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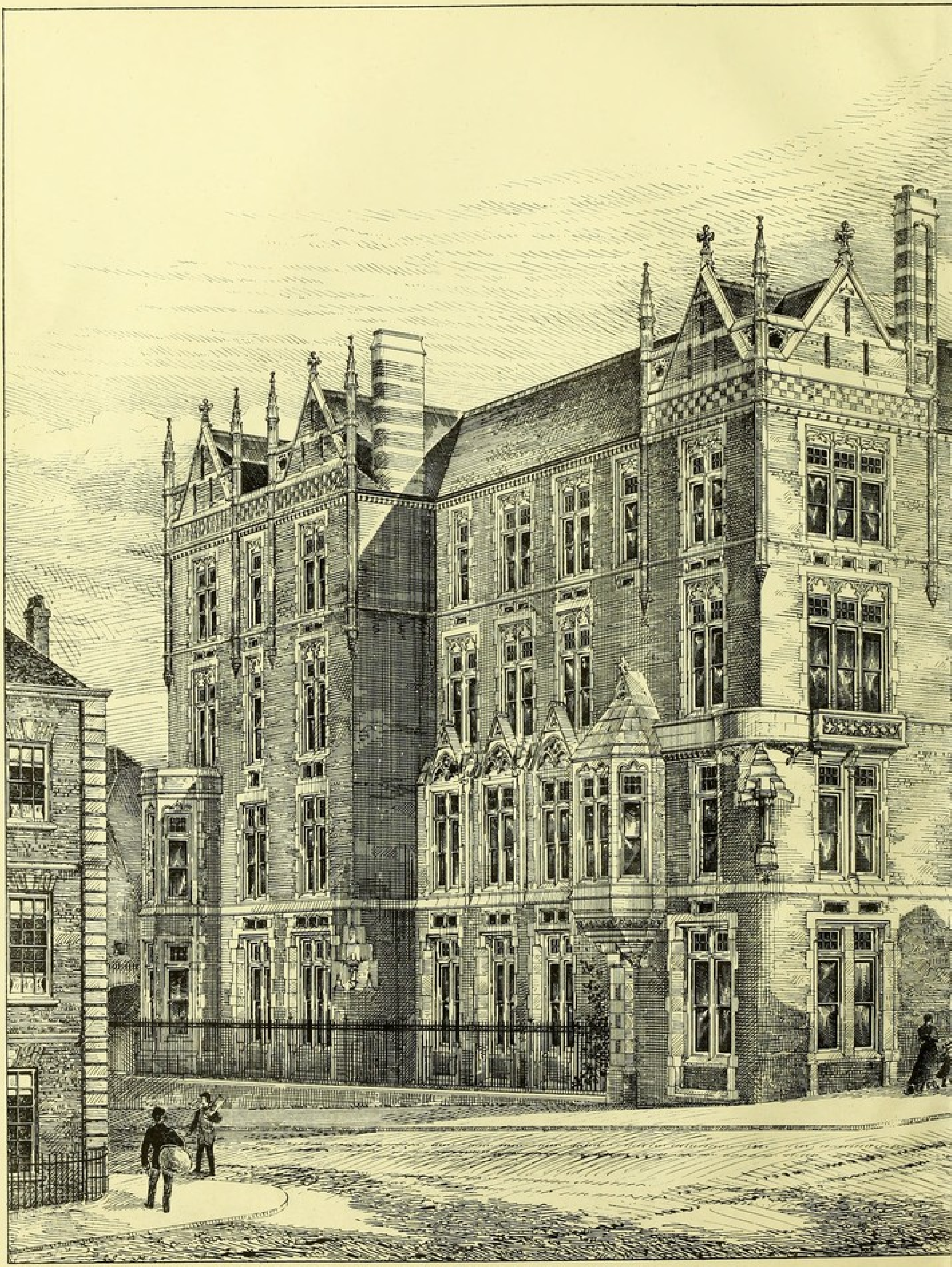

E. C. Robins F. S. A. Architect.

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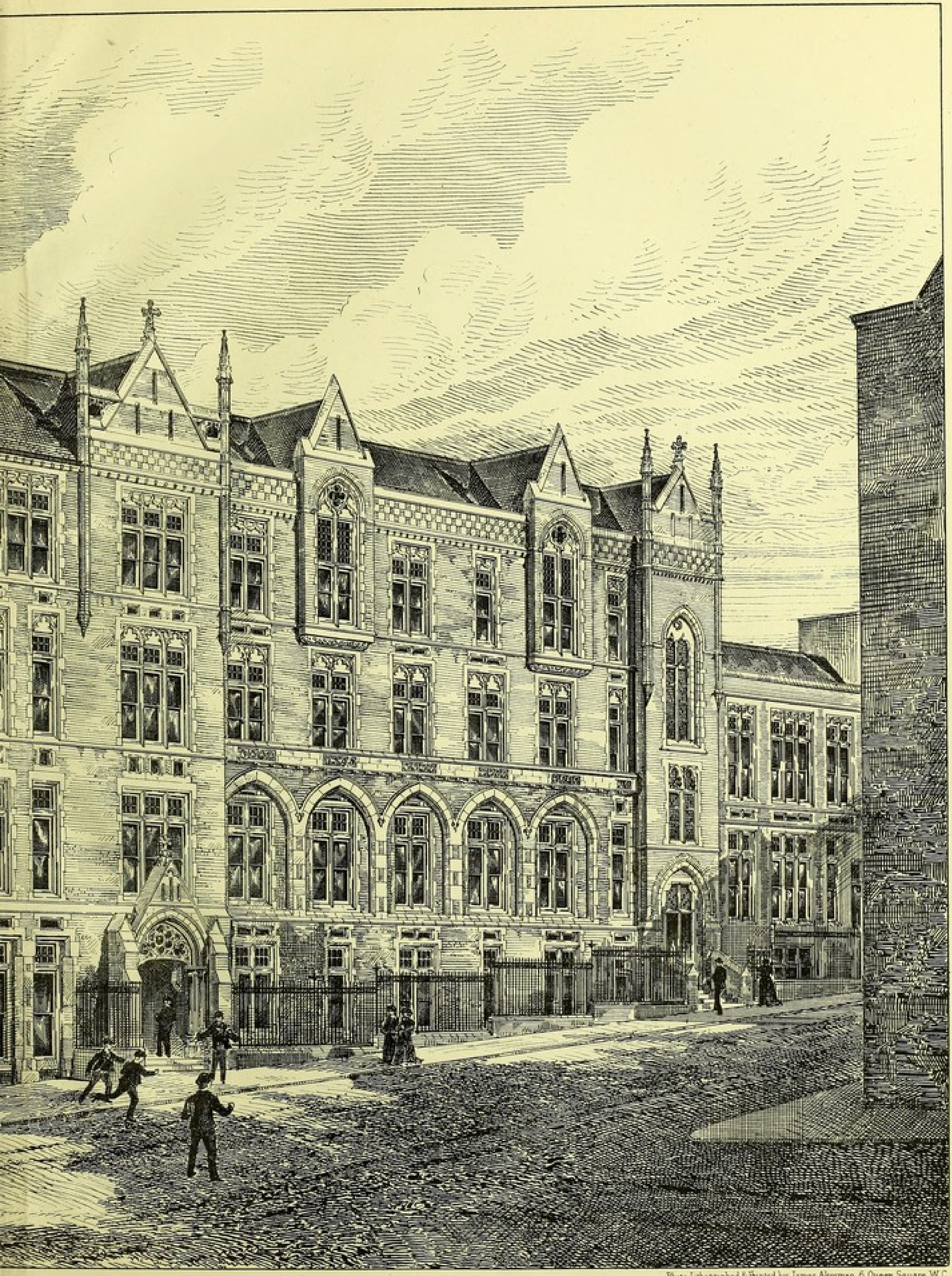

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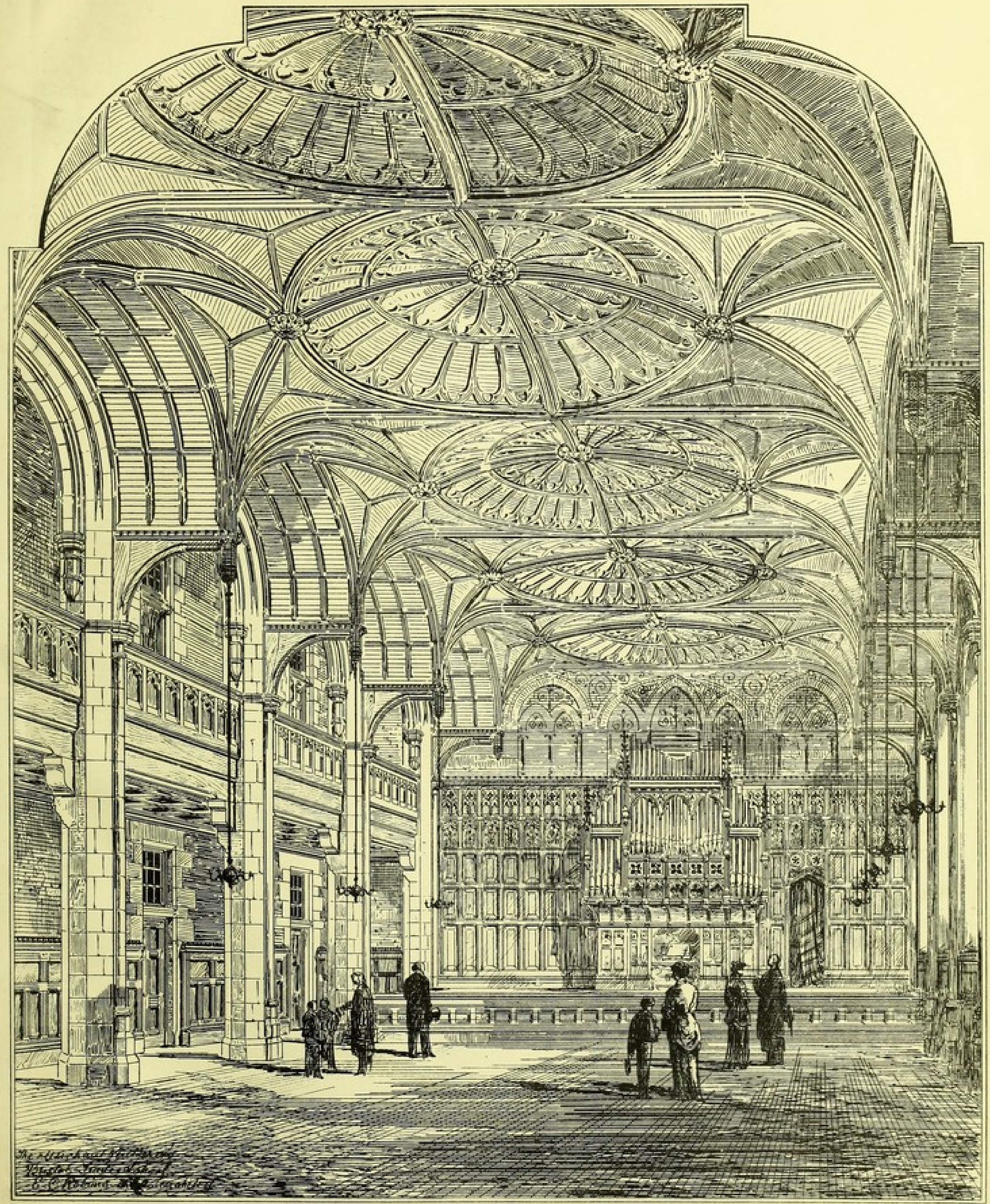
Bristol. North East View



E. C. Robins F.S.A. Architect.

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Merchant Venturers School, Bristol. The Great Hall.

PAPERS

ON TECHNICAL EDUCATION,

APPLIED SCIENCE BUILDINGS, FITTINGS

AND SANITATION.

BY

EDWARD COOKWORTHY ROBINS, F.S.A.

FELLOW OF THE ROYAL INSTITUTE OF BRITISH ARCHITECTS, MEMBER OF THE INSTITUTE OF SURVEYORS, MEMBER OF COUNCIL OF THE SANITARY INSTITUTE OF GREAT BRITAIN, MEMBER OF THE EXECUTIVE COMMITTEE OF THE CITY AND GUILDS OF LONDON INSTITUTE FOR THE ADVANCEMENT OF TECHNICAL EDUCATION, ETC. ETC.

LONDON:

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1885.

TO

SIR FREDERICK J. BRAMWELL, F.R.S.,

PRESIDENT OF THE INSTITUTION OF CIVIL ENGINEERS, AND CHAIRMAN
OF THE EXECUTIVE COMMITTEE OF THE CITY AND GUILDS
OF LONDON INSTITUTE FOR THE ADVANCEMENT
OF TECHNICAL EDUCATION,

(The example of whose untiring energy in the cause of Technical Education has inspired the Author to record his studies on the same subject),

these Pages are Inscribed.

INDEX OF SUBJECTS.

1. PREFATORY CHAPTER.
2. ENGLISH AND FOREIGN TECHNICAL EDUCATION, reprinted from *The Journal of the Society of Arts.*
3. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION, reprinted from *The Transactions of the Royal Institute of British Architects.*
4. FITTINGS, HEATING AND VENTILATION NECESSARY FOR APPLIED SCIENCE INSTRUCTION BUILDINGS, reprinted from *The Transactions of the Royal Institute of British Architects.*
5. BUILDINGS FOR SECONDARY EDUCATIONAL PURPOSES, reprinted from *The Journal of the Society of Arts.*
6. SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE, reprinted from *The Transactions of the Royal Institute of British Architects.*

APPENDIX.

THE REPORT OF THE CITY AND GUILDS OF LONDON INSTITUTE FOR THE ADVANCEMENT OF TECHNICAL EDUCATION FOR THE YEAR 1884.

PREFATORY CHAPTER.

THE studies recorded in this volume have resulted from the conviction of the author that the more general spread of technical education is of the greatest importance to this country, as a means of maintaining the superiority we have hitherto enjoyed as skilful designers, manufacturers, inventors and handicraftsmen.

By the original research of men of science, we are daily being brought face to face with Nature's laws as well as Nature's loveliness, and experimental knowledge is coming to be preferred to empirical teaching without the experimental test, because it is found that only in this way can theory and practice harmoniously coalesce and form new combinations culminating in fresh invention. In fact, intelligent doing, the result of artistic practice and scientific understanding generally, is rapidly superseding abstract thinking in dead languages and unapplied mathematical formulæ in this busy world of ours.

" It is through its practical value," say Professors Ayrton and Perry, that a knowledge of " mathematics must come; and any teacher who refuses to consider the instinctive preference " of his pupils to reason about *things* rather than about *ideas*, is a man who persistently " refuses the powerful aid of Nature."

" The danger in all these technical schools," said Professor Huxley in a letter to the author, " is this, that the scientific teacher generally begins his work on the high and dry " method, and fills the mind of the student with mere verbal formulæ before there is any " practical experience by which these ghosts can be embodied."

But while we may safely leave the educational *modus operandi* in the hands of our leading professors, it is manifest that so great a revolution in the systematic education of the period points to a corresponding change in the design of the buildings required for its development.

The object to be attained has been most happily paraphrased by Lord Shand in the third proposition of his opening address, delivered before the Watt Institution and School of Arts, Edinburgh, viz., " *Without* attempting the establishment of trade schools it is proposed " to *add* to the teaching of pure science, instruction in the practical application of scientific " principles to the operations of the trade (or profession) in which the student is engaged, " by *laboratory practice*, as distinguished from mere lectures on scientific subjects.

" In this way the student, having first acquired a certain amount of general scientific "knowledge, as the basis for advanced education, is thereafter taught the application of "science by actual laboratory experiments and practice of a kind bearing on the trade (or "profession) he is to follow; lectures by the teacher are by no means dispensed with, but "are made subordinate to the actual work in the laboratory, for which they are intended to be "a guide and an assistance."

My own interpretation of what should be comprised in the term "Technical Education" is very comprehensive, viz., that it is the complement and crown of all utilitarian education as contrasted with literary culture only—it is pure science carried to its legitimate issue: that is to say, its varied applications to human requirements; it is the practical application of scientific principles to special objects and purposes, and it is as necessary to professional men as it is acknowledged to be to manufacturers and artizans.

Technical education has at last obtained a firm hold of the public imagination, and the Government of the day long since deemed the times ripe for the establishment of a Royal Commission to enquire into the provisions made for its spread both here and abroad, and to report the result of their investigations with such recommendations as their experiences might authorize them to make. This has resulted in the publication of important papers full of facts and figures invaluable for reference.

The example of foreign nations has shown that the promotion of the ends in view will be greatly advanced by the provision of suitable buildings completely fitted for their purpose, and in the following pages the author has collected some of the most interesting facts concerning them. Professor Clowes has recently called attention to the same subject, and the illustration of the operating benches at University College, Nottingham, given herein forms the frontispiece of his book on chemical analysis.

The general question, from an educational point of view, both English and foreign, has been dealt with in the *first paper* of the series, written shortly after the author's tour in Germany, the discussion following which is very suggestive and interesting. Dr. Armstrong's paper, read at the Educational Conference of the Health Exhibition, indicates the lines upon which he believes scientific teaching should proceed in this country. Many specimens of his ingenuity in devising laboratory fittings for the City and Guilds of London Institute appear in this volume.

Examples of the various representative buildings at home and abroad, showing their general arrangement and system of planning, profusely illustrated, form the subject of the *second paper;* while in the *third*, the fittings required are given in detail, and the various systems of heating and ventilation applicable considered. Illustrations of the chemical laboratory operating benches of the Bristol School and of the Central Institution, South Kensington, and University College, Nottingham, have been added since the reading of the paper. So far as the works have been executed in the four representative English buildings, to which particular attention is called in the afore-mentioned papers, the heating and ventilation have answered the ends proposed; but at the Central Institution the internal iron smoke flue has been removed from the main ventilating shaft, the experience gained at Finsbury College proving that the draught is better without it. At Finsbury College the shaft was insufficiently heated, and resource was had to the direct action of a Blackman's fan upon the laboratory extract flues, with a perfect result. Professor Thorpe writes from the Yorkshire College, that

"The general ventilation of the main laboratory is excellent; it has the reputation of being "the best ventilated room in the whole building. The steam heating also works well in this "room."

The *fourth paper*, upon Secondary Educational Buildings, though the earliest written, fitly concludes the series, and dwells upon the importance of anticipating the ultimate requirements of laboratory science teaching in schools of this grade generally, and even in elementary schools.

In the *fifth paper*, Sanitary Science is separately considered and illustrated, and the systems of heating and ventilating applicable to public buildings discussed and compared.

Finally, the last report of the work of the City and Guilds of London Institute for the Advancement of Technical Education appears in an appendix, as an example showing what has been done in the Metropolis by the Institute; while the local description of the new Trade and Mining School of the Merchant Venturers at Bristol, erected from the designs and under the superintendence of the author (which is appended hereto) will suffice to show that the provinces are not far behind the Metropolis, and forms a fitting comment on the exterior and interior views of this Institution, which appear as frontispieces to this volume.

EDWARD C. ROBINS.

14, John Street, Adelphi.

[Extracted from *The Bristol Times and Mirror* of February 12th, 1884.]

"THE BRISTOL TRADE AND MINING SCHOOL."

"Progress of the New Building."

The distinguished career of the Bristol Trade and Mining School, now carried on in Nelson-street, combined with the vastly important and useful work in which it has been engaged for the past quarter of a century, has, we are pleased to say, been very properly recognized by the only remaining trade guild of the city—The Society of Merchant Venturers—and the action it has taken in relation to the schools will certainly prove advantageous, not alone to Bristol, but to the country generally. The Merchant Venturers having regard to the success attending this excellent institution, conceived the idea of further developing its usefulness, in hope, no doubt, of its forming the nucleus of a great school of scientific and technical education for those who, by and by, will be engaged in the various commercial, mining, engineering, and manufacturing industries of the West of England. The deliberations of the society upon the subject took a practical turn some four years since, when the members of the guild determined to erect new buildings for carrying on the school in all its branches, with due allowance for its anticipated growth ; and further that the new premises should contain provision for the experimental study of the applications of theoretic teaching to workshop practice, as well as a complete equipment for laboratory repetitions and investigations. For the realization of this idea an eligible site for the building was secured upon the ground formerly occupied by the old Bristol Grammar School, and from the plans of Mr. Edward Cookworthy Robins, F.S.A., of London, new schools were commenced by Messrs. Brock and Bruce, contractors, Albert-road, St. Philip's, about a year and nine months ago.

Before describing the new building, which, by the way, will cost considerably over £30,000., exclusive of the site, upon which several thousand pounds were expended, we should briefly draw attention to the work of the school. The Bristol Trade and Mining School has now been established over twenty-five years, being, we understand, one of the first in England to undertake the systematic teaching of science, and by degrees it has become an exceedingly comprehensive institution. Boys are received at the age of nine years, and are first passed through the elementary course, which constitutes the common groundwork of all branches of higher education. They are then offered the choice of a thorough commercial training or of a preparation on its scientific side for pursuits connected with manufactures and the constructive arts. Its mining department deals with the sciences required in mining and engineering, and it has a chemical laboratory for the study of practical chemistry, analysis, and assaying, which is open to others besides members of the school. Among the most important features of the institution are the evening classes, where courses of instruction for pupils of all ages in high mathematics, applied science, classics, modern languages, and other subjects of equal utility, are provided.

The present accommodation being somewhat meagre, the number of pupils is greatly limited, but nevertheless the school has within the last dozen years carried off a very fair proportion of the Royal scholarships which the Science and Art Department of the Committee of Council on Education has during the period mentioned offered for open competition throughout the United Kingdom. In addition to these honours it has won several scholarships and exhibitions at Oxford and elsewhere. This short reference to the work of the school speaks volumes for the soundness of the education imparted, and is a good augury for what it will be able to accomplish in its future and commodious abode, where all the newest and most improved appliances are to be introduced. The Society of Merchant Venturers deserves well of the city for providing not only a splendid and well-appointed building, which will be an ornament to Bristol, but for forwarding, as it surely will, the cause of scientific and technical education in so handsome a manner. We doubt not that the school, which already has won higher distinctions in some subjects than any other like establishment in England, will show itself worthy of the unbounded liberality displayed towards it, and also prove a big rival to similar institutions founded in the metropolis by the wealthier companies of London.

The building occupies a site at the corner of Unity Street and Denmark Street, in the rear of College Green, and is four stories in height. The site proved exceptionably troublesome in the matter of foundations, the builders having to excavate to a depth of 28 feet below the level of Denmark Street before obtaining footings, and 12 feet of concrete had to be laid down for bases. The excavations, however, have proved advantageous to Messrs. John Harvey & Co., Wine Merchants, Denmark Street, for they have been able to obtain spacious cellarage for the purposes of their business underneath the schools. The cellars extend the whole length of the new building in Denmark Street on to Unity Street end of the premises. The new schools cover an area of about 26,000 ft., and are of the fourteenth century Gothic style of architecture, the exterior being faced with the Cattybrook Company's red pressed bricks, with best Box ground stone dressings and green slating. There are two front elevations, one facing Unity Street and the other Denmark Street, and the total height of that in the last named street from the footings is 104 ft. whilst that in Unity Street is 80 ft. high. Upon the basement, which (owing to the situation of the building on the slope of the hill in Unity Street, connecting College Green with Denmark Street) is level with Denmark Street at the east end, and two-thirds below the level of Unity Street at the west end, there are three engineering workshops and testing rooms, a gymnasium, a dining hall 74 ft. by 22 ft., kitchen offices complete, engine and hot water apparatus rooms, and coal and fuel cellars. There is a long corridor separating the dining hall from the ten cloak rooms on the basement, and also covered and open playgrounds, 126 ft. long by 56 ft. wide. Messrs. Bacon & Co. will execute the heating and ventilation upon the principles laid down in a paper read some time since by the architect of these schools before the Institute of British Architects, on the "Relations of Sanitary Science to Civil Architecture." The electric light and the transmission of power by the electric current are also likely to find a field for its application to the various appliances contemplated. The ground floor is reached from the basement by a flight of steps, and here we find four class-rooms, each 25 ft. by 22 ft., and 15 ft. high ; committee, reception, and waiting rooms, and a library and museum 44 ft. square, several retiring rooms and conveniences. The great hall, the finest feature in the building, is situated on the same floor, but at the rear of the Unity Street front, facing the Mayor's chapel, and from that side it obtains its light. The hall is 80 ft. by 45 ft. and 28 ft. high. The class-rooms, we should here state, are entered from the great hall aisle or open corridor—Mr. Robins having applied to this building the principle of planning recommended in his lecture at the Society of Arts, in 1880, on "Secondary School Buildings," and termed by him "the hall passage system." Returning to the description of the great hall, we must state that it will be attractively fitted and adorned. Its style will be of a later period than that of the building generally, and will be lined with oak panelling 18 ft. high at the east end, where the platform will stand, whilst along the remaining sides it will be 7 ft. high. Gas is laid on to the hall, but in all probability it will be lighted, as will other parts of the building, by electricity. There will be a fan traceried ceiling of oak, designed to overcome the otherwise flat ceiling thereof. The open corridor arcade is of Portland stone, the pillars being 22 ft. high. The library and museum will be decorated in keeping with the hall—an 8 ft. 6 in. pitch pine dado will be fixed around the interior, whilst the other portions of the wall will be plastered, and the ceiling will be of pitch pine to match dado; the corridors will be faced with water-faced red bricks and Corsham stone dressings. The porter's and caretaker's quarters are also on this floor. The entrances to the school are from Unity-street, the boys entering from the western end of the block, whilst the principal entrance is in the centre of the Unity-street front. The most important and elaborate staircase will be that running up from the main or central entrance, the stairs being of hard Massa Carrara marble, and effectively arcaded. There will be six flights, the steps number 74. The second fireproof staircase—that for the boys—will consist of the same number of flights, but instead of marble will be cased with pennant stone. On the first floor there are four general class-rooms similar in size to those on the floor below, the Artificers' Drawing school, 59 ft. by 22 ft., obtaining lights both from Unity and Denmark-streets; next we find the Engineering Lecture-room, 32 ft. by 30 ft.; the Diagram-room; an Art Drawing school, 34 ft. by 23 ft.; library, cloak-rooms, &c. The upper portion of the great hall passes into this floor, and the class-rooms all open into the gallery of the great hall. On the second or topmost floor are situated the Chemical Lecture-room, 43 ft. by 28 ft.; the Physical Science Lecture-room, 42 ft. by 37 ft.; and the Chemical Laboratory, 53 ft. by 31 ft. Each room is lighted from the sides and by a skylight, and is about 17 ft. high. We also have on this floor, the Physical Science and Metallurgical Laboratories, each about 32 ft. by 22 ft. The latter laboratory contains a series of furnaces for the experiments carried on there. This is about the first building in which metallurgical laboratories have been placed upon the topmost floor. Previously they have been erected in the basement, and much inconvenience experienced from the fumes ascending to the other parts of the schools. The advantage, then, in having these laboratories or the upper floor is obvious. This floor also contains the combustion, balance, special operation, class, and master's rooms. A lift is provided from the basement to the uppermost floor, and this will prove a great convenience in bringing the various ores, fuel, &c., to the several flats. The ceilings of the majority of the rooms are to be panelled with pitch pine, and the internal facings of the walls of the principal rooms consist of Cattybrook red brick with Corsham stone dressings. The carving is being executed by Mr. Sheppard, of Paul-street. The boys' conveniences are external to the building and the sanitation has received minute attention. The bulk of the masonry is finished, the scaffolds are being lowered, and the fronts cleaned down. The contractors have so far executed their task in that thorough manner which always characterises the work of this firm, and the architect and the representatives of the society, who frequently inspect the progress of the building, are satisfied that every detail is being carried out. The clerk of the works is Mr. Withycombe, and the foreman for Messrs. Brock and Bruce is Mr. W. Tanner.

In the erection of the school the contractors have introduced some first-class machinery—some of it experimental only—and all has proved of invaluable service in the easy and speedy execution of their work. For instance, there are large mortar mills on the premises, worked by 30-horse power engine, two saws for cutting stone, horizontal and band, also worked by steam; a fine moulding machine, and a couple of steam lifts. In addition to these we observed a steam apparatus for pumping water from the basement to the various floors for the use of the masons, whilst all the stone, timber and other materials are fastened and lifted by means of steel ropes. These ropes have been used by the contractors to ensure safety, and as an evidence of the care taken by them we might state that no serious accidents to the workmen have occurred during the building operations. There is yet an enormous quantity of work to be done internally, and the building is not likely to be ready for occupation for another twelvemonth. We cannot conclude this notice without again expressing admiration at the magnificent proportions and substantial character of the structure, but it is to be regretted that it is so hidden from view of one of the principal thoroughfares of the City. This defect, however, could be easily remedied by the purchase and demolition of a few houses in College-green—from the corner of Unity-street to the Mayor's Chapel—and then not only would the new building, which is a grand acquisition architecturally to that part of the city, be thrown open to view, but the place of worship already named would likewise be seen on all sides.

[Extracted from *The Journal of the Society of Arts*, May 26, 1882.]

ENGLISH AND FOREIGN TECHNICAL EDUCATION.

By EDWARD COOKWORTHY ROBINS, F.S.A.

ONE of the special objects for which this Society was established, in 1754, and for which this Hall was erected twenty years after, is distinctly that which the title of the present paper suggests, viz., the extension of knowledge in respect of all those natural sciences which underlie the various industries of this and other countries. This circumstance (coupled with the fact that compulsory examinations have now become necessary to membership in many scientific societies) leads me to think it desirable to take note of the prospects of technical education, and the comparative value of English and foreign methods.

The very title itself is a "bone of contention," and on the present occasion I do not contemplate an exhaustive discussion of the whole subject in all its bearings, concerning which Sir William Thompson has said, "I do not know what a technical class is exactly." But I shall attempt an introduction to its study, by a classification of the objects to be obtained, of the classes of society intended to be benefited by it, and of the means proposed for adoption to that end.

It is impossible to listen to the various opinions from time to time expressed by speakers and writers on the subject, without being struck with the confusion of ideas which results from indefinite generalizations, made from a variety of standpoints, and usually empirically enforced as the only panacea for all the evils—real and fancied—which afflict the body politic of our industrial communities.

One enthusiast connects technical education with the development of manual dexterity, another with mental activity and scientific training, a third with a combination of both in one and the same person. One thinks the study of the application of scientific principles to industrial pursuits should precede apprenticeship, another that it should follow it, and a third that it should go on concurrently with it. One thinks our apprenticeship system the best, another the worst, and a third denies its present existence, and sighs for its resuscitation, or the substitution of something else in its place, neither English nor foreign, but emphatically suited to the needs of the age we live in and the racial peculiarities we represent. One thinks technical education should commence in our primary schools, another in our secondary schools, and a third, that every school should have its technical side as sharply developed as its classical proclivities were, are now, and ever shall be. One thinks it is our artisans who are at fault, another their masters, a third the altered conditions of both; but all agree that the maintenance of our acknowledged superiority in technical matters cannot long be continued while we ignore the deficiencies which may exist in our present practice, and complacently shut our eyes to the advantages which other nations are affording to their populations.

The energetic, independent, self-helpful qualities of the national character remain, its individuality as strongly marked as its insular position and prejudices, but as time rolls on, the conditions of life and labour are changed, and it follows that the ancient educational customs of the people, the old-world order of things, must needs change too, to meet the pressing wants of a superabundant population, and a revolution of thought and feeling, place, and circumstances, the result of fifty years of scientific development and commercial prosperity.

Within that period of time, bounded by my own life's experience, what have we not seen achieved? In fifty years to come what may we not expect? The steam-engine employed for manufacturing purposes, and for locomotion by land and sea, and all the developments of mechanical engineering sketched forth so ably by the Chairman of this Society's Council, Sir Frederick Bramwell, in a paper read before the British Association at York, last year, are already outstripped by the transmission of power by means of gas and the electric current, one system following upon another so quickly, that the breath is shortened and the brain bewildered by the quick succession of mechanical applications of physical laws, known to some extent in the abstract, but undeveloped before.

In this brief period of time, gas has succeeded oil lamps, and the electric light is extinguishing gas, as the sun eclipses all lesser luminaries. Railroads have supplanted stage coaches and inland canal navigation, steam vessels have well nigh superseded sailing craft, as iron has wood, and steel iron, in their construction; and armour-plating the "wooden walls of Old England."

Chemistry, physics, mechanics, biology, geology, mineralogy, crystallography, metallurgy, telegraphy, &c., are comparatively new sciences, the growth and applications of which have originated new centres of labour and thought, and constructed a new people out of an old stock, with new surroundings, new tastes, new wants, new purposes, hopes, and aspirations.

The intellectual and social condition of the industrial population, and the character of the education it should receive to fit the national mind to cope with the national progress, cannot be met by an extension of scholastic institutions based on the requirements of the middle ages.

Yet this is the spirit which has dominated our universities, and, until very lately, no concessions have been made to the reasonable demands of progressive civilization.

Secondary education has followed suit, and the study of intricacies of dead languages has been thought more profitable than the study of God's laws hidden away in the universe, and revealed only in answer to scientific research.

Primary education was left to the various religious denominations to wrangle over, till within the last decade; and the hopes of all men, untrammelled by vested interests, or party feelings, have come to centre round the roots of the national education tree, and not with its decaying branches.

The School Board is the starting-point of modern British educational legislation, and the improvement of the technical education of the masses which has begun, and is destined to widen, will necessitate a like improvement in all the grades above them. Intellectual superiority is the true mastery, and a knowledge of things, in preference to that of words, will be the distinguishing characteristic of the twentieth century. Who does not know (excepting, perhaps one class, that of mechanical engineers) that amongst skilled artisans, the master and apprentices of old time have been absorbed in the general contractor and his followers—the result of the inevitable competition accompanying the spontaneous growth of all nations? A sharp distinction is everywhere made between capital and labour, to the prejudice of the social status of the latter, because money can dispense with native work, and enlist the more intelligent foreign workman. This world-wide introduction of machinery has minimised handicrafts, and magnified mechanical production, with the unexpected but consequent result of raising the value of purely artistic developments everywhere.

If we are losing in scientific applications by competition with foreign countries, we are absolutely gaining in artistic development, for which alone we have made provision. The influence of South Kensington upon the artistic productions of the country has been great and beneficial, and the turn that fashion has taken in architecture has favoured the process; for whereas heretofore the exterior embellishment of a building was the chief aim of the designer; now, the attainment of interior comfort, beauty of detail, and harmony of colour, is the leading idea. Fecundity of artistic power in design is genius rather than talent—an instinct, rather than an acquirement—except so far as its means of expression are concerned. Well cultured speech best clothes fittest thought.

Art cannot walk freely in swaddling clothes, and thus it is that the freedom of choice and the individuality of the English artist is beginning to tell abroad, and the originality of English taste in architectural and ornamental design is rapidly supplanting continental. It is to England the Germans come for Christmas cards, original ornamental pottery, patterns for embroidery, &c.; and in Vienna lately, I could scarcely buy a *souvenir* that was not adorned with cuttings from Kate Greenaway's charming crudities. The new Industrial Art Museum and Schools in Vienna are professedly based on the example of South Kensington.

Comfortable as is this assurance in one department of art, it almost ceases there, if the following statistics may be depended on. The exports of English and Irish produce given in the statistical abstract of the Board of Trade, as quoted by Mr. Paul, of Dewsbury, at the Social Science Congress at Liverpool, in 1876, shows that, whereas, in 1872, the total exports of all kinds of British and Irish produce was £256,250,000; in 1875, three years later, it was £223,500,000 only, being a decrease of £32,750,000 sterling. And if we omit the colonies, the total exports to foreign countries in 1872 amounted to £195,750,000; while in 1875 it was only £152,500,000, being a decrease of £43,250,000. Contrasting these figures with our imports—the total imported in 1872 amounted to £354,750,000, while, in 1875, the amount had risen to £374,000,000, an increase of £20,000,000. In 1861, we only imported £217,500,000, and this shows a subsequent increase in our imports, in 1875, of £156,500,000.

Now, I am not an expert in political economy, but, on the face of it, it seems clear that, while we export much less, we import much more, and that foreign countries, must profit most on the exchange. But how it is to be explained I cannot tell, unless it can be shown that we are obliged to take goods instead of money in payment of what we export, to the equivalent extent of the difference. Failing this, the only thing that would occur to a private person in such a dilemma would be to search and see under what disadvantages he might be trying to work against his more prosperous neighbour. And this is exactly what public men are doing, and this feeling has given rise to the appointment of the Royal Commission on Technical Education, the preamble of their instructions commencing thus:—

"We have deemed it expedient that a Commission should forthwith issue, to inquire into the "instruction of the industrial classes of foreign countries in technical and other subjects, for "the purpose of comparison with that of the corresponding classes in this country; and into "the influence of such instruction on manufacturing and other industries at home and "abroad."

The Royal Commissioners have done wisely, as I think, in publishing their report in sections, and clearly defining the classes with whom they are about to deal.

1st. The instruction of the proprietors, and superior managers engaged in industrial pursuits.

2nd. That of the foremen engaged therein.

3rd. That of the workmen.

Their first report has been issued, and deals with primary education only, and almost exclusively the elementary education of France, and the extent to which technical education is comprised therein. That of Germany is to follow. Let us take the same course, and consider:—

1st. The technical education of the working classes.

2nd. That of their superiors and overlookers.

It is extremely gratifying to find that the conclusion to which the Royal Commissioners have come, with respect to the relative value of the technical teaching given in France and England, is so favourable to us. They state that:—

1st. "It will be manifest from the description we have given of the ordinary elementary and "apprenticeship schools in France, that, with the exception of the very recent introduction of "manual work into the schools of Paris, and of the instruction in trades, provided in a few "cases, for a small number out of hundreds of thousands of apprentices, French workmen "generally, as distinguished from those employed as foremen, or aspiring to that position, have "not till now, except as to systematic teaching in drawing, possessed during the school age, "better instructions than persons in a similar condition in this country."

From this it would appear that, in their judgment, it is not in the technical education of the ordinary working classes that we shall find the differences we are seeking to discover; which is the conclusion arrived at by the Conference of the Society of Arts in 1868 (hereafter given in detail).

On referring to the reports from her Majesty's diplomatic and consular agents abroad respecting the condition of the industrial classes in foreign countries, dated 1870, and made in answer to the circular of the late Lord Clarendon, primary education (which is gratuitously given in Paris, and in the provinces too, if the parents are poor) is said to comprise (in addition to the "three R's") the physical sciences, history, geography, mathematics and surveying, and even drawing, foreign languages, book-keeping, and geometry, by the laws of 1850, which also provided for the establishment of evening schools for adults over 18 years of age, and apprentices over 12. From this it would appear that the elementary technical education of the masses in France, had, at all events, a good start of us.

But the report of the French Commissioners on Technical Education in 1865, reveals a state of things much akin to our own, so far as these ordinary workmen are concerned; and in the great industrial centres, and especially at Paris, there was remarked by them "a growing tendency towards abandoning the system of apprenticeship, substituting the employment of lads as drudges, and as they began to learn by force of example, the masters raised their wages, which was their only encouragement to improve themselves."

Nevertheless, the Schools of Arts and Trades existed at Chalons, Angers, and Aix, and the

Conservatoire des Arts et Métiers in Paris, where workmen so fortunate as to be admitted might raise themselves to the position of skilled artisans and foremen in factories and workshops without expense, if they had sufficient energy to do so; no such corresponding advantage existing in this country. In the *Conservatoire*, at Paris, the courses were confined to lectures on science applied to industry, expressed in terms easily understood by the less instructed, but the pupils had access to a magnificent library and museum of models and machinery of art-workmanship. In the Schools of Arts and Trades the lads worked out the usual period of apprenticeship in special factories, in which a few hours of the day were devoted to the completion of their primary education. Of the twelve hours of instruction, five were devoted to theoretical instruction, such as geometry and mathematics, and seven hours to practical work in the workshop, where smiths, founders, turners and wheelrights, &c., were taught their trades, great attention being paid to instruction in drawing, as the art by which so many questions of mechanical science are solved.

The result of this system was not altogether satisfactory, however. The students expected to be foremen, not workmen, and were disappointed at finding that their fellow-workmen, without theoretical education, over whom they expected to rule, earned higher wages on account of their superior skill in manual labour.

In Switzerland, where education is more general, such expectations would not arise. Exceptional privileges are the proper complement of exceptional training. Since 1870, manual work has been largely introduced into the primary schools of Paris, showing that, on the whole, they find the advantages greater than the disadvantages. And in the school of the Rue Tournefort, rudimentary trade teaching is combined with ordinary elementary instruction, and workshops are being attached to some forty or fifty of the primary schools.

French apprenticeship schools for workmen have also been established, both as boarding and day schools. The municipal apprenticeship school of the Boulevard de la Villette, in Paris, is a day school for workers in wood and iron, and was established ten years ago. Similar institutions exist in the provinces, notably at Havre. The Royal Commissioners report that:—

"The authorities of the city of Paris have deemed the experiment of the apprenticeship "teaching in the school of La Villette sufficiently successful to induce them to erect a number "of similar schools in other parts of the city;"

And a sum of £80,000 has been voted for the purpose; the Prefect of the Seine reporting:—

"That in consequence of the virtual abolition of apprenticeship in most trades, and owing "to the specialisation and subdivision of manufactures, resulting from the introduction of "machinery, the number of skilful and intelligent workmen in all branches of industry and art "manufacture has decreased, and that the standard of technical knowledge has been lowered."

That this is precisely the case in England, cannot be universally admitted. We have improved, and are improving, though not nearly so fast, as we ought; and although the Royal Commissioners do not recommend the costly experiment of building similar schools in England, they still feel that, to give value to the manual dexterity, which is best acquired in the ordinary workshop, instruction in the use of tools during the elementary school age would greatly facilitate the learning of a trade, and shorten the time of probation, and they would be glad to see this kind of manual instruction introduced into some of our elementary schools. The labours of Mr. Thomas Twining, of Twickenham, in this direction, cannot be too highly praised.

From my professional point of view, the provision of good common workmen in all the trades connected with building, is a matter of vital importance. The worry of our lives, as architects, and the shortening of them too, is the anxiety attendant on the difficulty of getting reasonably good work done, except by picked men at high wages, attached to the leading firms.

Now let us look at Germany: what is she doing for the working classes? Very much the same as Switzerland, who preceded her and Austria in experimental technical education, but who is surpassing all the world in the provision made for higher technical education. I say, what is Germany doing for the masses of its working men?

Professor Weinhold, of Chemnitz, writes to me, in answer to this question, as follows:—

"Generally, the working classes get no technical education beyond what they learn in the "workshops during their apprenticeship days. A few of them visit a foreman's school, or any "of the *Fachschulen* which exist for the different branches of industry, and some, after having "gained enough money by their handicraft to live, devote one or two years to the school."

Professor Lunge, of Zurich, writes me:—

"There are schools, both in Germany and Switzerland, intended for giving a proper "technical and half scientific, but always practical, education, to workmen, so as to fit them for "foremen's places. These schools have proved very successful indeed, quite as much as the Poly- "technic schools in their higher aims, which latter do not touch the working classes in the "ordinary sense."

Dr. Witt, of Mulhouse, writes me thus:—

"Primary schools in Germany take pupils from their 6th to 14th year. The education is "compulsory. There are three classes, one of which every child must attend.

"*(a.) Volksschule* (the People's School).—Here the children learn, in addition to the three "R's, history, geography, natural history, and singing.

"Children who attend this school, generally finish their education with it. They then "become factory boys or farm boys or apprentices to artizans, until their 20th or 21st year, "when they have to become soldiers for three years. If, after the service, they are still good "for something, they return to their previous occupation, viz., they become workmen, labourers, "or artisans' assistants, until they get a chance to become artisans themselves.

(b.) Höhere Burgerschule (the Citizen's School).—The same subjects are here taught, but more carefully. This is the school selected by the parents of children who are intended to have some more training, but no university education.

(c.) Vorschulen des Gymnasium.—Schools preparatory for college education, and attached to colleges; same subjects taught, together with some Latin. These are for boys who are intended to go to the university.

The above are the primary schools, besides which there are other voluntary schools, with a marked object, as the *Fortbildungs Schulen,* intended to instruct boys leaving the primary school *(Volksschule)* at the age of 14, and to train them for becoming artisans; and the *Technikums,* which are schools entirely independent of all others, and generally supported by private means, or self-supporting. Their chief object is to educate practical engineers, foremen for workshops, dye-houses, &c. It is obvious that the scientific side of the compulsory primary education on the Continent is but little or no more advanced than our own, and the great majority of working men go straight to the workshop therefrom, while a few take advantage of

Technikums or *Fortbildungs Schulen*, preparatory thereto. But all suffer from the disadvantage of passing the desultory life of a soldier for three years, before they can earnestly set about their business.

Professor Perry thinks that the teaching formulated by the Irish Commissioners for Model Schools in Ireland, is probably better than any other scheme of primary instruction.

The preparation necessary for passing the examinations of the Science and Art Department, or of the Technological Examinations of the Society of Arts, now taken over and so remarkably extended by the City Guilds, would alone seem to counterbalance the so-called advantages of foreign systems of technical education for the working classes, to say nothing of the broken continuity of education, and prejudicial effect of three years' soldiering.

Professor Sylvanus P. Thompson, of Bristol, is, nevertheless, an ardent admirer of the foreign system, and would import it here; and Mr. H. Solly has also written a pamphlet on the same side, and many others are strong advocates of it.

It was, therefore, a wise step on the part of the City and Guilds of London Institute for the Advancement of Technical Education—the chairman of whose executive is no less a person than Sir Frederick Bramwell, F.R.S., and whose members are picked men from the contributing companies they represent—to call in the aid of such men as Sir William Armstrong, Mr. Bartley, Colonel Donnelly, Captain Galton, Professor Huxley, and Mr. Trueman Wood, to advise with them at the starting of their great undertaking—whose essays are bound up with the first report of the Executive Committee to the General Committee of certain of the Livery Companies of London. All these gentlemen were unanimously of opinion :—

1. That the teaching of the practical part of the particular trade or manufacture should not be carried out in certain establishments auxiliary to those devoted to theoretical instruction, and concurrently given in connection therewith.

2. That the practical part should be left to be acquired in workshops and manufactories, by means of apprenticeship or otherwise, supplemented only elsewhere.

3. That the function of the teacher should be confined to instruction in the various arts and sciences connected with industrial undertakings, and especially in their practical application.

It would seem that these views have been concurred in by the Presidents of the Royal Society, the Chemical Society, the Institution of Civil Engineers, as well as by the Chairman of the Society of Arts (at present also the Chairman of the Guilds Executive Committee), since associated with the City and Guilds Institute, and acting as members of their Executive Committee. At all events, the result has been that they (the Guilds) have resolved :—

1. To establish (and are now building) at South Kensington, at a cost of £100,000, a central institution, or High School of Applied Science and Art for advanced students and teachers, to include courses of free popular lectures, as at the *Conservatoire des Arts et Métiers*, Paris.

2. To establish (and they are now rapidly completing) Science and Art Trade Schools in the north and south of London, at a cost of £30,000 and upwards; morning and evening classes and lectures, and laboratory work for boys, apprentices, and workmen generally, and of all ages.

3. Grants in aid of local schools and classes suited to the industries of each locality.

4. Exhibitions in elementary schools to be held in trade schools.

5. Exhibitions in trade schools to be held at the central college.

6. Extended systems of examinations in technology, based on that of the Society of Arts.

7. The Affiliation or absorption of kindred societies, as the Art Carving School, the Horological and the Artisans' Institute, the City Art Schools, and others.

But we have yet to decide between the many opinions respecting primary technical teaching. Professor Huxley says :—

"I do not think that much good is to be done by attempting to deal with the trades " directly, in the scientific education of the masses of the people. The great object appears " to me to be, to construct such a scheme as should enable you to sift out and get hold of " the men who have really scientific ability, give them a fair scientific training, and you may " trust to the arts getting all they want out of them."

Professor Fleeming Jenkin (our Chairman this evening) says :—

"If you mean by technical education, attempting to teach a man his business by a college " course, I think it a very mischievous delusion indeed ; but if you mean that in addition to " his practical training, you would give him some theoretical training, some technical courses, " I think that would be very useful indeed."

Professor Ayrton says :—

"By a 'technical school,' I understand not one in which the manipulation or routine of a " trade is taught, but a school where a lad receives general instruction in the principles of " applied science, and special instruction in the application of these principles to the particular " trade he is following, or which he is about to follow."

I apprehend that no better definition than this last has yet been given of what the term "Technical Education" should really mean, and which is as applicable to primary as secondary schools. What, then, is Professor Ayrton's method ? Let me explain it to you in the language of Professor John Perry, given at the close of a very original paper, read at the Society of Arts in January, 1880, on "The Teaching of Technical Physics." He says :—

"I have studied carefully the method of teaching which Professor Ayrton is employing " for the City and Guilds of London Institute, in his lectures on 'Applied Physics,' at Cowper " Street, Finsbury, and I think that this method promises more success than any other which " I have heard of. His method is succinctly stated at the end of his syllabus.

"The aim of these lectures on Technical Physics will be to train the students by an " examination of the machines, instruments, &c., employed in the Arts (or of models of them), " to turn their attention to the scientific principles governing the action of these machines, and " without a knowledge of which neither their proper working can be ensured, nor improvements " in them affected. It is believed that the analytical method of experimental instruction, in " applied physics, will, for the class of students expected (boys, apprentices, and working men " of all ages), be preferable to the ordinary method adopted in the teaching of natural " philosophy, which consists in much time being spent in the study of the elementary principles " and then only subsequently the practical applications explained."

"It is to be understood [says Professor Perry], that he is taking up, more particularly, in " these lectures, the principles of watch and clock making, and he reasons from that part of the " subject which his students know, namely, from the appearances, and uses, and construction "of the various timekeepers shown to them, backwards (or forwards), to those mechanical and "physical principles with which most men begin to study a technical subject. In doing this, "he makes use of all the knowledge and habits of thought which he supposes workmen to have, "illustrating his lectures by means of experiments."

And, gentlemen, I perfectly agree with him, and what is more, the results have already proved its value. Professor Ayrton has created for the City Guilds a system of technical education in physics suited to the masses, who have flocked in greater numbers to be taught than was at any time foreseen (between 500 and 600 students have been enrolled), and this in spite of the temporary character of the accommodation available, while a new Technical College, or Model Trade School, is being erected for the accommodation of the professors of physics, chemistry, and mechanics. Professor Armstrong has his own methods of teaching technical chemistry; and the recent appointment of Professor Perry to the chair of Mechanics insures an original treatment of that subject, a foretaste of which he has given in his recent Cantor lectures before this Society.

At the same time, under the careful direction of Mr. Magnus, the technological examinations which were taken over from the Society of Arts have become so popular that, in spite of the standard of efficiency being raised, fifteen times the number of students have since presented themselves for examination from all parts of the country, in every industry, and thus a sound and sensible system of technical education has been inaugurated by the City Guilds, the value of which cannot be overrated. It only means an extension of the provincial trade schools, and that the School Boards throughout the country should give greater development to Froebel's system of object lessons, and follow it up with elementary classes on mechanical and natural science, taught by the analytical methods employed by Professor Ayrton, to give us a system of natural education for the masses, equal, if not superior, to that which has been initiated abroad.

2nd. I have now arrived at the second general division of my subject, viz., the technical education of the middle classes. If we have found nothing to alarm us in this contrast between the primary technical education of English and foreign nations, owing to its very recent and spasmodic application, and the limited area of its effective usefulness anywhere, the case is entirely altered when we come to deal with the secondary or higher class teaching.

It is here, if anywhere, that we have met our match abroad. It is here, and nowhere else, that we must look for the resurrection of our old precedence. But Englishmen do not mind being told of their shortcomings, they rather like it than not, it rouses the lion, and makes him rampant; it excites their competitive spirit and pugnacious instincts; it sets their brains on fire, a fire which, when thoroughly kindled, never goes out till success is again achieved. The persistency of the national character is its salvation—given a leader in whom its faith can be rested, and it is irresistible.

The time at my disposal is too limited to review the secondary educational provisions made in all foreign countries, nor is it needful. They have culminated in the system adopted in Germany and the nations bordering upon it, which has been followed in Sweden and Russia and elsewhere. A paper was read before the Foreign and Colonial Section of the Society of Arts, in February last, on Scientific and Technical Education in Russia, by Professor J. J. Hodgetts, of the Imperial College of Practical Science, Moscow, in which he said—

"In 1851, we, in England, were a-head of all civilized Europe—why are we so lamentably

" behind now ? From my own experience abroad, the reply would seem to be, that other nations " have had a scientific education, while we have had none. Other nations have effected a certain " amount of organisation, while we seem to stand historically pledged to avoid all systems, and " to dread the very idea of organisation."

This is one of the first impressions made on an Englishman abroad. The absence of paternal government at home, and the freedom from governmental restriction of any sort in his insular home, so long as he pays his taxes, unfits him to submit to the regulations which are maintained everywhere abroad, and I, for one, do not desire to import them. Our individuality would be gone, our personal energy sapped. No ! let us have unity of purpose, instead of uniformity of action. Let us agree that we are lacking in something, and let us all determine to overcome the deficiency, and it will be done—done by ourselves—each in his own sphere and particular domain of industrial work. The scheme should be suited to local requirements, and supported by the commercial magnates of each centre of special industry, our teachers being made independent of results, but allowed to reap the benefit of them. Government payment in the shape of grants in aid should be given in no niggardly spirit, but be in due proportion to the local interest manifested. It should depend not only on the sums voted by personal munificence or municipal local authorities, but on the response made to it in the shape of primary and secondary students flocking to the schools.

Secondary education in Germany (which is not compulsory) is for pupils from their 10th to their 17th or 19th year. Dr. Witt thus summarises it :—

(a). The *Gymnasium*, or college, in which is taught plenty of Latin, and a good deal of Greek, German, and a little French; English and Hebrew taught to those who wish to learn, which most do not; a moderate knowledge of mathematics, and a little natural history, geography, singing, gymnastics, drawing, plenty of Religion."

Pupils leaving any of the three highest classes (that is from the 17th year) are entitled, as a matter of course, to the " one year's instead of three year's voluntary service." For this service they may choose their own time as well as place to join the army.

From the gymnasium, pupils pass on to the universities.

(b.) Realschule of the 1st Grade, from 10th to 19th year. Here, German, French and English are taught; a little Latin, and plenty of mathematics; a fair knowledge of natural history chemistry, physics, &c.; history, geography, singing, gymnastics, drawing, machine-drawing, religion. In short, a manly, self-developing curriculum.

These schools differ very much; thus, in some of them they have no Latin, but practical carpentry and engineering instead. In some they have a fair training in practical chemistry and laboratory work, in others not.

These are the schools from which the *Polytechnikums* and similar institutions draw their supply of students. The Mulhouse Chemical Institute students generally come from them. Numbers of students only go as far as the seventeenth year, and then enter merchants' offices as clerks; others leave still earlier, and become articled pupils, for a term of two to three years, in factories or engineers' workshops.

Like the gymnasium, this school gives to the successful pupils on leaving one of the three higher classes (from the 17th year), the right to claim the one year's service. Young men who have not obtained that right by passing through one of these schools, may do so by passing a somewhat difficult examination. No greater incentive to personal educational improvement could be given than the knowledge that two years' military service is avoided by passing a successful examination.

(c.) Realschule. 2nd grade, from 10th to 17th year; same curriculum as the 1st grade, but without the two highest classes. Some of them are entitled to confer upon the pupils leaving the highest class, the right of the one year's service; others do not possess that privilege.

In some mercantile centres, such as Hamburg and Bremen, there exists a rigorous system of training the young merchants, from which nobody is excepted—not even the son of the richest banker; it is this:—The boy must finish at one of the above-named secondary schools. He then becomes for three years an articled pupil in a merchant's office. There he has, during the first year, the duties of an office boy; during the two following years, those of a junior clerk. When the three years are over, he gets a substantial present, according to the zeal he has shown. Now he goes to join the army for one year's service, and when returning he may either enter his father's business, or compete for a clerkship.

Besides the schools above mentioned, there are others, with a certain marked object. The *Fortbildung Schulen*, and the *Technikums* have already been described, under the head of primary education, since they are open to students who have had no better preparation for it, and could be entered by any workman, who desired to improve his technical knowledge and social position; a valuable provision for the energetic workman, but taken advantage of by much fewer than would be expected.

Then there are the *Cadetten Schulen*, which train boys entirely with a view to their becoming officers; the *Pagen corps*, for young noblemen exclusively, and intended to fit them for courtiers; and lastly, there are the two great schools in which all others culminate, namely: the *Polytechnikums* and the Universities. Of the latter, I need say little, except that, as the home of literary and classical learning, the pure sciences are carried much further, and are more completely studied than with us; separate buildings, magnificently fitted with all the most recent appliances, being provided for chemical, physical and physiological laboratories at Berlin, where men of European reputation, like Helmholtz, Hoffmann, and others, conduct their overflowing classes.

But it is the *Polytechnikum*, which is, or rather, perhaps, has been, the stronghold, of the scientific and technical education in Germany, Austria, and Switzerland. It is here that things take the place of words, and the true principles of nature and art, the result of scientific research, are applied to industrial pursuits. I say has been, because there are unmistakable signs that the high class teaching at the Polytechnics abroad will be the cause of their gradual supercession by the universities, where the best scientific knowledge may now be obtained, though hitherto minus its special application to specific trades. And this is not surprising, because university degrees will always take precedence of those of the Polytechnics, which, however, cost no less labour and concentrated study to secure. The provision of new buildings, which has been so generally made at the chief universities, has naturally followed the demand for increased scientific instruction, and the feeling is spreading in Germany that, owing to the growing importance of the *Real Schulen*, the universities will eventually absorb the Polytechnics, and that in future the university curriculum will be found to embrace all that formerly was the peculiar province of the Polytechnics, in addition to the abstract studies which formerly distinguished them. Our own universities and great public schools may do well to consider this new phase of educational development. It must, however, never be forgotten that the whole general education of Germans of every grade has long been in advance of the general education of Englishmen, comprehending a wider area, and a more thorough acquaintance with every branch included. This is a factor which must always be taken into account when contrasting the relative value of English and Foreign technical education.

With reference to the extent to which manual labour is introduced into middle-class schools, Dr. Witt tells me that there certainly are workshops connected with some, if not all, Polytechnic schools, and also with most of the *Real Schulen;* but that, of course, they are small and insignificant, as they are merely intended to give the student an idea of the work to which his theoretical knowledge shall be applied:—

"That apprenticeships for skilled artisans exist the same as in England, though the amount "of previous education required varies very much, and is generally very small;" and he adds, "My opinion is that theoretical instruction should always precede practical; if possible, "they should co-exist for a while in such a manner that theory gradually yields its place to "practice. In all examples I have seen of the reverse, I found the young man who considered "himself practically finished, despise all subsequent instruction. I also believe that previous "theoretical training facilitates his practical education by teaching to think logically in all he "does."

I may now refer to my own experiences in Germany.

The Executive Committee of the City Guilds recently instructed Professors Armstrong and Ayrton to make a tour of inspection of the polytechnic schools of the German-speaking countries, with the view of determining the most suitable fittings and apparatus for the new buildings in progress at Finsbury and South Kensington. As a member of that committee, I volunteered to accompany them, and I met Professor Armstrong at the beginning of January last at Strasburg, where a new university is being constructed, to cost, when finished, not far short of a quarter of a million of money. Besides the main block of the building devoted to classical learning, mathematics, &c., separate blocks of buildings, specially constructed under the supervision of the professors themselves, are being constructed for chemistry, physics, botany, &c. In short, it is to be a university and polytechnic in one and the same institution, for high class students. The architect of this princely foundation is the professor of architecture at Carlsruhe. Thither we went to find a new technical chemistry laboratory, and school of agriculture and forestry, in addition to the former buildings of the *Polytechnikum*, with museums of specimens and models of every kind. Thence to Mulhouse, a manufacturing centre, visiting the model dwellings, the dye-works and calico printing establishments, and the chemical schools, established by the manufacturers. Thence to Geneva, where Professor Ayrton met us, and we, together, inspected the new university, chemical and physical schools. Thence to Zurich, at which celebrated *Polytechnikum* every science is taught, both pure and applied; here are separate museums of models for teaching physics, chemistry, machine engineering, architecture, drawing, modelling, agriculture, forestry, botany, &c. Here are nine professors of mathematics, 46 full professors, 54 teachers—109 in all; 490 students, and 250 auditors—740 in all, which, however, is 500 hundred less in number than used to attend when this school (now 30 years old) had fewer competitors of its own kind, and felt less of the growing absorption of high-class students by the universities. Thence to Munich, to see the splendid new *Polytechnikum* there, the new university, chemical and physical laboratories, and Pettenkofer's Hygienic Institute, concerning which Dr. Renk writes to me to say, that it also is part of the university of Munich, its Director, Dr. Pettenkofer, being the professor of hygiene at the university. It was erected three years ago, and was a part of the Physiological Institute. It is designed for the education of students in medicine and hygiene, and for practical investigations therein. Officers of health have to obtain its diploma. Thence to Vienna, where has long been a vast *Polytechnikum* for 1,500 students, with a remarkable collection of models and objects for each department. Here are also new technological buildings, a new weaving and chemical school, just opened, &c., &c.; everywhere the provision for first-class secondary education of a technical character is extending. It has been found to give forth results which point to the desirability of this general extension.

At this stage, Professor Armstrong went on to Gratz, to see the new physical and chemical laboratories there, and to Buda-Pesth, whilst I and Professor Ayrton went to Dresden and Chemnitz, Professor Ayrton returning to his London classes, after visiting Würtsburg, while I rejoined Professor Armstrong at Dresden, and visited the new *Polytechnikum* there. Thence to Leipsic, in which university Professor Armstrong himself studied two-and-a-half years. Here is a street full of separate new buildings, for chemical, physical, and other laboratories. Thence we proceed to Berlin, where, besides, the new university buildings for science, referred to before, is a large stone building, erected at the instance of local manufacturers, for special chemical analyses. There are fine laboratories attached, and students admitted, but certain of the work done is considered private to the members, and it is in fact a school of research.

Mr. Felkin has published a book on the "Trade and High Schools of Chemnitz in Saxony," to which I must refer you, where every kind of technical instruction is given, in both primary and secondary schools.

Aachen was the last place we visited together, here is one of the finest and most elaborately fitted Polytechnics of the many buildings we saw; it is, in itself, a lesson in technical education, of a kind that we have no examples of in this country, not only in fitting, but in heating, ventilation, lighting, and electrical apparatus associated therewith. I spent the month of January in making this rapid survey, and noting the fittings, the chief purpose of our visit; and an impression of preparedness, on the part of the countries we visited, to fight out the question of scientific superiority in technical matters, was left on my mind, that I should like to communicate to others.

My belief is that the omission of high-class scientific education for the middle and upper classes, in England, is the true cause of our being apparently outrun in the industrial race of the period; and the movement which is now set on foot has come from the right quarter, viz. from the commercial and manufacturing centres, who begin to find its monetary value.

In these schools everything is taught that can be gained at the universities, except the dead languages, while modern languages and the applications of modern science to art and industry are added, and the thoroughness with which they are taught is best evidenced by the fact that nearly all our own leading men have found it desirable to spend some years in Germany, and they frankly acknowledge we have nothing to equal it in England. All secondary education in Germany is more general and thorough.

Professor Lunge, at Zurich, in answer to my queries, first, as to the difference made in teaching pure and technical chemistry in the three years' course, and secondly, as to effect of the system upon the originality and individuality of the men turned out, writes as follows :—

"My colleague, Victor Meyer, teaches the elements of chemical science, and, further, its "development in a purely scientific direction, treating the whole domain irrespective of any "practical application, and merely as a science; that is, stating the facts as such, and as they occur "to the chemist working in the laboratory. When his work is done mine begins. I treat only "those chapters which refer to practical applications of chemistry, naturally at a greater length, "and entering into a number of details on manufacturing plants, &c., which would be entirely out "of place in a course of pure chemistry." [Professor Lunge was partner in one of the largest "sulphuric acid and alkali works in England before he went to Zurich.] "In fact," says he, "I enter upon the various chemical industries, as such, placing the technical side foremost, "but laying the principal stress upon explaining the scientific principles underlying them. I "do not believe in dictating a number of recipes for dyeing, &c.; I believe that some schools in "England go too far in that respect. We have always tried to keep the mean between the "entirely theoretical university training, and the entirely practical course of dyeing, brewery "schools, &c.

"Thus some of our students are university professors themselves now, whilst the great "majority are in practical life, and very many, heads of large technical establishments (in "Switzerland, well nigh all of the younger generation) have come from us. On the whole, our "*Polytechnikum* (which to a great extent is the prototype of all German ones) has fulfilled its "object, and sees no reason to change its principles."

In answer to my second question, Professor Lunge says :—

"During the first year, we certainly do not aim at 'individuality.' During the last year, "whilst still upholding, in a general way, the course of studies for all students, we allow students "to deviate from this, so as to meet their individual likes and wants, and in the laboratories we "treat each of them according to his own standing, progress, and capacity. All this refers to "the ordinary students who follow the regular courses. As to the auditors, we allow them from "the first to specialise their studies, and treat them quite individually; but we do not like that "course, except with older men coming from practice, as many men do."

Except to the extent to which mechanical work and testing materials is done in the engineering school at King's College, and at the University College, London, we found no workshops attached to any of the *Polytecnikums* which we visited. Models of every kind of mechanical action, of every kind of machine, &c., &c., there were, but these were not made by the students; in fact, manual labour is excluded from the *Polytecnikums* generally, and is only to be found in the intermediate trade schools already described, and in them to a much less extent than is commonly supposed. Now, it is true that we have no such organisation in this country, but we are daily approximating to it. The influence of South Kensington is making itself felt, and our secondary schools are introducing science little by little, while great efforts have been already made in some of the chief towns in England.

For example, this has been done at Owens College and the Grammar School, Manchester, at Mason's College, Birmingham, the Yorkshire College, at Leeds; at Sheffield, Nottingham, Liverpool, Bristol, and elsewhere.

At the latter place the famous trade and mining school, so long established there, is about to be transferred to new quarters, at a cost of £30,000, and will be a monument of the munificence of the Society of Merchant Venturers. As their architect, I am enabled to state that no reasonable expense will be spared to render this a model school of the kind. Then, again, realisation of the complete scheme of the City Guilds will soon place London on a par with the other capital cities of Europe. The Central Institution will be an English *Polytechnikum* of the first order; the Finsbury College, a *Technikum* superior to its continental prototypes. In conclusion, what have we to learn from all this? In the first place, to support all efforts to improve the intelligence of the working classes; and secondly, to raise the standard of professional excellence.

In a paper read by Mr. Slater at the Architectural Association, the importance of the study of the natural sciences and their application to specific industries connected with the art of building, was forcibly insisted upon. Young men are too often pitchforked into the professions of engineer, architect, and surveyor, without any more relative preparedness than the working man.

Better preparation for articles of apprenticeship is the thing most wanted in the constructive professions. Apprenticeship is the best business school, but it might be improved on its educational side. The architectural and mechanical classes at the German *Polytechnikums*, which extend over three years, and the work done in which I carefully examined, is of a better class than is usually understood; from the very first, the student has to work out the strains of every floor, or roof, or speciality in construction, and to delineate the same in skeleton diagrams attached to every plan he draws. The mechanical draughtsman is not given a subject to copy, but only the parts of a machine which he has himself to piece together, to realise the machine to be drawn, so that, from the rough sketches of the master, he has to thoughtfully work out in practical draughtsmanship the theory he has been taught to apply constructively.

True, he is surrounded with models and drawings of every mode of construction and style of design, principles of motive power, its emission, transmission, and arrest; but they are ministering spirits, not arbitrary laws, fettering his freedom. At least, they need not be other than helps to his imagination.

We enter our articles to early; eighteen is surely early enough, but sixteen is the common time.

The establishment of examinations at our institutes will certainly help to bring about a change in this matter, and soon it is to be hoped that, just as candidates for entry to the technical educational advantages to be hereafter obtained at the Central Institution of the City Guilds will be required to produce certificates of having passed preliminary examinations at other schools of lower grade, so admission to the examinations of our professional institutes should be ultimately given only to such students as shall be able to produce similar educational certificates of competency up to a certain point, which can only be fixed from time to time, as the means of obtaining such certificates shall have been increased.

By this means, these professions will be aiding in the movement in which none can be more directly interested than they, and will prove their loyalty to our country in the best possible way, namely, that of raising the scientific tone of professional education, and fitting the students to compare with foreign competitors in the race for national predominance, in every good thing, but especially that of technical knowledge, theoretical as well as practical. As a final suggestion to aspirants to professional success, let me quote the Report of the Committee appointed by the Conference of the Society of Arts, held on the 24th of January, 1868, which states that:—

" Believing that our defects are far more due to the ignorance of those who direct works " than to imperfect technical education, want of skill, or incapacity in those who execute them, " the following resolutions are formulated to express our views :—

" 1. For the purpose of discussion, technical education should be deemed to exclude the " manual instruction in arts and manufactures which is given in the workshop.

" 2. That the term 'Technical Education' is understood by the Sub-Committee to mean " general instruction in those sciences, the principles of which are applicable to various " employments of life.

" 3. That technical instruction, as defined above, should not, as a rule, be given in separate " professional institutions, but in institutions established for general education.

" 4. That, with a view to the development of a system of scientific education, it is " desirable that schools be established, having for their main object the teaching of science as " a mental discipline. These science schools should prepare some youths for the higher courses " of a college, and other less ambitious pupils for their professional pupilage.

" 5. That the subject of secondary instruction, having been reported upon ably and " deliberately by the Schools Inquiry Commission, the Committee do not feel it necessary to " enter into the details of this subject, while they desire emphatically to express their opinion " of the necessity for the introduction of scientific teaching in all secondary schools.

" 6. That it is desirable that the higher scientific instruction should be tested by public " examinations, and that the proficiency of persons who pass these examinations should be " certified by diploma."

" 7. That the preparation for the businesses considered by the Committee is not sufficient " until due scientific instruction has been followed by practical pupilage in efficient work.

" The Committee recommend employers of labour, and those in the habit of taking pupils " apprentices, and clerks, to give preference, as far as possible, to those adducing evidence of " the possession of adequate instruction in the sciences applicable respectively to their " professions or occupations.

One word more, and I have done. The highly educated young men from the foreign *Polytechnikums* become masters when they can, but are not ashamed, till then, to act as foremen of manufactories, &c. Now, there is a great reform required in the system by which foremen and clerks of works are appointed here. The position of a clerk of works is a most difficult and responsible one, and should stand higher in the social scale than it does, and be paid better. This will not be the case so long as uneducated mechanics form the staple from which such men are drawn. I look forward to the time when a superior order of men will become the responsible agents both of the architects and contractors. And this will follow both from the growth of intelligence in the class below them, and the educational supremacy of those above them, a result which the general spread of technical education, as I have endeavoured to define it, must inevitably produce, as " men run to and fro, and knowledge is increased."

DISCUSSION.

PROFESSOR PERRY said he had not so much sympathy with the technical education of the middle classes of England, as he had with the technical education of workmen. When the middle classes were so foolish as to send their sons into offices, and pay large premiums where they could get no technical instruction in their profession, they deserved little sympathy; he rather sympathised with the working men, who could not help themselves, but who had been so long crying out, as well they might, for technical education in the popular schools, and who had not yet acquired it. He still stood by the views he had expressed with regard to the technical education of workmen, but he found that in practice they were exceedingly difficult to carry out. You stood up before an audience of working men, and for the first two nights, perhaps, you followed the programme you had drawn out, which was to talk to the workmen in their own language about a machine or an instrument; not beginning with the elementary principles of science which they had not learned at school, but taking up the machine as a whole, as they themselves understood it, and reasoning down from those general principles which they understood, to what they might have got as elementary instruction; but you found, in a short time, you gradually got into the way of thinking of these workmen as frightfully stupid, because they did not understand a little algebra and the sixth book of Euclid. The problem of teaching workmen was a very difficult one, which had not yet been sufficiently studied. It was the easiest thing in the world to draw up a programme for teaching middle-class science classes; so much so, that you found the same programme in use all over the world, from San Francisco to Japan, but a suitable scheme for working men he had never yet seen fully carried out. He hoped Mr. Robins would, at some future time, devote his attention to this subject.

MR. MAGNUS said it would be very difficult to follow Mr. Robins through the paper, and consider, in the detail they deserved, the many points he had brought forward. It would have been interesting to him to do so, as he had recently visited nearly all the places which had been referred to; but he should have an opportunity later on of stating where he agreed with Mr. Robins and wherein he differed from him. The whole question bristled with difficulties; and no one could have listened to the paper without seeing that the views of one set of professors differed very materially from those of another set. One main lesson to be drawn, therefore, was that they should be careful not to dogmatise on what was the best system of education, technical or otherwise, for any class of persons. It might be thought he ought not to say this, as he had a voice in the councils of a body which was preparing a scheme of technical instruction, the existence of whose schools could not but be regarded as dogmatic expression of the opinion of those who directed them. At the same time, he and those with whom he worked felt the difficulties of their position, and he was quite sure that the views at present being carried out would be modified, if necessary, on gaining further experience. As Professor Perry had pointed out, the problem of giving technical instruction to masters or superintendents, was by no means so difficult as that of giving instruction to the hands who were to work in the factory, but he might express a hope that even that problem would become much easier than it was at present, for the simple reason that, after a time, they would not require to instruct working men, inasmuch as they would have already instructed in their youth those who were to become working men. But even when the problem was reduced to that of instructing apprentices, it was not without difficulty, and the most conflicting views existed upon it in different parts of the Continent. France was moving in one direction and Germany in another. In the City of London they had endeavoured to find a solution, if only a temporary one, in the direction which he thought was a correct one, of giving evening instruction to apprentices. This system harmonised with the habits and customs of Englishmen; and a system which might be adapted to the sunny climate of Italy might possibly not be adapted to our more cloudy skies. The temptations to walk about and amuse oneself in the evening, were much greater in a beautiful climate; and here we could avail ourselves of the general desire of young men to be under some sort of cover during the evening, to impart to them that instruction which would be useful to them in their daily occupations. There seemed to be a general consensus of opinion that manipulative skill could only be acquired in the workshops, and that what was needed was to supplement that practical skill by theoretical instruction given in the evening, or at some appropriate time. It was the custom in many parts of Germany to give this instruction on Sundays, as well as on the evenings of other days; but that would probably be distasteful to the people of this country. With regard to higher education, there was a great conflict of opinion abroad as to the respective advantages of a university or *Polytechnikum* training for giving the requisite knowledge to those who were to become the managers of industrial works. But prior to this question, was another one, viz., what was the best training for a young man intended to take the lead in a manufactory, before entering the university or *Polytechnikum?* Here, again, their German advisers were by no means at one; they had established the *Real-Schule*, and on the other hand, the gymnasium; in the first science, mathematics and modern languages were taught; in the second, the old grammar school curriculum was followed. Then it seemed to the German educationalists that something between the two was wanted, and so they established a *Real-Gymnasium*, where part of the classics was done away with, and a little mathematics and drawing was added. Even this did not quite satisfy them, and now they were considering whether they should not establish something between the *Real-Gymnasium* and the gymnasium itself. Into these complexities he would not enter, but there lay at the bottom of all this a very important question, whether, after all, the old classical training was, or was not, the best preparation for those who were afterwards to be educated in the higher branches of science, and although the opinion was opposed to his own, he must say that there was a large number of scientific professors in Germany who were inclined to think that the old classical training was the best. What naturally occurred to one on hearing a view of this kind, was that possibly science was not so taught in the German schools as to yield that amount of mental discipline which could be obtained by a study of the classical languages. The classical languages had been made the instrument of education for centuries, whilst the teaching of science was comparatively new, and it was quite possible that the majority of teachers, both in Germany and England, were not sufficiently skilled in pedagogic principles to enable them to fetch out of scientific instruction that mental gymnastic, and discipline which, after all, was the object and end of all secondary education. On the whole, he did not think the course which was being followed in England was very far wrong.

Whilst some of the best minds were busily employed in considering what were the best methods of instruction for different classes of persons, those for whom the instruction is intended did not always seem sufficiently alive to its importance. If part of the energy of those who were elaborating schemes of education were directed to showing the importance of instruction, and not only the importance, but the difficulty of discovering any royal road to knowledge, they would be doing a very great thing. In this country people were too anxious to arrive rapidly at results to take a third year's course before the first; in Germany, this was not the case, and the students were more willing to go through a regular organized course of study. In England, education left off at too early an age, both for the workmen and the masters; and in discussing any scheme of instruction, the period over which it was to last was a most important element to be taken into account in arranging the curriculum itself. It was most necessary to impress upon all who desired to take advantage of any system of education, that time was an essential element, and that they must devote to the training for any profession a longer time than had hitherto been the custom. There were many problems in technical education yet remaining unsolved; one was the degree, if at all, to which manual work should be introduced into primary or secondary schools. They knew what was done in this way in France, and that very little was done in Germany. Another unsettled question was the relative advantages of apprenticeship schools, such as existed in France, and of the combined system to which he had referred, of work by day, and instruction in the evening. Then, as regards secondary instruction, there was the whole question of the value of science teaching, to which he had referred. Germany was looked to as the country in which science teaching was principally carried on, and yet a very eminent professor of chemistry in Germany had told him that he regarded it almost as nonsense to introduce chemical laboratories into secondary schools; it was quite sufficient for the pupils to receive instruction in the general principles of their science, the practice came soon enough. He need hardly say that he should give as much attention to these unsettled questions as he was able, and there were many others engaged in the same work. Meantime, any good teaching was better than none, and it was well that experiments in different directions were being tried. Those engaged in these experiments were giving their best thoughts to the question; and he believed that before many years there would be elaborated throughout the kingdom a system of higher scientific and technical education, which would favourably compare with any to be found in Europe.

MR. CHRISTIAN MAST said the discussion, to a great extent, had taken the turn of surveying education in general, and he agreed with Mr. Magnus that scientific education could not be separated from education in general. As long as there was such a gap between the lower education and the higher, and so long as the two were not organically connected, the problem could not be satisfactorily settled. As a teacher himself, what could he do to promote technical education? He was bound to give that curriculum which public opinion demanded; the conductors of schools had to live, and they could not arrange their instruction on any ideal plan they might believe to be best; therefore, anything which would act on public opinion would do a great deal to solve the difficulty. There was one point about the technical education of the higher classes, which seemed to have been lost sight of. In his native town, Wurtemburg, there was a school for the technical education of agriculturists, where gentlemen were instructed in everything relating to the science of agriculture; they paid high fees, and the course ranged over two or three years; and other establishments of a similar kind were scattered over Germany. One of his pupils was the son of a watchmaker; and as he wanted to have a complete practical and scientific education in watchmaking, which could not be obtained in England, when he had finished his education here he went to Geneva, where he would probably remain two years. The school to which he had gone was not exclusively technical, but took in a good deal of general education, and that was the case with many of the technical German schools. In Stuttgart there was a school for merchants, a *Handelschule*, to which his eldest son was gone, and there the instruction included not only things necessary for a merchant to know, but such as every gentleman ought to be acquainted with. As far as he knew, in none of the schools, not even in the *Polytechnikum* of Stuttgart, was the instruction merely technical. The great division was between the humanistic studies, which led to the university, and the realistic, which culminated in the *Polytechnikum*; and he thought it would be a great advantage if a similar division were observed in this country. It would not oblige him to teach Latin and Greek in his school, and at the same time, drawing, science, and mathematics. One branch of technical instruction ought to be taught to every child, and that was drawing, not merely free-hand, but the use of the ruler and compasses.

Mr. LUCRAFT wished to say a few words from a workman's point of view. The great difficulty at present was to find a substitute for the apprenticeship system, and that might probably be found, if they set to work in the proper way. He did not approve of work being done in primary schools, it would be simply taking up time which ought to be devoted to other things. In connection with the London School Board, there were a number of scholarships given to boys and girls, to carry forward their general education, but he doubted if in many cases this did them any real good; and he should like to see schools established similar to that at La Villette, where boys might have scholarships, which would really help them on in their after life. You might make a nation of professors, but if the artisan class were not instructed to do its work as it should be done, the nation would be very poor, although very learned. This was the kernel of the whole question, from the workman's point of view. The division of labour made men very clever at one particular thing, but in his own trade of a cabinet maker, when the old hands died off, those who were in the trade would be only those who worked at one small branch, and he did not think the cabinet work of the future would be equal to that of the present, which was equal to that ever produced in the world before. At the Paris Exhibition, people from all parts of the world expressed the opinion that some of the English work was the finest they had ever seen. When an apprentice was taught his whole trade, his intellect was at work, but a man who had to do one branch, whether it was cabinet making or anything else, could learn all he had to do, perhaps, in six months. This did not cause him to think, and he became more like a machine. In two Blue-books issued by the School Board, they had drawn out a scheme for technical education, whereby they could have some 3,000 or 4,000 boys continually at work in technical schools. The boys from the school at La Villette were sought for in the best shops in Paris, and became foremen, and many of them masters. The whole kernel of the question was how to make the artisan class what it ought to be in the future.

MR. LIGGINS hoped the rich manufacturers of England would read this admirable paper, and take some action to endeavour to get a better education for their workmen and foremen, which he knew to be absolutely necessary. That afternoon he had been examining the finishing off of a new ship, and was talking to a foreman painter who had about two dozen men under him. He drew the foreman's attention to the fact that the work was not equal to that on first-class American ships, which he acknowledged to be the case, and said he wished he knew how it was done. There was the case of a man in a responsible position who did not know what was being done by our cousins across the water in his own trade, though he was willing to learn. In the clock trade there was only one school in London, and that was more a series of lectures than a school. England had lost the clock and watch trades of the world. Nearly all the time-pieces in the London shops were Swiss and French, and American Waltham watches were fast superseding, in the English workman's pocket, the Coventry watch. Again, with regard to painting, he could not but admire the beautiful works round the walls of that room, which showed no signs of cracking, but in the National Gallery, many of the pictures were decaying, and one of Sir Edwin Landseer's showed cracks all over, simply from an improper medium being used. Being personally interested in this subject, he had taken some pains to obtain the recipe given to the students of the Royal Academy, and he found it was diametrically opposed to that mentioned in the standard work published by the South Kensington authorities. Being perplexed between the two, he fell back on what was done four or five hundred years ago by Van Eyck, the inventor of oil painting, who had more knowledge than we had now, as shown by the perfect preservation of his pictures. We had also lost the art of wood-carving, for he had seen that day ships in which beautiful work of this kind was all being done by Italian workmen.

THE CHAIRMAN (PROFESSOR FLEEMING JENKIN, F.R.S.) said the question divided itself into two great branches, which had very little connection the one with the other. The one which had been chiefly treated in the paper was the education of the supervisors of labour, and to that the conclusion quoted from the Conference of the Society, chiefly applied. He was proud to find that those resolutions still met with acceptance, and indeed, he saw very little in them to change. All he could wish for was that they should be more generally acted on. In all large towns there were now much greater facilities for acquiring scientific knowledge than existed twelve years ago, but the change had not gone on fast enough. What was chiefly required was not a new system, but more money, in order to endow more chairs, and so provide fresh professors with new museums. Establishments like King's College, University College, the Scotch Universities, the Victoria University, and similar institutions, in Liverpool, Dundee, and elsewhere, were proceeding from well established and accepted lines, but they wanted, especially the older ones, more funds. They had one professor teaching two or three hundred students, instead of 20 or 30 men, as was the case in Germany. It was in teaching power for the upper and middle classes that Germany was so superior to England; but we could not simply copy Germany; the whole social arrangements were so different that that would be impossible. We ought to attain the same end by means specially congenial to ourselves. The question of the gymnasium as compared with the *Real-Schule* was a very curious and interesting one. About twelve years ago he travelled in Germany with the same object as Mr. Magnus and Mr. Robins, and found the same feeling there, but less strongly marked, that the pupil who had been trained upon the humanistic studies ultimately beat his competitor in scientific work. If that were a necessary effect it ought to be taken to heart, and they ought not too hastily to insist on the abolition of the dead languages as a means of training. The explanation which commended itself to his mind was, not that scientific teaching was really inferior as a means of mental discipline, but that it was much more difficult at present to find in Germany or in England men who were capable of using scientific teaching in that way, and he much feared that it would always remain so. For this reason, Latin and Greek were dead languages and did not change; it was taught now as it was 50 years ago: but science changed with inconceivable rapidity, almost from day to day. What were the first fruits of science last year were already antiquated, and the difficulty was how to get a body of teachers who could follow all these constant changes at the same time that they were imparting instruction in secondary schools. He did not say it was impossible, but there was a great difficulty. After all, the personal influence of the teacher was of immense importance, perhaps quite as much so as the subject-matter taught; and if you had a man of broader culture and greater force of character teaching Latin than the man who taught science, Latin would prove the best preparation for life. On the other hand, if the man who taught natural philosophy was the better man of the two, the boy who studied natural philosophy would probably turn out the better man; and really, in entering on special work, the character of the lad mattered more than the specific information he had acquired up to that time. As far as the higher education went, therefore, he thought the main thing was not the introduction of a little science along with Latin and Greek, but the establishment of several great scientific colleges, where the professors should be first-rate university men—enthusiasts, who believed there was nothing in the world like science, and that they would turn out men superior in every respect (including cricket), to the men from the old fashioned schools, where they learned Latin and Greek. They would never get what they wanted while science was relegated to what was called the "modern side," and treated with more or less contempt. But while we had something to learn from the Continent in the matter of this higher education, with regard to the education of the artisan, which was of equal importance, nothing had been done in any part of the world whatever, except of the most rudimentary kind. His impression was that this would appear by the report of the Royal Commission. He could find nothing on the Continent twelve years ago, and though something had been done at La Villette, notwithstanding the eloquent picture drawn by Mr. Lucraft, he greatly feared it would be absolutely impossible to provide school training for the hundreds of thousands of working men in all the numberless sub-divisions of their trades. If there were others who took a different view, let them try by all means, and see how their scheme would grow. That was the real test in England; everything that had organic vitality would grow and develop. They all agreed that the work could not be done by the Government. He held very special views upon this subject, which at that late hour it was impossible to develop: and he would only say generally that he held that the education of the workman could be greatly improved by a systematic supervision of the manner in which work was done in the workshops themselves; and that this supervision might be carried out by the co-operation of the employers and the men. This might seem a very Utopian scheme, and he could not explain the details by which he thought it might be worked out, but they would all agree that there existed in this country the material for giving the best technical education in the world, and, therefore, all that was required was organisation. Instead of the workman being left to himself or to the tender mercies of capital, he should be guided, superintended, and rewarded; but this superintendence and organisation could not be carried on from without, but must be undertaken by those who were personally interested in the matter, and who had specific knowledge of the trade itself. He would conclude by proposing a vote of thanks to Mr. Robins.

The vote having been carried,

Mr. ROBINS said he was extremely gratified by the discussion. There was no doubt that the competition between nations was increasing every day in this question of technical education, and, therefore, its importance could hardly be overrated. It was true, as Professor Perry said, that those who did not take advantage of technical education when they might did not deserve pity; but his object was to see whether the information he had collected would throw any light on the cause of the great difference which seemed to exist in the amount to which technical education had profited in one country, and not another. The difference in the primary education did not seem to give the clue, but when he examined the provisions in foreign countries for higher education, he found something so superior to anything in England, that he thought a lesson might be learned from it. Whatever was done for working men, there must also be something done for those who might help themselves but did not, to make the difference between England and foreign countries less perceptible than it now was. The City Guilds had not said this, or that, and nothing else, should be done. They were all learning from day to day, but he was sure all would rejoice that something was really being done. He would not say much about the advantages of classical education, which had been so well discussed by the Chairman; but he did feel that if Latin and Greek were dead languages, and no new life could be got out of them, there was not much preference to be given to such mediums for the expansion of a man's mind. On the other hand, that which was growing every day so fast that there were not teachers to be found to teach it, would seem to be calculated to enlarge and expand the mind much more than a dead language could possibly do.* Without good teachers, of course, they could not expect much improvement; but there were teachers in Germany who took these things to heart earnestly, and good scientific teaching was going on there to a much greater extent than it was here, hand in hand with foreign tongues.

* But the comparison did not lie between dead languages and science subjects only, but also between them and modern living languages, and it would be interesting to know if those "trained upon the humanistic "studies," who are said to have beaten their "competitors in scientific work," would have been equally successful if opposed to scientific men proficients also in modern languages, as it is contended they should be.

[*Extracted from the* TRANSACTIONS, 1882-83, *of the Royal Institute of British Architects.*]

BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION.

BY EDWARD C. ROBINS, F.S.A., *Fellow*.

THE distinctive character of our times, according to Professor Huxley, lies in the constantly increasing part which is played by natural as contrasted with classical knowledge. The study of the natural sciences hitherto relegated to the "modern side" is rapidly being included in the curriculum of every liberal education. The application of the principles of physical science to the development of mental activity, as well as to industrial enterprize, will in all probability be the distinguishing peculiarity of educational progress during the remainder of this century, that is to say, the study of things themselves, and not only their names, is destined to accompany where it does not supersede the study of language and general literature as a mental exercise. So great a revolution in the system of education points to a corresponding change in the design of the buildings required for its development, and thus gives the *raison d'être* for the subject of this Paper.

My chief claim to the honour of addressing the Institute upon technical educational buildings is that I have visited the principal English and Foreign examples—in the former case accompanied by Professor Armstrong, and in the latter by both Professors Armstrong and Ayrton—who were instructed by the Guilds Institute to inspect the various *Polytechnica* of the German-speaking countries of Europe, prior to finally determining the fittings and apparatus which should be adopted at the Finsbury Technical College.*

Before proceeding with detailed descriptions it will be desirable to give attention to certain general principles underlying or rather governing the planning of technical buildings. I am not aware that any attempt has been made to formulate them, at least in my own case I found it necessary to collect the data from original sources in order to frame a system.† All technical education does not need special accommodation. The ordinary class-rooms attached to school buildings may be appropriated to certain kinds of technical instruction, provided they are efficiently lighted and ventilated. But there are many subjects which should be taught in specially-designed buildings, for example: chemistry and physics, biology and physiology, botany and forestry, mechanics and engineering, anatomy, architecture and the fine arts generally, and others involving the provision of laboratories, lecture-rooms, work-rooms, drawing-rooms, modelling-rooms, &c., separately grouped in a certain order and

* Some three or four years ago when occupying the Chair as Prime Warden of the Dyers' Company, I induced that Company to give its support to the City and Guilds of London Institute for the advancement of technical education, which led to my election to serve on the executive committee of that body; and last May (1882) I delivered a lecture at the Society of Arts on "English and Foreign Technical Education," to the Journal of which Society I must refer the Institute for my own general opinions on this subject. I have thereby cleared the way for this Paper, treating on the kind of buildings which will in future be required. In the lecture referred-to I gave no illustrations of buildings, but confined myself to the general description of prevailing systems of scientific education on the Continent, and contrasted them with our own, especially noting the extent to which strictly-technical subjects are included in the curriculum of each.—E. C. R.

† The Dictionary of the Architectural Publication Society contains a review of Professor Hofmann's report, made in 1866, on the Chemical Laboratories of Bonn and Berlin, then just completed.—E. C. R.

contiguity, specially floored, lighted, heated and ventilated, and arranged for particular furniture, fittings and apparatus—not to speak of the specific trade-schools for teaching weaving, dyeing, &c., &c.

In the older continental polytechnic institutions, as at Zurich and Vienna, all these subjects are taught in different departments of one and the same building; and where the technical education attempted is limited in extent, the same arrangement suffices. Special technological research has, however, necessitated extensions in this direction; and at Zurich, Karlsruhe and elsewhere, new and detached buildings have been added to the old foundations for technological and agricultural chemistry, botany and forestry. The great universities of the continent have also found it necessary to extend the laboratory accommodation, and to provide distinct buildings, which are erected in the neighbourhood. Thus, at Berlin, Professor Helmholtz's physical laboratory and its associated class-rooms and lecture-rooms are in one grand building; and Professor Dubois-Reymond's physiological laboratory is in an adjoining building—worthy companions of the handsome structure erected for Professor Hofmann so long ago as 1865. At Leipzic is a street full of separate and distinct buildings for these subjects, supplementing the old university provisions, which, however, are very good. At Geneva, Professor Græbe has designed and superintended the general arrangement and fittings of the new chemica laboratory, also situated apart from the university proper. Professors von Pebal and Toepler at Graz, Professor Landolt at Aachen and Berlin, Professor Bæyer at Munich, have each worked-out, with the respective architects, the details of their new and remarkably well fitted laboratories. At Strassburg the new university, which will be of a remarkably complete character, is being constructed in separate blocks. In addition to the main building for classical studies and general literature, distinct blocks are arranged for chemistry, physics, botany and forestry, mineralogy, &c., each block costing from thirty to forty thousand pounds, built in the classic style, faced with stone from the Harz mountains, and together covering several acres of ground. At Vienna the great university buildings in course of erection are similarly complete and extensive.

The study of the natural sciences abroad has become so popular that there is scarcely any educational centre that cannot boast of some magnificent addition to its public buildings for scientific instruction within the last decade. It is not surprizing, therefore, that this country should feel the same impulse, and that imposing structures should now be in demand in all our leading towns, some of which are already supplied by private benevolence or corporate funds, and in the case of Nottingham out of the municipal exchequer. The Science and Art Department at South Kensington is now too well known and appreciated to need any further reference. At University College, London, great additions have been made for the accommodation of applied science classes. Thus, besides the Slade School of Fine Art opened in 1871, new departments have been provided-for since 1878, viz.: zoology, comparative anatomy, physiology, technological chemistry, and an admirable engineering school.

To proceed to details: It is desirable in the first place to note the particular accommodation required for some of the leading special subjects,* number and relative position of the apartments,

* With regard to the accommodation required for the development of chemistry, physics and mechanics, a general statement will be found in the unpublished Reports of Professor Armstrong and Professor Ayrton, to whom in 1879 was referred the question as to what was the least provision they would think fitting for the

in short, the systematic general arrangement of the plan. In the arrangement of chemical laboratories,* the central points of interest are the main laboratory and the lecture-rooms; in the former the working-benches are required to be provided for each student, with convenient access to a sufficient number of sinks and draught-closets, both on the benches themselves and around the walls. The junior students or students of qualitative chemistry sometimes occupy different parts of the same main laboratory with the senior students or students of quantitative chemistry; and sometimes, as at Owen's College and most of the continental laboratories, they are provided with separate laboratories, in all cases overlooked from the demonstrator's raised operating-bench. In the generality of cases the students can all see each other and be supervized from the demonstrator's platform, but in some few cases, as at University College, London, they are so arranged that each student may be as far as possible separated from his neighbour, and from general supervision as a consequence. In all cases it is important that the re-agent store, the demonstrator's room, the special operating-room, and the balance-room should be in close proximity to and of easy access from the main laboratory or laboratories; their exact position varies, but on no account should any of the subordinate rooms form a passage to other rooms. Professor Hofmann's building in Berlin is defective in this respect, for the balance-room forms a passage between the two laboratories, and the delicate scales and weighing-apparatus are subject to the vibration and disturbance of passers to and fro. Professor Helmholtz's building is spoilt by the glazed passages formed on either side of his lecture-room, and when his assistant was taking Dr. Armstrong and myself over the building, we were cautioned to go on tiptoe to avoid disturbing the Professor, who was at that moment engaged in lecturing to a large class.

The lecture-room should always have a preparation-room adjoining the professor's end of the room, so that the preparation of examples and apparatus may be close at hand, and may be passed through the door, or the large glazed draught-closet immediately behind him, about 6 feet wide, 4 feet 6 inches high, 3 feet from the floor and 3 feet deep, the sashes provided being on each side of the closet. It is important that the lecture-room should also be in easy communication with the collections of models, apparatus and examples required by the lecturer. The position of the lecture-room should be such that no interruption of the lecturer may take place. The students' entrances should be at the upper end, farthest from the professor's table; his own end of the room should have doors of access to the corridor through the preparation-room and ante-room. There are numerous practical questions with which it is necessary to be familiar in order to avoid mistakes. Many thousands of pounds have been wastefully expended by architects who have only sought to meet the wishes of an irresponsible committee and have not been associated with the professor, whose appointment in one case known to me was not made till irretrievable mischief had been done. At the new Polytechnic in Dresden the Professor of Physics was contemplating the removal of his department owing to the vibration caused by the traffic in the street on that side of the building in which his department was placed. Delicate operations require the steadiest site. In the same way the special ventilation for chemical laboratories requires

purposes of the Finsbury Technical College or Trade-School then about being erected by the City and Guilds Technical Institute, and since completed.—E. C. R.

* See the sections of a large laboratory at Munich in Illustn. xxxvii.

both common-sense and care, for many otherwise admirable systems have failed in consequence of the neglect of obvious requirements—till too late to amend them—chiefly arising from the want of a complete understanding between the architect and the ventilating engineer or the professor himself. Professor Græbe, of Geneva, stated that all his room ventilation at his chemical laboratory was effected through the draught-closets, no use being made of the general room-ventilating exit-openings leading to the base of the furnace-shaft; this latter in fact was a failure so far as the chemical laboratory was concerned, the greater *pull* being through the draught-closets, the air of which was sucked-out by the fan fixed at the entry of the collecting channels, at the level of the roof, into the side of the great exhaust-shaft, within which was the iron chimney-flue from the furnace. A similar result followed the otherwise excellent ventilating arrangements at Munich, Aachen and elsewhere. In every case in which no special mechanical system was employed, the ventilation was practically nil, and in some cases, as at the comparatively old Polytechnics of Zurich and Vienna, was excessively bad.

The *Foreign Buildings* to which I venture to draw attention are the following:—*

1. Professor Hofmann's Chemical Laboratories at the Universities of Bonn and Berlin.
2. Professor Bæyer's Chemical Laboratory, Munich University [Illustns. xxxvi, xxxvii].
3. Professor Dubois-Reymond's Physiological Laboratory, Berlin [Illustn. xxxviii].
4. Professor Landolt's Chemical Laboratory, Aachen.
5. Professors von Pebal's and Toepler's Chemical Laboratory, University of Graz.
6. Professor Weinhold's Physical and Chemical Laboratory, Royal Trade School, Chemnitz.
7. Professor Kohlrausch's Physical Laboratory, Würzburg.
8. The Technical High School, Hanover.
9. The Royal Technical High School at Stockholm, Sweden.
10. The Chalmers Industrial and Technological School, Gothenburg, Sweden.

The *English Buildings* are the following:—

11. The Central Technical Institution, South Kensington, in course of erection by the City and Guilds of London Institute for the advancement of technical education [Illustns. xxxix-xliii].
12. The Yorkshire College, Leeds [Illustns. xliv, xlv].
13. The Technical College, Finsbury, erected by the City and Guilds of London Institute
14. The University College Additions, London.
15. Owen's College Laboratories, Manchester.
16. The Manchester Grammar School Laboratories.
17. The Mason College, Birmingham.
18. The Merchant Venturers' Trade and Mining School, Bristol [Illustn. xlvi].

The itinerary of my recent tour in Germany was as follows: In January 1882, I met Dr. Armstrong at Strassburg, whence we proceeded to Mülhausen and to Geneva, where Professor Ayrton joined us on his return from Algiers. From Geneva we proceeded to Zurich and thence

* Besides these, the grand Berlin Polytechnic, viz., the Fine Art and Building School at Charlottenburg, must be mentioned. The new college at Strassburg which I recently visited is also a most important work. In a paper read at the Society of Arts in April 1880, on "Secondary School Buildings," I described and illustrated the famous forerunner of English examples, viz., the Technical College at Japan.

to Munich; from Munich to Vienna, whence Dr. Armstrong went on to Graz and Buda-Pesth, while Professor Ayrton and I proceeded to Dresden and Chemnitz. The Professor took Würzburg on his road home, while I returned to Dresden to meet Dr. Armstrong. We then together pushed on to Leipzic, Berlin and Aachen, whence I returned home after a month's absence. In all these places we visited the University Science Buildings and the *Polytechnica*, as well as other buildings of lower grade.

Foreign Buildings.

1. THE CHEMICAL LABORATORIES OF BONN AND BERLIN.—One of the earliest laboratories is that at Bonn, beautifully situated in a park in the outskirts of the town, and erected some twenty years ago at a cost of £20,000. Almost simultaneously the Berlin laboratory was carried-out at a cost of £32,000. Both the examples serve to illustrate the remarks of Professor von Pebal.* At Bonn, the arrangements are confined to one floor, at Berlin to

* It will be appropriate to quote the opinions of Dr. von Pebal, of the Chemical Institute at Graz, whose remarks on the planning of chemical laboratories are exceedingly valuable. He tells us that no scientific institution requires the fulfilment of so many and such various conditions in its design and arrangements as a chemical laboratory, and the difficulties arising out of this increase considerably with the number of students for whom practical instruction must be provided. The greater the number of individuals working simultaneously in a laboratory, the more necessary is it to isolate work of different kinds into separate rooms, in order to avoid mutual disturbance. Not only the size, but also the number of rooms requisite, must be increased for a larger number of students; this, however, unavoidably entails additional distances, and the consequent disadvantages, viz.: loss of time, fatigue, and the difficulty of superintendence. After discussing various forms of plan, Dr. von Pebal comes to the conclusion that an arrangement of the rooms round inclosed yards answers the best to the need of short distances and light rooms, and in order to avoid a great expanse or area of building, the rooms must of necessity be in storeys one above another. The arrangement and relative size of the rooms in the building depend essentially upon the principle and the dimension according to which the above-mentioned division of groups is designed. In most laboratories the beginners are in separate rooms from the advanced students, or if the principle of separation is based on the different kind of work, the qualitative is separated from quantitative analysis, and again both of these from the organic chemistry department. In the Chemical Institute at Pesth, close to a large laboratory for beginners, are several small rooms, arranged as laboratories for from two to six advanced students. Each of these ways of separation has its own peculiar advantages; it is specially convenient for those who are engaged in independent scientific researches to have to share a room with a small number only, so that they can either make use of apparatus for any length of time or leave it standing unused according as required. The erection of special qualitative and quantitative laboratories appeared to Dr. von Pebal to be less worthy of imitation, because he considered it desirable for several reasons to give beginners practice in qualitative analysis simultaneously with simple quantitative methods. The incitement to work which a laboratory offers is proportionate to the varied character of the work which is carried-on in it. Improved planning and arrangement, as well as good methods of ventilation and sufficient superintendence, have tended to lessen the difficulties of carrying-out different kinds of researches at the same time and place. For this reason it is best to limit the number of these departments to two, each of which should be furnished with the most complete arrangements possible. Complete independence in the distribution of the working-places is thus preserved, which renders it unnecessary to over-crowd one department and leave the other almost unused. The necessary working space can be made to answer to the requirements of the students by placing half a working-table at the disposal of beginners, and a whole one at that of advanced students. For operations which require a large amount of room and which cannot be performed at each working-place, there must be certain spaces of which the necessary arrangements are at the disposal of each practical student. A university laboratory, however, cannot be expected to take the place of a chemical manufactory, either as regards the necessary appliances for the preparation of large quantities of chemical substances or the learning of methods of manufacture, though modern progress in technical education is tending in that direction—witness the numerous specially-technological institutions which have lately supplemented the older pure science colleges abroad—nevertheless, even in purely scientific researches it not unfrequently happens that large quantities of substances have to be dealt-with, and it is indispensable that

two, both having lofty basements. At Bonn the building has wide corridors surrounding and overlooking the great central quadrangle, in the middle of which is the large lecture-hall; while that of Berlin being a town building and surrounded by buildings has no such corridor, and is so arranged that the rooms are made passages, and even the balance-room is not sacred.

At both Bonn and Berlin the basement gives accommodation for store-rooms for dry solid and liquid re-agents, for large stores of glass and porcelain, for washing and for heating and ventilating arrangements. Laboratories for physiological chemistry, accommodation for the medico-legal investigations, and for animals undergoing chemico-physiological treatment, are also provided at Bonn, and at both, workshops, fuel and other stores are provided.

At Bonn, the basement, being more extensive, contains apartments which at Berlin are at the level of the ground, as furnaces for assaying, smelting, &c., with flues 60 feet in height, to insure good natural draught; also specially-arched niches, let into the walls and provided with inclosing iron doors, for the protection of the manipulator when experimenting with substances at high temperature in sealed tubes. At Bonn the ground-floor comprizes spacious vestibules and corridors. The front and southern block is devoted to scientific collections, mineralogical and chemical museums, and a small lecture-theatre for special subjects; the east wing is appropriated to the assistants, and the west wing to the private laboratory, &c., of the director. The great central hall for 250 students is 40 feet square and 28 feet high (that at Berlin is 37 feet high, but it would have been wiser in the latter case to have reduced the height and to have descended to the basement to it, so that the light to the rooms around might have been less obstructed). In close proximity to the lecture-hall is the lecturer's assistant's or preparation-room, then rooms for apparatus, models, diagrams, &c., the Professor's room, cabinets, &c. The two northern quadrangles on the right are surrounded with buildings devoted to practical instruction in chemical analysis and research; there are three laboratories each 54 feet by 22 feet, by 17 feet high, and fitted for twenty students each, or more in the junior classes. The first is for beginners, the second for advanced students, and the third for young chemists engaged in original experimental investigations. At the northern end of the laboratories are three operation-rooms communicating with each other, and by open covered colonnades. The remaining rooms are appropriated to volumetrical analysis; two balance-rooms, for balances, air-pumps, barometers and other delicate physical apparatus; two rooms for fusions and ignitions, a library, laboratory for gas analysis and photometric room. Professor Thorpe, who was a student there, tells me that the distances were too great and that the journey to the balance-rooms was postponed as long as possible, thereby confirming Professor von Pebal's injunction.

At Berlin the plan is more compact, but is full of defects, which have been overcome in later laboratories, and it is now regarded as by no means an example to be imitated even by Berliners. There are two large laboratories at Berlin, 48 feet by 31 feet wide, for twenty-four students each, divided by a preparation-room, 32 feet by 20 feet, and a third laboratory,

young experimental chemists (especially pharmaceutical chemists) should be practised in the manufacture of preparations, and in putting together and handling the most ordinary apparatus and appliances; consequently there should be particular rooms for this purpose, in the arrangement of which special provision must be made for the requisite number of flues.—E. C. R.

47 feet by 24 feet, for sixteen students engaged in original research, with a combustion-room attached. The open colonnades on the ground floor carry galleries, that on the right being for the beginners' laboratory and the library; that on the left is in three portions, the two ends being for fusions and ignitions for the second and third laboratories respectively, the balances being in the centre between them, a defect already noticed and brought home to me by an accident which occurred as I was passing. The fire ran along upon the ground of the balance-room, and though speedily extinguished proved the danger of making the subsidiary rooms passages between the main laboratories.

2. The Academy of Sciences, Munich.*—I propose to treat rather fully of the new chemical laboratories at the Academy of Munich, because the building is one of the best examples of modern German work. The building is cellared throughout, and consists of a ground and first floor [Illustn. xxxvi, figs. 96, 97]; the basement [fig. 98] is used for store-rooms, work-rooms, furnace-rooms, &c.

The ground floor is for the organic and the first floor for the inorganic divisions. The central point of the separate large laboratories, of which there are two on each floor, is occupied by the big chimney, which is placed in the internal angle between the north and west wings, which are at right angles with each other. At the ends of both wings on both floors are the two large work-rooms or laboratories; and from the connecting corridors between them access is given to the subsidiary rooms. A hoist near the chimney communicates with the store-rooms. At the end of each wing of the separate laboratories are buildings. That on the south-west is the servants' dwelling-house; that on the north-east contains the two private laboratories. A better position, I think, for the professor's private work-rooms would have been to the north of the western wing, so as to be as central as possible between the students' work-rooms, but the exigencies of the site necessitated otherwise. A grand staircase was not provided, but two smaller ones are at either end of each wing. The first serves as a staircase for the servants' house as well as the students' western laboratories; the second connects the private laboratories and the general collections with the students' northern laboratory. The students' entrances are at or near these staircases, passing the vestibules, opening into which are cloak-rooms and retiring-rooms. The sole distance which the students have to go during work consists of the short walk to the special rooms in the corridor. If they wish to cross from the western to the northern laboratory, or to the basement or first floor, they can do so by using the staircase without making a thoroughfare of the laboratories. There is a small service-staircase placed next the big chimney, and a hoist and a servants' store-room are

* In 1875 Professor Bæyer was commissioned to prepare the plans for a new chemical laboratory, in which he was associated with Professor Albert Geul, architect. In 1880 they published a pamphlet describing the same, and from this I have supplemented the information I obtained during my visit with Professors Armstrong and Ayrton. In dividing the plan the following points have had to be considered: 1, The laboratory must accommodate from 150 to 200 workers; 2, It must be divided into two spacious parts, one for inorganic and the other for organic chemistry, each to be under separate direction; 3, The director of each portion must have a private laboratory with the necessary extra rooms, the assistants to work in the large laboratories; 4, The main laboratories must be sufficiently spacious, smaller rooms for advanced students *not* to be provided, in order to promote the intercourse of the workers, corridors as far as possible to be avoided; 5, Living-rooms in connection with the building must be provided for the assistants and servants. The old laboratory and lecture room of Liebig forming the central block, and erected in 1852 by Liebig, were to be incorporated in the new building.—E. C. R.

provided. The staircases are of stone, and the basement and ground floors are arched over. The large lecture-hall is entered from without by two students' staircases; behind the professor's table is the glazed chamber opening to corridor, through which apparatus is passed-in from the preparation-room. A small theatre is situated on the other side of corridor. Beyond the preparation-room is the room for collections, over which is a similar room. The relative positions of these rooms are not so good as at Aachen, resulting from the adaptation of the old Liebig buildings. From the lecture-room is a corridor connecting it with the detached dwelling house of the professor. The main court yard is entered from the Sophien-strasse, between the servants' dwelling-house and the large lecture-room; it is inclosed on the west and north by the large laboratories. It is the thoroughfare to the three flights of entrance steps, and for carriages, carts, &c.

Now as to the internal arrangements [Illustns. xxxvi, xxxvii]:—

The Laboratories for the Organic Division, Ground Floor [fig. 97], are fitted alike, but in Laboratory II [fig. 97], which is for beginners, each table is intended for two students, whereas in Laboratory I [fig. 97], which is for advanced students, a whole table is assigned to one, accommodating thirty-two students in the former and sixteen in the latter. The floors for the sake of warmth are made of wood, with an asphalte border round, 3 feet wide, on which stand the wooden sinks and digestoriums or draught-closets. In the middle of this border is an asphalte gutter-channel; this gutter is trapped at the two opposite ends, and communicates with the main drain. This channel carries away the wastes from sinks and draught-chambers, and also any floor-droppings, being covered only with perforated boards. This arrangement is said to work well in practice, and allows of carrying on large operations in the immediate neighbourhood of the work-tables; the central avenue being the general thoroughfare.

The Laboratories III *and* IV *for the Inorganic Division, First Floor* [fig. 96], are similar to the former. In each room there are ten double tables, each with three working places on a side, so that there is accommodation for sixty workers in each room, about 3 feet being given to each.

The Subsidiary Rooms to the Organic Division, Ground Floor.—*a*, a room for heating sealed tubes, called the cannon room; *b*, glass-blowing room; *c*, small combustion room; *d*, preparations or specimen room; *e*, washing-up room, in which is the hoist, and it serves as a work-room for laboratory servants; *f*, large combustion room; *g* and *h*, balance rooms; *i*, stink chamber. Passing to the private laboratory block we come to the following subsidiary rooms:—*k*, library for the use of students; *l*, consulting room; *m*, professor's balance room; *n*, air-pump and blowpipe room; *o*, specimen room; *p*, washing-up and stink chamber; *q*, the private laboratory, which is at end of corridor. In addition to the work tables there is a hearth for combustions. There are also draught-closets, the ventilation being effected by gas flames in the private laboratory, owing to its distance from the chimney-shaft.

The Subsidiary Rooms to the Inorganic Division, First Floor.—*r*, filtration room; *s*, blow-pipe-room; *t*, smelting and air bath room; *u*, specimen room; *v*, washing-up and servants' room; *w*, stink chamber; *x* and *y*, balance rooms; *z*, sulphuretted-hydrogen room. In the private laboratory are the following subsidiary rooms:—*a a*, physical cabinet; *b b*, consulting room; *c c*, balance room; *d d* and *e e*, gas rooms; *ff*, washing-up room, with smelting furnace, &c.; *g g*, the second private laboratory.

The main building is heated by steam. The heating surfaces consist partly of chests, partly of coils. The steam is generated in two large boilers, contained in the boiler-house placed in the courtyard. The servants' house is heated by stoves; the director's house by hot water; the lecture-rooms by coils with two small stoves, in addition to the large lecture-room. In the laboratories are four stoves and two small coils.

The ventilation of the main laboratories is now effected by ascending flues from the draught-closets, sixteen in number. The laboratories are also connected with the general ventilating system, with descending extract-flues as shown in section [Illustn. xxxvii, figs. 99, 100], but these are no longer used, as they were found to interfere with the ventilation of the draught-places. Experience has shown that the rooms are sufficiently ventilated, provided that all noisome operations are carried-on in the draught-places, fresh air being admitted very generally. The air as it enters the laboratory is led through short channels round the four stoves. The sixteen draught-closets are connected by means of glazed earthenware pipes with horizontal canals leading to a space in the roof through which runs the big chimney, and with which this space is put into direct connection. The draught up the chimney from the steam-boilers is sufficient in winter to work the arrangement; in summer it is necessary to urge it by means of a fan worked by a small steam-engine in the basement. The same arrangement serves to ventilate in addition the sulphuretted-hydrogen-room and the stink-closets. The horizontal canals or channels, as well as the chamber with which they are connected, are made of bricks joined with asphalte and lined internally with the same material. The steam-boilers not only supply steam for heating, but also, by a special service, for the drying-closets and the distilling apparatus. They also work a pump and the fan which sucks-out the foul air from the basement channels with which the descending flues are connected.

3. THE PHYSIOLOGICAL INSTITUTE, BERLIN.—Through the kindness of Professor Lewis, who has lately made inquiries for me at Berlin, I am enabled to give plans [Illustn. xxxviii, figs. 101-104] of the new Physiological Institute at Berlin, which adjoins Professor Helmholtz's physical laboratory, and is in some respects explanatory of it, at least so far as the lecture-hall is concerned. It will serve as a good example of the manner in which these buildings are constructed, with the aid of government grants, by architects appointed by government, and usually themselves professors of architecture in one or other of the technical colleges. In this building the arrangement of the galleries of the hall is suitable enough because they communicate with the hall alone; but in the physical laboratory adjoining, similar galleries are made the means of access to rooms beyond the hall, and consequently, though the gallery-openings are glazed, traversing to and fro arrests the attention of both speaker and audience, which defect I noted in my previous remarks.

4. THE CHEMICAL LABORATORY, AACHEN.—The buildings at Munich, Aachen, Graz and Leipsic are examples of modern German chemical laboratories, as late as 1879 and 1880; and they each teach the same sound lesson, only in different ways suited to the peculiarities of the circumstances and the character of its director. Professor Landolt's building at Aachen is replete with every scientific convenience, and is of all others an example of successful heating

and ventilation. The fresh warm air is forced-in by a fan, and the foul air is sucked-out by two fans, without any conflict in the action: the *push* and *pull* principle pure and simple; and the whole is under the control of the engineer, who has an electrical tell-tale dial arrangement by which he can know the temperature of every important room in the building, and appliances to enable him to "temper the wind" when necessary. The arrangement of the plan is good, if we except the front corridors, which are vaulted and sumptuously painted, and as a matter of fact are more ornamental than useful.

