PART I.

Municipal Architecture in Boston.

From Designs by Edmund M. Wheelwright,
City Architect,
1891 to 1895.

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City Architect, 1891 to 1895

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PREFACE.

THE designs presented in this book are those made by Mr. Edmund March Wheelwright, in the four years from 1891 to 1895, when he was City Architect for the City of Boston, Massachusetts. Accompanying the plates are plans and working-drawings, descriptions of construction and working data,—all presented in unusual fulness of detail. The value of this publication lies in the merit of the buildings here described and illustrated, and in the fact that it is the first book of the kind to present a collection of designs for municipal work accomplished within a period of four years by a well trained American architect.

In a comparatively brief period Mr. Wheelwright designed and constructed many buildings for various public purposes; and he was, moreover, an administrator, economist, and artist. Except for the group of buildings composing the Hospital for Contagious Diseases, and the design for the proposed City Hall, his opportunity lay not in the solving of large architectural problems, but rather in the successful accomplishment of practical and artistic results, under the limitations set by the requirements of civic architecture. Not a little of the value of his work has been in showing that dignity and beauty may be obtained by simple and straightforward means without sacrifice of economy or the requirements of utility. This work has given further proof of the possibilities in brick architecture; for it is noteworthy for careful and skilful treatment of this material. The police stations, hospitals, buildings for the Park and the Fire Departments, and many schoolhouses display variety, directness in planning, and simplicity and refinement in design; while all bear the impress of one directing mind. This entire control of the artistic part of the work is the more noteworthy since the business administration of the department during the period under consideration has met with almost universal commendation. Professor Charles Eliot Norton, in speaking of indications of artistic progress in Boston, has said: "Mr. Wheelwright has shown the citizens of Boston that it is possible, at a cost not greatly increased, if at all, to build perfectly convenient schoolhouses which shall be pleasing to everybody, no matter how great his demand. He has made the beauty of his buildings to reside in their proportions and in the lines and arrangement of their doors and windows; and he has had the strength to discard the superfluous ornament of detail which another man might have been tempted to add." The influence which makes for fitness and beauty in our life is seldom better shown than in these schoolhouses. Without excluding from like commendation other work here illustrated, it can be said that, although generally hidden in unfrequented places, they will always rank as worthy ornaments of Boston.

INTRODUCTION.

THE nature and the value of the work done by Mr. Wheelwright may be better appreciated if some history of the Architect Department of the City of Boston is first given. The facts in brief are as follows: —

Previous to 1874 the municipal buildings of the City were constructed under the direction of the several department committees of the City Council, these committees choosing in each case the architects of the various buildings. In 1874 the City Council passed an ordinance for the employment of an architect and draughtsmen with an annual appropriation which at first was only $5,000. Under the administration of the first City Architect, Mr. George A. Clough, the City's buildings were well planned and economically constructed. The official architect system, however, as time went on, proved less satisfactory. In January, 1890, the Citizens' Association in its second Annual Report made the suggestion that the department should be abolished, and that municipal buildings should be constructed by private architects. The condition of things which led to these recommendations is indicated in the following quotation from its report: "The work of the City would then be done as private work is done, without the admixture of politics. There would be a keener watch kept over the contractors; the work of the City would be pushed; the enormous bills for inspection and watchmen caused by unnecessary delays and subdivisions of contracts would be much lessened; the City would get the benefit of a higher order of talent than is now possible under the salary that is paid, and the style of the City's architecture would be properly diversified. Furthermore, a building would be finished by the architect who drew the plans and began the work, whereas now the frequent changes in the office of City Architect bring a building under the care of several architects before it is finished. Under this system the architect's charges would probably amount to less than the present cost of the Architect's Department. In 1887-8 when the department cost $24,344.47 the cost of construction was $177,000." These criticisms by the Citizens' Association did not at the time result in the doing away with the department; but the Legislature of that year, 1890, endeavored to remedy at least one abuse. The awarding of "split contracts," a method of evading the statutory provision requiring that all bids for work exceeding $2,000 in cost must be advertised, had become a notorious evil in the Architect Department. The Legislature passed an act by which the number of contracts that could be made for a building for the City of Boston was limited to five. Nothing further was done that year to improve the methods by which the building operations of the City were conducted.

Establishment of the Architect Department, 1874.

Its Administration criticised by the Citizens' Association, 1890.

Legislative Act of 1890.

Mr. Nathan Matthews, Jr., became Mayor in 1891. Fortunately for the official architecture of the City, he had had wide experience in building matters; and as an intelligent lover of the fine arts he fully appreciated the importance of constructing worthy municipal buildings. Mayor Matthews realized that the abuses in the administration of the department of City Architect were serious. He saw, moreover, that, if the City buildings were to be built as economically and of as good architectural design as those built for private owners, reforms were necessary. He accordingly in his first inaugural proposed a complete reconstruction of the department of City Architect. The desirability of abolishing the department had been previously suggested by the Citizens' Association, but Mr. Matthews hesitated to take this radical action without first trying the effect of conducting the department on a purely professional basis. To this end he offered the position of City Architect to Mr. Wheelwright, whose good standing in his profession, and whose knowledge of conditions affecting the City's business peculiarly fitted him for the office. The duties of the City Architect, according to the revised ordinances of 1890, were as follows: "The Architect Department shall be under the charge of the City Architect, who shall be consulted whenever any building is to be repaired, and on all important matters relative to public improvements of every kind, where the advice of an architect would be of service; shall prepare all plans, specifications, and estimates which shall be needed by any department in the performance of its duties and can properly be required of an architect; shall, whenever any building of the City is to be built or altered for any department, prepare the plans, specifications, and estimates therefor; shall, after said plans have been approved by the department for which it is to be built or altered, issue proposals for contracts for the work to be done; shall make all contracts required therefor; shall carefully inspect all such work while in progress, and approve to the department for which the building is erected all bills for work done thereon, and if the building is not erected for any department, shall approve such bills to the City Auditor." In this revision the clause requiring that the City Architect should give his whole time to the City had been omitted, and the new incumbent was thus able to continue his private business while administering the City's work. In addition to this advantage, the professional opportunity offered by the office was large and attractive. The difficulties, however, were equally recognizable, and might well have caused any one to hesitate before accepting the task. In freeing the department from its political traditions, active opposition from those persons whose schemes and practices would be broken up was certainly to be expected. Fortunately for the City, Mr. Wheelwright accepted the position; on May 1, 1891, he became City Architect.

Ordinance Governing the Architect Department.

Mayor Matthews appoints Mr. Wheelwright as City Architect, May, 1891.

Annual Reports of the Architect Department.

For the next four years the history of the department of City Architect is best shown by its annual reports,—publications which at the time of their appearance marked the beginning of a new era of combined efficiency and liberality in municipal architecture, and which today are held by architects as useful and authoritative documents.

Report for 1891.

The first Annual Report of the Department for the year 1891 is an extremely thorough and able piece of work. It shows not only that the radical changes and improvements in system and administration had decreased the expenditures of the department relatively to the cost of construction, but also that there had been a considerable reduction in the expense of the buildings. This report contains an innovation in the records of municipal departments in this country which is instructive and important. A full transcript of accounts is shown for buildings under construction, and for the expenses of the department. Every item, including contracts, extras, and deductions for omissions, is put down with the utmost frankness. The appropriation is placed on the credit side, and the buildings are debited by all contracts and expenditures thereon. The "American Architect and Building News" in its notice of the report at the time said: "We commend the account to people who think that the ordering of extras is an unpardonable sin in an architect, as a good illustration of the way in which a careful and intelligent architect studies his work as it goes on, adding a little to the contract here, and saving something there, but by the revision constantly bringing his building nearer to the ideal of economy and utility." Finally, this same report contains a table of the cost of all the constructions which had been built by the department since its formation and of which drawings existed in the office.

Approval of the Citizens' Association. The satisfaction with which the first report was received was great. The Citizens' Association, which gives expression to the best public opinion, commented in its report of 1892 on the gratifying change in the Architect Department. After summing up the objectionable practices that had previously existed in the department, it went on to say: "Mr. Wheelwright, the new Architect, introduced at once radical changes and improvements both in system and administration. . . . . It must be a source of satisfaction to all right-minded citizens to find this important department of the City thoroughly and properly reorganized, and conducting the business of the City upon the same business principles which control private work. We feel that too much credit cannot be given to the Mayor for taking the Architect Department out of politics, and for the support he has evidently given to the Architect, or to Mr. Wheelwright for the valuable services he has rendered."

Report for 1892. The Report for the year 1892 shows the same care and accuracy of detail as that of the previous year, and continues the same method of accounting. The book is charmingly illustrated, with skilful and artistic designs representing an ideal presentation of well-ordered architectural work. The book also contains an interesting estimate of the expenses of the department. A private architect who conducts his business with close economy generally finds that his office expenses are about fifty per cent of the commissions earned. The expenses of the Architect Department in 1891-92, after deducting the Architect's salary and the amount paid to experts, clerks of the works, etc., which in private practice should be paid not by the architect, but by the owner, were shown to be $3,000 less than the probable expense to a private architect of doing the same work. This comparison was made, as the report explained, "simply to show that the office had been conducted upon the basis of private practice, and not at all as an argument in opposition to the abolition of the department."

Report for 1893. The Annual Report for 1893 is still more interesting and satisfactory than its predecessors. It is very fully illustrated by excellent heliotypes and attractive perspective sketches, for which in the architectural profession the office had become famous.

Report for 1894. The fourth Annual Report, the last issued by the department, contains the usual careful array of items of department expenses. The special characteristic of this report, however, is the analysis of the cost of schoolhouses. This analysis is particularly valuable, because it is based on statistics compiled from the cost of a large number of school buildings. As one result of a careful financial consideration, it is clear that the purely utilitarian schoolhouses are little or no cheaper than those with some pretence to architectural treatment. With undoubted truth it is maintained that the larger the building the greater the importance of some expenditure for the sake of beauty. The expenditures made for artistic reasons were, in the opinion of the Architect, fully justified. The "American Architect" at this time said of Mr. Wheelwright: "But he does not mention what we can say in his praise, that expenditure alone does not secure beauty, and that it is due to Mr. Wheelwright's own skill more than anything else that the City of Boston has been, during his term of office, supplied with a remarkably attractive collection of public buildings which have needed little else than brick and mortar used with the taste and discrimination that only an accomplished architect could apply to them to become, however modest their purpose, permanent adornments of the City."

In 1895 Mr. Edwin U. Curtis succeeded Mr. Matthews as Mayor of Boston. In his inaugural address he recommended that the office of City Architect should be abolished.

Mayor Curtis recommends abolishing the Architect Department.

