was a very formidable list of objections to the system, but it was far from complete. Mr Chamen had pointed out the only objection which could be made to the use of lead-covered cables; viz., that such cables were liable to injury from nails. Such a danger was, he thought, grossly exaggerated. He wished Mr Mavor, whose firm was the largest user of lead-covered cables in Scotland, had given some statistics on this point. Electric light cables should not be greater victims to nails than gas pipes, and if the gas department of the Corporation had found lead gas pipes satisfactory, it seemed strange that the electricity department should

Mr George A. Clark.

have had a different experience. Thousands of miles of lead gas pipes were in daily use in Glasgow, and it had only been with the advent of the electric light that they were asked to believe that it was the custom of the citizens to drive nails at random into the walls of their houses and offices. Electrical engineers invented difficulties which in practice were really non-existant, and then complained that their efforts to overcome them resulted in their being unable to cope in price with gas piping. Surely the wiring contractor had already enough to contend with without being troubled with imaginary difficulties. Mr Chamen stated that, two separate lead-covered cables were better than one twin, because, in the former case it was possible to drive a nail through one conductor without damaging the other, that was to say, to cause a leak, not a short circuit. He entirely disagreed with Mr Chamen, and considered it one of the most important advantages of a twin system, that the chance of damaging one conductor without damaging the other was very remote indeed, if not quite as remote as in the case of a concentric cable, and that a short circuit, not a leak, must occur in the event of a nail being driven into the cable. Later, Mr Chamen pointed out this advantage in the case of concentric cables, and he was entirely at a loss to see how Mr Chamen could reconcile the two statements to which he had referred, and which seemed absolutely contrary to each other. Assuming that the danger from nails was as great as Mr Chamen would have them believe, nothing was simpler than to pass the lead cable through a short length of gas barrel, where exposed to such danger; yet rather than resort to such a simple expedient, Mr Chamen recommended the adoption of a system teeming with much more serious difficulties, and very much more genuine defects. Mr Bathhurst, in the course of his remarks, stated that the lead sheathing of cables decayed when laid in plaster. This was another instance of a difficulty specially manufactured for the benefit of the electrical contractor, and he should be pleased to afford Mr Bathhurst an opportunity of examining gas and water pipes which had been in use for fifty years or more, and were still in daily use, in places

Mr George A. Clark.

where an iron tube would long since have become red oxide. It was well known that in many places, such as breweries, distilleries, urinals, etc., lead was about the only metal not affected by the fumes. In a twin lead-covered system, the metallic continuity of the sheathing could be obtained by the most reliable of all methods; viz., soldered joints throughout, and the cables were not liable to injury as in the case of wires drawn into tubes. Where necessary, efficient precautions could be taken to insure absolute safety from nails. There was no internal condensation with its attendant troubles; old buildings could be wired with the minimum of cutting away, in many cases with none; the cables were easily concealed; additional lamps were easily attached; joints were made in a manner far more reliable than lapped joints; careless or improper work was readily noticed; the job was neat; and the first cost was very moderate.

Mr JOHN M. M. MUNRO—Mr Chamen began with an apology, but he felt sure that all who heard his practical and useful paper would agree that no apology was needed. Mr Chamen was inclined to complain because wiring contractors had not worked out and standardised the parts of a satisfactory wiring system. He forgot, perhaps, that the local contractor was hampered by a brilliant galaxy of local consulting engineers, not to speak of local Corporation electricians. Each of those able men had his own notion of what was best. What pleased one would not please another, nay, being ingenious men the ideas of each were progressive, and a system which satisfied one to-day might not do so to-morrow. Be that as it might, the wiring contractors were not free to use their own systems. Again, when a detailed specification was received, tendered to, and accepted, a considerable part of the price had to be spent in preparing specified appliances, not always better than those in daily use by the contractor. The rest of the work was thus sometimes starved. These appliances often happened also to be more in the usual course—now of one contractor, now of another—so that the competition was not so open as it appeared. The contractor who obtained the work might have little faith in the appliances to be

Mr John M. M. Munro.

used. To meet competition under the prevalent fetish of the competitive estimate, the tenderer was gradually forced to omit all that could decently be omitted under the letter of specification, and especially to curtail the time to be spent on installing the work. If the work was not a success the contractor could blame the system. It was what he was told to do. There was besides no money to play with, for, in estimating, probably a dozen firms had worked out the cost, and the firm who unluckily under-estimated it of course got the work. Good firms working solely under those conditions might continue to do high-class work, but they were apt to be eliminated. He believed that to such causes might be attributed most of the troubles to which Mr Chamen had alluded. The fault did not lie with the consulting men as individuals, but with the over-eagerness of competition. In his opinion the worst possible system, fitted by capable workmen and foremen with a reasonable time to do the work, was safer than the best known system fitted under conditions too often prevailing. Some 14 years ago a large factory was fitted with bare copper conductors. Lately the insurance company wrote asking if it conformed to its insurance rules. The reply was that it systematically broke all the regulations, but the company's officials could come and examine the installation. The insurance was accepted at lowest rates. Of this installation Lord Kelvin wrote that, concerning durability and safety from fire it far exceeded what was usual in electric lighting. He quoted this in support of the statement that the fitting might be more important than the system. But all this was no reason why Mr Chamen should not search for, find, and then insist upon having, a perfect system of wiring. Yet, when found, the British workman could still make or mar it. The perfect system must have all the qualities so clearly stated by Mr Chamen. It must also be flexible enough to readily adapt itself to the structural details of a building, instead of needing to have the building cut and carved to suit its iron rigidity. It should be capable of easy renewal without extensive re-opening of the floors, panelling, plaster, and tile work which covered it, if it were a covered-up system, and it should be

Mr John M. M. Munro.

cheap enough to foster demand. The subject was too extensive to permit there and then of more detailed suggestion or criticism. There might be differences of opinion as to whether the Corporation ought to concern itself with fire risks and durability. If the fuses and primary connections were right, no accident could switch on much more current than the building had demanded. On the other hand, the town could not gauge the insulating condition of its mains if the outers of the consumers were full of leaks to earth, individually too small to melt the controlling fuses, and recurring too often to be controlled by periodic tests. Personally, as a contractor, he welcomed the stringency of the Corporation rules as tending to raise the level of work. Contractors could desire nothing better, from a commercial point of view, than that the civic electricians should select one or two systems, and after discussion with the trade, and subject always to infrequent revisal on good cause shown, lay down for each detail a stringent specification to which all must conform. If this was done they should undertake also the supervision of the work in operation. The usefulness of the consulting men might be thereby diminished, but contractors would then have one local electrical providence under whom they might live, and move, and have their being.

Mr Fred Bathurst, in rep~~ly to M~~r Sayers, considered it should not be more difficult to keep a properly designed and screwed joint electric pipe system, so that it was air-tight and water-tight, than to install the present gas pipe system. His experience with a bare copper wire inside a steel armoured insulating conduit showed that, if enough water had collected inside the pipe (by internal condensation or entrance from a faulty outlet box), the first tendency of the current leaking between the inner and outer conductors was to dry out the moisture, and, failing this, the final result was a short circuit, which immediately blew the circuit fuse. A slight trouble would automatically remove itself, and the continued blowing of the fuse indicated serious trouble, which must be duly attended to. A further point of interest was the fact that an insulating lining had been chosen which had some

Mr Fred Bathurst.

amount of resiliency, so that it was found that, when the ends were trimmed with specially designed tools which left a true and square surface upon both the outer iron armouring and the internal lining, the lining, although it appeared truly trimmed for the moment, within a short time pushed itself out again so as to project about a $\frac{1}{32}$-inch. It was evident that when two pipes were screwed end to end tightly into a socket, the tendency of the insulating lining was to automatically seal itself, and so make a water-tight junction from the inside, in addition to the protection given from the outside of the iron socket. A simple test apparatus had been arranged for the workman so that he could check exactly from a deflection whether his joint was a good one mechanically, and his experience showed that, if correct mechanically, its electrical perfection naturally followed. The practical value of putting insulation around the inner wire rather than directly upon it, showed up when a "fuse" had a larger carrying capacity than the conductor itself, then the inner conductor might be overheated until it was "burnt out" without destroying the insulation. A continuous heating trouble would indicate itself by smoke and smell. Briefly, insulation applied in a "tube" form had many practical advantages over the present practice.

Mr Chamen, in reply, said that the interest which had been taken in the subject, which he had ventured to describe as uninteresting, had considerably surprised him. He was gratified at the lengthy discussion which had followed upon the reading of his paper. Mr Henry Mavor spoke very strongly about the position that the Board of Trade had taken up. The Board of Trade officers were referred to in terms not always complimentary, but their duties were sometimes difficult. In fact, he knew that the Board of Trade electrical adviser had been utterly bewildered by having either deputations or individuals calling upon him with various recommendations and representations. The result was that he was obliged to lie low and do nothing, hoping that things would straighten out in the end. Mr Sayers' great

Mr Chamen.

point was that he would like to have hundreds of wires in one tube.

Mr SAYERS—There should be a limit. He did not want hundreds.

Mr CHAMEN—He would like to know the limit. He had seen work carried out on the lines recommended by Mr Sayers, and thought it was approaching hundreds of wires in one tube. The point raised in the paper about one wire being subjected to the current passing through several fuses accidently coupled in parallel was perhaps somewhat remote, but it was not the only objection. Wires certainly had got damaged in Mr Sayers system. Much larger tubes were required for bundles of small wires than for two larger ones, and it was much more difficult to get straight runs. Small wires were also treated with much less care than large ones. Mr Sayers had criticised his straight lines in the illustrations, but these were only diagrammatic. In one job carried out by Mr Sayers he had had an opportunity of running the pipes quite straight and of putting in large wires, but he did not do it. The principal idea in using bunches of small wires in one tube seemed to be that they could be treated like so many bell or telephone wires, and those which might go wrong be simply pulled out and replaced. This did not work well in practice, and it was not a mechanical engineer's way of doing things. He would suggest, though he had the greatest respect for the telegraph engineer, that they had been suffering somewhat through looking at the wiring question too much from the telegraphic engineer's point of view, and till that was got rid of they would not get much further. Mr Tidd remarked about wood casing, and referred to damp places. He had pointed out that any place might be damp at some time or another, and that was the great objection to wood casing. Mr Tidd was afraid of electrolysis, but probably many members of the Institution saw that the three-wire system was perhaps the greatest safeguard against electrolysis, if the Board of Trade would allow them to earth, not only at one point, but also at the feeding point. A

Mr Chamen.

proper balance between the loads on the two sides of the system, which did not always exist in every installation, was of course desirable, and this was what he wanted to arrive at before any departure could be thought of in the way of using concentric wiring in houses with the outer conductor uninsulated. The remarks of Mr G. A. Clark showed that he had thought the matter out very carefully, and it was a pleasure to meet with his criticisms. The draining of iron tubes to clear them of condensation water was no doubt a trouble, but a man of Mr Clark's ingenuity would be able to scheme out arrangements to avoid the water getting into the switches and wall sockets. If tubes were screwed to fit after the manner adopted in the Bathhurst system, probably there would not be any such trouble regarding break of continuity as Mr Clark feared. There was no comparison between the very imperfect contact made between rail ends and fish plates, and the kind of contact which could be made and maintained for any length of time with a really good and tight fitting screwed joint, not of course the kind of joint that was to be found in some of the places referred to in the paper. He was quite willing to concede Mr Clark's point, and admit that there was not any greater safety in using two bad covered cables as compared with one twin. Mr John Munro considered that Corporation engineers were a hindrance. He did not know what Mr Munro was aiming at, but he would endeavour to find out. Mr M'Whirter was not altogether right when he attributed corrosion of lead in some places simply to the action of the plaster.

Mr W'WHIRTER—No, no.

Mr CHAMEN—As far as he had been able to learn, the corrosion in lead sheathing was mostly due to electrolysis, though it was not known. The current got on to the lead, generally at the end connections, and it traversed away back till it found a convenient place to go to earth, and the cement was blamed for its chemical action on the lead, but in reality it was simply electrolysis. That perhaps threw some light on the Callender cable of which Mr M'Whirter had spoken. In Glasgow, he thought, he had taken an

Mr Chamen.

absolutely new departure for continuous current supplies by using a concentric cable. There were no cables, except a few house connections, in which there were not three conductors. His object had been throughout, to arrange matters by putting the earthed or neutral conductor outside the others and next to the lead, so that under no circumstances would the lead sheathing be at any different potential to the earth, and in that way electrolysis should be almost an impossibility. There were still, as they had learned, ways in which the lead could be made alive from the end connections. The end connections were always present to give trouble even with a concentric system. Professor Jamieson alluded to electrolysis not far from the place of meeting, but he did not know what he referred to. He had been on the watch for electrolysis, but had found none. He had had some cases of fusion through the lead getting alive, but that was a different thing altogether. Some one remarked that a good job could be made with any of the systems named, if properly carried out, and he would like to take this opportunity of saying that he had spoken indifferently of the Simplex tube system. Since he wrote the paper, however, he had been asked to see an installation carried out with that kind of tube, and he was astonished to see how well it could be done. He had no ground for refusing to pass it. It was a fact that people who were contractors, although they were not fit to be called contractors, used Simplex tubing without the elbows or joint-boxes which were designed by the makers for use with it, and he had inspected places where two tubes had been brought at right angles to each other and mitred off. In such a case it was only a matter of a very short time before the insulation of the wires would be cut through. He wished it to be clearly understood that there had been five or six cases of fire within a short time in Glasgow, owing to work being carried out in a most abominable way by men who should not have been allowed to touch anything electrical. He was sorry to hear gasfitters badly spoken of, because, though he had not seen much of them in Glasgow, those he had come across

Mr Chamen.

elsewhere had always been men who knew their business, and had handled compo tubes, solder and blow-pipes in a workmanlike manner. In wiring systems, if the number of different tradesmen could be reduced, it would be a good thing. He did not see why the whole of the installation should not be carried out by men of the stamp of the gasfitter. He did not think that the electrical bellhanger could do it. Mr Sam Mavor had been horrified at what he had seen in shop windows, and he had given a lot of advice about the fire office inspectors. He was afraid it was not they who required advice, but the fire managers. It might be of interest to the meeting to know that, feeling some alarm about the way certain buildings had been wired, he took the opportunity of writing to a representative of one of the fire offices to point out some of the horrors he knew to exist, and he ventured to think that, having a forcible letter from him, some attention would be paid to the matter. The Secretary wrote to the effect that, the Association was much obliged to him for the trouble he had taken and the interest he had felt in the matter, and hoped he would succeed in getting things better than they were. That was all he got for his trouble.

The PRESIDENT moved a vote of thanks to Mr Chamen for his paper, and said that they ought to congratulate themselves on the brisk discussion which the paper had evoked.

The vote of thanks was heartily accorded.

THE ACTION OF ELECTRIC TRAMWAY CURRENTS ON SUBMARINE TELEGRAPH CABLES AND OTHER ELECTRIC CIRCUITS.

By Professor ANDREW JAMIESON, F.R.S.E. (Member).

(SEE PLATE IX.)

Read 23rd January, 1900.

HAVING been asked to give a short account of my visit to Cape Town last year, I have only to mention that the subject of my remarks has to deal with one of the many causes of delay in the transmission of telegrams, in order to ensure your close attention.

PRESENT AND FUTURE CABLE ROUTES TO THE CAPE.

By referring to the map, it will be seen that there are at present two telegraph routes to the Cape from this country, the one and the older route being termed the "Eastern and South African," and the other the "West African." Both routes are worked by, and have their basis in, the first portion of the Eastern Telegraph Company's system. Messages for the Cape by the eastern lines go from London, *via* Porthcurno, Lisbon, Gibraltar, Malta, Alexandria, Suez, and Aden, where they branch off down to Zanzibar, Mozambique, Delagoa Bay (Lorenço Marques), and Durban. From thence they are transmitted by the Government land lines to Cape Town, etc. The cables from Aden to Durban were laid in 1879, at the time of the Zulu War, and only one section thereof has since been duplicated; viz., that between Zanzibar and Mozambique, in 1885. I have always been particularly interested in this 1879 cable, since I had to effect the first repair upon it, just south of Mozambique, in the

Spring of 1880, owing to its having been broken by a submarine earthquake!

The West Coast route returns to Great Britain *via* Mossamedes, Loanda, and many other places, such as Lagos, Bathurst, St. Vincent, Madeira, and Lisbon.

With the view of providing additional security to submarine telegraph communication between this country and South Africa, landing rights at Cape Town have been obtained from the Government by the Eastern Telegraph Company for a third cable. The first section, from Cape Town to St. Helena, was completed on the 26th November, and a further section to the Island of Ascension on the 16th December last year. The continuing cables to be laid to St. Vincent, Madeira, and Great Britain are now being manufactured. It is further expected that this much more direct cable will be extended from the Cape to Australia, and that the tariff will be considerably reduced.

OBJECT OF VISITING CAPE TOWN.

At the end of last July, I was requested to proceed to Cape Town for the purpose of acting as one of the advisers to the Cape Electric Tramways Company, in an action brought against it by the Eastern Telegraph Company. This action was raised owing to disturbances in the working of the submarine cables landed at Cape Town by the operations of the neighbouring electric tramways. I had an able colleague in Mr Frank Jacob, the chief electrician and technical adviser to Messrs Siemens Brothers & Company, of London. On the outward voyage we had the advantage of studying the many Bills and Acts of the Cape Parliament relating to telegraphs and tramways, as well as Mr A. P. Trotter's paper, which was read before the Institution of Electrical Engineers in 1897.* Upon our arrival at Cape Town we found that, although the Submarine Telegraph and Tramway Companies

---

* See "Proceedings of The Institution of Electrical Engineers," London, Vol. xxvi., page 501, for Mr Trotter's paper on "Disturbance of Submarine Cable Working by Electric Tramways."

had willingly afforded every facility to experts for carrying out numerous and varied experiments, and although the former Company had spent considerable sums of money in devising and executing plans for eliminating the vexatious electrical interferences, no perfect system had yet been adopted for thoroughly cancelling the disturbances, and, consequently, a considerable difficulty was still frequently experienced in deciphering the telegraphic signals.

HOW SUBMARINE CABLE SIGNAL CURRENTS ARE TRANSMITTED, RECEIVED, AND RETURNED TO THE SENDING STATION.

Looking at Fig. 1, it will be seen that the + and – electrical impulses which are set free from the sending battery by manipulating the double current key, charge (say + in the first case) the home side of the sending condensers, thereby inducing a – charge from the other side of the same and from the conductor of the cable. This naturally repels a + charge along the conductor of the cable to the receiving end, and charges the cable side of the receiving condensers +, inducing – on the opposite plates of the same, and repelling a + charge through the delicate Kelvin siphon recorder to the metal sheathing of the shore end. This current, as shown in Fig. 1, finds its way back to the sending station battery, not only along the sheathing of the cable, but also very largely, if not almost entirely, through the sea water and the earth. The splitting up of the return current in this manner, is due to the shore ends making intimate electrical contact with the water and earth.

Many electricians used to fancy, and even now fancy, that the return current passes back to the sending station *entirely* by the cable sheathing. I have, however, often proved that this is not the case, by alternately connecting and separating the sheathing at an intermediate station, without affecting the strength of the signals at either of the distant ends! It is important to note that the sending and receiving currents act by induction in and from the sending and receiving condensers. These condensers serve the double purpose of cutting off the interfering effects due to "earth currents" and of sharpening or defining the receiving signals, see Fig. 2; thus enabling a greater speed of working to be attained than would be the case without them.

RELATIVE POSITIONS OF THE SUBMARINE CABLES AND ELECTRIC TRAMWAYS LINES, &C., AT CAPE TOWN.

From Fig. 3, it will be seen that the Cape Town shore end of the main submarine cable to Mossamedes (which was laid in 1889, and is 1,383 nautical miles in length) passes round the south-eastern curve of Table Bay in order to avoid the anchorage. Further, that a part of the electric tramway lines (which are worked on the over-head, "Trolley-Wire System" with the return circuit through the rails) pass from the power house towards Wynberg on the one side, as well as to and through Cape Town on the other side, and lie almost parallel to the submarine cable. In fact, the first mile of the shore end is only at a mean distance of about half-a-mile from the tramway line; whilst the subterranean line from the cable telegraph office along Adderley Street to the cable house, a distance of 430 yards, lies for a certain distance thereof, quite close and parallel to the tramway rails. Ever since the opening of the electric tramway service on August 6th, 1896, the received signals at Cape Town from Mossamedes, or from Loanda a further distance of 530 nautical miles, have been seriously interfered with by the working currents of the tramway system. At first, the tramway lines only extended from the suburb of Mowbray to the corner of Darling Street and Adderley Street; but now, they are in full swing from the power house to Wynberg, a distance of seven miles to the left, and through Cape Town to Sea Point, a distance of five miles to the right. These extensions combined with the greatly increased traffic, and consequently increased strength of the working currents, have naturally augmented the amount and frequency of the disturbances. The Submarine Telegraph Company having been unprepared for such disturbances to its receiving signals, had its cables joined up exactly as depicted in Fig. 1. At first, the

Company was evidently under the impression that the erratic kicks, vibrations, and splashes, produced on the recorder slip, as seen in Fig. 4, were due to the local earth on the shore end being within the range of the stray currents from the tramway rails. Consequently many "earths" were sought beyond this supposed sphere of action, by running land lines, "such as a telephone line to the top of Signal Hill, a telegraph line ending at an earth plate in the sea near Sea Point, an earth at the observatory 3½ miles from Cape Town, an earth at Durban Road some twelve miles from Cape Town," &c., &c., without finding any reduction in the disturbances. In fact, the ordinary earth of the shore end gave better results than any of these land line earths. As these various earths had failed, more definite experiments were tried at night, when it was found that the amplitude of the kicks, shown on the recorder slip, were in proportion to the distance of the experimental car from the power station (but greater when on the Cape Town side), and that the direction of the "kick" was reversed whenever the said car passed from the one to the other side of the power house. I may here remark, that the current required to pass through the coil of Lord Kelvin's siphon recorder, in order to give well-defined receiving signals, is only about from $\frac{1}{20}$th to $\frac{1}{30}$th of a milliampère; and consequently, the currents delivered from the tramway power station to any one section of the tramway lines is often ten million times as great as that which creates the disturbances indicated by Fig. 4.

THE VARIOUS PROBABLE ACTIONS OF THE TRAMWAY CURRENTS ON THE SUBMARINE CABLE.

(1) *Electrolysis.*—The well-known action of electrolysis, on neighbouring underground conductors, such as gas and water pipes, whenever the fall of pressure along the rails exceeds a certain value, may be at once dismissed as having no effect upon the case in question. The underground cast iron pipe containing the 430 yards of insulated conductor from the cable office to the cable hut, never showed any signs of electrolysis, and no such action has been observed as taking place in the sheathing of the submarine cable.

(2) *Affecting the Potential of the Earth Connection to the Receiving Instrument.*—At first sight, the possible action of erratic stray currents from the tramway system more or less continuously altering the potential of the receiving instrument's earth connection, is a fascinating idea to many; and this idea, as will be seen later on, is still entertained by certain cable electricians. But, from the many attempts and failures of The Eastern Telegraph Company to obtain satisfactory results from a land or a sea "earth" connection placed in various positions, and at varying distances up to 12 miles from the receiving instruments, this action may also be dismissed as having no particular bearing upon the disturbances in question.

(3) *Direct Electro-Magnetic Induction.*—Although the well-known effect of electro-magnetic induction as shown by Fig. 5, and which was first proved and announced by Faraday in 1831, always takes place between a circuit wherein the current is suddenly altering in strength and any other closed parallel or approximately parallel conducting circuit, yet, I doubt, if the chief cause of the observed disturbances can be attributed to what may be termed *direct* electro-magnetic induction. By this term, I mean, the effect which would be directly, or at first hand, communicated to the insulated conductor of the submarine or underground cables from the erratic currents passing along the trolly wires in one direction and returning by the rails; or, by results due to the difference between these respective currents at any time. In the first place, the underground cable is contained in a strong cast iron pipe, and although this pipe is much nearer to the tramway rails than to the trolley wires along the seaward end of Adderley Street; yet, any direct electro-magnetic action due to the difference between the respective currents in them and their respective distances from the pipe, would naturally result in producing inductive currents in the pipe to a greater degree than in the so far magnetically shielded insulated conductor. A secondary inductive effect would, no doubt, be produced upon this insulated wire by the more direct induced currents in the cast iron pipe.

These secondary currents would, however, be opposite in direction to any direct electro-magnetic induction that might reach the wire. Again, the sheathing of the shore end of the submarine cable being not only double, but the outer armour being so heavy and compact, see Figs. 7 and 8, the insulated conductor contained therein would also be very much shielded from any *direct* electro-magnetic effect. Besides which, the mean parallel distance for the first mile between the cable and the tramway is fully half-a-mile, and, thereafter, the cable diverges, not only in distance, but also in direction from the tramway route; therefore, I do not think the chief or most prevalent cause of the interferences to the receiving signals can be attributed, under these circumstances, to what we have called "direct electro-magnetic induction." I do not for a moment doubt that, direct electro-magnetic induction would take place through air, or earth, or sea, or all combined at much greater distances, and even under less favourable conditions, with respect to parallelism and to sudden alterations in the strength of the primary currents, than in the case in question, if only the cast iron pipe surrounding the underground core and the heavy iron armour of the shore end were absent. These iron covers, however, in my opinion, not only to a great extent act as a magnetic shield, but, moreover, the electro-magnetic currents produced in them so act upon the insulated conductors contained therein, as to produce a current opposite in direction and in effect to any direct electro-magnetic induction in the cable conductor. No doubt the "splashes" or more violent "kicks" of the siphon in the Kelvin recorder, which were still observable up to the time of my leaving the Cape, may be attributed to the sudden closing or to the sudden freeing of a number of the motor circuits. For, whenever the pre-arranged limits of the automatic cut-out-switches are exceeded, due to a congregation of cars (say near the corner at the meeting of Darling and Adderley Streets, or elsewhere not far from the cable) being started more or less simultaneously, then electro-magnetic induction has the best chance of exhibiting its effects. One day while standing near the switch board in the power house, I noticed that certain of the automatic cut-out switches broke their circuits half a dozen times within a quarter of an hour, at the pre-adjusted limit of 350 ampères; and, of course, they had also to be switched on again before the cars on that section or sections could start. Such sudden stoppage and starting a current of 350 ampères at 500 volts does undoubtedly cause *direct* electro-magnetic induction in all neighbouring parallel electrical circuits, whether they are in the air as in the case of bare or specially insulated wires, or buried in the earth, or laid in the form of a sub-marine armoured cable in the sea. These sudden electro-magnetic disturbances are, however, distinguishable from another and more frequent source of interference which might now be considered.

(4) *Disturbances due to Leakage or Stray Return Currents from the Tramway Rails.*—In Fig. 6, I have depicted graphically, by dotted curved lines, the "stray shunted" currents as they leave the tramway rails and find their way back to the negative poles of the dynamos in the tramway power house. When the length and the electrical resistance of the rails is taken into consideration, as well as the very heavy traffic which at times prevails in each of the two main sections to Wynberg and to Sea-Point, there is no difficulty in believing that the limits of the fall of potential along the rails, as set down by the Board of Trade, are at times exceeded.

The seven-mile route from the power house to Wynberg is only a single line with numerous "turn-outs," whilst that to Sea Point is a double one. The rails in each case, are 81 lbs. to the yard, with double flexible Chicago copper bonds past the fishplates at the rail joints. Cross bonds are also introduced between each pair of rails, at certain distances apart. The consequence is that when the traffic is heavy, some 30 to 40 per cent. of the return current finds a way back to the power house through the earth and the sea. Since the hard rocky nature of the Table Mountain side offers a greater resistance than that of the damp low-lying shore side, the major portion of the stray currents naturally follow the latter course. These stray currents freely pass through the observatory grounds, a mile or more distant from the tramway line to Wynberg; and Dr David Gill, the Astronomer Royal at the Cape, informed me that ever since the electric tramway first passed the observatory, he had not been able to carry out a single delicate magnetic experiment within the grounds. These varying stray currents undoubtedly find a ready path to, and along, the heavy low resistance sheathing of the submarine cable on their way back to the power house, and in doing so, they produce by induction, correspondingly erratic currents in the cable conductor, which of necessity interfere with the weak receiving currents during their arrival at the Cape telegraph office No wonder, then, that such interferences mystified and defied the most skilled telegraphists to decipher the messages, so long as the tramways were working, and so long as no proper anti-inductive method had been applied to cancel their baneful effects. It will be readily understood that the Tramway Company, having received full Government and Municipal permission to adopt the overhead trolley system, with the rails for the return currents to the power house, and seeing that under such working conditions it could not possibly introduce any known and commercially satisfactory means of preventing the natural interferences, was willing to help the Cable Company as far as possible to effect the desired remedy.

ANTI-INDUCTIVE EARTHING CABLES LAID BY THE EASTERN TELEGRAPH COMPANY.

In the end of January, 1897, the Eastern Telegraph Company laid a short cable of about 5 nauts, as nearly as possible over the shore end of their main cable, Fig. 3, and connected it to the earth side of the telegraph office recorder by means of a second underground cable, inserted in another cast iron pipe which lay parallel and close to the first pipe and cable. The sea end of the conductor of this short cable was earthed by soldering it to its sheathing, the soldered joint being protected from the sea water. By this it was hoped that a "sea earth" would be found, beyond the range of the tramway stray currents, to neutralise all inductive effects upon the main cable. So long as the tramway traffic remained light, and until the tramways were extended from Adderley Street to Sea Point on the one side, and from Mowbray to Wynberg on the other side, the Telegraph Company's staff was able to receive messages by aid of this short cable. There cannot be the slightest doubt, however, that it could not be laid precisely over and parallel to the main cable from a telegraph steamer, for the main cable lay at such a depth as to be entirely out of sight. The short cable might therefore be hundreds of feet away from the original one at various places without anyone being aware of the fact. Further, since the sheathing of this short cable was not of precisely the same kind and weight as that of the main cable shore-end, the induction upon its conductor, however evoked, would not be equal to the induction in the conductor of the main cable Consequently, the induced currents through them would not exactly balance each other as they arrived at the opposite terminals of the receiving instrument. In other words, the balance was not perfect. It was, however, so very much better than with any of the previously mentioned plans, that members of the staff were able to receive messages until the extension of the tramways took place. After that, the Cable Company found it necessary to incur the still further expense of laying another cable, of 11 nauts, in a similar manner, and earthing the same at Robben Island. It was also connected to the siphon recorder through an underground insulated line, in the same way as had been done with the 5 naut cable, Fig. 3. With this second short cable the messages have been received ever since. But as I found, in the beginning of September, 1899, (when I inspected the receiving signals, and the specimens complained of which had been entered in the cable office diary) the Telegraph staff were still frequently bothered with "kicks" and "splashes." Upon joining up the 5 naut earthing cable to the recorder instead of the 11 naut one, I at once perceived that the interferences became much more pronounced; and with the earth side of the recorder connected directly to the sheathing of the main cable as in Fig. 1, these interferences became so bad that I could scarcely read a single word.

PREVIOUS ANTI-INDUCTION EARTHING CABLES.

I could give a large number of previous instances of interruption to sea and land telegraphy, and to telephony, due to faulty earth connections, leakage from other sources through earth plates and between circuits, direct electro-magnetic induction from lightning, and lighting and transmission of power circuits; but this is the first instance in which I have personally observed indirect or secondary induction from stray shunted tramway currents in the case of a submarine cable. The Eastern Extension Telegraph Company had experienced similar interferences from the electric tramway lines at Madras, in the working of its submarine cables landed there; but it overcame them in a so far satisfactory manner by running a parallel underground cable as well as one out to sea for a few miles. Here, however, the tramway lines were not nearly so favourably situated with respect to parallelism to the cables, and hence the disturbing effects were not so pronounced as at the Cape.

Messrs Siemens Bros. & Company had previously laid down a double cored underground land line and shore end cable at Coney Island, to enable the Commercial Cable Company to bring its lines direct to the New York office, and at the same time, be free from interferences due to the neighbouring electric tramways. A cross section of the cable laid by Messrs Siemens is illustrated by Fig. 7, where it will be observed that the second or return core is placed between the inner or light sheathing, and the outer or heavy stranded armour. Here, again, the submarine portion was not nearly so parallel to the tramway lines as at Cape Town.

PROPOSED REMEDIES FOR INDUCTION AND STRAY CURRENT INTERFERENCES.

Taking into consideration all the circumstances at Cape Town, I reported to the Commission, before which I recently gave evidence, that nothing short of a symmetrically arranged and specially made "twin *twisted* core with double armouring" would do for the shore end, and that it would not require to be more than from two to three nauts, see Fig. 8*. One core of this special cable would require to be jointed to the core of the main cable in the bay, the sheathings thoroughly well spliced together, and the conductor of the second core soldered to the outer sheathing of the main cable, and there sealed from the sea water. The ends of these two cores, at the cable hut, would require to be connected to corresponding ends of an armoured "double twisted core" encased in *one* thick cast iron pipe placed underground between the cable hut and the telegraph office, and the conductors connected to the signalling condensers and the receiving instrument (as shown in Fig. 9, in which the sending battery, switch, and keys have been omitted). Only thereby, could all inductive effects, from whatever source and however caused, be equally and simultaneously evoked in the main and the short earthing conductors.†

Further, I strongly recommended the Tramway Company to obtain and place in circuit, with separate return feeders from different points along the rails, a sufficient number of negative boosters (or sucking dynamos), in order to reduce the return currents in the rails at these points to zero potential, and thus prevent the fall of pressure along any portion thereof ever exceeding the limits of the Board of Trade rules. This would naturally stop electrolytic action on neighbouring pipes, and greatly reduce the potential, the strength, the range of stray currents, and hence the chance of their reaching the sheathing of the submarine cable and of acting inductively upon its conductor.

Finally, I believe that land telegraph, telephone, and other electric circuits, can be protected from all interfering influences

---

* The author showed a specimen of this cable, which was kindly lent to him by Messrs Siemens Bros. & Co. for the meeting.

† Since reading this paper, the author has been informed that the recently laid shore end of the new cable from Cape Town to St. Helena, has been made and connected in the above mentioned way.

of electric tramways by employing twisted forward and return insulated conductors, and that electrolysis may be prevented by employing heavy well-bonded rails with return feeders and sucking dynamos, whenever the fall of pressure along any section tends to exceed 5 volts.

Discussion.

The discussion on this paper took place on 20th February, 1900.

Mr W. M'Whirter (Member) said that what was technically known to electricians as earth conductivity must be exceedingly high at the Cape. He remembered, probably, 25 years ago, having a similar trouble with an earth fault, on a section of a railway in the English lake district near Coniston. Any one who had been there knew that the geological formation was largely slate. Much trouble was experienced with the telegraphs, and wires had to be run a long way to get good earth. On one occasion a break-down occurred at the next station to Coniston Lake, which gave great trouble. To his mind the fault as explained was clearly a bad earth connection, but there was a great deal of opposition to that. He was first of all told that there were earth wires carried out to the railway metals, and also an earth wire carried to a pump. Finally there was a total break-down, and it was arranged to dig trenches opposite the station, in a meadow, and to place therein huge earth plates. While this was in progress other things were tried to remedy the matter. The railway crossed a river about 100 yards from the station, and every one said that if the earth plate was placed into the river all would be right. A coil of No. 8 galvanised iron wire was laid out and put into the river, but to the astonishment of all it made almost no improvement. At first the earth was tested as 60 ohms, that was to the railway metals and the pump. When the earth plates were put into the meadow the resistance fell only 4 ohms, leaving 56 ohms, and with the coil in the river the resistance was reduced by 2 ohms more, leaving it at 54. He was told that his opinion was wrong, that it was not the earth but something else.

Mr W. M'Whirter.

He next examined the pump, and traced the earth wire, and found that it was bolted to the flange of the pump. The pump had a gun-metal body to which the suction pipe was attached by another flange. The flanges were carefully insulated from each other by means of a leather washer, the bolts, however, were rusty, and the connection, therefore, between the suction pipe and the earth wire, must have been electrically bad. He connected a bit of wire from the pipe to the earth wire above the flanges, and the resistence was then found to be under one ohm. He mentioned these details because it was quite evident to him that the river, the meadow opposite, and the rails, were carried in a rocky basin, which was, no doubt, thoroughly insulated. There was no means for the electricity to get away until the earth wire was connected to the water bearing strata by means of the suction pipe, then conductivity was obtained. It seemed that this, in a large measure, explained the state of affairs at Table Bay. The currents he granted were much heavier than they ought to have been, and such as the Board of Trade would not allow to exist in Glasgow. No doubt the leakage currents spread right out into the bay, getting into the salt water and the sheathing of the cable, which every one knew acted as a good conductor, then, largely following the cable route for a distance of a mile or more, they returned through the sea and earth to the tramway power station. He did not think there was any question of induction from the trolly wire. It was purely a case of electric leakage along the sheathing, thereby inducing, at every change of strength or direction, currents in the insulated core of the cable. He once had a case in Glasgow which threw a good deal of light on this point. Shortly after the North British Railway introduced their system of train lighting between College and Finnieston Stations, a telephone circuit gave a great deal of trouble. Occasionally it worked all right and he wondered where the fault occurred, till one day the assistant in charge said—"I cannot understand it, Mr M'Whirter, but the telephone is always right on Sundays." The wires ran parallel to the North British underground railway, at a distance of probably

100 yards from the train lighting currents on the low-level line. Listening carefully at the telephone he could hear the intermittent connection between the collector and the rail as the trains moved along the line. He then cut away the wires, and put up a return wire, and the trouble disappeared. He was certain that Prof. Jamieson's proposed remedy would be a perfect one whatever the fault was, let it be induction or conduction, but he believed it was due to the latter. Mr Trotter brought this same matter before the Institution of Electrical Engineers in 1897, and suggested a twin cable, but he said nothing about twisting the cores, and he (Mr M'Whirter) felt sure it would not be satisfactory unless the core wires were twisted as recommended by the author.

Professor JAMIESON in reply said he was glad to hear Mr M'Whirter's remarks regarding bad earths, for it reminded him of several mysterious and defective circuits with which he had to deal in connection with land line work in South America. He was also pleased that Mr M'Whirter agreed with him in considering that the greatest cause of the interferences was due to the return stray currents from the rails passing along the cable sheathing, and thereby inducing currents in the insulated conductor.

Mr W. B. SAYERS (Member) questioned if there would be any inductive effect due to the leakage current, seeing that in the part of the cable circuit affected, one conductor was completely enclosed in the other. He thought Mr M'Whirter was right in contending that the effects were due to the direct action of the stray currents, which would certainly produce a difference of potential in the circuit, and that the inductive disturbances must practically be zero. No magnetic field would be set up inside the sheathing due to stray currents flowing in it, and apparently the effective induction would act equally and opposite in the two parts of the cable circuit; viz., the core, and the sheathing and sea water, as these would be cut simultaneously by the magnetic lines of force generated.

Professor JAMIESON — Mr Sayers was evidently under the impression that, the interferences were due to these stray currents finding their way along the sheathing directly to the receiving instruments by the earth connection of the latter.

Mr W. B. Sayers.

Mr **Sayers** again requested the attention of the meeting, but owing to the lateness of the hour the chairman suggested that the point raised by Mr Sayers should be submitted to experiment, and that the report of the result should be embodied in the proceedings.

The **Chairman** (Prof. W. H. Watkinson) moved a vote of thanks to Prof. Jamieson for his paper.

The motion was heartily agreed to.

Correspondence.

Professor **Jamieson**.—Mr M'Whirter kindly placed his works and instruments at their disposal, for purposes of experiment, and joined up some 70 feet of well-insulated core sheathed with iron, as shown by Fig. 10.

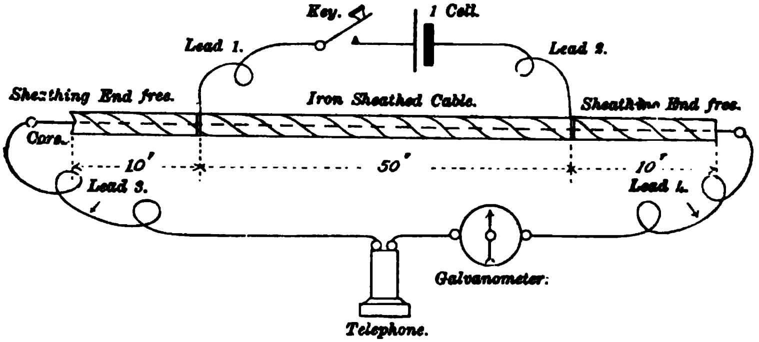


Fig. 10.

1st Experiment.—The two conducting wires from the storage cell and key were securely bound to the iron sheathing about 50 feet apart, leaving about 10 feet of the sheathing free at each end of the cable. The ends of the core of this cable were connected to a telephone and a sensitive D'Arsonval mirror galvanometer as shown. Each time the cell circuit was closed, a click from the telephone was heard and a deflection of the galvanometer observed. This proved conclusively that currents were induced in the central insulated conductor by the primary currents sent along the surrounding sheathing. The experiment was varied by substituting alternate currents from an alternator, with similar results.

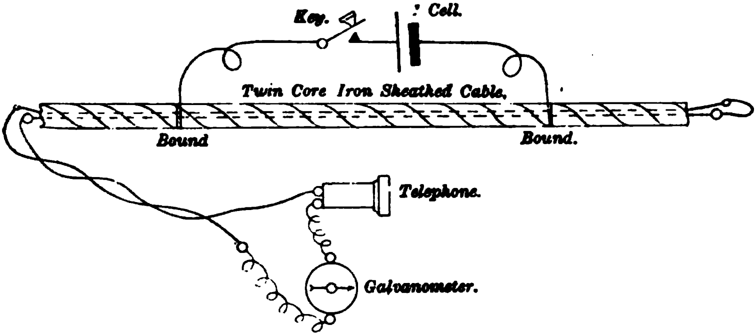


Fig. 11.

2nd Experiment.—The previous cable was now replaced by one having a twin twisted core with similar iron sheathing and connected up as indicated by Fig. 11. In this case, neither sound from the telephone nor any movement of the galvanometer was observable, thus proving the efficacy of the twin core as an anti-inductive protection against interferences from intermittent currents passing along the outside sheathing.

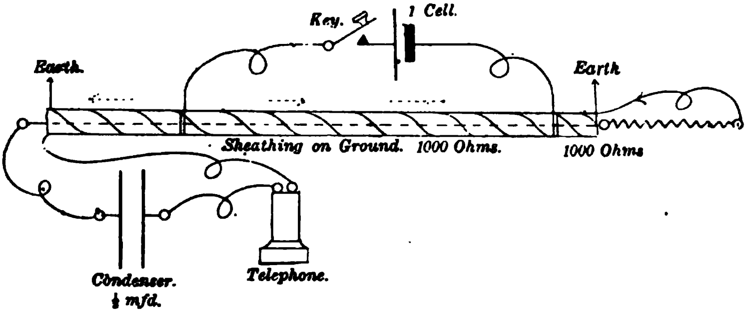


Fig. 12.

3rd Experiment.—Since Mr Sayers considered that the 1st Experiment, Fig. 10, did not truly represent the case at Cape

Prof. Jamieson.

Town, the single core cable was connected up in the manner shown by Fig. 12. Here a condenser was introduced between the central conductor and the telephone, and the other terminal of the latter was connected to the outside sheathing, which was duly earthed. The cable was laid on the workshop floor and the farther end of the central conductor was connected through 10,000 ohms to the sheathing, as represented in Fig. 1 of the paper, with the exception of a condenser at the farther end. In this case, when intermittent currents were sent along the 50 ft. of sheathing from the storage cell, the telephone immediately responded. But, Mr Sayers said, that, in this case, these effects were not produced from induction solely, for he thought that the battery current split at the point of attachment to the sheathing. If it did, the portion of current which came from this attachment along the sheathing to the telephone was opposed to the induced current from the central core, and so it was in case of the Cape cable. It should be observed, however, that the resistance of the 50 ft. circuit along the sheathing was only ⅓ of an ohm, since 6 ampères was registered therein from the 2 volt cell when the key was down; whereas, the telephone circuit, which truly represented the Kelvin siphon recorder circuit at the Cape in miniature, had almost infinite resistance, owing to the condenser and the 10,000 ohms. No apparent difference was experienced whether the sheathing was earthed or not at its ends.

4th Experiment.—The conditions in Fig. 13, as proposed by Mr Sayers, introduced an entirely different problem from that under discussion.

5th Experiment.—On a subsequent occasion, in the presence of Mr E. H. Parker, Mr David Robertson, and myself, Mr M'Whirter repeated *Experiment 1*, with a cable having only a lead sheath, in order to avoid any effect due to the lay or twist of iron armour. In this case the sounds in the telephone and the deflections of the galvanometer were even greater than in the first experiment. This proved conclusively that intermittent currents in a tube did induce currents in an insulated conductor within it.

Mr W. M'Whirter.

Mr W. M'Whirter—In order to test the difference of opinion brought out in this paper, he arranged, in his works at Holm Street, two lead covered and armoured cables to represent as nearly as possible the conditions at Cape Town, as explained by Prof. Jamieson. The cable used in the first and third experiments had an insulated core, lead covered, taped, and armoured. In the second experiment there were twin twisted cores laid up together, lead covered, taped, and armoured.

1st Experiment.—The cable was suspended so that it was practically insulated from earth; connections were made to two points on the armour 50 feet apart, by means of twin twisted cable, thus avoiding any interference from the connecting wires. The battery connections were joined together at the further end and strong currents were sent through without producing any effect on the telephone. Further, currents from an alternating dynamo were sent through these connections and gave a negative result. The insulated core was joined up through a delicate galvanometer and a telephone. Every current sent through the sheathing or armour was distinctly heard in the telephone and was plainly indicated by the galvanometer, which proved conclusively that the stray leakage currents along the cable sheathing were capable of inducing currents in the insulated core of the submarine cable.

2nd Experiment.—Currents were now sent, under similar conditions, through the sheathing of the cable with twin twisted cores, the cores being joined together at one end and to the telephone and galvanometer at the other end. In the telephone there was perfect silence, and the galvanometer was unaffected, thus proving that any inductive effect upon one core was met by an equal but opposite effect in the other, and also that the adoption of a cable with a twisted twin core earthed out at sea would remove the interference caused by the electric traction.

3rd Experiment. — The first cable was now laid out on the floor, so that the sheathing was practically earthed along its length; while in this condition one end of the sheathing was connected to the gas pipes, thus being *fully* to earth. The

Mr W. M'Whirter.

insulated core at one end was connected to the sheathing through 10,000 ohms. The other end of the core was connected through a condenser ($\frac{1}{3}$ microfarad) to the telephone and to the sheathing. Currents were now sent through the sheathing exactly as in the first experiment, and the induced currents were heard in the telephone as at first.

Mr W. B. Sayers—In accordance with the apparent desire of the meeting, he witnessed the experiments arranged by Prof. Jamieson and Mr M'Whirter.

1st Experiment.—The arrangement, in Fig. 10, did not fulfil the conditions, because the sheathing did not form part of the telephone circuit, and the inductive effect on the core of the cable was therefore unbalanced.

2nd Experiment.—Here there was naturally no effect.

3rd Experiment.—Here the effect was obtained, and was, in his opinion, due to the direct action of the battery circuit. In order to eliminate direct action from the battery circuit, he suggested the arrangement represented in Fig. 13.

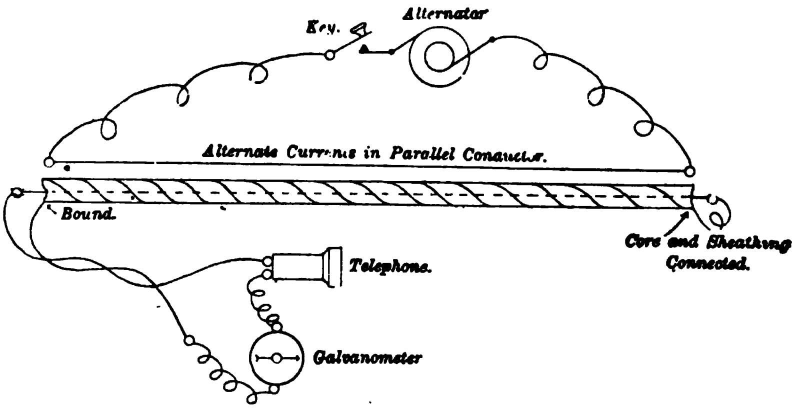


Fig. 13.

4th Experiment.—Here the sheathing and core of the cable both formed parts of the telephone circuit, Fig. 13, and thus reproduced so far the conditions of cable working. The concentric conductor was subjected to the inductive effect of a conductor laid alongside of it, and conveying alternate currents without effect on the telephone.

Mr David Robertson, B.Sc.—With reference to Prof. Jamieson's remarks on page 191: Did the fact that the cable sheathing exhibited no sign of electrolysis not show that the stray currents in it must be exceedingly small? And in connection with the shielding of the underground cable by iron pipes, it would be interesting to know in what way these pipes were jointed, as the value of shielding against change of induction depended very much on their conductivity.

Professor Jamieson — With regard to Mr David Robertson's communication, he might state that Mr Wilkinson, the Eastern Telegraph Company's Electrician, found a maximum of 5 ampères from the cable sheathing at certain times; and further, he (Prof. Jamieson) observed that the underground pipes were jointed with driven metallic lead.

Discussion.

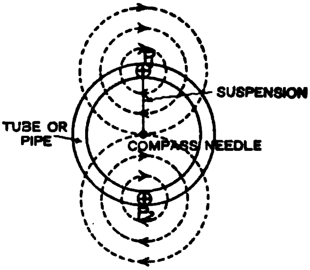
The discussion on this paper was resumed on 20th March, 1900.

Professor Jamieson said that at the last meeting it was proposed to submit the point raised in discussion between Mr Sayers and himself to experiment. That had been done, and he was glad to say the experiments proved conclusively that electro-magnetic induction did take place in an insulated closed conductor wholly surrounded by another, when variable currents were passed through the tube containing the insulated closed conductor. Since this was a *special* case of electro-magnetic induction, which did not seem to be explained in any text-book or paper, and since it was thoroughly well known that under such conditions no resultant magnetic field was observable within the space surrounded by a tube conveying steady or variable currents, perhaps he would be permitted to state his opinions regarding the nature of the action.

Prof. Jamieson.

1. It could be proved by mathematics, that no resultant magnetic field existed anywhere within a hollow conductor of circular section, through which a current was passing at the same intensity in each part of its cross section. Further, this might be proved experimentally by suspending a short light piece of soft-iron wire, or a tiny magnet in the centre of a circular tube, having the axis of the latter in the magnetic meridian, and passing currents along the tube, when the iron or magnet would not be affected. This arose from the fact that each diametrically opposite element of current produced an equal and opposite effect on the iron or magnet, as shown by the cross section, Fig. 14. This experiment might be extended to show that no field existed *anywhere within* the tube due to those currents.

Fig. 14.



2. If the iron or magnet were replaced by an insulated conductor, having a closed circuit through any delicate current detector, and currents passed through the tube as before, then the presence of induced currents in the interior conductor would be immediately detected. The interesting problem therefore arose: Why and how were these currents evoked, if there was no apparent field or change of field anywhere within the space surrounded by the tube?

3. If a closed conductor S, Fig. 15, were placed near and parallel to a primary conductor P, and a downward current started in P, then an upward or contrary current would be

induced in S. If the primary conductor were placed in *any* other position P at the same distance from S, Fig. 16, then on starting

Fig. 15

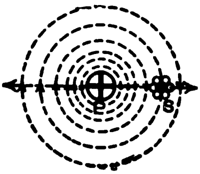
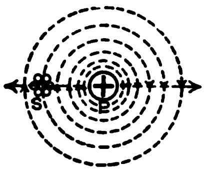


Fig. 16



a downward current in P the *same* effect would be produced in S as before.

4. If both primary currents acted simultaneously on the same secondary conductor and at the same distance therefrom, then, as each primary affected the secondary in the same way, their joint effect must be the *sum* of their several effects.

5. In the special case, Fig. 17, in which the two elementary primary currents P_1 and P_2 were diametrically opposite each other, it would be gathered from the above statement that, *they must*

Fig. 17

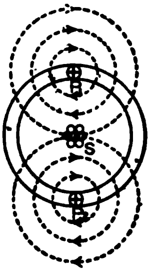
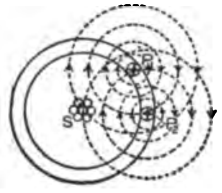


Fig. 18



assist each other in inducing currents in the secondary; but, it would be evident that if they were equal they *cancelled each other's magnetic fields* at the central point.

6. In the general case, Fig. 18, the primary currents P_1 and P_2

Prof. Jamieson.

did not cancel each other's fields at the centre of S, although of course they assisted each other's inductive action on the conductor as shown above.

7. If a current flowing in a tube were imagined to be made up of a number of small parts, of which P_1 and P_2 might be considered to be any two, Fig. 18. Every one of these elements would affect the secondary in the same way as P_1. Hence they would assist one another in inducing currents in S.