The subsidiary rooms to the lecture-hall are admirably grouped around it. The fine balance-room lies between this group and that of the quantitative laboratory, with which it directly communicates; organic chemistry, special operations, gas analysis, &c. are in the right wing, and in the left are the qualitative rooms and the small lecture-room. The laboratories are single-storey buildings in this case, and are lighted from the roof as well as the sides. It is a costly erection faced with stone, and the theatrical effect of the interior of the lecture-hall is extremely good.

5. The Imperial University of Graz.—The Chemical Institute at this university, begun in 1874, was not completed till 1879. Professor von Pebal published an account of it in 1880, from which my information is derived. It is economically built of brick, with plaster dressings internally and externally. The floors of the rooms are either of asphalte, cement, or deal as required. Great care has been taken in all that relates to the efficient working of the institution, as the construction of working-tables, draught-niches and places—experimental trials being first made—and the total cost was upwards of £50,000. The fresh air is forced-in by fans through five distinct steam-heated heating chambers, and the air is changed three times in the hour. The *push* principle, pure and simple, is adapted here without conflicting draughts. The entrance vestibule and great corridor is a decided improvement on Aachen. The residences occupy the right wing; the lecture-hall the central block, and the laboratories the left wing. The subsidiary rooms in connection with the lecture-hall consist of the professor's retiring-room and private corridor to front hall; the preparation-room, and two rooms for collections. The students have a fine ante-room for hats and coats, giving access to the upper part of the lecture-hall. The subsidiary rooms in connection with the laboratory are arranged at both ends of it, but the opposite doors opening into the spaces between the benches and the draught-closets, leads to making a thoroughfare of what at Munich is so much more usefully added to the working space. Nor do I think that the arrangement of this room, with a working-bench in each window, besides the central rows of double benches, is an improvement on the Munich plan of putting the draught-closets in the windows, and the sinks against the piers between, although the accommodation may be relatively greater.

6. The Royal Trade School, Chemnitz.—The town of Chemnitz in Saxony has recently been brought into prominent notice, through the publication of Mr. Felkin's pamphlet upon the educational advantages of a technical character which it possesses. It has no university, it has not even a polytechnic, so called, but it is full of High schools for general and special education, and is especially strong in Trade schools. I select for illustration the Royal Trade School, comprizing the *Gewerbschule*, the *Werkmeisterschule*, and the *Baugewerkenschule* for artizans, which I visited with Professor Ayrton. The grand staircase is opposite the main entrance. The chief corridor runs right and left, and returns at right angles in both wings,

but except in the basement the wing corridors are utilized as rooms. Left of the staircase on the ground floor is the chemical store-room, and the general chemical collection is next to it. The chemical laboratories for students in the first course of the Trade School occupy the whole of the left wing. The lecture-room adjoins, and the teacher's rooms are on either side of the main entrance. The room on the right is at disposal. The right wing is devoted to mineralogy; first the teacher's laboratory, next the mineralogical collection, then the lecture-room, a room for delicate work and a waiting-room, bring us round to the main staircase again, on either side of which are conveniences. Descending to the basement, and taking the same route, we come to the gasmetre-room and two store-rooms, and a galvanic battery-room. In the left wing is accommodation for furnace operations, for steam operations, and a mechanical workshop. Then come two rooms for fire operations, and under the main entrance a photometric room, the gas analysis-room, and the large fuel store-room, which is now used for physical experiments. The right wing is devoted to house-stores; the small room at the back, which is the pendulum-room, extends the whole height of the building, with a small gallery at each floor, where experiments in connection therewith are made. A similar pendulum-room or tower is provided in the central well of a circular staircase at the physics laboratory of the new University of Strassburg.

Ascending to the first floor we enter the technical chemistry collection. The left wing is devoted to the *werkmeister* or foreman's school, first a teacher's laboratory, next the students' laboratory, next an experiment-room, and last, a spectrum analysis-room. Adjoining the left wing in front is the lecture-room for technical chemistry, and there are three work-rooms for assistants and lecturers on physics. The remaining rooms are for the department of physics, first the lecture-room for physics, for students of the foreman's schools, with a preparation-room, between it and the lecture-room for physics, for students of the *Gewerbschule*. It will be observed here that the lecturer's table in each lecture-room has a portion which is made moveable, so that apparatus arranged thereon may be moved along the tramway to and fro, for the service of both classes of students. Professor Weinhold gives details of this table in his book. The other three rooms are occupied by physics-apparatus collections, without which no technical physics-teaching can be effective. The small room next the large lecture-room is used as a dark room for experiments on light, and being situated at the end of the long corridor, a ray of light may be thrown through the door the whole length thereof. The arrangements for darkening the lecture-rooms at the professor's will, the spectrometer, the vacuum process, and a variety of special arrangements for gas, water, quicksilver baths, steam-drying cylinders, electrical apparatus, &c. are far too numerous to mention. Professor Weinhold's perfect command of the English language enables him to give full information to Englishmen, and to no better place than Chemnitz could any student go to perfect himself in technical or applied science school requirements.

On the second floor of this building, starting from the left of the main staircase we come to a store-room, an apparatus-room, a work-room for the chemistry assistant, and a balance-room. The chemical laboratory of the students of the first and second course of the *Gewerbschule* occupies one side of the left wing, adjoining which is a room for elementary analysis, and a sulphuretted-hydrogen-room. The next front room is for general experiments by students as above, with a waiting-room adjoining. Then comes the balance and microscope room, then the technical chemistry teacher's work-room. The rest of this floor, except the physics collection on the right of main staircase, is devoted to the teacher's apartments. This is an interesting example of the sort of building required at every industrial centre, for the development of elementary technical science and art among foremen and practical men generally.

7. THE PHYSICAL INSTITUTE, WÜRZBURG.—Professor Kohlrausch's Physical Institute is an interesting building, specially devoted to one purpose; and Professor Ayrton, who recently visited it, highly commended all its arrangements. The entrance to the principal floor is at the west end, the assistants' apartments are on the left of the entrance, and on the right is the passage to the lecture-hall, in communication with which are the preparation-room and two collections of apparatus, models, &c., between which is the staircase. The main corridor extends from west to east, from which seven laboratories are entered, and a third collection-room towards the north. Descending the staircase we reach a large hall, with exit to yard, next which is the engine-room, with a gas engine and electrodynamo; on the north side, communicating with each other, are two laboratories, fitted with stone tables, sinks, evaporating-closets, next to which is a store-room; there is also a lavatory with circular stairs to the floor over; a large work-room is at the east end, and next it a chemical-room; the heating-apparatus and coal-cellar adjoin, and a workshop, with forge and sink. The building is heated with hot air by flues, and the foul air is withdrawn by the furnace of the heating apparatus by descending channels. The remaining rooms are for servants' residence and domestic offices.

8. THE TECHNICAL HIGH SCHOOL, HANOVER.—This important, complete and well-appointed technical school consists of a cellar storey, a ground storey, the principal or first storey, the second and third storeys. It is designed in the palatial manner, which always distinguishes German educational buildings. There are five open courts inclosed in the ground plan of the building, which measures 500 feet long by 250 feet in depth. Flights of external and internal steps give access to the great corridor, 120 feet long by 20 feet wide, forming one side of the central quadrangle, which is entirely surrounded by wide corridors, and intersected in the middle by the two grand staircases, connected by the *foyer* on this floor. On the right of the chief entrance we find a passage to the chemistry and physics departments, a lecture-room and a preparation-room for analytical chemistry, a long hall for practical chemistry, divided by a room for ordinary operations. Passing up the corridor of the extreme right wing at right angles to the front we have the room for gas analysis, the library and balance-room, the instrument-room and the staircase to the next storey of this wing, which is entirely devoted to chemistry. The professor's private rooms and laboratory occupy the rooms over those last described; on the other side of the staircase to the left is the chemical manufacturers' collection. The lecture-room for technical chemistry, its preparation-room, and its chemical collection, follow, and beyond is an assistant's laboratory.

On the right are the collections of models or examples, and more assistant's rooms; opposite the end of the corridor is the entrance to the gallery of the examination-hall, and to the left is the large lecture-room for chemistry with its satellite the preparation-room. Descending the staircase to the floor below we enter the physics department; on the left of the corridor is the small lecture-room for physics, with its preparation-room and physics collection-rooms. The whole of the rooms on the right side of the corridor are devoted to the physics work-rooms or class-rooms. The examination-hall is at the end of the corridor, and to the left is the large theatre for physics, with its preparation-room and professor's room. Returning to the main corridor and along the corridor of the right intermediate wing we pass the botanical and zoological collections, the housekeeper's room and the engineering lecture-room; at the end of this corridor to the right is the refreshment-room; turning to the left the whole of the remaining rooms in this front are devoted to the engineering classes, with a collection of drawings adjoining the professor's room in the centre, drawing class-rooms on either side, and a lecture-room for mathematics and mechanics, in all 330 feet in length. Returning to the left intermediate wing, and passing the engineer's waiting-room, the teacher's private room and sitting-room, and cloak-room, we come to the passage to the library, the reading-room, and the librarian's room. The remaining portion of this floor is given to the offices and the residence, the domestic offices being on the floor below. Ascending the rear main staircase we arrive in the midst of the drawing-rooms and lecture-rooms for architecture and building, divided into four classes of students; the professor's room and the collection are in the centre, and the lecture-rooms at each end. The left wing is occupied by a collection of models of building-construction, a lecture-room for technology, a professor's room, and large rooms for technological collections. Returning to the left intermediate wing we pass another lecture-room for second and third classes in building and architecture, and we come to the laboratory for geology and mineralogy; then the geological collections, the lecture-rooms for geology and mineralogy, the mineralogical collections, divided into two halls by the professor's room in the tower over the main entrance. The right intermediate wing contains two professor's rooms, a practical geometry class-room, a collection of mathematical instruments, and a lecture-room for practical geometry and mechanics. Proceeding up the rear or north grand staircase we arrive in the midst of the mechanics' department. The drawing class-rooms occupy the whole of the northern front, except the lecture-room for the mechanics students and teachers; a professor's room is at each end of the corridor. The western side of the quadrangle is the large room for the first building and geometrical drawing classes. The eastern side is entirely devoted to the mechanics collection. The southern side, with windows looking north, is the freehand drawing school, and the collections are on the southern side: three professor's rooms occupy the south-west angle. The ground floor is chiefly devoted to residences for the various officers, as the professors of chemistry and physics and their assistants; the workmaster and machinists, the housekeeper, the secretary, &c. &c. Under the library and reading-room is a vast room for technical experiments, and on the western side of the northern front, under the engineer's drawing school, is a second freehand drawing class-room. The important part which drawing takes in this institution is one of its most remarkable provisions. The basement contains the heating-apparatus and ventilating arrangements, and a series of cellars for the chemistry and physics departments is in the east wing.

9. The Royal Technical High School, Stockholm.—The earliest provision for technical education in Sweden was in 1809, when lectures were given to artizans privately in chemistry and physics. In 1813 the Mechanical School was founded at Stockholm; in 1822 the School of Mines; in 1825 the Royal Technological Institute; by 1860 £25,000 had been spent in new buildings, and £2,500 a year granted by the State. In 1866 the School of Mines was

incorporated with the Royal Technological Institute, and the whole denominated the Royal Technical High School; £6000 more capital was granted, and £1000 a year more income. In 1876 the department of architecture was instituted in addition to practical mechanics, mining science, and civil engineering. The High School possesses rich collections of models, instruments, &c., geological and mineralogical specimens; and a library of 18,000 vols., besides 95,000 English Patent Office reports. There are about 300 students, and the expenditure is some £10,000 a year.

10. THE CHALMERS INDUSTRIAL SCHOOL, GOTHENBURG.—Founded in 1829 with half the fortune of William Chalmers, of English parents, and a merchant of Gothenburg, this industrial school, is now a thriving institution, with 162 students, and an income of £2000 a year. Spinning, weaving, navigation, hydraulics, chemistry, and mechanics are there taught.

English Buildings.

11. THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON.—The drawings for this magnificent enterprize are particularly deserving of study. The architect of the building has developed the intentions of the Executive Committee in the broad spirit in which they were conceived. In this case not only have the professors of the Finsbury College lent their aid, but the presidents of the Royal Society, of the Institution of Civil Engineers, of the Chemical Society, and of the Society of Arts have each acted on the Sub-Committee, to whom the arrangements of this building have been specially intrusted under the presidentship of Sir Frederick Bramwell, whose untiring labours have mainly contributed to the remarkable success of the Institute. But to the great experience of Mr. Alfred Waterhouse, A.R.A., to his personal supervision of details, and his adoption of the latest improvements in fittings, and in heating and ventilation, we shall chiefly owe one of the most efficient technical colleges of modern times; and although the particular details of the fittings generally are still under consideration, preparation has been made for them as indicated in the plans which are reproduced in Illustrations xxxix-xliii, figs. 105-109.

The building has a frontage of 300 feet, and a depth of 120. The main front building is five storeys in height; the north-western wing is 80 feet wide, and four storeys in height; the south-western wing is postponed for the present. In the rear of the central portion of the main front is a single-storey top-lighted workshop, 100 feet long, by 50 feet wide. The main staircase is in the centre of the building, and a 10-feet wide corridor runs right and left the whole length of the building. The west wing is divided by a central corridor at right angles with the main corridor, connected by the northern staircase, on the south side of which is the great chimney and ventilating shaft, 120 feet high.

The special subjects to be taught technologically are limited to physics, mechanics, chemistry and art, as chiefly required in industrial art development.

The whole of the basement, ground and first storeys of the front building, situated on the southern side of the main central entrance, is devoted to physics, which for the present will share with mechanics one of the lecture-rooms in the north-western wing, under which is the room for metallurgical operations.

The remainder of the basement and ground floor is devoted to mechanics. The chemistry and mechanics lecture-rooms are in the north-west wing.

On the first floor over the main entrance is the reading-room and library, and the remainder of the north end of the main building is devoted to administrative offices and the council chamber. The whole second floor of the main front building, except the four northernmost rooms, is devoted to art and mechanical drawing. The remaining rooms on this floor and on the next, as well as on the two upper floors of the western block over the lecture-rooms, are given up to chemistry. The museum is on the top of the central block.

12. THE YORKSHIRE COLLEGE, LEEDS.—This college, of which the foundations are now being laid, is one of the latest outcomes of applied science teaching and construction. The contract was signed in July (1882) last, and comprizes the three sides of an irregular quadrangular building, the central inclosure of which is destined to be the museum of specimens, models and apparatus required for illustrating the various sciences and arts to the teaching of which the building is to be devoted. This central museum gives the key-note to the general arrangements of the plan. It is an inexpensive way of obtaining what is never absent in Continental examples and rarely present in our own. This museum does not form part of the present contract; but it will doubtless be included in the subsequent contract for the fourth side and its wings, intended to provide the administrative chambers, the library and the arts department, which have to be temporarily provided-for in the present contract.

The masterly planning of Mr. Waterhouse has been chiefly inspired by Professor Thorpe and his professional associates, by whom the various requirements have been carefully considered, and after several years of anxious thought and comparison with earlier examples, the numerous problems so difficult to solve have been worked-out in a remarkably able manner. The irregularity of the site has provoked an original treatment of plan [Illustns. xliv, xlv, figs. 110-122] and a picturesqueness of exterior design which has nevertheless in no way injured the internal convenience.

A 13-feet wide cartway entrance from Clavering Road gives access to the centre of the northern corridor, and through it to the central museum or general scientific collection; and at this point some spare rooms, the coal and heating-apparatus cellars, occupy the basement. East of the cartway, on the ground floor, are the physics lecture-room and preparation room, beyond which is the physics laboratory, fitted with stone wall-tables on stone brackets and with draught-closets. A draught-place and a glazed hot-closet are provided between the preparation-room and the lecture-room. The lecturer's table has a stable foundation of piers and arches, with a concrete floor behind it. To avoid magnetic influences deranging the delicate experiments carried-on here, no iron is admitted into the construction of this room; even the steam-heating pipes are excluded, and the warm air therefrom is conducted thither by special flues. Special arrangements, under the control of the professor, are made for darkening the room and exhibiting diagrams.

The building is to be heated by steam and ventilated by extracting-fans, the fresh air inlets passing over the steam boxes situated at every window-back. A point in this building will be the distribution of steam power throughout, not only for turning shafting for machinery and dynamos, but for chemical laboratory operations, evaporating and drying closets, &c.; and on the whole this institution bids fair to deserve the high encomiums which Professor Roscoe has passed upon it, and of which Yorkshire may well be proud.

13. The Technical College, Finsbury.—This building is just completed or very nearly so. It is the first important work of the City and Guilds of London in point of time, if we except the Kennington Art Schools under the care of Mr. Sparkes. And it represents a model of the kind of structure which should be within the means of every important provincial town. Originally designed as a Trade School, it has developed into a Technical or Applied Science College for working-men and apprentices. Chemistry and physics were first provided-for, but ultimately mechanics was added, and the Professors Armstrong, Ayrton and Perry have done the best they could with the limitations prescribed by the only available site abutting Tabernacle Row on the one side and the playground of the Cowper Street schools on the other. The architect of the building is Mr. E. N. Clifton. The general arrangement of the building is as follows: On the second floor, the iron staircase occupies the centre of the place. The great chemical laboratory occupies the east side, and is divided by two iron columns into senior and junior laboratories. The senior students are on the south side, with five double benches down the centre of the room and wall-benches next the south wall. On the north side are the junior students' detached benches and wall-tables; and the demonstration table and platform are on the east side.

The hooded draught-flues from these tables supersede special stink-closets. On either side of the great chimney-shaft are the exit doors to landing, from which on the north side is the balance-room with its stone wall-brackets, &c., and on the south side are the demonstrators' rooms. The adjoining small staircase leads to the flat roofs and to a large mechanical drawing school. Beyond the staircase are the conveniences for students.

At the western end of the landing, on the south side, is the chemistry professor's room, out of which are his laboratory and his room for special operations, carefully fitted with working-benches, sinks, draught-closets, &c. The chemical glass store and the re-agent store-rooms come next. There is also a large class-room, between which and the balance-room is the gas analysis-room. On the first floor, under the chemical laboratory, are the two large lecture-rooms—one for physics and mechanics, the other for chemistry—with the students' common-room under the upper part of galleries. Each lecture-room has its preparation-room adjoining, and glazed opening in centre behind lecturer, giving access to same for apparatus, besides the door of communication. There are foul air-shafts and floor draught-channels in connection with the lecturers' tables and preparation-rooms. At the western end are rooms for experiments on light and for mechanical engineering, adjoining which is a physics plan-drawing room.

On the ground floor is the entrance to the building from Tabernacle Row, under a stone portico, and opposite the vestibule is the great central staircase with landings on its three sides. On the right of the entrance are rooms for the secretary and the clerks; next which are the mechanics professor's room and the physics workshop with class-room adjoining, fitted with Moss's patent benches. At the north-east corner is a mechanical drawing office, and a physics laboratory adjoins. At the west end are two physics laboratories and the physics professor's private room. Seven steps below level of ground floor and lined with white glazed bricks is the chemical brewing-room. In the basement under the brewing-room and six steps below the general basement level are the heating furnaces and boiler-room, and the heating-chamber, fitted with wrought-iron hot water pipes, with the fan at one end and the channel flues at the other. West of this room is a physics laboratory with gas-engine, adjoining which is the physics store-room, with a brick wall to carry stone tables above. At the south-west corner is the chemistry gas-testing room, adjoining which is the metallurgical laboratory. The eastern half of the basement is devoted to mechanics—first a general laboratory or class-room, then a wood workshop, then an iron workshop, and finally the engine-room, with 14-horse-power condensing engine and multitubular boiler.

This engine not only turns the shafting, but provides the power for working the dynamo for producing the electricity with which the building is lighted, and the electrical experiments are carried-on in connection with all the laboratories. There are areas at the back and in front, with a series of vaults under the pavement. The whole of the basement is lined with white glazed bricks.

14. UNIVERSITY COLLEGE, LONDON.—This college, founded in 1826, incorporated in 1836, and chartered in 1869 for special purposes, was extended in 1871 for the Slade School; and, in 1878, the foundation stone of the north wing, last completed, was laid by Lord Granville. The new buildings, designed by Professor Lewis, and carried-out by Messrs. Perry and Reed, provide improved and extended accommodation for the Slade School of Fine Art; and for zoology and comparative anatomy. The whole upper floor of the north wing has been devoted to physiology. On the ground floor and basement, chemistry is provided not only with space in the north wing itself, but also with a large annexed laboratory on the ground behind. Rooms set free in the centre of the building, by these new arrangements, have been so dealt-with as to secure proper accommodation for the School of Engineering and a laboratory for practical botany. The physiological department consists of a set of eleven rooms, among them being a lecture-room for 170 students, and a working-room for 100 students, with large windows to the north. Each worker is provided with gas supply for heat and light, water supply, and a locker or cupboard for his microscopes, instruments, &c. The seats and tables are in parallel rows facing northwards, each row being three feet above the row in front of it; in this way the light which it receives nearly horizontally cannot be intercepted. The other rooms are for various purposes. In the department of chemistry, the new analytical laboratory is a lofty hall (74 by 25) lighted from above. It contains working-benches for 50 students, all of whom are as far as possible prevented from communication with or overlooking one another; and in this respect it is quite unique. In the middle of the laboratory are draught-tables and appliances for general use.

15. OWEN'S COLLEGE, MANCHESTER.—The chemical laboratory at this College, executed from the designs of Mr. Waterhouse, in accordance with the arrangements prescribed by Professor Roscoe, is one of the earliest and best of English examples. The chief features of the building are two large laboratories, each 70 feet by 30 feet, and 29 feet high. One laboratory is devoted to the first year or qualitative Students, in which there are working places for 60 students in 6 blocks of 10 places in each. The other is ranged for 40 advanced or quantitative students, and contains 10 blocks of 4 places in each. Parallel with the quantitative laboratory, and divided therefrom by a corridor, is a series of rooms, viz.: two balance-rooms, organic analysis and gas analysis rooms, a library and organic chemistry lecture-rooms. At one end of the two laboratories is the staircase, on one side of which is the chemical store and re-agent room, and on the other the Professor's private room—over which are Professor Roscoe's private room, overlooking both laboratories, and his private laboratory and balance-room. In the

basement is a third large laboratory for fifty medical and for evening students, a metallurgical laboratory containing furnaces, a store-room, class-room, lavatory and cloak-room, spectroscopic room, photographic-room, dark-room for photometry, boiler-house and three preparation-rooms. The large theatre for 380 students is detached from the working laboratories, and has its lecturer's laboratory or preparation-room, draught-closets, sinks, &c. adjoining in the rear, and communicating directly with the space behind the lecturer's table.

The ventilation of the laboratory is both general and special. The general ventilation is effected by a perforated boarded ceiling running the whole length of both laboratories and conveying the vitiated air, by a large air-trunk, to the shaft, within which rises the smoke-flue of the furnace. The supply of fresh air is obtained from a high level by a fresh air-shaft, down which the air passes, being drawn over the hot air-pipes by the aspiration of the chimney, and passing into the laboratories through gratings placed in the walls. The special ventilation is also worked by the main shaft, and is divided between the evaporating-niches in the walls and the sulphuretted-hydrogen-closets. Each of the niches is provided with an upright glazed earthenware pipe, 4 inches in diameter, running into a horizontal pipe of the same material 12 inches in diameter, communicating with the draught of the main chimney. The large niches at the end of the laboratory aspirate 100 cubic feet of air per minute, each of the smaller ones in side walls 12 cubic feet per minute. The sulphuretted-hydrogen-closets in each working-bench are joined together in groups of two and four, and placed in connection with a 7-inch or 4½-inch glazed earthenware pipe, communicating with a horizontal flue shown in section, running between the fire-proof arching and the floor, and passing into the chimney shaft. Each closet in No. 1 laboratory aspirates at the rate of 5 cubic feet per minute, whilst those in laboratory No. 2 aspirate 20 cubic feet per minute —those at the farthest end of the laboratory differing but slightly from those nearest the chimney.

16. The Manchester Grammar School.—The best is here made of a very limited space. The arrangement of the rooms is singularly good, and the fittings are admirable. The architects were Messrs. Mills and Murgatroyd, and high praise is due to Mr. Jones the Master, who made a study of every detail. The chemical science department occupies six rooms on the second floor. The gymnasium is in the centre of the school quadrangle, and the galleries form the gangway to the laboratory and lecture-room. The chemical laboratory is fitted-up with operating-benches for ninety students—with demonstrator's table at one end, and assistants' table at the other—and both at right angles to the benches they command. Draught-places are placed in three of the five windows. There is a special sulphuretted-hydrogen-room at one end, with draught-place and sink and furnaces. The ventilating shaft, with central iron smoke-flue is at hand, and ready for the withdrawal of all the vapours. At the other end of the laboratory are the balance-room, the class-room with lecturer's table, the apparatus-room and preparation-room adjoining the chemical lecture-room; between the lecture-room and the apparatus-room is a draught-closet, and there is a sink communicating with each.

17. Mason College, Birmingham.—This College, founded by Sir Josiah Mason ten years ago, has only been completed within the last two years. It was originally designed to teach only chemistry, physics and mathematics. When the building was partly roofed-in, it was determined to add to the above sciences, physiology, geology, mineralogy and botany.

Considerable modification of the original plan was obviously necessitated. When the work was well-nigh completed engineering was added, and afterwards biology. In judging, therefore, of the arrangement of this college, these facts must be borne in mind. The site also was very circumscribed and surrounded by buildings, so that the principal lighting had to be derived from internal quadrangles, and great height was necessary—the blocks varying from three and four to five storeys in height.

18. THE MERCHANT VENTURERS' SCHOOL, BRISTOL.—Finally, I will cite this school as an example of a provincial city Trade and Mining School. The building comprizes four storeys, on the topmost of which are situated the chemical, physical, and metallurgical laboratories and lecture-rooms, the combustion-room, balance-room, special operation-room and the master's rooms, with an observatory in the turret. The first floor contains the engineering lecture-room, the drawing schools and the plan-room, also a series of four general class-rooms opening into the gallery of the great hall. The ground floor [Illustn. xlvi.] has a similar series of class-rooms, entered from the great hall open aisle. This is one of my own buildings, and in it I have applied the principle of planning (which Dr. Abbot termed the "hall-passage system)," in accordance with the views expressed in my lecture on "Secondary School Buildings," delivered at the Society of Arts in 1880. Beyond the hall class-rooms are the library and museum, the waiting-room, the head master's and committee rooms. The basement floor is level with Denmark Street at the east end, and two-thirds below the level of Unity Street at the west end, of the building, owing to the slope of the hill from College Green. It comprizes an art-school, and the engineering workshops and machinery, the luncheon-room, cloak-rooms, also engine, boilers, hot water-apparatus and coal-stores; the kitchen offices complete form the basement floor of the caretaker's house—the top storey of which is to be devoted to a general drawing school. The cost of this building will be over £35,000, and it affords another example of the public spirit still remaining among the ancient guilds.

[Remarks by Professor H. E. Armstrong, Ph.D., F.R.S.]

On comparing together the plans of the various laboratories described by Mr. Robins, it will be noticed that there is a somewhat important difference between the English and foreign schools. In the latter, separate laboratories are provided for students engaged in qualitative analysis and for those engaged in quantitative analysis, and therefore usually the junior are separated from the senior students. In the English schools the division is less absolute, and the two classes of students are accommodated either in contiguous apartments, as at Manchester, or in one large room which is partially subdivided, as at the Finsbury College. The English plan has the advantage that it renders it easier to supervize the students, a point of some importance, as the teaching staff is, as a rule, much smaller in proportion to the number of students in the English than in the foreign schools. As the requirements of the two classes of students are very nearly the same, however, there is no reason why the one plan should always be adopted in this country. The comparative smallness of the provision for the teaching of organic chemistry in the English schools will also be noticed; this mainly arises from the fact that unfortunately the English student, or rather his father, does not as a rule think it necessary to prolong his studies for nearly so long a period as is usual abroad. With reference to the all-important question of ventilation, after inspecting the chief foreign examples, I am of opinion that it is proved over and over again that artificial ventilation must of necessity be resorted-to, and that in all probability a purely mechanical system is the best. The extraction of the foul air by means of a shaft with the aid of a furnace is, I believe, theoretically a less economical method than that involving the use of a fan, and it is well known that fans are now largely employed in mine-ventilation with great success. The latter method, moreover, has the great advantage that a fan may easily be worked at any desired speed, and at a regular and even rate, and requires scarcely any attention; whereas it is difficult always to maintain a current of uniform velocity in a shaft by means of a fire, more especially on account of the difficulty of insuring regular firing, and to a less extent owing to the variation in the specific gravity of air at the different seasons of the year; not to speak of the influence of air-currents blowing across the top of the shaft and in at the open windows. The fan should always be used as an extractor, I think; if, as at Aachen, air can also be injected, so much the better. With regard to the hood covering the benches which I have devized, I am satisfied from actual experience that it will be most efficient, provided that the current be of a sufficiently high velocity. My experiments go to show that the current in the 4-inch square downcast pipes connecting the hoods with the flue below should flow at a rate of certainly not less than about 5 feet per second. There would, so far as the hood is concerned, be no great objection to making the downcast flues of larger dimensions, that is of greater width, in which case currents of less velocity might perhaps be employed to withdraw the foul air from under the hood, but in this case the side openings which are provided in the downcast flues would be of less service when evaporating liquids, &c. The sanitary and other advantages of the hooded covering to all working-benches are, in my opinion, very great in comparison with those arising from the adoption of the system which has hitherto prevailed of having draught-closets against the walls, and I think that we should be prepared to make considerable sacrifices in favour of their adoption, especially in school laboratories, where very young students are engaged, and that vigorous efforts should be made to arrive at the most perfect method of constructing them.

HENRY E. ARMSTRONG.

VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (XXXVI)

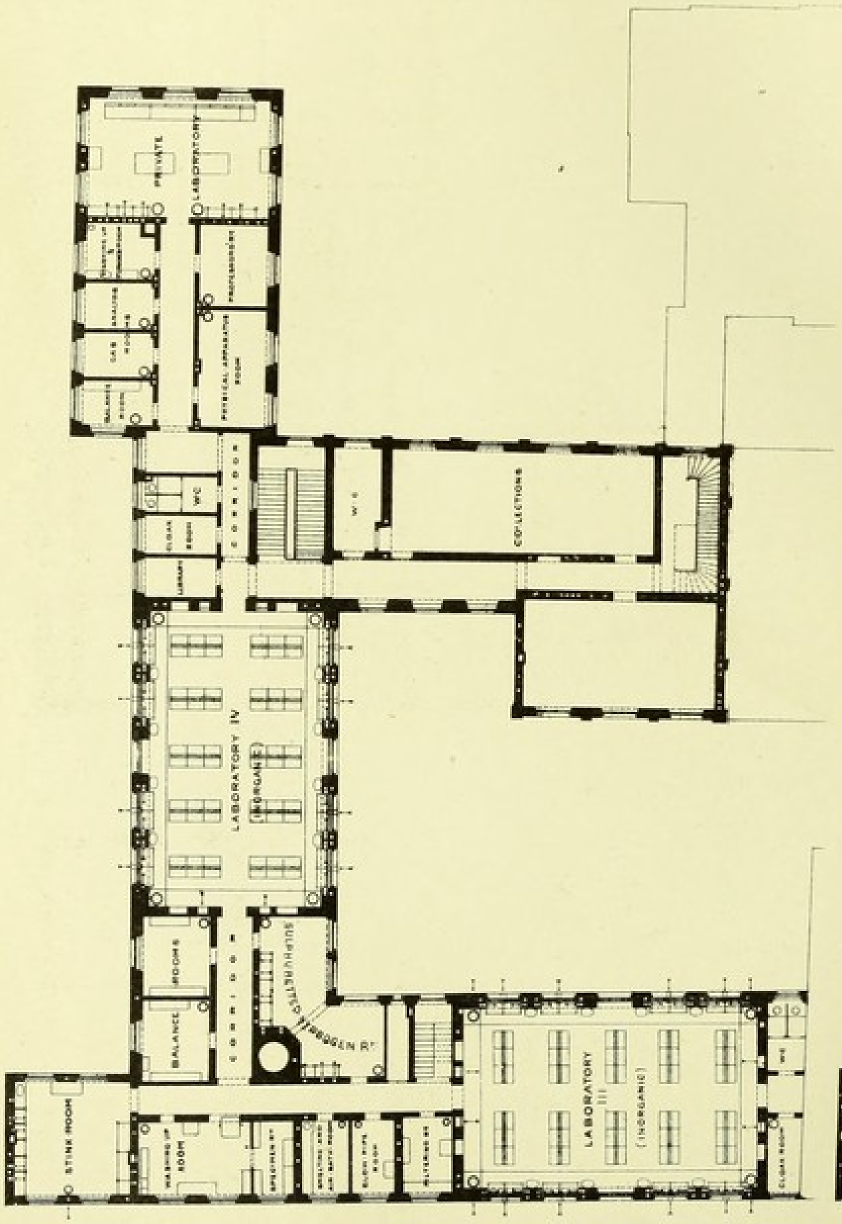


FIG. 96. FIRST FLOOR PLAN.

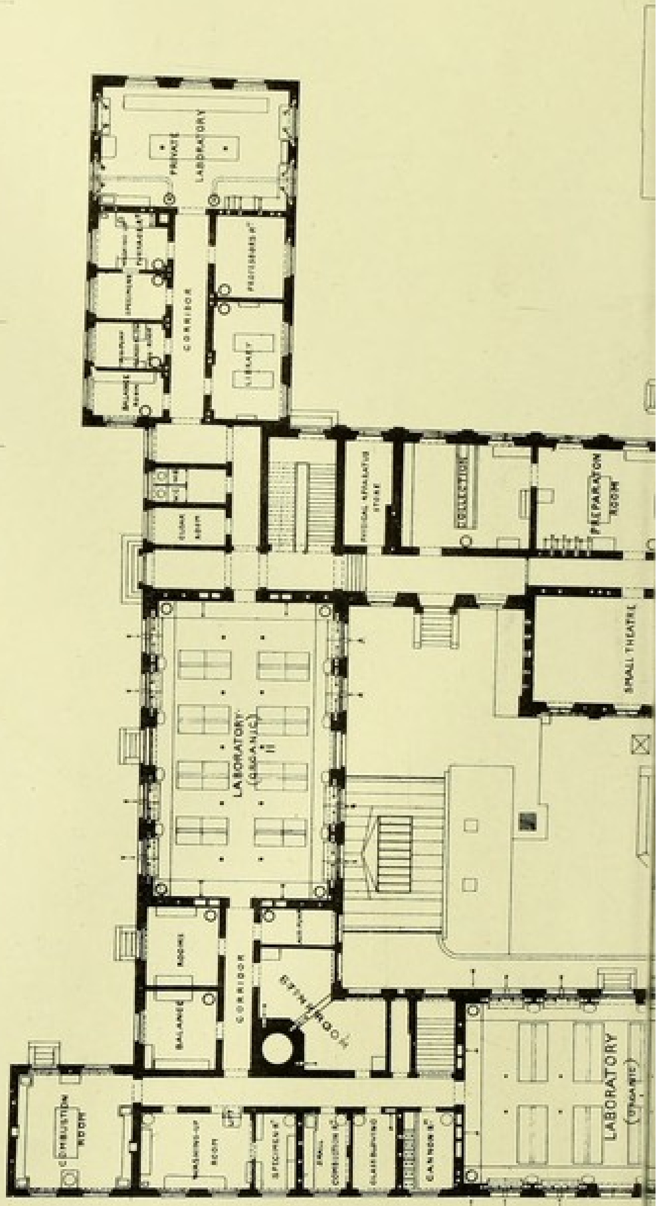


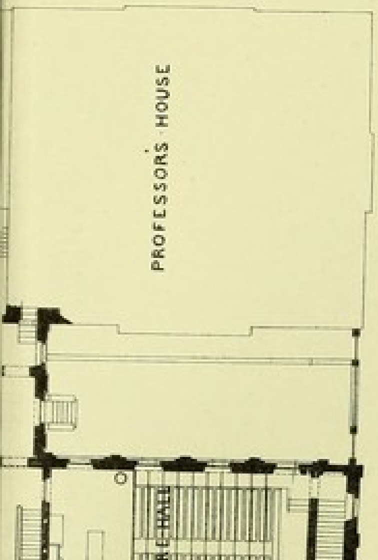
FIG. 97. GROUND

Edward C. Robins, del.

NEW CHEMICAL LABORATORIES, A

10 5 0 10 20

Scale of



FLOOR PLAN.

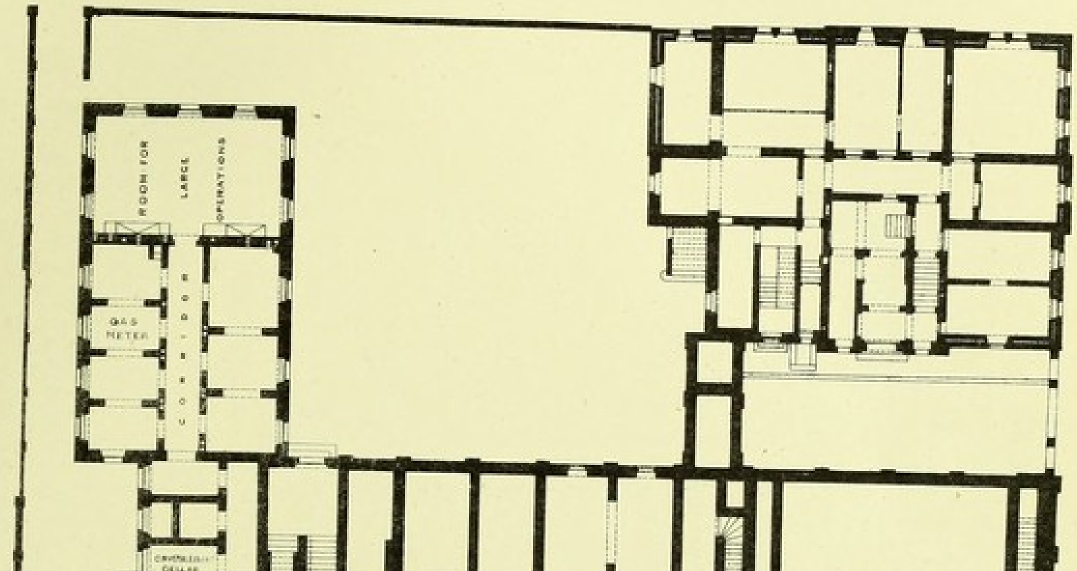


FIG. 98. BASEMENT PLAN.

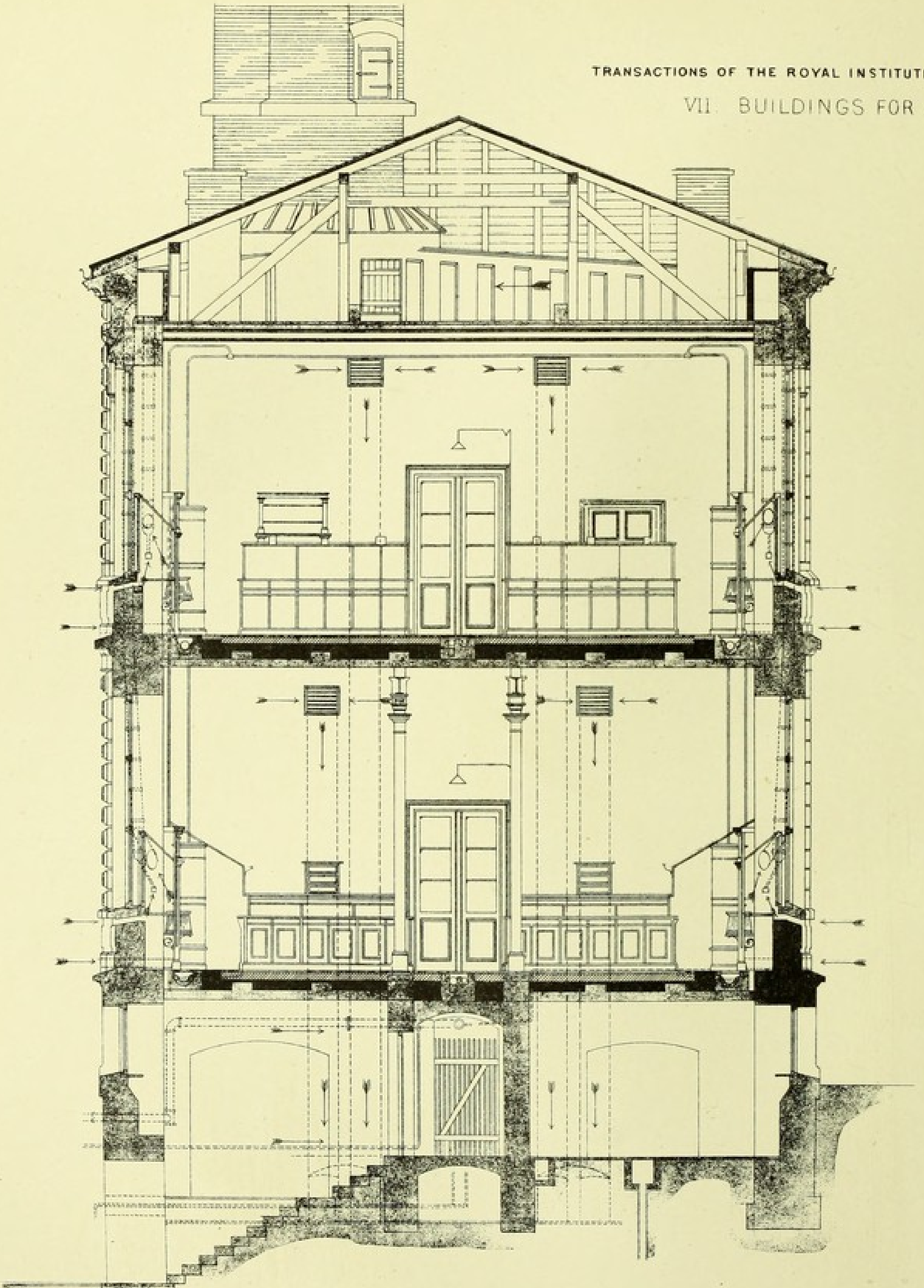
DEMY OF SCIENCES, MUNICH.

30 40 50

et

C.F. Kell, Photo-Litho. Castle S^t Holborn, London, E.C.

NEW CH
ACA



10 5 0

FIG. 99. TRANSVERSE SECTION THROUGH LARGE LABORATORIES.

Edward C Robins del.

MICAL LABORATORIES,
MY OF SCIENCES,
MUNICH.

0 20 30 40 50
Scale of Feet.

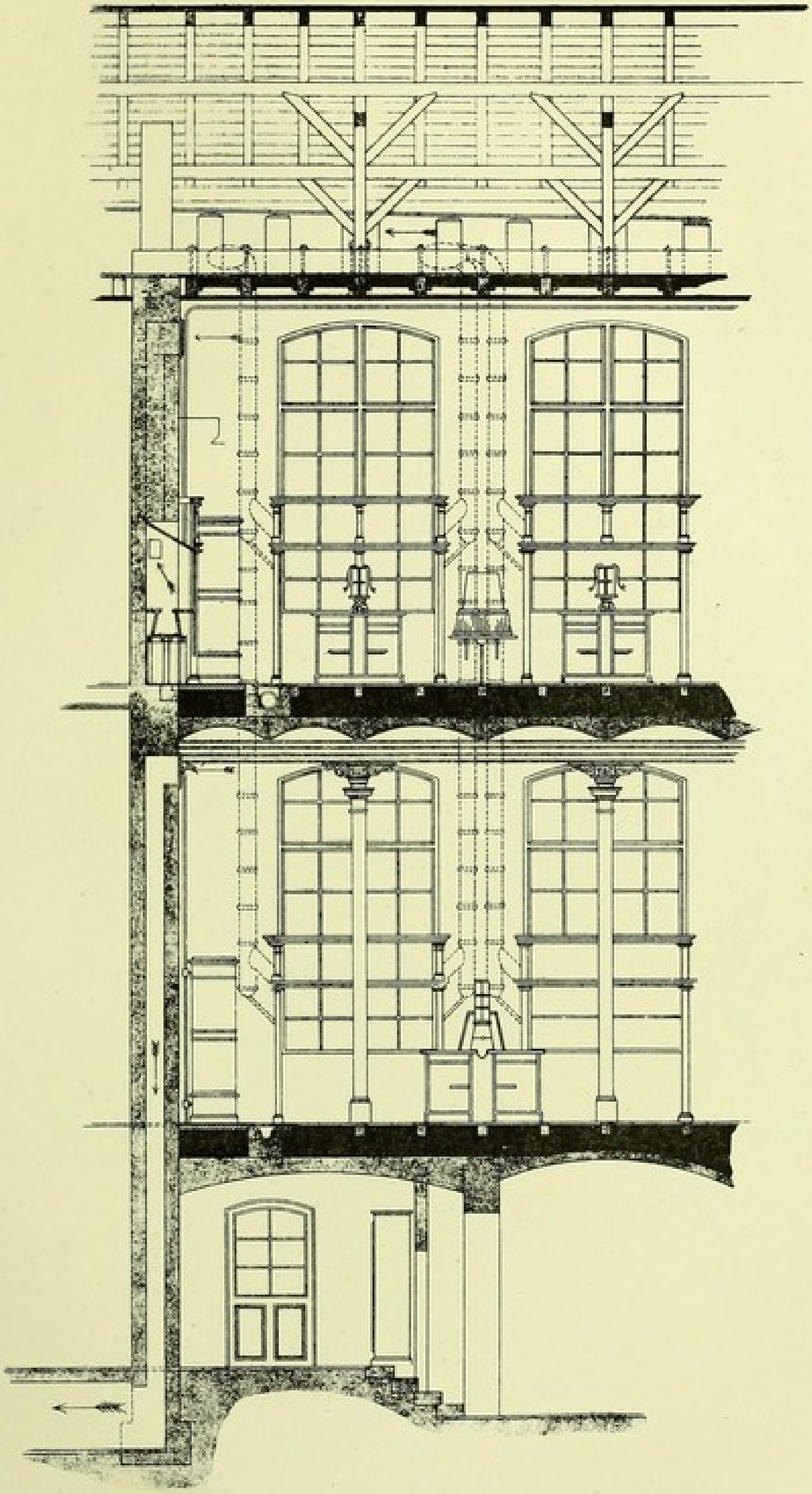


FIG. 100. PART LONGITUDINAL SECTION THROUGH LARGE LABORATORIES.

C.F. Kell, Photo-Litho. Castle S^t Holborn, London, E.C.

VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (XXXVIII)

THE PHYSIOLOGICA[L]
BERLI[N]

26-30. Chemical research rooms.
31. Spectrum analysis room.
32. Sulphuretted Hydrogen room.
33. State Testing room.
34-35. Assistants' apartments.
36. Incubating ovens.
37. Injecting room.
38. Balance and pump room.
39. Gas analysis room.
42. Microscopic Gallery.

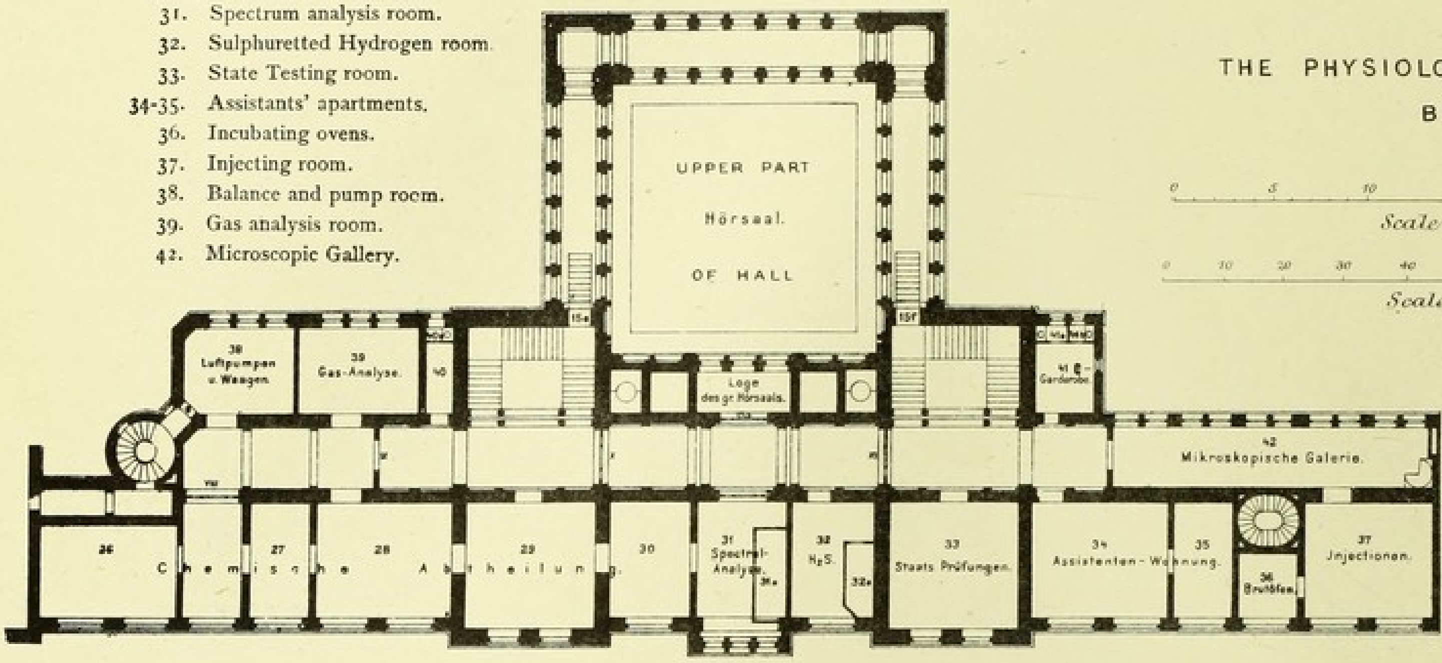


FIG. 103. FIRST FLOOR PLAN.

59. Combustible materials.
60-62. Chemical research rooms.
64. Gas and water metres.
65-70. Porter's apartments.
71. Aquarium reservoir, &c.
72-73. Private dog-kennels and frog store
74. Heating chamber.
76. Rabbit hutches.
79. Engineer's apartments.
80. Combustible materials.
83. Ice cellar.
84. Mortuary.
85-86. Battery room.
87-90. Dog kennels.
91. Frog store.

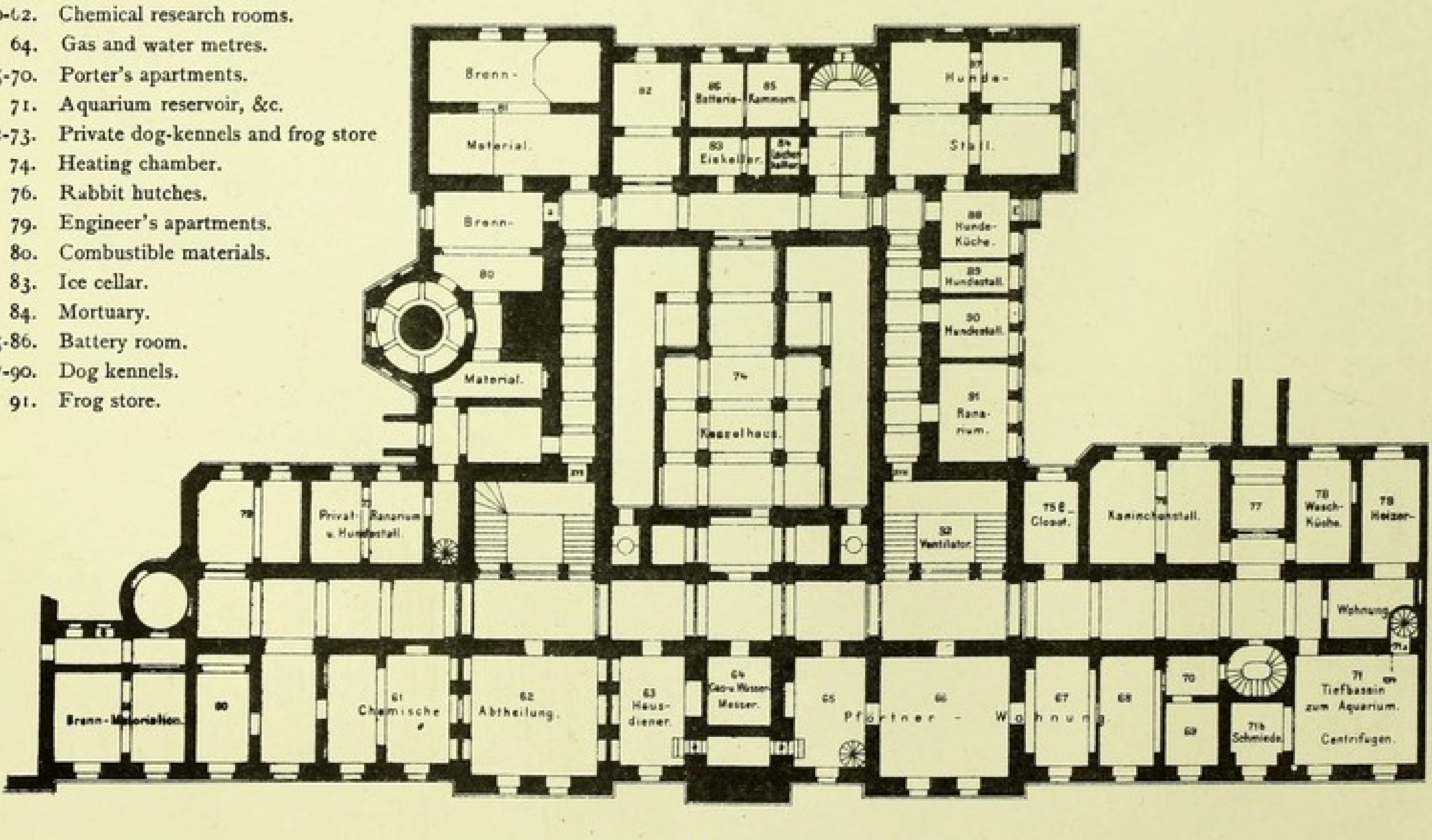


FIG. 101. BASEMENT PLAN.

INSTITUTE.

43-44. Light and dark optical rooms.
45. Photography.
48-50. Servants' apartments.
51-53. Assistants' apartments.
54. Machinists' apartments.
55. Photographic room.
56. Upper part of Hall.
57. Staircase to attics.

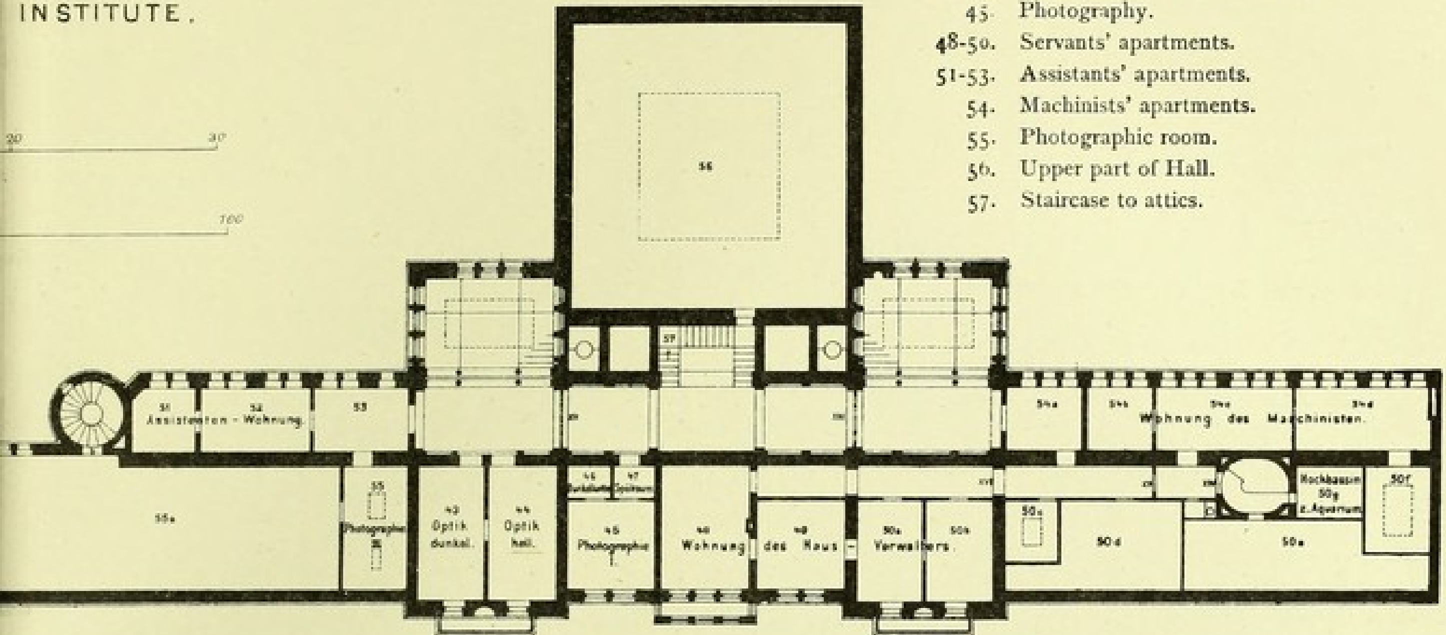


FIG. 104. SECOND FLOOR PLAN.

. Assistants' apartments.
. Collection of instruments.
. Mechanical workshop.
. Library.
. Assistants' apartments.
. Ante-room.
. Private Chemical laboratory.
. Ante-room.
. Small Lecture room.
. Aquarium.

15. Large Lecture Hall.
16. Battery room.
17. Private Physical laboratory.
18-20. Physical Physiology laboratory.
21. Diagrams.
22. Preparation room.
23. Professors' room.
24. Vivisection room.
25. Microscopic Gallery and anatomical collec

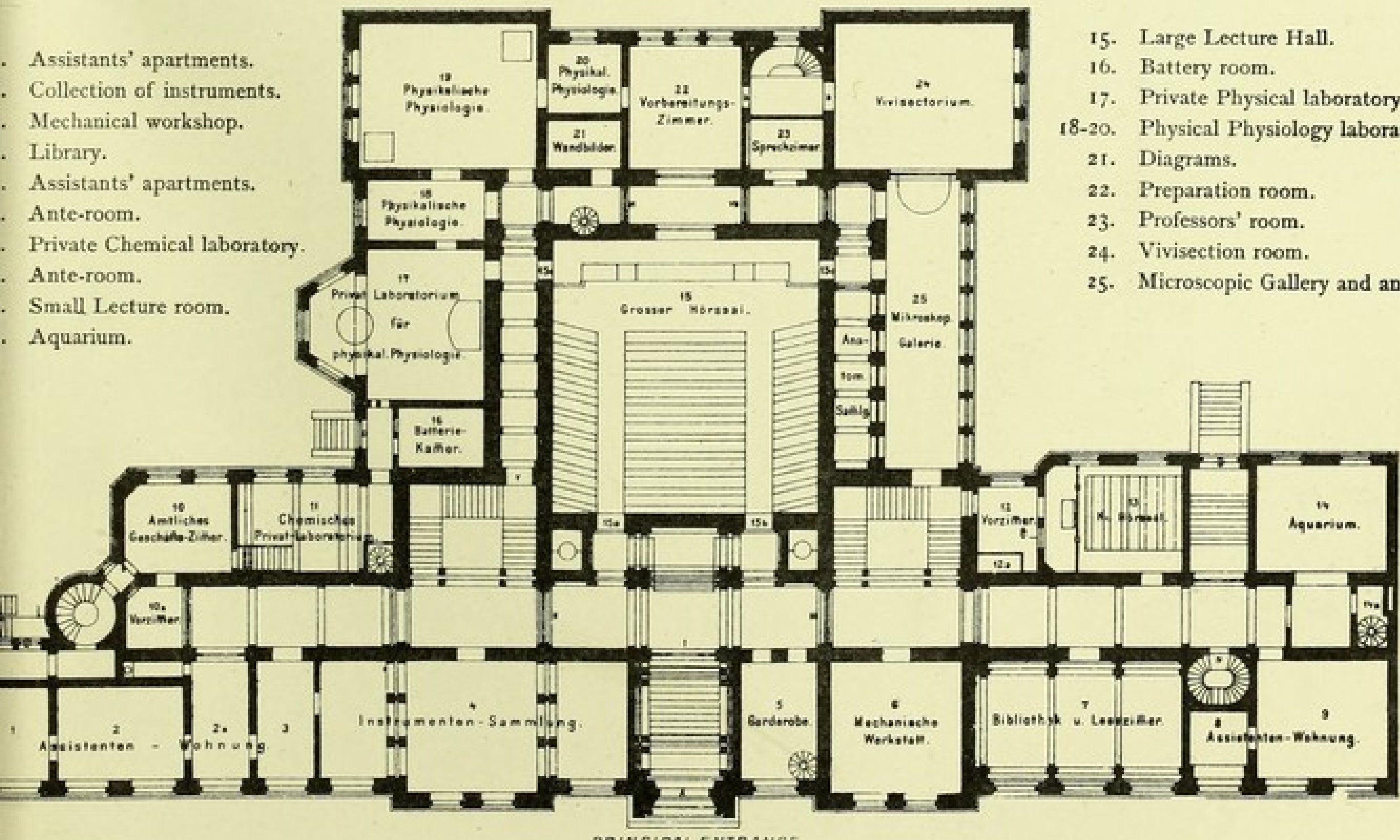


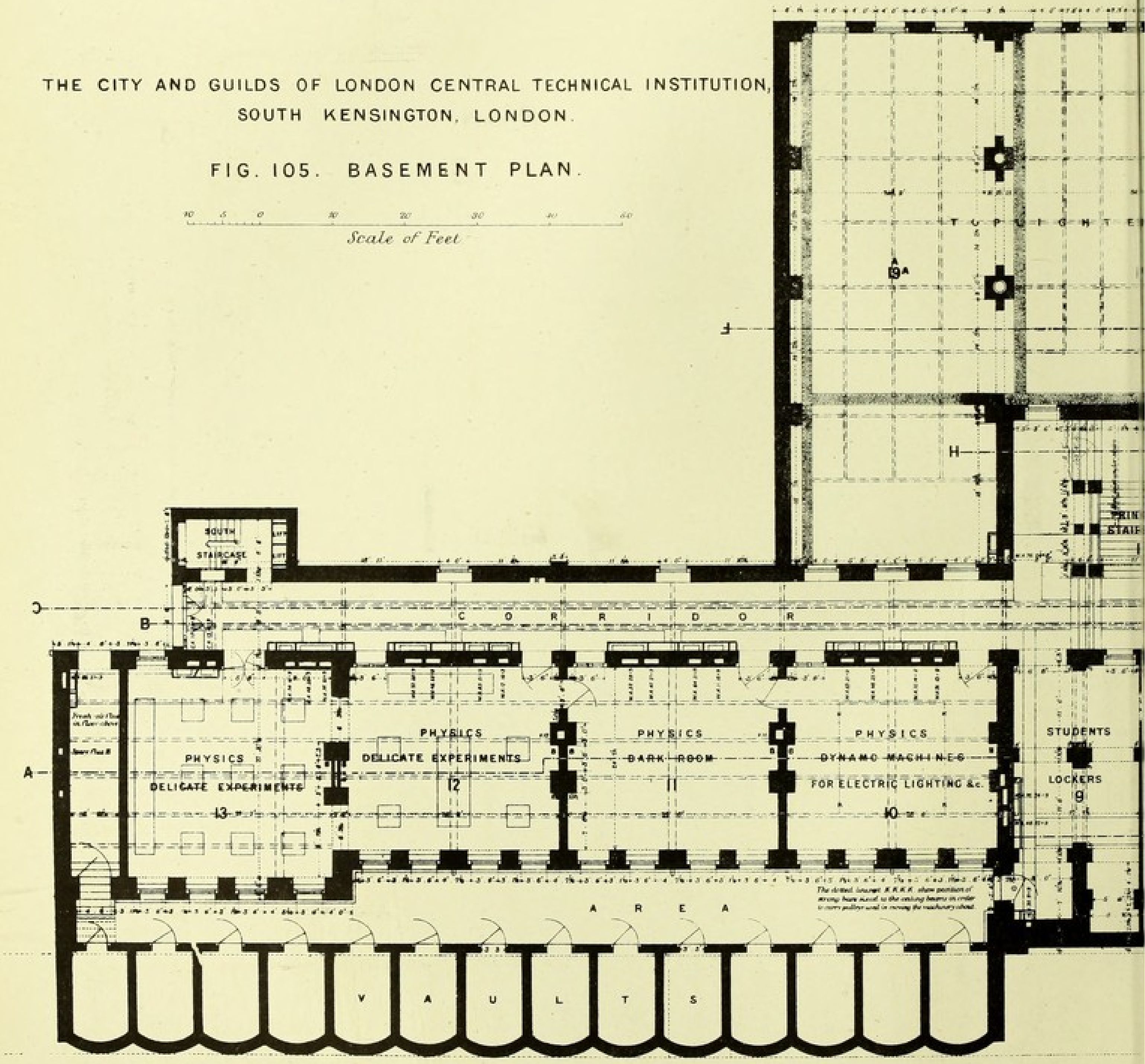
FIG. 102. GROUND FLOOR PLAN.

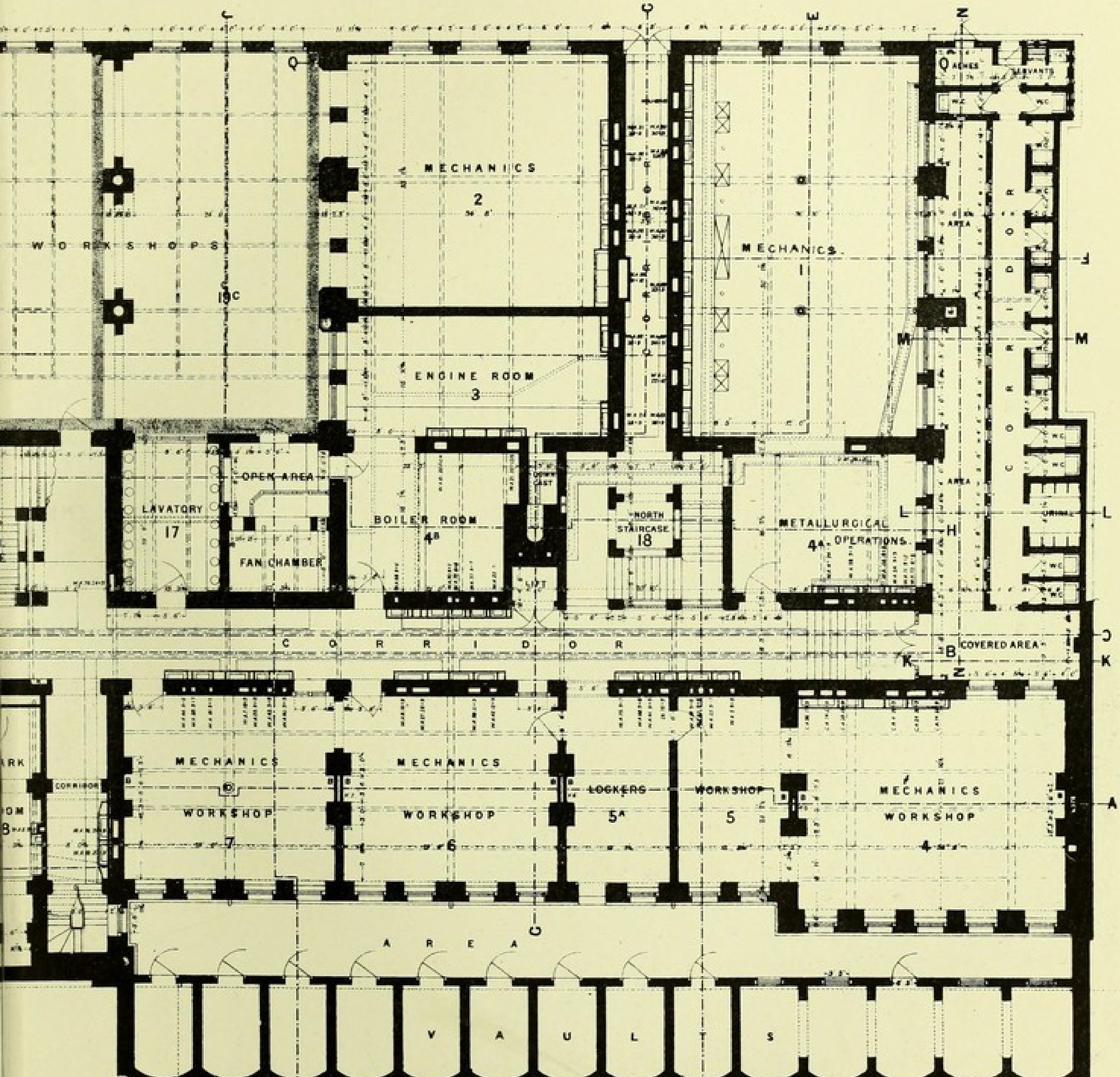
C.F.Kell, Photo-Litho. Castle St. Holborn, London, E.C.

VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (XXXIX).

THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON, LONDON.

FIG. 105. BASEMENT PLAN.

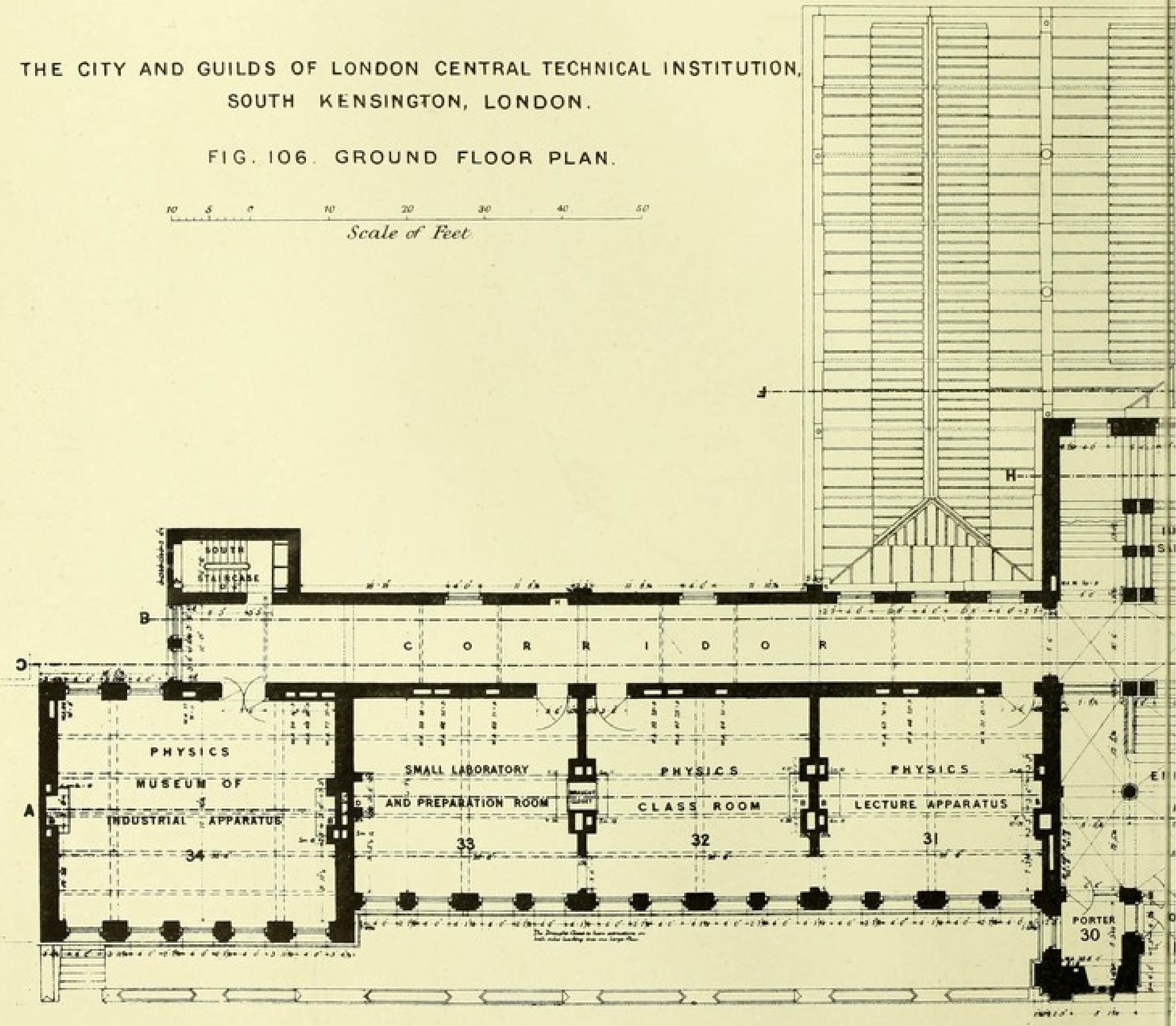


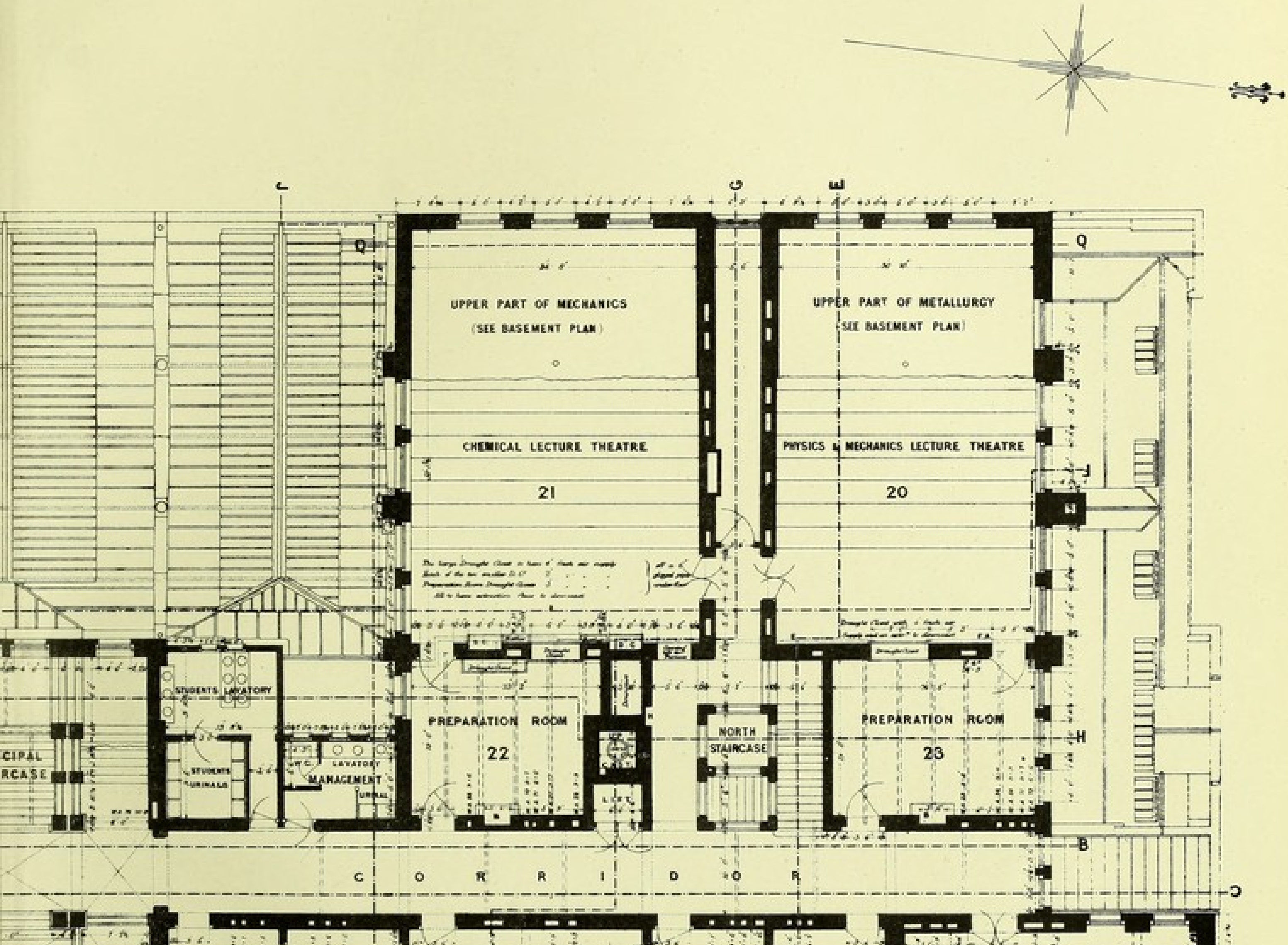


C F Kell, Photo-Litho. Castle St Holborn, London, E.C.

THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON, LONDON.

FIG. 106. GROUND FLOOR PLAN.





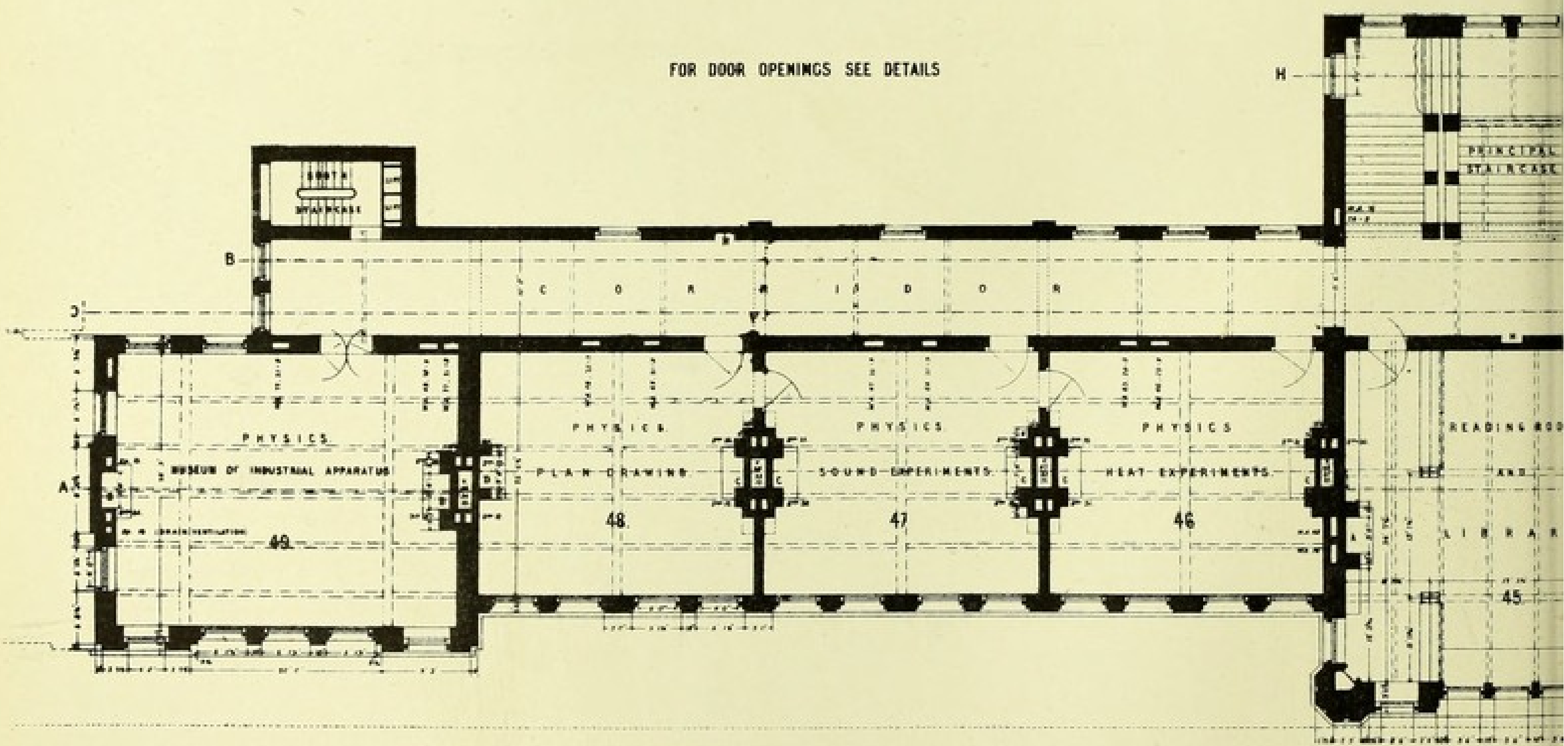
C.F.Kell Photo-Litho.Castle S^t Holborn, London, E.C.

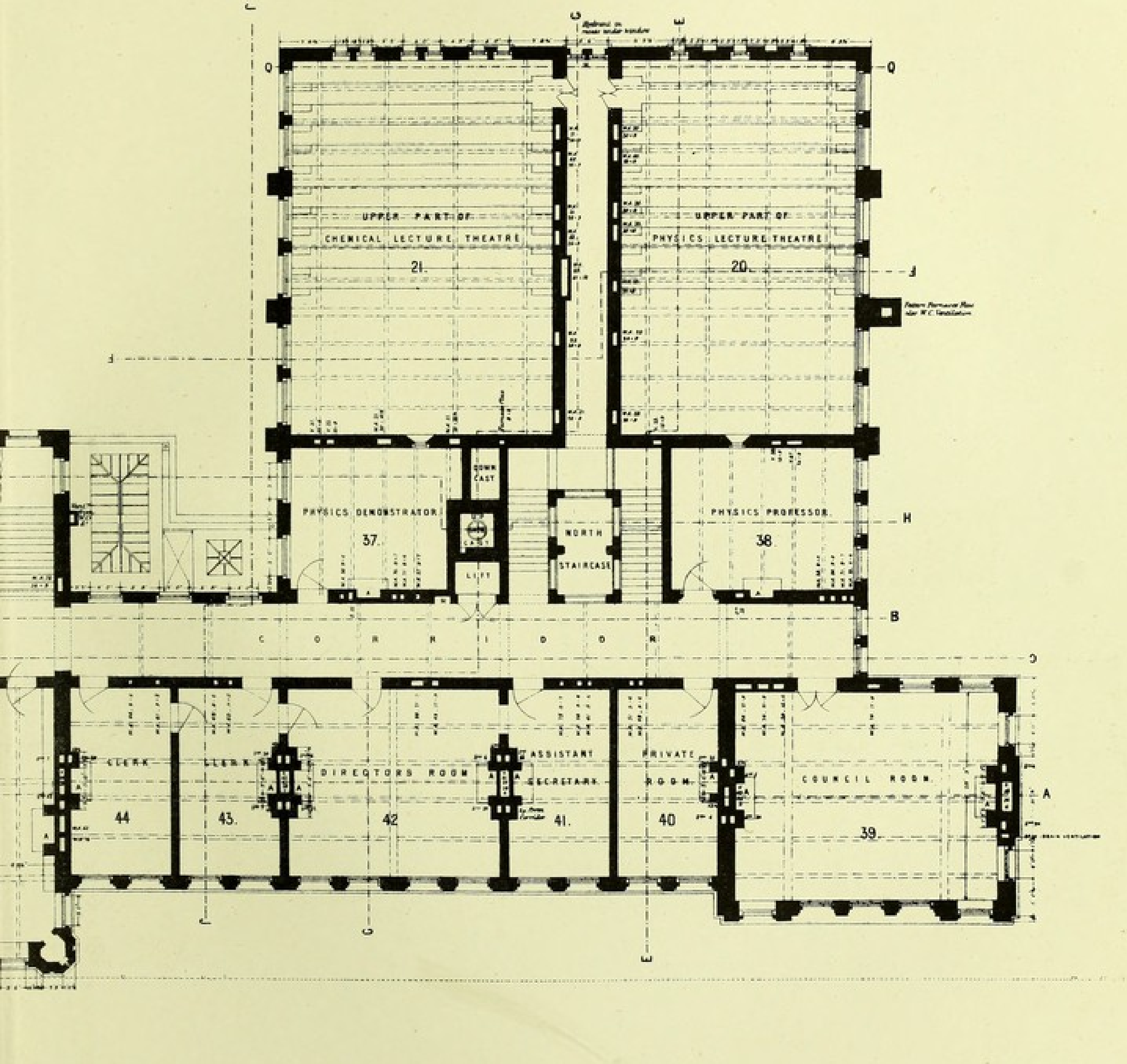
THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON, LONDON.

FIG. 107. FIRST FLOOR PLAN.

10 5 0 10 20 30 40 50

Scale of Feet

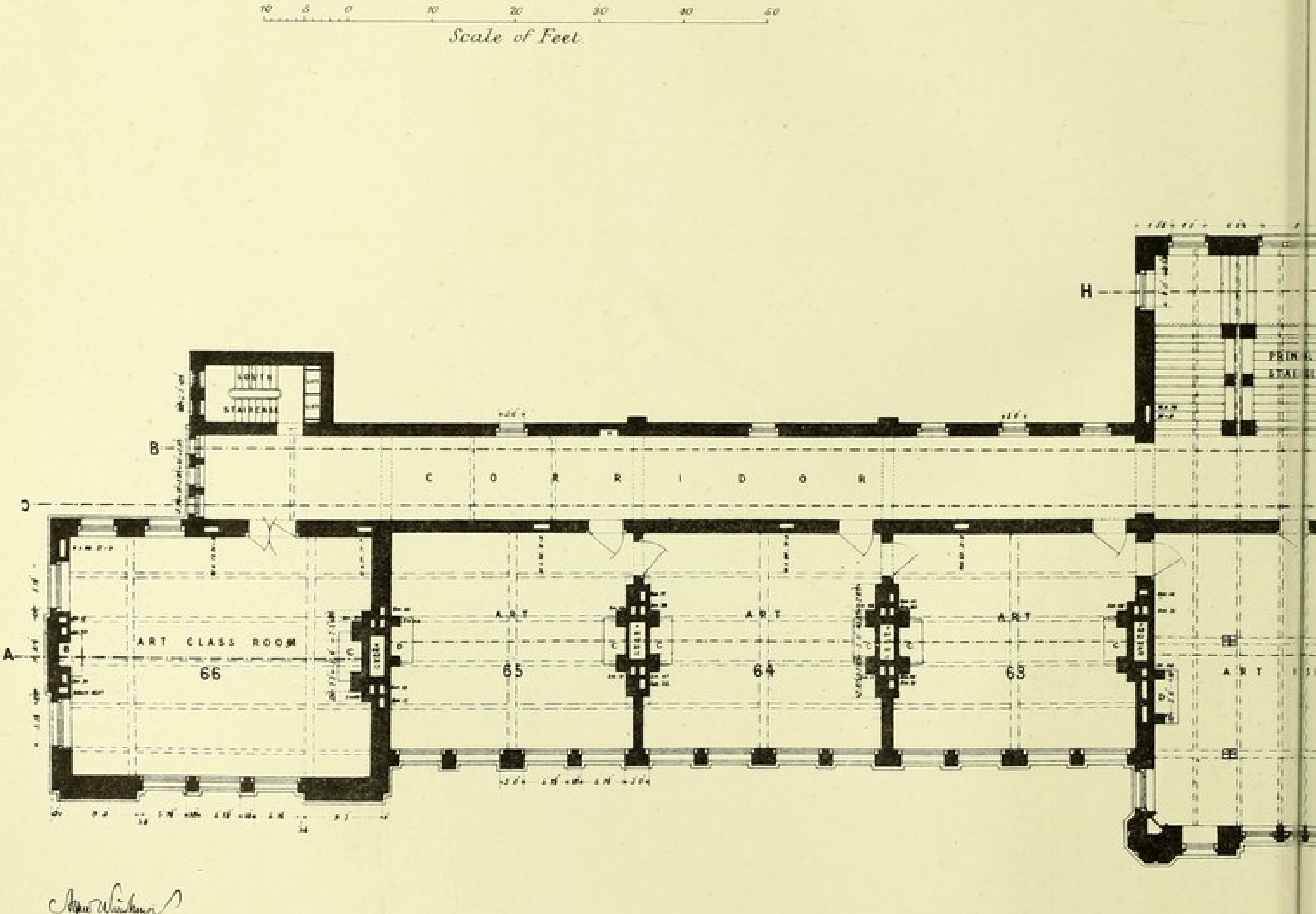


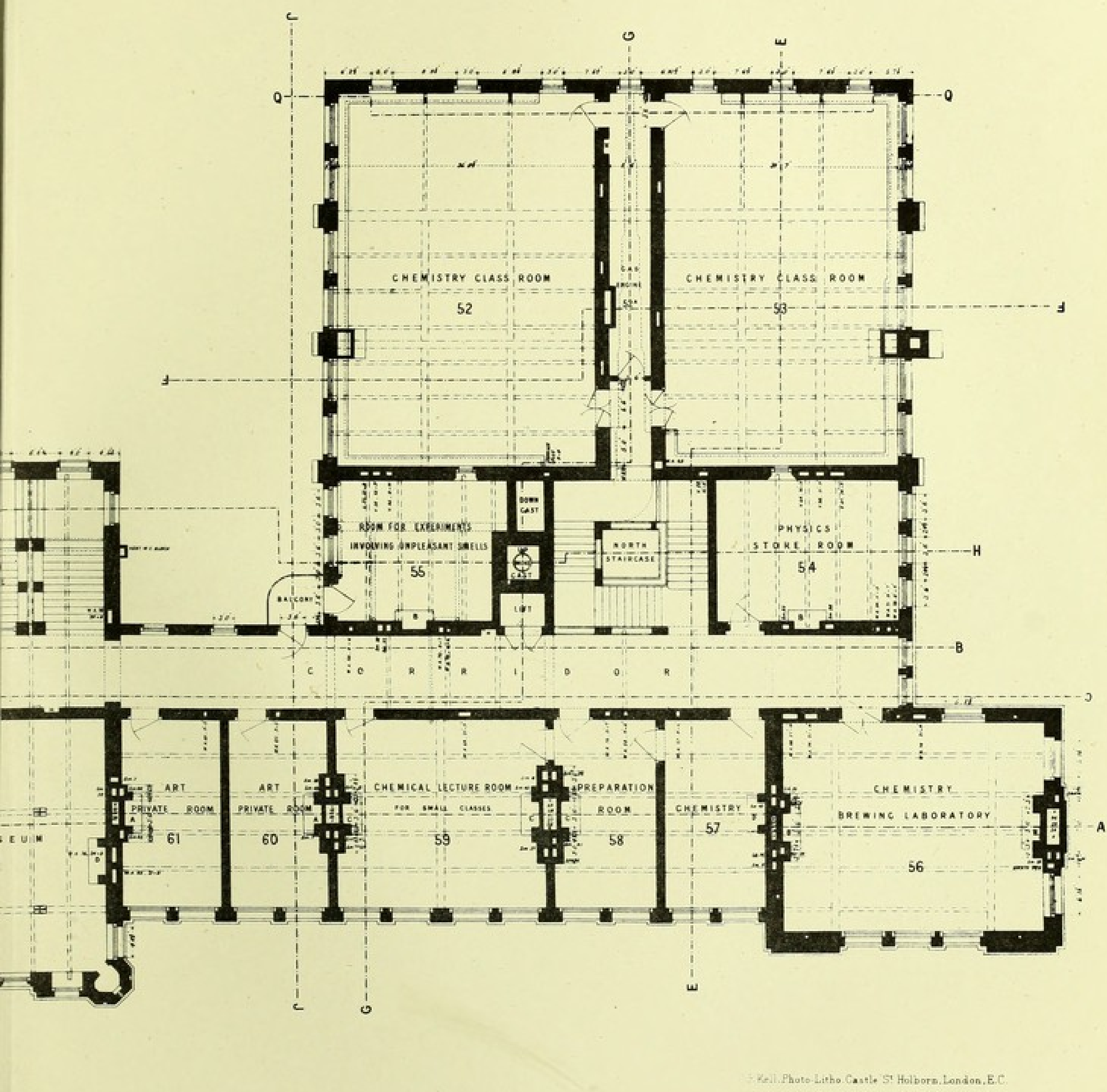


C.F. Kell, Photo-Litho. Castle St Holborn, London, E.C.

THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON, LONDON.

FIG. 108 SECOND FLOOR PLAN.





Kell. Photo-Litho. Castle St Holborn, London, E.C.

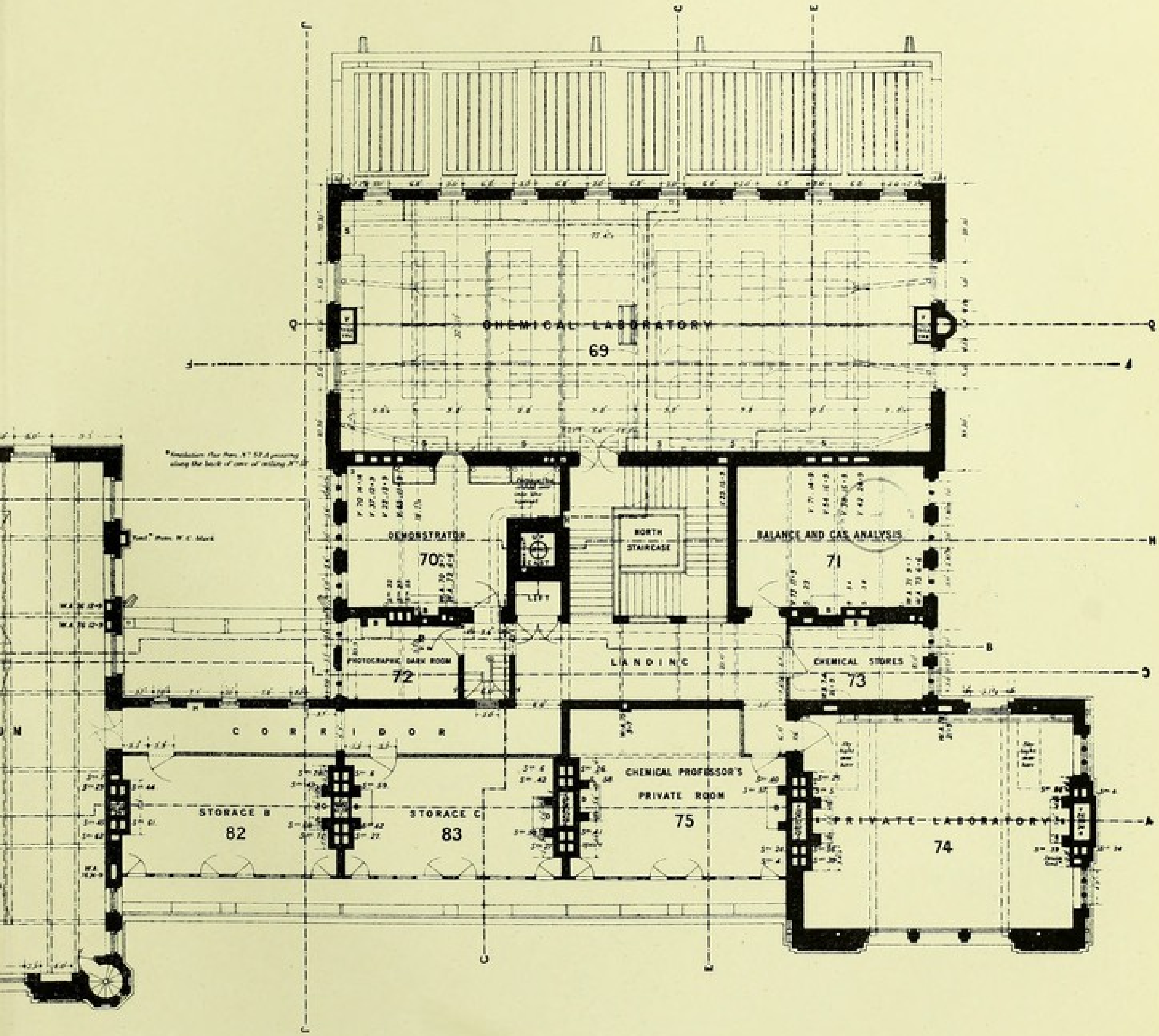
VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (xliii).

THE CITY AND GUILDS OF LONDON CENTRAL TECHNICAL INSTITUTION, SOUTH KENSINGTON, LONDON.

FIG. 109. THIRD FLOOR PLAN.

10 5 0 10 20 30 40 50

Scale of Feet.



C.F. Kell, Photo-Litho. Castle St Holborn, London, E.C.

VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (xliv)

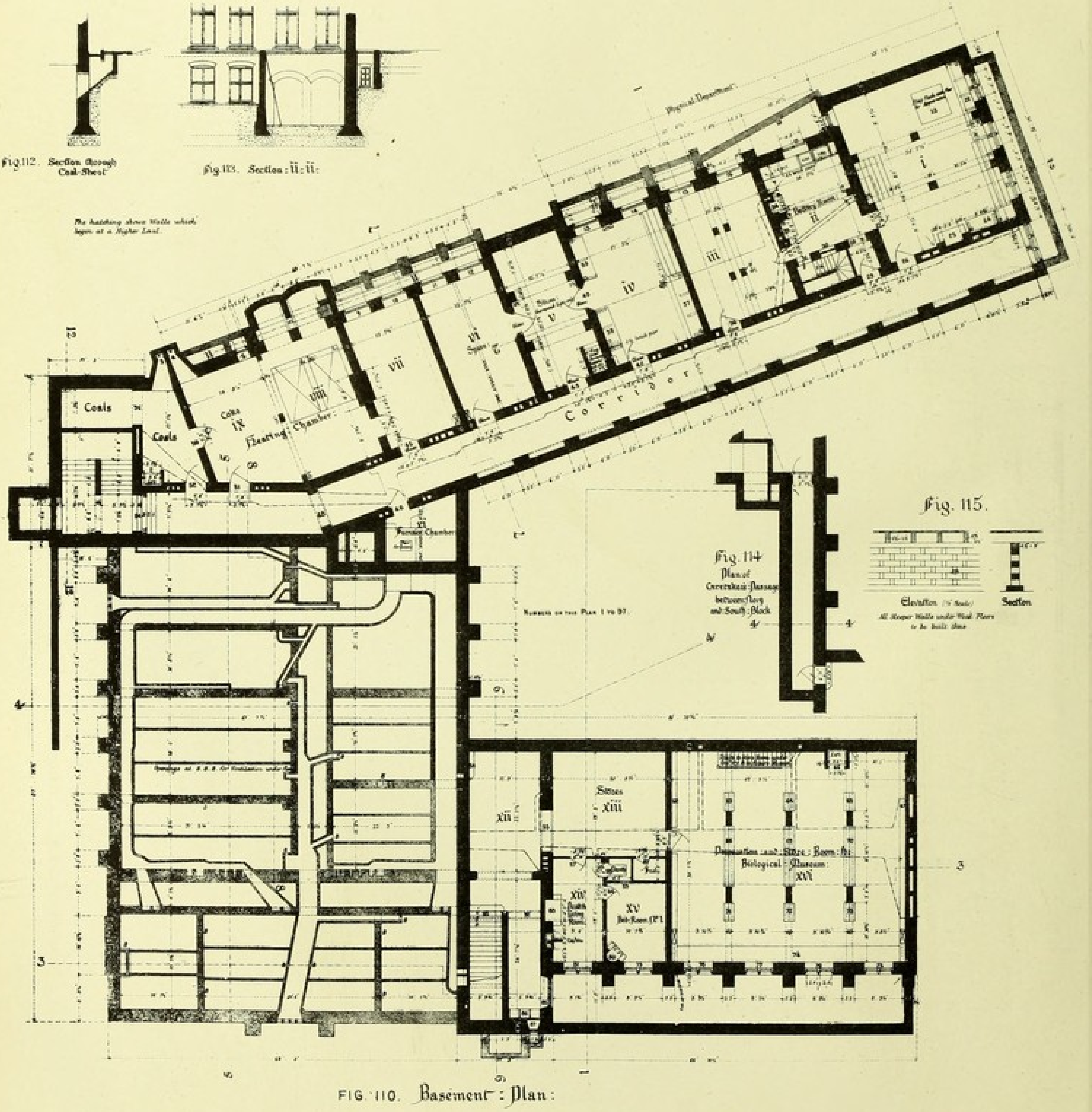


FIG. 110. Basement: Plan:

Scale: of: Feet:

The: Yorkshire: College:

Clavering: Road: Chemical: Laboratory: and: Baines: Memorial: Blocks:

Leeds:

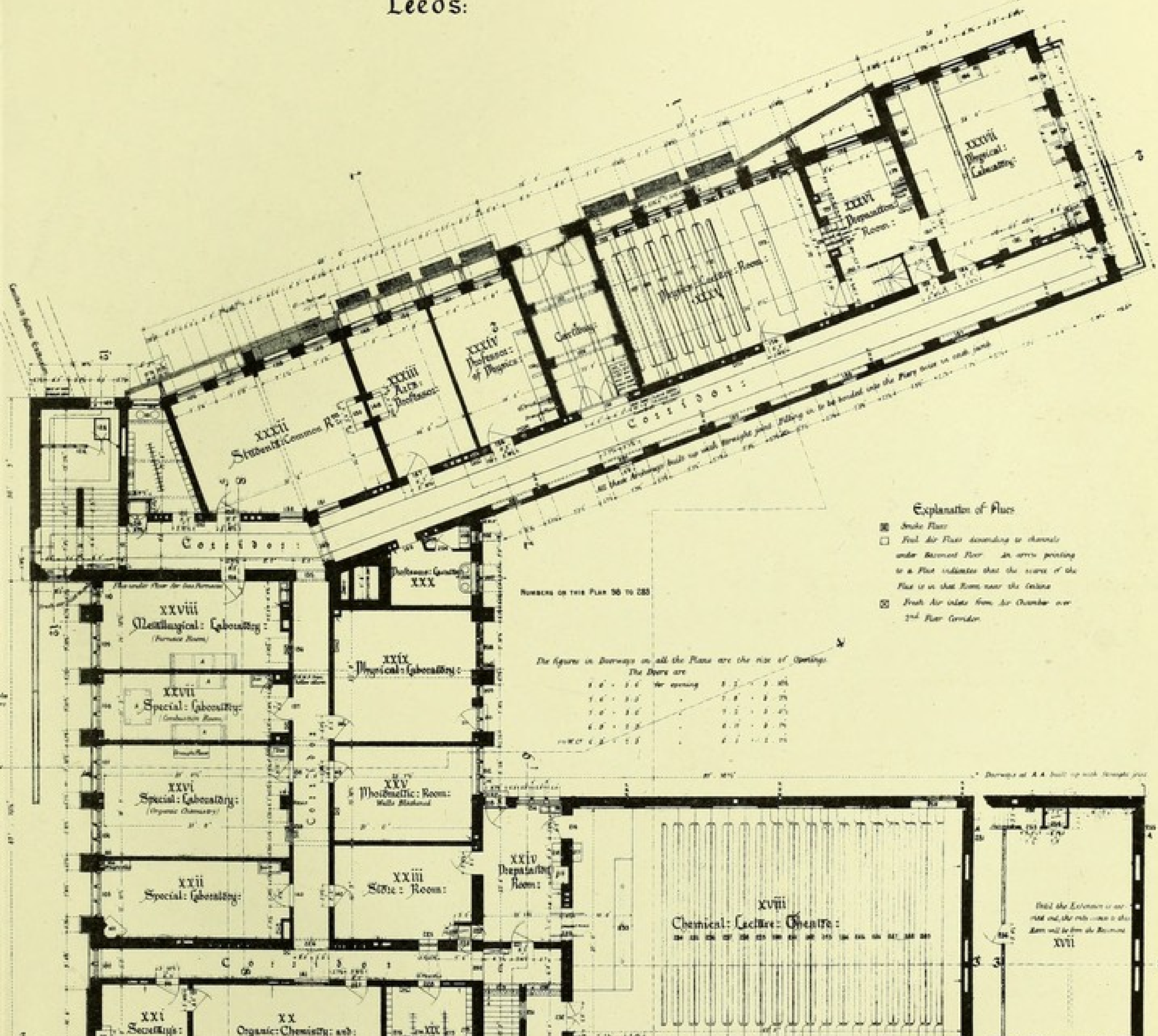


FIG. III. Ground: Floor: Plan:

Scale: of: Feet:

C.F. Kell, Photo-Litho. Castle St. Holborn, London, E.C.

VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (xlv)

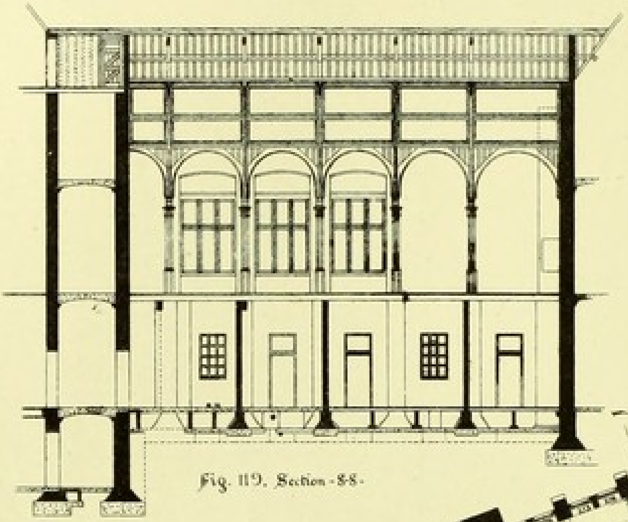


Fig. 119. Section - 8-8 -

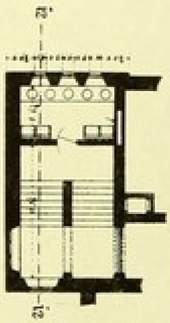


Fig. 118. Plan of the Lavatory: Mezzanine.

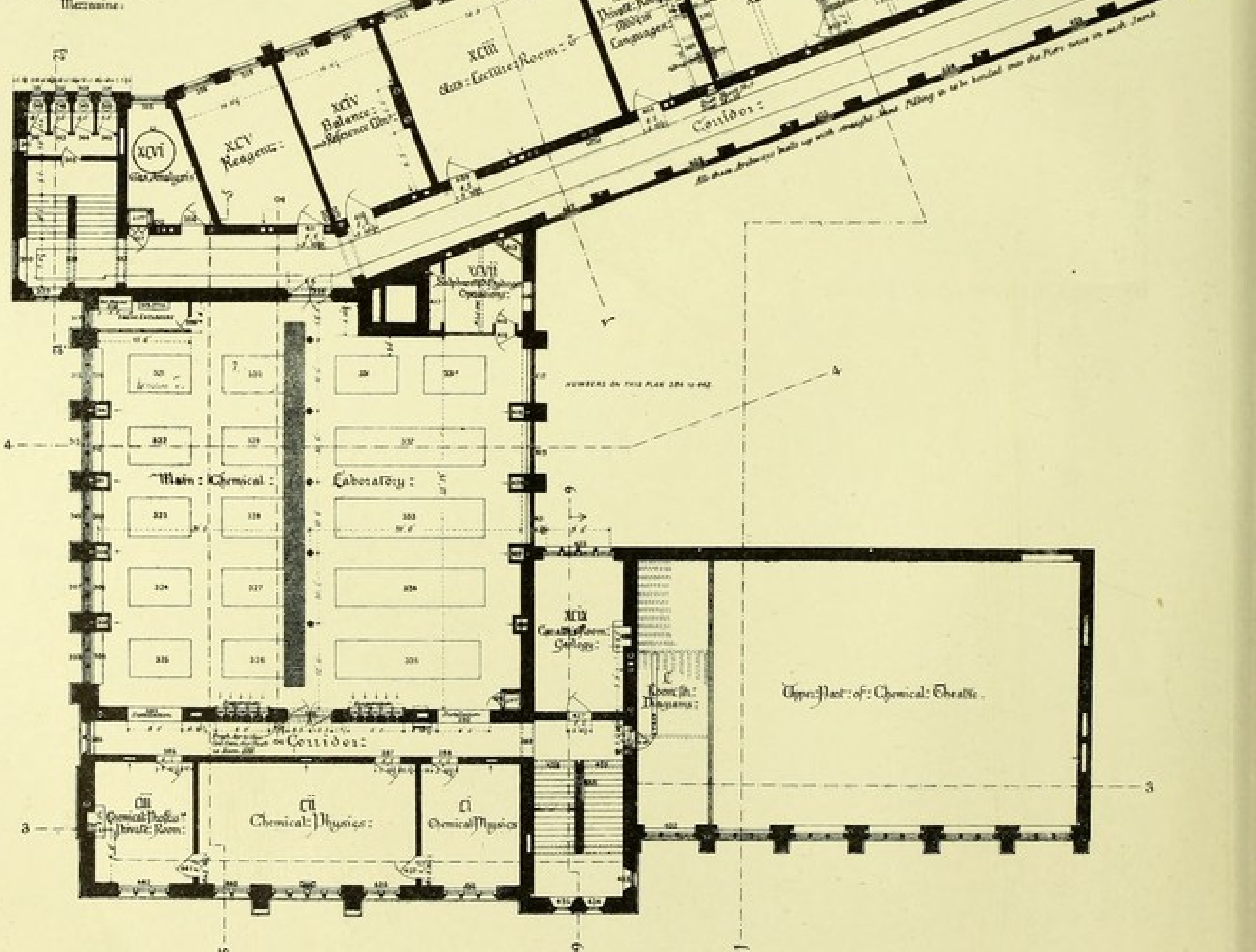


Fig. 116 First: Floor: Plan:

The: Yorkshire: College:

Clavering: Road: Chemical: Laboratory: and: Baines: Memorial: Blocks:

Leeds:

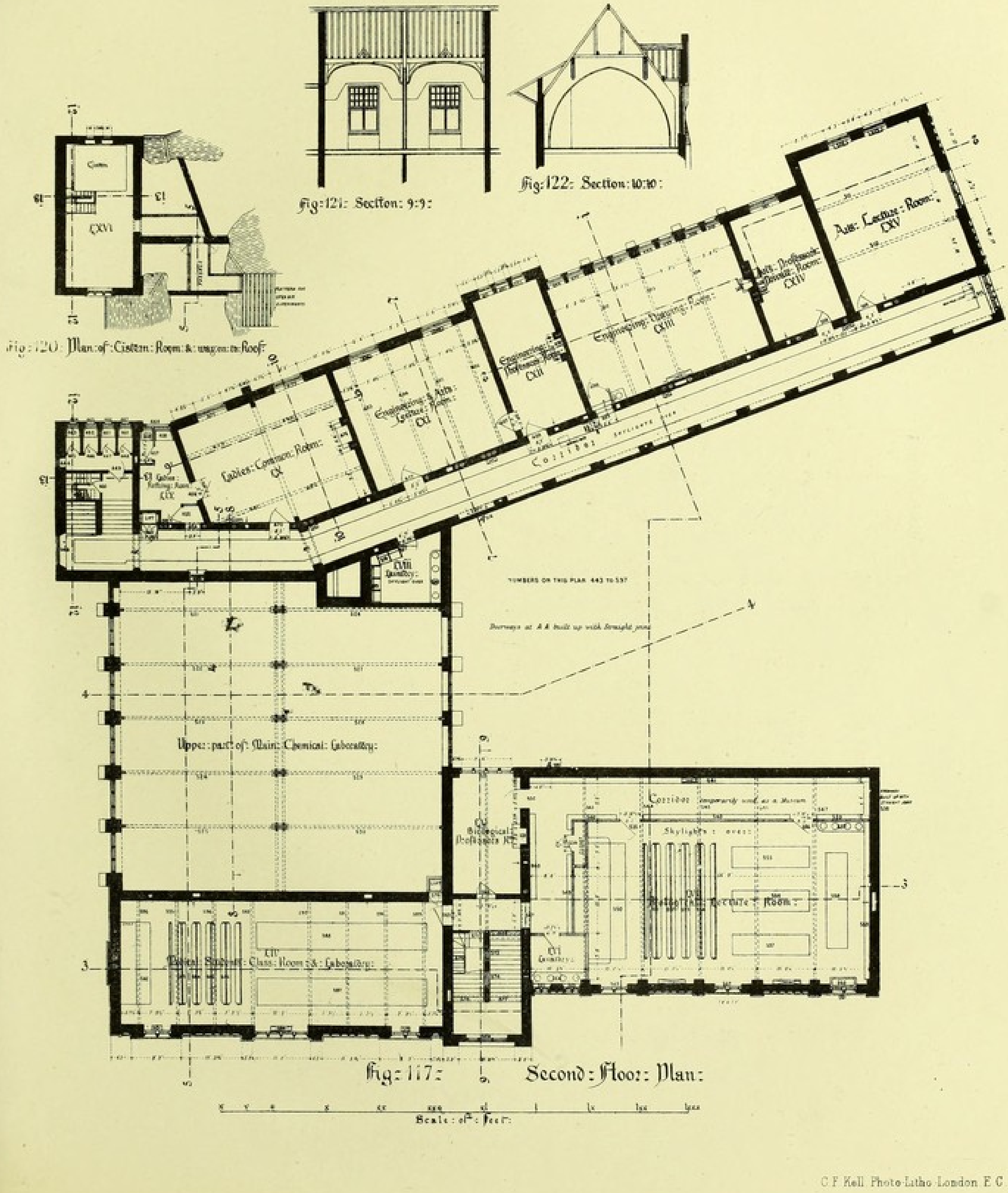


Fig: 120: Plan: of: Cistern: Room: & wagon: on: Roof:

Fig: 121: Section: 9: 9:

Fig: 122: Section: 10: 10:

Fig: 117: Second: Floor: Plan:

C.F. Kell. Photo-Litho. London. E.C.

VII. BUILDINGS FOR APPLIED SCIENCE AND ART INSTRUCTION (xlvi)

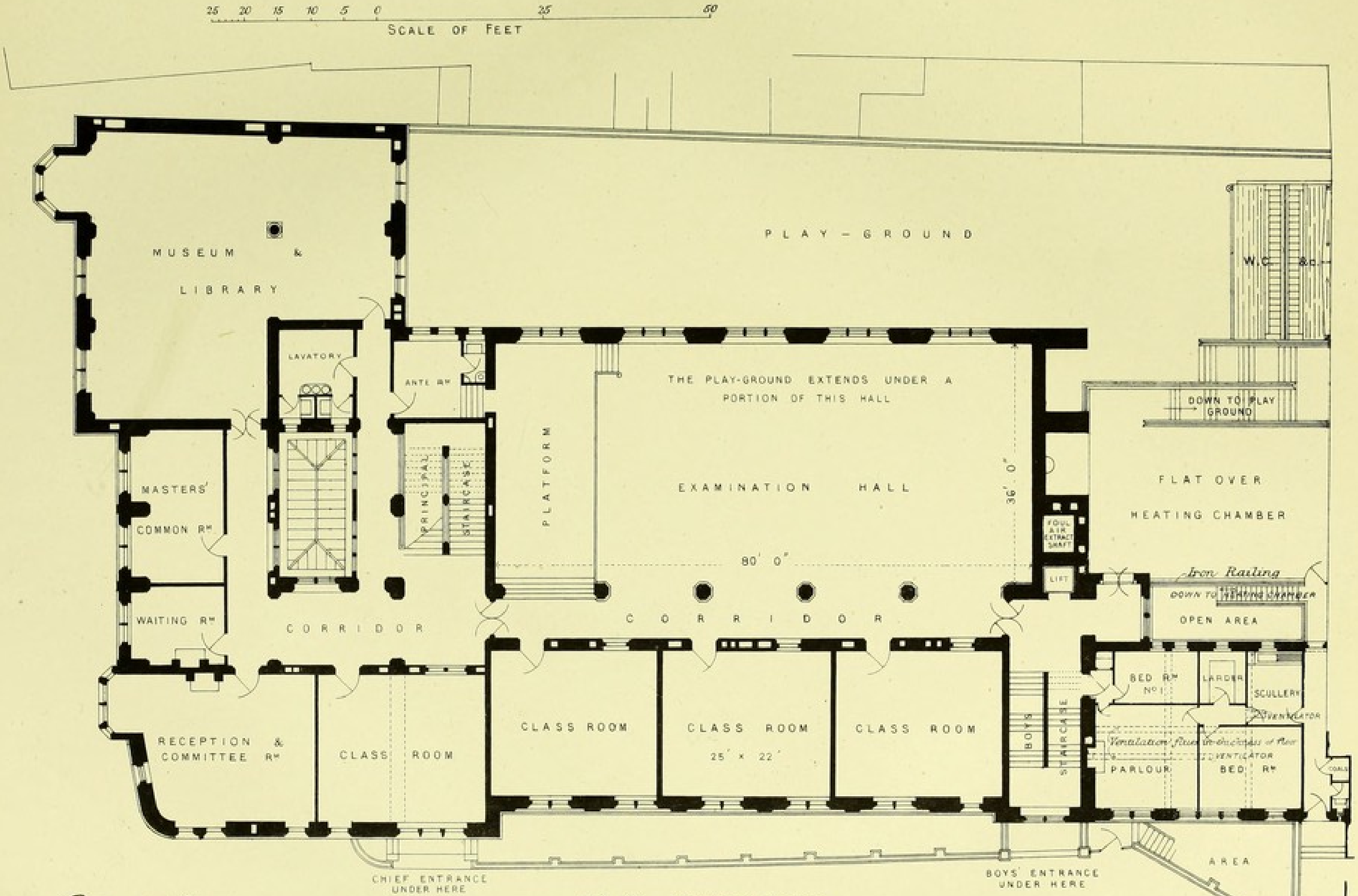


FIG. 123. GROUND PLAN.