The City Architect was requested by the Joint Committee of the City Council on the Architect Department to give his opinion on the proposed change. This he did in a letter which was afterward published by the Committee. It was shown in this letter that the small salary attached to the office and the insecurity of its tenure were the principal reasons in favor of the proposed change, and that these two conditions would under existing circumstances prevent surety of its constant incumbency by architects of the best standing. Attention was also called to the fact that, from a financial as well as from an artistic point of view, the permanent control of the construction of a building from beginning to end was of the highest importance. This advantage the City would gain from the employment of private architects, and it would more than compensate for increased expense for professional services. It was further shown that it would be advantageous for the City's interests if responsibility for buildings should be thrown on the several departments for whose use they were built; and that therefore each department should select its own architects, their appointment and the designs for all buildings being subject to approval by the Mayor. In order that the Mayor might give such approval understandingly, the suggestion was made that he have the assistance of a professional adviser, for without such expert official supervision the heads of departments and boards would not be likely, in the long run, to choose architects whose work would be a credit to the City. The recommendation of the Mayor that architects for City work should be chosen by competition was not approved. The reasons given were that architects entering a competition should in justice be paid for their services; and that, if the practice of awarding the City's architectural work by competition should be adopted, a large expense would be put upon the City, while the comparatively low cost of many of the buildings would make such competitions unattractive to the best architects. It was recommended instead that each department should appoint an architect to whom should be intrusted all its work, and that the position of such an architect should have some measure of permanency. By this means each architect thus appointed might become familiar with the laws and methods of procedure governing official practice and the special needs of the types of buildings required for the department, and his usefulness would thus be increased with his experience. One great advantage of the system under the City Architect lay in the accumulation of a large amount of special data; and this benefit could be best maintained under a system of departmental architects, rather than under a system of separate appointments of architects for individual buildings.

Office of City Architect abolished July 1, 1895.

Mayor Curtis, in pursuance of his plan, petitioned the State Legislature of 1895 to have the office of City Architect abolished. The essential point in this administrative change was the creation of the office of Consulting Architect. The Citizens' Association made efforts to have included in the bill a provision by which the City Architect might be allowed to finish the contracts of work which would be still in the course of construction on the date set for the abolishment of the department. The attempt, however, proved unavailing; and the clause of the revised City Charter of 1895, under which the office of City Architect was abolished, read as follows: "The Architect Department, and the office of City Architect of said City are hereby abolished and all buildings now in process of construction by said Department shall be placed under the charge of the Superintendent of Public Buildings, who shall see that the buildings are completed in accordance with the contracts already made therefor." On July 1, 1895, the date set in the act for the department to be abolished, Mr. Wheelwright's connection with the government as City Architect ceased, as did also his control of the completion of the City buildings designed by him and then under construction. In January, 1896, Mayor Quincy, as one of his first acts on entering upon his office, appointed a Consulting Architect.

Consulting Architect appointed January, 1896.

To systematize the conduct of the City's building operations in accordance with Mr. Wheelwright's recommendations, it yet remains for all the departments and boards to establish the practice of appointing departmental architects, instead of especially choosing, as is done in most cases, an architect for each new building to be constructed. In this event the work of the School Committee should be divided among three or four architects. The several architects so appointed might act with the Consulting Architect as a board similar to that into which the architects of the World's Fair at Chicago constituted themselves with results so beneficial to each individual building and to the work as a whole. Such a system, if not the only method, is by far the most effective one for securing economical and satisfactory architectural work for our municipalities.

PART ONE

SCHOOLHOUSE ARCHITECTURE.

I.

IN America, except within recent years, little has been published on the subject of schoolhouse planning. Public attention seems to have been first drawn to the importance of this subject in 1830, when Mr. W. J. Adams of New York delivered a lecture before the American Institute of Instruction on "Schoolhouses and School Apparatus." This was immediately followed by the offer from the same Institute of a premium of twenty dollars for the best "Essay on the Construction of Schoolhouses." The prize was awarded in 1831 to Dr. William A. Alcott of Hartford, Connecticut, afterwards of West Newton, Massachusetts. It was published as a pamphlet, and was freely distributed throughout the country. In 1833 the Essex County Teachers' Association published a "Report on Schoolhouses," prepared by Rev. G. B. Perry, in which the too general defective construction and arrangement of schoolhouses was severely condemned and the resultant evils exposed. This article seems to have attracted a good deal of attention, and as a result decided improvements in schoolhouse planning and furnishing were made, especially in the larger cities. Commenting on the condition of school buildings at this time, the Hon. Horace Mann wrote, in the Report of the Secretary of the Massachusetts Board of Education for 1846: "In 1837, not one-third part of the public schoolhouses in Massachusetts would have been considered tenantable by any decent family, out of the poorhouse, or in it."

"Construction of Schoolhouses," William A. Alcott, 1831.

In 1838 Horace Mann "submitted a report on schoolhouses as supplementary to his first annual report as Secretary of the Board of Education in Massachusetts, in which the whole subject, and especially that of ventilation, is discussed with great fulness and ability." The struggles of educators during these early years are well brought out in this report. Mr. Mann speaks of the difficulty of finding competent teachers for the common schools. He adds, however, that "they are as good as public opinion demanded." The salaries then paid were on "an average, exclusive of board, fifteen dollars and forty-four cents per month for males and five dollars and thirty-eight cents for females."

Report of Horace Mann, 1838.

In 1842 Mr. George B. Emerson, the distinguished teacher, who is also well known as the inventor of the Emerson ventilator, wrote an article on "The Schoolhouse," "in which sound and practical views of the location, size, and ventilation and warming of edifices for

"The Schoolhouse," George B. Emerson, 1842.

school purposes are presented and illustrated by appropriate cuts." This publication was considered of such value that a copy of it was presented to each of the eleven thousand school districts in the State of New York and to each of the three thousand and four hundred districts in Massachusetts. In 1846 Mr. Nathan Bishop, Superintendent of Public Schools in the City of Providence, published a report on the schools of that city which had been constructed "after an examination of the latest improvements which had been introduced in the schoolhouses of Boston, Salem, and other large cities and villages in Massachusetts, and have been much consulted by committees and builders as models."

"School Architecture," Henry Barnard, 1838, 1848, 1854.

The most important work of this period, however, is that of the Hon. Henry Barnard. In 1848 he prepared a new edition of his essay on "School Architecture," first published in 1838; and in this edition he incorporated, with permission of other laborers in the field, all that had been written of greatest value up to that date. In 1854 he published the fifth edition of the work, under the title "School Architecture, or Contributions to the Improvement of Schoolhouses in the United States." This is the only American work that can properly be considered a text-book on schoolhouse planning and construction. Mr. Barnard was then Superintendent of Common Schools in Connecticut. A cultivated man of wide experience, he was well fitted to consider the subject of schools and schoolhouses in a thoroughly comprehensive manner. So many improvements have been brought about in schoolhouse architecture since 1854 that the value of the book, which is now rarely seen, is chiefly historical. Still, even today it is a very interesting work, well illustrated, and complete in every detail relating to schoolhouses of his time. Of this treatise Mr. Edward Robert Robson, Fellow of the Royal Institute of British Architects and author of the well known work entitled "School Architecture," says, "There is no work in the English language on the same subject so complete."

In the next twenty years the most important contributions to the subject were "Pennsylvania School Architecture, a Manual of Directions and Plans for Grading, Locating, Constructing, Heating, Ventilating, and Furnishing Common Schoolhouses," by Thomas H. Burrowes, published in 1855; and "A Manual of Schoolhouses and Cottages for People of the South," by C. Thurston Chase, Superintendent of Education of Florida, published by the Freedman Bureau at Washington in 1868. This latter, a cleverly written and illustrated little book, was for free distribution, and was intended primarily to interest the poorer people in improving the surroundings of their every-day life.

"School Architecture," E. R. Robson, 1874.

The condition of schoolhouse architecture in the year 1874 is admirably shown in "School Architecture," by E. R. Robson, the English architect. His experience had been gained in the erection of a hundred new schoolhouses, and as architect to the School Board for London; and he was thus well prepared to discuss the subject with authority. The work treats fully of the subject, as it was then understood in England, Europe, and America, and is of the highest standard of excellence.

"Rural School Architecture," T. M. Clark, 1880.

In 1880 the Bureau of Education published in Washington a small book, No. 4 in its Circulars of Information, prepared by the well known Boston architect, Mr. T. M. Clark. It was called "Rural School Architecture," and was intended to be "specially serviceable in the construction of schoolhouses in rural districts and in small villages in every part of the country." This work is skilfully prepared and embraces a great deal in a small compass. It deals with Site, Aspect and Lighting, Surroundings, Arrangement, Construction, Ventilation and Heating, Sanitation, Acoustics, Attractiveness and Economy in Buildings, and concludes with a good specification and form of contract. The book was prepared for free distribution, and it earned a well deserved popularity.

"The Hygiene of the Eye in Schools," Hermann Cohn, 1886.

In 1886 was published an English translation of "The Hygiene of the Eye in Schools," by Hermann Cohn, M.D., Ph.D., Professor of Ophthalmic Science in the University of Breslau. This valuable work was first published in 1882 as an essay written for an encyclopædia. At the desire of the Government of Breslau, Dr. Cohn, after rewriting and extending the article, published it in book form in 1883; and from this book the translation above referred to was made. Cohn gave great impetus to the study of school hygiene, and his researches in this field were most important, since they led the way to reform in schoolhouse design by basing it on scientific principles. Recent writers have hardly done more than verify and continue his investigations, for they have accepted his general conclusions. Dr. Cohn's great reputation was principally won by his examination of the eyes of ten thousand and sixty children in the schools of Breslau and vicinity, his investigation into the causes of the defective eyesight which he found in so many of these children, and his recommendations for an improved school hygiene, to check if possible the grave danger of short sight which was so steadily and surely gaining ground.

Two other valuable articles are "The Sanitary Condition and Necessities of Schoolhouses and School Life," published in Boston in 1886, by D. F. Lincoln, M.D.; and "School Hygiene and Schoolhouses," a long and carefully prepared article in the Annual Report for 1891 of the Maine State Board of Health, written by A. G. Young, M.D., of Augusta, the Secretary of the Board.

"School Hygiene," S. D. Risley, 1897.

In 1897 appeared a very complete contribution to this subject by S. D. Risley, A.M., M.D., Ph.D., Professor of Ophthalmology in the Philadelphia Polyclinic and College for Graduates in Medicine, Attending Surgeon to the Wills Eye Hospital, Philadelphia. This interesting and valuable treatise entitled "School Hygiene" is found in the second volume of "System of Diseases of the Eye," Norris and Oliver, published by the J. B. Lippincott Company of Philadelphia. It is to be sincerely hoped that this article will appear in a book by itself, that it may have the widest possible circulation. Dr. Risley speaks of the great value of the work accomplished by Cohn, with which the results of his own researches in this country agree. Dr. Risley's investigations have shown the existence of the same problem in the United States as in the countries of Europe. According to Cohn, the number of short-sighted children is in direct relation to the length of time during which the children's eyes are worked; according to Risley, the percentage in the lower classes in America differs but little from that shown in foreign statistics. Accepting these conditions, Dr. Risley continues with a full and interesting dissertation on "The Significance of Myopia," as to whether from its very frequency and uniformity it might not be a "manifestation of normal evolution" rather than an indication of the lack of hygienic requirements in the school room. Cohn had found that in schools of which the hygienic conditions were all that could be desired the percentage of the increase of myopia was not lessened, and Dr. Risley's experience was the same. Dr. Risley's inference is that the methods of educational training have much to do with the increase of this evil, that the child's eyes are severely tried while he is very young, before the tissue of the eyeball is strong enough to withstand the continued strain of school work. He is convinced that children begin their school life at an age too tender, "and that during their first years at school the methods of instruction should be so modified as to avoid as far as possible continuous work at a near point." Dr. Risley adds that if his conclusions are true, the most perfectly designed school room will not suffice to arrest the spread of myopia and its attending pathological conditions. He further lays great stress on the importance of a systematic method of inspection, with the object of warning parents in case there should be found in their children's vision any defect that would increase if neglected. He asserts that "if at the beginning of the school life these congenital anomalies of refraction could be carefully corrected by suitable glasses, we should hear much less complaint of the harmful influence of the schools upon the eyesight of our children." It has seemed to me well to refer to this subject of myopia even thus slightly, if only to call the attention of both architect and educator to the fact that, in the broad sense of minimizing all conditions inimical to the pupil's well-being, they must work together. These investigations, although they relieve the architect of much of the responsibility for this percentage of increase of myopia, show that it is none the less imperative that schools should be as well lighted as circumstances admit, and should be otherwise in the best possible hygienic conditions, as all affections of sight are aggravated by bad lighting and unwholesome rooms. Adequate lighting must accompany adequate ventilation in the school room of the future; and this result can be brought about only by radical changes in the system of classification which now holds in our graded schools.