8. Another way of looking at this problem was to take into account the total number of magnetic lines of force *linked* with the secondary circuit. Evidently all the electro-magnetic lines of force which existed at any instant *outside of the tube* were linked with the central conductor S, since each was a complete circuit in itself. Hence, whenever the current in the tube altered, the number of these lines would correspondingly alter, and a current would be induced in S in accordance with Faraday's Law.*

Mr W. B. SAYERS said the diagram now put on the board by Prof. Jamieson was not the same as he had drawn at the previous meeting. The present diagram showed an unbalanced arrangement as regarded induction from external sources. In the first diagram the sheathing was shown as the return conductor, and whatever induction cut the cable cut both parts of the circuit; they had in fact practically the same condition as obtained in a twisted conductor. There was one point, however, in connection with the question which he had not mentioned. An infinitesimal part of the induction was unbalanced, and was due to the self-induction in the portion of the sea water which conveyed the currents; the resulting difference of potential due to this cause would be of a very minute value. The unlikelihood of any practical effect from that cause might be inferred from Mr Evershed's experiments. Mr Evershed found, in making trials with his device for signalling to lighthouses by means of a submerged coil, that while it worked perfectly well in

---

* The above conclusions were the result of discussions with Mr David Robertson, B.Sc.

fresh water, the sea water was too good a conductor, and so screened off the induction water to such an extent that he could get no result; and for the same reason he (Mr Sayers) thought there would be no appreciable disturbance of the telegraphic circuit due to this unbalanced, but exceedingly minute, part of the inductive system set up by the tramway currents. With regard to the question as to whether there was any magnetic field set up inside a tubular conductor, due to a current flowing longitudinally through the tube, as Prof. Jamieson now admitted that the field at any point inside the tube was zero it was unnecessary for him (Mr Sayers) to say any more.

A NEW BALANCED PISTON-VALVE AND ITS APPLICATION TO FOUR-CRANK ENGINES

By Mr William O'Brien (Member).

(SEE PLATE X.)

Read 23rd January, 1900.

Not many years ago the ordinary marine-engine was of the two-crank compound type, and it occupied comparatively little room on shipboard. With the introduction of the triple-expansion engine the space required was greater; and when the four-crank engine was adopted a further encroachment on space was made for its accommodation. To minimise as far as possible the space occupied by the latter type of engine, as well as to reduce weight, the Clyde balanced piston-valve has been designed; and by its application to the four-crank engine, the space taken up fore and aft will only be about the same as formerly required by the three-crank engine. The space thus saved may be utilised in warships for the better equipment of magazines, etc., and in merchant vessels for cargo carrying purposes or passenger accommodation as required.

In Figs. 1 and 2, a comparison is made between an engine of the four-crank type, recently completed by an eminent engineering firm to indicate 2500 H.P., with two piston-valves and two flat slide-valves for the four cylinders, or one valve for each cylinder, and four sets of valve-gear, and an engine fitted with cylinders of the same dimensions to indicate the same H.P., having only two Clyde balanced piston-valves and two sets of valve-gear for the four cylinders. The latter engine is 5 feet 3 inches shorter over all and with fewer working parts than the former. There are only two sets of valve-gear against four sets, while the reversing shaft is only half the length required for the four sets of valve-gear. Some of the pipe connections between the receivers are dispensed with; the intermediate pressure receiver pipe is done away with, saving about 11 feet of 12-inch copper pipe; the low pressure receiver pipe is 8 feet long, thus saving about 2 feet of 12-inch copper pipe; and the eduction pipe is only 4 feet long, saving over 6 feet of 15-inch pipe. With these reductions, and the amount of metal saved in designing the engine for the Clyde balanced piston-valve, the weight is considerably less. What might also be claimed as a very important feature, with engines designed for this type of valve, is the lessened number of joints; thus minimising the danger of leakage, saving workmanship, and reducing the cost of production. It will be seen from Fig. 2 that there is only one joint between the cylinders, which is not a steam joint; whereas in Fig. 1 there are four joints, two of the latter being steam joints and two not.

In the illustration showing the combined high-pressure and intermediate-pressure valve with five ports, the top and bottom ports take the boiler steam pressure into the high-pressure cylinder, through the straight ports at the top and bottom of the cylinder. The exhaust steam from this cylinder passes over the top and bottom ends of the valve into the interior of the valve, and from there it passes through the ports on each side of the middle or exhaust port into the intermediate-pressure cylinder, through the curved ports leading to the top and bottom of the cylinder. The exhaust from the intermediate-pressure cylinder passes into the middle port of the valve, then into the receiver or connecting-pipe to the valve for the two low-pressure cylinders. This valve, which differs somewhat from the afore-mentioned valve on account of the steam pressure in the two cylinders being the same, has only three ports. The two end ports convey the steam from the intermediate-pressure receiver to the forward low-pressure cylinder, by the straight ports at the top and bottom of the cylinder; and the exhaust steam passes over the ends of the valve into its interior, thence to the exhaust or middle port of the valve, which is open to the condenser. The steam to the after low-pressure cylinder is admitted through the same two end ports of this valve, by the curved ports leading to the top and bottom of the cylinder; the exhaust from the cylinder passes into the middle port of the valve, and from there to the condenser.

From what has been said, and what is shown in the illustration, it will be apparent that the advantages gained for the same power by adopting the Clyde balanced piston-valve, are saving in space, reduction in weight, and fewer working parts. Fig. 3 shows two high-pressure valves inside one casing, and Fig. 4 shows two low-pressure valves inside one casing. The subject appears to the writer to be of sufficient interest and importance to warrant his bringing it under the notice of the Institution; in fact, it seems to him to bid fair to cause some revolution in ship design, at least in the internal arrangements, by devoting the space saved to other purposes.

Mr O'Brien, having consented to reply in writing to the following correspondence, was, on the motion of the CHAIRMAN (Prof. A. Barr, D.Sc.) awarded a vote of thanks for his paper.

Correspondence.

Mr E. C. PECK (Member)—One weak point in the design which Mr O'Brien had brought forward in his paper, was the existence of a considerable receiver space between the No. 1 and No. 2 Cylinders of what was practically a Woolf arrangement. In a pair of compound cylinders working on cranks at 180°, it was necessary to reduce the clearance between the two as much as possible to get a good result. A very large clearance, however, appeared in Mr O'Brien's design, together with an unnecessary amount of complication. In the whole height of the valve-casing there were seven passages, and this might be looked upon as rather a serious matter in casting two cylinders and valve-chest in one, together with communication passages between the top and bottom. Although Mr O'Brien's valve gave release at the top and bottom edges to No. 1 cylinder, it did not really represent release, Mr E. C. Peck.

as, when it opened, No. 2 cylinder was not ready to receive steam, and the result was that the exhaust of No. 1 was bottled up until

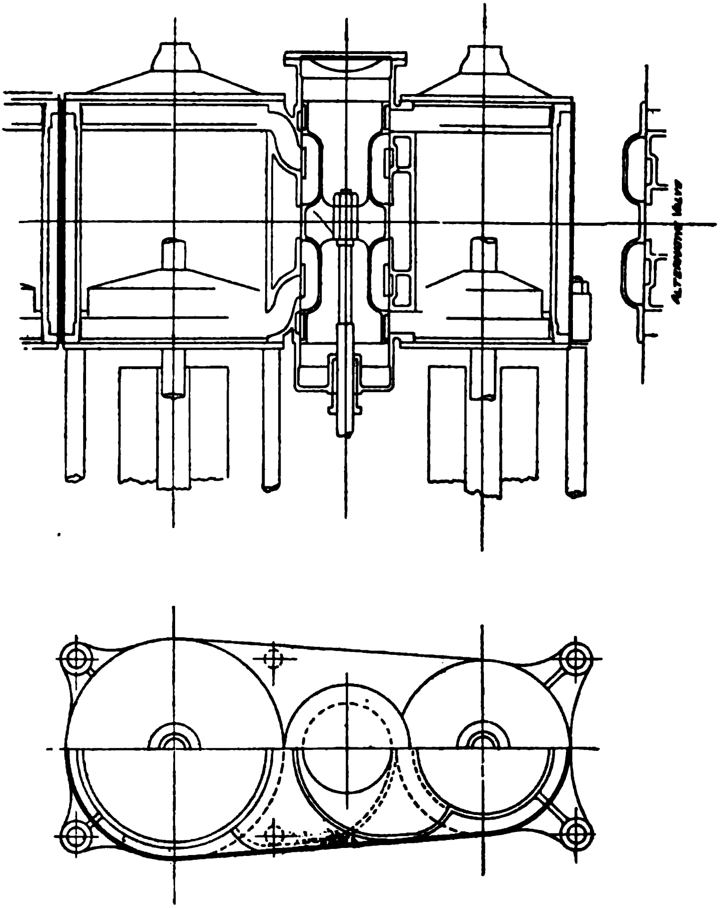


Fig. 5.

the valve had travelled at least as far as corresponded to No. 2 cylinder lap. This second land in his design was necessary, of

Mr E. C. Peck.

course, to prevent the steam port of No. 2 extending throughout the receiver space to the exhaust edge of No. 1, which would otherwise give an abnormally large clearance and go far to counterbalance any advantages obtained otherwise in the design. In 1889 he (Mr Peck) designed a set of quadruple-expansion engines for torpedo-boat work, with the object of reducing vibration, and possessing the various simplifications Mr O'Brien claimed. The design of the engine was practically the same as that illustrated by Mr O'Brien, but the valve and passages (as would be seen from Fig. 5) were of much simpler form, and the clearance between the ports of No. 1 and No. 2 was restricted to the comparatively small pocket in the valve. Of course it was hopeless to get anything more than a fairly close approximation to a correct distribution with any arrangement of this kind, but he considered it sufficiently so in the case of a fast running quadruple-expansion engine carrying steam well down the stroke.

Mr John Thom (Member)—When two piston-valves were used for cranks working directly opposite, it was not necessary to have a complicated valve with six faces, as would be seen from the illustration, Fig. 6, which was quite a common arrangement. The valves F and A worked the forward and after cylinders respectively. The crosshead connected the two valves inside the steam casing, and therefore only one stuffing-box was required. With this arrangement the crosshead expansion was in about the same proportion as that of the cylinders. This method of fitting the crosshead was first adopted by Mr James Lang, superintendent engineer of the City Line of steamers. The valve shown in Fig. 7 was similar to that illustrated in the paper, excepting that the high pressure steam was admitted at the inside instead of at the outside edges of the valve. The high-pressure steam was thus kept off the valve-spindle packing and the casing joints. The sketch was an exact copy of one accompanying a United States patent specification, dated 1893.

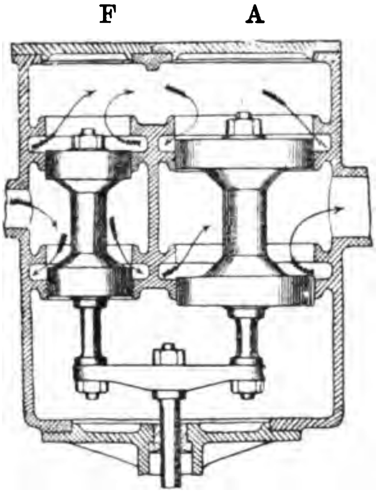


Fig. 6.

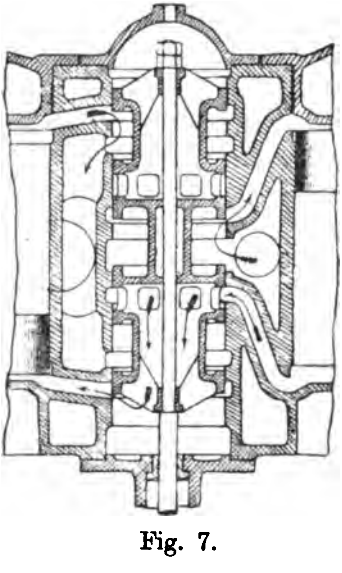


Fig. 7.

Mr O'Brien.

Mr O'Brien, in reply, observed that he had no knowledge of the Woolf arrangement referred to by Mr Peck, and, therefore, could not say anything about it. He did not think the clearance, as shown in his illustration, was unnecessarily large, and he was at a loss to understand what Mr Peck meant by complication, as the valve-casing did not exceed the length of the cylinders, whereas, in Mr Peck's arrangement it exceeded the length of the cylinders at top and bottom. Further, Mr Peck did not seem to give moulders credit for what they were able to do, and no complaint had been made in this direction. It occurred to him that Mr Peck's remark regarding the release at top and bottom of the cylinders, and the bottling up of the steam, carried no weight with it, as that was exactly what would take place in the design shown in Fig. 5. Mr Thom considered it unnecessary to have a complicated valve with a number of ports, when piston-valves were used for cranks working opposite. He would point out that Figs 3 and 4 in his paper only showed what could be done with this design of valve when adopted for a large size of engine. From Fig. 2, it would be seen that only one valve was required for the two cylinders, with the advantages already noticed as to the crosshead for fixing two valve-spindles. The design shown by Mr Thom was not commendable. He did not know who first adopted that method of fitting the crosshead; but this he did know, that it was a good many years ago since he had charge of engines with the crosshead fixing the two valve-spindles. But the crosshead was where it should be—namely, outside the valve casing—the expansion being allowed for in the holes of the crosshead where the valve-spindles passed through. With respect to the high-pressure steam coming in contact with the packing or casing joints, it was well known that this difficulty had been entirely overcome.

TYPICAL FORMS OF RACING YACHTS.

By Mr J. R. Barnett.

(SEE PLATE XI.)

(Held as read 20th February, 1900.)

In looking back over the last 25 years, it is apparent that racing yachts have undergone many radical changes. Some of these changes are of immediate interest only to a few persons, but others stand out so prominently that they cannot fail to strike the most casual observer.

During the period mentioned, two types of racing yachts, of distinctly opposite character, attract special attention; and in this paper it is intended to contrast a few of the peculiarities of form exhibited in them.

There is A the extremely "narrow" type with enormous displacement, and B the "broad" type with comparatively little displacement, Figs. 1 and 2. Each was successful in its day, for success is only a comparative term, and both had good qualities as well as bad ones.

When examining these two types, it becomes evident that neither the one nor the other represents exactly the kind of vessel that would be built if the object were simply to produce a fast vessel. As the principles involved in the design of a yacht are the same as in the case of every other vessel, there must therefore be good reasons for such peculiar and diverse types being constructed, and these are not difficult to find. The racing yacht is merely a natural development under certain conditions that are enforced by way of measurement for racing purposes. And, from time to time, it has been found desirable to modify or change the methods of measurement, in order to check extreme tendencies, for these have made their appearance under every measurement formula adopted in the past. It is easily understood, therefore, why different types have occurred.

From what has been said, it is evident that, in designing a racing yacht, the problem is not merely to produce the best boat, but rather to produce the boat which best suits certain particular conditions. Of course the conditions are imposed with a certain end in view; viz., to bring into existence a good wholesome type of boat; but, as already indicated, the various changes that have been made, from time to time, show that none have exactly fulfilled the desired end. To pursue this point is, of course, apart from the present purpose, but, as the results of the application of some of these measurement rules concern us, it is advisable to briefly notice a few of the characteristics of these rules. There are certain valuable elements to be judiciously combined in a yacht, and these have a great effect on its form. Perhaps the most important of these elements are: (1) Length, a necessary factor for high speed; (2) Breadth, for stability; (3) Depth and displacement, for sea-worthy qualities; and (4) Sail area, which is a measure of the driving power. There should be no preponderance of any one of these at the expense of another; but in both types under consideration there is a great excess in one or more of these elements, in consequence of the measurement rules in force at the respective periods.

It is a comparatively short time since yachts were first systematically classed for racing. Previous to that, outbuilding by size was the natural development, so there was no direct effect upon the general design. Since then, however, several measurement rules have been adopted. Of these only two need be specially mentioned, as it was under their influence that both types mentioned reached their limit. In computing the tonnage by the "1730" rule, measurements are confined altogether to the hull, and only breadth extreme and length on water-line are taken. The formula is $\frac{(L+B)^2 \times B}{1730}$ and, though vessels had been gradually growing longer and narrower under the rule previously in force, they went still further in that direction under this one. The full development of the extremely "narrow type" of yacht was the ultimate result. The breadth became absurdly small in proportion to the length, simply because, according to the rule, it paid to have it so. The power applied to drive the vessel was not taken into account at all, consequently year by year the new boats had an increased sail area, although the tonnage remained the same, and the stability was maintained by having a greater displacement, with a heavier and deeper keel. A state of affairs had been reached which called for some alteration, and a change was made which caused a decided reaction. The "length and sail area" rule was introduced, and it was in some respects the converse of the previous one, being as imperfect in its own way. The formula is $\frac{\text{L} \times \text{Sail Area}}{6000}$. Only those elements which directly go to produce speed (length on W.L. and sail area) were reckoned in this formula. The change resulted in the development of the "broad type." The weight to be driven through the water was, as before, of no consequence as far as the racing measurement of the vessel was concerned, so the displacement was reduced to a minimum, and stability maintained by great breadth and great depth of keel.

Like the swing of a pendulum, when the formula which was responsible for the production of A had been abandoned, another was adopted which went to the other extreme and ultimately produced B.

The one-sided nature of these measurement rules makes it evident that development in each case would naturally take place in the direction which was untaxed. Observe, therefore, that in both of these extreme types the elements had grown disproportionate, for it is part of the designer's aim to take every advantage offered to him while complying with the conditions stipulated. A, has too little breadth and too much displacement for the dimensions; whereas B has too much breadth, and too little displacement, and, at the same time, an excessive draught. Having failed to produce a wholesome type of yacht, the rules mentioned were superseded, and the one at present in force adopted. This is a great improvement on all its predecessors, though, like them, it is a purely empirical formula. It was introduced four years ago with the object of inducing a better type—one with larger displacement, and more moderate breadth and draught than B, and it seems to be gradually having an effect in the desired direction. Though the general appearance of the most recent racing yachts closely resembles B, a type appears to be coming into existence which will embody the good features, and check the bad ones of the two previous types—in fact a kind of compromise.

It is, however, intended to confine all comparisons to the form of types A and B, as they stand out so prominently from all others. In doing so, it is not intended to notice the greatest extremes that were reached in certain vessels, or in the small classes. The diagrams have all been drawn for boats of 60 feet water-line length, as giving a better idea of the general type than either the smaller or larger yachts, and these diagrams are fair examples of successful boats of that length.

Figures 1, 2, and 3 give comparative profiles, midship sections, and deck plans, and show generally the chief features.* In making comparisons of the two types selected, the most evident difference is the ratio of length to breadth, Figs. 2 and 3. A has a length on the water-line of about 5¾ times the breadth, whereas B is only 3½ times, and under their respective conditions, such proportions fulfilled the end in view. Though the draught of the narrow type was at the time considered very great, in the broad type it steadily increased to a still greater depth, Figs. 1 and 2.

As would be expected with such radical differences in proportions, the form of the midship section is quite different in the two cases, Fig. 2. The co-efficient of the mid-area (below water) of A is ·54, and that of B is only ·31. The area in both

---

* In the diagrams the "narrow type" is referred to as A, and the "broad type" as B.

cases is not so very different, but the depth of the actual body of the boat, as apart from the keel, is much shallower in the case of B, and this accounts for the great increase in the size of the overhanging ends, forward and aft, Figs 1 and 3. Such prolonged ends were quite impossible with the long, deep body of A. The area of that part of the section which is above water in relation to the part below is, however, very different in the two. In A the ratio is ·57, whereas in B it is ·89. And this is characteristic of the whole form of the two yachts; viz., there is much more of the boat above water in B than in A. The form of the profile of B is a great departure from that of A, for reasons given later.

The next point to consider is the buoyancy and displacement of the two. With such dissimilarity in proportions and form of midship section, there is naturally a corresponding variation in the volume and its disposition, both of the part below water and of that above. The displacement curves, Fig. 4, show the difference in the disposition of the volume vertically in each case, below and above water. In A the volume above water is ·83 of the volume below water, whereas in B it is 1·5. Comparing the two, the displacement of B is 14 per cent. less than A, but the total volume of the vessel is 17 per cent. more than A.

The curves of sectional areas, Fig. 5, indicate the variation in the fore and aft disposition of the volumes of displacement, while the form of the profiles, Fig. 1, explains this variation to a great extent. The cutting away of the keel at both ends of B is the natural outcome of the shallow body below water in conjunction with a very deep keel, for it is necessary to keep down the surface below water to the minimum while retaining a sufficiently large plane for lateral resistance. The surface of B is however rather more than that of A. Fig. 5 also gives an idea of the relative fineness of the entrance and run of the two types. The broad boat has the finer ends, the prismatic co-efficient being ·52, whereas that of A is ·56. Fig. 8, shows in a graphic way the comparative dimensions, areas of mid-ship section, and volumes of A and B.

Such changes in form necessarily have a great effect on stability, which is one of the most interesting and at the same time most difficult points in a design. The stability must be such as will allow the necessary area of sail to be carried; it is therefore evident how dependent the speed of the vessel is upon her stability. While in the narrow yacht, A, stability is obtained more by a heavy keel, giving a low centre of gravity; in the broad one, B, form plays a more important part in this connection. The difference in the vertical distribution of the volume of displacement has raised the centre of buoyancy in the case of B to a considerable extent, and this together with the great breadth gives a high metacentre. In A the distance of the centre of buoyancy below the water-line is ·3 of the extreme draught, but in B it is only ·2. The weight of the keel of A is a little more than half the displacement, and in B it is a little less than half.

In the diagrams of stability curves, instead of the lengths of "righting levers," the lengths of what is usually termed "B.R." are shown, Fig. 6, as giving a better indication of the effect of the difference in form. The curves of righting moments, Fig. 7, show relatively the ability of each yacht to carry sail. As would be expected, the initial stability of B is much greater than that of A. Yet A carries a little more sail area than B, and it is only when great angles are reached that the curves cross. This will be easily understood by examining the sections, Fig. 2. The narrow yachts, however, were sailed at considerably greater angles, though less effectively, than the broad ones.

Fig. 9 is merely added to show the proportions to which yachts of each type went in the smaller classes.

A few words may be added regarding the construction of these yachts. Notwithstanding the great difference in form, the general construction of the types and size under consideration remained the same. Of course the form of the broad type, being very weak in many points in comparison with the other, necessitated many modifications to meet the change. But "composite" was the favourite construction adopted, and it has remained so to the present in all but the smaller yachts. This method of construction has many advantages, being easy to build, and it is not extravagant in cost. It is also strong and, at the same time, reasonably light. Composite yachts keep their shape well, and last for many years if well taken care of. Nickel steel is now preferred for the framework, being stiffer than ordinary steel, besides allowing smaller scantlings to be adopted. In details of construction and fittings, however, great changes have taken place in hull, spars, rigging, and sails, but these cannot be dealt with at present.

Discussion.

The discussion on this paper took place on 24th April, 1900.

Mr Harold Jackson (Member) said that this paper, although of interest and of value to some extent, did not of itself provide any scope for discussion. Mr Barnett dealt with only two of the rules for racing yachts, and these were obsolete rules. It was a pity that the rule at present in force had not been dwelt upon in detail by the author. On page 222 Mr Barnett said: "Having failed to produce a wholesome type of yacht, the rules mentioned were superseded, and the one at present in force adopted. This is a great improvement on all its predecessors, though, like them, it is a purely empirical formula." That was practically all that he said about the present rule. He (Mr Jackson) thought there was no evidence that the present rule was leading to a "wholesome" type of yacht. The rise of the "one design" classes all over the kingdom was evidence that people were rather tired of the unwholesome type which had been the outcome of former rules, and which also seemed to be the outcome of the present rule. On page 219, Mr Barnett said: "When examining these two types, it becomes evident that neither the one nor the other represents exactly the kind of vessel that would be built if the object were simply to produce a fast vessel." It was doubtful whether the unwholesome form of yacht was due to any rule. It seemed rather to be a *sine qua non* of speed under the conditions in which yacht racing was carried out. On the Clyde there were the

Mr Harold Jackson.

23-feet and the 17-feet classes, in which the only limits of dimensions were those of length over all and length on the waterline, and the type of vessel represented in these classes was very much the same as that which had been evolved from the various other formulæ. There was very little difference in the speed of yachts of different types in a good breeze with the wind abaft the beam or on the beam; but in a light breeze, and especially when close hauled in a light breeze, a vessel with small underwater body would run away from the "wholesome" type of vessel; and hence, so long as yacht-racing was confined to that season of the year when light breezes and smooth water prevailed, it seemed hopeless to expect that yachts would conform to a wholesome and seaworthy type of vessel.

Mr BARNETT in reply said it was not intended to discuss the measurement rules. He thought that had been stated clearly in his paper. He merely put forward a few comparisons of two extreme types that had been developed within the last 25 years. To have gone into a discussion of rules, or types of vessels, would have been too exhaustive, and would have taken up too much time.

On the motion of the CHAIRMAN (Prof. A. Barr, D.Sc.), Mr Barnett was awarded a vote of thanks for his paper.

WORKSHOP ADMINISTRATION.

WORKSHOP ADMINISTRATION, WITH SPECIAL REFERENCE TO TRACKING WORK AND PROMPTLY ASCERTAINING DETAILED COSTS AND PROFITS.

By Mr DAVID COWAN (Member).

Read 20th March, 1900.

MUCH has been done by engineering and other institutions towards the advancement of the scientific and technical branches of the profession, and for the instruction of younger members in knowledge which lies beyond their own experience. There is, however, an apparatus of production that has not received the attention from such institutions which its importance merits; viz., the workshop itself, treated as a whole. This is the more to be regretted, since, under the stress of modern conditions a higher complexity of development is called for. The responsibilities of public undertakings are greater than those of individual proprietors. The importance and value of scientific shop management have been more fully realised in America than here. All students of mechanical engineering in their fourth year of study at the Massachussetts Institute of Technology are, among other subjects, required to "study the organisation and rules of the various departments of an industrial establishment, both in the office and in the workshop, the conduct of accounts, the methods of compensating labour and superintendence, and the effect on the cost of production, by different methods of indirect expense."

The purpose of this paper is not to discuss the whole subject of such study, but to induce this Institution, if possible, to treat the study of shop administration as a branch of the productive art. The consideration of this subject by the Institution does not involve the giving away of matter which is purely private, but the members can, with advantage to themselves and to the community, from their own practice, contribute towards the advancement of this much neglected science.

That the subject is sufficiently broad, and that there is ample scope and opportunity for making the administration of productive engineering enterprises a special subject of study, will be gathered from the chart, Fig. 1, which shows a graphic analysis of the more important acts requiring to be performed.

The items specially referred to in this paper are those printed in italics in the chart.

Workshop organisation should have, as its fundamental principle, unity of action; it should eliminate all guess work, and depend for its efficiency on a constant knowledge of all individual acts. It should be simple in its conception, automatic in its working, and impartial in determining results; it should force instant recognition of "on-cost" fluctuation and the constant comparison of co-related cost factors; it should permit of results being obtained in such detail as the special circumstances of each case warrant; and it should be based on those properties which enable analyses to be made at considerable intervals after the work is completed, without making calls on the time of the executive officials.

The more diversified the products of the worshop the more necessary becomes the knowledge of the differences in cost, although the greater the diversity of products the more expensive is the obtaining of that knowledge. Without this knowledge, principals are unable to make themselves intimately acquainted with what is going on, and they cannot, with any degree of confidence, introduce modifications of detailed routine which their judgment would indicate to be necessary.

The prevailing idea regarding shop records is that they are only necessary for determining the selling price of the product. For arriving at the final results the accountant and his needs are considered all important, and it is held that any clerical labour over and above is needless. The important functions of records in pointing out where economies may be effected, production quickened, and supplies regulated, are usually lost sight of; and the practical officials are depended upon for the performance of those functions which ought not properly to devolve upon them in detail.

The selling price of the product is determined not so much by its cost as by competition.

If the manager finds that the cost of an article is too high, he must find a means of reducing the cost if he is to continue its manufacture, and this can only be done by reducing the amount or the cost of labour and material, or by reducing the rate of oncost, or both. In order to do any of these intelligently, with a minimum of trouble, he must be provided with fully detailed economic information with regard to the product in all its parts. The personal supervision of the manager may in a small business accomplish these objects, but personal supervision is limited in its range, and when this limit is reached, subordinate authority, in the shape of the "leading-hand," foremen, or heads-of-departments, becomes a necessity. Then the duties of the principal become those of collecting and recording the data needful for formulating the arrangements whereby secondary authorities have the necessary freedom of action under superior control. Clerks without practical knowledge of work, who make *ex post facto* analyses by the aid of foremen, cannot be depended on for collecting the information necessary for efficient administration.

To secure a useful analysis, it is essential that the demands of the administration be anticipated, and the various acts of all the subordinate officials recorded, at the moment of their performance. To ensure accuracy of description, and at the same time reduce as far as possible the volume of such records and the time required for their production, simple symbolic momenclature covering all the elements in such a record is a necessity. This cannot well be entered into here, but is of great importance in the detailed working out of any well-considered scheme of administration. To properly initiate such records implies a constant analysis of the work beforehand, and a continuous record of all the acts by those executive officers who know most about them, at the time of performance, and, if this is properly attended to, a subsequent synthesis is easy.

Generally the acts of a workshop may, for administrative purposes, be divided into two kinds—

1. Those of the executive, whose acts result in the continuous expenditure of materials and labour, and the delivery of the finished product.
2. The recording of these acts.

Hitherto, shop records have been usually kept in bound books. The disadvantages of books for this purpose are many—

1. They can only be used by one person at a time.
2. The combining of similar entries made at different times and places is laborious.
3. Effete matter soon obscures current information, so that the longer an entry has escaped attention the more certainly will it continue to be neglected.
4. The use of type-writing machines, mechanical adders, time-recorders, and other labour-saving appliances, is impracticable.

For these reasons it is suggested that the use of books be dispensed with, except for final records, and a "card" system adopted.

Cards lend themselves to the production of a complete system of self-indexing all memoranda, letters, papers, and records of every kind. Such groups of data may always be kept in exact order; eliminations and additions can be instantly made without disturbing the sequence. By restricting the entries on each card, to *one only*, the number of possible combinations is endless. In this atomic state, information may be treated analytically and synthetically, in every form, and for every purpose. Examples of such cards for the records of, and synthesis of, costs are given later. The production of a suitable card for the use of any particular business requires much experience. No makeshift gives any satisfaction.

The first essential in setting on foot a complete system of record is the analysis of the work to be done into distinct objects of expense. This analysis should be full and complete, and should be made at the outset by persons acquainted with the whole process. Diagram, Fig. 2, shows how a customer's order for work may be analysed into special products, and how these products may each in turn be resolved elementally.

Fig. 3 shows an example of a shop specification analysing a product into separate objects of expense.

The shop officials are thus put into simultaneous possession of full details of all work requiring to be performed in connection with the product. These details, arranged and grouped on a systematic basis, are applicable to both office and shop requirements; they promote the smooth working of the establishment, and minimise worry on the part of all concerned. It is a mistake to suppose that such a preliminary analysis, if judiciously carried out, involves any delay in putting the work in hand and passing it through the shop.

A complete specification should embrace all the information necessary for the following purposes, among others:—

1. The issue of shop orders for work, in terms of processes and operations necessary.
2. Ordering materials from outside.
3. Ordering materials from work stores.
4. Standardising details.
5 Recording conditions of work in process, packing and forwarding.
6. Erecting in shop and on sites.
7. Compiling cost accounts.
8. Permanent records of the special product.
9. Identifying replacements or repairs.

In practice many more uses, special to individual shops, will become apparent. The specification is the pivot round which the whole mechanism of the establishment revolves. To conveniently embody all this information on the specification involves the use of the symbolic nomenclature already referred to.

The issue, the trail, and the records of authorizations of expense.—An order from a customer to supply him with goods is the source of all production orders. Special products made for the establishment or for stock are treated exactly as customers' orders, and all such orders are entered in the customers' order book, and there dissected into separate objects of production. Special care should be exercised in keeping this book, in all its details, up to date. When this is done it forms a summary showing the condition of all work in hand as well as a record of all past performances.

The products special to any customer's order being dissected into special production orders, Fig. 2, these may be sub-divided thus:—

Production Orders.—Issued by the office to the manager for the production of complete products, Col. 3, Fig. 4, and Fig. 6.

Sub-production or Shop Orders.—Issued by the managers to the foremen under their charge, for the production of separate members, components, or pieces of a given product, a separate order being issued for each separate object of expense, the whole product being itemised to such an extent as is considered necessary. Should it be necessary to issue the work to more than one department simultaneously, a copy of the shop order with the process special to each department should be given to the respective foremen, Col. 4, Fig. 4, and Fig. 5.

Job Orders.—The authority for the issue of these is the shop order issued to the foremen. The job order is personal to the workmen, and to each operation; it authorizes the individual units of expenditure, and specifies the conditions of performance, Col. 7, Fig. 4, and Fig. 7.

Forwarding Orders.—As any product nears completion, such an order is issued by the manager on form, Fig. 8.

Foreman to Foreman Orders.—In many cases the foreman receiving a shop order may require the co-operation or assistance of a foreman in another department, in which case he issues a *shop order* form, a duplicate of which is of course sent to the cost office.

Alternatively, the first foreman may hand the *shop order* card originally received by him to the second foreman and so on, recording receipts and completions at the time of transference. In this way one shop order may serve for the instruction of any number of foremen, but possibly at the expense of time.

Standing Orders.—For shop expenses or oncost. These are dealt with generally in a manner similar to special shop orders, and they may be further subdivided into orders for components and pieces, a separate job order being issued for each, Fig. 4, Cols. 2 and 3. For the sake of distinction, order cards for standing shop orders may be distinguished by difference in colour, or in some other way.

The manager and foremen are each provided with a card index cabinet, in which they set apart a file for each production order, or for a given number of orders as circumstances render necessary. All orders are issued by the respective executive officers in duplicate, one copy being sent to the cost clerk and the other to the person responsible for the production. The issue of production orders is recorded on the original shop specification. Shop orders are recorded on the production order cards analysing the work. Job orders are recorded on the shop order cards, thus giving trace of all subordinate acts.

On the front of each card its course is recorded by every recipient entering, into the space set apart for the purpose, his name or symbol and the date of receipt and completion.

On the back of the duplicate cards sent to the cost clerk, are printed the forms for use in ascertaining the cost of the product, Figs. 9, 10, and 11.

It has been assumed that the manager and foremen make out and attend to all "receipts" and "completions" of order cards; but it may easily be conceived how this could be better attended to by a clerk, who at the same time may attend to the orders for withdrawing materials from the stores and the time record cards, referred to later on. The offices of timekeeper and job clerk may with advantage be combined. When such a combination is made, the job office should be as nearly central in the shop as possible, and should be fitted with a complete equipment, including a service card index-file. The job clerk and timekeepers should be in the office during the whole hours of work, and the foremen and shop manager should also be on duty the whole time as well.

Records of the Condition of Work.—For the record from time to time of the state of progress of work in the shop, the shop specification is used, suitable distinguishing signs being used for the purpose, Fig. 3, Columns 11 to 23 inclusive. These symbols are posted up daily in the shop specification. This is done by a boy who makes use of the duplicate order cards, "issue" and "completion" records for this purpose. This system of recording the condition of work from time to time is already in use in many of the Glasgow shops in some form or another, and a description has been published in "Engineering."

The index spaces on the different order cards may also be made to serve the same purpose, by crossing out the numbers of such job orders as are completed from day to day.

Elementary Shop Records.—A reference to Fig. 12 will show that the element of Shop Orders should be as follows :—

1. Materials, delivered direct.
2. do., drawn from store.
3. Out-services.
4. Labour.

Materials.—In most shops, particularly those employed in building the heaviest kinds of machinery, where transportation is an important factor, materials are handled in two ways.

The heavier pieces as received are delivered direct to the job on the shop floor, checked with the delivery note, and a receipt given for the same by the foreman to the storekeeper, shortage or breakage or other faults being reported on the same form of card, and steps at once taken for replacement.

The lighter materials are usually bought in quantity, and passed through the rough stores, being retailed in exchange for a requisition made on a "material card," stating the estimated quantity required by the foreman or other responsible person. This card is received by the storekeeper, who fills in the daily serial number, and enters on the card the actual quantity issued, and at same time enters it in the corresponding stores "journal card;" thereafter the original requisition card is forwarded to the cost clerk, who, after filling in the value, files it away, with other cards of the same kind, under its job order number.

Credits of material, whether returned to suppliers or to rough stores, are made on "material cards" by making the necessary entry in the credit space. These cards are also sent to the cost clerk, who gives due effect to these credits at the proper time.

Outside Services.—Outside services are paid for either through the Supplier's Journal or the Petty Cash Book. The items are transferred therefrom on "material cards" by the purchasing clerk, or by the cashier, and are dealt with in the same way as material delivered direct, being charged to the shop, or job orders, against which they are issued.

Labour.—Labour is recorded direct on cards, Fig. 13, either by the workmen themselves or by the timekeeper. The time on which the workmen are paid is taken by checks at the shop entrance in the usual way; but, before any wages are disbursed, the total time units and values as recorded on the cards must be in agreement with the corresponding time in the wages book.

The Cost of the Product.—Whilst the accountant is chiefly concerned with final results, the manager of the shop requires continuous records showing how the current expenditure on the various objects in course of construction is creeping up towards the total estimated cost. Hence, any system of shop accounting to be of real value should, in the first instance, serve this purpose. Before enquiring how this may be obtained, it may be well to define some of the leading terms, since they may have different meanings in different shops.

Prime Cost is the summation of the cost of materials, labour, and outside service, chargeable solely and directly against the product.

Oncost is the indirect expenditure incurred for the purpose of increasing the productive power of labour, and includes every outlay whatever, not chargeable to a specific product. Oncost includes depreciation for tear and wear, obsolescence, and all safeguards of capital against risks and casualties, but the remuneration of capital is not included as oncost.

Gross Cost is the sum of prime cost and oncost.

Nett Cost is the gross cost, less the value, for future use, of any plant or tools made specially for the production of the special product.

Plant includes drawings, patterns, models, moulding-boxes, gauges, and similar appliances for common use, also mandrils, boring bars, etc., which have more or less special value apart from the special product for which they are originally obtained.

Tools include the ordinary loose tools, hammers, chisels, files, reamers, cutters, etc., and also those perishable portions of machines which act directly upon the objects of production, and are subject to consumption from wear during the execution of the order for which they are made, the most important being templates, cradles, jigs, and such like. When tools are consumed in the manufacture of products, these should be charged direct to the work. When consumed in miscellaneous work they should be charged to oncost.

Tools and fixtures when made for a specific job are usually charged in the first instance to the job as such, and afterwards credited at their estimated value for future use.

Machinery includes all prime-movers, shafting, gearing, and machines of all kinds actuated thereby.

Work, as distinguished from plant, is the transformation of materials (stores) by organised labour into products.

Stores (Rough) are materials of every kind on which labour is to be expended for converting into work or stock. These may include finished articles such as screws, bolts, bright shafting, finished pulleys, finished special parts and so on.

Stores (Finished) are the parts or components of machines, often made in quantities in shops. These when completed are sent into the warehouse to await the demand. Were the same articles purchased from outside they would be classed as rough stores; dealt with as finished stores they are included in the general term "Stock."

Stock is the finished product resulting from the conversion of Stores.

Production Account.—In most establishments, it is usual to keep in the general books a production account, to which is debited all expenses whatever, as relative to production, and to which is credited the value of all products, the balance being the profit or loss. The debit-side, less balances brought forward, should balance with the total of the cost returns as made on the elementary cards.

Balancing Production and Cost Accounts. — The first step towards accuracy in shop returns is to make sure that the expenditure, represented by the total of all the elementary record cards, agrees with the corresponding charges in production account. The routine of this balance is as follows:—

The labour and material cards as they come into the cost office are examined, the prices filled in and extended, and filed in a cost index cabinet, a separate drawer-file being set apart for each product in course of construction; the order of filing being that set out in the shop specifications. Guide cards are inserted between the record cards belonging to each shop order, and these again are cross-indexed by the insertion of tab cards between the records pertaining to each job order. The record cards corresponding to each of the four main divisions of prime cost—viz., materials-charged-direct, materials-charged-through-stores, out-services, and labour—may be distinguished by being made on different coloured papers or otherwise. The credits may also be distinguished in the same manner. All the cards of the same colour corresponding to each job order are collected into one group.

At the end of each balancing period the current-service file-index cabinet is gone over, by taking each product in succession, and entering every current shop order number corresponding thereto into the weekly cost sheet. These numbers may be got from the index section of production order card. The corresponding job orders, the number of which may be obtained from the index section of shop order card, are treated in the same manner by entering them in another column, the sequence to be observed being that in the shop specification.

Then classify all elementary cards by job orders, and each pack according to elements. Sum up the values and units on the back of the last card in each lot. Next enter their totals in the columns under their corresponding headings, opposite the job-order numbers. When all job entries have been made for any one shop order, sum up the vertical totals, and the result gives the total of the elements going to make up the prime costs expenditure on that shop order for the week.

Proceed thus to ascertain the expenditure on all shop orders —special and standing—in progress.

Bring forward the gross expenditure from the week preceding. Compute the oncost for the current week in the matter hereinafter indicated, and enter the same in its proper column. The cross totals of each line of all the columns give the gross expenditure to date on all current job orders, grouped according to shop orders. The sum of all shop orders gives the cost of the product, grouped according to its members' components and parts as set out by the analysis made in the shop specification.

The total cost of all work in progress and completed during the week is the total expenditure for the week. The vertical grand totals of the columns of the cost sheet should agree with the corresponding totals charged to production account through the general books.

These costs of completed work are summarised every four weeks in a suitable register, where all credits are deducted, and where the nett cost is set out parallel with the invoice price, the difference between these being, of course, the profit or loss on the respective products.

It will be observed that it is thus practicable to interlock the shop costs account with the accounts kept in the general books. They may, however, be worked independently and parallel with the commercial books. In either case they should agree as regards total expenditure.

So far, attention has been directed only towards determining the cost of shop orders in terms of shop processes, if the order and elementary record cards are properly filled in when the work is initiated, extended detail can always be had when desired, but it is unnecessary to make up the details until they are wanted for some specific purpose.

Oncost.—It has been shown how the prime cost may be determined with accuracy, but the oncost addition which it should carry is always an assumption, usually based on an average of past years, but subject to modifications arising from improvement or otherwise in shop efficiency or other causes. Oncost should be treated like an insurance account, the amount of recoveries or credits being equivalent to the insurance premiums, and the actual oncost or debits to the casualties. There is much difference of opinion as to how the oncost should be allocated. The most satisfactory method appears to be to distribute the expense in ratio to the productive labour; and since the lower grades of labour require the greater share of those facilities for which expenses are incurred than do the higher grades, it follows that each class should at least equally share that expense, and that the distribution should be made in terms of the quantities of labour, and not upon labour values. The most fitting unit for this purpose is the hour of direct labour.

Permanent Records.—Cards having been used for the purpose of determining prime cost and oncost of products, they can also be arranged to give the entire cost of any construction however elaborate. The following is an example of each application of the cost cards to these purposes:—

The Job Order Work Ticket, made on the back of a job order card, shows the cost of the jobs in terms of material, out-services, and labour, Fig. 11.

The Shop Order Work Ticket shows the cost of shop orders in terms of shop processes, and may also be made to show the cost of members by processes, and in terms of materials, out-services, and labour, Fig. 10.

The Production Order Work Ticket shows the cost of the product according to its members, and in terms of materials, out-services, and labour, Fig. 9.

The Consolidated Work Ticket is, as regards nomenclature, a duplicate of the shop specification, Fig. 14, and may be posted up weekly from the cost sheet, or may be posted up on completion of the product, as the special requirements of each shop may determine. As soon as the work ticket is completed, the totals of all separate objects of expense are posted to *comparison cards,* all like items being entered on the same card. These are filed into a permanent record cabinet, and are the base of all sound workshop administration. The consolidated work-tickets may, if it be desirable, be bound up into books. As each product is completed, the total prime cost is transferred from the consolidated work ticket to the nett cost return, which is a return of the nett cost of all work done during the week; and the total of the credits of the several columns headed with the names of the elemental and oncost items should agree with total debits to production account. Another column should show the credits to this account. If the work is correct, both sides of this account should balance.

The advantages arising from such methods of records may be briefly summarised as follows:—

1. The comparison cards permit of ascertaining how many objects of the like kind are required within a given period, the variations in their costs, and whether the quantities are sufficient to warrant the expense of standardising.
2. They afford the information necessary for arranging workmen's rates, whether by hour, piece, or premium.
3. They enable the manager to point out what items can be reduced in cost, and to suggest the methods whereby this may be done.
4. They are invaluable for estimating purposes.
5. They avoid transcriptions—the first writing serving all purposes, except when specific analysis is required; yet the system is so elastic in its working as to yield readily, when, and as required, either classified or elementary detail, or both.
6. They are available for the valuation of the individual energy of each official or workman, the relative efficiency of the different machine tools, and the comparative value of designs.

Space does not permit of giving examples showing how the latter operations are worked out.

The continuous use of such records, and the wealth of information thus ascertained, will suggest many other uses to which they may be applied.

They are invaluable, because reliable.

For ordinary working purposes the compiling of too much detail should be avoided, except in the case where a special study as to the means of reducing the cost of a product, or for the determination of efficiencies; extended analysis is seldom necessary.

Ascertainment of the nett profits or losses arising from operating the whole establishment during any given period.—

When the general books are designed so as to admit of their summarized results being classified, and the respective totals for each class of entries transferred to a general check journal; and if proper store journals are kept and means adopted for continuous stock-taking (consequently dispensing with a general annual stock-taking); and if the day-books or sectional journals are written up daily as they should be; a balance of the financial books, showing the profit or loss during any predetermined period, may be brought out in an hour or two after the closing of the sectional journals. The result so obtained should agree with the total profits, less losses, on the completed production orders for the same period, and in order that this may be so it is essential that no profits be taken cognisance of until they are actually earned.

Where there are sources of profit or loss other than completed shop work, this has, of course, to be given effect to in concording the results obtainable by either method.

There is a group of subjects outside either general or cost accounting, bearing upon capital—its protection and renumeration, and a second group bearing on the workshop and office and their methods—which have a most important bearing on the administrations of engineering undertakings, but which space does not even permit me to enumerate. They underlie all that has been already touched upon; they are the fundamentals of financial success, and no study of workshop administration is complete without an examination thereof. This, however, with regret, we are obliged to defer.

General Establishment.—In many of the older shops little attention has been given to matters outside the accommodation which may be described as purely productive. General office accommodation, store rooms, works office, etc., have been looked upon more or less as luxuries and sources of unnecessary expense. Proprietors have ever before them the weekly outlay in wages paid to all kinds of indirect producers, but it is only with difficulty that they can realise the losses arising from waste and leakage. They are particularly careful in the handling of actual cash.

They do not object to a bookkeeper spending days or weeks in looking for an error of a few pence in his balance, but they are not equally alive to the necessity for supervising other items which just as really represent cash. We are now wakening up to the necessity of eliminating waste in every form. The methods of administration here referred to have this object in view. They demand accurately balanced records for all items of expense.

These methods can only be introduced gradually into an already established shop. In a new shop they may be introduced at once. In that case they should be so designed as to yield not only that amount of detailed information which the administration finds necessary for ordinary working purposes, but a fully detailed analysis of cost at any future time, or when occasion may require; and the complete scheme should, in the first instance, be formulated by an expert, whether it be for an old or for a new shop, so that the initiatory work may be such that the ultimate arrangement will be harmonious and complete. These reforms cannot be initiated by any manager on his own responsibility, however ambitious he may be to make his mark. They must originate with the principal, who must thoroughly realise their importance. When he does, and resolves on making an earnest effort to transform his business from the conditions of non-homogeneous management to those of complete homogeneity of action, he will require to exercise a good deal of courage and have a stiff backbone; but his anxieties would be much ameliorated had he at his disposal a band of men thoroughly trained both scientifically and technically in the art of management. The old hands who have honestly and conscientiously toiled to build up a business in its early stages under a "leading hand" and "head-of-department" system, which permits of the operation of independent control subject to little or no itemised criticism, are at the outset likely to resent the recording and examination of their individual acts. The march of events will, however, force compliance with the inevitable, and so will arise the necessity for bringing forward a class of men trained in the general principles of administration, and in the scientific and technical priciples of design and construction.

The engineer can now, in a large measure, receive his practical training in certain of our universities and colleges, and there is a near prospect of these facilities being augmented in our city, when the engineering laboratory in the University is in operation. The Institution of Civil Engineers provides that students, before being admitted to the full privileges of membership, shall show a certain proficiency in theoretical and practical attainments. The accountant has to satisfy his guild of his knowledge of accounting and commercial law. Unfortunately as yet no provision has been made in this country, so far as the author knows, for securing efficiency in the art of management. As matters now stand, each aspirant for such a position has to pick up his qualifications as best he can; and he has to commence almost every new effort with a ground start. Were he to get a good flying start in the shape of preliminary training, in which the fundamental principles are taught, and if he possessed the necessary natural ability, how much more rapidly would he pick up those finishing touches which practical shop and office experience alone can give.

The hope is that the members of this Institution, interested as they are in productive engineering, will bring their influence to bear in order to get our universities and higher scientific and technical colleges to take this matter in hand, and elevate shop management from the position in which it now stands into the realm of scientific study, so that it may rank in these respects alongside the kindred professions of civil engineering and professional accounting.

Discussion.

The discussion on this paper took place on 24th April, 1900.

Mr Henry A. Mavor (Member) considered that this subject was one of primary importance to all engineers. The attention of engineers to the questions raised in the paper had been directed largely to the accounting side, and less to the administration of

Mr Henry A. Mavor.

the shops. He had had the pleasure of making an experiment with the methods defined in Mr Cowan's paper, not directly on the lines of the paper, but on the principles embodied in it, and, after an experience of nearly a year in working, he found the result was very surprising. Every engineer wanted to be able to feel the pulse of his shop and see what state any particular piece of work was in—if it was delayed, why it was delayed,—and to be able to forecast the date of its completion. Cost came into all administration, because when one grasped the question from the beginning, and had the record carried out in an orderly and systematic fashion, the cost revealed itself automatically and without special attention. No doubt all had been making attempts to find out the cost of their products, and it had generally been found that the information thus obtained, however useful it might be for them in forecasting the cost of future work, was hardly ever available for taking the cost during the progress of the work. Speaking from experience, the system such as he described made it possible to place one's finger upon a sore place quickly. Whenever a mistake or delay in the execution of the work occurred, cards lent themselves to investigation of the causes. Mr Cowan had described very clearly how necessary it was to fully specify what was to be done, before the work was proceeded with. Some experienced engineers had the view that, to specify everything in full detail before it came into the shop was a waste of time, but there was no greater error. The Americans had worked this out and fully specified every detail, mentioning every operation to be performed and the time it would take, and, so far from being a waste of time, it was that method alone which would produce efficiency in the shop. With the card system, anyone who required an analysis of the work had the whole material at hand without further trouble. It was a mistake to suppose that the introduction of such a system was a saving of labour in the office. He did not think it was anything of the kind. It involved a great deal more labour in the office, but it gave a result which was not attainable by any other means, and the additional labour which

Mr Henry A. Mavor.

was required for manipulating the cards was of a very cheap kind. A small boy would do the work better than a skilled cost clerk on the old system.

Mr J. R. Richmond (Member) said the Institution owed a debt of gratitude to Mr Cowan. It was curious that in looking over the Transactions of the Institution for a number of years back, he had not found a single paper dealing with this particular subject, and he thought it was a very significant thing that at this time Mr Cowan should have brought it before them; because, in latter-day engineering there was more attention being paid to improvements in shop system than had hitherto been the case. In fact, engineers had come to recognise that method and system were paying factors. In reading over the paper he wished that Mr Cowan, instead of writing a paper, had written a book on the subject, because he felt that the paper had suffered slightly from limitations of space. At the same time, if Mr Cowan had done nothing else than cause them to think on this subject, a very valuable result had been obtained; and if it made them go further and induced them to revise their methods according to some of his suggestions, then it had attained even a still more valuable object. No doubt some of the members of the Institution had seen the papers by Mr Roland in the *Engineering Magazine*, and it was a curious thing about those papers that it seemed that no one could take them *en bloc* and apply them to any particular shop. The same thing might be said about Mr Cowan's paper. Mr Cowan did not put it forward as a universal panacea for all the ills that shops were liable to; each particular shop must be studied by itself, because, after all, shop-method was systematised common-sense, and they must take each as a problem and apply common-sense to it as well as they could. Regarding the card system, he was very pleased to hear Mr Mavor speak on this subject, and he hoped that at some future date Mr Mavor would see his way to put before the Institution, in some detail, the results that he had obtained by the card system. No one that he knew had gone into this subject more deeply or more carefully than Mr

Mr J. R. Richmond.

Mavor had, and it would be of considerable value to the Institution to have a paper dealing with shop system and management on the lines he had spoken on. While Mr Mavor was speaking he was led to think over the application of the card system to a particular shop, and found that if applied in the manner indicated by Mr Mavor, he would have 135,000 cards in circulation, which seemed to him an unwieldy mass of matter to be dealt with. He thought that some of the disadvantages that Mr Cowan had spoken of in his paper as applied to books *versus* cards, were rather more fanciful than real. There were many good points about cards in the way of keeping records of patterns and drawings, because when they were used, the card could be taken out and replaced by others if necessary; but a card-cost system was not applicable to all shops.

The discussion on this paper was resumed on 15th May, 1900.