MERCHANT VENTURERS SOCIETY'S SCHOOL, BRISTOL.

Edward Hobies.

C. F. Kell Lith 8, Castle St. Holborn London. E.C.

[*Extracted from the* TRANSACTIONS, 1883-84, *of the Royal Institute of British Architects.*]

FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS.

By EDWARD COOKWORTHY ROBINS, F.S.A., *Fellow*.

THE title of my Paper sufficiently indicates its supplemental character. Last session I had the honour of introducing to the notice of the profession a series of very interesting English and foreign buildings erected for applied science and art instruction, but only incidental reference could be made in that Paper* to the fittings of the various buildings therein described. The subject of the general arrangement of rooms, and their relation to each other and the several departments, was more than sufficient to occupy your attention for one evening, and the space available in the TRANSACTIONS was obviously limited. In yielding to the request of the Council that I should complete the subject by a more particular description of the fittings required for their effective use, I am the more willing to do so because it is of the utmost importance in a truly economic aspect of the question that the architect should possess, from the very outset, a clear preconception of the structural provisions involved in the adoption of the particular system of fittings intended; and I must here premise that it is not, I venture to think, to the interest of promoters of buildings for science instruction to ignore the valuable suggestions of the men who will have to impart the instruction for which the whole expenditure is made, nor to treat as mere "whims" the practical outcome of their careful study and comparison of the best means and appliances available.

In my anniversary Address to the Sanitary Institute of Great Britain in 1882, I endeavoured to make clear that there was a work of research to be done by the teachers of pure science which architects could not be expected to include in the numberless subjects already engaging their attention and absorbing their energies, which nevertheless their constructive faculties and powers of adaptive design were best calculated to utilize for the benefit of the community when once they had grasped the scientific principle involved. Since then I have seen the Address of Professor Stuart of Cambridge, at the inaugural meeting of the Dundee University, wherein, under the head of "Modern demand for Technical Instruction," he says:—"But now we have come to a time when there is again a great change in human "knowledge. The material part of human life calls for its scientific treatment, and is capable "of it.† This is the age of a new University movement, which, in all directions, is manifesting

* See the TRANSACTIONS, 1882-83, pp. 81-100.

† The Universities of Germany, through the influence of Liebig, have long since taken the lead in the culture of the natural sciences. The Polytechnics supplement them, but consequent upon this breadth in University teaching referred to by Professor Stuart, and the increasing honour paid to the study of science and its applications to various industries, added to the greater prestige attaching to University degrees, the Polytechnics no longer present such exceptional advantages, and in all probability they will eventually be absorbed by the Universities to make room for a new class of technical institution of lower grade, which event it would be wise for us to anticipate.—E. C. R.

"itself either by additions to existing Universities or by the foundation of new ones. The "buildings of the past are only the quarry, and not the model for the new buildings you "are to erect."

PHYSICAL LABORATORIES.

The great desideratum of a physical laboratory is a steady working table,* and this is difficult to secure. Stone brackets and stone or slate tables built into the walls, with and without stone brackets underneath, are common; and solid piers, brought up from the basement to about 3 feet from the floor, are also quite usual; but Professor Ayrton incloses certain of the tables on these solid bases, distinct from the general flooring, in glass cases as working-benches, the window having rising sashes, which can be raised while working, but closed, locked and kept free from dust and meddlesome fingers at other times. He also designed for Japan a students' gallery for the lecture-room, in which solid piers from below were carried up to sustain the working-benches at the different levels of gallery staging, making it possible for the students to repeat the professor's experiments without leaving their places; thus the lecture-room became also a laboratory, and was surrounded with cases for the collections of instruments, &c. In every town, however, the solid soil trembles more or less, and the brick piers themselves, even on concrete foundations, vibrate. To overcome this many suggestions have been made: that they should be more deeply founded, and surrounded by an area with or without water filled in, so that the top surface of the ground should not be in contact, and recently, also, a professor has proposed that stout lead should be laid in the joints in place of mortar, and the piers built of stone blocks. Test experiments are being made at South Kensington in reference to this difficult matter.

CHEMICAL LABORATORIES.

In the description and critical analysis of the fittings of Chemical Laboratories, upon which a considerable amount of ingenuity has been displayed, I have been greatly assisted by my friend Professor Armstrong; if, quite unintentionally, I seem to speak dogmatically, it will be due to the results of consultation with him and many other eminent chemists, among whom I should mention Professor Roscoe, Dr. Perkin, Professors Thorpe, Ramsay, Tilden, Carnelly, Clowes, Fisher, McLeod, and Jones, as having given me valuable aid. Messrs. Waterhouse, Clifton, Murgatroyd, Cossins, Eagles, Ireland and Maclaren, and other architects, have furnished me with illustrations of their works.

i.—Working Benches and their Fittings.

(*a*) *Dimensions and distance apart.* The dimensions of the Benches in a Laboratory intended for the ordinary operations of qualitative and quantitative chemical analysis, and the distance between the benches (that is, the width of the gangways) must necessarily depend more or less on the space at disposal. In all the best laboratories they are placed at right angles to the windows in the flank walls [Illustns. i, viii, xiv, fig. 43], and invariably so in Germany.

The chief points to be borne in mind are. 1. *That the bench should be of such a depth that the student can without difficulty reach from front to back, say 2 feet 3 inches.* 2. *That the top of the bench should be at such a height above the floor level that the student standing at the bench can carry out the various ordinary operations of filtering, etc., without raising his elbow much above*

* See the illustrations to a Paper I read at the Society of Arts, in April 1880, on Secondary School Buildings.—E. C. R.

its natural position, say 3 *feet.* 3. *That the benches should be sufficiently far apart to admit of at least one person passing between the students who are working back to back at contiguous benches, say* 4 *feet* 6 *inches to* 5 *feet.*

With reference to the first and second points, it is obvious that, since there is a considerable variation in the length of reach and height of different individuals, only the average requirements in these respects can be met in the case of public laboratories; for these must necessarily accomodate a variety of students. As a rule, it is only in school laboratories that the very special requirements of a particular class of students can be consulted. In institutions where separate rooms are provided for beginners and advanced students, it has been usual to afford greater space to the latter class. As a matter of fact, however, I am informed that the beginner has often to deal with larger apparatus than the advanced student of quantitative analysis. Be this as it may, it is not improbable that in future the work of the beginner and of the advanced student will tend more and more to approximate in character, and to differ rather in the extent and thoroughness with which similar subjects are studied. The architect consequently may not be called upon to perpetuate the system which has hitherto prevailed.

(*b*) *Drawers and cupboards, &c.* The space under the working bench is always fitted with drawers and cupboards, which necessarily vary in number and size. The character of the arrangements commonly met with may be seen at Leipzig, Owen's College, Finsbury College, Dundee University and Manchester Grammar School [Illustns. ii, iii, iv, ix, xv, xvii]. Usually at least two cupboards and two drawers are fitted in the space allotted to each student's use, or a drawer and cupboard may be assigned to each of two students attending at different times. Except in the case of students engaged in research, no other provision is required. A long narrow drawer extending across the entire double bench as at Leipzig and Manchester and the Yorkshire College is of the greatest use to advanced students for storing long tubes, &c. The cupboards are generally fitted with one or at most two shelves, but it is desirable that one or both of them should not extend the whole distance from back to front, in order that tall articles may be put away. Open niches take the place of cupboards in some cases. To minimize the number of locks and keys several devices have been introduced. At Leipzig the two cupboards and two drawers are kept closed by means of a T-shaped piece of brass and a single lock. At the Firth and Finsbury Colleges, the drawer has no lock, but is kept closed, by an oaken spring beneath it, so that only the cupboard doors have to be unlocked and the spring pushed up, which the student does in commencing work. The bottom of the cupboards should be raised a few inches, and space for the fore-part of the foot be thus provided as at the Manchester Grammar School. In some cases the cupboard fronts are themselves set back 4 or 5 inches from the front edge of the bench top.

(*c*) *Materials employed.* Either deal or pitch pine according to the funds at disposal is almost invariably employed for all but the bench top. At the Nottingham University College, American walnut has been largely used.

Considerable diversity is met with in the treatment of the bench top. It need scarcely be stated that the materials employed should be as durable and impervious as possible, having little tendency to absorb liquids, to be stained, or to shrink and crack under the influence of heat radiating from the burners employed in heating flasks, &c. Pine, deal, beech, oak, mahogany, teak, nut and American walnut have been used. The last only at Nottingham, and nut only at Geneva. Deal is commonly used from economical motives, but it is probable that the economy is more apparent than real. Most tops are oiled only, as required; all woods for bench tops are improved by ironing-in ordinary solid paraffin with a box-iron, or better still a gas iron. Paraffin has the great advantage over oil or wax that it resists the action both of acids and alkalies. Oil and wax are readily affected by alkalies and slowly even by acids. The only objection to paraffin is that it melts under a heated sand bath or when a hot flask is placed on the bench, but a small square of Asbestos cardboard, and a few small squares of carpet or felt supplied to the student meets this difficulty. Of the hard woods above mentioned, teak appears to be the best. Professor Roscoe of Owen's College (where the bench tops are of oak) says that he would prefer teak. The bench tops at the Finsbury College are covered with 7 lbs. lead. Lead is used at Bristol University College; and it is also employed, and highly approved of, in all the numerous laboratories of the Badische Anilin and Soda Fabrik, where some thirty chemists are actively engaged in research and in technical analysis. It is said that lead "blows up" underneath heated objects, and that glass apparatus, &c., in use in chemical laboratories is more easily broken when set down upon it. The former difficulty is easily overcome by the use of Asbestos cardboard, and the latter Dr. Armstrong assures me is entirely imaginary. The best mode of fixing the lead in front is to bend it down over the perfectly square edge of the table top and, after lightly copper nailing it, to fix a rounded fillet of hard wood to the edge of the bench top, bedded in red and white-lead putty, before screwing up. In private laboratories, glass and slate have been used, but these are not suited to average requirements. The edge of the bench top should overhang one or two inches.

(*d*) *Sinks.* It is customary to provide sinks, about 9 inches diameter, in the benches for beginners, as has been the case at Owen's College, the Manchester Grammar School [Illustns. iii, iv] and the Yorkshire College, and they are usually placed so as to be accessible to students on both sides of a double bench, and serviceable to four students. These sinks are in some cases circular, in others oval or oblong. For advanced students the sinks as a rule are placed at the ends of the benches, as at Owen's College. At the Finsbury College there are sinks at each end of the senior students' benches, but no sinks are attached to the benches which are chiefly intended for the use of "occasional students," but a long demonstration table on a raised platform runs at right angles to these benches, and in front of this is a lead-lined sink, 16 feet long by 12 inches wide, and 12 inches deep, with a reservoir under the top of the demonstration table [Illustn. x]; this upper tank is kept filled by the ball tap, and thus the water is delivered from the taps at a constant low pressure, and splashing avoided. In this case the students must leave their places whenever they wish to wash their apparatus, but the distance is short and there is ample accommodation for eight students at the sink. If the sink be on the bench it is difficult to avoid splashing.

Sinks are constructed of various materials—of porcelain, stoneware, enamelled iron, wood, and lead. Stoneware and porcelain are most commonly employed; they are easily kept clean, and if properly glazed will resist chemical action, but they are easily broken both by falling objects and very hot liquids. The best illustration of the use of wood is at Munich, where oval-shaped iron bound oaken tubs are found, made narrower at the top than the bottom to check splashing, and these appear to answer well. Lead sinks do not look so neat as porcelain basins, but they are not so easily damaged; they should, however, be constructed without the use of solder, and there should be a good fall towards the outlet, otherwise the lead may decay rapidly through corrosion. At the Manchester Grammar School, and at the Yorkshire College, the sinks empty into a V-shaped open drain to outfall.

(*c*) *Re-agent shelves and upper works.* In nearly every laboratory hitherto constructed, a rack of shelves to hold re-agent bottles is placed along the centre of the bench, and is either fixed or moveable, the shelves being about 6 inches wide and 9 inches apart. In some cases a hinged or sliding glazed front is fitted to these racks, as at Owen's College and at Dundee, or revolving shutters are lowered over all, as at Berlin; but this addition is of doubtful utility. In the Medical Schools at Owen's College the shelves are not closed. At Graz two distinct glazed cupboard fronts are provided; one inclosing the bottles for strong acids, and the other the ordinary re-agents; but this is an unnecessary refinement. At Munich only a single shelf is provided for re-agent bottles, and it is carried on iron standards. This arrangement has the advantage that the students on either side of the bench can see each other and converse; to which Professor Williamson, however, distinctly objects. He has so fitted up his new laboratory at University College, London, that each student is isolated as much as possible from his neighbour: a system which does not commend itself to me, and is nowhere else attempted, besides which the professor cannot thus have an uninterrupted view of the students in the entire laboratory as in the former case. At Bristol College the re-agent shelves are moveable. Professor Schmidt, of the Dresden Polytechnic, has his double benches made in three portions. The re-agent shelves (of which there are two besides the top) there form the central division, underneath which are arranged the pipes and wastes, and the benches on either side form the other two divisions. At the Finsbury College a novel plan has been adapted, the large illustration of which will be fully described further on. The re-agent bottles are placed under the " heating shelf " on a raised ledge down the centre of the bench [Illustn. ix].

ii.—Draught Closets for General Use.

Draught closets are closets in which operations can be performed which give rise to the production of noxious fumes or gases. Some provision of this kind appears to have been made from the time of Liebig, the first teacher of chemistry; but the original closets were, in most cases, few in number and of large size, being mainly intended for large operations.

Hofmann first introduced the small closet now so universally met with in chemical laboratories, and recommended by the South Kensington authorities.

(*a*) *Position of draught closets.* The position of the draught closets intended for operations incidental to ordinary qualitative and quantitative analysis, indicated in the Owen's College, the Dundee* and the Yorkshire College plans may be regarded as typical. In both cases the closets are near to the ends of the students' benches, being, in the one case, fitted in the walls, and in the other, in the piers between the windows. At Munich the closets are formed in the window spaces, by which ample illumination is secured.

(*b*) *Dimensions of draught closets.* The required sizes are shown in the illustrations of Professor Hofman's closets† constructed at Bonn and Berlin, and Professor Roscoe's wall closets at Owen's College. Those at Munich are considerably larger, being chiefly intended for use by students engaged in research. Several larger closets are provided at Owen's College, and

* Illustn. xiv, fig. 43.

† Illustn. xviii, figs. 66-69.

elsewhere. In all cases, however, the variation is mainly in length; the depth and height differing but little. The depth of the closet and the distance of the top of the floor of the closet above the laboratory floor are regulated by the same considerations as those to which allusion has already been made in connection with the working benches in the laboratory. In respect to the height of the closet it is obvious that inasmuch as it is important that the fumes be carried away as fast as possible, it is desirable to reduce the capacity of the closet to its narrowest limits, and therefore it should not be higher than necessary. As ordinarily constructed the closets are too high, because, in the majority of operations which the student in an analytical laboratory has to perform, the apparatus employed rarely, if ever, exceeds 2 feet in height. At Finsbury College the smallest closets are 2 feet 10 inches in height; at Yorkshire College, 2 feet 6 inches; where the students are engaged in research, as at Munich, it is desirable to make a considerable number, if not all the closets, to contain an apparatus some 5 feet high; and in every laboratory one or more such closets should be provided according to the character of the work likely to be carried on. The position of these will necessarily depend on the nature of the space at disposal for the purpose. The average width of the draught closets is 2 feet; ditto depth, 1 foot 9 inches; ditto height, 2 feet 9 inches; and for the larger draught closets the average width is 4 feet 6 inches; ditto depth, 1 foot 9 inches; ditto height, 5 feet; height of bottom of closets above floor, 3 feet.

(*c*) *The sashes of draught closets.* The front of the closets is always inclosed by the rising sashes. The larger the pullies the easier run the lines, which may, with advantage, be of steel, copper covered. But, better still, the breaking of lines and the provision of pullies and weights may all be superseded in light sashes by the spring attachments in common use in railway carriage windows. When the draught closets are in use, it is necessary to raise the sash a short distance in order to admit air, which causes the gas flame burning within to become deflected. To avoid this, at Leipzig, a small subordinate sash is provided, and thus the width of the air slot and its distance above the closet floor can be regulated. At Manchester, this subsidiary sash takes the form of a small glazed flap hinged to the bottom of the closet. At Berlin, a "hit and miss" arrangement is introduced in some of the larger closets, two sliding glass plates with holes being fixed at the bottom of the closet front. On raising the ordinary rising sash, there is necessarily a space between the inner side of the glass and the upper edge of the closet from which fumes escape. Dr. Armstrong has remedied this by fixing to the top of the closet a kind of "squeege" which scrapes against the plate glass. India rubber was at first tried, but this is not only expensive if of sufficient thickness, but it produces considerable friction which ends in twisting, so that it does not preserve a straight line throughout its length. A lath coated with a double thickness of the best carpet felt has, however, been found to answer the purpose completely.

(*d*) *Materials to be employed.* It is almost more important, in the case of the draught closets than of benches, that the "top" should be of an impervious material. In some places slate is used, sandstone and lead are also met with, the former being more generally adopted. It is important, however, to select a stone which is neither readily acted upon by chemical agents, nor liable to crack when moderately heated. Saturation with paraffin, or many of the solutions used for indurating freestones, would probably render it to all intents and purposes non-porous. In many laboratories provision is made for carrying away the liquids which may be spilt on the floor of the closet, a chase being cut round the edge of the slab, and a pipe being fixed therefrom to the receptacle below. In many cases a jar or other receptacle is placed there into which the students throw all solid waste as well. There is some difficulty in securing a proper material for the roof of the closet. Wood is very liable to warp and crack under the combined influence of the heat arising from the burners and acid fumes and moisture. Slate, although not acted upon by acids, &c., is a treacherous material and liable to crack if heated. Glass, which is always used when the draught closets are in front of the laboratory windows, as at Munich, is less porous than slate, and would, in most cases, be the cheaper material, but it is equally liable to crack. At Strassburg, frames of angle iron have been fitted to the walls and hipped at the angles; upon these a very coarse iron-wire gauze has been stretched, and coated on both sides with Portland cement. The condensation of the vapours under slate, glass, or impervious stone, is an inconvenience which has to be provided against. At Finsbury, the closets have a curved roof of galvanized iron which is coated inside with tar or pitch-varnish. Probably the best and cheapest roof would be made of enamelled iron, which could be cast in one piece, the required size, and be coated with enamel of such a quality that it would resist the action of acids.

(*e*) *The draught flues.* Fumes, &c., are usually extracted from the draught closets through a single opening, square or circular, high up in the back of the closet, the draught being produced in the older laboratories, as at Bonn and Berlin, by means of a gas jet burning in the flue. Each closet has a separate flue, and there is no simpler and more generally effective plan than this, where there are no down draughts or cross currents between the flues to upset their steady action. But several, say a row of, closets may be all readily ventilated by one flue, aspirated by one or more Bunsen burners. This, I am told by Mr. Waterhouse has been found to work well at Owen's College, especially where the "Bunsen" is inclosed with a cast iron cone, with an opening at the top, the iron becoming heated by the burning of the gas accelerates the rush of air. Dr. Armstrong's private laboratory is thus ventilated, as I shall hereafter describe, with considerable success. In most of the recently constructed large public laboratories, however, the flues from the various closets, are all connected with a central flue, and the draught is produced either by means of a tall shaft, at the base of which is a furnace, as at both the Manchester examples and at Birmingham, or by means of a fan as at Munich, Geneva and Aachen, and at the Bristol Trade School.

The question of shaft *versus* fan, has already been discussed in my former Paper, and by Dr. Armstrong in his remarks appended thereto, but it may be well to repeat the caution that competing draughts should never be introduced into a chemical laboratory. No two opposite ways should be provided for the escape of air, and as the draught closets cannot well be too efficient, the whole of the air of the laboratory may be extracted through them.

The introduction of fresh air to the closets, is like introducing fresh air opposite and under a fire-place, it prevents the draught closet, or the fire and its flue, from withdrawing the expired air from the room for its sustenance. Besides which it may permit of air passing into the laboratory whenever the sash of the closet is raised, or it may result in weakening the force of the current of air which should be away from the operator, towards the closet flue. Again, as the closet has a maximum efficiency only when the sash is raised sufficiently to give an opening of about the same area as the area of the flue, it is important that the whole force of the draught should be in one direction, namely, from the operator towards the flue. Schmidt of Dresden has removed his closet windows in some cases for ordinary operations, finding them work equally well under the hoods without them.

Professor Carnelly writes from University College, Dundee, to say that he believes the system of ventilation adopted there is exceptional, and that it answers very well indeed, contrary to his own expectations, both as regards heating and ventilation. It consists in blowing the air into the building by five large air pumps over heated pipes, which escapes up the ventilating flues and the draught closets. This is the first application of the principle of forcing the warm and cold air into the general laboratory and not otherwise aspirating the draught closets, a principle which has been successfully applied to large assembly rooms by Mr. W. W. Phipson.

The current of air in a draught closet has a maximum force in a direct line with the flue opening, and the other parts of the closet are more or less in "shadow," and vapours hang about them. This may be obviated by making the outlet in the form of a slit (extending along the back of the top of the closet) of equal area to the flue with which it communicates. Very long closets should be provided with trumpet-mouthed slits. Dr. Armstrong has presented us with an example of this kind, which has been constructed in his private laboratory at Finsbury College. It is shown in Illustn. xi, figs. 28-30. The closet is 11 feet 9 inches long and 21 inches deep, but it is divided into three compartments, two of these, one at either end, are 4 feet 5 inches long and 2 feet 9½ inches high in the centre of the curved roof, and 2 feet 7 inches high at the back and front. The central compartment is 2 feet 9 inches long and 5 feet 3 inches high; across the entire width, in the rear, a wooden back is fixed about an inch away from the wall, extending to within 9 inches of the roof, but also having a slit-opening an inch wide 18 inches above the floor, which can be closed by a moveable slide. The corresponding backs of the end compartments are formed of glass to within 2 inches of the roof. The openings thus formed between the wall and the back of the closets extend downwards into the horizontal box flue, 13 inches by 13 inches, which is connected with an ordinary 18 inch by 9 inch brick flue built in the wall. The draught is produced by a Bunsen's gas burner at the base of the shaft, and a velocity of 7 feet per second or about 400 feet per minute in the flue is easily secured by a consumption of about 10 feet of gas per hour.

When draught-closet flues pass directly upwards it is found that condensed liquid and dirt are very liable to drop down into the closet and vitiate experiments there being performed. To obviate this, Professor Hofman made the provision shown in Illustn. xviii. These arrangements have been repeated at Owen's College and at Birmingham, and they are mentioned also in the recommendations of the Science and Art Department at South Kensington. At the Yorkshire College Professor Thorpe has preferred to have descending flues.

(*f*) *Dr. Armstrong's hood arrangements.* In practice, the closets thus far described, although intended for general use, are, on account of their position relatively to the benches, only made use of by students on special occasions, that is whenever it is necessary to perform an experiment with noxious materials, or one which is likely to produce specially noxious fumes. Consequently the hundred and one experiments in which small quantities of acid vapours, &c., are produced are performed in the open laboratory, to the manifest detriment of the purity of the atmosphere, which is further contaminated by the products of the combustion of one or more gas burners for heating purposes usually kept burning on every student's bench. Dr.

Armstrong conceived the idea that this was a very needless and very illogical arrangement and that none of the noxious gases or fumes should be allowed to escape into the room, but on the contrary that all of them should be collected under hoods and carried away, and that the general ventilation of the room should be effected through the same channel. Attempts have been made to bring the draught closet so near to the student that he should not be tempted to vitiate the atmosphere; and at Aachen, Owen's College, the Bristol College and the Manchester Grammar School, a small draught closet is provided on each student's bench, illustrations of which are given. That at the Manchester Grammar School,* which was planned by Mr. Francis Jones, the Head Master, is especially deserving of attention. As will be seen by the drawings, each closet is 15 inches high by 10 inches by 10 inches area; two such closets are placed back to back, and the flue which is common to both is of porcelain, being ingeniously constructed with a diaphragm down the centre, so that each closet may have its fair share of the "pull." But there is little to enforce the use of this provision when made, and the gas burners are mostly exposed as before. Therefore I view with considerable interest the system which has been initiated by Dr. Armstrong and carried out under his supervision at the Finsbury Technical College,† because it promises to afford a satisfactory solution of the problem under consideration. A "heating shelf," 22 inches wide, is fixed 12 inches above the bench, and over this is a hood 24 inches wide of the shape and size shown. At intervals of 4 feet under this hood, 4 inches square iron down-cast flues, pitched inside, are connected with the horizontal flue channels in the floor. Wing plates are attached to these down-cast flues, forming a continuous extract flue opening, extending the whole length of the hood. By raising and lowering these plates, by means of the screws at B B and B, the width of the opening can be graduated at will, and made wider at B than at A A in order to secure an even pull along the entire distance between the down-casts. The flexible tube of the gas burner attached to the tap below, is passed through a hole (C) in the heating shelf, and all operations, other than those with a mouth blow-pipe, must be performed on the heating shelf, and thus necessarily under the hood, so that whatever fumes are evolved they are sucked away. In order to compel the student to heat large vessels, such as flasks or dishes in the most favourable position, that is, well within the hood, no moveable stands are provided, but instead thereof, rings, such as are shown in the drawings. The arm opposite to the ring is bent at right angles and is filed to a conical shape, so that it fits closely into a corresponding eye-hole in the brass plate, screwed on to the down-cast pipe. An opening XX, 3 inches by 2 inches, is made in either side of each down-cast, and all operations involving the sudden evolution of noxious fumes, are conducted immediately in front of this opening. When not required it is closed by a small door. Hoods of this kind have been made 12 feet long and used with most satisfactory results. Before very long a whole series will be seen at work at Finsbury Technical College. Alterations are at present being made, and experiments carried on to test the most efficient of several modes of actuating the draught in the main extract shaft. When this is satisfactorily completed, a very interesting and useful addition will have been made to chemical laboratory fittings. The whole of the hood and even the wing plates might be made of glass, but in this case the depending sides are alone glazed.‡

* Illustn. iii. This School was erected from the designs of Messrs. Mills & Murgatroyd. † Illustn. ix.

‡ Professor Roscoe expresses himself in favour of draught places for heating purposes on each bench, with down draught to chimney.—E. C. R.

iii.—Draught Closets for Special Purposes.

(*a*) *Sulphuretted-Hydrogen Closets.* At Owen's College small closets, 12 inches high and 85 inches in area, are provided on each bench [Illustn. iv, figs. 10-14]; a wooden flue, 5 by 5½ inches, in the corner of the closet, connects it with the floor channel flue leading to the shaft. Each student himself prepares the gas as wanted. In most laboratories, however, a special room is provided for operations with this most unpleasant smelling gas. Either a constant automatic apparatus for generating the gas is provided for common use, or it is stored in a gas holder and served by pipes to the bench or special closets—such special closets are represented in the drawing of the sulphuretted-hydrogen chamber at Leipzig [Illustn. xvii, figs. 63, 64]. A series of small wooden closets are provided, all of which communicate with the main flue in the manner indicated through narrow slit openings at the back. There is a supply of the gas to each student. Two of the closets are larger than the others, and there is one for still larger operations, which are also provided with gas burners for heating. A similar form of sulphuretted-hydrogen closet, at the Graz Laboratory, is shown in Illustn. xvii, fig. 62. The chambers are of glazed stoneware; no fronts are provided, but these chambers are all inclosed within an ordinary large draught closet. A somewhat more novel arrangement, at the Finsbury College, is shown in Illustn. iii, fig. 9; small copper funnels, 3½ inches wide at mouth and 4 inches high, are fixed to the flue X at the top of the closet; the gas is generated in the central chamber Z, and thence passes to the copper tubes soldered into the sides of the funnel, a small pinch-down cock being fixed to the flue as at B. The student attaches a length of glass tubing to the copper tube by a short piece of caoutchouc tubing, or raises the flask on a stand, and then proceeds to pass the gas into the solution he is testing. All excess of gas is thus delivered directly into the flue, the connecting tube being of such length that the mouth of the vessel containing the solution is within the funnel. Any further operations with the solution, such as boiling or filtering, are also conducted in the closet, gas burners being connected with the taps, and filtering arms being hinged to the panels of the closet. Usually the student uses the closet only to pass the gas into his solution, all further operations being conducted at his bench.

(*b*) *Evaporating closets.* It is customary to provide one or more evaporating closets, *i.e.*, closets in which evaporations by steam can be conducted. These closets, however, do not materially differ from those already described, the fittings being the special part of them. Dr. Armstrong has explained to me that it is particularly desirable to have a sharp draught across the surface of the evaporating liquid, and it is to be expected that a slit opening combined with a low roof will be found of especial service in such closets. The main difficulty is to prevent condensed liquid dropping into the vessels below; and there is still ample opportunity for the exercise of ingenuity in the construction of a really efficient evaporating closet. Probably much that is now done by steam might be more economically and satisfactorily performed by hot air; that is to say—properly regulated burners might be placed in such a situation relatively to the heated vessels that the temperature could not exceed that of boiling water. Professor Thorpe has elaborated a good example.

iv.—Demonstration Table and Fittings.

A demonstration table is not provided in every laboratory, but only in those where large classes have to be dealt with, as at the Finsbury College, the Manchester Grammar School, and St. Bartholomew's Hospital. It is seldom found in German laboratories, where, as a rule, the students are engaged during the greater part of their time, and get much individual attention from the teaching staff. The table should be placed so as to command the working benches, and set upon a platform raised about 12 inches—see the Manchester, the Finsbury, and the Dundee examples. At the Grammar School, and at Dundee, the table is fitted with drawers, cupboards and recesses, for storing the various articles which have to be issued to the students during the lesson, and is also provided with gas, water and a sink, so that experiments can be performed upon it before the students. At Finsbury, as already explained, the space under the table is not actually used as a demonstration table; but the balances for the junior students are placed at the one end, and the assistant has his desk at the other. In a small cupboard below are a series of wooden trays, into which bent hooks are screwed for the student's keys, a number corresponding to that on the student's bench being stencilled below each key. By thus keeping and giving out the keys at the commencement of the class, and insisting on their being returned at its close, loss is avoided, and the key board also serves as an "attendance indicator."

V.—Lecture-room Fittings.

(*a*) *Lecture Table.* This is the most important fitting in a lecture-room, though one which does not greatly vary in form or character in different laboratories. It is and should be always a long rectangular bench, never curved or circular on plan. Its general height is about 3 feet, its breadth about 2 feet 9 inches, and as it is not desirable that one piece of apparatus should be placed before another, there is little advantage in having wide tables. As to length, there is no limit; the longer the better would be the dictum of most chemists. The table should have a hard-wood top; and now-a-days, as a matter of course, "down draughts" must be provided, that is to say, there are openings (usually two), not less than 4 inches diameter, in the table-top, which can be closed with moveable covers, and pipes from these communicate either with the main flue, or, where there is no special system of ventilation, the taps are carried down under the floor into a flue in the wall, where there is a gas burner to produce a draught. A portion of the table-top is often made moveable, and underneath is a large sink, which can be filled with water and used as a pneumatic trough in transferring gases, &c. This sink is sometimes glazed back and front as at Dundee. A shallow tray for operations with mercury is also sometimes constructed in a similar manner under the table-top. The space under the table should be fitted with drawers and cupboards for the store of various articles and apparatus required by the lecturer. A considerable number of gas and water taps are necessarily provided, and are usually fixed in such positions that they can be readily got at without being in the way of apparatus. In many of the luxuriously appointed modern laboratories there are numerous other taps fitted to the lecture table, some being for the delivery of compressed air, while others are in communication with a vacuum pump; others again furnish a supply of oxygen, and others steam. Wires from a dynamo-machine or some other source of electricity are also attached to proper terminals affixed to the table. Obviously all these special requirements can only be properly provided for when the architect is placed in direct communication with those who will have charge of the teaching; it is important that he should know of them, in order that he may not be led into the error of assuming that a mere table is all that is required. The chemical and natural philosophy lecture-tables at Dundee [Illustns. xiv-xvi], are very complete, taken with their surroundings. The former is 20 feet long, 3 feet wide and 3 feet 1 inch high, on a platform 12 inches high. Teak is used for the table-top and for the frames of the mercury and pneumatic trough. The front and ends are of pitch pine and the back and framing of yellow pine.

(*b*) *Draught Closets.* One or more draught closets are usually provided behind the lecture table, one being of large size for the performance of experiments with large apparatus, the others being small. Where draught closets are provided on the table small closets are scarcely necessary. The large closet is frequently so constructed that its working bench is put on wheels, and thus it can be moved either into the preparation-room or into the lecture-room, as at Dundee. This arrangement renders it possible to bring forward, when required, a furnace or other piece of apparatus which it is not desirable to keep on the table during the whole of the lecture. The drawings of Dundee [Illustn. xv, figs. 48-51] and Finsbury Colleges are good typical examples of the treatment of wall-space in the rear of the lecture table.

(*c*) *Other Lecture-room Fittings.* One or more black boards, a diagram screen, a large white spring roller blind or screen for use with the "magic lantern," and a set of reagent shelves, are all requisite fittings for the lecturer. The "black boards" are frequently arranged to come down over the glazed fronts of the draught closets; they should be suspended from large pulleys by copper-covered steel bands, to move easily. Usually they are of wood; best ground plate glass, securely mounted in a wooden frame, may be used with advantage if coated on the under side with a mixture of lamp black and size. For use at night, a white board is very convenient, the back of the glass being coated with ordinary white distemper. A "flashing platform" should be arranged for projecting pictures on the screen, and so placed as not to obstruct the students' view of the table. For darkening the lecture-room special black holland blinds are usually provided, running in grooves at the sides, or revolving shutters.

vi.—Preparation-room Fittings.

Here there should be a large table, on which the apparatus to be used in the coming lecture is set out, and also a working bench for the assistant's use. Cupboards, shelves and drawers for apparatus in constant use should be as liberally provided as possible. A number of glazed cases for the storage of apparatus and for specimens and diagrams are necessary, but these may be in an adjoining room. Space should be allowed for a carpenter's bench, lathe and vice, an anvil, a soldering bench, and a blow-pipe table. There should be a large sink and draining table, with perforated shelving above; and near to this, if possible, there should be a large drying closet, in which glass can be placed to dry. A supply of hot water to a sink is also very useful [Illustns. i, vii].

vii.—Store-room Fittings.

It is desirable, if possible, to have two store-rooms, one for glass and other apparatus, the other for chemicals, this being used also in making up the reagents for students' use. The former should be liberally fitted with bins, cupboards, drawers and shelving, solid and skeleton. The latter should be similarly provided, but should also have a working bench for the use of the assistant in making up reagents.

viii.—Class-room Fittings.

These should be of the same kind, although not nearly so extensive, as the lecture-room fittings. The indispensable requisites are a table supplied with gas and water, one or more glazed cupboards for apparatus, chemicals and specimens, a black board, a diagram screen, and some arrangement for carrying off noxious fumes. For the last purpose either a down draught may be provided on the table, or a draught closet may be constructed against the wall behind the table. If the latter, a sink may be conveniently placed within the cupboard instead of upon or near the lecture table, and the black board may be arranged to fall down in front of the closet.

ix.—Balance Room and Library.

The main requisites of a balance room are a number of benches to carry the balances. To diminish vibration as much as possible, it is best to have a separate small bench for each balance, and to fix these upon brackets let into the wall. As the balance room is frequently made use of as a reference library, a table at which students can read and write should be provided, and a cupboard for books; although, if space and funds permit the balances are better kept apart. A large table for use in the preparation of diagrams is an important requisite, and may conveniently find a place in the balance room [Illustn. xiii, fig. 40]. The top ought to be moveable and adjustable to any angle, so that the draughtsman may stand in front of the board; brass scales are let in at the top and at one side, so that lines may be readily drawn at any required distance with the aid of a T-square. This table takes the centre of the room at Finsbury. On the drawings are shown the details of the benches.

x.—Assistants' Room.

In the assistants' room there should be a working bench for their use, a draught closet or hood, and a sink and draining table, cupboards, drawers and shelves should also be provided, in which special apparatus, such as measuring vessels, platinum crucibles, agate mortars, &c., continually required, may be kept, as also pure chemicals, &c., for analysis.

xi.—Rooms for various Special Purposes.

The number and character of these must depend to a large extent upon local requirements, but the following are met with in all large laboratories:—

(*a*) *Gas analysis room.* This is a room in which analyses of gases are performed. It is usually regarded as essential for its temperature to be maintained as uniform as possible, and therefore the room has almost invariably a northern aspect; now, however, that it is becoming customary to make the measurements in water-jacketted tubes, this is less important than formerly. As mercury is liable to be spilt, the floor should be laid with special care; but as it is almost impossible to make the floor continuous, it is well to cover it with linoleum or some such material, and to fix a bead over this, so that whatever mercury is spilt may be swept into a corner and collected. At the Central Institution a cement floor is formed with a semi-circular sunk groove round to catch the quicksilver. The fittings comprise, one or more mahogany-topped tables, and a cupboard for storing apparatus; gas and water should be laid on, and a sink provided.

(*b*) *Spectroscope and polariscope room.* In working with these instruments it is necessary to exclude light, and therefore to provide blinds for darkening the room; in other respects the only requisites are steady benches, a supply of gas and water, and a sink. The benches should be somewhat low, so that the observer at the instrument can be seated.

(*c*) *Photometric room.* This room may be distinct from that last referred to, but the two are sometimes combined. It should, if fitted with the requisites for testing the quality of illuminating gas, be provided with a dark blind, and in order to accommodate not only the photometer, but also a working bench, a draught closet, a gas holder, &c., it should be spacious in size. A liberal supply of water and gas, as well as a sink are necessary.

(*d*) *Combustion room.* This is a room in which gas furnaces for heating long glass tubes are placed. It is usual to provide one or more benches against the walls, with stone tops about 2 feet wide and 2 feet 9 inches above the floor level, iron hoods communicating with flues in the walls being fixed over these benches. The gas main is best fixed in front of the bench.

(*e*) *Explosion or cannon room.* This is a room in which sealed tubes are heated in air or oil baths. The benches should be of stone, and in several laboratories the baths are placed in small open-fronted closets with stone sides and top, so that when an explosion takes place the glass may not be scattered about the room. The room should be especially ventilated and there should be an opening into the flue from each of the compartments referred to.

xii.—Metallurgical Laboratory.

Here the wind, muffle and other furnaces, required for assaying and for fusion of metals, &c. are placed. The fittings are of a special character, and may be seen in laboratories like that at the School of Mines, and at King's College. Fittings of the kind are in course of construction at the Merchant Venturers' School, Bristol. The room should be very well ventilated into the shaft provided, and the heated air collected by a hood over the range of metal ovens and furnaces.

xiii.—Special Operations Room.

In every laboratory there should be one or more rooms for the performance of large operations, which cannot well be carried on upon the student's bench in the main laboratory. It is desirable that, while some of the benches in the special operations room are of the average height, others should be lower. They should be as free as possible from upper works. The floor should be of asphalte; and some of the benches should be of hard wood or covered with lead, while others should be of stone. A large sink and a draining table are required, and a supply of both hot and cold water. Several large draught closets should be ranged round the room. Steam should be laid on, and if possible motive power should be introduced into this room. Shelving and cupboards must not be omitted.

MECHANICAL LABORATORIES.

i.—The Lecture Room.

At Finsbury this is also the physics' lecture room, with large diagram space, and a large and easily moved black-board. It is not sufficiently well known that black-boards require to have great length horizontally. In many mathematical class rooms they are fixed to the wall, because of the difficulty of hanging them so that they shall be easily moved. Professor James Thomson of Glasgow has originated a method of hanging black-boards from levers, which proves very convenient at Finsbury [Illustn. xii, figs. 31-37]; there, a black-board 14 feet long and 6 feet high, can be moved up or down, through a vertical height of 6 feet, by the lecturer, who need not stop his writing as he shifts the position of the board. A separate lecture room is necessary for the mechanical department of a college. Firstly, because the room ought to be to some extent a general mechanical laboratory, and requires special wooden beams on the walls and supports in the ceiling for carrying heavy apparatus. Secondly, because students ought to be able to sit at the desks if the lecture is one of which they have merely to take notes; and they ought also to be able to stand at the desks. Indeed, the tops of the desks ought to be constructed to rise and become more horizontal, as a lesson on practical geometry or graphical statics requires the students to stand while drawing. At Finsbury moveable tops give a broad horizontal table for students when they require to draw; these can be lifted off for ordinary lectures, and stowed underneath the fixed desk, where they create no inconvenience. It is only to every other row of desks that it is desirable to provide this moveable top, to allow passages for students between the rows of draughtsmen. In a specially arranged lecture room this moveable top for draughtsmen who stand would sink in position, and become inclined for note-takers who sit. In all cases grooves and recesses for drawing instruments and colour saucers must be provided.

ii.—General Laboratory.

The aim of the professor of engineering at a college has hitherto been that of providing one laboratory where he and a few senior students may obtain results which shall be of use to all engineers. With one exception there has been no attempt to create, and there is probably no great desire for, a general laboratory, in which *all* students at a college may make quantitative experiments during their whole study of mechanics. It is, however, the opinion of Professor Perry that there should be such a general laboratory, and although his space at the Finsbury College is quite inadequate, he has there attempted to carry out this idea. He says that there ought to be one room not less than 25 feet in breadth, and 50 feet in length, with a small room partitioned off at one end, say 25 feet by 10 feet, for students using the more delicate apparatus, and a room of about 25 feet by 15 feet partitioned off at the other end. This should have a concrete floor, a sink, and high and low pressure water supply for hydraulic experiments. The ceiling and walls ought to be crossed everywhere with timber beams sufficiently large for the fixing or hanging of machines and apparatus. A supply of small stout tables of about 3 feet high; plenty of light; the ceiling as high as possible, but not less than 15 feet.

iii.—Special Laboratory.

The character of the fittings of this room which is (except at Finsbury) the only kind of mechanical laboratory usually provided at a College, depends on the nature of the researches to which the professor devotes his leisure time. A mechanical laboratory, says Professor Unwin, may be intended for researches of any kind. Testing materials for strength (iron, steel, cement for example), or testing lubricants, or testing fuels; testing the efficiency of hydrants steam or transmissive machines; for hydraulic researches and researches on the resistance of ships, &c. Therefore the arrangement of a mechanical laboratory must depend on the particular line or lines taken up. Professor Kennedy at University College and Professor Unwin at Cooper's Hill, have laboratories in which the chief work is that of testing the strength of materials. Professor Smith of Birmingham chiefly makes experiments on the steam-engine; Professor Huntingdon at King's College, London, devotes his laboratory mainly to metallurgical work. That is, not only for assaying, &c. but to the composition and testing of alloys of metals with a view to the discovery of the best proportions for the various uses of brass, and other compound metals in engineering works and mineral extractions. At Cooper's Hill, the testing laboratory is 60 feet by 25 feet, with open roof and a small room for plotting results and keeping valuable apparatus. There is a hundred tons testing machine, a lathe, slotting machine, drill, emery wheel, small forge, vice-bench and gas engine for driving machines. There is also a cement testing apparatus, a small lubricant tester, and some German hydraulic experimental apparatus. Professor Unwin considers the light should be northern if possible, the room should be lofty, and the shafting fixed at a good height. A travelling crane over the large machine is a great advantage. Professor Perry tells me that his students in Japan experimented with a large testing machine on numerous specimens of Japanese timber as well as on metals. They tested oils, the strength of cement on a special machine, the strength of bricks and stones with a hydraulic press. The same room also contained an engine and boiler with special fittings, to enable the efficiency of the steam-engine to be investigated. It is therefore obvious that in the matter of special laboratory fittings, the architect must consult the professor who is to be in charge of the instruction researches.

iv.—The Engine Room.

Where the Professor of the department cannot be consulted, it is well to recollect that the engine must not only drive the workshop and other shafting of the College, but must be available for experiments. It ought therefore to be high pressure and condensing with expansion valve controlled by a good governor. The room must be large so that extra tanks and pipes may be introduced. It is found that the evaporative condenser on the roof causes less water to be consumed than in the same size engine when non-condensing; as it is felt that this kind of engine will probably be largely introduced, the nature of the two large pipes for circulating pump and two for steam, shown on the drawing, going from the basement to the roof, is of some importance to the architect. It would be better that they should not be exposed to the weather. At Finsbury where they had to be placed outside, they are emptied of water every night in the winter time. The arrangements of boiler, boiler seating and chimney, and of the shafting to the various parts of the College, are matters in which the advice of a mechanical engineer is necessary to the architect. The shafting to various workshops, &c., must be arranged before walls are built, as metal wall boxes must be provided for.

v.—Workshops.

The fittings which concern the architect after the shafting has been put up, are the vice-benches in the iron workshop and concrete foundations for some particularly heavy tool, such as a shaping machine. The lathes will not require special foundations. The carpenter's benches are the principal fittings of the wood workshop, which also possesses a few wood-working lathes and a hand saw. The benches not less than 4 feet apart ought not to be less than 3 feet wide, and ought to be provided with at least one drawer for every two students; vices of the sliding-clip pattern; plenty of space allowed round the ends of the benches. A space of not less than 12 feet square ought to be available for hand-sawing. The iron and wood workshops ought to be kept distinct, and the area of each shop ought not to be less than 1,300 square feet for twenty students working at one time in one shop. At Finsbury the allowance is only about 900 square feet per twenty students, more space being greatly needed. A room for workshop stores must be provided at least 20 feet in one dimension, the other dimensions depending on the size of the workshops. This room ought to be filled with pigeon-holes, racks and shelves. Every student ought to have a locker at least 24 inches by 15 inches, by 15 inches.

vi.—Melting-Room and Smithy, or Metallurgical-Room.

In the basement plan [see Illustn. v] of Finsbury College is shown the smith's forge, with bellows worked by the shafting provided and shown. A brass furnace, brass moulder's trough, stone benches and other fittings, are required. This room belongs partly to the Mechanical and partly to the Chemical Department, but the three furnaces belonging to the chemists or metallurgists are not shown on the drawings.

vii.—The Drawing Office.

At Finsbury the space is so limited that it has been necessary to give one common flat table to eight students, two of whom generally use it at the same time. For every twenty students using the drawing office a space of at least 1600 square feet should be provided, and the light ought to come in as much as possible to the left front of a student. It will be seen from Sir F. J. Bramwell's design [see Illustn. xiii, figs. 38, 39] that no cupboards for drawing-boards or squares are required, but a set of large shallow drawers are needed for a stock of paper, finished drawings and other stores. It is well to provide a black-board for this room, and a set of wash-hand basins.

viii.—Museum.

Professor Perry tells me that the arrangement adopted in Japan was found to be very satisfactory. A room which was probably 120 feet long and 24 feet broad, had a row of windows along one side. It had three long stout benches—two along the walls, and one along the middle of the room, and on these benches, not too close together, rested specimens of mechanism and structures, models of steam and other engines, broken specimens of iron, &c. There was no attempt to put the models one behind the other. Each was easy to get at, and there was no resting place (except for a few exceptionally large models), except on benches all of the same height. Photographs of machinery hung on the wall fronting the windows.

EDWD. C. ROBINS.

[Remarks by Professor Carey Foster, F.R.S.]

The requirements of physical laboratories are more difficult to treat, from a general point of view, than those of chemical laboratories, seeing that the operations are of a more varied kind. The routine work of a student's laboratory for chemistry mainly consists in analytical operations which do not require a great deal of space, and for which the arrangements, in the case of all the students, are very similar. But in the physical laboratory a variety of subjects is dealt with. Experiments with light, heat, electricity or sound—all these different subjects require special arrangements in order that the operations may be properly carried out; and very often, even an elementary operation, such I mean as would be put into the hands of a beginner on the subject, may require a very great deal of room. In a physical laboratory we must have steady supports independent of any shaking of the room due to traffic outside the building, or to people walking about in the building itself. How this steadiness is to be obtained when the ground itself is in tremour is a difficult matter. It has occurred to me that it may be possible to obtain it by means of floating supports, but I do not know that any experiments have been made in this direction. Years ago I had some knowledge of chemical laboratories and, amongst these, of the old chemical laboratory at University College, London, which has not been referred-to to-night, namely, the Birkbeck Laboratory, which I think I am right in saying was the earliest student's laboratory established in this country. Each working-bench was there provided with a ventilating hood of stoneware, and a separate sulphuretted-hydrogen chamber, besides which there were evaporating closets for general use on a large scale. It was built in 1845, or thereabouts, by Professor Donaldson, and though later laboratories have carried out the arrangement attempted there in a more effective way, the old Birkbeck was certainly good as a first attempt.

T. CAREY FOSTER.

[Remarks by Professor Thorpe, Ph.D., F.R.S.]

Steadiness in buildings destined to contain laboratories for chemical and physical research is essential. In buildings which have not been originally arranged for the purposes of a physical laboratory, this may be somewhat difficult to secure. Professor Andrews, of Queen's College, Belfast, as most physicists are aware, has had to make experiments, in which a very high degree of steadiness was necessary. The building at Queen's College, Belfast, was not well adapted to his work, but he found he could get a sufficient degree of steadiness by introducing underneath the floor heavy wooden beams, in which all the apparatus necessary was directly placed, so that the experimenter in walking over the floor, the floor being entirely disconnected from those beams, only gave the smallest possible tremour to the apparatus.

The width between the working benches, in which the practice of designers of laboratories seems so variable, is a matter of importance. I am not aware that any other principle guided me in the selection of the special width we adopted, than to take care that there was sufficient passage-room for a student to pass between the cupboard doors on either side, when open. A great deal has been said with respect to the character of the wood, of which the table-tops should be, and numerous experiments have been made. There is nothing more annoying or unsightly than either to see the wood become discoloured or see it split, as not unfrequently happens from the heat radiated from various pieces of apparatus in use. I believe, Dr. Roscoe, some years since, when devizing the fittings for the laboratory of Owen's College, made a number of experiments on this point, and found that, of all the woods he tried, green-heart came out the best; but I understood there was a practical limitation to its use on account of its expense.

With regard to the question of sinks, we find, at the Yorkshire College, in the temporary sinks with which we have been working for some years, that very much less of sink accommodation than that usually provided suffices us. I find, for example, that one tolerably large sink of rectangular shape, placed so that four men can make use of it at once, is all that is necessary. It seems to me waste of table space, and of course of money, to put up a sink for every student. We have tested that matter rather thoroughly, and I find not the slightest objection raised by the students to the arrangement now adopted. One point more in connection with this matter is perhaps worth noting. In most large towns the water-pressure is of course very considerable, and in some public laboratories care is taken to reduce the water-pressure. The high pressure has this great disadvantage, that it is almost impossible in using the taps to prevent a great deal of water being spilled about the tables. The water rushes into the basin with such force that it is projected over the table. That was got over in a very simple way in Professor Baeyer's laboratory in Munich. There the sinks, instead of being made rectangular, had oblique sides, so that, when the water was shot in, it struck the side inclined inwards, and was not so readily spilled over the tops. It was, I understood, on account of the difficulty of making stone-ware sinks of that kind, that Professor Baeyer used oaken troughs, which he says, in his published account of the laboratory, answer fairly well. There is one slight disadvantage about the use of stoneware, owing to the liability of fragile glass vessels to get broken, for of course if they strike against a hard non-yielding substance they are apt to get fractured; there is an advantage in the use of wood on that point. I shall try to get over that in my case by putting, at the base of the sink, a very thin movable slip of perforated india-rubber.

Much has been said about the use of the sulphuretted-hydrogen closets and properly so, because they are very essential in the fittings of a laboratory. With respect to their working, it is an excellent system to have a large store of sulphuretted-hydrogen, but, as evolved from gasometers, it has this disadvantage: it is almost impossible to properly regulate the currents through the various liquids into which the gas may be passing at any one time. What I mean is that supposing you have a very small volume of liquid of only 2 or 3 inches in depth, such an amount for example as a student engaged in qualitative analysis may have to deal with, and that you have side by side with him a student engaged in quantitative analysis, who may have large beakers full of fluid, the qualitative student gets far more gas than he wants, and the quantitative student gets very little.

E. T. THORPE.

[Remarks by Professor Armstrong, Ph.D., F.R.S.]

A Paper like this is a little likely to mislead, inasmuch as Mr. Robins has brought forward principally what may be called high-class examples. Most of the requirements for ordinary school laboratories are not so extensive as those of laboratories of the class mainly dealt-with in the Paper, and if anyone would follow Mr. Robins, and deal with the question of school laboratories, and would point out what can be done in providing for their more modest requirements, material service might be done towards introducing experimental science-teaching into our schools. Unquestionably every school in the country will, within a few years, have its physical science laboratory. There are certain points which have not been dealt with in the Paper, notably, the lighting at night. Up to the present time it has been customary to employ single burners. In my opinion it is very important that we should get rid, as far as possible, of the products of combustion from the gas-burners, and economize as much as possible in the use of gas. At the present day we know certain very improved methods have been introduced, and that we can get almost double as much light out of our gas as we do by the use of ordinary burners, and that we can so burn our gas as to entirely withdraw the products of combustion. Another point of great importance is the provision of regulators on the gas supply. It is very well known that, when you increase the pressure of gas, you do not get an increase of light in proportion to the increased amount of gas burnt. Therefore it is essential that these governors, of which there are now numerous efficient forms, should be used to regulate the gas supply. But certain points have to be taken into consideration when this is done. In the first place it is necessary to have larger mains—otherwise the supply is not sufficient; and it will be necessary to abolish sun-burners, as in order to maintain the flame horizontal it is necessary to burn the gas at a high pressure—about 1½ inches at least. I have met with two cases lately in which it was attempted to use governors, but they were soon discarded because then it became impossible to make use of the sun-burners.

HENRY E. ARMSTRONG.

[Remarks by Professor Perry.]

The construction of the black-board will probably not have been sufficiently evident from the drawing [see Illustn. xii], and as it is of some importance in connection with the hanging of all heavy objects, which ought to move up and down easily, I will describe the principle of Professor James Thomson. It is absolutely necessary that the lecturer should not rub out a mathematical formula until the end of the lesson, and this requires a very long black-board, the longer the better. As one who has to teach mathematics, I should say that a black-board ought not to be less in length than 30 feet. A long black-board is usually fixed to the wall. You can write, perhaps, at from six feet from the ground to three feet, but it saves much mental worry to be able to write all formulas at about five feet from the ground. It is therefore of importance to move the whole of the black-board up and down with a touch of the finger, as Professor James Thomson's arrangement enables you to do, instead of doing what might suggest itself at once to everybody: hanging the black-board by two chains over four pulleys, and having a very heavy balance-weight for the whole of the board, which involves a most tremendous amount of friction. We hang the ends of the well-framed board by two chains from the long arms of two levers. The shorter arms of these carry a heavier balance-weight, and the only places where friction can occur are the fulcrums of the levers. This allows a very large motion of the board for a small motion of the balance-weight, and is exceedingly convenient. When these fulcrums are slightly oiled, a touch of the chalk at any part of the board is sufficient to lift the black-board. I put this before the members, because I am quite sure that there are many cases in which heavy hanging things have to be put up, and in which this simple principle might conveniently come in.

JOHN PERRY.

HEATING AND VENTILATION NECESSARY FOR APPLIED SCIENCE INSTRUCTION BUILDINGS.

By Edward Cookworthy Robins, F.S.A., *Fellow*.

IN the design of apparatus intended to heat and ventilate buildings destined for the purposes of technical education, a powerful and constant system is essential and should be capable of ventilating both in summer and winter without the assistance of the general heating apparatus; and in consequence of the delicate and sensitive appliances employed in many experiments, the position of the radiating surfaces and their composition must be taken into consideration. In addition to ordinary room ventilation for the removal of the expired air and gas lighting, special means for the removal of noxious fumes generated in the laboratories for experimental chemistry has to be provided. The description of the means adopted in four of the latest applied science buildings may therefore be useful, namely: the Finsbury Technical College, the Central Institution (South Kensington), the Yorkshire College (Leeds), and the Merchant Venturers' School (Bristol). The Finsbury College is exceedingly compact in plan, while at Kensington the frontage of the Central Institution is over three times that of Finsbury College in length, and is of greater depth; but both buildings have a solid internal construction, while the Bristol example, though very compact in plan, presents very little solid wall in its interior arrangement for the passage of ventilating flues and shafts. The Leeds College is straggling in plan and, on account of the varying heights presented by the section of the several parts, presents difficulties for the arrangement of the apparatus quite different to all the others. Three of these examples, viz.: Finsbury, Kensington and Bristol have all been calculated on the same basis of temperature and volume of fresh air for ventilation, viz.: 60° Fahrt. in the class rooms, and 55° in the entrances, staircases and corridors during an external temperature of 25° Fahrt.; with a ventilation equal in volume to 700 cubic feet per person per hour for the class rooms, and 3000 cubic feet per person per hour in the chemical laboratories and draught closets. At Leeds these liberal terms could not be attempted because funds were limited, and therefore only 350 cubic feet per person per hour has been adopted as a basis for the class rooms—the basis for the laboratory being left intact. At Kensington and Leeds the heating apparatus consists of steam radiating chests, while at Finsbury and Bristol the heating surfaces are high pressure hot water tubes, but as each apparatus is distinct in its character, a separate special description is necessary.

Finsbury Technical College.*—Here, as already stated, the apparatus for heating the building is on the high pressure principle, and is constructed for warming by means of "propulsion." The heating power is capable of being directed in its effect, solely or chiefly, to those parts of the building in use for the time being; while at the same time the capacity

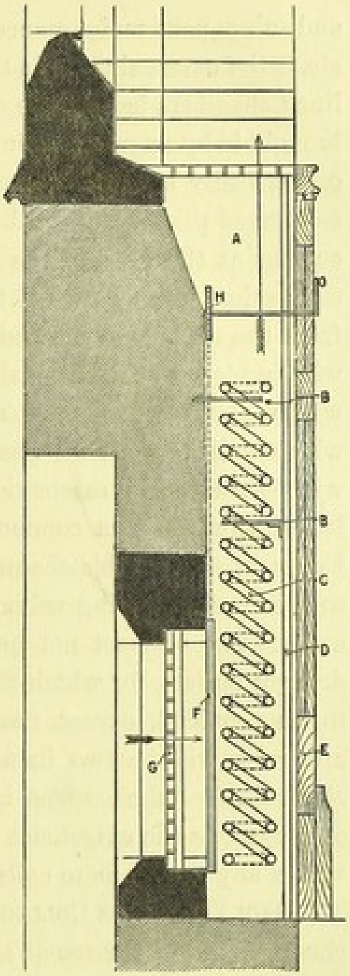
* See, for the plans of this building, Illustns. v-viii.

of the apparatus to, at any moment, suddenly raise the temperature of any portion of the building is notably increased. The heating surfaces (consisting of 13,000 feet run of wrought iron tubing $1\frac{5}{16}$ in diameter), have all been massed in a central hot chamber in the basement [see basement plan], through which fresh air in considerable volume (viz. 750,000 cubic feet per hour), is driven by a screw-fan of Schiele's construction, working silently and making 250 or 500 revolutions per minute. The fresh air thus propelled is heated in this chamber to a temperature of 102° Fahrt. (the heating surfaces or pipes have a mean temperature of 237° Fahrt.), and passes along horizontal channels under the basement floor, from which it is distributed over the building and into the several rooms by means of vertical shafts in the walls, in quantities proportionate to the volume of ventilation it is desired to effect, and to the extent of the cooling surface they severally present. As already mentioned, the apparatus is constructed to yield a general temperature of 60° Fahrt., while the external air is at 25°, and with the normal power of ventilation. Since, however, this difference of temperature is of but rare occurrence (the mean winter temperature for England is 39° Fahrt., or about 14° higher than the accepted base), the heating surfaces have been distributed over two furnaces, of which one or other, or both, may be used as circumstances may dictate. The fan employed is capable of delivering twice the cube of air necessary for winter ventilation, so that in summer the volume delivered into the building can be notably increased. Since in the case of such an apparatus the intake of fresh air is due to mechanical force, the extract has been left to natural means. Flues have been carried up in the walls to the roof of sufficient area to carry off the volumes of air intended for summer ventilation with the velocity arising from the impulse of the fan at the mean summer temperature; and since in the winter the velocity in these flues would be in excess of what was required, the openings into them from the rooms have been provided with closing-gratings, thus providing the means of regulating the egress. The reason for adopting the high-pressure system in preference to any other for the heating is, that by the use of short circuits, and many of them, this apparatus can be constructed to be almost instantaneous in action, attaining its full heat within twenty minutes from the time of lighting the fire, cooling as rapidly also when the fire is extinguished.

Central Institution at South Kensington.*—This apparatus, though very similar to that already described, as far as the bases adopted in calculating for difference of temperature, &c., are concerned, is widely different in system and method of application. The southern wing of the building is only partially constructed, and the system adopted has therefore been chosen with a view to its later extension; and although the limits of the present construction might have permitted of the use of a common hot chamber, its future size altogether excluded the adoption of such a means of warming, and even its present size would have rendered necessary an enormous loss of temperature to the hot air passing along the channels, so that it would no longer have been either desirable or economical to adopt such a system of heating. Messrs. Bacon therefore designed and executed a system of steam heating apparatus with separate hot chambers for each room. These hot chambers are arranged in a row along the basement corridor, and contain the requisite amount of heating surface, consisting of cast-iron ribbed steam chests, jointed together with flanges and bolts with an asbestos ring between by

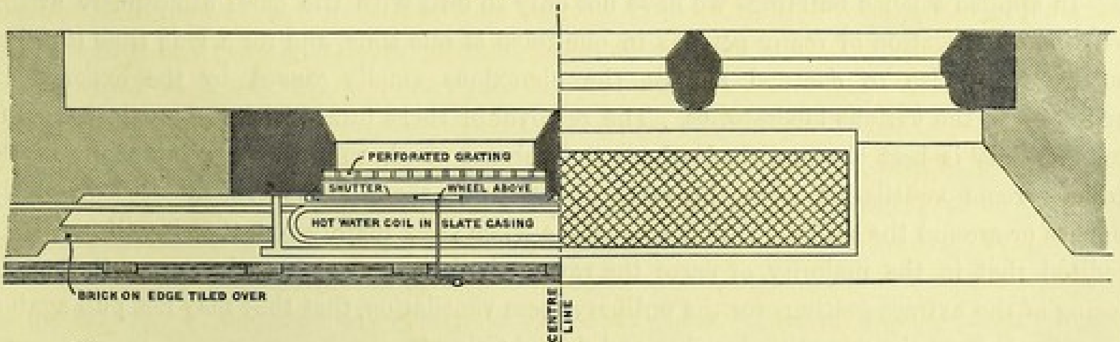
* See, for plans of this building, the Transactions, 1882-83, Illustns. xxxix-xliii, attached to Mr. Robins's Paper on "Buildings for Applied Science and Art Instruction," page 81 of that volume.

way of packing. Each group is fitted with valves for its exclusion from the rest of the system, and is supplied with fresh air from a pressure chamber extending over the whole corridor, into which the air is driven by a large screw-fan as in the former case. Throttle valves are provided to each cold air downcast, so that the supply can be regulated according to the temperature of the room served, which it is proposed to indicate by distance thermometers connecting the rooms with the groups themselves. The section of the warm air upcast shafts is in every case calculated according to the normal temperature of the warm air escaping from the hot chamber, and the volume of such air which is to be delivered into the rooms. The distributing steam mains will be placed overhead in the pressure chamber already described, while the condensed water returns to the reserve tank, placed in channels under the floor. The apparatus is provided with pressure reducing valves, limiting to two atmospheres the pressure of the steam escaping from the boilers to the several groups of heating surfaces, while steam-traps on the condensed water returns prevent the waste of steam. The extraction of foul air is in this case also due to natural means; the various upcast shafts being arranged in groups one over the other, concentrated in a common central shaft ever increasing in size as they rise. The extraction from the laboratories, &c., is specially provided for by a powerful fan, twice the power normally intended, so that a strong summer ventilation may be readily obtained.



Section.*

The Merchant Venturers' School at Bristol.—In this building, the necessity for keeping within limits of expenditure dictated by economy, together with the very light nature of the internal construction, precluded the adoption of an indirect heating apparatus and rendered desirable the direct application of the high pressure system, which is more economical in first cost



Half-plan through window-back, showing coil casing, &c.

Half-plan of window-board, showing air grating.

* A. Warm and cold fresh-air chamber; B. Baffle plates; C. Wrought-iron coils; D. Slate casing; E. Oak panelling; F. Shutter; G. Fresh-air inlet; H. Wheel for opening and closing shutter (Bristol example).—E. C. R.

and subsequent maintenance than any other. The heating surfaces will therefore be distributed along the external walls in the form of coils, which will be placed in the window-backs in slate-lined chambers behind the oak dados [see the two marginal illustrations]. The fresh air being brought in by external gratings through internal regulating valves working in grooves horizontally or vertically as the case may require. On passing into the coil chambers the fresh air is conducted past horizontal baffle plates over the hot-water pipes entering the rooms in a vertical current at the level of the window sills; well warmed in winter and cool in summer. The connection pipes between the coils will be carried on cast-iron standards projecting 2 inches from the walls over all, and will in all cases be arranged for two flows and two returns, which will be placed behind the skirting, covered with asbestos lining, so as to heat only by the coils which are under control. The hot-water pipes will be charged with a non-freezing solution which will prevent all possibility of accident through frost. The extraction of expired air will be effected by mechanical contrivance, and for this purpose all the extract shafts will be led downwards to a common collecting horizontal channel under the central corridor of the basement floor. This channel is graduated in size towards the screw-fan actuating the current to the ever increasing volume carried, and the increasing velocity due to the extractor. This extract fan will act not only in the ordinary ventilation, but also in the laboratories and draught closets, for which therefore in this case no further special means of extract will need to be provided, except that the flues will be tarred inside. The furnaces for the heating apparatus will be two in number, each furnace working, as far as arangements will permit, about half of the surface in each room, so as to allow of one or the other, or both being employed, as the exigencies of the external temperature may demand. By the use of four-way valves any one or more coils may be disconnected [see Illustn. i.].

THE YORKSHIRE COLLEGE AT LEEDS.*—The apparatus for warming will be by steam heating chests placed in the rooms themselves, with fresh air passed over them, similarly arranged to the hot-water coils at Bristol. As at Kensington, each group will be provided with valves for regulating the temperature; and the pressure of steam in the whole apparatus will be limited, by aid of pressure reducing valves, to two atmospheres.

LABORATORY VENTILATION.

In applied science buildings we have not only to deal with the close atmosphere arising from the congregation of many persons in one room at one time, and for a long time together, but we have also to contend against the obnoxious smells caused by the experiments carried on in the various laboratories. The removal of these fumes with the greatest rapidity and certainty is best accomplished where the current of air in the extracting shafts of the ordinary room ventilation is in the same direction as that of the draught closets on the benches or around the walls. This is so obvious when thus plainly put, that it will hardly be credited that in the majority of cases the reverse is the practical fact, thus necessitating the closing of the extract gratings for the ordinary room ventilation, that they may not pull against the extracts from the operating benches and draught closets.

The velocity at which the extraction of air should take place in the draught closets is not less than 5 feet per second. To ensure this draught at a constant velocity, it is necessary to

* See, for plans of this building, the TRANSACTIONS, 1882-83, Illustns. xliv, xlv.

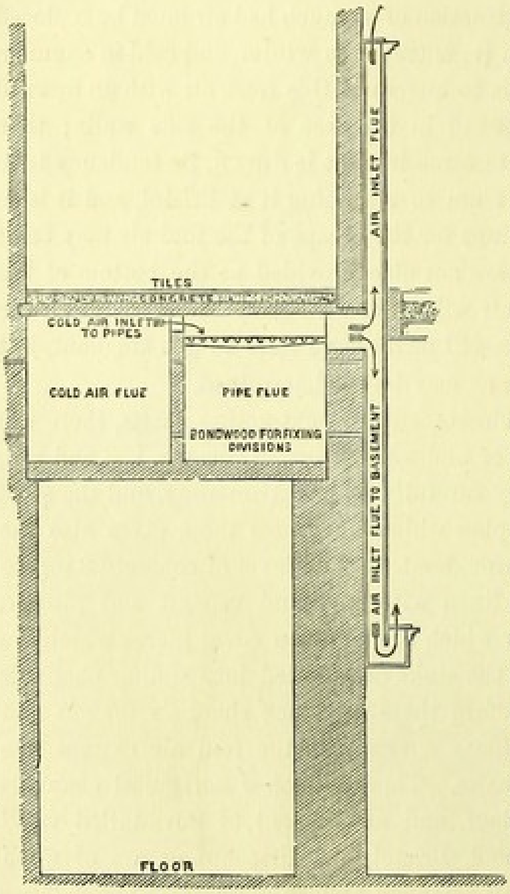
be independent of casual winds and changing temperature as a means of motion. This requires the employment of certain apparatus to produce either a propelling or a sucking force, of which the latter is usually either a common upcast shaft, heated at its base by a furnace, or the product of furnaces, attached to engines or heating apparatus. Neither of these, however, can be depended on for constancy, and therefore the best agency is a fan; the rotation of which, propelled by a steam, gas, or electric engine, where water power is not available, steadily exhausts the air from the air-channels and establishes an upward and outward current in the shaft from the point at which it debouches. The position in which this extract fan is placed in the shaft, determines whether the vertical warm air-channels shall have an ascending or descending current established within them before reaching the shaft. If placed below the basement and at the foot of the shaft, the current will be descending—if placed at the roof level the current will be ascending—to communicate in each case with horizontal channels, graduated in size, till they reach the spot where the fan is situated.

In many cases on the Continent there are fans both above and below, as at Geneva; in others above for the draught closets only, and a furnace below for the room ventilation. This is the case at Munich, for example, with the result I have already mentioned, but I should explain, that fresh air is separately admitted to the draught closets as well as the room, and it was thought that this would overcome the difficulty, but it does not in practice, and we should take warning. Of course it is apparent that the extraction of so much bad air must be replaced by a corresponding amount of fresh air, warmed on its entrance in winter, and cold in summer, the only way I know of to prevent cross draughts is to introduce this fresh air with an upward current through vertical shafts, or openings not fixed in the face of the side walls; then whether you force the air in by fans or leave it to come in as it is drawn, its tendency is to rise before mingling with the air of the room. I am so arranging it at Bristol, and it is so introduced at Dundee. In summer the room openings for the escape of the foul air may be at the top of the opposite wall, but in winter, if they are not also provided at the bottom of the room, so that the upper can be closed, the warm air will be carried away before warming the room; in either case the air will be pure, because it will never have time to get stagnant, but will always be changing as many times in the hour as may be predetermined.

Between the operating benches and draught closets, and the extracting shafts, there are horizontal foul air channels of communication over or under the floors. [Illustns. i, ii and viii, *ante*]. At Finsbury the channels were arranged very carefully by Dr. Armstrong, and the sizes were calculated by Messrs. Bacon & Co., and the plan which illustrates them gives also the exact graduated width, the depth being the same throughout, set in a layer of concrete 8 inches thick over the fire-proof floor of the laboratory, lined with Portland cement and pitched inside and covered with plate glass puttied in, over which are the iron cover plates which are flush with the floor. At Finsbury the wastes from the sinks are carried into similar channels to the out-fall pipe; and as at Munich and Strassburg there are other channels for gas and water piping, these channels of course have no glass covers like the foul air extract flue channels; the foreign examples are lined with asphalte. There are other horizontal channels at Finsbury which are above the level of the floor, and are formed of dove-tailed wood pitched inside. At the Merchant Venturers' School, Bristol, the air-channels are of wood pitched inside, and with slight variations will be all arranged under the floors, in the manner shown in the drawings of the topmost floor of that building, showing the arrangement of the rooms, the fittings, flues and waste water pipes.

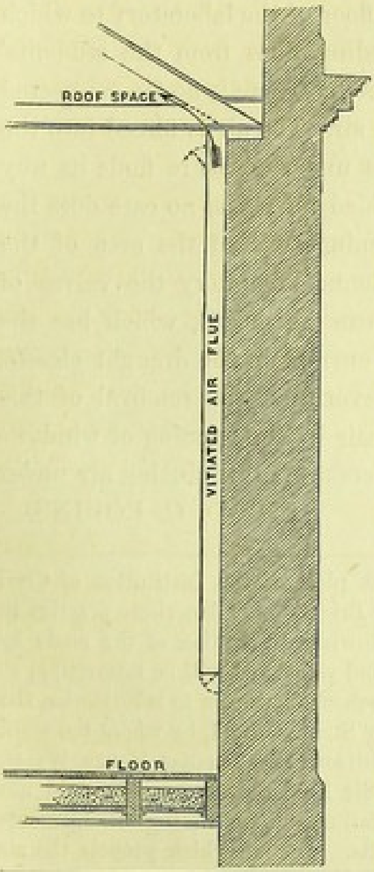
In the Finsbury College, the general ventilation of the chemical laboratories is effected by the bench draught flues, to prevent any counter-action by subsidiary extract shafts. These bench flues will have their openings about five feet from the floor, and be covered with sheet-iron and glass hoods. Their exact form, and the detail of their appurtenances, have been decided by Professor Armstrong after a series of exhaustive practical experiments; each flue is in direct communication with horizontal channels running underneath the floor, radiating towards the ventilating shaft. In the case of the four schools described, the area of the flues and channels have been carefully calculated by the aid of Professor Wolperts' elaborate formulæ, at every juncture, with reference to the probable velocity to be attained, and the quantity of air to be carried per second. As an example of the sort of calculations involved, the table prepared for the school at Bristol is hereto appended. The cost of the apparatus exclusive of the bench and floor and wall flues, the mason and carpenters' work and painting amounts to £4,000 for Kensington, and about £2,000 each for the other three buildings.

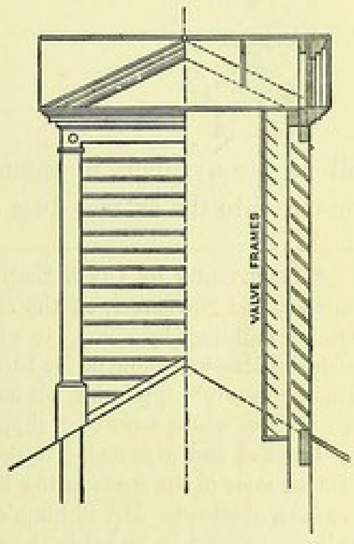
The application of this principle of forcing in air, and leaving it to find its way of escape by any outlets designed or undesigned that may exist, has been applied to the new Chemical Laboratory at Dundee. There the mode of ventilation is known as Cunningham's, and the heating by Perkins's system of wrought-iron piping at high pressure. The machine chamber, situated in the basement floor, is a large room, and contains five of Cunningham's air pumps driven by a two-horse-power Otto gas engine. The fresh air is taken in by two inlet shafts at the back of the building, carried up almost to the height of the eaves, the upper portions of which are louvre-boarded. The pipe and air flues are placed as far as possible under the ground-floor corridor, and are 3 feet square, but those under the laboratory and lecture theatre are 3 feet deep and 4 feet 9 inches wide, and all the air flues have openings into the machine-room. There are twelve pipes abreast in the 3 feet and twenty-four pipes in the 4 feet 9 inches flues. The pipes are placed at 6 inches from the top of flues, and are supported on notched cast-iron brackets. There are two furnaces employed in heating; the pipes from No. 1 are taken in one direction through the flues, and the pipes from No. 2 in another, made to have the flues equally heated. When the weather is mild one furnace may only be used. The flues are formed of brick with concrete bottom, and covered with pavement flags



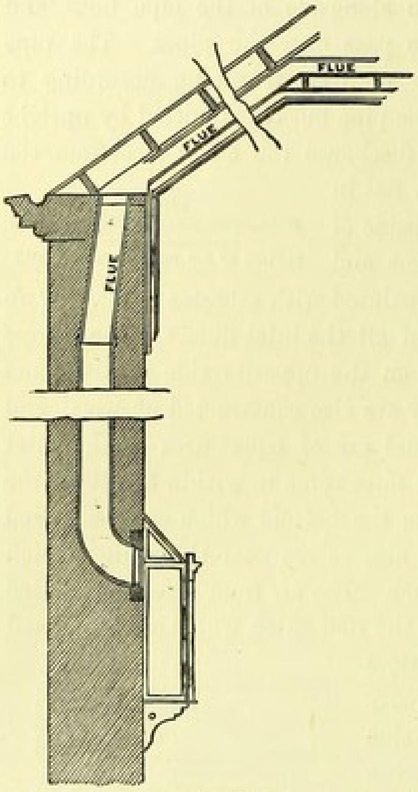
jointed with cement. The air flues are in all cases run alongside of the pipe flues, and openings are left in these at stated places for the air to pass over the pipes. The pipe flues have also close divisions to regulate the number of feet of piping according to the size of the room to be heated. The heated air from the pipe flues is admitted by upright inlet flues placed on the walls of the rooms, and these discharge the air 5 feet from the floor in an upward direction. These flues are made very flat in order to diffuse the air well and prevent draughts. The inside of the whole of these upright flues, and all the close divisions and other wood-work in the pipe flues have been thoroughly painted with asbestos paint. Wire netting, half-inch mesh, has been placed over the mouths of all the inlet flues.* The *extract* flues are placed generally on the opposite side of the room from the inlet flues; they are also constructed of wood, and are placed on the walls and are of equal area to the inlet flues in the rooms. These flues come to within 2 feet of the floor, and have a valve on the bottom which can be closed when required; they have also valves near the ceiling which will only be used in summer. The air from these flues is led into larger flues formed in the roof space, which are connected to louvre--boarded ventilators placed on the ridge of roofs. These ventilators have value frames placed about 6 inches from the inside of the louvre boards, and are formed into squares of about 4 inches. Each square has a valve or flap of indiarubber cloth, which shuts when the wind blows and the opposite side from the wind opens. The area of the openings in each side of these roof ventilators is equal to the area of the whole of the exhaust flues

SECTION OF AIR INLET FLUE IN ROOMS





* Sir Frederick Bramwell remarked that architects as a rule thought more of extracting the foul air than of supplying fresh air, and were satisfied with making holes in the roof for its exit and none for its entry; whereas he would reverse that operation, and provide for the inlet of fresh air, leaving to its own sweet will the manner of its escape. In all the examples referred-to in the present Paper the architects have considered the introduction of fresh air as, at least, of equal importance to the extraction of the foul air. I may also refer to the system successfully applied by me to the meeting-room of the Society of Arts, with the approval of Sir Frederick, which earned for me the formal thanks of the Council when the late Sir William Siemens was Chairman. Here the fresh air enters by five inlets, and, passing over warmed piping, is admitted through an iron grating 6 inches deep, extending the whole length of the north, and part of the east side of the hall, at about 10 feet from the floor. Moveable horsehair screens are placed at the inlets, to filter out the impurities in the air which might otherwise damage James Barry's pictures. A coil of hot-water pipes, situated in a shaft above the level of the ceiling, extracts the foul air through the openings in the ceiling by means of zinc connecting channels, assisted by the central sun-burner.—E. C. R.



connected with it, so that when two sides are closed by the wind the other two allow the vitiated air to escape. The whole of the evaporation niches, stink hoods and closets of students' tables in the building are connected to the large air flues in the roof space by fire-clay pipes built into the walls, and by lead flues from the wall heads to the flues in the roof. The draught from these different places is found to be excellent. The quantity of air forced into each room is calculated to renew the whole air in the room at least every twenty minutes. There is a horizontal flue under the floor of the laboratory to which the whole of the descending flues from the students' working tables are connected. There is no fan connected with the discharge of the air. The air is forced into the rooms, and being always under pressure finds its way out at the openings provided for it; in no case does the area of the exhaust openings exceed the area of the inlet flues. In the students' laboratory the valves of the exhaust ventilators can be closed, which has the effect of increasing the current in the draught closets, &c. It is obvious however that the removal of this pressure of the incoming air by the opening of windows will be inconvenient in summer time, but this might be overcome by introducing air under pressure into the extract flues of the draught closets.* EDWD. C. ROBINS.

* INSTITUTION OF CIVIL ENGINEERS.—An interesting discussion took place at the Institution of Civil Engineers last November, on the reading of a Paper by the late Robert Briggs, on "American practice in warming buildings by steam," to which I must refer the reader. The following description of the mode by which the Meeting-Room of the Institution of Civil Engineers is warmed and ventilated will be interesting, as giving an example applicable not only to the large lecture halls of science schools, but even to laboratories, the particulars of which have been supplied to me by Mr. Phipson, of Salisbury Street, Strand, by whom the work was designed and executed. It should be noted that, had not the architect, Mr. Thomas Henry Wyatt, sacrificed some of the space in the lower rooms, the result mentioned by Sir Frederick Bramwell would not have been obtained. Mr. Phipson's experience has convinced him that failures in ventilating arrangements can in many cases be traced to the want of sufficient area in the inlet shafts. The fan which propels the air is worked by a Ramsbottom patent water engine, driven direct off the high pressure water main. The air shafts leading from the fan are so arranged that, by working a valve, the air propelled and forced into the building can be either passed through the heating chamber containing coils of hot-water pipes, or direct up the air shafts to the meeting-room. On a level with the meeting-room floor a secondary or distributing chamber is formed by utilizing the space under the raised platform of the rising seats, and the air from the fan being distributed on the three sides of it. The perforations from this chamber are calculated to supply a volume of air to the meeting-room equal to six times its cubic contents in the hour, diffused at a velocity not exceeding six inches per second. No special means for carrying away the vitiated air are provided except the usual outer shafts around the sun-burners that light the room, the area of these outlets being much less than that of the inlets. By this you will perceive that the principle adopted is to ensure a supply of fresh air equally diffused, that any stagnation of vitiated air is improbable, for though the outlets around the sun-burners are not equal in area to the inlets, the pressure maintained ensures an outlet at other points, and thus prevents any local inlet currents of air from the exterior of the meeting-room.—E. C. R.

[Remarks by Mr. W. W. Phipson, Ventilating Engineer.]

The principle at the Bute Hall, Glasgow, is somewhat similar to that employed at the Institution of Civil Engineers. The object of this apparatus is to ensure in Halls and Assembly Rooms an outward current. We all know as a fact, that an inward current into a Hall or Assembly Room follows the opening of a door; in comes the air and there is a draught, but by increasing the inward pressure by means of a fan, and having few outlets less in area than the inlets, the air then finds its way out through the nearest openings. The last time I was at the Bute Hall, Glasgow, although there was a very strong wind blowing against the windows on the one side, I put the fan to work; Sir William Thomson happened to be present at the time, and we very much doubted whether it would be possible to overcome the inlet draught caused by the high wind, which was then very strong, for the University is built on a high site in Glasgow, but imperceptibly the air was blown out through the windows by the action of the fan, and this was very satisfactory. In order to overcome any prejudice that might exist as to the outlet of the air, there are four turret stair-cases, and in them a provision is made at the level of the floor for allowing the air to escape, so as to prevent any stagnation in the room. There must be an outlet of some sort, and after all the doors and windows were closed, then the outlet would naturally be through the openings near the floor at the staircase. Again, I have had a rather difficult problem set me at the new Medical School at Edinburgh. There we are to have a good many draught closets in the chemical department, and although I find at present a little difficulty in getting horizontal draughts in what are called the experimental tables fixed in the centre of the Laboratories, yet with the side draughts I have no difficulty, and I find that in one simple draught for the side closets, going direct down the wall and communicating immediately with the underground flues to the main shaft, I got as much as 8, 9, and 13 feet per second velocity, and I am convinced that if the draught is less than 6 to 8 feet in these horizontal draught-chambers, the chemical fumes will not be removed sufficiently for the requirements of the professors. I have tried the horizontal experiment tables in the same vertical shafts: the velocity was reduced to 4 or 4·8, as nearly as my memory can carry me. The chemical fumes produced by the professor, for the purposes of this experiment, were far more powerful than those which will usually have to be dealt with, and nearly the whole of the fumes were removed with the velocity just mentioned, but certainly no velocity under 5 or 6 feet per second will remove them entirely.

W. W. PHIPSON.

[Remarks by Professor Perry.]

With regard to ventilation, I may remark that the velocity at which the air is passing through an orifice in a certain neighbourhood gives us really very little information as to the amount of draught in that neighbourhood. Of course, we know that, if the orifice is small, we shall have much greater velocity, so that we ought to have a little more information as to the size of the orifices before considering whether a certain velocity of air is sufficient for removing chemical fumes. I think that Dr. Armstong found that 4 or 4½ feet per second was quite sufficient velocity at the orifices to produce a very perceptible clearance of the fumes. When on this subject, I may say that Professor Ayrton, three years ago, brought before the Institute some of the calculations that he and I had made with regard to draught, and he then asserted,* after giving the mathematical formula, that ventilation by the rise of heated air cannot be $\frac{1}{30}$ as efficient as ventilation by fans, even taking into account the want of efficiency in steam engines which might drive the fans. In our opinion, the ventilation of the future would, we believed, be performed by electric machines driving fans. I hope that the experiments Dr. Armstrong is making, which, I believe, are almost the first made in an actual building for the purpose of obtaining specific results with an electro-motor driving a fan, will lead architects to turn their attention to the actual method of experimenting at Finsbury. When they see the small size of the electro-motor that is required to give out two horse-power, the weight being only about 100 pounds; that it can be placed in any position; that it can give off the power at any distance from the steam engine or water wheel; and when they find that only two dangling wires need come up the outside of the house, entering the room by an opening in the window, if necessary, they will give greater attention to the suggestion of Professor Ayrton than perhaps they have done heretofore.

JOHN PERRY.

[Remarks by John Slater, B.A., *Fellow*.]

The system of exhaust closets is one of very great importance, and merely another branch of the wider question of proper ventilation of large halls and buildings containing a number of rooms. This is a subject much too complicated to discuss in a few remarks, and I only allude to it for one reason. If you have to exhaust a comparatively small quantity of air, and if the rate at which that air is exhausted is not very rapid, heat is a sufficiently powerful agent. You can have an exhaust shaft, and by burning gas-jets in it the air will be rarified and a continuous current will be set up, but if you have a much greater quantity of air to exhaust, and at a much more rapid rate, this will not be sufficient, and you must employ some mechanical means. Fans have been mentioned once or twice to-night, and hitherto they have been the only method, as far as I am aware, by which this has been accomplished, but there are certain great drawbacks to the fan, as I have had occasion to experience. The vanes of a fan are generally the weakest part of the whole structure, and the consequence is a great tendency on the part of these vanes to become slightly worn at the extremities. This will not be so much the case when ordinary air is dealt with; but cases occur in which fans have to be used for exhausting gases that have a very deleterious effect upon the metals and other materials of which the fans may be made. If the edges of the vanes of the fans get slightly worn away considerable difference is made in their efficiency. A few weeks ago I visited some large ironworks in the Midland counties to inspect some castings, and I found in operation at one of them an apparatus which struck me as the most perfect specimen of exhauster or propeller that I have ever seen. It is called the Baker patent Rotary-Pressure-Blower, and is, I believe, an American invention. It was used for the purpose of forcing air into a blast furnace, but it is quite different in action from a fan. It is impossible to describe a machine of this kind without diagrams, but it consisted of a series of three discs, which revolved one upon another within an iron casing, and its effect was very

* See the TRANSACTIONS, 1880-81, for Professor Ayrton's remarks and calculations, pp. 97-100.

powerful. I was told that these machines are made of varying capacities, and are capable of extracting from 600 to 2000 cubic feet of air per minute. The enormous advantage is this, that if the gas you have to exhaust is deleterious, it need not pass through the machine itself, but can be drawn away on one side and propelled through another aperture. If any one had to design any scheme for exhausting air or ventilating a building I should strongly advise him to see the machine to which I refer.

JOHN SLATER.

[Notes by Professor Armstrong, Ph.D., F.R.S.]

Our experience has shown that the system adopted here* of warming and ventilating the building is on the whole satisfactory, but several defects have been discovered which are partly inherent in the system and partly faults of construction. The chief merit of the system of propelling fresh air through a heating chamber by a powerful fan is its simplicity, and, provided that the flues are so proportioned as to deliver the exact amount of air required to maintain the various rooms at the proper temperature, there should be no difficulty on this score. Although calculated with the aid of Professor Wolpert's elaborate formulæ, we find in practice, by careful test experiments, that the various flues do not all deliver air at just the rate and of just the temperature which is required for the efficient warming of all the rooms, and in some we are over-heated and in others underheated. Whether this is due to a misapplication of the formulæ or to the omission of sufficient allowance for distance, or to the irregularity in the direction or formation of the flues, further experiments will probably reveal. The most serious objection to our Finsbury system arises from the fact that ventilation and warming are inseparable; in other words, if the temperature in any room be sufficiently high, and it is required to introduce more air, this cannot be done by the apparatus without also raising the temperature. It ought to be possible to admit warm and cold air in varying proportions or, which is the same thing, to increase or diminish the supply of air, and at the same time diminish or increase its temperature, so as to ventilate more sufficiently while maintaining the temperature constant.

Another difficulty arises from the large amount of dust injected into the rooms with the air. This partly arises from the fact that the flues have been "parged"—a grave sanitary mistake; but it is partly unavoidable. The interposition of a screen, sufficiently close to prevent dust being sucked in by the fan, interposes too great a resistance; we are intending to try the effect of a very fine water spray. Probably there would be much less dust had the air been taken in at a higher level—near the roof.

Graduating the flues in the manner shown by the plan of the laboratory floor (viii) has not been altogether satisfactory, and theory evidently does not quite accord with practice; the pull, in fact, instead of being equal throughout gets less and less as the distance from the extract shaft increases, and will need to be experimentally adjusted.

It was originally proposed to produce the draught in the flues leading from the benches in the chemical laboratory by connecting them with a downcast shaft which, at the basement, joins the main upcast shaft, 120 feet high, within which is a circular iron smoke shaft,

* At the Finsbury Technical College. See Illustns. v-viii.

18 inches in diameter. The waste heat from the heating furnaces and the steam boiler was to produce the necessary draught. This, however, has not been successfully accomplished, and a number of experiments which we have made seem conclusively to establish the inefficiency of the arrangement: we find that whether we allow merely the waste heat from Messrs. Bacon's furnaces, or also that from our large steam boiler furnace, or even the heat from these two sources, *plus* that from a furnace 18 inches square at the very base of the shaft, to escape into the central cast-iron smoke flue, there is practically but little difference in the velocity of the current in the downcast. The explanation would appear to be that the velocity of the current in the iron smoke shaft is so great that the smoke does not part with its heat with sufficient rapidity to the air in the lower part of the upcast shaft external to it at the point whereat the downcast is connected. This has led to the interception of the laboratory ventilation, and the results, which we have obtained with a 2-feet Blackmann fan in connection with the laboratory flues, leave no doubt, in my mind, of the ultimate success of my hood arrangement; and, in the future, mechanical ventilation will, I believe, unquestionably be the right thing for a chemical laboratory. All we require now to do is to experimentally study the conditions requisite under our system to obtain an even flow in all the flues.

HENRY E. ARMSTRONG.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS. (I).

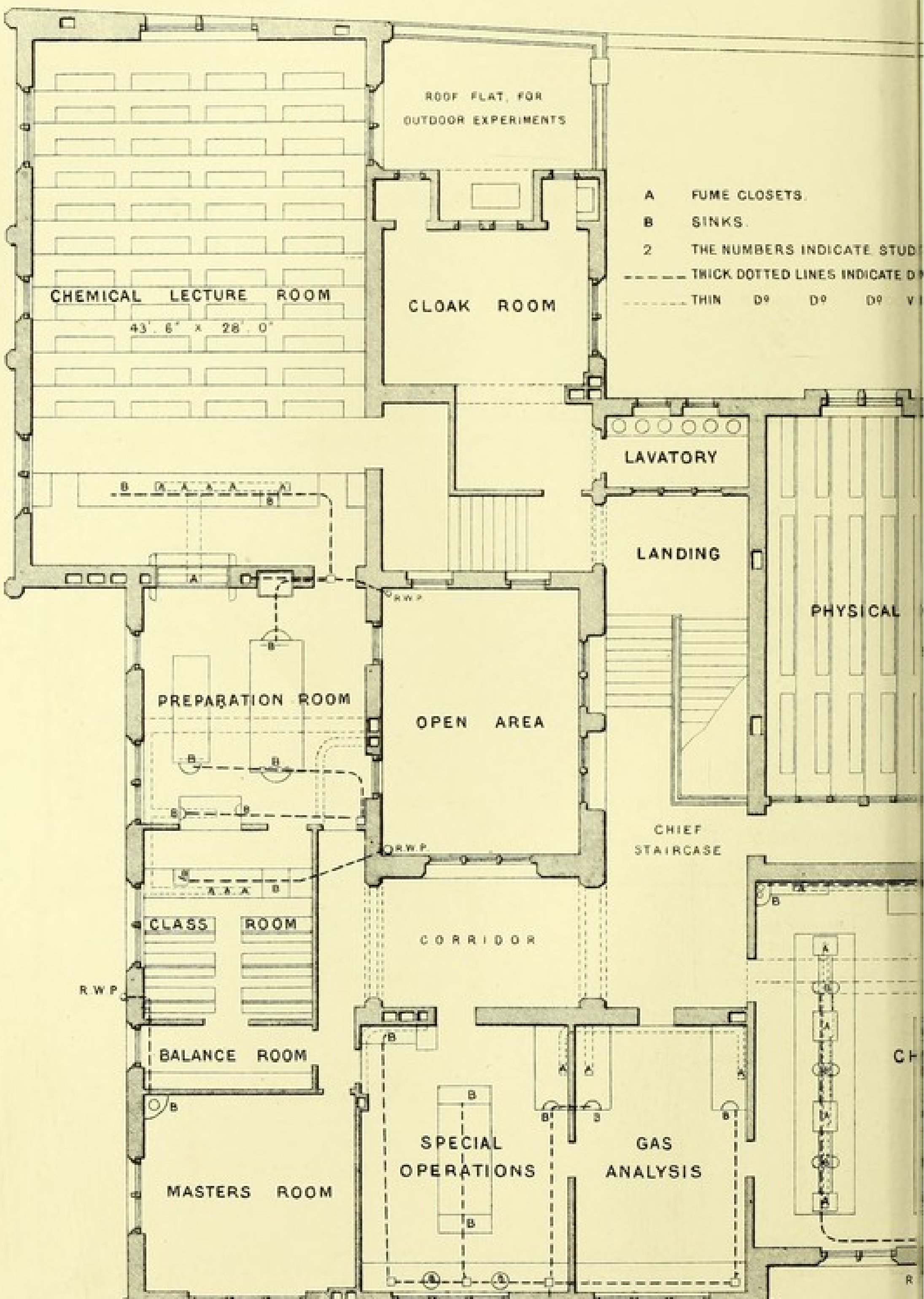
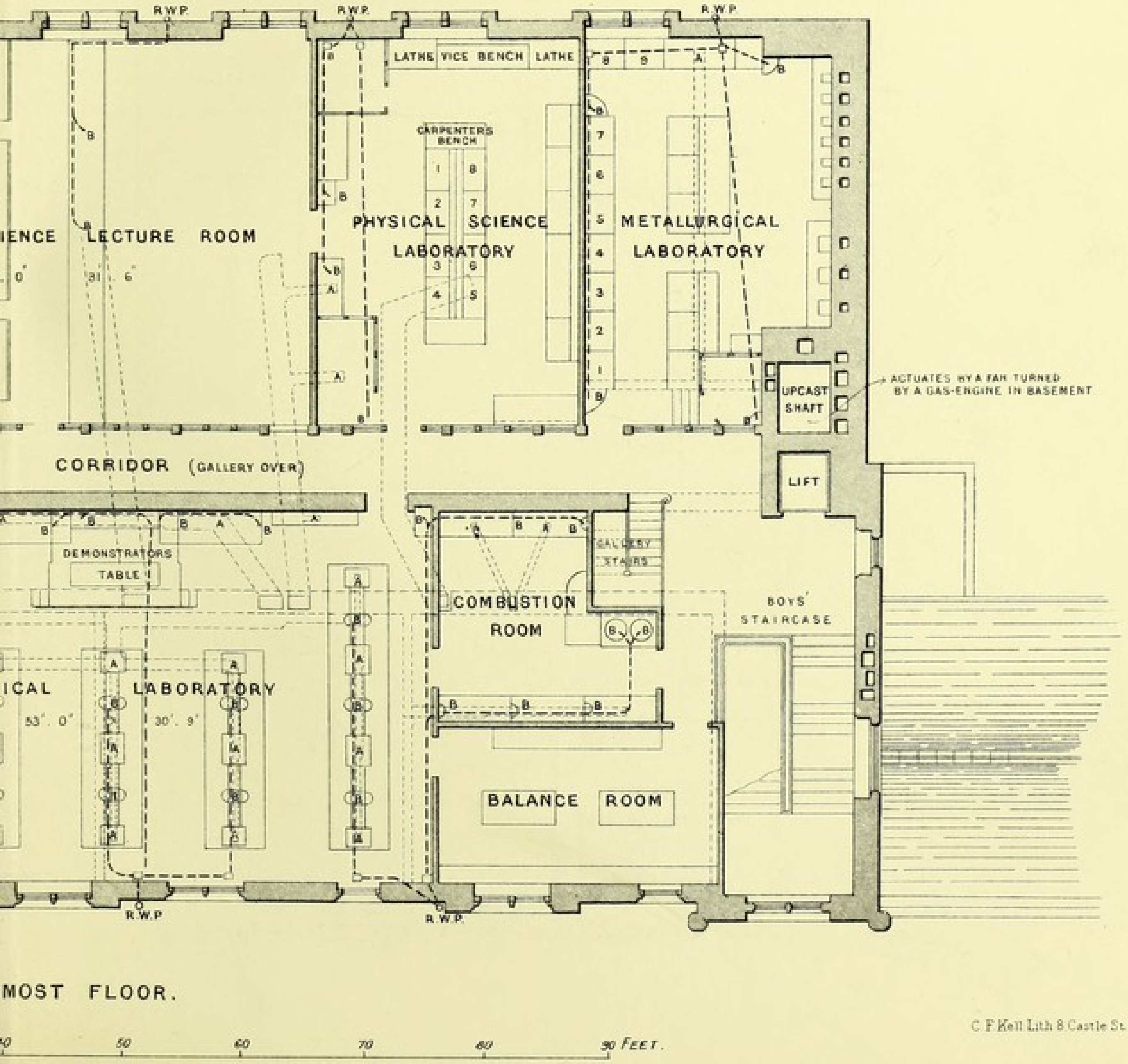


FIG. I. TO

SCALE OF 10 5 0 10 20 30

THE MERCHANT VENTURER'S TRADE & MINING SCHOOL, BRISTOL.

E. C. Robins, F. S. A. Archt.



C. F. Kell. Lith. 8 Castle St. Holborn. London. E.C.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (II)

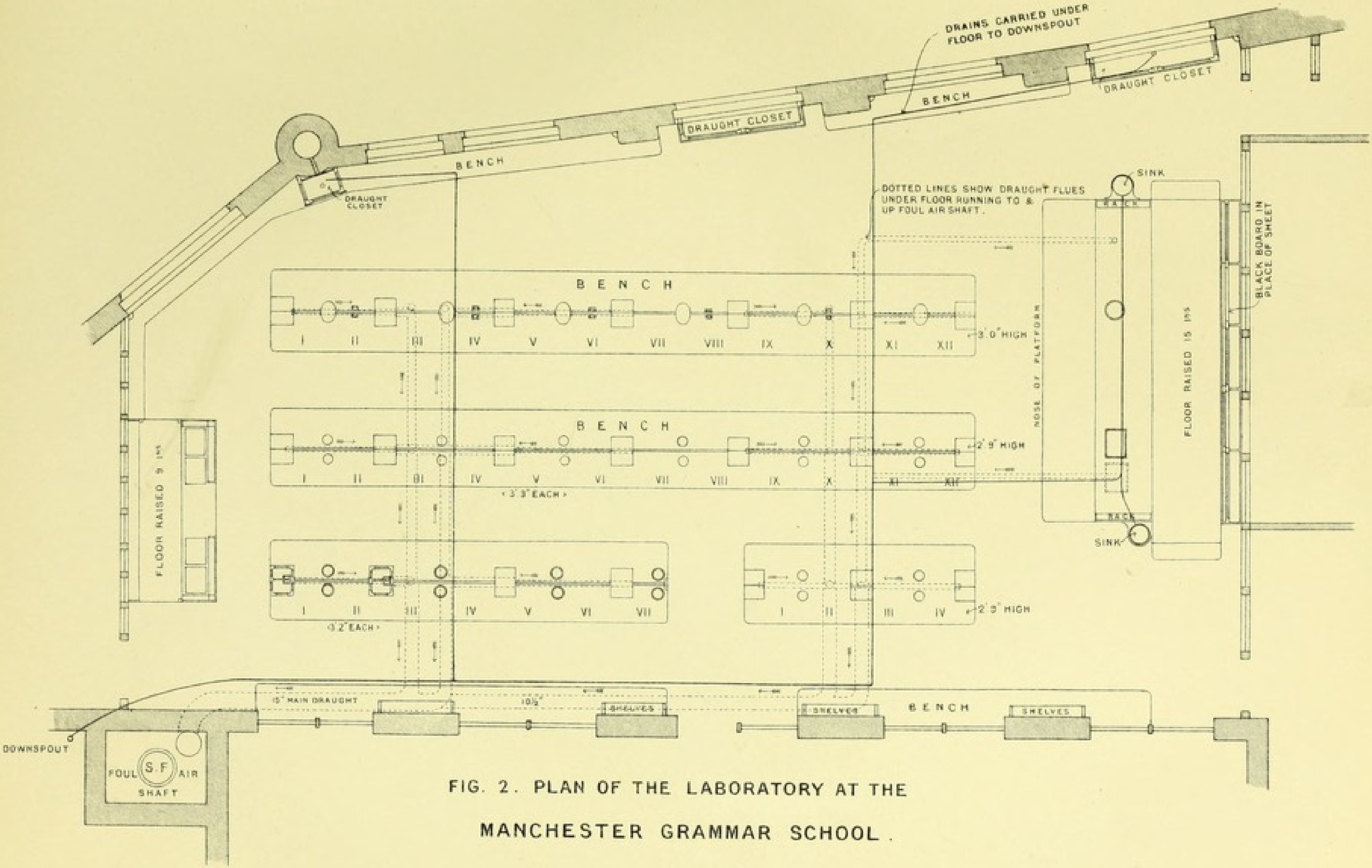


FIG. 2. PLAN OF THE LABORATORY AT THE MANCHESTER GRAMMAR SCHOOL.

SCALE.

INS 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 FEET.

C F Kell Lith 8 Castle St Holborn London E.C.

II, FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (iii).

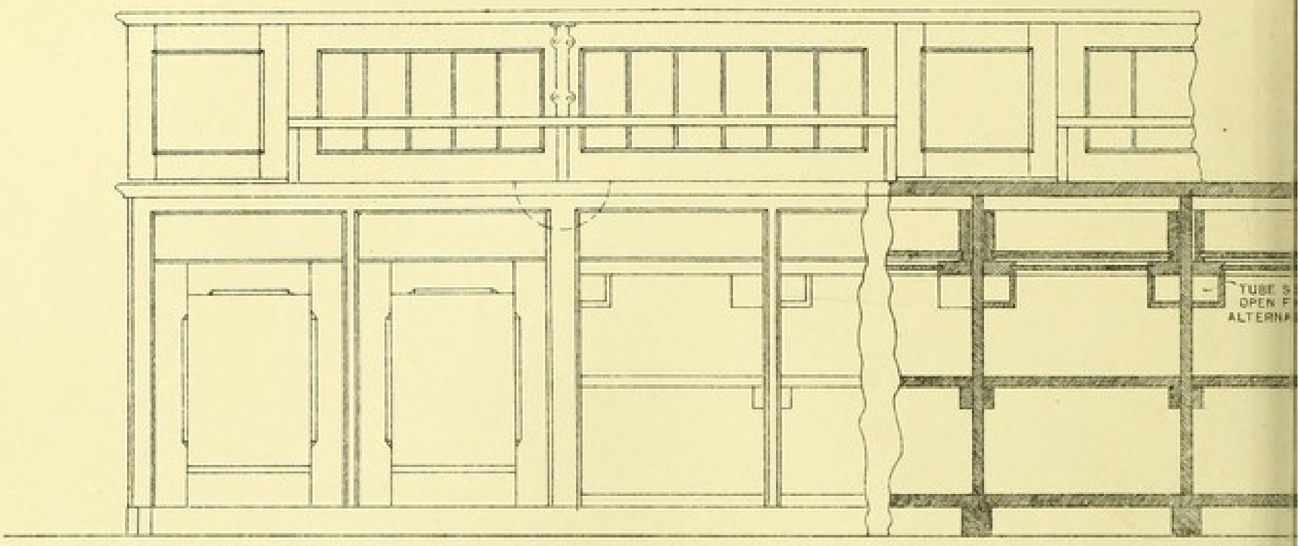


FIG. 3.
FRONT ELEVATION.

FIG. 4.
LONG^L SECTION

MANCHESTER GRAMMAR SCHOOL,
STUDENTS BENCHES.

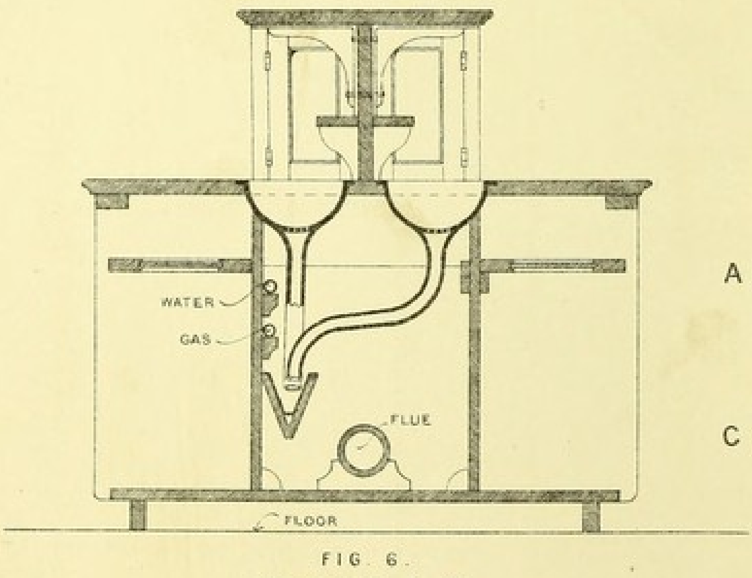


FIG. 6.
SECTION A.B.

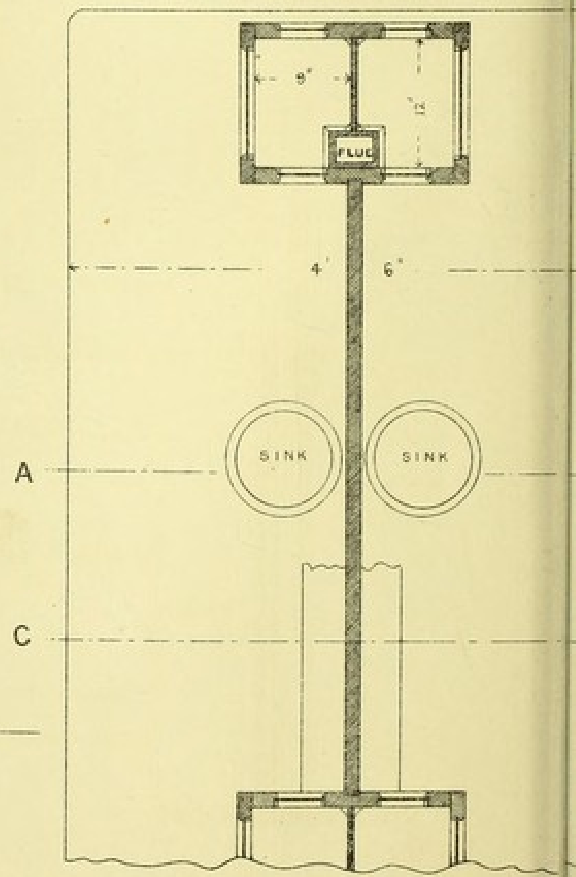
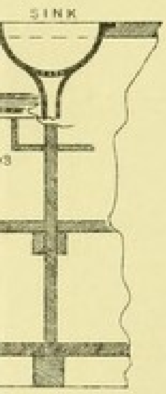


FIG. 7.
PART PLAN OF BENCH.

Sc[ale]

Ins 12 6 0 1



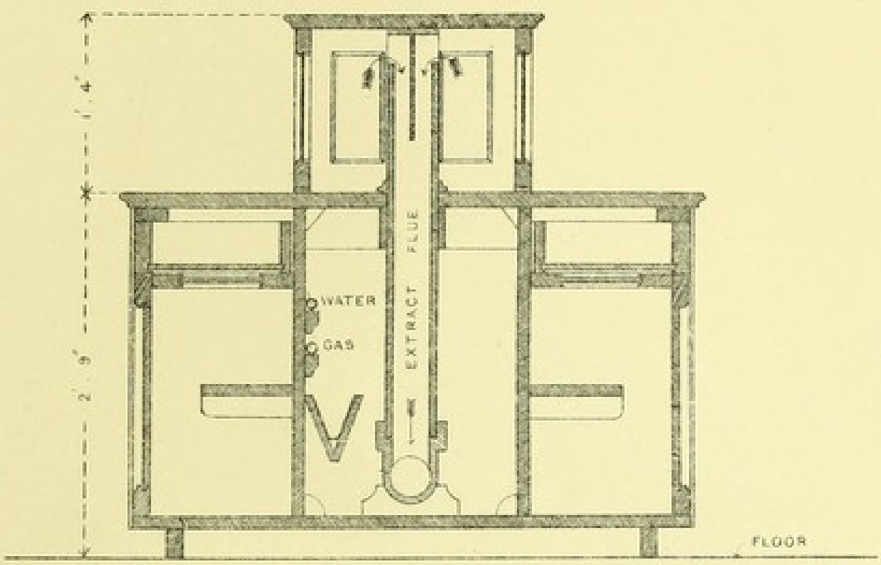


FIG. 5.
SECTION C. D.

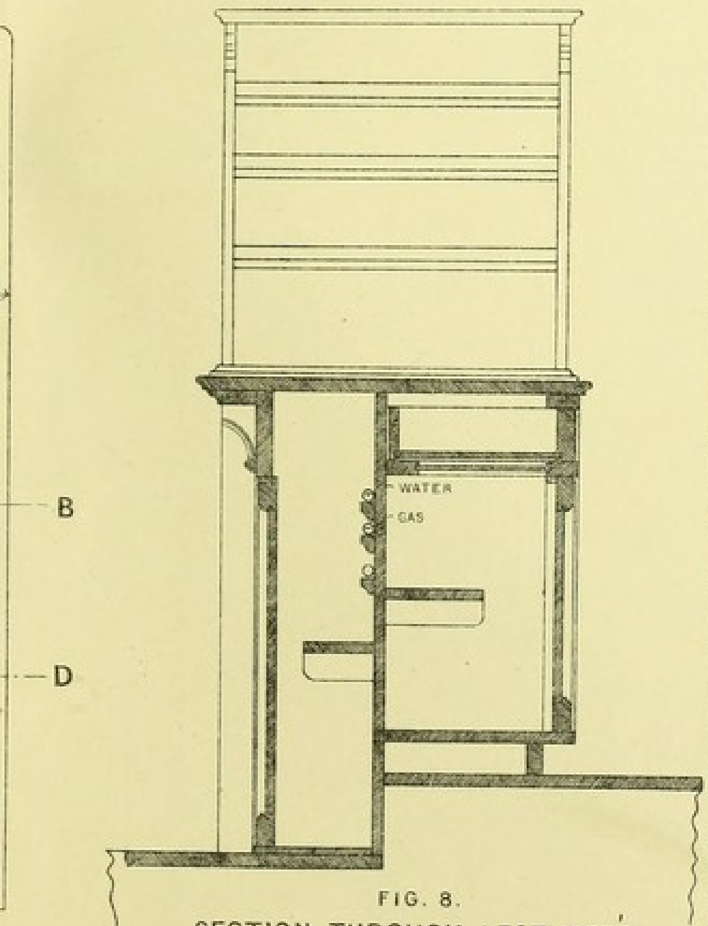
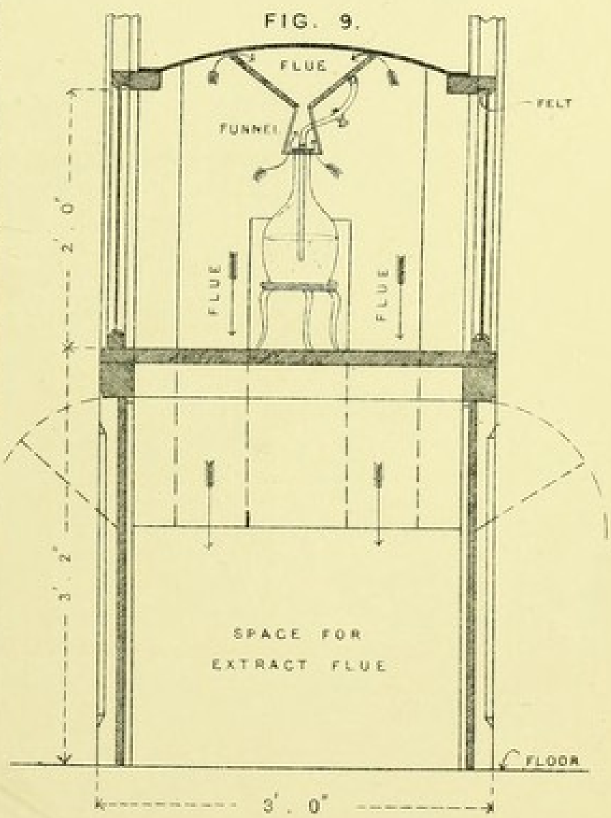


FIG. 8.
SECTION THROUGH LECTURER'S BENCH.

3 4 5 FEET

FINSBURY TECHNICAL COLLEGE.

FIG. 9.



SECTION THROUGH SULPHURETTED HYDROGEN CLOSET.

C.F. Kell, Photo-Litho. Castle St Holborn, London, E.C.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (IV).