"Circulars of Information," published by the Bureau of Education.

Of other articles published within the last few years, many of interest are to be found in the annual reports of School Boards of different States, and in the "Circulars of Information" issued by the Bureau of Education at Washington. A number of these papers deal with general questions of the hygiene of school life, a subject which, in all its bearings, is now receiving increased attention from medical authorities. In a valuable chapter in the present work Prof. S. Homer Woodbridge has treated one important phase of this subject,—that of heating and ventilation,—presenting it with the completeness of detail which is to be expected from one having such thorough practical and theoretic knowledge of the subject. The science of heating and ventilation has become so exact, and the methods for its accomplishment are so well understood, that at the present day there is no excuse for a poorly heated or ventilated school room. There is still need, however, of continuing the most painstaking investigations in regard to the influence of a hygienically defective school room upon the health and mental activity of the scholar.

Articles on the "American Schoolhouse" in the "Brickbuilder," 1897.

A series of papers on the "American Schoolhouse" by Mr. Wheelwright was begun in 1897 in the "Brickbuilder," and is not yet completed. The papers are written from the architect's point of view, and contain much useful information, which the publishers have permitted me to use freely in the present work.

To Mr. Edwin P. Seaver, Superintendent of the Boston Schools, is due no small part of the credit for the plan of the American schoolhouse in its development of later years. He has worked steadily for the attainment of improved hygienic conditions in school buildings, and his advice and experience have been of great assistance to the several architects who have served the school board. Mr. Seaver's study of the subject has indirectly influenced others far and near, since in recent years the plans of Boston schoolhouses have in many points served as models throughout the country.

In all that has been published since 1830 on the subject of schoolhouse construction,—articles of the value of which I have given merely the barest indication,—it is significant to note that these writings deal chiefly with what, up to the present date, has been the most imperative aspect of the matter,—proper sanitary condition, especially in regard to the improvement of ventilation. All the earlier articles laid great emphasis on the proper heating and ventilation, and on the cleanliness of the schoolhouse. There was then as there is now a constant struggle between the comparatively few who believe that the health, morals, and intellectual progress of children and the success of a teacher are immensely influenced for good by a proper sanitary condition of school life, and an apathetic public whose first consideration is whether it is worth the cost. It is extremely valuable to compare the recommendations of these earlier writers, and to contrast their ideas in the matter of size, ventilation, and lighting of school rooms with those which are followed today in the construction of modern schoolhouses.

Comparison of recommendations made since 1831.

The plan which Dr. Alcott recommended in his prize essay in 1831 was for a single room schoolhouse lighted on opposite sides. It contained seven rows of seats with eight seats in each row. In this number of fifty-six seats to a room there has been no change to this day. Horace Mann's plan was in most respects the same as Dr. Alcott's. George B. Emerson in 1842 advised "for the accommodation of fifty-six scholars so as to give ample room for moving, for recitations, and for air," a room about 30 feet long and 25 feet wide by 10 feet in height. The most approved dimensions today for a room of equal accommodation are 32 feet long and 28 feet wide by 13 feet 6 inches in height. In Emerson's school room the allowance per pupil was about 13½ square feet of floor area and 134 cubic feet of space, while in the modern grammar school the allowance is 16 square feet with 208 cubic feet of space to each pupil. In Burrowes' work, published in 1855, heating and ventilating were thoroughly discussed; and, that no mistakes should be made, as "the schoolhouse is to last for ages," methods and means were carefully explained, and a table was given of the "proper sizes" of ventilating ducts. For a room to be occupied by fifty pupils, the size of the duct given in this table is 10 by 18 inches. At the present day a room amply accommodating fifty pupils requires a ventilating duct measuring 24 by 30 inches, an area which Burrowes would have held sufficient for a room accommodating three hundred pupils. Elsewhere, when describing in terms of highest praise the Philadelphia High School, he says: "The flues are all made large, both those for admission and those for the exit of the air. In the class rooms, which are 38 feet by 22, the warm air flues average 1⅙ square feet, and the venti-ducts 2⅓ square feet." These dimensions in the model school room of today would become at least 5 square feet for each; for modern science demands that at least 30 and preferably 40 cubic feet of fresh warm air be supplied each pupil per minute, and that an equal amount of vitiated air be withdrawn from the school room in the same time, without any discomfort to the occupants by drafts of air. Thus what was formerly considered amply sufficient for thorough ventilation of a school room would often at this day be deemed practically worthless.

Retrospect and Prospect.

Even in the last fifteen years great changes have taken place. The model school room of today shows many recent improvements in heating, ventilating, lighting, and in the arrangement of seats and desks on more scientific principles. The school building and its fittings are beginning to be as carefully considered as the appointments of a hospital, and every detail is regarded by the most intelligent students of the question as worthy of the most careful thought by reason of its hygienic importance. Still of these later years as of the earlier periods the same fact is true,—that notwithstanding the critical investigations and discussions of education, little advance has been made in the construction of the school room except in regard to heating and ventilation and to the use of more and higher windows. Our large classes have not been reduced in size since 1831, when Alcott's model plan for a room containing fifty-six pupils was published, although the room has been enlarged to meet the demand for increased air space for each pupil. Too little consideration has been paid to the fact that this widened room cannot be well lighted from one side only; that the teacher's supervision of the room is made more laborious; and that the large size of the class makes individual teaching of the pupils impossible. In the last decades of this century the schoolhouse has been made hygienic. It is evident that the best method of lighting it is to be left to the next century for settlement; and in dealing with this question architect and educator must work hand in hand. For the present century, through the extreme conservatism of our educational and school committees, we apparently must content ourselves with the fact that we no longer construct improperly ventilated schoolhouses.

II.

IN this section of the work I shall endeavor to explain in what way the general principles that govern modern school architecture are applied to the various details of construction; and for this purpose I shall discuss these details in order.

Site of Schoolhouses.

The city schoolhouse site if possible must be considered in respect to surrounding buildings, and to the probability that its sunlight may be intercepted and its ventilation and safety of exits hazarded by buildings which may be built in the future. It rarely happens that the architect is given choice as to the orientation of a city building. The most advantageous position of windows with reference to the sun may of course be nullified by the shadowing of trees or by adjacent high buildings. Zwez, one of the best German authorities, thinks that an opposite building does not materially injure the school if the angle of elevation, measured from a window-sill of the school, does not exceed 20 or 25 degrees. The French authority, Javal, says that, to prevent injurious shadowing, the distance of the adjacent buildings should be equal to twice their height. These opinions would undoubtedly make good rules to follow for all exposures, although towards the south an angle of 45 degrees with the top of the opposite building is usually considered enough for ample protection.

Cohn speaks strongly of the importance of isolating the schoolhouse. While he freely admits that the percentage of increase of myopia has not been lessened in schools where the hygienic conditions were all that could be desired, he emphasizes the fact that he found that the percentage increased according to the narrowness of the street on which the schoolhouse was situated. This at least proved that the disease was aggravated by bad lighting. He says: "In comparing the lighting of the class rooms with the number of short-sighted children, I found in 1865 that *the narrower the street in which the school room was situated, the higher the opposite houses, and the lower the story on which the lessons were given, the more numerous the cases of myopia among the elementary scholars.* I purposely say *elementary* scholars. This was a question, not of two or three schools, but of twenty, all having the same standard of work for the children; a question, therefore, not of a freak of chance but of a law. *Twenty* elementary schools of the same grade actually showed differences of from 1.8 to 15.1 per cent M; the M-number increasing always with the narrowness of the street, so that the new schools built in wide streets had 1.8 to 6.6 per cent M, while in the heart of the old town, the schools buried in streets of 'crushing narrowness' had 7.4 to 15.1 per cent M. This fact deserves the attention of the authorities. It justifies the conclusion that the *darkening* of the school rooms, caused by the situation of the building, *must* have decidedly contributed to the production and increase of myopia. Indeed, in many of these rooms it is so dark that in the winter the reading and writing lessons have to be omitted both in the early morning and in the afternoon. In higher schools I should not draw such a conclusion, because the manifold home employment of the children prevents us from making any such simple experiment as in elementary schools, where but little is given in the way of home lessons."

Use of ribbed glass in lighting School-houses.

It should be remembered, however, that schoolhouses must often be built in thickly settled tenement quarters where hardly more room can be found than will fit the plan. These are the buildings that require the most careful study. The use of finely ribbed or prismatic glass in the sashes will, it is hoped, help to solve the problem of satisfactorily lighting school rooms on these narrow streets. Mr. Edward Atkinson in a pamphlet written in 1895 says: "A recent discovery of the properties of finely ribbed glass which has been justified in factory construction will have a very important bearing upon the glazing and lighting of school rooms. By the use of fine ribbed glass more absolute light is brought into a room, and by the diffusion of the light the inner section of a 28 foot room may be made very nearly as light as the outer section, while the glare is wholly overcome and the shadows which are apt to be injurious are wholly done away with."

The right way, however, of meeting unfavorable conditions of site and lighting is to design the schoolhouse for its particular situation. Narrower rooms and smaller classes should be considered the most important factors in accomplishing the best results. Corner rooms with lighting from two sides could be kept of the present standard dimensions, to contain fifty-six scholars, but such rooms as could be lighted from only one side should be made narrower, and their classes be proportionately reduced. Artificial means of aiding illumination should be considered last. Such a plan as this involves the introduction of one of the new factors which I have already spoken of as inevitable in the construction of schoolhouses in the future. If it is determined to preserve the present unit of the school room 32 feet long, 28 feet wide, and 13 feet 6 inches high, seating fifty-six grammar grade pupils, there can be little original work left for the architect to do. The exterior effect may of course give evidence of his personality, but the plan resulting from the combinations of the unvarying school room unit can hardly admit any new or better arrangement than is found in the best designed schoolhouses of the present day. If, on the other hand, the architect is to be allowed to adapt the size of the rooms to the needs of the building, the results will be much more satisfactory, both in ample supply of light for each room, and in greater freedom and originality in his treatment of the whole.