Mr JOHN MANN, Jun., M.A., C.A. (Visitor), observed that from his professional standpoint as a chartered accountant, this subject was of particular interest to him; at the same time, he was afraid anything that he might say would be rather tabooed by the expert engineer, as the tendency was rather to minimise anything that the expert accountant had to to say relating to matters of practical engineering. In cost account, however, the two professions found a common ground, and the expert accountant and the expert engineer had a great deal in common when they dealt with the records and accounts of processes of engineering. For the last ten years it had been to him a kind of hobby to deal with the application of scientific records to cost accounts. When he first mooted the question in his own professional institute in Glasgow, he was laughed at as a faddist in proposing to record at all the intricacies of costing, especially in engineering works. Since then the subject had advanced by leaps and bounds, and within the last two years it had assumed a prominence which ten years ago would have been undreamt of. What appealed to the accountant most of all was the desirability of bringing into

Mr John Mann, Jun.

agreement the results of the cost accounts and the commercial books. To many that might seem an ideal that was quite impossible of attainment; but, speaking from some little experience on the subject, he might say that it was by no means impossible. Often, in ordinary cases, the results the commercial books revealed, which were certified by the chartered accountant, were nothing more nor less than an "undiscovered difference" in the books; while, by the addition of a scientific system of costing, these results were traced back to their origin—to the particular contracts or jobs handled throughout the year. The profits, less the losses, could be made to tally within reasonable nearness with the results shown in the commercial books. The very difficult question of "oncost," could not be treated in cost accounts by anything more or less than an estimate; and, so far as he remembered, Mr Cowan had hit upon what seemed to him the only scientific way of dealing with that question; viz., by apportioning the shop expenses by the *time unit*, according to the *time spent* upon particular jobs. The rough and ready way of measuring this was by the *wages spent* upon the different jobs, instead of the hours spent upon them. For all practical purposes, where there were no rapid fluctuations in rates of wages, that method was no doubt sufficiently near; but the scientific measure was the time unit—that was to say, superintendence and general expenses varied in a more or less exact proportion to the time spent upon the work. With regard to the card system, it was to some extent a novelty. He had studied it in one or two different aspects, and, so far as he could see, it was really the introduction of an additional labour saving appliance. It dispensed with a tremendous amount of detail in arriving at results, and arrived at them by a shorthand process, which brushed aside a great many of the elaborate steps in the records. No doubt there were difficulties, and very great difficulties, in introducing the card system into an existing engineering shop, but he thought it was possible by working in stages to gradually arrive at complete installation of the system, beginning perhaps by a record of the wages, passing on to a record of materials, and finally to a record of the whole processes. The disadvantages were very trifling. One might hear of the loss of cards occasionally, but that was no greater than the omission to make an entry. There was no doubt a great deal of stationery required; but that was a mere trifle compared with saving in time and labour in arriving at results. These results were summarised, and presented in what might be called a "graphic" form, which no one who had not seen the system in operation could really appreciate. The important cards were to be found standing up in the drawers, so that one could pick out what he wanted without having the result complicated by an enormous mass of detail. No doubt it might cost a little more money, but he believed, after some experience, that the extra expense would be found to be more than repaid by the promptitude by which results could be arrived at. Under the old system, in particular cases he had in mind, the cost books were always a perfect bugbear, generally with such an amount of work in arrears that they were positively disheartened to tackle it. Under the other system, by the cheapest form of labour, the results were, with comparative ease, always up to date. What he had said was offered under correction, and simply from the layman's point of view—that of the accountant.

Mr **Archibald Denny** (Member) considered there were many in the same position as himself; they could not possibly absorb the paper in one night, or even in many nights, as it was of extreme complexity. They might get a broad general idea such as Mr Mann had so well expressed, and doubtless the basis idea of the system was good. While in the United States last year he observed that the card system was being used in every factory which he visited, not only for costing, but for keeping records of costs, and for every kind and description of record one could think of. Some went so far as to keep their ledger by cards; they had no books at all. When he pointed out that a card could be taken out and the account lost, and with it all means

Mr Archibald Denny.

of checking, it was admitted that that was a possible difficulty. In regard to adopting it in his own business, that of a shipbuilder, while he could see how it could be done in other people's business, it was very difficult to see how it could be done in his own. He knew that Mr Mavor had adopted it in quite another way from what Mr Mann suggested. Mr Mavor did not adopt it sectionally, but right away in a single day. He himself was trying to introduce it in Mr Mann's way, and he began at what Mr Mavor would think the wrong end, at the records of costs, and instead of having large books with the records of costs, these were now concentrated in ten small cards for each ship. Whether he would succeed in introducing it universally he could not say, but he feared that with their riveters and gentlemen of that description they might have a little difficulty in accounting for the rivets. That the system was good, and that Mr Cowan had explained it in a very full manner, he thought there was no doubt, and he was sure that while many like himself felt a difficulty in rewarding Mr Cowan with a full discussion, they were none the less grateful to him for what he had brought before them.

Mr Henry A. Mavor (Member) said Mr Denny had mentioned that the cards could be suddenly introduced. That was quite true, but nobody could ever initiate them in a day. The book records might be stopped on any day and the card records started the next day, but the books must have been worked up and a systematic arrangement established before this was possible, because the haphazard method of costs in many places could not be departed from, and a skilled record kept on the following day, without the training of men into systematic keeping of records.

Professor A. Barr, D.Sc. (Member) hoped that this was only the first of a number of papers the Institution might receive upon this and kindred subjects. Most sections of engineering work could be as well done in this country as elsewhere, and the Americans were a very long way ahead in the matter of tracing work through the shops and in that which followed from it, the production of work cheaply,

Prof. A. Barr.

more especially where it was of a repetition kind. He had looked into the card system for a considerable length of time with very great interest. He had seen it used in America for almost all purposes. There he saw an index which struck him as being one that would be absolutely impossible to keep on any system whatever other than the card system. Although it was not engineering he might mention it. The Library Bureau of Boston, which was the first to introduce the card system commercially on a large scale, had instituted a record of everybody who applied for life insurance within the United States; and if a person went to any insurance Company in America and said that he had never been refused life insurance, all the Company had to do was to go to the card catalogue and there his name and his description would be found, and when and where he made the application previously, if his statement were untrue. That would not be possible by any other system than the card system. Each card went into its alphabetical place and could be immediately produced. The Library Bureau itself received intimations from the Insurance Companies, and a sufficient number of copies were typewritten and put by the Bureau's own staff into their places in the record cabinet of each Insurance Company. That was an example of how far the system could go. Mr Mann's remarks were very interesting, and they should not look upon him as discussing the subject from an outside point of view, because it was as much a matter of accounting as it was of engineering. The paper was one which it would be almost impossible to discuss fully at the present moment. It hung very largely upon the card system certainly, but it involved a number of other things which would require a greater amount of consideration than they had been able to give to it. The question of nomenclature was one of the greatest importance, because a good nomenclature would simplify the whole system. He could not say that he altogether liked the nomenclature which Mr Cowan had proposed for the various divisions of work, but that was simply a detail. He was afraid also that no system of

Prof. A. Barr.

cards could possibly be of general application. What applied to a shipyard must necessarily be somewhat different from what was applicable to an electrical engineer's workshop. In the workshop with which he himself was connected a beginning had been made to introduce the card system, but he would not go now into any details. Mr Jackson could relate his (the speaker's) experience much better than he could himself. He considered the paper one of the most valuable that had been brought before the Institution.

Mr H. D. D. Barman (Member) agreed with Mr Mann that it was better to start step by step. He had started with wages cards, and had found them exceedingly simple and of the greatest use, especially for estimating varied classes of work; but he dreaded starting cards for material, where, to carry out the system properly, not only the chief items, of say an engine, had to be dealt with, but also every bolt and nut. The materials for cards should evidently be issued from the drawing office, and he would be glad to have further information of the methods used from those who had already adopted the system.

Mr Harold Jackson (Member) said it appeared to him that one point mentioned by Mr Cowan and Mr Mann should be very much insisted upon in organising a system of cost accounts. Everyone knew how accountants insisted upon a search for hours for a penny. It really did not matter whether they found it or not, but they searched diligently for that penny until they found it. On page 239, Mr Cowan said, "It will be observed that it is thus practicable to interlock the shop costs account with the accounts kept in the general books. They may, however, be worked independently and parallel with the commercial books." In order to ensure cost accounts being kept correctly and up to date, he thought it was necessary that they should form an integral part of the commercial books. The diligence spent in searching for the lost penny would then be applied equally to the cost accounts. A card system had been adopted in the works with which he was connected, and he had drawn up the cost of that system. As at

Mr Harold Jackson.

present in use, the cards would cost one-fortieth of a penny a-piece, and each man used on the average two time cards and one material card per day, but the number of cards in use might at any time be varied, so as to show operations in more or less detail. They could be arranged to show a whole piece of work on one card, or they could be detailed so as to give the cost of a single piece on one card. There were about 85 men employed, and the total number of cards used per day was about 250, making the total cost of cards per day about 6d. The time taken to check the cards with the men's time record, to affix the various rates of wages, and to allocate the cards to the various jobs, etc., was not more than two hours per day, and the work was done by two boys. On Tuesday morning, at the latest, he had handed to him the allocation of the wages and materials for the week ending on the previous Thursday night, showing that the cost accounts were absolutely up to date. Before the system mentioned above was adopted this had never been the case. In order to deal efficiently with the varying prices of material, and to ensure that the correct price was put against material given out for any job, a scheme had been devised which would shortly be put into operation, and, although it appeared somewhat bulky, he believed it could be worked at a very low cost. Mr Mavor told him that he believed, from his experience, the system would work correctly; and he felt sure it would, but he was not sure that it was not too bulky to be practicable. It was proposed that *every item* of every invoice should be entered on a *separate* card under a reference number. As the invoice came in, the reference number would be written on the card, and on a tag or tags, the latter being sent to the storeman to be affixed to the material in question. The card would also bear the date that the material came in, and the total value and price per unit of the material. On giving out material the reference number would be entered on the card by which the men drew it from the store, and when that card was handed to the boy who priced the cards, he would have simply to refer to the reference number, and there find the correct

Mr Harold Jackson.

price per unit. He believed, in that way, it would be possible to cost correctly all the material in the place. It seemed to him very essential that all material, of whatever nature, should be entered and given out in one way only, as where two ways existed there was always the possibility of the same material being treated through both channels, or being forgotten altogether. One great advantage cards gave in furthering this idea, was the possibility of each card being stowed away out of the road as soon as the material entered upon it had been all given out to the job or jobs for which it was intended; with books, such a system as he had sketched would be utterly impracticable.

Correspondence.

Mr A. D. Smith (Member)—It was an easy matter to point out the vastness and expensiveness of Mr Cowan's system. Shop management now a days, from its complexity and the keenness of competition, required more and more technical ability on the part of the manager, and he would best succeed in the task who made the *work proper of first importance*, and any system of costing, etc., connected therewith secondary; this he would find to be the first essential of any system which, to quote Mr Cowan's own words, "is simple in its conception, and automatic in its working." This order of things, however, Mr Cowan completely reversed. On page 229, Mr Cowan spoke of a manager finding means of reducing the cost of a product. He (Mr Smith) admitted that a manager now and again might institute particular inquiry into the cost of some piece of machinery, but to continue this minute inquiry at all times added a cost to the product which defeated the end in view; viz., the cheapening of that product. In the last sentence of the clause already referred to on page 229, Mr Cowan made the following remark: — "Clerks without practical knowledge of the work, who make *ex post facto* analyses by the aid of foremen, cannot be depended on for collecting the information necessary for efficient administration." How would Mr Cowan make this agree with his remarks on page 234? His whole system depended on clerks, and, in a symbolic system such as his, mistakes were bound to be of no uncommon occurrence; and further, he might say that a mistake rendered the whole information that had been collected, and the conclusions drawn from it, valueless. Mr Cowan considered simple symbolic nomenclature necessary to secure a useful analysis. On that point he differed from Mr Cowan. How had engineering concerns got on without this system so long? The simplicity of the symbol was purely imaginary. For example, let reference be made to Fig. 14, Sheet V. A workman might have been employed fitting a key to a spur wheel for a particular job, but before he could return his time as S.O., 111 B 3, he would have to consult his foreman with respect to the symbolic specification, and to those symbols add another for the operation he had performed. It was possible to imagine the symbolic number to reach 1000! The advantages of issuing cards instead of books was dealt with on page 230. In his opinion, the practical disadvantages were as follows :—

1. The number of cards to handled;
2. The ease with which they were lost;
3. The labour in turning them over and examining every one of them before the one wanted could be found;
4. The impossibility of docketing them in such a manner as to ensure their ready accessibility; and
5. The expense of printing them.

.With regard to the subject of a shop specification as described on page 231, and illustrated in Fig. 14, Sheet V., Mr Cowan divided the job into members, components, and pieces, and it would readily be seen that the whole was so interwoven, one piece hanging on another for its symbol, that *before the work could be issued to the shop the complete specification required to be written out.* This necessarily meant that all the drawings had to

Mr A. D. Smith.

be made, and the details all worked out. Great care and no small amount of ingenuity required to be shown in the construction of such a specification, and how all this could be done without causing the most real and vexatious delays, Mr Cowan did not seem to have inquired into. When the shop specification had been distributed through the shop, various cards had to be written from it. He would only take one example; viz., Fig. 7, Sheet III., job order card. Mr Cowan said this order was personal to the workmen, and to each operation. Could anyone possibly imagine what this would mean in a large engineering establishment? The number of cards would be fabulous, and the cost of dealing with them in many cases would far outrun the cost of the operation recorded. He would give an example of what he wished to point out. One of the leading hands in a fitting shop required a piece of wood to go across the mouth of a pump barrel, so that he might mark off the holes in the flange. He required first to find his foreman, and together they would consult the symbolic specification, and a card would be written out for the man to present to the foreman patternmaker or joiner. The man then went in search of this foreman, and after he had written out one or more cards the man was given the piece of wood. Returning to his job, he found he had spent more than half-an-hour, and cost the firm at least 6d for a piece of wood valued at less than a halfpenny. Mr Cowan dealt entirely in symbols; his system was simply endless. On page 234 he described the symbols for recording the condition of work in the shop. To his mind it was hardly conceivable that a manager would get any intelligent idea of the condition of work in the shop by wading through a pile of specifications every other day, and tracing out the various symbols. On the subject of oncost, Mr Cowan said "*oncost is always an assumption.*" *In this remark Mr Cowan gave his system away.* What was the use of imposing on workmen such an elaborate system of costing, seeing that all methods of ascertaining cost must contain a variable and uncertain amount called "*oncost*" to be added to material and labour? To make use of the infor-

Mr A. D. Smith.

mation collected on cards was sufficient work to keep any manager fully employed without time to give a thought to anything else, except that one thought might arise in his mind as he saw the mountain of cards piled up before him. What was the cost of this costing system of Mr Cowan's?—a question that naturally arose in the mind of any one who read his paper. By this system a principal might get information on minute details which he had not been in the habit of getting before; but at what cost would it be ascertained? He would have to—

1. Treble his staff;
2. Double or perhaps treble his stationery account;
3. Make the costing system of paramount importance;
4. *Demoralise his men by ruining their memories;*
5. Compel them to waste their time learning and consulting on the system;
6. Retard the work indefinitely at the outset, and all through its progress in the shop; and
7. He would find in the end that he had got his information in a form which necessitated his reading it by the aid of a symbolic dictionary.

He believed Mr Cowan's paper only gave the beginning of the system, and that its developments were endless. He would warn the members from being persuaded to try Mr Cowan's system. He was surprised that Mr Cowan should have brought up such a subject, *as it was tried lately in a well-known engineering work in Glasgow, and had to be abandoned as keeping back the work proper, being too expensive, and altogether unworkable.*

Mr Cowan, in reply, said he did not know that he was exactly in a position to answer the various points raised that night; points that had not exactly been anticipated in his paper. His paper, at the outset, distinctly pointed out, that the scheme as

Mr Cowan.

there set forth was specially intended for the operation of an *engineering shop turning out heavy products.* It was further stated that every particular manufacturing business required the scheme modified to suit its own particular wants. The discussion had, irrespective of any of these considerations, proceeded on the assumption that the scheme, as set out in the paper, was a universal panacea for all the ills that engineering works were subject to. That was not so, but he had not the slightest hesitation in saying that the scheme as outlined would work satisfactorily in all manufacturing businesses except a chemical one, when intelligently modified to suit. It required to be modified very considerably for what might be called light work; viz., machines under two tons in weight, such as that carried on by Mr Mavor; and to a still greater extent would it require to be modified for the work as carried on in a regular factory, for instance, in a concern performing thousands of operations of the same kind in a day, by the aid of machines specially constructed for the performance of each operation. Mr Denny's work (shipbuilding), on the other hand, differed widely from that of constructing range-finders, as carried on by Mr Jackson. Still, a system to meet most of Mr Denny's requirements could, he thought, be devised by one who had a full knowledge of all the underlying principles on which this system of administration was based, and with an opportunity of studying all the intricacies of a shipbuilder's business; but the study would probably require to extend over a year or two before it would be safe to introduce the system into that particular business. One thing required in introducing the system seemed to have been overlooked by all the speakers, unless perhaps by Mr Mavor, namely, that before any attempt should be made to introduce the use of cards for recording detailed costs, and more particularly for the purpose of keeping those accounts in a concern where heavy materials had to be treated in one way and light materials in another, the general business books should be put in such a condition that they could be worked parallel with the shop

Mr Cowan.

accounts; because, under such circumstances, the shop cost accounts should form an integral part of the whole scheme of accounting in use by that particular concern. Unless this was done, and all other preliminary arrangements necessary to the system were properly carried out—such as the providing of shop-specifications more or less detailed, the setting out of each item of expense separately, the providing of proper office accommodation, and appliances for the use of works-manager, foremen, time-keepers and job-clerks, also rough stores accommodation of a sufficient kind—they generally failed. If these provisions were not made, most people would get disgusted at the outset, and the not uncommon verdict would be pronounced—the thing would not do. It would do, however, if intelligently gone about at the start. A beginner usually attempted too much, as Mr Mann properly pointed out. In an old established concern the process of introduction should be a very gradual one, and the proprietors should not be disappointed although a year or two passed before the system was even properly blocked out, and not in full running for all details. *The employment of an expert with a thorough knowledge of the subject would simplify materially the process of its introduction*, and might be the means of avoiding the repetition of much which would require to be undone in order to get the scheme into one harmonious whole; but, even with such assistance, the change should be brought about slowly, especially in an old established shop. In a new shop the system could be started right away. Mr Mavor had given them to understand that he did not anticipate any great saving in expense in substituting the card system of cost accounts for the book system now generally in use. He (Mr Cowan) did not suppose that many of the members anticipated much lowering in the expense of lighting by introducing the electric light, but most of them who had adopted it did so simply because, by an additional outlay for light, they would get a better return for their money in the form of increased shop output. If Mr Mavor and others who had adopted the card system of cost accounts would be content to accept the same

Mr Cowan.

amount of light with regard to the internal economy of their shops as they had to remain satisfied with under the time-honoured book system, they would find that the expense of the card system would not be greater, but probably less. There was, however, no advantage to be gained by making the change unless greater value was obtained in some form or another. The book system did not lend itself to yielding full economic information in regard to a product in all its parts, without incurring an unjustifiable outlay. The card system, on the other hand, did this at a very small outlay, and in a manner which provided just such detail as was wanted in each particular case, and only when it was required, not before. It only demanded that the objects of expense should be defined at the outset, and the items of expense at the time that the work was being performed; the synthesis of expense could then be compiled whenever wanted, and in such form as the administration deemed proper to meet each particular case. Mr Mavor had informed them that evening that he made his change from books to cards in a day, and that he had as yet scarcely a year's experience of the new system. That being so, it was not surprising that he did not find any saving in expense. In all probability he had been doing much of his work twice over, because his general account books had not been designed specially in anticipation of his introducing the use of cards. Until all were equally efficient the best results could not be looked for. The author felt confident, from the flattering way Mr Mavor had spoken of the advantages that had accrued by the use of the cards during his short trial, that when he (Mr Mavor) had three or four years more experience, with more perfected arrangements, he would have great reluctance in going back to the older method, if compelled to do so by circumstances outwith his control. Prof. Barr had mentioned that cards had been much more largely used in America than in this country. Certainly they had been made use of there to a greater extent than here for records of all kinds; but, on reflection, it would be seen that their use was not altogether new here. In this country one of the most

Mr Cowan.

striking instances of their use was in hotels, and it was that which first drew the author's attention to the possibilities of their use. A person sat down to breakfast, ordered his bill, and in a few minutes the waiter presented it. If he examined the hotel books to see how that was done, he found that for each meal there was a separate ticket or card, which on its receipt at the office was entered up instantly. Thus he got his bill when he called for it, and the hotel proprietor had recorded in his books a complete analysis of all services and materials supplied, which he could post the same evening to the secretary of his company, if desired to do so. What was a railway ticket but a card? By the use of these tickets the receipts were apportioned to the different railways over which the passenger was carried. It was chiefly for this purpose that the railway clearing house was originally established. One pound notes were simply cards. The great bulk of the financial business of the world was carried on by the use of loose bank notes, cheques, and such like. What were these but loose cards? Cards which they were very careful in looking after. They were seldom lost; the loss of a card was equivalent to the omission of an entry, with this difference, that one could tell when a card was lost; but who could tell how many entries had been omitted from book records which were squared by an undefined balance? Engineers for many years had been using cards in the shape of orders for stores, and latterly as "premium tickets." Some had made use of these store orders for grouping the cost of stores according to "blocks of expense," and charging the slump values of these "blocks of expense" into the cost books; but it did not appear, until recently, that anybody had the courage to use them directly as an integral part of his accounts. Instead, numerous transcriptions had been preferred. Prof. Barr did not altogether approve of the symbolic nomenclature proposed for distinguishing the machine details as exemplified in the paper. He (Mr Cowan) knew of none better, but doubtless there might be others, not published, which were more suitable for the purpose. He would only mention here a few of the conditions that should

Mr Cowan.

be complied with by such a nomenclature, and would be very thankful to any member who should bring before the Institution a scheme which covered the whole and of a simpler character. These requisites of a symbolic nomenclature were:—

1. Isolation of names, each object having a name which did not belong, or ever could belong, to any other object.
2. Brevity, simplicity, and clearness in description.
3. Suggestiveness of the objects dealt with.
4. Simplicity of use.
5. A common principle by which substantially the same notation might be determined by independent notators working on the same product.

It was understood that names were more or less scientifically arranged, depending, of course, upon the amount of study and ability expended. Mr Richmond mentioned that in a particular shop he had in view, 135,000 cards would be in circulation. As each man might use five cards per day—the average in practice was three or four—it would thus appear that Mr Richmond's shop was employing something like 27,000 men. In such a shop the mass of paper floating about under any system would be difficult to wield; but, if the hands employed only amounted to 1000, the number of cards floating in the shop would be 135 per man. If this latter figure even represented the true state of the administration or organisation in that shop, it was high time that the search-light of the card system was thrown upon it, so as to reduce the number of special objects of expense (jobs) floating about the shop in an unfinished condition. It looked very much as if Mr Richmond was labouring under some misapprehension. Mr Barman had asked about the use of the material cards. That was too long a subject to be discussed that evening, but if Mr Barman arranged his general account books properly, and if he referred to the consolidated work-ticket, Fig. 14, he would see that the materials had been divided into two sections—materials

Mr Cowan.

delivered direct from outside to the job, and materials delivered from the shop rough stores—and if he recalled that the paper dealt specially with a scheme applicable to heavy work, where the proportion of labour to materials was about four to one, it would be evident that the great bulk of the materials would be charged direct from outside to the job, that from the stores being comparatively small. Separate methods of treatment were required for each class; but the general principle was that all materials were supplied to an order on a requisition card, Fig. 12, and that only one entry should be made on each card so as to permit of a full analysis of the expense when required. If the providing of opportunities for analysis was deemed unnecessary, he could make as many entries on each card as he liked, but at the expense of flexibility. Mr Mann, who modestly put himself down as an outsider, had shown a noble example to the other members of his profession in coming there and bearding the engineer in his den. The union between the accountant and the engineer, in the matter of shop administration, could not be brought about too soon; at present there was too little attention given by practical engineers to the economies of the workshop. The great importance of the accountant's work was generally underrated, because, as usually applied, it proved too cumbersome to set out in full detail all the acts of engineering workshops, to say nothing of the expense. Hence managers had been forced to favour methods savouring more or less of the rule of thumb in tracing the work through the shops. The use of cards altered all that. He (Mr Cowan) could say from experience that it was quite possible to make the cost accounts and the general accounts agree as to balance, and run parallel with each other; and that it was also an easy matter, when one knew how, to devise a system of financial books which would admit of being balanced in two hours after the sub-journals had been written up and their totals of the different classes of transactions ascertained, and to keep a balance ledger in a state of constant balance. Mr Smith seemed a little at sea in his remarks, and was apparently full of reverence for

Mr Cowan.

existing methods. He referred to a trial of the system in a well-known shop as having been abandoned. It was apparent that he did not understand the facts of the case. The assertion was incorrect, and he (Mr Cowan) was only prevented from replying to his allegations by considerations of not introducing matters of private business into a public discussion. To one point he might, however, refer. Mr Smith seemed alarmed at the cost of the proposed system, and at the demoralizing of his men by ruining their memories. The cost in one establishment where the system had been in operation three years--the work being light, and the proportion of materials to labour four to one—for keeping the general accounts of the establishment and the cost accounts of the work, costing about £30,000 per annum, was that of one book-keeper, one cost clerk, and one boy, and one man acting as time-keeper and store-keeper, or slightly over one per cent. on the cost of the work. Regarding the demoralizing of the men by ruining their memories, the prime object of the system was to trust nothing to memory, and to trust entirely to written records. By means of the records which the proposed system could furnish, one of the great needs of modern production was met, since the first requisite of agreement between employer and employee was the mutual understanding of one another's views and of the approaches by which they had been reached. Whether the methods proposed to that end would serve this purpose time only would show. Those features of the plan which were in accord with this object would serve their uses, and eventually give place to others still more highly adapted for their purpose. He sincerely hoped and trusted that this was only the beginning of a discussion upon the economic side of industrial engineering. When he came before the Institution it was not so much to give information, but to get information on certain details which required clearing up, presuming that the members were all fully conversant with the economic details of the working of their shops. The paper merely sketched out, and linked together in a general way, both in the text and the diagram Fig. 1, the various

Mr Cowan.

processes that had to be dealt with in an engineering business. He hoped that in some manner the Institution would see its way to express itself as to what was wanted in the way of improved shop management, and recognise its value in the same way as was now done by their friends across the water, who not only discussed it in their institutions, but had established institutes for the regular teaching of scientific shop management.

Special ... ... scientific
operations

WORKSHOP ADMINISTRATION,

By Mr David Cowan.

- RECORDS OF THE ACTS
  - PRODUCTION ... ...
    - *Issue orders*
      - *Special objects*
        - Special ... ...
          - scientific operations
          - Tests of all products
          - Photographs, &c.
    - *Cost Accounting*
      - *Current Costs*...
        - *Prime costs* ...
          - *Out-services*
          - *Labour*
        - *On-cost* ...
          - *Current expenses*
          - *Safeguarding expenses*
        - *Credits* ...
          - *Surplus materials*
          - *Plant*
      - *Comparative Costs*
        - Like objects...
          - Prime cost
          - On-cost
        - Elementary analyses ...
          - Materials
          - Out-services
          - Labour
        - Contracts between ...
          - Cost Price
          - Selling Price
      - Comparative Labour Rates
        - Day rates ...
          - Time values
          - Time units
        - Piece rates ...
          - Time values
          - Time units
        - Premium rates
          - Time values
          - Time units
  - SALES ... .
    - Comparisons
      - Competing products ... ...
      - Products which serve same purpose ... ...
    - Analysis of Sales ... .
    - Collection of Accounts due ... ...

PR

ORKSHOP ADMINISTRATION,

By Mr David Cowan.

Sheet II.

, LIMITED.

O., *501.* Date, *28th January, 1899.*

als.	Detail Drawing References.	Symbols showing condition of Work.	CONDITIONS OF WORK.												
			Stores.		Processes.										
			Rough.	Finished.	Drawing.	Pattern-making.	Smithing.	Boiler-making.	Machining.	Fitting-ins.	Erecting.		Painting.	Fitting-outs.	Order out.
	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
ron	*A-10*	*Required,* + *Ready for Process,* ÷ *In Hand,* − *Completed,* ×			× *670*	× *671*			× *685*						× *690*
el							× *200*		÷ *410*	+ *420*	− *300*				+ *700*
Steel *el*	*A-40*				× *897*		× *491*		× *500*	÷ *501*					× *700*
el	*A-60*				× *751*		× *690*		− *965*	÷ *706*					
el	*A-90*				− *550*										
ron *el*	*A-110*			× *703*	× *560*										
Iron	*B-10*				+ *300*										
Iron	*B-30*				+ *307*										
el															

VORKSHOP ADMINISTRATION,

By Mr David Cowan.

Sheet III.

FIGURE 8.

ING ORDER No. *1234.* Charge to CUSTOMER'S ORDER No. *650.*

y *G.M.* Gen. Manager, Sig. and Date, *1st Nov., 1899.*

e Reference, *Sect. I.* Symbol, *P S X*

G Instructions, Marks, and Numbers, *All cases to be zinc and made air-tight.* *Marks, T* (S) *K.*

ING AND FORWARDING INSTRUCTIONS, *Deliver alongside s.s. Prince's Dock, Glasgow, to be alongside not later than 5th Jan., 2000.*

rward or Paid.

DED BY *Cameron & Co., Carriers.*

ternal Dimensions, ft., ins., ... *7' 6" × 3' 0" × 1' 6"*

t of Machinery, cwts., ... *10 2 28*

ht, " *12 1 17*

TS.	NAMES.	COMPLETIONS.		
Day.		No.	Mo.	Day.
30	*Shop Manager's Register,*	*SM*	*10*	*30*
1	*Foreman Joiner,*	*101*	*11*	*5*
5	*Foreman Fitter,*	*108*	*11*	*10*
1	Shop Manager's Signature and Dates, ... *C*	*SM*	*11*	*15*
25	Shipping Clerk " " " ... *C*	*SK*	*11*	*20*
27	Sales Clerk, Journal Folio.........	*SC*	*11*	*25*

On completion, to be gummed on front page of Shop Specification.

BLANK & COMPANY, LIMITED.

ORKSHOP ADMINISTRATION,

By Mr David Cowan.

Sheet IV.

FIGURE 11.

O.

ber CKET.	Prime Cost—Processes or Operations.				Permanent Index Reference No.
mbo O.	C.	O.—Full Symbol	T.	N.	

18 Materials ect Delivery.			Materials from Stores.			Out-services.			Labour.			Credits.		
ttin	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.

ILANK & COMPANY, LIMITED, GLASGOW.

WORKSHOP ADMINISTRATION,

By Mr David Cowan.

- TION
  - RECORDS OF THE ACTS
    - PRODUCTION … … …
      - *Issue orders*
        - *Special objects*
          - Special … …
            - scientific operations
            - Tests of all products
            - Photographs, &c.
      - *Cost Accounting*
        - *Current Costs…*
          - *Prime costs* …
            - *Out-services*
            - *Labour*
          - *On-cost* …
            - *Current expenses*
            - *Safeguarding expenses*
          - *Credits* …
            - *Surplus materials*
            - *Plant*
        - *Comparative Costs*
          - Like objects…
            - Prime cost
            - On-cost
          - Elementary analyses …
            - Materials
            - Out-services
            - Labour
          - Contracts between …
            - Cost Price
            - Selling Price
        - Comparative Labour Rates
          - Day rates …
            - Time values
            - Time units
          - Piece rates …
            - Time values
            - Time units
          - Premium rates
            - Time values
            - Time units
    - SALES … … …
      - Comparisons
        - Competing products … … … … … …
        - Products which serve same purpose … … … … … …
      - Analysis of Sales … … … … … … … … … …
      - Collection of Accounts due … … … … … … … … …

GLASGOW MAIN DRAINAGE.

By Mr A. B. McDonald.

(SEE PLATES XII., XIII., XIV., XV. AND XVI.)

Read 24th April, 1900.

"In the Neither-ward of Clydsdale and shire of Lanerk, stands deliciously on the banks of the river Clyde, the city of Glasgow, which is generally believed to be of its bigness the most beautiful city of the world, and is acknowledged to be so by all forreigners that comes thither."

"This city, with the suburbs of Gorbels and Caltoun, stands on 300 acres of ground."

So wrote M'Ure in 1736, his enthusiasm being in some degree vindicated by authors of wider experience, such as Defoe and Burt.

An earlier writer waxes even more eloquent, in speaking of the river. He descants on the "pleasant medows, and the portable streams of the river Cloyd, eminent in three capacities. The first is because of her numberless numbers of trout. The second is because of her multiplicity of salmon. But the third and last is from her native original, and gradual descents, because so calmly to mingle her streams with the ocean."

As the 300 acres, on which the city and its suburbs stood, expanded towards the 13,000 acres of the present civic territory, the different buildings, enumerated by M'Ure with affectionate and high-sounding commendation, were converted by neglect and avarice into congeries of mediæval squalor, and became the habitations of disease and crime, while "the portable streams of the river" assumed the aspect with which we are all familiar, and which is now suggestive of nothing so remote from experience as trout or salmon.

About the middle of the present century, the Corporation of Glasgow, under the impulse of the first wave of sanitary reform, set aside the large sum of £30,000 to be applied in clearing out some of the most conspicuous plague spots in the Wynds and Vennels; while later on, in 1866, the City Improvement Act was sanctioned by Parliament, which enabled the municipal authorities to efface nearly all that remained of ancient Glasgow, and to reconstitute the demolished areas on a scale of enlightened liberality that has commanded the approval, and provoked the emulation of other great centres of population, including the Metropolis itself.

In more recent years, the Corporation broadened its endeavours toward the solution of the great problem of improving the conditions of habitation, and under the energetic and enlightened direction of the present occupant of the civic chair, has attained such a degree of success that if the indweller of to-day should fail to acquiesce in the hyperbole of M'Ure, he has abundant cause to indulge his civic patriotism with the conviction that he is indeed a citizen of no mean city.

While the city itself underwent these transitions, the river was not altogether neglected. It appears indeed from the researches of Sir James Marwick, that, as long ago as 1602, the convention of burghs "ordained Glasgow, Dumbarton, and Renfrew to see that the river and all parts near to them, and especially within their respective bounds, were kept clean and unpolluted with dead carrion, and such other matter hurtful to the fishing." The "water sergeant" was enjoined to see to this and other matters, with little apparent effect, as six years later the burghs were required to "cause pen an article to be given into the next Parliament for effecting the cleansing of the river, and punishing the persons who defiled it."

The functions of the "water sergeant" were obviously not sanitary, and we hear little more of him. The increasing importance of the navigation gradually supplanted the fishing industries, and it was very many years later that the Town

Council directed any systematic attention to the purification of the river.

The history of the subject is peculiarly interesting, but the limits of the present opportunity prevent anything further than a cursory glance at the projects submitted during the last half century.

Omitting some earlier informal suggestions—based, for the most part, on the results of the treatment of part of the drainage of Edinburgh by irrigation in the Craigentinny Meadows—it appears that the state of the river in 1851, when the population of Glasgow was only 333,000, was such as to bring forth a proposal to construct a great reservoir in the Upper Ward of Lanark, to discharge artificial spates, during the droughts of summer, to scour the sewage of the harbour of Glasgow, and the lower reaches of the river, out to sea.

The application of sewage to agricultural purposes was at this time engaging general attention, not merely in Glasgow but in all centres of population in the country, and everywhere most sanguine anticipations were indulged regarding the success and financial advantage of that method of sewage disposal.

Among many schemes of this description, which proposed to conduct the city drainage to the sand-wastes of Ayrshire, was one which suggested that the sewage of Glasgow, collected by four large main sewers, should be pumped to a height of 260 feet, in order that it might be conveyed by gravitation in a conduit, 40 miles in length, to the Ayrshire coast, tanks being formed, at different points on the route, for distributing the sewage for agricultural purposes. The author of the scheme expected that it would prove, at least, self-supporting.

While these voluntary investigations, as they may be termed, were from time to time being presented, the Town Council was directing official attention to another method; viz., sweetening the river by deodorisation. Public opinion was at this time so greatly exercised by the statements advanced by patentees of chemical processes regarding the value of the fertilizing ingredients of sewage, that the Sanitary Committee, in 1858, asked a report from Professor Anderson, of Glasgow, and Mr Bateman, of London, on the best means of deodorising the sewage of the city, with observations on the probability of recovering part of the cost by the sale of the deposit as a manure.

The general conclusions of this report are that the most advisable plan would be to use a deodoriser which did not precipitate, which could be thrown into the sewers, so as to sweeten their contents, and admit of their being run into the river, without producing a nuisance. The reporters admit that, although the river might thus be deodorised, it would remain as disagreeable as ever to the eye.

As regards the question of recovering outlay, it may be useful to quote from the report the following:—

"We have no hesitation in asserting that this problem does not admit of an economic solution, and we are satisfied that the first step towards arriving at useful practical results, is to disabuse the public mind of any such expectation. No process of precipitation can possibly recover the whole of these excreta, because the most important and valuable of their constituents cannot be thrown down by any agent, and must necessarily escape with the clear water; while that actually precipitated carries down with it a large quantity of valueless matters, which increase the bulk and deteriorate the value so much as to render the product of little practical use, and prevent its competing, except at a mere nominal price, with concentrated manures."

Subsequent to Mr Bateman's report, the subject was laid aside by the Town Council for a number of years, although its attention was from time to time directed to schemes and recommendations brought forward by voluntary endeavour.

One of these was a proposal to divide the river into two portions by a longitudinal wall, with arrangements for stopping the mouths of the channels, to compel the tidal water to flow up one and down the other, so as to produce greater dilution of the sewage, and a more powerful current to carry it out to sea.

A similar suggestion was made for the construction of a canal from Erskine House to the harbour, and the accumulation of fresh water above the city, by damming the river, and constructing outlets for scouring out the lower reaches.

No fewer than three separate proposals were brought forward for the reclamation of the tidal foreshore of the river, between Newshot Isle, at the mouth of the Cart, and Port-Glasgow.

In 1867, a joint-committee of the Corporation, of the Magistrates and Council, of the Clyde Trustees, and the Police Board, asked Messrs Bateman & Bazalgette, of London, to report on the purification of the river and the disposal of the sewage otherwise than by allowing it to flow into the harbour; and on 20th July, 1868, these eminent engineers presented an exhaustive and most elaborate report on the subject, which may be briefly described as a scheme for intercepting the sewage of the higher, middle, and lower levels of the city, and conveying it from a pumping station at Pollokshields, in a circular outfall conduit, nine feet in diameter, to a point on the Ayrshire coast, about midway between Saltcoats and Troon.

Between Ayr and Saltcoats, and especially between Troon and Irvine, several thousand acres of sandy land were indicated, upon which the sewage might be poured, and thus made of great value. This ground would of itself be sufficient to deprive the sewage of all objectionable character, before flowing into the sea, even if none of it were taken by farmers, or applied to land on the route of the sewer between Glasgow and the coast.

The outlay on this scheme, including the accumulation of interest during the construction of the works, was estimated at £1,253,256, and the annual charge for interest and working was reckoned at £55,000, which was equivalent to an assessment at that date of 5½d in the pound—this being based on the assumption that the whole sewage would be discharged into the sea, unutilised and unproductive.

Messrs Bateman & Bazalgette's scheme was duly considered by the separate departments of the administration, who had instructed the preparation of the report, but it was eventually set aside.

About six years after Messrs Bateman & Bazalgette presented their scheme to the joint-committee, the Corporation sought to grapple with the subject in a more comprehensive way, and, having had unfortunate experience of the difficulties arising from subdivided jurisdiction, they secured the issue of a Royal Commission to Sir John Hawkshaw, to institute an inquiry into the pollution of the river Clyde and its tributaries, and the best means of securing its purification, and remedying the evils and inconveniences arising from its polluted state. Under the powers of this Commision, a searching investigation was conducted regarding the condition of the the rivers and streams within the whole watershed of the Clyde, an area of about 1480 square miles.

Sir John Hawkshaw's report was issued on the 21st March, 1876, when it was found that the method which he recommended for the disposal of the sewage of Glasgow and its suburbs, and the adjacent localities of Airdrie, Coatbridge, Tollcross, Rutherglen, Cambuslang, Renfrew, Paisley, Johnstone, Elderslie, and Kilbarchan, was conveyance in a great tunnel to the sea. The sewage of the northern bank of the Clyde was to be carried in separate syphon pipes under the river at Whiteinch to a pumping station on the opposite side.

Three alternative positions were suggested for the outfall—the Cloch Point, Farland Head, and a point about midway between Saltcoats and Irvine. Farland Head was the place which, in Sir John's opinion, seemed most free from objection.

The drainage of Greenock, Port-Glasgow, Helensburgh, Dumbarton, Kilpatrick, Duntocher, Milngavie, Kirkintilloch, Hamilton, Motherwell, Wishaw, Lanark, and other centres of detached population was to be dealt with locally.

The length of the Farland Head outfall sewer was 26 miles, and the gradient about 1 in 6000. The cost of the scheme, so far as Glasgow and the conjoined districts were concerned, was estimated at £2,500,000, of which £1,500,000 represented the cost of the outfall sewer. The annual charge for interest, pumping, and maintenance was £108,000.

As the outcome of Sir John Hawkshaw's recommendations, the Town Council, under pressure by the Home Secretary (now Viscount Cross), gave notice of its intention to promote a Clyde Conservancy Bill, which was prepared and lodged in Parliament; but this evoked much opposition, and the Bill was withdrawn, at the request of the Home Secretary, on the written assurance of the Government that it was its intention to introduce a general measure, to amend and provide for the enforcement of the provisions of the Rivers Pollution Act, in the case of such polluted waters as the Clyde. This pledge has not been fulfilled, and the strenuous efforts of the Corporation to obtain imperial sanction to a complete scheme for the purification of the river Clyde were thus rendered futile.

In 1887 a Bill was deposited in Parliament for the construction of a railway to be formed in tunnel, under the leading streets of the city. The Corporation were strongly opposed to the authorisation of this work for many reasons, one of them being the derangement of the drainage system of the city. The Bill was originally promoted by a number of private individuals, but the scheme was taken up by the Directors of the Caledonian Railway, who negotiated with the Corporation for the withdrawal of its opposition. An agreement was eventually concluded between the parties, one of the articles of which was an undertaking that the Company should sustain the whole expense of rearranging the interrupted drainage of the city, in such manner as the Town Council should deem most fitting. In terms of this agreement, a system of new drains, devised by the late Mr Carrick, in consultation with the deceased Sir Joseph Bazalgette, were constructed to convey the sewage of the north-eastern and eastern districts of the city to Dalmarnock, where, under the design of the late Mr G. V. Alsing, works were erected for the treatment and disposal of the sewage. These works have been in successful operation for six years, with results that compare favourably with any that have been obtained in this or any other country.

The area to be drained eventually into the Dalmarnock works is 3465 acres, with a present population of 252,000. It is estimated that ultimately, when all the sewer connections are made, the quantity of sewage passing through the works daily will be 17 million gallons. The area drained in the Dalmarnock works is shown on the map on Plate XII.

The unquestionable success of the treatment of the sewage at Dalmarnock, removed all uncertainty regarding chemical methods, and the Corporation resolved, in the autumn of 1895, to proceed with the works necessary for the collection and disposal of the remainder of the sewage of the northern bank of the river, and instructed the preparation of a Bill, to obtain the requisite authority from Parliament. The scheme, which received the Royal assent in 1896, enables the Corporation to dispose of the sewage of Glasgow, and Partick, the districts of Temple, Knightswood, Jordanhill, Scotstounhill and Yoker, the landward part of Renfrewshire, Dumbartonshire south of the canal, the Burgh of Clydebank, Radnor Park, Bearsden, and also, if need be, Duntocher, Faifley, Old Kilpatrick, and Bowling. This drainage area will include rather more than 9000 acres, or about 14 square miles, and the dry weather flow of sewage will be 49 million gallons each day, allowing 50 gallons per day for each person, augmented occasionally by rainfall to 100 million gallons.

In 1898 the Corporation obtained an Act of Parliament authorising similar works for the disposal of the sewage of the southern bank of the river, the scheme comprehending an area of 5893 acres, or 9½ square miles, and including not merely the municipal territory, but also Rutherglen, Cathcart, Thornliebank, Mansewood, Pollokshaws, detached parts of the county of Renfrew, the burghs of Kinning Park and Govan, and the district of South Lanarkshire.

The works for the treatment of the sewage will be situated at Braehead, about a mile from Renfrew. The ultimate dry weather flow from the districts enumerated will be 30 million gallons, assuming 50 gallons per day for each person, which will be increased occasionally by rainfall to 63 millions. The land at

Braehead is sufficiently extensive to provide room also for the sewage arising from the burghs of Paisley and Renfrew.

The result of these combined undertakings will be that an effectual means will be provided for the interception of all pollution that at present enters the Clyde between Carmyle Weir and the mouth of the Leven, and that those of us who survive for a very few years longer will have their senses gratified by that most attractive of all attributes of a beautiful city—the flow of a perfectly pure river; for it may safely be predicted that the water sergeant of the seventeenth century will reappear in new authority, with a sufficient number of his brethren of the watch, to protect the river and its affluents from the defilement of all outlying transgressors.

For the collection and disposal of the 79 million gallons of sewage within this combined territory, there will be constructed 30 miles of sewers, varying in size from 2 feet 6 inches in diameter to 10 feet, which have been calculated to discharge, in addition to the sewage, an amount of rainfall equivalent to one quarter of an inch per day, or 163 million gallons of combined flow.

In briefly describing the various works, it will be convenient to glance separately on those which are on either bank of the river, taking the north side first.

The leading features of the northern scheme are the construction of an outfall sewer, which will convey the drainage of the higher levels of Glasgow and Partick to Dalmuir, where it will be treated at the works which are to be constructed there, on the lands acquired for that purpose by the Corporation; the construction of an intecepting sewer, to collect the drainage of the lower levels of the city; the construction of an intercepting sewer, to collect the drainage of the lower levels of the burgh of Partick; and a third intercepting sewer, which will convey to Dalmuir the drainage of the burgh of Clydebank.

The Glasgow and Partick intercepting sewers will be pumped into the outfall sewer at Partick Bridge, the difference of level being 35 feet. The Clydebank intercepting sewer will be pumped at

Dalmuir, the difference of level being 15 feet. Rather more than one-half of the total sewage will be carried to Dalmuir without pumping. The whole sewage carried by the outfall sewer will be delivered at such a height above the tidal level as will enable it to be discharged at once into the precipitation tanks.

OUTFALL SEWER

The dimensions of the outfall sewer, from its commencement till it reaches the works at Dalmuir, vary from the capacity of a circle 7 feet in diameter to that of a circle 10 feet in diameter.

The inclination between the pumping station and the Dalmuir Sewage Works will be 1 in 2062 for a distance of 5½ miles, and 1 in 2810 for the remaining distance of 1¼ miles. The mean velocity of the flow will be 3 miles per hour, so that the whole volume of sewage will pass from the Partick pumping station to Dalmuir in two hours and a quarter. There will thus be no possibility of the generation of noxious gases, or the emanation of offensive or injurious odours.

The levels are fixed by the point of discharge at Dalmuir, which is 10 feet above ordnance datum, or about 4 feet 3 inches above high-water of ordinary spring tides, by the crossing of the Glasgow Subway, the lines of the North British Railway, the Caledonian Railway, the Lanarkshire and Dumbartonshire Railway, the Whiteinch branch of the North British Railway, and the Yoker and Clydebank Railway.

The route of the sewer follows the line of existing and intended streets, wherever that is practicable. In the undeveloped territory between Partick and Clydebank, for the greater part of its course it follows the line of the Yoker and Clydebank Railway, and it is carried through the burgh of Clydebank along a track that causes as little local disturbance as possible. The land traversed is for the most part flat, so that the upper part of the sewer is in some places above the level of the ground. The form of the sewer is generally circular, but it has been necessary in various places to change its form, while maintaining its capacity.

The dimensions of the outfall sewer, between the pumping station and Dalmuir, have been calculated on the basis that, with the full complement of sewage and rainfall, the sewer will only be charged to the extent of two-thirds its capacity. The sewage and rainfall in Partick are calculated on the same principle as in the Glasgow area, but the ultimate population of the undeveloped territory between Partick and Dalmuir has been taken at the rate of fifty persons per acre, instead of one hundred persons, as in Glasgow and Partick.

INTERCEPTING SEWERS.

The lower levels of the city will be drained by the intercepting sewer to the Partick pumping station on the west side of the River Kelvin, where the sewage will be pumped about 35 feet into the outfall sewer. The intercepting sewer is 3¼ miles in length, and its inclination is 1 in 2640, or 2 feet per mile. The drainage area is 930 acres.

The lower levels of the burgh of Partick will be drained by an intercepting sewer which will convey the sewage eastward to the pumping station at the Kelvin, where it will be pumped into the outfall sewer, in the same manner as the low level drainage of the city. This intercepting sewer will be two miles long, and its inclination 1 in 2000. The area dealt with is 1025 acres. The level at which it is intended to construct these sewers is such as to admit the connection of all the existing sewers in the low level of Glasgow, and in the burgh of Partick, without liability to regurgitation during periods of ordinary flow. Provision will be made for the release of sewage, during times of exceptional rainfall, by maintaining the connection which these sewers have at present with the river, and they will be protected by balanced tide valves from the back flow which surcharges them at the present time. An example of special construction in connection with the Partick intercepting sewer is shown on Plate XIII.

The intercepting sewer, which will convey the drainage of the burgh of Clydebank to Dalmuir, will be 2¼ miles long, with an inclination of 1 in 2000. It will be deep enough to connect all the existing sewers in the burgh. The area to be drained is 1900 acres. The population is here taken as fifty persons to the acre, and the sewage as 50 gallons per head. The invert level of the sewer, at the western termination, is 15 feet lower than the invert of the outfall sewer. A pumping engine will raise the sewage to the level of the precipitation tanks.

The gradients of all the sewers are inevitably flat, although they do not differ from the inclinations usually adopted in the design of main drainage works. The outfall sewer had a minimum gradient of 1 in 2810. The Glasgow intercepting sewer has a fall of 1 foot in 2640; the Partick sewer and the Clydebank sewer have each 1 foot in 2000. These levels were made the subject of great comment and simulated apprehension on the part of opponents, in the proceedings in Parliament. The outfall sewer, it was alleged, would possess no flow; the stagnant sewage would fester and emanate poisonous gases, which would be highly dangerous to the inhabitants of the districts traversed, and especially to the passengers on the Yoker and Clydebank Railway, whose jeopardy would be extreme. These apprehensions were not appreciated by the Committees of either House, which accepted the statements of the engineers who supported the Bill, that there would be a sufficient velocity of flow in the flattest part of the sewer. Were there any doubt on the subject, it would be removed by the fact that one of the sewers constructed by the Caledonian Railway Company, in Gallowgate, has a gradient of only 1 in 3000, and although it is of comparatively small size, and lined with common brickwork, it has given no trouble since it was built.

To ensure the best possible results in the outfall and intercepting sewers, the interior surfaces are to be constructed of the highest quality of pressed brickwork, in order to reduce friction. The outer rings of brickwork will be of a less expensive description.

RAINFALL.

The requisite capacity of sewers to carry the volume of domestic and industrial discharge, measured by safe approximation by the district water supply, is an easy thing to determine, but the extent to which their capacity ought to be enlarged, to meet the increased volume due to rainfall, is a matter difficult to arrive at. It is impossible to construct sewers of such a size as will carry away rainfall on occasions of sudden and excessive atmospheric disturbance, such as occur in the neighbourhood of Glasgow, but the incidence of such emergency must be regarded, and so far as possible provided for.

The recognised practice in dealing with the sewering of large centres of population, is to provide for the delivery of rainfall, calculated on a quarter of an inch of rain in 24 hours, over the inhabited area. This is the quantity provided for in the scheme submitted by Messrs Bateman and Bazalgette in 1868, by Sir John Hawkshaw in 1876, and by Sir Joseph Bazalgette, in the great Main Drainage Works of the Metropolis, with which his name will be for ever associated.

In making a similar provision for the Glasgow Main Drains, it is intended to construct the sewers of dimensions sufficiently ample to discharge the combined flow of sewage and rainfall, without taxing their capacity beyond one-half in the case of the intercepting sewers, and two-thirds in the case of the outfall sewer. There is thus left a large surplus of what may be described as storage capacity, to cope with emergency; but it is necessary to make further provision than this, and in order to deal with the surcharge that will arise from excessive rainfall, overflows are provided in the outfall sewer for the escape of storm water. These are arranged for at the crossing of the river Kelvin, at the Hayburn sewer in Partick, at Yoker Burn, and at Duntocher Burn. The details of the Yoker Burn overflow are shown on Plate XIII.

The storm waters thus liberated, being much diluted by excess over the dry weather flow, can be discharged without offence into these streams, which will at the time be flooded to a degree sufficient to render the overflow from the sewers innocuous. The intercepting sewers will be relieved of storm water by means of the communications which the existing sewers have with the river, protected from regurgitation by balanced tide flaps.

The estimated volumes of sewage and rainfall which, for purposes of Parliamentary evidence, had been arrived at by calculation, had to be verified by gauging the actual delivery of existing sewers during different states of the weather, the sufficiency of the dimensions proposed for the new sewers had to be tested, and the whole arrangements laid down on the deposited plans scrutinised in every detail, before anything could be done towards the preparation of the working drawings and specifications. These investigations, carried out in the most thorough manner by a special staff of qualified assistants, have resulted most satisfactorily, and it has not been found necessary to rectify any of the earlier propositions, on the ground of discrepancy with ascertained fact, although it has been thought prudent to increase the allowance for dry weather flow in the intercepting sewers, somewhat beyond the original calculations.

In designing the works for the treatment of the sewage at Dalmuir, it is intended to depart to some extent from the arrangements carried out at Dalmarnock by the late Mr Alsing. These works have been most justly described by all competent authorities in terms of the highest enconium, and they are beyond question creditable in every sense to the reputation and the memory of their lamented designer.

The position of the intended works at Dalmuir is, however, different from those at Dalmarnock, and although there is no physical difficulty in combining at Dalmuir the processes of precipitation and filtration, it does not appear to be either requisite or expedient to do so. The general arrangements and details of the Dalmuir Works are shown on Plates XIV., XV., and XVI.

The whole of the working drawings, specification, and forms of tender for the works on the north side of the river were completed a considerable time ago, and contracts for the complete length of the outfall sewer were entered into. Part of this work has been disturbed through disagreement with one of the contractors, and the remaining works, so far not yet contracted for, have been suspended in the expectation that ere long financial conditions will become more favourable.

SOUTHERN SCHEME.