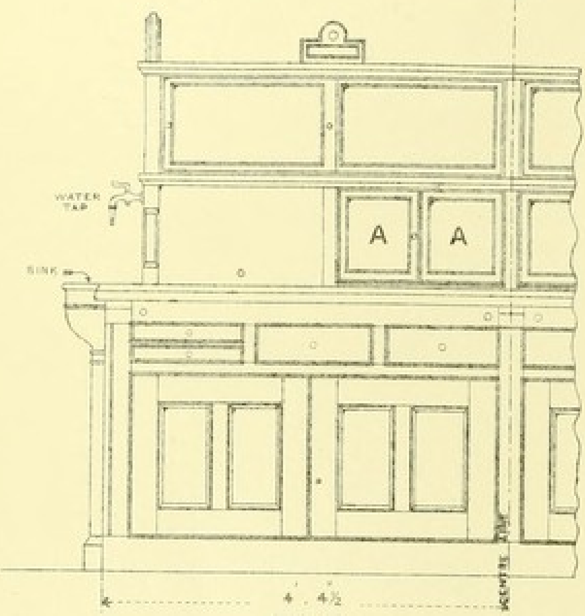


FIG. 10.
QUANTITATIVE TABLE
HALF FRONT ELEVATION.

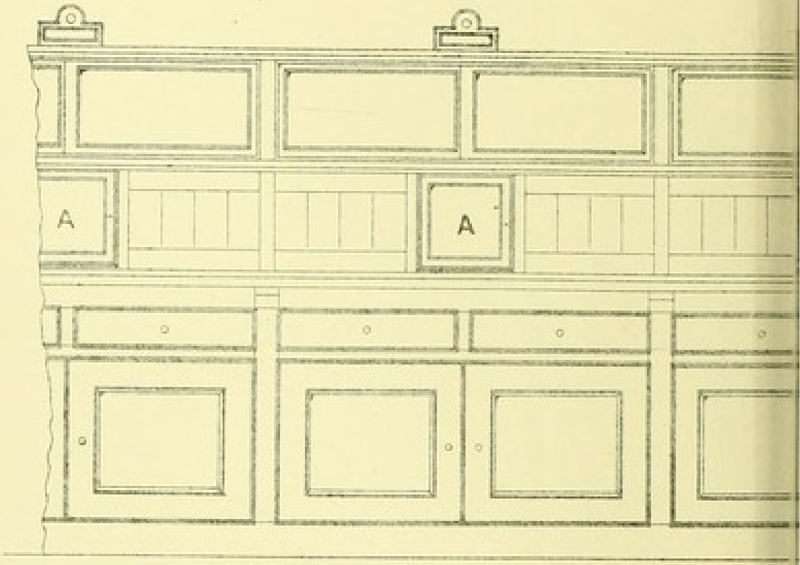


FIG.
QUALITATIVE TABLE, PAR

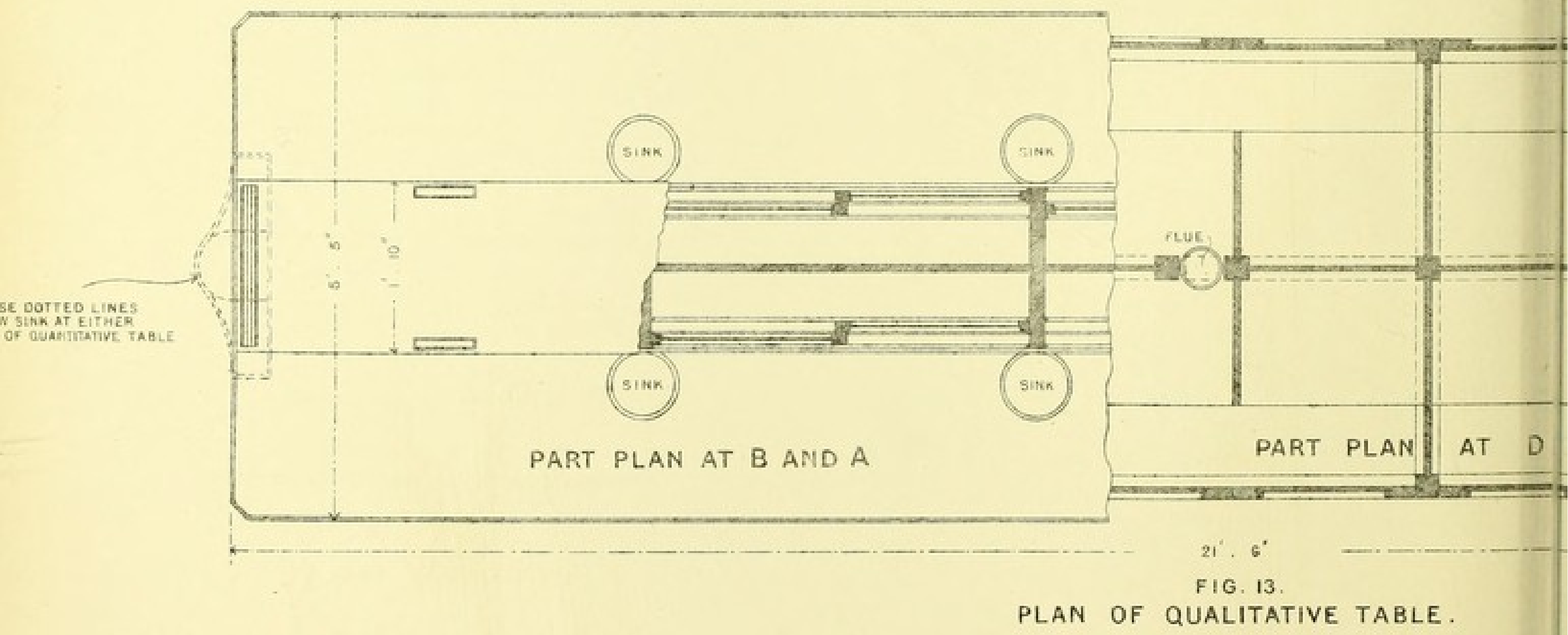
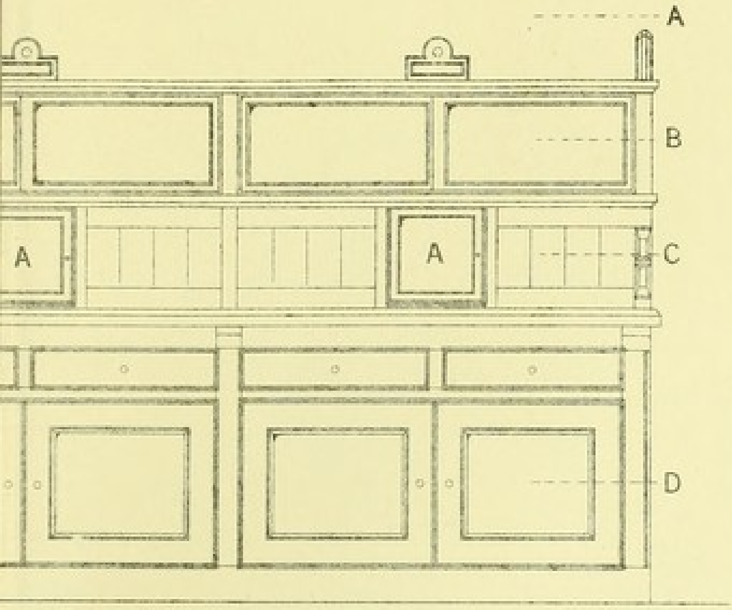


FIG. 13.
PLAN OF QUALITATIVE TABLE.

Sc

OWENS COLLEGE, MANCHESTER.



FRONT ELEVATION.

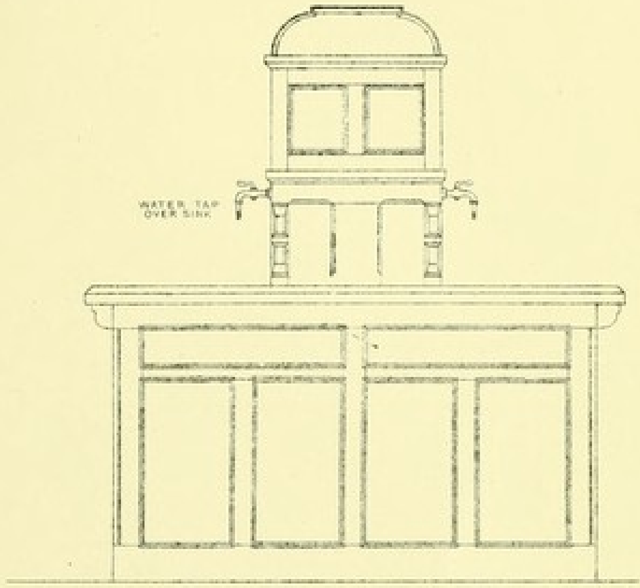
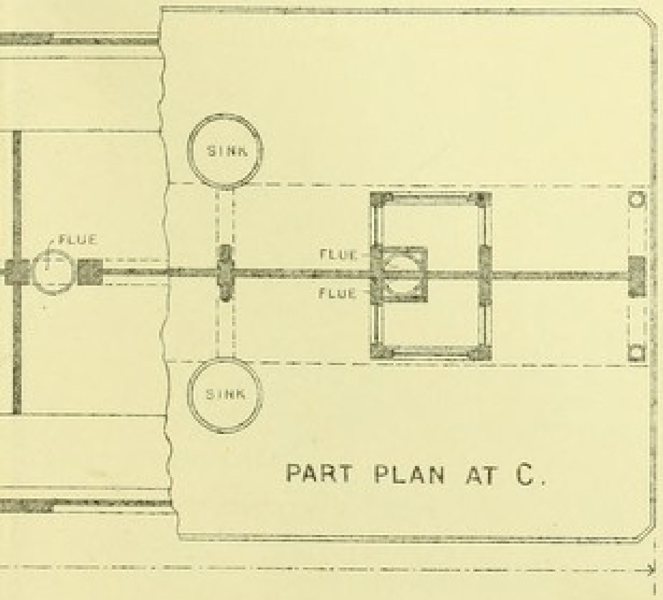


FIG. 12.
END ELEVATION OF QUALITATIVE TABLE



PART PLAN AT C.

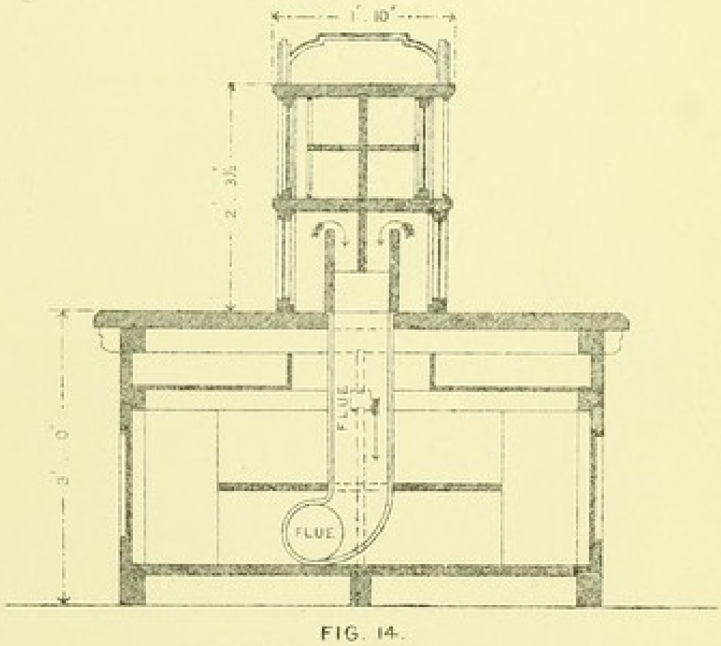


FIG. 14.
SECTION OF TABLES

3 4 5 FEET

C.F. Kell, Photo-Litho, Castle St. Holborn, London, E.C.

II, FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS. (v)

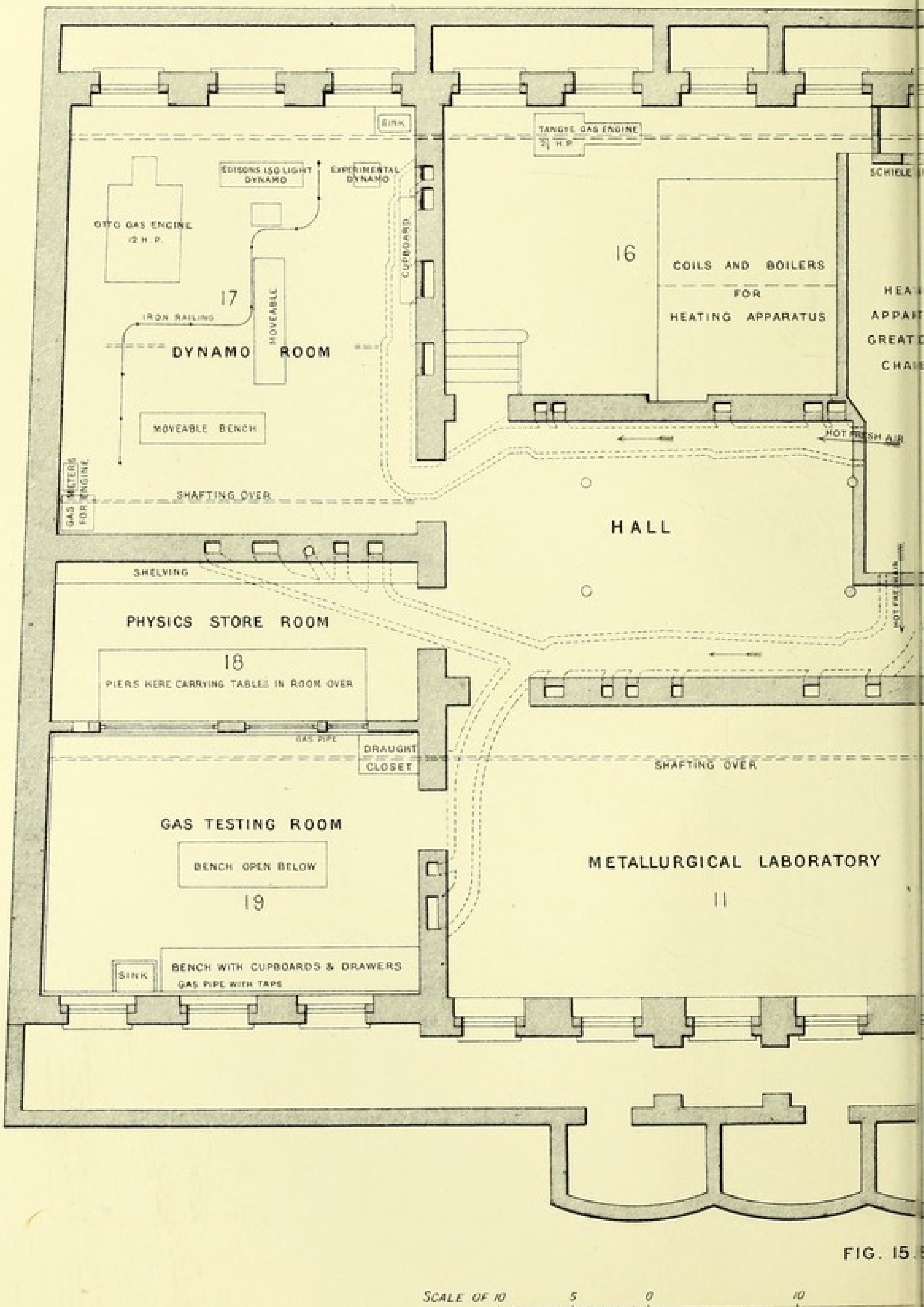
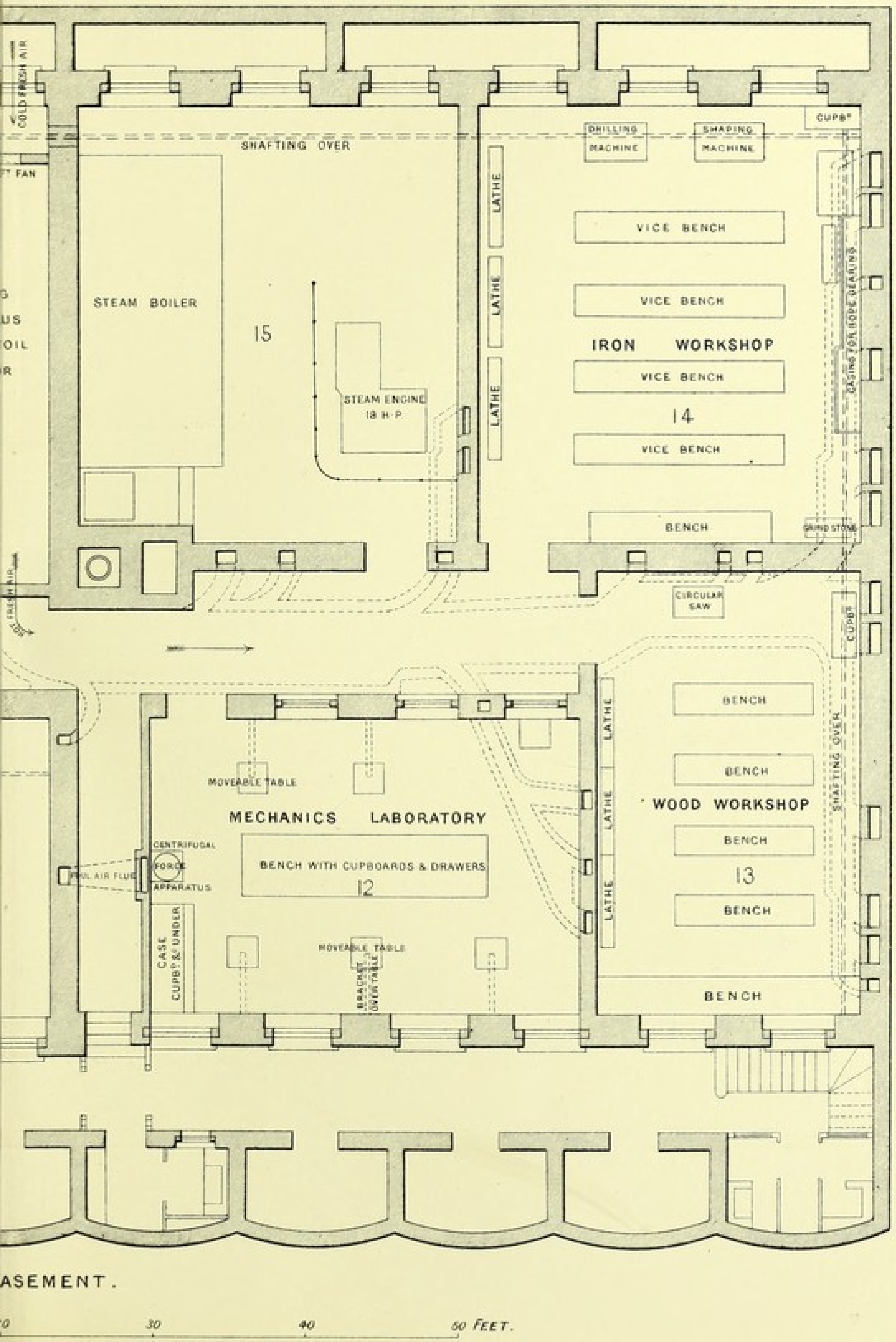


FIG. 15.

TECHNICAL COLLEGE, FINSBURY.



C F Kell Lith 8 Castle St. Holborn London E.C.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (VI)

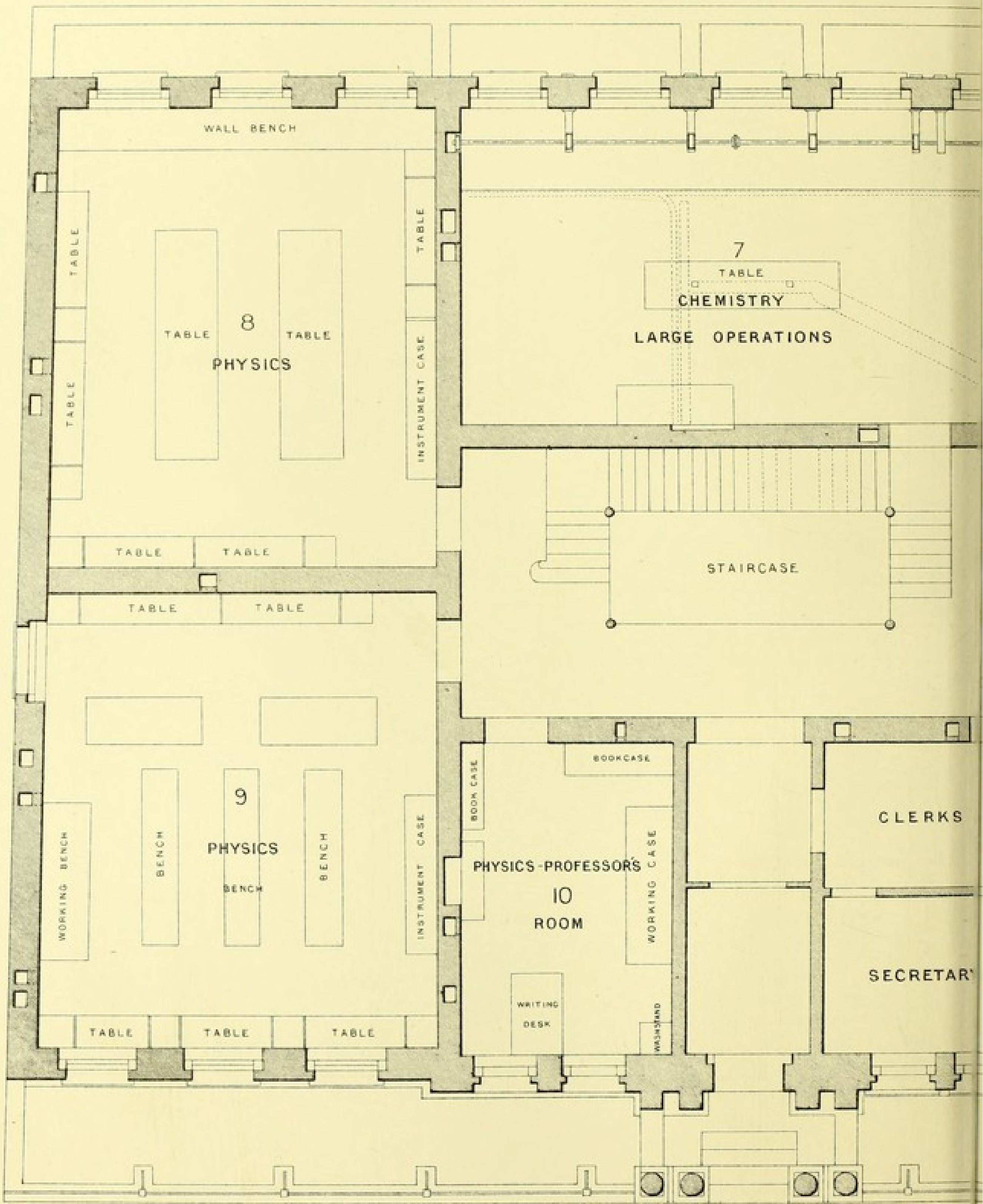
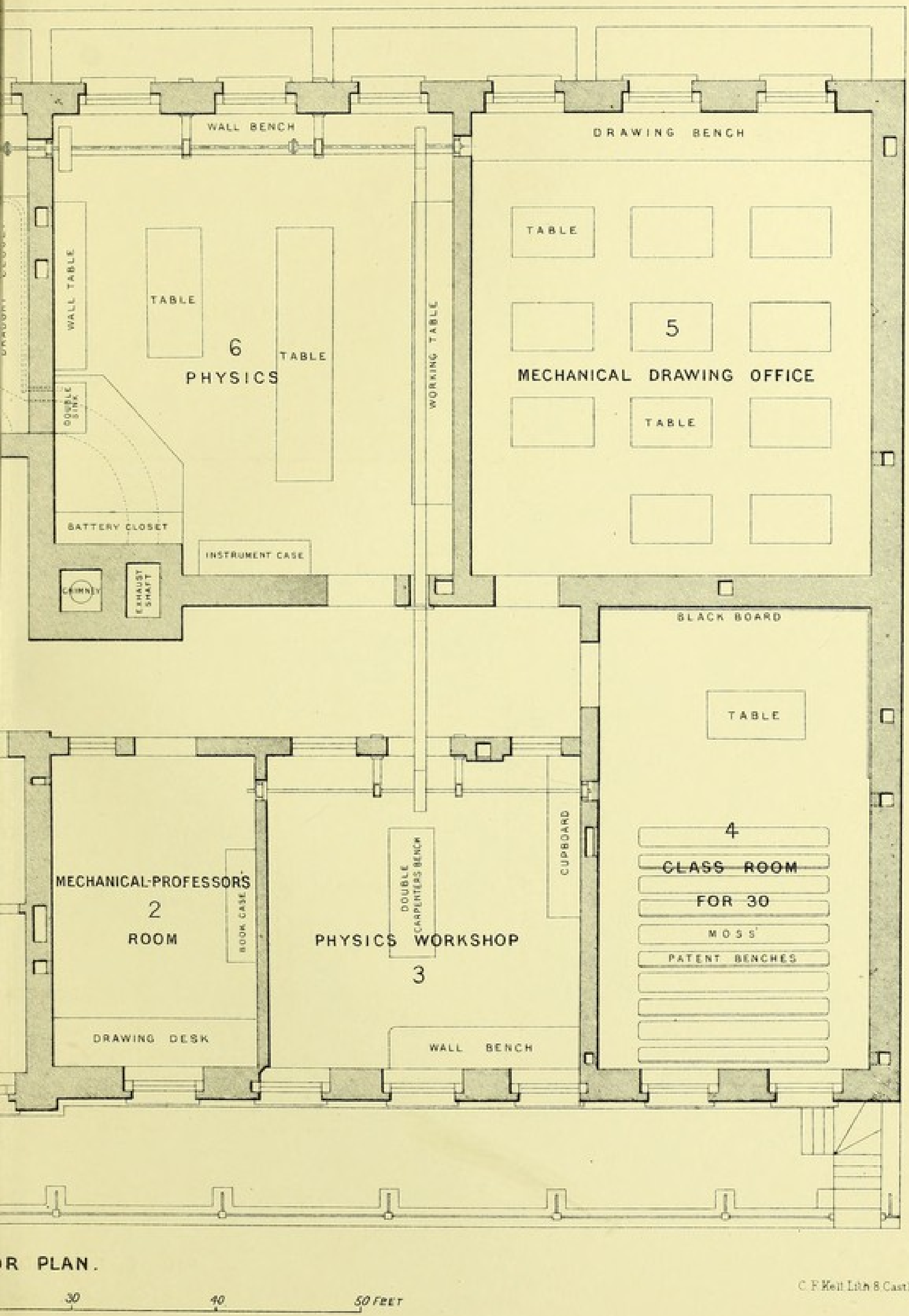


FIG. 16. GROUND FL

SCALE OF 10 5 0 10 20

TECHNICAL COLLEGE, FINSBURY



...R PLAN.

C. F. Kell Lith 8 Castle St. Holborn London E.C.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS.(VII)

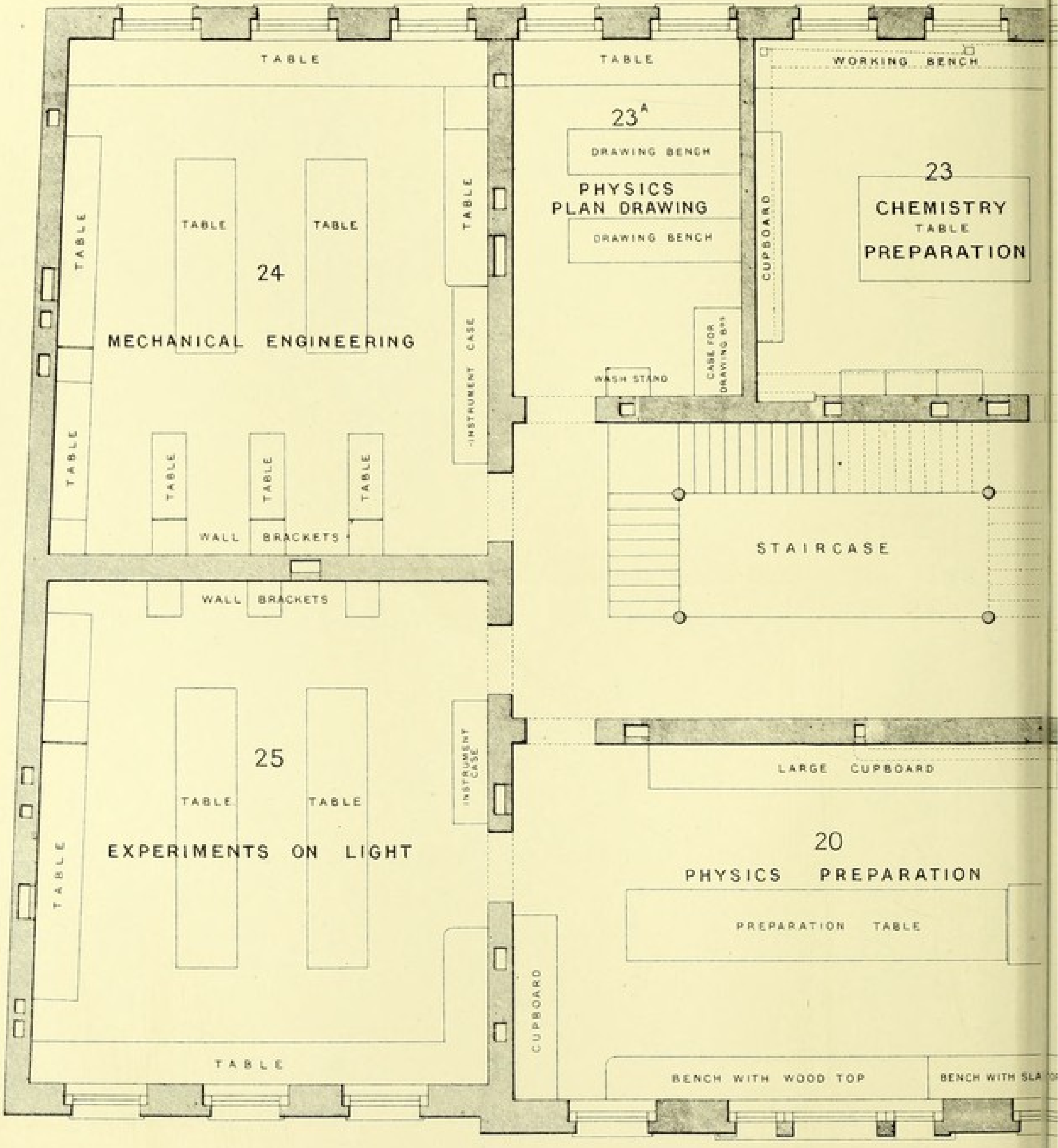
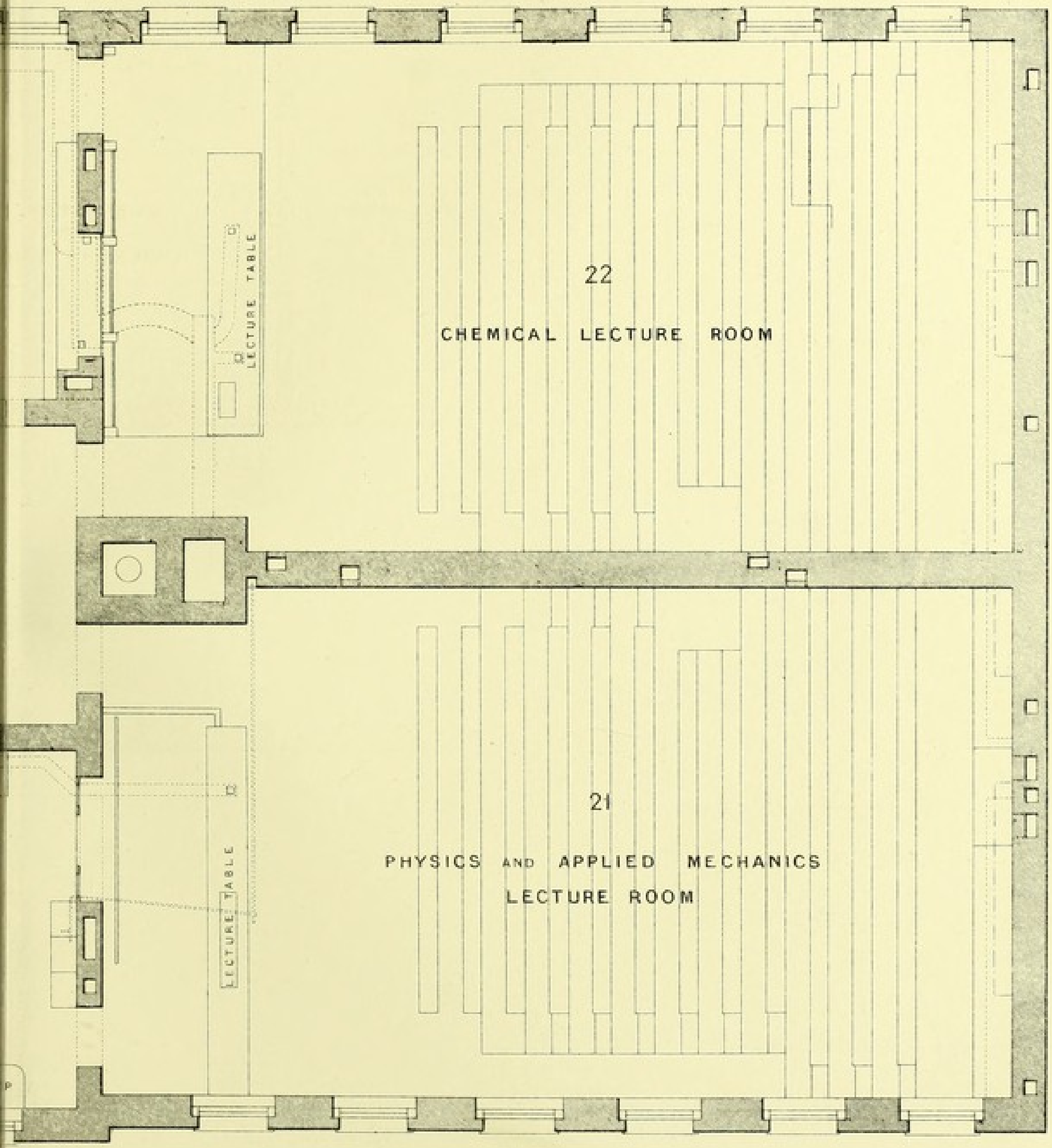


FIG. 17. FIRS

SCALE OF 10 5 0 10

TECHNICAL COLLEGE, FINSBURY.



FLOOR PLAN.

30 40 50 FEET.

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II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (viii)

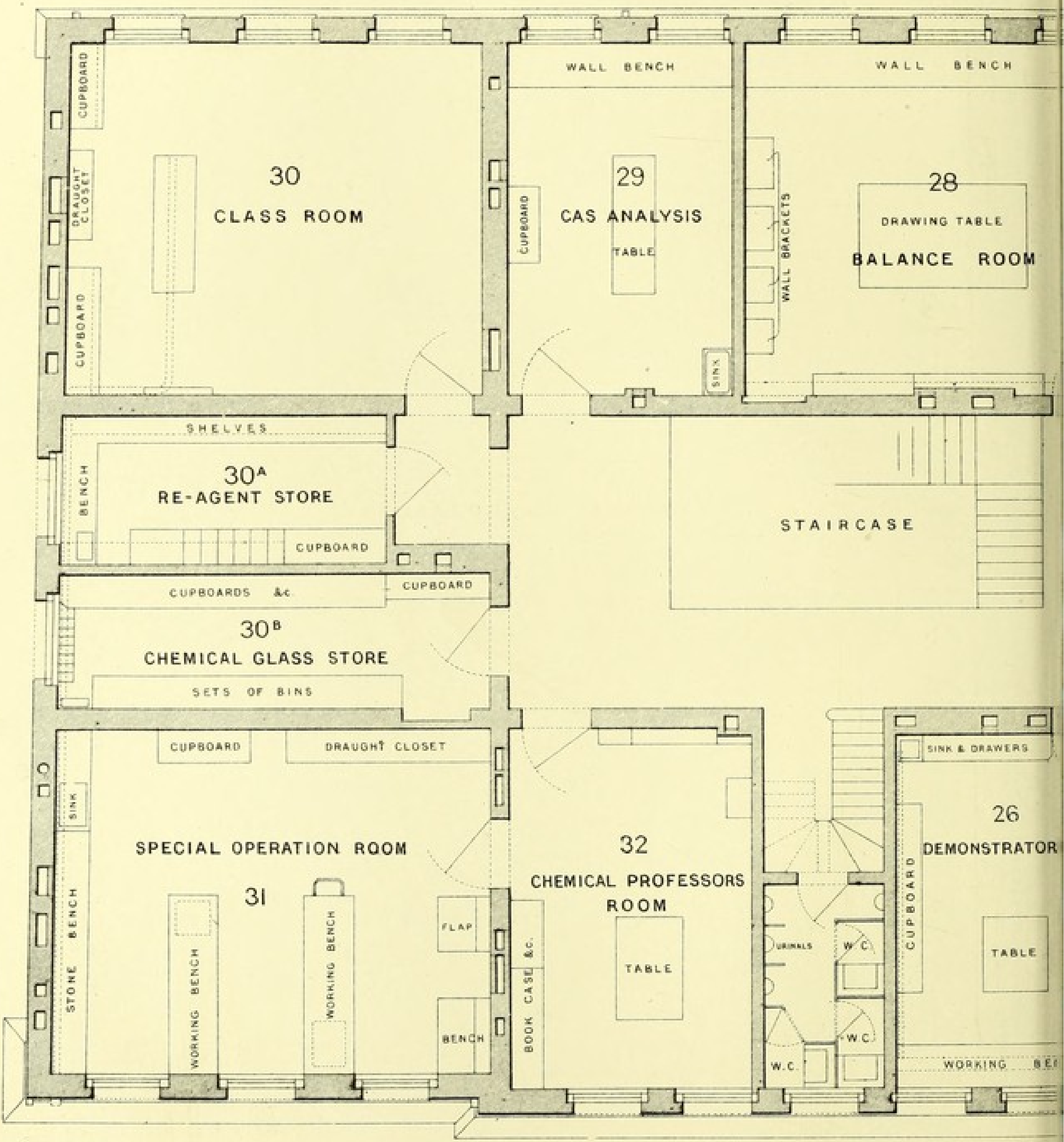
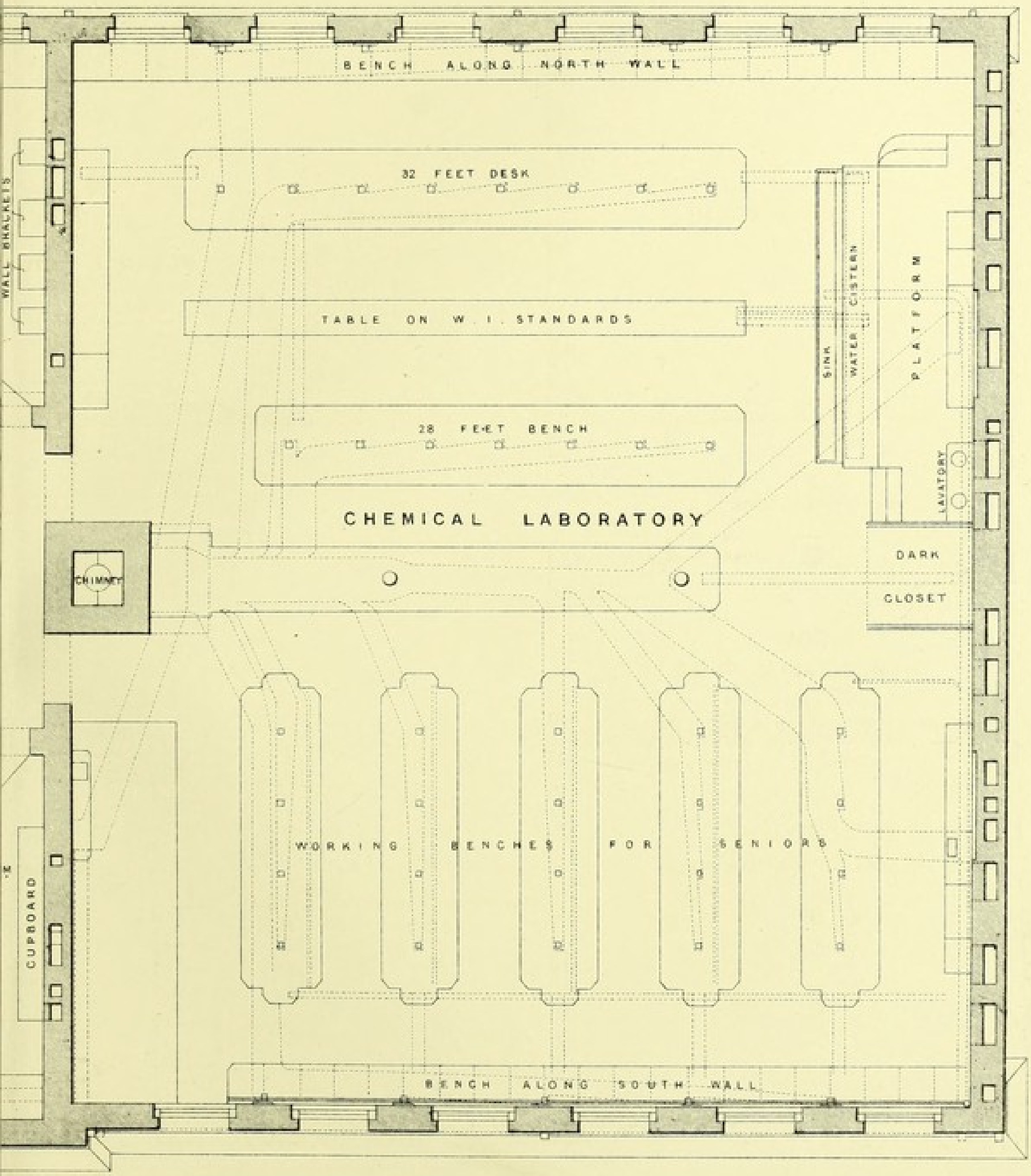


FIG. 18. SECOND

SCALE OF 10 5 0 10 20

TECHNICAL COLLEGE, FINSBURY.



OOR PLAN.

30 40 50 FEET.

C. F. Kell Lith 8 Castle St. Holborn London E.C.

TECHNICAL COL

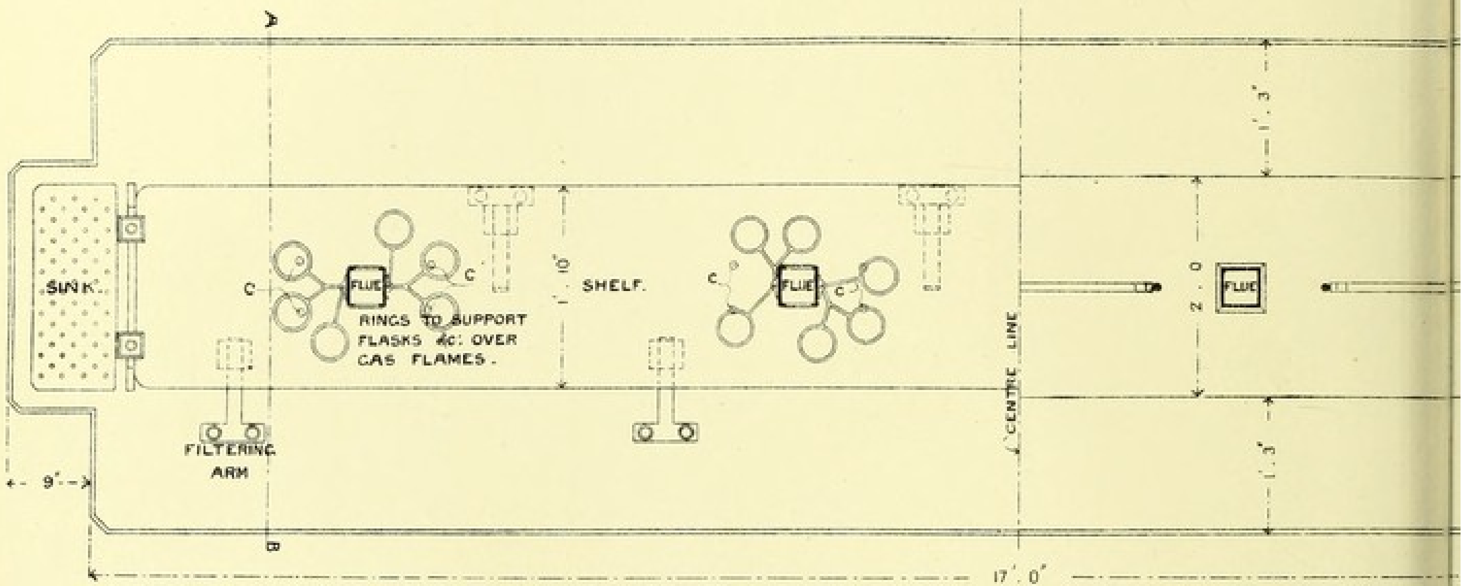


FIG. 19. HALF PLAN AT LEVEL ✕

FIG. 20 H

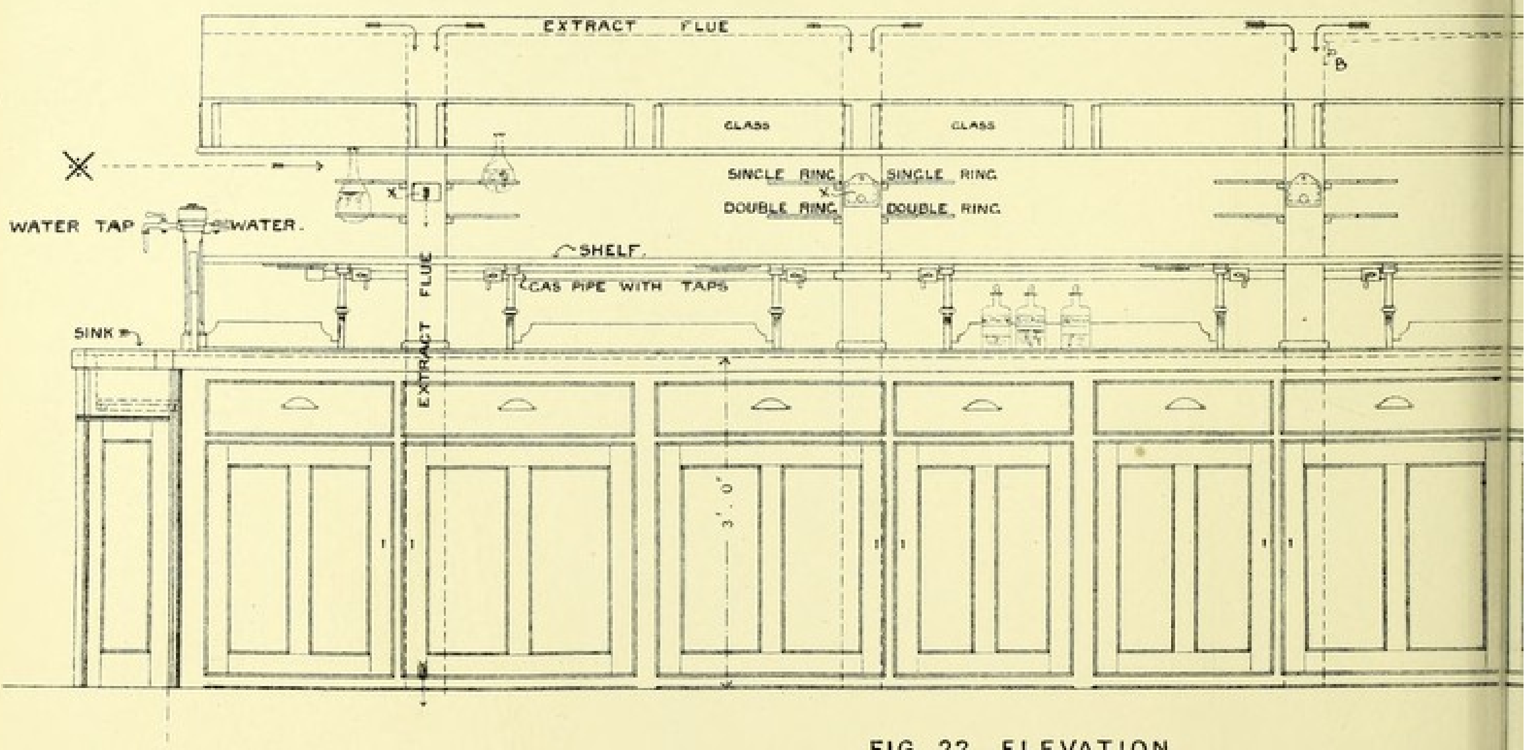
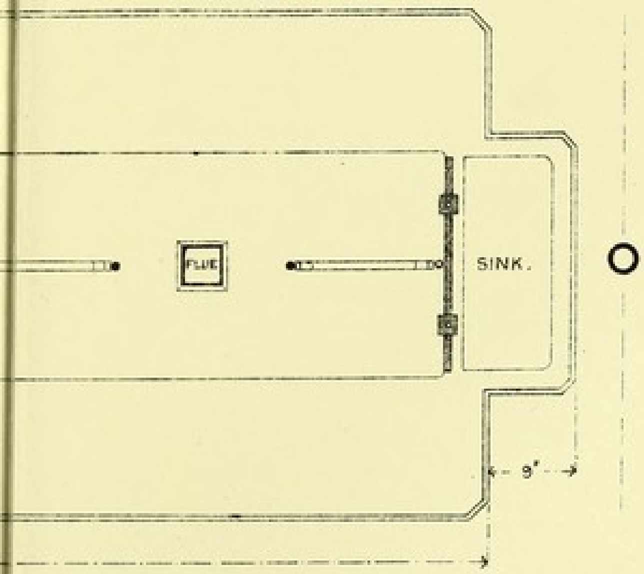


FIG. 22. ELEVATION.

SCALE
INS 12 6 0 1 2 3 4 5 FEET.

STUDENTS' BENCH WITH PRO

IGE, FINSBURY.



ALF PLAN AT LEVEL ⊗

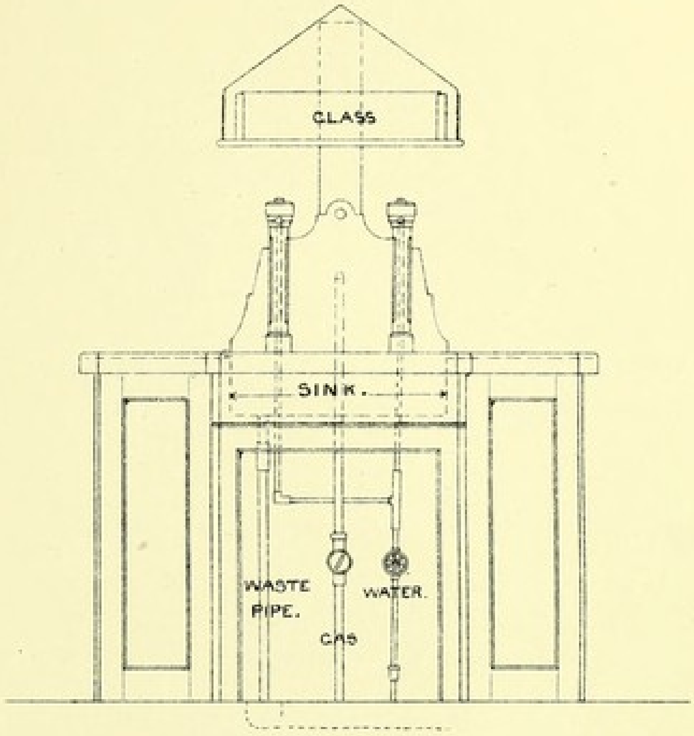
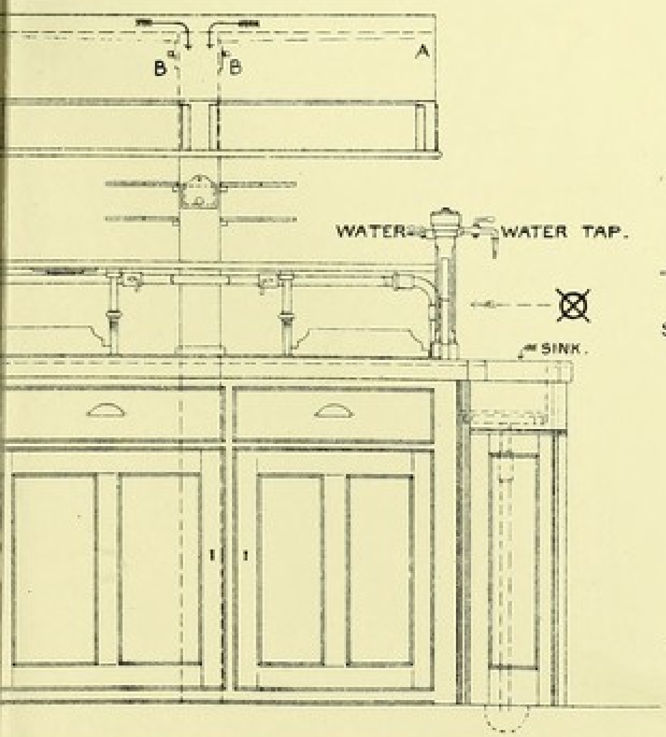


FIG. 21.
END ELEVATION.



SHEWING SLIDING BRACKETS.
FIG. 23

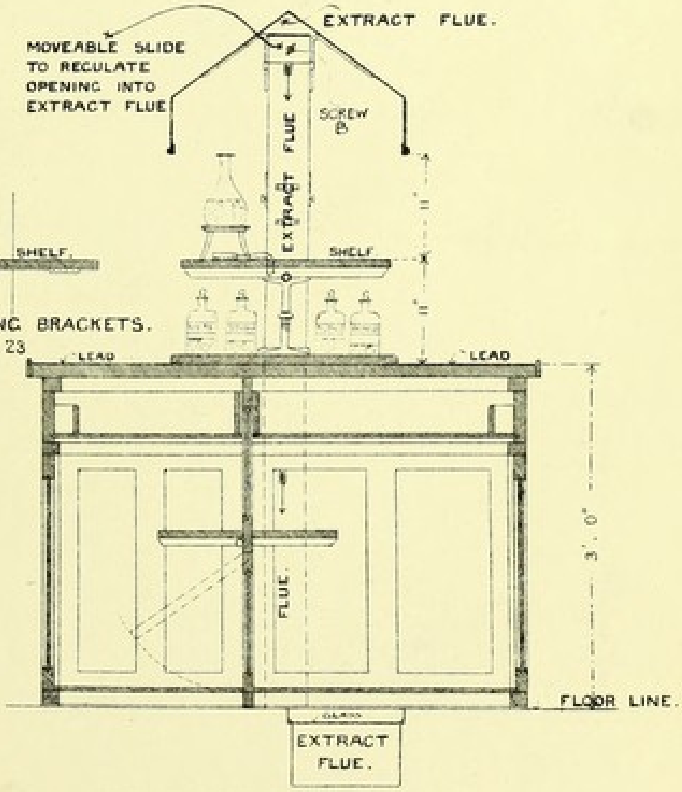


FIG. 24. SECTION A. B.

ROF. ARMSTRONG'S HOOD.

C.F. Kell, Photo-Litho. Castle St Holborn, London, E.C.

II, FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (X)

TECHNICAL COLLECE, FINSBURY.

DEMONSTRATION TABLE & STUDENTS SUITS IN THE LARGE LABORATORY

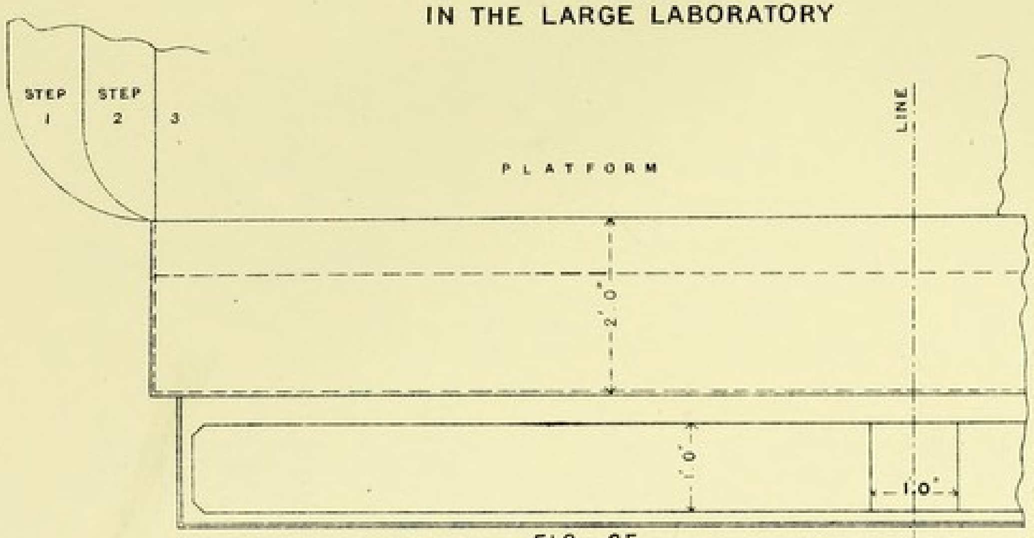


FIG. 25
HALF PLAN

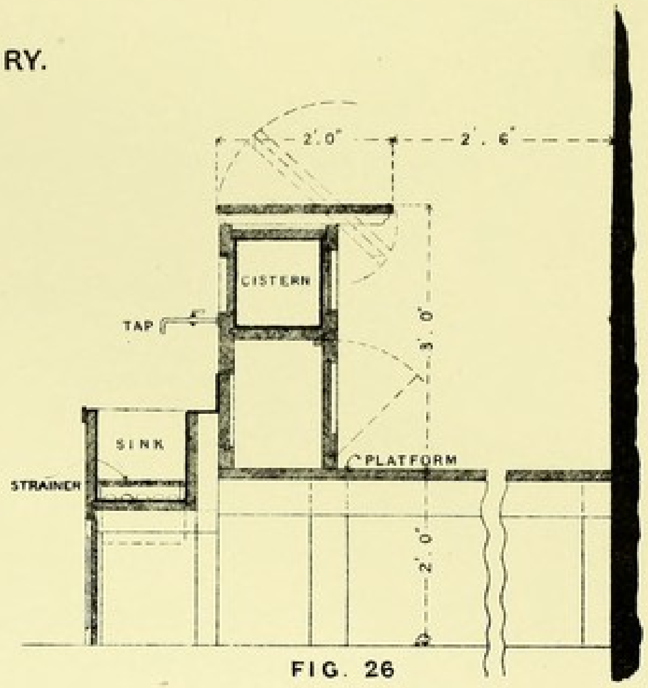


FIG. 26
SECTION.

SCALE
INS 12 6 0 1 2 3 4 5 FEET

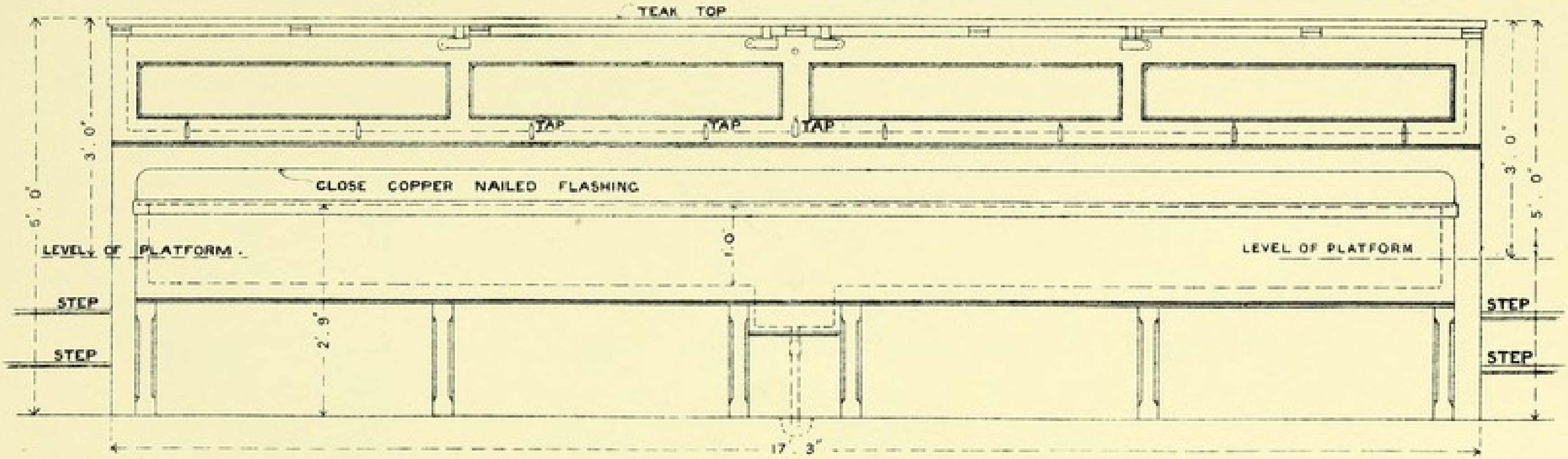


FIG. 27. ELEVATION.

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TECHNICAL COLLEGE, FINSBURY.

SCALE.

INS 12 6 0 1 2 3 4 5 FEET

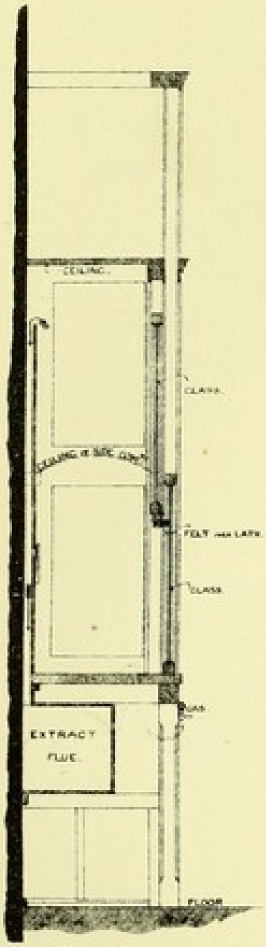


FIG. 28.
SECTION A.B.

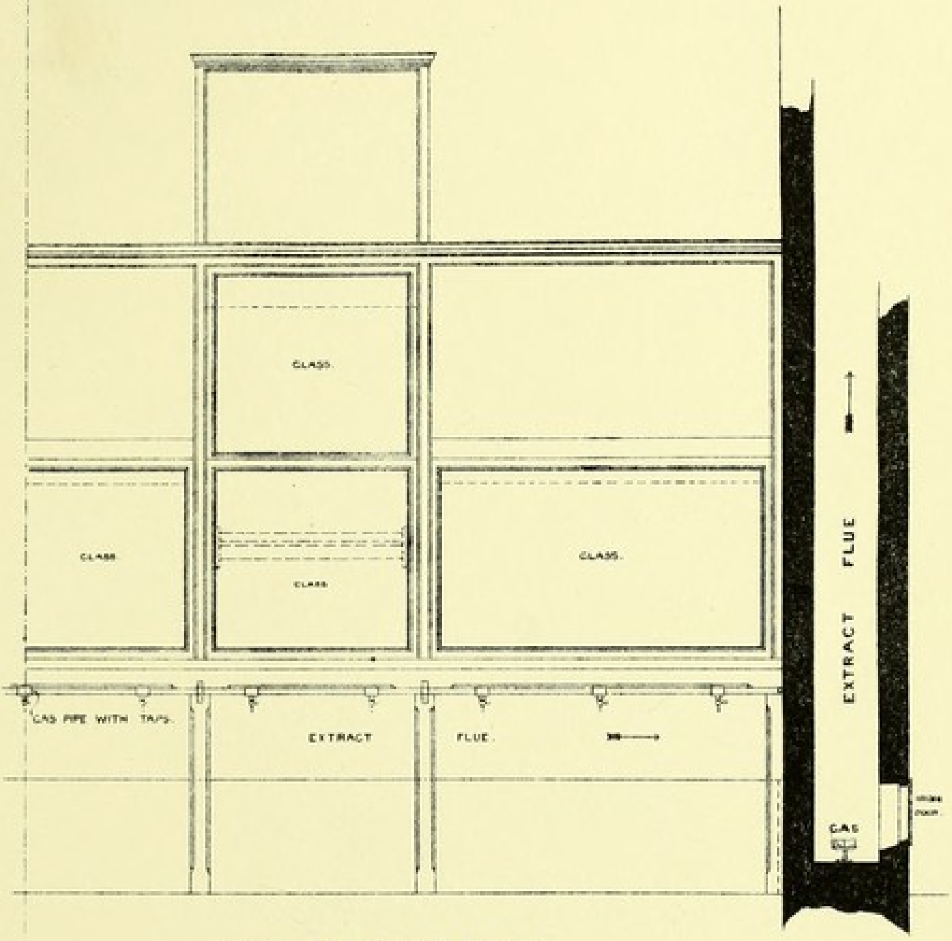


FIG. 29. ELEVATION.

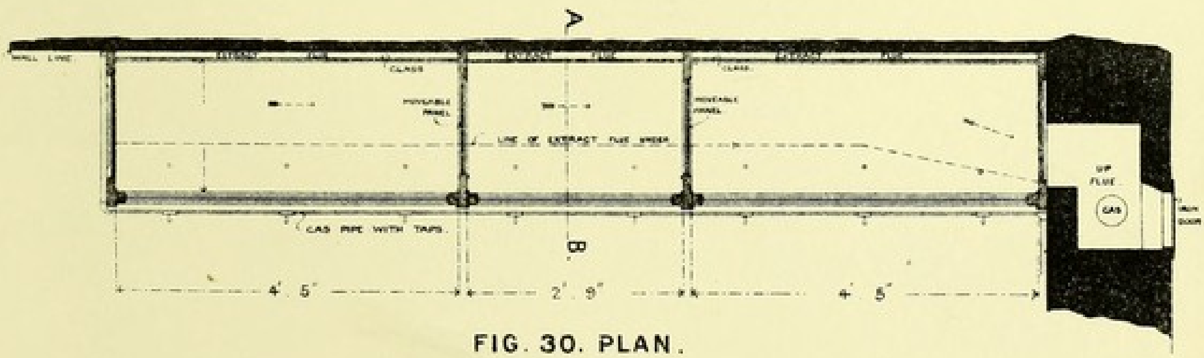


FIG. 30. PLAN.

DRAUGHT CLOSETS IN PRIVATE LABORATORY.

C.F. Kell, Photo-Litho. Castle St Holborn, London, E.C.

TECHNICAL COLLEGE, FINSBURY.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (XII)

FIG. 31. PLAN THRº COUNTER WEIGHT

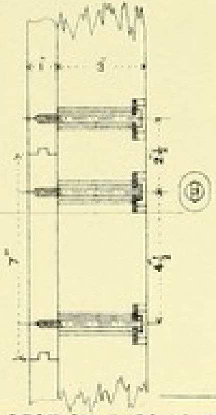


FIG. 32. PART SECTION THRº BOARD

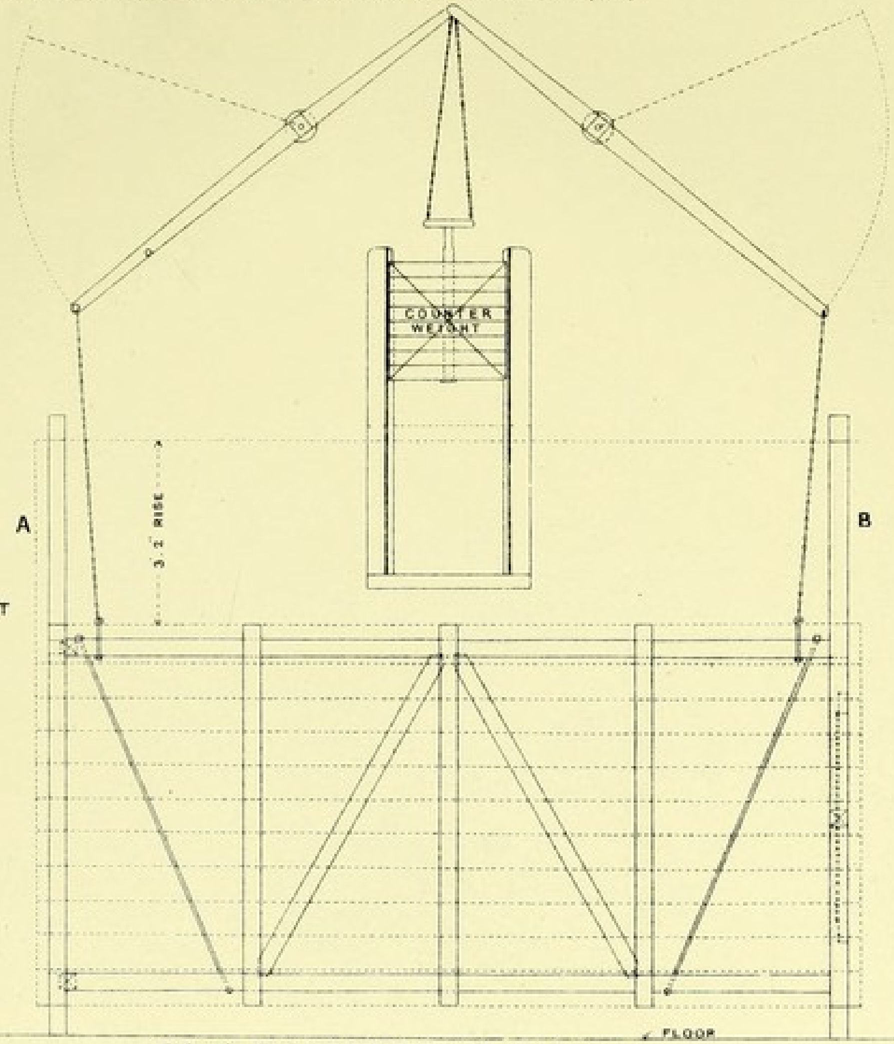


FIG. 33. ELEVATION SHEWING FRAMING &c.

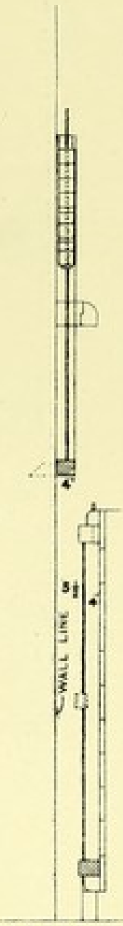


FIG. 34. SECTION

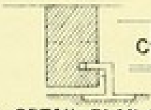


FIG. 35. DETAIL PLAN AT C

FIG. 36. PLAN AT LEVEL A.B.

SCALE OF 0 1 2 3 4 5 6 7 8 FEET

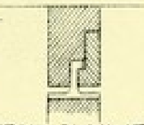


FIG. 37. DETAIL PLAN AT D

BLACK BOARD

Designed by Prof. James Thompson, Glasgow.

C. F. Kell Lith. 8 Castle St. Holborn London E.C.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (XIII)

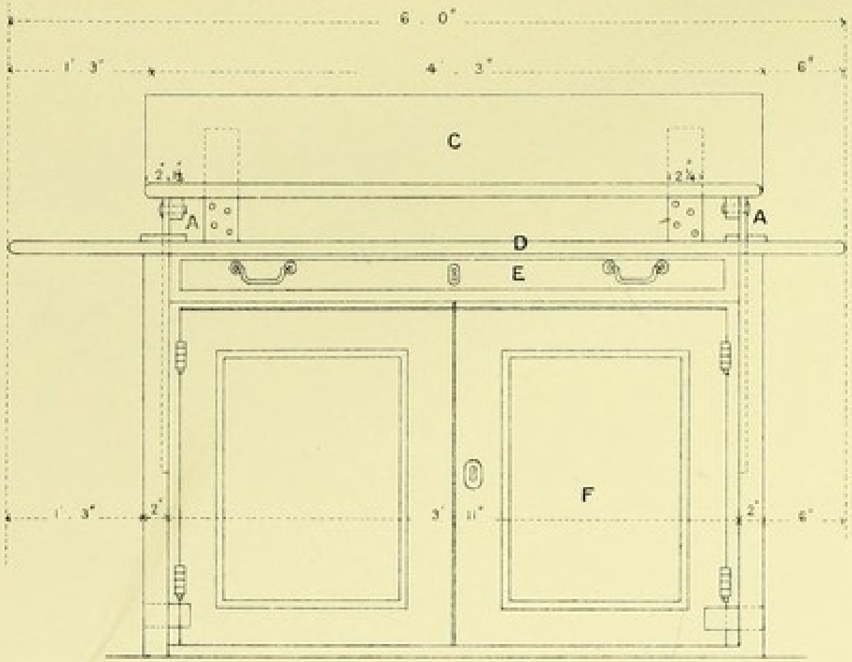


FIG. 38. ELEVATION OF DRAWING BENCH

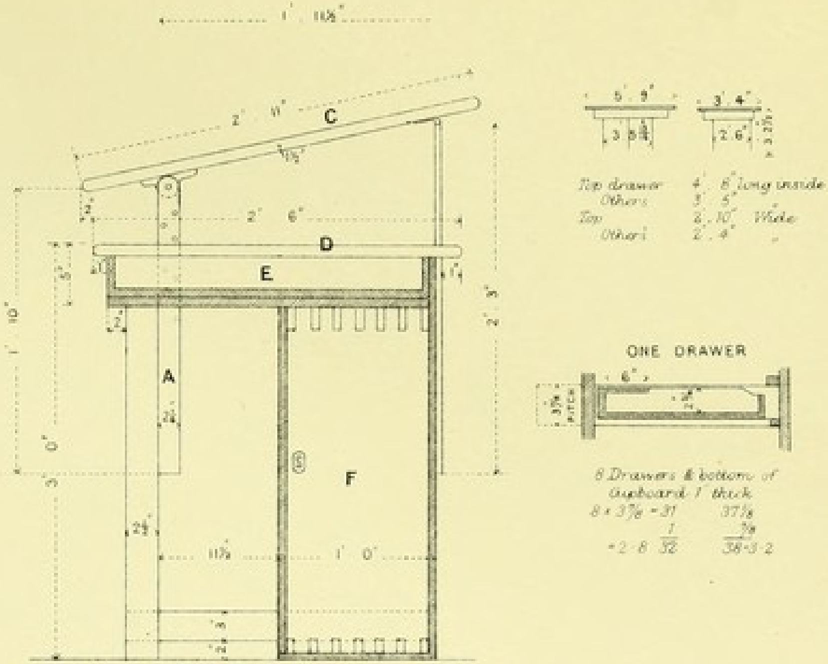


FIG. 39. SECTION OF DRAWING BENCH.

FINSBURY COLLEGE.

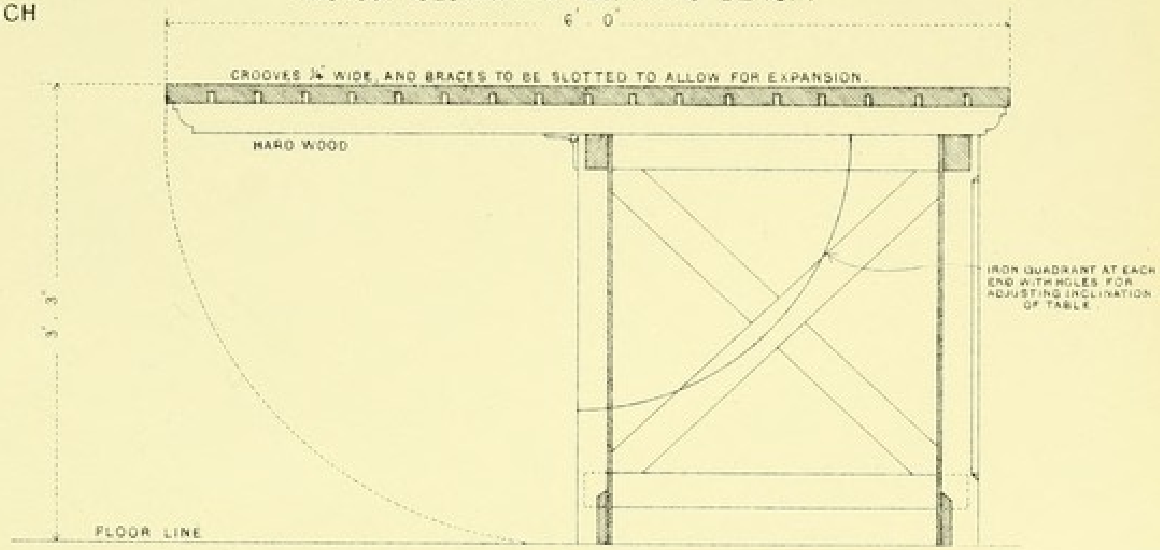


FIG. 40. SECTION OF DIAGRAM TABLE IN BALANCE ROOM.

II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (XIV)

UNIVERSITY COL

DETAILS OF L

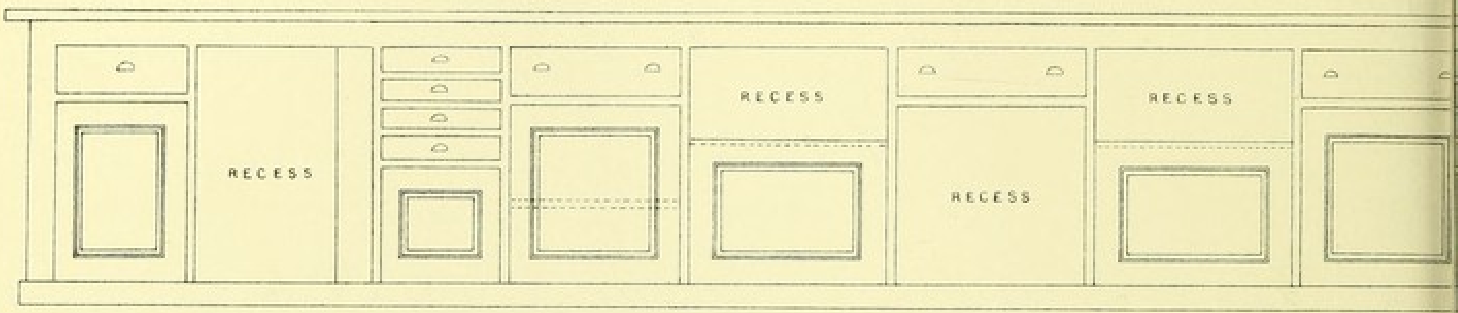


FIG. 41. BACK ELEVATION. PITCH PINE FRONTS.

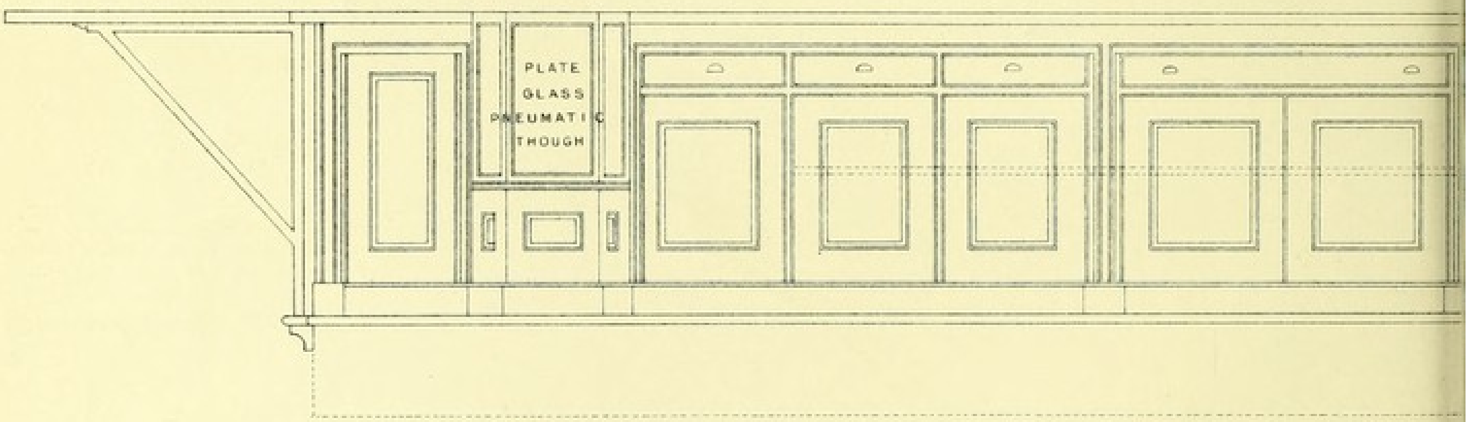
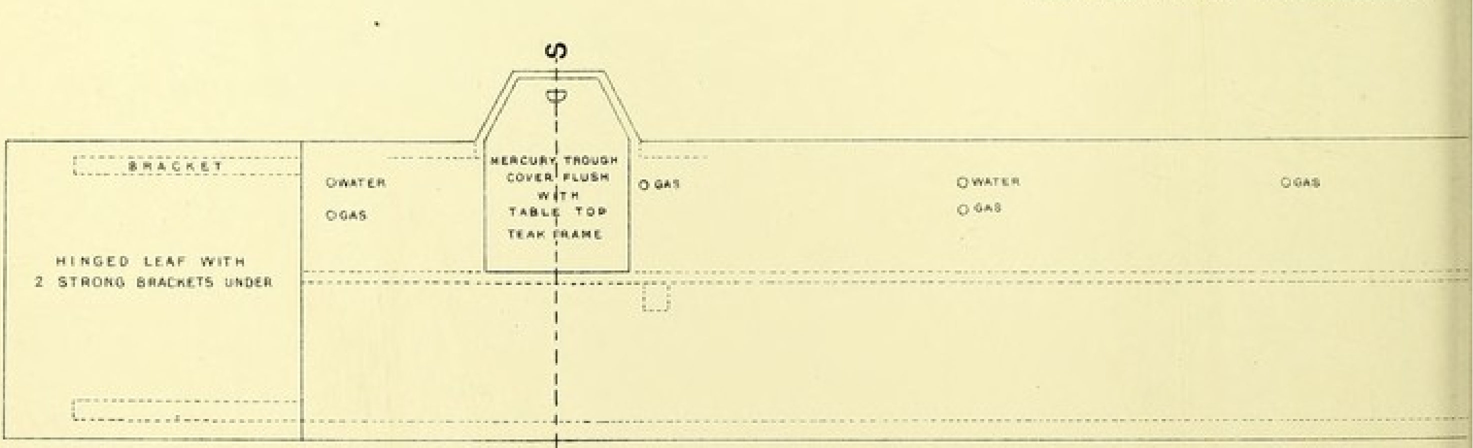


FIG. 44. FRONT ELEVATION. P



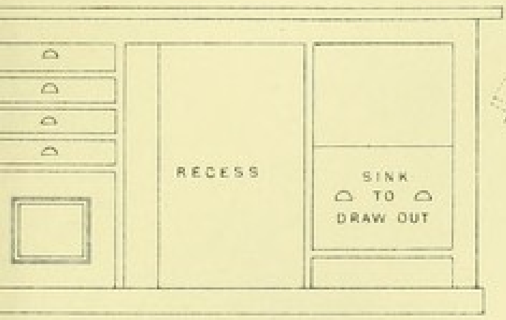
R

FIG. 46
PLAN OF TABLE TOP.

FIG. 43.
SKETCH PLAN OF UNIVERSITY COLLEGE, DUNDEE.

GE DUNDEE; CHEMICAL LABORATORY,

TURE TABLE IN LECTURE THEATRE.



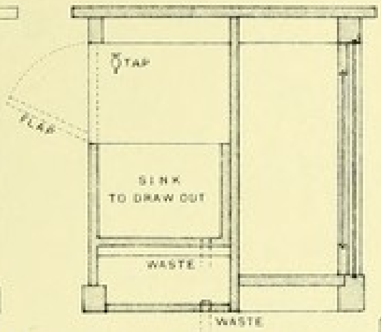
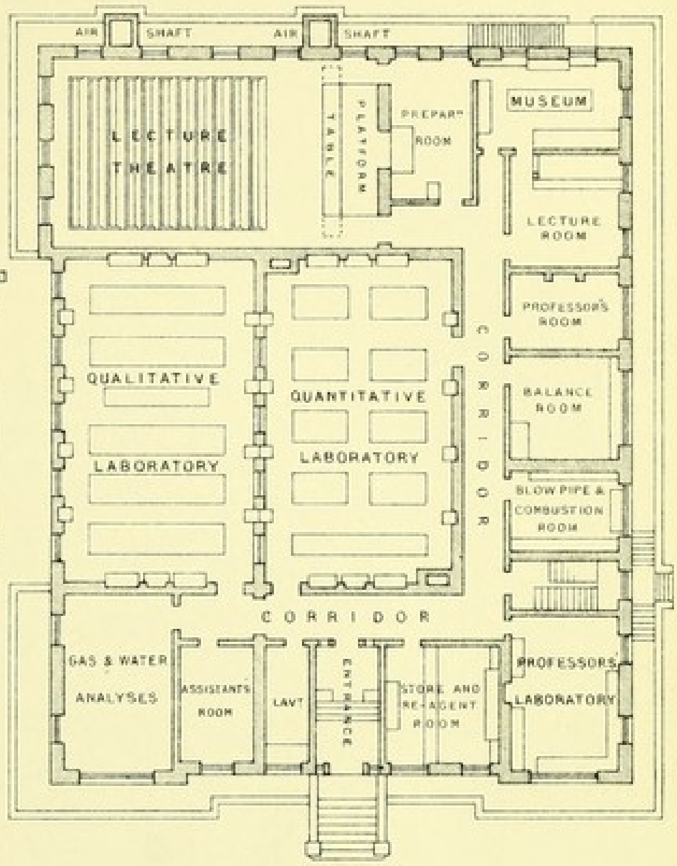
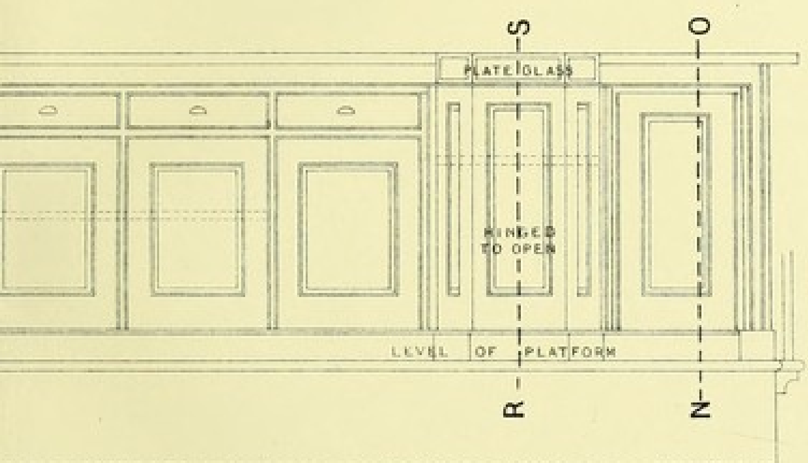


FIG. 42. SECTION N.O.





PINE FRONTS.

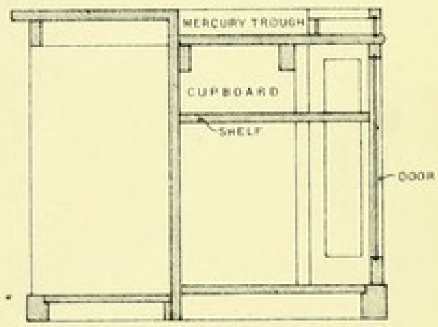
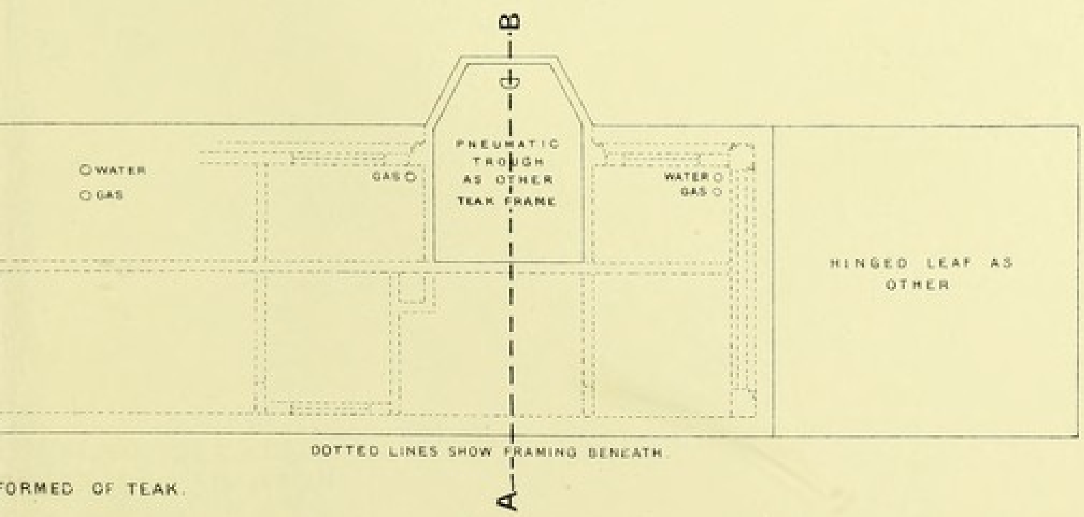


FIG. 45
SECTION R.S.



FORMED OF TEAK.

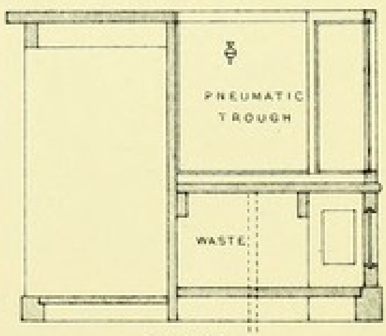


FIG. 47.
SECTION A.B.

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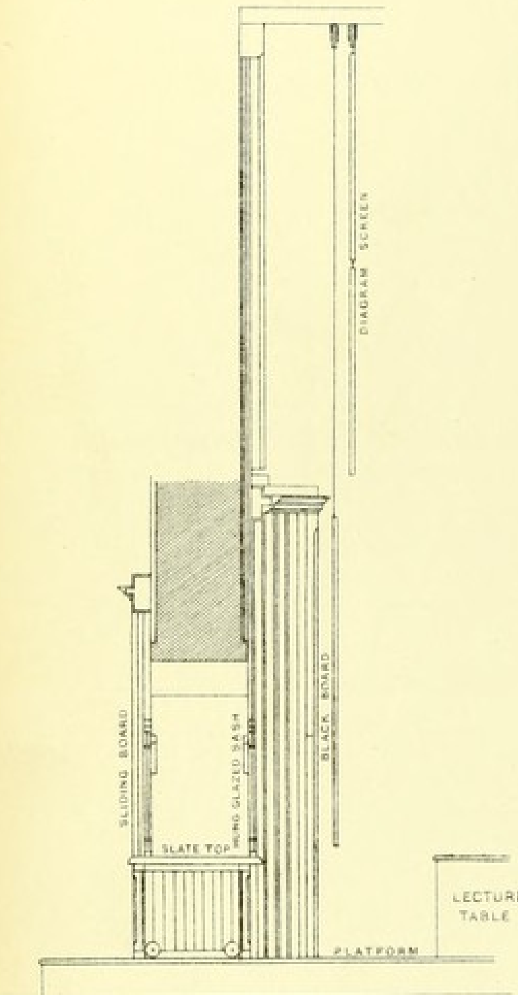
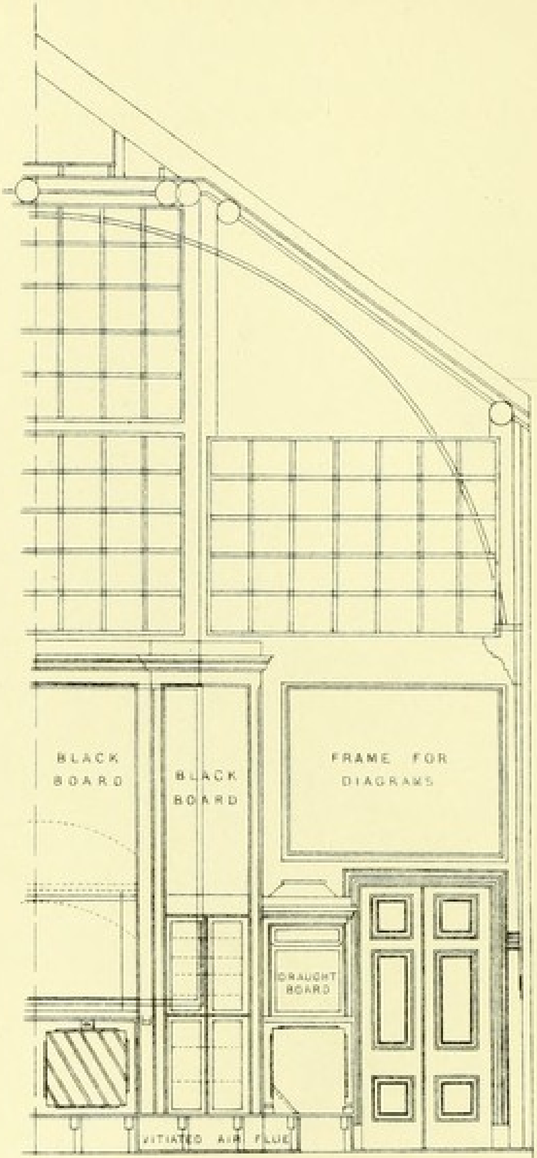
II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (XV)



SECTION THRO' A.B.
FIG. 48.



HALF ELEVATION OF LECTURE ROOM.
FIG. 49.

12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 FEET

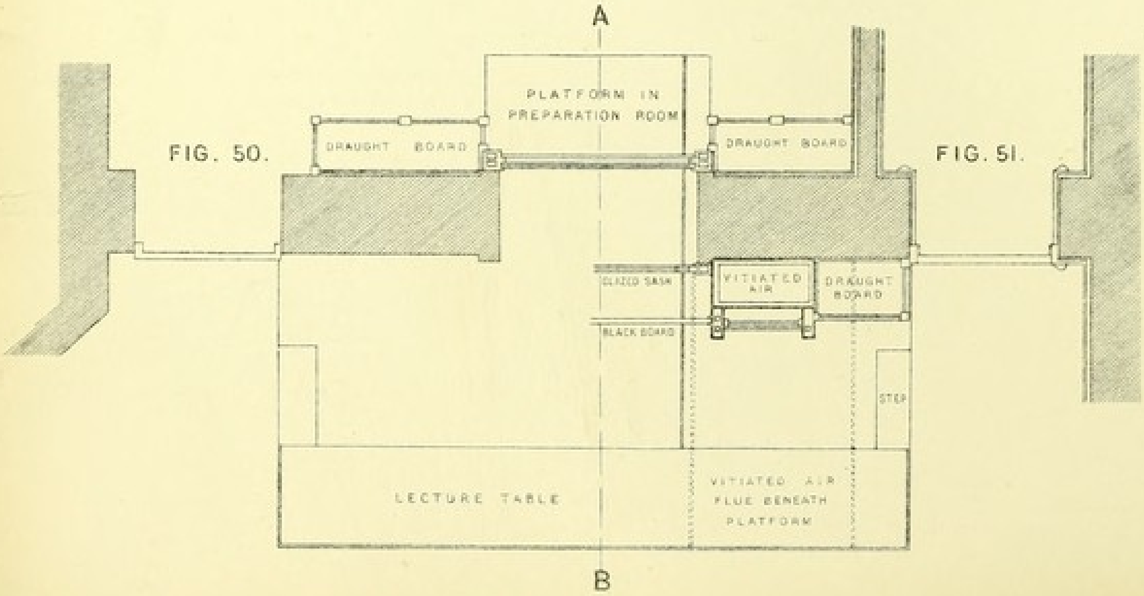
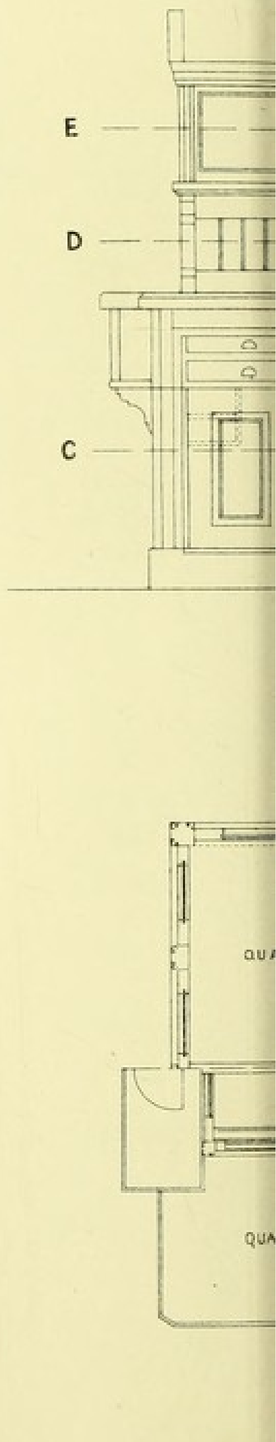


FIG. 50.

FIG. 51.



UNIVERSITY COLLEGE DUNDEE; CHEMICAL LABORATORY.

STUDENTS' WORKING TABLES.

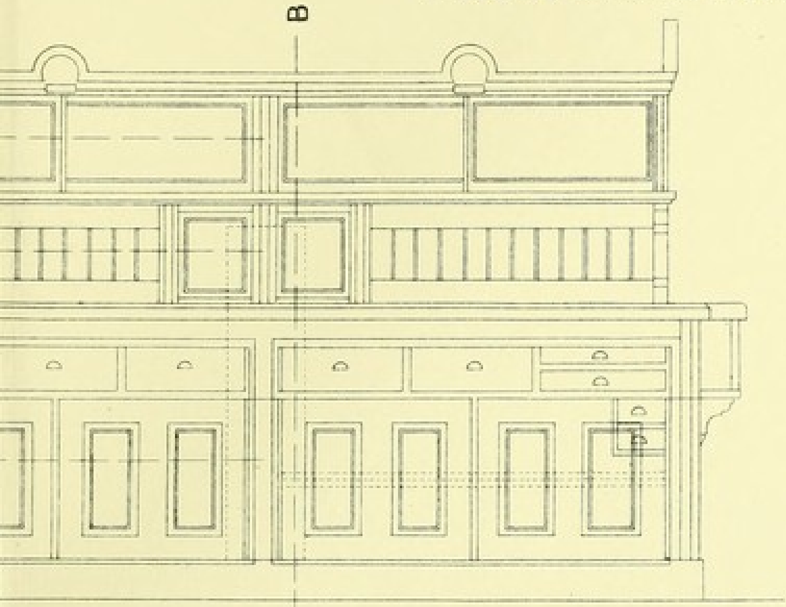


FIG. 52. ELEVATION.

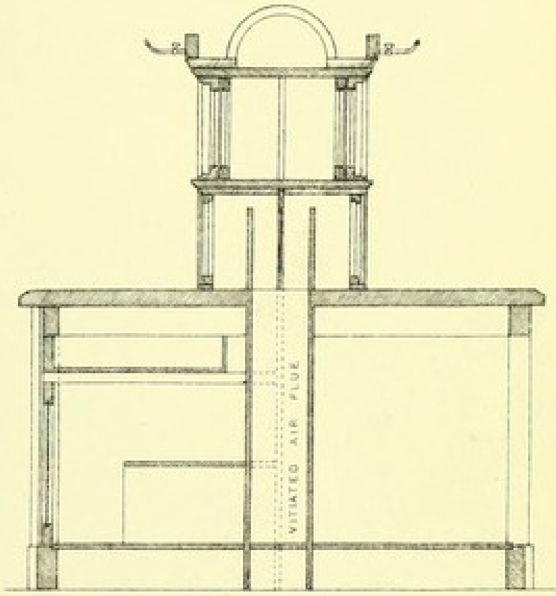


FIG. 53.
SECTION ON A.B.

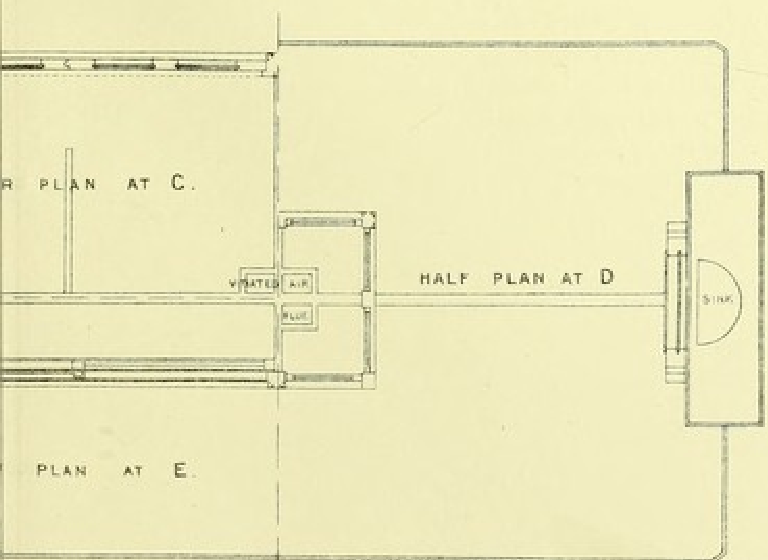


FIG. 54. PLAN.

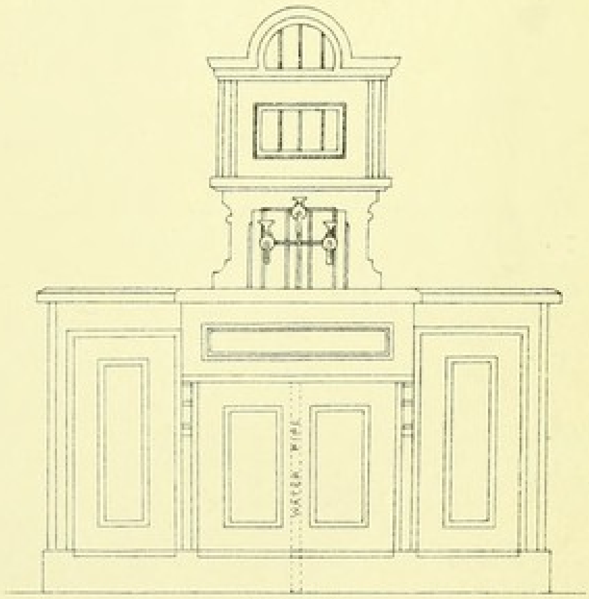


FIG. 55.
END ELEVATION OF SAME.

12 6 0 1 2 3 4 5 6 FEET

Edw^d C Robins

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II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS (XVI)

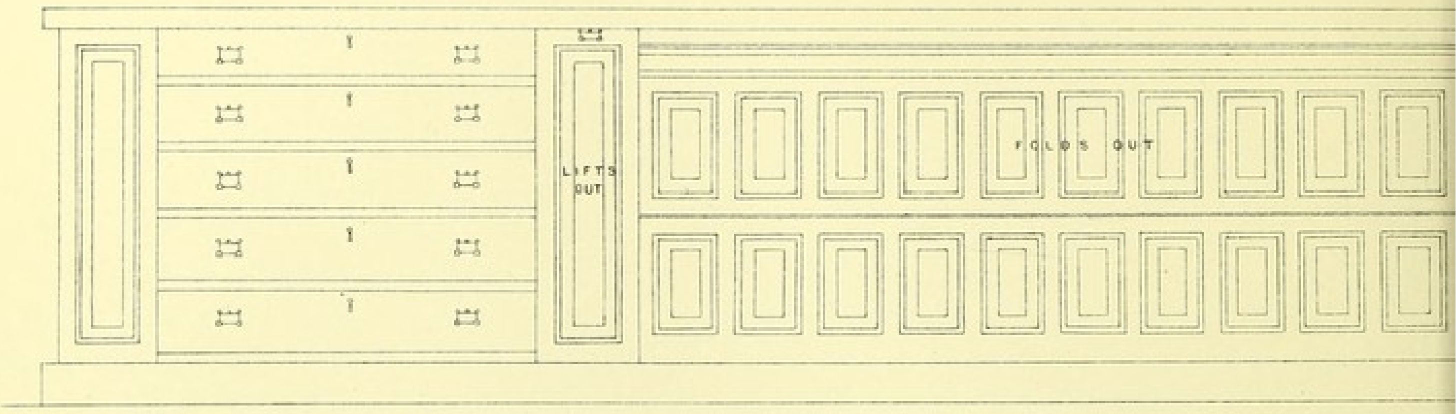


FIG. 56. FRONT OF TABLE.

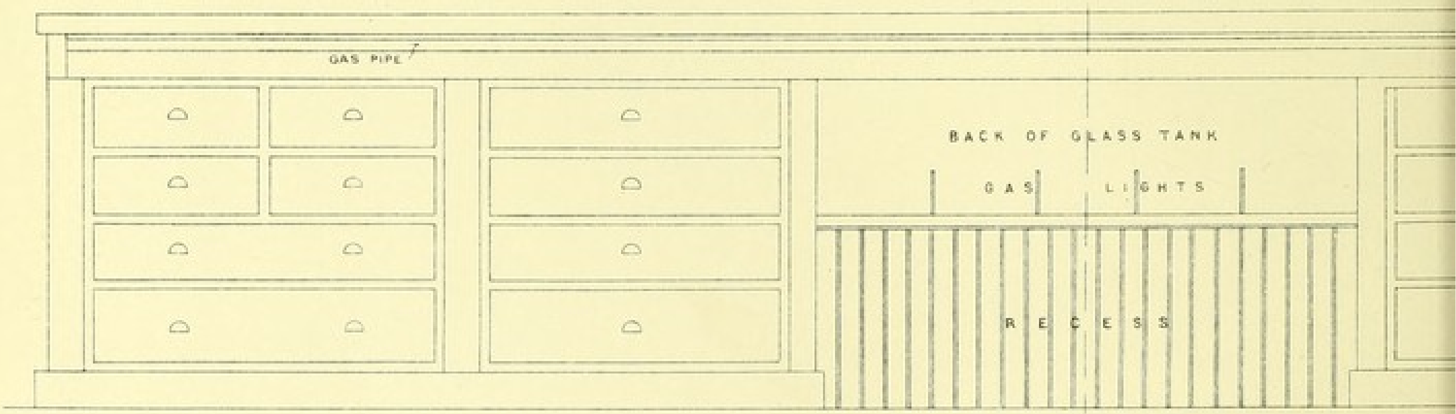


FIG. 58. BACK OF TABLE.

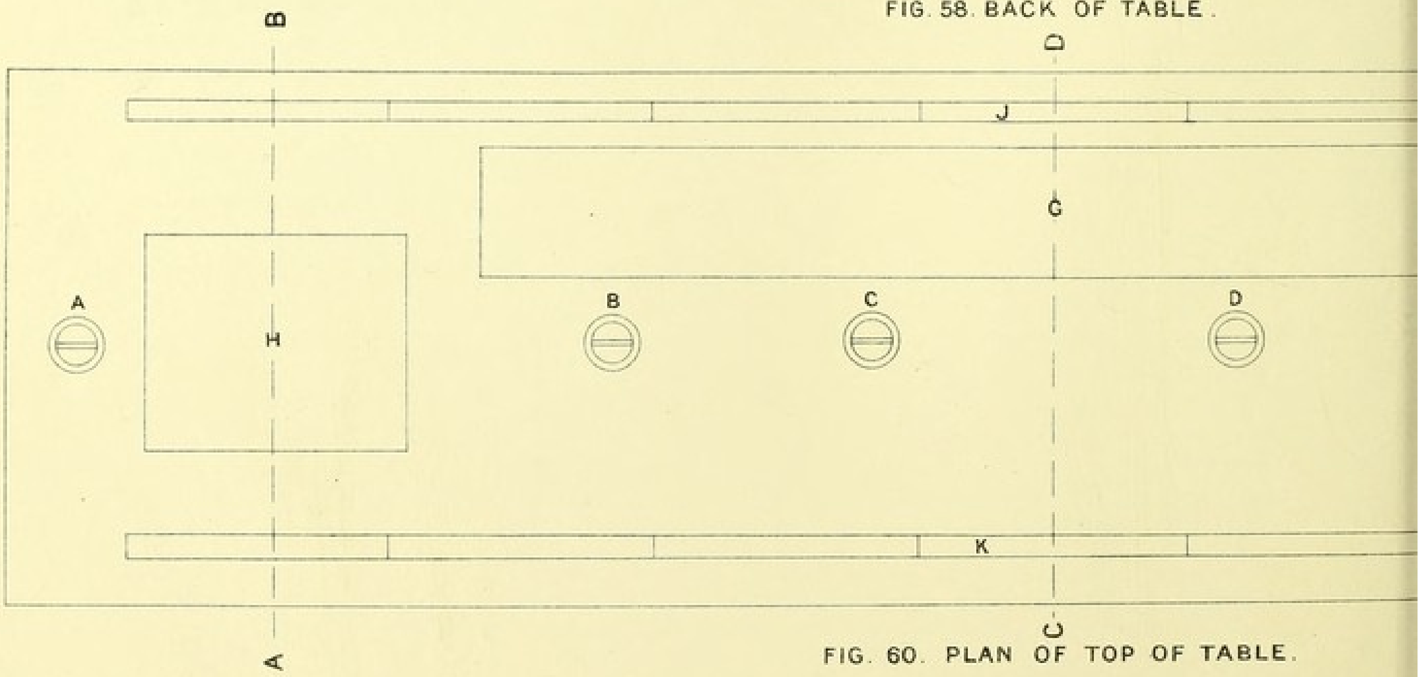
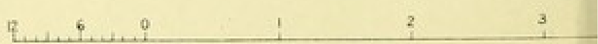


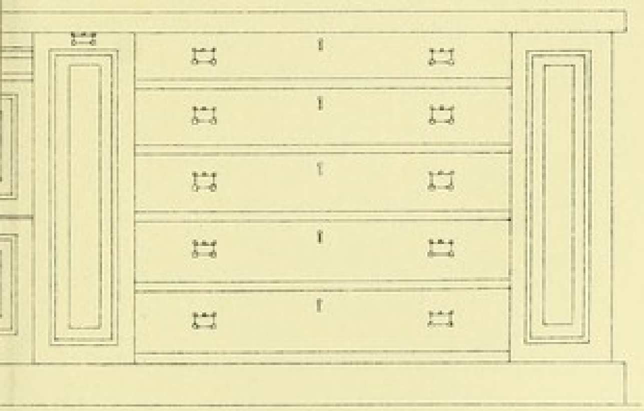
FIG. 60. PLAN OF TOP OF TABLE.



A.B.E.F. *Traps for Gas*
C. *do* „ *Water*
D. *do* „ *Exhaustion*

H.H. *Tank Covers*
J.K. *Electric Wire Covers*
G. *Large Tank Cover*

UNIVERSITY COLLEGE DUNDEE ; NATURAL PHILOSOPHY & MATHEMATICS DEPT
LECTURE ROOM TABLE.



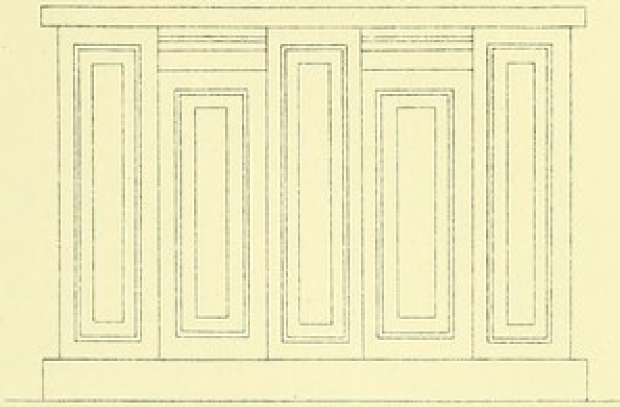
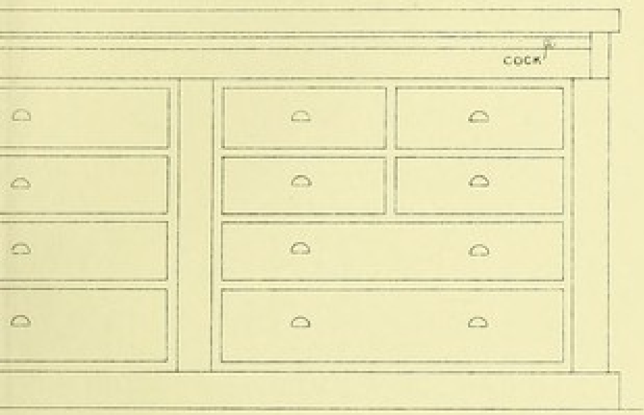


FIG. 57. END



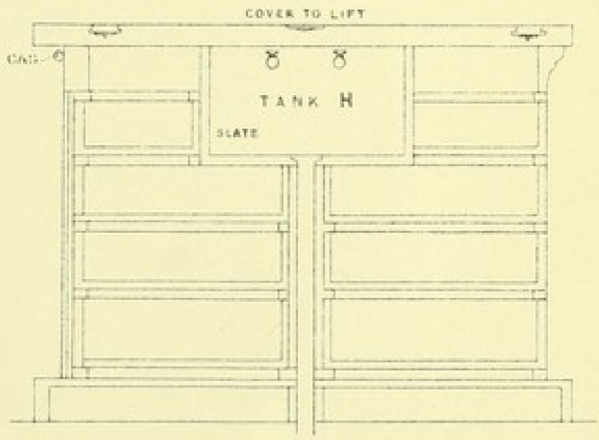
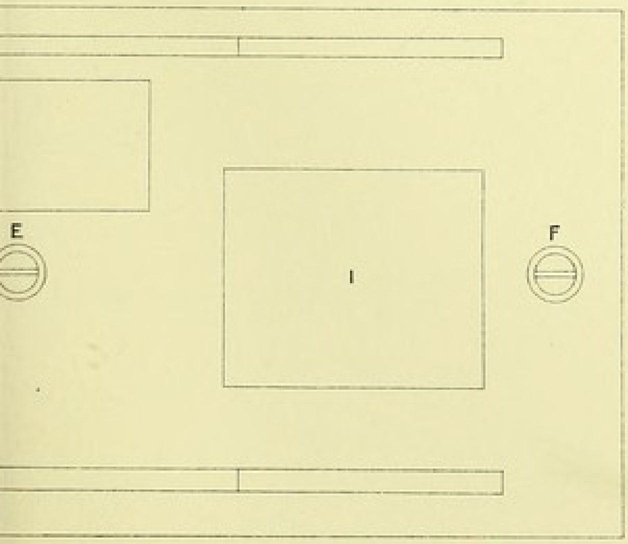


FIG. 59. SECTION AT A.B.



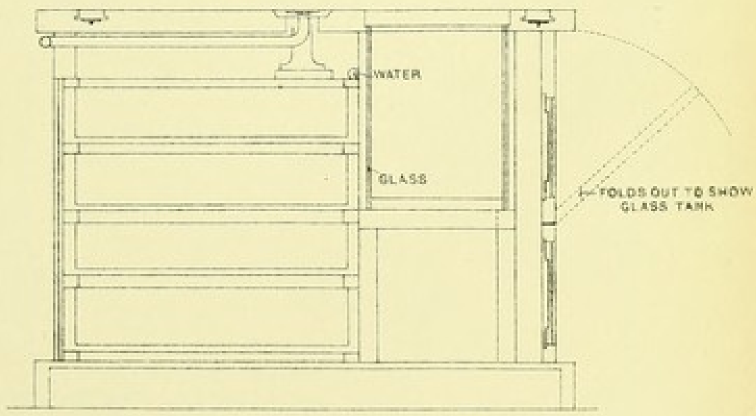


FIG. 61. SECTION AT C.D.