This question of smaller rooms has also recently been discussed from the educational point of view. Public attention has been called to the possibility of more rapid promotions in the grades if classes are made smaller, so that the teachers' energies may be concentrated on a smaller number of pupils and thus give greater care to the training of the individual scholar. It is to be hoped that the experiment will be tried of building a large schoolhouse in accordance with the most rational forms of construction, the most skilful method of lighting, and the most scientific class system. In such a building it will be found that these three conditions are as really concomitant as in the model of the present school room they are greatly at variance.

Shape of the School Room.

The school room should be oblong in shape and the width should be to the length about as three is to four. Authorities are agreed that the length of a class room should not be greater than 32 feet. In France and Germany 30 feet is preferred, though it is not unusual to find this dimension varying a little either way. The teacher's voice can reach 32 feet without effort, and this distance is not too great to make it difficult for the pupil's work on the blackboard on the end wall to be seen from the platform.

Width of the School Room.

The width of the school room is primarily governed by a proper arrangement of desks. In the grammar grade the passageways against the two walls measure 2 feet 6 inches each, though it would be better if the one against the blackboard could be made wider. The desks are 2 feet wide, and the distance between them should not be less than 18 inches. Thus seven desks with their aisles and the two outside passages make up 28 feet, the width of our standard room. Eight rows of these desks allow for fifty-six pupils with an area of 16 square feet of floor space to each pupil. Primary school rooms, although intended for the same number of pupils, are made narrower, as the furniture and fittings occupy less space. The room is made 24 feet wide, allowing an area of about 13½ square feet to each pupil if the room is 32 feet long, or nearly 13 square feet, if, as often happens, the room is made 30 feet long. Although in European schools this area varies from 9 to 12 square feet for each pupil, it is due to the fact that thorough ventilation, though regarded as important, is not in actual practice carried so far as it is in America. According to our ideas, the area of 13 square feet for each pupil should on no account be diminished.

A width of 24 feet, nevertheless, should go with a length of 32 feet, if the proportion of three to four is to be followed. Nowhere but in America is it the custom to build the school room to the abnormal width of 28 feet. The London School Board advises a width of 22 feet for rooms of large size, and 21 feet or even 20 feet for smaller rooms. In Germany the rule is practically the same. In France, according to the new code of rules published to guide architects in designing schoolhouses, the school room must not exceed 21 feet in width. In Holland the law is that the class room shall not be wider than 7 metres, about 23 feet. These narrower rooms permit much more scientific methods of lighting, a decidedly more economical construction, and doubtless make it easier for a teacher to supervise. The eye can never take in a whole school room at once and the wider the room the greater the need of exertion in its oversight. The distance into a room for which a window can be depended on to give satisfactory lighting is usually considered to be one and one-half times the height of the window from the floor. Even in our later grammar class rooms this height is usually but 13 feet, which, according to the above formula, would properly light a room only 19 feet 6 inches wide. The French code of rules fixes the least height of the room at 13 feet, and requires that, if the light comes from one side only, the height of the room must be at least equal to two-thirds of its width plus the thickness of the wall in which the window is placed. This would require for a 28 foot room the impossible height of 19 feet 6 inches. The most approved height of the grammar school room with us is from 13 to 14 feet. In the latest schoolhouses built in New York the rooms are from 14 to 15 feet high. Dr. Risley prefers 15 feet, but this height seems too great. The longer stairs mean greater fatigue to both teachers and pupils when a schoolhouse has two or more stories, and the increased height adds somewhat to the cost of the building. The heights of 13 feet 6 inches for grammar schools and 12 to 13 feet for primary schools are the measurements which are usually employed in Boston schoolhouses. If a greater amount of air space than at present allowed should be found necessary for each pupil, it would be better to increase other dimensions rather than to add to the height.

Height of School Room.

Smaller School Rooms better lighted.

In diminishing the size of the school room, the unit of reduction should be the width of a desk and aisle of the width used in the grammar schools, 3 feet 6 inches. Therefore by leaving off one from the seven rows of desks, the 28 foot room is reduced to 24 feet 6 inches, with seats for forty-eight pupils. In the primary grades, however, which require smaller furniture, there would still be room for the usual number of fifty-six desks. Better still, by cutting off two rows of desks, thus leaving seats for forty pupils, the room may be reduced to 21 feet. For a primary school, Mr. Wheelwright recommends a room 22 by 32 feet and 13 feet in height, with desks set six in the width and nine in the length. The loss of two desks necessitated by this arrangement is a slight objection in comparison with the better lighting acquired. Such a decrease in the width of the room must, of course, be the result of the adoption of the small class system. On no account should the present standard of floor area and cubical space for each pupil be diminished or the system of individual desks be changed. The grammar school room 32 feet long by 28 feet wide by 13 feet 6 inches high, has a floor area of 896 square feet, which allows 16 square feet for each of the fifty-six pupils. The contents of the room equal 12,086 cubic feet, nearly 216 cubic feet to each pupil. These dimensions may be considered none too large, and they certainly make provision for an ample supply of heated fresh air. Dr. Young allows at least 20 square feet of floor space to each pupil, and 240 cubic feet of air space. Dr. Risley, the latest writer on this subject, recommends 19 square feet of floor space and 256 cubic feet of space for each pupil. The dimensions which he thinks meet the ideal requirements of a school room for forty-five pupils are length 32 feet, width 24 feet, height 15 feet. The ideal room is invariably considered by medical writers to be 15 feet high. It is a simple way, at least on paper, of getting a required amount of air space; and the higher the windows the better lighted the room will certainly be. Every other method, however, should be employed before building to this extreme height for a schoolhouse of more than one story.

Side of room through which light should enter.

In the lighting of the school room the maximum of well diffused light should come from the left hand side of the pupil. All agree with Cohn when he says: "I adhere still to the opinion I expressed eighteen years ago: that there can never be too much light in a school. Javal in his essay, 'La Physiologie de la Lecture,' also contends for the freest possible lighting. He says most truly: 'The school must be flooded with light, so that the darkest place in the class may have light enough on a dark day.'" In the methods of obtaining this proper amount of light there is much difference. In Germany and Switzerland, while lighting the school room from one side is the rule, additional light is sometimes sparingly introduced through the wall opposite the teacher. In France lighting through the wall opposite the teacher is expressly forbidden, and additional lighting through the wall opposite to the outside one is required. In some French plans, it is true, are seen two windows in the wall opposite the teacher, but they are placed well in the angles, so that a broad blank wall is directly opposite the platform. This arrangement is also advised by some of our school superintendents. In America it is difficult to light our large rooms properly from one side only; and our schoolhouses, built on a compact plan, offer little opportunity for lighting otherwise than through the outside walls. The rooms often have windows in the walls opposite the outside ones, and draw some little light from the corridors; the corner rooms almost invariably have windows on the side and one end.

Value of ribbed and prismatic glass in diffusing light.

In general it may be said that although the wall facing the pupils should never have windows in it, there is every reason why light through the rear and right hand walls should serve to increase the maximum illumination derived from the proper quarter. So long as the eyes are not dazzled and no shadow falls on the reading or writing, it is impossible to have too much diffused light in the school room. The possibility of such conditions is fully justified by the results of Mr. Edward Atkinson's investigations into the properties of various kinds of glass in softening, refracting, and diffusing light. This subject is of the highest importance and should receive the most careful study. The upper half of a high window furnishes the best light, and so, in the consideration of present methods of lighting, the height of the school room is an important factor. If by means of ribbed or prismatic glass the light can be so refracted as satisfactorily to illumine the room whatever its height, one of the factors in the problem will be eliminated, and a great gain in school economy will be accomplished. We shall then need to consider the room only in relation to the proper amount of space for each pupil. If the windows behind the desks face the north, clear glass can be used; but if they face any other direction a quality of glass should be used that will illumine the room, and not dazzle the teacher's eyes. Otherwise the teacher cannot resist keeping the curtains drawn, and the object in having these windows is defeated. If there is an opportunity in any of our large school rooms for outside windows at the scholars' right hand, it should certainly be made the most of. These windows should begin above the blackboards, and they may be as wide and as numerous as those in the opposite wall, always provided that the illumination from this side simply reinforces the proper light without casting any shadow.

Amount of Light in the School Room.

In regard to the amount of light that should enter the room the results of Cohn's investigations are again of the greatest value to us. The lighting of the room and its orientation must be considered together. Cohn says: "There can be no doubt that, other things being equal, windows facing south admit more light into a room than windows facing north. How greatly the degree of light depends upon the position of the windows will be best seen from the fact that a number of children in the Zwinger Real School at Breslau, who could not distinguish my reading tests at 4 feet in a room facing north, were well able to do so in a room facing south, on the same floor, with windows of the same size and with surroundings equally clear." Cohn also proposed that there should be 1 square foot of glass (excluding sash) to every 5 square feet of floor, as he found that rooms built in accordance with this principle were sufficiently lighted. It is doubtful if this should be considered enough, unless our school rooms are made from 20 to 24 feet wide instead of 28 feet. Cohn's module, however, is accepted by all the latest writers. Dr. Risley makes the further recommendation that this ratio should be more liberal for rooms with a northern exposure, and for those on the ground floor, where the schoolhouse is more or less shut in by surrounding buildings. In other words, he believes that the window space should be estimated for the least favorable conditions, for even the room with a southern or eastern exposure is not so well lighted in the afternoon as in the morning.

Treatment of Windows.

As to the arrangement of windows, there can be no question that windows placed at regular distances along the whole length of the room light it much more effectively than windows in groups with narrow and wide piers between them. The distribution of the windows as of great importance is particularly spoken of by the German authority Kleiber, who thinks that it is "better to have *three* windows than two, even if the two windows have just as much glass as the three. For since the light decreases, not as the distance, but as the *square* of the distance, the more distant scholars receive less light from two windows than from three." As far as advantageous spacing is concerned, there can be no better arrangement, within architectural limitations, than the system employed in the Boston schools, of four windows on the long side, and, in corner rooms, unless some requirement of design or plan prevents, three on the other side. Even this area of glass falls far short of that set by Cohn's rule, for in the rooms not on corners the ratio of glass to floor area in our standard grammar school rooms is only as 1 to 6.2, while the corner rooms with their seven windows show a ratio of 1 to 3.5. Five windows on the side of the inner rooms would just fulfil the requirements of Cohn's rule; or of course the conditions could be met by having here a narrower room fitted for a smaller class. The windows of the Boston schoolhouses have never less than 4 feet between the outside jambs. They finish 3 feet above the school room floor, and are carried to within 6 inches of the ceiling. The basement windows are usually 4 feet 6 inches high. The school room windows should not have transoms, as the transom bar cuts off the most valuable top light. Cohn strongly recommends that the piers between the windows should be not rectangular, but bevelled on the inside. He adds, however, that the base of the window should not be bevelled, lest the light fall too far below the desk and a troublesome reflection be caused. In France the window-sill both inside and out must be bevelled. Dr. Risley also advises bevelling the inside sill. The most satisfactory method is to finish the sill as a shelf; with its top only 3 feet from the floor it can hardly affect the lighting of the first row of desks, and that is the only row that would at all suffer. Wide windows widely spaced are preferable to narrow windows with mullions. This is evident if the proper ratio of glass to floor is taken into consideration. As the most effective light enters at the top of the windows, the importance of giving them square heads is self evident. For this reason the arched window should be used only in those rooms in which the height can be readily increased and the proper proportion of glass to floor area be thus preserved. The minimum allowance of absolute glass surface is 36 square feet for the window of the grammar school room of 13½ foot stud, and 32 square feet for the window of the primary school room of 12 foot stud.