On the south bank of the river, the surface levels of the drainage area are less favourable for the conveyance of sewage and rainfall by gravitation than they are on the north side, dealing with the figures that represent the distribution of population at the present time, although the future development of the included territory will bring the volumes conveyed by the gravitation and pumped sewers into less disparity. The ultimate estimated quantities are approximately in the proportion of 31½ million gallons of combined sewage and rainfall by gravitation, as against 42 million gallons requiring to be pumped. Nearly 13 million gallons of this excess of pumped sewage and rain will be chargeable against the Burgh of Govan, with which authority equitable terms have been arranged.

The sewers to be constructed on the south side of the river follow for the greater part of their course the line of public streets and roads, and the charge for wayleave will be less than that incurred on the northern division of the undertaking.

The outfall sewer commences in Pollokshaws, and, passing under the River Cart, traverses the whole length of that burgh, and, entering Glasgow, near the Macquisten Bridge on the Kilmarnock Road, follows the line of various roads in the Langside and Queen's Park districts, when it turns westwards across Pollokshaws Road. Thence it proceeds northward, and again westward, through Pollokshields, Bellahouston, Ibrox, Craigton, and Cardonald, towards the Works at Braehead. It is 8¼ miles in length, varying in size from 2 feet 6 inches to 7 feet 8 inches in diameter, with a minimum gradient of 1 in 2640.

Three separate systems of sewers collect the drainage of Cathcart, Mount Florida, Polmadie, Inglefield, Coplawhill, Dumbreck, and Ibroxhill, which districts will all be connected with the outfall sewer. They are all small sewers, of 3 feet diameter, with good working gradients.

The pumped sewage of Glasgow will be intercepted by a sewer commencing at Shawfield, and carried westward along Rutherglen Road, Govan Street, Kirk Street, Oxford Street, King Street, and Paisley Road, to Pollok Street, where it turns southward to join the outfall sewer in the Pumping Station, at the corner of Shields Road and St. Andrew's Drive, where it will be lifted 35 feet. The Plantation district of Govan and the Burgh of Kinning Park will be served by a low level sewer, carried eastward along the Govan Road and Paisley Road, to connect with the Glasgow sewer at Pollok Street. These pumped sewers are about 3 miles in length, from 2 feet 6 inches to 6 feet in diameter, the minimum gradient being 1 in 2000.

The whole of the remaining sewage of the Burgh of Govan requires to be pumped, and the intercepting sewer is to be constructed by the Burgh Commissioners, and connected at the western boundary of the Burgh with a sewer included in the Glasgow undertaking, which will drain the flat land in South Lanarkshire. This sewer is 2½ miles in length, from 3 feet to 5 feet in diameter, with a gradient of 1 in 1760. It will be pumped at Braehead, the lift being 25 feet.

The sewage of Paisley and Renfrew will be brought to the Works in low level sewers, which will also require to be pumped.

The Braehead Works for the treatment of the sewage will, like those at Dalmuir, have the great advantage of river frontage, with every facility of water carriage for receiving and transporting materials.

Progress has been made with the verification of the Parliamentary surveys and sections, and with the working drawings to such an extent that, if no obstacle intervenes, it will be quite practicable to commence work during the present year, although the Corporation are in the meanwhile inclined to pause, until the high price of labour and materials, due to the abnormal activity of the building trade, will exercise less disturbance on the

Parliamentary Estimates, which represent £1,000,000 for the combined undertaking of the Northern and Southern Main Drainage Works, authorised in 1896 and 1898.

The citizens of Glasgow have never been unwilling to expend money in large amount on schemes devised for the wellbeing of the community. The water supply, the acquisition of parks and of art galleries, the City Improvement Scheme, the Streets Improvement Scheme, the acquirement of the various gas undertakings, the markets, the bridges, and other enterprises of great pith and moment, are separate evidences of the faith of the electorate in their representatives, whose grasp of public policy and enlightened administration have made Glasgow the just theme of commendation among other communities at home and abroad, as a prominent example of what can be done in the amelioration of the conditions of urban life.

The present undertaking is one of these gratifying examples of civic spirit. The schemes laid before Parliament, in 1896 and in 1898, were each strongly opposed by railway companies, land owners, local authorities, and other petitioners, but there was not a single dissentient voice raised among the constituencies, on whom the whole financial responsibility was laid, although it was made abundantly clear to all, that a large increase of rating was involved, and we are thus advanced another step in the direction of compelling the admiration of "all forreigners that comes thither."

This manifestation of confidence on the part of the ratepayers furnishes a stimulus to their representatives in their endeavour to secure that this large outlay will be expended to the best advantage; that what is done for the purification of the river will, beyond doubt, make the river pure; that it will not, for instance, present to the eye the appearance of the flood tide of the Thames, as it may be seen from the Committee windows of the Houses of Parliament, or the parapet of the Thames Embankment: a stream so heavily charged with suspended matter that an observer might incline to suppose that inexhaustible volumes of dense brown smoke were being mysteriously conveyed beneath the surface of the water. The waters of the purified Clyde will, it is hoped, be not merely free from all organic objection, but as clear and limpid as the sewage effluent which is now exhibited.

And this brings up a matter of great importance, which, it is hoped, will justify separate remark.

The various works, which have been described in detail, present no features of debate. They have been sanctioned in principle by Parliament, and approved in minute detail by the Corporation. They convey to separate points of discharge, two great volumes of never-ceasing flow, that approach the magnitude of rivers.

The questions then arise — What is to be done with these polluted streams? How are they to be hallowed and restored to the purity of "their native original" before they "mingle calmly with the ocean"?

Here we enter upon debateable matter, concerning which it is necessary to say something; but it must, at the outset, be distinctly understood that for what follows, the author of this paper is alone responsible. No one is in any way committed by his opinions—neither the Corporation nor any of its officers. No one is even aware of his intention to express himself on the subject, and he suggests no line of policy, nor does he seek acquiescence in opinions that are certain to incite objection.

The problem can be very simply and clearly stated, and all that has to be said about it will be uttered in everyday words.

Pure water has an easily remembered chemical name—H_2O.

Sewage is H_2O + a great many things with chemical names that are not easily remembered, and which the author will not presume to recite. The plain English names of some of them present little difficulty—ordinary domestic and industrial refuse, the sweepings of streets, courts and pavements, discharges from dye works, chemical works, breweries, distilleries, gas works, glue works, grease works, foundries, oil works, tanneries, slaughter houses, tallow works, paper works, tar distilleries, and many others; the usual proportion of flotsam and jetsam of city life, a measure of dead dogs and cats, and occasionally a railway sleeper—not an over-somnolent passenger—but a piece of larch, 9 feet long, 10 inches broad, and 5 inches thick.

The problem is to convert this collection of "matter in the wrong place" into H_2O, and the answer is, of course, that it cannot be done, even in the laboratory, much less on the prodigious scale of eighty million gallons per day.

That it can be done to some extent, and done well, is proved by the sample of sewage effluent, drawn to-day from the precipitation tanks at Dalmarnock, but although the sample is very clear, and quite free from any traces of suspended matter, it contains many things besides H_2O. I am informed, however, on reliable authority, that it has fewer elements of objection than are to be found in the effluent derived from any other method of sewage treatment; that it may be discharged into the enormously greater volume of the river, without the slightest possibility of detriment; that, of itself, it will support fish life, and that it can even be drunk with impunity.

This degree of purification we are able to accomplish with certainty, at an ascertained cost, which is already reduced below the initial charge, and which will be still further reduced, if the same method of treatment is adopted in the works which are to be constructed at Dalmuir and Braehead. This result is obtained by chemical precipitation, the precipitating agents being lime and sulphate of alumina.

There is, however, a strong disposition, on the part of an increasing section of opinion, to regard this method with disfavour, as unscientific, and uneconomical. The adherents of this school of opinion, advocate the substitution of natural agencies, which, it is alleged, will effect a greater degree of purification at less cost. The methods which they employ are named bacteriological, and their advocacy of the system fills the technical press. Even the daily newspaper can hardly be looked into, without stumbling over some more than usually startling reference to the subject.

The results obtained by the methods advocated are, up to the present time, of limited extent, and do not, I venture to suggest, altogether warrant the extravagant assertions, and ultra sanguine anticipations, of those who occupy the principal place among the exponents of the doctrine.

It is scarcely necessary to explain the nature of the theory of bacteriological treatment of sewage, which is embarassed by a most abstruse terminology, concerning which the exponents themselves are apparently not quite agreed. It practically means, however, that, in the process of filtration, certain results, that were formerly ascribed to atmospheric action, are now ascertained to be due to the presence of micro-organisms, called bacteria. The result is not greatly changed, neither does a filter accomplish more work when it is called a bacteria bed.

It is necessary to mention that bacteria are divided into two classes—aërobic and anaërobic, according as they dwell in the air and in the water. It is altogether beyond the province of an engineer to discuss the nature and the functions of bacteria, and he may well refrain from doing so, when the foremost authorities on the subject are diametrically opposed.

In the *Sanitary Record*, for 26th January, Mr W. J. Dibdin sternly rebukes a correspondent, in the following terms: "Mr Candy seems to be labouring under the idea that the line to be drawn between aërobic and anaërobic organisms is very sharp indeed. This is really not so; the division is a useful one for general description, but the two classes merge into one another so gradually as to make it very difficult to say when the action of the one begins and the other ends." While on the 12th February, Dr S. Rideal, an authority more eminent, if possible, than Mr Dibdin, informed his students in the University College, London, that: "In both cases these two classes were specially developed, and had great powers in their respective spheres. From other experiments he recognised that there was a sharp line of distinction between the work done by the anaërobe and by the aërobe, and concluded that the two processes should be kept as distinct as possible."

I have ventured to say that the subject of bacteriology is defaced with extravagant statements.

At the Leeds meeting of the Sanitary Congress, in 1897, Colonel Jones, traversing some of Mr Dibdin's statements, said ". . . . Mr Dibdin estimated that by careful treatment and attendance they might raise the rate to perhaps 30,000 persons per acre upon his Bacteria Beds."

Mr Dibdin: "A million per acre."

The sewage of a million persons per acre! Fifty million gallons, containing fifty tons of matter. It is impossible to characterise such a statement, without exceeding the limits of convention. Surely counsel was never darkened by words more unwise.

The subject is also obscured by a looseness of definition that is the more strange when used by men, who, of necessity must be exceptionally cultured, and who are altogether beyond suggestion of misrepresentation.

One of the most important recent contributions to the subject is entitled "Bacterial Treatment of Crude Sewage." What meaning would 999 out of 1000 persons attach to that? Crude, according to the dictionary, means "not altered or prepared by any artificial process," and we have already seen what sewage is. The average man might well be excused for supposing that this bacterial treatment of crude sewage means that the domestic and industrial residua—the dogs, cats, and the railway sleeper—were to be cast upon the filter, that the bacteria were to be unchained, and the work of purification incontinently accomplished. Of course, we know that this is not the way it is done, or that it will be done, but how is the bewildered ordinary reader to translate to himself language so loose, and deliver himself at the same time from the confusion of Mr Dibdin and Dr Rideal?

As a matter of fact, the crude sewage, referred to in the report, was in the first place laboriously freed, by mechanical agency, from every ingredient that was not liquid, and it was thereafter allowed a long period of rest, in a special tank, in order that the suspended matters might deposit themselves by sedimentation, before the liquid, thus additionally cleared, was discharged upon the filters.

And this brings us to the only phase of the question that concerns the engineer: Does the principle of bacteriological treatment of sewage possess an economic aspect? Will it compete with chemical precipitation in actual practice, on the great scale on which it has never yet been tried? The answer appears almost inevitably in the negative.

Bacteriological treatment is another name for filtration, and sewage cannot be filtered. Nothing is more clearly admitted than this. The conclusions of the recent report of the Manchester experts (page 54) are too definite to be mistaken :—

"In order that a bacterial contact bed may exercise its full powers of purification, it is necessary—

"(*a*) That it should be allowed sufficiently frequent and prolonged periods of rest;

"(*b*) That the sewage applied to it should, as far as possible, be free from suspended matters;

"(*c*) That the sewage applied to it should be of as uniform a character as possible."

If the separation of solids be essential before the filter stage is reached, and if the filters themselves have to be allowed indefinite periods of rest, no reliable estimate of the cost of treatment can possibly be arrived at. The whole matter remains in the theoretical stage: this only being plain, that the system indisputably requires for its operation more time and more space than are required for chemical precipitation.

But there is no time to spare, for the flow of these eighty million gallons of sewage is relentlessly permanent, and increased space means augmented cost for land and for construction to a degree that must far transcend the charge for chemical treatment.

The CHAIRMAN remarked that they had heard a most interesting paper. Mr McDonald was engaged in this work from a professional point of view, but he thought, if he rightly interpreted the applause he heard when the Lord Provost entered the Hall, that they would like to hear a word or two from his Lordship, who was interested in other aspects of the subject, and who had honoured the Institution by being present.

Discussion.

The Hon. Lord Provost CHISHOLM (Visitor) observed that he little expected that he, who was so far from being a professional or expert on this question, should have been asked or expected to say a single word on a paper given by their professional adviser; but, since Prof. Barr had asked him, he would like to take advantage of the opportunity to say a word or two. He would not attempt to pronounce a single word on the professional aspect of the subject; that would be impertinence on his part at a meeting of engineers. The leading interest to him was in other aspects of the subject, the social, municipal, and economical. He was profoundly thankful that the citizens of Glasgow had, as Mr McDonald had said, been so cheerfully acquiescent in this vast undertaking on which their municipal representatives had embarked. He regarded it as one of the most pleasing symptoms not only of the confidence which the citizens had in their representatives, but of their readiness to bear any burden that would contribute to the amenity and also to the health of the community. Nothing was more encouraging to the representatives than the conviction that where a scheme was proposed which was in itself reasonable, and which was designed to accomplish great outstanding benefits of a social kind, the citizens willingly submitted to the burden. The scheme, as Mr McDonald had indicated, was really started when the underground railway, constructed by the Caledonian Railway Company, was brought before the Corporation. Mr Carrick, who was Mr McDonald's senior and predecessor, and whose mantle had fallen on worthy shoulders, at once saw an opportunity for accomplishing that on which for a long time his heart had been set, and towards which his thoughts and attention had been directed, and he advised the Corporation to acquiesce practically, The Hon. Lord Provost Chisholm.

with various modifications, of course, in the Caledonian Railway Company's proposals. He supposed he was not overstating the case when he said that when the Caledonian Railway Company started, it was expected that a sum of from £100,000 to £120,000 would have to be expended in altering the main drainage of the eastern part of the city, but it could not have been accomplished without spending something approaching £250,000; and having done that for the east-end of the city, it was obvious that the money would be thrown away unless the Corporation proceeded with schemes to overtake the remainder of the city, because if only one portion of the city had been dealt with, the Clyde would not be appreciably the better. As he had said, his interest in the subject was not only that this had been done, but he regarded as a singularly interesting feature the fact that the Corporation of Glasgow had made friendly arrangements, and had come to friendly terms with all the adjacent Local Authorities, so that the sewage of Partick, Govan, Pollokshaws, and parts of the Counties of Lanark and Renfrew was dealt with; and by a running assessment leviable over the whole, and payable to the City of Glasgow, this vast work was done for the entire area. He considered that also as a tribute to the good sense and good feeling prevailing amongst those somewhat rival municipal authorities, that they agreed to have their citizens rated by another authority, and Partick and Govan, for their sewage, would pay a rate to Glasgow. He regarded that as a foretaste of coming events casting their shadows before. He would not detain them further than to say that he had heard with very great delight Mr McDonald's paper. He did not suppose that anyone had dreamt of questioning the ability of Mr McDonald to grasp and to foresee a vast undertaking such as this extending over such an area, and involving such an enormous expenditure; but if anyone had, the manner in which he had laid the matter before them that evening was sufficient evidence of his devotion to the subject, as well as his ability to grasp it; and it showed that they had got the right man to superintend this scheme of social and city amelioration.

Dr JAMES ERSKINE, Member of Glasgow Town Council (Visitor), observed that the historical part of Mr McDonald's paper had been very interesting to him. He thought it was very considerate of the Institution to ask the members of the Town Council to be present. He had had an opportunity, along with the members of the Sewage Committee, of going over the southern and western parts of the scheme described by Mr McDonald, and it was very interesting to them, but it had never presented itself to him in the comprehensive and graphic manner in which it appeared that night. It had impressed him in a manner that would really be useful to him in thinking over the various moves that were being made in the direction of carrying out this great scheme. As the Lord Provost had remarked, it was interesting to notice the large number of local authorities all round Glasgow that were co-operating with the city in this scheme. In fact it could only be successful in such a way. Mr McDonald had not spoken in any favourable manner of the bacteriological treatment of sewage. He knew that certain members of the Sewage Committee were regarding that method of dealing with sewage much more favourably than in the past. In fact, one of the Sanitary magazines, in a leading article, had mentioned that the members of the Corporation of Glasgow were being converted to the bacteriological method of dealing with sewage. Certainly, since he became a member of the Committee, he had been very much interested in the system, and with regard to it he did not think finality had yet been reached. It seemed to him that the great objection to the adoption of that system was the amount of space that was required, which meant great expense.

Mr WILLIAM MARTIN, Member of Glasgow Town Council (Visitor), said the aspect of the meeting which impressed him most was that there were a number of gentlemen present who had been trained to look on this question from the applied science standpoint. He thought it was a happy omen. He meant that the exponents of engineering in Glasgow were not content only to look at a question which might be said to affect their own trade or industry,

Mr William Martin.

but that they were prepared to take their part as citizens to make Glasgow more habitable for the great mass of its inhabitants. He was a great admirer of John Ruskin, whose influence, he believed, would extend and deepen as time went on. While there were some things about his teaching that might be open to criticism, and perhaps even ridicule, it must be admitted that he did a great work in showing this generation that the development of industry, which this century had witnessed, ought not to mean a desecration of the fair places of nature; and that they should not be content to accumulate more material wealth, but see that the natural conditions which obtained were preserved for the people at large. The only thing that had made them feel somewhat ashamed of Glasgow was the condition of the Clyde. The Glasgow people themselves did not go down the river, but there were those who came from a distance who wished to see the river and the great industries on its banks. They ought to be able to show their friends a pure river and not a cesspool, and this scheme that was being carried out would enable them to do this. It was only a matter of fifteen months since he had the honour of being elected to the Glasgow Town Council, and he had not been consulted as to what committees he should be placed on. While he did not look upon Mr McDonald in the aspect of the Lord High Executioner, he had a great respect for him, for he had enabled him to see the wood. There was a saying that "one could not see the wood for the trees," and that had been his position. However, to-night he had had a general survey of the wood at large, and it would enable him as a member of the Sewage Committee to grasp more intelligently the questions that were brought forward for consideration. It was a great encouragement to members of the Corporation to know that they had the intelligent sympathy of experts, and if they were engaged on schemes that some might consider doubtful, it was reassuring to the citizens to know that they could count on the intelligence and skill of this Institution and such bodies as it.

The discussion on this paper was resumed on 15th May, 1900.

Mr Charles P. Hogg (Member) thought that the Institution was greatly indebted to Mr McDonald for his valuable paper on the Main Drainage of Glasgow. Being interested in the subject for many years, he had followed the historical summary given by Mr McDonald with great interest, but there were two or three omissions which he would like to mention, so as to have on record the various schemes which had not been referred to in the paper. In 1876, the year of Sir John Hawkshaw's report, the Town Council appointed a deputation to visit all the chief towns in England where sewage was being treated, and in the following year a most valuable report was presented, in which it was recommended that the sewage should be treated by the process of precipitation and filtration. In 1878, Mr Bateman submitted a report to the Town Council showing that three alternative schemes were possible. The *first* was to take all the sewage to Dalmuir, by pumping the sewage of the south side of the city across the river. The *second* was to take all the sewage down to Shields, near Braehead, not far from Renfrew, which involved the pumping of the north sewage over to the south side. The *third* scheme was to take the sewage of the north side of the city down to Dalmuir, and the sewage of the south side to Shields, near Braehead. Mr Bateman himself rather favoured the taking of the whole sewage to Shields, on the south side of the river, his reason evidently being that some day it might be necessary to carry the effluent to a further distance from Glasgow than Shields. That was followed by a supplementary report by Mr Bateman, in 1879, dealing chiefly with an increase of his estimates of cost. Again in 1880, a deputation visited various places, and afterwards recommended that all the sewage should be taken to Dalmuir. About this time the Town Council bought the property at Dalmuir —he thought about 200 acres at a cost of about £100,000. The scheme was in abeyance for some years, and in 1884 a valuable pamphlet was published by the late G. W. Muir, pointing out that it was a mistake to concentrate the whole of the sewage of

Mr Charles P. Hogg.

Glasgow at one particular place, and that it ought to be dealt with in districts. He suggested a good many districts—perhaps too many—but to Mr Muir belonged the credit of having been the first to point out the suitability of the site at Dalmarnock for sewage works, and, as they all knew, the first instalment of the Glasgow sewage works was established there. Later on it was seen that Mr Muir was on the right tack, and the scheme had now been modified to three precipitating stations. As already mentioned, the Town Council favoured taking the whole of the sewage to Dalmuir, while Mr Bateman, the engineering adviser of the Council, favoured taking it to Shields. Speaking as an engineer, he thought the lines on which the main drainage of Glasgow had been laid out were sound. They were devised to reduce the pumping to a minimum, and laid out to form a wide and comprehensive scheme, so that it would be possible, not only for Glasgow, but for the adjacent towns and considerable areas of the counties to purify all the sewage entering the Clyde between Carmyle and Dalmuir. Mr McDonald had referred to the very flat gradients, but these were not unduly flat for main drainage works, because, when they were dealing with sewers of 8 and 10 feet diameter, a fall of 2 feet per mile was a very good one. Mr McDonald said there would be a velocity of something like 3 miles an hour. He himself had made it rather less, but as a matter of interest he would like to have on record the formula which Mr McDonald had used in his calculations. Mr McDonald had referred to the very flat gradient of the Gallowgate sewer, 1 in 3000, and said no difficulty had been experienced with it. Some years ago he (Mr Hogg) had to advise regarding a very flat sewer, and, after a great many inquiries, he found that the Gallowgate sewer was the flattest of all those he could get any information about. He had forgotten the size of the Gallowgate sewer, and he would like to ask Mr McDonald to put that on record, because it was important in dealing with gradients. From his calculations the velocity appeared to be something like 100 feet per minute, and he was informed at the time that there

Mr Charles P. Hogg.

was a little trouble with silting. He would like to know what the actual velocity was by observation, and whether or not it was the case that a little silting did take place. In dealing with sewage, the real crux of the question was how to get rid of the sludge. That had been dealt with very successfully, he believed, at the Dalmarnock works, where the sludge was sold at some profit. These works had been in operation for about six years, and the precipitants used were lime and sulphate of alumina. The results seemed to be so much better than anything else they knew of in the way of precipitation work that, he would like to ask Mr McDonald whether he would be kind enough to say what were the quantities used. Mr Tatlock, in 1892—two years before these works were started—made a valuable series of experiments on the different precipitants, and it was he who recommended lime and sulphate of alumina as being the best. At the time the works were started, he believed that the quantities used were something like 6½ cwt. of lime and 11 cwt. of sulphate of alumina per million gallons of sewage, and he would like to know whether that was the proportion still used, because he found in a recent report by Mr Tatlock, issued some six months ago, that in Glasgow 68 per cent. of the oxidisable and putrescible matter was removed, while in London only about 17 per cent. was removed. That seemed very remarkable, and he would be glad if Mr McDonald, who had been visiting the London works on various occasions, could throw any light on that point. He was surprised at the attitude Mr McDonald had taken up towards the bacteriological method of treating sewage. Mr McDonald had visited all the works where it was in operation, and had recently been at Manchester, where he had seen at first hand many things which others had not seen. He (Mr Hogg) had studied the question, and in advising the District Committee of the Middle Ward of Lanarkshire, had introduced that method, and from all he had seen of it he thought it gave exceedingly good results. Of course, each case must be dealt with upon its merits, and he did not say that it was by any means the best method for

Mr Charles P. Hogg.

Glasgow, but he knew that the Manchester experts, in reporting recently, said that it was the best system for Manchester, and that being so, he was very much surprised at the attitude which Mr McDonald had taken up in his paper in regard to it. Mr McDonald was careful to say he only expressed his own views, and did not commit the Corporation or any of the officials of the Corporation; but he (Mr Hogg) had been looking through the report of the Manchester experts, and he felt that Mr McDonald had scarcely given a fair version of their report in dealing with it. Mr McDonald had referred to Mr Dibdin's statement at the Leeds Congress in 1897, where Mr Dibdin was quoted as having said that he could deal with the sewage from a million persons per acre. That was a mere remark uttered during the discussion, and Mr Dibdin, who threw millions about him with the prodigality of a geologist, certainly had himself to blame, but really he meant a million gallons per acre, and not sewage coming from a million people. It all came back to Mr McDonald's statement on page 288, and to that he had no objection. That brought them to the only phase of the question which concerned the engineer—"Does the principle of bacteriological treatment of sewage possess an economic aspect? Will it compete with economical precipitation in actual practice, on the great scale on which it has never yet been tried"? and he said that the answer appeared to be almost inevitably in the negative. That was the answer that he (Mr Hogg) would like to traverse, and he would suggest that Mr McDonald should, in the present state of their knowledge of the subject, keep an open mind. He hoped that this was only the beginning of a series of papers from Mr McDonald on the subject, and that he would, as Mr Gale had done in the past, with reference to the water supply, favour them with several papers detailing the full history of the sewage disposal of Glasgow.

Mr A. C. Holms, Member of Glasgow Town Council (Visitor), observed that, being one of the Sewage Committee, he naturally took an interest in this matter, and he thought that the position of affairs was very well expressed in the questions raised by Mr McDonald, Mr A. C. Holms.

" Does the principle of bacteriological treatment of sewage possess an economic aspect?" Will it compete with chemical precipitation in actual practice, on the great scale on which it has never yet been tried?" The Sewage Committee were inclined to think that it would not, because the process which would be carried out in the works about to be undertaken at Dalmuir was simplicity itself. It was not like that at the Dalmarnock works, which was largely chemical, and reduced sewage to a condition of comparative purity by precipitation and chemical treatment, varying with the ever changing character of the sewage, the residual products being partially utilised as fertilizers. The large amount of sewage to be disposed of further down the river would be dealt with on a system of extreme simplicity. The sewage from the low levels would be raised at the pumping station at the bridge over the Kelvin at Partick, and fall into the main sewer there. Then flowing down by gravitation to the works at Dalmuir, it would be run over a large area for the purpose of filtration, or, rather, precipitation. The tanks in this connection would each be about 700 feet long, and the precipitants would be lime and sulphate of alumina. Undoubtedly the bacteriological treatment of sewage required a very large area for precipitation, and hence a large capital expense and no residual products, so that the gain was infinitesimal, if anything at all. Arrangements had been made within the last month to turn a section of the works at Dalmarnock to the purposes of bacteriological treatment, and it would have a fair trial. As to how it would suit every circumstance was difficult to tell, but Mr McDonald said that one of the disiderata was that the sludge should be, as far as possible, of a uniform quality. That could not be in Glasgow with the continued chemical changes owing to the different works situated in the northern parts of the city. With the matter that would pass through the Dalmuir works, there were fewer chemical works to be dealt with, and therefore the quality of the sludge would be more uniform. The course it was intended to pursue was simplicity itself, and the cost a minimum. The whole works would be almost self-acting.

Dr John T. Wilson.

Dr. John T. Wilson, Medical Officer of Health for the County of Lanark (Visitor), said he was extremely grateful to Mr McDonald for his paper, and, in making a few remarks would refer, first of all, to the Dalmarnock works, then to the proposed new works at Dalmuir, and then, very briefly, to Mr McDonald's criticism of bacteriological methods of sewage purification. He had visited the Dalmarnock works not long after they were put in operation, and was delighted with what he saw. In Lanarkshire the County Council had been trying to administer the Rivers Pollution Prevention Acts, and in dealing with offenders they were often met with the question, "Well, what are we to do?" Now, the extensive works at Dalmarnock were very helpful in answering such a question, as he was able to point to the results the City Authorities had attained, and to say, "Go there and see what we wish you could do." Subsequent to this visit, he was surprised to learn from the daily press that an eminent Glasgow analyst (Dr. Clark) had made a chemical examination of the Dalmarnock effluent, and found that it was not so pure as the Clyde above those works. That comparison did not prove that the Dalmarnock works were not a success, but the results seemed to him disappointing, because the Clyde still received a great deal of pollution above Glasgow—a pollution which was being diminished year by year, and which he hoped would ultimately be dealt with so that the purity of the Clyde might be preserved, as far as possible, in its course towards the city. Statements, however, had since been made which created not a little disappointment, and which led one to believe that the Dalmarnock works were not in every way satisfactory. These statements were made quite recently in connection with proceedings taken against a Burgh Authority in Court for polluting streams affecting the Clyde. During these proceedings two city experts gave evidence as witnesses for the defence. One of these was the analyst for the Dalmarnock works who, in the course of his sworn evidence, advised that this particular burgh should really do nothing, although it had adopted no proper means of purifying the sewage; and this advice seemed to be based upon his experience at the Dalmarnock works, as he said—"In Glasgow, after you have spent your money, you do not get the results." It might be said that such a statement was made by a chemist incompetent to judge of the value of the results; but the other expert was an eminent city engineer, who gave similar advice, and seemed to indicate that the results obtained in sewage purification works were not really worth the money that would have to be expended. Now, Mr McDonald had told them as plainly as possible that the Dalmarnock works were an "unquestionable success." There was no doubt in his mind on the matter, and for such a statement, coming from such a reliable source, he was very much indebted to Mr McDonald. Although the particular method of purification carried out at Dalmarnock might not be suitable for every other district, it was very satisfactory to know that the works there were considered a success by such a responsible official. If they were asked, in the words of the statute, "What were 'the best practicable and available means' to render sewage harmless?" they could point to those works as an instance where evidently such means had been adopted. He would like, however, to point out that while the authorities in London and Manchester had published, from time to time, valuable reports giving the actual results of the purification obtained, he had not seen any similar results in published reports regarding the Dalmarnock works. The statement made by Mr McDonald might suffice, but in view of the statements made by other authorities he would be glad if Mr McDonald would, in his reply, give the chemical results of analyses made at those works. Besides the chemical results, there were other tests which might be applied for determining the amount of purification obtained—thus, in the reports of the London experiments it would be found that the effect of the effluent upon fish life had been tried. If not only common fish but trout or salmon were put into the effluent and found to survive, the results would be extremely satisfactory. Mr McDonald said something to the effect that fish would live in

Dr John T. Wilson.

the Dalmarnock effluent. But had the experiment actually been made? And what kind of fish had been used? Still another test had been applied to sewage effluents at Manchester to find whether the effluent could be kept without becoming offensive—what might be termed the keeping power of the effluent. When there was a large flow of water in the Clyde, and during winter, it did not become offensive, but when the summer came round the odour in Glasgow was easily distinguished. If, therefore, sewage effluent were kept at a warm temperature it could be determined whether, when discharged, the effluent was likely to become offensive. They were told that the effluent from sewage, treated by bacteriological methods, kept well without becoming offensive, while that treated chemically did not keep at all. With regard to the proposed works at Dalmuir, he would like to know if it was quite certain that, having regard to the number of storm overflows, there would be no danger of the Clyde being seriously polluted thereby. It was shown that after a prolonged drought, when a heavy rainfall came, there was a large amount of offensive matter carried into or discharged from sewers. With regard to the purfication works themselves, it would seem that means of filtration were not to be provided, and he had only learned that night that filtration had even been abandoned at the Dalmarnock works. As there seemed to be a large amount of ground at Dalmuir available for additional works, perhaps the City Authorities had in view the possibility of constructing filters. If that were so, he thought it might be stated. It was with considerable regret that he recognised the hostile attitude assumed by Mr McDonald in his criticism of the bacteriological method of sewage treatment. As an official concerned in administering the Rivers Pollution Prevention Acts, he had often met with the contention that nothing should be done towards preventing pollution on the ground that nobody seemed to be agreed as to any proper means of purification. Now, reference might be made to Mr McDonald's remarks as another instance where one person said it was a first-rate system, while another said it was no system at all. He hoped, therefore, Dr John T. Wilson.

that gentlemen present—such as Mr Hogg—who had put up installations of these bacteriological works, would, in the course of time, go into the matter fully and give them the benefit of their experience and results.

Mr JAMES B. WYLLIE (Member) said he had taken an interest in this subject for some years back, and had visited Exeter and other places where the bacteriological and chemical systems were in operation, and he thought that what one saw with his eyes was more convincing than whole volumes of theory. At Yeovil he had seen sewage discharged into a covered tank where it was kept quiescent for about twenty-four hours and then passed over filter beds. Notwithstanding that the sewage before it entered the tank was as strong as ever entered any drain, the filtrate which issued from the filters was practically pure and almost colourless, and was discharged into a small stream without occasioning any nuisance. The Commissioners of the City of Exeter were so satisfied with their previous experiment that they were now carrying out works to treat the whole of the sewage of the city, which had upwards of 50,000 inhabitants, on the same system. Differences of opinion with respect to the bacteriological treatment of sewage on the septic tank system might be expected, but he thought the least that Glasgow could do was to give it a fair trial. The works at Manchester and Leeds would prove conclusively whether this system could purify the sewage that was contaminated with various kinds of drainage matter from different manufactories. In Scotland they had the experience of the septic tank system at Barrhead, where the population was 10,000. Other installations were being put down throughout Scotland, and it seemed remarkable that Glasgow appeared to be so exceptionally different from any other town. With regard to the question of the ground required for this system, he thought anyone with the least practical mind at all would understand that when taking a piece of ground for purification works, such as at Dalmuir, a few additional acres was of no vital importance. It was a question of small outlay when the matter was being taken in hand. Mr McDonald had

Mr James B. Wyllie.

made a statement regarding the costs of the bacteriological and chemical systems, and he would like to know whether Mr McDonald could show by any data the actual cost of the treatment per 100 gallons, or per one million gallons, by the bacteriological system compared with the cost of chemical treatment of the same quantity of sewage. He considered that the Dalmarnock works were extremely good as far as chemical operations were concerned, but the outlay must be very great indeed. There, no doubt, the most troublesome part of the proceedings was—dealing with the sludge. The chemical treatment of the sludge had not yielded the revenue that was originally anticipated. The manurial value of the sludge was lessened by chemical treatment, and an endeavour had been made to restore the value, but with what success he did not know. It was most important to know the cost of the Dalmarnock works. He hoped that Mr McDonald would complete his paper and state the figures with regard to the cost of this great scheme.

Dr JAMES ERSKINE (Member of Glasgow Town Council) said he was sorry that Mr McDonald was not present, because he would like to have heard him reply to some of the questions that had been put by the previous speakers. He had expected that this discussion would turn upon the question of the bacteriological treatment of sewage; but he would not expect Mr McDonald to profess to be an authority on that question—it was rather outwith his province. As they all knew, he was an authority on a good many departments of science; but he did not think Mr McDonald meant to deal exhaustively with this question; and, that being so, he regretted the attitude that had been taken up with regard to this system. Regret had also been expressed by other speakers, and he thought that Mr McDonald should keep an open mind on the subject. He (Dr Erskine) had not been very long on the Sewage Committee, but he had noticed a great difference of opinion on the part of the members of that committee with regard to the bacteriological treatment.

Dr James Erskine.

What had made the Sewage Committee direct their minds to the bacteriological system was the recent publication of the report of the bacteriologist and the chemist of the London County Council. A deputation went to London, Manchester, and elsewhere, and gave a very favourable report in reference to bacteriological treatment, and the fact that a tank and filter beds had been put down at Dalmarnock showed that opinion had not been unanimous in considering chemical precipitation the best way of dealing with the sewage of the city. It had been said that the acid contents of Glasgow sewage would interfere and prevent the action of bacteria. He did not admit that that had been proved; but as a large amount of the sewage that had to be dealt with was of an organic character, he would say that that could be dealt with very successfully by the bacteriological method. The sewage going into Dalmarnock had been altered very much recently by the addition of a lot of material from breweries, and, that being of an organic character, could be dealt with bacterially. He did not think they had substantial proof that the Dalmarnock works were an unquestionable success by converting the sludge into fertilising material, and he did not think it would ever pay. The great question was how to get rid of the sludge; and the bacterial method, in his opinion, was the only way to get rid of it altogether. As one speaker said, they had never had scientific reports with reference to the effluent from the Dalmarnock works; but they had now two officers appointed by the Corporation—a chemist and a bacteriologist—and they had had reports from Mr Tatlock regularly. The chemist and the bacteriologist would be able to give their time specially to that department, and he knew the bacteriologist was at present making examinations as to the bacteriological character of the sewage. Very recently Leeds had bought an enormous extent of ground with the view to carrying out this system, and Glasgow was, to some extent, comparable with Leeds. The Corporation of Glasgow was really keeping an open mind on the subject, and had not yet concluded what was the best method, and whether to adopt chemical precipitation or

Dr James Erskine.

use it along with the bacteriological method. It would perhaps be found that the bacteriological system would be adequate, but until sufficient evidence was forthcoming from other cities, which were carrying out experiments on a very large scale, no definite conclusion could be arrived at.

Mr Gilbert Thomson, M.A. (Visitor) observed that Mr McDonald's paper was practically of two parts, one describing what had been and what would be done, and the other concerning the best method of sewage disposal. Mr McDonald had said, with regard to sewage disposal, that the question was a debatable one. Not only in the sanitary press, but in private correspondence, had he seen it vigorously discussed. For example, he had a letter from an engineering friend in which it was hinted that Mr McDonald's attitude with regard to the bacteriological system resembled that of abusing the plaintiff's attorney. He had read much the same thing in some of the technical journals. Mr McDonald had spoken about the older sanguine anticipations regarding bacterial treatment, and he thought he was justified in holding that the anticipations which had been indulged in had not yet been entirely realised; but whether they would be or not he could not tell. Mr McDonald's definition of crude sewage was one which he would scarcely be disposed to accept, and he did not think it was a fair ground of attack on the bacteriological system that it could not deal with railway sleepers and dead cats. No system had been devised for dealing with these, or with tin cans and spoons—they had to be taken out, but the sewage might still fairly be called crude. Filtration was a word which was, perhaps, an undesirable one to use in this connection, because the old notion of filtration and the current one were very different, and the use of the term led to a good deal of ambiguity. The so-called filtration in bacteria beds was a totally different thing from the old idea, which was more or less of the nature of straining. The point, as the author said, was in the question which he had asked and answered in the negative. There were really two questions, and while Mr McDonald had answered them collectively he (Mr

Mr Gilbert Thomson.

Thomson) was strongly inclined to separate them, and to answer the one—"Does the principle of bacteriological treatment of sewage possess an economic aspect?"—in the affirmative. In the second one—"Does it compete with chemical precipitation in actual practice on the great scale on which it has never yet been tried?" he quite agreed with Mr McDonald's negative answer; but if the word "will" were substituted for "does," he was not prepared to give any answer at all. Knowledge in connection with the problem was advancing by leaps and bounds, and results were being accumulated day by day. They wanted to know what the bacteriological process would do before they said yea or nay, or whether it was to be an unqualified success. Certainly it had the prospect of being a success. There was a good deal of interest and instruction in the experiments of Mr Tatlock, already referred to. Before the Corporation adopted its present precipitant it made a very large number of experiments on different substances. Some which had done good service in other places were reported on by Mr Tatlock as being unserviceable for the conditions which here obtained. In the same way, the general principle might not always be equally serviceable. An open mind had been advised, and, he thought, very rightly advised. He called to mind three different systems which he had seen giving excellent results, but regarding each of which he had heard, in one way or another, less satisfactory reports. In one place the authorities had decided to abandon the system. He was not prepared to accept Mr Wyllie's view that, going to a purification work and seeing the clear effluent, was a proof that a system was a good one. It might be a good one, but he did not think it was proved in that way. It had been an object lesson to every engineer that the process of treating sewage by lime gave an apparently excellent effluent, but this effluent was destructive to fish life, and had none of the "keeping" powers which had been described that evening. A greater amount of information was wanted than could be obtained from casual observation. In that connection it seemed to him that a good many local authorities began at the wrong end when, after

Mr Gilbert Thomson.

visiting a number of places, they came to a conclusion that such and such a process was the best, and therefore they resolved to adopt it. It might or might not be a satisfactory process for that particular place. The want of unanimity which had been referred to was an inseparable accompaniment of the present state of knowledge. There was unanimity in believing that many systems, or some systems, could give good results, but there was a want of agreement as to which was the best, and his own opinion was that there was no best system, but that each particular place had a particular system for which it was best suited. Mr Wyllie remarked that he had at one time anticipated that the rates would fall and reach a vanishing point from the selling of sludge; he (Mr Thomson) was surprised at that statement. Mr McDonald's paper showed that in 1858 the fallacy of that idea was pointed out, or Mr Wyllie was more sanguine than he himself would be inclined to be. Reduction of expenditure by getting a certain return from the sludge was another matter, but he did not think that anyone seriously believed that sewage treatment could be a source of profit.

Correspondence.

Mr Robert T. Napier (Member)—While the general plan—Plate XII.—showed extensive provision for intercepting the drainage flowing to the White Cart, none was shown for intercepting the presumably greater quantity flowing from the municipal area to the Kelvin. As the question of dealing with the latter was quite apart from that of purifying the Kelvin at its upper waters, he would be pleased to hear from Mr McDonald if any decision had been come to regarding it. He also would like to know, in respect to the waters of the Molendinar and other natural streams flowing through the city, if it was intended that these should simply be sent down the outfall sewer, or if the necessity of dealing with this quantity of water was to be avoided by diverting the sources of the streams. It was obvious to everyone

Mr Robert T. Napier.

who paid attention to the river, that the volume of water, in time of drought, that passed the arches of Dalmarnock Bridge, was no great multiple of the volume that entered via the sewers, and by the diversion of the latter to Dalmuir, the present slow flow of water seawards would be certainly made slower. This brought up the question of the pollution of the river by ships' sewage, which was as "raw" and objectionable as sewage could well be. He had no information as to the floating population, but it must be considerable, and for it to defile the river, while the citizens taxed themselves to keep it pure, was out of the question. Provision, by tank or otherwise, would be required to receive such sewage, and he urged that shipowners and shipbuilders should have notice that this would be a condition enforced after a certain date.

The PRESIDENT said they must thank Mr McDonald very heartily for presenting this paper to them. It had led to a very interesting discussion, and notwithstanding the fact that there was so much diversity of opinion as to the most economical means of disposing of the sewage of Glasgow, he trusted that before many years were over the Clyde might be once more a pellucid river. He begged to propose a hearty vote of thanks to Mr McDonald.

The vote of thanks was carried by acclamation.

Mr A. B. McDONALD regretted that his attendance in London on official duty, prevented him joining the meeting of the Institution of Engineers and Shipbuilders when the postponed discussion took place on 15th May, and he desired to offer his grateful thanks to those gentlemen who had expressed themselves in such courteous terms on the subject matter which he had the privilege of laying before the Institution on the 24th of April. It was a valuable addition to the recognition then conferred on him to find that his paper had evoked so much exhaustive and incisive criticism. The major part of the criticism bestowed upon the paper was directed to the concluding observations on the bacterio-

Mr McDonald.

logical treatment of sewage, but it would be convenient, in replying to the different remarks, to follow the order taken in reading the paper itself. It would be noticed that Mr Hogg referred to omissions in the historical sketch, which formed the introductory part of the paper; and the author quite agreed that the narrative could have been amplified with advantage had there been time available for such a purpose. He was not, however, able to agree with Mr Hogg's claim that the late Mr G. W. Muir was the first to suggest a sub-division of sewage stations, nor would it serve any useful purpose to enter upon the details of his scheme, which involved the construction of no fewer than eight different sewage works in various parts of the city and the suburbs. Greater interest attached to an earlier proposal of another amateur engineer, the late Mr T. L. Paterson, of Dowanhill, who, nearly ten years before Mr Muir's scheme was laid before the public, addressed to the Lord Provost and Magistrates of Glasgow a communication giving the outlines of a method of sewage disposal, which might fitly be described as heroic in its proportions. Like Mr Muir, he was entirely free from all appreciation of the details that usually embarrass the engineer in practice. The separated drainage of the north and south banks of the river was to be conveyed westward to Dunglass Castle, on the north bank, and to Bishopton, on the south bank, and there delivered into vast basins, those on the north side having a capacity of 2,000,000,000 gallons, and those on the south side 1,500,000,000 gallons. In these enormous reservoirs the sewage was to be diluted with sea water and discharged upon the ebb tide, when Mr Paterson believed it would be carried down the Firth beyond Gourock. The basins of the north bank were about 2 miles in length, and those on the south 1½ miles. Mr Hogg was not altogether correct in his exposition of the opinions of the late Mr Bateman, who was not influenced in the selection of the Shields site by the consideration that it might be necessary some day to carry the effluent to a greater distance; the plain fact being, that Shields was adopted by Mr Bateman as a site for

Mr McDonald.

sewage works on the suggestion of the late Mr Carrick. The formula employed in estimating the velocity of flow referred to in the paper, was that introduced by Messrs W. Santo Crimp and C. Ernest Bruges—

$$v = 124 \sqrt[3]{r^2} \sqrt{s}$$

which gave results that approximated closely to those obtained by the very cumbrous formula of Kutter—

$$v = \left\{ \frac{41{\cdot}6 + \frac{1{\cdot}811}{n} + \frac{{\cdot}00281}{s}}{1 + \left(41{\cdot}6 + \frac{{\cdot}00281}{s}\right) \frac{n}{\sqrt{r}}} \right\} \sqrt{rs}$$

Messrs Crimp and Bruges' formula was described at length in the proceedings of the Institution of Civil Engineers, Vol. CXXII. p. 198. Mr Napier's question regarding the interception of the pollution of the Kelvin was best answered by stating that arrangements were already far advanced for intercepting the whole drainage that entered the Kelvin within the city boundaries, and that the volume thus intercepted would, along with the waters of the Molendinar Burn, Camlachie Burn, St. Enoch Burn, Pinkston Burn, and other streams presently discharged into the harbour, be conveyed in the outfall sewer to Dalmnir. The important matter to which he referred, of the pollution of the river by ships' sewage, would undoubtedly require careful attention, and would probably be best grappled with by the constitution of a conservancy authority. Great interest very properly attached to the observations of Dr John T. Wilson, Medical Officer of Health for the County of Lanark. His remarks as to the contentious aspect of the chemical work done at Dalmarnock did not come within the province of the author of the paper, but the success with which sewage was treated there could scarcely be questioned when it was stated that the whole suspended matters were removed, and 70 per cent. of the dissolved impurities eliminated by the single operation of chemical precipitation. The tank

Mr McDonald.

effluent could be still further improved, if necessary, by passing it through sand filters, when the purification effected would be raised to 90 per cent. There did not appear to be on record any instance of another work, of dimensions at all comparative, where such results were obtained. The reference to fish life being sustained in the sewage effluent related to gold fish, which were kept in the office of the manager for many months. The results of the working at Dalmarnock were not published for sale in the same manner as the reports of the London County Council were placed before the public, but all that was done at the Dalmarnock works was duly recorded in the minutes of the Town Council, which could be seen by any one in the Mitchell Library. Dr Wilson's remarks as to the keeping value of the effluent were rather difficult to answer, but it did not seem likely that the down-stream flow of the river would be deteriorated by the Dalmarnock effluent, as there was on exhibition at the manager's office, at the present time, a well-sized sea trout that stranded itself in a pool left by the ebb tide, a short distance above the sewage works. The proportion of the chemical ingredients in use at Dalmarnock works varied rather widely with the character of the sewage discharged. Mr Hogg accurately described these purifying agents as lime and sulphate of alumina, but the character of the sewage passing through the works varied to such a degree that the proportion of lime required ascended from 4½ grains per gallon to 22 grains, and the quantity of alumina varied from nil to about 7 grains per gallon. The cost of dealing with a flow of sewage so untractable as that was bound also to vary considerably, and it accordingly appeared that the cost for lime varied from 4s 9d to 23s 10d per million gallons, while the cost for alumina ranged from 6s 8d to 11s 9d per million gallons, the average for the 15th day of May being 12s 6d for lime and 4s 5d for sulphate of alumina. The average cost of chemicals per million gallons, in the working year 1897-98, was 19s 5d, which was reduced in 1898-99 to 13s 9d; notwithstanding the fact that the operations at Dalmarnock had been

Mr McDonald.

much embarrassed by the uncontrolled discharge of a very intractable chemical effluent from the works of the Tharsis Sulphur and Copper Co. If the system of chemical precipitation was adopted at Dalmuir, better results would be obtained at a much less cost, as the precipitation tanks—750 feet in length—would enable the process to be carried out quite effectually with a smaller charge for precipitating agents. In making his reply to the criticism addressed to that part of his paper dealing with the subject of bacteriological treatment, he ventured to point out that the gentlemen who had favoured him with their remarks were in error when they supposed that his attitude to the bacteriological treatment of sewage was hostile, and that he did not preserve an open mind on the question. He submitted that a reperusal of his paper would make it clear that his sole object was to display the uncertainty that pervaded the theory, and the contrariety of the assertions made regarding it. The most diligent study of the voluminous literature of the subject did not reconcile these divergences, nor would any result yet obtained on a comparative scale sustain the claims of the prominent advocates of the doctrine. Reference was given to specific instances in which obscure and misleading statements tended to mystify the mind of the lay reader, and which could not with propriety be ignored in the presentation of a complex problem, the solution of which was not yet arrived at, and which indeed hardly appeared to be understood. These statements were deliberately set forth, in the assured conviction that they would evoke severe ccmment and in the hope that they might bring out some explanation that would tend to clear up the difficulty which they presented. The comment had indeed been evoked, but, unhappily, no one had yet said anything that tended to remove the difficulty that associated itself with hysterical and contradictory utterances on a subject which, beyond all others, ought to be expressed with the utmost precision of language and moderation of statement. The author of the paper respectfully suggested that he had said nothing that indicated an attitude of hostility towards the use

Mr McDonald.

of bacteriological methods. On the contrary, he had to express great regret that imperfect information and intemperate language continued to be employed which could not fail to arouse increased distrust in the minds of all who were responsible for the expenditure of public money. This was illustrated in the following extract from the *Public Health Engineer* of July 7th:—" A writer in the *Daily Express*, on the 'Sewage Problems,' says, 'There is no doubt that the problem how to remove sewage most satisfactorily and most effectively from the abodes of men constitutes one of the most important topics with which hygiene has to deal. I am safe in saying that in the past no one method of treating sewage has been wholly satisfactory when regarded from the collective standpoint of expense, effectiveness, and ease of application. It has been reserved for the bacterial treatment of sewage to bring into vogue a natural and efficient process whereby the waste of towns and cities may be practically annihilated at a cost relatively trifling when compared with the expense involved in carrying out other methods of sewage disposal.' But where is the proof that the bacterial process involves a relatively trifling expense? Further, it may be asked, how is bacterial treatment at the outfall going to affect 'the satisfactory and effective removal of sewage from the abodes of men?' rightly described as 'one of the most important topics with which hygiene has to deal' (we think, in connection with the disposal of sewage, the most important); but bacterial treatment at the outfall has obviously very little to do with its solution." Without desiring to repeat anything already said, it had to be pointed out (Mr McDonald continued) that the process of treating sewage bacterially was a threefold operation, consisting of separation, sedimentation, and filtration. What extent of tank accommodation was necessary for the sedimentation of large volumes of sewage and rainfall there was nothing in actual experience to enable an opinion to be formed, while the extent of surface required for filtration ranged, in the opinion of various authorities, from 50,000,000 gallons per acre to 1,000,000 for eight acres; for, with all deference to Mr

Hogg, Mr Dibdin must be allowed to speak for himself. A problem enshrouded in such vagueness did not give much promise of speedy settlement, and, unhappily, the preservation of an open mind would not hasten the result. As he (Mr McDonald) had said elsewhere, "With unlimited filter space and unlimited time at command, every form of impurity can be extinguished and the last trace of sludge effaced, but space and time are alike limited in daily practice. What the future contains no man knows, but it would be unwise to depreciate the possibilities and advantages that depend on the progress of chemical science, and it may be that some of us may witness the realisation of that which now appears visionary. But while the future teems with gracious promise, the requirements of the present are urgent and immediate and do not permit us to await the fulfilment of these predictions." The caution with which experienced professional men, responsible for the conduct of public affairs, regarded the subject, was exemplified in the reply which Professor Clowes made to a question, addressed to him by the author, regarding the experiments conducted by him on behalf of the London County Council at Crossness. It was always an ill thing to tell tales out of school, but it did not involve any betrayal of state secrets to quote from a published report, which might interest the readers of this paper. "Dr Clowes was kind enough to inform the Sub-Committee, quite unreservedly, that he did not indulge the anticipation of getting rid of sewage sludge in the event of the experimental methods which he had conducted being applied on a large scale to the treatment of London sewage; and he also said that the fleet of sludge vessels would in all likelihood require to be maintained. He further stated that, in order to obtain from the filters described in the report an effluent that would satisfy the London County Council, a certain degree of chemical treatment would almost certainly be necessary before the sewage was discharged on to the filter beds, as the mechanical sedimentation to which the screened sewage is subjected at present does not arrest wood fibres and other minute kindred matters which

Mr McDonald.

are carried in the sewers and at present tend to choke the filters." In concluding, Mr McDonald said the Corporation of Glasgow was at the present time constructing an experimental plant at the Dalmarnock Sewage Works, for the investigation of some aspects of bacteriological treatment of sewage. The work was being carried out in the most implicit conformity with the directions of Mr Harris, the Corporation chemist, himself an accomplished bacteriologist, and it was to be hoped that the results obtained there would throw some light upon that most difficult and obscure subject, which, notwithstanding all that had been said, was unquestionably fraught with the very highest interest and importance to the common weal.