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II. FITTINGS FOR APPLIED SCIENCE INSTRUCTION BUILDINGS. (XVII)

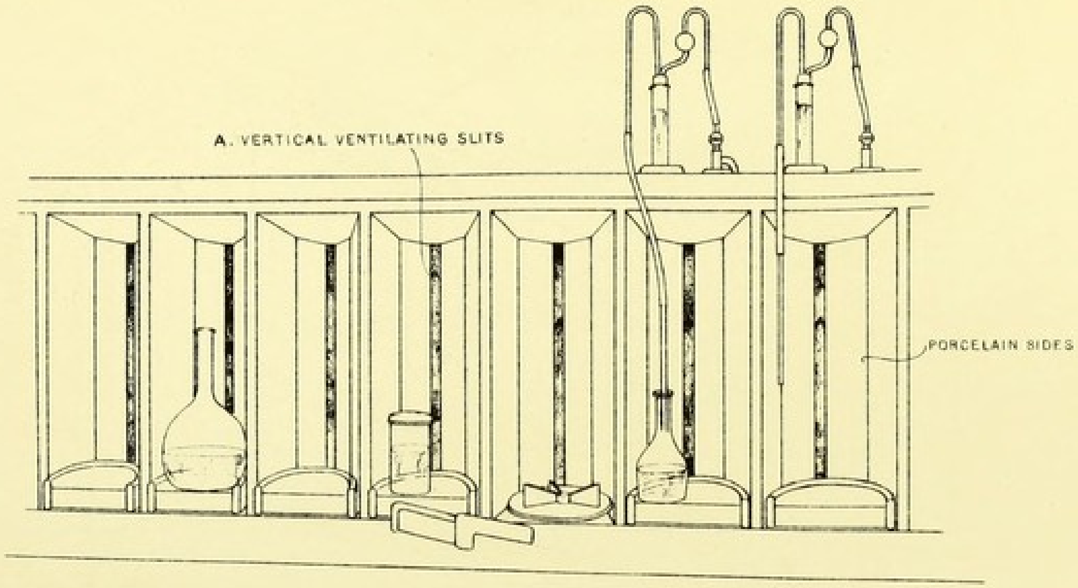
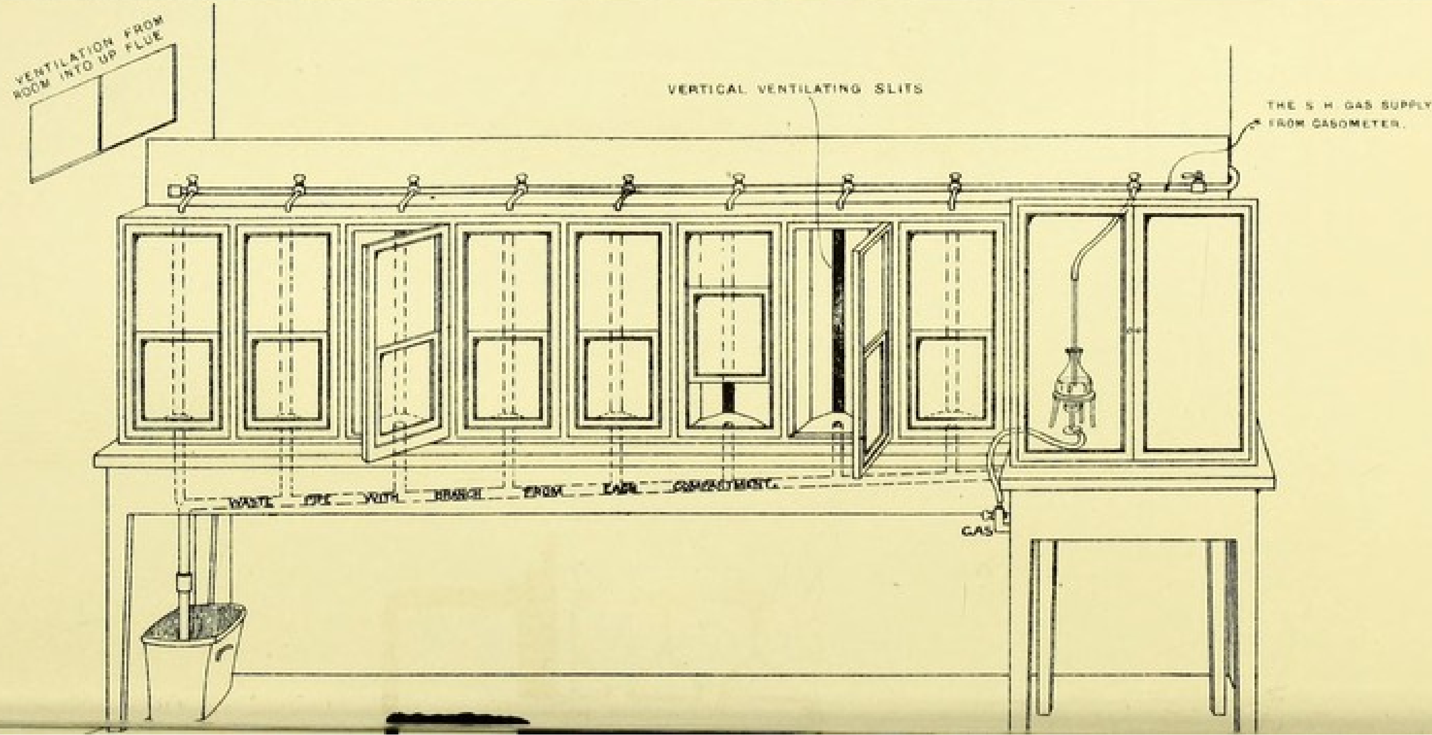


FIG. 62. GRAZ. PEBAL'S SULPHURETTED HYDROGEN CLOSETS, PERSPECTIVE SKETCH.



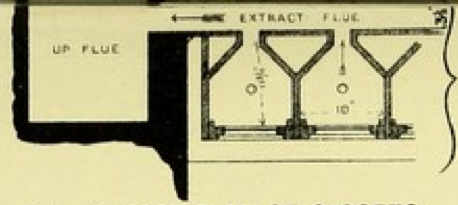


FIG. 63. PART PLAN OF CLOSETS.

FIG. 64. LEIPSIC, KOLBE'S SULPHURETTED HYDROGEN CLOSETS, PERSPECTIVE SKETCH.

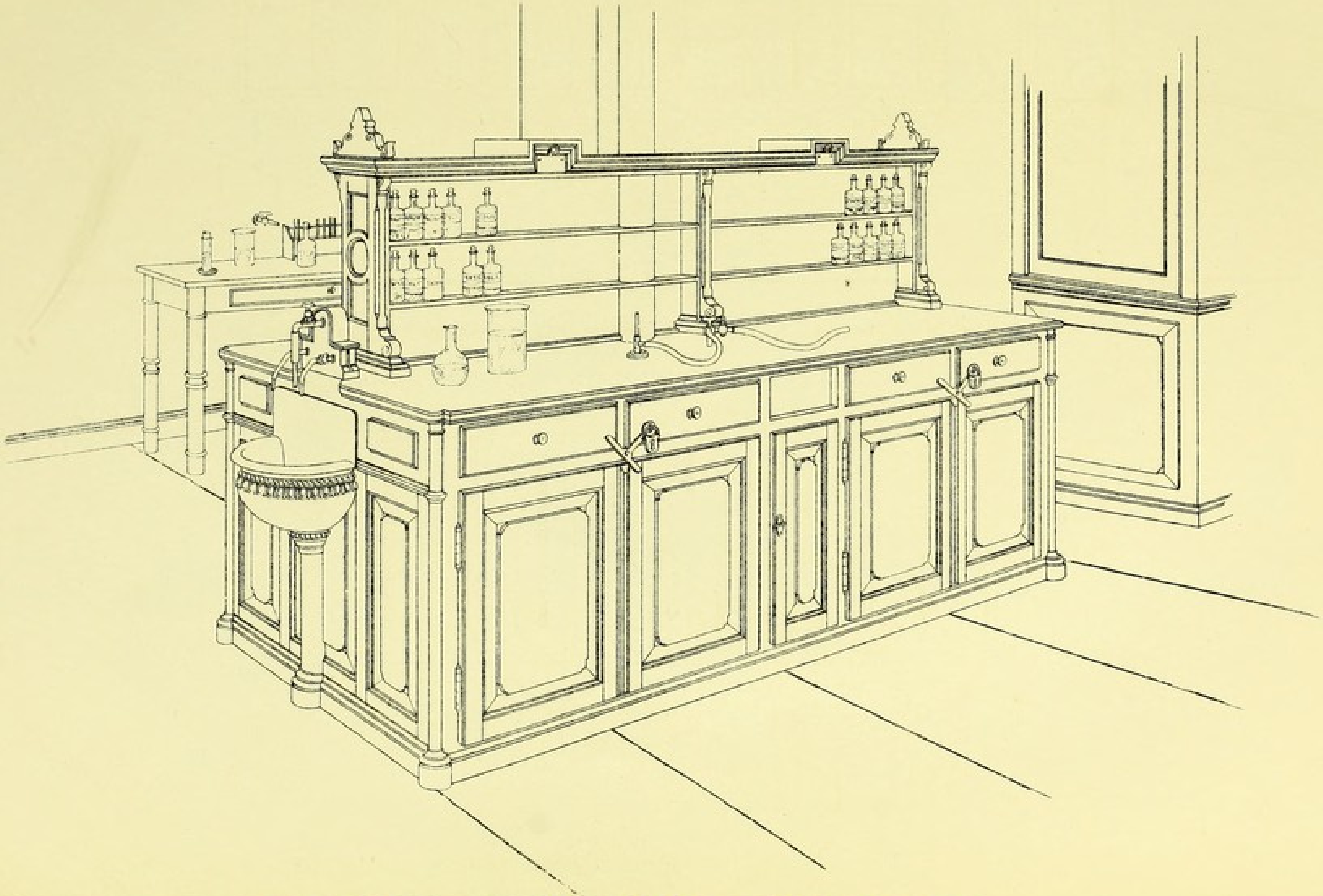


FIG. 65. LEIPSIC, PERSPECTIVE SKETCH OF OPERATING BENCHES.

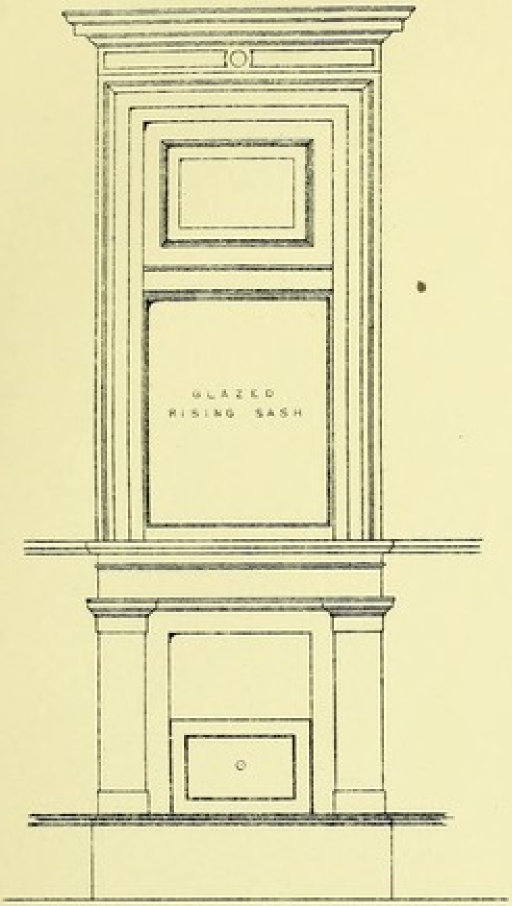


FIG. 66.
ELEVATION.

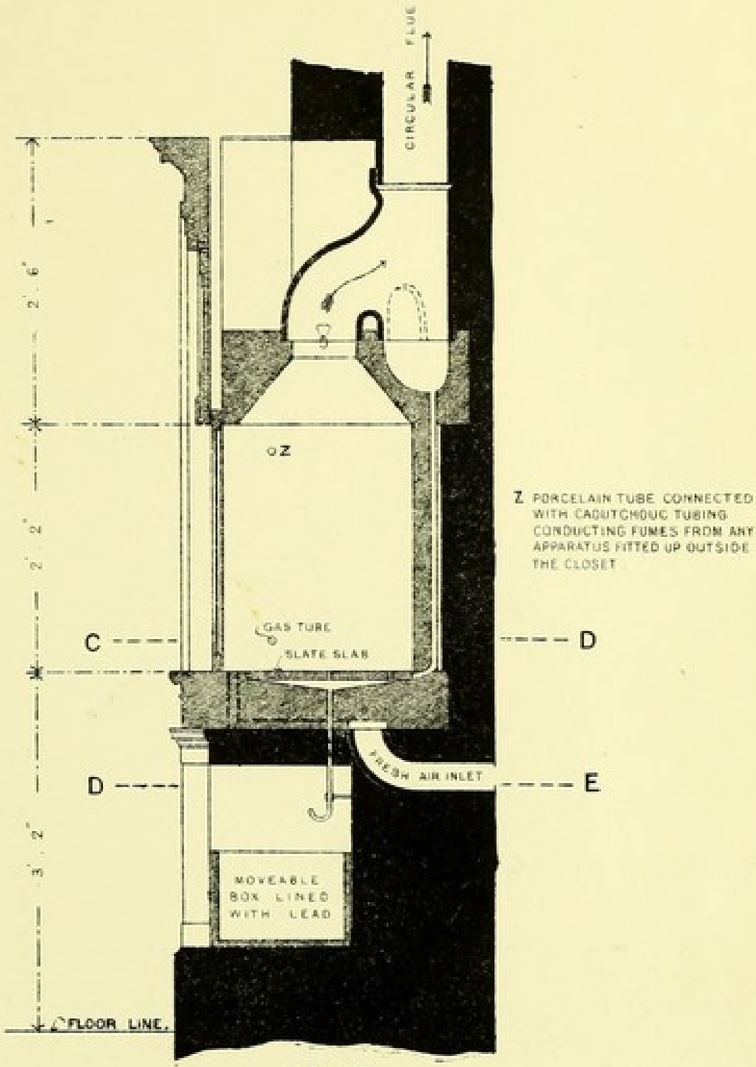


FIG. 67.
SECTION.

SCALE.
12 6 0 1 2 3 4 5 FEET

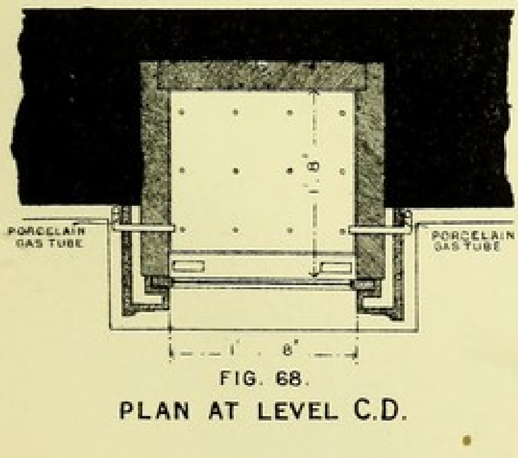


FIG. 68.
PLAN AT LEVEL C.D.

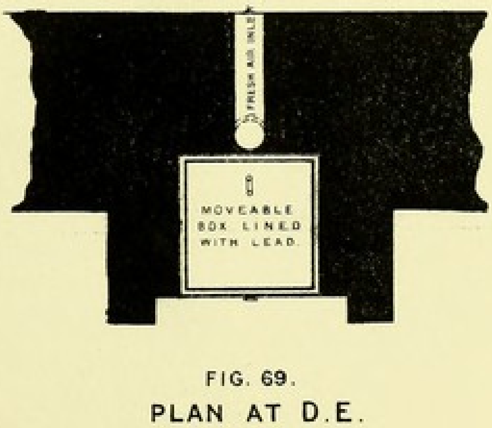


FIG. 69.
PLAN AT D.E.

LABORATORIES AT BONN & BERLIN, DRAUGHT CLOSETS, (HOFMANN.)

C F Kell. Photo-Litho. London. E.C.

Table of Calculations for Heating and Ventilating the New Bristol Trade & Mining School.

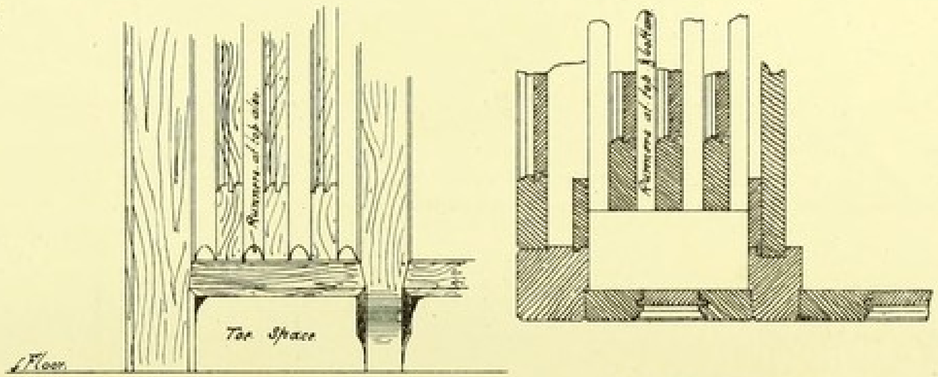
No.	Name.	Cubic content in feet.	Fresh air required per hour for ventilation, in cubic feet.	Ditto, ditto, in lbs.	How calculated.	Heat lost per hour by deperdition, in units.	Heat necessary to raise fresh air to temperature, t, per hour, in units.	Heat given off by tubes per hour, in units.	Internal temperature, = t, with extl. air at + 25° Fahrt.	Length of tube proposed, 1½ in. extl.
A	B	C	D	E	F	G	H	I	K	L
1	Dining Hall	18544	140000	10682	200 pers. at 700 c. ft. ea.	22206	88981	111187	60°	1112
2a10	Cloak Rooms	9384	—	—	—	16875	—	28125	60°	281
10a	Lobby	9035	—	—	—	5159	—	8595	55°	86
10b	Slope	2173	—	—	—	2980	—	4966	55°	50
10c	Stairs	12528	—	—	—	17251	—	28751	55°	287
10d	Ditto	20132	—	—	—	20319	—	33865	55°	339
11	Museum and Library	24300	24300	1882	1ce. cubic cont.	30172	15443	45615	60°	456
12	Master's Com. Room	4830	9660	730	2ce. ditto	9072	6949	16021	65°	160
13	Waiting Room	2730	—	—	—	5187	—	8645	65°	86
14	Committee Room	8250	16500	1247	2ce. cubic cont.	12318	11871	24189	65°	242
15	Class Room	8250	35000	2646	50 pers. at 700 c. ft.	10182	25190	35372	65°	354
16	Ditto	8250	35000	2646	50 persons at ditto	7777	25190	32967	65°	330
17	Ditto	8250	35000	2646	50 persons at ditto	7714	25190	32904	65°	329
18	Ditto	8250	35000	2646	50 persons at ditto	8869	25190	34059	65°	340
19	Examination Hall	106800	350000	26705	500 pers. at 700 c. ft.	43592	222452	266044	60°	2660
20	Retiring Room	2430	—	—	—	4317	—	7195	55°	72
20a	Corridor	1875	—	—	—	11036	—	18393	55°	184
20b	Ditto	6641	—	—	—	3273	—	5455	55°	54
20c	Ditto	2250	—	—	—	4875	—	8095	55°	81
21	Engineer's Lect. Room	11925	42000	3204	60 pers. at 700 c. ft.	13282	26689	39971	60°	400
22	Engineer's Diagram „	4770	—	—	—	3644	—	6073	60°	61
23	Artificer's Drawing „	15619	21000	1587	30 pers. at 700 c. ft.	28293	15108	43401	65°	434
24	Class Room	8250	35000	2646	50 persons at ditto	10171	25190	35361	65°	354
25	Ditto	8250	35000	2646	50 persons at ditto	6400	25190	31590	65°	316
26	Ditto	8250	35000	2646	50 persons at ditto	6400	25190	31590	65°	316
27	Ditto	8250	35000	2646	50 persons at ditto	5675	25190	30865	65°	309
27a	Corridor	5040	—	—	—	3150	—	5250	55°	53
27b	Ditto	3240	—	—	—	7930	—	13221	55°	132
28	Chemical Lecture Room	18802	84000	6409	120 pers. at 700 c. ft.	46983	53386	100369	60°	1004
29	Preparation Room	5670	22680	1715	4 times cubic cont.	12721	16326	29037	65°	290
30	Class Room	2906	10500	794	15 pers. at 700 c. ft.	7163	7559	14722	65°	147
31	Master's Room	5940	11880	898	2ce. cubic contents	13722	8549	22271	65°	223
32	Operation Room	10560	21120	1597	Ditto	14993	15103	30096	65°	301
34	Chemical Laboratory	21600	120000	9072	40 by 50 by 60	24912	86365	111277	65°	1113
35	Phys. Sci. Lect. Room	26048	84000	6409	120 pers. at 700 c. ft.	28620	53387	82007	60°	820
36	Phys. Sci. Laboratory	9280	37120	2806	4 times cubic cont.	12070	26713	38783	65°	388
37	Metall. Laboratory	14208	28416	2148	2ce. cubic cont.	15752	20449	36201	65°	362
38	Special Work Room	2992	11968	904	4 times ditto	3397	8608	12005	65°	120
39	Room	6045	12090	914	2 ce. ditto	10661	8701	19362	65°	194
40	Corridor	2904	—	—	—	2126	—	3560	55°	36
41	Ditto	3592	—	—	—	1164	—	1940	55°	19
42	Ditto	4950	—	—	—	4350	—	7250	55°	72
43	Ditto	1575	—	—	—	546	—	943	55°	9

Merchant Venturers School, Bristol.

—Fittings · in · Room · Nº 34.—

Students · small · Working · Tables ·

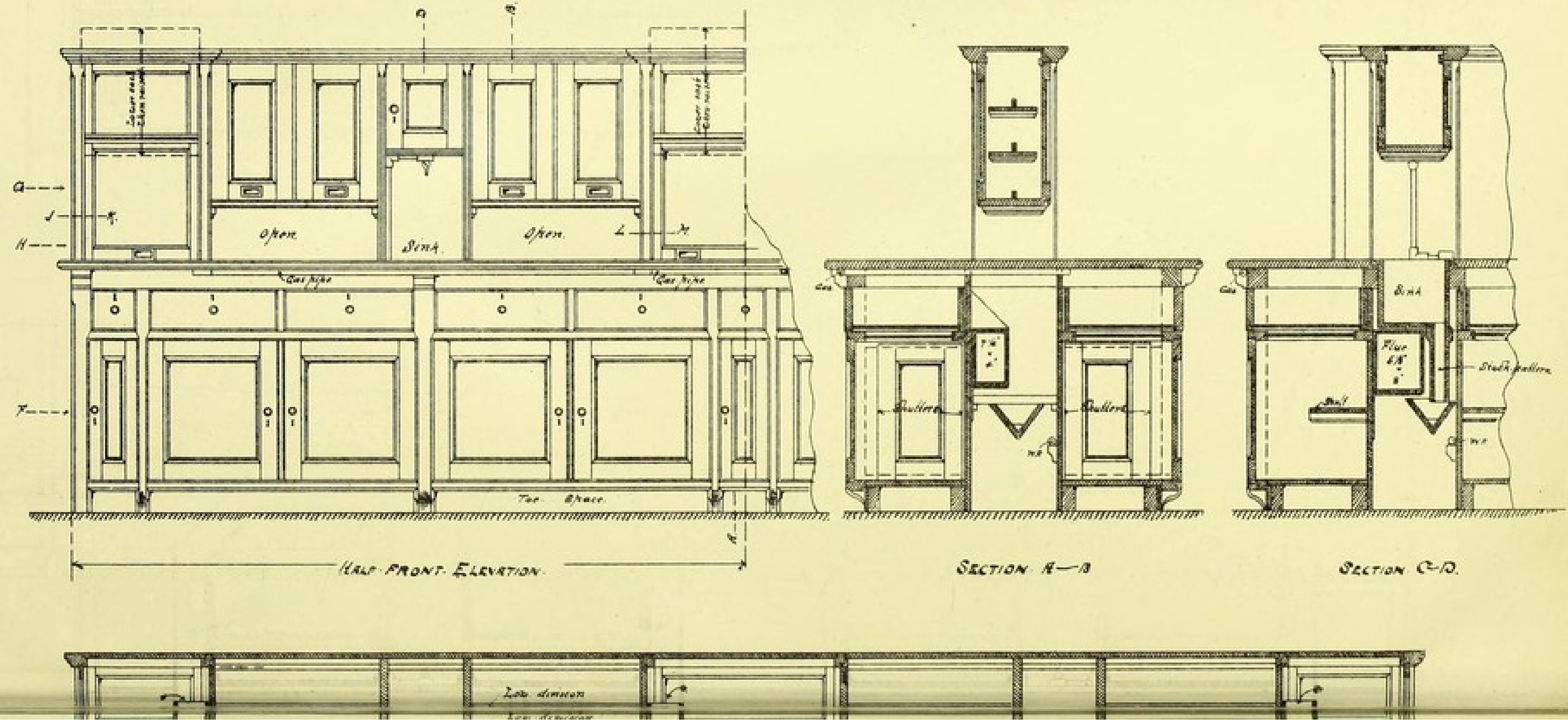
N.B. Of the 3 Students small-Tables in Chemical Laboratory this one has the largest Draught Flues. Note however that the Draught Flues vary in each of the 5 Tables in Laboratory, and that their sizes will have to be taken from the figures marked on the General Plan of Top Floor (⅛ Scale) which figures (Endanthus 64ᵈ) indicate the area of Flue inside.



Part · Elevation.

Plan thro' Shutters.

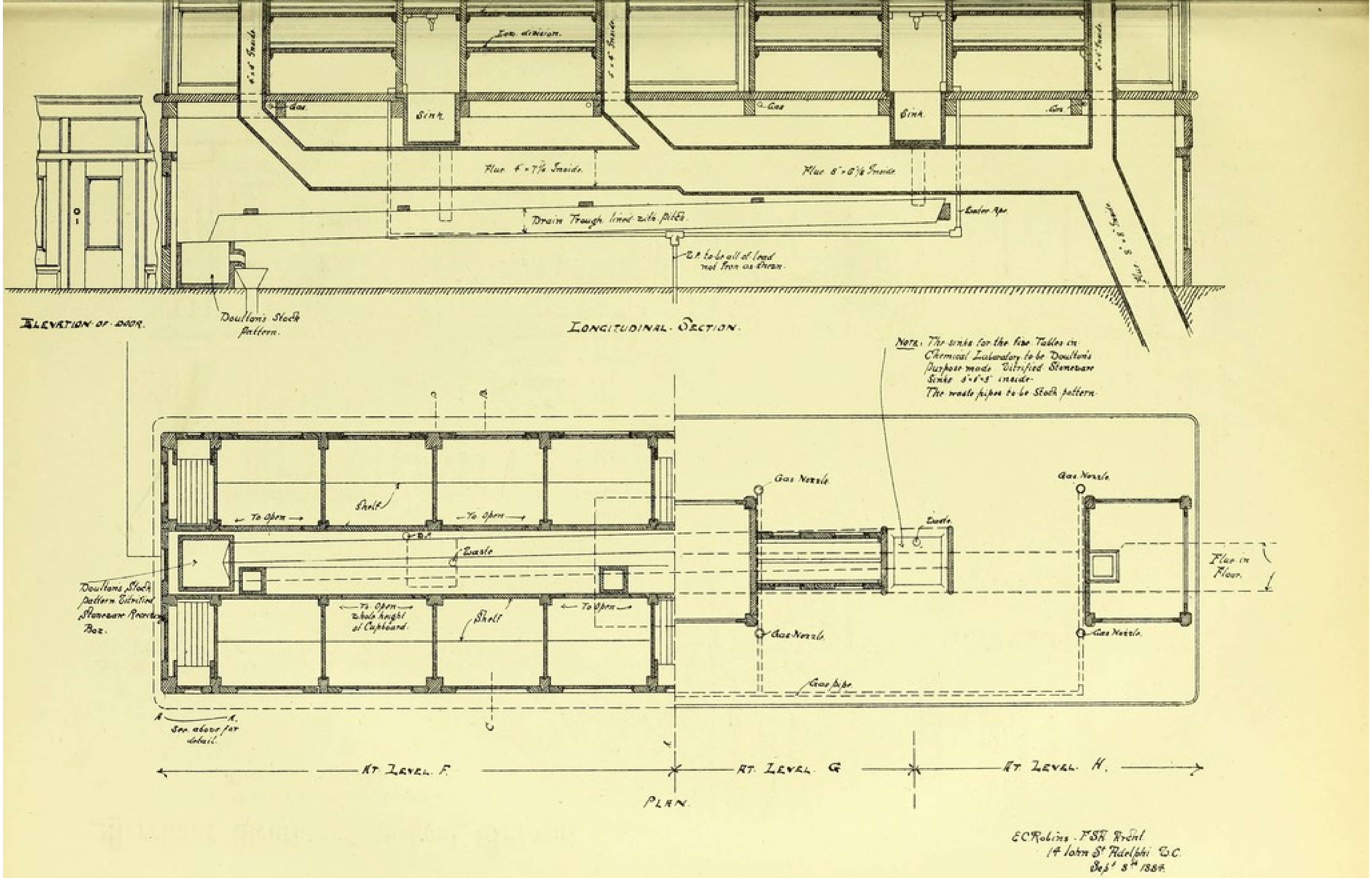
Detail of Cupboards for Shutters. (at A—A) with door removed.



Half · Front · Elevation ·

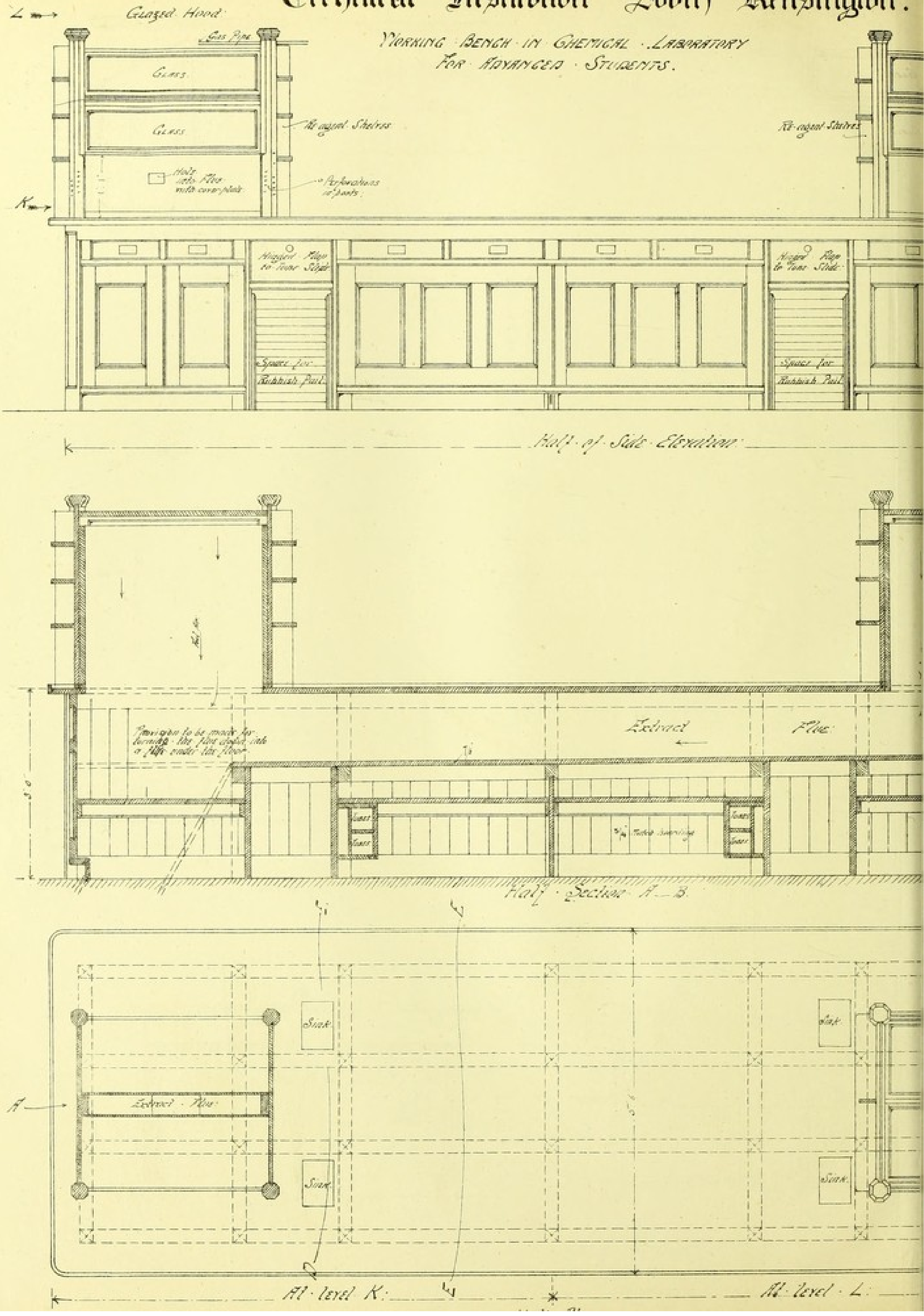
Section · A—B

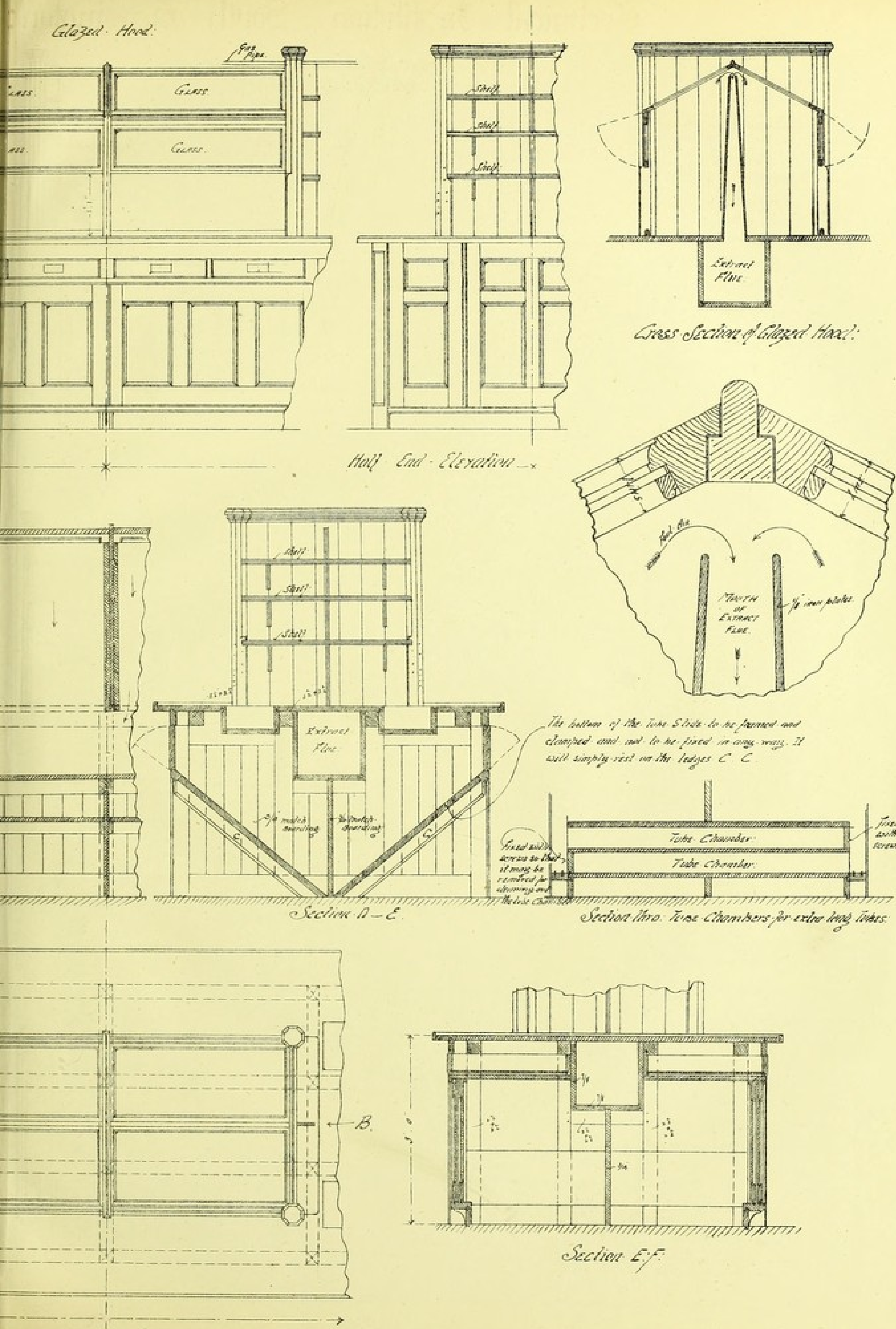
Section · C—D.



Elevation of door.
Doulton's Stock pattern.
Longitudinal. Section.
Sink
Gas
Ice division
Flue 4' × 7½ Inside
Flue 8' × 6⅛ Inside
Drain Trough lined with pitch
Leader Pipe
S.P. to be all of lead not iron as shewn.
Note. The sinks for the five Tables in Chemical Laboratory to be Doulton's Purpose made Vitrified Stoneware Sinks 5' × 5' × 5' inside.
The waste pipes to be Stock pattern
To Open
Shelf
Waste
To Open whole height of Cupboard
Doulton's Stock pattern Vitrified Stoneware Receiving Box.
See above for detail.
Gas Nozzle
Gas pipe
Flue in Floor.
At Level F.
At Level G
At Level H.
Plan.
E.C. Robins. F.S.A. Archt
14 John St Adelphi W.C.
Sept 8th 1884.

Technical Institution South Kensington:





Glazed · Hood.
Gas Pipe
Glass
Glass
Glass
Glass
Shelf
Shelf
Shelf
Half · End · Elevation
Extract Flue
Cross Section of Glazed Hood.
Mouth of Extract Flue
1/8 iron plates
Shelf
Shelf
Shelf
Extract Flue
The bottom of the Tube Slide to be framed and clamped and not to be fixed in any way. It will simply rest on the ledges C. C.
Tube Chamber
Tube Chamber
Fixed with screws.
Fixed with screws so that it may be removed for cleaning out the tube Chamber
Section D – E.
Section thro. Tube Chambers for extra long Tubes.
B.
Section E·F.

THE accompanying engraving* represents a group of students' benches in the Chemical Laboratory of the Nottingham University College. Four benches are arranged in one block, and each bench has beneath it a duplicate set of two drawers and a cupboard, the set being fastened by means of an iron bar swinging on a pivot from above and secured by a padlock and staple.

At each end of this block there is a deep stoneware sink with a straight half-inch outlet pipe, the end of which terminates in a stoneware trap-pot. The pot prevents any solid particles from passing into the drain pipes and renders a grid unnecessary; it is occasionally taken out and emptied into a pail.

Over each sink there are three low-pressure water taps for washing apparatus and supplying condensers, and two high-pressure taps for supplying aspirators.

A round pipe projects above the middle of each working bench; this is the opening into the system of draught-pipes drawn upon by a tall chimney shaft outside the building; this shaft is heated by the chimney from the boiler furnaces passing up its middle, and has yielded a satisfactory current. The draught opening over the bench is closed by a wooden plug when it is not in use, and when open it is either used directly or a metal hood is fitted into it.

Two gas taps for Bunsen's burners are supplied to each bench, and there is one illuminating burner placed at a convenient height over the middle of the bench.

The bench is made of stout American walnut, which is stopped and varnished except on the working surface, and this is saturated with oil and rubbed up. The height of the bench is 3 feet, its depth 25 inches, and the length of the double bench is 9 feet. A space of 3 feet is allowed between successive blocks, and a gangway 6 feet in breadth is left between the rows of bench blocks.

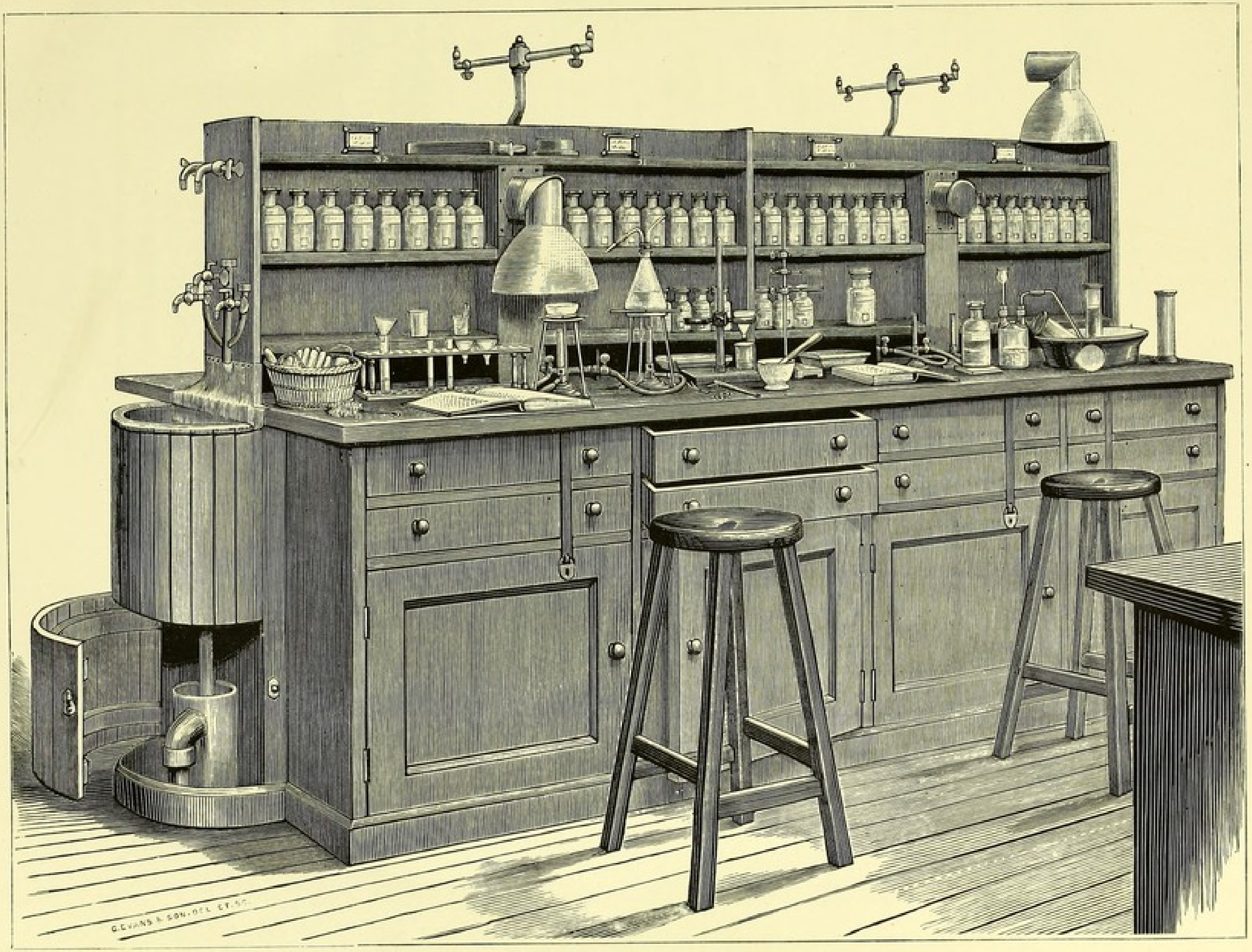
The shelves for reagent bottles are 4 inches deep and 7 inches apart.

This arrangement of benches is not economical of space, but it presents the great advantage of giving each student a sink close at hand and so placed as not to wet the bench surface when it is used; and, further, it affords ready means of access to all parts of the laboratory.

Each block contains lockers for eight students, and working space for four engaged in qualitative analysis, or for two who are performing quantitative work; the lockers being so allotted that students do not clash in their time of working. Each has a different key, but the whole of the locks are controlled by one or more master keys.

F. CLOWES.

* The engraving forms the frontispiece of a "Treatise on Practical and Analytical Chemistry," by Frank Clowes, D.Sc., Professor of Chemistry, Nottingham University College (J. & A. Churchill).



Laboratory Bench University College, Nottingham.

pages 1 to 124
to follow here

[Extracted from *The Journal of the Society of Arts* of April 9, 1880.]

BUILDINGS FOR SECONDARY EDUCATIONAL PURPOSES.

IT has long been the meritorious privilege of this Society to inaugurate valuable reforms in social and political economy, and to materially aid in the development of educational, industrial, and commercial enterprise. It is here that the enthuasiast, charged with some fixed idea as to the particular mode by which improvements may be effected in any time-honoured custom, or antiquated system of doing or thinking, may deliver himself of his crotchet, and bring to the test of discussion the result of his lucubrations. The earnestness and honesty with which opinions may be stated are sure of appreciation here, even though the convictions themselves do not find approval; and therefore it is that one feels free to speak one's mind in this room without let or hindrance, knowing well that the wheat will be separated from the chaff by the interchange of ideas, and that progress of a more or less substantial character will result from the consideration of the questions at issue.

Upon the subject before us to-night, an immense variety of opinion has existed, and still exists, and it is no purpose of mine to claim exceptional superiority to, or even exemption from, the weaknesses of others. Nor shall I stay to magnify their deficiencies, but rather try to add what I may towards the solution of a problem which is every day becoming more interesting as its importance is more keenly felt.

The inconsistency subsisting at the present time, with reference to the supervision and control of educational buildings, will be obvious to to all whose attention has once been drawn to it. While in elementary schools, workhouses, and lunatic asylums, restrictions are imposed, and rules and regulations are enforced, which prescribe the minimum superficial area and cubical space to be allotted to each inmate, in secondary and higher class school buildings no such supervision exists, and the middle and upper class boys and girls of the period are allowed to be packed away in close, ill-ventilated, badly arranged apartments, without any controlling authority, in premises not originally constructed for educational purposes, and with none of the appliances common to every Board school. A private house, originally intended for the accommodation of less than a dozen persons, is seized upon for a middle-class school for several hundred pupils.

Properly certificated teachers are demanded for primary tuition, but any speculative person whether certificated or not, may establish a secondary school; and no Minister of Education may interfere with the glorious independence of the bold Briton who, perchance, may add to his intellectual incapacity entire ignorance of sanitary laws, the consequent effect of which upon the physical and mental vigour of his pupils, however deleterious, passes unchallenged.

Mr. Matthew Arnold has well said :—

"The middle classes in England have every reason not to rest content with their private "schools; the State can do a great deal better for them. By giving to schools for these classes "a public character, it can bring the instruction in these under a criticism which the knowledge "of these classes is not in itself at present able to supply: thus, the middle classes might, by "the aid of the State, better their instruction, while still keeping its cost moderate. This in "itself would be a gain, but this gain would be nothing in comparison with that of acquiring "the sense of belonging to great and honourable seats of learning, and of breathing in their "youth the air of the best culture of their nation. This sense would be an educational influence "for them of the highest value; it would really augment their self respect and moral force: it "would truly fuse them with the class above, and tend to bring about for them the equality "they desire."

How this desirable end may be brought about, it concerns us all to enquire. I can do no more, on the present occasion, than call attention to it, in the hope that it may yet receive the consideration it demands from a patriotic people.

The recent growth of intelligence in the design and construction of national schools, and their appliances, is too obvious to need more than a passing remark, when comparison is made between the latest efforts of the London School Board and the system which preceded it. The effect of this improvement is, however, beginning to be felt in secondary schools; and its influence will be still more marked in the future, as time rolls on, and the necessity for the same constructional advantages is better understood and appreciated. Humble as yet may be the educational results of the London School Board curriculum beyond the three R's, the social and moral influences of their ample provision of space, suitable fittings, and sanitary arrangements, cannot be otherwise than considerable.

The older educational endowments for higher education are associated with buildings erected at a period when sanitary laws were little understood. As Mr. Robson observes:—

"Our old foundation grammar schools furnish us with few ideas as to the future planning "of public middle schools; their sole provision was usually a single lofty and noble hall of "oblong form, in which the whole of the boys might be seen engaged in their various lessons, "learning by 'art,' or carefully plodding with grammar and dictionary within sight of the "master, who was placed on a raised platform. No class room ever, until quite recent years, "spoiled the simple dignity of these architecturally excellent school-houses, and their fittings "were of the rudest and simplest kind."

Through the action of the Endowment Commissioners, many of these old institutions are being remodelled, and schemes for their wider use and development are constantly being thought out, as new buildings are required to meet the increasing demands for space. Opportunity is thus occasionally given to exercise the ingenuity which has been so well displayed in primary school-houses, on middle-class school buildings.

Private schools in particular, as we have already observed, usually suffer from the disadvantages of being located in houses not specially constructed for them. Public schools will inevitably become more and more popular as the teaching power improves, and as the opportunity for proper classification—which is increased with the larger numbers to be taught in one and the same building—is recognised. Public schools for boys have always been more or less in vogue, but public schools for girls are a modern innovation, calling for special contrivance in the buildings appointed for their use.

Concerning public day-schools for girls, and with respect to their suitability for the purposes contemplated, Miss Wolstenholme emphatically says :—

" The experiment of large day-schools has been successfully tried, and the results are con-" clusive as to the superiority of the system from whatever point of view we regard it; " their superior economy is obvious. Morally, we believe the gain to be also great. We want, " in every considerable town in England, a high school for girls, which should offer the best " possible education on moderate terms—one which should serve as a model to all those private " establishments for which in future, as at present, there will no doubt be abundant room. " To such a school as this it would be very easy to attach all manner of appliances and appa-" ratus in the way of lectures and special classes, which might be attended from private " families or smaller schools."

Since these words were penned, eighteen* schools for girls have been established by the Girl's Public Day-schools Company, originated by Mrs. Gray, who sagaciously hit upon this commercial means of extending this new system of education for girls. The system, however, is equally applicable to boys, and a Boys' Public Day-school Company would not fail to achieve a similar success.†

The resources of the company have, as yet, been chiefly employed in the establishment of new schools, and they have been obliged to hire houses for school buildings. Except at Croydon and Blackheath, which are very creditable examples, I am not aware that they have erected any new schools. At Gateshead and Oxford new schools are projected, and I am, myself, engaged in the preparation of plans for a new school-house for the South Hampstead branch, of which I was one of the original promoters, and in which I am desirous of giving an inexpensive illustration of the principles hereainfter advocated, adapted to a school for 300 pupils. [See plate I.]

The system of teaching adopted in these schools is very similar to that elaborated at those which may be regarded as the earliest of girls' day-schools, viz., the North London Collegiate and Camden School for Girls, founded by Miss Buss nearly 30 years ago. The remarkable success of these upper and lower middle-class day-schools is proverbial. They now contain nearly 1,000 pupils, and several hundreds more are patiently waiting their turn for admission as vacancies occur.

On the application of the Brewers' Company, the Charity Commissioners projected a scheme whereby certain valuable educational endowments, belonging to that company and the Clothworkers' Company, have been devoted to the development of these schools, thus enabling the trustees, to whom Miss Buss had handed them over, to erect, for her foundation, representative buildings of their class. As the architect to the trustees for carrying on the said day-schools, I shall have occasion to point out the peculiarities of their construction, the drawings of which are exhibited on the walls, as is also my design for the Harper Trust Girls' Day-school, at Bedford.

With these preliminary remarks, I now proceed to offer some practical suggestions, with the view of popularising a subject not, generally, too well understood. It may be convenient if I arrange what I wish to say under two general heads :—

---

* There are now 30 G. P. D. Schools.

† Such a Company has since been established.

1. The general arrangement of the buildings as a whole.
2. The particular planning of the parts.

Part I.

We will take it for granted, if you please, that the site is all we could desire, with a hard gravel subsoil, slightly elevated, well drained, surrounded by play-grounds, chiefly extended towards the sunny side, the aspect being such that a few northern-lighted rooms may be obtained for artistic purposes; but the main class-rooms to be east by south, or west by north, that they may not be too cold in winter, nor too warm in summer, and may at all times be bright and cheery. The class-room windows to be not less than 50 feet from any opposite buildings, and their area of light not less than one-fourth of the floor-space, and, if the windows are on one side wall, the opposite wall should not be more than 25 feet distant, so that the farthest desk may have sufficient light; 15 square feet is the maximum area required for each pupil, and 14 feet a maximum height; the minimum area should be 12 square feet, and 12 feet height. Inlets for fresh air should be opposite the foul-air extracts, arranged for use in the varying proportions required in summer and winter, and entirely under the control of the teacher; some, at least, of the extract-shafts to be heated at the base, and some, at least, of the inlets for fresh air to be capable of being warmed on its passage into the room. However contracted the site, it is to be hoped that room will be found for a fives-court, and for the simpler kind of gymnastic exercises, both covered and uncovered.

With reference to the general arrangement of school buildings, they naturally divide themselves into two distinct classes, viz., boarding-schools and day-schools.

I. *Boarding-schools.*—With reference to the first, it is not my intention to say very much, because it is not in this direction that the extension of educational buildings is likely to be very greatly increased; nevertheless, it is very important that the improvements made in day-schools should be imported into boarding schools, and that the accommodation required for residentiary purposes should not overbear or prejudicially influence the educational department and its appliances.

It has been one of the drawbacks to the proper development of voluntary schools, that the promoters were too often willing to sacrifice the school conveniences for the sake of obtaining space for popular lectures and general assembly rooms, and the Education Department very properly set their faces against innovations of this sort wherever their influence extended. At the same time, the great cost of extensive dormitories and domestic offices in boarding-schools renders it essentially necessary to bear in mind the double purpose of such buildings, so that each may be economically arranged, and the provisions necessary for the one purpose may not lead either to curtailment or extension beyond the requirements of the other.

As an example of the kind of building which, in practice, has been found to answer the ends proposed, I will draw your attention to the plans on the walls, which illustrate Milton-mount College, Gravesend. The educational division of the building occupies the ground floor of the main block, consisting of a southern front and eastern and western wings, over which are two stories of dormitories; the dining hall—a single-storey building, with an open-timbered roof—is situated in the centre, and is placed at right angles with the main building, and, being situated immediately opposite the entrance-hall, is easily accessible for public uses or school lectures and examinations, while at the other and northern end are the kitchen offices, quite distinct from the rest of the building, yet closely associated therewith by the corridor running on the side of the hall. The pupils' staircases occupy the internal angles at the junction of the main building with the wings, while in the centre is a service staircase, at the southern end of the corridor, connecting the main building with the domestic offices. [see plate II.]* By this arrangement, the several parts of the building are in close connection and yet perfectly distinct:—The educational apartments, with the teachers' and pupils' dormitories above them; the kitchen offices, with the servants' dormitories over them; and the dining and lecture-hall between.

The architect of the London School Board, Mr. E. R. Robson, F.S.A., in his admirable work on school architecture, has chosen this building as an example of a middle-class boarding-school, and has given four illustrations of it. I cannot do better than quote his succinct description. He says:—

"Milton-mount College, Gravesend, intended for the daughters of Congregational ministers, "and erected from the designs of Mr. Robins, forms a rare specimen of a carefully-considered "school-house for 150 girls, on the boarding principle. The sleeping apartments on the first "floor are planned on the model of the ancient monastic dormitories, a central corridor down a "large hall or room, leading, on right and left, to cells, chambers, or cubicles, formed by wooden "panelled or match-boarded partitions, 6 ft. 6 in. high, arranged along both sides.

"The monks' dormitory at Durham, erected in the 15th century, and now used as a library, "was identical with this in plan. The advantage of the arrangement is that each scholar has a "room to herself, while ventilation is promoted by the upper part of the room being entirely "unencumbered by divisions. The cubicles measure 9 ft. 6 in. by 5 ft. 6 in., and occasionally "two are thrown together, by the omission of the partition, for occupation by two sisters or "friends. A drawing shows an interior view, supposing the partition removed for the purposes "of a sketch.

"On the ground floor are the school-rooms, class-rooms, teachers' and visitors' rooms, "library and music-rooms; the last are fitted with shelves and portfolio lockers. The little "practising-rooms each contain a piano, and it is found that sound from room to room is "sufficiently deadened by the plan for the purpose in view. In each of the school-"rooms bookclosets are formed against the wall-dado, and surround the room. One "school-room is fitted with a raised gallery and Dr. Leibriech's desks; there are four "class rooms, each for 20 pupils; the bonnet and cloak-rooms are fitted with separate closets "for every three girls; the dining hall is capable of accommodating 150 girls and eight "mistresses. The arrangements of the dormitories on the second floor are identical with "those of the first floor."

Now there is nothing in the design of this building, which would not make it equally suitable for boys, excepting only the music-rooms, which might be converted into science class-rooms. The same may be said of another example of this description of building, viz., the

* These original plans have been somewhat varied in execution. The infirmary has been omitted, and the left wing has been extended northwards for a science laboratory and lecture-room with dormitories over. The laundry has been built on another site, and a gymnasium occupies the right quadrangle.

Educational Home for the Daughters of Missionaries, Sevenoaks, now in course of erection, the foundation-stone of which was laid by the Right Hon. W. E. Forster, M.P. [see plate III.]

In this building I have carried out the same principle of planning, but so varied as to suit the special circumstances of the case. In this boarding school, 100 children have to be accommodated and divided into senior and junior schools, the senior occupying the left wing and the junior the right. Cubicles are provided in the dormitories for the seniors, but not for the juniors, for which latter class nurses' rooms are required, and bath-rooms for all.

The dining hall is in the same relative position as at Milton-mount College, with the kitchen offices and servants' dormitories in the rear; but in this case, and in consequence of the delicacy of children, born mostly in foreign countries, it was thought desirable to form the building into a quadrangular shape, with internal courts on either side of the dining-hall, so as to be less exposed to northern winds, and more compact and warm, the corridors themselves being heated. Both here and at Milton-mount ample space is given for cloak-rooms and conveniences, which, in each case, are projected from the main building, under lean-to roofs, towards the internal courts. An unwise economy usually contracts the space allotted to cloak-rooms, lavatories, &c., so as to make them greater nuisances than conveniences.

The plans exhibited sufficiently explain themselves, and will render any tedious description unnecessary; for the same reason I do not think it desirable to detain you by describing the Misses Lushington's mixed middle-class school at Kingsley, opened by Lord Selborne and Mr. W. E. Forster, which is similar, but, for economical reasons, the kitchen offices occupy a different position, to enable a pair of existing cottages to be brought into use. [see plate IV.]*

II. *Day-schools.*—We now come to the general arrangement of middle-class day-schools. In considering these, it will be useful to observe the recent growth of elementary schools; for this purpose I have exhibited drawings of Christ Church Schools, Battersea, which were erected by me many years ago for 600 children—200 boys, 200 girls and 200 infants; they were designed on the old system then required by the Educational Department, and consisted of one long room and one class-room to each division, the classes in the long room being divided by curtains drawn out at right angles from the walls. This school was erected at the then stipulated cost of £4 per head, exclusive of the two teachers' houses. [see plate VI.]

On the establishment of the London School board, various architects were engaged on the first schools projected, one of which fell to my share, viz., the Wapping School. The improvements very early made by the School Board, are exhibited in this design for a school for girls and infants only, as shown in the more compact planning, the increase in class-room accommodation, and the introduction of dual desks, &c. [see plate VII. fig. 1.]

This tendency towards the increase of class-room accommodation is in accordance with German examples, and one of the most approved by Mr. Watson and Sir Charles Reed is Haverstock-Hill School, designed by Mr. Robson. In this case there are four class-rooms to each large school-room, all of which are on the ground floor, each of the large school-rooms giving space for as many desks as the four class-rooms belonging to it together contain; but with this striking peculiarity, that the central space, around which these school and class-rooms

* Since the reading of this paper the author has designed and executed the Congregational School at Caterham for 150 Boys, which was opened by Mr. Samuel Morley in October 1884. An illustration is given. [see plate V.]

are arranged, is covered, and forms a hall of assembly, wherein the whole school meets daily, and in which examinations can be held, and through which access is gained to all the classes, the glazed doors to each of these being commanded from the daïs in the hall. This hall was originally designed as a girls' covered play-ground, and is so described in Mr. Robson's book, but experience has proved its great convenience in administration, and it is no longer used as a play-room, but contributes not a little to the educational success of the institution, at which my wife is a visitor. The "hall-passage system" had thus an accidental birth. [see plate VII. fig. 2.]

In Jonson-Street School, Stepney, designed by Mr. T. Roger Smith, the large school-rooms were thrown aside altogether, and the one great hall alone retained, with separate class-rooms surrounding it on three sides, and all in direct communication with it. This school was professedly based on the Prussian system, but is a great improvement upon it, and is the best example of what Dr. Abbott has happily termed the "hall-passage system," adapted to schools of more than one storey in height. I look upon this as the culminating point to which primary school buildings have grown, and I take this as the starting-point from which progress is to be made in the future development of secondary schools. [see plate VII. fig. 3.] That I am justified in this opinion, the latest design for a secondary day-school by both these gentlemen is confirmatory. And, through their kindness, I am enabled to show you Mr. T. Roger Smith's design for the Grocers' School, and Mr. E. R. Robson's design for the Blackheath School, of the Public Day-schools Company, both of whom have adopted the said "hall-passage system" in these middle-class schools, the one for boys and the other for girls.

Mr. Henry Clutton has also adopted the same principle in his design for St. Francis Xavier's College, at Liverpool, erected, in 1875, as a middle-class day-school for 500 boys.

The advantage of so planning a school building that the head master may, with the least loss of time and trouble, have the whole school under his supervision and control, must be manifest to every one who thinks of the difficulty of personally controlling a school of 500 or 1,000 pupils and their various masters. A hall into which every class-room door shall open, where the pupils may congregate for prayers, for lectures, for examination, for separate instruction in such groups as may be required by special circumstances, where they may meet and retire in an orderly manner to their several classes or to their homes, under the eye of the presiding genius of the school, is obviously an addition of no small importance to the welfare and discipline of the school.

The moment that you introduce the corridor you destroy the possibility of exercising the same kind of influence; the hall, if you have one, becomes a costly appendage, of a stately character, but of no daily practical use, reserved only for special occasions. The teaching being done in the class-rooms, it has not the excuse for its existence which the old foundation-schools had, for in them no class-rooms were provided.

For these reasons I prefer Mr. Smith's design for the Grocers' School to that which has been chosen and erected, a plan of which I exhibit, and by which it will be seen that the hall is carefully cut off from the class-rooms by a corridor, which effectually isolates it, and gives to the head master no personal control whatever of the movements of the school, as a whole, from such a vantage ground, and thus the hall is rendered an expensive and comparatively useless luxury.

In designing the buildings required for the North London Collegiate School, at Sandall-road, Camden-town, and the Camden School for Girls, at Prince of Wales-Road, Kentish-town, I laboured under the disadvantage of having to incorporate therewith existing buildings in each case, and in the former to complete the new portion before I touched the old, so that the pupils might be transferred from the one to the other; but, feeling very strongly the representative character of these schools, I endeavoured to bring them into subjection to the latest, and, as I think, the best improvements in school planning. The task has been a difficult one, but success seems to be assured, even before the amended old part of the building has been entirely handed over for occupation, as in the case of the Sandall-road School.

Camden Schools.—The plans on the wall illustrate the general arrangements, concerning which I may remark that the Camden School was first built and finished. The freehold of the Governesses' Institution, founded by Mr. Laing, was purchased for £5,500, and, at a cost of some £7,500, was adapted to the uses of the school. In this case, for economical reasons, no hall was desired, it being determined that the Clothworkers'-hall at the Collegiate School should be jointly used by the two schools on prize days, &c. [see plate VIII.]

The education given at this school is at a much lower rate than the former, and the classes number 50 pupils in each; on the ground and first floors there are nine such class-rooms, a gymnasium, a drawing-school, a lecture-room, library and committee room, teachers' rooms, office, and caretaker's apartments; in the basement are the extensive cloak-rooms, drying closets, dining-room, kitchen, and domestic offices.

The girls enter by the basement steps on each side, proceed to the cloak-rooms, thence pass up to their several class-rooms, where each has a separate desk to herself; the use of the gymnasium, drawing-school, lecture-room, and playground being timed with great precision. Both hot-water and open fire-stoves are used for heating and for drying clothes, and every class-room has arrangements for admitting fresh, and extracting foul air, independently of the windows. Owing to the administrative abilities of the head mistress, Miss Elford, no less than the completeness of the arrangements, this school goes like clockwork.

North London Collegiate Schools.—The old portion of the North London Collegiate School for Girls was originally an emporium, or general store, and was adapted by me for school uses. It is now undergoing considerable alteration and addition, an extra floor and a new façade being constructed. The new buildings occupying the remaining portion of the site are finished, and were opened by the Prince and Princess of Wales last July.

It will be seen by the plans exhibited [see plate IX and X.*] that the accommodation comprises the following:—The great hall, presented by the Clothworkers' Company, and called by their name, 70 ft. by 39 ft., and 32 ft. high, with a wide gallery at the end and a shallow one on the side at the level of the first floor, the raised daïs and organ recess being at the opposite end on the ground floor. Three storeys of class-rooms are arranged on one side of the hall. The five class-rooms on the ground floor, and those over them on the first floor, are in direct communication with the hall by the ground floor of hall and the side gallery on each floor. Two of the class-rooms may be thrown into one, by opening the sliding doors

* These plans have been slightly altered in execution ; the angle being terminated with a slated turret, and the Gymnasium extended to 100 ft. in length, &c.

provided between them. There are three of the class-rooms on the second floor and a large drawing-school lit in a similar manner to the Gloucester Art School.

Under the hall is the dining-hall, and the kitchen, scullery, and housekeeper's room; under the class-rooms are the cloak-rooms and conveniences, the store-room, the teachers' room, the strong room, the head mistress's retiring-room, and the drying room.

The basement and staircases are heated with fresh warm air by hot-water pipes in channels to which fresh air is admitted in large quantities. The class-rooms have Boyd's School Board ventilating grates and fresh air admission shafts, and foul air extraction shafts are everywhere so that the necessity for opening windows is not felt, though cross ventilation by windows is easily attainable, not only by the fanlights over the doors to the hall, but by windows in the same intermediate wall. The triangular space over the boarded ceiling of the great hall forms a warm air extraction shaft, hot-water pipes being placed at the foot of a vertical flue at one end.

There are two staircases to this new building, one at each end of the corridor. This portion of the school has been in occupation some eight months, and the advantages of the system have been fully proved; otherwise, in spite of the known administrative ability of the head mistress, it would have been impossible to have accommodated the whole school of upwards of 400 pupils without the use of the old part of the building.

It is an interesting sight to see the pupils come in through the basement entrance to the cloak-rooms, where they enter at one door and retire at another, changing their shoes as well as leaving their hats and cloaks, and passing up the staircases to the great hall, where they file in to their accustomed seats and await the organ peal giving forth the morning hymn, followed by the prayers read by the head mistress, at whose command each teacher leads her class to its class-room: after which the doors are shut, and work begins within and also without, in the great hall and gallery, which, at present, supplement the class-rooms in the old building not yet handed over, but about to be so next term.

The Old Building.—On either side of the main entrance to the old building are small triangular offices, at which inquiries may be made without further entering the building, at small windows provided; beyond these, on one side, are the head mistress's rooms, and on the other side, general office and waiting room; adjoining this is the board-room, which is also the library and museum. Over the board-room, on the first floor, is the science lecture-room, with a chemical laboratory adjoining; the other two rooms are respectively a class-room and the teachers' retiring room and library. The old staircase is retained to reach this floor, but the new staircase gives access to the second floor, in which are two large and five smaller class-rooms for music-lessons and practice. The caretaker's rooms are reached by a special staircase, and extend from the front under the turret to the back; a box-room is situated in the turret itself, and a lumber room in the general roof. Behind the organ are passages on each floor, and a lift from the sub-basement and coal-cellar to the lift and cistern room on the top-most floor. Two drinking fountains are provided for each floor, supplied with filtered water, and lavatories and w.c.'s in addition to those entered from the cloak-room. The basement is occupied by a cloak-room 30 feet square, a cooking school and scullery, &c.

It must be confessed that, upon this very awkwardly shaped site, very little else could have been done had the buildings been re-built instead of only enlarged. The playground is much too small, and is partly occupied by the gymnasium, which is fitted with Stempel's apparatus; a fives-court is to be attached to the gable-end wall.

Such is a general description of these schools. I now come to consider one twice the size, which has recently been the subject of much discussion, viz. the City of London School.

I have exhibited on the walls my competition design for this building, in which you will see a further development of the same principle of planning which I have been advocating, but which was as fatal to my success as to Mr. Smith's in the Grocers' School competition. The public has not yet been educated up to the "hall-passage system," and the selected plan in this competition repeats what I considered a defect in the former case—the great hall is made a solitary apartment, carefully cut off from the uses of the school by the corridors surrounding it. In other respects the plan is suited to the site, but would be as complete without the hall as with it.

In the design submitted by me, the hall is the centre of civilisation to the school; into it every door to every room in the building opens, and from the raised daïs is commanded every part of the building and all the people in it. This hall is lit like the nave of a church, with a range of clear-storey windows above the roofs of the class-rooms surrounding it. It takes away the necessity for close, stuffy, dark and dreary passages, and gives a cheerful hall as a promoter of light and ventilation. It has a gallery round it, at the level of the first and topmost floor. The class-rooms on three sides open into it, and the great lecture-room for 400 students is at one end, in easy communication with the chemical laboratories and class-rooms.

Under the lecture-room on the ground floor is the dining-room, capable of being divided into four class-rooms, and supplied by a lift from the kitchen on the second floor, which is part of the caretaker's apartments. Benches are provided for the whole of the school on the ground floor, with aisles 10 ft. wide running round and forming open passages of communication, never needing to be screened by curtains except on examination days, as experience has proved at Sandall-road School. The head master's and secretary's room, the clerk's offices, and the board-room, with the separate waiting-rooms, are ranged on either side of the chief entrance from the Embankment. The basement is almost entirely devoted to covered playgrounds and cellarage, the fives-courts and conveniences being planned carefully with covered ways to the latter from the staircases. The head master's private room overlooks the south-western corner, and the teachers' private common-room overlooks the playground at the north-west corner, so that out of school the masters are in the best position for observing the pastimes.

Mr. T. R. Smith's design for the Grocers' School is most compact, and a glance at the drawings makes the arrangements quite clear, leaving little by way of description necessary. The class-rooms are arranged on three sides of the hall, with which they are in direct communication, similar to the admirable Board school erected by him at Stepney.

Mr. Clutton's design for St. Xavier's College, already referred to, is also well illustrated by the plans and sections which he has kindly lent me. I was not aware of its existence till, in searching for corroborative examples of the principles I am advocating, I found an illustration of it in the *Building News*. I wrote to the master to learn what his opinion is of the practical advantages to be gained from this arrangement, and the Rev. Father Harris replied as follows:—

"The opening of the class-rooms directly into the great hall has very great advantages.

" 1st, as regards general supervision ; 2nd, as regards saving of time ; 3rd, as regards all general "discipline. It is, however, difficult to use the hall for any general purpose during school "hours ; but, as far as the good of the boys, which is the principal matter to be studied in a " college, is concerned, the system answers admirably."

I have also received the following note from Miss Buss, whose testimony is of great value:—

"During the time that we have had the use of the hall, we have found it exceedingly "pleasant. The opening of the school-rooms directly out of the hall is certainly a great "advantage. The supervision is much more easy, as is also the control of pupils while "assembling and dismissing. The light and ventilation are excellent, far better and more " complete than they would have been if you had given us a passage."

Part II.

I now proceed to consider the second formal division of my subject, viz., the particular planning of the parts; but I fear the time at my disposal will necessitate a very limited discussion of the details.

The Lavatory and Cloak-rooms.—Every school is, or ought to be, entered through the hat and cloak-rooms, and the most convenient mode of retirement should also be by the same route, supposing always that the cloak-room does not form a separate adjunct to each class-room, as in the case of the City of London School. In this design I endeavoured to realise the expressed wishes of the head master, and arranged for the boys' entry into the cloak-room on one side of each class-room and out at the other, the custom at the dismission being for the master to order the boys to file off from their class seats into the cloak-room, and enter again by another door to their seats, with the hats and coats with them ; when all are ready, the order is given to leave ; in this way the loss of clothes is prevented. But the better plan is to have separate cloak-rooms, which may be heated and ventilated quite independently of the class-room, and may also be dried by hot-water pipes as they hang, or, if very wet, taken to the drying room. One of the most complete cloak-rooms, as well as the most extensive, in a boy's school of this kind, is that of Cowper-street School, Finsbury. And I am sorry to say, about the worst, are those provided in Board schools, where, if anywhere, it surely is most necessary to avoid the transmission of disease and other evils, by providing cloak-rooms of sufficient size, and not, as is most common, having two or more rows of pegs over each other, so that the garments hang one upon another ; but the outcry against expenditure in Board schools will, doubtless, make it difficult to improve in this respect. In secondary schools, however, this ought not so to be, and yet it is the commonest sin in the most elaborate and expensive buildings in other respects, and not less in girls' than in boys' schools.

The provision made in the North London and Camden Schools is as economical as it is efficient, and the plan is this :—The cloak-rooms are situated in the basement, and consist of a series of rooms the same size as the class-rooms above them, surrounded on all sides with a single row of pegs, not less than 9 inches apart, a shoe-rack, and umbrella hook, with continuous metal water-channels, made moveable in short lengths. A screen down the centre gives space for a similar arrangement on either side of it ; hot-water pipes pass under each screen, above the floor ; between the rows, forms are placed for the girls to take off their walking-shoes ; every peg is numbered, and every pupil has her number.

The lavatories are situated in the cloak-rooms, and the external conveniences, are entered from the cloak-room ; so that every arrangement is open to inspection, and under the control of the teachers on duty in each room. Some teachers prefer to keep the lavatories and conveniences separate from the cloakrooms, so that the cloak-rooms may be locked up during school hours. In boarding-schools it is usual to provide closets and doors with looking-glasses in the upper panels, &c.; but in all cases plenty of room is essential to the discipline and *morale* of the school.

The Class-rooms.—The arrangement of the class-rooms is one of the most important of the parts. The number of scholars varies with the system of classification adopted. The Public Day-school Company prefer from 20 to 25 in a class; the North London Collegiate School, for the higher education, apportions 30 to a class; the Camden School has classes of 50 ; a common number is 40, which is that adopted at the City of London School but 60 is not an unusual number in great schools.

Continuous forms and desks, four, five and six rows deep, are usual, but I prefer the dual desk to the continuous, and think the best arrangement is that adopted at the North London and Camden Schools, where each student has a single Swedish desk, set 15 or 16 inches apart so as to allow of a passage between each from front to back ; the rows will need no space between them from side to side, but a 2 ft. passage or more is desirable at the sides next the wall, though not essential, the resulting area being from 12 to 15 ft. each scholar. In all cases the light should fall on the left side of the desks ; and, if the rooms are not heated by warm-water pipes, the fires should be opposite the desks ; and not in the centre of the wall, but between the teacher's desk and the entrance door, so that the teacher's raised desk may stand in the centre, and the draught, if any, from the door may only feed the fire, without annoying the teacher, or the students.

On the opposite side to the fire, and behind the students' desks, vitiated air extract shafts should be built in the walls, with a large grating fitted with a gas jet inside, and the means of closing, if desired, one at each side and close to the ceiling. The stoves should be on the principle of Boyd's School Board stoves, with fresh air passing through them into the room. Further fresh air shafts, on what is known as Tobin's system, may be added, if desired, or by shafts in the wall, under window sills, opening through hit-and-miss ventilating gratings fixed in the window-boards. The latter is adopted at Sandall-road, but has the disadvantage of admitting the air too low, and the descending cooler air, next the cold window panes, checks the upward current of the inlets. The wall opposite the windows, in which is the door, should be supplied with a large fanlight over the door, and corresponding dwarf window openings in the upper part of the wall, so that cross ventilation may be obtained at pleasure, and particularly in the intervals of teaching. The rooms should be 13 or 14 feet high, as wisely required in all Board schools. Class-rooms so designed and arranged on one, two, or three sides of the great hall, form the largest part of the school buildings, and are adapted to every purpose required.

Drawing Class-rooms.—In addition to a northern light, a high light is desirable ; and not only so, but a skylight also ; and this is best attained by a curved roof, similar to that adopted at the Gloucester Fine Art School, and to that which I have built for the North London School. In this case, I have formed the roof with iron ribs and sash bars on one side, and glazed it like a conservatory, lining with boarding so much of the interior as the circumstances of the case required as proved by actual experiment.

Science Class-rooms.—I have already referred to the great changes which have recently taken place in school buildings, the single lofty hall which constituted the whole school 50 years ago being now superseded by a variety of separate class-rooms and other conveniences. But this change in the architecture has been accompanied by a yet more marked revolution in the mode of teaching, and in the matter taught. The education of the memory, which was all that was provided for our fathers, is in these latter days giving place to the education of the mind. To develop the reasoning faculty is now considered a nobler task than to manufacture walking encyclopædias, and, since it is now generally accepted that one of the most powerful instruments for the cultivation of the reason is the study of science, it is evident that chemical and physical laboratories—and, possibly, even mechanical laboratories—will henceforth be considered essential parts of a first-rate secondary school. These laboratories will also be associated with one or more lecture-rooms to accommodate from one hundred to four hundred students, or from a third to half the school, if not exceeding 800; above that number, it is better to have two lecture-rooms.

The particular form of chemical operating stalls, the service of gas and water, the sand-baths, and the fume-closets, are illustrated in drawings on the walls, and may be further studied by reference to the published illustrations of the admirable laboratories at Owens' College, Manchester; but, as I am not aware that similar publicity has been given to physical laboratory fittings, I have exhibited on the walls a few illustrations of the very clever arrangements designed by Professor Ayrton for the college at Yedo in Japan, which his kindness has put at my disposal.*

I may, however, remark that the chemical laboratory operating stall should be from three to four feet wide and two feet three inches deep, with two tiers of bottle-shelves at the back, two gas jets with Bunsen's burners, a basin of lead or of stoneware; the latter is less affected by acids, but the former is easily repaired or renewed, and fewer breakages occur in its use. If the laboratory is small, one sink in the corner, or next walls, will be all-sufficient, as at Sandall-road. Different sized drawers are required under the oak table top, and the remaining space may be provided with shelves, with doors to enclose the same, set back to allow space for knees when sitting at the stall.

The fume-closets should be formed with lead-lined sink and closet under, enclosed with panelling (if not recessed in the wall), with rising sashes in front; in the bottom rail of the lower sash hit-and-miss ventilators should be fixed, to admit air from the room to the chamber, at the upper part of which is a ring of gas jets at the foot of an extract flue. A better plan is adopted at Owen's College. All the fume and exhaust closets are connected by channels with a lofty chimney, at the base of which a furnace is constantly burning, and the draught created by this sucks up the air from the fume-closets, and carries it far above the buildings. A directors' room, best apparatus-room, balance-room, and special operation rooms are desirable additions.†

Since writing the above passage, I have received from the Science and Art Department of the Committee of Council on Education at South Kensington, their science form, No. 1013,

* See illustrations in the *Builder* of April, 1880. † See illustrations to Paper No. 4.

descriptive of fittings for laboratories; and with it a series of drawings, which I have exhibited on the walls; but as, on the payment of 1s. 6d., anyone may obtain a copy of these documents, I will not detain you by description now, except to say that they are the result of much deliberation, and practical experience has proved their value. The Royal Institute at Hull is fitted up with these fittings, which are suitable for advanced classes. The Gloucester and the Watford Art and Science Schools are illustrated in Colonel Donelly's reports, and may be consulted there. These buildings aptly illustrate what is required to complete secondary school buildings. Their existence as separate institutions proves that the want has been felt and provided for in this way; in future buildings the want should be anticipated. The chemical and physical laboratories—designed for the Finsbury Technical College of the London Guilds Institute—are fully described and illustrated in the report of the Governors of the 10th of March last; and since any one interested in the subject may obtain a copy on application to the secretaries of the Institute, I abstain from entering upon any description of them, but at once proceed to the consideration of*—

The Physical Department of the Imperial College of Engineering at Yedo, Japan.—From the particulars given to me by Professor Ayrton, I have been enabled to prepare a ground plan of the department of which he was professor, and it is no small satisfaction to me, as a member of the Executive Committee of the City and Guilds Technical Institute, that his able services have been secured to develop the physics classes at Finsbury, for which costly buildings are in course of realisation, such as it is hoped may give full play to his talents, to the great advantage of the youth and working classes of the City of London.

Room No. 1 is the demonstration room, 50 feet square, and occupying the whole height of this portion of the building, which is shown in the exterior perspective view of the same. It was fitted up in the following manner:—On a level with the first floor, a gallery about 3 ft. wide ran round the whole room, from which wires and other apparatus were suspended for experiments; it also gave access to the shutters by which the upper windows could be closed to darken the room for optical and other experiments. The students' benches occupied the centre of the room, and around three sides of the room, next the walls on the ground floor level, were instrument and working cases; the under side of the gallery being utilised for cupboards, entered from behind.

Room No. 2 is the general laboratory, fitted up with instrument cases, covered-in working cases, the tables being on concrete foundations, and uncovered instrument cases on brick piers.

Room No. 3 is the professor's private room and private laboratory.

Room No. 4 is the instrument room.

Room Nos. 5 and 6 are for electrical experiments, No. 5 being fitted up with six brick pillars, each about two feet square, and descending six feet into the ground. No. 6 has long tables on brick piers.

Room No. 7 is the lavatory attached to the laboratory, for washing bottles, &c.

Room No. 8 is a small, artificially-dried room, in which experiments with frictional electricity could be conveniently performed.

On the first floor, which extended over all but the demonstration-room, were rooms for

* See the illustrations given of Finsbury College plans and fittings, at the end of the Papers Nos. 3 and 4 of this volume.

experiments on light, a small class-room for the teaching of applied physics, rooms for special experiments, store-closets, and the battery-room.

The detail drawings, which I have had prepared from those made by Professor Ayrton, are exceedingly interesting and valuable on account of their originality, and because they have stood the test of the use in the college at Yedo.

Fittings in Demonstration-room.—The sloping platform, or student's gallery, is shown on the drawings, and in the side sectional view I have indicated in dotted lines the brick piers which sustain the students' tables distinct from the general flooring, so as to be quite free from vibration. There is also a front, back, and top view of the students' benches, and a section showing sinks and gas-fittings.

By this special arrangement of students' benches (which is believed to be unique of its kind), it was possible for the students, without leaving their places, to repeat the experiments made by the professor during the lecture, with apparatus placed ready for them on these firm benches. Between the lectures, these benches or tables could be utilised as part of the laboratory proper.

Illustrations are also given of the instrument cases, with folding-doors and glass panels, as arranged around a portion of the demonstration-rooom, which are also used in the laboratory.

Details are shown of the professor's lecture-table in this room, resting on a platform, the whole of which was sustained by a concrete foundation distinct from the general flooring, and its fittings included a pneumatic trough sink.

Fittings in the Laboratory.—Besides the instrument cases, the drawings also exhibit the working cases, furnished with glazed sash windows, as used in the general laboratory and in the professor's private laboratory.

The tables in the cases rested on a concrete foundation, quite distinct from the flooring, to avoid the transmission of vibrations; so that, except where the sash was closed, after work, to exclude dust or meddling fingers, no part of the case rested on the table, there being no connection between the table carrying the apparatus and the floor, on which rested the sash frames and glazed enclosure, and on which the experimenter stood. With such working cases a delicate investigation could be carried on from day to day, the apparatus being always ready whenever the experimenter had leisure to work at it. Some of the working cases, so enclosed, and fitted with window sashes to exclude dust, &c., not being required for very delicate experiments likely to be spoiled by small vibrations, stood upon the common floor without concrete foundations.

There is the charm of novelty in these arrangements so far as I know, and of the following fittings for the battery-room.

Battery-room.—Illustrations are given of these designs as carried out in the aforesaid Technical College of Yedo, under Professor Ayrton's direction.

Accommodation was provided for about 200 Grove's cells and 300 Daniell's, used for general electrical work and for the electrical testing of the students of telegraph engineering. The peculiarity of these special fittings was that all the cells were under glazed covers, and, therefore, dust was excluded; yet all the cells were visible, and all obnoxious gases were led up the flues; the cells were easily got at by opening any portion of the double-hinged cover.

When taking a Grove's battery apart, after use, the zincs were put at once into the long, narrow leaden sink, immediately in front of the battery-stand; and the porous cells to soak in the long leaden sinks immediately behind the operator. After soaking, the porous cells were put on the racks to dry, and were ready for use within reach of the operator putting up the battery on the next occasion.

Of Professor Ayrton's drawings I have seen ten, and of these I have chosen the most interesting examples.

It is to be observed that the fittings of the physical department at Yedo were contrived to enable the students to learn by advancing the bounds of knowledge, and not merely by assimilating existing information, as is evidenced by numerous published accounts of original research conducted in that laboratory; and it is this method of teaching which has given to Professor Ayrton the *prestige* which he enjoys.

Now, I trust that I have not wearied you already, but I was anxious to take this opportunity to give publicity to a series of very ingenious contrivances, which I hope one day to see more or less realised in the higher class secondary schools of the country.

The need of technical knowledge, based on scientific principles, is daily becoming more apparent, and our secondary school teachers will find it to their own interest, no less than that of the middle classes generally, to give increasing attention to it.

In conclusion, while thanking you for the patient hearing you have given me, let me express a hope that buildings for secondary educational purposes will no longer be considered unimportant accessories to the fuller development of the teaching power of the master, and the acquiring capabilities of the students, and, whether the authority of Government is applied to the removal of the present inconsistencies or not, that the good sense of the English people will in this, as in most other things upon which it exercises independent thought, achieve its own emancipation from the thraldom of habitual apathy and contented submission to things as it commonly finds them.

DISCUSSION.

The CHAIRMAN, in inviting discussion, said he felt sure that all who were interested in the great work of education must feel the extreme importance of having the arrangements suited to the work, and must appreciate, as he himself did, the able and thoughtful address which had just been delivered by Mr. Robins. He had been asked to submit a few remarks bearing not directly on the architect's question, but rather on the state of technical education at the present time, and with the permission of the meeting he would do so before the discussion upon the paper closed.

Mr. J. G. FITCH said the important matter always to be considered was, first, how to get the most effective teaching, and then how to adapt the mechanical arrangements to that teaching. Two or three things had struck him during the reading of the paper, which he should like to have considered by teachers, and by architects who built for teachers; one was that architects generally considered it sufficient if they provided a seat at a desk for every scholar; they built upon the theory that that was the scholar's place, and that he would seldom leave that seat; but his own feeling was, that in order to keep up the intellectual life and animation of a school, it was desirable that at least one lesson out of every three or four should be given standing. It was not desirable that children should remain seated during the whole of the time, and, therefore, he hoped that, in planning class-rooms, architects would remember that it was not wise to fill them up with desks, so as not to leave room for the scholars to take one lesson while standing. There was a great contention as to the character of the desks, whether they should be long continuous desks, dual desks—like those adopted by the School Board—or Swedish desks, in which the children had each a separate seat like a chair. He was not going to try to settle this question, but he hoped those that did try would bear in mind that the comfort of the teacher in teaching had to be considered as well as the comfort of the scholar in sitting. The more you scattered the scholars over a wide area, the more you increased the difficulty of a teacher in getting the class into a proper focus. That seemed to be a great objection to the arrangements as proposed, because if the scholars were spread over too wide an area, the teacher could not teach effectively without a trying expenditure of voice. No doubt class-rooms should be in the main isolated from each other, and if the class consisted of 30 scholars, it was well that the teacher should have them all to himself; but he would remind architects that there were some lessons which could be given with advantage to two classes at the same time, and therefore it would be as well to have the class-rooms separated by a moveable partition. After all, it was the character of the teaching staff, and a proper consideration of the sort of subjects to be taught in separate rooms or not, which should be looked at in determining the construction and fitting of a school; and, therefore, he hoped teachers would consider that, when they came into council with architects and others who looked at the matter from a purely mechanical point of view.

Mr. C. MAST thought that too much attention was paid to large schools to the neglect of the smaller ones, in which the greater part of secondary education was taught. He hoped that the system of designing large schools would not be extended, because he believed that the grouping of a great number of children under one roof was a bad plan. Every teacher would admit that, if his teaching was to be effective, he must act upon a small number, and though it was, no doubt, more economical to have large buildings, still the object of the teacher was better attained in a small room. He thought the desks ought to be moveable, and agreed with the last speaker that there was nothing more objectionable than the present system of giving all the lessons to the scholars while seated. The difficulty of arranging a school to meet the requirements of every master was, no doubt, very great, but he thought every practical teacher would soon find the means of adapting a building to his purposes.

Mr. T. ROGER SMITH said he could not add much to the careful account which had been given of school buildings, as they were being designed and erected now; but, speaking as an architect, it struck him that a good deal was being done to give to buildings that kind of adaptation to the requirements of modern tuition which Mr. Fitch pointed out was necessary, and which he hinted architects hardly thought of sufficiently. Bnt there was nothing which an architect was so pleased to get as the ideas of the person for whom he was building, and a definite account of the requirements to be met. The difficulty was not so much to provide for the requirements as to ascertain them thoroughly and consistently. He was glad to hear the advocacy which Mr. Robins gave to the system of class-rooms clustering round a central hall, without that abomination called a corridor; and he felt sure that a great many schools, even those for primary education, would be built on the improved system, and the number of class-rooms increased. There were one or two points with regard to class-rooms, which it might be desirable to dwell upon, not that they would be overlooked by men engaged in the construction of schools, but because upon occasions like the present hints might be thrown out which would bear fruit hereafter. Nothing should be neglected to make the class-room as good for its purpose as possible, and it should be made easy to hear and speak in. A perfectly square room was convenient for arrangement, but was not usually successful for hearing and speaking in; and, therefore, it was desirable that the room should be oblong, but not very far removed from a square. Then came the question how the children were to be ranged; were the windows to be at the end or the side of the room. The advantages and disadvantages were, briefly, these: if the children sat along the side of the room, they formed a wide group, but if at the end, they formed a narrow group, and were more under the eye of the teacher. This arrangement would generally be found to be successful, besides having the advantage of a greater spread of light. Another point to be considered was that of having sufficient provision for ventilation. The difficulty of working and of teaching in a hot or close room was so great as to neutralize every other provision for comfort; and ill-designed rooms, if they were only thoroughly ventilated, would, in many cases, be more happy places to work in than the best-lighted rooms if they were allowed to become close. He felt sure that they had not yet reached the culminating point in the designs for schools; probably they would obtain greater simplicity, compactness, and completeness than they had hitherto reached, and in time a model would be produced capable of general adoption, though he did not flatter himself that any one had hit upon that model yet.

Mr. WM. J. SPRATLING said, upon the subject of cloak-rooms, he might mention that, having had occasion to go over some plans for the enlargement of a secondary school, he found the architect had arranged for a long room, with forms for the children to sit upon to change their shoes, along the length of the room, the cloaks being hung upon each side of the form. It occurred to him that was rather inconvenient, because if there were a large number of children the crowding would be excessive, and he suggested that a corridor should be made down the centre, the sides being divided into cubicles, with a door in the centre, thereby obtaining a larger space upon which to hang the cloaks. Mr. Robins had suggested that the lavatories should be in the cloak-room, but he questioned whether it should be desirable to have them in a room where you wished to dry wet clothes, as children very often threw the water about the room. Architects seemed to take a class-room as a type, and said because a lecturer would stand in a room and have the black board behind him, therefore the room would be good for a class-room; but the teacher had to keep his audience in order, and if he had to turn his back to the class, little pranks would sure to be carried on. He thought it would be desirable that the teacher should stand at an angle, so that he might, when writing on the board, have his eye upon the class. As singing was generally taught in schools, it was important they should have a gallery, which might be used also upon occasions such as the distribution of prizes, when the children might be massed in the gallery, facing the chairman who distributed the prizes, the audience being in the middle of the room.

Professor AYRTON said, as Mr. Robins had referred to the physical department in

Japan, he might, perhaps, be allowed to make a few remarks. It was pretty generally admitted that the only way to acquire a knowledge of a language was to hear it spoken, and that a grammatical study, however perfect, would not fit a person to converse with a foreigner. One could not be said to know a language until you spoke it properly, and to do this it was necessary to have a large amount of experimental practice; and as in the study of a language, so it was in the study of science. Advance in science must be brought about by the combination of mathematics and experiments, and he ventured to think that the same sort of course must be followed in teaching science. As a rule, boys and girls could only give a small portion of their time to experimental work; hence arose the important question, what sort of laboratory practice should they be set to; should they, for example, repeat the experiments, or, at any rate, some of the experiments, which they had seen the lecturer perform. That was very good practice, no doubt, for teaching them the physical manipulation, and impressing on their minds the well-known laws of physics, but it was open to this objection, that in their experiments they would be aiming to arrive at the result given in the text-book, and not really searching for the true principles of the matter; they would be more inclined to manipulate the experiment, so as to agree with the book, than to acquire habits of scientific research. All young children were really experimental philosophers; they were always trying to find out something that they did not know. A very much better kind of experiment for boys and girls in laboratories, would be an experiment that had for its object the advancement, in some small degree at any rate, of existing knowledge.

Mr. FLUX begged to call attention to the fact that they were met that evening to discuss a paper on school building, and he thought Professor Ayrton was going rather wide of the subject.

Professor AYRTON said he was rather trying to come to the point how the building should be constructed to suit the education given in it; but if the meeting thought the question was too far apart from the subject before it, he would not proceed further.

The CHAIRMAN said the meeting would, no doubt, be glad to hear the outline of Prof. Ayrton's general ideas as well as their application.

Professor AYRTON said he wished to show the necessity for the architect and instructor going hand-in-hand in the designing of a physical laboratory. The illustrations on the wall of the laboratories at Yedo might seem, at first sight, to be complicated, if the object were simply for the purpose of repeating experiments; but if it were accepted that the more important branch of experimental work was the doing of original work by lads, then the necessity would be seen for not throwing difficulties in the way of students, by unsuitable accommodation, or by the necessary appliances not being forthcoming, because the difficulties inherent in any original investigation were quite large enough in themselves.

The CHAIRMAN said it was wished that the technical education to be given to the young people of the country, should be of such a kind as would prepare them for a useful career in life. It would lead them too far if he gave any outline of the various principles which had been proposed to guide a system of technical education, but he had recently formed, in his own mind, a notion which he should be glad to submit to the consideration of the meeting, and partly for the reason that it differed essentially from one which he had brought forward on other occasions, and which he was still inclined to think correct as far as it went.

The technical education, which is now being taken up by the great and powerful corporations in the City of London, ought to do something really great. The rich can take care of themselves; they can easily get, more or less efficiently, the various good things of life, but the poorer classes cannot, and it is these whom it is most important to reach. What had been done up to the present time fell short of what was intended. Mechanics' institutes, as the name denoted, were intended to give education to the sons of mechanics, but they had not thoroughly succeeded. They had been useful, and successful to a great extent, but they were, in the main, attended by the middle classes. It was a difficult problem to solve what kind of instruction was suited to children of from 14 to 18; and in order to render what he was about to say more clear, he might contrast it with the opposite view which he had previously referred to. The general notion which was entertained of the most complete system of technical education, is that it should consist of two phases; first, a most thorough scientific teaching; and secondly, actual experience in the workshop. Of course, for the children of the poorer classes, it was utterly out of the question that they could have anything approaching a thoroughly scientific training, and the difficulty was to see what could be done for them in that direction. The idea which had latterly been assuming shape in his mind was this, that it would be natural, and practical, to begin at the other end; not to begin, as was at present done in the higher schools, with science itself, but to begin with the workshops and factories. In the case of lads in factories performing operations which they did not understand, but which they had learned to do empirically, they might be taught by competent teachers, in laboratories fitted up at the works, the particular conditions upon which the success of their different operations depended; as, for instance, in the case of dyeing, they might be taught the common impurities, and how to detect and remove them; they should be taught just as much, and no more, of the scientific principles as was needed for the clear and accurate performance of the operation in which they were engaged. In some cases, this was already being done, as, for instance, in the art of brewing, where Dr. Graham had already instructed many pupils how to detect and remedy defects which had existed for years. The difficulty of doing this was, no doubt, enormous, owing to the fact of their not having the necessary teachers; and these teachers would have to be grown, so to speak, before the difficulty was overcome. For secondary training, he believed that laboratories were destined to occupy a more prominent place; in fact, that technical education for the masses would consist in teaching them, not merely to perform the operations of their respective trades, but to understand the nature of the conditions required for the success of those operations. In the interest of science, very great results might be anticipated from such work as he had described. He could hardly doubt that, if perfectly accurate, though not high, instruction were given to large numbers of the youth of working classes, many would be stimulated, from the delight of doing things in an accurate and intelligent way, in which they had never done them before, to educate themselves further by any available means. He trusted that what he had said was sufficient to render his general idea intelligible. The great thing to aim at was to give the lower classes an accurate knowledge of rudimentary scientific facts, so that they might, after a short time, be able to earn higher wages than they did now, and so encourage others to follow their example.

Mr. ROBINS, in reply, said he was indebted to Mr. Fitch for reminding him that he had not mentioned the fact that, in each of the schools described, it was provided that two or more class-rooms could be thrown into one ; but he thought the charm of a separate class-room was that it gave the teacher a private room. He considered that single desks were very useful things under all circumstances, as you had more space in which to move about, and the books could also be kept in the desks. As to the remarks about the form of the class-room being oblong, he had found that a great difference of opinion existed upon this point among teachers, some preferring one shape and some another, depending very much upon their long or short-sightedness. And as to the acoustic proportion of the class-rooms, they were rarely of such dimensions as to cause any difficulty of hearing. Ventilation in schools was an important matter, but the architect must be treated with some tenderness, on account of the public not liking new inventions. It was quite a common thing to enter a class-room and find the ventilators closed, and he had often heard it remarked, that it would be as well if the ventilators were made so as not to close ; but his own opinion was that the teachers ought to have the sole control of the ventilating apparatus, and to be interested in its success. He trusted that the valuable remarks of the Chairman would be well pondered, and exert that influence which they decidedly merited.

Upon the motion of the Chairman, a vote of thanks was voted to Mr. Robins, for his paper.

HIGH·SCHOOL·FOR·GIRLS·S^T·JOHN'S·WOOD·BRANCH

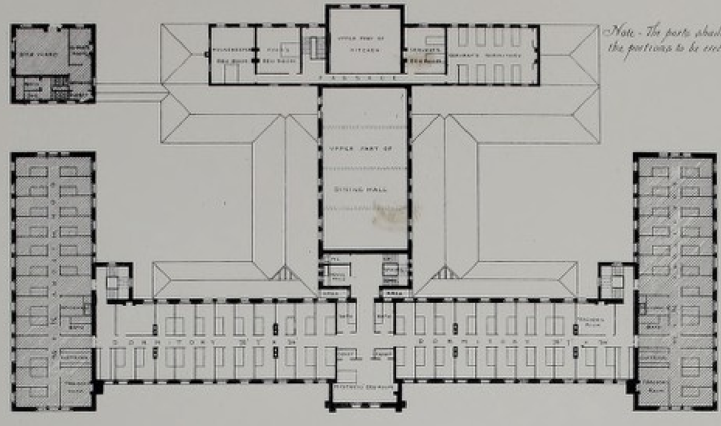
Edward C. Robins F.S.A. Arch^t. 1881·

Photo Lithographed & Printed by James Akerman, 6, Queen Square, W.C.

College for Congregational Minister's Daughters.

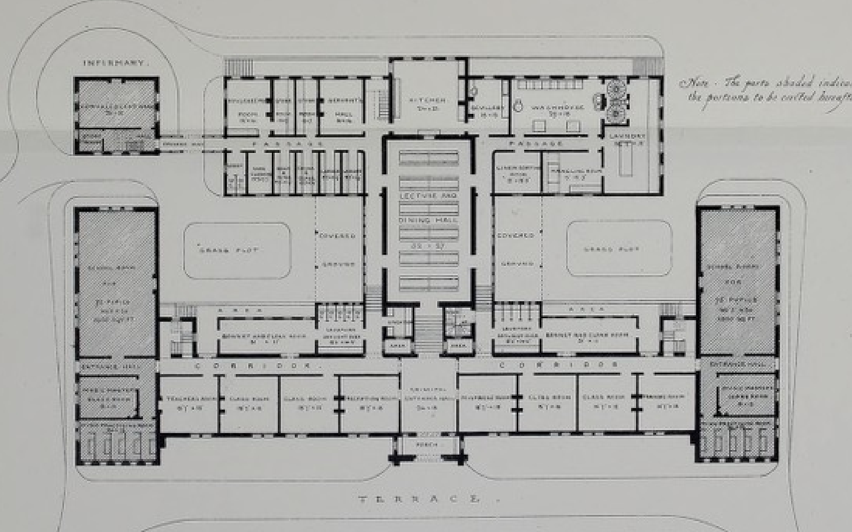
Milton near Gravesend.

Plans of Completed Building.



Note. The parts shaded indicate the portions to be erected hereafter.

First Floor Plan.



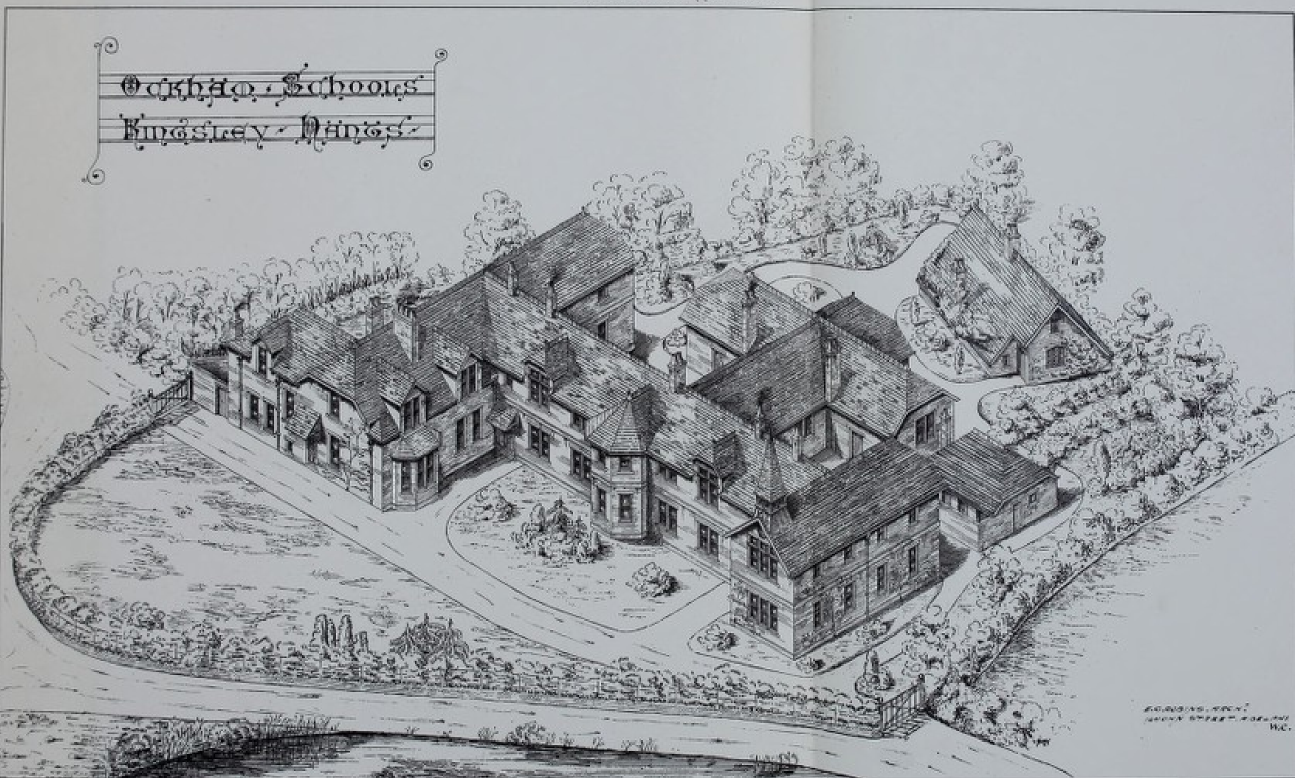
Note. The parts shaded indicate the portions to be erected hereafter.

Ground Plan.

Edw^d. C. Robins Archt. 16 Southampton St. Strand.

Photo-Lithographed by Whitman & Bass London.

Foreign · Missionaries · College · Sevenoaks · Edward C. Robins Archt 14 John St Adelphi W.C.



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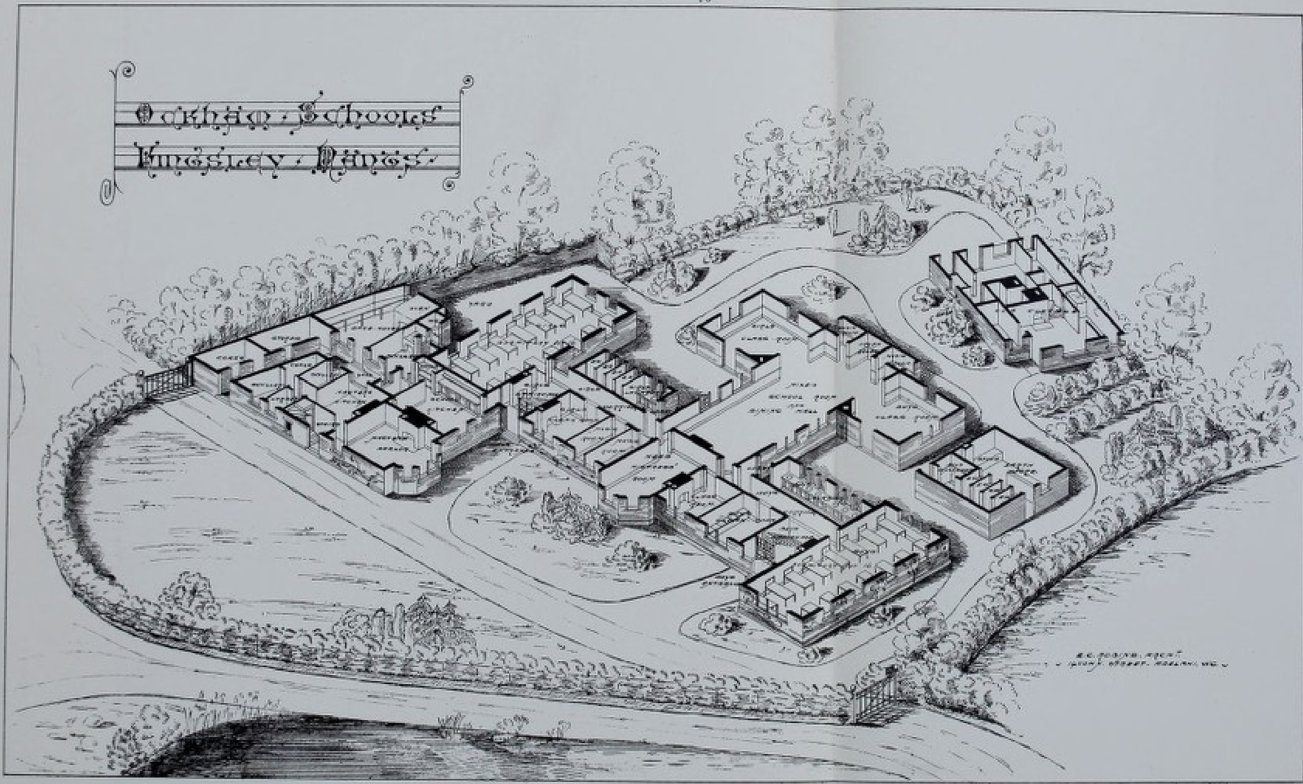

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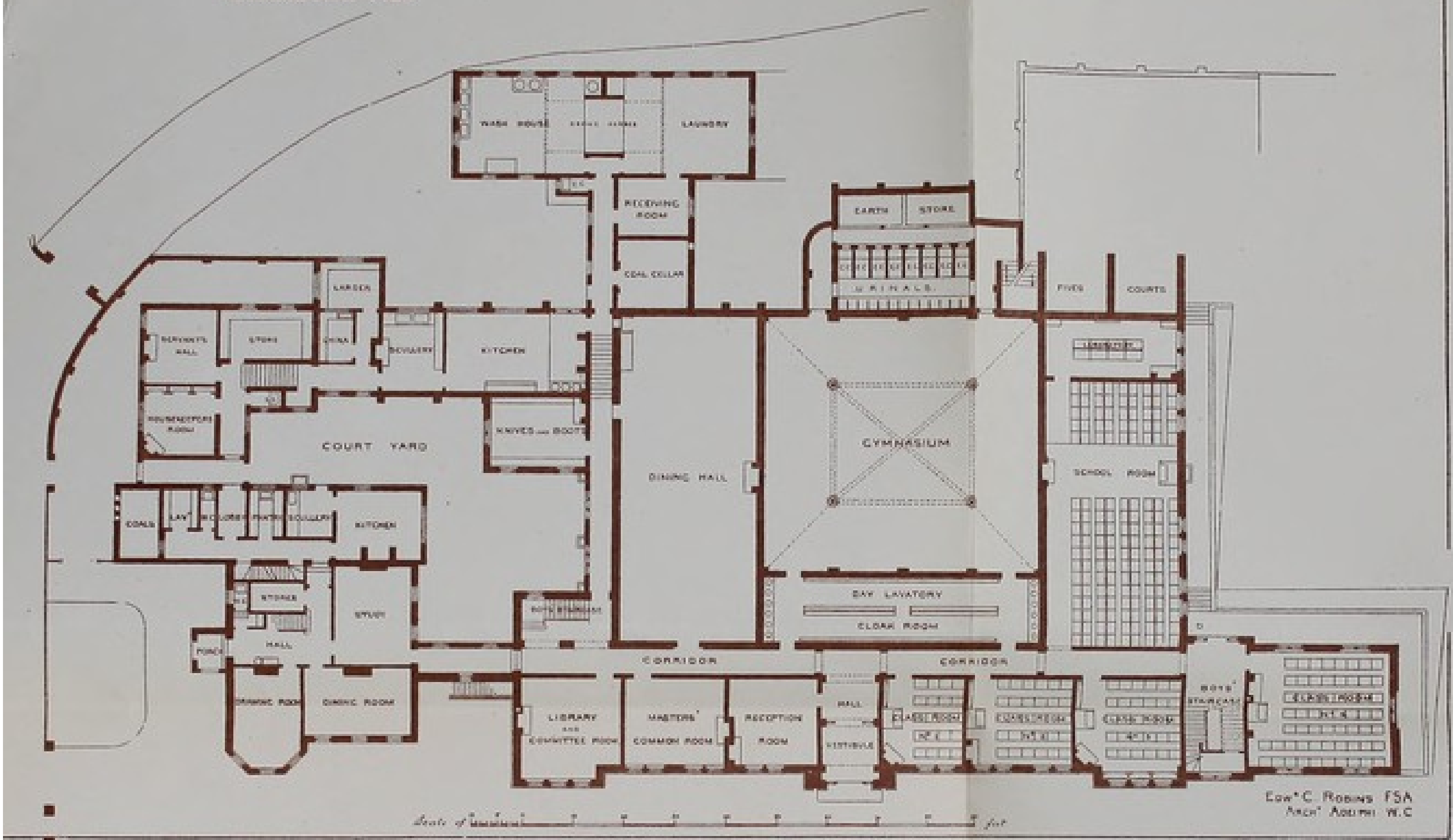
Congregational · School · Caterham ·

Ground · Floor · Plan

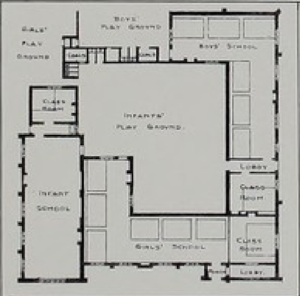


Waterman & Bass Photo Litho

Waterman & Bass Photo Litho 226 High Holborn

Congregational · Schools · Caterham · Valley ·

Edwᵈ C. Robins. F.S.A. Archᵗ
14 John. Sᵗ W.C.



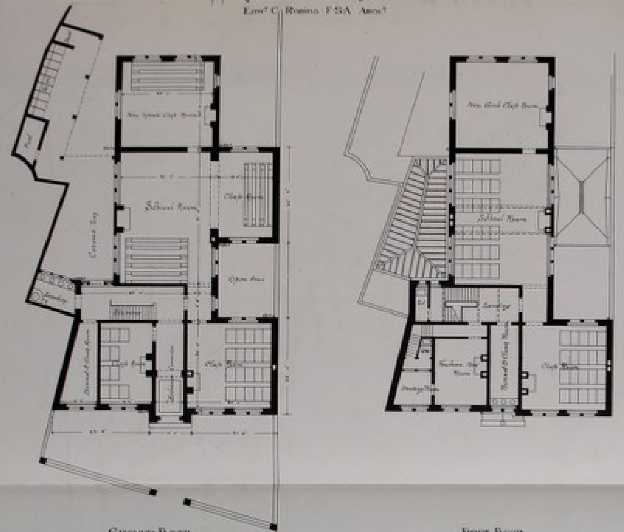
Christ Church Schools. Battersea.

E. C. Robins. Arch^ct.

Photo-Lithographed by Whiteman & Bass London.