Windows in relation to heating and ventilation.

Double runs of sash are considered vitally important in the economy of Boston schoolhouses. The first expense in the items of window openings and sash is more than doubled, for in addition to the extra sash greater thickness of brick wall is at times required. The increased outlay is, however, more than compensated for in the more economical and satisfactory arrangement of the heating and ventilating, and in the greater freedom of the school room from the dust and noise of the street. In an article called "Sanitary Conditions for Schoolhouses," written for the Bureau of Education by Dr. A. P. Marble, Superintendent of the Public Schools of Worcester, Massachusetts, he says: "If one-fourth of the wall space of a room is glass, in zero weather this glass has the same effect upon the air as the same number of square feet of sheets of ice would have. The air simply parts with its heat and falls to the floor. No good ventilation can be had and much fuel is wasted. To obviate this loss and to insure good ventilation, double windows should be provided in all cold climates. The cost of these will be saved in two winters; but if there were no saving in cost, the increased comfort of pupils would compensate for the extra expense, because the temperature of the room can then be made uniform throughout." A more economical method, though not so effective, is double glazing a single sash. The windows of the new buildings of the Massachusetts Institute of Technology are so treated, with very satisfactory results. Great care needs to be taken that the glass is clean before the panes are fixed in the sash, but there is never any trouble from condensation of moisture between the panes. Skylights arranged in the same way are entirely satisfactory.

Proposed methods for better lighting.

Cohn thinks that the best scheme for lighting a school room would be to have the whole left side practically filled with glass. He refers to the Microscopical Hall in the Pathological Institute at Breslau, where the ratio of glass to floor is as 1 to 2.7, and he adds, "children who are learning to read and write need just as much light as students learning the use of the microscope." Dr. Risley in his model school room attempts to carry out this scheme within the limitations of masonry architecture. As a result, he obtains for his middle rooms a ratio of glass to floor as 1 to 2.9, and for his corner rooms approximately as 1 to 1.5. Dr. Risley also speaks of the value of fluted glass in refracting light into the room. A question might well be raised as to the desirability of treating the whole side of the school room like a modern show-window. The city schoolhouse in its usually confined space would certainly be better for the change, and the method of steel-frame construction where a fire-proof structure is demanded would lend itself admirably to such a purpose. As a rule, however, such a construction, if built when conditions do not absolutely require it, would lead to an expense that might not be justified by the results. Besides, the limitations of brick and mortar have not as yet prevented the building of skilfully conceived and practically well lighted schoolhouses.

Best exposure.

As to what is the best exposure opinions differ. There is a strong minority in favor of a north light as being more uniform and agreeable than that from any other point. Since it is preferred by microscopists, draughtsmen, photographers, artists, and those whose work is trying to the eyes, it is claimed that for the same reasons the advantage of north light should be given to children. The majority, however, recommend a southern exposure, so that during some part of the day the room shall be filled with sunshine. Although of course the warmth of the sun-bathed room is thus considerably increased in summer, this discomfort lasts only a short time, for in this country, as a rule, school vacations begin at the end of June, and continue during the hottest months; and by way of compensation there is the cheerful brightness of the room in winter. No direct ray of sunlight should ever fall on a desk. Each window should have two shades made of Holland, of a light gray or straw color. They should be mounted on rollers, one at the top and one at the bottom of the window, and each shade should be long enough to cover the entire window.

Color of walls and ceiling.

The quality of light entering a room is greatly modified by the color of the walls. Delicate shades of green, yellow, blue, or gray are the most satisfactory; and bright colors should be avoided. Green or blue should be used for the walls of rooms having a southern exposure, and yellow or buff for rooms that receive little or no sunlight. The ceiling is an important light distributer, and its coloring should be only strong enough to remove the glare of the white plaster. Ceilings may be painted soft shades of gray or buff. French regulations require that a line indicating the direction of the North Pole be traced on the ceiling of every room. For all plaster work above the top of the blackboard water-color may be used.

Artificial lighting.

Dr. Risley gives an important paragraph to artificial lighting. It may not call for particular consideration in schoolhouses of modern construction, although there are always enough dark days to make such means for lighting a valuable accessory; but in the improvement of poorly planned rooms in older buildings artificial lighting may be extremely valuable. For this purpose Dr. Risley considers the incandescent electric lamp the best. He recommends a group of sixteen-candle lamps in the centre of the ceiling under a large porcelain reflector, and a row of single lamps about a metre apart along the cornice. The lamps should be of lightly ground glass, thus concealing the glowing carbon and making the globe itself seem to be the source of illumination. Dr. Risley also considers it an excellent arrangement to distribute at regular intervals over the ceiling a sufficient number of lamps; and these, if properly arranged, do not cause dazzling or cast shadows, as he has taken pains to verify. "In a room 5 metres high, 10 metres long, and 8 metres wide, containing therefore 400 square metres, twenty-five incandescent lamps would furnish one candle for each cubic metre of space in the room. In a room with *one and a half* candles to each cubic metre, all distributed from a central chandelier, I was able to read D = .50 (diamond type) readily at one-third of a metre in any part of the room, with the lamps as the sole source of illumination. Therefore in a room of the dimensions suggested, designed for forty-five pupils, twenty-five lamps would furnish approximately *nine* candles for each pupil, and, added to the daylight, even on the darkest days would afford ample illumination in any part of the room."

Best material for blackboards.

Slate blackboards are the most economical in the long run, and as there is no difficulty in getting a proper quality and color they are decidedly preferable to a painted board, or to any of the compositions applied to the plastered walls. The strong contrast between the blackboard and the white chalk is often extremely trying to the eyes of young children. In a Cambridge school this was recently found to be the cause of complaints from many pupils who, until they came to do blackboard work, had had no trouble with their eyes. The boards in this school have been since colored a dark green; but the experiment has not been of long enough duration to obtain definite results. In one of the Boston schools now approaching completion, green slate is specified for the boards.

Arrangement of blackboards.

In English schools it is considered better to have the boards or slates movable rather than fixed on the walls, because if they are hung on pivots they can be easily adjusted to any desired slope for writing. The blackboard occupies so much room in connection with our system of education that such an arrangement would not be feasible; but the suggestion has been made that if the board were set up at an angle with the wall, children would not be forced into such a constrained position as they are obliged to take when they write on a vertical surface. Such a slope, however, to be of any value would diminish the room space; and this fact in itself is a sufficient reason why the experiment is not tried. When set, the blackboards should occupy all the available space in both class and recitation rooms. They should all be 5 feet wide, though 4 feet 6 inches is the usual width. The wider board allows an example or text written by the teacher to remain without infringing on space needed for the pupils' work. The slate stock is usually from 3/4 inch to 1/2 inch thick, and the pieces should be not less than 4 feet in running length, except that in filling out the wall spaces they should be worked in even sizes. It is a good plan to support the slabs on 1 1/2 inch by 2 inch angle-irons secured to the wall. In primary schools the bottom of the boards should be from 2 feet 1 inch to 2 feet 4 inches, and in grammar and high schools 3 feet above the floor. A chalk shelf 2 3/4 inches wide should be set at the bottom. This shelf should be hinged and made of woven brass or copper wire with a quarter inch mesh, to allow the dust from eraser and chalk to fall through into a trough which can be cleaned out at regular intervals. A wood moulding should complete the top finish of the board.

Finish.

In regard to the finish of the school room, exactly the same rules hold that govern the treatment of a hospital. All inaccessible projections which catch and harbor dust must be avoided as far as possible; no mouldings or cornices should be allowed. Wherever hard plaster or cement finish can take the place of wood, it is much better to use it. To facilitate the cleaning of the building, angles formed by the junction of walls with floors and ceilings should be replaced by concave surfaces. Dadoes of wood sheathing should never be allowed in a school room on account of the opportunity they offer for holding dust; and they have been found in many cases to be infested with vermin. Gauged mortar does very well for dadoes, but the best are made of Portland cement with a skim coat of American Keene's cement, the whole being 1 inch thick. This should be applied directly to the walls and should take the place of the regular three coat work in plaster. Not only should this cement finish complete the circuit of the school room below the blackboards, but the walls of corridors and coat rooms should be treated in the same way. The usual height specified for the dado here is 3 feet 6 inches, but it is better to have it reach above the height of the pupils' shoulders. Where there are no blackboards in the school rooms, either a plain wooden chair-rail or a moulding run with Keene's cement should form the cap of the dado. A similar moulding should also cover the joints between the cement and the plaster finish in the halls and stairways. The principal objection to a cement moulding is the danger of its becoming marred and shabby when within the reach of mischievous children. For this reason the cement finish is not so popular as it deserves to be. Jambs of windows and doors may also be finished with rounded corners in Keene's cement, and Mr. Wheelwright strongly recommends making door and window architraves of the same material. He would reduce to a minimum every absorbent and combustible material used in a schoolhouse.

Floors.

For finished floors there is no more satisfactory wood than selected rift Georgia pine. The strips should not be wider than 2 1/2 inches including the tongue, and should be matched and blind nailed. Of the inexpensive hard woods, ash is usually considered to make the most satisfactory finish. In France the floor is of hard wood parquetry, set when possible in bitumen. The base everywhere should have its lower portion finish with a cavetto, made of a separate piece to be tongued and grooved with the base, and with a ribbon floor-board 5 inches wide running round the room parallel with the base. As a rule, the floors of Boston schoolhouses do not receive any painter's finish. It is well, however, for floors to have two coats of boiled linseed oil; and if the wood has first been slightly stained the effect is even better. It has occasionally been found desirable to use for floors of corridors, wardrobes, toilet rooms, and staircase halls above the basement some other material than wood. There are various good constructions such as mosaic, tarazzo, or granolithic. Nevertheless, the additional expense is not justified by any appreciable gain in durability. In the basement, however, and in the play rooms and lavatories, asphalt is desirable. It is preferable to concrete, as that material is likely not to wear well, and to form a disagreeable dust. If a wooden floor on the concrete without an air space is desired, an excellent way is to lay first a hemlock plank floor thoroughly mopped with liquid coal tar; on top of this two thicknesses of tarred paper well lapped; and finally the upper floor at right angles to the planks. Mr. Wheelwright recommends for the same conditions screeds bedded in the concrete with water-proof paper under the upper floor, or if the site is damp, to lay on top of the concrete, before setting the floor screeds, a thick coating of hot asphalt or of tar concrete.

Minor Details. The teachers' platforms should be on heavy brass casters, to be easily movable, as many teachers prefer not to have an elevated seat. The floor should have the same finish under the platform as elsewhere. The platform averages from 9 to 10 feet long and 5 to 6 feet wide and 7 inches high. It is a good plan to have picture mouldings at least 2 inches by ¾ inch on every wall above the basement, except on stairways. In every school room there should be a bookcase and a teacher's wardrobe, and where possible they should be built in flush with the walls. They should average about 7 feet high, or their cornices may be the continuation of the cap-moulding of the blackboards. The bookcase is usually made about 5 feet wide, the lower half 15 inches, and the upper half 10 inches deep. The lower half may be made into two divisions with two panelled doors. One of the divisions should contain a set of drawers to run on ball bearings. The upper part should also be in two divisions fitted with shelves, and each part should have two glazed doors. The school room door should open into the corridor. It is customary to have a clear glass panel set into it at such a height that a person in the corridor may easily look in.