THE "JAMES WATT" ANNIVERSARY DINNER.

The Annual "James Watt" Dinner was held on Saturday evening, 20th January, 1900, in the Windsor Hotel, St. Vincent Street, Glasgow. The reception by the President of the Institution took place at six o'clock, and half an hour later 270 gentlemen sat down to dinner.

Mr Robert Caird, President, occupied the chair, and his supporters were — The Honourable Lord Provost Chisholm; Captain R. P. Humpage, R.N., H.M.S. "Benbow;" Captain Usui, Imperial Japanese Navy; Mr W. R. Copland, chairman of Governors of the Glasgow and West of Scotland Technical College; Mr Samuel M. Taylor, United States Consul; Bailie James M. Thomson; John Inglis, LL.D., Messrs A. & J. Inglis & Co., Partick; Provost Black, Greenock; Mr Matthew Holmes, North British Railway; Mr James Mollison, Lloyd's Register; Provost Anderson Rodger, Port-Glasgow; Mr John Galloway, president, Chamber of Commerce; Dr Freeland Fergus, secretary, Glasgow Philosophical Society; Mr Robert Watson, president, Graduates' Section, Institution of Engineers and Shipbuilders in Scotland; Mr G. T. Beilby, F.I.C., president, Chemical Society; Sir David Richmond; Sir William Arrol, LL.D., M.P.; Mr Andrew Stewart, Messrs A. & J. Stewart & Menzies; Prof. A. Gray, LL.D., F.R.S., Glasgow University; Mr George Beard, president, West of Scotland Iron and Steel Institute; Prof. A. Barr, D.Sc., Glasgow University; Fleet-Engineer J. S. Rees, R.N., H.M.S. "Benbow;" Mr James Weir, Messrs J. & G. Weir; Mr James E. Christie, president, Glasgow Art Club; Mr Thomas Kennedy, Glenfield Company, Kilmarnock; Provost James Kirkwood, Govan; Mr G. M'L. Blair, Messrs P. & W. M'Lellan; Mr H. A. Hedley, manager, Glasgow Exhibition; Mr T. B. Seath, Messrs T. B. Seath & Co.

The croupiers were Prof. W. H. Watkinson, Wh.Sc., Vice-President, and Mr William Foulis, Member of Council.

The dinner having been done ample justice to,

The CHAIRMAN rose and said he had the honour to propose the toast of "The Queen." Under ordinary circumstances, this toast could not be better proposed than by simply naming it. Her Majesty's name, unaccompanied by any formal expression of sentiment, was always certain to elicit a unanimous and heart-stirring outburst of loyalty. He felt, however, that to-night it was only fitting that they should express, however briefly, their deep sympathy with their beloved Sovereign in the anxieties with which the situation in South Africa had harassed her declining years, and their heartfelt appreciation of the interest Her Majesty had shown in the well-being, not only of her troops in the field, but also of those dear to them whom they had left behind. They congratulated Her Majesty on the magnificent bravery exhibited by her soldiers who were fighting in her cause. They congratulated her, too, on the loyalty so effectively displayed by all her colonies, the action of whose sons in spontaneously rallying in arms around her throne was the best possible counterblast to the black-hearted treason which had brought about and was animating the present war. It would be a source of great pride and satisfaction to the Queen that the whole country, sinking all differences, had come into line, fired by a single sentiment, to see this war through at all hazards, at all sacrifices, to a triumphant termination. However as a nation they might have incurred the jealousy and hatred of their Continental neighbours, those sinister sentiments were not extended to the person of Her Majesty. She was universally held in the highest reverence. Why, even in Charles Boissevain's open letter to the Duke of Devonshire, a brilliant and exhaustive, if somewhat hysterical, eulogy of the Boers and vituperation of ourselves—even in that letter he spoke of the Dutch people "who have such a veneration for your Queen that they hope and pray their young Queen may take her for example." A shadow may apparently be cast upon this picture by the foul aspersions of the reptile and venal press of France. But he could not for a moment look upon those as representing the true sentiments of a great, a noble, and a gallant nation. Rather were they to be considered as expressing the attitude of that section of the French people — unhappily for France, a numerous and a turbulent one — by whom those grand moral qualities which in Her Majesty had won from her own subjects an unwavering devotion, and from the world at large had wrung a deep respect, were not held in any esteem. God grant that the evening of her long and beneficent reign might bring, after crowning victory, a lasting peace, and, with peace, goodwill.

The toast was pledged with much enthusiasm, the band playing and the company singing "God Save the Queen."

Professor A. Barr, D.Sc., gave "The Navy, Army, and Reserve Forces." He said it was not known to them, as it was to the chairman and himself, that his name had been substituted for that of Prof. Oliver Lodge, to whom, if he had been present, the toast would have been assigned. They had very few toasts that evening, and he thought the chairman, in reserving to himself that of the "Guests," had the idea that it was the toast of the evening. That might be so, but he held that the toast he (Prof. Barr) had now to propose was "the toast of the day." Standing as they did just on this side of the threshold of the twentieth century (Oh! Oh! and laughter). He protested against that unseemly interruption (Renewed laughter). He had not said on which side of the threshold they stood. Standing then on one side of the threshold of a new century, it appeared to him that the time was appropriate for taking into review the position of our naval and military forces, and making some forecast as to what those services might be to the Empire in the centuries to come. And he thought he might flatter himself on possessing in an eminent degree the essential qualifications for undertaking such a task— he believed he could claim that ignorance of the subject which was the most essential equipment of the present-day critic. He was inclined, however, to leave those who had the direction of

Prof. A. Barr.

Her Majesty's forces to conduct the naval and military affairs of the nation. There had been no reduction in their confidence that the Navy was able to maintain a free way for them across the waters. In the course of recent events they must also have been struck with the extraordinary strength exhibited by some sections of the Navy as a fighting force on land. And when they turned from the Navy to the Army, he thought the present conditions under which the Army fought in South Africa were almost equally unique. The Army had for many years hardly ever had rest from active service. It was indeed a remarkable fact that, in all the great armies on the Continent, there was, comparatively speaking, scarcely a man who had seen active service, while in our little Army there was hardly a soldier who had been any time in the service who had not faced the foe in some part of the world. In South Africa our soldiers were fighting an enemy that had invaded British territory, and yet who had thrown up defences behind which he was sheltering himself as if defending the fortresses of his own country. The conditions were very novel, and the wonder was not that we had had losses, but rather that these had not been greater. He coupled the toast with the names of Captain Humpage and Col. Archibald Denny.

Captain R. P. HUMPAGE, R.N., in responding for the Navy, said that there had recently been issued an official return about the naval strength of the Powers, in which it was stated that in October, 1898, the battleships of Great Britain numbered 53, while the other Powers combined had 84. In October, 1899, Great Britain had 17 building, and the other Powers 42, so that when these vessels were all completed Great Britain would have 70, and the other Powers 126. He need hardly say that the position of Great Britain with 53 battleships against other Powers combined with 84, was hardly so satisfactory as it would be when Great Britain possessed 70 and the other Powers 126. It was not a time to look behind. It was a truism to say that our nation depended on its food supply. It was a matter of life and death, and he trusted there would be no looking back. It was gratifying to know that of the 42 battleships which were being built 11 belonged to the United States Navy, from some of whose officers so much had been learned. In the present war our Navy, of course, had had no chance, because the Boers unfortunately had no ships. Everyone, however, must heartily admire the heroism displayed by the officers and men of the British Army. They in the Navy were very proud indeed of what the few who had been able to be landed in South Africa had been able to do.

Colonel Archibald Denny, for the Army and Reserve Forces, replying—said it was not usual for a Volunteer officer to be asked to reply for the Army; but recently the distinction between the Army and the Volunteers had been pretty much broken down, and he thought the time might come when the difference might disappear altogether. With reference to the war in South Africa some of the daily papers, the London papers—for to their credit the Glasgow papers had kept their heads—had been crying out hysterically, finding fault with everything and everybody. Here in Scotland victory and check had been taken with equal meekness. He mentioned the different engagements in which our generals in South Africa had been successful, the enumeration being received with applause, and added that he considered the way some of the London papers had written about our officers was contemptible. But while he denied that there had been defeats, there had been checks, and he thought these would do a great deal of good, because successes in the past had perhaps made Britons just a little too conceited. This was the first time for many years that this country had had to fight against a comparatively white race. The result of the war might be that the system of army recruiting would be somewhat changed, but he would be loth to believe that the compulsory system would be adopted. It might be necessary, but he would deplore it. After all, it was only a comparatively small number of our citizens who could go forward to the front to fight the battles of the nation.

The Chairman said before proceeding to propose the next

The Chairman.

toast, he would call attention to a somewhat drastic departure from the customary programme. It had certainly not escaped observation that the toast list had been greatly curtailed. Some would doubtless hail the curtailment with joy; others might possibly resent the revolution. When the suggestion was made to him, he must confess, it had his hearty concurrence, and he should not be frank unless he avowed that the omission of a very important toast, which would almost inevitably have fallen to his lot, and which was generally considered the toast of the evening —"The Immortal Memory of James Watt"—the omission of that toast, acting upon a spirit of shrinking modesty not unassociated with indolence, was a determining factor in his decision. He would have them remember that the President held office for his sins during two years, so that there would be an opportunity next year of reverting to time-honoured custom. It occurred to him that it was usual, in arranging a toast list, to give prominence to certain leading institutions, such as the Houses of Parliament, the University, the Municipality, Kindred societies, etc., etc.; and gentlemen representing these institutions attended as guests, and responded. Finally, lest anyone should be forgotten, the guests were toasted as almost a negligible residuum. To-night, however, seeing that these divisions had been suppressed, the toast which he had the honour to propose fell to be treated as a magnificent generalisation. They were proud to see present, leading spirits of many of their greatest institutions and learned societies, and they bade them a hearty welcome. He took it that just as a particular society was a collection of individuals for the promotion of special aims and pursuits, so there was a wider grouping in which these societies became the individuals, and which worked toward general progress and the advancement of science. Occasions such as this furnished opportunities of bringing these corporate units together, and he flattered himself that they were likely to be agreeably cemented into at least a mutually tolerant body by the means provided—community of creature comforts, the strains of soul-inspiring music, and "my Lady Nicotine." The great increase in the membership of the Institution of recent years had naturally added to its social responsibilities, and he thought it likely that next year the banquet would have to be held in some large hall. He felt that some apology was due to those guests and members who had been unavoidably relegated by the exigencies of restricted area to "another place," an outer chamber. The Lord Provost had done them the honour of consenting to reply for the guests. This was, he believed, the first time he had sat at their board, and he gladly seized this opportunity of congratulating him, in the name of the Institution, on his accession to the proud position of head of this great municipality. He felt, too, that he could most sincerely, and apart from the mere spirit of compliment, congratulate the city of Glasgow on its choice of a Lord Provost for a term which very specially required, in its official representative, qualities which His Lordship had shown in his public utterances and in his public appearances he so pre-eminently possessed.

Lord Provost CHISHOLM, in reply, said he wanted first of all to thank the company for the honour they had done him in inviting him to be present, and for the still higher distinction with which they had honoured him, in coupling his name with a toast the subject of which embraced so many gentlemen of mark and eminence in their respective professions. Few walks of industry were strewn with such magnificent results as the paths which they trod. The roads of the old Romans along which that ancient people conveyed the lessons of their civilisation into far barbarian lands were over hills, along valleys and the banks of rivers, and across plains. The engineers and shipbuilders of Scotland had not been content to merely follow in their wake. They had made a way, where the Romans were afraid to tread, over the deep. Not only had they done so, but they had created highways, both by land and sea, for that enormous modern commerce, which, in addition to bringing wealth had brought peace, prosperity, comfort,

Lord Provost Chisholm.

and happiness to all those who had engaged in it, and to all the inhabitants of the various lands. If the guests would permit him for a moment to drop the representative character in which he spoke in their name, and to adopt the representative one which his office as Lord Provost warranted him in taking, and speaking for the city of Glasgow, he desired to say that the Corporation esteemed and appreciated very highly indeed the services which members of the Institution had rendered to it, the additions they had made to its enterprises, and the development they had given to its greatness. The Clyde would never have been deepened, widened, and straightened, had it not been that the shipbuilders made that a necessity, if they were to retain the position they desired to have in the commerce of the world.

MINUTES OF PROCEEDINGS.

FORTY-THIRD SESSION.

THE FIRST GENERAL MEETING was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 24th October, 1899, at 8 P.M.

Mr **GEORGE RUSSELL** introduced Mr **ROBERT CAIRD**, F.R.S.E., the New President, to the meeting.

The Minutes of the Annual General Meeting, held on 25th April, 1899, were read, confirmed, and signed by the President.

The Annual Report of the Council and Treasurer's Statement were submitted. Mr **JAMES GILCHRIST**, Vice-President, proposed the adoption of the Report and Treasurer's Statement, and Mr Matthew Paul seconded the resolution, which was unanimously agreed to.

The Premiums awarded at the Annual General Meeting of April 25th, 1899, were presented, viz.:—A Premium of Books to Mr T. R. **MURRAY** for his paper on "The Theory and Practice of Mechanical Refrigeration;" to Prof. E. J. **MILLS**, D.Sc., F.R.S., for his paper on "Photo-Surveying;" to Mr F. J. **ROWAN**, for his paper on "Water-Tube Boilers;" to Mr G. **GRETCHIN**, for his paper on "Notes on the Belleville Boilers of the T.S.S. 'Kherson.'"

The President delivered his Inaugural Address.

On the motion of Prof. **ARCHIBALD BARR**, D.Sc., seconded by Mr **ARCHIBALD DENNY**, the President was awarded a vote of thanks for his Address.

Thereafter a paper by Dr J. A. **PURVES**, F.R.S.E., on "Lighthouse Engineering at Home and Abroad," was read.

The President announced that the following candidates had been elected, viz.:—

AS MEMBERS.

BOYD, WILLIAM, Works Manager, The Tharsis Sulphur and Copper Co., Ltd., Hebburn-on-Tyne.

BUTTERS, MICHAEL W., Contractor's Engineer, 20 Waterloo Street, Glasgow.

DUNCAN, ROBERT, Chief Inspector of Machinery for the Colony of New Zealand, 7 Queen's Chambers,, Wellington, New Zealand.

GEMMELL, THOMAS, Electrical Engineer, St. Enoch Station, Glasgow.

GOVAN, ALEXANDER, Manager, Hozier Engineering Co , 346 Great Eastern Road, Glasgow.

JACKSON, DANIEL, Shipyard Manager, Levenford Villa, Dumbarton.

KINGHORN, A. J., Engineer, 59 Robertson Street, Glasgow.

M'CALLUM, H. MALCOLM, Mechanical Engineer, 10 Midlothian Drive, Shawlands, Glasgow.

RAEBURN, CHARLES E., Electrical Engineer, 1 Hillhead Street, Glasgow.

SHEDDEN, WILLIAM, Mechanical Engineer, 3 Andrew's Street, Paisley.

AS MEMBERS FROM ASSOCIATES' SECTION.

ANDREWS, H. W., Engineer, 128 Hope Street, Glasgow.

HOLLIS, H. E., Steel Manufacturer, 40 Union Street, Glasgow.

AS MEMBERS FROM GRADUATES' SECTION.

BARMAN, HENRY, D. D., Mechanical Engineer, 27 University Avenue, Glasgow.

DELMAAR, FREDERICK ANTHONY, Mechanical Engineer, Banda-Neira, Netherlands East Indies.

AS ASSOCIATES.

CLYDE, WALTER P., Secretary, Messrs T. S. M'Innes & Co., Ltd., 42 Clyde Place, Glasgow.

WHIMSTER, THOMAS, Shipowner, 67 West Nile Street, Glasgow.

AS GRADUATES.

BARTY, THOMAS, Engineer, 3 Albany Street, Glasgow.

BRYSON, WILLIAM, Draughtsman, 21 Cartvale Road, Langside, Glasgow.

COWAN, D. G., Draughtsman, 5 Balgray Terrace, Springburn, Glasgow.

CUNNINGHAM, A. R., Apprentice Electrical Engineer, 53 Bothwell Street, Glasgow.

DOBBIE, ROBERT B., Draughtsman, Laurel Bank, Ayr.

GRANT, WILLIAM, Draughtsman, Croft Park, High Blantyre

HUTCHISON, ROBERT, Engineering Draughtsman, 76 Kenmuir Street, Pollokshields, Glasgow.

LOWE, JAMES, Draughtsman, 22 Willowbank Crescent, Glasgow.

MUNDY, H. L., Apprentice Electrical Engineer, 58 Bothwell St., Glasgow.

RIDDLESWORTH, W. H., B.Sc., Naval Architect, 39 Caird Drive, Glasgow.

SHARP, JAMES R., Draughtsman, 227 Berkeley Street, Glasgow.

WALLACE, HUGH, Draughtsman, Bloomfield, Dalmuir.

WILSON, W. RENFREW, B.Sc., Civil Engineer, Thorncliff, Greenock.

THE SECOND GENERAL MEETING was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 21st November, 1899, at 8 P.M.

Mr ROBERT CAIRD, F.R.S.E., President, occupied the chair.

The Minutes of the First General Meeting, held on 24th October, 1899, were read, confirmed, and signed by the President.

The discussion on Dr J. A. PURVES' paper on "Lighthouse Engineering at Home and Abroad" was begun and concluded.

On the motion of the President, Dr Purves was awarded a vote of thanks for his paper.

The following papers were read:—

On "A Record of Experiments on Flow of Water over Bell-mouthed Pipes," by Mr JOHN BARR.

On "The Means Adopted for Moderating the Rolling of Ships," by Mr W. J. LUKE.

The President announced that the following candidates had been elected, viz.:—

AS MEMBERS.

ANDERSON, WILLIAM SMITH, Engineer, Manager, Bogie Wood, Port-Glasgow,

BLAIR, GEORGE, Mechanical Engineer, 16 Albert Road (East), Crosshill, Glasgow.

DOWNIE, A. MARSHALL, Engineer, London Road Iron Works, Glasgow.

GRAY, DAVID, Mechanical and Consulting Engineer, 77 West Nile Street, Glasgow.

MACLEAN, MAGNUS, Professor of Electrical Engineering, Technical College, 38 Bath Street, Glasgow.

MORTON, DUNCAN A., Engineer, Errol Works, Errol.
STEWART, W. MAXWELL, Electrical Engineer, 95 Bath Street, Glasgow.
WEBSTER, THOMAS LAWSON, Chief Draughtsman, 11 Stuart Street, Shawlands, Glasgow.

AS GRADUATES.

AINSLIE, ALEXANDER F., Engineer, 50 St. Vincent Crescent, Glasgow.
ALLAN, FREDERICK WILLIAM, Marine Engineer, 1 Cecil Street, Glasgow.
BACON, HENRY DOUGLAS, Naval Architecture Student, 23 Queen Margaret Drive, Glasgow.
BIANCHI, MANUEL, Naval Architecture Student, 18 Glasgow St., Glasgow.
BUCHANAN, JOSHUA MILLER, Assistant Engineer, 7 Glenton Terrace, Kelvinside, Glasgow.
CUTHBERT, JAMES G., Civil Engineer, 33 Cartvale Road, Langside.
FAIRLEY, JOHN, Student, Park Road, Hamilton.
FIELD, EDWARD PEARSALL, Naval Architecture Student, 29 Queen Margaret Drive, Glasgow.
GOUDIE, ROBERT, Jr., Apprentice Engineer, 14 Alloway Place, Ayr.
HAMILTON, WALTER, Jr., Electrical Engineer, 44 Cleveland Street, Glasgow.
HORN, GEORGE S., Draughtsman, 34 Annette Street, Govanhill, Glasgow.
LORIMER, ALEXANDER SMITH, Apprentice Locomotive Engineer, Kirklinton, Langside, Glasgow.
LORIMER, HENRY DÜBS, Apprentice Locomotive Engineer, Kirklinton, Langside, Glasgow.
MACDONALD, ROBERT C., Draughtsman, 138 Garthland Drive, Glasgow.
MCLEAN, JOHN, Draughtsman, 4 Springfield Terrace, Glasgow, S.S.
MORISON, THOMAS, Apprentice Ship Draughtsman, 41 St. Vincent Crescent, Glasgow.
MUIR, JAMES, Apprentice Locomotive Draughtsman, 9 Garturk Street, Glasgow.
NEILL, HUGH, Jr., Mechanical Engineer, 44 Brisbane Street, Greenock.
SNEDDON, RICHARD M., Draughtsman, 45c Whifflet Street, Coatbridge.

THE THIRD GENERAL MEETING was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 19th December, 1899, at 8 P.M.

Mr ROBERT CAIRD, F.R.S.E., President, occupied the chair.

The Minutes of the Second General Meeting, held on 21st November, 1899, were read, confirmed, and signed by the President.

The discussions on Mr JOHN BARR's paper on "A Record of Experiments on Flow of Water over Bell-mouthed Pipes," and on Mr W. J. LUKE's paper on "The Means Adopted for Moderating the Rolling of Ships," were begun and concluded.

On the motion of the President, the authors were awarded votes of thanks for their papers.

The President announced that the following candidates had been elected, viz.:—

AS MEMBERS.

DAVIE, JAMES, Engineer, 69 Albert Drive, Crosshill, Glasgow.
DUNLOP, THOMAS, Civil Engineer, 22 Derby Crescent, Glasgow.
HARVEY, THOMAS, Shipbuilder, Grangemouth Dockyard Co., Grangemouth.
HUBBARD, ROBERT SOWTER, Shipyard Manager, 3 Downie Place, Crow Road, Partick, Glasgow.
HUTSON, ALEXANDER, Engineer, Westbourne House, Kelvinside, Glasgow.
HUTSON, JAMES, Engineer, Laurel Bank, Crow Road, Partick, Glasgow.
MILLAR, WILLIAM, Shipbuilder, Sunnyside, Grangemouth.

AS MEMBERS FROM GRADUATES' SECTION.

MORT, ARTHUR, Mechanical Engineer, c/o Miss Glen, 8 Hillside Street, Edinburgh.
MYLES, DAVID, Engineer, Northumberland Engine Works, Wallsend-on-Tyne.
WALKER, JOHN, Engineer, 1 Church Road, Ibrox, Glasgow.

AS AN ASSOCIATE.

DONALD, JAMES, Shipowner, 123 Hope Street, Glasgow.

AS GRADUATES.

BONE, QUINTIN, Draughtsman, 5 University Avenue, Hillhead, Glasgow.
DE KEYSER, FELIX, Naval Architecture Student, 18 St. James Street, Hillhead, Glasgow.
DICKIE, JAMES, Naval Architecture Student, c/o Currie, 3 Sandbank Place, Partick.
FAUT, ALEXANDER, Naval Architecture Student, 722 Holland Street, Glasgow.

FINDLATER, JAMES, Engineer, 124 Pollock Street, Glasgow, S.S.

HENRICSON, JOHN A., Naval Architecture Student, 3 Sandbank Place, Partick.

HERSCHEL, A. E. H., Draughtsman, 6 Roxburgh Street, Hillhead, Glasgow.

MACLEOD, ARCHIBALD, Naval Architecture Student, c/o Mrs MacNicol, 1 Princes Street, Pollokshields, Glasgow.

ROBERTSON, DAVID, Jr., B.Sc., Electrician, 46 Queen's Drive, Crosshill, Glasgow.

TAYLOR, ANDREW P., Draughtsman, 47 St. Vincent Crescent, Glasgow.

THE FOURTH GENERAL MEETING was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 23rd January, 1900, at 8 P.M.

Mr ROBERT CAIRD, F.R.S.E., President, occupied the chair.

The Minutes of the Third General Meeting, held on 19th December, 1899, were read, confirmed, and signed by the President.

The following papers were read:—

By Mr F. J. ROWAN on "Pile-Driving Machines"; by Mr W. A. CHAMEN on "The Electric Wiring of Buildings"; and by Prof. ANDREW JAMIESON, F.R.S.E., on "The Action of Electric Tramway Currents upon the Working of Submarine Telegraph Cables and other Circuits."

A paper by Mr WILLIAM O'BRIEN on "A New Balanced Piston-Valve and its Application to Four-Crank Engines," was held as read.

The President announced that the following candidates had been elected, viz.:—

AS MEMBERS.

CAMPBELL, DUNCAN, Engineer, Carntyne Foundry and Engineering Works, Parkhead, Glasgow.

CHALMERS, WALTER, Mechanical Engineer, 3 Barloch Terrace, Milngavie.

COLVILLE, ARCHIBALD, Engineer, 149 Govan Road, Glasgow.

BERGIUS, W. C., Engineer, Queen Street, Glasgow.

BUCHANAN, JOHN H., Consulting Engineer, 5 Oswald Street, Glasgow.

MacKay, Robert, Engineer, 7 Leslie Street, Pollokshields, Glasgow.
Robertson, Thomas, Assistant Professor, Glasgow and West of Scotland Technical College, 13 Broomhill Avenue, Glasgow.
Williams, William, Mechanical Engineer, Grand Hotel, Glasgow.
Woodburn, J. Cowan, Electrical Engineer, 18 Beechwood Drive, Jordanhill, Glasgow.

AS MEMBER FROM ASSOCIATES' SECTION.

Guthrie, Allan, Mechanical Engineer, 17 Whittinghame Drive, Glasgow.

AS ASSOCIATES.

Allan, Henry, Shipowner, 25 Bothwell Street, Glasgow.
Donald, James, Shipowner, 123 Hope Street, Glasgow.
Pairman, Thomas, Shipowner, 54 Gordon Street, Glasgow.
Service, William, Shipowner, 54 Gordon Street, Glasgow.
Taylor, William Gilchrist, Shipowner, 123 Hope Street, Glasgow.

AS GRADUATES.

Cubie, Alexander, Jr., Engineer, 146 Dalmarnock Road, Glasgow.
Lamb, Stuart, Civil Engineer, Engineer's Office, St. Enoch Station, Glasgow.
Piggott, Joseph T., Draughtsman, 94 North Frederick Street, Glasgow.

The Fifth General Meeting was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 20th February, 1900, at 8 P.M.

Prof. W. H. Watkinson, Vice-President, occupied the chair.

The Minutes of the Fourth General Meeting, held on 23rd January, 1900, were read, confirmed, and signed by the Chairman.

The discussions on Mr F. J. Rowan's paper on "Pile-Driving Machines," and on Prof. Andrew Jamieson's paper on "The Action of Electric Tramway Currents upon the Working of Submarine Telegraph Cables and other Circuits," were begun and concluded.

On the motion of the Chairman, the authors were awarded votes of thanks for their papers.

The discussion on Mr W. A. **Chamen**'s paper on "The Electric Wiring of Buildings," was begun and adjourned.

The discussion on Mr **William O'Brien**'s paper on "A New Balanced Piston-Valve and its Application to Four-Crank Engines," was postponed.

Mr J. R. **Barnett**'s paper on "Typical Forms of Racing Yachts," was held as read.

The Chairman announced that the following candidates had been elected, viz :—

AS MEMBERS.

Adamson, Alexander, Shipbuilder and Engineer, Messrs Vickers, Sons, & Maxim, Barrow-in-Furness.

Burden, Alfred George Newkey, Mechanical Engineer, Messrs Harvey & Co., Hayle.

Cowie, William, Draughtsman, 48 Church Street, Coatbridge.

D'Oliveira, Raphael Chrysostome, Engineer, Campos Rio de Janeiro, Brazil.

Gilmour, John H., Forgemaster, River Bank, Irvine.

Henry, Erentz, Mechanical Engineer, 13 Ann Street, Hillhead, Glasgow.

Hunter, James, Mechanical Engineer, 34 Ancaster Drive, Glasgow, W.

Key, William, Engineer, 109 Hope Street, Glasgow.

AS MEMBER FROM GRADUATES' SECTION.

Mumme, Ernest Charles, Assistant Engineer, Bengal & North-Western Railway, India.

AS ASSOCIATES.

Gardiner, Frederick Crombie, Shipowner, 24 St. Vincent Place, Glasgow.

Gardiner, William Guthrie, Shipowner, 24 St. Vincent Place, Glasgow.

Mann, William, Shipowner, Whitecraigs, Giffnock.

M'Leod, Norman, Shipowner, 53 Bothwell Street, Glasgow.

Raeburn, William Hannay, Shipowner, 81 St. Vincent Street, Glasgow.

Roxburgh, John Archibald, Shipowner, 3 Royal Exchange Square, Glasgow.

Sloan, George, Shipowner, 8 Gordon Street, Glasgow.

Sloan, William, Shipowner, 8 Gordon Street, Glasgow.

AS GRADUATES.

BRUNTON, ROBERT, Civil Engineer, Engineer's Office, St. Enoch Station, Glasgow.

MELVILLE, ALEXANDER, Civil Engineer, Engineer's Office, St. Enoch Station, Glasgow.

MORLEY, JAMES STEEL, Mechanical Engineer, 3 Buckingham Square, Govan.

RICHMOND, TOM, Draughtsman, 4 Rosemount Terrace, Ibrox.

SANGUINETTI, W. ROGER, Civil Engineer, Engineer's Office, St. Enoch Station, Glasgow.

WILLIAMS, R. R., Engineer, 17 Newton Street, Glasgow.

WILSON, THOMAS, Draughtsman, 66 Alexandra Parade, Glasgow.

THE SIXTH GENERAL MEETING was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 20th March, 1900, at 8 P.M.

Mr ROBERT CAIRD, F.R.S.E., President, occupied the chair.

The Minutes of the Fifth General Meeting, held on 20th Feb., 1900, were read, confirmed, and signed by the President.

The discussion on Mr W. A. CHAMEN's paper on "The Electric Wiring of Buildings," was resumed and concluded.

On the motion of the President, Mr CHAMEN was awarded a vote of thanks for his paper.

The discussions on Mr WILLIAM O'BRIEN's paper on "A New Balanced Piston-Valve and its Application to Four-Crank Engines," and on Mr J. R. BARNETT's paper on "Typical Forms of Racing Yachts," were postponed.

A paper on "Workshop Administration," by Mr DAVID COWAN, was read.

The President announced that the following candidates had been elected, viz.:—

AS MEMBERS.

GOW, GEORGE, Superintendent Engineer, c/o Messrs Gourlay Bros. & Co., Dundee.

SMITH, ROBERT, Engineer, 24 Claremont Street, Glasgow.

AS AN ASSOCIATE.

BARCLAY, THOMAS KINLOCH, Engineering Agent, 55 Lochleven Road, Langside, Glasgow.

AS GRADUATES.

Neil Robert, Draughtsman, 116 Forth Street, Pollokshields, Glasgow.
De Sola, Juan Garcia, Draughtsman, 45 Orchard Street, Renfrew.

The Annual General Meeting was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 24th April, 1900, at 8 P.M.

Prof. Archibald Barr, D.Sc., Vice-President, occupied the chair.

The Minutes of the Sixth General Meeting, held on 20th March, 1900, were read, confirmed, and signed by the Chairman.

Before proceeding to the business of the evening, Mr Archibald Denny observed that he had a pleasurable duty to perform. Since the last meeting, the University of Glasgow had seen fit to honour two of their members, and he thought they should convey to those members their congratulations. Mr Robert Caird, their President, and Mr Andrew Stewart, had each been honoured with the degree of LL.D. He did not require to repeat what Prof. Moir had said in presenting Mr Caird for the degree; as a co-worker with the great teacher Ruskin, they all acknowledged Dr Caird as a worthy recipient of the degree, and they felt that the University, in conferring the distinction on him, had indirectly honoured the Institution. Mr Andrew Stewart had rendered valuable service to the Institution, and had conferred great benefits on the city of Glasgow. He had the interests of all the professions which were represented in the Institution warmly at heart, and there again he thought that the University had done well in bestowing the distinction on Dr Stewart. Mr Denny then moved that the Secretary be instructed to place on record the Institution's congratulations to Dr Caird and Dr Stewart on the honour which had been conferred upon them, and to send an excerpt of the minute to Dr Caird and Dr Stewart. The motion, having been seconded by Mr William Foulis, was carried unanimously.

On the motion of Mr A. S. Biggart, Prof. W. H. Watkinson and Mr R. T. Moore were appointed to scrutinise the voting papers for new Members of Council. The Scrutineers retired, and, having submitted their report, the Chairman announced that Mr Archibald Denny and Mr William Foulis had been elected Vice-Presidents, and Prof. J. H. Biles and Messrs W. A. Chamen, James Mollison, Charles C. Lindsay, and James Weir, Members of Council for Sessions 1900-1901 and 1901-1902.

On the motion of the Chairman, Messrs Peter Stewart and James Syme were appointed to audit the Annual Accounts.

The following awards were made for papers read at the ordinary meetings during the Session 1898-99.

1. The Institution Gold Medal to Prof. Archibald Barr, D.Sc., for his paper on "Comparisons of Similar Structures and Machines."
2. A Premium of Books to Mr C. A. Matthey for his paper on "The Mechanics of the Centrifugal Machine."
3. A Premium of Books to Mr James Weir for his paper, read at Sheffield, on "Water-Tube Boilers."
4. A Premium of Books to Prof. John Oliver Arnold for his lecture, delivered at Sheffield, on "The Internal Architecture of Metals."

The discussions on Mr William O'Brien's paper on "A New Balanced Piston-Valve and its Application to Four-Crank Engines," and on Mr J. R. Barnett's paper on "Typical Forms of Racing Yachts," were begun and concluded.

On the motion of the Chairman, the authors were awarded votes of thanks for their papers.

A paper on "Glasgow Main Drainage," by Mr A. B. M'Donald, was read.

The discussion on Mr David Cowan's paper on "Workshop Administration" was begun and adjourned.

The Chairman announced that the following candidates had been elected, viz.:—

AS MEMBERS.

Cowan David, Engineer, Clevedon, Cove, Dumbartonshire.

DAVIS, CHARLES M., Engineer, Glasgow Locomotive Works.
DELACOUR, FRANK PHILIP, Engineer, Baku, Russia.
HUTCHISON, JOHN S., Electrical Engineer, 126 Bothwell Street, Glasgow.

AS AN ASSOCIATE.

ANDERSON, JAMES, Draughtsman, c/o Masson, 26 Merryland Street, Govan.

AS GRADUATES.

M'LEAN, ARTHUR, Apprentice Engineer, 16 Pollok Street, Glasgow.
STEVENSON, GEORGE, Electrical Engineer, 50 Roselea Drive, Dennistoun, Glasgow.

AN EXTRA GENERAL MEETING was held in the Hall of the Institution, 207 Bath Street, on Tuesday, 15th May, 1900, at 8 P.M.

Mr ROBERT CAIRD, LL.D., President, occupied the chair.

The Minutes of the Annual General Meeting held on 24th May, 1900, were read, confirmed, and signed by the President.

The President stated that before commencing the business of the evening he desired to express his regret that he had not been present at the last General Meeting, as he should have liked to have conveyed his thanks to the Members for the resolution they then passed. Speaking for Dr ANDREW STEWART and himself he had much pleasure in thanking them for that resolution, and Mr DENNY and Mr FOULIS for the flattering terms in which they proposed and seconded it. Speaking for himself he was doubly grateful, because he could not but feel that the Academic distinction which the University had conferred upon him was in a great measure due to his connection with the Institution of Engineers and Shipbuilders in Scotland.

The discussion on Mr DAVID COWAN's paper on "Workshop Administration" was resumed and concluded; and

The discussion on Mr A. B. McDONALD's paper on "The Main Drainage of Glasgow" was begun and terminated.

On the motion of the President, the authors were awarded votes of thanks for their papers.

The President announced that

JOHN K. HAMILTON, Engineer, 53 Waterloo Street, Glasgow,

had been elected a Member of the Institution.

REPORT OF THE COUNCIL.

SESSION 1898-99.

In presenting its Annual Report the Council desires to express its satisfaction at the continued progress of the Institution. During the past Session the Roll strength has been materially increased, and the financial position improved, while speaking generally the numbers attending the Meetings have been greater than usual.

The changes which have taken place in the Roll are shown in the following statement :—

	Session 1897-98.	Session 1898-99.	Increase.
Honorary Members,	9	 9	
Members, ...	719	 799	80
Associates, ...	66	 64	-2
Graduates, ...	274	 288	14
	1068	1160	92

Of the seven Meetings held, the first was devoted chiefly to an address by the President, and to the delivery of the Premiums awarded in respect of papers read during the previous Session. At the remaining meetings the following papers were read and discussed :—

"Feed-Water Filters," by Mr A. E. Shute.

"Meters and Systems of Charging for Electric Energy," by Mr William Arnot.

"M. Tchebycheff's Formula," by Professor J. H. Biles.

"Examples of Four-Crank Engines and their Auxiliaries," by Mr John Thom.

"The Mechanics of the Centrifugal Machine," by Mr C. A. Matthey.

"The Machinery of the Clyde Trustees' No. 3 Graving Dock," by Mr George H. Baxter.

"Comparisons of Similiar Structures and Machines," by Prof. Archibald Barr, D.Sc.

The meetings held by the Graduates' Section have been six in number. The Session was opened with an address from the President, Mr Robert Watson, on "The Relations of the Engineer to Society." At subsequent meetings the following papers were read and discussed:—

"A Few Notes on Paddle Steamers and Engines," by Members of Council.

"Some Effects of Increase in Size of Steamers," by Mr H. C. Sadler, B.Sc.

"Air-Pumps," by Mr J. I. Fraser.

"Prevention of Accidents in Factories," by Mr John Calder.

"Factors of Safety in Marine Practice," by Mr J. P. Brown.

The Silver Medal for the best paper in this Section was awarded to Mr H. C. Sadler, B.Sc.

The terms of office of the four representatives of the Institution on the Sub-Committee for Surveyors of Lloyd's Register of British and Foreign Shipping having expired last December, the Council was called upon to appoint new representatives. Mr John Ward and Mr James Gilchrist were re-elected, and Mr Sinclair Couper and Mr F. P. Purvis were appointed to fill the vacancies caused by the retirement of Dr John Inglis and Mr D. J. Dunlop. For their past services Dr John Inglis, Mr D. J. Dunlop, Mr John Ward, and Mr James Gilchrist, were awarded the thanks of the Council.

The Annual "James Watt" Dinner, held in the Windsor Hotel on Saturday evening, 21st January, 1899, was attended by upwards of 280 Members and distinguished guests, a company larger than ever present at any previous function of the kind held under the auspices of the Institution.

An excursion took place on Friday, 23rd June, 1899, when the Glasgow and South Western Railway Company's steamer "Glen

Sannox" was chartered. On that occasion the guests included several ladies and gentlemen from Sheffield, where the Institution was so warmly welcomed and hospitably entertained during the Summer Meeting of 1898. Favoured by good weather the company enjoyed a pleasant cruise round Arran and through the Kyles of Bute to Ormidale.

The Council notes with satisfaction the amount of the fund raised chiefly among the Members of the Institution on behalf of a Member, who, through total loss of sight, has been rendered unable to follow his customary vocation.

The Council regrets to have to announce the loss the Institution has sustained through death of the following:—Members—Messrs George Alexander Agnew, David Auld, Howard Bowser, Edward Walton Findlay, Joseph Goodfellow, George Graham, Charles Randolph Harvey, William Laing, James Murdoch, James Tait, John Wilson; Associate—Mr William Gray.

The Treasurer's Statement, verified by the Auditors, and appended herewith, indicates that the total capital, including the Medal Funds, amounts to £4300 8s 8d compared with £3990 1s 9½d at the close of the previous session.

TREASURER'S

INCOME AND EXPENDITURE ACCOUNT

GENERAL

ORDINARY INCOME.			1898-99.	*1897-98.*
I. *Annual Subscriptions received—*				
707 Members	at £1 10 0	£1060 10 0		
60 Associates	,, 1 0 0	60 0 0		
244 Graduates	,, 0 10 0	122 0 0		
			£1242 10 0	*£1065 10 0*
II. *Arrears of Subscriptions received*, ..		...	66 10 0	*33 10 0*
III. *Sales of Transactions*, ...		...	14 9 4	*9 7 3*
IV. *Interests and Rents—*				
Interest on Clyde Trust Mortgage for £300, less tax, ...		£9 8 4		*9 8 6*
Students' Institute C.E., for use of Library, ...		12 6 0		*12 0 0*
Interest on Deposit Receipts, ...		6 0 6		*1 11 4*
			27 14 10	*[22 19 10]*
EXTRAORDINARY INCOME.				
Surplus from "James Watt" Dinner, ...		...	3 16 5	*4 12 2*
			£1355 0 7	*£1135 19 3*

STATEMENT.

FOR YEAR ENDING 30TH SEPTEMBER, 1899.

FUND.

ORDINARY EXPENDITURE.		1898 99.	*1897-98.*
I. *General Expenses—*			
Secretary's Salary, ...	£300 0 0		*£300 0 0*
Institution's proportion of net cost of maintenance of Buildings,	118 16 10½		*102 0 3½*
Interest on Medal Funds invested in Buildings, ...	21 12 0		*21 12 0*
Library Books, ...	22 18 0		*30 1 0*
Binding Periodicals and Papers,	6 15 10		*12 18 1*
Stationery and Postages, etc.,	37 5 4		*30 5 0*
Office Expenses, ...	35 12 9		*41 17 3*
Advertising, Insurance, etc., ...	5 4 10		*2 8 6*
Assistance at Meetings, ...	1 4 6		*2 6 1*
		549 10 1½	*[543 8 2½]*
II. "*Transactions*" *Expenses—*			
Printing and Binding,	£340 8 7		*330 17 6*
Lithography, ...	137 1 5		*127 10 9*
Postages, ...	58 13 10		*51 16 10½*
Reporting, ...	14 7 3		*12 4 3*
Delivery of Annual Volume, ...	10 10 0		*8 17 6*
		561 1 1	*[531 6 10½*
III. *Awards—*			
Premiums for Papers, ...		9 19 8	*10 3 0*
IV. *Surplus* carried down, ...		234 9 8½	*51 1 2*
		£1355 0 7	*£1135 19 3*

BALANCE SHEET, AS AT

LIABILITIES.			As at 30th Sept., 1899.	*As at 30th Sept., 1898.*
I. *Sundry Creditors,*			£15 11 6	*£21 2 3½*
II. *Subscriptions paid in advance,*			17 10 0	*29 10 0*
III. *Medal Funds—*				
Marine Engineering—				
Balance as at 1st Oct., 1898,	£508 12 2			
Interest received during year; *less* Premiums for Papers, £9 19s 2d,	4 1 11	512 14 1		*508 12 2*
Railway Engineering—				
Balance as at 1st Oct., 1898,	£312 15 2			
Interest received during year,	8 6 8	321 1 10		*312 15 2*
Graduates'—				
Balance as at 1st Oct., 1898,	£26 5 8			
Cost of medal, £1 7s 6d; *less* interest received during year, 16s 1d,	0 11 5	25 14 3		*26 5 8*
			859 10 2	*[347 13 0]*
IV. *Capital Accounts—*				
General Fund—				
Balance as at 1st Oct., 1898,	£1049 18 8½			
Surplus, 1898-99,	234 9 8½	1284 8 5		*1049 18 8½*
Building Fund—				
Balance as at 1st Oct., 1898,	£2092 10 1			
Life Members' Subscriptions, £25; Entry money, £39.	64 0 0	2156 10 1		*2092 10 1*
			3440 18 6	*[3142 8 9½]*
			£4333 10 2	*£4040 14 1*

30TH SEPTEMBER, 1899.

ASSETS.			As at 30th Sept., 1899.	*As at 30th Sept., 1898.*
I. *Heritable Property*—				
Total Cost,	£7094 16 3			
Of which one-half belongs to Institution, ...		£3547 8 1		
Less Institution's proportion of Bond, ...		500 0 0	£3047 8 1	*3047 8 1*
II. *Investment*—				
Clyde Trust Mortgage, ...			300 0 0	*300 0 0*
III. *Books in Library*—				
Valued at, say			500 0 0	*500 0 0*
IV. *Furniture and Fittings*—				
Valued at, say			65 10 0	*65 10 0*
V. *Sundry Debtors*—			9 1 10	
VI. *Arrears of Subscriptions*—				
Session 1898-99—				
44 Members at £1 10/,		£66 0 0		
4 Associates at £1,		4 0 0		
44 Graduates at 10/,		22 0 0		
		£92 0 0		
Previous sessions—				
16 Members,	£57 0 0			
3 Associates,	5 0 0			
25 Graduates,	24 10 0	£86 10 0		
Total,		£178 10 0		
Valued at, say			50 0 0	*50 0 0*
VII. *Cash*—				
In Bank,				
On Deposit Receipt, ..		£77 15 9		
On Current Account, ...		278 13 4		
In Secretary's hands ...		5 1 2	361 10 3	*77 16 0*
			£4333 10 2	*£4040 14 1*

ABSTRACT OF "HOUSE EXPENDITURE" ACCOUNT FOR SESSION 1898-99.

INCOME.	12 months, to 30th Sep., 1899.	*12 months, to 30th Sep., 1898.*	EXPENDITURE.	12 months, to 30th Sep., 1899.	*12 months, to 30th Sep., 1898.*
Rents for Letting Rooms, ...	£77 0 0	*£74 7 6*	Salary to Curator, ...	£135 0 0	*£135 0 0*
Balance, being excess Expenditure, ...	257 19 9	*224 6 7*	Salary to Attendant at Library, Cleaning, etc., ...	61 1 6	*52 6 7*
Payable by Institution, ... £118 16 10½			Feu-duty, Taxes, and Insurance,	41 8 2	*22 1 0½*
,, ,, Philosophical Society, 139 2 10½			Interest on Bond, ...	49 6 0	*49 6 0*
			Alterations, Repairs & Renewals,	12 1 3	*7 14 10*
			Coal, Gas, and Electric Light,	35 12 8	*29 8 0*
			Stationery, Postages, and Incidental Expenses, ...	0 10 2	*2 17 7½*
	£334 19 9	*£298 14 1*		£334 19 9	*£298 14 1*

Note.—The Account of the House Committee, of which the above is an abstract, is kept by Mr John Mann, C.A., Treasurer to the Committee, and is periodically audited by the Auditors appointed by the Institution and the Philosophical Society.

EDWARD H. PARKER, *Secretary to the House Committee.*

GLASGOW, *13th October*, 1899.—We have examined the foregoing Financial Statement of the Treasurer, the Accounts of the Marine and Railway Engineering Medal Funds, the Graduates' Medal Fund, the Building Fund, and the "House Expenditure" Account, and find the same duly vouched and correct, the Amounts in Bank being as stated.

(Signed) PETER STEWART, } AUDITORS
W. A. CHARLTON, }

REPORT OF THE LIBRARY COMMITTEE.

The additions to the Library during the year include 55 volumes by purchase; 7 volumes and 13 pamphlets by donation; while 64 volumes and 90 parts were received in exchange for the "Transactions" of the Institution. Of the periodical publications received in exchange, 22 are weekly, 17 monthly, and 3 quarterly. Fifty-four volumes were bound during the year.

The Library now comprises 2771 volumes.

As the proceedings of the most important engineering societies are to be found in the Library of the Institution, the Committee begs to draw the attention of Members to the existence of this particular section.

DONATIONS TO THE LIBRARY.

Barr, Archibald, Address on the Application of the Science of Mechanics to Engineering Practice. Pamphlet, 1899. From Institution of Civil Engineers.

Corthell, E. L. Report upon the Seventh International Congress of Navigation, held at Brussels, July, 1898. Washington, 1900. From the Author.

Dittmar, W. Report on the Scientific Results of the Voyage of H.M.S. "Challenger," 1873-76. Physics and Chemistry. Vol. I., Part 1. Report on the Composition of Ocean-Water. 4to, Edinburgh, 1884. From Mr Nisbet Sinclair.

Duncan, Louis, Present Status of the Transmission and Distribution of Electrical Energy (Smithsonian Report, 1896). Pamphlet. Washington, 1898. From Smithsonian Institution.

Fifteenth Annual Report of the Hydraulic Engineer on the Water Supply of Queensland. 1899. From Mr J. B. Henderson.

Fletcher, H. Descriptive Note on the Sydney Coal Field, Cape Breton, Nova Scotia, to accompany a Revised Edition of the Geological Map of the Coal Field. Ottawa, 1900. From Geological Survey of Canada.

Glasgow School of Art: Prospectus of the Classes, and Local Prize Scheme for Session 1899-1900. From the Governors.

Guédon, M. P., Locomotives a Tiroirs Cylindriques Système Rigour et la Distribution Système Guédon (Société des Ingenieurs Civilis de France, Bulletin, April, 1899). Pamphlet, 1899. From the Author.

Guide to Queensland. From the Agent-General for Queensland.

Jahrbuch der Schiffbautechnischen Gesellschaft, Berlin. Vol. I., 1900, and continued. From the Society.

Koenigsberger, Leo, Investigations of Hermann Von Helmholtz on the Fundamental Principles of Mathematics and Mechanics (Smithsonian Report, 1896). Pamphlet. Washington, 1898. From Smithsonian Institution.

Labrosse, F. Navigation of the Atlantic Ocean. Translated by J. B. Coghlan. 2nd Edition. Washington, 1887. From Mr Nisbet Sinclair.

Maginnis, A. J. Atlantic Ferry; its Ships, Men, and Working. 3rd Edition, 1900. From Messrs Whitaker & Co.

Manchester Steam Users Association, Memorandum by Chief Engineer, 1898. Pamphlet. Manchester, 1899. From the Association.

M'Connell, R. G. Preliminary Report on the Klondike Gold Fields, Yukon District, Canada. Ottawa, 1900. From Geological Survey of Canada.

Naville, E. La Question du Transvaal; 6th Edition. Genève, 1899. From Sir Digby Murray.

New Rules for Shafting. Pamphlet, 1900. From the British Corporation for the Survey and Registering of Shipping.

Report of the British Association, Meeting at Bristol, 1898.

Röntgen, W. C., The X-Rays (Smithsonian Report, 1897). Pamphlet. Washington, 1898. From Smithsonian Institution.

Seaman, Henry B., Launhardt Formula and Railroad Bridge Specification (Transactions American Society of Civil Engineers, June, 1899). Pamphlet. From American Society Civil Engineers.

Thomson, Elihu, Electrical Advance in the past Ten Years (Smithsonian Report, 1897). Pamphlet. Washington, 1898. From Smithsonian Institution.

Thomson, J. J., Cathode Rays (Smithsonian Report, 1897). Pamphlet. Washington, 1898. From Smithsonian Institution.

BOOKS ADDED TO THE LIBRARY BY PURCHASE.

Archbutt, L. and R. M. Deeley. Lubrication and Lubricants: A Treatise on the Theory and Practice of Lubrication, and on the Nature, Proportion, and Testing of Lubricants. 1900.

Baldwin, W. J. Baldwin on Heating; or, Steam Heating for Buildings, revised—14th Edition. New York, 1897.

Barr, W. M. Boilers and Furnaces considered in their relations to Steam Engineering. Philadelphia, 1899.

Bertin, L. E. Marine Boilers: their Construction and Working, dealing more especially with Tubulous Boilers. Translated by L. S. Robertson. With a Preface by Sir Wm. White, 1898.

Boulvin, J. Entropy Diagram and its Applications. Translated by B. Donkin, 1898.

Busby, Carl. Marine Steam Engine; its Construction, Action, and Management. 3rd Edition, Parts I. and II. and 4to Vol. of plates. Kiel, 1892 and 1898.

Cajori, F. History of Physics in its Elementary Branches. New York, 1899.

Campbell, H. H. Manufacture and Properties of Structural Steel. 2nd Edition, 1896.

Church, J. P. Mechanics of Engineering. New York, 1898.

Cochrane, E. H. Wonders of Modern Mechanism. 1896.

Cornwall-Jones, R. J. British Merchant Service, being a History of the British Mercantile Marine. 1898.

Dawson, P. Engineering and Electro-Traction Pocket Book. 1899.

Du Bois, H. Magnetic Circuit in Theory and Practice. Translated by E. Atkinson, 1896.

Electrical Directory, 1900.

Ewing, J. A. Strength of Materials. Cambridge, 1899.

Fahie, J. J. History of Wireless Telegraphy. 1838-99. Edinburgh, 1899.

Fisher-Hinnen, J. Continuous-Current Dynamos in Theory and Practice. 1899.

Fulton, D. Practical Treatise on Patents, Trade Marks, and Designs; with a Digest of Colonial and Foreign Patent Laws. 1894.

Gibbings, A. H. Commercial and Business Aspects of Municipal Electric City supply. Bradford, 1899.

Gibbs, W. E. Lighting by Acetylene. 2nd Edition, 1899.

Goodman, J. Mechanics Applied to Engineering. 1899.

Heaviside, Oliver. Electro-Magnetic Theory. Vol. 2. 1899.

Hertz, H. Principles of Mechanics presented in a New Form, with an Introduction by H. Von Helmholtz. Translated by Jones and Walley. 1899.

Jordan, W., and Gore-Browne, F. Handy Book on the Formation, Management, and Winding Up of Joint Stock Companies. 22nd Edition. 1899.

Kapp, G. Dynamo Construction: Electrical and Mechanical. 4to n.d.

Lewes, V. B. Cantor Lectures—

Acetylene. (Reprinted from the Journal Society of Arts. Vol. 47, 1898-99.)

Explosives and their Modern Development. (Reprinted from Journal Society of Arts. Vol. 43, 1894-95.

Gaseous Illuminations. (Reprinted from Journal Society of Arts. Vol. 39, 1890-91.)

Generation of Light from Coal Gas. (Reprinted from Journal Society of Arts. Vol. 41, 1892-93.)

Use of Gas for Domestic Lighting. (Reprinted from Journal Society of Arts. Vol. 45, 1896-97.)

Lewis, J. S. Commercial Organization of Factories. 1896.

Lodge, O. J. Signalling Across Space without Wires. 3rd Edition.

Louis, Henry. Handbook of Gold Milling. 2nd Edition, 1899.