Wapping · Elementary · School ·

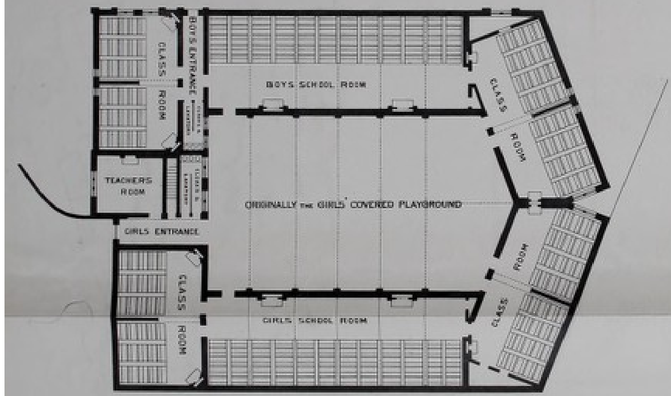
Edw^d C. Robins F.S.A. Arch^t



Ground Floor

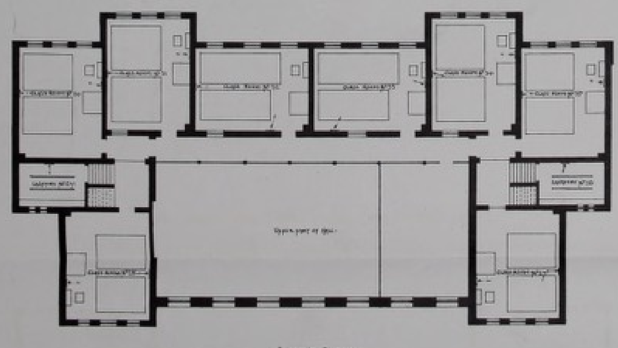
First Floor

Haverstock · Hill · School ·

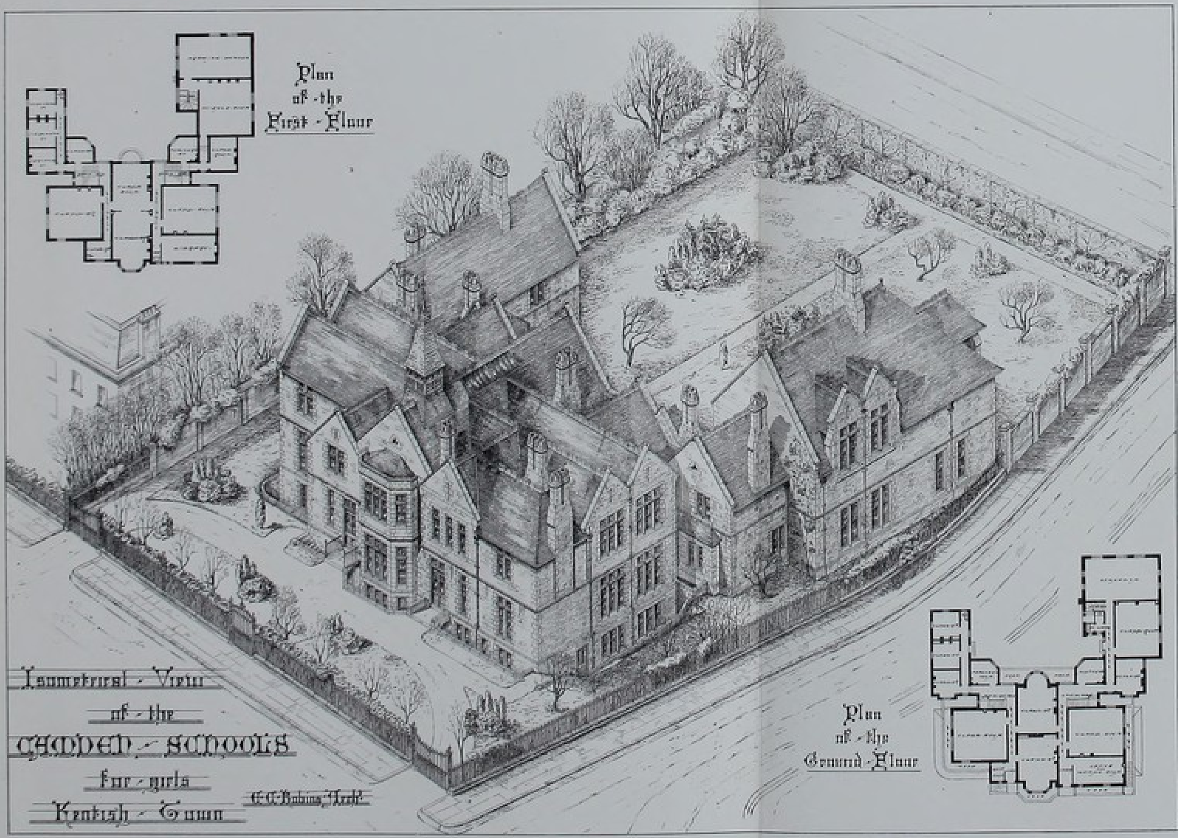


Ground · Floor ·

Johnson · Street · School : Stepney ·

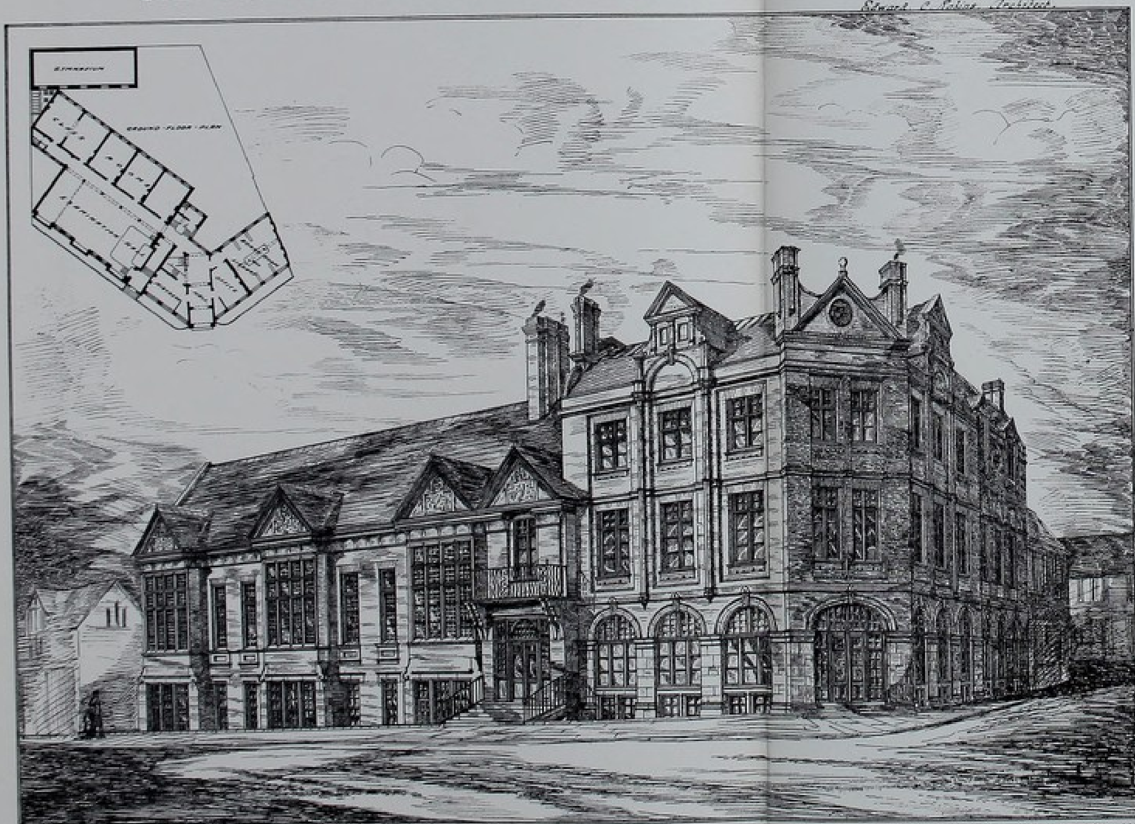


Second Floor.


Plan
of the
First Floor
Isometrical View
of the
CAMDEN SCHOOLS
for girls
Kentish Town
E. C. Robins Archt.
Plan
of the
Ground Floor

THE · NORTH · LONDON · COLLEGIATE · SCHOOL · FOR · GIRLS

Edward C. Robins, Architect.



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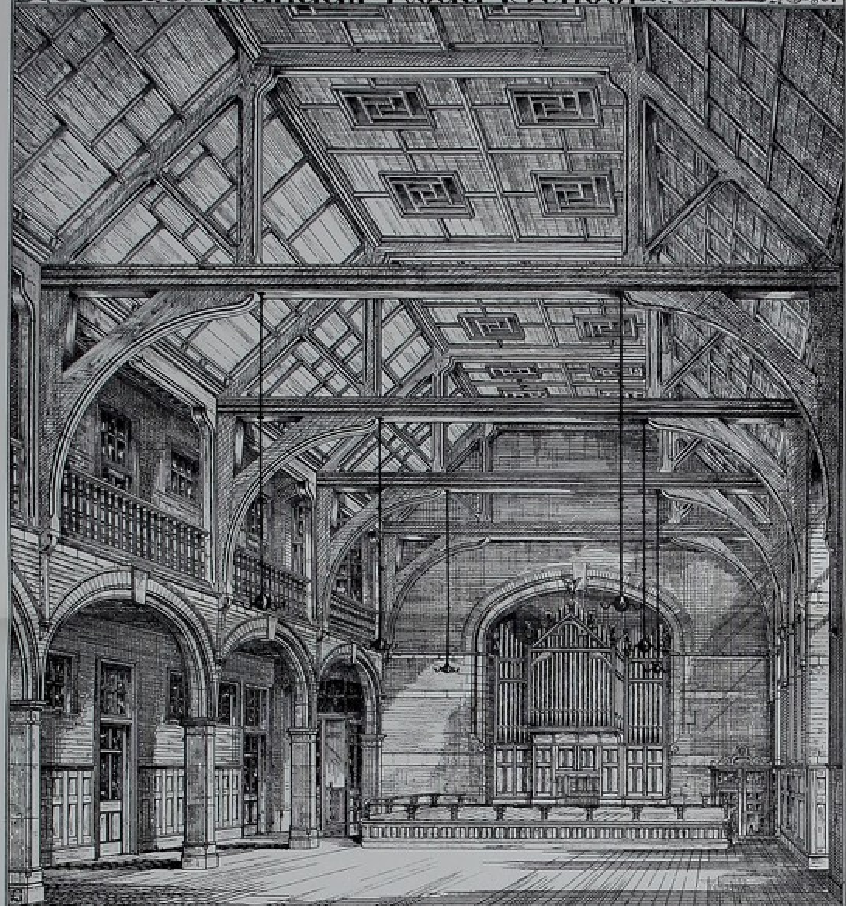
The · Clothworkers' · Hall ·

THE · NORTH · LONDON · COLLEGIATE · SCHOOL · FOR · GIRLS

Sandall · Road · School



Interior · View · of · Proposed · Examination · Hall

E. C. Robins Archt. 14 John Street W.C.

Photo-lithographed & Printed by James Akerman, 6, Queen Square, W.C.

III. SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE.

By Edward Cookworthy Robins, F.S.A., *Fellow*.

[Read on Monday, 29th November, 1880, John Whichcord, F.S.A., *President*, in the Chair.]

No subject of study can be more useful and honourable than that of the principles which should govern the direct application of Sanitary Science to the development of our national architecture—no duty greater than the recognition of our responsibilities in this matter, and of fitting ourselves for it. The growth of contaminating influences injuriously affecting the healthfulness of the elements, the earth upon which we live, the air we breathe, and the water whereof we drink, is commonly the result of culpable ignorance of the simplest sanitary laws, and the appropriate mechanical appliances necessary to give effect to them. This is generally acknowledged in the abstract, and there are few subjects upon which philanthropists are more ready to expatiate, or more reckless in the adoption of any suggestion which sounds sufficiently iconoclastic or revolutionary.

Those of us who, for the last thirty years, have practically proved our interest in this subject of course cannot be otherwise than pleased to observe the improvement in public opinion, and the quickening of the professional conscience, thereupon. Such men as Mr. Chadwick, Dr. Richardson, Captain Galton, the late Dr. Parkes and many more, are working with us and not against us, and we shall not grudge to them the credit they undoubtedly merit, because the public are less familiar with the names of those architects, who, led by Mr. George Godwin, the accomplished editor of the *Builder*, have fought for long years, through good report and evil report, against the prevailing ignorance and apathy.

The useful and eloquent articles in that newspaper, during the visitation of cholera in the year 1852, first led me to take a personal interest in this question, and ultimately to allow myself to be associated, as Honorary Architect and Secretary, with the Local Board of Health for the parochial district of Regent Square Church, St. Pancras, under the presidency of the Incumbent. In this capacity an opportunity was afforded to me of establishing a precedent for local sanitary exertion, and preventing the spread of disease in that particular locality, which comprized one-17th part of the whole parish of St. Pancras. The result of this experimental inquiry was published in the year 1854, in a pamphlet entitled *A Practical View of the Sanitary Question*, a copy of which I now lay on the table. A thousand copies were printed and circulated throughout the country, and the receipt of one was acknowledged by the late Mr. Tom Taylor, then Secretary of the General Board of Health, as follows :—

> "I beg to acknowledge with thanks the receipt of the Report of the Local Board of Health for the Parochial District of Regent Square Church, St. Pancras, and to express the great satisfaction which the contents of that Report have caused to the President of the Board (Sir B. Hall)—a satisfaction expressed to me in the strongest terms—and to myself, as a record of a most successful effort of local activity, which cannot be too widely disseminated. I should be much obliged if I could be furnished with twelve copies of the Report for the use of this office."

The Commissioners of Sewers asked for sixteen copies of that document, from a perusal of which it will be seen that no less than 1017 separate sources of infection were abolished by the Board's action.* Two Metropolitan graveyards were closed by special appeal to Lord Palmerston, the then Home Secretary, and assistance was rendered in revizing the Bill to amend the Nuisances Removals Act of 1848-49, at the solicitation of Sir Benjamin Hall, its proposer, a Bill which subsequently became law. That was the period at which the Main Drainage of the Metropolis was under discussion, resulting in the establishment of the Metropolitan Board of Works to carry it out.

As a member of the then Metropolitan Sanitary Association, I was most earnest about the establishment of a corps of sanitary surveyors to be appointed by the Act, as well as medical inspectors, and I was one of a deputation to the Home Secretary on the subject. It was with great pleasure, therefore, that I read the following paragraph in the concluding chapter of Captain Galton's *Observations on the Construction of Healthy Dwellings*:—

"It is the function of the sanitary engineer, or local surveyor, to adopt measures to prevent or to remove those sources of danger to health which the medical officer is called upon to detect. The community does not permit any man to practice medicine without having satisfied a careful and responsible board of examiners that he has educated himself for his position, and education in the principles of Sanitary Science is just as necessary to insure the efficient fulfilment of the duties of a sanitary engineer or local surveyor, as is the study of medicine to the medical man. . . . . . . When the public realize that the progress of the Nation in healthiness is to be attained by a careful attention to these details, they will insist that the local surveyor or sanitary engineer shall have a complete education in the science of the healthy construction of buildings, and in the arrangements for health to be adopted in towns and villages; that is to say, in the conditions necessary for the *prevention* of disease, just as at the present time they require education in those who minister to the *cure* of disease."

Mr. Chadwick is of opinion that the subject of house drainage should be cultivated as a speciality, and he attributes to our professional negligence many existing evils. Sanitary science is indeed not so old but that architects of the last generation may be found often as ignorant of sanitary law as were their medical contemporaries. I readily admit that the education of an architect is incomplete when he allows his mind to be so absorbed by the artistic side of his profession as to look with contempt on the practical. It is true that the architect is *par excellence* an artist, and his works should take their stand among the fine art memorials of his age; but the arts of construction are important means to that end, and are to him what

* "The Local Board of Health owed its origin to the exertions of the Incumbent of Regent Square Church, the Rev. Geo. Albert Rogers, who invited a few benevolent individuals, being members of his congregation, to unite themselves with him for the purpose of remedying the sanitary evils existing in the district. The following are the names of those gentlemen who were invited by the Incumbent to attend the first meeting held at his house on the 18th of October, 1853 :—Rev. J. Hilmer, J. E. Clowes, Esq., Dr. Sawyer, J. Nokes, Esq., Henry Raven, Esq., J. A. Russell, Esq., Chas. Wyman, Esq., Mr. Brown, Mr. Genever, Mr. Thomas and Mr. Westbrook. Several other gentlemen of the district were afterwards associated with them, and ultimately the Ministers of other congregations included therein ; the object being to make it as much a district matter as possible. Their first care was to ascertain the real state of the district in a sanitary point of view. The City Missionaries, Messrs. Genever, Brown and Thomas, assisted most energetically in obtaining this information by means of a house to house investigation, noting down from the lips of the occupants and from their own observation the various annoyances to which they were subjected. From the reports of the City Missionaries, Mr. Robins and Mr. Russell drew up a statement showing the then present state of the district, and the great need that existed for some interference on behalf of the poorer classes. This statement was printed and circulated among the higher class of residents throughout the district. The Incumbent also forcibly appealed to his congregation to support the Board by their liberal contributions, and on three successive Sundays he appropriated to its funds the collections made in the boxes at the church doors, which, added to subsequent donations, enabled the Board to proceed to the appointment of an Inspector, and from his appointment the aggressive operations of the Board commenced."—*Extract from "General Report," November*, 1854.

anatomy is to the figure painter. It is equally true that the engineer is *par excellence* a constructor, and not necessarily a man of taste at all. The grand effects produced by the vastness of the structures he designs are commonly fortuitous and not the distinct aim of the designer; their beauty (if any) is that which grows out of the fitness of things, the perfect adjustment of the means to the end desired, in the absence of which conditions real beauty is non-existent, and like faith without works is dead.

One good result which might have been expected to issue from the temporary cessation of the battle of styles amongst us, consequent upon the benign influence of good Queen Anne, was the increased study of comfort and convenience irrespective of eclectic considerations, the element of picturesque grouping atoning for all irregularities in design. Certainly design is now unfettered by symmetrical rules of sentimental proportion or balance of ornamental associations either of gothic or classic origin. It is well that the public should understand this, and be able to rest content that, when an architect is employed to build a house, it will not be necessary to call in the sanitary officer in order to be sure that it is properly lighted, heated, drained and ventilated. I do not say that this has never been necessary, for I cannot forget how the artistic nature of a late popular and justly esteemed young architect rebelled against the prosaic duties of the hour. Once when I was with him, a letter came from a client complaining of some defective piping, &c. "Pipes," said he, "what do I know about pipes, let him send for his plumber." But this indifference is becoming less every day.

British Sanitary Archæologia has yet to be satisfactorily compiled. Prior to the Great Fire of London, no provision was made for the conveyance of the storm waters by underground sewers, and the waters found their way to the river by natural means. In the Act of 19th Charles II. for rebuilding the city, the City Commissioners of Sewers were first appointed, but they were intrusted with this power for seven years only. By an Act in the 7th year of Queen Anne, they were made perpetual. It is to be regretted, however, that the storm waters were ever mixed up with the house drainage. In 1834, a Civil Engineer stated, before a Parliamentary Committee, that when in the previous year some French engineers were sent over to England by their Government nothing seemed to attract their attention more than the sewers of London, the drainage of Paris being then under consideration. Their ideas of the proposed drainage never extended to more than taking away the surface drainage, and they seemed astonished when he told them that the water from our lowest cellars drained into those great sewers. The state of Paris before the Second Empire is known to many here, the foul drains that ran upon the surface of the ill-paved streets, and the abominable stenches, everywhere proved the want of sanitary reform; and Paris is still anything but sweet.

Illustration No. 4 is the copy of a design for draining Paris, projected by the architect, Patte, and published in the year 1769. A vast sewer in the centre of the road is ventilated by vertical shafts over it, and has ledges on either side, above the springing of the lower semi-circular inverted arch, for the carriage of water pipes. The road gullies, house wastes, water-butt overflow and water-closet soil, all descend direct to the sewer. The description will be best given in Patte's own words:—

"La propreté des villes s'est toujours exécutée le plus maladroitement, par rapport à la salubrité de l'air. Je ne connais dans l'antiquité que les Romains qui aient fait des efforts, pour opérer avantageusement le nettoiement des rues : encore y furent-ils nécessités par la position même de Rome, qui comprenait dans son enceinte sept montagnes. Dans l'impossibilité d'étendre leur ville au milieu des vallons qui formaient autant de ravins, ces peuples furent contraints de pratiquer pour reçevoir les eaux, ces cloaques ou aqueducs souterrains dont on voit encore aujourd'hui des ruines [ce n'est pas qu'on n'ait construit des égoûts souterrains sous une partie de plusieurs villes ; à Londres entr'autres, il y a quelquefois un égout des deux côtés des principales rues, le long de chaque trottoir. Mais nulle part on ne les a disposé de manière à ne point infecter les rivières dans leur trajet à travers des villes ; jamais ils n'ont eu pour but que de reçevoir les eaux des ruisseaux ; et aucunement d'opérer le nettoiement des rues, le transport de leurs ordures, et de faciliter les réparations des tuyaux de conduite], et desquels ils se servirent en même temps avec avantage pour l'écoulement et le transport de toutes les ordures. Ces cloaques ne parcouraient pas toutes les rues, ils étaient seulement distribués dans les lieux les moins élevés de cette Capitale, et venaient tous se rendre dans un autre beaucoup plus grand, appellé *cloaca maxima*, qui se débouchait dans le Tybre entre le mont Aventin et Palatin. On avait réuni sept sources ou sept ruisseaux dans de vastes réservoirs, qu'on lâchait fréquemment dans ces voûtes souterraines, pour les nettoyer et entraîner successivement tout ce qui y avait été jeté. . . . .

"Il ne s'agirait que de saisir l'esprit du procédé des anciens Romains, et d'appliquer à la totalité d'une ville, ce qu'ils firent pour opérer la salubrité d'une partie de la leur ; c'est-à-dire, qu'il n'y aurait qu'à pratiquer sous toutes les rues, des aqueducs souterrains, capables non seulement de servir aux transports des ordures et à leur écoulement sans embarras, mais encore d'assurer la solidité des conduits et de favoriser leur entretien. Voici comme j'imagine que l'on pourrait opérer la réunion de ces différents objets : Ce serait de placer sous le milieu des rues, à cinq pieds au-dessous du pavé, un aqueduc soûterrain d'environ six pieds de largeur sur sept pieds de hauteur. On assurerait la solidité, en construisant sa partie inférieure en forme de voûte renversée avec des claveaux de grès ou de pierre dure, et en faisant sa partie supérieure aussi voûtée, soit en pierre de meulière, soit en petits moellons de roche avec des chaines de pierre dure, de douze pieds en douze pieds. . . . D, (*see illustration No.* 4) fait voir en profil toute sa construction. . . . .

"À droite et à gauche, et à quatre pieds du fond de l'aqueduc, on pratiquerait deux banquettes F, F, en saillie, d'à-peu-près quatorze pouces de largeur, sur lesquelles seraient placés deux tuyaux de fer fondu 5, 6, qui conduiraient les eaux des différents réservoirs, provenant soit de la rivière, soit de diverses sources, dans les fontaines publiques, et dans les maisons, à l'aide de petits conduits de plomb, soudés aux gros tuyaux vis-à-vis des endroits en question. . . . .

"Il est évident qu'à l'aide de notre arrangement, il ne serait plus besoin, pour faire les réparations des tuyaux, de dépaver les rues et d'embarrasser la voie publique. Par dedans l'aqueduc souterrain, on remédierait avec facilité à tous les accidents qui surviendraient. . . . .

"Par le moyen de nos aqueducs souterrains, il est encore aisé de réformer les fosses d'aisance qui causent dans les maisons d'une ville une infection journalière, et empestent tout un quartier quand il s'agit de les vider. Il n'y aurait qu'à établir toujours les latrines au rez-de-chaussée, et tenir leur fosse peu profonde en forme d'égout : alors en plaçant dans le fond un tuyau assis solidement, et disposé en pente vers l'aqueduc, les matières y seraient conduites à mesure. Dans l'intention de précipiter leur écoulement, il faudrait faire en sorte de diriger à travers les petites fosses en question, toutes les eaux d'une maison, celles des toits, celles qui proviendraient des cuisines, celles des cours et autres. Par ce procédé ces endroits seraient sans cesse lavés. . . . . . Il est à observer que l'issue des tuyaux de ces fosses dans le cloaque serait placée dans le socle des banquettes qui portent les conduites d'eau. . . . . On voit dans la Planche (*see illustration No.* 4) le profil d'une latrine : S est le siége ; T est la fosse ; X est le tuyau destiné à conduire les matières dans l'aqueduc, lequel est assis sur un petit massif de maçonnerie ; V est un petit réservoir occupant le dessus des latrines, lequel peut être rempli naturellement par les eaux des toits, à l'aide d'un tuyau de communication avec celui de conduite, &c. Cette eau servirait à lacher successivement dans la fosse T, pour précipiter l'écoulement des matières. Enfin, Y est un tuyau destiné à diriger l'eau de la cour à travers de la fosse."*

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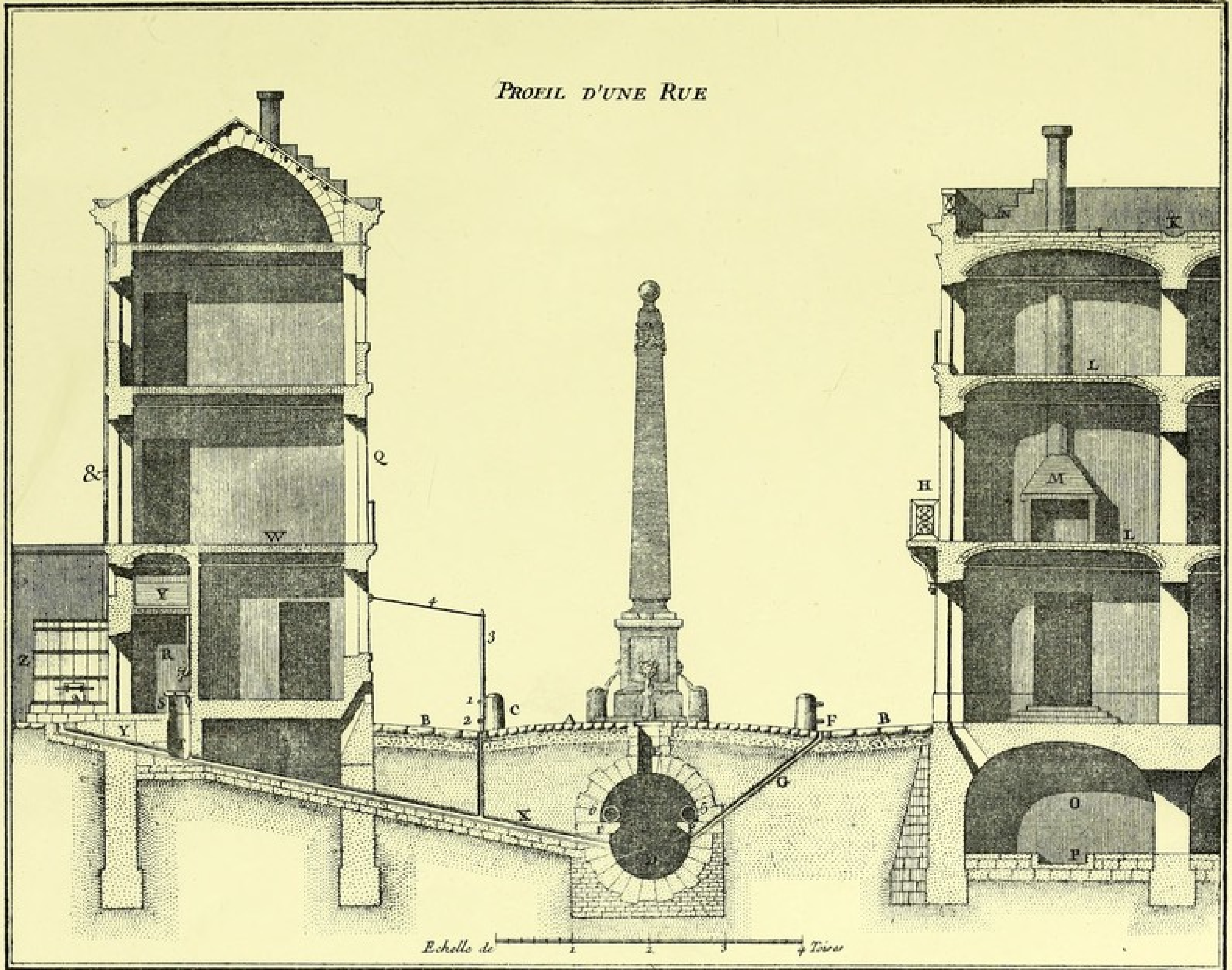
* See Chapter I, "Considérations sur la Distribution Vicieuse des Villes, &c." in the *Mémoires sur les objets les plus importants de l'Architecture. Par M. Patte, Architecte de S. A. S. Mgr. le Prince Palatin Duc régnant de Deux-Ponts.* Paris, 1769.

Further references to the illustration, not mentioned above, are—"B, B, Chemins le long des maisons pour les gens de pied, séparés chacun de la chaussée par un ruisseau, F. C, Bornes placées près des ruisseaux en deça de la chaussée, pour mettre les habitants à couvert de tout accident de la part des voitures ; 1, 2, colliers de fer, dans lesquels sont passées des perches, 3, pour soutenir une banne, 4, de toile cirée, lors des mauvais temps. E, Trou en forme de puits, pour recevoir toutes les ordures des rues. G, Direction d'un des conduits des ruisseaux dans l'aqueduc. Z, Fontaine domestique destinée à rassembler l'eau de pluie pour la boisson. &, Tuyau de conduite dirigeant l'eau des toits vers la fontaine, pour la remplir quand on le jugerait à propos."

SANITARY SCIENCE IN ITS RELATION TO CIVIL ARCHITECTURE. (Nº 4.)

Pl. II. Pag. 70.



C.F. Kell, Photo-Litho. Castle St. Holborn, London, E.C.

Patte del.

PHOTO-LITHO. OF PATTE'S DESIGN FOR DRAINING PARIS, A.D. 1769.

Drainage, &c. There are two distinct systems of sewer construction, broadly distinguished by the phrases, *sewers of deposit* and *sewers of suspension*, both having reference to the water carriage of excrementitious matter. The former is adopted in many great towns, and does not necessarily provide for the immediate removal of the soil from houses except in times of storm or very wet weather. At other times a system of flushing more or less intermittent is involved, owing to the absence of sufficient water for the carriage of the soil accumulations and refuse. The latter is adopted in some provincial towns, and requires the removal of the soil at once at all times of the year, or at the very least before the solid matters in suspension have had time to enter into that putrid state when sewage gases of a most deleterious character are generated within the sewer. Obviously the former system is one which by providing for occasional storm waters, or heavy rains, over a large surface of land, as well as the ordinary house sewage, necessitates the construction of vast cavernous sewers, which in dry weather, from the absence of adequate rain-fall and of sufficient flushing arrangements, constitute sewers of deposit, the emanations from which are often so deadly, owing to the insufficiency of ventilation, that disease and death are pent up within them, ready to find a way through every aperture into the dwellings of rich and poor alike, so that the prince and the peasant are equally endangered by living in houses or hovels whose drains are in direct communication with the sewer, unless those precautions are taken which it is the business of Sanitary Science to discover and to enforce. Only recently in the City of Paris it was reported that five men were killed outright through entering an insufficiently ventilated sewer—simply poisoned by the malaria. The latter system is one which provides a separate sewer for the storm waters, or leaves them to take care of themselves and find their own way into the rivers and the sea, and thus necessitates the conduct of the house drainage only in comparatively small pipes, the smallness of the bore concentrating the stream of water which carries with it the soil held in suspension along the narrow channel provided. The constant flushing of such sewers is an easy matter, and an example of its apparent success as a system has recently been the subject of rejoicing at Memphis in the United States of America, concerning which it may suffice to say that designs were prepared on both systems, the first providing for the storm waters with sewers from 1 ft. to a 7 ft. outlet main. The second design, which has been adopted, has pipes only ranging from 6 inches to 20 inches at the outfall. 3000 feet length of 6-inch sewers communicate with 8-inch branches falling into 12-inch aud 15-inch sewers, meeting and ending in the 20-inch outfall pipe. At the head of each line of sewers is a Field's flushing tank, from 120 to 150 of which will flush the sewers daily or twice a day with 100 gallons of water at each automatic discharge. In connection with this system are 4-inch house drains, on the back drainage plan, no drains being allowed to pass under a house.

It is well known that in London a system of sewerage prevails which, despite many excellencies as a scientific work of modern engineering skill, nevertheless entails the necessity of recognizing the insanitary condition of the main sewers, aggravated of late years, not merely by the increase of the population but by the fact that, simultaneously with the construction of these sewers, cesspools were abolished, and all solid as well as liquid matters now find their way into the main sewers. This condition of things, resulting in the conduction of sewer air into the dwellings of the people, affects not merely the air but the cistern water supplied to the houses; and the architect has further to consider what may be the effect on the health of those who drink the water thus impregnated with a poisonous gas, considerations which necessitate special contrivances to prevent the possibility of any contamination of the air, or of the water, by the emanations from sewers or from foul house drainage.*

We may now consider:—1. The common defects in sanitary construction. 2. The remedies generally available.

To describe in very great detail defects in sanitary construction is not now necessary;

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* The following Extracts are from a Report upon the Metropolitan Sewers, made by Mr. Edward Monson, Assoc.-M.Inst.C.E., for the information of the Society of Arts:—

"In accordance with your instructions, I have made inquiries intothe condition of the metropolitan sewers, and beg to report that I find the subjects given me for inquiry are so large that I have been unable to deal with the whole metropolis. . . . . The subjects given for investigation are:—First, as to the extent of the existence of sewers and drains of deposit in the metropolis. Second, their effects in the development of the gaseous products of decomposition. Third, the mode of cleansing the sewers. Fourth, the defects in sanitary science and art evinced in their construction and working.

"I.—From the inquiries I have made, extending over a period of twelve months, I find that the sewers of the metropolis are, in many cases, sewers of deposit, and not constructed on the self-cleansing principle. In proof of this, I need only point to the fact that a great number of men are required by the Board of Works and the various Vestries to keep them open and in working order. The low-level sewers are constructed at a level sufficiently low to pass under the existing outfall sewers; they have no available outlet, except by pumping. In point of fact, they are not sewers at all, but sewage tanks, adits, or reservoirs, and hold the supply of sewage for pumping. They are the sludge chambers of the district and receive the filth of the adjoining parishes. They are elongated cesspools and unquestionably sewers of deposit. Not being in duplicate, and having no outlet except by pumping, they are never entirely emptied. The sewage thus becomes putrid, and the offensive smell from these sewers is the subject of frequent complaints. . . . . In some places the old flat-bottomed sewers, originally constructed for surface water and rainfall have been utilized for the conveyance of sewage. These sewers, as a rule, are not self-cleansing, but sewers of deposit—a natural consequence of the sewage being spread over a wide surface and retarded by friction. . . . . Again, some of the large old sewers are not self-cleansing, but sewers of deposit. A flusher has told me of a case where, from subsidence or otherwise, the sewer bottom is not regular, and the sludge lays in pot-holes, to the depth of a foot or eighteen inches. . . . . Some of the smaller sewers belonging to the Vestries are not self-cleansing, and being inconvenient to work in, and difficult to inspect, they get neglected.

"II.—Sewers of deposit mean the decomposition of putrid matter, and the constant formation of sewage gas. Sewage gas being constantly formed, it constantly escapes through the ventilators in the streets, and through any untrapped openings. In consequence of the traps being left off, through the carelessness of servants, it is discharged into dwelling houses, and finds its way into bedrooms through the open joints of the rain-water pipes. Again, during a storm, the low level sewers are filled and the sewage heads up. As the sewage rises, the sewage gas becomes more and more concentrated, and if sufficient means of ventilation are not provided, it is forced up the drains and discharged into dwelling houses through the traps.

"III.—The sewers not being self-cleansing, it is necessary to employ manual labour to keep them open and in working order. So great is the deposit, that for the main sewers alone, 130 men are constantly kept by the Metropolitan Board at this work, and the sewers for this purpose are divided into six sections, three on either side of the river. The men are called flushers, and are paid 4s. 6d. a day. They are divided into gangs of about five men. To every gang there is a foreman, and to every twenty men there is an inspector. The open sewers are cleansed out about once a year, the other sewers in rotation, and as required. The sewers are flushed by means of a dam board, which is constructed to fit the sewer, and has a hole in the shape of a V cut in the lower edge. The dam board being fixed, the sewage heads up, and rushing through the aperture in the lower edge of the dam board, stirs up the deposit and separates the drift from the organic matter. The organic matter is flushed on, and at length discharged into the Thames. The drift and other inorganic matter is conveyed in barrows to the man-holes, brought to the surface and used in road-making, or sold to jerry builders for about sixpence a load. My informant says, that 'Vestries are not obliged to construct catch-pits, and slosh is frequently forced down the gullies and into the main sewers to the extent of two or three hundred loads of deposit at a time.' The ventilation of the sewers is by open gratings, and, as a rule, no deodorants are used.

so many pamphlets have appeared, and so many books have been written about them, that a very short summary will suffice. Indeed that summary is provided in a small volume prepared by Mr. Teale, the Surgeon to the Leeds Infirmary, entitled *Dangers to Health*, a book which contains 55 page-illustrations of domestic sanitary defects and their obviation. A grim humour pervades them all. The book is dedicated by the author to his medical brethren, and is intended to afford graphic illustration of the dangers of carelessness in sanitary matters, and to give at a glance to the uninitiated a clue whereby the existence of defects may be discovered and amended. These defects consist not only in those things

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Sometimes there is inflammable gas in the sewers, and, on more than one occasion, it has been fired by the light which the men carry on their heads when at work, and the men have been injured. Recently, at Wandsworth, two flushers were suffocated whilst working in the sewer, owing to a discharge from some chemical works; two gangs of men had previously refused to work in the sewer. The Main Drainage of London has greatly improved its sanitary condition, and given an improved outfall to the low-lying districts; and, whilst the main sewers were being constructed by the Metropolitan Board of Works, the various Vestries and District Boards have spent large sums in the construction of self-cleansing sewers of the egg-shaped pattern. The Vestries also employ flushers to cleanse the old flat-bottomed sewers. In the Westminster district five flushers are employed by the District Board, and they work by day; they are expected to keep the sewers clean and are not paid for overtime. The wages are £1 5s. per week and two pairs of boots per year. Deodorants are used in special cases. My informant says that 'the deposit comes chiefly from the macadam roads. The sewers are mostly egg-shaped, the inverts of the flat-bottomed sewers having been taken out and the sewers altered by underpinning. The gullies are trapped and the sewers ventilated in the middle of the roads. The pipe sewers are kept clean by occasional flushing and may be called self-cleansing. The sewers never head up now and the main drainage is a decided advantage to this district.' In the St. James's district there are about two miles of main line sewers in Oxford Street, Regent Street and Piccadilly, and there is a local sewer over the main line sewer. Three flushers are employed by this Vestry; the foreman has 30s. per week and the others a £1; the hours are from six to half-past five o'clock, and if additional flushing is required it is done by contract. Many of the sewers in this district are 5 feet 6 inches by 3 feet, the Westminster pattern. Upon the inverts of some of these a pipe was formerly laid for the conveyance of sewage, but it became silted up, and the surveyor has had all the pipes taken out and the sewers reinstated. The fat and other stuff coming from the clubs consolidates in the sewers and is a great deal of trouble. There are fourteen miles of sewers, but it is the three miles in the neighbourhood of Piccadilly upon which the men are principally employed, and their work is greatly facilitated by the rats and by the vagabonds who go down into the sewers to see what they can find. This district is said to be much improved by the Main Drainage. A table, showing the various sewers, hangs in the surveyor's office. In the district of St. George's, Hanover Square, the number of flushers employed is six. The wages of the foreman are 25s. and the wages of the men 24s. per week; the hours are from seven to four o'clock. The men work during the day, and it is estimated that they bring to the surface 450 cubic yards of deposit in a year, which is removed at 4s. per cubic yard; it consists chiefly of drift and macadam. The flushers are not troubled with fat in the sewers. The population resides only during the season. There are about 52 miles of sewer, and, as a rule, they have a good fall, but in Belgravia it is bad. They are ventilated in the middle of the streets and the gullies are trapped. The old sewers are of the Westminster pattern and the new ones are egg-shaped. The inverts of the old sewers have been taken out and replaced by inverts of the egg-shaped pattern. There are very few pipe sewers in the district. The Metropolitan Main Drainage has not made it much better, except for the purpose of letting off the rainfall.

"IV.—The disposal of the sewage of London has always been a matter of difficulty, and this difficulty has not been removed by the present system of drainage. The brickwork has been executed in the very best manner, and the pumping machinery is a wonderful specimen of mechanical skill, but still, so far as regards the disposal of the sewage, the works are a failure. It is disposed of by discharging it into the river sludge, and all without any treatment whatever. The damage to the river is at present disregarded, and no account is taken of sewage mud and filth which is being constantly cast upon its banks. The old plan was to store the sewage in cesspools constructed in yards, gardens, and under houses; it was next turned into the Thames, and it is by the present system moved on and turned into the river lower down. The nuisance is recurring. It for which an architect might be blamed, but in the faulty construction and workmanship of the work done by the artisans employed—defective jointing of bad iron, lead, or stone-ware piping, false levels and bad laying of drains, perverse connections on the wrong side of the traps, contaminations of water supply, ill-supported vertical soil pipes, and the thousand-and-one evils growing out of the want of properly educated and properly trained workmen and foremen. The City and Guilds Institute for the advancement of Technical Education has done wisely by introducing the subject of "Plumbers' work" into the new list of Technological Examinations. Happily such common defects in drainage construction as were, till lately,

has been removed, but not abated. It will crop up again and again, and this is a grave sanitary defect. We are told that the sewage not only does no harm, but from the improved scour of the river it actually does good. The fact is that the streams, used to flow into the river above bridge, are now passed through the main sewers, and this large body of water being diverted from its natural course, and poured into the river at a new point, produces a scour at the point of discharge, but the soil thus removed is deposited elsewhere along with the filth from the sewage. The works are defective in not being self-cleansing. It must be a wrong system which requires so much labour to keep the sewers open and in working order, and which depends very much for its efficiency upon manual labour. In the intervals between the visits of the flusher, the sewers must be left to themselves, and a deposit must be constantly forming, and the organic matter constantly decomposing and liberating noxious gases which pollute the air. The flushing may be well done and well looked after, but still, with sewers which are not self-acting, these things must happen. If a system of self-cleansing sewers had been constructed (and all main sewers ought to be self-cleansing), so many flushers would not be required, the sewage would not have time to decompose, and the formation of sewer gases would, to a considerable extent, be prevented. The washing of the sand out of the sewage by the flushers is a novel and brilliant idea, but this might be accomplished at much less cost. The drift, which finds its way into the sewer, ought to be excluded, and after it has entered the sewer, it might be intercepted by properly constructed catch-pits. The flat-bottomed sewers might be altered so as to be self-cleansing, and inequalities in the sewers might be removed by reconstruction or lining. The decomposition of the sewage might, to a considerable extent, be prevented by a proper deodorant skilfully applied. The metropolitan system of drainage, in its present form, is not complete. Much has been done, but still there is much to do. The District Boards are fully alive to the advantages of self-cleansing sewers, and in many cases the old sewers have been taken up, and an improved form substituted. The water-courses, which have been most improperly diverted from the river, ought to be reinstated; the sewage ought to be purified before turning it into the river; the removal of filth from the sewers, to a considerable extent, ought to be effected by mechanical means, instead of by manual labour. The sewers require to be rearranged, so as to make them self-cleansing. The drainage of London, which is upon the combined principle, provides for only a quarter of an inch of rainfall in 24 hours, but, during a thunderstorm the rain falls at the rate of two or three inches per hour, and at times, steadily, two inches in 24 hours. It will thus be seen that the sewers are totally inadequate to carry off the rainfall, and the lower parts of the district are sometimes flooded from this cause. If the separate system of drainage were even now adopted, the capacity of the sewers for removing excrementitious matter and foul and waste water from the district would be greatly increased. At the present moment, there is a difficulty with regard to the drainage of several towns situate on the banks of the Thames. Some of these towns are intimately connected with the metropolis for drainage purpose; they have been heavily taxed for drainage works executed within the metropolitan area, and they have a right of drainage into the metropolitan system. In reply to applications for that purpose, they are met with the remark, 'Oh, we cannot take you in, our sewers are not large enough.' Now, such a remark may be perfectly correct if it means that the sewers are not large enough to take in the rain water and the sewage also, but it is not correct to say that the sewers are not sufficiently large to take in the sewage of these towns. The western sewers, for instance, were constructed for this very purpose; if not, why were they constructed so large? First-class sewers to drain streets are ridiculous. The sewage for the western district at the present time is so small in quantity that if the streams were excluded the pumps would have comparatively nothing to do. If the agricultural drainage and streams were allowed to flow along their natural channels to the river it would reduce the expense of pumping, and the carrying capacity of the sewers for removing sewage proper would be so greatly increased that all the towns along the valley of the Thames might be taken, say, as far as Teddington at least, to the great benefit of all concerned."

existing in Boston, United States of America, and recently illustrated in the Society of Arts Journal, are daily becoming less common in London, but as Colonel Waring, the engineer of the new drainage works at Memphis, states, when reporting on the condition of Washington, "the particular idea of the size of a drainpipe required to receive the drainage of a house, or of a number of houses, is strangely in error. A pipe 6 inches in diameter, having an inclination of 4 inches in 100 feet, or less than half an inch in 10 feet, has a capacity of discharging nearly 200 gallons per minute, say 12,000 gallons per hour, or averaging between 3 and 11 in the morning 30,000 gallons. Such a pipe then," says he, "even at such a slight inclination would be adequate for the removal of 150,000 gallons per day. If each household averages six persons, and if the daily consumption is even 50 gallons per head, the service would suffice for 500 houses, or supposing the sewer to run half full, for 250 houses." These figures are attested by facts collected by Colonel Waring, concerning the passage of water through existing pipe-drains elsewhere, which had been carefully guaged. Mr. Chadwick confirms these statements, and states that his experience coincides therewith. It will thus be seen that certainly no single house needs a larger outfall pipe than 6 inches diameter. In some provincial towns it is limited to 4 inches, where proper flushing arrangements exist.

Nevertheless, ignoring all progress, in the last edition of a justly esteemed Encyclopædia, at page 701, under the head of "Specifications" the bewildered student may read as follows:—

"To execute proper barrel drains for draining the premises, as shown on the plans, to fall into a main sewer or cesspool as the case may be. The principal drains to be 18 inches, and the smaller ones 12-inch barrelled drains, with half brick rims, and the lower half of each drain composed with pure Parker's cement. . . . N. B.—We have here described the sizes of drains as for a moderate-sized mansion. We might say that 30 inches is the maximum diameter likely to be required for a large building, and none should be made less than 9 inches wide with half brick sides, three courses high, curved top and bottom."

I may add that Mr. Henry Robinson gives the following rule for calculating the flow in sewers:—

x = Area of sewer ÷ the wetted perimeter in feet.
f = Fall in feet per mile.
v = Velocity in feet per minute. $v = 55\sqrt{x \times 2f}$
a = Area in square feet. $c = v \times a$
c = Cubic feet delivered per minute.

And now with regard to my second point: The remedies generally available for the reduction of the sanitary evils we condemn. In the first place I will draw your attention to the practice of specialists, whose system is more or less in harmony with the previous practice of those architects who have also given considerable attention to this subject. At the Annual Conference of the Society of Arts on the progress of public health, in June last, Mr. Rawlinson stated that house drainage was at the root of all sanitary reform, and he was pleased to inform us that Lord Spencer had kindly permitted the inspection of the system of drainage adopted at his Lordship's house at St. James's. Mr. Rawlinson added that, at that moment, as far as his knowledge extended, it was the most perfectly drained house in London or elsewhere. The principles upon which this mansion and many more, including Mr. Edwin Chadwick's at Mortlake, have confessedly been drained, will be found laid down by Mr. Rawlinson, of the Local Government Board, in his *Suggestions as to the preparation of district maps, and of plans for main sewerage, drainage and water supply.* The engineer employed was Mr. E. F. Griffith, one of three gentlemen—engineers and specialists in sanitary matters—who have devoted themselves to sanitary engineering, and hold a representative position therein; and in the recently issued report of the Meeting of the Sanitary Section of the Society of Arts, in June last, the evidence of Messrs. Eassie, Rogers Field, and E. F. Griffith is given in full. Mr. Griffith thus summarizes the principles adopted by him :—

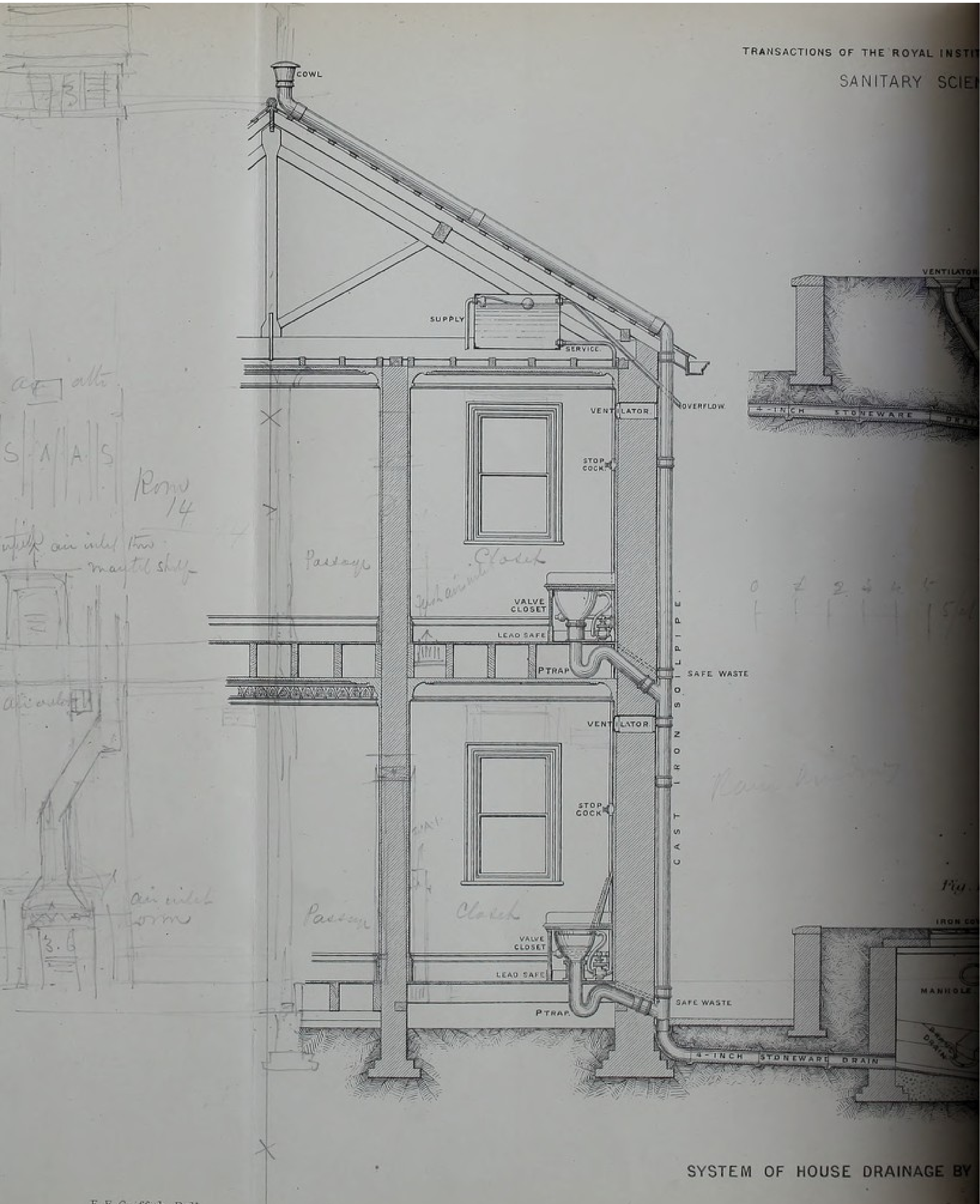
1. Communication between main sewer in street and housedrain should be disconnected or severed by an open air space being left between housedrain and sewer.
2. The housedrain should be laid to such a fall as to be self-cleansing, free from deposit, and ventilated; besides which it must be air and watertight.
3. The soilpipe should be fixed outside the house and taken up full-size above the roof.
4. The wastepipes from the safes of all closets should discharge into the open air instead of into the soilpipe or D-trap.
5. Then there should be no means of drawing water from the cistern or cisterns supplying closets, other than through the closets.
6. The wastepipes from sinks, baths, lavatories, &c., should be trapped underneath, and made to discharge immediately into the open air over trapped gullies.
7. There should be no connection or branch with the main housedrain, where laid underneath the house, except outside the main walls of the building.
8. "Pan-closets" with "D-traps" should never be used, nor should D-traps be fixed under sinks, &c.

Then follows the description of the manner of applying these principles, and in answer to the question, "After your examination of an ordinary London house, what course do you usually recommend?" Mr. Griffith said :—

"If I am instructed to place the house in a thoroughly sanitary condition, I first make a plan of the house showing exactly how the new drainage can be laid, and then proceed to have all the old drains and contaminated earth removed. Unless absolutely necessary I never lay a new drain underneath the house. Should it be necessary to lay a new drain under the house, I use an iron pipe, laid perfectly straight from a disconnecting manhole constructed in the front area to a manhole in the back area. Between these two manholes the iron pipe is laid perfectly air-tight and water-tight, and no branch drain or wastepipe is discharged into this iron drain between these two points; besides which it is laid to a good fall, which will ensure its being self-cleansing. This iron drain is completely severed from the main sewer in the street by the disconnecting manhole, which is constructed in the front area. All the branch drains discharge into a manhole, and every pipe is laid perfectly straight from point to point, a manhole or turning chamber being constructed where a change of direction takes place. Every drain and wastepipe is so laid that, in case of stoppage, it can be cleaned out without opening the ground, removing the paving, or cutting about the walls either inside or outside the house; besides which every drain and wastepipe is thoroughly ventilated. I fix the soilpipes from the closets *outside* the house, and take them up full-size above the roof. The closets would be fixed against outer walls only, and the soilpipes from them would discharge direct through the wall into the iron soilpipe fixed outside. In each closet some permanent ventilation would be made. The wastepipes from all sinks, baths, lavatories, &c., would discharge direct through the wall over the trapped gullies, or if above the ground level, into rainwater pipes, which would discharge over trapped gullies at the foot. The overflow from cisterns would discharge direct through the wall into the open air, so that in the case of the ball valve in the cistern being defective, the overflow water would immediately attract attention, and by this means prevent the waste of water which now often takes place, and, in many cases, continues for months without being remedied. The valve and wastepipes of the bath are made of such a size that whenever used, the housedrain will be flushed. The cistern or cisterns which supply the closets would be so made that no water could be drawn from them except through the closets, special reservoirs for the drinking water being supplied."

In answer to the question, "Why do you prefer cast-iron drains underneath the house?"

h Castle St. Holborn, London E.C.



SYSTEM OF HOUSE DRAINAGE BY

E. F. Griffith, Delt

TUTE OF BRITISH ARCHITECTS, 1880-81.

ENCE IN ITS RELATION TO CIVIL ARCHITECTURE (Nº 5.)

Fig. III.

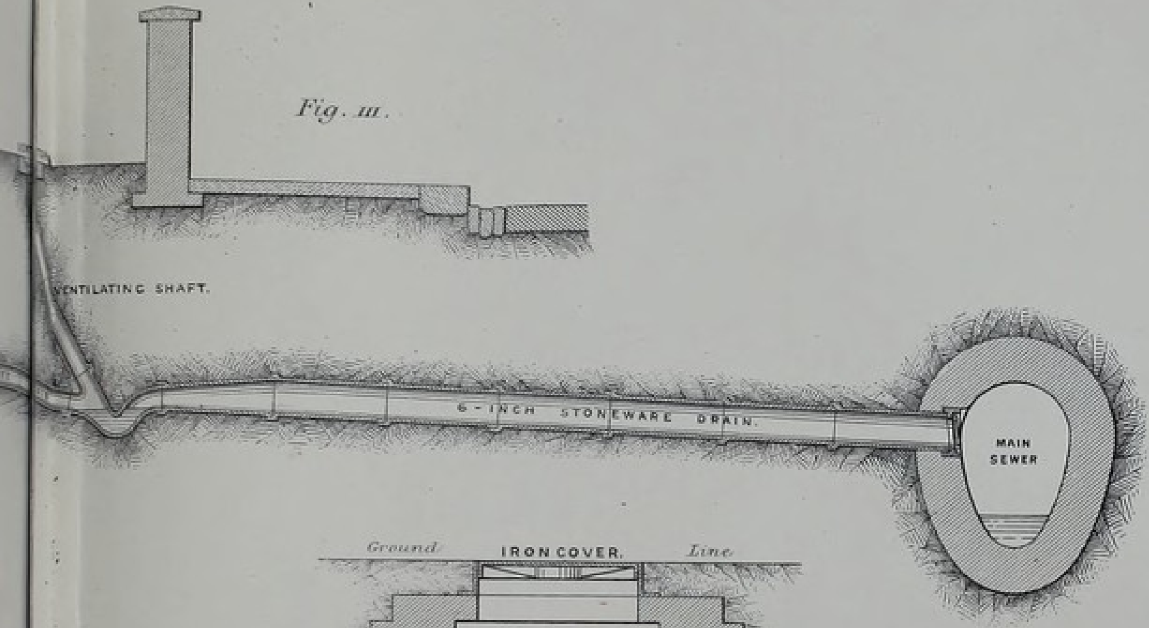
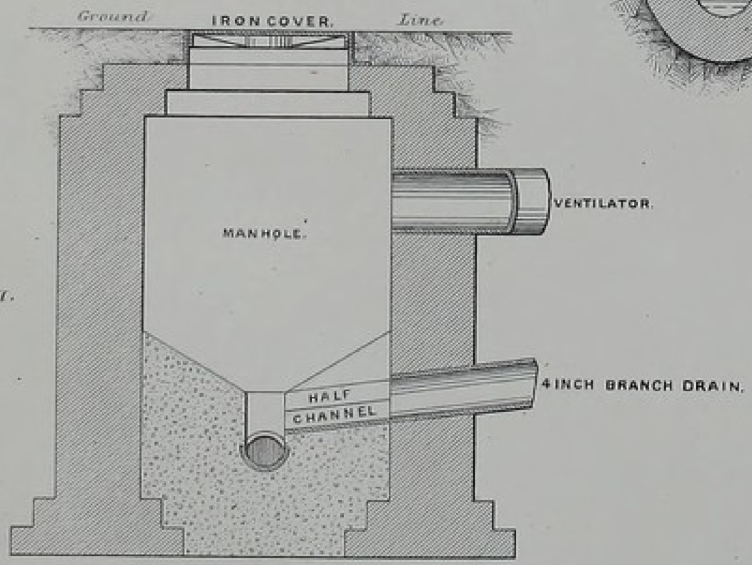
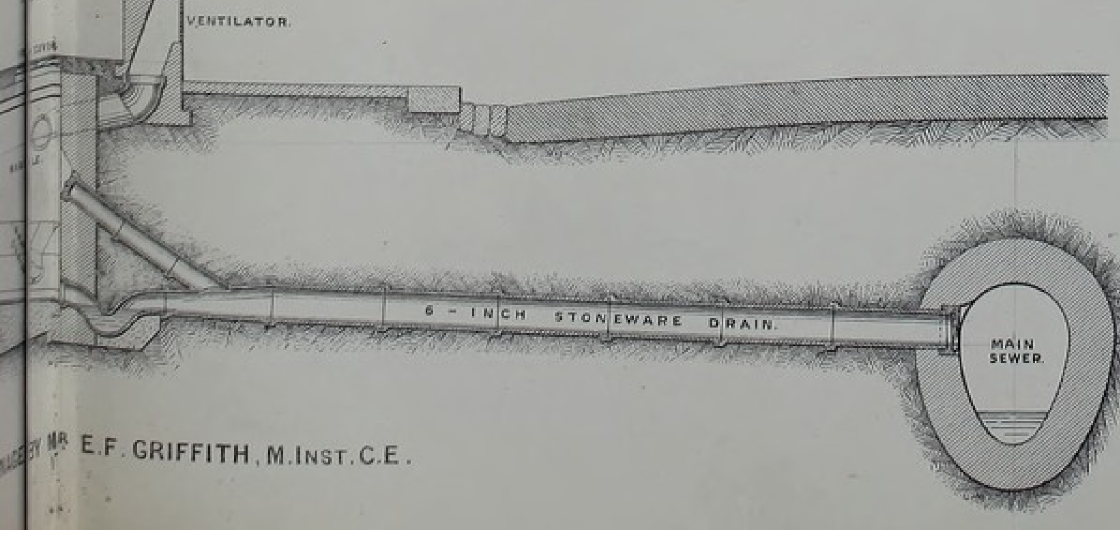


Fig. II.





BY Mr E.F. GRIFFITH, M.Inst.C.E.

C.F. Kell Lith. Castle St. Holborn, London E.C.

Mr. Griffith replied, "Stoneware pipes laid on a bed of good concrete can be used, but there is more chance of leakage through defective workmanship than with cast-iron drains, with lead and yarn joints." And as to the *fall* to be given to drains, he said : "All housedrains should be so laid that they are self-cleansing, not when running half full, as is usually calculated, but when they have only about an inch of sewage flowing in them. I never lay a 4-inch drain to a fall of less than 1 in 30, a 6-inch to a fall of less than 1 in 40, and a 9-inch to a fall of less than 1 in 60. When these falls cannot be obtained, then automatic flushing arrangements should be made. All houses, in my opinion," concludes Mr. Griffith, "should be so drained that when water is discharged into the housedrain from any bath or sink, closet, &c., the said water should be discharged in a body or volume so as to flush the drain."

The following is Mr. Griffith's description of the illustrations here given :—"It will of course be understood that these illustrations (Nos. 5 and 6) are purely typical and the conditions may vary greatly in each case which has to be dealt with. Fig. i illustrates a case in which the drains are all outside the house; a manhole or chamber is constructed on the line of drain both for the purpose of obtaining easy access to the drains in case of stoppage and for providing an 'air break' or 'disconnection;' a section (to a larger scale) of this manhole is given by Fig. ii. The syphon trap fixed in the side of the manhole next the sewer prevents, as a general rule, the passage of sewer gas into the house drain, but if by absorption or otherwise the gas does find its way into the manhole, it is there so much diluted that if it makes its escape through the ventilator to the manhole (as may be possible in certain states of the atmosphere) it is quite harmless. Generally speaking, however, there is a strong upward current of air in the housedrain caused by the soilpipe being carried full size above the roof, as shown, in which case the ventilating openings to the manhole serve as inlets for fresh air. Fig. iii shows another and cheaper mode of making the 'disconnection' of the housedrain from the sewer. In this case, a special syphon trap is fixed with a branch pipe carried to the surface as a ventilator. The principle is precisely the same as in fig. i, and is equally efficient in one respect, but if at any time it becomes necessary to examine the drain the ground or pavement has to be opened up. Water-closets should always be situated against two outer walls if possible and should have a small anteroom (which may be used as a lavatory) between them and the main part of the house. In a case where there are no windows near, it is sufficient to carry the soilpipe just above the eaves gutter. The closets themselves call for no special description, except that they should not have overflows, for two reasons, one being that defects in the water fittings are not so easily noticed, and the other, the danger of admitting foul air through the overflow pipe. Instead of the overflows, a lead safe should be fixed, and in all cases the waste from these should be taken direct through the wall. Illustration No. 6 gives the method adopted for disconnecting sink wastes. The section, fig. iv, shows a scullery sink on the ground floor and a housemaid's sink above; a plan of the scullery sink is shown at fig. vi, is fitted with a trap, and the waste (usually 2 inches in diameter) is carried to discharge over a stoneware gully fixed outside; the housemaid's sink, fig. v, if on the ground floor, is dealt with in exactly the same way, but if on an upper floor, as shown, the waste is carried into a rain-water head, the down-spout from which discharges with a shoe at the foot over a similar gully."

The evidence of Messrs. Eassie and Rogers Field coincided with that of Mr. Griffith in all material points, and to quote their opinion is the less necessary, inasmuch as Mr. Eassie has published a book on *Healthy Houses*, of 250 pages, with 300 illustrations, which may be bought for a shilling; and Mr. Rogers Field's practice is well explained in his pamphlet published by Spon, entitled *Bye Laws and Regulations with reference to House Drainage adopted by the Uppingham Sanitary Authority, and allowed by the Local Government Board, with explanations and suggestions.* The following are the rules to be observed in the construction of all buildings erected under the Surveyors to the Office of Works and Public Buildings:—

1. All water-closets and urinals shall be constructed so that one wall at least of such closets and urinals shall be an outer wall of the building.
2. All soilpipes shall be carried outside the building and ventilated by means of pipes leading the foul gases above the highest point of the building, such pipes to be carried to points removed from chimney stacks.
3. Separate cisterns shall be constructed for the water-closets and for the general purposes of the building; no tap or "draw off" shall be affixed to any pipe communicating with a cistern supplying a water-closet or urinal.
4. All wastepipes and overflow pipes of cisterns shall terminate in the open air, and be cut off from all direct communication with drains.
5. Great attention shall be paid to insuring through ventilation in all rooms. Rooms so high that their ceilings shall be more than 2 feet above the top of the windows, corridors, staircases, and other open spaces, shall be specially ventilated so as to prevent the accumulation of stagnant air.
6. All main drains should, where practicable, be formed outside the building. In the event of its being necessary to carry a main drain underneath a building it must be trapped immediately outside the main wall, and a ventilating pipe must be carried from that point to the highest part of the roof, as under Rule 2."

These sanitary principles will be found variously applied by different architects, but not so generally as should be. A syphon trap is usually put on the sewer side of the manhole, and no manhole should be without ventilation, both an inlet and outlet clear of accesses to the interior of house. But the iron door of the manhole should only possess an open grating, when situated next a blank wall clear of all openings or children's approach, lest they should receive or inhale the impure air as it escapes by the grating.

Mr. G. Godwin's valuable papers on Hospital Construction, 20 years ago, were greatly influential in bringing about the present improved system of hospital planning. His profusely illustrated little books entitled *London Shadows, Town Swamps and Social Bridges, Another Blow for Life*, &c. have enlightened the public to the many trials of the poorer classes arising from their insanitary surroundings, and given an impetus to the work of various societies for improving the dwellings of the labouring classes. The late Mr. Henry Roberts's name must also be remembered with respect by all interested in this subject; his long connection with Lord Shaftesbury's Society, and the improvements made by him in cottage building and ventilation can never be forgotten. Mr. J. P. Seddon is the author of twelve Papers published in the *Architect* in 1873, under the title of "Sanitary Suggestions." He has also written Papers on "Sanitary Reports," "Cowls," "Water Supply Regulations," "Warming and Ventilation," &c., and his brother Major Seddon, a Royal Engineer, is too well known as an expert in sanitary matters to need further reference. Mr. Norman Shaw, R.A., has shown

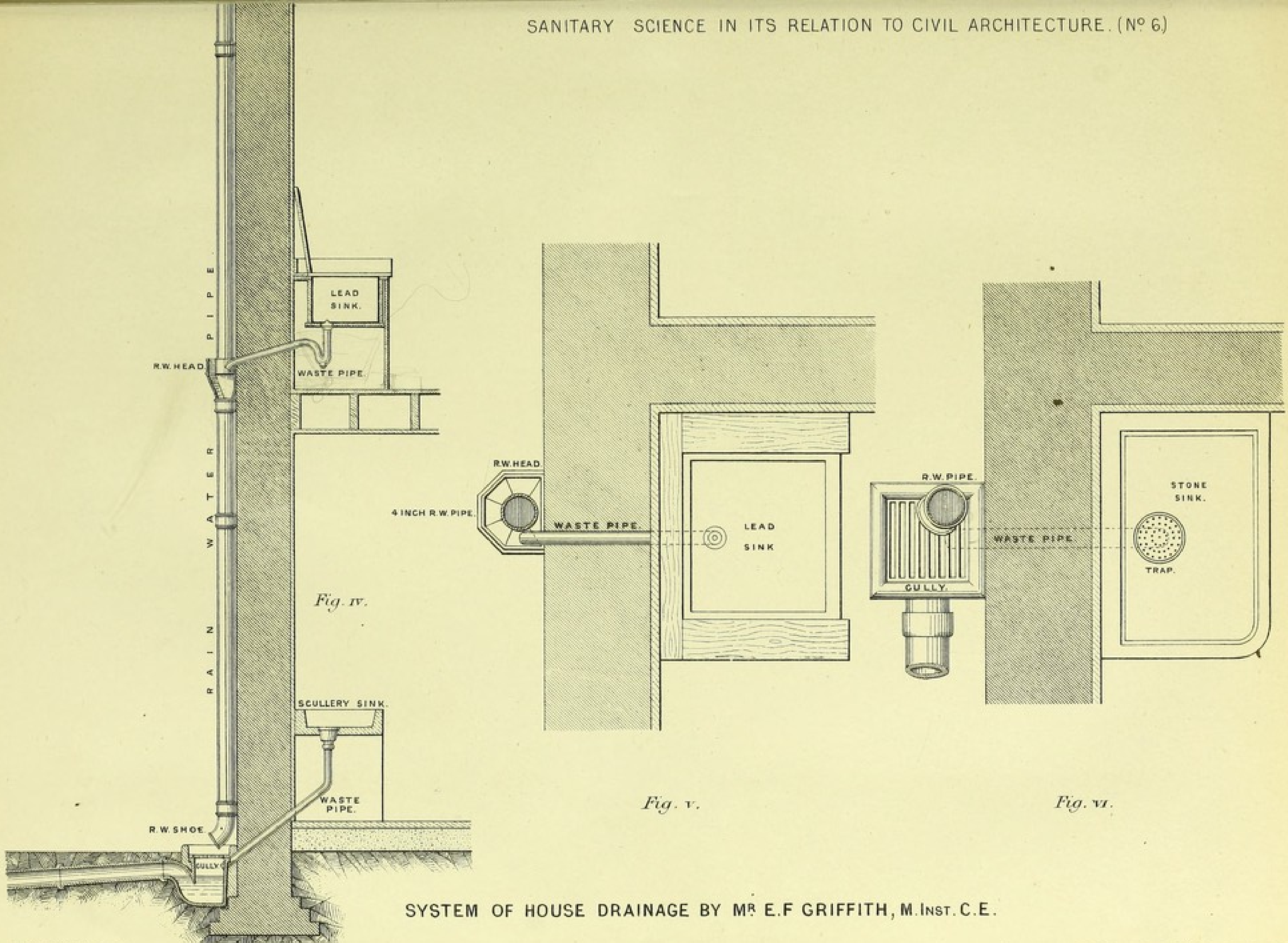


Fig. IV. *Fig. V.* *Fig. VI.*

SYSTEM OF HOUSE DRAINAGE BY MR E.F GRIFFITH, M.INST. C.E.

E. F. Griffith, Delt

C.F. Kell, Lith Castle St. Holborn, London. E.C.

by what simple means sewer gas may be absolutely disconnected from our dwellings; his process is well described in a pithy pamphlet he has published, wherein he speaks of "a little baby of his own, with which he is reasonably content after a trial of some five years." His plan is to use external stackpipes, open at both ends, for the passage of soil and other wastes, and he ignores and deprecates the intervention of all traps except one between his disconnecting open-mouthed drain, hopper and the pipe leading to the sewer. His answer to theoretical objectors is simply this: he does not find the evils suggested to occur in his own house nor in the many buildings to which he has applied his system, therefore he supposes it answers. At all events it has the great merit of singular simplicity and inexpensiveness, and the worst that can happen is but temporary inconvenience. Mr. William White, F.S.A., has written several Papers on the subject, and a valuable contribution in form of a pamphlet, entitled *Domestic Plumbing and Water Service.* Mr. Henry Saxon Snell has done good service by the conscientious manner in which he has worked out the sanitary contrivances which distinguish the various Metropolitan Workhouses erected under his superintendence. In the Parkes Museum may be seen his "Duplex lid" to water-closet fittings, an arrangement by which the purity of the air is secured within the apartment devoted to its use. He is also the inventor of an excellent hot water stove, heated by the open fire of the room, a singularly happy combination, also exhibited at the Parkes Museum.

I have mentioned these few names because something like a crusade has set in, not only by specialists, but by associated societies, such as that founded in 1878, at the suggestion of Professor Fleming Jenkin of Edinburgh, entitled "The Sanitary Protection Society." Professor Jenkin read a Paper at the Social Science Congress at Edinburgh, in which he stated that in consideration of an annual payment of one guinea the members obtained: 1st, a Report on the condition of his house; 2nd, Inspection of alterations made; 3rd, an annual experimental test of the condition of the drainage system. It was a mutual system then confined to Scotland, and there were already 500 members. The success of the Northern Society has led Professor Jenkin, who read a Paper at the Society of Arts on the subject, to establish a London Sanitary Protection Society, with Professor Huxley as president. There is yet another London Society called the "Sanitary Assurance Association," recently inaugurated at the Langham Hotel. The object of these societies is to bring the benefits of sound sanitary construction and design within the reach of the humblest householder.

With reference to the removal of excreta from buildings when no system of water carriage for sewage exists, I think it important to mention that the inodorous system of cesspool emptying by steam, adopted in France according to a patented process, invented by M. Talard, and introduced into this country by Mr. Laurie of Twickenham. I was one of a large company of gentlemen interested in sanitary matters who recently witnessed at Kew the process of emptying a large cesspool in this manner. The whole thing was done in a few minutes without the least effluvia being observable, though effected in the midst of a hot afternoon sun. As described by Mr. Laurie the process consists in pumping the excreta by the natural pressure of the atmosphere into a receiver from which all air has been first exhausted and a vacuum produced—in short, it is done with "pneumatic despatch." A steam vacuum pump is attached to a small portable locomotive engine to exhaust the air from the receiver, the pipes between this and the engine never being so much as soiled. The receivers are made of light steel plates barrel shape, and of a capacity of about 3½ cube yards; they are mounted on framework, on four wheels, being easily moved from place to place by a pair of horses; each receiver is fitted with a glass indicator at one side to show how full it is, and has a large fullway valve at the lower end, to which the flexible tube is attached. On the cesspool being opened, a strong 5-inch flexible tube is plunged to the bottom of the contents, the other end of this tube being connected with the valve of the receiver; this has already been connected to the engine by a smaller tube from the upper part of the receiver. The engine being started the noxious gases are first extracted from the cesspool, passed through the furnace and burned; the air is then exhausted from the receiver, and on the valve being opened, the contents of the cesspool rush up through the galvanized iron connecting pipes, 6 inches in diameter, filling the vacuated receiver in about three or four minutes. The valve is then closed, the pipes disconnected, and the receiver taken away to be replaced by others, until the cesspool is entirely empty. It is obvious that at no time in the process is there any exposure of the excreta to the atmosphere. The receivers are either discharged into close barges for transit, or emptied into reservoirs, or run upon the land in the usual manner for fertilizing purposes. The secret of success, however, lies in the singularly simple yet perfectly air-tight system of joining pipe to pipe and to the receiver, occupying less than half a minute to adjust each joint; each length of pipe is capped at both ends when not in use, with a similar joint for securing same. In Paris the price paid for extraction is 5 francs per cubic metre or 3s. 6d. a cubic yard, or one third of the cost of our present mode of operating in this country, which averages half a guinea a yard.*

WARMING AND VENTILATION.—I have now arrived at the second general division of my subject, namely, "Ventilation," with which I must associate "Warming," owing to their close relationship. As Professor Jenkin once remarked to me, the study and control of the *pressure* of the atmosphere, and not the temperature only, is the key to all sound ventilation. As this pressure is increased or diminished in its utilization, so is ventilation promoted or retarded. The right government and direction of the currents of natural atmospheric pressure is the business

* A description of the method employed in some of the *maisons-à-loyer* recently erected near the Champs Elysées, for the separation of the liquid and the periodical removal of the solid matter was given in the *Builder*, in November, 1877, in an article entitled "Paris after ten years," of which the following is an extract:—"This block of houses possesses three *fosses* or cesspools; and we had the honour of entering one while operations for which a *fosse* is specially intended were proceeding. First, an ordinary wooden door was opened; we found ourselves in a narrow lobby, and it should be understood that this *fosse* was on the same level as the stables and cellars. Then an iron door was opened, and some pains had evidently been taken to render the door air-tight. There was no offensive odour; instead of a pool of liquid, we stepped upon a clean cement surface. A large opening near the top of the vault faced us; it was the ventilator. Next to it there was a large pipe descending into an iron cylinder of portable dimensions, raised a few feet from the floor. From the cylinder another pipe descended into the earth, and it was connected with the cylinder by a guttapercha tube. This machine, of a frightfully primitive nature, acts in the following manner: solid matter, descending by the common pipe which receives the discharge of each floor, remains in the cylinder, at the bottom of which is a narrow, well-protected grating; through that all the liquid oozes, by means of the guttapercha tube, into the drains, whereby it is conveyed by the street sewers to the Seine, at a distance from Paris. Every two days this chamber is visited by the servants of the company—undertakers, or rather contractors, for this system of drainage. The cylinder, disconnected from the pipe descending from above, and the guttapercha tube before mentioned, is carried off on the shoulders of two men; another empty cylinder is put in its place. Such a *fosse* is simply a clean empty cellar containing in one corner the rough machine which we have described."

of scientific ventilation, which pressure is always in the direction of the least resistance. There is what is called natural and artificial ventilation. The former acts by the force of diffusion by winds and by the difference in weight in masses of air of unequal temperature. Diffusion is an insufficient agent in ventilation, but it penetrates stone walls and permeates the soil and helps to produce damp basements only to be overcome by concrete laid over the whole site of the building.* But wind is a powerful ventilating agent, and finds its way everywhere. Märcker of Göttingen shows that it will penetrate through a loamy brick wall at the rate of 5-12 cubic metres per hour, when the difference in temperatures is 1° Centigrade. It is the unequal weight of atmospheres that gives rise to wind, and the pressure of dry cold air against moist warm air produces rapid interchange of cross currents and movements of the air largely available for ventilating purposes. The inequality of temperatures is a fruitful source of change in the air, and the direction of the forces produced by it is a necessary aim in ventilating processes. By a difference of temperatures of 70° inside and 40° outside (Fahrenheit), the air will force itself through a square yard of limestone wall at the rate of 10 cubic feet per hour. The preservation of the purity of the air about us is therefore as essential as that of the spring at its source.†

Dr. Parkes has shown in great detail the various sources of impurity to which the air of inclosed spaces is subject, and the particular diseases to which such impurities give rise. In our present inquiry, and as he suggests, it will be desirable to restrict the term ventilation to the removal, by a stream of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of the combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions of surrounding dwellings. We have, therefore, firstly to consider what quantity of fresh air is required for the above purpose, and secondly the best method of supplying it. Assuming that we have succeeded in ventilating our drains and in excluding sewer gases from our buildings by the means and appliances already detailed in the first section of this Paper, our first inquiry must be, what is to be the measure of the impurities to be removed? Taking the presence of carbonic acid as the index of impurity, Dr. De Chaumont has shown by experiment that the organic impurity of the air is not perceptible to the senses until the carbonic acid rises to the ratio of ·6 per 1,000 volumes. At ·2 it is fresh, or not sensibly differing from the outer air; at ·4 it begins to be close; at ·6 it is decidedly close, the organic matter being disagreeable; at ·9 it is

* See Appendix C for note on subsoils, extracted from the author's lecture on "Situation," delivered at the Parkes Museum.

† TABLE showing pressure of wind per square foot at different velocities :—

3 miles an hour,		¾ of an ounce on each square foot.			7 miles an hour,		4 ounces on each square foot.		
3½	do.	1 ounce	do.	do.	10	do.	8 do.	do.	do.
5	do.	2 ounces	do.	do.	14	do.	1 lb.	do.	do.

TABLE showing passage of wind through walls. Märcker has given the following as the amount of air passing in one hour through a square metre of wall space, when the difference of temperature is 1° C. :—

	Cubic Metres of Air.		Cubic Metres of Air.
Sandstone	1·69	Tufaceous Limestone	3·64
Limestone	2·32	Loamy Brick	5·12
Brick	2·83		

very close, the organic matter present being offensive and oppressive. The Doctor has also prepared *tables* which show the deterioration of the purity of the atmosphere produced by the respiration of one man in rooms varying from 100 to 1,000 cubical contents, and the amount of air necessary to dilute to the standard of ·2 for the first hour and for each succeeding hour, which are readily available in practice.* The amount of air required to do this has been fixed at 3,000 feet for each adult healthy person in an hour, and it follows that, the larger the air space, the less is the necessity for the frequent renewal of air, and the less the chance of draught. Thus a space of 100 cubic feet must have its air changed 30 times in the hour, if 3,000 cubic feet of air are to be given; while a space of 1,000 cubic feet need only have it changed three times in an hour for equal ventilation. Every foot of gas consumed is equivalent to the vitiation of the air produced by the respiration of one person. The difficulty of thus changing the air without draught is, however, very considerable, and Dr. Parkes observed that "*a change equal to four or three times per hour is generally all that can be borne under the conditions of warming in this country.*" In practice the change made rarely exceeds 750 cubic feet per head per hour. It is obvious, therefore, that warming the incoming air is a necessity in cold climates like our own; and consequently the principles of warming and ventilation are too intimately connected to be completely studied or applied alone. Changing the air of a room is not the less necessary because the cubical space included within its walls is large; the largest space can only provide sufficient air for a limited time. Even in a space of 10,000 cubic feet per head, the limit of admissible impurity would be reached in 3 or 4 hours; after which the same constant hourly supply of 2 or 3,000 feet would be as necessary as in a space of 100 cubic feet. Obviously it is not only important that the air should be changed, but that that change shall be for the better, by being drawn from a pure source, and carried through clean channels.

Ventilation means passage for the wind, change of air, or to use an expressive Americanism, atmospheric recuperation—both a way in for the air, and a way out for the same, which is the sole means of changing it, in any place or building, and no recuperative process can go on without it. Some people would seem to be possessed with a belief in infinite atmospheric compression; that it is only necessary to let air into a receptacle and that it will continue flowing on for ever. But to take an analogous element, the difference between air and water is only in degree; and as the full receptacle will hold no more water, so the vessel filled with air can take no more without unnatural compression. The temperature determines its bulk, and if equals be added to equals the remainders are equal. Airs of equal temperature are stagnant whether pure or impure; it is the ever varying temperature that chiefly constitutes the motive power and creates currents by varying pressures. As the difference in weight and temperature of the all embracing atmosphere in which we live and move and have our being gives motion to the winds, so wherever the winds are excluded from the interior of any place or building, an artificial difference in temperature becomes the needful provocative cause of movement through the inlets and outlets provided.

Natural ventilation is, then, the simple process of mingling the external with the internal atmosphere of a building. Scientific ventilation is one and the same thing, but with this difference, that in the former case it is free to mingle or not as it pleases, and in doing so to

* See Appendix E.

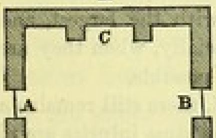
create many inconveniences; in the latter, direction is given to currents of air produced by its interchange, and a healthy commingling of the oxygen with the carbonic acid gas is secured without the dangerous and disagreeable accompaniment of draughts. In short, the business of ventilation is to direct the pressure of the currents of air admitted and required to overcome its stagnation, under conditions where no draught is admissible; and to do this by mechanical appliances for the introduction and withdrawal of the air directed by the scientific apposition and control of varying temperatures. With the thermometer for measuring the temperature of the air, the hydrometer for testing its humidity, and the barometer for determinating its weight, we have the means of estimating and testing by experiment the pressure of the atmosphere in any direction. The measurement of the force of the currents of air produced by the difference of temperature, &c., existing between the external and internal air of a building is accomplished by the use of the anemometer or manometer. The natural process by which the temperature of the air is raised is twofold—by radiation and by conduction. Radiated heat has the peculiarity of passing directly through any intervening space or air without parting sensibly with its heat, and warming the first obstacle to its passage, such as a wall or window, with which it comes in contact. Conducted heat, on the other hand, is the warmth given off by any surface by direct contact with any substance, whether air or otherwise. The sun shining from its distance cannot part with any conducted heat, excepting the minute quantity given off by its rays to the dust in the air when passing through the same. It therefore heats practically by radiation alone, the warmth passing into the earth, and from that being given off gradually to the surrounding atmosphere—hence the difference of temperature in the sun and in the shade. In the case of open fires nearly the same result is attained, though at great outlay in fuel. The conducted heat of the fire passes into the air escaping up the chimney, and is lost for heating purposes, while the radiated heat alone is available for raising the temperature of the room; this warmth first passes into the outer surfaces, and is then given off by them by conduction into the atmosphere. Radiated cold from the outer surfaces, which is the chief source of the feeling of cold, is thus avoided, and a pleasant and agreeable result is quickly attained. Artificial heating, on the other hand, inverts the above principle by employing hot surfaces placed in immediate contact with the atmosphere. These, though giving off a certain proportion of their heat by radiation (which proportion increases with their temperature), yield the greater quantity by conduction to the surrounding air, which in turn gradually warms the inclosing walls, &c., instead of, as before, first warming the walls and then the air. The moisture contained in the air, or which should be contained by it, varies directly with its temperature, and when the atmosphere is violently raised in heat without provision for the proper additional proportion, it will seize on any moisture within its reach, causing a dryness of the skin, drawing the woodwork in the building, and producing other disagreeable effects. This is another reason why an Englishman's instinct leads him, while ignorant of the cause, to hold to his open fire. Draught is, however, an inconvenience inseparable from the use of open fires in unventilated rooms, especially where they are placed opposite the doors, since they draw large quantities of air across the floor, and pass it up the chimney: to reduce the evil they should be placed side by side, and if this were carried into effect far less would be heard of cold feet. Cleanliness is a virtue for which the open fire is not usually praised, whereas, as a matter of fact, it is far cleaner in its use than any means of heating by conduction. The latter, circulating the air and always in the same lines, causes the dust particles to settle over the whole surface of the walls and ceiling, and gradually to discolour everything, whereas in the case of the open fire, where the upper stratum of the air is uniform in its motion, this is not the case. This phenomenon may be noticed at any vertical opening for emitting hot air. Thus at the New Station in Magdeburg there are, in the walls of the Refreshment-room, four such openings about eight feet from the ground, and each one is ornamented from thence to the ceiling, some 15 feet, with a broad black streak produced solely in this way, the sooty particles in the air being drawn towards the stream of air rarefied by heat and settling on the walls. With justice, therefore, an Englishman may love his open fire, the comforts of which cannot be denied, or its advantages disparaged; but it is practically impossible to adopt it in all cases. It is not inexpensive either in first cost, when all its adjuncts, in the shape of chimney breasts, mantel pieces, stoves and hearths are taken into account; when adopted, as a rule, it is only used for heating a few particular rooms (the rest being left cold) and it heats these at a great outlay of fuel. A German, Russian or Belgian with his little fire in a colossal stove obtains five times the effect in half the time, more especially because he builds his house with some reference to the heat he loses by his outer surfaces. All the best authorities agree that no system of warming or ventilation is better for the absence of the open fire stove; it is not only the best heater by radiation, but it is the best ventilator by extraction as opposed to propulsion. Ventilation by extraction is produced by the application of heat either at the bottom or the top of a ventilating shaft so as to cause an upward current therein by the action of a fire, steam jet, hot water, or by a fan or screw used for the purpose of drawing out air. The constant current up a chimney when the fire is burning is in proportion, of course, to the size of the fire and the flue therefrom, but the usual current of a sitting-room fire of ordinary dimensions, as tested by the anemometer, is from three to six feet per second. If the area of the section where the anemometer is placed is known, the discharge can be stated in cubic feet; and even when there is no fire, the velocity of the upward current in the flue is usually from 1½ to 3 feet per second. With an ordinary fire a chimney gives a sufficient discharge for four or five persons, above that number special appliances are required. The strength of the draught in the fire often causes down draughts in flues intended to act as outlets, unless there are inlets of equal area or greater to the outlets and to the smoke flue of the chimney. The ventilation of mines is carried on upon the same principle as this—that is, by lighting a fire at the base of the upcast shaft, by which the air is drawn down the intake shaft, and permeates all the workings of the mine in its endeavour to reach the vacuum formed by the rarefaction of the air in the heated upcast shaft. The skilfulness with which the air is directed may be judged of by the fact that in some mines a portion of the air makes a circuit of from 30 to 40 miles before it can arrive at the upcast shaft.

Much difference of opinion exists both as to the size and the position of inlets and outlets. With regard to size, it is desirable to make each individual inlet opening not larger than from 60 to 80 superficial inches in area, or enough for three or four men, and to make the outlets about a foot square, or enough for six men. Distribution is more certain with several small openings variously placed, but the total area of inlets and outlets may be equal. The position of inlets should be opposite outlets, and on the same side of the room as the fire if there is one, or if the room is heated by a coil of pipes the incoming air should pass through the coil; if no means of heating the incoming air is available, the inlet should be in the upper part of the room and be directed towards the ceiling, or through shafts from the floor level known as "Tobin's." Cold air should either be heated on its entrance, or the inlets brought so near to the fire that it may draw from them without creating draught or checking the flow in the upcast extract shafts in the opposite wall. But both inlets and outlets may be at the bottom of the room, provided the fresh air is passed through the warming apparatus and the vitiated air is drawn through descending flues to the foot of a lofty shaft heated by a furnace; the lower the level at which the extract shaft enters the furnace the greater the extracting power, provided always the horizontal flue is not too long. The "Hygiastic" stoves bring in fresh air after passing it under the hearth and heated back and sides of the stove; the size of the gratings is determined by the cubical contents of the room to be warmed and ventilated, and it is under control by an endless screw handle for opening and closing the louvres provided. I know no better exposition of the principles which should govern the design of such stoves than that given in Captain Galton's last book, illustrated by stoves of his own design, which have long been in use in military buildings. The introduction of air by vertical shafts suggested, nearly a hundred years ago, by a Mr. Whitehurst, is a sound principle eminently suited to the requirements of ordinary-sized rooms heated by the open fire grate only. A minimum of draught is achieved by it over any other system of direct introduction of cold air. So much has been written and said upon this so-called modern invention that I venture to print here some extracts from the pamphlet containing Mr. Whitehurst's ingenious suggestions, together with its title and preface:—

"Observations on the Ventilation of Rooms; on the Construction of Chimneys; and on Garden Stoves. Principally collected from Papers left by the late John Whitehurst, F.R.S. London: Printed for W. Bent, Paternoster-Row, 1794. ADVERTISEMENT.—About ten years ago the late Mr. John Whitehurst, who died in 1788, had nearly completed for the press, a Treatise on Ventilation, on Chimneys, and the Construction of Garden Stoves, which was accidentally destroyed, and never afterwards replaced. The papers on which that treatise had been founded, were referred to me [R. Willan] for examination some time after his death. They consisted chiefly of remarks and memorandums relative to the subject, put down without order or connection. On a careful perusal of them, thinking the observations judicious, and not unworthy of public attention, I endeavoured to arrange them and to supply several deficiencies. This I was the better enabled to do, from having had frequent opportunities, during a long intimacy with Mr. Whitehurst, of learning his sentiments on the most material points . . . The latest publication on the same subject is by the celebrated Dr. Franklin. His letter to Dr. Ingenhousz on the construction and use of chimneys affords many useful hints, but does not, I think, supersede the more enlarged plan of Mr. Whitehurst. Without derogating from the merit of Dr. Franklin's Essay, I may be allowed to observe, that we are in some respects indebted for it to Mr. Whitehurst, the Doctor having been first induced by him to attend to the subject of ventilation and chimneys, while on a visit at Mr. Whitehurst's house in Derby during the summer of the year 1774. . . . .

"CHAP. II. . . . . Let fig. 11 represent the plan of a cottage, having one chimney C, one door D, and two windows A, B. Suppose first the door and windows to be air-tight, or so closely

11



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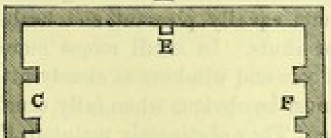

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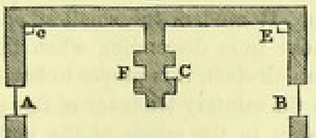
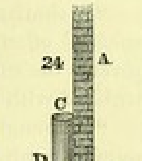




fitted, that they do not admit a quantity of external air sufficient to carry up the smoke in the chimney. The house will in that case be incommoded with smoke and stagnant air. If then a window or door be opened, the chimney obtains a supply of fresh air, and performs its office in carrying off the smoke properly. This circumstance points out to us a remedy for the defect, by making some convenient aperture into the house, which, however, must be done with caution, for if the opening is either at the door or window, the stream of cold air flowing from thence, will not only be unpleasant, particularly in winter, but very injurious to the inhabitants. What I should propose for the purpose, is an air-duct, three or four feet long, to be fixed in either corner of the room most remote from the fire, as at E, and communicating with the external air through the wall. The diameter of the duct must be from five to six inches. The air admitted by this means will ascend in a perpendicular direction to the ceiling; and being gradually diffused will soon acquire the temperature of the room. While this process goes on, no person within is sensible of it, nor is the flame of a candle in the least disturbed by it. At the same time smoke and stagnant air are effectually removed. If the air should be admitted near the fire, the chimney will act equally well, but the circulation through the room cannot be so perfect, for as the fresh air must take the nearest course to the chimney it would leave that which is contained in other parts of the room nearly quiescent, whereby it would become less fit for respiration.

"Let us next consider the consequences arising from two chimneys in one and the same room, as at C F, fig. 12, other circumstances remaining as before.

1. If a fire be placed at C that chimney will not smoke, although the door and windows be perfectly close, because a supply of air must come from the other chimney.
2. If it were requisite to have a fire at F also, the smoke in that chimney could not ascend at all, on account of the current of air passing down it to supply C, or reversely if the fire were placed first at F, the chimney C would then smoke for the same reason.

"To remove the defect in this case without injuring the inhabitants, and to enable both chimneys to act well at the same time, it becomes necessary to apply an air-duct as in the foregoing instance, but in a different situation. Its capacity must also be enlarged, since two chimneys are to be supplied with air instead of one. A duct whose side is seven inches may answer the purpose, its area will then be forty-nine inches, or nearly double to that of the former, whose side was estimated only at five inches. The most proper situation for it is at an equal distance from each fire, as at E, because a stream of air flowing up from thence will have the greatest possible effect in ventilating the room. An air-duct at any of the corners might indeed afford a supply to the chimneys, sufficient to prevent them from smoking, but could only change the internal air partially. Let fig. 13 represent the plan of a cottage, consisting of two rooms with the door D, and windows A B, close. A fire in the chimney C would not smoke since it must have a constant supply of air from the chimney F. But if the wind should happen to blow in the direction from C to F, the smoke rising from C would be carried down again with the air in F, and fill both the rooms. One air-duct might here also prevent the chimneys from smoking; but with a view to ventilation I should recommend two, situated as at E and e, which would always keep up a proper circulation of air through both the rooms.* . . . .

"Having provided for a general supply of air to the house, we should in the next place regulate the mode of its admission into each room separately, both above and below stairs, so as not to injure the architecture or to occasion any deformity, which may be done easily and without expense in the first construction of a building. I have employed in several instances the following method with advantage: I leave an open space between the upper part of the architrave, surrounding the door and the wall, on each side of the door, and likewise an open space between the casing and the lintel.

"The air then descends between the architrave and the wall on the outside of the door, and ascends between the architrave and the wall on the inside of the room. The current thus admitted rises in a perpendicular direction toward the ceiling, and acquires the temperature of the room, circulating through it imperceptibly to the inhabitants. At the same time it prevents any accumulation of stagnant air, and removes the smoke of candles, which is otherwise very pernicious.

"A similar mode of ventilation may be applied to all the rooms, however great their number, with the same beneficial effects. It renders the smallest apartments equally pleasant and healthful with the largest, and prevents the smoke from descending when the door shuts. In small rooms more especially, when they are furnished with an air-duct, it is proper to have the doors and windows as closely fitted as possible.

"Although the salutary tendency of this plan must be obvious when fully considered, there still remains a prejudice against it in the minds of the multitude. They obstinately maintain that the same injuries are to be expected from air admitted in this manner, as from the cold streams of it which usually flow into a room through the crevices of the door or window. However, the plan I propose is not recommended from theoretical

* The form of the suggested air-duct is shown in fig. 24 (see woodcut). A, represents an external wall; B, C, is the air-duct. Mr. Whitehurst further suggests that "the part C, D, should be a box of wood, the rest brick;" and "if necessary an iron grate may be laid over the aperture B."

speculation; it has sufficiently stood the test of experience, and to that alone we can properly appeal. Beside its own peculiar advantages, it effectually prevents those disagreeable sensations, occasioned by lateral currents of air, which chill the body on one side, while it is heated on the other, nor can its operation at all produce the same dangerous consequences, since the air introduced by it, being gradually and insensibly diffused, distributes an uniform heat round the room.

"I do not propose the method of ventilation above stated as the best in all possible cases. There is so great a diversity in buildings that a variety of modes may be adapted to produce the same effect. The application of the principles must then be regulated by circumstances, and by the discretion of the architect.

"A few general hints will, however, serve to facilitate the process. If the kitchen be connected with the house by a passage, or by any other means, it becomes necessary to apply an air-duct of considerable size for the use of that room alone. The area of the tube should not be less than one hundred and forty-four inches in a moderate kitchen; for if the chimney there have not a full supply independently it will draw air from some or all of the chimneys in the house.

"Different modes may be adapted to answer this purpose :—

1. A perforation of twelve inches square may be made in the kitchen wall near the bottom, to which a tube must be fitted as usual.
2. If circumstances do not allow of such an opening, air may be admitted by raising the sash five or six inches above the sill, and applying a board at about the same distance from the window to direct the stream of air towards the ceiling. This board should be one foot broad or somewhat more, and may be suspended on hinges so as to let down in the night if the window shutters require to be then closed. In lofty kitchens, where there are small sashes, one of the windows is often hung upon an axis horizontally, so as to open or shut at pleasure by a line fixed to it. The inclination of the open windows affords a supply of air to the chimney, and defends the floor from rain; but it does not prevent the inconvenience from the wind blowing downwards into the room.

"In some rooms where it is not convenient to make a perforation, air may be admitted between the folding of the sash-frames by cutting away about the eighth of an inch from the frame, leaving the whole substance at each style. This is only practicable when there are shutters on the outside, and not on the inside of the window. For by inside shutters the current of air upwards is obstructed, whence it rushes through the crevices in various directions, and produces unpleasant effects."

Mr. D. O. Boyd has spent his life in trying to aid us in our endeavours to satisfy our clients and to please ourselves in laudable efforts to warm and ventilate at one and the same time. His latest stove combines many advantages and is adopted at Lincoln's Inn by Mr. Waterhouse. The incoming air is received into a sub-basement purifying chamber after it has been cleansed of all impurities by passing through a moistened filtering apparatus. The air so purified is conducted by flues to a chamber underneath the iron hearth of the new stove, which stands clear of the walls and allows the fresh air, after taking a tortuous passage through the warm air chambers of the stove to rise out of and over the centre of the stove into the room, on the same principle as that of Mr. Whitehurst, but pure, sweet and warm, and in large quantities. The air flue ceases at the stove hearth, but is continued again above the same in the form of a smoke flue from the upper part of the stove. No other ventilation than this incoming air withdrawn, after its revolution through the room, by the open fire grate, is necessary, when there are not more than four or five persons, but in class rooms and where numbers congregate supplementary inlets and extract shafts would be required if the exchange of from 750 to 3,000 feet per head per hour is to be maintained. It is more than 20 years ago since I used Mr. Boyd's cast iron flue plates to divide smoke flues, the merit of which was that the 4½ withe was left hollow between the smoke flues, and provided at a minimum of cost and space, a warmed air extract shaft for ventilating the apartment without entering the smoke flue. I used them with success in 1861, when I erected Mr. Horniman's house on the Warren Hill at Croydon. Then there is Mr. Henry Saxon Snell's "Thermhydric

Ventilating Hot Water Open Fire Grate." This invention consists of an open fire grate surrounded on three sides and on the top by a wrought iron chamber containing water, which when warmed by the fire circulates through upright coils of pipes placed on either side. The hearth is made of iron, and the whole space below the grate and pipes is formed into a chamber for the admission, collection and warming of air from the outside. The air cannot be burnt or be heated above the temperature of boiling water, and the water contained in the vase, being slightly warmed, evaporates and thus keeps the air of the room moist. I have drawn attention to this stove because it was approved and used at the Norfolk and Norwich Infirmary and elsewhere by the late Mr. Thomas Henry Wyatt, whose practice in hospital building was extensive and carefully studied from a sanitary point of view. This leads me to refer to his latest work carried out in association with his son, who now acts as architect to the New Hospital for Consumption at Brompton; my attention to which hospital was called by my friend Dr. R. E. Thompson in a letter describing the heating and ventilating processes, in which he has greatly interested himself.

Dr. Thompson thus summarizes his own views:—"I think that air should be admitted at the level of the various floors, and not from an underground chamber; also that the air so admitted should come from the east and west sides if practicable, and should in any case be passed over tubes of hot water. Air of uniform temperature is disagreeable and oppressive, it is better that the upper air should be colder than that of the floor, and that the warm air as it rises from the floor level should be cooled and agitated as it mixes with the upper air by the incoming cooler air. The foul air should be extracted by the open fire and by the extracting flues at the top of the room, which should be heated by gas jets below, or made to communicate with a hot air chamber above and in connection with turrets forming ventilating towers." With regard to water-closets he considers that the room they occupy should be heated to a higher temperature than the passages leading to them, and a separate means of extraction should be adopted—and he is right. These principles have been attempted to be carried out at the New Hospital. Mr. Haden has been intrusted with the heating and ventilating arrangements under contract to change the air some 4000 feet per head per hour. He has provided low pressure coils to stand in the recess formed by the back of nearly every window in the building, through which the external air is to come by the gratings provided under every window. The rooms will be rather over than under ventilated. Open fires are in every ward, and extract shafts as required, communicating with the hot air chamber which surrounds the attic at the base of the mansarde roof, and is connected with the four ventilating towers. The hot air chamber is heated by the steam pipes from the engine boilers in the basement. The boilers for heating the hot water piping are very large, but when cost and space is not a difficulty, the low pressure system is most manageable and least deleterious in its action upon the air which is warmed by contact with its surface.

I agree with Dr. Thompson that there are some disadvantages in the system which has been adopted in many important buildings with varying success, namely, that of underground reservoirs for the accumulation of heated air to be transmitted through shafts to the different rooms in a building, the fresh air being admitted to this heated chamber through the floor of it. I have adopted it myself at the Choir Schools attached to St. Andrew's Church, Wells Street, using low pressure piping—with the effect on the walls noticed at Magdeburg. It has been employed at the Jonson Street Board Schools at Stepney, and many other buildings, but notably that of Sir Joshua Mason's Science College at Birmingham. A chamber about 7 feet high and 9 feet wide and above 100 feet long is filled from end to end with low pressure hot water pipes, and the brick arch forming the floor is also the roof of another chamber for the reception of the fresh air from without, which is admitted through the same by the openings left for that purpose. The flues conducting the air to the several rooms lead from this chamber, and the current of air is very strong, carrying the warmed fresh air which is admitted at pleasure by gratings provided with a means of limiting the supply to suit the needs of the moment. Everything depends on the cleanliness of these vast chambers, and there have been cases in which, from the carelessness of the attendants, decayed organic and vegetable matter has been allowed to accumulate in or near the chambers, and in one case within my knowledge, a defective soil drain delivered its contents therein. It is obvious that the whole institution is rendered unwholesome if anything go wrong with this great lung of the building, whereas by separately heating each apartment, any defects are confined to the space where the damage may have occurred. It has been found in practice that cumbersome systems of ventilation are less manageable and more costly than simpler means, and in not a few cases, both here and in Paris, the original comprehensive plan of artificial ventilation has been superseded for less ambitious but more effective means. There are circumstances wherein a system of heating and ventilating by propulsion is alone applicable, and wherever a strong draught is required to draw off the vitiated air of any building, or where great distances have to be traversed, no more effective means can be resorted to, especially where a steam or gas engine is available for the motive power required to turn the fans.

There are many systems of heating by hot air, by steam, and by gas, but my experience

* In the new Technical Schools at Finsbury is an example of heating and ventilating by propulsion. The heating surfaces are placed in a common central chamber, with fresh air driven over them by two powerful fans and distributed by means of horizontal channels through the whole building, connected by means of rising shafts to each floor and room, and delivering into the upper part of the same. High pressure wrought iron small bore piping is to be used, of which the heating chamber contains some 3500 superficial feet. The boilers are adjacent—and so is the three-horse power engine required for driving the fans, which are 7 feet in diameter with blades 3 feet 6 inches across; 100 revolutions a minute are made, delivering the air at the rate of 15 feet per second, but it is made to enter the rooms at the rate of 3 or 4 feet and not exceeding 6 or 8 feet per second. Taking the air from the outside at a mean winter temperature of 39°, 1640,000 cubic feet of air can be driven through the building per hour—each fan blowing one half of the above quantity. The air is driven into the hot chamber, entering at the bottom, and is compelled by a plate iron division to pass up and down through the heating surface before reaching the main distributing channel, which passes under the flooring right and left, graduated in area according to the number and size of the upcast shafts they have to serve. The iron gratings through which the warm air is forced into the rooms are sufficiently large to permit of a current of 3 or 4 feet per second, and are fitted with valves to regulate the supply. The fresh warmed air is admitted, either above or below the ordinary level of the pupils' heads, by a double set of ventilators. For the exit of the foul air, shafts are left in the walls running through to the roof, having extract openings into the same near the floor or ceiling and as far as possible from the fresh air inlets, and thus provision is made for both summer and winter ventilation. The central chimney shaft from the furnace in basement rises to the height of 120 feet, and is used for drawing off the foul gases and vapours from the great laboratory and experimental closets in the various chemical departments. There are above a dozen large stink closets to be evacuated once every minute, from which collectively 52,320 cubic feet of air are drawn off per hour. And there are forty-seven draught tubes from the various operation benches, which withdraw 141,000 cubic feet per hour. The draught chimney extracts 196,420 cubic feet per hour in

is not greatly in favour of them; when I get beyond the power of open fire stoves, I generally resort to hot water as a means of conducting and concentrating heat wherever I most require it. Twice I have had to substitute hot water for hot air systems in churches.

There are two leading principles governing the supply of hot water piping for heating purposes, termed high pressure and low pressure; that is to say, the latter provides for the supply of water in more or less large pipes at a low temperature, which cannot exceed boiling point, and the former circulates the water at a high temperature, but usually under 300°, in very strong wrought iron pipes of very small bore, rarely exceeding 1 inch in diameter. A particular description of this high pressure system will be given in the appendix and contrasted with other systems, because I do not think its convenience and inexpensive effectiveness are so well known as they should be. I have had equally good results from the use of the low pressure system, and have by no means omitted to avail myself of its advantages in a variety of cases where the means were forthcoming for its first cost, and it is too well known and too often applied to need any particular mention. The only danger to be apprehended from the use of water for heating purposes is the risk of its freezing in frosty weather when only intermittently used, but this evil is quite overcome by the non-freezing liquid now used for the purpose, at least in the high pressure system, which latter, as now practised and associated with proper ventilation, is as free from danger as any other. In the appendices to this Paper will be found a comparative description of the various systems of heating, and the various formulas in use by which their relative effectiveness is arrived at, prepared for me by Mr. A. J. Bacon.* I am now simply urging the greater consideration of the subject generally as it applies to ventilation, because of its bearing upon the health of the community through the healthful construction or otherwise of buildings generally; and I have, with the generous assistance of Mr. Bacon, worked out in detail the heating and ventilation of a single class room.† The application of the foregoing principles to dwelling-houses generally is given in an extract‡ from my lecture on "Ventilation, Lighting and Warming" delivered at the Parkes Museum. But I have said enough to show that the practice of Civil Architecture cannot be divorced from Sanitary Science, for obviously it underlies all our work and is as important an element in it as any one of the constructive sciences with which we are bound to be familiar.

Professor CORFIELD, M.A., M.D. (Oxon).—I could have wished that the President had called upon some one more experienced and older than myself to open this Discussion, but when I was asked to do so it was put before me in this way: it was considered that some one not a Member of the Institute should open the Discussion; and as I had been a

summer, and 269,845 cubic feet in winter. And this is achieved by causing the extract flues to descend to the base of the shaft, which being 120 feet high carries the air up with a great draught. The quantity of fresh air admitted to the laboratory only in summer is 160,200 cubic feet, and in the winter 217,525 cubic feet per hour. The velocity in the branch flues is 5 feet per second, the descending flue 5 feet 6 inches, and the upcast shaft 6 feet per second. In summer the fans drive in cold fresh air by the shafts, the pipes of the heating chamber not being at work as in the winter; and it can be admitted at the top or the bottom of the rooms at pleasure. The extract shafts which in winter are at the bottom, in summer are at the top or near the ceiling. In all seasons the fume closets and suction shafts of operating tables in the laboratory and elsewhere are evacuated by the descending shaft to which the fumes are led by the floor channels to the base of the chimney shaft.

* See Appendix A. † See Appendix B. ‡ See Appendix D.

good many years practically connected with the carrying out of sanitary work, and with sanitary science generally, I felt I could not refuse. Another matter that removed further hesitation was my anxiety to take advantage of the opportunity to state in this place the great debt of gratitude that I owe to many members of the architectural profession for the cordiality and courtesy with which they have met me in business matters. A great deal has been said lately, as you know, about architects. They have been told that they do not know their business, that they are ignorant of drainage, and that all the faults connected with houses (and goodness knows there are plenty of them) are to be laid at the door of architects; but I can safely say that I have never met any architect whom I did not find solicitous for the welfare of those who employed him. Mr. Robins has said at the end of his valuable Paper that civil architecture can never be divorced from the experience of sanitary science. I would go rather further even than that, and would say that if it were not for the experiments made by scientific men no alteration in principle would be carried out, not only in architecture but in almost anything else. If it had not been for the chemist Pasteur, for instance, all the vine-growers in the world would never have discovered the cause of the destruction of their vines; the fowl-keepers would never have discovered the reason for the loss of hundreds of thousands of their poultry; the prevention of the silkworm disease would have remained an unknown problem; and so it is in these matters. For a very long time we have been going on in a way with regard to the drainage of our houses, which has not been sufficient, which has been what is called "the bottling-up of the foul air system." That has been found not to be sufficient by practical experiment, but even after this we might have been content to go on for the next hundred years constructing sewers continually full of foul air if it had not been for some remarkable series of experiments that have been conducted by scientific men. What is it that has of late years caused anxiety? What is it that has caused us to think so much of sewer air? There is one reason and only one, and that is, that it has been shown by scientific experiment—by the experiments of sanitary science—that enteric or typhoid fever is produced by a constituent of that air. Since then it has been shown that other diseases are produced by that air. It is quite true that before this we knew in a general indefinite way that a bad state of health was caused by breathing bad air, but until it was found that there was a fatal disease called enteric fever—the existence of which we were not even aware of forty years ago—communicated largely by means of foul air, the public mind was not aroused to the necessity for its prevention. Nor was it aroused until one or two members of the Royal Family suffered from that disease. Another important series of experiments demonstrated the fact that the poison of this disease is not a gas, that it is not a vapour, but that it consists of particles. It seems most probable that these particles are living things—germs or spores; they are certainly organic and probably living. When we have got to know for certain that the poisons of this disease and of diptheria, a disease communicated in the same way, consist of particles suspended in the air, we begin to feel that we are not working so much in the dark. We begin to see how we can prevent those particles from getting into houses. We know perfectly well that those particles are contained in the air in the sewers. I understood Mr. Robins to say, at the commencement of his Paper, that a good deal of the modern practice of ventilation has been carried out for a considerable number of years, and I am bound to say I was very much astonished at that statement. Among the many hundreds—I was going to say thousands—of houses I have seen in London there is not a single one (except those in which the drainage has been carried out quite recently) that is a healthy house in so far as the sewerage arrangements are concerned. I do not hesitate to say that most distinctly. I was about to refer to two other sets of experiments, by means of which we have been able to devize this system of ventilation or disconnection of the housedrain from the main sewers. They have been these: one has shown that foul gases will pass through water, that on one side of the water in a trap theyare absorbed and on the other side given out,and that this process goes on continually,so that it is quite clear that if you have a water-trap in connection with pipes containing foul air, foul gases can go through the water. The other series of experiments are those of Dr. Frankland with regard to particles in foul air. He showed that when water containing foul matters, or any particulate matters, was distributed mechanically or by bubbles of gas given out by decomposition in the water, which is always the case when foul matters are contained in water, whether these particles were given out, by either of these methods, the particles were dispersed into the air above, and this became contaminated with them. These experiments show us what the water-trap will do and what it will not do. A water-trap will, to a very large extent, prevent particles, such as the poison of typhoid fever, from getting into a house, but it will not do so completely, because the particles may fall into the water on one side, and if the water is disturbed they may be thrown up into the air of the house on the other side. No water-trap will prevent foul gases getting into a house. Those are the results of scientific experiment, and I maintain without those results we should not be able to say that we can make a house perfectly secure from typhoid fever. We did not, I repeat, know of the existence of typhoid fever forty years ago. It was then separated from typhus fever by Dr. Stewart, a man now living, and we positively know more now about the ways in which it spreads, and how we can prevent it, than we do in the case of any other fever with which we are acquainted, smallpox alone excepted. We can put a house into the condition shown in one of the diagrams, and say with perfect certainty that if there is typhoid poison in the main sewer it will not get into the house, and with almost equal certainty that if typhoid fever is taken into that house it will not spread. It is not long ago since I was called to a large school where there was a case of typhoid fever, and where the sanitary arrangements had been carried out by one of our eminent specialists. My opinion was asked as to whether the fever would spread in that school. I looked at the sanitary arrangements and at the method of isolation adopted; I told them that in my opinion it would not spread, and that no other boys would get it unless they had already caught it, which did not appear likely. The authorities considered themselves justified on that report in not dispersing the school, and the result answered their expectations. That could not possibly have been the case five or six years ago—well say ten years ago, but I will not go a bit further back. It would have been impossible at that time to have said that this case of typhoid fever would not spread. I should like to say this also—to come to the carrying out of sanitary alterations—that although the principles by which these things are managed are perfectly simple, the putting of them in practice is almost infinite in its variety. It is one of the most difficult things one has to deal with, to go into an old house with pipes hidden in all sorts of extraordinary places, and wrongly arranged in the most perverse manner, and devize means by which that house can be put into an efficient sanitary condition without, I was going to say, pulling it down entirely, so that although the principles of sanitary science are perfectly simple the practice is in many cases very difficult indeed; and to tell a person, as I positively have heard persons told, to go and read a book about sanitary matters and then try and put their houses in order, or tell a builder how to do it, is just about as absurd as if a person were to study a book about the methods of cutting off a leg, and then go and try and cut off one of his friend's legs. One of the most amusing things that ever comes within my ken is to come across a house where the householder has tried to remedy the defects himself. I suppose everyone here will agree with that statement. I will just mention one very practical point, and it has come within my knowledge over and over again lately, that in houses which have been apparently put into excellent sanitary condition, with a ventilating manhole, valve closets with syphon traps, all the overflows disconnected, &c., &c.—in such houses it has happened that there have been outbreaks of sore throat, diarrhœa, &c. (not specific diseases) distinctly and definitely connected with foul air. There have been several causes for that, but the cause which I have found most universal is that one simple direction has been overlooked in carrying out these things, that is to say, it is not sufficient merely to disconnect the wastepipes of sinks and carry them through the walls to end over gratings—that is not sufficient. The wastepipes of sinks are not proper places for air of any kind to come through into houses, and if you do not put syphon traps upon the wastepipes of sinks (immediately under the sink), you will have sewer sore throat and diarrhœa produced in houses by the fact that during the night a large quantity of the air in these houses has come into them through the insides of foul sinkpipes.