Wardrobes. In all primary and grammar schools a children's wardrobe should adjoin each school room. No schoolhouse can be considered first class that has these wardrobes in the corridors, however careful their construction and ventilation. Certainly in the schoolhouses of large cities, and preferably in all schoolhouses, every wardrobe or cloak room should be enclosed within four walls, and should be not only heated and thoroughly ventilated, but also directly lighted from outside. Under no other conditions is it possible to prevent the odor of damp or unclean clothing, if nothing worse, from entering the school room. Dr. Young in his article on the schoolhouse in the report of the Maine State Board of Health for the year 1891 says: "The history of epidemics is full of instances in which the clothing of school children has served as the medium for conveying infection from one child to another, and from one home to another." The old-fashioned corridor system is undoubtedly the least expensive, as it does not add materially to the area of the building. When low cost is necessary, however, a far better arrangement is to provide a well lighted and ventilated room in the basement with lockers for the children's clothing. In the lower grades this plan makes it somewhat harder to maintain school discipline; but in high schools, with older children, it is altogether the most satisfactory as well as the most economical method. In the best grade of schoolhouses single wardrobes, never less than 4 feet wide, are designed to run between class rooms from the corridor to the outside wall, in which there is a window. There are two doors, one opening into the wardrobe from the corridor, and the other at the farther end opening into the class room. The door opening from the school room into the corridor is in such a position that a teacher can command from the corridor school room and cloak room at the same time. The best scheme for furnishing the cloak room is to put up shelves 15 inches wide supported by strong brackets the whole length of the two long walls. In grammar schools they are set 5 feet from the floor, and in primary schools 4 feet. Into the under side of these shelves are screwed double-pronged clothes hooks of bronze about 15 inches apart. It is better to hang clothing in this way, as it will dry and air much more thoroughly than when it is hung against the wall. Racks for overshoes should be built above the baseboard or above the upper rows of hooks; and in the best work they are lined with planished copper and supported on iron standards. Rack stands for umbrellas should also be provided.

Other rooms.

In all schoolhouses there should be a teachers' room with proper sanitary arrangements adjoining, and in the larger schools there should be in addition a master's room, a reception room, and a library.

In discussing the remaining details of the construction of schoolhouses, I have availed myself of Mr. Wheelwright's papers in the "Brickbuilder" on "The American Schoolhouse,"—articles which fully epitomize, from the architect's point of view, the conditions governing the construction and furnishing of schoolhouses. The rest of the chapter is therefore in substance his work, interspersed wherever I have deemed it necessary with comments of my own.

Entrances and corridors.

"Schoolhouses should, if possible, be provided, in addition to the main entrances, with outside entrances to the basement for each sex, and there should never be less than two entrances on the first floor. Where the conditions of the building admit, there should be an ample porch provided at the entrance to shelter the early comers who cannot gain admission to the building. The entrance doors should open outward to prevent possibility of disaster in case of fire or panic. The vestibule doors should be hung with double swing spring butts. The main corridors should be of ample width, not less than 10 and preferably 12 feet wide, and should be thoroughly lighted. Fire protection by tinned doors, making it possible to shut off the staircases on each floor, is a desirable fire and panic precaution. It is very important that there should be such fire doors to shut off the basement, and that these doors should be fitted with spring butts or door checks."

Staircases.

"The staircases should be of iron throughout, the treads fitted with rubber mats, or, better, with some one of the recently introduced combined lead and steel treads. Both rubber mats and lead treads should be set in a sinkage cast in the iron tread. The lead treads need not exceed 5½ inches in width. The staircase risers for primary school should be 6 inches high, and in other schools they should not exceed 7½ inches; the balusters and posts of iron, of plain pattern; and the hand rails of each of plain round section. There should always be wall rails except at platforms. Staircases are required in Boston to be at least 5 feet in width. Some authorities consider that such staircases should not be wider than to admit of the comfortable passage of two files of children, each thus having a hand rail; and therefore that they should be but 3 feet 6 inches wide, to prevent possible crowding between files in case of panic. The excellence of the discipline of our school children has been proved during alarms of fire, and therefore we may safely retain the comfort and convenience of the 5 foot stairway. There should not be more than fifteen or less than three risers between landings. Landings should be at least 4 feet between steps. No schoolhouse should have less than two stairways, each readily accessible from all the rooms of the upper floors."

Basement.

"The uses to which a basement may be put depend upon the size of the school. In every schoolhouse in addition to the boiler room, coal room, etc., there should be well lighted play rooms for both sexes, with lavatories adjoining, shut off by fly doors with spring butts." A good height for a basement is 10 feet. The ideal plan has the boiler room and lavatories in a structure by itself, 14 or 15 feet in height, distinct from the main building, and approached by covered ways. Such an arrangement secures safety to the schoolhouse and its inmates in case of any accident to the heating apparatus; and also adds to the security against possible unpleasant odors from the sanitaries. "When sufficient size permits, manual training and cooking class rooms and gymnasiums for both sexes, and where possible, ample bathing facilities, which at the present day are almost a constant feature of continental schools, may well be provided. Where there is space there should be a well lighted janitor's closet. An entrance with runway and storage room for bicycles is to become a necessity in modern schools, and in the latest high school buildings a lunch room is always provided."

"Fire-proof" construction.

"It is a wise precaution to build schoolhouses of four or more stories in height wholly of indestructible materials, that is, they should be of 'fire-proof' construction. It would appear unnecessary under ordinary conditions to use such expensive construction in buildings of three stories or less in height. The first floor of all schoolhouses should be of 'mill' or 'fire-proof' construction. With the present low cost of structural steel, a steel and arch construction of the floors is preferable to that of heavy timbers and plank, as the latter construction, though less expensive, is liable to cause considerable annoyance from shrinkage, as practically the market does not afford seasoned stock of large dimensions." From my own experience, I should consider it by no means advisable to use the "mill" construction for a span of 28 feet. I have examined many floors built after this manner, and never yet have seen one in which the timbers have not shrunk or sagged so badly as to cause ugly cracks in plastered walls and wooden finish. It may be well adapted to factory construction, where there are short spans, and where there is no finish by which its defects are made apparent; but in good work where it is necessary that accurate finish should be maintained, the so called "mill" construction must be used with great caution. For the construction of first floors for a span of 28 feet, if steel and arch construction cannot be afforded, joists of hard pine planks, 3 inches thick, and 14 inches on centers, make a more permanent floor; and with proper fire-stops and metal lathing for plastering there is practically little more danger from fire than in the "mill" construction.

Further precautions against fire.

With the first floor constructed of incombustible or slow-burning materials, all interior partitions solid, the plastering laid directly on brick walls, ceilings wire-lathed, and the basement staircase protected by fire doors, even if the floors above the first story and the roof are constructed of the ordinary narrow joists with ⅞ inch floor boarding, there is practically no danger from a fire started in the interior of a schoolhouse. If the roof is flat and protected by a battlement wall of ample height, under ordinary surroundings a fire outside of such a schoolhouse would not be a practical danger to the lives of the occupants. In a building constructed as above described, and in the isolated position of most schoolhouses, the scholars would be led to the street before there could be any dangerous condition of the building. There is, however, danger from panic. To avoid this danger by giving the greater sense of security to teachers and pupils which goes with a solid construction, it would appear advisable to have the floors of fire-proof construction in primary schoolhouses in excess of two stories in height, when in closely built localities. The inner lining of outer brick walls should be of hard-burned hollow brick, with soft brick set to receive nailings for finish. The interior partitions should be either of brick, terra cotta lumber, or thin partitions of metal lathing on angle-irons. The advantage of such solidity of construction and absence of wood furring is to protect not only from fire but also from vermin."

Cost of Schoolhouses.

The cost of the schoolhouse is an important consideration, and the one which first appeals to the architect and the school board. Here again I quote Mr. Wheelwright: "An attempt at exhaustive analysis of the subject would be a task disproportionate to the value of the result. General conclusions drawn from data gathered in my own practice, and from that of others, may, however, prove serviceable to architects and school committees. These data should be used with judgment and with careful consideration of the conditions governing each particular case. Estimates based upon cost per square or per cubic foot can never be as safely relied upon as those based upon a survey of quantities, and reckoned according to the prices which maintain at a given time in each locality; but none the less a fairly close approximation of the probable cost of a building can be made by estimates based upon the cost per square or per cubic foot. The basis of cost per school room is the fairest method of comparing roughly the cost of grammar or primary schoolhouses. To come to a closer judgment of such comparative costs, that per cubic foot has often to be taken into account, while as their plans present less constant characteristics than do those of the schoolhouses for the lower grades, the cost per cubic foot appears the fairest basis of comparison of costs of high schools."

Analysis of the increased cost of Boston Schoolhouses.

In Mr. Wheelwright's fourth Annual Report appears an interesting table, quoted below in full, for the purpose of showing the cost of Boston schoolhouses as compared with those built elsewhere in the State. A six room building on account of its simplicity of type serves as the basis for analysis. On such a building the various improvements that are not generally to be found in schools outside of Boston would cost as follows, the total being 16 per cent of the cost of the building: —

Fire-proof stairs instead of wooden ones	$468 00
The excess in the thickness of brick walls	1,173 12
The excess in framing throughout	1,000 00
Fire-proofing floors	200 00
Fire-stops	100 00
Increased size of building, occasioned by above requirements of the Boston building laws	1,500 00
Slate blackboards in place of composition	209 44
Bookcases and finishings not ordinarily included	180 00
Asphalt and brick instead of wood and concrete	500 00
Double sash instead of single sash	420 00
Tinting ceilings and walls	200 00
Cement finish in place of wood	96 00
Hospital base instead of common base	106 56
Fire-proof partitions instead of stud partitions	121 50
Wire lath on ceilings instead of wood lath	296 45
	$6,571 07

Mr. Wheelwright estimates that 2 per cent of the cost of the schools is due to features for whose introduction he himself was responsible, such as fire-proof partitions throughout, floor and window trims of Keene's cement, gauged mortar dadoes, wire lathing on ceilings, and hospital baseboards; that about 3 per cent is due to recommendations of the School

Committee and the Superintendent of Schools, such as double sash, asphalt flooring in the basement, and slate blackboards; and that about 11 per cent is due to the requirements of the building laws, which, in Boston as in all large cities, are more exacting than in small towns. Moreover, besides this increase of 16 per cent there is a further increase of 10 per cent, 5 per cent being for enlarged duct areas, and 5 per cent for the additional heating and ventilating power thus rendered necessary. This extra expense is required by the recent State laws in regard to the heating and ventilating of schoolhouses. Finally there is "the increased cost of nearly all building material and of labor in Boston over the cost elsewhere in the State. This latter element of cost, in connection with the many features not generally in use, suffices to increase the cost of Boston schools about 20 or 25 per cent—varying with locality—above the cost of schools of the same size as ordinarily constructed elsewhere in the State."