Marks, G. C. Hydraulic Power Engineering. 1900.

Maycock, W. P. Electric Wiring, Fittings, Switches, and Lamps. 1899.

Meyer, O. E. Kinetic Theory of Gases. 2nd Edition. Translated by R. A. Baynes. 1899.

Middleton, R. E., and O. Chadwick. Treatise on Surveying, Part I. 1899,

Millis, C. T. Metal-Plate Work. 3rd Edition, 1899.

Mills, E. J. Destructive Distillation: A Manualette of the Paraffin, Coal Tar, Rosin Oil, Petroleum, and Kindred Industries. 4th Edition, 1892.

Neison, Adam, and Kemp, Dixon. Practical Boat-Building for Amateurs. 2nd Edition. n.d.

Ogden, H. N. Sewer Design. New York, 1899.

Parshall, H. F., and Hobart, H. M. Armature Windings of Electric Machines. 2nd Edition. New York, 1899.

Patton, W. M. Practical Treatise on Foundations. First Edition. New York, 1898.

Perry, John. Steam Engines, and Gas and Oil Engines. 1899.

Poole, H. Calorific Power of Fuels. 1st Edition, New York, 1898.

Redwood, J. J. Practical Treatise on Mineral Oils and their Bye-Products. 1897.

Ripper, W. Steam Engine Theory and Practice. 1899.

Roots, J. D. Cycles of Gas and Oil Engines. 1899.

Sanford, P. G. Nitro-Explosives. 1896.

Sloane, T. O'C. Liquid Air and the Liquefaction of Gases. 2nd Edition, 1899.

Thompson, P. S. Polyphase Electric Currents and Alternate Current Motors. 2nd Edition, 1900.

Walker, J. Introduction to Physical Chemistry. 1899.

Wheatstone, Sir Charles. Scientific Papers of. Published by the Physical Society of London, 1879.

Wiener, A. E. Practical Calculation of Dynamo-Electric Machines. New York, 1898.

Wilson, H. S. Practical Tool-Maker and Designer. Philadelphia, 1898.

Wolff, A. R. Windmill as a Prime Mover. 2nd Edition. New York. 1899.

Zeuner, G. Treatise on Valve-Gears, with special consideration of the Link-Motions of Locomotive Engines. 4th Edition. Translated by J. F. Klein. 1884.

THE INSTITUTION EXCHANGES TRANSACTIONS WITH THE FOLLOWING SOCIETIES, &C. :—

American Institute of Electrical Engineers.
American Philosophical Society.
American Society of Civil Engineers, New York.
American Society of Mechanical Engineers, New York.
Association des Ingénieurs des Ecoles Speciales de Gand, Belgium.
Austrian Engineers' and Architects' Society, Vienna.
Bristol Naturalists' Society, Bristol.
Bureau of Steam Engineering, Navy Department, Washington.
Canadian Institute, Toronto.
Canadian Society of Civil Engineers, Montreal.
Edinburgh Architectural Association.
Engineering Association of New South Wales, Sydney.
Engineering Society of the School of Practical Science, Toronto.
Engineers' and Architects' Society of Naples, Naples.
Franklin Institute, Philadelphia, U.S.A.
Geological Survey of Canada, Ottowa.

Hull and District Institution of Engineers and Naval Architects, Hull.
Institute of Marine Engineers, London.
Institution of Civil Engineers, London.
Institution of Civil Engineers of Ireland, Dublin.
Institution of Junior Engineers, London.
Institution of Mechanical Engineers, London.
Institution of Naval Architects, Japan.
Institution of Naval Architects, London.
Iron and Steel Institute, London.
Liverpool Engineering Society, Liverpool.
Liverpool Polytechnic Society, Liverpool.
Literary and Philosophical Society of Manchester, Manchester.
Lloyd's Register of British and Foreign Shipping, London.
Manchester Association of Engineers, Manchester.
Master Car Builders' Association, Chicago, U.S.A.
Midland Institute of Mining, Civil, and Mechanical Engineers, Barnsley.
Mining Institute of Scotland, Hamilton.
North-East Coast Institution of Engineers and Shipbuilders, Newcastle-on-Tyne.
North of England Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.
Patent Office, London.
Philosophical Society of Glasgow.
Royal Academy of Sciences, Lisbon.
Royal Dublin Society, Dublin.
Royal Scottish Society of Arts, Edinburgh.
Royal Society of Tasmania, Hobart.
Sanitary Institute of Great Britain, London.
Scientific Library, U.S. Patent Office, Washington, U.S.A.
Shipmasters' Society, London.
Smithsonian Institution, Washington, U.S.A.
Société d'Encouragement pour l'Industrie Nationale, Paris.
Société des Ingénieurs Civils de France, Paris.
Société des Sciences Physiques et Naturelles de Bordeaux, Bordeaux.

Société Industrielle de Mulhouse, Mulhouse.
Society of Arts, London.
Society of Arts, Massachusetts Inst. of Technology, Boston.
Society of Engineers, London.
Society of Naval Architects and Marine Engineers, New York, U.S.A.
South Wales Institute of Engineers, Cardiff.
Technical Society of the Pacific Coast, San Francisco, U.S.A.
West of Scotland Iron and Steel Institute, Glasgow.

COPIES OF THE TRANSACTIONS ARE FORWARDED TO THE FOLLOWING COLLEGES, LIBRARIES, &C.:—

Advocates' Library, Edinburgh.
British Corporation for the Survey and Registry of Shipping, Glasgow.
Cornell University, Ithaca, U.S.A.
Dumbarton Free Public Library, Dumbarton.
Glasgow and West of Scotland Technical College, Glasgow.
Glasgow University, Glasgow.
Lloyd's Office, London.
Mercantile Marine Service Association, Liverpool.
M'Gill University, Montreal.
Mitchell Library, Glasgow.
Royal Naval College, Greenwich.
Stevens Institute of Technology, Hoboken, U.S.A.
Stirling's Library, Glasgow.
Trinity College, Dublin.
Underwriters' Rooms, Glasgow.
Do. Liverpool.
University College, London.
Yorkshire College, Leeds.

PUBLICATIONS RECEIVED PERIODICALLY IN EXCHANGE FOR INSTITUTION TRANSACTIONS:—

American Machinist.
American Manufacturer and Iron World.

British Refrigeration.
Cassier's Magazine.
Colliery Guardian.
Contract Journal.
Engineer.
Engineering.
Engineering Magazine.
Engineering and Mining Journal.
Engineers' Gazette.
Fielden's Magazine.
Indian Engineering.
Iron and Coal Trades' Review.
Iron and Steel Trades' Journal.
Journal de l'Ecole Polytechnic.
L'Industria.
Light Railway and Tramway Journal.
Machinery.
Machinery Market.
Marine Engineer.
Marine Engineering.
Mariner.
Mechanical Engineer.
Mechanical World.
Nature.
Portefeuille Économique des Machines
Practical Engineer.
Revue Industrielle.
Shipping World.
Stahl und Eisen.
Steamship.
The Indian and Eastern Engineer.
Transport.

W. H. WATKINSON,
Hon. Librarian and Convener.

The Library of the Institution is open daily (except Saturdays) during the Winter Session from 9.30 A.M. till 8 P.M., and on Meeting Nights of the Institution and Philosophical Society till 10 P.M.; throughout the Summer months from 9.30 A.M. till 5 P.M., save during July, when it is closed for the Glasgow Fair Holidays, and open for the remainder of the month from 1 P.M. to 5 P.M.; and every Saturday from 9.30 A.M. till 2 P.M., during the Winter Session, and from 9.30 A.M. till 1 P.M. during the Summer months.

Books will be lent on presentation of Membership Card to the Sub-Librarian.

Members have also the privilege of consulting the Books in the Library of the Philosophical Society.

The use of the Library and Reading Room is open to Members, Associates, and Graduates.

The Portrait Album lies in the Library for the reception of Members' Portraits. Members are requested when forwarding Portraits to attach their Signatures to the bottom of Carte.

The Library Committee are desirous of calling the attention of Readers to the "Recommendation Book," where entries can be made of titles of books suggested as suitable for addition to the Library.

Copies of the Library Catalogue and Supplement, price 6d; or separately, 3d each, may be had at the Library, or from the Secretary.

A List of the Papers read and Authors' Names, from the First to the Thirty-Third Sessions, will be found in Vol. XXXIII. of the Transactions.

As arranged by the Council, a Register Book for Graduates now lies in the Library for the inspection of Members, the object being to assist Graduates of the Institution in finding suitable appointments.

Annual Subscriptions are due at the commencement of each Session; viz.:—

MEMBERS, £1 10s; ASSOCIATES, £1; GRADUATES, 10s.
LIFE MEMBERS, £20; LIFE ASSOCIATES, £15.

Membership Application Forms can be had from the Secretary or from the Librarian, at the Rooms, 207 Bath Street.

The Council, being desirous of rendering the Transactions of the Institution as complete as possible, earnestly request the co-operation of Members in the preparing of Papers for reading and discussion at the General Meetings.

Early notice of such Papers should be sent to the Secretary, so that the dates of reading may be arranged.

Copies of the reprint of Vol. VII., containing a paper on "The Loch Katrine Water Works," by Mr J. M. Gale, C.E., may be had from the Secretary; price to Members, 7s 6d.

Members of this Institution, who may be temporarily resident in Edinburgh, will, on application to the Secretary of the Royal Scottish Society of Arts, at his office, 117 George Street, be furnished with Billets for attending the meetings of that Society.

The Meetings of the Royal Scottish Society of Arts are held on the 2nd and 4th Mondays of each month, from November till April, with the exception of the 4th Monday of December.

OBITUARY.

Members.

Howard Bowser, the son of a manufacturer of malleable iron bars, was born in London on 1st September, 1824. At the age of seven he was sent to a proprietary school, called "Nettlebed," on the road between London and Oxford (eighteen miles from the latter). Leaving school in 1837, he served an apprenticeship of seven years as a printer, and afterwards, as a journeyman, five at Leicester and four at London. Mr Bowser came to Glasgow in 1848 to enter as partner the firm of Messrs D. Y. Stewart & Co., cast iron pipe manufacturers, and subsequently became the guiding spirit and responsible head of that concern. In 1898 the jubilee of his partnership was celebrated, when his employees presented him with an illuminated address and other tokens of their esteem. On that occasion he gave cogent proof of his interest in his workmen in the large-hearted provision he then made for cases of illness and infirmity.

Mr Bowser was universally respected for his sterling worth of character, and admired for his marked ability in the discharge of life's affairs. Of a benevolent disposition, he was not appealed to in vain on behalf of any worthy object. At the end of August, 1899, he went to Deeside for a brief holiday, and, while there, a sudden illness seized him, and he passed away at Aboyne on 8th September, 1899.

Mr Bowser joined the Institution as a member in 1874.

Joseph C. Campbell was born in Glasgow. He began his engineering career under his father in the well-known firm of Messrs Crawhall & Campbell, Finnieston Lane, Glasgow. After completing his apprenticeship, he entered the drawing office of Messrs McDowall & Sons, Johnstone, as a draughtsman, where he remained for some years, finally severing his connection with that firm to assist his father in the management of the new works of Messrs Campbell, Smart, & Co., Stobcross Street, Glasgow. On the death of his father, he became the managing partner of that business, which was subsequently removed to more commodious premises in Old Dumbarton Road. For three or four years prior to his death, he was the representative of Messrs Kendall & Gent, Manchester.

Mr Campbell took a keen interest in the welfare of the Association of Foremen Engineers and Ironworkers of the West of Scotland, and for a number of years acted as its honorary secretary, in which capacity he commanded both respect and love. He joined the Institution as a member in 1896, and passed away at Partick on 21st October, 1900, after a lingering illness, at the age of fifty-two.

THOMAS DANIELS was born at Stoney Stratford, Buckinghamshire, on 8th October, 1841. He served an apprenticeship at Wolverton, and thereafter gained experience in Glasgow and Hull and the Midland Railway Company's Works at Doncaster. From the latter place he went to the Worcester Engine Works, where he was made foreman of the erecting shop. After remaining there some time under Mr Edward Wilson, he was appointed foreman at the erecting shops of Messrs Sharp, Stewart, & Co., Manchester. Shortly after entering the service of Messrs Sharp, Stewart, & Co., he became a member of the Manchester Association of Engineers, and was elected its president in 1893 and 1894.

In March, 1883, he accepted the position of works manager with Messrs Nasmyth & Wilson, and for the last four years of his life he was a director of that firm.

As a works manager and director it would be impossible to bear too high testimony to his ability and business qualities. He was thoroughly acquainted with the labour organisations and their systems; and remarkably tactful in the management of men, considering them as individuals, and studying their temperament and capacities. He endeavoured to hold the scales of justice fairly between employers and employed, and achieved what few can claim; for, while retaining the confidence and esteem of the firm, he was popular among the men. He several times by his tact averted strikes, and the only stoppage at the Bridgewater Foundry during his connection with it was not a local one—the engineers' strike of three years ago. On that occasion he gave the men the greatest satisfaction by keeping every man's place open until the end of the dispute.

Some two or three years prior to his death, Mr Daniels suffered from an attack of influenza and before he had entirely recovered returned to his work. In consequence, he sustained a relapse, and, complications arising, succumbed on 6th March, 1900.

Mr Daniels joined the Institution as a member in 1893.

JAMES DEAS was born in Edinburgh on 30th October, 1827, and there his school days were passed. On leaving school, he entered the locomotive workshops of the Edinburgh and Glasgow Railway, at Haymarket, Edinburgh, then under the charge of Mr Robert Thornton, where he remained for three years, gaining a knowledge of mechanical engineering. He then served for three years in the office of Mr John Miller, civil engineer, Edinburgh, a gentleman who was widely known in the palmy days of railway enterprise, and who carried on an extensive practice in Scotland. Leaving Mr Miller's office, Mr Deas became an assistant to his father, one of Mr Miller's trusted resident engineers, who then had charge of the construction of an important portion of the Glasgow and South Western Railway, between Dumfries and Carlisle. On the opening of the southern division of this railway, Mr Deas was appointed a superintendent of way and works with the control of the staff of workmen employed thereon. From 1855 till the middle of 1861 he filled an important position in Glasgow at the head offices of the Glasgow and South Western Railway Company, as assistant to Mr William Johnstone, who was manager and engineer-in-chief. From this post he was promoted to resident engineer on the southern division of the railway, and also of the Castle Douglas line, for a combined distance of 70 miles. In this position he remained until 1864, when he returned to Glasgow to take charge of the Edinburgh and Glasgow Railway as engineer-in-chief.

A few years later, however, that company became amalgamated with the North British Railway Co., and Mr Bell, the engineer of the latter company was appointed engineer of the combined companies, while to Mr Deas was allocated the engineership of the western division, which office he retained until 1869, when he was appointed engineer of the Clyde Navigation. Here it may be said Mr Deas found his life work. He entered on his duties full of enthusiasm, and soon found ample scope for his energies. The first work undertaken by him was the designing and carrying through Parliament, in conjunction with the late Mr Bateman, at that time consulting engineer of the Trust, of an important extension of the harbour of Glasgow on the south side, and the Stobcross Dock, now called the Queen's Dock, on the north side of the river Clyde. The execution of these works was immediately put in hand, and in course of years they were followed by No. 2 Graving Dock, the Prince's Dock, and No. 3 Graving Dock, besides many other works of lesser note. But while these works were going on, the river claimed much of Mr Deas' attention, constant dredging being carried on in deepening and widening it to provide for the ever increasing size of vessels, and several years were spent in the removal of a large deposit of rock across the bed of the river at Elderslie, a short distance above Renfrew. For the greater portion of Mr Deas' tenure of office, he was responsible for the varied mechanical works within the scope of the Trust, viz. —the construction and upkeep of dredgers, hopper barges, steam ferries, passenger steamers, cranes, swing bridges, pumping machinery, hydraulic installations, etc., until in later years, when the work had grown too extensive, he was relieved of the greater portion of this class of work by the appointment of a mechanical engineer.

To show the great expansion of the Clyde Trust, and to give an indication of the amount of work which fell upon Mr Deas' shoulders, it may be mentioned that during his term of office he saw the revenue increase from £150,000 to £428,000, the quayage of the harbour and docks from 5,604 lineal yards to 15,116 lineal yards, the water area from 75 acres to 206 acres, and the creation of three graving docks, with all such contingent works as sheds, cranes, tramways, etc. Mr Deas was possessed of unbounded diligence, and was unsparing in his devotion to the interests of his employers. More than most men he possessed the gift of being capable of taking infinite pains with every detail of work which came before him. Having an unusually active and eager mind, and endowed with great energy, he was able to undertake and carry through an amount of work which many would have avoided. Mr Deas had considerable facility in writing, and was fond of it. His literary productions were, however, practically confined to the improvement of the Clyde, and he never wearied of preparing papers on this subject for engineering societies and periodicals. Indeed, the claim may well rest with him of having been the historian of the Clyde in this respect.

Mr Deas' advice was sought after by various harbour authorities, and amongst other schemes he supported the promoters of the Manchester Ship Canal in their applications to Parliament for the authorisation of that great undertaking. In the course of his long career, he acquired considerable Parliamentary experience, and often appeared as a witness before Committees of both Houses, rather enjoying what others disliked, the ordeal of examination. Mr Deas literally died in harness, having been at his usual work up to within half-an-hour of his death.

Mr Deas joined the Institution as a member in 1869.

Archibald Gilchrist died on the 7th January, 1900, in his seventy-eighth year. He served an apprenticeship with the Canal Basin Co., Glasgow, with Messrs H. & R. Baird, and in the Kirkintilloch Foundry. He was engineering manager with Messrs Tod & Macgregor till 1857, when he joined the firm of Messrs Barclay, Curle & Co., as engineering partner, and continued a member of the firm till his death, at which time he occupied the position of chairman. He was also chairman of Messrs Sharp, Stewart & Co., Limited, locomotive builders, Springburn. At his death Mr Gilchrist was the oldest engineer and shipbuilder in the district, and with him passed away one of the very last of the old Clyde engineers who brought the marine engine from its infancy to its present high pitch of development. He was a man notable for the thoroughness of his grasp of every detail of his profession, for his tact and business shrewdness, and for his geniality and kindness of heart.

In earlier days he contributed many valuable papers to the Institution, and evinced a deep interest in its advancement. He was a prominent member of the Trades' House, was elected Deacon Convener in 1875, and as such sat in the City Council for two years. He was also twice elected Deacon of the Incorporation of Hammermen, and was a Justice of the Peace.

He joined the Institution as a member in 1859.

Archibald Kerr was born in the parish of Ardrossan, but by family connections and sympathies he was a Lochranza man, and throughout his whole career he took an enlightened interest in Arran matters. In early life Mr Kerr was a marine engineer, and spent a number of years in South America. In 1874 he started the business of an iron pipe founder, which finally developed into the large concern of Messrs Kerr & Co., Caledonia Foundry. He took an active interest in public affairs, and in 1896 was elected as one of the representatives of the Maryhill

Ward in the Glasgow Town Council, where his practical skill and intimate knowledge of local matters were much valued, especially in committee work. He also served for a number of years as a member of the Barony Parochial Board.

For twelve months Mr Kerr suffered from an internal malignant trouble, which caused his death on 21st January, 1900, at the age of 56.

Mr Kerr joined the Institution as a member in 1894.

ALEXANDER KIDD was born at Chester. He commenced his professional career with Messrs Scott & Co., Greenock, and was afterwards employed in the engine works of Messrs Laird Bros., Birkenhead. In January, 1889, he joined Lloyd's Register as an engineer surveyor, and was attached to the Glasgow district. Six years later he was appointed ship and engineer surveyor to the Society at Singapore, where he died on the 29th November, 1899.

Mr Kidd became a member of the Institution in 1890.

EDWARD MACKAY was born in Glasgow on 18th August, 1839, and commenced his apprenticeship as an engineer in 1854 with Messrs. Scott, Sinclair & Co., engineers, Greenock; which was the original name of the Greenock Foundry Company, now perhaps better known as Messrs. Scott & Co. On the completion of his apprenticeship he spent some time in the drawing office of the Company, and afterwards studied at Glasgow University under the late Prof. Rankine. Subsequently he entered the service of Messrs. A. & J. Inglis, Partick, as head draughtsman of their engineering department. Leaving Glasgow Mr Mackay went to the North-Eastern Marine Engineering Company at Sunderland, where he was chief draughtsman under Mr William Allan (now M.P. for Gateshead), who was the manager of that establishment.

In 1871 Mr Mackay returned to Greenock, and was appointed manager of the Greenock Foundry Company, which position he held until his death. During his long connection with that firm he superintended the construction of the propelling machinery for numerous mercantile steamers, and also for several large battleships and gunboats for the British Navy. Among the latter may be mentioned the battleships Barfleux, Centurion, Hercules, and Canopus; and the gunboats Swallow and Thrush. As manager he enjoyed the respect and esteem of his employers, and was held in high regard by the numerous employees under his control. He died suddenly at Greenock on 27th November, 1899.

Mr Mackay joined the Institution as a member in 1887.

JOHN NAPIER was born at Camlachie, Glasgow, on 18th June, 1823, the same year that his father, the well-known Robert Napier, turned out of his workshop, Camlachie Foundry, the first of the long series of marine engines which brought him fame and fortune. John got the best education that Glasgow could give, at the High School and the University. He had the faculty of working steadily, and, while studying mathematics under Dr Connal, took the prize in advance of his more brilliant brother James. At the University he did not graduate (in those days few did, save those destined for the learned professions), and at the close of his University career his father sent him into his workshops, by this time transferred to Washington Street, and known as " The Vulcan Foundry."

Robert Napier's manager was David Elder, an engineer with few equals in his day, and from him John Napier learned much; but it was not until the early sixties came and the veteran engineer retired from active management that John got a free hand.

In 1855, Robert Napier made his sons partners in his business, thenceforward known as R. Napier & Sons. A few years later the elder son retired, and John Napier was left to carry the burden which his father's increasing years laid upon him. In 1859 his firm undertook for the Government the building of the "Black Prince," sister ship to the "Warrior," the two being the pioneer ironclad ships of the British Navy. Great trouble and anxiety, and the unavoidable sacrificing of other and remunerative work, attended the building of this ship and the immediately succeeding ironclad, "Hector." The anxiety was needlessly prolonged by the Admiralty delaying to acknowledge in the case of his firm, as they had acknowledged in the case of the Thames firm, that the building of such an entire novelty as an ironclad was an experiment, the loss on which the nation could fairly be asked to make good.

Brighter days came. The "Scotia," the last of the once famed fleet of Atlantic paddle steamers, was launched in 1862, and for long was first favourite for comfort. The engines of the "Scotia" were the first in the designing of which John Napier was free to exercise his own judgment as an engineer. Various war vessels for the British and other Governments, besides passenger steamers for home and foreign owners, were built in the following years, and in the steamers "Ville de Paris" and "Pereire," built for the French Transatlantic mail service, the firm made a success in the matter of speed that filled the gap between the "Scotia" and the era of the modern racers.

Robert Napier died in 1876, leaving his son sole partner of the firm of R. Napier & Sons. An ambitious man thus finding himself at the head of a renowned business, might have formed a Company, remodelled his workshops, and aimed at holding premier position in the shipbuilding world. But John Napier had had enough of a shipbuilder's anxieties and worries. Cares did not at any time sit lightly on his shoulders, and, a purchaser being found for the business, he took his leave of Lancefield and Govan with a light heart.

London had for long seemed to him the most desirable place of residence, and there he finally settled in 1877, employing his time, so long as strength was left to him, in connection with the Castle Steam Packet Company, a Company for which his firm had built extensively. He outlived all the other members of his father's family, and died in London on 29th December, 1899. His only son, Lieutenant R. Assheton Napier, R.N.R., the author of "A Manual of Navigation," died in 1894.

Mr Napier, at the date of his death, was the senior elected member of the Institution, having been admitted at the meeting in December, 1857.

Robert Andrew Robertson was born at Islington, London, on 3rd April, 1843. He served his apprenticeship with Messrs James Simpson & Co., of Pimlico, and in the years 1864-5 successfully carried out, as assistant to the late Mr David Thompson, some extensive tunnelling in connection with the South Staffordshire Water Works. From 1866 to 1872 he managed the Clyde Wharf Sugar Refinery for Mr James Duncan, where he laid the foundations of an extensive knowledge of sugar refining which served him well in later years. In 1872 he came to Glasgow as manager to Messrs Mirrlees, Tait & Watson, manufacturers of sugar machinery. In 1881 he became a partner of the new firm of Mirrlees, Watson & Co., and became a director of the Mirrlees, Watson & Yaryan Co., Ltd., which took over the business of Messrs Mirrlees, Watson & Co. in 1889. He was also a partner of Messrs Watson, Laidlaw & Co., of Glasgow.

The greater part of his professional work was devoted to the design and improvement of sugar making and sugar refining machinery. He studied the requirements of the sugar trade in many countries and under many conditions. His aptitude for making friends and his application to any difficult or interesting problem which he encountered, rendered his technical correspondence large and most interesting, and, to the last, among those who knew him he was looked to as an authority on his own subject, though his naturally modest character kept him from the publicity he deserved but did not seek.

He died suddenly of apoplexy on June 2nd, 1900, while on a voyage to the Argentine Republic, and was buried in the English cemetery at Corunna.

Mr Robertson joined the Institution as a member in 1884.

PETER STEWART was born in Glasgow on 11th August, 1834. He served an apprenticeship to Messrs W. Cook & Co., and acquired a knowledge of mechanical drawing under the late Mr Robert Harvey, subsequently succeeding him as teacher of that subject in the Glasgow Mechanics Institution. After being a short time in the service of Messrs A. W. Smith and Co., Mr Stewart was appointed engineer and works manager to the Tharsis Sulphur and Copper Company, a position he occupied for upwards of thirty years. At the end of June, 1900, he left home for a short holiday, and, after spending a few days at Kingussie, journeyed to Inverness, where he died suddenly on the 3rd July, 1900. He took a keen interest in the affairs of the Institution, and, conjointly with Mr W. A. Charlton, acted for many years as auditor of the Institution accounts.

Mr Stewart joined the Institution as a member in 1874.

Sir WILLIAM RENNY WATSON, of Braco Castle, died at Edinburgh on 7th April, 1900. Born in 1838 at Hawick, he served an apprenticeship to engineering with Messrs James Melrose & Sons there, after which he spent a year with Messrs Gourlay Brothers, Dundee, and thereafter, till 1868, worked in the employment of Messrs Platt Brothers & Co., Oldham, latterly as their Glasgow representative. In 1868 he joined the firm of Messrs Mirrlees & Tait, which then became Messrs Mirrlees, Tait & Watson, and is now the Mirrlees, Watson & Yaryan Company, Limited. He was also a partner of the firm of Messrs Watson, Laidlaw & Co. For the last thirty years he was one of the foremost figures in engineering circles in the west of Scotland, and his name and strong personality were well known in England, on the continent, and in America, and he was universally recognised as deservedly a leader in his profession. He acted for many years as a director, and latterly as chairman, of the Glasgow and South-Western Railway Company, and also as a director of the National Bank of Scotland.

Sir Renny took a prominent part in philanthropic and educational movements in Glasgow, and did his full share of municipal work. He was a promoter and chairman of governors of the Victoria Infirmary, a governor of the Glasgow and West of Scotland Technical College, served on the City Council, and was at one time a member of the Clyde Navigation Trust. He took a keen interest in the modern developments of science and literature. In recognition of his eminence as an engineer, and of his prominence as a citizen, he was knighted in 1892.

Sir Renny Watson joined the Institution as a member in 1864.

Alexander Hall Wilson was born at Aberdeen in 1840, and was educated at the Grammar School in that city. On leaving school he gained practical experience in shipbuilding under his uncle, in the shipyard of Messrs Alexander Hall & Co.; and after completing his apprenticeship he came to Glasgow to acquire a knowledge of iron shipbuilding, then in its infancy, and spent a few years in the shipyard of Messrs Barclay, Curle & Co. Returning to Aberdeen in 1864 he became manager of the shipbuilding department of Messrs Hall, Russell & Co., and started iron shipbuilding in that establishment. Soon thereafter he was assumed a partner in that firm, and spent the remainder of his life in extending and developing its business. He was not only a capable designer, but was thoroughly familiar with every detail in connection with ship construction.

While health and strength allowed, Mr Wilson took an active share in the public work of his native city. For nine years he was a member of the Harbour Board, he also rendered praiseworthy service in connection with various charitable organisations, and for a number of years was director of the Town and County Bank.

He left Aberdeen in the middle of November, 1899, for the Riviera. There his strength declined, and he died at Mentone on 25th December, 1899.

Associate.

George Smith, senior partner of the old-established ship-owning firm of Messrs George Smith & Co., "City Line," died at "Glenmorag," Dunoon, on 2nd November, 1899. Mr Smith, a native of Glasgow, was educated at the High School, and, on attaining his majority, he entered the firm of Geo. Smith & Sons, of which his father and uncle were then the partners. Through the opening of the Suez Canal, the large fleet of sailing ships owned by the firm had to be displaced by steamers, and in the new development of the Eastern trade Mr Smith took a leading part. The death of his uncle and father left him, while yet under thirty years of age, the head of the firm. Under his able guidance its progress was steady and sure, and the name of the firm for probity and a high sense of justice in all its business relations was fully maintained. One of the pleasing features of his character was the close personal interest he took in all his employees; while seamen found in him a true friend, and his energies were constantly devoted to their welfare. He was one of the founders of the Sailors' Orphanage, and the last public work which engaged his attention was the inauguration of the movement for the assistance of aged seamen of the port of Glasgow.

Mr Smith was held in high regard in his native city for his unostentatious manner, his business ability, and his generous support of all good and worthy objects. He was a member of the Clyde Trust for ten years, a Director of the Chamber of Commerce, and a Justice of the Peace.

Mr Smith joined the Institution as an associate in 1876.

LIST OF HONORARY MEMBERS, MEMBERS, ASSOCIATES, AND GRADUATES

AT CLOSE OF SESSION 1899-1900.

HONORARY MEMBERS.

	DATE OF ELECTION.
KELVIN Lord, A.M., LL.D., D.C.L.. F.R.SS.L. and E., Professor of Natural Philosophy in the University of Glasgow,	1859
ARMSTRONG, Lord, C.B., LL.D., D.C.L., F.R.S., Newcastle-on-Tyne,	1884
BRASSEY, Lord, K.C.B., D.C.L., 4 Great George street, Westminster, London, S.W.,	1891
BLYSTHWOOD, Lord, Blythswood, Renfrewshire,	1891
KENNEDY, Professor A. B. W., LL.D., F.R.S., 17 Victoria street, London, S.W.,	1891
MURRAY, Sir DIGBY, Bart., Hothfield, Parkstone, Dorset,	1891
WHITE, Sir WILLIAM HENRY, K.C.B., F.R.S., LL.D., Admiralty, London,	1894
DURSTON, Sir A. J., K.C.B., Admiralty, London,	1896
FROUDE, R. E., F.R.S., Admiralty Experiment works, Gosport,	1897

MEMBERS.

	DATE OF ELECTION.
AAMUNDSEN, JENS L., 57 Classensgade, 2 Sal, Copenhagen, Denmark,	24 Jan., 1899
ABERCROMBIE, ROBERT GRAHAM, Broad Street Engine Works, Alloa,	21 Mar., 1899
ADAM, J. MILLEN, Ibrox Iron works, Glasgow,	G. 25 Mar., 1890 M. 22 Jan., 1895
ADAMSON, ALEXANDER, Croslands, Furness Abbey, Barrow-in-Furness,	20 Feb., 1900
ADAMSON, JAMES, St. Quivox, Stopford road, Upton Manor, Essex,	23 Apr., 1889
AILSA *(The most Honourable the Marquis of)*, Culzean castle, Maybole,	25 Jan.. 1898

Names marked thus * were Members of Scottish Shipbuilders' Association at Incorporation with Institution, 1865.

Names marked thus † are Life Members.

AITCHISON, WILLIAM, 6 Midlothian drive, Shawlands, Glasgow,	22 Oct., 1889
AITKEN, H. WALLACE, 140 Bath Street, Glasgow,	G. 24 Jan., 1888 M. 24 Jan., 1899
AITON, J. ARTHUR, 25 Laurence Pounteney lane, Cannon street, London, E.C.,	24 Nov., 1896
ALLAN, J. R., Bintang, Dumbreck, Glasgow,	25 Jan., 1888
ALLAN, JOHN M.,	21 Jan., 1890
ALLAN, ROBERT, Demerara foundry, George Town, Demerara,	30 Apr., 1895
ALLAN, ROBERT, Engineer and Shipbuilder, Singapore, S. Settlements,	26 Apr., 1898
ALLAN, WILLIAM, M.P., Scotia Engine works, Sunderland,	20 Jan., 1869
ALLEY, STEPHEN E., Langside house, Langside, Glasgow,	23 Nov., 1897
†ALLIOTT, JAMES B., The Park, Nottingham,	21 Dec., 1864
ALSTON, WILLIAM M., 24 Sardinia terrace, Hillhead, Glasgow,	G. 15 Feb., 1865 M. 18 Dec., 1877
†AMOS, ALEXANDER, Public Library of N.S.W., Sydney, New South Wales,	21 Dec., 1886
†AMOS, ALEXANDER, Jun.,	21 Dec., 1886
†ANDERSON, E. ANDREW, c/o Clinton, 13 Holmhead street, Glasgow,	21 Feb., 1899
ANDERSON, JAMES, 100 Clyde street, Glasgow,	G. 24 Feb., 1874 M. 23 Nov., 1880
ANDERSON, JAMES H., Caledonian Railway, Glasgow,	20 Dec., 1892
ANDERSON, ROBERT, Clyde Street, Renfrew,	26 Jan., 1897
ANDERSON, WILLIAM SMITH, Bogie Wood, Port-Glasgow,	21 Nov., 1899
ANDREWS, H. W., 128 Hope street, Glasgow,	A. 21 Dec., 1897 M. 24 Oct., 1899
ANDREWS, JAMES, Holm Foundry, Cathcart,	22 Nov., 1898
ANIS, Professor MOHAMED, Bey, Ministère des Travaux Publics, Cairo,	24 Apr., 1894
ANGUS, ROBERT, Lugar, Ayrshire,	28 Nov., 1860
ARCHER, W. DAVID, 47 Croham road, Croyden, Surrey,	20 Dec., 1887
ARNOT, WILLIAM, 79 West Regent street, Glasgow,	23 Jan., 1894
ARROL, THOMAS A., Germiston works, Glasgow,	21 Dec., 1875
ARROL, THOMAS, Jun., Oswald gardens, Scotstounhill, Glasgow,	20 Nov., 1894
†ARROL, Sir WILLIAM, LL.D., M.P., Dalmarnock Iron works, Glasgow,	27 Jan., 1885
AULD, JOHN, Whitevale foundry, Glasgow,	28 Apr., 1885
AUSTIN, WM. R., 11 University avenue, Glasgow,	23 Feb., 1897

BAIN, WILLIAM N., 40 St. Enoch square, Glasgow,	24 Feb., 1880
BAIN, WILLIAM P. C., Lochrin Iron works, Coatbridge,	28 Apr., 1891
BAIRD, ALLAN W., Eastwood villa, St. Andrew's drive, Pollokshields, Glasgow,	25 Oct., 1881
BALDERSTON, JAMES, Anchor mills, Paisley,	25 Jan., 1898
BALFOUR, GEORGE, Messrs London Bros., Dundee,	21 Mar., 1899
BALLINGALL, DAVID, 33 Dudley crescent, Newhaven road, Edinburgh,	27 Oct., 1896
BAMFORD, HARRY, M.Sc., The University, Glasgow,	24 Nov., 1896
BARCLAY, GEORGE, Vulcan works, Paisley,	25 Jan., 1898
BARMAN, HENRY D. D., 27 University avenue, Glasgow,	G. 24 Apr., 1888 M. 24 Oct., 1899
BARNETT, J. R., Westfield, Crookston,	22 Dec., 1896
BARNETT, MICHAEL R., Engineer's Office, Reservoir works, Cray, near Swansea,	22 Nov., 1887
BARR, Professor ARCHIBALD, D.Sc., Royston, Dowanhill, Glasgow,	21 Mar., 1882
BARR, JOHN, Glenfield Company, Kilmarnock,	A. 28 Oct., 1883 M. 25 Jan., 1898
BAXTER, GEORGE H., Clyde Navigation works, Dalmuir,	22 Mar., 1881
BAXTER, P. M'L., Copland works, Govan,	G. 22 Dec., 1885 M. 15 June, 1898
BEARDMORE, JOSEPH, Parkhead forge, Glasgow,	27 Oct., 1896
BEARDMORE, JOSEPH GEORGE, Parkhead Forge, Glasgow,	22 Nov., 1898
BEARDMORE, WILLIAM, Parkhead forge, Glasgow,	27 Oct., 1896
BEGBIE, WILLIAM, P.O. Box 459, Johannesburg, South Africa,	15 June, 1898
BELL, CHARLES, The Birches, Stirling,	26 Jan., 1875
*†BELL, DAVID, 19 Eton place, Hillhead, Glasgow,	
BELL, IMRIE, 49 Dingwall road, Croydon, Surrey,	23 Mar., 1880
BELL, STUART, 65 Bath street, Glasgow,	26 Feb., 1895
BELL, THOMAS, Messrs John Brown & Co., Ltd., Clydebank,	G. 26 Apr., 1887 M. 27 Apr., 1897
BELL, W. REID, Box 191, Lourenço Marques, Delagoa Bay, South Africa,	22 Jan., 1889
BENNIE, H. OSBOURNE, Clyde Engine works, Polmadie, Glasgow,	25 Jan., 1898
BENNIE, JOHN, Auldhousfield, Eastwood, Pollokshaws,	22 Feb., 1898
BERGIUS, W. C., 77 Queen street, Glasgow,	23 Jan., 1900
BEVERIDGE, RICHARD JAMES, 53 Waring street, Belfast,	22 Feb., 1898
BIGGART, ANDREW S., 279 Nithsdale road, Pollokshields, Glasgow,	G. 20 Mar., 1883 M. 25 Nov., 1884

BILES, Professor JOHN HARVARD, The University, Glasgow,	25 Mar., 1884
BINNEY, WM. H., Marine Superintendent, Holyhead,	26 Jan., 1897
BIRD, JOHN R., 10 Morrison street, Glasgow,	25 Mar., 1890
BISHOP, ALEXANDER, 3 Germiston street, Glasgow,	G. 24 Mar., 1885 M. 24 Jan., 1899
BLACK, DAVID, 12 Huntly terrace, Shettleston,	22 Mar., 1898
BLAIR, DAVID A., Scotland street Copper works, Glasgow,	23 Mar., 1897
BLAIR, GEORGE, 16 Albert road (East), Crosshill, Glasgow,	21 Nov., 1899
BLAIR, GEO., Jun., 38 Queen street, Glasgow,	G. 22 Jan., 1884 M. 23 Feb., 1897
BLAIR, GEORGE M'L., 129 Trongate, Glasgow,	17 Feb., 1869
BLAIR, H. MACLELLAN, Sentinel works, Polmadie, Glasgow,	G. 22 Jan., 1884 M. 22 Oct., 1889
BLAIR, JAMES M., Williamcraigs, Linlithgowshire,	27 Mar., 1867
BONE, WILLIAM L., Ant and Bee works, West Gorton, Manchester,	23 Oct., 1883
BORROWMAN, WILLIAM C., Newstead, West Hartlepool,	G. 27 Oct., 1885 M. 26 Oct., 1897
BOST, W. D. ASHTON, Adelphi house, Paisley,	25 Jan., 1898
BOW, WILLIAM, Thistle works, Paisley,	27 Jan., 1891
BOWDEN, GEORGE HARLAND, 53 Bothwell street, Glasgow,	21 Feb., 1899
BOWSER, CHARLES HOWARD, Charles street, St. Rollox, Glasgow,	21 Mar., 1899
BOYD, WILLIAM, The Tharsis Sulphur and Copper Co., Ltd., Hebburn-on-Tyne,	24 Oct., 1899
BRACE, GEORGE R., 25 Water street, Liverpool,	25 Mar., 1890
BRAY, E. N., 81 St. George's place, Glasgow,	22 Nov., 1898
BRIER, HENRY, 1 Miskin road, Dartford, Kent,	22 Dec., 1891
BROADFOOT, JAMES, Lymehurst, Jordanhill,	G. 23 Dec., 1873 M. 22 Jan., 1884
BROADFOOT, WILLIAM R., Inchholm works, Whiteinch,	25 Jan., 1898
BROCK, HENRY W., Engine works, Dumbarton,	30 Apr., 1895
*BROCK, WALTER, Engine works, Dumbarton,	26 Apr., 1865
BROCK, WALTER, Jun., Levenford, Dumbarton,	27 Oct., 1896
BROOM, THOMAS M., Oakfield, East Greenock,	25 Apr., 1893
BROWN, ALEX. D., Dry Dock, St John's, Newfoundland,	22 Dec., 1896
BROWN, ALEXANDER T., 18 Glencairn drive, Pollokshields, Glasgow,	G. 25 Feb., 1879 M. 27 Oct., 1891
*BROWN, ANDREW, London works, Renfrew,	16 Feb., 1859
BROWN, ANDREW M'N., Strathclyde, Dalkeith avenue, Dumbreck, Glasgow,	G. 25 Jan., 1876 M. 24 Nov., 1885

Brown, Ebenezer Hall-, Helen street, Engine works, Govan, Glasgow,	G. 18 Dec., 1883 M. 26 Feb., 1895
Brown, George, Kirklee, Dumbarton,	23 Mar., 1886
Brown, James, Engine Department, Astilleros del Nervión, Bilbao, Spain,	G. 26 Oct., 1886 M. 26 Jan., 1892
Brown, James M'N., Glenfruin, Renfrew,	26 Jan., 1897
Brown, Matthew T., B.Sc., 233 St. Vincent street, Glasgow,	G. 25 Jan., 1881 M. 18 Dec., 1894
Brown, Walter, Monkdyke, Renfrew,	28 Apr., 1885
Brown, William, Meadowflat, Renfrew,	G. 27 Jan., 1874 M. 22 Jan., 1884
Brown, William, Albion works, Woodville street, Govan, Glasgow,	21 Dec., 1880
Brown, William, Messrs Dubs & Co., Glasgow Locomotive works, Glasgow,	17 Dec., 1889
Brown, William Dewar, 22 Ranelagh villas, Hove, Sussex,	25 Mar., 1890
Brown, William S., Jr., 67 Washington street, Glasgow,	21 Dec., 1897
Bruce-Kingsmill, J., Capt., R.A.,	21 Dec., 1897
Bruhn, Johannes, 49 Sydenham park, Sydenham, London, S.E.,	G. 24 Oct., 1893 M. 22 Feb., 1898
Bryson, William Alexander, Chambers, 16 Charlotte street, Leith,	27 Oct., 1896
Buchanan, John H., 5 Oswald street, Glasgow,	23 Jan., 1900
Buckwell, George W., Board of Trade Offices, Sunderland,	27 Apr., 1897
Budenberg, Christian Frederick, 31 Whitworth street, Manchester,	20 Dec., 1898
Burden, Alfred George Newkey, Messrs Harvey & Co., Hayle,	20 Feb., 1900
Burns, James W., 19 Clifford street, Glasgow,	21 Dec., 1880
Burt, Thomas, 60 St. Vincent crescent, Glasgow,	22 Mar., 1881
Butters, Michael W., 20 Waterloo street, Glasgow,	24 Oct., 1899

Caird, Arthur, Messrs Caird & Co., Ltd., Greenock,	27 Oct., 1896
Caird, Edward B., 777 Commercial road, Limehouse, London,	29 Oct., 1878
†**Caird, Patrick T.**, Messrs Caird & Co., Ltd., Greenock,	27 Oct., 1896
Caird, Robert, LL.D., Messrs Caird & Co., Ltd., Greenock,	20 Feb., 1894
Calderwood, William T., Stanley villa, Kilmailing, Cathcart,	25 Jan., 1898
Caldwell, James, 130 Elliot street, Glasgow,	17 Dec., 1878
Cameron, Donald, City Surveyor's office, Exeter,	25 Feb., 1890

CAMERON, J. C., 24 Pollok street, Glasgow,	21 Dec., 1875
CAMERON, JOHN B., 111 Union street, Glasgow,	24 Mar., 1885
CAMERON, WILLIAM, 6 Gordon terrace, Shettleston, Glasgow,	25 Mar., 1890
CAMPBELL, DUNCAN, Carntyne foundry and Engineering works, Parkhead, Glasgow,	23 Jan., 1900
CAMPBELL, GEORGE, Albany villa, Orrell lane, Aintree, Liverpool,	22 Mar., 1898
CAMPBELL, JOHN, 8 Broomhill drive, Partick,	21 Jan., 1890
CAMPBELL, WALTER HOPE, 42 Krestchatik, Kieff, South Russia,	25 Apr., 1899
CAREY, EVELYN G., 4 Sunnyside avenue, Uddingston,	22 Oct., 1889
CARLAW, ALEX. L., 11 Finnieston street, Glasgow,	24 Dec., 1895
CARLAW, DAVID, Jun., 11 Finnieston street, Glasgow,	24 Dec., 1895
CARLAW, JAMES W., 11 Finnieston street, Glasgow,	24 Dec., 1895
CARRUTHERS, JOHN H., Ashton, Queen Mary avenue, Crosshill, Glasgow,	22 Nov., 1881
CHALK, JAMES,	23 Feb., 1892
CHALMERS, WALTER, 3 Barloch terrace, Milngavie,	23 Jan., 1900
CHAMEN, W. A., 75 Waterloo street, Glasgow,	22 Feb., 1898
CHRISTIE, JOHN, Corporation Electricity Works, Brighton,	22 Nov., 1898
CHRISTIE, R. BARCLAY, Messrs M‘Lay & M‘Intyre, 21 Bothwell street, Glasgow,	25 Apr., 1893
CHRISTISON, GEORGE, 13 Cambridge drive, Glasgow,	22 Feb., 1898
CLARK, GEORGE ALEXANDER, 34 Ann street, Glasgow,	22 Nov., 1898
CLARK, JAMES LESTER, 75 Buchanan street, Glasgow,	24 Nov., 1896
CLARK, JOHN, British India Steam Navigation Co., 9 Throgmorton avenue, London, E.C.,	23 Jan., 1883
CLARK, WILLIAM, 208 St. Vincent street, Glasgow,	25 Apr., 1893
CLARK, WILLIAM, 88 Renfield street, Glasgow,	22 Dec., 1896
CLARK, WILLIAM GRAHAM, 27 Lawton road, Waterloo, Liverpool,	22 Feb., 1898
CLARKSON, CHARLES, Milner's Safe Co., Ltd., Liverpool,	27 Oct., 1891
CLEGHORN, ALEXANDER, 10 Whittinghame drive, Kelvinside, Glasgow,	22 Nov., 1892
COATS, JAMES, Talara, Katharine drive, Govan,	21 Dec., 1897
COCHRAN, JAMES T., Messrs Cochran & Co., Annan, N.B.,	26 Feb., 1884
COCHRANE, JOHN, Grahamston foundry, Barrhead,	25 Mar., 1890
COCKBURN, GEORGE, Cardonald, near Glasgow,	25 Oct., 1881
COCKBURN, ROBERT, Cumbrae House, Dumbreck, Glasgow,	25 Jan., 1898
COLLIE, CHARLES, 19-21 Eaglesham street, Plantation, Glasgow,	26 Apr., 1898

Colville, Archibald, 149 Govan road, Glasgow,	23 Jan., 1900
Colville, Archibald, Motherwell,	27 Oct., 1896
Colville, David, Jun., Jerviston house, Motherwell,	27 Oct., 1896
Connell, Charles, Whiteinch, Glasgow,	G. 19 Dec., 1876 M. 25 Mar., 1884
Conner, Alexander, 41 Thornwood drive, Partick,	G. 26 Feb., 1884 M. 24 Jan., 1899
Conner, Benjamin, 196 St. Vincent street, Glasgow,	G. 22 Dec., 1885 M. 26 Oct., 1897
Conner, James, Assistant Locomotive Engineer, Highland Railway, Inverness,	G. 18 Dec., 1877 M. 24 Nov., 1885
Cooper, James, Aberdeen Steam Navigation Company, Aberdeen,	19 Dec., 1893
Copeland, James, 24 George square, Glasgow,	17 Feb., 1864
Copestake, S. G. G., Glasgow Locomotive works, Little Govan, Glasgow,	11 Mar., 1868
†Copland, William R., 146 W. Regent street, Glasgow,	20 Jan., 1864
Cormack, John Dewar, B.Sc., The University, Glasgow,	24 Nov., 1896
Coulson, W. Arthur, 47 King street, Mile-end, Glasgow,	15 June, 1898
Couper, Sinclair, Moore Park Boiler works, Govan, Glasgow,	G. 21 Dec., 1880 M. 27 Oct., 1891
Courtier-Dutton, W. T., Shipbuilder and Engineer, 69 St. Vincent street, Glasgow,	22 Dec., 1896
Coutts, Francis, 25 Roslin Terrace, Aberdeen.	G. 27 Oct., 1885 M. 24 Jan., 1899
Cowan, David, Clevedon, Cove, Dumbartonshire,	24 Apr., 1900
Cowan, John, Ingleholme, Greenock,	27 Apr., 1897
Cowan, M'Taggart, 109 Bath street, Glasgow,	28 Nov., 1866
†Cowie, William, 48 Church street, Coatbridge,	20 Feb., 1900
Craig, Archibald Fulton, Belmont, Paisley,	25 Jan., 1898
Craig, James, Lloyd's Registry, 14 Cross-shore street, Greenock,	G. 20 Dec., 1892 M. 21 Dec., 1897
Craig, John, Rosevale, Port-Glasgow,	26 Mar., 1895
Crawford, James, 30 Ardgowan street, Greenock,	27 Oct., 1896
Crawford, Samuel, Messrs John Scott & Company, Kinghorn,	18 Dec., 1883
Crichton, James L., 3 East Park terrace, Maryhill, Glasgow,	18 Dec., 1894
Crockatt, William, 179 Nithsdale road, Pollokshields, Glasgow,	22 Mar., 1881
Crosher, John, 87 Portman street, Kinning Park, Glasgow,	24 Jan., 1899
Crosher, William, 31 Great Wellington street, Kinning Park, Glasgow,	24 Jan., 1899

Crow, John, Engineer, 236 Nithsdale road, Pollokshields, Glasgow,	25 Jan., 1898
Cruickshank, J. E., 157 Hope street, Glasgow,	24 Jan., 1899
Cumming, Wm. J. L., Motherwell Bridge Co., Motherwell,	24 Jan., 1899
Cunningham, Peter N., Easter house, Kennyhill, Cumbernauld road, Glasgow,	28 Dec., 1884
Currie, James, 16 Bernard street, Leith,	20 Jan., 1869
Cuthill, William, Beechwood, Uddingston,	24 Nov., 1896

Darroch, John, 27 South Kinning place, Paisley road, Glasgow,	24 Jan., 1899
Davidson, David, 17 Regent Park square, Strathbungo, Glasgow,	G. 22 Mar., 1881 M. 18 Dec., 1888
Davie, James, 69 Albert drive, Crosshill, Glasgow.	19 Dec., 1899
Davis, Charles M., Leslie house, Pollokshields, Glasgow,	24 Apr., 1900
Davison, Thomas, 248 Bath street, Glasgow,	11 Dec., 1861
Delacour, Frank Philip, Baku, Russia,	24 Apr., 1900
Delmaar, Frederick Anthony, Mechanical Engineer, Sourabaya, Netherlands East Indies,	G. 24 Apr., 1883 M. 24 Oct., 1899
Dempster, James, 7 Knowe terrace, Pollokshields,	24 Jan., 1899
Dempster, John, 49 Robertson street, Glasgow,	22 Feb., 1898
Denholm, James, 5 Derby terrace, Sandyford street, Glasgow,	21 Nov., 1883
Denholm, William, Meadowside Shipbuilding yard, Partick, Glasgow,	G. 18 Dec., 1883 M. 21 Nov., 1893
Denny, Archibald, Braehead, Dumbarton,	21 Feb., 1888
Denny, James, Engine works, Dumbarton,	25 Oct., 1887
Denny, Col. John M., M.P., Garmoyle, Dumbarton,	27 Oct., 1898
Denny, Leslie, Leven Shipyard, Dumbarton,	30 Apr., 1895
Denny, Peter, Bellfield, Dumbarton,	21 Feb., 1888
Dick, Frank W., Palmer's Steel works, Jarrow-on-Tyne,	19 Mar., 1878
Dickson, B. Gillespie, c/o J. T. Sellar, 8 Blackfriars street, Perth,	19 Nov., 1890
Dickson, William, Lanarkshire Steel Co., Motherwell,	15 June, 1898
Dimmock, John Wingrave, 2 Grantly gardens, Shawlands, Glasgow,	22 Mar., 1898
Dixon, James S., 127 St. Vincent street, Glasgow,	G. 24 Dec., 1873 M. 22 Jan., 1878
Dixon, Walter, 59 Bath street, Glasgow,	26 Feb., 1895
Dixon, William, H., 59 Bath street, Glasgow,	A. 15 June, 1898 M. 25 Oct., 1898