E. R. ROBSON, F.S.A., *Fellow.*—Speaking of the sanitary conditions of a house, I am very sorry Mr. Robins has not entered into the question of the level of the water in the land and the methods of keeping a house free from damp, for I believe dryness to be one of the most essential points in all healthy houses. Following the question of drains, I am quite certain Professor Corfield is right in what he says, and I do not think he need go further back than six or seven years without coming to a time when all houses were built in a more or less insanitary manner, not perhaps perfectly dry, without air to the drains and without ventilation to the rooms. One defect—the worst of all—is that the cisterns which supply the closets are almost always found to supply also the drinking water of the house, and to have their standing wastes in direct communication with the sewers. In my own experience of houses where I have been called in, I have found that to be almost always the parent of the disorders which have occurred. Everyone knows that bad water is the first and most prolific cause of typhoid fever, and Professor Corfield will agree with me that, although bad air is a cause, bad or infected water is the more usual cause. The point as to trapping the pipes of sinks discharging into the open air, which Professor Corfield has raised, is quite a new one to me, for I have never known a wastepipe discharged from sinks into the open air to be the means of generating sewer gas. Leaving the question of closets and coming to that of warming and ventilation, my impression is that those terms mean sunshine and fresh air as nearly as we can get both artificially. It is very difficult to control the pressure of the atmosphere as Mr. Robins seems to suggest, and it appears to me that all we have to do is to follow natural laws in the main. Natural laws in our artificial warming and ventilation have certainly not been hitherto followed. The open fire no doubt is the most charming way of warming a room so far as appearance goes, but it has the great disadvantage of being necessarily placed where it is least wanted. It usually warms a wall which is already warm and not the window where the cooling surfaces are; and this is the usual artificial method of warming by the open fireplace. We should on the contrary put the heat where it is most wanted or most useful for checking draughts, and we ought to begin by making the halls and corridors thoroughly fresh and warm and full of fresh air—fresh air in the hall being the keynote to the warmth and fresh air of the whole house. I have, in connection with the London School Board, two schools both in process of erection, one being warmed by Boyd's Hygiastic Stove, and another on Leeds's American system, or low-pressure steam. When those schools are completed, I propose to communicate to the Institute some particulars and results of each method, so that Members may form their own conclusions. With regard to the use of any kind of steam, Members must remember the peculiar provisions of the Metropolitan Building Act, a most obsolete piece of legislation. In warming by the high pressure hot-water system, advantage is taken of an enactment intended only for low pressure, while in warming by steam there is no enactment except for high pressure steam, which is absurd. With regard to the use of the Tobin tubes it is perfectly true that they were suggested by Whitehurst in the last century, and indeed a copy of the book may be seen at the Patent Office, but Mr. Tobin has had the merit of drawing general attention to their great value. I do not agree with Mr. Robins in his size of the pipes or the position in placing them. My experience is that they may be made as large as 144 square inches and placed as far from the fire as you can get them, and that the trunks connected therewith (like all extract flues for foul air) should have as little horizontality as possible. Broad horizontal flues only create friction and destroy the effect you are desirous to produce. Another point on which I venture to differ from Mr. Robins is in relation to the inlets and outlets that air ought to have for ventilation. Unless you have an absolute exhaust for your outlets you must make your inlets considerably larger to produce the desired power, and you are always erring on the safe side if you err on that of fresh air. I differ from Mr. Robins also where he extols the air current passing from the lower to the upper part of the house. The dirty chambers below ground never will be clean, and the air proceeding through them, being vitiated at the outset, cannot be desirable for the upper rooms. The air you breathe, when produced by stoves placed in underground chambers, has the effect of making you languid and miserable. In a school heated from below ground I found in the course of an hour that the teachers complained of lassitude, fatigue and weariness. Therefore you come back to this, that unless you can apply your heat in a direct manner, just in the same way as sunshine heats the earth or the fireplace heats the room, you are wrong practically in all the results you want to produce. You must keep to direct radiation as a method of warming, which means that every radiating plan must be *in* the room and not in chambers below. I see some quotations from medical gentlemen who do not give us their formulas or their reasons, but they do give us their conclusions and their applications. I would rather that they would give us their formulas and so enable practical architects to apply them in their own manner. One gentleman talks of fresh air being admitted over hot pipes. Let us take a frosty day, one side of the pipe will be cold and another hot, and the consequence is that your pipe will very likely go to pieces. I think the air should never be admitted over the pipes. In conclusion I would venture to call attention to six books which would be of great value, at all events to the younger members of the profession. First there is Hood's *Practical Treatise on Warming Buildings by Hot-water,* *Steam and Hot-air; on Ventilation, &c.* (the only scientific work on the subject), then Parkes's *Manual of Practical Hygiene*, Buck on Hygiene, Leeds on Warming and Ventilation, Galton on Healthy Houses, and of the many works on plumbing and drainage that of Hellyer is the best.

Captain DOUGLAS GALTON, C.B., F.R.S., *Hon. Associate.*—I think I should like to add to the books which Mr. Robson has mentioned that of Box on Heat, a very valuable work. There is a point referred to by Mr. Robson which is I think quite as great a cause of disease in many houses perhaps as sewer gas, and that is ground air. There are a great many houses in London which have been built upon very impure materials. The builders have taken away the gravel and the sand, and have allowed the site to be filled in with rubbish; when the site has been made up again to the original level they have then built houses upon it, and those houses have been notoriously beds of fever for years and years. I think Dr. Corfield will bear me out there. [Professor CORFIELD.—Certainly.] Ground air in towns is also liable to various pollutions from the sewers, which, when of brick, allow of a considerable percolation of air. I think it very probable that many of the evils which have been suggested as arising from the system of warming by means of a reservoir of air in the basement arise from the ground air being drawn in through the walls and floor of the basement, because when the air is warmed, it naturally causes a great indraught, and the air is taken up into the upper part of the house. This evil is noticeable in towns especially, and the question of the ground air is one to which architects cannot pay sufficient attention. They should endeavour by every possible means to cut it off from the house, because whenever the house is warmed in the winter the air will be drawn up from the basement through the house, and thus all these impurities pass up into the upper part of the house. The Paper read by Mr. Robins is one covering such an enormous extent of ground that it is quite impossible thoroughly to deal with it in one debate, and I am sure we owe the greatest thanks to Mr. Robins for having brought the subject in such a comprehensive way before the Institute. I have recently visited America, and I took the opportunity of seeing what is being done there in some of the most important systems of sanitary architecture. The American architects seem in many cases to have a greater scope afforded to them than is to be found in this country. I visited a church and a theatre in New York, where certainly the arrangements for ventilation far surpassed anything that has ever been suggested here. Perhaps it was owing to the scope given to the architect and to the fact that money had not been stinted in any way, rather than to any greater talent. If, in England, he had equal opportunities I should hope for equally good results from an English architect. The church I allude to is a Presbyterian church of which Dr. Hall is the pastor. It contains 2,000 sittings and is of course arranged so as to enable people to hear well, and hence they are in close proximity to each other; and there the ventilation is partly by means of propulsion and partly by means of extraction. It is beyond the limits of to-night to describe the system, but I only wish to say that, as regards both this church and this theatre (the Maddison Square theatre), the ventilation in both is carried to far greater perfection than anything at present done in this country. I was also very much struck with the perfection to which they have carried their system of heating by means of steam. The steam has great advantages in the high temperature which you can give in a very cold climate like that of the winter of North America, but it also presents certain inconveniences. The advantage of the hot-water system over the steam is that you can regulate the temperature in your pipes to any extent you like, whereas with steam you have always the temperature of the steam; and although no doubt there has been a system adopted of working the steam at a low pressure rather the reverse of Perkins's system of hot-water, that is to say, you work the steam under the exhaust in order to keep it at a lower temperature, yet I do not think that that seems to be a very universal or successful arrangement. You always have in the arrangement with the hot-water a power by which you can regulate your temperature in your pipes to anything you like. In steam you must have a high temperature always, and it is very difficult to prevent the steam pipes from making noise, partly from the condensed water and partly from the sudden expansion of the pipes, &c. I think in this country, where we have no such great variations of temperature, it is better perhaps to adopt the hot-water system than to resort to the more economical system of steam heating. No doubt you can produce a greater result with a lower expenditure of fuel in one case than in the other when you have to do it on a large scale.

EWAN CHRISTIAN, *Vice-President.*—I can quite confirm one part of Captain Galton's remarks, for I attended the Church in New York, to which allusion has been made, one Sunday, when the external temperature was 76°, and I was never in a more pleasant place of worship; it was perfectly comfortable and thoroughly well ventilated. As to heating I saw, when at Detroit, the arrangements by which, for one set of engines placed by the river side, all the buildings within the radius of a mile were warmed by steam pipes to a temperature of 65° during a winter when the air outside was often 20° below zero; and not only were the houses, the stores, the churches, the theatres so warmed, but the lifts in the stores were worked by the surplus steam. It appeared to me to be a most admirable system for a country where the winter cold is excessive, but I do not think it would be suitable here. As regards house drainage, one thing has not been specially referred to, I mean Mr. Norman Shaw's system of soilpipes, and their disconnection from drains. I have myself tried it in a large house with complete success. The soilpipes are fixed on the outside of the house, and the air is allowed freely to pass through them from the bottom to the top, rendering traps unnecessary. I think it is an excellent arrangement. The information given by Professor Corfield, in connection with sinkpipes, is certainly new to me. I have for many years advocated the system of pipes from sinks discharging in the open on gratings outside, but have not found as a result of that system that the wastepipes have proved to be conductors of foul air into the house, when those pipes have been used without traps. I am inclined to get rid of traps where possible, excepting in the drains outside. There ought never to be a chance of foul air getting into a house from drains; every pipe should be disconnected, and all should be external. Then as to the passage of cold air through walls, much may be done to prevent this by the use of cavities; walls built hollow may be made perfectly strong by the use of courses of long and hard hollow bricks as bonders. Cavities, full of still air, are most valuable in equalizing temperature inside houses with external walls so constructed. [With reference to the question of cavities MR. CHRISTIAN showed a rough section of a wall six inches thick. It represented the external walls of a cottage which he built some years ago in a very exposed part of Surrey]. The walls of that cottage are of timber six inches thick;

on the outside there are boarding and tiling; on the inside there is plaster. In the middle there are perpendicular fillets fixed on the uprights, and on each side of the fillets rough lathing and plastering, so that you have in that space three distinct cavities. That little cottage happens to have been inhabited by more families than any house I have ever built, because it has been let winter and summer for a number of years, and almost every person who has inhabited it, has borne testimony to its comfort, its warmth and dryness, and this I believe to be due simply to those blankets of air between the inside and the outside. Such a structure is both warmer in winter and cooler in summer than if it were built of solid walling more than double the thickness. I believe this to be a matter of very considerable importance in the construction of houses. To return to the subject of drains and bad smells, and the way in which the latter will travel all through a large house. I had a curious illustration in the early part of the present year. The Archbishop of Canterbury told me that there were some mysterious smells in his house at Addington, and asked me to try and discover what was the matter. I accordingly went down, looked all round the house, and found them very bad in several places, some at long distances from soilpipes or sinks. The cause was, however, soon discovered. There was no smell in the basement; the servants had no complaints below, but all the family were persecuted above. I found that the main drain was carried right underneath the centre of the house, and the soilpipes of the closets were connected with it from within. I found also that, from an imperfect joint at the floor level, the foul air was rising from the drains, passing up by the side of the soilpipe inside the house, and as all the walls were battened, it traversed behind the plaster to every room in which a fire was lighted. The defect was quickly corrected by taking every pipe and drain out of the house, filling the place of the latter with concrete, and sweetening the rooms by pulling down the plaster and clearing out the foul air which had gathered behind and clung there. I have my own notions about warming and ventilating, and as regards houses I do not agree with a great many of the schemes which are constantly propounded, because I have never in my own experience found any one which, within a year, was not got rid of. The generality of people will not tolerate ventilation openings in rooms. If there is a chance left of seeing a hole and the possibility of a draught from it, you may be sure that it will be stopped up; a duster, or something like it, will be stuffed into it, and all your science goes for nothing. The oldfashioned plan of opened windows and good fires in the grates is after all one of the best things to depend upon in our dwellings.

Captain DOUGLAS GALTON, C.B., F.R.S., *Hon. Associate.*—I should like to give one instance in corroboration of Professor Corfield's remark, that wastepipes from sinks delivering in the open air are liable to be foul. At University College Hospital there were a series of tanks for the purpose of providing fresh water in case of fire; nothing else but the overflow from those tanks passed through the wastepipe, and yet after two or three years those wastepipes became so offensive, although they delivered directly into the open air, that we had to provide traps to prevent the smell coming into the hospital. Yet there was nothing in them but the water which was delivered from the London water companies.

Mr. J. G. SYMONS, F.R.S., President of the Meteorological Society.—With respect to the last remark, I should like to ask whether they examined those pipes to see whether a rat had got into them. [Captain GALTON.—A rat could not have got into them.] Nevertheless, rats do very often get into such pipes, and we all know how fond they are of going after water. With respect to the list of books named I should like to add the Parliamentary Blue Book on Warming and Ventilation of Buildings (ordered to be printed August 25, 1857). It recounts the experiments tried at the old Board of Health on Richmond Terrace. With respect to the condemnations Dr. Corfield passed on the houses built up to the present time, there is one little thing to be thought of—we must not blame our ancestors. They acted up to their lights. It is simply that we have discovered better ways. The old ones are bad as compared with ours, but not bad as compared with the knowledge at that time. We have found out many things, and perhaps are going to live to a patriarchal age, but do we not proceed the wrong way to work? We first make the foul sewer air, and then discover means by which we may get rid of it. Perhaps we should be more clever if we did not make it at all. The blame must not be too much attached to architects on account of the old houses. Builders and not architects are responsible for a large proportion of them; and this leads to a suggestion I should like to throw out before the architects, which is whether it would not be possible to have some inferior order of architects?—if I may speak of such a being as an inferior architect. Take a case in point. I wanted to build a little office at the bottom of my garden. I was perfectly afraid to go to any of my architectural friends, for there would, I feared, have been a dreadful bill of fees. If I could have got advice cheaply I would have taken it, but I took counsel with a builder, and we stuck up something. Might not an architect have done a great deal better? and I am not at all clear whether I should not have saved money—perhaps I should. However, there is no doubt that as a rule an architect is looked upon as a very lofty and exalted being, who is rather beyond the run of ordinary mortals; and in consequence miles and miles of *things*—I won't call them houses—are run up, for which builders, not architects, are responsible, and which we must hope will not tumble down before the end of the time for which the leases are granted. With respect to the ventilation of large public buildings, Captain Galton is such a traveller, that he perhaps knows all about, and could better describe than I can, a plan adopted in Edinburgh. There is a firm in Glasgow (Pennycook by name), the head of which I on one occasion met; and he told me he was ventilating a room in Edinburgh, which was to seat about 3,000 people, and that he had done it upon a plan which to me was novel. It was that of having in the roof two large vessels, very much like two gasometers balanced over a couple of pulleys, and worked by machinery, so that one rose as the other fell. There were a series of valves, and directly the double gasometers were set in motion they were opened, and the effect was this: the air from the room was drawn into the one in order to fill the vacuum caused by its ascent. Then the motion became reversed, and the foul air taken from the top of the room was discharged into the open air. I do not know whether that plan is generally known to the Members of this Institute. It is independent of all questions of pressure and temperature; the weight of the vessels being balanced, you have simply to provide the motive power.

Professor AYRTON.—It occurs to me that one reason why science has not been more applied, in this new subject of sanitation, is because from habit we have come to regard disease as a natural state of things, like the common diseases of children for example, which every mother considers her child must have sooner or later; and better she thinks in early life than when the child has grown up. But that disease is, as I venture to think, unnatural, and a result of our want of knowledge of scientific principles, does not enter her head. Consequently I think we must not trust too much to our sensations of what is unpleasant and unhealthy. May there not be much in a large town like London of a most unhealthy character, but to which we have become habituated, and therefore which escapes notice? This idea must especially suggest itself to one who, like myself, has travelled much. In Japan for example the people warm themselves with charcoal braziers without chimneys, and which therefore, in spite of the rooms being fairly open, pollute the air with a considerable percentage of carbonic acid gas and with carbonic oxide. But the Japanese from habit do not regard this atmosphere, in which an Englishman cannot live, as unpleasant, nevertheless the Japanese are by no means a healthy people in spite of their glorious climate. Again in America an Englishman finds the warming arrangements, whether it be the cast-iron or wrought-iron stove, the latter of which, when at a high temperature, is known to be porous to carbonic acid gas, very disagreeable. The American does not however notice anything unpleasant, but I would ask are the Americans a particularly healthy people? And may not the Englishmen of the future make some such remarks about our homes of to-day and talk about our unhealthy arrangements, to which like large doses of opium we had grown accustomed? With reference to the question of warming, it seems to me that just as at last we are beginning to imitate the sun for lighting, by using a few very bright electric lights to light up a large space, so in time we shall come to imitate the sun in warming our houses. As explained by Mr. Robins, the sun warms the earth by radiated heat, not by directly warming the air. So does an ordinary open fire-place warm a room. A room full of hot air is intensely unpleasant, the sensation after a sharp walk on a sunshiny frosty day intensely agreeable; we must therefore, I think, consider in what way our houses can be warmed by *radiated* heat in a more economic manner than at present. And the problem must not be regarded as an impossible one, because the solution does not immediately suggest itself to every one; twenty years ago it would not have been right to conclude that the artificial lighting of a large space by a single light could never be economically carried out.

Lt.-Colonel LENOX PRENDERGAST, *Hon. Associate.*—I think the attendance here to-night sufficiently shows the vast importance of the questions we have come to discuss, I hope that this matter will be taken up on another occasion, for we have two distinct matters before us—one Drainage, the other Ventilation and Warming, each of which is quite sufficient for a night's discussion. One or two things have been mentioned to which I cannot help alluding, and I am led to do so because nearly all those who touch the questions of warming and ventilation are very apt to forget the persons who are going to live in the rooms; moreover, there are often two or three sets of persons engaged at work on the arrangements of the same building. It is only a few days since that I happened to be going through the men's rooms in the new barracks at Knightsbridge, and I found this condition of things, in rooms warmed by that admirable grate of Captain Galton's: the rooms themselves were so intolerably cold that the wretched men were shivering, though three blankets had been given to them. All this has happened because you there have the doctors and the engineers to deal with, besides the architect and Captain Galton's grate! The doctors insist upon having the windows of a barrack at both sides of the room; but in the name of Fortune why are these windows to be as low down as three feet from the floor, so that the wind blows in upon the men in their beds? Why is the wall to be made of brick and nothing else?—seeing the extent that wind passes through bare bricks. The result therefore is, in this case, that every extraction opening is closed! Such a failure appears to me to be worthy the attention of such an audience as this, and we should be able to put forward some formula by which these cross purposes between architects, doctors and engineers may be avoided. I venture to think there is another point in connection with ventilation which will be quite worthy of discussion, and that is the smaller matter of the houses in which we ordinary people live. There is a good deal said about churches, schools and hospitals, but it would be well to recollect that in this town we have a population larger than the whole of Scotland, and that we who live here are occupying houses which we did not build for ourselves. If these terrible stories, which we have been hearing, about bad drainage and ventilation are only partially true, the subject, I venture to think, is worth the attention of this Institute; we should devize, or at any rate discuss, the means by which existing dwelling houses may be made somewhat more in accordance with the principles laid down here to-night. I may mention that I made a small attempt in this direction some twelve years ago in my own house. We are all aware that it is difficult in houses with ornamental stone facings to cut openings for the admission of fresh air for ventilation, but I was anxious to supply air to a number of grates. I therefore built a tunnel under the whole length of the house, and utilized what are called "sweep flues," diverting them from their original purpose, to admit the air to some of the grates which were made for me with terracotta chambers. The air, being sifted at the mouth of the tunnel through strainers of paper-stainers' canvas, which go periodically to the wash, is not warmed in the tunnel, but passes direct to the heated terra-cotta chambers, and the atmosphere of the rooms so heated shows this plan to be a complete success. The foul air is extracted by its own chimney, for unless you have a chimney that does nothing else but extract the foul air of a room you are sure to fail; at any rate such is my experience. We must have the greatest simplicity in any arrangements that may be proposed in connection with sanitary science applied to existing houses, otherwise the tide of improvement in this direction will be thrown back. The public are already getting alarmed at the wholesale uprooting of everything required of them, involving the most serious expense, directly the drain doctor makes his appearance.

ADJOURNED DISCUSSION.

[Held on Monday, 17th January, 1881, John Whichcord, F.S.A., *President*, in the Chair.]

Professor T. HAYTER LEWIS, F.S.A., *Vice-President.*—Having moved the adjournment of the debate, it is my duty to offer a few observations upon the Paper, and in order to have the Discussion as exhaustive as possible, I venture to treat the subject in a somewhat different manner from that in which it has been already treated. I will assume that we have a town which, in regard of sanitary requirements as hitherto laid down (and in which I entirely agree), is perfect, namely:—1. That the soil and other offensive pipes are ventilated; 2. that the admission of foul air from the sewers into the housedrains is prevented; 3. that the sewers themselves have their foul gases carried off by ventilating openings; 4. that the storm waters are carried off by separate drainage; 5. that the smoke nuisance is altogether abated; and, 6. that the foul contents of the sewers are returned to the land in place of being hurried away from it to poison our rivers. Then, to take our own city as an example, we should have the following results. There are, I believe, about 550,000 houses in London, and allowing a due proportion of outlets for the soilpipes, drains and sewers, we may reckon, fairly well, upon having about a million and a half to two millions of pipes discharging their delightful contents into the air. I say nothing as to the æsthetic appearance of these pipes. They must be prominent, and yet one would scarcely suggest that they should be treated artistically, in such a way as would show their office. Anyhow, they must be dealt with, as all must agree that their presence is necessary, but I fancy that they would have an aspect not much more agreeable than that of those chimney-pots the appearance of which, at a recent Meeting of the Society of Arts, was eloquently dwelt upon by Dr. Alfred Carpenter. Now I cordially agree as to the necessity of this ventilation, but I wish in all seriousness to realize what the effects of the perfect ventilation would be. By the absence of the storm water, the contents of the sewers would lose the benefit of its oxygenating power and be still more foul than now, and however agreeable the absence of fog might be, we should be deprived by it (as Dr. Alfred Carpenter describes) of the carbon and sulphurous acid in the atmosphere, which are at present a part protection against the emanations from the sewers. I am of course quite aware that the air does usually rapidly oxygenate and purify these emanations; but it will, I think, scarcely be denied that, under some conditions of the atmosphere, the pouring into it continually of foul air and germs of disease from 1½ millions of foul air pipes would make it an unlikely kind of air for anyone to breathe: and yet this is the air which we *must* breathe. Now, this being the case, it seems to me that we ought to put before our engineering fellow-workers the necessity of aiding us by endeavouring to destroy in the sewers those foul gases which invade our houses or pollute the air. I will not venture to suggest a mode, but I am sure that this is not beyond their skill, and the method which General Scott has brought into notice appears to be, so far at least, a step in the right direction. In close connection with our subject come the system of earth-closets and ash-closets, the Rochdale system of pails, and other kindred systems; though they would probably lead into too wide a discussion to be attempted now.

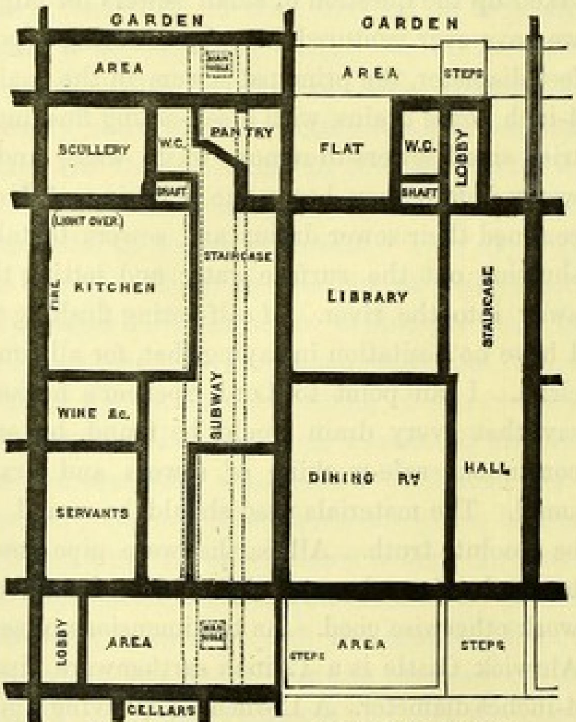
Major-General H. Y. D. SCOTT, C.B.—I think that whether we adopt the so-called "separate system" (the only one which can be advocated upon sanitary grounds) or are contented to put up with the ordinary type of large sewers, rendered necessary to carry off a considerable proportion of the rainfall and the subsoil water mixed with the liquid refuse from our dwellings, we must in either case run the risk of the generation of large quantities of sewer gas in the elongated cesspools which serve to convey away the polluted waters to the outfall. In the small sealed mains or iron pipe-drains which are employed in the ingenious pneumatic system, named after its inventor Mr. Shone, the danger from noxious gases is reduced to a minimum, and many of the worst defects of the water carriage system are, from the sanitary point of view, done away with. Even, however, under Mr. Shone's system, which may be regarded as perhaps the most perfect plan yet proposed of carrying out the "separate system," it is impossible to obviate entirely the evils of the gravitating sewers, as it is still necessary to provide large shallow-laid drains to take away the surface water, and under certain conditions it is well known that the drainage from courts and roadways is a far from pure and clean liquid. We may take it for granted, then, that under the water-carriage system, however it may be practised, it is impossible to obtain entire immunity from sewer gases and deleterious emanations; but it will no doubt readily be conceded that any plan by which the foul liquid can be deodorized, and the quantity of noxious gases reduced, is worthy of consideration. When the plan which is proposed for the accomplishment of this object has the further advantage of causing little additional expense, and has the effect of preserving the sewers to a marked extent from the slimy and adhesive growth or incrustration arising from the glutinous nature of the fœcal matters, and of preventing deposits on the bottoms and sides of the sewers caused by these incrustations, no one will deny the material benefit which would accrue from the adoption of such a scheme. Briefly, my proposal is to introduce the precipitants used to clarify the sewage, at or near the summit levels of the sewers, in the centre of the town, so that the sewage, in its passage through the town to the outfall, may become thoroughly mixed and incorporated with the chemicals, instead of receiving the necessary admixture of the precipitating materials at points remote from the town, at or near the outfall, as is at present usually the case. I assume that, for the purpose of dealing with the sewage, lime or some other cheap re-agent is to be added at the sewage works. All the change entailed by my plan is the introduction of the lime at several points in lieu of at one spot, and the contrivance of some simple plan of automatically apportioning the precipitant to the volume of sewage water to be dealt with. It may be thought that this plan might be liable to occasion a certain amount of deposit of the lime precipitate in the sewers, and it will occur to some that certain noxious gases would be set free by the lime; but the simple answer to such objections is that the plan was tried for several months at Ealing during the hottest months of the year without any evil effects. Not only was the smell from the drains greatly diminished, but the curdling action of the lime scoured and cleansed the sides of the sewers to such an extent that the scavengers stated they had never seen them so free from deposit. The action of the lime would obviously be to lock up the carbonic acid, which materially increases the tendency of the sewer gases to escape, and the sulphuretted hydrogen, which is one of the most active gases in causing the bad smells from the drains. The small volume of ammonia which would be liberated by the lime would be of trifling importance. The evidence of the officers at Ealing, under whose superintendence the above trials were conducted, was that the smell from the manholes and untrapped gulley-holes was greatly diminished; and the deposit and incrustations in the sewers totally disappeared under this mode of treatment. The plan adopted at Ealing was the introduction of the requisite quantity of milk of lime into a sewer in the upper part of the town. This lime became mixed with the sewage in its passage down to the outfall and effected a very perfect and thorough precipitation, producing, as already seen, a great amelioration in the condition of the sewers.

MR. ROGERS FIELD, B.A., M.Inst.C.E.—I will confine myself almost entirely to the question raised by Professor Lewis, which seems to me of the greatest possible importance. In fact, it goes absolutely to the root of sanitation. If I understand his question it comes to this: If you have all your sewers and housedrains thoroughly ventilated, you will have a million and a half of ventilating pipes in London emitting foul emanations and poisoning the air, and he asks is this to be the be-all and end-all of sanitary science, or ought we not rather to find some means of destroying the foul gases in the sewers? Now I entirely agree with Professor Lewis that some means of preventing the emanations ought to be found, and I think a little careful consideration of the question will show that it is perfectly easy to prevent them. What do they come from? Foul gases arise from the decomposition of organic matter. Wherever organic matter is allowed to rest so that it decomposes, there you will get foul gases. If this is true (and I believe every one admits that it is) all that has to be done to prevent any considerable accumulation of foul gases is to ensure the immediate and complete removal of all foul matter immediately it is produced, so that there may be no time for it to decompose. That is to say, that you must so arrange all your drains and sewers that everything is washed away immediately. Now this proposition is so extremely simple that there is great danger of its paramount importance being overlooked, yet if you consider it a little in detail I believe you will find it goes to the root of the whole matter. First of all, there is the question of the public sewers, and as this is more of an engineering question I will not further allude to it than to say, that if sewers are properly constructed, properly flushed and thoroughly ventilated, you will have practically no smell from them—no appreciable smell. Where you get the smell is where the sewers do not carry the foul matter away, where it remains, and where it decomposes. It is, however, a great mistake to imagine that foul emanations (which unfortunately do exist, and which are generally called sewer air and sewer gas) come exclusively or principally from sewers. They come quite as much from defective housedrains. I have had in my practice very striking instances where foul smells have arisen from ventilators and sewers which were attributed to the defects in sewers, but which on investigation were found solely and only due to defective housedrains, and which were cured directly those defects in the housedrains were remedied. It seems, moreover, to be generally agreed that in a well-designed system of house drainage there should always be a system of cutting off the housedrains from the sewers, so that the air from the sewers should not get into the housedrains. All you have to do, therefore, is to deal with the housedrains themselves, and if you can make these so as not to retain deposit you have got over the difficulty of the foul emanations. Now this is perfectly practicable, though I cannot say it is easy, as there are a great many points to be attended to. Housedrains and all the arrangements connected with them must be made *self-cleansing*, and this can only be effected by very careful attention to all the details. In order to make the drains self-cleansing they must be of a proper size, have sufficient fall, and be truly laid. It is a mistake to make drains too large, because small drains are often the most effective. Some years ago I was asked to advise respecting the drainage of a large house at the West End, where there had been a death from diptheria. The drains had been laid by an eminent builder not long before. They were 9-inch drains and they had a 9-inch syphon trap between them and the sewer; this was completely choked with foul matter and the sewage all blocked back. I recommended the alteration necessary, but it was not convenient to have the work done immediately. I had the drains for the time being thoroughly cleaned out, and some weeks later the house was handed over for the alteration. I then opened the drains and found that the 9-inch syphon was as nearly as possible blocked again. I took the drainage up and (as there was a good fall) for the 9-inch syphon I substituted a 4-inch syphon, and for the 9-inch drains I substituted 4-inch drains, and from that day to this there has never been any trouble. The syphon has kept free and the drain too. Of course I do not mean to imply by this that 4-inch drains should always be used. There are, however, very few cases indeed in which it is advisable to use 9-inch. Now as to the fall, no hard and fast line can be laid down; but I may say that the fall, which seems such a favourite one with the builder, and is even sanctioned by some architects, of 1½ in 10 feet is, as far as my experience goes, quite insufficient: you ought to have at least double and if possible more. Of course I am speaking of drains under ordinary circumstances. If self-acting means of daily flushing are adopted, the inclinations of the drains may be greatly reduced. I have often laid 6-inch drains at a fall of 1 in 100 and 1 in 200, and at the present time I am laying a 9-inch drain in a large mansion in the country with a fall of 1 in 330, flushed by one of my self-acting syphons. Last but not least, then, is the question of laying the drains, and the important point is that the drain should be truly laid, both as regards line and level. This is not at all as simple as is generally supposed; if the drains are laid in curves, as is so often done, it is almost impossible to insure their being truly laid. The only way to ensure accurate work is to lay them in the manner pointed out by Mr. Robert Rawlinson, namely, in straight lines from point to point; it is then easy to lay the drains truly, and the least error in line or level can at once be detected and remedied. This system has the further immense advantage that, by providing manholes and inspection chambers at proper points, the drains can be examined, and if necessary cleansed at any time without breaking into them. This question of providing ready means of access to the drains, without having to break into them, appears to me to be one of the greatest importance, and to be too often overlooked; the drains must also of course be made water-tight, and they should be actually tested to see that they are so. It is not however sufficient to deal with the drains, for if you neglect the apparatus all your labour will be in vain. The water-closet apparatus must be self-cleansing, that is, the flush must carry everything away. If foul matter remains, then decomposition is a sure result. There are many kinds of traps that will always retain foul matter: the D-traps, which are unfortunately in such common use, are terrible offenders. I will give an instance which occurred in my practice years ago: I had made openings at the foot of a soilpipe, and there was very little smell in the drain, I then had the closets removed and some water poured down the branches of the closets to test what the condition of the soilpipe was, and the smell was abominable; we had to run away from it. I repeated the experiment several times with the same result, and came to the conclusion that the soilpipe was very foul and must be removed. Before doing this, however, I had the D-traps removed which were attached to the branches, and the water then poured down the branches, when to my surprise there was absolutely no smell, showing positively that the smell was simply and solely due to these D-traps. If you had adopted any of the modern methods of disconnection without removing the D-traps you would have had that abominable smell at the disconnection opening every time the closets were used. The pan-closets are also so constructed that they cannot flush themselves ; the defects of pan-closets and D-traps are now recognized by all the best authorities. These closets and traps are forbidden by the Model Bye-Laws of the Local Government Board. In the United States they are paying great attention to that question; at Memphis, which has lately been so successfully sewered by Colonel Waring, pan-closets and D-traps are forbidden; the plumbers laid in a large stock of them but the authorities made them take them all away. There are a number of other closets which retain foul matter, in fact any closet which has not a proper flush will do so; the difficulty now is that there are such an immense number of contrivances, that it is difficult to say what is good or what is bad. I think the Sanitary Institute of Great Britain is doing good service in this way, because at its annual exhibitions it will give no prizes to water-closets and similar apparatus without actual trial: architects will do well, therefore, to look up the closets which have received prizes from the Sanitary Institute. From what has been stated it will be seen that to make the whole of the drainage arrangements self-cleansing requires skilful design and careful attention to details, but it is well worth spending time and trouble on, as the result is that foul gases are no longer generated and the ventilating pipes no longer send forth foul emanations. So true is this that by smelling at a ventilating pipe one can generally tell whether the drainage is good or bad, a bad smell from the pipe being a sure indication of some defect in the drainage. This I believe to be the real solution of Professor Lewis's problem. I should like to confirm what Professor Corfield said, that if drainage is carried out according to modern sanitary principles you can prevent typhoid fever from spreading in a house. In addition to the case he quoted (the details of which I know, as the school was drained under my superintendence) I could give you another—a Collegiate Institute, in which typhoid fever was introduced from outside, but did not spread. In both these cases the drains were very freely ventilated, and many of the ventilating openings were on the ground level. I cannot agree with Mr. Robins that the principles now insisted upon by sanitary science were carried out by architects many years ago. It seems to me that the open air disconnection of all soil and wastepipes was a new point of departure. When I commenced that, five or six years ago, there were all sorts of practical objections, the chief of them being that the open disconnection would create an abominable nuisance and would block up with frost. The nuisance question has been settled, as it is now proved beyond doubt that there is no nuisance if the disconnection is properly carried out. The freezing question can only be determined by experience. In 1878-9, the most severe winter we had had for 40 years, I recorded my observations on considerably more than 100 open soilpipes and disconnections, in a letter sent to the *Builder* (March 1st, 1879). From this it will be seen that in only one case was there any trouble from frost. Mr. Norman Shaw gave his experience in a letter to the *Builder* (Feb. 15, 1879). Mr. Eassie gave his in the *Sanitary Record*, and Mr. Buchan has recently given his with reference to his open disconnecting trap, of which large numbers have been fixed. The whole of this evidence was to the same effect as mine, and I think therefore we may conclude that open soilpipes and disconnections, if properly carried out, will not suffer from frost in this climate, unless placed under very unfavourable or exceptional conditions.

Mr. J. WALLACE PEGGS, Assoc.-M. Inst. C.E.—The general principles involved in house drainage are very simple, and when once we have mastered these the special details of each case will easily be worked out. The great point to attend to is that all drains shall be self-cleansing and not drains of deposit. This is effected by giving proper gradients to your drains and making them the proper size—not too large—as the former practice has been. In our older towns and cities where we had "sewers of deposit," it was very essential to block off a house entirely from the sewer system, and this was achieved by open-air disconnection of all drains and by placing a trap on the housedrain between the house and the public sewer. In a well devized system of house drainage and public sewerage there should be a continuous flow from the house to the outfall of the sewerage system; namely the drainage from a house should never be allowed to rest at any point, but deliver at the outfall in a few hours after leaving the house. The great point of departure in house drainage was when the soilpipe was disconnected. The disconnection of sinks and bath wastes was of course practised many years ago, but the soilpipe disconnection has only been adopted within the last few years. Professor James Thompson as early as 1866 disconnected the soilpipe of his own house by delivering it over a stoneware gully. The open-air disconnection with ventilation of soilpipe was very early dealt with by Mr. Rogers Field, and he has given us the beautiful arrangement of the disconnecting manhole. By this arrangement you have perfect control of your housedrains ranging forwards to the public sewers and backwards through the house, so that any stoppage is at once dealt with without the expense of breaking open the ground.

Mr. ROBERT RAWLINSON, C.B.—Before making some general remarks I beg to state briefly that I think, with regard to modern drainage, I can claim some credit for the systems that are being adopted at present, namely, small drains laid in direct lines with manholes or lamp-holes at changes of line and gradient. This mode of working was introduced about 1850 by Mr. Hugh McKie, one of the most intelligent assistants I ever had. I made the first drawing of the moveable manhole cover. These covers were first made in Lancaster and have been generally adopted. It has been said by one of our most eminent civil engineers, the late Robert Stephenson, that for any man to know his mistakes is the readiest way to correct them, and with the permission of the Chairman I will mention a few mistakes in housedrains that have come within my own observation. For instance it has been customary, and it may be so now for anything that I know to the contrary, for large houses to have drains laid within the basements. I can refer to a house that has been built within the last half-dozen years in which there was a drain and a bell-trap in every cellar throughout the basement, and the main drain outside had cesspools along its line, to intercept and retain the effete matter that came away from the water-closets. On this outlet sewer there was no provision for ventilation, the consequence being that the house, although it was new, upon occupying, became unfit to live in. This is an example of one form of mistake. The remedy for that state of things was to have the drains in the basement pulled up, and the bell-traps removed. Those drains it was not convenient to pull up were filled solidly up with cement concrete. All the sinks, and places where water had to be passed away from the building, were carried to outside walls. The main sewer was stopped short outside the walls and there ventilated, the pipes from sink were passed through the wall to empty over receiver on outside drains. Of course all the cesspits were emptied and filled up with cement concrete, and ventilators were put on manholes, so as to permit the gases to escape to the open air. Another case, Dunrobin Castle, the seat of His Grace the Duke of Sutherland: the castle stands on a beautiful site overlooking the sea; it is drained, and some of the drains run through the buildings. It is, I think, four years ago (it was in the autumn) the Duke requested me to go down. I went, and found that some of the water-closets within the castle had been closed and papered up. They had had the house full of company part of the autumn and the stench had proved so intolerable that many of their guests left. On examination I found that the main outlet drain from the castle to the sea had a good fall, but that this sewer, as in the other cases, had deep cesspits along it, and over each cesspit was a shaft up to the surface, which the clerk of the works had, during the summer, most carefully covered and sealed up with cement, so that the foul gases which had partially escaped before were closed up and had then no outlet but to and through the drains, sinks and water-closets connected with them, which made the place simply unbearable. After I found this state of things I had every one of those cesspits uncovered (at first I had not time to cause them to be emptied), and told the housekeeper to unpaper every closet, leave the windows closed and then to go into every closet in the house at midnight and tell me in the morning what she found. Well, in the morning she said, "I have been into the closets and they are every one as sweet as possible." I then took his Grace and showed him the openings in the line of sewer, where all the tops were off, and explained that as the sewer gas could not get readily out into the open air, it consequently had to go into the castle. The remedy, I explained, consisted in having the cesspools emptied, filled up with concrete, and permanent ventilators put over every shaft where it came to the surface. The main sewer of the castle was continued to a considerable distance beyond where a ventilating shaft was placed in the plantation in the open air so that no gas could remain in that sewer. The closet soilpipes were also ventilated and some other little things done, and from that day to this there has not been any further complaint made to me, and I do not suppose that the alterations cost his Grace more than £150. I will now draw attention to what ought to be the condition of houses and drains where you have to begin at the beginning. I have come to this conclusion, namely, that it is not necessary to have sewers and drains within houses, however large the building may be. If you have a building to design as large as the building which I am now in at Whitehall, it need not have one single sewer or drain beneath it. I say deliberately that it is not necessary, if the architect takes thought beforehand, to have sewers or drains within the four walls of any building however large it may be; and he should also see that all his gutters, and his roofs and everything connected with them, are arranged in such a manner that he can get his outlets where it is not necessary to put his drains within his basement. Then there is another rule, which both the engineer and the architect should bear in mind from the beginning: it is, that no portion of his work should ever be done in a way that it is beyond his reach for examination and repairs, or that he has something serious to pull to pieces for repairs. He should so plan, arrange and construct, that he or his successor will be master of the position, and, as Mr. Rogers Field has told you, without disturbing a single brick. This is possible and quite easy upon sewers and housedrains which have been laid in right lines, and have the other arrangements already referred to. You can then examine what a sewer and drain is doing, by having moveable manhole covers. A correct record of all branches and junctions of sewers and drains should be made and preserved, and thus you will remain master of the position. With regard to the ventilation of sewers, the letter that was read only shows how dangerous a little knowledge is. London is held up as an example of defective sewer ventilation, but if London is an example in one way let it be taken all round. It is an example, a marvellous example, of the largest aggregated population in the world enjoying the best health, but it is by no means perfect in its sewerage. There are many miles of sewers just as bad as they can be, and the most difficult and worst sewered part is in the west—that is, Belgravia. The sewers there have upright sides, flat bottoms, and they retain deposit. The main sewer that comes out of Marlborough House is about the worst of them, and was, and probably now is, swarming with sewer rats, and the grit deposit never comes out of it, except when severely flushed or removed by hand labour. Now that state of things is not necessary, even on a flat surface, as the inverts may be improved and self-acting flushing tanks of adequate capacity may be provided; and if London is not sooner or later dealt with by a system of regular self-acting flushing, the main drainage may prove (some scorching dry summer) to be a curse instead of a blessing, because it will carry away that volume of water which would have diluted the deposit and rendered it comparatively innocuous. It is possible by self-acting tanks to establish a system of automatic flushing. The volume of water required would not be anything very serious after all, because 1,000 gallons would flush the largest housedrain in London. Now with regard to emanations. These, as Mr. Rogers Field has told you, are due to the corrupting of the deposit retained in badly formed sewers that do not evenly and regularly deliver the sewage, but either allow the fluid to soak away and leave the solid matter to accumulate, or the sewers are too wide or too irregular to admit of the volume of water poured in carrying the crude sewage away; but, with all that, and bad as they are (and Professor Corfield will correct me if I am going to say anything wrong), the air in these large sewers is singularly free from taint. I remember the British Association meeting at Liverpool, where a chemist said that the air in every main sewer in London which he had tested he found purer than in the room that he was then speaking in to the section; in consequence of the abundant open street ventilation. That mode of open street ventilation is nevertheless constantly being denounced by persons who do not understand it. They say that the openings stink. Well, no doubt some of them do, when they are too few and imperfect, but do away with them and what will become of London? When sewer ventilators stink in the open air, as they do, it is a minimum evil. I admit that they should not stink, but it is a thousand times better than that you should seal them up. At the beginning of the century when sewers began to be made in London generally and water-closets were introduced and the sewers were totally unventilated, they became so foul that men who went in to cleanse them were killed as if they had had a dose of prussic acid; typhoid fever broke out in the houses situated in the streets that were drained and connected with the unventilated sewer. To avoid these risks from water-closets, drains and sewers, in the future, Acts of Parliament were passed for preventing housedrains that had water-closets being connected with the sewers. Hence came the construction all over London of cesspools which you find now in the basement of old and especially of large houses. In Gwydyr House, Whitehall, appropriated for the first general Board of Health in 1848, they found nine cesspools all full. Any large London house that is a century old will generally be found to have cesspits on the premises, because the Acts of Parliament in that period forbade the communication of water-closets with the sewer. In 1844 even Windsor Castle had 53 cesspools, within or upon the premises, all full and overflowing. Now, the first regulation in any town is that the sewer shall receive and remove the contents of all water-closets. I am not going to argue whether closets are in all cases preferable to the dry-earth system or the wet-earth, that is, tub system. Anybody has my consent to use such apparatus. But the best are only half measures. Imagine London turned into a dry-earth system or moveable pail system, and see what would be the consequence. Each house would have one or more small moveable cesspits within it. The householder would be tied to an external agency to remove it, and wait till that agency took the excreta away, and there would be not only the materials to remove but the weight of the apparatus backwarks and forwards. At Rochdale the pail system is carried to the greatest perfection, and the Town Clerk and Surveyor inform me that the money loss to the Rochdale people is from £10,000 to £12,000 per annum, although they were getting from £3 to £4 per ton for the manure they manufacture. We are found fault with, when towns are on the sea shore, for throwing crude sewage into the sea, and as true political economists this will be the proper mode if it is to cost thirty shillings for a sovereign to be returned. At Edinburgh, on one side of the city suburbs, the Craigintenne Meadows, sewage is used in irrigation, bringing in large money returns, but on another side, from the Water of Leith, an equal volume of sewage is, at a first cost of about £80,000, sent by a cast-iron outlet to sea. System of sewering on the modern principle is an economical principle, because instead of laying down sewers at £2, £3 and £4 per lineal yard, you can lay them down at shillings per lineal yard, which will take the sewerage, and the cheaper sewers will be the best. The Americans have taken up the question of small sewers for large populations, and have carried it further than we have ever ventured here, by sewering a population of 40,000 with an outlet sewer of two feet diameter, the principal sewers in the main streets having 9-inch and 6-inch sewers and 4-inch house drains, with a self-acting flushing tank at the head of each block of houses. They tried small sewers to remove waste water and excreta from houses, shutting out all surface water, before they began the sewering of Memphis, and found it answer. As stated, they confined their sewer drains and sewers to taking household waste water and excreta alone, shutting out the surface water and letting that go off the surface, taking the crude sewage away into the river. If self-acting flushing tanks are judiciously placed and regularly used, I have no hesitation in saying that, for all time after, those sewers and drains will be preserved clean. I can point to Lord Spencer's house in St. James's Place, and I can undertake to say that every drain would be found, by anyone inspecting it, to be clean. To secure the continuous safe-working of sewers and drains, the cross sectional dimensions should be small. The materials used should be sound, and in form, lines and gradients, there should be absolute truth. All earthenware pipe sewers and drains should joint evenly and should be made air and water-tight. One defective joint may cause much mischief and discredit work otherwise good. As to dimensions of sewers and drains for large houses, the outlet from Alnwick Castle is a 12-inch earthenware pipe having six branches of 9-inches, 6-inches and 4-inches diameter. A 12-inch pipe, having a good fall, will deliver 200,000 gallons in eight hours.

PROFESSOR KERR, *Fellow.*—It is very plain that engineers have provided us outside our houses with a most pestiferous system of sewers; and whatever curative measures are necessary outside our houses we must expect the engineers to contrive and adopt. But there is no necessity for introducing into a house, whether it be a large house in the country or a small house in town, any of those prodigiously complicated appliances with which we are surrounded, and which are perfectly bewildering; to my mind they convey no expectation except that of an interminable vista of increasing trouble and complication, a continual succession of attempts to get rid of false conditions, and a continual succession of failures. The course that I should adopt if I were called upon to lay down a plan for making an ordinary house healthy would be this:—that there should be no water-closets inside the house, no pipes, no plumbery of any kind. It is only a very few years since there was no such thing as a water-closet inside the house, nor a pipe. It is these ingenious gentlemen themselves who have produced all this complication. It is within my own recollection and, Sir, of yours that the system of "scientific plumbing," as it has been called, has grown up to be only an ever-increasing source of perplexity; and when we hear of such things as a multitude of water-closets to be "tried" for prizes in an exhibition, and a great deal more, I can only ask, where will it all end? I cannot pretend to describe to the audience to-night how I should propose to deal with a house on a large scale, because it would take too long a time. I have brought down a drawing in order to shorten my remarks.* I will describe to you what I think would be a very simple mode of dealing with the still more important case of ordinary London houses. To begin with, it is of no use to tell us that we must not put a drain under the basement. We must take London as we find it and this is how we find it. There is a sewer running along the front of the house, and we must drain into that sewer; the water and the gas are delivered



BASEMENT. GROUND FLOOR.

* The intention is to illustrate the general idea of the proposal, without going into details. The case assumed is that of an ordinary London house of simple arrangement, with two rooms on the floor. A small annexe is placed at the back, in such a position as to render it accessible from the staircase, and leaving space on each side for the windows. An upright shaft within this annexe would run from the basement floor to the roof, with an escape for air at the top. The annexe would contain all the water-closets, the bathroom, all cisterns, and the housemaid's sinks and draw-off taps. The shaft would then accommodate all vertical pipes whatever—water pipes up and down, wastes, soilpipes, gaspipes, the heating circulation, perhaps the rain-water pipe; and the ventilation of the kitchen, and perhaps of the principal rooms, might be accomplished by its means. The sinks in the basement would be close to it, and the kitchen boiler not far off. The subway under the basement floor is supplementary to this shaft. It would contain all the horizontal continuations of the pipes from the shaft to the street, and also the housedrain. It would extend from the usual open area in front of the house to an open area at the back, and at each end there would be a manhole for access. The vertical shaft might be of sufficient size to allow a workman to ascend and descend within it, or access to it might be had from the successive stages of the annexe. If sufficiently warmed by the hot-water pipes, or by gas-burners, the frost would not affect the pipes. Of course the gaspipes must have branches under the floors, and so might the water pipes; but the less of this, the less risk of inconvenience. R. K.

at the front of the house. My plan is to provide an annexe for all water-closets, &c. at the back of the house, with a vertical shaft to contain all pipes, and a subway from back to front under the basement for the drain, the pipes, and whatever else. First we must have a thoroughly air-proof bed under the house. I cannot go into this question at the moment, but it is now fortunately made matter of statute, and provided then that all obnoxious appliances are put in the annexe at the back and quite separated from the house, what more does the house want to make it perfectly wholesome? On the subject of heating and ventilation, I would only add that if we would consent to do with a little less of this heating, and wear a little more clothing, and keep windows occasionally open instead of always closely shut, I think we should be more healthy than we are. Although I am quite aware that in this country no impression can be made upon the public without a considerable amount of exaggeration, I would deprecate the very great amount of exaggeration which is imported into this question of house sanitation at the present day. All these tales about typhoid fever, I say plainly, I cannot believe. I have never met with an instance yet in which fever could be clearly traced to drainage such as an architect would put in. But I am anxious to admit that foul emanations from the sewers ought not to be allowed to get into our houses on any consideration whatever. I also cordially agree with Mr. Rawlinson scientifically on the importance of ventilating sewers by openings in the streets everywhere. If people do not like the smell, this cannot be helped: it need not be very offensive and need not be at all noxious.

Mr. BOXALL GRANTHAM, M.Inst.C.E.—I am now draining an old Roman town with streets 12 or 14 feet wide; in other parts of it the streets are a fair width, but it is by no means easy to ventilate the sewers in the narrow streets. The plan adopted is to carry up the ordinary ventilating shafts in the streets, but eventually I believe we shall be compelled to construct ventilating shafts up the sides of the chimney stacks. With regard to the treatment of sewage at Ealing by General Scott. A Committee of the British Association was formed, and as I was the Chairman of that Committee I had the opportunity of investigating that question. The process for a long time caused a separation of the matters in suspension in the sewage from the liquid, and clarified the water, but only at great expense, and the experiments could not be continued. The materials used in the process were clay and lime, which were afterwards burnt into cement.

Dr. GEORGE V. POORE, F.R.C.P.—Let me say a word as to Professor Kerr's plan. The method of putting all the sanitary offices in an annexe is a good one, but why should it not be in front of the house instead of at the back? If there is a disagreeable part of a London house it is the front. There you get all the noise of the streets which makes the front rooms almost uninhabitable. Now an annexe in the front is capable of being treated æsthetically, and I hope, if we are to have an annexe, it will be at the front nearest to the sewers, and not at the back and farthest away from them. One of the speakers said that he did not believe sewer gas caused typhoid fever. I am sorry for any gentleman who has that belief. In connection with such matters I may be allowed, perhaps, to state what happened to myself three or four years ago. I was called to one of the great public schools to see a boy who was living in a master's house—a new house—and who had been attacked with pneumonia. On examining him I came to the conclusion that it was secondary to typhoid fever. It turned out to be so and in a few days, unfortunately, the boy died. I said, "Let us go over the house and see if we can discover any cause for this," because the master had told me that another boy had died some months before, and that there had been other cases of inflammation of the lungs. He took me to the place where the boy had slept—a dormitory on the first floor. He slept in a cubical in the dormitory. A sink was there close to the foot of the deceased boy's bed, and the first question I put was, "Where does the wastepipe of that sink go?" "Oh!" he said, "that's all right, that goes through an outside wall; it is cut off and it opens over a wide trumpet-ended ordinary water-pipe, so that there can be no smell back from the cesspool." "Let us go outside," I said. We did so, and by the light of a lantern, for it was night, we could see the soilpipe disappear inside the top of the water-pipe. We got a ladder and found that the wastepipe of the sink emptied itself into this water-pipe and the two pipes were tightly cemented together so that the wastepipe of the sink went directly into a cesspool. Above this dormitory was another dormitory, and above the sink on the first floor was a sink on the second, and these two sinks emptied into a common pipe. The fall of water from the top sink probably emptied the trap of the second sink, so that boy had been sleeping literally with his nose almost over a cesspool. Whether that caused his typhoid fever or not it is impossible to say, but the probability is immensely in favour of the theory, and all would allow the sufficiency of the cause. I quite agree that our houses should not be complicated in their sanitary arrangements. If we could go back to the days of Abraham, who shifted his camp at frequent intervals, we should know nothing probably of typhoid fever. I do not think, however, that the ladies of London would subject themselves to the simple sanitary laws of Moses, and I am afraid water-closets in the interior of houses have become an established system, so that the question we have to consider is how not to be killed by our higher civilisation. With regard to the statement that the air of London is antiseptic, I think that is very much open to question. I doubt if a respirable air has any antiseptic influence over the germs possibly floating in the air; and supposing it has, I do not think we can point to London as a city particularly free from germs, for we in the medical profession see our full share of those types of disease which are called zymotic, and which are presumably spread by means of germs, such as typhoid fever, scarlet fever and diphtheria.

WILLIAM WHITE, F.S.A., *Fellow.*—Mr. Robins ought to have connected his Paper with architects rather than with civil architecture, because his treatment of the question has rather gone upon that; and at the Sanitary Congress at Exeter there appeared to be an attempt made by several medical men and engineers to fasten upon architects as such the responsibility of various mistakes which had been made in the carrying out of some very important works. It would ill have become me to have replied with the *tu quoque* argument, "You gentlemen are capable of doing the same thing;" but still in defence of my profession I did feel and think it well to say that I knew of certain cases in which an architect, in order to avoid the responsibility which they knew in certain cases attached to the architect, threw the whole of the sanitary arrangements into the hands of engineers and medical men. The result was a total failure. Really, as a fact, it is no discredit to my own profession, or to engineers and medical men, or other men of science, to admit failure. In reference to what Dr. Poore said, it may be interesting to know that at the present moment I have just completed in my own house very much the same kind of thing as suggested, and Dr. Poore would know why the closet could not be in front, from the very fact that he is my neighbour occupying the whole of my back wall. Nevertheless my closet being on the staircase there was no possibility of putting it elsewhere; and leaving it there, I was obliged, in order to meet the difficulty of the drainage, to have the pipes, which ran down necessarily through the house, taken up and relaid. But I brought the soilpipe down under the basement into the area with a ventilation opening 5 or 6 feet from the floor. It is also carried upwards above the roof and left open at the top. But then I isolated this 4-inch ventilated soilpipe within another 9-inch ventilated stoneware pipe, which I terminated in the same manner by a separate opening to the top. These pipes are inside the house and I have, in both of them, found a strong and constant upward current. I am satisfied that this arises from the pipes being entirely within the house, so that they do not get chilled. I have been told of an instance where, in an exposed situation, pipes have been put externally, and have had to be moved inside again on that very account. I do not insist on this as a necessity, or say that an outside pipe is a mistake. The most serious question with us is that there are so many diverse opinions upon all these matters that the whole subject of sanitary science is at the present moment tentative and experimental; and that is the reason why many of those principles which are laid down by one and another, as most invaluable and certain, are not so decided in various men's minds. A friend of mine, who is very strong upon sanitary points, tells me that he believes the old pan-closet is really after all as good as any; the only thing he would insist on is that it should be properly burnt out once a year—a good prospect for the plumber whatever it may be for the householder. And there will always be great difficulty in influencing public opinion so long as the very worst appliances are advertized in the same pages side by side with the best. How can the public distinguish between the merits of the respective apparatus when such variety of opinion exists amongst men of science here and at the Institution of Civil Engineers, as well as in the Medical Societies?

Lieut.-Colonel JONES, V.C., Assoc.-M. Inst. C.E.—I regret very much the way in which this debate was opened by Professor Corfield. He exalted the science and *spécialité* of sanitary drainage, and said that householders ought to have nothing to do with this work themselves. I think, with regard to the aim and object of all sanitation, that the knowledge of it should be spread as widely as possible; that it is matter of common sense to admit plenty of oxygen, to purify all foul air, and as soon as possible to disconnect the house from any communication with sewers outside if possible. Sanitary Science has very simple principles, and the more we cloud them with too much counsel, the worse it is for the real aim of sanitation. If it is to be for the prevention of sickness it should be made as widely known as possible what a very easy matter has to be treated. If it is to be made the aim of deep science, and people are told that only scientific men are to deal with the subject, I think we shall not make the progress we otherwise might if we put before people the main facts, and asked them to take some interest in the matter. In cases where I have been called in I have found the greatest assistance from eliciting the intelligence and knowledge not only of the householder himself, but even of his servants.

ADJOURNED DISCUSSION.

[Held on Monday, 14th February, 1881, John Whichcord, F.S.A., *President*, in the Chair.]

HENRY DAWSON, *Fellow*.—It has been proposed to restrict this evening's discussion to the subjects of ventilation and warming; and this seems most desirable, inasmuch as the previous evening was exclusively occupied with the subject of drainage. But seeing that, on that evening, the majority of the speakers were engineers, and the opinions of architects upon some of the important statements were, from want of time, imperfectly represented, I ask permission, just for a few moments only, to refer very briefly to matters of drainage, which I will put more in the form of an addenda to that evening's debate, and not so as to provoke further controversy, which would encroach upon the time set apart for the special subjects of this evening's discussion. As to the alleged superiority of small over large bore sewers and drains, still insisted upon by some of the engineers, I think to a dangerous degree, I will mention the following fact of recent experience with which I am intimately acquainted, namely, that the town of Croydon, less than thirty years ago, was sewered throughout its main thoroughfares with small diameter pipes; but these sewers for the last ten years have gradually become so inadequate to convey away the sewage and refuse of the town, that the whole is now in course of reconstruction, and for the main lines they are laying down cement concrete sewers large enough for a man to crawl through. The most urgent improvement at present needed in our sewers is the easy removal of the chief cause of the deleterious gases which are generated there, and if this is to be done by the aid of some precipitant, such as lime, as suggested by Major General Scott, how can we with safety adopt the small pipe sewers? Again, the solvent power of rain water renders it so valuable an agent for cleansing the interior of sewers, that it should make the engineer hesitate to adopt (except only partially) the separate system of sewers for rain water and sewage. As to house-drains, some of the engineers have told us that a 4-inch pipe, with a fall of 1 in 30 is, in general, amply sufficient for the main drain. I must say I think this to be most dangerous advice, having regard to the frequent difficulty in London and large towns in getting a quick fall, and more especially to the frequent presence of those obstinate obstructionists, such as cloth remnants, hair and grease. My experience teaches me that for any dwelling larger than a six-room cottage a 6-inch main pipe is the least which should be adopted. The production of foul gases through deposits in housedrains originates almost invariably not from the size, but from their unsound beds, irregular gradients and abrupt junctions; and I would urge that the only practical prevention (albeit an onerous one) of this common neglect of workmen is a rigid inspection by the architect, or his responsible deputy, first, of all the trenches before the pipes are laid, and a second inspection of pipes before any filling in. I will, also, refer to two dogmas which have been unsparingly insisted upon by some modern sanitary doctors. 1st. That "no drains should be laid under the house." I submit that the inapplicability to the majority of urban dwellings of this otherwise salutary rule has been well shown by Professor Kerr and others; I will only further urge that if, in addition to the excellent practice of laying down the main drain in a straight line from back to front of the house, with manhole at each end, there could be in all ordinary houses a flushing tank of say 100 gallons, fixed in the annexe about 10 feet above the head of the drain, and its contents passed through the drain every week, there would be a practical security against all decomposition therein. The only serious hindrance to the general adoption of this weekly cleanser might be the insanitary regulations and exorbitant charges of the Water Companies. 2nd. That "there should be no trap inside the house in connection with wastepipes, especially where the ends are open to the air." The error of enforcing this direction in the case of sinkwastes was well shown to us by Professor Corfield. But I would urge that the error equally applies to the soilwastes of water-closets, not only on account of a similar liability to the ingress of foul air from the unclean coatings of the pipes, but also of the frequent inconvenience and bodily injury arising from draughts of cold air through the overflow pipe of the water-closet pan. The old but useful warning, reiterated by Professor Corfield, that no water-trap will necessarily prevent the passage of foul gases, can only of course apply where there is a sufficient pressure of air in the drain on the lower side of the trap, and this pressure will not exist where there is ample ventilation and sufficient cleansing. With regard to ventilation. It may, I think, for our present purpose be most simply and comprehensively defined as the operation which secures a free and constant, but gentle, circulation of air through the interior of our dwellings, or of any apartment occupied by human beings, and by which the exhalations from their lungs and bodies, as well as the products of combustion from artificial lights, are regularly removed by the pressure of a constant inflow of pure fresh air from the external atmosphere. I cannot agree with Mr. Robins's classification of the methods of ventilation, which he describes as either "natural" or "scientific," because I hold that the system which is most scientific is the most natural: that is, it is the simplest and truest application of natural laws. I submit that the two distinctive methods in use would be more correctly defined as "natural" and "mechanical" ventilation. By the former method, the air of a room is set and kept in motion through the simple process of its rarefaction, by some heating medium near the floor, whether it be an open fire, or that given off by hot water pipes, and which cause it to ascend to the ceiling with the heated products of respiration and combustion to be carried off by extraction flues, and as a necessary consequence, compelling a corresponding inflow of fresh air into the lower stratum of the room to be warmed in its turn, and to ascend and escape as before. Whereas by the latter method, or "mechanical" ventilation, the fresh external air, after being warmed, is propelled by some artificial means into the room, and the vitiated air is extracted by the exhaustive process of revolving fans, or a steam blast, or the suction of a powerful furnace flue. I may say that I am no advocate for the mechanical or artificial method, because I think it is only suited to extraordinary buildings, and that the instances of its success are rare, doubtless from the difficulties in ensuing an equable temperature and velocity of the air. We shall all agree, I suppose, that the chief difficulty we have to surmount, even in the "natural" system, is to change the air by continuous circulation without violent currents or unpleasant cold draughts; and in discussing the means which are best adapted to prevent these frequent concomitants of ventilation, we have at once to consider the available methods of warming. Unquestionably, the open blazing fire is the most cheerful and genial, and therefore, notwithstanding its wastefulness, it will probably continue to be in demand, as indispensable in our British homes. But, although it must be admitted that its past use in the majority of our dwellings has been attended by chilling draughts from the windows and doors, I cannot agree with Mr. Robins that these draughts are inseparable from the use of open fires; on the contrary, I maintain that it is quite feasible to avoid them by giving to each room its separate supply of fresh external air, which shall be sufficient both for the purposes of combustion and the recuperation of the internal atmosphere for respiration, and so render imperceptible any ingress of cold air through the window crevices. But then it is indispensable that this fresh air supply shall be capable of being warmed (when required) to a moderate temperature before it enters the room; and this can easily be accomplished in ordinary-sized sitting rooms by using the heat from the open firegrate itself—all that is needed is a slight modification in the usual register stove having fireclay linings to the grate, a warm air chamber formed round the back and sides of the stove, through the bottom of which are properly proportioned inlets for fresh air, and at the top on each side is an outlet flue for the warm air which is made to enter the room about 2 feet 6 inches from the floor, and at such distance on each side of the fireplace as may be found most convenient. I may add that the warm air stove, &c., such as I have here described, and which I have used in considerable numbers, was originally made and arranged from my own design, because I found that those which were offered me were either too complicated, costly or clumsy. For the completion of the ventilation of ordinary dwelling rooms, as well as of schools and like buildings, which shall possess the means of conveying away the hotter vitiated air as it ascends to the ceiling, I have made still further use of the waste heat from the open fire by carrying up two vertical extraction flues on each side of the smoke flue, about 11 inches by 9, all made in single pieces of hard burned terracotta, 2 feet wide and 2 feet 8 inches long. These flues have openings just below the cornice, fitted with Boyle's or other self-acting valves, and their extracting power may frequently be increased by conducting the heat from gaslights direct into them by double tubes through the thickness of the floors. The adoption of this simple method of warming and ventilation in my practice has been attended with good success, not only in dwelling houses, but even on a larger scale in halls and schools, and in one church where I really was allowed my own way. While treating of the interior of our dwelling houses, I would urge very strongly that one great *desideratum* in most of even our modern houses is a due supply of fresh warm air at moderate temperature, through the hall, staircase and corridors, at all times during the winter months. Seeing that these intersecting channels of the house are the feeders of air to the rooms, and especially to the bedrooms at night, I think nothing can contribute more to the health of the inmates, particularly those who are liable to catarrh, than such a constant renewal of the internal atmosphere; and it also prevents cold draughts through the doors of sitting rooms. I have been particularly impressed with the value of the system adopted at the Long Room at the Custom House by Mr. Boyle. I must give my testimony that his air-pump ventilators are really so constructed as to act like air-pumps. They do exhaust the air in the top, and my impression is that they are most useful, and may be made very valuable for the extraction of foul air from large buildings. To say, however, as is so frequently said, that there is never any down draught is saying too much, and when I went up there to examine the system, I found that the outlet tubes instead of being as described—carried up straight from the ceiling direct through the roof—have a bend in them, and in that almost horizontal bend is placed a contrivance for the purpose of checking any little down draught, and there is also a little receptacle for soot. As to the admission of fresh air by vertical tubes from the floor, it is available in large halls, and where high enough no doubt with success. I believe Mr. Robins states that he considers it particularly suited to a room with an open fireplace, but from that opinion I must entirely dissent. I think there can scarcely be anything worse than an ordinary room with an open fireplace, into which cold air is admitted by a tube of that sort; and for this reason, that the in-current of cold air must be drawn towards the open fire, and so inflict chills upon the occupants, and this conviction scientifically based has been quite confirmed by experience in two instances. At the particular request of clients (but against my advice) the system was tried, and in both cases it most ignominiously failed. It failed, as I said it would, from the fact that the cold air—unless the room is at least 20 feet in height—has a rapid upward direction to the ceiling and is sure to descend again at a low temperature on the heads of the persons in the room, more especially if there is a large open fireplace. At the time that this system, popularly known as Tobin's, was first loudly trumpeted in some of the public journals, the public were referred to the rooms of the Society of Arts as an instance of its application, and I accordingly went there a few days afterwards to ascertain the results. The late Mr. Le Neve Foster was then there, and upon my asking him what he thought of the new means of ventilating his room, he replied that, although the ventilators had of course relieved the room of its former closeness, yet ever since they had been put in he had been scarcely free from rheumatism; he said he had moved from one side of the room to the other to escape the current of cold air, but it was impossible to do so. Other instances, where I have known it to have been similarly applied, have been attended with the same complaint. But there is another serious ground upon which I submit that this attempted method of ventilation is palpably unscientific and bad in its operation, which will appear evident when you reflect that these columns of cold air are forced up to the ceiling, to mix with the warmer but *vitiated* stratum of air; and the impure mixture then descends continuously to be breathed into the lungs of the persons who have previously expired some portion of it. Therefore, although I admit that this system gives a means of purifying the atmosphere of a room in some degree, where there is no other fresh air supply, yet I must regard it as a most imperfect system anywhere, because it introduces the fresh air at the wrong level, with the evil results I have just described. In very large halls, and even in churches, it may sometimes be introduced with impunity or no great harm, but I do submit that the more natural system of bringing in the fresh air at the bottom and carrying it over such a heating medium as hot water pipes is a far more scientific, effective and healthy plan. With regard to the Custom House I found that the fresh air tubes (about 6 feet from the floor) were covered over with ledgers, and I asked them why this was? "Because we feel a draught," was the reply.

J. P. SEDDON, *Fellow.*—I must disclaim having taken any very active or deeply scientific part in the present movement for sanitary reform. Had I any claim, it would be perhaps due to the letters which from time to time I have written, during spasmodic fits of indignation, to the *Times* in vindication of the architectural profession when charged with ignorance of, or indifference to, this important subject. When outbreaks of typhoid fever occur and some person of eminence has succumbed to them, architects are invariably made the scapegoats for defects due to inferior builders, to whom the public trust blindly the construction of houses, as to which architects are comparatively rarely consulted. Nevertheless though we architects thus suffer unjustly, we cannot but rejoice in the sanitary crusade that is in progress, trusting that, sooner or later, justice may be done to us, and that at any rate some good may result from it to the community. So we welcome the interest which very recently has been shown in the matter by members of the medical profession, as the public will listen to them, though deaf to us who have piped to them still longer in the same strain. We may, however, be allowed to smile a little among ourselves at the tone assumed by a few gentlemen, somewhat savouring of the zeal of new, if somewhat tardy, conversion. Smiles, nevertheless, yield to frowns when we see inventors, as they consider themselves, adopt appliances well known to us if not to them, and who, forgetting that even the Greeks symbolized oxygen as Minerva, try to tax the admission of that goddess or her representative into our dwellings. I wonder whether it would surprize such learned gentlemen to be told that a discussion upon the practical ventilation of buildings was held in this room eighteen years ago. A glance at the remarks then made, and published in our TRANSACTIONS, would show them that architects, even then, were alive to the grave importance of the subject and had devoted, before then, much time and attention to it. Nevertheless it is a matter for unmixed congratulation that now more minds and other professions have sanitary reforms under consideration; that fresh information is being gleaned, that rules and regulations are being laid down and enforced to give practical effect to theory. The few remarks which I have to offer, on the present occasion, I will arrange under the four ancient, if empirical, elements of *earth*, *air*, *fire* and *water*, dealing, as time is scant, with general principles rather than with details in each case. To begin with *Mother Earth:* As has been pointed out by others the isolation of dwellings from immediate contact with her bosom is essential. This should be secured over the whole interior area of buildings as well as of their walls; the damp-courses in ordinary use suffice for the latter, but I think more stringent measures than usually adopted are needed for the former. I am and have for years been in the habit of allowing no spaces under ground floors, but concreting up to the under surface of the boards, leaving no room for vermin, and obtaining ventilation elsewhere than from where it can hardly be fresh and sweet or dry. A saving in cost of excavation of steeper walls is so effected, and the only danger anticipated, namely, dry rot to the timbers embedded in the concrete, I have not encountered. Upon this point I should be glad to hear the experience of others. *As to Air:* I should wish simply to recapitulate some remarks which I made during the discussion in this room already referred to, in 1863,* several years previous to Mr. Tobin's alleged invention. I then said that I must join issue with gentlemen who had spoken as to the position of openings for the admission of air. It seemed to have been assumed that this must be either at the bottom or top of the rooms, but I suggested that it should be near the middle. Not long ago a physician (Dr. Bird, now deceased) called my attention to the way in which his rooms were ventilated in considerable volumes through a bracket 6 feet from the ground just, above the level of the heads of those occupying the apartment, with an upward direction. This he contended was the only proper method and position for admitting fresh air, no small quantity of which was needed to supply what was extracted by the fire, and which entering from any other point (except the fireplace) usually causes unpleasant draughts. Undoubtedly, I then said and say now, in my opinion the best point for bringing cold air into a room is at so high a point as to blow over the

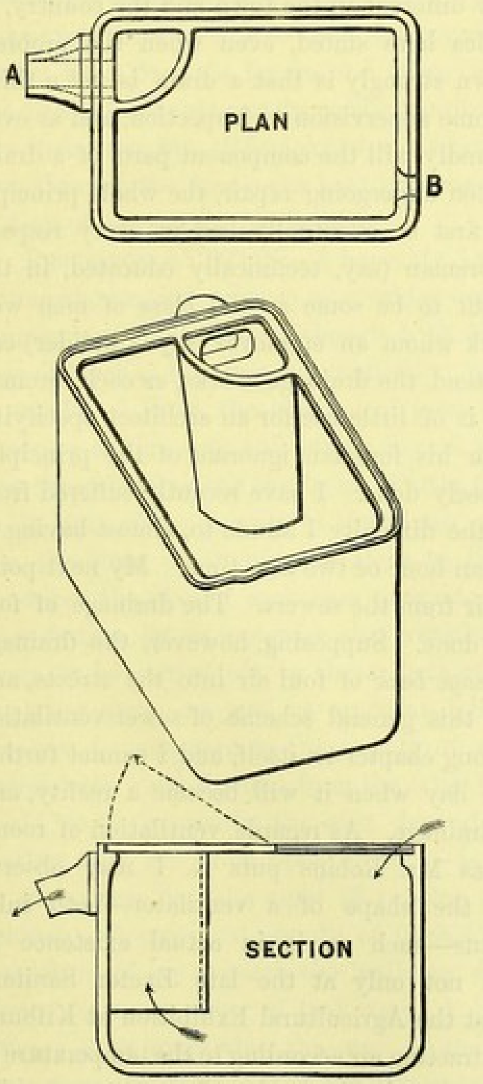
* See the report of Mr. Seddon's Speech in the TRANSACTIONS, 1862-63, page 132.

occupants and at as low a point as possible to secure that condition. But that if the air be not cold the case is different. I went on to contend then and I contend now, that every fireplace or warming apparatus should be made a fountain for the admission of air at a moderate temperature. I will summarize my views on this point by asserting that it is as necessary to lay on air to houses as water, and by other means than through the soilpipes, actually the only pipes which do admit air to nine houses out of ten when the windows are shut; and that the fireplaces are the best places for its admission to prevent draught, as even from Tobin's tubes cold air makes a short cut often to the fire, to the annoyance of those in its course. Still I will not quit this subject without acknowledging that much is due to Mr. Tobin, short of the tax he would impose for having gained the ear of the public where others before him have failed to do so. There are now so many excellent appliances for the purpose of bringing air around fireplaces that it is needless to specify them, all that is wanted is to get the public to use them. *As to fire:* I have myself made many efforts to reform grates and other appliances, but I have found all that I have aimed at so perfectly fulfilled by what has gained the name of "The Wonderful Stove,"* an invention of Mr. Samuel Russell, that I have suspended my own efforts in the hope that he would be able to bring out his grate, which in my opinion only needs care as to its artistic treatment. In this invention the fuel is inserted into a receptacle arranged in the mantel above the fire and spreads itself as required over a bright fire, by which all smoke is consumed. *As to Water:* The great essential is freedom from contact with foul drains. This is now so universally acknowledged that it only requires the experiment of regulations perfectly agreed upon. I do think, however, that a great evil as to our water supply is hardly suspected, and that in fact some advertizements are so misleading that I would in conclusion make a few remarks on this subject, and detail a dispute I have lately had with a so-called Water Purifying and Filtering Company. It having been suggested to me by my brother, Major Seddon, R.E., that my annual payment to such Company was unnecessary, I had several samples of water taken from the same cistern, both which had passed through and which had not passed through that so-called sanitary appliance, a filter, changed every other year. The result was that the filtered water proved the worse of the two. Subsequently I invited the Company to experiment with me on the contents of a filter in a similar condition, belonging to Sir Rutherford Alcock. The results corresponded with that above recorded, and a further result was that both Sir Rutherford Alcock and myself had our respective filters removed and not replaced. The fact is that charcoal, though useful perhaps for a short time for filtering purposes, soon loses under such conditions its purifying powers.

CHARLES FORSTER HAYWARD, F.S.A., *Fellow.*—In contributing to this discussion, I would observe that the practical side of the question is the one which architects have chiefly to consider; and the necessity of their applying true principles in daily practice makes it the more needful for them to be careful in enunciating any doctrine as being exactly and always perfect, while experience shows them how even a perfect theory fails often in its practical application. It fails, not necessarily perhaps from inherent want of correctness in principle, but rather perhaps from its leaving out of account some of the special circumstances with which

* A full description of this Stove, given by the inventor, is printed in the PROCEEDINGS, 1880-81.

an architect as a practical man has continually to deal. Though this may make it all the more desirable for an architect, to be from time to time reminded of the true abstract principles up to which he must endeavour to work, it is nevertheless a reason why the architect should hesitate where a theorist, or an enthusiast would rush on, for an architect often sees at a glance some defect in the chain of argument or its application to the ventilation, warming and drainage questions, which less practical men accept as indisputable dogma at once. Reference has been made to the old system of ventilation and drainage (or the want of it) which has been stated to have been utterly bad; but it is in a great measure the same which, after all, is now being pointed to as scientifically correct, and mentioned as if a new discovery had been made. The new discovery consists rather in the fact that where we have, in recent times, departed from some of the old arrangements we have been wrong, not that houses were never ventilated nor healthily drained before the era of the modern water-closet. True, it was a "haphazard," or shall I say "natural" system—if system it may be called—which our forefathers adopted before the introduction of socket glazed pipes made it possible to carry drains safely (as it was thought for a time) under and through house-floors, and before the present scientific water supply made it safe for a house to have water-closets and slop-closets, permanently fixed inside a building. The old or natural plan with the sink water was the letting it run unimpeded through the scullery wall into an open grating to some near outlet, also open to the air and often too visible; but these outlets or reservoirs of filth were not generally domed-over cesspools, as they subsequently became; they were *thoroughly ventilated by the open air.* They did not form close stills, whence all manner of evil and dangerous nuisance emanated. Now the importance of the ventilation of these improved cesspools, being unknown, this *ventilation* was the thing which was neglected, and the modern discovery is that it must follow with any system of improved drainage, and it is just what we are aiming at in our open air gratings and ventilated gulley-holes. Moreover, the doing away with water-closets where possible in favour of earth-closets only reminds me, and I dare say all others at my period of life, of home experiences as a boy when water-closets existed not, but when ventilation to such places as there were was most unimpeded. Now where we can in the country we revert to the principles embodied in these old arrangements though in an improved form, and find ourselves to be scientifically right according to recent theories. Yet we have been accustomed in the meanwhile to laugh at such simple arrangements as wanting in modern enlightenment, and have built water-closets, D-traps and drains, carefully sealed (and recently carefully unsealed and ventilated)—only to abandon them for something like the old unimpeded ventilation—when we can see any substitute which promises better without the old disadvantages, though often indeed developing some of its own. We see then that ventilation cannot be separated from drainage, nor can one be touched without discussing the points of the other. And the ventilation of drains is perhaps the most important point of all, while the draining away of bad air is as essential as bad water, and comes to the same thing in the end. The town and country differ much of course, but in all cases I adopt the same motto—" Divide and conquer"—that is always, where you can, divide your drainage system into (1) sewage, (2) slop, and (3) rain waterdrains. It is astonishing how these have been, and often still are, mixed up together in one confused mass of pipes and traps. Keep control of each and you will conquer most difficulties. Field's flushing tank will be most valuable for flushing, where it is wanted and can be used, but at present it is rather costly. The great difficulty is the dealing with the greasy water, and a really good grease trap is the one great want. Other traps have been made, but a really effectual vessel for collecting hot water charged with grease, and straining it off cold, leaving the grease itself congealed, floating on the surface to be easily skimmed off or picked out, has not been invented, to my knowledge yet. Nor have all my efforts to substitute some contrivance for it succeeded fully hitherto. It is well known that this grease water is liable to hang to almost anything accidentally flowing with it, and is sure to be foul and offensive. Yet it is quite a valuable commodity—(I believe one eating-house pays its scullerymaid's wages entirely out of it)—and if only an effectual trap could be used that would make it possible easily to collect the skimmings, and so worth the while of the scullery servants to do so, there would be some chance of the matter being attended to in the generality of households; but while it is simply allowed to run away to some drain to fester and obstruct, I submit that there is something scientifically wrong and wanting a practical remedy. I may say, of course, we all have some remedy, but I want a perfect and universal one. I have invented and used a slate undersink on wheels with a bent syphon tube—only to see it neglected and thrown aside because the servants would not trouble to use it. I have a fixed galvanized iron one in use now—an interceptor box I call it—but it fills up soon and wants constant attention, and though it saves an immensity of foulness from going through the drain, it does not entirely prevent the necessity of frequent cleansing at the open air outlets not far distant. I should like to learn what others do to meet the case. In town, of course, the flushing out of the open air drain, sending all the grease, &c., into the sewer as soon as possible, is the only plan adopted, and Field's tank and grease trap before alluded to may be, and doubtless is, very useful in this. I know of nothing worse than large grease traps —generally unventilated—allowed to accumulate filth—sometimes even under the kitchen floor—and I have had to have them removed in such neighbourhoods even as Grosvenor Square, Mayfair, Piccadilly, &c., and showing a most frightful condition of things long existent. So now, I have tried to design, and with the help of Messrs. Doulton to execute, a common grease *trap* (in the proper sense of the word trap—where what you catch you can keep yourself) or interceptor-box, applicable to all buildings



and for everyday use; and here is a model* of it, on which I invite your criticism. The object is simply to catch, or intercept, the hot greasy water, and give it time to cool so that the grease may float on the surface, while the water runs away from a lower level and discharges in the usual way over an open grating or gulley. This is in common earthenware, and would cost about as much as the sink itself, or a little more. It can have an iron grating, a wooden or wire top, or have no covering whatever—can be fixed inside or outside, under or beside, the sink, being quite independent of it, and of course can be added to any sink now existing; and its use will obviate the necessity of the built traps so frequently required. In all cases as I have said, separate this water as much as possible from *slops*, as generally understood, and this again from the outcome of soilpipes in every way. I need not enlarge further on this, but simply observe that the problem is often entirely different in the town and the country, as well as in the practical application of the principles here stated, even when the problem happens to be the same. One point I would lay down strongly is that a drain is not a thing to work for ever, or even for a long time, without some supervision or inspection, and as even the granite steps of a house will wear away, so assuredly will the component parts of a drain, and require repair; and unless care is exercised when undergoing repair, the whole principle of action may be reversed, and what was good at first be eventually bad in every respect. Thus the want of some good sanitary instructed foreman (say, technically educated, in the modern phraseology) is greatly felt, and there ought to be some special class of men well known to be skilled in ventilation and drainage work whom an employer (say a builder) can engage for the special job to take up and superintend the drainage works, as each foreman of other trades does his own special department. It is of little use for an architect specifying the best kind of drainage works when the builder or his foreman, ignorant of the principles and details of the work, cannot see to its being properly done. I have recently suffered from this myself, and I dare say others can understand the difficulty I allude to, almost having to do the work oneself, or to stand over the drains for an hour or two at a time. My next point is the ventilation of, or rather the drainage of, foul air from the sewers. The drainage of foul water into the sewer is of course one thing to be done. Supposing, however, the drainage into the sewer properly done, why should the *drainage back* of foul air into the streets, and houses if it can get in, be allowed at all? But this general scheme of sewer ventilation combined with smoke extraction, would deserve a long chapter to itself, and I cannot further pursue the subject now, but I look forward to the day when it will become a reality, and so solve many of the present difficulties of town drainage. As regards ventilation of rooms and houses, that is "atmospheric recuperation," as Mr. Robins puts it, I may observe that I look forward to a self-acting system in the shape of a ventilator—both inlet and outlet being worked by a sensitive apparatus—such as is in actual existence in conservatories, and which could have been seen not only at the late Exeter Sanitary Exhibition (where it gained a medal I am told), but at the Agricultural Exhibition at Kilburn. By this or some other simple means of adding and extracting air according to the temperature of the apartment, so much can of course easily be done, and at the times when fires are necessarily

* Diagrams of this model are given on the preceding page. In the section of this grease trap or interceptor, the arrows suffice to indicate its action; in the plan, the entry is at B., the exit at A.

in use much greater facilities are offered in the process. Why should we pay to get rid of foul water and yet have to take back, if we cannot bar it out, the foul air generated in the sewers? In a word, why not attack the evil at the sewers themselves? The question whether the sewers should be publicly ventilated, instead of privately at each man's expense, and sometimes against his will (and remembering the millions of pipes referred to in Professor Lewis's remarks), requires, and is at least worthy of, discussion. There are certain spots that I know of where the sewers are ventilated into the pathway, near a certain square, which would enable my nose to tell me where I was if I was blindfolded. I venture to say that, as the ventilation of mines is a scientific study there is every reason and need to make this subject of sewer ventilation a scientific study also—and the subject of the ventilation of the main sewers of a town, and how best to do it, a subject of serious discussion. The one great remedy against foul return gas is to have it all properly drained away out of the sewers, and the draught created *away from* the houses and inlets instead of as now *towards* them. If the current of air was directed towards certain public ventilation shafts, with fires beneath them consuming, not only their own, but the smoke of the adjoining neighbourhood, which should be drained into them through the flues—the heat generated might serve for motive power to effect the electric lighting of our streets and houses.

Professor AYRTON.—I hope Mr. Dawson will not think me unsound, even if he thinks me unorthodox, if I propose to consider warming quite apart from ventilation. The two things, warming and ventilation, although both in winter performed by our open fireplaces, ought to be as distinct as lighting and ventilation, which again in summer are both left to one agency—the window. From the absence of glass, you cannot look out of a Japanese house without opening a sliding door and letting in cold air, and you cannot keep out the rain without at the same time shutting out the light. Partly from this, any attempt to warm the Japanese houses has, in spite of the severity of the winter, not been carried out. We have in England emerged from the state of trusting at night to the fire-light to see by, just as in towns we have abandoned the plan of each man pumping up water from his own well. Let us then advance a step farther, let us recognize that ventilation, warming and lighting are three quite distinct things, to be carried out by three distinct agencies. We are now sufficiently familiar with supplying water as well as artificial light, or gas, from centres; can we not then bring ourselves to contemplate the supply of warmth as well as the supply of ventilation from centres, each quite distinct from the other? That the ventilation of a crowded public building should, as is frequently the case, depend on the whims of the people near the windows—whether they are to be open or shut—is as ridiculous as it would be if the people nearest the gasburners had the right of turning them off and plunging the rest of the audience into darkness. A continual supply of fresh air in a room which shall be independent of wind, of percolation of air through the walls, as well as of diffusion through open windows, can be effected in one or other of two ways: 1. by propelling the air into the room through proper orifices; 2, by extracting the air. In the first case, the air in the room is caused to have a pressure greater than that of the atmosphere, and consequently it has a tendency to flow away by any openings it may find. In the second case, the air in the room is caused to have a pressure less than that of the atmosphere, and air tends to enter the room by any possible inlet. In the first case, we have full control of the entering air, since no air will enter the room by open doors or badly-fitting windows, or by any other orifices than those provided for this purpose. This is a consideration of some importance, but it is more than balanced by two others, namely, that a fan when propelling air seems, according to Burat, to give only three-fifths of the effect that it gives when sucking it out, and again when air is propelled into a room the whole supply passes through the propelling arrangement, and there may be great risk of the freshness of the air being destroyed with such an arrangement. Mr. Robins has told us that 3,000 cubic feet of air should be supplied per hour for each adult, although practically only about 750 are furnished, and it is not difficult to arrive approximately at the power necessarily expended to produce such an inflow. When air is set in motion, it tends to lose energy by friction, and the loss of energy in a passage through which the air is passing is proportional to the cube of the velocity, so that if the velocity be doubled, the energy that has to be supplied by a fan or chimney to maintain the flow is eight times as great. Again, the loss of energy in a passage is about proportional to the length. Any bend, or sudden expansion or contraction, or any obstruction, considerably increases this loss, the addition depending on the character of the alteration produced in the streams of flow, the suddenness with which the paths are altered, and the increase of velocity. Without venturing to inflict on you any mathematics, the expressions for the loss of power can be written down so simply that I venture to give the formulas my friend Mr. Perry and myself have arrived at and employed in such calculations. To maintain a flow of Q cubic feet of air per second through a flue l feet long, A square feet in section, and having a perimeter or circumference of c feet requires an expenditure of nearly—

$$\frac{l\ c\ Q^3}{10{,}000{,}000\ A^3}\ \text{horse-power},$$

a result that can be easily remembered. If for example we wish to maintain a flow of 10 cubic feet per second (which is Mr. Robins's full supply of fresh air for 12 adults) through a pipe 50 feet long, one foot in diameter, about three-hundredths of a horse-power must be expended; whereas if the diameter of the flue be reduced to half a foot in diameter the expenditure must be increased about 30 times, or about one horse-power will have to be used, a result which shows the extreme importance of large pipes. The formula for the loss of energy the air undergoes, on entering and leaving the pipe, can also be equally simply expressed. If, for example, the total area of the pipes bringing air into the room be A square feet in section and similar extract pipes be employed, and if there be no enlargement nor contraction of the pipes at their ends, there will be an additional loss of energy of about—

$$4\frac{23}{10{,}000{,}000}\ \frac{Q^3}{A^2}\ \text{horse power},$$

which for the supply of 10 cubic feet per second amounts, for pipes having a total sectional area of one square foot, to about one-hundredth of a horse-power, or for pipes of half the diameter, to sixteen times as much, or nearly two-tenths of a horse-power. The subject of ventilating by chimney draught seems to be somewhat misunderstood even by practical men, which is the more unfortunate as the calculations on the subject are quite simple. The motive power in a chimney simply, of course, depends on an ascensional force possessed by each cubic foot of hot air, and which is equal to the difference between the weights of a cubic foot of hot and cold. But the effective work got out of such an arrangement is very small compared with the waste of heat necessary to warm the air, and the following calculations, which Mr. Perry and myself have made, show this fully. If Q cubic feet of fresh air are to be made to enter a room per second by a draught in a chimney h feet high, in which the temperature is maintained at T° Fahrenheit, while the external temperature is t°, the horse-power usefully expended by the chimney is—

$$\frac{7}{10{,}000{,}000}\, Q\, h\, (T^\circ - t^\circ)\, \frac{459 + T^\circ}{459 + t^\circ}$$

If, for example, the chimney be 50 feet high, the temperature inside it 300° Fahr., while the outside temperature is 60° Fahr., the power usefully employed in making 10 cubic feet per second of fresh air enter the room would be only about five-hundredths of a horse-power. But merely to heat this 10 cubic feet of cold air, introduced into the chimney per second, requires about 46 units of heat, which is equivalent to 65 horse power. Hence to obtain a useful ventilating effect of only five-hundredths of a horse-power we expend as much as 65 or 1,200 *times as much as is necessary*. Now the efficiency of a fan is about $\frac{1}{3}$ or $\frac{1}{4}$, and that of a good steam engine $\frac{1}{9}$ or $\frac{1}{10}$, or of the two combined, say, as little as $\frac{1}{40}$, that is nevertheless 30 times as great as that of a chimney when used as a ventilator. But it may be said the fire is maintained not merely for ventilating purposes but for warming, or for domestic, or for some other purpose, and consequently the chimney draught must be produced whether we require it for ventilation or not. This argument is, however, quite fallacious since, in an open fire-place, very much more air goes up the chimney than is required for combustion, as is seen from the roar that takes place when a blower or a newspaper is held in front of the fire-place. Now, in a proper furnace we do not have a quantity of air drawn up the chimney which is not required for combustion, so that unless the amount of air to be withdrawn for ventilating purposes is not more than the amount of air required for combustion, and unless also this air is tolerably fresh and suitable for combustion, there must necessarily be an increased expenditure of fuel to cause a ventilation draught up the chimney, and as I have shown, this expenditure will be made in a most expensive way; and this reasoning is equally correct, whether the air that is drawn into the chimney for ventilating purposes be introduced at the bottom, and so warmed by the fire, or whether it be sucked up by a pipe entering the chimney at the top, similar to a jet pump. But it will be objected, how can we work a fan? In many buildings a steam engine is already working, and the extra cost of driving a few fans would be inconsiderable. In other cases, the use of hydraulic power is at first sight very tempting, since there is a supply of water in nearly every house; but a simple calculation will show that such a system would not be economical, since, while a gas engine can be worked at a penny per horse-power per hour and a steam engine at between a halfpenny and a farthing, a water-motor in London will cost over a shilling per horse-power per hour. If, however, the ventilating arrangement be only required in exceptional cases, as at the Institution of Civil Engineers, a small hydraulic engine driving a fan may be as economical as paying the weekly wages of a stoker, but not so economical as using a gas engine, which, unlike a steam engine, can be worked without having a special stoker. Water power is too expensive, even for public buildings, dining rooms, &c., where many people congregate, and separate steam engines are, of course, out of the question, for working fans for ventilation. What are we to fall back on then if we wish the ventilation to be independent of windows and fires? We must of course use distributed power, and the one which is at our command is gas. Now, judging from the amount of success that has been attained with gas engines, of even so small as ½ and ¼ horse power, I do not see the impossibility of a small gas engine with a fan being employed, in every building of any size, to ventilate the rooms, summer and winter. Possibly in the future, when electricity is supplied like gas, these may be replaced by small electro motors, which experiment shows have an efficiency about eight times that of the best steam engine. Next as to warming, which, in Mr. Perry's and my mind, is quite a distinct thing from ventilation. In a room heated by an open fireplace, the air directly heated goes up the chimney, and since the greater the heat the greater the draught, we may say that all the heating of the room and its occupants is performed by radiation. The want of economy in this method of heating is more than overbalanced in most people's mind by the result. When stoves or hot air, hot water or steam pipes, are employed, the heat given to the room is partly by radiation and partly by convection, or the circulation through the room of air heated by actual contact with the hot pipes. This heating of the air appears to destroy its freshness, and whether this is due to the destruction of some chemical constituent like ozone, or of aromatic particles, such as come from living vegetation, or whether it is merely a drying of the air, or lastly, whether the practical unpleasantness arises from heating without proper ventilation, it is probably preferable to employ simply radiation, and to dispense altogether with the circulation of heated air through the room, if this can be easily and economically done. Now we think this may be effected in one or other of two ways: either the open fire-places may be retained in form but the small radiating surface of incandescent coal replaced by a larger radiating surface of pipes heated by water or steam supplied by a boiler in the building, or better still to a whole street or neighbourhood from a common centre; the chimney might remain to carry off the heated air and produce the ventilation of the room, or better, the ventilation might be performed quite separately and the chimneypiece furnished with a small ledge projecting donwards to prevent the air heated by direct contact with the hot pipes escaping into the room, so that the pipes should warm the room simply by radiation. Or the present form of fireplace might be abandoned and the pipes placed vertically in the room *reaching to the ceiling*, but not necessarily to the floor, in which case the heated air would cling to the pipes and not circulate, and this result might be attained with still greater certainty if the vertical pipes were furnished with several small ledges surrounding them, and sloping downwards so as to trap any ascending hot air. It might be objected that our heads will be chiefly warmed by this radiated heat and that would be unpleasant. But we must not jump to the conclusion that because the radiation of violet rays from the sun on our heads is unpleasant in summer that the radiation of dark heat, such as comes from a kettle of boiling water, or indeed, at present, from the walls of an ordinary room, would be necessarily unpleasant.* And if this be true there does not seem to be any serious objection to our radiating pipes being on the ceiling, when we shall be sure that all the heat we receive from this will be radiated and not convected. The other objection that might be made, namely, that we should suffer then still more from cold feet, is met when it is remembered that one of the chief causes of the draughts along our floors is the open fire-place, which is situated so near

* The recent experiments of Dr. Siemens, which show that, while the ultra-voilet rays of the electric light are highly injurious to vegetation, the less refrangible rays are highly beneficial, is a case in point.

the floor. In conclusion, let me add that I think a Paper like that of Mr. Robins, thought out carefully, illustrated by many practical examples, and written not to advocate some particular hobby or the patented methods of some special firm, but in the earnest desire merely to arrive at what is the best and the most right, must stand forth prominently in the battle of science against disease.

WILLIAM WHITE, F.S.A., *Fellow*.—There are one or two considerations which the last speakers have opened up, and which it would be well to take into account. One is the equable, or the unequable, temperature of the different strata of air in the room. I cannot quite agree with Professor Ayrton that it would be better to warm the ceiling of the room, because that would rather increase the difference of contrast between the temperature at the ceiling and at the floor, and I think there are already many people who suffer as well from hot heads as from cold feet. Some years ago I suffered seriously from the gaslights in my sitting room, and one evening, when the curtain was unhooked, on getting to the ceiling I was struck with the immense heat into which I was putting my head. On that account I do think these so-called Tobin pipes are of great value, because the natural course of the air is towards the ceiling, tending to make the warmth more equable; and I think the bad air may be carried off without objection by having the exit some feet below the ceiling, some six or seven feet from the floor. This could prevent the upper stratum mixing much with, or vitiating, the air below. It would assist in carrying off the unchanged air much better. As regards the warming of the house generally, I have found great comfort from having an air warmer in or under the hall; the room doors can then be kept constantly open, and fresh air being admitted into the hall will create a considerable change of air through the house if there is a proper exit also for the vitiated air above, as there was in my case.

Mr. C. SPENCER ROLFE.—I had desired to discuss somewhat at length many points connected with the drainage and drain ventilation of buildings, but since the hour is late and the discussion has been very long, I will confine myself in the few remarks I shall make solely to the warming and ventilation of rooms. All who desire to render a system of ventilation thoroughly efficient should be guided by two fundamental principles which are rarely considered. In living-rooms the air near the ceiling is hot, and vitiated in closed rooms with gas burning, so much so as to be intolerable, whilst below this, it is both cooler and less and less vitiated, until at the floor level we find the coolest and purest air in the room. Hence it follows: Firstly, that in all cases the inlet or inlets should be placed as near the floor as possible, and the outlets as high up as possible; and secondly, that it is necessary to increase the volume of inflow in direct proportion to the height at which it is permitted to enter. Unfortunately it has become the practice to employ a few large openings for this purpose, and to place them some distance up the side of the room, thus insuring the air being somewhat warmed before reaching the lower strata, but that any departure from the principle I have laid down is injurious can be easily demonstrated. Take for example a case where the inlets are near the ceiling, and the outlet is the chimney opening. The cool air entering, is by virtue of its velocity, spread over the ceiling, and, being of greater density than the heated air, commences to fall down. In its passage it meets with ascending currents, due to the expired air of the occupants being of somewhat high temperature, to lights and so forth, with which it gets warmed by admixture, and finally reaches the breathing level in a semi-vitiated condition. It will be readily understood that under such conditions the air of a room can never be pure. I cannot too strongly impress upon you the fact that air being a non-conductor must be heated by direct radiation, and, failing this, by admixture with warmer air. In introducing air through a tube (say a so-called Tobin's tube) it is necessary to compromise the principle by forming the terminations at some height above the floor, in order that the air may get partially warmed before reaching the faces of the occupants, and otherwise causing a sensation of cold. Doubtless it will be thought that all I have now said points to the conclusion that we cannot hope for effective ventilation unless the incoming air is warmed, but whilst this is true for nearly all the plans usually followed, it is by no means universally applicable. It is only necessary that the openings shall be *small, numerous and correctly placed,* and a room may be thoroughly ventilated on a cold winter's night, without in any way inconveniencing the most sensitive occupant. In one or two cases in my own practice I have placed the skirting boards at a slight distance from the wall (specified at a quarter of an inch, but scarcely visible when the paper was put on) and frequent inlets for air were made behind them. Whilst the plan fulfilled its purpose admirably and without perceptible draught, it was, whilst suitable to the class of houses to which I applied it, open to great objections on account of their being no means of removing accumulations of dust, &c.; but I believe the same plan somewhat more elaborated will hereafter prove of considerable value. All who have had any experience in such matters will agree with me as to the importance, or rather the absolute necessity, of having some means of filtering the air, more especially in large towns such as London. A very good plan is to have a flap sufficiently large to cover the opening (which must be considerably larger than the inlet tube) formed of two thicknesses of wire gauze, or perforated zinc, between which should be placed some "silicate" (virtually glass) wool; it must be put in very carefully, because the slightest obstruction outside the ventilating opening would stop its action. This flap should be hung by hinges, so as to rest against the tube, which should be made of zinc, or wood varnished inside; when it is desired to clean it, it is only necessary to pass a bucket-full of water through it, the flap being raised by its passage, and at the same time thoroughly cleaned. The silicate wool will last an indefinite time, as it is indestructible under ordinary circumstances. I certainly cannot agree with Mr. Robins in his advocacy of Tobin's tubes, not only on account of the objections to them which I have previously mentioned, but also because I consider that any system of ventilation of rooms should not be too distinctly visible, and should be placed beyond the control of the occupants. Should there be any such control, or should the openings for the entering of the fresh air be prominently placed, sensitive people would be constantly imagining that they felt a draught. The tube would then be closed by the arrangement provided for the purpose, and the chances are that it would never again be opened. With regard to warming, despite what Professor Ayrton has said, I find it extremely difficult to dissociate warming from ventilation, our house ventilation being entirely dependent upon heat for the production of the necessary currents. I must also disagree with Professor Ayrton in his ideal sketch of a heated ceiling, such an arrangement would not only prove very injurious to the occupants, but would render the efficient heating of the room extremely difficult. One of the best and most feasible means of heating a house throughout, is by a system of hot water pipes, not arranged as in the ordinary manner to be heated by one furnace, but receiving an increment of heat from every fire in the house. By such an arrangement all, otherwise wasted, heat would be utilized and ventilation promoted, since the major portion of the heat would be derived from the lower rooms, which would be more highly heated in consequence than the upper ones, thus promoting upward currents of air. It is becoming the custom to use, somewhat largely, open stoves provided with a heating chamber at the back, the incoming air being heated in it, and delivered through gratings in the front. It is a fact generally lost sight of that the major portion of the fresh air entering is directly drawn up the chimney unless care is taken that the chimney opening is sufficiently reduced. This remark of mine applies also to ordinary grates, and it is astonishing with what a small opening an ordinary fire can be maintained with a very great gain in its heating effects. Openings for the entrance of air, be it heated or cool, should be as far as possible from the chance of being carried directly up the chimney.

EDWARD C. ROBINS, F.S.A., *Fellow.*—My friend, Professor Corfield, who opened the discussion on the 29th November last, deserves our thanks for his testimony to the general willingness of architects to entertain sanitary questions and to render every assistance in their power to rectify old abuses; and I think I may truly say that architects as a body very highly estimate the labours of the medical profession in this field of which the Professor is an eminent example. But he thinks I claimed too high a place for architects when I said that the practice of specialists was in harmony with the previous practice of architects. All I meant to say was that architects had less to undo than was generally supposed; and that, with the growth of public opinion and professional experts, architects also grew, and were not behind the best of specialists whenever they gave their minds to it. The inlet and outlet ventilation for housedrains, the better aeration and means of inspection and gaseous disconnection of housedrains from the sewer by means of manholes, and other matters, are modern improvements; so also is the admirable system of automatic flushing by means of Field's syphon flushing tanks, which I have used with great success, and fearlessly recommend anywhere and everywhere. In the year 1852-3—now nearly thirty years ago—I myself carried out in St. Pancras the various suggestions made by Mr. Chadwick in the blue-books of the General Board of Health. And my practice then was to put the syphon trap in the last length of the housedrain next the entry into the sewer—on the principle that to keep the gases out of the housedrain was better than letting them into it, to be trapped within the house or in the area outside the same, as was then and still is the prevailing custom. Moreover, I supposed that, if a stoppage took place, it would be easy for the sewer men to cleanse the trap from the sewer itself; but the sudden fall of housepipes towards the sewer in the last few lengths was likely to keep the syphon clear. I agree with Professor Corfield as to the importance of trapping sinks with ∽ traps before passing outwards to discharge over the gulley grating. To avoid the freezing up of sink-outlets, through the dripping or leaking of taps, plugs may be used instead of gratings to the sink itself. I was glad to find that Mr. Robson, of the London School Board, author of a valuable work on schoolbuilding, was able to agree with me in most things. On the old system of supplying water-closets from service boxes in the cistern, the direct supply of drinking-water therefrom was highly objectionable, especially as the cistern was commonly placed in or over the highest water-closet, but waste preventors as now used overcome the first evil, and service boxes are quite discarded. However, just as the fear of bad workmanship makes it desirable to put soilpipes outside instead of inside the walls, so the chance of defective planning and execution makes it not less desirable to have separate cisterns to supply water-closets only, and even where constant service exists, an intermediate cistern is desirable. The modern waste-preventor of the Water Companies provides such a separate service; and if these contain from two to three gallons of water for each discharge, I see no objection to waste-preventors, except you choose to employ some water-closet apparatus, which will not clean itself without such a scour as no waste-preventing system, short of the noisy "Shrewsbury," will provide. It is this that inclines me to favour trapless closets, in well ventilated drainage, the water seat being above the plug, which when raised hurries everything away without the intervention of an invisible trap, which checks the flow and is rarely quite cleared before the supply of water ceases. I was glad to hear Captain Galton's remarks on ground air, and Mr. Ewan Christian's on hollow walls, their advantages and disadvantages. I have elsewhere treated of both. Mr. Symons touched upon a wide subject, namely, the existence of inferior speculative building in the metropolis. Professor Lewis, in his memorandum opening the second discussion, proved too much for his argument, because, as Mr. Rogers Field showed, if his six points were accomplished facts, there would be no special ventilators required. If the storm waters were to be separated from the soil drainage, and a new system of soil drainage were to be constructed on the latest principles of sanitary science and economic construction, it would involve the immediate and complete removal of all organic matter as soon as it was formed; and sewers so constructed, properly flushed and ventilated, would be comparatively innoxious. Nevertheless, as the Professor wisely suggests, chemical means might be employed to neutralize or deodorize the contents of the sewers as a precautionary measure. The memorandum read by Mr. Redgrave, from General Scott, carries out Professor Lewis's idea. Colonel Malone, of Ryde, has sent me a description of his system of doing the same thing in a more complex manner, separately treating each housedrain with liquid precipitants. Mr. George Barnard, a retired Indian medical officer, has fitted up, at his house in Kensington, an apparatus by which the ordinary trapped water-closet may be connected with a removable receptacle for the solid matters, the liquid passing through the perforated bottom and dripping in to long boxes filled with earth, fixed under one another in zigzag form, five in number. The earth absorbs all the nutritious matters, and the clear water I hold in this bottle is all that comes from the last earth filter, which has no smell. The air from the upper part of the solid excreta receptacle is taken by a pipe into the bottom of a charcoal air filter, and the pipe that issues from the top brings no smell. The box of solid matter and the supersaturated earth are both valuable articles of agricultural use, and may be sold not only to pay expenses, but to pay a profit. No soildrains and no foul sewers would be required if it were practicable to carry out such a scheme as this, and he thinks it is. Mr. Rogers Field's remarks, as might be expected of him, were all to the point. He was one of the first, if not the first, to employ the new manhole disconnecting arrangement, and external well-ventilated soilpipes. His evidence on the subject of frost is valuable, but it was not given in sufficient detail to be of more than general service. Under all the circumstances, doubtless, it is best to have the soilpipes external to the building, provided always that the arms of overflows and wastes are protected from the effects of frost—the pipe being carefully set in cement, in the hole in the wall through which it passes. My experience has shown me that the most frequent defect is in the setting of the apparatus, and leakage is most common at the junction of the pan or syphon with the soilpipe before it passes through the wall to the exterior. Mr. Rawlinson's vast experience and practical way of looking at everything give great value to all he says; and the new volume of the Sanitary Institute, detailing the doings and sayings at the Exeter Congress, is full of matter for serious reflection, to which he has contributed largely. I may say that I have used the earth-closet system with great success in country boarding-schools. Professor Kerr's suggestion as to a subway he will soon have the opportunity of seeing realized in the new premises approaching completion in Maddox Street, for Mr. Boyd. The iron housedrain and other pipes will pass through a subway, 6 feet 9 inches in height and 4 feet wide, situated below the basement. As he justly observes, the engineers are at fault in constructing sewers so as to be in many places elongated cesspools, or sewers of deposit instead of suspension only. It is all very well to complain of our laying on sewer gas to the houses, but it must not be forgotten that the production of such gases has no business to be. I have elsewhere answered some of the objections made by Mr. Dawson, and have only to repeat what I said in my second lecture at the Parkes Museum, with reference to the advantage of vertical shafts for the introduction of fresh air. The Opthalmic Ward at St. George's Hospital is perfectly ventilated by vertical wall shafts, as in this room, and there is no other extract shaft than the chimney of the fire, yet there is no perceptible draught in any part of the room. It is only fair to say this in justice to Mr. Tobin. Professor Ayrton's ingenious remarks were exceedingly suggestive, as showing how radiated heat may be obtained from hot-water or steam pipes without introducing the conducted heat; but I should hesitate to adopt it for ceilings, since the first object to be warmed by the radiation would be the heads of the people under it. I owe him and Professor Perry many thanks for the great interest they have shown in working out by calculation many interesting questions arising out of the discussion of my Paper. The useful remarks of Mr. Rolfe, Mr. Seddon and Mr. Hayward need no comment, and I am glad to find myself on the whole *en rapport* with my professional brethren, whose patient hearing demands my acknowledgment, and whose interesting discussion of the Paper has contributed in no small degree to its value. I have not very fully responded to some of the remarks made, because it is my intention to take advantage of the new system upon which the Papers of this Institute will be published, and to furnish careful Appendices. I have but one more remark to make and it is this. As a member of the Council of the Sanitary Protection Society, I know enough of the details of its working to be able to assure my friends that the work done by that Society is well done, and the co-operation of the philanthropic element, which quickens their action, is invaluable for the popularization of sound principles of sanitary reform. Those who are jealous of their interference have but a small conception of the vastness of the field which the metropolis alone provides for its exercise.

APPENDICES.

A, see page 64.—The following comparative analysis of the principal systems of Heating, namely, by Hot-Air, Steam and Hot-Water has been supplied to Mr. E. C. Robins by Mr. A. J. Bacon:—

Deperdition of Heat. Before describing individual systems of heating-apparatus, a glance may be taken at the basis of calculation on which such apparatus must be constructed. It may be premized that scientists, in order to define given quantities of heat, have assumed as their unit of measure the specific heat of water—

i.e., the amount of heat necessary to raise 1 lb. of water 1° Fahr. in temperature—and that they express all other quantities in terms of this measure. The specific heat varies with the class of material acted upon. Thus, the specific heat of air is 0·238 units, or about a quarter that of water. Another point that must be remarked, before entering further on this part of the subject, is the conducting power of heat that materials possess in various degrees, and which plays a considerable rôle in making such calculations. Thus, the heat, in terms of units, transmitted per hour for a difference of 1° Fahr. in temperature throughasurface 1 in. in thickness is:—

For marble	28·0	For plaster	3·86
„ ordinary stone	13·68	„ oak—perpend to fibres . .	1·70
„ glass	6·6	„ fir	0·83
„ brickwork	4·83	„ paper	0·346

Hence it is evident that the amount of warmth lost by a room or building, heated above the external temperature, varies with the nature of the building material and the quantity used. By the aid of the above and other data, which it would take too long to explain, Mr. Box has constructed the following table, which may be useful :—

Loss per Hour for 1° difference of Temperature.

Brick Wall.		Stone Wall.	
Thick.	Units.	Thick.	Units.
4½"	0·371	6"	0·453
9 "	0·275	12"	0·379
14 "	0·213	18"	0·324
18 "	0·182	24"	0·284
27 "	0·136	30"	0·257
36 "	0·108	36"	0·228

The co-efficient for ordinary window-glass is 0·53, and for double glass 0·27 units.

An examination of the above tables will at once show that an architect, by careful choice of his building materials, can himself do much towards economizing the expense of heating hereafter—it being patent that the use of good brickwork in place of stone, of double windows instead of single, of thick or hollow walls instead of thin or solid, is always of ulterior advantage and economy. The above tables will serve to determine roughly the amount of heat lost per hour under fixed conditions of temperature, though in practice several other factors, such as height, aspect and number of external faces, would have to be taken into consideration. The probable frequency of use would also require to be taken into account: thus it is evident that where a building is used only occasionally—a church, for example—it is useless putting in a heating-apparatus only sufficiently powerful to make good the hourly deperdition of heat, whereas, in turn, this might be amply sufficient in the case of a hospital or similar building, where the fire is constantly kept going.

Having determined the amount of heat necessary for the loss per the walls, &c., that required for the air introduced for ventilation must be ascertained. This can be done roughly by the aid of the formula :—

$$(1)\quad 0{\cdot}01817\, n\, (T - t)$$

Where n = ventilation in cubic feet per hour

„ T = internal temperature

„ t = external temperature

„ 0·01817 = specific heat of a cubic foot of air at 32°.

This formula, however, does not give exact results, because the specific heat of air when considered in volume varies with the temperature as its density. It is therefore usual in practice to reduce volumes of air to weight in pounds, when the specific heat is practically constant at 0·238 units. The total thus obtained, added to that previously calculated for the deperdition, is the amount of heat the heating surfaces must yield per hour, and their surface can then be readily deduced.

Artificial Heating-Apparatus can be divided into five chief classes—viz., radiating fires, hot-air stoves, steam, hot-water large-pipe, and hot-water small-pipe apparatus. The first of these has already been considered by Mr. Robins.

Hot-Air Apparatus.—These are innumerable in shape and arrangement, some of good, some of bad construction. Their chief advantage is that great quantities of air can be produced at high temperatures, with a minimum of space occupied. They are, however of practically little service where ventilation is desired, inasmuch as they deteriorate the air they introduce, by over-heating and tainting. They are, however, very economical in first cost, when not coupled with an extended system of brick flues, but should not be introduced into buildings with roofs of different pitch, such as Gothic churches, &c., because the air will not properly circulate, and the effect is unequal. They should always be constructed so as to draw their supply of fresh air direct from the outer atmosphere, and not, as they frequently do, from the building itself. Great care should be used not to let the flues be in contact with any woodwork, as they are then highly dangerous. At Christ Church, Battersea, when such an apparatus was taken out, by the advice of the architect, Mr. Robins, the floor of the vestry under which the stove stood was found to be charred on the under side, to a depth of half an inch. On the Continent these apparatus are daily growing in disfavour, new constructions being, for hygienic reasons, generally provided with some system of heating employing surfaces at lower temperature. The heat given off per square foot of hot-air-stove surface varies from 1500 to 4000 units per hour.

To calculate the surface of such an apparatus the temperature of the air at its outlet must be determined (not higher than 100° Fahr.), and, the deperdition per hour being previously ascertained by calculation, the internal and external temperature fixed, the amount of air necessary for introduction must be evolved by the formula :—

$$(2) \qquad n = \frac{d}{0{\cdot}01817\,(T - t^1)}$$

Then, assuming 1 □ ft. of heating surface = 2750 units, the necessary surface will be :—

$$(3) \qquad S = \frac{{\cdot}01817\,n\,(T - t)}{2750}$$

In cases where the supply of fresh air is drawn from the building itself less surface is necessary, and the formula becomes :—

$$(4) \qquad S = \frac{d}{2750}$$

The consumption of fuel in such apparatus varies so much with their construction, that it is impossible to give any reliable data, though it may be taken :—

$$(5) \qquad \text{At } w = \frac{{\cdot}01817\,n\,(T - t)}{5000} \text{ in the one case ; or} \qquad (6) \qquad \text{At } w = \frac{d}{5000} \text{ in the other.}$$

d = deperdition in units per hour
n = quantity of air in cubic feet
T = temperature of air on entering room
t^1 = temperature of room
t = temperature of external air
w = weight of gas coke in lbs. per hour.

Steam-Heating is specially useful where the distances at which the heat is required from the boiler are very great, the velocity of the heating agent being far superior to any other that can be employed. It is, however, very expensive in combustion of fuel, inasmuch as it passes the water into the return pipe as useless just where a hot-water apparatus commences to flow—viz., at 212°. Roughly speaking, water rises in temperature at the rate of 1 unit per pound and per degree Fahr., until it reaches a temperature of 212°, when it boils. It then takes up 966 units of heat in a latent state in the act of vaporization, or of becoming steam. If, under pressure, the temperature at which ebullition commences rises ; but the amount of heat necessary to produce steam at any pressure remains practically the same. The calorific value of a pound of steam is nearly the same—viz., 966 units (the latent heat of vaporization), whatever the pressure of the steam employed. The only advantage, therefore, derived from high-pressure steam apparatus is a slight difference in the first cost, on account of a higher mean temperature of the heating surfaces ; this advantage is, however, more than counterbalanced by the increased risk of leaky joints and defective tubes. It is usual, therefore, to employ steam at low pressure—say, at 1 atmosphere for the purposes of such apparatus.