Effect of the Building Law of 1897 on the cost of Boston Schoolhouses.

The revised Boston building law of 1897 requires that all schoolhouses built in the future in Boston shall be wholly constructed of incombustible materials. This requirement unnecessarily increases from 15 to 20 per cent the already large cost of schoolhouse construction in Boston. While there are advantages in fire-proof construction for the floors of schoolhouses, the provision that such floors should be required to "carry a live load of 150 pounds in addition to the weight of the floor" itself involves an absurdly unnecessary expense. No school room floor need be constructed to carry a live load of more than 80 pounds per square foot, and as Mr. Wheelwright rightly says, so far as the safety of pupils and teachers is concerned, there is really no need of building even the roof of incombustible material. Further, except in the case of schoolhouses of three stories or more in height, situated in closely built districts within the fire limits, it is an unwise expenditure to require that any floors except the first should be fire-proof.

Needless expenses.

The steadily increasing cost of schoolhouses is certainly a serious burden to the community, and it is to a certain extent unnecessary. That good exterior design can be had with the simplest material is fully proved in this work. Economy of interior design and fittings, which the drawings cannot fully show, is equally attainable. No attempt need be made to obtain sumptuousness of effect in corridors, stairs, and dressing rooms by the use of marble or other expensive material. There surely is no more need of marble floors in the corridors and wardrobes than in the school room. The steadily increasing desire to surround the scholar with everything beautiful during the receptive period of school life can be satisfied more effectively by the use of color decoration, wall pictures, and plaster casts. The aim in dispensing the public money for schoolhouses should be first to construct them, in regard to the demands of hygienic laws, on the most liberal scale; then to use nothing in construction or finish that is not needed to accomplish these ends,—marble floors, for example, if not required in school rooms, are surely unnecessary in corridors; next to demand as careful methods of construction and workmanship as are employed in hospital wards, for there is more danger to be feared from the spreading of contagious diseases by children in a large room of a city schoolhouse, than by the patient in the isolated ward of a hospital; and finally to decorate the walls simply and quietly in color, and hang them with such pictures as will best appeal to the child's imagination.

Above all, the building of a schoolhouse calls for a thoroughly trained architect; the work should not be entrusted to young architects merely to give them an opportunity to develop their talents at the public expense. The success of such a building, which is proved by the comfort and well-being of the scholars, depends on the experienced care which must be given to every detail of construction and of schoolhouse economy, and such results can as a rule be best secured only by the employment of those whose reputation is already assured.

III.

THE subject of school furniture is of such great importance that it has seemed well to devote a section of this work to the matter, both to emphasize the need of its continued discussion, and also to show the importance of preserving and extending the single desk and seat system.

Suggestions of Dr. Risley as to desk and chair.

With regard to the best form of desk and chair to be used, Dr. Risley, in the articles already referred to, has many valuable suggestions. To Henry Barnard he gives the credit of first calling attention, in 1860, to the serious defects in the seating arrangements of American school rooms. The desk was usually placed so far away from the chair that a plumb line dropped from the edge of the desk would be at some distance in front of the seat of the chairs. Thus a pupil when writing was obliged to reach forward, taking a position which is decidedly injurious. The subject was taken up by German investigators in their usual thorough manner, and the mechanical problems involved in faulty and correct posture in sitting were clearly shown. Nevertheless Dr. Risley is forced to remark that "there is much cause for just condemnation of school authorities in the fact that thirty years after the clear and convincing demonstrations made by these authors, thousands of school children are still required to pass their school lives at desks with the old faults uncorrected." Such a condition of things will probably continue to exist until the voters of our cities see the importance of choosing each member of a school board for his fitness for so responsible a position, rather than for the purpose of strengthening a political party. In considering the various forms of school furniture that have come under his notice, Dr. Risley insists on the use of none but adjustable chairs and desks. It is not enough merely to provide furniture made in several sizes to meet approximately the requirements of different grades; besides this each desk and chair must have means of adjustment of its own. The best adjustable forms that have come to his notice are those of the New York Hygienic School Furniture Company and those of the Chandler Adjustable Chair and Desk Company of Boston. Finally Dr. Risley says that "no class should be considered fully organized for the work of the term until each pupil has been measured and the seat and desk have been adjusted to meet the requirements of the individual. While this will occasion additional trouble at the beginning, I am convinced that in the end it will avoid much annoyance and trouble, since a properly seated class will not suffer from the restlessness occasioned by compressed viscera and impeded circulation and respiration, and will therefore perform their allotted tasks with less fatigue and be more orderly."

Report of committee on adjustable school furniture.

In 1896 a committee of five, consisting of Drs. Edward M. Hartwell, H. P. Bowditch, Oliver F. Wadsworth, E. H. Bradford of Boston, and Prof. Edward F. Miller of the Massachusetts Institute of Technology was appointed to investigate the subject of adjustable school furniture for school seating. Professor Miller has kindly allowed me to reprint a paper from the Journal of the Boston Society of Medical Sciences, in which is described the chair which he constructed to meet the views of the committee.

"As there was nothing in the line of adjustable school furniture either here or abroad that was entirely satisfactory, the committee has constructed one or two experimental chairs with the hope that builders of school furniture may profit by and improve upon the good points of each chair. It fell to me to carry out mechanically the ideas of the committee, and it is simply to explain the mechanical side of this chair that I am here this evening.

Form of chair recommended.

"The two styles of adjustable furniture in most common use are the Chandler and the Bobrick. In each of these the heights of both chair and desk can be varied to suit the requirements of the pupil. The top of the desk is made to slide, thus enabling the pupil to bring the desk nearer to his body when he desires to use the desk for writing or drawing. The chair after being set at the proper distance from the desk and at the right height cannot be moved by the pupil. The chair which I have here shows the line along which the committee thought improvement could be made. This is an experimental model built up from an old school seat; the iron is very much heavier than it need be, and other details can of course be much improved. It will, however, serve to show the principle. By a method similar to that used by the Chandler and Bobrick Companies, the seat can be raised or lowered to suit the height of the pupil. The seat is carried by two cast-iron links running up from the movable casting which forms the upper part of the pedestal. The links turn on pins at either end. The link at the front is much longer than the link at the back. The castings, which are screwed to the chair bottom and to which the upper ends of the links are attached, are so located that when the pupil is leaning forward (as he would be when about to write) his centre of gravity falls to the front of the supporting pedestal, and the links come into the position shown in Fig. 1. As the pupil leans back his centre of gravity falls back of the supporting pedestal, and the links move into the second position (Fig. 2). In the first position the back link comes up almost to a vertical line and the chair bottom is level; at the same time the chair seat is carried forward toward the desk about three inches. This obviates the necessity of a sliding top on the desk. In the second position the front link is almost vertical, and the short back link has lowered the back of the seat so that the chair is now tipped backward. As the links come up toward the vertical, they bring up against rubber buffers which prevent noise and shock. It is believed that by dropping the back of the seat and thus making the position in which the pupil sits more comfortable, he will be less inclined to slide down on the small of his back. By the use of the long link on the front side and the short link on the back side, the chair may be tipped back while raising the front edge but little, thus avoiding the danger of stopping the circulation of blood in the legs. A number of experiments were made with chair backs. The back of this chair has but two horizontal cross-bars, each made adjustable. The top bar is adjustable in height, and the bottom bar is adjustable both vertically and horizontally. By loosening four screws, two on each side, both supports can be moved and fitted to the back of the pupil.

FIG. 1.

FIG. 2.

"Probably three sizes of chairs would be needed to cover the grades from the kindergarten through the high schools. This chair would be more expensive than those now in use; but since the desk would not need to have a sliding top its cost would be cheapened. Thus the total cost of both desk and chair would be but little greater than at present."

IV.

THE plumbing of a schoolhouse is a matter that demands the most careful attention, as it directly affects the health of all the inmates of the building. In the section of the work assigned to me, I have tried to show how the general principles of sanitation are carried out in the arrangements in schoolhouses of the present day.

Situation of toilet rooms.

First of all, in regard to the position of urinals and water closets, there is a growing opinion that it is unsafe for them to be placed inside the school building. Such is the judgment of many sanitary experts who, insisting upon precautions to provide against all uncertainties, realize that in the arrangement of such apparatus it is not possible to give absolute assurance of safety, and that serious defects, not discoverable at first, may develop in the course of time. It may be safely said, however, that, providing the ventilation is adequate, it is practically immaterial where urinals and water closets are placed. Other considerations, nevertheless, may lead to the practice of establishing them in a separate building. The principal reasons for such a change are that the basements of schoolhouses are coming more and more to be used for classes in cooking and other industrial work, and for play rooms. On the other hand, where a separate building is provided, extra heating is demanded in addition to increased service in the care of the apparatus, and further, there is the danger to the pupils of exposure in bad weather.

Ventilation of apparatus.

Wherever placed, the lavatories must under all circumstances have the assurance of effective ventilation. Whether water closets, brick latrines, or iron ranges are used, they should be ventilated downward through the seats by what the plumbers call a local vent, each seat having a vent-outlet of not less than 5 square inches of cross-section area, and the vent pipe being enlarged at each branch connection. The absolute volume of air to be moved in this process is not necessarily large; on the contrary, if every piece of apparatus has its share of ventilation, and if the movement is made positive, the volume may be relatively small. This movement can be guaranteed only by means of a powerful aspiration; and for this purpose must be provided a shaft moderate in size, but strongly heated, and high enough to reach above any part of the roof of the main building. The shaft containing the boiler flue will serve for this use, but no other vent-duct must enter the shaft, and a stove should be placed at its base to furnish the requisite heat when the boilers are without fires. Stoves for this purpose were installed in Mr. Wheelwright's schoolhouses; but it was found in several instances that the janitors were too lazy or too ignorant to use them. The stove selected, although it needs to be of somewhat greater capacity than would at first be supposed, may yet be of the simplest type. A common "scorcher" is serviceable; but in large schoolhouses Mr. Wheelwright used on my recommendation either a common grate with a fire-brick fuel box or furnace, or the base and firepot of a cast iron furnace, allowing the gases and heat to pass directly into the shaft, no separate chimney being used. The aspirating power of the shaft depends of course upon the heat imparted to the air, and to obtain sufficient power the quantity of heat expended will be considerable. The grate of the heater should accordingly have not less than 20 square inches for each class room in the building, and for a twelve room schoolhouse this means a surface of nearly 2 square feet. This compared with the usual size seems large; but aspirating shafts as commonly arranged and operated are deficient in power, and therefore, especially in mild weather, are ineffective as a mode of ventilation. A familiar example of this is the occasional regurgitation of foul air in the well-known but unsuitable "dry" sanitary systems.