Dobson, William, The Chesters, Jesmond, Newcastle-on-Tyne,		17 Jan., 1871
D'Oliveira, Raphael Chrysostome, Campos Rio de Janeiro, Brazil,		20 Feb., 1900
Donald, B. B., 275 Onslow drive, Dennistoun, Glasgow,	G. M.	20 Mar., 1888 24 Jan., 1899
Donald, David P., Johnstone,		21 Mar., 1899
Donald, James, Abbey works, Paisley,		20 Jan., 1864
Donald, Robert Hanna, Abbey works, Paisley,		22 Nov., 1892
Donaldson, James, Almond villa, Renfrew,		25 Jan., 1876
Downie, A. Marshall, London road Iron works, Glasgow,		21 Nov., 1899
Doyle, Patrick, F.R.S.E., 7 Government place, Calcutta, India,		23 Nov., 1886
Drew, Alexander, 22 Rutland square, Edinburgh,		29 Apr., 1890
Drummond, Walter, The Glasgow Railway Engineering works, Govan, Glasgow,		26 Mar., 1895
Drysdale, John W. W., 37 Westercraigs, Dennistoun, Glasgow,		23 Dec., 1884
Dubs, Charles R., Glasgow Locomotive works, Glasgow,		24 Oct., 1882
Duncan, George F., 209 Hillhouse gardens, Broomfield road, Springburn, Glasgow,	G. M.	23 Nov., 1886 20 Mar., 1894
Duncan, Hugh, London road Iron works, Glasgow,		15 June, 1898
Duncan, John, Ardenclutha, Port-Glasgow,		23 Nov., 1886
Duncan, Robert, Whitefield Engine works, Govan, Glasgow,		25 Jan., 1881
Duncan, Robert, Maarowa crescent, Wellington, New Zealand,		24 Oct., 1899
Dunlop, David John, Inch works, Port-Glasgow,		23 Nov., 1869
Dunlop, John G., Clydebank, Dumbartonshire,		23 Jan., 1877
Dunlop, Thomas, 22 Derby crescent, Glasgow.		19 Dec., 1899
Dunlop, William, N. Odero fer Alesso, Sestri Ponento, Italy,	G. M.	22 Jan., 1884 24 Jan., 1899
†**Dunn, Peter L.**, 815 Battery street, San Francisco. U.S.A.,		26 Oct., 1886
Dyer, Henry, D. Sc., M. A., 8 Highburgh terrace, Dowanhill, Glasgow,		23 Oct., 1883

Easton, Wm. Cecil, B.Sc., City Engineer's Office, Glasgow,	22 Feb., 1898
Edwards, Charles, 41 Westbourne gardens, Glasgow,	26 Oct., 1897
Elgar, Francis, LL.D., F.R.SS., L.& E., Fairfield Shipbuilding and Engineering Co., Limited, 113 Cannon street, London, E.C.,	24 Feb., 1885

ELLIOTT, ROBERT, B.Sc., Lloyd's Surveyor, Greenock,	G. 24 Mar., 1885 M. 21 Feb., 1898
ELSEE, THOMAS, c/o W. S. Brown, Esq., Clydeside Tube Co., 53 Bothwell street, Glasgow,	28 Jan., 1896
EVANS, MALCOLM T., 3 Ashville, Skegoniel avenue, Belfast,	23 Feb., 1897
EWEN, PETER, The Barrowfield Ironworks, Ltd., Craigielea, Bothwell,	21 Mar., 1899
FAIRWEATHER, WALLACE, 62 St. Vincent street, Glasgow,	24 Apr., 1894
FEDDEN, SAMUEL EDGAR, Corporation Electric Supply Department, Commercial street, Sheffield,	21 Mar., 1899
FERGUSON, DANIEL, 27 Oswald street, Glasgow,	26 Apr., 1898
FERGUSON, J. STRATHEARN, 19 Arundel drive, Langside, Glasgow,	23 Nov., 1897
FERGUSON, JOHN JAMES, Blax-Tulloch, Kirn,	24 Jan., 1899
FERGUSON, PETER, Phœnix works, Paisley,	22 Oct., 1889
FERGUSON, WILFRED H., 4 Thornwood terrace, Partick,	22 Nov., 1898
FERGUSON, WILLIAM D., Albert villa, Ravenhill road, Belfast,	G. 27 Jan., 1885 M. 20 Mar., 1894
FERGUSON, WILLIAM R., Messrs Barclay, Curle & Co., Ltd., Whiteinch, Glasgow,	G. 22 Feb., 1881 M. 22 Jan., 1895
FERRIER, JAMES, China Merchants Steam Nav. Co., Shanghai,	22 Dec., 1896
FIELDEN, IMMER, 420 Holderness road, Hull,	24 Feb., 1874
FINDLAY, ALEXANDER, Parkneuk Iron works, Motherwell,	27 Jan., 1880
FINLAYSON, FINLAY, Clydeside Tube works, Whifflet, Coatbridge,	23 Dec., 1884
FISHER, ANDREW, St. Mirren's Engine works, Paisley,	25 Jan., 1898
FLEMING, ANDREW E., Kandy, Ceylon,	23 Jan., 1894
FLEMING, GEORGE E., Messrs Dewrance & Co., 163 St. Vincent street, Glasgow,	27 Oct., 1896
FLEMING, JOHN, Dellburn works, Motherwell,	24 Jan., 1899
FLEMING, WILLIAM, 10 Heathfield terrace, Springburn, Glasgow,	25 Jan., 1898
FLETCHER, JAMES, 15 Kildonan terrace, Paisley road, Ibrox, Glasgow,	G. 28 Jan., 1896 M. 23 Nov., 1897
FLETT, GEORGE L., 5 Abercromby terrace, Ibrox, Glasgow,	22 Jan., 1895
FORSYTH, LAWSON, 97 St. James road, Glasgow,	18 Dec., 1883
FOSTER, JAMES, 11 St. Andrew's drive, Pollokshields, Glasgow,	26 Jan., 1897
FOULIS, WILLIAM, City Chambers, John Street, Glasgow,	18 Jan., 1870

FOX, SAMSON, Blairquhan Castle, Maybole,	2 Nov., 1880
FRAME, JAMES, 6 Kilmailing terrace, Cathcart, Glasgow,	23 Feb., 1897
FRASER, WILLIAM, 121 North Montrose street, Glasgow,	19 Dec., 1893
FRYER, TOM J., "Brookdean" Hope, Sheffield,	G. 18 Dec., 1894 M. 20 Dec., 1898
FUJII, JERUGORS, c/o Admiralty, Tokio, Japan,	21 Feb., 1899
FULLERTON, ALEX., Vulcan Works, Paisley,	22 Dec., 1896

GALE, EDMUND WILLIAM, c/o Mrs Clinton, 4 Kilbowie cottages, Clydebank,	23 Nov., 1897
†GALE, JAS. M., Corporation Water works, City Chambers, Glasgow,	24 Nov., 1858
GALE, WILLIAM M., 18 Huntly gardens, Kelvinside, Glasgow,	24 Jan., 1893
GALLOWAY, CHARLES S., Greenwood City, Vancouver, B.C.,	22 Jan., 1895
GARDNER, WALTER, 8 Percy street, Ibrox, Glasgow,	20 Dec., 1898
GEARING, ERNEST, Fenshurst, Clarence drive, Harrogate,	20 Mar., 1888
GEMMELL, E. W., Board of Trade Offices, 7 York street, Glasgow,	18 Dec., 1888
GEMMELL, THOMAS, Electric Lighting Department, St. Enoch Station, Glasgow,	24 Oct., 1899
GIBB, ANDREW, Garthland, Westcombe Park road, Blackheath, London, S.E.,	G. 23 Dec., 1873 M. 21 Mar., 1882
GIFFORD, PATERSON, 101 St. Vincent street, Glasgow,	23 Nov., 1886
GILCHRIST, JAMES, Stobcross Engine works, Finnieston quay, Glasgow,	G. 26 Dec., 1866 M. 29 Oct., 1878
GILLESPIE, ANDREW, 34 St. Enoch square, Glasgow,	20 Nov., 1894
GILLESPIE, JAMES, 21 Minerva street, Glasgow,	G. 24 Feb., 1874 M. 24 Mar., 1891
GILMOUR, JOHN H., River Bank, Irvine,	20 Feb., 1900
GLASGOW, JAMES, Fernlea, Paisley,	25 Jan., 1898
†GOODWIN, GILBERT S., Alexandra buildings, James street, Liverpool,	28 Mar., 1866
GORDON, JOHN, 152 Craigpark street, Glasgow,	26 Mar., 1895
GORRIE, JAMES M., 9 Park drive, Whiteinch,	22 Nov., 1898
GOURLAY, H. GARRET, Dundee foundry, Dundee,	25 Apr., 1882
GOVAN, ALEXANDER, 346 Great Eastern road, Glasgow,	24 Oct., 1899
GOW, GEORGE, Bellevue road, Mount Eden, Auckland, New Zealand,	20 Mar., 1900
GOWAN, A, B., Messrs Vickers, Sons & Maxim, Barrow-in-Furness,	G. 24 Jan., 1882 M. 22 Jan., 1895

GRACIE, ALEX., Fairfield Shipbuilding and Engineering Company, Govan,	G. 26 Feb., 1884 M. 24 Nov., 1896
GRAHAM, DAVID R., Messrs A. Stephen & Sons, Engine Department, Linthouse, Glasgow,	25 Apr., 1893
GRAHAM, JOHN, 60 Cambridge drive, Kelvinside, Glasgow,	25 Jan., 1898
GRAHAM, WALTER, Kilblain Engine works, Nicholson street, Greenock,	G. 28 Jan., 1896 M. 15 June, 1898
GRANT, THOMAS M., 222 St. Vincent street, Glasgow,	25 Jan., 1876
GRAY, DAVID, 77 West Nile street, Glasgow,	21 Nov., 1899
GRAY, JAMES, Riverside, Old Cumnock, Ayrshire,	8 Jan., 1862
GRAY, WILLIAM, 2 Veir terrace, Dumbarton,	23 Feb., 1897
GRETCHIN, G. L., 10 Tschernomorskaia street, Odessa, Russia,	25 Jan., 1898
GRIEVE, JOHN, Engineer, Motherwell,	25 Jan., 1898
GROVES, L. JOHN, Engineer, Crinan Canal, Ardrishaig,	20 Dec., 1881
GUTHRIE, ALLAN, 17 Whittinghame drive, Glasgow,	23 Jan., 1900
GUTHRIE, JOHN, The Crown Iron works, Glasgow,	27 Oct., 1896

HAIGH, WILLIAM R., 6 Elmwood gardens, Jordanhill,	22 Dec., 1896
HALKET, JAMES P., Glengall Iron works, Millwall, London, E.,	26 Oct., 1897
HALL, WILLIAM, Shipbuilder, Aberdeen,	25 Jan., 1881
HALLEY, WILLIAM LIZARS, Lennoxlea, Dumbarton,	21 Dec., 1897
HAMILTON, ARCHIBALD, Clyde Navigation Chambers, Glasgow,	G. 24 Feb., 1874 M. 24 Nov., 1885
HAMILTON, CLAUD, 247 St. Vincent street, Glasgow,	15 June, 1898
HAMILTON, DAVID C., Clyde Shipping Company, 21 Carlton place, Glasgow,	G. 23 Dec., 1873 M. 22 Nov., 1881
HAMILTON, JAMES, Messrs R. Napier & Sons, Govan, Glasgow,	G. 26 Dec., 1863 M. 18 Mar., 1876
*HAMILTON, JOHN, 22 Athole gardens, Glasgow,	
HAMILTON, JOHN K., 53 Waterloo street, Glasgow,	15 May, 1900
HAMILTON, W. D., 116 St. Vincent street, Glasgow,	21 Mar., 1899
HARMAN, BRUCE, 35 Connaught road, Harlenden, London, N.W.,	G. 2 Nov., 1880 M. 22 Jan., 1884
HARRISON, J. E., 160 Hope street, Glasgow,	G. 26 Feb., 1889 M. 22 Feb., 1898
HART, P. CAMPBELL, John Finnie street, Kilmarnock,	24 Nov., 1896
HARVEY, JAMES, 224 West street, Glasgow,	24 Jan., 1899
HARVEY, JOHN H., Messrs Wm. Hamilton & Co , Port-Glasgow,	22 Feb., 1887

HARVEY, ROBERT, 224 West street, Glasgow,	24 Nov., 1896
HARVEY, THOMAS, Grangemouth Dockyard Co., Grangemouth,	19 Dec., 1899
HASTIE, WILLIAM, Kilblain Engine works, Greenock,	17 Jan., 1871
HAYWARD, THOMAS ANDREW, 18 Carrington street, Glasgow,	22 Mar., 1898
†HENDERSON, A. P., 30 Lancefield quay, Glasgow,	25 Nov., 1879
HENDERSON, FREDERICK N., Meadowside, Partick, Glasgow,	26 Mar., 1895
HENDERSON, J. BAILIE, Government Hydraulic Engineer, Brisbane, Queensland,	18 Dec., 1888
†HENDERSON, JOHN, Meadowside, Partick, Glasgow,	21 Jan., 1873
†HENDERSON, JOHN L.,	25 Nov., 1879
HENDERSON, WILLIAM STEWART, 6 Radnor street, Sandyford, Glasgow,	24 Nov., 1896
HENRY, ERENTZ, 13 Ann street, Hillhead, Glasgow,	20 Feb., 1900
HERRIOT, GEORGE, 24 Moray place, Strathbungo, Glasgow,	20 Feb., 1877
HERRIOT, W. SCOTT, The Calico Printers' Association, Ltd., 56 Mosley street, Manchester,	28 Oct., 1890
HETHERINGTON, EDWARD P., Messrs John Hetherington & Co, Ltd., Pollard street, Manchester,	22 Nov., 1892
HIDE, WILLIAM SEYMOUR, Messrs Amos & Smith, Albert Dock works, Hull,	18 Dec., 1888
HILL, THOMAS, Inzievar, Newlands, Langside, Glasgow,	22 Jan., 1895
HINES, JAMES, Dunedin lodge, Lenzie, Glasgow,	28 Jan., 1896
HODGART, JOHN, Lumsburn, Paisley,	22 Dec., 1896
HOGG, CHARLES P., 53 Bothwell street, Glasgow,	2 Nov., 1880
HOGG, JOHN, Victoria Engine works, Airdrie,	20 Mar., 1883
HOLLIS, H. E., 40 Union street, Glasgow,	A. 20 Nov. 1897 M. 24 Oct., 1899
HOLMES, F. G., Town Hall, Govan,	23 Mar., 1880
HOLMES, MATTHEW, Netherby, Lenzie,	20 Mar., 1883
HOLMS, A. CAMPBELL, Lloyd's Register, 2 White Lion court, Cornhill, London,	24 Apr., 1894
HOMAN, WILLIAM M'L., c/o D. M'Call, Esq., 10 Rosslyn terrace, Kelvinside, Glasgow,	G. 26 Jan., 1892 M. 26 Oct., 1897
HOME, HENRY, 208 St. Vincent street, Glasgow,	23 Feb., 1897
HORNE, GEORGE S., 18 Berkeley terrace, Glasgow,	21 Feb., 1899
HORNE, JOHN, Rokeby villa, Carlisle,	23 Nov., 1897
†HOUSTON, COLIN, Harbour Engine works, 60 Portman street, Glasgow,	25 Mar., 1890
HOUSTON, JAMES, Jr., Brisbane house, Bellahouston,	25 Jan., 1898
HOWAT, WILLIAM, 121 Raeberry street, Glasgow,	22 Feb., 1898

†HOWDEN, JAMES, 195 Scotland street, Glasgow,	Original
HUBBARD, ROBERT SOWTER, 3 Downie place, Crow road, Partick,	19 Dec., 1899
HUME, JAMES HOWDEN, 195 Scotland street, Glasgow,	22 Dec., 1891
*†HUNT, EDMUND, 121 West George street, Glasgow,	Original
HUNTER, GILBERT M., The Dorada Railway Co., Ltd., Honda, Columbia, S. America,	G. 26 Oct., 1886 M. 19 Nov., 1889
HUNTER, JAMES, Aberdeen Iron works, Aberdeen,	25 Jan., 1881
HUNTER, JAMES, 34 Ancaster drive, Glasgow, W.,	20 Feb., 1900
HUNTER, JOHN, 13 Queen's Gate, Dowanhill, Glasgow,	A. 22 Jan., 1895 M. 21 Mar. 1899
HUNTER, JOSEPH GILBERT, 29 Regent quay, Aberdeen,	24 Feb., 1891
HUTCHESON, ARCH., 37 Mair street, Plantation, Glasgow,	22 Dec., 1896
HUTCHESON, JOHN, 37 Mair street, Plantation, Glasgow,	22 Mar., 1898
HUTCHISON, JAMES H., Shipbuilder, Port-Glasgow,	26 Mar., 1895
HUTCHISON, JOHN S., 126 Bothwell street, Glasgow,	24 Apr., 1900
HUTSON, ALEXANDER, Westbourne house, Kelvinside, Glasgow,	19 Dec., 1899
HUTSON, GUYBON, Kelvinhaugh Engine works, Glasgow,	G. 23 Dec., 1873 M. 24 Nov., 1885
HUTSON, GUYBON, Jun., 3 Bute mansions, Glasgow,	21 Mar., 1893
HUTSON, JAMES, Laurel Bank, Crow road, Partick,	19 Dec., 1899
†INGLIS, JOHN, LL.D., Point House Shipyard, Glasgow,	1 May, 1861
IRELAND, WILLIAM, 7 Ardgowan terrace, Glasgow,	25 Feb., 1890
JACK, ALEXANDER, 164 Windmillhill, Motherwell,	21 Nov., 1893
JACK, JAMES R., Mavisbank, Dumbarton,	27 Apr., 1897
JACKSON, DANIEL, Levenford villa, Dumbarton,	24 Oct., 1899
JACKSON, HAROLD D., 10 Hillend gardens, Hyndland road, Glasgow,	G. 24 Mar., 1891 M. 20 Dec., 1898
JACKSON, PETER, 109 Hope street, Glasgow,	24 Mar., 1891
JACKSON, WILLIAM, Govan Engine works, Govan, Glasgow,	21 Dec., 1875
JAMIESON, Professor ANDREW, F.R.S.E., 16 Rosslyn terrace, Hillhead, Glasgow,	26 Mar., 1889
JARDINE, JOHN, Fairholm, Motherwell,	26 April, 1898
JOHNSTON, DAVID, 9 Osborne terrace, Copland road, Glasgow,	25 Feb., 1879
JOHNSTON, ROBERT, Kirklee, Wallace street, Kilmarnock,	22 Mar., 1898

JOHNSTONE, GEORGE, Messrs Mackinnon, Mackenzie & Co., Calcutta,	21 Mar., 1899
JONES, LLEWELLEN, Chesterfield house, 98 Great Tower street, London, E.C.,	25 Oct., 1892

KELLY, ALEXANDER, 100 Hyde Park street, Glasgow,	28 Feb., 1897
KEMP, DANIEL, 129 Kenmure street, Pollokshields, Glasgow,	G. 23 Nov., 1886 M. 20 Dec., 1898
KEMP, EBENEZER, D., Birkenhead Iron works, Birkenhead,	G. 20 Feb., 1883 M. 25 Oct., 1892
KEMPT, IRVINE, Jun., Foresthill, Kelvinside, Glasgow,	G. 26 Feb., 1895 M. 27 Apr., 1897
KENNEDY, ALEXANDER M'A., Rosslea, Dumbarton,	30 Apr., 1895
KENNEDY, JOHN, Messrs R. M'Andrew & Co., Suffolk House, Laurence Pountney Hill, London, E.C.,	23 Jan., 1877
KENNEDY, ROBT., B.Sc., Glenfield Company, Kilmarnock,	23 Mar., 1897
KENNEDY, THOMAS, Glenfield Company, Kilmarnock,	22 Feb., 1876
KENNEDY, WILLIAM, 13 Victoria crescent, Dowanhill, Glasgow,	24 Apr., 1894
KERR, JAMES, 342 Argyle street, Glasgow,	22 Feb., 1898
KEY, WILLIAM, 109 Hope street, Glasgow.	20 Feb., 1900
KINCAID, JOHN G., 30 Forsyth street, Greenock,	22 Feb., 1898
KING, A. C., Motherwell Bridge Co., Motherwell,	24 Jan., 1899
KING, DONALD, 1 Montgomerie cottages, Scotstoun, Glasgow,	G. 21 Dec., 1886 M. 20 Mar., 1894
KING, J. FOSTER, The British Corporation, 69 St. Vincent street, Glasgow,	26 Mar., 1895
KINGHORN, A. J., 59 Robertson street, Glasgow.	24 Oct., 1899
KINGHORN, JOHN G., Tower Buildings, Water street, Liverpool,	23 Dec., 1879
†KIRBY, FRANK E., Detroit, U.S.A.,	24 Nov., 1885
KNIGHT, CHARLES A., 21 St Vincent place, Glasgow,	27 Jan., 1885
KNOX, ROBERT, 10 Clayton terrace, Dennistoun, Glasgow,	24 Nov., 1896
KREBS, FREDERICK, 22 Amaliegade, Cophenhagen,	23 Mar., 1880

LACKIE, WILLIAM W., 75 Waterloo street, Glasgow,	22 Nov., 1898
LADE, JAMES A., c/o Madame Fenton, Place Michel, 8, Bordeaux, France,	27 Jan., 1891
LAIDLAW, JOHN, 98 Dundas street, S.S., Glasgow,	25 Mar., 1884
LAIDLAW, ROBERT, 147 East Milton street, Glasgow,	26 Nov., 1862
LAING, ANDREW, The Wallsend Slipway Company, Newcastle-on-Tyne,	20 Mar., 1880

Laird, Andrew, 8 Derby terrace, Sandyford, Glasgow,	22 Nov., 1898
Lamberton, Andrew, Greenhill, Coatbridge,	27 Apr., 1897
Lang, C. R., Holm Foundry, Cathcart, Glasgow,	G. 20 Nov., 1888 M. 26 Nov., 1895
Lang, James, Messrs George Smith & Sons, City Line, 75 Bothwell street, Glasgow,	24 Feb., 1880
Lang, John, Jun., Lynnhurst, Johnstone,	26 Feb., 1884
Lang, Robert, Quarrypark, Johnstone,	25 Jan., 1898
Laurence, George B., Clutha Iron works, Paisley road, Glasgow,	21 Feb., 1888
Laws, Bernard Courtney,	26 Oct., 1897
Le Rossignol, A. E., Corporation Tramway Office, City road, Newcastle-on-Tyne,	22 Nov., 1898
Lee, Harrison Wm., Hampden Residential Club, Phœnix street, London, N.W.,	25 Apr., 1899
†Lee, Robert, The Whiteinch Galvanizing Co., Ltd., Harmsworth street, Whiteinch,	G. 21 Dec., 1886 M. 22 Mar., 1898
Leitch, Arch., 40 St. Enoch square, Glasgow,	22 Dec., 1896
Lemkes, C. R. L., 5 Wellington street, Glasgow,	A. 26 Feb., 1884 M. 22 Mar., 1898
Leslie, James T. G., 148 Randolph terrace, Hill street, Garnethill, Glasgow,	25 Apr., 1893
Leslie, William, Resident Engineer, Coolgardie Water Scheme, Resident Engineer's Office, Mundaring, West Australia,	24 Feb., 1891
Lester, William R., 11 West Regent street, Glasgow,	G. 21 Nov., 1883 M. 24 Jan., 1899
Lewin, Harry W., 154 West Regent street, Glasgow,	20 Dec., 1898
†Lindsay, Charles C., 217 W. George street, Glasgow,	G. 23 Dec., 1873 M. 24 Oct., 1876
Lithgow, William T., Port-Glasgow,	21 Feb., 1893
Livesey, Robt. M., c/o Topham Jones & Railton, H.M. Dockyard Extension, Gibraltar,	26 Jan., 1897
†Lobnitz, Fred., Clarence house, Renfrew,	G. 24 Mar., 1885 M. 20 Nov., 1896
Lockie, John, Wh.Sc., 2 Custom House Chambers, Leith,	26 Jan., 1897
Lonergan, Alfred E., Whitefield Engine works, Govan, Glasgow,	17 Dec., 1889
Longbottom, John Gordon, Technical College, 38 Bath street, Glasgow,	22 Nov., 1898
†Lorimer, William, Glasgow Locomotive works, Gushetfaulds, Glasgow,	27 Oct., 1896
†Loudon, George Findlay, 10 Claremont Terrace, Glasgow,	25 Jan., 1898
Luke, W. J., Messrs John Brown & Co., Ltd., Clydebank,	24 Jan., 1896
Lusk, Hugh D., c/o Mrs Nelson, Larch villa, Annan,	21 Feb., 1888

Lyall, John, 34 Randolph gardens, Partick,	27 Oct., 1885
Macalpine, John H., Rossbank, Port-Glasgow,	20 Dec., 1898
M'Arthur, James D., 7 Westbank place, Hillhead, Glasgow,	26 Apr., 1898
McAulay, W., 34 Ann street, Glasgow,	22 Nov., 1898
†M'Call, David, 160 Hope street, Glasgow,	17 Feb., 1858
M'Callum, H. Malcolm, 10 Midlothian drive, Shawlands, Glasgow,	24 Oct., 1899
M'Coll, Peter, 284 Dumbarton road, Partick,	G. 18 Dec., 1883 M. 24 Jan., 1899
†MacColl, Hector, Bloomfield, Belfast,	24 Mar., 1874
MacColl, Hugo, Wreath Quay Engineering works, Sunderland,	G. 20 Dec., 1881 M. 22 Oct., 1889
M'Creath, James, 208 St. Vincent street, Glasgow,	23 Oct., 1883
M'Culloch, Frank, c/o Messrs William Watson & Co., 7 Waterloo place, Pall Mall, London, S.W.,	27 Jan., 1891
Macdonald, D. H., Brandon works, Motherwell,	24 Mar., 1896
Macdonald, John, 146 West Regent street, Glasgow,	21 Mar., 1899
Macdonald, Thomas, 180 Hope street, Glasgow,	25 Jan., 1898
M'Dowall, H. J., Johnstone,	21 Mar., 1899
M'Ewan, James, Cyclops Foundry Co., Whiteinch, Glasgow,	26 Feb., 1884
M'Ewan, Joseph, 35 Houldsworth street, Glasgow,	27 Jan., 1891
Macfarlane, James W., 12 Balmoral villas, Cathcart, Glasgow,	2 Nov., 1880
Macfarlane, James, Anniesle, Motherwell,	15 June, 1898
Macfarlane, Walter, 12 Lynedoch crescent, Glasgow,	26 Oct., 1886
M'Farlane, George, 34 West George street, Glasgow,	G. 24 Feb., 1874 M. 24 Nov., 1885
M'Farlane, Hugh,	21 Feb., 1899
M'Gechan, Andrew, 232 Paisley road, West, Glasgow,	26 Apr., 1898
M'Gee, David, The Cottage, Clydebank,	22 Dec., 1896
†M'Gee, Walter, Stoney brae, Paisley,	25 Jan., 1898
M'Geoch, David Boyd, Messrs Blackwood & Gordon, Port-Glasgow,	28 Jan., 1896
M'Gregor, J. Grant, Canadian Pacific Railway Engineering Department, Montreal,	G. 21 Dec., 1886 M. 28 Apr., 1891
M'Gregor, John B., 19 Bell street, Renfrew,	G. 18 Dec., 1883 M. 27 Apr., 1897
M'Gregor, Thomas, 10 Mossesfield terrace, Springburn, Glasgow,	26 Jan., 1886
M'Indoe, John B., Scottish House to House Electricity Co., Coatbridge,	21 Mar., 1899

M'INTOSH, DONALD, Dunglass, Bowling,	20 Feb., 1894
M'INTOSH, JOHN F., Caledonian Railway, St. Rollox, Glasgow,	28 Jan., 1896
M'INTYRE, HUGH, 17 Oswald street, Glasgow,	22 Nov., 1887
MACK, JAMES, 22 Rutland street, Edinburgh,	G. 21 Dec., 1886 M. 20 Dec., 1898
MACKAY, ROBERT, 7 Leslie street, Pollokshields, Glasgow,	23 Jan., 1900
M'KEAND, ALLAN, 1 St. James terrace, Hillhead, Glasgow,	G. 19 Dec., 1882 M. 20 Mar., 1894
MACKECHNIE, JOHN, 342 Argyle street, Glasgow,	20 Dec., 1898
M'KECHNIE, JAMES, Messrs Vickers, Sons, & Maxim, Barrow-in-Furness,	24 Apr., 1888
MACKENZIE, JAMES, 8 St. Alban's road, Bootle,	G. 25 Oct., 1881 M. 24 Jan., 1899
MACKENZIE, THOMAS B., 342 Duke street, Glasgow,	G. 23 Jan., 1883 M. 26 Nov., 1895
M'KENZIE, JOHN, Messrs J. Gardiner & Co., 24 St. Vincent place, Glasgow,	25 Apr., 1893
M'KENZIE, JOHN, Speedwell Engineering works, Coatbridge,	25 Jan., 1898
MACKIE, WILLIAM A., Falkland bank, Partickhill, Glasgow,	22 Mar., 1881
M'KIE, J. A., Copland works, Govan,	25 Jan., 1898
†MACKINLAY, JAMES T. C., 110 Gt. Wellington street, Kinning park, Glasgow,	27 Oct., 1896
M'KINNEL, WILLIAM, 234 Nithsdale road, Pollokshields, Glasgow,	A. 21 Feb., 1893 M. 22 Feb., 1898
MACKINNON, James D., 93 Hope street, Glasgow.	24 Nov., 1896
M'LACHLAN, EWEN, 4 Abbotsford place, Glasgow,	21 Feb., 1899
M'LACHLAN, JOHN, Saucel Bank House, Paisley,	26 Oct., 1897
MACLAREN, JOHN F., B.Sc., Eglinton foundry, Canal street, Glasgow,	23 Feb., 1892
MACLAREN, ROBERT, Eglinton foundry, Canal street, Glasgow,	G. 2 Nov., 1880 M. 22 Dec., 1885
McLAREN, JOHN ALEX., 34 Ann street, Glasgow,	22 Nov., 1898
M'LAREN, THOMAS, 342 Argyle street, Glasgow,	20 Dec., 1898
MACLAY, Prof. ALEX., B.Sc., Camptower, Bearsden,	28 Apr., 1891
*MACLEAN, Sir ANDREW, Viewfield house, Partick, Glasgow.	
MACLEAN, MAGNUS, Prof., Technical College, 38 Bath street, Glasgow,	21 Nov., 1899
MACLEAN, WILLIAM DICK, 3 Weymouth terrace, Cessnock,	25 Jan., 1898
†MACLELLAN, WILLIAM T., Clutha Iron works, Glasgow,	21 Dec., 1886
M'LELLAN, ARCHIBALD, Carron Co., Carron, Stirlingshire,	25 Apr., 1899

M'Master, Robert, Linthouse, Glasgow,	25 Feb., 1890
*†MacMillan, William, Holmwood, Whittinghame drive, Kelvinside, Glasgow,	
M'Millan, John, Corporation Electric Light Station, Dewar Place, Edinburgh,	G. 27 Jan., 1885 M. 24 Jan., 1899
M'Nair, James, Norwood, Prestwick road, Ayr,	26 Nov., 1895
M'Neil, John, Helen street, Govan, Glasgow,	23 Dec., 1884
Macouat, R. B., Victoria Bolt and Rivet works, Cranstonhill, Glasgow,	21 Mar., 1899
Macpherson, John, 128 Hope street, Glasgow,	20 Nov., 1894
Macrae, Norman, Northern Gold Fields Company, Salisbury, Mashonaland, South Africa,	26 Nov., 1895
M'Whirter, William, 214 Holm street, Glasgow,	24 Mar., 1891
Manson, James, G. & S. W. Railway, Kilmarnock,	21 Feb., 1899
Marr, James Brown, c/o Messrs Kirkland & Capper, 17 Victoria street, Westminster, London, S.W.,	21 Dec., 1897
Marriott, Reuben, Plantation Boiler Works, Govan, Glasgow,	23 Feb., 1897
Marshall, David, Glasgow Tube works, Glasgow,	22 Jan., 1895
Martin, E. L., 122 Leadenhall street, London, E.C.,	27 Oct., 1896
Mathewson, George, Bothwell works, Dunfermline,	21 Dec., 1875
Mathewson, Robert C., Glenburn Iron works, Greenock,	22 Jan., 1895
Mathieson, Donald A., 3 Germiston street, Glasgow,	26 Jan., 1897
Matthey, C. A., c/o W. Hope Campbell, Esq., 42 Krestchatik, Kieff, S. Russia,	26 Oct., 1897
Mavor, Henry A., 47 King street, Bridgeton, Glasgow,	22 Apr., 1884
Mavor, Sam, 37 Burnbank gardens, Glasgow,	20 Nov., 1894
May, William W., Woodbourne, Minard avenue, Partickhill, Glasgow,	25 Jan., 1876
Mayer, Wm., Morwell House, Dumbarton,	23 Feb., 1897
Mechan, Henry, 13 Montgomerie quadrant, Glasgow,	25 Jan., 1887
Mechan, Samuel, 5 Kelvingrove terrace, Glasgow,	27 Oct., 1891
Meldrum, James, 10 Victoria street, Westminster, London, S.W.,	G. 24 Oct., 1876 M. 28 Nov., 1882
Melville, William, Glasgow and South Western Railway, St. Enoch square, Glasgow,	23 Jan., 1883
Middleton, R. A., Messrs Vickers, Sons, & Maxim, Barrow-in-Furness,	G. 24 Jan., 1882 M. 28 Oct., 1890
Millar, Sidney, Harthill house, Cambuslang,	G. 26 Feb., 1889 M. 21 Dec., 1897
Millar, William, Sunnyside, Grangemouth,	19 Dec., 1899
Miller, John F., Greenoakhill, Broomhouse,	G. 23 Dec., 1873 M. 22 Nov., 1881
Minty, William, 40 Gilnow road, Bolton, Lancashire,	25 Apr., 1899

†MIRRLEES, JAMES B., 45 Scotland street, Glasgow,	Original
MITCHELL, ALEXANDER, Hayfield house, Springburn, Glasgow,	26 Jan., 1886
MITCHELL, GEORGE A., F.R.S.E., 5 West Regent street, Glasgow,	25 Jan., 1898
MITCHELL, THOMAS, Gower street, Bellahouston, Glasgow,	20 Nov., 1888
MOIR, ERNEST W., c/o S. Pearson & Son, 10 Victoria street, Westminster, London,	G. 25 Jan., 1881 M. 24 Jan., 1899
MOIR, JOHN, Clyde Shipbuilding and Engineering Company, Port-Glasgow,	23 Feb., 1897
MOLLISON, JAMES, 6 Hillside gardens, Partickhill, Glasgow,	21 Mar., 1876
MOORE, JOSEPH, The Cottage, St. John's road, Richmond, London, S.W.,	21 Nov., 1883
MOORE, RALPH D., B.Sc., 13 Clairmont gardens, Glasgow,	27 Apr., 1897
MOORE, ROBERT T., B.Sc., 13 Clairmont gardens, Glasgow,	27 Jan., 1891
MORISON, WILLIAM, 41 St. Vincent crescent, Glasgow,	20 Mar., 1888
MORRICE, RICHARD WOOD, 24 Battlefield road, Langside, Glasgow,	23 Feb., 1897
MORT, ARTHUR, Ellenslea, Wilson street, Motherwell,	G. 26 Jan., 1897 M. 19 Dec., 1899
MORTON, DUNCAN A., Errol works, Errol.	21 Nov., 1899
MORTON, ROBERT, 237 West George street, Glasgow,	G. 17 Dec., 1878 M. 23 Jan., 1883
MOTION, ROBERT, Ladywell, Motherwell,	23 Feb., 1892
MOTT, EDMUND, Board of Trade Surveyor, 7 York street, Glasgow,	24 Mar., 1885
†MUIR, ALFRED, Machine Tool Maker, Sherbourne street, Manchester,	23 Feb., 1897
†MUIR, HUGH, 7 Kelvingrove terrace, Glasgow,	17 Feb., 1864
MUIR, JAMES E., 45 West Nile street, Glasgow,	22 Dec., 1896
†MUIR, JOHN G.,	24 Jan., 1882
MUIR, ROBERT WHITE, 97 St. James road, Glasgow,	21 Dec., 1897
MUIRHEAD, WILLIAM, 37 West George street, Glasgow,	26 Oct., 1897
MUMME, CARL, 30 Newark street, Greenock,	22 Oct., 1895
MUMME, ERNEST CHAS., Hajipur-Begam Sarai Railway Extension, Begam Sarai P.O., Tirhoot State Railway, India,	G. 22 Nov., 1892 M. 20 Feb., 1900
MUNN, ROBERT A., 137 West George street, Glasgow,	22 Dec., 1896
MUNRO, ROBERT D., Scottish Boiler Insurance Company, 111 Union street, Glasgow,	19 Dec., 1882
MURDOCH, FREDERICK TEED, Atbara, 18 Emanuel avenue, Acton, London W.,	25 Feb., 1896

MURRAY, ANGUS, Strathroy, Dumbreck,	G. 14 May, 1878 M. 19 Nov., 1889
MURRAY, HENRY, Shipbuilder, Port-Glasgow,	22 Dec., 1896
MURRAY, JAMES, Westfield, Port-Glasgow,	22 Dec., 1896
MURRAY, JAMES, 94 Washington street, Glasgow,	26 Jan., 1886
MURRAY, RICHARD, 109 Hope street, Glasgow,	26 Oct., 1897
MURRAY, THOMAS BLACKWOOD, B.Sc., 15 Roxburgh street, Dowanhill, Glasgow,	22 Dec., 1891
MURRAY, THOMAS R., Messrs. Spencer & Co., Melksham, Wilts,	25 Feb., 1896
MYLES, DAVID, Northumberland Engine works, Wallsend-on-Tyne,	G. 20 Dec., 1887 M. 19 Dec., 1899

NAPIER, HENRY M., Shipbuilder, Yoker, near Glasgow,	25 Jan., 1881
†NAPIER, ROBERT T., 75 Bothwell street, Glasgow,	20 Dec., 1881
NEILSON, JAMES, Ironmaster, Mossend,	23 Mar., 1897
NELSON, ANDREW S., Snowdon, Sherbrooke avenue, Pollokshields, Glasgow,	27 Oct., 1896
NESS, GEORGE, 128a Queen Victoria street, London, E.C.,	23 Feb., 1897
NICOL, THOMAS, 2 Glenavon terrace, Partick, Glasgow,	18 Dec., 1883
NISH, WILLIAM, c/o W. L. C. Paterson, Finnieston-quay, Glasgow,	6 Apr., 1887
NORMAN, JOHN, 131a St. Vincent street, Glasgow,	11 Dec., 1861

O'BRIEN, WILLIAM, 21 Ibrox terrace, Govan, Glasgow,	27 Jan., 1891
ODAGIRI, ENJU,	24 Jan., 1899
O'NEILL, J. J., 14 West Princes street, Glasgow,	24 Nov., 1896
OLDFIELD, GEORGE, Atlas Works, Springburn,	22 Nov., 1898
OLIPHANT, WM., Brittannia Engine works, Kilmarnock,	23 Feb., 1897
ORMISTON, JOHN W., Douglas gardens, Uddingston,	28 Nov., 1860
ORR, ALEXANDER T., Marine Department, London and North Western Railway, Holyhead,	24 Mar., 1885
ORR, JOHN R., Motherwell Bridge Co., Motherwell,	24 Jan., 1899

PAASCH, HEINRICH, 27 Rue d'Amsterdam, Antwerp,	28 Oct., 1890
PATERSON, W. L. C., 5 Elmwood terrace, Jordanhill, Glasgow,	21 Nov., 1883
PATTERSON, JAMES, Maryhill Iron works, Glasgow,	22 Nov., 1898
PATON, ALEXANDER R., Redthorn, Partick, Glasgow,	G. 25 Nov., 1897 M. 20 Nov., 1894

PATON, Professor GEORGE, Royal Agricultural College, Cirencester,		22 Nov., 1887
PATON, JOHN, 27 Melville street, Pollokshields, Glasgow,		26 Feb., 1889
PATRICK, ANDREW CRAWFORD, Johnstone,		25 Jan., 1898
PATTIE, ALEXANDER W., 24 Sutherland street, Hillhead, Glasgow,		22 Jan., 1895
PAUL, ANDREW, Levenford works, Dumbarton,		24 Apr., 1877
PAUL, H. S., Levenford works, Dumbarton,		24 Jan., 1899
PAUL, MATTHEW, Levenford works, Dumbarton,	G. M.	26 Feb., 1884 21 Dec., 1886
PEACOCK, JAMES, Oriental Steam Navigation Co., 13 Fenchurch Avenue, London, E.C.	G. M.	22 Nov., 1881 21 Feb., 1899
PEAT, JAMES D., Finnieston quay, Glasgow,		18 Dec., 1894
PECK, EDWARD C., Messrs Yarrow & Company, Poplar, London,	G. M.	23 Dec., 1873 23 Oct., 1888
PECK, JAMES J., 9 Broomhill gardens, Partick, Glasgow,		22 Dec., 1896
PENMAN, ROBERT REID, 16 Annfield place, Glasgow,		25 Jan., 1898
PENMAN, WILLIAM, Springfield house, Dalmarnock, Glasgow,		25 Jan., 1898
PHILIP, WILLIAM LITTLEJOHN, 7 Sherbrooke avenue, Pollokshields, Glasgow		24 Jan., 1899
PHILP, WILLIAM T., Messrs Workman Clark & Co., Ltd., Belfast,	G. M.	25 Oct., 1881 27 Oct., 1891
PICKERING, ROBERT YOUNG, Railway Wagon and Wheel works, Wishaw,		24 Nov., 1896
POOLE, WILLIAM JOHN, 19 Waverley park, Shawlands, Glasgow,		20 Dec., 1898
POLLOCK, DAVID, 128 Hope street, Glasgow,		23 Feb., 1897
POLLOK, ROBT., Craiglea, Dumbarton,		22 Dec., 1896
POPE, ROBERT BAND, Leven Shipyard, Dumbarton,		25 Oct., 1887
PRATTEN, WILLIAM J., Mornington, Derryvolgie avenue, Belfast,		22 Dec., 1896
PURDON, ARCHIBALD, Inch works, Port-Glasgow,		27 Apr., 1897
PURVES, J. A., D.Sc., F.R.S.E., 53 York place, Edinburgh,		25 Oct., 1898
PURVIS, F. P., Don villa, Greenock,		20 Nov., 1877
PUTNAM, THOMAS, Darlington Forge Co., Darlington,		15 June, 1898
PYLE, JAMES H., 38 Elliot street, Glasgow,		23 Feb., 1897

RAEBURN, CHARLES E., 1 Hillhead street, W., Glasgow,	24 Oct., 1899
RAINEY, FRANCIS E., c/o Mr F. Nell, 97 Queen Victoria street, London, S.E.,	27 Apr., 1897
RAIT, HENRY M., 155 Fenchurch street, London,	23 Dec., 1868
RAMAGE, RICHARD, Shipbuilder, Leith,	22 Apr., 1873

RAMSAY, CHARLES, 33 Thurlby road, West Norwood, London,	21 Dec., 1897
RANKIN, JOHN F., Eagle foundry, Greenock,	23 Mar., 1886
RANKIN, MATTHEW, Messrs Rankin & Demas, Engineers, Smyrna,	G. 2 Nov., 1880 M. 20 Mar., 1894
RANKINE, DAVID, 238 West George street, Glasgow,	22 Oct., 1872
REED-COOPER, T. L., 12 Queen's terrace, Glasgow,	22 Dec., 1896
REID, ANDREW T., Hydepark Locomotive works, Glasgow,	G. 21 Dec., 1886 M. 18 Dec., 1894
REID, CHARLES, Lilymount, Kilmarnock,	25 Jan., 1881
REID, GEORGE W., Locomotive Department, Natal Government Railways, Durban, Natal, S. Africa,	21 Nov., 1883
REID, J. MILLER, 110 Lancefield street, Glasgow,	23 Mar., 1897
REID, JAMES, Shipbuilder, Port-Glasgow,	17 Mar., 1869
REID, JAMES, 3 Cart street, Paisley,	25 Jan., 1898
†REID, JAMES B., Chapelhill, Paisley,	24 Nov., 1891
REID, JAMES G., 58 West Regent street, Glasgow,	G. 23 Dec., 1684 M. 21 Feb., 1899
†REID, JOHN, 14 Montgomerie crescent, Kelvinside, Glasgow,	G. 21 Dec., 1886 M. 18 Dec., 1894
REID, ROBERT SHAW, 161 Hope street, Glasgow,	21 Mar., 1899
REW, JAMES H., Grahamshill house, Airdrie,	27 Oct., 1896
REYNOLDS, CHARLES H., Sir W. G. Armstrong, Mitchell & Co., Walker Shipyard, Newcastle on-Tyne,	G. 23 Dec., 1873 M. 22 Nov., 1881
RICHMOND, Sir DAVID, North British Tube works, Govan,	21 Dec., 1897
RICHMOND, JOHN R., Holm foundry, Cathcart, Glasgow,	28 Jan., 1896
RIDDELL, W. G., 296 Renfrew street, Glasgow,	21 Feb., 1899
RISK, ROBERT, Halidon Villa, Cambuslang,	23 Mar., 1897
RITCHIE, GEORGE, Parkhead Forge, Glasgow,	15 June, 1898
ROBB, JAMES W., 15 Huntly terrace, Shettleston,	25 Mar., 1890
ROBERTSON, ALEX., Jun., Forgemaster, Kilmarnock,	22 Dec., 1896
ROBERTSON, ANDREW R., 8 Park Circus place, Glasgow,	G. 12 Nov., 1892 M. 23 Feb., 1897
ROBERTSON, DUNCAN, Baldroma, Ibrox, Glasgow,	24 Oct., 1876
ROBERTSON, THOMAS, 13 Broomhill avenue, Glasgow,	23 Jan., 1900
ROBERTSON, WILLIAM, 141 St. Vincent street, Glasgow,	25 Nov., 1863
ROBIN, MATTHEW, 15 Clifford street, Glasgow,	G. 20 Dec., 1887 M. 25 Jan., 1898
ROBINSON, J. F., Atlas works, Springburn, Glasgow,	24 Apr., 1888
ROBSON, GEORGE J., 22 Bath street, Glasgow,	21 Mar., 1899
*†ROBSON, HAZELTON R., 14 Royal crescent, Glasgow,	Original
RODGER, ANDERSON, Glenpark, Port-Glasgow,	21 Mar., 1893
ROSENTHAL, JAMES H., 147 Queen Victoria street, London, E.C.,	24 Nov., 1896

Ross, J. MacEwan, Ardenlea, Lenzie,	G. 28 Nov., 1882 M. 27 Oct., 1891
Ross, James R., Parkhead forge, Glasgow,	24 Nov., 1896
Ross, Richard G., 21 Greenhead street, Glasgow,	11 Dec., 1861
Rowan, Frederick John, 40 Millbrae crescent, Langside, Glasgow,	26 Jan., 1892
Rowan, James, 231 Elliot street, Glasgow,	G. 21 Dec., 1875 M. 27 Jan., 1885
Rowley, Thomas, Board of Trade Offices, Virginia street, Greenock,	18 Dec., 1888
Rudd, John A., 177 West George street, Glasgow,	G. 24 Jan., 1888 M. 15 June, 1898
Russell, Frederick Alexander, 132 West Regent street, Glasgow,	25 Jan., 1888
†Russell, George, Alpha Works, Motherwell,	G. 22 Dec., 1858 M. 4 Mar., 1863
†Russell, James, 15 Kyle park, Uddingston,	G. 24 Nov., 1891 M. 25 Jan., 1898
Russell, Joseph, Shipbuilder, Port-Glasgow,	22 Feb., 1881
Russell, Joseph William, 50 Charles street, St. Rollox, Glasgow,	G. 6 Apr., 1887 M. 25 Jan., 1898
Russell, Thomas W., Admiralty, 21 Northumberland avenue, London, W.C.,	27 Apr., 1897
Rutherford, George, Mercantile Pontoon Company, Cardiff,	23 Mar., 1897

Salmon, Edward Mowbray, 2 White Lion court, Cornhill, London, E.C.,	21 Jan., 1890
Sambridge, James R., Messrs J. H. Holmes & Co., Portland road, Newcastle-on-Tyne,	22 Dec., 1896
Sampson, Alex. W.; Barns place, Clydebank,	22 Dec., 1896
Samson, Peter, Board of Trade Offices, Bedford street, Covent garden, London, W.C.,	24 Oct., 1876
Samuel, James, Jun., 185 Kent road, Glasgow,	24 Feb., 1885
Sanderson, John, Lloyd's Register, Royal Exchange, Middlesbro'-on-Tees,	20 Feb., 1883
Sayers, William Brooks, Glenwood, Bearsden,	25 Oct., 1892
†Scobie, John, Box No. 93, Sierra Leone Railway, Freetown, West Coast of Africa,	G. 25 Mar., 1879 M. 23 Oct., 1888
Scott, Charles Cunningham, Greenock Foundry, Greenock,	27 Oct., 1896
Scott, Charles Wood, Dunarbuck, Bowling,	15 June, 1898
Scott, James, Engineer, Tayport,	22 Dec., 1896
Scott, James, Jun., Strathclyde, Bowling,	15 June, 1898
Scott, James E., 52 Coal Exchange, London,	30 Jan., 1872

Scott, John, Abden works, Kinghorn,	25 Jan., 1881
Scott, John, D., 63 Pitt street, Sydney, Auckland,	21 Nov., 1893
*Seath, Thomas B., 42 Broomielaw, Glasgow,	28 Nov., 1860
Selby-Bigge, D., 27 Mosley street, Newcastle-on-Tyne,	21 Feb., 1899
Sexton, Professor Humboldt, Glasgow and West of Scotland Technical College, 204 George st., Glasgow,	25 Feb., 1896
Shanks, Alexander, 5 Broomhill avenue, Partick,	26 Jan., 1875
Shanks, Alexander, Jun., Hamilton street, Polmadie, Glasgow,	26 Apr., 1892
Shanks, William, Tubal works, Barrhead,	15 June, 1898
Sharer, Edmund, 8 Belhaven crescent, Glasgow,	30 Apr., 1895
Sharp, John, 11 Windsor Terrace, Glasgow,	G. 24 Oct., 1882 M. 22 Nov., 1898
Shedden, William, 3 Andrew's street, Paisley,	24 Oct., 1899
Shepherd, John W., Carrickarden, Bearsden,	26 Mar., 1889
Sheriff, Thomas, 4 Wolseley villas, Whiteinch, Glasgow,	22 Dec., 1896
Shute, Arthur E., 12 Clydeview, Partick, Glasgow,	27 Oct., 1896
Shute, Charles W., 4 Thornwood ter., Partick, Glasgow,	27 Oct., 1896
Shute, T. S., 3 Kensington terrace, South, Sunderland,	G. 19 Dec., 1893 M. 22 Feb., 1898
Sime, John, 96 Buchanan street, Glasgow,	26 Jan., 1897
Simons, William, Tighnabruaich, Argyleshire,	24 Nov., 1858
Simpson, Alexander, 175 Hope street, Glasgow,	22 Jan., 1862
Simpson, Robert, B.Sc., 175 Hope street, Glasgow,	25 Jan., 1887
Sinclair, Nisbet, 29 University avenue, Glasgow,	G. 20 Mar., 1877 M. 20 Dec., 1887
Sinclair, Russell, Consulting Engineer, 97 Pitt street, Sydney, N.S.W.,	G. 25 Mar., 1884 M. 24 Mar., 1891
Slight, George H., Jun., c/o James Slight, 131 West Regent street, Glasgow,	G. 28 Nov., 1882 M. 22 Oct., 1889
Sloan, J. Lumsden,	22 Nov., 1898
Small, William O., Carmyle avenue, Carmyle,	28 Feb., 1897
Smart, Lewis A., Messrs Burroughs, Welcome & Co., Dartford, Kent,	22 Mar., 1898
Smillie, Samuel, 71 Lancefield street, Glasgow,	A. 24 Jan., 1888 M. 22 Feb., 1898
Smith, Alexander D., 487 Shields road, Pollokshields, Glasgow,	2 Nov., 1880
Smith, Hugh Wilson, Netherby, N. Albert road, Pollokshields, Glasgow,	25 Jan., 1898
Smith, James, Orange Grove Estate, Tacarigua, Trinidad, B.W.I.,	23 Oct., 1888
Smith, Osbourne, Possil Engine works, Glasgow,	24 Dec., 1895
Smith, Robert, 24 Claremont street, Glasgow,	20 Mar., 1900

Smith, William, 50 Hotspur street, Tynemouth,	22 Nov., 1892
Smith, William J., 7 Newark drive, Pollokshields, Glasgow,	24 Jan., 1899
Snowball, Edward, Hydepark Locomotive works, Springburn, Glasgow,	22 Feb., 1870
Somervail, Peter A., Dalmuir Ironworks, Dalmuir,	25 Jan., 1887
Somerville, Thomas A., Valleyfield, Province of Quebec, Canada,	22 Feb., 1898
Stark, James, 13 Princes gardens, Dowanhill, Glasgow,	27 Oct., 1896
†Stephen, Alexander E., 9 Princes gardens, Dowanhill, Glasgow,	18 Dec., 1883
†Stephen, Frederick J., Linthouse, Govan, Glasgow,	30 Apr., 1895
*†Stephen, John, Linthouse, Govan, Glasgow,	
Steven, John, Messrs Steven and Struthers, Eastvale place, Kelvinhaugh, Glasgow,	26 Oct., 1897
Steven, John Wilson, 18 Sandyford place, Glasgow,	20 Dec., 1898
Steven, William, 18 Sandyford place, Glasgow,	23 Jan., 1894
Stevens, John, Ayton, Albert drive, Renfrew,	23 Mar., 1897
Stewart, Alexander W., Crescent, Dalmuir,	23 Jan., 1894
Stewart, Andrew, LL.D., 41 Oswald street, Glasgow,	25 Feb., 1890
Stewart, Duncan, 47 Summer street, Glasgow,	30 Jan., 1867
†Stewart, James, Harbour Engine works, 60 Portman street, Glasgow,	25 Mar., 1890
Stewart, James, Messrs L. Sterne & Co., 155 North Woodside road, Glasgow,	25 Oct., 1898
Stewart, John Graham, B.Sc., Bredisholm, Baillieston,	22 Mar., 1892
Stewart, W. B., 10 Buckingham terrace, Hillhead, Glasgow,	G. 23 Dec., 1873 M. 24 Oct., 1882
Stewart, W. Maxwell, 95 Bath street, Glasgow.	21 Nov., 1899
Strachan, Robert, 55 Clifford street, Ibrox, Govan,	22 Nov., 1898
Strathern, Alexander G., Hillside, Stepps, N.B.,	25 Apr., 1899
Stuart, James, 115 Wellington street, Glasgow,	22 Oct., 1889
Stuart, James, B.Sc., Stanley villa, Langside, Glasgow,	23 Nov., 1897
Sutherland, Sinclair, North British Tube works, Govan,	21 Dec., 1897
Syme, James, 8 Glenavon terrace, Partick,	23 Jan., 1877