Given the quantity of heat necessary for warming and ventilation, and allowing 10 per cent. for loss of heat in mains, the amount of steam required would be :—

$$(7) \qquad S = \frac{d \times 1{\cdot}1}{966}$$

S = quantity of steam in pounds per hour
d = heat required for warming and ventilation.

Supposing the feed water to enter the boiler at 60°, the quantity of heat necessary for producing this steam would be :— (8) $966 + (212° - 60°) S = 1118 S$,

and the fuel necessary :— (9) $w = \frac{1118 S}{7500}$ = weight in pounds of gas coal per hour.

Messrs. Geneste, Herscher & Co., of Paris, have erected steam-heating apparatus, where the main pipes have led away from the boilers, a distance of 1000 mètres, or 3280 ft., with perfect effect ; and in America district steam apparatus have been constructed, distributing steam for varying purposes at distances over a mile from the boiler.

On the Continent, steam-heating apparatus have been brought to a high state of perfection—tubular boilers built on the Belleville principle are employed for the steam generation; the mains are laid in channels under the roof, covered with non-conducting substance, and branch from thence to the several heating surfaces placed in the rooms below. Each branch is fitted with a pressure-reducing apparatus, and each heating surface is connected with the condensed-water mains fixed in the basement, which lead back to the boiler. Every such connection is fitted with an automatic steam trap, which opens whenever the water accumulates, and allows the same to pass, closing, however, at once on the arrival of non-condensed steam and thus economizing the amount of steam used.

The heating surfaces employed are various, consisting of double-jacketed cylinders, vertical-ribbed tubes, or cast boxes. Messrs. Gebrüder, Sülzer, of Winterthür, who have perhaps the greatest name on the Continent for steam apparatus, employ double-jacketed cylinders chiefly, of which the internal hollow space is filled with tubes of small diameter. Messrs. D'Hamelincourt, of Paris, again, employ cast tubes fitted with ribs ranged either longitudinally on the outside of the pipe or transversely, according to circumstances. In Germany, boxes having a surface varying between 2, 3, and 4 □ mètres are employed. The boxes are made with vertical cast ribs, and are used singly or connected together in series, according to the surface required, with flanged joints and asbestos packing. The calorific value of these various forms of surface is 390 units per □ ft. per hour for plain, and 260 units per □ ft. per hour for ribbed, surfaces.

Such apparatus should, however, only be put up by capable persons, and left in the charge of responsible hands. At St. John's Cathedral (Catholic), Salford, a steam apparatus was taken out some years ago of which the boiler was of single-flued Cornish pattern. The steam pipes, 4 in number, leading from same passed down the whole length of the nave, and terminated with $1\frac{1}{4}''$ tubes fitted with a cock (!) for regulating the escape. Fortunately for the congregation, these cocks had never been used, since, when taken out, the boiler was found to have its safety-valve jammed down by means of a block of wood (! !) inserted between it and the arch over.

Large-pipe Hot-water Apparatus.—This, the most common form of heating apparatus in England, is perhaps also the best understood in the country ; but, being often put up by persons utterly ignorant of its principles of action, the effect produced is not always satisfactory. This system has the great advantage over all its competitors of retaining its heat for a longer period after the fire is extinct, though of course it also possesses the corresponding disadvantage of requiring the most fuel to attain its effective heating temperature. Properly constructed, it is simple and certain in action, and, if its joints are made on a good principle, should last a long time. The tubes consist generally of cast-iron, fitted with either flange or spigot and socket joints, caulked with red and white lead and yarn. Lately, however, several forms of joints have been introduced, based on the employment of india-rubber rings or slips—such joints being now used generally by Messrs. Haden and Sons, of Trowbridge, and others. The boilers used for this apparatus are legion in pattern, the most common form being that known as the saddle-backed boiler. Tubular and Cornish boilers are used for larger apparatus. Messrs. Hártley and Sugden of Halifax, construct a series of very ingeniously designed boilers for this system of apparatus, made of welded plate iron. Taking the temperature of the pipes on leaving the boiler at 212°, and at the return at 100°, the surfaces would have a calorific value of about 160 units per □ ft. per hour. On account, however, of the large body of water and weight of material in such an apparatus—which has to be raised to the mean heat before it begins to yield its full effect—it is very extravagant of fuel. Thus, taking the mean heat as above at 156°, and the temperature of the apparatus before lighting the fire at 40°, the materials have to be raised 116°, and the amount of heat necessary for the several sizes of tube would be per foot run :—

For 2-inch pipe = 288·4 units
„ 3-inch pipe = 539·4 „
„ 4-inch pipe = 868·8 „

Given the amount of pipe, it is easy with the above data to ascertain the amount of fuel necessary for raising the apparatus to its effective point, the formula being for:—

$$(10)\quad 2'' \text{pipe} = \frac{l \times 288{\cdot}4}{6500} = \text{weight in pounds of coke.}$$

l being the length of pipe in feet, and so on.

When once hot, the fuel used would only be :—

$$(11)\quad \frac{d}{6500} = w = \text{per hour};$$

but, in order to secure such economy, a good stoker is required, since necessarily the grate service of the boiler is calculated for the larger quantity of fuel, and it stands to reason, therefore, that it is seldom attained.

Small-pipe Hot-water Apparatus.—This system, first introduced about fifty years since by Mr. A. M. Perkins, is based on a different principle to the foregoing—namely, on the fact that by the introduction of pressure the phenomena of ebullition are avoided, and water will rise beyond 212° at the rate of 1° per lb. per unit of heat, and that, in consequence, a far smaller diameter of tube can be employed. Allowing for the necessary expansion, owing to increase of heat—but not sufficient to permit of the accumulation of steam—and using a strong wrought-iron pipe, he produced a very useful apparatus, and one that might successfully have beaten all its competitors from the field, had not the principle been carried too far, and the use of too highly heating surfaces produced many of the evil effects for which the hot-air system is so justly disparaged. Conviction has, however, since introduced many improvements in this apparatus, and it can now fairly compete with its fellows. The old form of apparatus was constructed of tubes having an internal diameter of ⅝ in., which, owing to the friction offered to the circulating water, rendered it impossible to attain an effective heat on the return pipe without the employment of excessive temperatures on the flow. Mr. Bacon, however, in conjunction with Mr. L. Perkins, introduced a larger section of tube—⅞ in. diameter—in the year 1864. This improvement rendered it possible to attain a greater equality of temperature at the two extremities of the circulation, and hence obtain the same mean result as formerly without the necessity of excessive heat in any part. This improvement was first introduced in Hamburg, and gave the system a wide extension in Germany, where it is universally esteemed, and thousands of apparatus have since been erected; it has also revived its adoption in England of late years.

Besides the above, Mr. Bacon has further improved the system in several details, fixing the pressure of working by the use of valves instead of the above-mentioned expansion tubes, carefully regulating the fire-grate and furnace heating surface to the power of the apparatus, and introducing numerous minor improvements.

In 1878, Mr. Stainton introduced another important improvement in the shape of an alkaline solution for charging the apparatus. This overcame the necessity for keeping the fire going in frosty weather (even when not required for heating purposes), as was formerly the case, and thus improved, the apparatus may be universally adopted without fear of any evil result.

This system offers considerable advantages, viz., the rapidity with which the apparatus may be raised to its effective heat, and the small quantity of fuel necessary for doing so; the ease with which it may be adapted to old or new buildings; the simplicity of its management and its freedom from liability for repair. In place of a boiler its furnace contains a coil of precisely the same kind of tube as used for the *heating* surfaces, and since the temperature of this coil is ever increasing throughout its length, from the return to the flow, it is evident that, in a carefully constructed furnace, nearly the whole heat given off by the fuel may be passed into the apparatus. As a matter of fact the heat utilized in these furnaces is greater than that in any other form of boiler, being 90 per cent. of the actual total value of the fuel. The amount of heat required to raise one foot of this pipe to its effective heat is 112·48 units, which, as compared to that required in the case of large-pipe hot-water apparatus for equivalent surfaces, stands in the favourable proportion of 1 : 3·18, while the calorific value of equivalent surfaces of this tube and hot-water tube show the proportions of 1 : 0·6. The apparatus is therefore eminently economical as regards its extension of surface and the fuel it consumes.

Ventilation.—This is a subject in which England stands far behind its sister countries. Architects very frequently neglect the subject entirely, or introduce untried and often impracticable means, with less regard to the result required than to what the design of their building permits. This arises chiefly from their considering the matter only when the construction is so far advanced as to permit of no properly matured scheme; and from their regarding the ventilation as a suitable portion of their programme upon which to exercise the pruning knife. But since there are no governmental precepts laid down, and the public are not exacting, this oversight is not astonishing.

On the Continent, however, this matter is considered of the very first importance, being usually decided before the commencement of a building, and entered upon at great cost. Nor do architects overlook the importance, even if their clients would do so; for instance, Mr. Baeckelmans of Antwerp actually refused to carry out the erection of the town hospital—a building of considerable importance, and for the design of which he had obtained first premium in competition—because the Hospital Commission would not appoint an engineer to consider the plans with him, with regard to the heating and ventilation, before the foundations were laid.

The first point to determine, before planning a scheme of ventilation, is the amount of fresh air it is necessary to introduce for the purpose, and to assist in this it may be useful to quote various authorities.

Thus Ferrini gives a table which may be of service. Morin gives another in his volume on ventilation; and Wazon, in his "*Rapports sur l'Exposition de* 1878," part VI., p. 209, after quoting the preceding table gives a third—based on his own calculations. The three placed together and converted into cubic feet read thus :—

Species of Building.	Cubic Foot per person per hour.	Cubic Foot per person per hour.	Cubic Foot per person per hour.	
	FERRINI.	MORIN.	WAZON.	
HOSPITALS :—				
General Wards	2450	2100	2100	3970 (Chaumont)
Operation Rooms	2700—3500	—	—	—
Infectious Wards	5250	—	—	—
PRISONS—By day	1750	—	1400	—
" By night	—	—	1050	—
BARRACKS	1400—1750	1400	1050	2970 (Chaumont)
Stables	6300—7000	—	—	—
Ordinary Workshops	2100	—	—	—
Unhealthy do.	3500	2800	2800	—
Concert Rooms—Theatres . . .	1400—1750	1400	1400	—
Assembly Rooms	2100	—	—	—
Schools	525—700	420—525	700—1050	—
" for adults	1050—1225	875—1050	1400	—
" night	1225—1400	—	—	—
Ordinary Dwelling-houses . . .	525—700	—	1400	—
Offices	—	—	—	—

Dr. De Chaumont proposes for ordinary hospitals and barracks a ventilation of 85m^3 or 2975 cubic feet per head per hour, and proposes further that this quantity, which is deduced from chemical experiments, should in the case of hospitals be increased one-third in order to insure a good result. This is quoted by Ferrini in his work, who, however, at the same time, remarks that the figures are excessive and at variance with other results obtained by the same author.

That the quantity of air necessary for ventilation is daily acknowledged to be far greater than was originally supposed is evidenced by the advancing opinions of all authors. Thus Péclet in his second edition of "*Traité de la Chaleur*," fixed 6m^3 or about 210 cubic feet per person per hour as the maximum necessary for respiration; however, in his third edition he raised this figure to between 245 and 385 cubic feet, while later on, in the same volume, he advises 2100 cubic feet for the ventilation of hospitals; and in his last edition speaks of 3500 cubic feet as necessary for ordinary wards, 7000 for infectious, and 10,500 for lying-in wards.

Authorities being so various it may be as well to give some idea of what is demanded in practice. In Belgium, for example, the Government requires for all schools a ventilation equal to 700 cubic feet, and for barracks 40^{cm} or 1400 cubic feet per head per hour.* For the hospital at Antwerp, 2800 cubic feet per patient

* Since this was written, the amount of fresh air required for schools, by regulation, has been increased to 875 cubic feet per person per hour.

per hour, with power to increase to 5250 cubic feet, was demanded in the instructions to competitors for the warming and ventilating apparatus. In the Trocadéro at Paris 1400 cubic feet per person per hour are introduced; the fresh air enters at the ceiling and passes out through 5000 openings in the floor. This work was executed by Messrs. Geneste, Herscher & Co. of Paris, and is very satisfactory. At the Opera House in Vienna, ventilated on Bohm's system, 9000m^3 are driven in per hour by means of a fan=to 1050 cubic feet per person per hour; the fresh air is introduced at every level and every point throughout the building, and passed off by the ceiling—the system being a perfect success. In designing a system of ventilation it is necessary, after determining the quantity of air required, to fix the principle on which it is to be introduced and warmed. Of these there are several:—

a, Ventilation by warm air drawn or driven from a common hot chamber.
b, id. id. id. from separate hot chambers.
c, id. by cold air passed over hot surfaces in the rooms themselves.

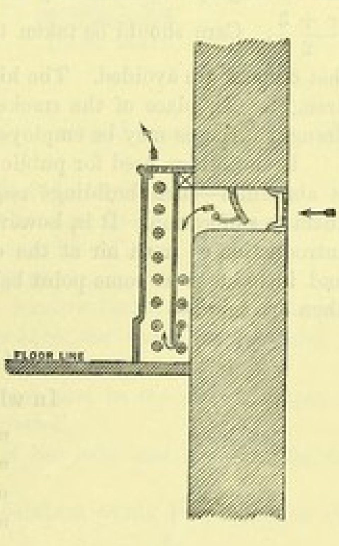
In the case (*a*) it is impossible previously to fix the quantity of air if the temperature is determined, because, as the air is heated to a common temperature, a sufficient quantity must be admitted, so that escaping by the exit openings, at the normal temperature of the room, it leaves in its passage the amount of heat necessary to make up for the deperdition per the walls, &c.

To calculate such an apparatus, therefore, the quantities of warm air necessary must be determined by the formulas used in the case of hot-air apparatus, and when thus fixed, the amount of heating surface must be determined according to the calorific value of the special kind of apparatus employed.

If, however, as in the cases (*b* and *c*), the heating surfaces necessary for each part are separate, the quantity of fresh air may be determined as well as the temperature of the room. Sufficient heating surface is placed in the hot chambers so as to deliver the air at such a higher temperature, that after replacing the deperdition per the walls it passes off, at the normal temperature, by the exit opening.

In this manner the great hall of Mr. Robins's Sandall Road Schools is heated. The heating surfaces are placed in vertical shafts in shape of 6 coils, each containing 100 feet run of small hot-water tube, the shafts are 14 in. by 18 in., and the height from floor of chamber to exit opening is 14 feet. The fresh air for these hot chambers is led along horizontal channels under the basement floor, being temperated slightly in its passage by the connection tubes leading to the coils. When at work the hall attains a temperature of 55° easily, with a freezing temperature outside, and a ventilation equal to 106,776 cubic feet or 356 cubic feet per person per hour. Under a difference of 55°—30° the deperdition of this hall is about 31,694 units per hour; the velocity in the shafts varies from 2·5 to 4·7 feet per second, with a mean for the six shafts of 3·3 feet, and the total amount of heat passed up in this air is equal to 60,000 units per hour. The total amount of heat added by the audience=to 300 persons is 300 × 191=57,300 units; the total amount of heat in the air is therefore 57,300 +60,000=117,300 units. The hall can therefore be maintained at a temperature of 55° even with an external cold of:—

$$55^\circ - \frac{117300}{\frac{31694}{25} + (106776 \times \cdot 01817)} = 55^\circ - 36.6^\circ = 18.4^\circ$$



The system *c*, namely, that of heating surfaces placed in chambers or boxes in the rooms themselves, has been introduced by Messrs. Bacon in several school buildings on the Continent. The heating surfaces, calculated according to the deperdition of the heat required, and the heat required for the air admitted for ventilation ($20^{m\ 3}$ per person), are fixed in a cast-iron box, ranged dado fashion along the outer wall, with a grating above to permit the passage of the warmed air. This box is placed in communication with the outer air by means of openings contrived under the windows, fitted with automatic regulating valves which close with any gust of wind, thus:—The air entering at the base of this hot box passes through the same and out by the grating—the difference of temperature attained in the classes being 40° Fahr. despite constant ventilation. Such an apparatus has been erected by them at the Athénée at Tournai, with such satisfactory results that they have since been instructed by the same municipality to heat the theatre and a large girls' school, and have through its recommendation obtained the contract for warming a large school of 35 classes in Brussels and another at Couvin.

The action of the various apparatus above described is based on the principle of the air passing up the shafts through its own lightness of weight—the rules for calculating the velocity, where not known, or if known, the temperature in the shaft necessary to attain such velocity, being, according to Wolpert's formulas, (as corrected for English units of measure):—

$$(12) \quad v = \sqrt{\frac{2gh(T-t)}{459+t}}$$

$$(13) \quad T = t + \frac{v^2(459+t)}{2gh}$$

Where v = Velocity in feet per second
„ h = height of shaft in feet
„ t = temperature of room
„ T = „ of shaft.

In certain cases, however, it is convenient to substitute mechanical means in order to attain the velocity: for instance, where the ventilation is required both winter and summer, and no difference in temperature can consequently be relied on to actuate the current, or where the amount of air admitted cannot be allowed to fluctuate with the external temperature, or where the quantities of fresh air required are greater than can be conveniently attained at low velocities. In such cases a fan driven by steam or water or wind power is employed.

Messrs. Verity & Sons have lately brought out a fan of this description, driven by a fine jet of water, which is very useful for small purposes, but the expense of working it prevents its adoption in buildings of importance. In such cases a large fan, driven a slow rate, is more expedient; and where the use of a steam engine is objected to a gas engine on the "Otto" principle may be advantageously employed.

Extract Ventilation.—No system of ventilation is complete unless the extraction of the air is provided for, as well as the inlet, and in equal volumes. To carry off the foul air, shafts should be constructed in the walls, working naturally in the case of inlet ventilation by means of a fan, and artificially where the inlet is provided for by natural means. The best system of extraction in the latter case is a draught chimney heated by the smoke from the boiler or furnace. The volume of air passing through the shaft being known, the temperature can readily be determined by the formula:—

$$(14) \quad T = t + \frac{1.44\, s\,(t^1 - T)}{2 \times 0{\cdot}238\, w}$$

Where s = surface of flue—and
„ w = the quantity of air to pass over same in lbs. weight per hour
„ t^1 = mean temperature of flue.

T being thus ascertained it can at once be inserted in formula (12), the velocity found and the area fixed.

The section of the downcast shafts, leading from the several rooms, should be sufficiently ample to allow of a velocity not exceeding 3 feet per second, and the area of channels connecting these with the upcast shaft can be roughly determined by taking the mean of the velocities of the downcast and upcast shafts together, or $\frac{v+3}{2}$. Care should be taken that these channels flow as directly as possible to the main upcast shaft, and that corners are avoided. The higher the shaft the greater the velocity, and the less heat necessary for the draught. In place of the smoke flue, heating surfaces of the same nature as the apparatus, gasburners, or draught furnaces may be employed, the same formulas serving in all cases.

In buildings used for public assemblies, such as theatres and concert rooms, the question of ventilation is abnormal—such buildings requiring absolutely no artificial warmth since the audiences suffice to heat them to suffocation. It is, however, impossible in winter to cool them down without inconvenience by the introduction of fresh air at the external temperature, and the air admitted must therefore be temperated first, and introduced at some point below the normal temperature, say 15°. The volume necessary for ventilation then becomes:—

$$(15) \quad v = \frac{191a - d}{.01817\,(T-t)}$$

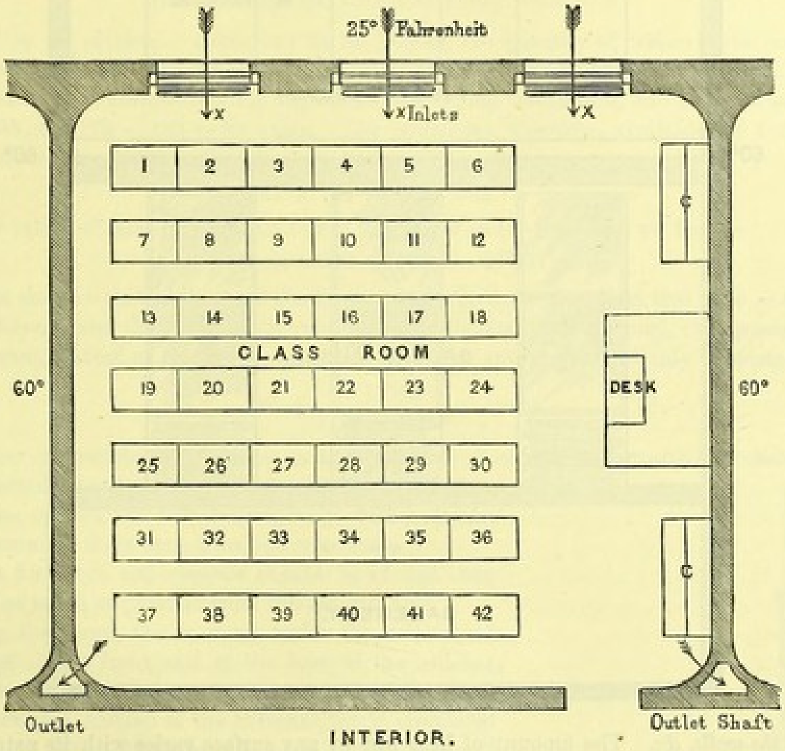
In which a = number of persons in audience
„ d = deperdition at fixed difference of temperature per hour
„ T = temperature of air at entry
„ t = normal temperature of building
„ v = volume of fresh air in cubic feet per hour.

B, see page 64.—The following demonstration has been supplied to Mr. E. C. Robins by Mr. A. J. Bacon :—

PROPOSITION made to Mr. A. J. Bacon by the author of this Paper. A class-room for 40 (the diagram shows benches for 42) pupils in a secondary school or college, wherein 15 square feet of area are allowed for each pupil, requiring a room measuring 25 × 24 feet. The height of the room to be a clear 13 feet—the angles of the room being rounded at a radius of 2 feet ; 60° Fahr. to be maintained per hour as a constant temperature concurrently with a change of air at the rate of 700 cubic feet per head ; the windows to be on one side and on the left of the pupils, and to measure 9 feet high by 4 feet wide ; the door to be in the opposite wall, lef of the teacher. There would be accommodation, in desks opposite the teacher, for seven desks in a row, six rows deep with interspaces.

PLAN.

EXTERIOR.



INTERIOR.

CORRIDOR.

The class-room is presumed to be one of a series arranged on either side of a central corridor 10 feet wide two storeys in height, with a low basement under.

The minimum thickness of wall is imagined, namely, 14-inch outer walls and 9-inch internal walls.

The class-rooms on each side of it and the room over it, as well as the room itself, are supposed to be heated to a temperature of 60°, while the outside temperature is 25°, and the corridor 50°.

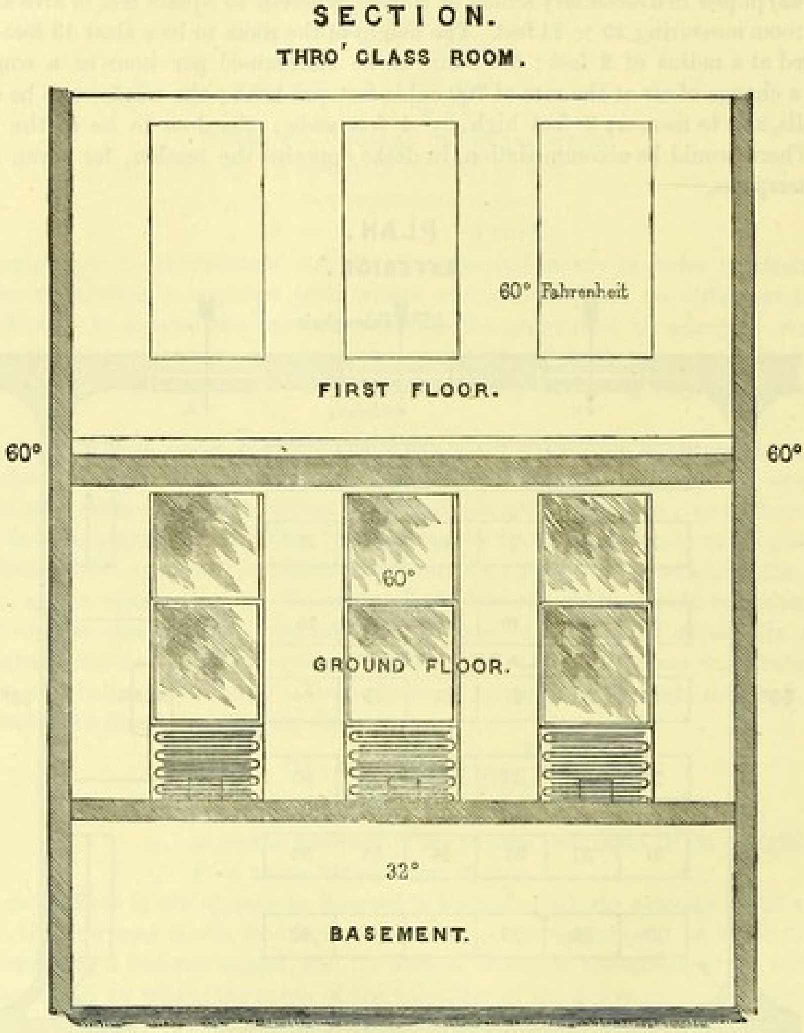
The artificial system of heating may be by hot-water, either high or low pressure, or steam apparatus.

The inlets for fresh air are to be at the lower part of the centre of the window-backs, and the air to pass through the hot-water or steam coil or box occupying the whole of the window-back, the openings from which to be at the top of the case. (*See* page 115.)

The outlets are to be opposite the windows, in the spandrils of the corners, and in the winter to open at the bottom of the room, and in the summer at the top, and are to be under control.

ANSWER. The method of calculating the losses of heat, the areas of the inlet and outlet shafts, the consumption of fuel, &c., would be as follows :—

The amount of heat required to keep the class-room at its normal temperature would be the sum of the quantities $d + a - c$: where $d =$ heat lost by radiation and conduction of the outer surfaces, $a =$ heat necessary to warm the incoming air, and $c =$ heat given off by the children. For convenience of calculation these various quantities are usually calculated for the fixed period of one hour.



Heat lost per the walls, &c. The amount of heat lost by any surface varies with its nature and thickness; but the calculations necessary to determine such losses are very involved, and too abstruse to be entered into here. We can, therefore, only state the coefficients necessary for determining the loss in the supposed instance, which are per degree Fahr. difference of temperature. (See *Practical Treatise on Heat*, by Thos. Box, London, 1880) :—

9-inch wall (brick)	0·275 units per □ foot.
14-inch ditto	0.213 „
Glass	0·53 „
Floor	0·164 „

Applying these to our case, we arrive at the following results :—

14-inch outer wall . .	$\left[\{(25 \times 13) - (3 \times 9 \times 4)\}(60 - 25)\, 0{\cdot}213\right]$	= 1617 units.
Windows	$(9 \times 4 \times 3)\,(60 - 25)\, 0{\cdot}53$	= 2003 „
9-inch wall towards corridor	$\left[\{(25 \times 13) - (8 \times 3{\cdot}5)\}\,(60 - 50)\, 0{\cdot}275\right]$	= 816 „
Door in same . . .	$(8 \times 3{\cdot}5)\,(60 - 50)\, 0{\cdot}53$	= 148 „
Floor	$(25 \times 24)\,(60 - 32)\, 0{\cdot}164$	= 2755 „
	7339 units $= d$.	

Heat necessary for ventilation. The quantity of fresh air necessary being 700 cubic feet per head per hour, and the number of children in the class—40, it is evident that, allowing for one teacher, $700 \times (40 + 1) =$ 28,700 cubic feet must be admitted. Since the volume of air varies directly with the temperature and the "specific heat" inversely, it is usual to reduce quantities of air to weight in lbs., in order to be able to neglect these variations. Thus, supposing that the fresh air is taken from outside at 25°, its volume at that temperature, calculated by Regnault's rule,

$$V^1 = V \frac{458 \cdot 4 + t^1}{458 \cdot 4 + t}$$

would be 26,761 cubic feet only, but the weight would remain the same :—

$$\frac{28700}{13 \cdot 1} = 2191 \text{ lbs.}$$

and 0·238 units being the specific heat of air, the heat necessary to raise this weight of air to 60° would be

$$2191 \times 0 \cdot 238 \; (60 - 25) = 18242 \text{ units} = a$$

Heat given off by the children. According to M. Dumas, the quantity of carbon given out by an ordinary person is ·022 lb. per hour, and the heat thus developed is $12906 \times \cdot 022 = 284$ units per hour. A considerable part of this heat, however, is absorbed by the vapour formed during respiration, and becomes latent, the amount from 62° being $\cdot 0836 \times (1178 - 62) = 93$ units. The remainder, therefore, available for heating purposes is $284 - 93 = 191$ units. In our case, therefore, we have :—

$$41 \times 191 = 7831 = c.$$

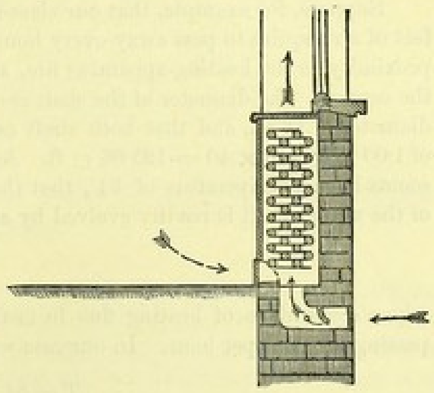
Setting the various values obtained, according to our formula $u = (d + a) - c$, we find :—

$$u = 7339 + 18242 - 7831 = 17750 \text{ units.}$$

The above equation shows—that while the walls lose a certain proportion of heat, this is more than supplied by the children themselves ; and that after the normal temperature has been attained, the apparatus serves really to cool the room down, instead of heating it, inasmuch as the air entering would only be heated to :—

$$25 + \frac{17750}{2191 \times 0 \cdot 238} = 59^{\circ}$$

The best manner of arranging the heating surfaces would be in stacks, underneath the windows and recessed in the walls, connected directly with the outer air by means of an opening under them, opened and closed alternately, with a similar opening from the room at their base, thus (see woodcut) :—



The coverings for these coil recesses should be of cast-iron, in order to benefit as much as possible from the radiant heat.

When heating the room, the opening under the coil would be closed, and that in the front and at the base of the coil-box opened—so that the temperature may be the more quickly raised, inasmuch as the internal, instead of the external, air is circulated through the hot box. When, however, the class commences, and ventilation is required, this principle is reversed, and the cold air enters the box. The air thus heated may be allowed to pass through gratings in the window-sill directly into the class-room, or, if preferred, up shafts constructed in the piers between the windows, and into the room through openings near the ceiling. In our case, where the air would not enter at a high temperature, the former arrangement is preferable, because there is no difference of temperature between the inlet shafts and the room itself to actuate the current, and the latter would therefore be induced solely by the extract apparatus—and since this would exert an equally powerful influence on the window cracks as on the shafts the result might be very doubtful.

A further advantage of the former arrangement is that the currents of hot air, passing in front of the windows, tend to neutralize their cold radiation.

As already stated, the motive power of such an apparatus is the extract shaft. This can either lead directly up through the roof to the open air, or be taken down to the basement, and there connected with a common upcast shaft.

Granted that we ventilate our class-room by shafts leading directly up from the floor level to the outer air. Having a floor above of similar height and the pitch of the roof above that, we may assume 40 feet as the height of our shaft. The temperature in the same would naturally be that of the room, 60°, and for the outer air we can take the mean temperature—say, 50·4°. Calculating by Wölpert's formula :—

$$v = \sqrt{\frac{2\,g\,h\,(T - t)}{459 + t}}$$

v being velocity in feet per second, h being height in feet, T temperature of shaft, t that of external air, our case would give :—

$$v = \sqrt{\frac{64{\cdot}35 \times 40\,(60 - 50{\cdot}4)}{459 + 50{\cdot}4}} = 6{\cdot}96 \text{ ft. per second, as the theoretical velocity.}$$

According to Péclet (see *Traité de la Chaleur*, by E. Péclet, Paris, 1878), however, 60 per cent of this is lost in practice through friction, and we must therefore only calculate on a velocity of $6{\cdot}96 \times 0{\cdot}4 = 2{\cdot}78$ ft. per second. The velocity being thus determined, the area required for the extract shafts is readily fixed, namely :—

$$\frac{28700}{2{\cdot}78 \times 60 \times 60} = 2{\cdot}86 \;\square\; \text{ft.}$$

On the first floor even a greater section would be required, since there would only be 26 ft. of height available to promote draught, and the equation would become :—

$$v = \sqrt{\frac{64{\cdot}35 \times 26\,(60 - 50{\cdot}4)}{459 + 50{\cdot}4}} = 5{\cdot}6 \text{ ft. per second,}$$

which, multiplied by 0·4, gives a real velocity of 2·24 ft. and an area for the shafts of 3·57 □ ft. It is evident, therefore, that to ventilate naturally by chimneys leads to the use of very large shafts, where the renewal is great, and hence is not of practical utility in cases such as the one under consideration. Of course a higher temperature might be obtained by rarifying the air passed up these flues in some way—either by placing heating surfaces similar to those used in the apparatus for warming, or gas-jets at their base; but since for every degree of increased temperature we should require $2191 \times 0{\cdot}238 = 521$ units of heat per hour, involving the burning of $\frac{521}{7500} = 0{\cdot}07$ lb. of coke in the furnace or boiler, it is manifestly expensive, both in the first instance and in the long run.

It is the more inexpedient seeing that, wherever a heating apparatus, of whatever system, is introduced, there is always a ready means of ventilating at hand—at once inexpensive and powerful.

Suppose, for example, that our class-room forms one of a series of six, and that $6 \times 28700 = 172200$ cubic feet of air require to pass away every hour. All that is required is to build a shaft of moderate dimensions in proximity to the heating-apparatus fire, and to pass the smoke and waste heat from same up an iron flue in the centre. The diameter of the shaft is quickly determined. Assuming that the smoke-flue have an external diameter of 12 in., and that both shaft and flue have a height of 40 ft. as before, the flue will have a surface of $1{\cdot}00 \times 3{\cdot}1416 \times 40 = 125{\cdot}66$ □ ft. Assuming further that the air arriving at the base of the shaft from the rooms have a temperature of 54°, that the mean temperature of the smoke flue is 300° ; the mean temperature of the upcast shaft is readily evolved by aid of the formula :—

$$T = t + \frac{1{\cdot}44\,s\,(t^1 - T)}{2 \times 0{\cdot}238\,w}$$

where s = surface of heating flue in □ ft. ; t^1 = temp. of same in degrees Fahr. ; w = weight of air in lbs. passing up shaft per hour. In our case we find therefore :—

$$T = 54 + \frac{1{\cdot}44 \times 125{\cdot}66\,(300 - T)}{2 \times 0{\cdot}238\,(6 \times 2191)} = 60{\cdot}9^\circ$$

$$v = \sqrt{\frac{64{\cdot}35 \times 40\,(60{\cdot}9 - 50{\cdot}4)}{459 + 50{\cdot}4}} = 7{\cdot}3 \text{ ft. per second,}$$

which, multiplied by 0·4, as before, gives a velocity of 2·92 ft. per second. The area of the main upcast shaft can now be determined, and would be :—

$$0{\cdot}7854 + \frac{172200}{2{\cdot}92 \times 60 \times 60} = 17{\cdot}16 \;\square\; \text{ft.} = 4{\cdot}14 \text{ ft. square,}$$

0·7854□ ft. being the space occupied by the flue. In our case we have taken the mean temperature forthe whole year to determine the velocity; but in practice, where the ventilation in school buildings is only intended for winter use, the mean for the winter, or 39·6°, may be employed : and in metropolitan schools, where a far greater height may easily be had for the draught, it will be found that double the above velocity can readily be obtained. Thus, with a 70 ft. shaft and a winter mean, the velocity would be for equal volumes 16·46, which reduced to practical value = 16·46 × 0·4 = 6·58 per second. From the foregoing remarks, it will be seen that such an apparatus cannot be constructed for any fixed base of ventilation, since the quantity of fresh air passing through a building thus heated will vary inversely with the external temperature—not in direct proportions, since, there are several factors exerting their influence on the result, but still in inverse directions. The only way to obtain a fixed means of ventilation is to employ a fan to drive the air into the rooms in a heated state; but as this involves a better class of attendant, or even a regular engineer, the above method may be considered sufficiently effective for ordinary purposes. Care must, however, be taken that the bases of calculation are sufficiently broad, so that, while the ventilation is ample on warmer days, the heat is sufficient when the outer atmosphere is cold.

The amount of heating surface necessary will vary with the kind of apparatus employed. Thus, supposing the class-room to be heated by steam pipes having a diameter of 3 in. and a temperature of 240°, 46·1 □ ft. of surface would be necessary; if the apparatus, however, contained hot water at a mean temperature of 150°, 111·63 □ ft. of surface would be necessary; again, were a small-pipe hot-water apparatus employed, the use of tubes of $1\frac{5}{16}$ in. external diameter, and having surfaces at a temperature of 237°, 61 □ ft. would be necessary.

To raise the steam apparatus to effective heating point 21280 units would be required, supposing the temperature at commencement to be 40°. To effect the same object in the large-pipe apparatus, there would be necessary, under similar conditions, 63379 units, and for the small-pipe hot-water apparatus 19845 units. Allowing 10 per cent. for loss by connections, &c., the amount of heat required for each apparatus, to keep it at its full effective heat, would be for 10 hours :—

Steam apparatus $\{ 21280 + (17750 \times 9) \}\ 1{\cdot}1 = 199133$ units.
L.P. hot-water do. $\{ 63379 + (17750 \times 9) \}\ 1{\cdot}1 = 245442$ „
S.P do. do. $\{ 19845 + (17750 \times 9) \}\ 1{\cdot}1 = 197554$ „

Supposing that gas coke were consumed, the amount of fuel necessary in each case would be about :—

Steam apparatus $\frac{199133}{6500} = 30{\cdot}64$ lb.

L.P. hot-water do. $\frac{245442}{6500} = 37{\cdot}76$ lb.

S.P. do. do. $\frac{197554}{9000} = 21{\cdot}95$ lb.

C, see page 55.—Extract from a Lecture on "Situation," recently delivered at the Parkes Museum by Mr. E. C. Robins.

The nature of the subsoil, or the stratification of the earth upon which the building stands, is the next important inquiry, but not second in importance. A damp site makes a damp house, not only by the surface dampness of the surrounding ground, but by the ground air, which forces the moisture under and into the house, drawn forward by the means adopted for warming the interior, which, by lightening the weight of the internal air, makes a free passage for the damp ground air in the direction of the least resistance. There are two general divisions in classifying soils, the permeable and the impermeable, and in proportion as the site is free from moisture, in the same proportion is it fitter for residential occupation. But it does not follow that impermeable soils are the driest—on the contrary, it is usually the permeable.

Pervious soils are those like gravel, sand, and soft limestones, which allow of the free passage of water through them, and if there is nothing to obstruct its free passage, and the level of the water in the ground is sufficiently deep, the upper surface upon which the house is built is always dry and healthy. If, however, the gravel has no deep outlet for water which passes into it, owing to its being situated in a basin of impervious soil, so that the level of the water in the soil is brought very near the surface, then it is necessary to find an outlet for the accumulated water by artificial means, called land drainage.

Impervious soils are those chiefly composed of the various clays, which do not allow the waters to sink into their depths, but only suffer it to flow over their surface; and consequently the garden soil gets super-saturated, and if the land is level the water is long in getting away, and the evaporation of the moisture, in and upon the soil, produces a humid, damp atmosphere, very injurious to health and requiring very careful surface drainage to overcome.

The public roads, forecourts and areas of houses in a town are usually so well drained that no evil comes from this source, as a rule, in front of the houses; but the back gardens are commonly neglected, and the basements suffer in proportion. It is obviously important to investors in house property, for income or for residential purposes, to look to the surface and subsoil drainage of the site of the house you buy or build, as the case may be. But this is not all. Suburban villas are not always built on natural soils. The brickmaker has sometimes preceded the builder on impervious soils, and the gravel and sand merchant has sometimes sunk great gravel pits for the sale of gravel and sand on pervious soils; and to bring the land to its uniform level, the well-known notice-board has been put up, inscribed, "Rubbish may be shot here," which is only another form for "The seeds of disease sown here." Avoid such sites altogether. I could point to many; but common sense is shocked at the folly and wickedness of raising human dwellings over such abominable deposits. Happily the Public Health Acts all over the country are gradually influencing the age, and the action of the Nuisances Removal Acts, the Local Management and Building Acts, is aiding the public in the acquisition of sounder and healthier dwellings, and instead of grudging the fees paid to District Surveyors and local officers, it would be wiser to secure their influence and direction, and to support their authority. Meantime to obtain a solid and practically impervious basement floor with a surface of wood, provide deal, fir, pitchpine, oak or other wood blocks, 7 by 3½ by 2 inches thick, burnetized, and lay them in herringbone or other patterns, bedded in guaged lime and hair mortar, after first dipping the blocks half their depth in pitch, the whole resting on a solid foundation of ground lime or cement concrete averaging 6 inches thick. The interstices of the blocks should be filled in with Portland cement powder swept over them, the surface to be then washed with water, which, setting the cement in the joints, makes a permanent floor which may be polished. This kind of floor was, I believe, first used by Mr. Gregory from the description of Mr. William White, F.S.A., architect, at a church in Battersea.

D, see page 64.—Extract from a Lecture on "Ventilation, Lighting and Warming of ordinary Dwelling Houses," recently delivered at the Parkes Museum, by Mr. E. C. Robins:—

It is usual to measure the impurity in the atmosphere by the proportion of carbonic acid it contains—not because this is the only or even the chief cause of its unhealthiness, but because the presence of carbonic acid is indicative of the proportional existence of other impurities, namely, foul organic matter and moisture, and also because the amount of carbonic acid can be accurately measured, and therefore may be usefully taken as an index of impurity generally. The average amount of carbonic acid in the air outside of the house, is four parts in 10,000; when it reaches six parts in 10,000 inside, the room begins to be stuffy. Dr. De Chaumont has shown that about 3,000 cubic feet of fresh air per hour are necessary to preserve the air quite fresh; practically, however, no more than 750 cubic feet per hour are attainable in this country without producing draughts. As Dr. Corfield observes:—"The air in our houses is rendered impure in various ways, but chiefly by our respiration, and by the products of combustion that are allowed to escape into it from lights and fires. Thus the air that we *expire* contains a certain quantity of foul or putrescent organic matter. It is charged with moisture, and contains about 5 per cent. less oxygen, and nearly 5 per cent. more carbonic acid, than the air we *inspire*." Add to this that every foot of gas consumed is equal to the addition of one person's expiration, and the need of changing the air is quite obvious. This change of air can only be effected by the admission of fresh air and the concurrent abstraction of foul air. It is not enough to provide for the *extraction* of air *without* providing for its *incoming*, because the effort of natural forces seeking equilibrium will cause the air to be drawn through every crevice in doors and windows, and even through solid walls and floor, creating currents of air en route to the motive power, the partial vacuum which the fire in the grate produces. Neither is it sufficient to provide for the *admission* of air, if there is *no means* of *outlet*, and if the chimney-flue is closed it will not enter of itself at all, but will require to be forced into the room, by which process the occupants of the apartment will feel no more delightful sensation than is to be experienced by a descent in the diving-bell at the Polytechnic. In ordinary houses the chimney is a sufficient ventilator when associated with a means of feeding the chimney with a supply of air, to prevent it feeding itself by drawing from every crevice as afore-mentioned. To feed the fire directly, however, would probably prevent the draughts, but it would decrease the warmth, and leave the room unrefreshed by the change of fresh for expired air. Consequently, it is obviously desirable to introduce the air in such a way that it may do all the good it can before it reaches the fire and is swallowed up by the chimney current. Now it is admitted that the ordinary current up the flue of a sitting-room fireplace is at the rate of from 3 to 6 cubic feet per second, or 300 cubic feet per minute, or 18,000 cubic feet per hour. Consequently, allowing 1,000 cubic feet of air per hour as necessary to be extracted for each occupant of any chamber, obviously one sitting room fireplace is a sufficient extractor for eighteen persons; if 3,000 cubic feet are insisted on, as recommended by Dr. De Chaumont, then six persons are efficiently provided for by this means, which is all sufficient for all practical purposes in dwelling-houses, except on party nights, when a still larger volume of expired air will be required to be extracted, to make way for the equivalent of fresh air which it is necessary to introduce, to keep up the interchange and to maintain the purity of the air generally. Proceeding on this assumption, Mr. Tobin has the credit of putting in practice an old suggestion by the application of vertical fresh air shafts. But the entrance of air through these shafts has to be regulated. This may be done by a hinged lid on the top, with side cheeks opening towards the wall, or by a diaphragm plate hung on centres in the middle of the length of the shaft, and turned with a brass handle at pleasure. In the next place, dust and smoke blacks find their way into the room along with the so-called fresh air. At first, perforated zinc was put in and failed, then cotton-wool was lightly put over, which upset the whole principle by checking the current which was needed to carry the air to the top of the room, that it might fall like the spray of a fountain by its own gravity, only weakened as its temperature was raised by contact with the upper strata of the air of the room.

The Sanitary Engineering and Ventilating Company have contrived a distinct improvement by making use of the horizontal part of the inlet pipe or elbow which passes through the wall as a trap to catch the blacks, by directing the incoming air through iron plates, set at an angle to cause the air to be thrown on the surface of the water, which is held in a tray over which the air must pass. But this freezes in winter, and at Christmas parties, when most air is required, the chances are it is frozen, and the blacks must enter with the air. This has led to another plan being substituted: a canvas bag of the shape of a dame-school fool's-cap is fixed inside, and the air passes freely enough through the extended meshes, and comes in pure and in sufficient force. The lower in the shaft the bag is fixed the better.

The double-hung rising sashes, which I prefer to any other sort of sashes, give a similar kind of access for air, by simply raising the lower sashes 2 inches and fixing a piece of wood to fill up the space below: between the upper part of the lower sash so raised and the lower part of the upper sash which is closed, there will be a space through which the air will pass in an upward direction. Or the same end may be attained by cutting slots in the meeting rails of the sashes, and fixing hit-and-miss brass ventilators over the slots and so admitting or excluding the air at pleasure. Tonks of Birmingham has presented to the Museum Currall's patent for admitting air vertically through the pierced bottom rail of window sashes covered by metal plates directing the current. By no other means is the introduction of cold air directly from without admitted with an upward current at a low level, except through Pierce's pyro-pneumatic, Boyd's last new hygiastic, and H. S. Snell's thermhydric stove; these and others like them stand free of the wall, and the air is brought from without and passed through vertical shafts within the stove-case into the room.

There are a variety of other stoves, which in summer are to be used as cold air admission inlets, so also there are a great many wall ventilators, but none of them deliver the air into the room with a vertical current. At best it is with a cant upwards at an angle of 45° towards the ceiling, like the Sherringham wall ventilator.

Stevens's drawer ventilator, of which an example may be seen in the Parkes Museum, is an attempt to achieve a vertical current from a side opening, but it is not sightly.

Crossley's improved louvre ventilators, both for the admission and extraction of air, are good of their kind and may be seen here.

Boyd, Batty, Edwards, and heaps of stovemakers, arrange for the admission of fresh air through the stove fronts, and very valuable is this means of inlet, because it can be regulated to a nicety by the handle furnished to open and close the louvres, which, in the case of Boyd's School Board stoves, are provided.

In winter time, the value of the introduction of fresh air through the stove is most obvious, because, by taking off the extreme coldness of the outer air, by causing it to pass over warmed surfaces on its way to replace the air exhausted by the attraction of the fire flue; less amount of fuel is required to heat the air of the room than if it came in at the same temperature as the outer air. It is therefore a matter of economy that influences the rejection of any plan which introduces crude cold air, even though it is done without draught on the Whitehurst principle.

The difference between the temperature of the air in the entrance hall and staircase of a house has led to the introduction of door ventilators, for the admission of the cooler air of the hall through brass hit-and-miss ventilators set in the top rail of the door, but this was found to bring the draught straight down upon the occupants between the door and the fire, and consequently Currall's patent door ventilators were invented, to establish an upward current. This principle has received a further development by the architrave ventilator, an apparatus designed by Mr. Judge, the curator of the Parkes Museum. In ordinary dwelling houses hot-water heating is rarely introduced, but if it were, then a most convenient mode of introducing air is available by passing it through a chamber surrounded by a coil of hot-water pipes.

We have now considered the various means of admitting fresh air, and you will have observed my preference for the preservation of a vertical current. And even where that cannot be obtained I think that air should never be introduced directly, but always through a flue built in the wall at a lower level than the opening into the room, so as to break the force of the wind, but at the same time to encourage a vertical current.

Let us now consider *Extract Ventilators.* At present we have remarked only upon the chimney-flue. But there are occasions when it is desirable to supplement this flue, and sometimes there is no fireplace at all, and consequently no chimney by which to ventilate. But supposing that a fire-place *does exist* it is common to supplement it by other appliances; of these Dr. Arnott's chimney-valve, and its varieties, are the earliest and most generally accepted; they are usually fixed, as you know, near the ceiling and form a communication between the upper air of a room and the heated chimney-flue in winter, when there is a fire. And where there is *no down draught* they answer very well, provided proper inlets for air, equal in area to the outlets, are included in the arrangements. In summer, they are also available as ventilators, but down draught is common in flues where there are no fresh-air inlets, or that have no fire to provoke a partial vacuum and consequent upward current therein, the air descending the sooty flue and penetrating the chinks around the talc flaps, (intended to close tightly but rarely doing so). A disagreeable smell is often introduced by this means. For this and other reasons I am not much in favour of ventilating in this way by the chimney-flue. I prefer that a separate flue should be constructed for this purpose, which, going up with or between the heated smoke flues, is sufficiently warmed to rarefy the air and increase the upward current. This special air-flue should be carefully pargeted or lined with plaster, and should not open at the top of the chimney-stack on the same level as the smoke flues, but should open through metal or slate louvres on opposite sides of the stack and about 3 feet below the top. But if it be objected to, as it often is, by those who cannot abide spending money in any form of ventilation—contenting themselves with Mr. Hinckes Bird's so-called costless ventilation (which of course is infinitely better than *none*, and oftentimes is found more effective than *much* that is made to come very expensive)—I say if it is objected to, that this would be equal to doubling the size of the chimney-breasts and backs, then, *don't do it*, but adopt the simple but most efficient plan suggested by Mr. Boyd thirty years ago, and which I myself have carried out in large and in small buildings, but which is particularly suitable for dwelling houses. Instead of making the withe or division between the flues of solid half brickwork (4½ inches), make it a hollow flue by the introduction of cast-iron flue-plates, the thickness of a slate, leaving a clear 4 inches for a ventilating flue warmed on either side by the smoke-flues between which it is situated, and occupying no more space than the ordinary flue withe. I have used these flue-plates to form extract ventilating flues, for the last twenty years, with uniform success. Ordinarily it will be found that there is a sufficient upward draught in extract flues, such as these which I have now described, to form proper exhaust shafts, provided always inlets for fresh air of the same area also exist. But if from any cause there is a failure in the upward current and a down draught is the result, then there are many simple mechanical means for overcoming the evil. In the first place there are a variety of cowls which are so constructed that the action of wind passing by them shall overcome the stagnation of the air in the flue, and give it a tendency to follow in the direction in which the wind is inclined by the form of the obstruction which the cowl presents to its progress. Such cowls are made by Kite, Howorth, Verity, Boyle, Buchan, Banner, and a host of smoke doctors and house-drain ventilaters, and sanitary reformers generally. Some of these are exhibited in the Parkes Museum. But expired air, ventilating or exhaust shafts, carried up with the smoke flues, and therefore opening to the air on the sides of the chimney-stacks through louvres 3 feet below the top of the stacks, cannot have cowls to help the upward draught. In these cases the motive power may be applied at the foot of the shaft, by the application of a small Bunsen burner gas-jet just within the grating, through which the vitiated air makes its escape into the upcast flue. Such ventilators so furnished are made by Mr. Boyd, of 23, Maddox Street, Regent Street. For many years I have used these appliances, and they may be seen in action at various public buildings erected by me, namely, the National Industrial Crippled Boys' Home, Kensington, in the school rooms and lavatories, the North London Collegiate School for Girls, in the class-rooms and science lecture-rooms, and other buildings.

The introduction of fresh air and the extraction of foul air, simultaneously, both at the upper part of a room, has been attempted with considerable but not unvarying success, by Mr. Potts of Charing Cross and Birmingham. It consists of a metal, or carton pierre, or papier maché, or other hollow cornice, taking the place of the usual plaster cornice, which cornice is divided longitudinally for the whole length of it by a plate attached to the lower portion. The fresh air is admitted from without to the lower horizontal division of the cornice, and is passed into the room through ornamental perforations in the bed mouldings of the cornice. The foul air is extracted through similar perforations in the upper part of the cornice, giving access to the upper horizontal division of the cornice, the outlet pipe from which is taken to an air flue built in the wall, with a cowl on top or a gas jet at bottom, or into a smoke flue, the kitchen chimney flue being preferred as the hottest and most generally available at all seasons of the year, for we must dine ! Mr. Robson, the Architect of the London School Board, speaks in commendation of this plan. He says : "I can speak strongly in its favour for facility of application, sightliness, economy of first cost, and self-acting properties. In the case of new buildings, where warm vertical air flues can easily be provided, its action must be so perfect as to induce a very general adoption of the principles of the system."

But it is time that I passed on to the subject of lighting and warming, not that they can ever be treated without reference to ventilation, but rather because ventilation cannot be studied or practised without due consideration of the mode of heating and lighting, intended to be adopted in the room to be ventilated. Indeed, the temperature of the air within a room and without it, being different in density, in the proportion that either is hotter or colder than the other, is one cause of the pressure of one atmosphere against another atmosphere in search of that equilibrium which nature is ever seeking and never finding for any length of time together. "The whistling wind rushing through the woods and forests, bloweth where it listeth and we cannot tell whence it cometh or whither it goeth," until we have traced to its source the provocative cause, which will be found to arise from variations in humidity and temperature and consequent density of pressure of the heavier against the lighter and brighter atmospheres, with which the former impinges against the latter. Thus the draughts in a room are the result of the pressure of the cold air of the street or passage in its struggle to get to the warm air of the room, and particularly to that part of it whence the heat is generated and projected. Where two rooms are of the same temperature the air is stagnant, that is to say, no movement of the air from one to the other will take place by the opening of a means of communication between them. It is obvious, therefore, that if the whole of the interior of a house were equally warmed there would be no change of air between one part of the house to another, and the building would be in the most favourable condition for the introduction of the means of special ventilation already described. Each room might be separately lighted, warmed and ventilated, and yet the same temperature might be maintained, but with the difference that there would be no stagnation, but pure fresh air warmed as it entered for free inspiration, and withdrawn as by expiration or combustion it became impure.

Now this Utopia is not to be attained if the hall and passages and the staircases be not considered in the general warming of the house—for myself I am much impressed with the economy in heating an interior which comes from first warming the lungs, so to say. The best salvation from the wasteful consumption of fuel, is the withdrawal of the cause of the draughtiness of rooms, arising from the otherwise uncontrollable difference in temperature between the sitting-room and the hall, by the introduction of a good hall fire or other system of warming the entrance hall and staircase.

With reference to the lighting of rooms, of course, the softest and most agreeable method of lighting is by wax candles ; but the expense of this method precludes its general adoption, except in the drawing-rooms and boudoirs of the rich. But there are many candle lamps (with reflectors for reading, and without them for general lighting) which were in common use before the introduction of colza oil, paraffin, and other lamps. The inconvenience attending the preparing and cleaning of such lamps has, however, lessened their use, and the cheapness and ready application of gas has led to its most general adoption. The brilliancy of its light too, when once it has been experienced, adds so to the cheerfulness of the house that it has superseded in a great degree every other. But as Dr. Corfield observes, in the little book I recommended to you in my first lecture, candles, lamps and gas all help to render the air impure. It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man's respiration does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men or even more. This is why it is commonly considered that gas is more injurious than lamps or candles; and so it is, when the quantities of light are not compared; but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles. If, in the dining room, instead of using five or six gasburners, as we too often do, without any provision for the escape of the products of combustion, we used forty or fifty sperm candles instead of six or eight, we should have a fairer comparison between gas and candles. Common sense at once suggests that the products of combustion should be carried away, and the heat generated by the process should be utilized to expedite its removal, and several manufacturers have turned their attention to this desirable end.

Messrs. Strode's sunburner, used for lighting large assembly-rooms, is conceived on this principle. Thirty or forty or more gas-jets are placed close together under an enamelled iron reflector, from which the heated air is conducted, through the roof or floor, to the exterior. This first tube is inclosed in a second tube forming a jacket a few inches from the first, which is employed to withdraw the expired air of the apartment.

Messrs. Benham and Sons have provided a globe light for use in ordinary apartments, which is very ingenious and effective. The globe is suspended from the ceiling and is open at the top; the suspension rod is a hollow tube into which the glass chimney surrounding the burner conveys the products of combustion, which are carried away through tubes to the exterior or into a chimney flue. A metal jacket surrounds this tube in the thickness of the floor, and the ornamental rose, forming the junction between the pendant and the ceiling, is pierced to allow of the exit of the vitiated air of the apartment. But in addition to this, between the rose and the ceiling is a small space through which fresh air is admitted to feed the light, thus at once adding to its brilliancy and replacing the air withdrawn by the extracting tubes.

Messrs. Richardson, Ellson and Co. have many ventilating contrivances and they publish them in a separate catalogue.

A still simpler and less expensive arrangement is Messrs. Faraday and Son's ventilating gas pendant, also exhibited in the Parkes Museum. This pendant is designed to afford a strong concentrated light with means for carrying away the products of combustion. The gas supply pipes are fixed outside the ventilating shaft, which is thus kept clear of obstruction for the purpose of securing a good draught. Screens of opal glass are provided to soften the light which can easily be removed for cleansing. The trumpet-shaped glass, terminating the ventilating shaft, is released by simply pinching the buttons of the spring clip together. The argand burner is fitted with a lever check to regulate the flame. Horizontal extract tubes connect the upper end of ventilating tube with the exterior or flue.

General Franzini has presented to the Parkes Museum his patent globe reflector. This lamp consists of two hemispherical pieces of crystal—one of these is a bottle used to contain filtered water. The other is of opal, in which may be placed gas, oil, electric or any other light. The light placed between the two crystals is magnified by the water; with the globe is included a conductor to carry off heat, smoke and smell from the burning light into the water.

The same person has invented what he terms the "Healthy" gasburner, and presented one to the Museum. It consists of two small burners fixed side by side to secure more perfect combustion, and an increased amount of light, from a given quantity of gas. The two flames blend together in one large flame and give seven times the light, with no greater expenditure of gas and less product from combustion.

The Silber Light Company have a similarly contrived burner, which I have introduced into my own office with great advantage; a special globe is made for it, and the result is a clear, bright, steady flame like an argand.

With regard to gasburners generally, they should be provided with some disc (in steatite or terra cotta), or other means of checking the pressure, and that the orifices should be large and also of some non-corrosive material.

The Brönner and the Bray are good flat flame burners, and the Sugg and the American "regulator" as argands or "ring" flames. Any of these give a good light in proportion to the gas consumed, and are vast improvements upon the burners made of iron or brass, without pressure check, and drilled with very small orifices, such as were commonly in use till the last three or four years.

The Bunsen, or air and gas burner, is still much used for heating purposes, as it has something of the energy of the blow-pipe and makes no smoke. A small one of this class may be seen in Faraday's nursery or kettle bracket in the Parkes Museum, and it is now being adapted for stoves, something on the principle recently advocated by Dr. Siemens.

The electric light will be soon a household thing, and then we shall have no products of combustion to think about, and no injury to our furniture and frames to deplore.

Gas stoves for cooking purposes are various and economical—from the simple ring of gas-jets, mixed or unmixed with air, to the vast machinery in use at the London Hospital, where £400 a year is saved by the use of Leoni's gas cooking apparatus.

Gas stoves for warming are highly convenient, though not at present economical for continuous use ; but for occasional employment they are most economical, and by the arrangement of pumice stones, asbestos, terra cotta lumps, or a combination of all three, very bright and sparkling furnace-looking fires with considerable radiating power are attainable.

Hall stoves may be usefully contrived for burning gas since they need no tending and take no space. But for ordinary room fires it will be long before we shall be able to dispense with wide and open coal fires. Nothing can compare with them in the opinion of the home-loving British public. Certainly nothing is more healthy, cheery or wasteful. We cannot give it up for the close stoves of the Germans or the Americans, and so we may as well turn our minds to its improvement.

The natural process by which the temperature of the air is raised is either by radiation or conduction. Conduction or rather conducted heat is the warmth given off by any surface by direct contact with any substance, whether air or otherwise. Radiated heat is like that of the sun which passes through the air as light without heating it, into the earth or any intervening substance, from which the heat is given off gradually to the atmosphere, creating the difference between sun and shade temperature. Thus it is that the conducted heat of an open fire goes up the chimney—and about a sixth part is radiated into the room, passing through the air without sensibly heating it—but warming the first obstacle to its free passage, such as the inclosing walls and furniture, by which the radiated heat is given off to the air of the room, raising its temperature as required. It cannot be called an economical mode of heating, but it is the most enjoyable and most healthy. All the products of combustion pass up the chimney and draw after them the impurities and denser air of the room lying lowest, whilst the vivifying rays of the crackling fire heat without scorching the surfaces that warm the air of the room insensibly.

The primary but not the exclusive object in the improvement of an open fire stove, must obviously be the increase of its radiating power by reflection from heated polished surfaces in close contact with the fire, and this is done by many of the best stoves. One of the best forms is where the fire-cheeks are of polished steel, set at an angle of 45° with the back of the stove and projecting in front of the fire-bars, so as to receive the brightest radiation—the upper part of the front of the stove being made to be set at a similar angle to the same end and the hearth of encaustic glazed tiles, or covered with a radiating steel fender. Such a stove has an immense power of radiation, and many old fashioned stoves are so constructed.

The latest improvement with this design is the new register stove, patented by Messrs. Comyn Ching & Co., called "The Paramount." In this case the fire-grate or basket is quite disconnected from the brickwork surrounding it, and equally so from the metal case, or shell or encaustic tile lining of the chimney back and sides, excepting only at the point of contact with the bracket which supports it, giving a free space all round. Thus the fire is enabled to radiate as from a centre ; the rays of heat emitted from the back of the fire-basket impinging on the metal reflector, or on the tiled lining of the fireplace, are reflected forward into the room and utilized instead of lost, as heretofore. This back reflection plate and centrally fixed rotary movement of the fire-basket is novel, and calculated to economize fuel, promote cleanliness, insure uniformity of combustion, double the radiating power, and being moveable, may be carried from one room to another. The letters to the *Times* of "Another Country Parson" and the late Mr. Mechi, of Tiptree Hall, drew the public attention to a valuable series of economical slow combustion, yet large radiating fire fronted stoves, made by Messrs. Barnard and Bishop of Norwich. These stoves heat by direct radiation, and have no reflecting surfaces. The bars are six in number, and of various widths to suit the size of the rooms to be heated. They are rightly called the "Front Fire Grate Stove," and are fitted with blowers to encourage the draught at pleasure. The bottom of the grate is closed (which produces slow combustion) and within 4 inches of the hearth to which it slightly inclines ; the sides, back and bottom are of terra cotta.

E, see page 56.—TABLE by Dr. De Chaumont to show the degree of contamination of the air (in terms of carbonic acid) by respiration, and the amount of air necessary to dilute to a given standard of ·6 per 1000 volumes of air, of which ·4 is the carbonic acid naturally existing, and ·2 is from respiration. In the table a deduction is made of the initial ·4 volumes of carbonic acid per 1000 for the sake of clearness :—

Amount of cubic space (= breathing space) for one man in cubic feet.	Ratio per 1000 of carbonic acid from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of ·2, or including the initial carbonic acid, of ·6 per 1000 volumes, during the first hour.	Amount necessary to dilute to the given standard every hour after the first.
100	6·00	2900	3000
200	3·00	2800	3000
300	2·00	2700	3000
400	1·50	2600	3000
500	1·20	2500	3000
600	1·00	2400	3000
700	0·85	2300	3000
800	0·75	2200	3000
900	0·66	2100	3000
1000	0·60	2000	3000

*** Mr. James Mansergh, of Victoria Street, Westminster, writes :—Mr. Rogers Field says that the open-air disconnection between the housedrain and the sewer was a new point of departure. I believe the little gully which bears my name was the first in which this principle was distinctly recognized, although I confined its use to the wastepipes from cisterns, sinks, lavatories, baths, &c., and dealt with the water-closets by carrying the soilpipes above the roofs. I designed this trap in January, 1868, in consequence of having been asked by Mr. Rawlinson to superintend some alterations at the house of Mr. John Simon, then the chief of the medical department of the Privy Council. At that time I ransacked all the yards in Lambeth, but could find nothing to effect what I wanted, namely, first, with certainty to prevent a back flow of foul air into the house ; secondly, to avoid the nuisance of having slops frozen and grating stopped where they were delivered on the surface ; thirdly, to provide a small receptacle which should require frequent attention in place of the large foul grease-traps common in large houses. The cutting off water-closets in addition on the same principle (which I have done for some years), and the provision of an inlet for fresh air, are no doubt most valuable improvements, but with regard to the system devized by Mr. Norman Shaw, although I would not quarrel with the principle I consider the mode of application objectionable. In a house in my neighbourhood there are several bare lead pipes of various sizes, planted against the walls and finished with plain hopper heads nearly under and at no great distance from windows. If there is no actual nuisance to the sense of smell from these openings they are in my opinion needlessly unsightly and unpleasantly suggestive. Where a few pounds' expense are no object I think the following mode of treating a soilpipe, which I have recently adopted in a new house, is less objectionable. On the first floor against an outside wall 18 inches thick were a water-closet and a slop-closet adjoining each other. A chase 9 inches wide and 4½ inches deep from the outside face was left in the wall, and this was made into a 9-inch square chamber by building a 9-inch projection. In this chamber a 4-inch Stanford jointed stoneware pipe was carried up vertically and surrounded with fine concrete. A little below the level of the first floor this pipe was finished with a lead hopper, and the discharge pipes from the two closets were brought from their respective traps and turned down so as to deliver fairly into this hopper. At this point an iron door was built in on the outside for inspection, and then the 9-inch chamber or flue was carried up like a chimney and—pending the result of the battle of the cowls—finished with a plain bell-mouthed terminal. Of course at the low end of the housedrain there is a proper disconnecting chamber and fresh air inlet. In this arrangement, which has answered perfectly, the soilpipe is kept out of the house, is most efficiently ventilated, and in my opinion is in no degree unsightly, because it is taken for an ordinary chimney.

APPENDIX E (*continued*), see page 56.

[To face page 124.

TABLE to show discharge of air in linear feet per minute calculated from Montgolfier's formula. The expansion of air being taken as 0·002 for each degree Fahrenheit, and one-fourth being deducted for friction (round numbers have been taken):—

DIFFERENCE BETWEEN INTERNAL AND EXTERNAL TEMPERATURE.

Height of Column.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30	Height of Column.
10......	88	102	114	125	135	144	153	161	169	176	183	190	197	204	210	216	222	228	233	239	244	249	254	279	10
11......	92	107	119	131	141	151	160	169	177	185	192	200	207	213	220	226	233	239	245	250	256	261	267	292	11
12......	96	111	125	136	147	158	167	176	185	193	201	209	216	223	230	237	243	249	255	261	267	273	279	305	12
13......	100	116	130	140	153	164	174	183	192	201	209	217	225	232	239	246	253	259	266	272	278	284	290	318	13
14......	104	120	135	147	159	170	181	190	200	209	217	225	233	241	248	255	262	269	276	282	389	295	301	330	14
15......	108	125	139	153	165	176	187	197	207	216	225	233	241	249	257	264	272	279	286	292	299	305	312	341	15
16......	111	129	144	158	170	182	193	204	213	223	232	241	249	257	265	273	281	288	295	302	309	315	322	353	16
17......	115	133	148	162	176	188	199	210	220	230	239	248	257	265	274	282	289	297	304	311	318	325	332	363	17
18......	118	136	153	167	181	193	205	216	226	237	246	255	264	273	282	290	298	305	313	320	327	335	342	374	18
19......	121	140	157	172	186	198	210	222	233	243	253	262	272	281	289	298	306	314	321	329	336	344	351	384	19
20......	125	144	161	176	190	204	216	228	239	249	259	269	279	288	297	305	314	322	330	338	345	353	360	394	20
21......	128	147	165	181	195	209	221	233	245	255	266	276	286	295	304	313	321	330	338	346	354	361	369	404	21
22......	131	151	169	185	200	214	226	239	250	261	272	282	292	302	311	320	329	338	346	354	362	370	378	414	22
23......	134	154	173	189	204	218	232	244	256	267	278	289	299	309	318	327	336	345	354	362	370	378	386	423	23
24......	136	158	176	193	209	223	237	249	261	273	284	295	305	315	325	335	344	353	361	370	378	386	394	432	24
25......	139	161	180	197	213	227	241	254	267	279	290	301	312	322	332	342	351	360	369	378	386	394	402	441	25
26......	142	164	183	201	217	332	246	259	272	284	296	307	318	328	338	348	358	367	376	385	394	402	410	450	26
27......	145	167	187	205	221	237	251	264	277	290	302	313	324	335	345	355	365	374	383	392	401	410	418	458	27
28......	147	170	190	207	225	241	255	269	282	295	307	319	330	341	351	361	371	381	390	399	408	417	426	467	28
29......	150	173	194	212	229	245	260	274	287	300	312	324	335	347	357	368	378	388	397	407	416	425	433	475	29
30......	153	176	197	216	233	249	264	279	292	305	318	330	341	353	363	374	384	394	404	414	423	432	441	483	30
31......	155	179	200	219	237	253	269	283	297	310	323	335	347	358	369	380	391	401	411	420	430	439	448	491	31
32......	158	182	204	223	241	257	273	288	302	315	328	341	353	364	375	386	397	407	417	427	437	446	455	499	32
33......	160	185	207	226	245	261	277	292	307	320	333	346	358	370	381	392	403	414	424	434	443	453	462	506	33
34......	162	188	210	230	248	265	282	297	311	325	338	351	363	375	387	398	409	420	430	440	450	460	469	514	34
35......	165	190	213	233	252	269	286	301	316	330	343	356	369	381	393	404	415	426	436	447	457	467	476	522	35
36......	167	193	216	236	255	273	290	305	320	334	348	361	374	386	398	410	421	432	442	453	463	473	483	529	36
37......	170	196	219	240	259	277	294	310	325	339	553	366	379	392	404	415	427	438	448	459	470	480	490	536	37
38......	172	198	222	243	262	281	298	314	329	344	358	371	384	397	409	421	432	444	454	465	476	486	496	543	38
39......	174	201	225	246	266	284	302	318	333	348	362	376	389	402	414	426	438	450	461	471	482	492	503	551	39
40......	176	204	228	249	269	288	305	322	338	353	367	381	394	407	420	432	444	455	467	477	488	499	509	558	40
45......	187	216	241	264	286	305	324	341	358	374	389	404	418	432	445	458	471	483	495	506	518	529	540	591	45
50......	197	228	254	279	301	322	341	360	377	394	401	426	441	455	469	483	496	509	522	534	546	558	569	623	50
Height of Column.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30	Height of Column.

To use the foregoing table, determine the height of the warm column of air from the point of entrance to the point of discharge. Ascertain the difference between its temperature and that of the external air. Take out number from table and multiply by the section area of the discharge tube or opening, in foot or decimals of a foot. The result is the discharge in cubic feet per minute, multiply by sixty—result, discharge per hour.

EXAMPLE.—Height of column, 32 feet; difference of temperature between internal and external air, 17 deg. Looking in the table, we find opposite to 32 and under 17, 375 feet. That would be an area of one square foot.

But supposing our air opening to be only ¾ of a foot, we must multiply 375 by ¾ or 0·75 of a foot.

$$\begin{array}{r} 375 \\ \cdot 75 \\ \hline 1875 \\ 2625 \\ \hline 281 \cdot 25 \end{array}$$

Therefore we get 281 feet (per minute), multiplied by 60=16,860 feet per hour.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

[The foregoing table and description are extracted from *A Manual of Practical Hygiene*, by Edmund A. Parkes, M.D., F.R.S.; fifth edition, edited by F. S. B. François de Chaumont, M.D. London, J. & A. Churchill, 1878.]

REPORT OF THE COUNCIL

OF THE

CITY AND GUILDS OF LONDON INSTITUTE

FOR THE ADVANCEMENT OF

TECHNICAL EDUCATION,

PRESENTED TO THE GOVERNORS AT A MEETING HELD WEDNESDAY, MARCH 25th, 1885.

In presenting to the Governors the Fifth Annual Report of the Institute since its incorporation, your Council have to call attention to various matters of interest in connection with the year's work.

The most noteworthy event during the past year has been the completion of the building of the Central Institution, and the opening of it, on June 25th, by His Royal Highness the Prince of Wales, President of the Institute. A full notice of the proceedings is given in Appendix A. Some delay has unavoidably taken place in the preparation of the fittings; but it is confidently expected that the Institution will be in good working order before the close of the present educational session.

Nothing can be more satisfactory than the progress of the Finsbury Technical College. The number of pupils in the day classes increases year by year, and the evening classes are well attended.

The South London School of Technical Art is continuing its useful work, the development of which in new directions is under consideration.

The number of Technical Classes throughout the country, held in connection with the Institute's scheme of Examination, goes on steadily increasing, and the attendance at these classes is highly satisfactory. A new feature in these examinations are the tests of technical skill in workmanship, which are being gradually added to the requirements for a certificate.

As announced in the last Report, your Council lent a portion of the Central Institution, then unoccupied, to the International Health Exhibition, for the display therein of some of the appliances and results of technical schools here and abroad. This part of the exhibition was most successful. An interesting feature in it were the exhibits from the Finsbury Technical College, which obtained from the Jury the award of a Certificate of Honour.

In connection with this Exhibition, an International Conference on Education was held, under the Presidency of Lord Reay, during the week commencing August 4th, 1884. This Conference was numerously attended by representatives from all parts of Europe, from the United States, and from other countries. In the Technical section, to which Professor Armstrong contributed a paper on Science Teaching, the introductory address on "Problems in Technical Education" was delivered by Mr. Philip Magnus, and the papers and discussions on the various subjects have since been edited by Mr. Richard Cowper and published in four large volumes. As an indication of the appreciation by the Executive Council of the Health Exhibition of the services rendered by this Institute, in lending to them a portion of the Central Institution, the valuable educational section of the library of the Exhibition has been presented to the Institution.

Your Council gladly avail themselves of this opportunity of expressing their thanks to the Corporation of London for founding a scholarship of £50 a-year, tenable for three years at the Central Institution, in memory of His Royal Highness the late Duke of Albany, whose services to the Institute in laying the foundation stone of the Finsbury Technical College are still gratefully remembered by the Council. It is to be hoped that this memorial scholarship may continue to be annually awarded by the Corporation.

Your Council are equally thankful to Lady Siemens for having placed at their disposal the sum of £1,500 for the foundation of a similar scholarship, in memory of the late Sir William Siemens, one of the representatives of the Goldsmiths' Company on the governing body of the Institute. With the view of more closely associating the memory of Sir William Siemens with that branch of Applied Science in which he took so deep an interest, Lady Siemens has kindly promised to found a Memorial medal to be given, each session, to the most proficient student of the Central Institution in the Department of Electrical Engineering.

The thanks of the Institute are also due to the Trustees of the Mitchell City of London Charity, who have prepared a scheme for the annual award of two scholarships of £30 a-year, each tenable for two years at the Central Institution, and of four exhibitions of the same amount tenable for two years at the Finsbury Technical College. With the view of increasing the value of one of these scholarships, the Council have agreed to grant free education at the Central Institution to the candidate recommended to receive it. These scholarships, and the very generous gift of the Clothworkers' Company of three scholarships of £60 a-year, tenable for three years, one to be awarded annually, referred to in the last Report, will be the means of enabling several deserving and talented students in humble circumstances to profit by the instruction given in the Institute's colleges.

Your Council attach great value to such scholarships, as placing the highest technical instruction within the reach of the poorer classes; and they trust that in the liberation of trust funds from purposes to which they are no longer applicable, the advantages of founding such scholarships may be duly considered.

An event of some importance in the history of the progress of technical education in this country was the issue, in May last, of the first two volumes of the Report of the Royal Commissioners on Technical Instruction. This Report deals with the state of technical education in the principal countries of Europe and in the United States, and with the influence of such education upon the improvement of trades and of manufacturing industry. The Report contains most favourable notices of the value of the work initiated and controlled by the City and Guilds of London Institute, and the section of it devoted to the description of this work concludes with the statement from which the following is an extract:—

" Your Commissioners are able generally to endorse the several " schemes of technical instruction now in operation or about to be " carried on by the City and Guilds of London Institute; and, in " view of the efficient and permanent working of these schemes, we " should be glad to see the funds of the Institute made fully adequate " to the efficient carrying out of the objects it has in view, which, " in our opinion, is not yet the case."

The annual distribution of prizes to the students of the Finsbury Technical College, and of the South London School of Technical Art, as well as to the successful candidates at the recent Technological Examinations, who were examined at Finsbury, was held on December 4th, 1884, at the Fishmongers' Hall, the Right Hon. the Lord Mayor, Mr. Alderman Nottage, being in the Chair, when your Chairman, the Lord Chancellor, delivered an address, which, together with a full account of the proceedings, will be found in Appendix B.

I. Central Institution.—As stated in the previous Report, the cost of erecting the building, exclusive of Architect's fees and of fittings, was expected to amount to £75,000, and it will be seen from the financial statement that this sum is not likely to be exceeded. At a meeting of the Council, held on February 25th, it was decided that a special appeal should be made to the Corporation and to the Livery Companies of London, with the view of raising the necessary funds for the provision of fittings and of apparatus, which it had been estimated would involve an outlay of little less than £20,000. The matter having been brought under the notice of His Royal Highness the President, by the Treasurer of the Institute, Sir Sydney Waterlow, His Royal Highness addressed the following letter to the Lord Mayor and to the Master of each of the Livery Companies of London :—

"MARLBOROUGH HOUSE,
"PALL MALL, S.W.,
"*March*, 1884.

DEAR SIR,

"As President of the City and Guilds of London Institute, "I have marked with considerable interest and satisfaction the "progress that the Institute has already made in promoting "Technical Education in London and in some of the principal "manufacturing centres of the Kingdom, and I commend to your "careful consideration the accompanying Report of the Governors, "in which you will find an account of the useful and varied work "now being carried on under its auspices.

"The Report shows that the Institute is greatly in need of funds "for the equipment and maintenance of the Central Institution, as "well as for the development of other branches of its operations.

"While fully aware of the valuable assistance which many of "the Guilds have already rendered to the cause of Technical "Education, I shall be much gratified, considering the importance "of the Institute's work in relation to the commercial prosperity of "the country, if the Corporation and the Livery Companies of "London will further extend their help by placing such funds at "the disposal of the Institute as shall enable the Council to success- "fully continue the efforts they are making for affording Technical "Instruction to persons of all grades engaged in industrial pursuits.

"I am, dear Sir,
"Yours faithfully,
"ALBERT EDWARD."

The result of this appeal was that the Corporation voted £1,000, and that the sum of £16,416. 5s. 0d. was promised by fifteen of the Guilds of London, as follows:—

Mercers' Company, £2,000; Grocers' Company, £1,000; Fishmongers' Company, £4,000; Goldsmiths' Company, £4,000; Skinners' Company, £1,000; Salters' Company, £525; Clothworkers' Company, £2,000; Dyers' Company, £105; Leathersellers' Company, £500; Tallow Chandlers' Company, £105; Armourers and Braziers' Company, £300; Carpenters' Company, £500; Cordwainers' Company, £250; Scriveners' Company, £105; Clockmakers' Company, £26. 5s.

The readiness with which His Royal Highness gave his valuable assistance in soliciting additional help from the Companies may be accepted as a further proof of the interest which he has always shown in the work of the Institute.

The Committee, recognising the importance of appointing, without delay, under the scheme sanctioned by the Council at their meeting on February 4th, 1884, the four principal Professors, with the view of obtaining from them advice and assistance in the preparation of the fittings, proceeded to elect gentlemen for these important posts ; and Professor Armstrong, F.R.S., of the Finsbury Technical College, Professor Ayrton, F.R.S., of the Finsbury Technical College, Professor Henrici, F.R.S., of University College, London, and Professor Unwin, of the Royal Engineering College, Cooper's Hill, were appointed to the Chairs of Chemistry, of Physics, of Mechanics and Mathematics, and of Engineering respectively. The plans for the preparation of the fittings have involved a considerable amount of labour; but a large portion of the work is now in hand, and it is expected that the Institution will be open for the reception of students, in all the more important departments, during the current session. Arrangements are being made for special courses of lectures and laboratory work to commence in June, to which the registered teachers of the Institute will be admitted without payment of fees. Your Council are persuaded that if the Institute's teachers avail themselves of the educational advantages to be thus placed within their reach, a gradual but important improvement will be shown in the work sent up by the candidates at the Technological Examinations.

To give effect to the objects of the Central Institution, as set forth in the scheme of organisation appended to the last Report, very much larger funds will be required than the Council at present possess. It is estimated that about £15,000 a-year will be needed for this purpose; and it is a matter of regret to the Council that in consequence of the demands on its funds of other departments of the Institute, which are already in operation, they are only able to apportion £8,800 towards the current expenses of the College. It is expected, however, that this year, owing to the Central Institution not being in full working order, and to the provision of apparatus from the funds specially collected for the purpose, the grant of £8,800 will suffice.

Your Council call attention to the important facts that during the past year the new buildings of the Ecole Centrale at Paris, erected at a cost of £260,000, have been completed, and that a new Polytechnic School, erected at a cost of £340,000, has been opened in the capital of the German empire. The sums spent on these institutions, partly contributed by the State, and partly derived from other public sources, indicate the importance which foreign countries attach to the provision of higher technical instruction.

II. Finsbury Technical College.—The first complete session of the Finsbury Technical College terminated on July 16th, 1884. The results of the session's work were most satisfactory.

In the Day Classes, 108 students were in regular attendance, taking the complete courses as laid down in the Programme. Of these, 71 entered the Department of Electrical Engineering, 20 that of Mechanical Engineering, 14 the Chemical Department, and 3 that of Building Trades.

The fees received on account of the Day Students during the Session amounted to £831. 16s. 0d.

Of the 108 day students, 12 were admitted without payment of fees, viz.:—6 from the Cowper Street Middle Class Schools, 1 from the Mercers' School, 1 from the United Westminster Schools, 1 from the Brewers' Company's Schools, 1 from the Haberdashers' Company's School, 1 from the City of London School, and 1 from the Coopers' Grammar School, in addition to the holder of the Holl Scholarship, a pupil of the United Westminster Schools.

In the Evening Classes, 876 tickets were sold to 685 individual students.

Of the 876 tickets, 112 composition tickets admitted the students to any of the classes of the College. Of the remaining 764, 199 were taken for Physics and Electrical Technology, 122 for Chemistry, 137 for Mechanical Engineering and Mathematics, 158 for Applied Art, and 86 for Trade Classes (Metal Plate Work, Plumbers' Work, Carpentry and Joinery, and Bricklaying), 45 for Practical Geometry, and 17 for the course on Gas Engines. Of the 112 students who paid composition fees, several attended the special course of lectures on Gas Engines.

It is again satisfactory to report that as many as 123 tickets were taken by apprentices, who, on producing their employers' certificate, were admitted at half the ordinary fees. Of these apprentices, 12 paid composition fees, 13 entered the Physical Department, 4 the Chemical Department, 23 the Mechanical Department, 53 the Applied Art Department, and 18 the Trade Classes.

At the commencement of the new Session in October last, there was a considerable increase in the number of day students who presented themselves for the Entrance Examination, and a noteworthy improvement was shown in the state of preparation of the candidates.

Of the 81 candidates examined, 65 were admitted. At the examination at the commencement of the Easter Term, the admission of 12 new students was sanctioned.

The day students now in the College are distributed in the several Departments as follows :—

	1st year.	2nd year.	Total.
Electrical Engineering Dept. .	53	29	82
Mechanical ,, ,, .	29	13	42
Chemistry.	12	6	18
Building Trades / Applied Art } . .	6	...	6
	100	48	148

Of these 148 students, 9 have been admitted without payment of fees, viz. :—6 from the Cowper Street Schools, 1 from the United Westminster Schools, 1 from the Haberdashers' Schools, Hoxton, 1 from the City of London School, in addition to the holder of the Holl Scholarship, a pupil of the Cowper Street Schools.

Hitherto, these free students have been admitted on the recommendation of the Head Master of their School, without passing the Entrance Examination, but the Sub-Committee are considering the advisability of requiring these candidates to go through the same examination as other applicants before being admitted to the College.

The success of the Day Department of the College has been very marked, as may be seen from the fact, that at the opening of the College, in February, 1883, the number of Students increased from 29 to 98, and that although students have been subsequently admitted only after passing an Entrance Examination, the number has now increased to 148. It is interesting to note that the Finsbury Technical College serves not only for the technical instruction of selected pupils from some of the more important Middle Class Schools of the Metropolis, but that among the students are many who have received their early education at schools in the provinces.

The Exhibitions and Scholarships established by the Trustees of the City of London Mitchell Charity open the Finsbury College to pupils from Public Elementary Schools, and enable some of these to continue their education at the Central Institution. Under this Trust, five pupils were admitted to the College in October last, with Exhibitions of the value of £30 per annum.

In the Evening Department, the attendance since October last has also been satisfactory. In the term ending December, 1884, 533 class tickets were sold to 482 individual students. The number of Students on the College Register in the several classes was as follows:—Machine Design, 72; Practical Mathematics, 43; Practical Geometry and Metal Plate Work, 56; Electrical Technology, 147; Practical Physics, 39; Inorganic Chemistry, 70; Organic Chemistry, 13; Drawing and Design, 134; Gas, 28; Carpentry and Joinery, 34; Bricklaying, 4.

In the Applied Art Department, several students have received instruction in Tapestry Painting, and it is expected that many of these will thereby be able to obtain remunerative employment.

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A special feature of the Evening Classes are the complete courses of instruction that have been drawn up as a guide to artizans engaged in different industries, and 86 of the evening students have taken tickets for these complete courses.

During the past term, 118 apprentices have been admitted to the College at half fees, 10 of whom have entered the Physical Department, 3 the Chemical, 32 the Mechanical, 60 the Applied Art Department, and 13 the Trade Classes.

The students' fees during the past term have amounted to £1,178. 6s. 0d. Of this sum £843. 10s. 0d. was received in the Day Department, and £334. 16s. 0d. in the Evening Department.

The Council hope, in the future, to give greater prominence in the curriculum of the College, to the course of instruction to be pursued by those who are preparing to enter some branch of the Building trade, and they are only waiting for further funds to enable them to extend the building with the view of giving practical instruction, during the daytime, in Applied Art, and of increasing the number of Trade Classes for artizans.

The appointment of gentlemen to fill the vacancies caused by the election of Professors Armstrong and Ayrton to the Chairs of Chemistry and Physics at the Central Institution is now engaging the attention of the Committee; and in the rearrangements consequent on these changes it has been thought desirable that one of the Professors should discharge the duties of Principal of the College, temporarily undertaken by Mr. Philip Magnus, whose other duties, as organizing Director and Secretary, now occupy too large a portion of his time to enable him to continue to hold this post.

The total cost of the maintenance of the Finsbury Technical College during the year ending December 31st, 1884, has amounted to £7,292. 13s. 5d., including £407. 11s. 10d., the cost of permanent apparatus, as against £6,483. 5s. 7d. in the previous year.

The students' fees have also increased from £1,391. 19s. to £1,483 3s. 6d.

III. South London School of Technical Art.—The attendances at the several classes of the school during the session ending July, 1884, was as follows :—

Subjects.	Male.	Female.	Total.
Modelling	53	7	60
Design (Elementary)	9	30	39
Design (Advanced)	9	11	20
Wood Engraving	7	14	21
Life Classes (Drawing and Painting) . .	27	7	34
	105	69	174

By comparing this statement with that contained in the last Report, it will be seen that the attendance has increased from 155 to 174.

The greatest proportional increase has been in the class for wood engraving, which now numbers 21 as against 16 last year.

As regards the total increase, it may be noted that it consists almost entirely of male students.

The occupations of the students who have attended the school during the past year have been as follows:—40 designers, 23 wood engravers, 21 stone carvers, 14 China painters, 12 art students, 9 teachers, 6 modellers, 6 clerks, 6 lithographers, 5 draughtsmen, 3 pattern makers, 3 wood carvers, 2 mould makers, 1 cabinet maker, 1 steel engraver, 1 chemist, 1 bootmaker, 1 artist, 1 commission agent, 1 embroiderer, and 4 as no occupation.

The total cost of maintaining the school during the year 1884 has amounted to £1,217. 18s. 10d., and the students' fees have amounted to £132. 16s. 0d.

It has been proposed, that a class for instruction in ornamental wrought-iron work should be established in connection with the South London School, and the suggestion has been made that the workshops of a local firm, whose efforts to revive this art-industry have recently attracted some attention, might be made use of for this purpose.

If this suggestion is adopted an additional grant will be needed. There are other technical processes which might with advantage be carried on in connection with the South London School and which might be the means of creating or reviving industries in this country, if sufficient funds could be placed at the disposal of the sub-committee.

IV. Technological Examinations.—From the Director's Report, given in Appendix C, it will be seen that the number of Candidates who presented themselves for examination in May, 1884, was 3,635, showing an increase of 1,238 on the previous year. This is the largest increase that has yet occurred in any two consecutive years during which the Examinations have been held. Comparing the results of the Examination in 1884 with those in 1883, we find that whilst in 1884, 3,625 candidates were examined at 164 centres in 43 subjects, of whom 1,829 passed; in 1883, 2,397 candidates were examined at 154 centres in 37 subjects, of whom 1,498 passed.

The addition of practical tests to the written examinations previously held constitutes a new and important feature in the conduct of these Examinations. The Council are very desirous that these Examinations should serve the double purpose of improving the trades in connection with which the Examinations are held, and of affording a test which shall satisfy employers that the holders of the Institute's certificates are competent workmen, and at the same time practically acquainted with the scientific principles underlying the details of their trade.

In addition to the practical examination in Mine Surveying, held at the Peases West Collieries and occupying three days, practical examinations have this year, for the first time, been held in Weaving and Pattern Designing, and in Metal Plate work. In Weaving and Pattern Designing, a candidate is required, in addition to his written examination, to design an original pattern, to weave it in suitable material, and to furnish the Examiners with full particulars of its cost of production.

This year, for the first time, will be held a practical examination in Carpentry and Joinery.

The Institute is now endeavouring to arrange for similar Examinations, to take place simultaneously in some of the principal towns of the kingdom, in Printing; and the Council hope gradually to organise practical tests of the skill of artizans in other subjects. It is proposed that the specimens of work sent in by the Candidates shall be annually exhibited in the rooms of the Central Institution.

Nothing is more satisfactory than the influence which these Examinations have exerted in the progress of Technical Education throughout the country; and, in the report of the Royal Commissioners on Technical Instruction, abundant testimony is afforded of their usefulness. To this testimony the Lord Chancellor, in his address at the Fishmongers' Hall (Appendix B), makes an important reference. The Commissioners, however, further state: "The City Guilds "are trying a most important experiment in their practical "classes. If empiricism be avoided, a great point will be "gained by the attraction to working men and women of a "mode of instruction in which the direct application of "scientific principles is the means by which a knowledge of "those principles is conveyed to their minds. As to this point, "we refer to the almost unanimous expression of opinion con-"tained in the letters of eminent manufacturers, in reply to "our circular asking their advice as to the best means of "promoting technical instruction."

In pursuance of a requisition from the new Technical School at Leicester, to the erection of which the Institute has contributed £700, the Council have added to the Programme of Examinations, recently issued, the subjects of Boot and Shoe Manufacture and of Framework Knitting. Classes in these subjects have already been established, the students of which, it is expected, will present themselves for the Institute's Examination in May next.

From the returns received at the office of the Institute, it appears that the number of persons who are receiving technical instruction in the registered classes of the Institute continues to increase. The returns show that, in addition to the students who are attending classes at University College and King's College, London, the Finsbury Technical College, the Owens College, Manchester, the Yorkshire College, Leeds, and other similar institutions, from which a large number of candidates presented themselves at the recent examinations, 6,396 persons are studying 34 subjects, in 263 classes, in various parts of the United Kingdom. In most of the subjects, the number of students in attendance at the Institute's classes is about the same this year as it was last year; but an important increase is shown in the attendance in Weaving and Pattern Designing, in Dyeing, in Plumbers' Work, in Lace Manufacture and in Carriage Building.

The Council hope, in accordance with statements in previous reports, to connect the work of these Examinations with the instruction to be given at the Central Institution. They anticipate a considerable improvement in the character of the teaching afforded in the classes affiliated to the Institute by the arrangements which will be made for the instruction of teachers at this Institution. At the recent Examinations, 49·7 per cent. of the candidates failed to satisfy the Examiners, and these results clearly indicate that the teaching is not yet as satisfactory as it is hoped it will be.

In the scheme for the organisation of the Central Institution, appended to last year's Report, special provision has been made for the instruction of the Registered Teachers of the Institute; and in connection with this important question your Council think it might be desirable to organise a series of Trade Exhibitions, which might be annually held at the Central Institution in the rooms not yet occupied, and which would serve to illustrate processes of manufacture and some of the improvements in machinery, &c., connected with the several trades to which the Institute's Examinations refer. Exhibitions of this kind might be held in such subjects as Plumbers' Work, Carriage Building, Metal Work, Gas Manufacture, and other industries included in the Programme.

The list of Registered Teachers is now undergoing revision, in order that a record may be formed of the qualifications of each instructor, and also of the amount of success which has attended his teaching, as shown by the number of his students who have passed the Examinations. When complete, this Register will afford material assistance in the selection of candidates for the proposed Summer courses at the Central Institution.

The total cost of the Examinations for the year 1884 amounted to £3,054. 15s. 7d., or about 16s. 9½d. per candidate, as compared with £1. 2s. 3½d., the average cost per candidate in 1883.

V.—GRANTS IN AID OF OTHER INSTITUTIONS.—(A) *Metropolitan Schools and Colleges.*—From the following statements, it will be seen that satisfactory work has been done in the several Metropolitan schools to which the Institute has continued its former grants.

University College and King's College, London.—The grants of £400 a-year to each of these Colleges have been continued. There has been an increase in the number of students attending the courses of instruction in Mechanical Engineering during the past year; and especially in the case of the Laboratory, in which many of the students are engaged in experimental work connected with Elasticity, Strength of Materials, &c.

Several students nominated by the Institute have received gratuitous instruction in the Laboratory under Professor Kennedy.

At the time of the last year's annual report there were in the Department of Chemical Technology, under Professor Graham, 20 students working in the Laboratory and 30 attending Lectures; there are now 30 attending the Laboratory, and 60 the Lectures. It has recently been necessary to greatly enlarge the Laboratory by adding rooms for Metallurgical, Microscopic, and Polarimetric work, together with a Museum for specimens of raw and manufactured products.

The students of this Department obtained several silver and bronze medals at the last May examination. During the year ending July, 1883, of the students who presented themselves at the May Examination of the Institute, no less than 8 obtained good situations, and for the year ending July, 1884, there were 7 such cases. Since January 1, 1885, three students have left the Laboratory to fill positions of trust, of whom two are medallists of the Institute; and in every instance quoted, the students obtaining those situations had previously passed the Honours Examination of the Institute in the First Class. Professor Graham again reports that he finds the Institute's Examinations of great value in stimulating the work of the students.

At *King's College,* the work in the Metallurgical Department has progressed satisfactorily. The various classes held during the year have been attended by 102 students, as against 74 in the previous year. In the evening classes, 32 students have attended the course of Lectures, of whom seven have been admitted, without payment of fee, on being nominated by the Institute; and of the 32 in attendance at the Laboratory, nine have been similarly admitted. The want of more thorough and systematic instruction in "Fuel" induced Professor Huntington to commence in October last a course of evening lectures specially devoted to that subject. Judging from the number of candidates who present themselves for the Institute's Examination in Fuel, it would seem that this subject, of prime importance in all manufacturing work, has not yet received the special attention which it merits from those engaged in technical education.

Professor Delamotte reports that considerable progress has been made in the work in the School of Practical Fine Art. The Council of King's College have admitted ten additional free students, who have been selected from the apprentices of some of the leading firms in London.

School of Art Wood-carving, Royal Albert Hall, London.— The satisfactory progress of this school has been maintained. The number of students in 1884 was 73, as against 72 last year. At the same time, there is an increase in the average period during which each student has remained in the school.

The distribution of the students in 1884 has been as follows:—

	Free Students.		Fee-paying Students.		Total.
	Male.	Female.	Male.	Female.	
Day Classes . .	7	5	14	24	50
Evening Classes . .	17	1	3	2	23
	24	6	17	26	73

Among the more noteworthy works executed in the School during the year 1884, the following may be mentioned. A carved picture-frame for J. C. Hook, Esq., R.A.; two carved oak architraves, 5 feet by 3 feet, for the Earl of Wharncliffe's billiard room at Worsley Hall; some carved Italian bellows, Italian frame and several panels and studies, as well as a carved piano back, carved fire-place and Flemish chair.

At an Art exhibition held at Eastbourne in October, the School took the highest award for wood carving, and Miss C. Williams, a pupil from the School, was awarded a certificate of merit as demonstrator for wood-carving and modelling during the exhibition.

In the educational section of the International Health Exhibition at South Kensington the School was awarded a silver medal; Miss M. E. Reeks, assistant teacher, obtained a silver medal; and Miss H. E. Wahab and Mr. D. Chisholm, pupils in the School, each a bronze medal.

Classes under the direction of one of the pupils of the School have been successfully started in Dublin, in Cork, and in some of the surrounding villages, and one has also just been commenced at Keswick. The number of village schools throughout the country, in which wood-carving is taught, in the afternoons and evenings, to the children attending elementary schools is increasing, and several of the teachers who give instruction to these children have received their training at the Royal School of Art Wood Carving.

British Horological Institute.—The subsidy of £350 a-year to this School has been continued.

During the past session, 20 students have received practical instruction in the workshop in the various branches of watch-making on Mondays, Tuesdays, Wednesdays, Thursdays and Fridays, from 10 till 5. Besides the practical teaching in the day school, theoretical instruction is given on Tuesday and Thursday evenings, the course being attended by the day students as well as by others. The workshop accommodation has been much increased, in consequence of the large number of applicants for admission to the practical classes. The progress of some of the older students has led to a demand for instruction in the more advanced branches of the art of watch-making, and Wednesdays have accordingly been devoted to the teaching of "Springing" and "Timing." An Evening Class for practical instruction is held on Mondays, Wednesdays and Fridays, and is regularly attended by twelve students. On Tuesday and Thursday, evening classes are held for instruction in Mechanical Drawing. The classes for instruction in Mechanics and Theoretical Horology and for Drawing are each attended by thirty students. Most of the students attending these classes presented themselves for the Institute's Examinations in Watch and Clockmaking, and several have satisfied the Examiners.

Society for Promoting Employment of Women.—Of the sum of £100 placed by the Council at the disposal of the Sub-Committee for the payment of Apprenticeship Fees, £85 has been devoted, on the recommendation of Miss King, the Secretary of the Society for Promoting the Employment of Women, to the apprenticeship of six girls. Three of these have been apprenticed to decorative artists, and three to printers.

(B.) *Provincial Branch Institutions.*—Your Council refer with satisfaction to the encouraging results of the grants that have been made to provincial schools.

Sheffield.—The movement for the establishment of technical classes in connection with Firth College, Sheffield, has made rapid progress. The donations received up to Christmas, 1884, amounted to £10,375, including £3,000 from His Grace the Duke of Norfolk and £2,000 from Mr. F. T. Mappin, M.P., and subscriptions, for five years, amounting to £845 per annum, have been promised. This sum includes the conditional grant of £300 per annum, for five years, made by the Institute towards the establishment of a School of Practical Engineering. Mr. W. H. Greenwood, Assoc. M.I.C.E., has been already appointed Professor of Metallurgy and Mechanical Engineering, and Mr. W. H. Ripper, A.I.M.E., Assistant-Professor of Mechanical Engineering.

Pending the completion of the workshops, laboratories and lecture rooms of the technical school to be opened in October, courses of instruction are being given at Firth College in Geometrical and Machine Drawing, Metallurgy, &c. Besides the day courses, Professor Greenwood will deliver an evening course of eight lectures on Fuel, during the Lent term, and Professor Ripper will give evening courses of instruction in Geometrical and Machine Drawing.

The proposed arrangements for the Session 1885–86, are now published. The prescribed course for the Engineering Diploma will extend over three years, but a Junior Certificate may be obtained at the end of two years. There will be an entrance examination in Elementary Mathematics, very similar to that at Finsbury, for students wishing to enter for the Engineering course. The Metallurgical course will extend over two years.

Leicester.—The Technical School, Leicester, towards the completion of which your Council have granted the sum of £700, was formally opened on November 20th by Sir Henry Roscoe. Sir Sydney Waterlow, M.P., and Mr. Philip Magnus were present on behalf of the Institute. It will be remembered that the grant by the Institute was made with the view of enabling the Committee to erect a new wing to the Wyggeston Schools for the accommodation of artisans' classes in subjects having special reference to the teaching of the principles of Hosiery and of Boot and Shoe-making, the staple industries of the district.

The classes commenced on February 3rd, and are held on three evenings in each week. Already, 129 students have entered the class in Boot and Shoe-making, and 88 the class in Frame-work Knitting. Mr. W. J. Rowlett and Mr. C. W. B. Burdett, have been appointed instructors. Besides the technology of these industries, the instruction comprises the Anatomy of the Foot, Geometrical and Freehand Drawing, and elementary science.

A school for Hosiery has for some time been in existence at Limbach, in Saxony, a full account of which is given in Mr. Felkin's book published for the Institute ; but the school at Leicester is the first that has been established in this country.

Manchester.— The second instalment of the Institute's promised contribution of £200 a year for five years to the Manchester Technical School has been paid. The session, 1884—85, of this School opened with a very great increase in the number of students attending the Science, Art and Technical Classes, due, doubtless, to the very successful results of the previous session, and to the efficient arrangements made for teaching in the various departments.

The Council of the school report that a very honourable position was gained at the technological examinations of 1884, 107 students, all strictly members of the evening classes, being successful, as compared with 69 in 1883. They gained 11 first class honours, 11 second class; 35 first class ordinary, 51 second class; 3 silver and 12 bronze medals, and £45 in money prizes. The school stands first in the kingdom in respect of its awards in medals. This Session, 11 Classes are held in 14 subjects of technology, embraced in the programme of the technological examinations as well as in 7 other technical subjects not so included, namely, Staircase-making, Masonry, Bricklaying, Practical Joinery, Practical Mechanical Engineering, Wood-carving and Dressmaking.

The number of evening students in subjects included in the Programme of the Institute, is 344 ; in other technological subjects, 107. This is exclusive of 1,365 students in the evening Science and Art Classes.

The utmost resources of the building are taxed to supply the requirements of the various departments.

New tools have been added in the department of Mechanical Engineering, as well as additional looms and appliances in that of Weaving and Designing.

A complete course of theoretical and practical instruction in Mechanical Engineering for day students is arranged, and is attended at present by 18 students.

Through the munificence of Messrs. Dobson and Barlow, of Bolton, a range of machinery from the Carding-engine to the Mule, illustrative of the various processes of cotton-spinning has been set up, and is now in full operation.

Nottingham.—The Engineering Department of University College, Nottingham, towards the establishment of which the Council agreed to contribute £300 a-year for a period of five years, besides a donation of £200 for the purchase of apparatus, has made satisfactory progress during the past year. Students who are qualifying for the Engineering profession attend in the day time, spending most of their time in the workshops, and the remainder in the Machine Drawing class and at lectures. Electrical Engineering students spend part of their time in the physical laboratory and part in the workshops. The day students construct engines, lathes, and dynamos for themselves, and also assist in the general work of the establishment.

In the evenings the shops are open for the benefit of artisans.

Technical Classes are now carried on in Mensuration and Mechanics, Fitting, Turning and Foundry, Lace Manufacture, Carpenters' Work, Mechanical Engineering, Use of Tools, Iron and Steel Manufacture, Practical Telegraphy, Electric Lighting, and Electrical Measurements. The number of tickets taken for these classes was 564.

The annual income of the Technical School is now about £750, inclusive of the £300 contributed by the Institute. The annual expenditure is about £950, and it is expected that the deficit will be soon covered by local and other subscriptions.

Dr. Ryan has succeeded Professor Garnett as Professor of Mechanics and Engineering, on the appointment of the latter to the Principalship of the Durham College of Science, Newcastle-on-Tyne.

Pulborough.—The grant of £25 made by the Council towards the expenses of a school for Wood Carving at Pulborough has enabled instruction in this Art to be given to 20 young persons. An application for an increased grant has been received from the Secretary, Mr. W. L. Bourke, and is now under consideration.

Petworth.—In response to an application for a grant towards the establishment of a similar school at Petworth, a grant of £10 has been made by the Council towards the purchase of tools.

It will be seen from the preceding statements that the grants of the Institute have been of great service in enabling the supporters of the schools to obtain subscriptions from local sources; and your Council have reason to be satisfied that their grants have been made with judgment and discrimination. During the past year many deserving applications have been received from London and from the provinces, which the straitened financial condition of the Institute has prevented the Council from entertaining. Your Council believe that much good may be effected by assisting in the establishment of Technical Schools in some of the chief centres of industry, and by affording help to existing educational institutions, the authorities of which are endeavouring to add to their curriculum instruction in technical subjects.

VI. Finance.—The gross income of the Institute during the past year has amounted to £25,864. 18s., as against £25,986. 5s. in the previous year.

The income is made up as follows :—	£	s.	d.
Subscriptions	24,122	10	0
Dividends and Interest . . .	81	0	11
School Fees, &c.	1,661	7	1
	£25,864	18	0

The subscriptions show an increase of £652. 10s. The diminution of income is due to loss of dividend, consequent on the sale of the sum of £20,000 New Three per Cent. Stock, temporarily invested until needed to pay for the cost of the buildings. The school fees show a slight increase.

The total expenditure during the past year in connection with all branches of the Institute's operations has amounted to £17,346. 11s. 8d., of which sum £923. 19s. 10d. belongs to current expenses of the Central Institution, incurred since the appointment of the Professors. Deducting this sum, the expenditure on the other branches of the Institute's work has amounted to £16,422. 11s. 10d, which is only £122. 11s. 10d. in excess of the amount approved by the Council at their meeting in February, 1884, and included in the Report adopted by the Governors. In October last, the Council made an extra grant of £250 for the purchase of additional apparatus at the Finsbury College, and it will be seen therefore that the total expenses of the Institute have been kept well within the whole amount sanctioned.

The items of expenditure are given in the following table, as also the corresponding items for the preceding year :—

	1884.			1883.		
	£	s.	d.	£	s.	d.
Finsbury Technical College	7,292	13	5	6,483	5	7
Technological Examinations	3,054	15	7	2,671	13	5
South London School	1,217	18	10	1,381	9	8
Provincial Grants	1,185	0	0	1,150	0	0
Metropolitan Grants	1,485	0	0	1,500	0	0
Holl Scholarship	19	17	10	——		
Expenses of Administration	2,167	6	2	1,999	13	9
	16,422	11	10	15,186	2	5

The gross expenses of the Finsbury Technical College have been somewhat in excess of the amounts voted, viz., £6,750, but in the sum of £7,292. 13s. 5d. is included the Professors' share of the students' fees, the amount of which, of course, increases with the number of students in attendance at their classes. It also includes a sum of about £20, being the value of the materials in hand on sale to the students. The students' fees have amounted to £1,483. 3s. 6d., as against £1,391. 19s. in the previous year.

In future, in accordance with a resolution of the Council passed at a meeting held on October 28th, the College will receive a grant of £6,000 a-year from the funds of the Institute in addition to the students' fees.

The sum expended in payment of the teachers of the technical classes registered by the Institute and in the conduct of the Technological Examinations is £3,054. 15s. 7d., which is within the sum voted, viz. £3,250.

The cost of the maintenance of the South London Technical Art School is £32. 1s. 2d. less than the amount at which it was estimated in the Report; and the expenses of administration are also within the sum granted for the purpose.

The following table shows the amounts voted to, and expended by, each Sub-Committee :—

	Sub-Committee B.			Sub-Committee C.			Sub-Committee D.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Amount voted . .	2,300	0	0	8,250	0	0	6,000	0	0	16,550	0	0
Amount expended	2,167	6	2	8,497	11	3	5,757	14	5	16,422	11	10

It is expected that the income from subscriptions for 1885 will not be less than £24,000.

In estimating the probable expenditure for the year 1885, it has been considered advisable to credit each School with its students' fees, and to make the grants to the Sub-Committees exclusive of these amounts.

Your Council, accordingly, on the recommendation of the Executive Committee and of the Finance Committee, have resolved to apportion their expected income as follows :—

Sub-Committee A.

Central Institution £8,800

SUB-COMMITTEE B.

Expenses of Administration—Salaries, Printing, Stationery, Postage, &c., &c.	£2,300

SUB-COMMITTEE C.

Finsbury Technical College		£6,000
Provincial Agencies—		
Nottingham, University College	£300	
Sheffield, Firth College	300	
Manchester, Technical School	200	
		800
Contingencies		200
		£7,000

SUB-COMMITTEE D.

Technological Examinations	£3,250
South London Technical Art School	1,150
Horological Institute	350
School of Art Wood Carving	250
Society for Promoting the Employment of Women	100
University College and King's College, London	800
	£5,900

Of the Building Fund, amounting to £44,591. 10s., £43,341. 10s. has been already received, and the balance, £1,250, may be expected to be paid during the present year. The sum already paid on account of the building and fitting of the Finsbury Technical College is £34,662. 17s. 10d., and there are one or two small sums not yet paid amounting to £305. 10s. 8d., bringing the entire cost of the building and of the fittings of the College to £34,968. 8s. 6d., which is within the estimate of £35,000.

As regards the Central Institution, the sums already paid on account of the building amount to £76,032. 8s. 6d., besides £507. 7s. 5d. on account of machinery and fittings. From the

Architect's statement, it would appear that the sums still unpaid on the building amount to about £3,000, and in this statement are not included additional works now in progress, including ventilation of laboratory, foundations for engines, &c., which may be estimated at about £1,000. It will be seen, therefore, that the sums still to be paid on account of the Finsbury Technical College and of the Central Institution amount together to about £4,300. To this must be added the sum of £20,000, less £507. 7s. 5d. already paid, the original estimate for the furniture, fittings and apparatus of the Central Institution, showing that about £23,793 is still needed to pay existing liabilities on the building account, and to complete the equipment of the Central Institution.

To meet this liability and estimated expenditure, the Institute has £9,855. 0s. 6d. cash balance (being £9,937. 0s. 6d. as shown in the Balance Sheet, less £82 held on account of the Mitchell Scholarships), £2,830 uncollected subscriptions, £1,250 balance of Building Fund and £9,400, the balance of the promised donations to the Equipment Fund, making a total of £23,335.

Your Council regret that the funds, at present at their disposal, do not enable them to provide for the further development of the Institute's operations, the more especially as the demand for technical instruction in London and in the provinces is every day increasing.

Further accommodation is already required at the Finsbury Technical College.

At South London, the School is full, and the Council have been unable to add the Science side to the School, the want of which has been referred to in previous reports.

The steady increase in the number of teachers registered under the Institute, now engaged in the provincial centres in giving technical instruction, leaves little doubt that the whole of the grant for the Technological Examinations will this year be required, and that next year an increased grant will be needed.

There are other directions in which it appears to your Council desirable that they should aid in promoting technical education, provided the necessary funds could be placed at their disposal.

EXECUTIVE COMMITTEE

Of the City and Guilds of London Institute for the Advancement of Technical Education.

Chairman—Sir Frederick J. Bramwell, F.R.S., M.Inst.C.E.

The Rt. Hon. The Lord Mayor	*Ex-officio.*
The President of the Royal Society	
The President of the Chemical Society	
The President of the Institution of Civil Engineers	
The Chairman of the Council of the Society of Arts	
Rt. Hon. Earl of Selborne, F.R.S., Lord Chancellor (*Chairman of Council*)	
Sir S. H. Waterlow, Bart., M.P. (*Treasurer*)	
The Rt. Hon. Sir R. A. Cross, Bart., G.C.B., M.P.	
Mr. Samuel Morley, M.P.	
Ald. Sir Thomas Dakin (*Fishmonger*)	*Corporation of London.*
Mr. Joseph Beck, F.R.A.S. (*Goldsmith*)	
Mr. W. W. Aston (*Master*)	*Mercers' Company.*
Mr. D. Watney	
...	*Grocers' Company.*
...	
Mr. R. P. Barrow	*Drapers' Company.*
Mr. J. S. C. Heywood	
Mr. J. R. Jennings	
Mr. J. H. Daniell	
Mr. John Samuel	*Fishmongers' Company.*
Mr. E. L. Beckwith	
Mr. A. W. Gadesden	*Goldsmiths' Company.*
Mr. George Matthey, F.R.S., F.C.S., F.I.C.	
Sir Frederick J. Bramwell, F.R.S., M.Inst.C.E.	
Sir Frederick Abel, F.R.S.	
Mr. Charles Barry, F.S.A.	*Skinners' Company.*
Mr. H. C. Saunders, Q.C.	
Mr. R. B. Woodd	*Salters' Company.*
Mr. H. Rokeby Price	*Ironmongers' Company.*
Mr. Henry Aste	*Vintners' Company.*
Lt.-Col. John Britten, F.R. Hist. S.	*Clothworkers' Company.*
Mr. James Wyld, F.R.G.S., D.C.L.	
Rev. Prof. Thomas Wiltshire, M.A., Treas. G.S.	
Mr. E. C. Robins, F.S.A., F.R.I.B.A.	*Dyers' Company.*
Mr. Ebenezer Viney	*Leathersellers' Company.*
Mr. C. Sawbridge	*Pewterers' Company.*
Mr. R. G. Lloyd	*Cutlers' Company.*
Mr. Benjamin Brecknell Turner	*Tallow Chandlers' Company.*
Mr. Charles J. Shoppee, F.R.I.B.A.	*Armourers' and Braziers' Company*
Mr. Ald. William Lawrence, M.P.	*Carpenters' Company.*
Mr. William Heath	*Cordwainers' Company.*
Mr. George Shaw	*Plumbers' Company.*
Mr. Alfred Chantler	*Coopers' Company.*
Mr. Frederick Blasson Carritt	*Plaisterers' Company.*
Mr. John Murray	*Stationers' Company.*
John Watney, F.S.A.	*Joint Honorary Secretaries.*
W. P. Sawyer	
Owen Roberts, M.A., F.S.A.	

They concur with the Royal Commissioners on Technical Instruction in their recommendation, that workshop teaching should be encouraged in the elementary schools of the country; and they fully recognise that the giving effect to this recommendation very properly falls within the general objects for the advancement of which the Institute has been established.

Your Council, therefore, find themselves again obliged to appeal to the liberality of the City Companies to enable them to successfully develop the work they have begun, and to supplement it by further provision for the technical instruction of artisans and of their children, as well as of other classes of the population engaged, or preparing to engage, in productive industry.

SELBORNE,
Chairman of Council.

March 2nd, 1885.