Tannett, John Croysdale, Vulcan works, Paisley,	25 Jan., 1898
Tatham, Stanley, Montana, Burton road, Branksome park, Bournemouth, W.,	G. 21 Dec., 1880 M. 15 June, 1898
Taverner, H. Lacy, 48 West Regent street, Glasgow,	22 Dec., 1896

TAYLOR, PETER, c/o Messrs Taylor & Mitchell, Garvel Shipyard, Greenock,	28 Apr., 1885
TAYLOR, ROBERT, 49 Brisbane street, Greenock,	27 Oct., 1896
TAYLOR, STAVELEY, Messrs Russell & Company, Shipbuilders, Port-Glasgow,	25 Mar., 1879
TERANO, SEIICHI, College of Engineering, Imperial University, Tōkyō, Japan,	21 Feb., 1899
THEARLE, SAMUEL J. P., 2 White Lion Court, Cornhill, London,	22 Dec., 1896
THODE, GEORGE W., c/o Deutsche, Babcock and Wilcox, Dampftkessel Werke, Actien Geselchaft, Aberhausen Rhld, Germany,	27 Jan., 1885
THOM, JOHN, 5 Westbank quadrant, Hillhead,	26 Feb., 1889
THOMSON, Prof. ARTHUR W., D.Sc., College of Science, Poona, India,	26 Apr., 1887
THOMSON, G. CALDWELL, 23 Elisabeth street, Riga, Russia,	24 Oct., 1893
THOMSON, GEORGE, 14 Caird drive, Partickhill, Glasgow,	18 Dec., 1883
THOMSON, GEORGE, 35 Marchmont crescent, Edinburgh,	G. 23 Nov., 1880 M. 20 Nov., 1894
THOMSON, GEORGE C., 4 The Green, Bromborough Pool, near Birkenhead,	G. 24 Feb., 1874 M. 22 Oct., 1889
THOMSON, GEORGE P., 4 Queen's gardens, Dowanhill, Glasgow,	25 Apr., 1882
THOMSON, JAMES, M.A., 22 Wentworth place, Newcastle-on-Tyne,	23 Mar., 1886
THOMSON, JAMES M., Glentower, Kelvinside, Glasgow,	12 Feb., 1868
THOMSON, JAMES R.,	21 Mar., 1882
THOMSON, JOHN, 3 Crown terrace, Dowanhill, Glasgow,	20 May, 1868
THOMSON, R. H. B., Govan Shipbuilding yard, Govan, Glasgow,	26 Feb., 1895
THOMSON, ROBERT, Messrs Barr, Thomson & Co., Ltd., Kilmarnock,	25 Jan., 1898
THOMSON, W. B., Ellengowan, Dundee,	14 May, 1878
THOMSON, WALTER M., Motherwell house, Motherwell.	G. 20 Nov., 1894 M. 24 Dec., 1895
THOMSON, WILLIAM, 27 University avenue, Glasgow,	G. 23 Dec., 1884 M. 27 Oct., 1896
THUNDERBOLT, EDWARD, Argus House, Portland place, Hillhead, Glasgow,	23 Feb., 1897
TIDD, E. GEORGE, 25 Gordon street, Glasgow,	22 Oct., 1895
TODD, DAVID R., Messrs Babcock & Willcox, Renfrew,	G. 25 Jan., 1887 M. 25 Oct., 1892
TULLIS, DAVID K., Kilbowie Iron works, Kilbowie,	23 Nov., 1897
TULLIS, JAMES, Kilbowie Iron works, Kilbowie,	23 Nov., 1897

Turnbull, Alexander, St. Mungo's works, Bishopbriggs, Glasgow,	21 Nov., 1876
Turnbull, Alexander Pott, 264 Maxwell road, Pollokshields, Glasgow,	25 Jan., 1898
†**Turnbull, John**, Jun., 190 West George street, Glasgow,	23 Nov., 1875
Turnbull, Wm. George, Hallside Steel works, Newton,	21 Dec., 1897

Waddell, James, 15 Moray place, Glasgow,	23 Mar., 1897
Walker, John, 1 Church road, Ibrox, Glasgow,	G. 20 Nov., 1894 M. 19 Dec., 1899
Wallace, Duncan M., 65 Union street, Greenock,	27 Oct., 1896
Wallace, John, 15 Parkview gardens, Crosshill, Glasgow,	26 Jan., 1892
Wallace, Peter, Ailsa Shipbuilding Co., Troon,	23 Jan., 1883
Wallace, W. Carlile, Atlas Steel and Iron works, Sheffield,	24 Mar., 1885
Ward, J. C. A., 75 Waterloo street, Glasgow,	22 Nov., 1898
Ward, John, Leven Shipyard, Dumbarton,	26 Jan., 1886
Warde, Henry W., 71 Waterloo street, Glasgow,	15 June, 1898
Warden, Willoughby C., 25 Gordon street, Glasgow,	24 Mar., 1896
Watkinson, Prof. **W. H.**, The Pines, Crookston,	19 Dec., 1893
Watson, G. L., 53 Bothwell street, Glasgow,	23 Mar., 1875
Watson, William, Superintendent Engineer, Clyde Shipping Company, Greenock,	24 Nov., 1896
Watt, Alexander, Inchcape, Paisley,	25 Jan., 1898
Webb, R. G., Messrs Richardson & Cruddas, Byculla, Bombay,	G. 21 Dec., 1875 M. 26 Oct., 1886
Webster, James, Messrs Sharp, Stewart, & Co., Ltd., Atlas works, Springburn, Glasgow,	21 Mar., 1899
Webster, Thomas Lawson, 11 Stuart street, Shawlands, Glasgow,	21 Nov., 1899
Weddell, Jas., Park villa, Uddingston,	22 Dec., 1896
Wedgwood, Arthur D., Forgemaster, Dumbarton,	26 Jan., 1897
Weighton, Prof. **R. L.**, M.A., Durham College of Science, Newcastle-on-Tyne,	G. 17 Dec., 1878 M. 22 Nov., 1887
†**Weir, George**, Yass, near Sydney, New South Wales,	22 Dec., 1874
†**Weir, James**, Holmwood, 72 St. Andrew's drive, Pollokshields, Glasgow,	22 Dec., 1874
Weir, John, Messrs John Scott & Co., Kinghorn,	G. 22 Apr., 1884 M. 26 Nov., 1895
†**Weir, Thomas**, China Merchants' Steam Navigation Co., Marine Superintendent's Office, Shanghai, China,	23 Apr., 1889

WEIR, THOMAS D., Messrs Brown, Mair, Gemmill & Hyslop, 162 St. Vincent street, Glasgow,	G. 19 Dec., 1876 M. 26 Feb., 1884
WEIR, WILLIAM, Holm foundry, Cathcart, Glasgow,	G. 28 Jan., 1896 M. 22 Nov., 1898
WELSH, JAMES, 3 Princes gardens, Dowanhill, Glasgow,	G. 24 Nov., 1885 M. 26 Oct., 1897
WELSH, Thomas M., 3 Princes gardens, Dowanhill, Glasgow,	17 Feb., 1869
WEST, HENRY H., 5 Castle street, Liverpool,	23 Dec., 1868
WHITE, RICHARD S., Shirley, Jesmond, Newcastle-on-Tyne,	20 Feb., 1883
WHITEHEAD, JAMES, 6 Buchanan terrace, Paisley,	6 Apr., 1887
WILKS, HARRY,	22 Nov., 1898
WILLIAMS, LLEWELLYN WYNN, B.Sc., Cathcart, Glasgow,	22 Feb., 1898
WILLIAMS, WILLIAM, Grand Hotel, Glasgow,	23 Jan., 1900
WILLIAMSON, ALEXANDER, 67 Esplanade, Greenock,	21 Mar., 1899
WILLIAMSON, JAMES, Director H.M. Dockyards, Whitehall, London,	23 Dec., 1884
WILLIAMSON, JAMES, Marine Superintendent, Gourock,	24 Mar., 1896
WILLIAMSON, ROBERT, Brithdir works, Alexandra docks, Newport, Mon.,	20 Feb., 1883
WILSON, ALEXANDER, Dawsholm Gasworks, Maryhill, Glasgow,	28 Jan., 1896
WILSON, ALEXANDER, Hyde Park Foundry, Finnieston street, Glasgow,	23 Feb., 1897
WILSON, DAVID, Arecibo, Porto Rico, West Indies,	25 Oct., 1887
WILSON, GAVIN, 107 Pollok street, S.S., Glasgow,	22 Oct., 1889
WILSON, JAMES, Corporation Water Works, Edinburgh,	23 Dec., 1868
†WILSON, JOHN, 165 Onslow drive, Dennistoun, Glasgow,	22 Feb., 1870
WILSON, JOHN, 101 Leadenhall street, London, E.C.,	24 Dec., 1895
WILSON, W. H., 34 Maxwell drive, Pollokshields, Glasgow,	22 Feb., 1898
WILSON, WILLIAM, Lilybank Boiler works, Glasgow,	30 Apr., 1895
*†WINGATE, THOMAS, Viewfield, Partick, Glasgow,	20 Jan., 1858
WOOD, ROBERT C., 3 Robertson street, Greenock,	23 Mar., 1897
WOODBURN, J. COWAN, 18 Beechwood drive, Jordanhill, Glasgow,	23 Jan., 1900
WORKMAN, HAROLD, B.Sc., Dunluce, Dullatur,	21 Dec., 1897
WRENCH, WILLIAM G., 27 Oswald street, Glasgow,	25 Mar., 1890
WRIGHT, ROBERT, 172 Kilmarnock Road, Shawlands,	22 Dec., 1896
WYLIE, ALEXANDER, Kirkfield, Johnstone,	26 Oct., 1897
WYLIE, WILLIAM, 33 Maxwell drive, Pollokshields, Glasgow,	26 Apr., 1898
WYLLIE, JAMES BROWN, 134 St. Vincent street, Glasgow,	G. 25 Oct., 1887 M. 26 Jan., 1897

YOUNG, J. DENHOLM, 2a Tower Chambers, Liverpool,	G. 24 Jan., 1888 M. 23 Jan., 1894
YOUNG, JOHN, Galbraith street, Stobcross, Glasgow,	27 Nov., 1867
YOUNG, THOMAS, 4 West Regent street, Glasgow,	20 Mar., 1894
YOUNG, WILLIAM L., 33/35 Stanley street, Kinning Park, Glasgow,	22 Nov., 1898
YOUNG, WILLIAM ANDREW, Millburn House, Renfrew,	26 Mar., 1895
YOUNGER, A. SCOTT, B Sc., 8 Walmer crescent, Glasgow,	24 Nov., 1896

ASSOCIATES.

*AITKEN, THOMAS, 8 Commercial street, Leith.	
ALLAN, HENRY, 25 Bothwell street, Glasgow,	23 Jan., 1900
ANDERSON, JAMES, c/o Masson, 26 Merryland street, Govan,	24 Apr., 1900
ARMOUR, WILLIAM NICOL, 175 West George street, Glasgow,	24 Nov., 1896
BAILLIE, ARCHIBALD, 2 Balmoral terrace, Glasgow,	25 Jan., 1898
BAIN, ANDREW, 17 Athole gardens, Glasgow,	26 Oct., 1897
BARCLAY, THOMAS KINLOCH, 55 Lochleven road, Langside, Glasgow,	20 Mar., 1900
BEGG, WILLIAM, 34 Belmont gardens, Glasgow,	19 Dec., 1886
BLAIR, HERBERT J., 30 Gordon street, Glasgow,	23 Feb., 1897
BROWN, Capt. A. R., 34 West George street, Glasgow,	21 Dec., 1897
†BROWN, JOHN, B.Sc., 11 Somerset place, Glasgow,	25 Jan., 1876
BRYCE, JOHN, Sweethope cottage, North Milton road, Dunoon,	18 Jan., 1865
CASSELS, WILLIAM, Cairndhu, 12 Newark drive, Pollokshields, Glasgow,	21 Feb., 1893
CLAUSSEN, A. L., 118 Broomielaw, Glasgow,	22 Jan., 1892
CLYDE, WALTER P., Messrs T. S. M'Innes & Co., Ltd., 42 Clyde place, Glasgow,	24 Oct., 1899

Names marked thus * were Associates of Scottish Shipbuilders' Association at incorporation with Institution, 1865.

Names marked thus † are Life Associates.

DEWAR, JAMES, 11 Regent Moray street, Glasgow,	22 Dec., 1897
DOBBIE, W. L., 101 Waterloo street, Glasgow,	20 Dec., 1898
DODDRELL, EDWARD E., 11 Bothwell street, Glasgow,	26 Oct., 1897
DONALD, JAMES, 123 Hope street, Glasgow,	19 Dec., 1899

FERGUSON, PETER, 19 Exchange square, Glasgow,	27 Apr., 1897
FISHER, WALTER L., Glenburn Iron works, Greenock,	26 Mar., 1895

GALLOWAY, JAMES, Jun., Whitefield works, Govan, Glasgow,	27 Oct., 1891
GARDINER, FREDERICK CROMBIE, 24 St. Vincent place, Glasgow,	20 Feb., 1900
GARDINER, WILLIAM GUTHRIE, 24 St. Vincent place, Glasgow,	20 Feb., 1900
GARDNER, JAMES S.,	23 Mar., 1897
GOODRICH, WALTER FRANCIS, 66 Victoria street, Westminster, London, S.W.,	21 Dec., 1897

HALLIDAY, GEORGE,	21 Dec., 1897
HOLLIS, JOHN, 40 Union street, Glasgow,	23 Nov., 1897

KINGHORN, WILLIAM A., 81 St. Vincent street, Glasgow,	24 Oct., 1882
KYLE, JOHN, Cathay, Forres, N.B.,	23 Feb., 1897

M'ARA, ALEXANDER, 65 Morrison street, Glasgow,	22 Nov., 1892
MACBETH, GEORGE ALEXANDER, 65 Great Clyde street, Glasgow,	24 Jan., 1899
MACBRAYNE, LAWRENCE, 11 Park Circus place, Glasgow,	26 Mar., 1895
MACDOUGALL, DUGALD, 1 Crosshore street, Greenock,	26 Jan., 1897
M'GECHAN, ROBT. K., 17 Oswald street, Glasgow,	26 Apr., 1898
M'INTYRE, JOHN, 33 Oswald street, Glasgow,	23 Feb., 1897
M'INTYRE, T. W., 21 Bothwell street, Glasgow,	24 Jan., 1893
M'LEOD, NORMAN, 53 Bothwell street, Glasgow,	20 Feb., 1900
M'MILLAN, ARCHIBALD, Dunollie, Dalmuir,	25 Jan., 1898
M'PHERSON, Captain DUNCAN, 8 Royal crescent, Crosshill, Glasgow,	26 Jan., 1886

MANN, WILLIAM, Whitecraigs, Giffnock,	20 Feb., 1900
MERCER, JAMES B., Broughton Copper works, Manchester,	24 Mar., 1874
MILLAR, THOMAS, Hazelwood, Langside, Glasgow,	22 Mar., 1898
MORTON, ALFRED, 8 Prince's square, Glasgow,	22 Feb., 1898
MOWBRAY, ARCHIBALD H., c/o Messrs Smith & M'Lean, Mavisbank, Glasgow,	22 Feb., 1898

*NAPIER, JAMES S., 33 Oswald street, Glasgow.

PAIRMAN, THOMAS, 54 Gordon street, Glasgow,	23 Jan., 1900
PRENTICE, THOMAS, 175 West George street, Glasgow,	24 Nov., 1896

RAEBURN, WILLIAM HANNAY, 81 St. Vincent street, Glasgow,	20 Feb., 1900
REID, JOHN, 30 Gordon street, Glasgow,	22 Dec., 1896
RIDDLE, JOHN C., 8 Gordon street, Glasgow,	15 June, 1898
RIGG, WILLIAM, 3 Grantly place, Shawlands, Glasgow,	22 Jan., 1889
RITCHIE, JAMES, 40 St. Enoch square, Glasgow,	22 Mar., 1898
ROBERTS, WILLIAM IBBOTSON, Rawmoor, Sheffield,	15 June, 1898
ROBERTSON, WILLIAM, Oakpark, Mount Vernon,	27 Apr., 1897
ROSS, THOMAS A., Glenwood, Bridge-of-Weir,	20 Mar., 1894
ROXBURGH, JOHN ARCHIBALD, 3 Royal Exchange square, Glasgow,	20 Feb., 1900

SERVICE, GEORGE WILLIAM, 175 West George street, Glasgow,	24 Nov., 1896
SERVICE, WILLIAM, 54 Gordon street, Glasgow,	23 Jan., 1900
SLOAN, GEORGE, 8 Gordon street, Glasgow,	20 Feb., 1900
SLOAN, WILLIAM, 8 Gordon street, Glasgow.	20 Feb., 1900
SMITH, JOHN, 2 Doune quadrant, Kelvinside, Glasgow,	22 Feb., 1898
STRACHAN, G., Fairfield works, Govan,	26 Oct., 1897

TAYLOR, WILLIAM GILCHRIST, 123 Hope street, Glasgow,	23 Jan., 1900

WALLACE, H., 544 St. Vincent street, Glasgow,	27 Apr., 1897
WARREN, ROBERT G., 115 Wellington street, Glasgow,	28 Jan., 1896

Watson, H. J., 134 St. Vincent street, Glasgow,	
Webster, J. A., Clydesdale works, Sheffield,	23 Nov., 1897
Weir, Andrew, 102 Hope street, Glasgow,	25 Jan., 1898
Whimster, Thomas, 67 West Nile street, Glasgow,	24 Oct., 1899
Wild, Charles William, Broughton Copper Company, Limited, 49-51 Oswald street, Glasgow,	24 Mar., 1896
Wrede, Frederick Lear, 25 Bentinck street, Greenock,	25 Jan., 1898

Young, John D., Scottish Boiler Insurance Company, 111 Union street, Glasgow,	19 Dec., 1882
Young, William, Galbraith street, Stobcross, Glasgow.	

GRADUATES.

Agnew, William H., Messrs. Laird Brothers, Birkenhead,	28 Nov., 1882
Ainslie, Alexander F., 50 St. Vincent cres., Glasgow,	21 Nov., 1899
Albrecht, J. August, c/o A. Albrecht, Esq., Constontia, near Cape Town, South Africa,	23 Nov., 1897
Alison, Alexander E., Devonport, Auckland, New Zealand,	22 Nov., 1898
Allan, Frederick William, 1 Cecil street, Glasgow,	21 Nov., 1899
Allan, James, 144 Buccleuch street, Glasgow,	24 Jan., 1888
Anderson, Adam R., Croftvale, Renfrew,	23 Mar., 1897
Anderson, George C., 2 Florentine gardens, Hillhead, Glasgow,	24 Dec., 1895
Arbuthnott, Donald S.. c/o Messrs Charles Brand & Son, 172 Buchanan street, Glasgow,	23 Oct., 1888
Arnott, Hugh Steele, Ravenswood, Annfield road, Partick, Glasgow,	26 Oct., 1897
Arundel, Arthur S. D., Penn street works, Hoxton, London, N.,	23 Dec., 1890

Bacon, Henry Douglas,	21 Nov., 1899
Baker, Frederick, W., 149a Tremont street, Boston, U.S.A.,	20 Mar., 1894
Barba, Alfonso G., c/o Messrs. J. M. & E. Montoya, Puerto Birrio, Republic of Colombia,	22 Dec., 1896
Barty, Thomas, 3 Albany street, Glasgow,	24 Oct., 1899

Baxter, Edmund G.,	22 Nov., 1892
Bennett, Duncan, 12 Louis street, Leeds,	26 Oct., 1897
Bertram, R. M., 9 Walmer road, Toronto, Canada,	24 Jan., 1899
Bianchi, Manuel, 18 Glasgow street, Glasgow,	21 Nov., 1899
Binley, William, Jun., Box 36, Newport, News, Virginia, U.S.A.,	21 Mar., 1899
Black, D. John, 51 Montgomerie street, Kelvinside, Glasgow,	25 Oct., 1892
Blair, Archibald, 15 Craigmore terrace, Partick,	27 Oct., 1885
Blair, Archibald, Jun., 7 Corunna street, Glasgow,	27 Oct., 1891
Blair, Frank R., Ashbank, Maryfield, Dundee,	22 Mar., 1892
Bone, Quintin George, 5 University avenue, Hillhead, Glasgow,	19 Dec., 1899
Bowie, Robert, c/o Messrs William Baird & Co., New Cumnock,	20 Nov., 1894
Bowman, W. D., 21 Kersland terrace, Hillhead, Glasgow,	22 Dec., 1891
Boyd, Guy W.,	26 Oct., 1897
Boyle, Edward S. S., 9 Arlington street, Glasgow,	25 Jan., 1898
Brand, Mark, B.Sc., Barrhill cottage, Twechar, Kilsyth,	24 Jan., 1888
Brown, Alexander Taylor, 2 Parkgrove terrace, Sandyford, Glasgow,	26 Oct., 1897
Brown, David A., 18 Willowbank street, Antrim road, Belfast,	23 Feb., 1897
Brown G. J. L., 2 Sandringham terrace, Ayr,	21 Mar., 1899
Brown, J. Pollock, 2 Park Grove terrace, Glasgow,	18 Dec., 1894
Brown, James,	20 Mar., 1888
Brunton, Robert, Engineer's Office, St. Enoch Station, Glasgow,	20 Feb., 1900
Bryce, John, Burgh Surveyor's Office, Partick,	22 Dec., 1896
Bryson, William, 21 Cartvale road, Langside, Glasgow,	24 Oct., 1899
Buchanan, Joshua Miller, 7 Glenton terrace, Kelvinside, Glasgow,	21 Nov., 1899
Buchanan, Walter G., 17 Sandyford place, Glasgow,	27 Jan., 1891
Burnside, Bertram W., c/o Mrs Stewart, 16 Flemington street, Springburn, Glasgow,	24 Feb., 1891

Caird, William, 12 Avenell road, Highbury, London,	21 Jan., 1890
Calder, John, Lees avenue, Collingswood, New Jersey, U.S.A.,	24 Feb., 1891
Caldwell, Hugh, Oak house, Blackwood, Newport, Mon.,	27 Jan., 1891
Cameron, Hugh, 40 Camperdown road, Scotstoun, Glasgow,	25 Oct., 1892

Campbell, Angus, 25 Stafford road, Southampton,	24 Jan., 1888
Carslaw, William H., Jun., Parkhead Boiler works, Parkhead, Glasgow,	23 Dec., 1890
Cassells, Robert D., B.Sc., 62 Glencairn drive, Pollokshields, Glasgow,	28 Oct., 1890
Chalmers, Alex. D., Electricity works, New Brompton, Kent,	27 Oct., 1896
Cleland, John, B.Sc., Mansion house, Easterhouse,	26 Feb., 1884
Cleland, W. A., Yloilo, Philippine Islands,	25 Apr., 1893
Cochrane, James, Resident Engineer's Office, Harbour works, Table Bay, Capetown,	27 Oct., 1891
Cowan, D. G., 5 Balgray terrace, Springburn, Glasgow,	24 Oct., 1899
Craig, Alexander, Netherlea, Partick, Glasgow,	26 Nov., 1895
Craig, James, Netherlea, Partick,	22 Feb., 1898
Craig, James C. M., 3 Tulliallan place, Paisley road, W., Glasgow,	22 Nov., 1898
Crawford, James M., 50 North Frederick street, Glasgow,	22 Nov., 1898
Crichton, J., 155 Berkeley street, Glasgow,	23 Nov., 1897
Cubie, Alexander, Jr., Engineer, 146 Dalmarnock road, Glasgow,	23 Jan., 1900
Cuninghame, A. R., 53 Cecil street, Hillhead, Glasgow,	24 Oct., 1899
Cunningham, P. Nisbet, Jun., Easter Kennyhall house, Cumbernauld road, Glasgow,	22 Nov., 1898
Cuthbert James G., 33 Cartvale road, Langside, Glasgow,	21 Nov., 1899

Davidson, Wm. J. J., Castlehill, Renfrew,	22 Nov., 1898
Davies, Harry L., c/o Messrs Cochran & Co., Annan, N.B.	18 Dec., 1888
Davies, Percy M.,	24 Jan., 1899
Dekke, Kristian S., Bergen, Norway,	22 Dec., 1891
De Keyser, Felix, 30 Granby Terrace, Hillhead, Glasgow,	19 Dec., 1899
De Sola, Juan Garcia, Westonlee Villa, Ronhill road, Dumbarton,	20 Mar., 1900
Deveria, Lewis M. T., c/o Messrs P. M'Intosh & Son, 129 Stockwell street, Glasgow,	10 Feb., 1883
Diack, James A., 4 Rosemount terrace, Ibrox, Glasgow,	22 Jan., 1895
Dickie, James, c/o Currie, 3 Sandbank place, Partick,	19 Dec., 1899
Dobbie, Robert B., Laurel bank, Ayr,	24 Oct., 1899
Dobson, James, Queen street, Kidsgrove, Staffordshire,	22 Dec., 1896
Donald, Patrick D., B.Sc.,	24 Feb., 1891

DONALDSON, A. FALCONER, Beechwood, Partick, Glasgow,	27 Oct., 1896
DONALDSON, GEORGE, 44 Gardner street, Partick,	22 Nov., 1898
DOUGLAS, CHARLES STUART, B.Sc., "St. Brides," 12 Dalzell drive, Pollokshields, Glasgow,	24 Jan., 1899
DUNCAN, JAMES GRIEVE, 137 Shields road, Glasgow,	22 Nov., 1898
DUNLOP, ALEX., 14 Derby terrace, Sandyford, Glasgow,	21 Dec., 1897
DUNN, TURNER, 20 Park circus, Glasgow,	21 Feb., 1893

EDMISTON, ALEXANDER A., Ibrox house, Govan,	22 Feb., 1898

FAIRLEY, JOHN, Park road, Hamilton,	21 Nov., 1899
FAUT, ALEXANDER, 122 Holland street, Glasgow,	19 Dec., 1899
FEIST, JOHN ARNOLD,	24 Mar., 1896
FERGUS, ALEXANDER, 7 Ibrox place, Glasgow,	22 Dec., 1891
FERGUSON, JAMES M.,	25 Oct., 1892
FERGUSON, LEWIS, Fergus villa, Paisley,	22 Jan., 1895
FERGUSON, PETER, Jun., Fergus villa, Paisley,	22 Jan., 1895
FERGUSSON, W. L., Hawcoat lane, Abbey road, Barrow-in-Furness,	22 Dec., 1891
FIELD, EDWARD PEARSALL, 29 Queen Margaret drive, Glasgow,	21 Nov., 1899
FINDLATER, JAMES, 124 Pollok street, Glasgow, S.S.,	19 Dec., 1899
FINDLAY, LOUIS, c/o Mrs Ferguson, 29 Bentinck street, Glasgow,	21 Feb., 1893
FRANCE, JAMES, 8 Hanover terrace, Kelvinside, Glasgow,	26 Oct., 1897
FRASER, J. IMBRIE, 13 Sandyford place, Glasgow,	27 Apr., 1886
FULTON, NORMAN O., Woodbank, Mt. Vernon, Glasgow,	23 Feb., 1892
FYFE, CHARLES F. A., 38 Burnbank gardens, Glasgow,	18 Dec., 1894

GALBRAITH, HUGH, 75 Waterloo street, Glasgow,	20 Dec., 1898
GALLOWAY, ANDREW, 11 Camphill avenue, Langside, Glasgow,	24 Oct., 1893
GARDNER, HUGH, Minas Schwager, Coronel, Chili,	23 Apr., 1889
GIBB, JOHN, 43 Waterside street, Kilmarnock,	24 Jan., 1899
GIBSON, ROBERT E., Engineer's Department, S. Eastern and Chatham and Dover Railways, Tooley street Offices, London Bridge Station, S.E.,	25 Jan., 1898
GILMOUR, ALEXANDER, Barrhead,	22 Nov., 1898
GILMOUR, ANDREW, 3 Nursery place, Annan,	20 Dec., 1898

Goudie, Robert, Junr , 14 Alloway place, Ayr,	21 Nov., 1899
Goudie, William J., B.Sc., 92 Albert drive, Crosshill, Glasgow,	21 Dec., 1897
Gourlay, James, 11 Crown gardens, Dowanhill, Glasgow,	27 Oct., 1891
Gourlay, R. Cleland, 11 Crown gardens, Glasgow,	24 Dec., 1895
Govan, William A., Westholme, West Kilbride,	18 Dec., 1894
Graham, George, 18 Caird drive, Partickhill, Glasgow,	22 Nov., 1898
Grant, William, Croft park, High Blantyre,	24 Oct., 1899
Gruning, Henry H., 5 Park terrace, Govan,	20 Dec., 1898

Hamilton, Walter, Junr., 44 Cleveland street, Glasgow,	21 Nov., 1899
Hay, William,	20 Dec., 1892
Henderson, Charles A., Corporation Electrical Department, Cotton street, Aberdeen,	24 Jan., 1899
Henderson, Harry Esdon, c/o Mrs Howell, 28 Orwell road, Liverpool	22 Nov., 1898
Henricson, John A., 3 Sandbank place, Partick, Glasgow,	19 Dec., 1899
Hepting, F. W. L., c/o Miss Goudie, 120 Frederick street, South Shields,	20 Nov., 1894
Herschel, A. E. H., 6 Roxburgh street, Hillhead, Glasgow,	19 Dec., 1899
Holland, Henry Norman, 68 Commercial road, Grantham,	22 Nov., 1898
Horn, George S., 34 Annette street, Govanhill, Glasgow,	21 Nov., 1899
Horn, Peter Allan, 201 Kent road, Glasgow,	26 Oct., 1897
Houston, Percival T., 22 Lancaster Gate, London,	22 Nov., 1898
Houston, William C., 4 Abbotsford place, Glasgow,	26 Oct., 1897
Howson, George, c/o Mrs Findlay, 5 Craignethan gardens, Partick,	22 Dec., 1891
Hudson, Gerard, 47 W. Cumberland street, Glasgow,	22 Jan., 1895
Hutchison, Robert, 76 Kenmure street, Pollokshields, Glasgow,	24 Oct., 1899

Inglis, John F., Pointhouse Shipyard, Partick,	26 Oct., 1897
Innes, W., 11 Walmer terrace, Glasgow,	22 Feb., 1898
Irvine, Archibald B., 8 Newton terrace, Glasgow,	20 Nov., 1894

Johnstone, Alexander C., 7 Blackburn street, Paisley road, West, Glasgow,	25 Jan., 1898

JOHNSTONE, ROBT., c/o Mrs M'Vicar, 20 Rothesay gardens, Partick,	26 Apr., 1898
JONES, T. C., Kent Avenue, Jordanhill, Glasgow,	23 Nov., 1897
JUDD, EDWIN H., 65 South Cromwell road, Crosshill,	20 Dec., 1898

KAY, ALEXANDER J., Messrs Mackie & Thomson, Govan,	24 Oct., 1893
KEMP, JOHN, 1 Thornwood terrace, Partick, Glasgow,	28 Oct., 1890
KEMP, ROBERT G., 2 Ravenscroft avenue, Connswater, Belfast,	28 Oct., 1890
KING, CHARLES A., 12 Kew gardens, Kelvinside, Glasgow,	25 Apr., 1893
KING, JOHN, 16 Lefroy street, Newcastle-on-Tyne,	26 Jan., 1886
KINMONT, DAVID W., Railway Contractor's office, Larkhall,	20 Feb., 1894
KIRK, JOHN, Oakfield, University avenue, Glasgow,	20 Nov., 1894
KNOX, ALEX., 12 Westbank terrace, Hillhead, Glasgow,	23 Nov., 1897

LAING, ROBERT,	21 Feb., 1893
LAMB, STUART, Engineer's Office, St. Enoch Station, Glasgow,	23 Jan., 1900
LAMONT, THOMAS W., Hawkhead works, Paisley,	22 Nov., 1892
LAUDER, THOMAS H., Parkhead forge, Glasgow,	19 Dec., 1893
LAW, ALEXANDER, 44 Dowanhill street, Partick,	26 Apr., 1898
LE CLAIR, LOUIS J., 115 Donore terrace, South Circular road, Dublin,	24 Nov., 1896
LEE, JOHN, 15 St. John street, Mansfield,	26 Jan., 1886
LEITCH, WILLIAM ORR, Jun., Engineer's Department, Imperial Railway, Tientsin, North China,	22 Dec., 1891
LENNOX, ALEXANDER, 34 Glasgow street, Hillhead, Glasgow,	23 Jan., 1894
LENNOX, GEORGE K.,	28 Apr., 1896
LESLIE, JOHN, 29 Elder Park street, Govan, Glasgow,	20 Dec., 1892
LLOYD, HERBERT J., c/o Miss Woods, Canal street, Johnstone,	21 Dec., 1897
LORIMER, ALEXANDER SMITH, Kirklinton, Langside, Glasgow,	21 Nov., 1899
LORIMER, HENRY DÜBS, Kirklinton, Langside, Glasgow,	21 Nov., 1899
LOWE, JAMES, c/o Mackie, 90 Thistle street, Glasgow,	24 Oct., 1899

M'Arthur, Archibald, 91 Hyndland street, Partick,	24 Jan., 1893
Maccallum, Patrick F., The Athenæum, Glasgow,	2 Nov., 1880
Macdonald, John F., 5 Caird Drive, Partickhill,	21 Dec., 1897
Macdonald, Robert C., 138 Garthland drive, Glasgow,	21 Nov., 1899
MacEwan, Henry, 5 Cathkin terrace, Mount Florida, Glasgow,	27 Oct., 1891
M'Ewan, John, 3 Norse Road, Scotstoun, Glasgow,	26 Oct., 1887
Macfarlane, Duncan, Jun., 25 St. Andrew's drive, Pollokshields, Glasgow,	26 Oct., 1897
M'Gillivray, John A., 167 Broomloan road, Govan,	26 Oct., 1897
M'Gregor, John L., Coatbank Engine works, Coatbridge,	28 Jan., 1896
M'Houl, John B., 2 Windsor terrace, Langside, Glasgow,	24 Jan., 1899
M'Intosh, George, 5 Douglas terrace, Paisley,	22 Jan., 1895
M'Intosh, John, Oak bank, Bowling,	22 Jan., 1895
Mackintosh, John, 7 Park quadrant, Glasgow,	18 Dec., 1894
Mackintosh, Robert D., Bellevue place, Garngad hill, Glasgow,	20 Nov., 1894
Mackay, Harry J. S., 13 Spring Head, Edgbaston, Birmingham,	22 Feb., 1898
Mackay, Lewis C., Jun., 2 Maybank street, Crosshill, Glasgow,	22 Dec., 1896
Mackie, James, 478 St. Vincent street, Glasgow,	23 Mar., 1897
Mackie, Thomas P., 27 Alexander street, Glasgow,	23 Feb., 1897
Mackie, William, 29 Thomson street, Govan,	21 Dec., 1897
M'Kinnell, Robert, 56 Dundas street, S.S., Glasgow,	26 Feb., 1883
M'Lean, Arthur, 16 Pollok street, Glasgow,	24 Apr., 1900
M'Lean, Joseph M., c/o Shaw, 53 South street, Huddersfield,	26 Apr., 1898
McLean, John, 4 Springfield terrace, Glasgow, S.S.,	21 Nov., 1899
Macleod, Archibald, c/o Mrs MacNicol, 1 Princes street, Pollokshields, Glasgow,	19 Dec., 1899
Macleod, T. Torq. M., c/o Robertson, 5 Prince of Wales terrace, Byars road, Glasgow,	27 Oct., 1896
Macmillan, Campbell, B.Sc., 32 Gibson street, Glasgow,	24 Nov., 1896
M'Vitae, Andrew, 4 Clutha street, Paisley road, West, Glasgow,	21 Dec., 1886
M'Whirter, Anthony C., 214 Holm street, Glasgow,	21 Dec., 1897
Maitland, Cree, Sunger Ujong Railway, Port Dickson, Malay Peninsula,	22 Feb., 1887
Maitland, John,	20 Nov., 1894
Mather, John Boyd, Kirkhill, Mearns,	20 Mar., 1894
Melville, Alexander, Engineer's Office, St. Enoch Station, Glasgow,	20 Feb., 1900

Menzies, George, 20 St. Vincent crescent, Glasgow,	22 Jan., 1889
Menzies, Robert,	22 Jan., 1889
Mercer, John, c/o Mrs Duncan, 35 Crow road, Partick,	22 Oct., 1895
Millar, John S., 22 Rothesay gardens, Partick,	20 Nov., 1894
Millar, Thomas, Sir W. G. Armstrong, Whitworth & Co., Ltd., Walker Shipyard, Newcastle-on-Tyne,	25 Nov., 1884
Miller, Alexander, 2 Ailsa terrace, Hillhead, Glasgow,	22 Nov., 1898
Miller, James, 20 Iona place, Mt. Florida, Glasgow,	22 Nov., 1898
Miller, James William, 13 Drumoyne drive, Govan,	20 Dec., 1898
Miller, John, 811 Govan road, Govan, Glasgow,	23 Apr., 1889
Miller, Robert F, Wardlaw & Miller, 109 Bath street, Glasgow,	25 Feb., 1890
Mitchell, Charles, 10 Berlin terrace, Pollokshields, Glasgow,	25 Jan., 1898
Mitchell, R. M., 24 Howard street, Bridgeton, Glasgow,	23 Nov., 1897
Mollison, Hector A., B.Sc., 6 Hillside gardens, Partickhill, Glasgow,	22 Nov., 1892
Morison, Thomas, 41 St. Vincent crescent, Glasgow,	21 Nov., 1899
Morley, James Steel, 3 Buckingham square, Govan,	20 Feb., 1900
Morrison, Arthur M., 15 Albion crescent, Dowanhill, Glasgow,	17 Dec., 1889
Morrison, A., Alt-na-craig, Greenock,	23 Nov., 1897
Morton, Charles C., Ingleside, The Park, Waterloo, Liverpool,	25 Jan., 1898
Morton, W. Reid, Strathview, Bearsden,	26 Oct., 1897
Mowat, Magnus, Indian Midland Railway, Jharisi, N.W.P., India,	26 Oct., 1897
Muir, Andrew A., 189 Renfrew street, Glasgow,	22 Nov., 1898
Muir, James, 9 Garturk street, Glasgow,	21 Nov., 1899
Muir, James H., 140 Bath street, Glasgow,	26 Jan., 1892
Muirhead, William, Cloberhill, Knightswood, Maryhill, Glasgow,	28 Apr., 1891
Mundy, H. L., 99 Elland road, Holback, Leeds,	24 Oct., 1899
Murdoch, John A., 7 Park Circus place, Glasgow,	25 Oct., 1892
Murphy, B. Stewart, c/o C. H. Bailey, Esq., Barry Dock, Cardiff,	24 Oct., 1893
Mylne, Alfred, 116 Woodlands road, Glasgow,	26 Jan., 1897

Neil, Robert, 116 Forth street, Pollokshields, Glasgow,	20 Mar., 1900
Neill, Hugh, Jun., 44 Brisbane street, Greenock,	21 Nov., 1899
Newton, Charles A., 47 Full street, Derby,	25 Jan., 1898

Nicholson, Thomas,	26 Jan., 1886
Niven, John, 36 Princes square, Strathbungo, Glasgow,	22 Nov., 1898
Nowery, William, c/o Fraser, 46 Elderslie street, Glasgow,	21 Dec., 1897

Orr, J., 53 Bentinck street, Glasgow,	22 Oct., 1895
Orr, John, B.Sc., South African College, Cape Town,	26 Mar., 1895
Osborne, Hugh, 8 Broomhill terrace, West, Partick,	22 Dec., 1891
Osborne, Marshall, Ashlea, Clooney, Londonderry,	22 Dec., 1891

Paterson, James V., 307 Walnut street, Philadelphia, U.S.A.,	24 Jan., 1888
Paterson, Joseph Barr, 15 Eldon street, Glasgow,	22 Mar., 1898
Paton, Thomas, 1 Rosemount terrace, Ibrox, Glasgow,	20 Dec., 1892
Piggott, Joseph T., 94 North Frederick street, Glasgow,	23 Jan., 1900
Pollock, Gilbert F., 10 Beechwood drive, Tollcross, Glasgow,	27 Jan., 1891
Pollok, John, Portland park, Hamilton,	22 Feb., 1898
Portch, Ernest C., 37 Vicars hill, Ladywell, Kent,	26 Oct., 1897
Prentice, Hugh, Millbank, Yoker,	26 Apr., 1898
Preston, John C., Assistant Engineer, Brisbane Board of Water works, Brisbane, Queensland,	6 Apr., 1887
Pringle, William S., 15 Elm place, Aberdeen,	24 Oct., 1893

Ralston, Shirley B., 34 Gray street, Glasgow,	23 Feb., 1897
Raphael, Robert A., 150 Renfrew street, Glasgow,	24 Dec., 1895
Reid, David H., Attiquin, Maybole,	25 Oct., 1887
Reid, Henry P., 12 Grantly gardens, Shawlands, Glasgow,	20 Dec., 1898
Reid, James, 128 Dumbarton road, Glasgow,	22 Oct., 1895
Reid, Walter,	26 Feb., 1884
Richmond, James, 24 Sutherland terrace, Hillhead, Glasgow,	23 Jan., 1894
Richmond, Tom, 4 Rosemount terrace, Ibrox, Glasgow,	20 Feb., 1900
Riddlesworth, W. H., B.Sc., 39 Caird drive, Partickhill, Glasgow,	24 Oct., 1899
Ritchie, James, Wraymont villas, Bloomfield, Belfast,	26 Oct., 1897
Robertson, Alexander, 272 Darnley street, Pollokshields, Glasgow,	26 Oct., 1886

Robertson, David, Junr., B.Sc., 46 Queen's drive, Crosshill, Glasgow,	19 Dec., 1899
Robertson, Edward F.,	28 Oct., 1890
Rodger, Anderson, Jun., Glenpark, Port-Glasgow,	15 June, 1898
Roger, George William, Irvine Shipbuilding and Engineering Coy., Ltd., Irvine,	24 Nov., 1896
Ross, J. R., 64 Sandyford street, Glasgow,	25 Oct., 1898
Roy, William, 66 Meanley road, Manor park, Essex,	25 Jan., 1898
Russell, James, 63 Southfield road, East, Middlesbrough,	22 Dec., 1891

Sadler, Herbert C., B.Sc.,	19 Dec., 1893
Sanguinetti, W. Roger, Engineer's Office, St. Enoch Station, Glasgow,	20 Feb., 1900
Scobie, Alexander, Culdees, Partickhill, Glasgow,	27 Oct., 1885
Scott, John R., 51 Love street, Paisley,	21 Dec., 1897
Scott, Thomas R., 101 Mayfield road, Edinburgh,	22 Dec., 1896
Seath, Thomas R., Sunny Oaks, Langbank,	28 Mar., 1886
Seath, William Y., Sunny Oaks, Langbank,	23 Mar., 1886
Sexton, George A., 1 Hamilton terrace, W., Partick,	24 Nov., 1896
Sharp, James R., 227 Berkeley street, Glasgow,	24 Oct., 1899
Sharpe, William, B.Sc., Engineer-in-Chief's office, Natal Government Railway, Maritzburg, Natal,	24 Dec., 1895
Shaw, John J.,	24 Apr., 1894
Sibbald, Thomas Knight, c/o Messrs Cook & Son, Ltd., Cairo, Egypt,	26 Oct., 1897
Simpson, David C., 1 Fairlie Park drive, Crow road, Partick,	20 Dec., 1892
Sloan, John Alexander, 11 Rose street, Garnethill, Glasgow,	25 Jan., 1898
Smith, Alexander, 16 Court Hill, Bearsden,	24 Nov., 1891
Smith, Charles, 3 Rosemount terrace, Ibrox, Glasgow,	24 Apr., 1894
Smith, George F., 11 Woodside terrace, Glasgow,	26 Oct., 1897
Smith, James, 20 Dumbarton road, Glasgow,	20 Dec., 1892
Smith, James A., Union Bank house, Virginia place, Glasgow,	18 Dec., 1894
Smith, James S., c/o Miss Davidson, 101 Forth street, Pollokshields, Glasgow,	22 Nov., 1898
Sneddon, Richard M., 45a Whifflet street, Coatbridge,	21 Nov., 1899
Spalding, William, 532 St. Vincent street, Glasgow,	25 Oct., 1892
Sperry, Austin, 2100 Pacific avenue, San Francisco, U.S.A.,	23 Mar., 1897

Stark, James, Penang; Straits Settlements,	22 Dec., 1891
Steel, James, 84 Old Broad street, London, E.C.,	26 Jan., 1892
Steele, David J., Davaar, Albert drive, Pollokshields, Glasgow,	20 Dec., 1898
Steven, David M., 18 Sandyford place, Glasgow,	15 June, 1898
Steven, J. M., 2 Hampton Court terrace, Glasgow,	20 Dec., 1892
Steven, John A., 12 Royal crescent, Glasgow,	22 Nov., 1881
Stevens, Clement H., c/o Messrs Blandy Bros. & Co., Las Palmas, Grand Canary,	22 Dec., 1891
Stevenson, Archibald, Yloilo, Philippine Islands,	25 Apr., 1893
Stevenson, George, 50 Roselea drive, Dennistoun, Glasgow,	24 Apr., 1900
Stevenson, George, Hawkhead, Paisley,	22 Nov., 1898
Stevenson, William, Bank Chambers, Sandhill, Newcastle-on-Tyne,	25 Jan., 1881
Stewart, Henry, 26 Evelyn avenue, Bloomfield, Belfast,	26 Oct., 1897
Stirling, Andrew, Messrs Denny & Co., Engine works, Dumbarton,	21 Dec., 1875
Swan, James, Arcadia street, Dorchester, Mass., U.S.A.,	23 Mar., 1897
Symington, James R., Dardene, Kilmalcolm,	21 Dec., 1886

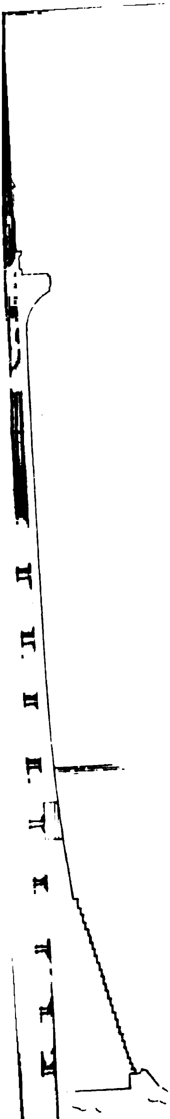
Taylor, Andrew P., 47 St. Vincent crescent, Glasgow,	19 Dec., 1899
Taylor, J. F., c/o Young, 300 Duke street, Glasgow,	23 Nov., 1897
Thomson, Ambrose H., Surveyors' Department, Court house, Marylebone lane, London, W.,	24 Mar., 1891
Thomson, Frederick, 18 Westbank terrace, Hillhead, Glasgow,	26 Jan., 1892
Thomson, Graham H., Jun., 2 Marlborough terrace, Glasgow,	22 Feb., 1898
Thomson, James, Hayfield, Motherwell,	20 Nov., 1894
Tod, Peter, c/o E. H. Williamson & Co., Engineers, Lightbody street, Liverpool,	27 Oct., 1885
Tod, William, c/o Miss Grauger, 24 St. Vincent crescent, Glasgow,	22 Feb., 1898
Turnbull, Campbell, 39 Victoria street, Westminster, London,	27 Oct., 1891
Turnbull, James, Hillcrest, Mansion-house road, Langside, Glasgow,	22 Mar., 1892
Turnbull, W. L., 190 West George street, Glasgow,	27 Oct., 1891
Turpin, C., 874 Govan road, Govan,	23 Nov., 1897

Walker, G. Underwood, 56 Woodhead street, Dunfermline,	21 Mar., 1893
Wallace, Hugh, Jr., Bloomfield, Dalmuir,	24 Oct., 1899
Wallace, John, Jun., c/o Messrs Donald Currie & Co., 137 West George street, Glasgow,	26 Jan., 1892
Wallace, John, 224 Meadowpark street, Glasgow,	21 Feb., 1899
Wannop, Charles H., Messrs Barclay, Curle & Co., Limited, Finnieston quay, Glasgow,	24 Feb., 1885
Watson, John, c/o Alexander Fleming, Esq., 9 Woodside crescent, Glasgow,	22 Nov., 1898
Watson, Robert, 2 Glencairn drive, Pollokshields, Glasgow,	22 Mar., 1881
Watt, Harry, 2 Cambridge terrace, Pollokshields, Glasgow,	20 Dec., 1892
Watt, Robert D., Messrs Butterfield & Swire, French Bund, Shanghai, China,	27 Apr., 1880
Weddell, Alexander H., B.Sc., Park villa, Uddingston,	22 Dec., 1896
Welsh, George Muir, 3 Princes gardens, Dowanhill, Glasgow,	21 Dec., 1897
Wemyss, George B., 57 Elliot street, Hillhead, Glasgow,	28 Nov., 1882
Wharton, Fred.,	26 Oct., 1897
White, Hedley G., 3 Glenan gardens, Helensburgh,	24 Jan., 1899
Whitehead, John, Eccleston, Wallace st., Kilmarnock,	18 Dec., 1883
Whittelsey, Henry N., 33 Substation, New York,	23 Mar., 1897
Williams, R. R., 17 Newton street, Glasgow,	20 Feb., 1900
Wilson, John H., 4 Underwood, Paisley,	27 Oct., 1896
Wilson, Thomas, 66 Alexandra parade, Glasgow,	20 Feb., 1900
Wilson, W. Renfrew, B.Sc., Thorncliff, Greenock,	24 Oct., 1899
Woods, Joseph, L.C.C. Offices, 547 Old Ford road, Bow, London,	25 Feb., 1896
Wright, Robert, c/o Hepple, 17 Co-operative terrace, Sunderland,	26 Oct., 1897
Wright, Thomas B., 2 Berkeley terrace, Glasgow,	20 Dec., 1898

Young, John, Jr., Fernbank, Kirkintilloch,	23 Nov., 1897

INDEX.

PLATE I



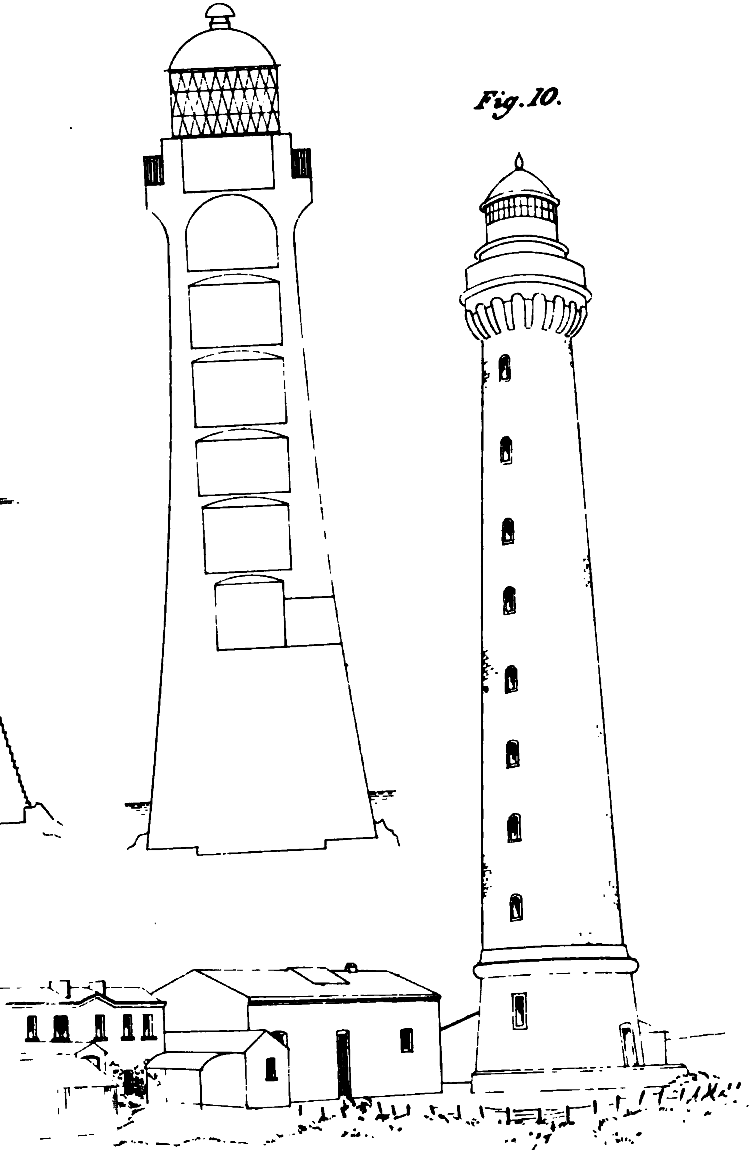


Fig. 12.

Fig. 10.

ROBERT GARDNER & CO.
ENGINEERING LITHOGRAPHERS, GLASGOW