Of the styles of apparatus mentioned above,—water closets, brick latrines, and iron ranges,—all three are found in Boston schoolhouses. The comparative advantages of the several systems are noted here. *Water closets.* No water closet should be used which has a self-contained trap, unless the joint between the trap and the soil-pipe is below the water line of the trap. No putty, wax, or other packed or gasketted joint is safe. Water closet doors should be only 2 feet high, and should be hung 30 inches clear of the floor. There should be one water closet for every fifteen girls and one for every twenty-five boys. There should also be one or more closets on each floor. It is inexpedient to provide separate closets for the teachers. If any child is too dirty in person or too filthy in his habits to be allowed to use a convenience common to others, he is an improper person to be received in the school. The difficulty with the water closet system is that children can never be depended upon to deluge the separate closets, and that the various mechanical devices for automatic flushing which are attached to doors or seats are generally ineffective. For these reasons the latrine or the range system is much more satisfactory. Into these fixtures the water can be turned at recess by the janitor, the apparatus being adjusted to flush out during that time every two or three minutes. *Brick latrines.* The advantages of the brick latrine system are that it can be ventilated at one point for all the seats, and that it cannot be choked by rubbish ignorantly or mischievously thrown into it. A well made latrine, designed as shown in Figs. 1 and 2, is entirely satisfactory if kept clean; and if it is well ventilated, it may even be neglected without harm to the occupants of the building.

FIG. 1.

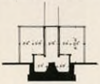


FIG. 2.

The construction of latrines demands some care: the bricks should be laid in Portland cement mortar, and should be plastered with Portland cement; then the surface should have a final coat of neat cement hand-floated, made perfectly smooth, and covered from the air and thus kept moist until the cement has set perfectly hard. The latrine seats where not made of iron should have woodwork that may be exposed to water, lined with sheet lead. The seats should be self closing, in order to prevent too large a volume of air from entering the vent shaft and in that way diminishing the draft at the other seats. The woodwork of the seats should each year be finished in shellac rubbed down to a dead finish. Mr. Wheelwright made use of brick latrines *Iron ranges.* in preference to iron ranges because the former could be well ventilated. The latter were introduced to meet a change in the plumbing law requiring that water closets should be used, and the Board of Health decided that by this law brick latrines were excluded. The ranges are constructed so that a small quantity of water stands in each section, and when they are flushed the flow of water clears out the trough thoroughly. The toilet rooms in which these iron ranges were placed in the Boston schoolhouses built before 1895 were well ventilated, but the ranges themselves had no ventilating attachments. At present, however, as a result of the

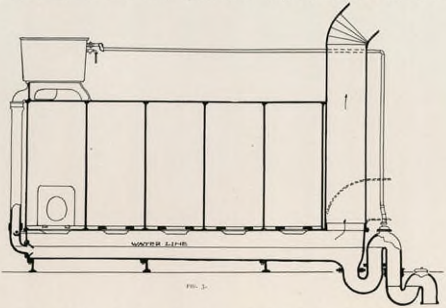


FIG. 3.

experience with these schoolhouses, the ranges are fitted with local ventilation. The modification of the Mott ranges (Fig. 3) which permits such local ventilation was suggested by me. No woodwork whatever should be used about the ranges.

There may arise cases in suburban districts or in towns not yet sewered where the use of water must be restricted, and the resort to some kind of privy or dry system appears unavoidable. My opinion is that any apparatus of that sort is permissible only as a temporary expedient. In no event is it to be placed within doors. I do not say that it is impossible so to arrange and care for a privy within doors that it will be always harmless; but from the point of construction it is a difficult matter; the safety of the privy is made uncertain from the variety of conditions which may arise, and proper continuous care cannot be assured,—any one of which conditions is a sufficient objection to the method. It should be borne in mind that if there is a back draft from a "dry" latrine system, this soil, powdered as it is by heat, is in a condition which makes it most dangerous to health. Under the restriction imposed by the absence of town water-supply and sewerage, there remains only the exterior privy as the proper receptacle for excreta. I do not accept as admissible in the case of any building, much less any community or public building, the employment of the common privy. It is time to take a decided stand on this question, and, in accordance with the principles of sanitation, to insist upon the abolishing of this ancient and death-dealing abuse. There are cases in Boston schoolhouses where privy vaults have not been disturbed in twenty years. In a civilized community no apparatus for receiving filth is to be tolerated which does not provide for the immediate removal of such filth and for its complete disinfection. In the absence of the *Privies.*

cleanly and efficient water-carriage system, there remains disinfection by means of dry earth (loam or humus). The establishment of this system, however, is not complete without provision for constant and faithful supervision, and for the removal of the disinfected material and the supply of fresh earth at regular intervals. There may be some things which will take care of themselves or which if neglected will do no harm, but the sanitary appliances of a schoolhouse cannot be classed with them. To guarantee such care as will assure the scrupulous neatness of the privy, a stove for heating it should be provided. With the stove should be used an aspirating shaft, by which the air may be exhausted from the pit, and the earth thrown upon the excreta kept dry. This shaft should also be connected with a drying chamber for preparing and storing fresh earth. The fire should be kept continually going in summer and winter, and the work of the attendant should be supervised and approved by the teacher, who should be held responsible for the condition of the privy.

Urinals.

Regarding urinals nothing wholly satisfactory seems to have been yet introduced. I do not favor the use of urinal bowls, and troughs are still more objectionable. They are difficult to keep clean, and in the care of the average janitor are sure to be neglected and to become

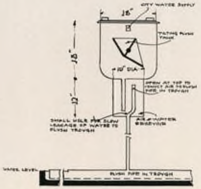


FIG. 4.

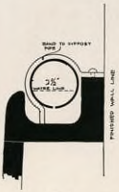


FIG. 5.

actively offensive. For this reason the plain slate slab has been used in Mr. Wheelwright's schoolhouses. The objection to the plain slab is the difficulty of keeping it thoroughly wet and washed by the flushing water without the production of a spattering spray. In France there is in use a successful type of plain urinal which is flushed by water overflowing from a neatly formed weir extending the whole length of the urinal. This weir is formed in the capstone surmounting the upright slab of slate, and insures perfect washing with no annoyance from spray. To this arrangement I have added an intermittent flushing apparatus by means of a tilting tank, and thus the only objection to it,—a rather extravagant use of water,—is removed. At first some difficulty was found in giving a uniform rate of overflow for the whole length of the weir at the instant of flushing action. This difficulty was overcome however, by the aid of pneumatic pressure produced by the discharge of water from the tank, and distributed over the entire extent of the weir by means of a partly submerged pipe (Figs. 4 and 5). Urinals should be divided into stalls and there should be at least seven stalls to every one hundred boys. In the construction of urinals care must be taken to give the back a slope of 1 in 10, and to incline the foot slab toward the urinal not less than 1 in 20, all joints being made waterproof. Ventilation may be provided in two ways: as shown in cut (Fig. 6) or by a row of outlets cut in the bottom of the urinal slab and opening into a vent shaft at the back. In either case connection is made with the aspirating shaft.

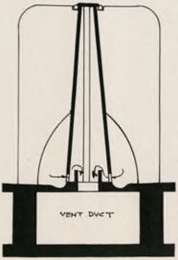


FIG. 6.

When set bowls with plug and chain or an equivalent are used in the toilet rooms, there should be one bowl to every twenty-five pupils. In my own opinion a better arrangement is either a running stream of water supplied by a pantry faucet, or else a row of nozzles well above a sink. Every child should own a cake of soap, and should fetch to school with him every week a clean towel and a supply of toilet paper. *Set Bowls.*

It is hardly necessary here to insist on the importance of extending the soil-pipe above the roof, or to refer to other rules always observed in well regulated communities. One detail, however, which is not generally found in the plumbing ordinances, needs mention. There should be no sewer connection except that by way of the main trap, which should be in a vault outside the building. This vault should be ventilated by the soil-pipe through the roof. I am aware that some authorities permit the house traps to be inside the wall, but such an arrangement is often a menace to health, as the tightness of the joint between the house trap and the sewer is not always assured. The trap vault, on the other hand, intercepts and through its ventilation carries off the ground air, which may often contain sewer gas. *Trap vault.*

When the apparatus is complete and in the condition of regular use it should be tested, and without such test no system of plumbing should be accepted. Testing by smoke or peppermint without pressure is not sufficient. The only test that is satisfying and convincing is made by tightly closing the outlets on the roof, and then applying pneumatic pressure to the entire system. This method was introduced by me in 1884, and is now gradually coming into general use. *Test for plumbing.*

The great interest that has been shown of late years in public bathing facilities in Europe and especially in Germany has manifested itself to some extent in the provision of special bathing apparatus for schoolhouses, and the practice is gradually spreading in this country. The employment of tubs for bathing in schools or in any building where numbers must be provided for is decidedly objectionable. It is necessary that the tub should be cleansed after each time that it is used, a duty that may be neglected and that when performed consumes time. Further, the large amount of space and the complication of apparatus required by bath tubs have made their use impracticable. In modern bathing plants the shower is the only bath employed. In large public baths it is supplemented by a swimming tank which, however, no one is permitted to use until he has first taken a shower bath. The efficiency of this apparatus where a large number of persons bathe is very great, as is also the economy of water and attendance. *Baths.*

Finally, the all important principle in the plumbing of schoolhouses, as indeed of all plumbing, is that no plumbing fixture is absolutely self cleaning. No matter how satisfactory in design, construction, and ventilation, the apparatus, if it is to be kept free from stench and *Care of apparatus.*

disease-spreading matter, must be often washed with soap and hot water. To do this the average janitor cannot be trusted unless he is under the constant supervision of a competent person who has unrestricted power of removal. Such a superintendent not only should have the power to enforce the cleaning of the apparatus, but should also be competent to direct its proper repair. Certainly no person who has witnessed some of the conditions that exist in the old schoolhouses in Boston would fail to see the great need of a system of supervision and control of janitors. The imperative necessity of this I realized when acting on a special commission appointed by Mayor Quincy to report upon the sanitation and fire protection of Boston schoolhouses. We found the privy seats wet and slimy, excrement on the floor, trough urinals full of frozen urine, and the privy floor and yard surface covered with the frozen overflow. On thawing days this saturated the boys' shoes and was tracked in upon the floors that by the city's defective rules have been never washed since they were laid. It seems hardly credible that such conditions should exist, since there are many public officials whose duty if rightly understood and accepted should have long since led to the discovery and remedy of these evils. But owing to the administrative system prevailing, no one person is willing to be held responsible for them. Not even yet have any promising efforts been made to abolish these evils or to remedy them by the appointment of a responsible chief of janitors. In many instances, indeed, the political influence of these servants of the public is so great that those members of the School Committee who are desirous of inaugurating such an administrative system do not venture to make the attempt. Upon the character and efficiency of these janitors, nevertheless, the success of any system of sanitation depends, and until their work is regularly supervised no satisfactory results can be expected.

V.

THE principles of warming and ventilation are essentially the same for all types of buildings in common use in cold climates. The problems connected with their application to schoolhouses are, however, so many and so varied that they present almost every possible form of treatment. This chapter, though nominally only a brief discussion of the principles of warming and ventilation as applied to schoolhouses, thus necessarily includes the wider aspects of the subject.

Complex character of the problems of warming and ventilation in Schoolhouse work.

What the respiratory system is to an animal the ventilating system is to a building. As the habits of an animal determine the type of respiratory system most appropriate to it, so the type and use of a building are the principal factors in determining the characteristic features of the ventilating system best adapted to it. The large and modern high school building presents a complex type far removed from the simpler patterns found in the dwelling house, the office building, the audience hall, the church, or even the theatre. It presents an involved combination of rooms designed for widely different purposes, each room requiring an equipment adapted to its special use, and the building as a whole demanding a treatment with proper reference to its periodic use and its peculiarities of arrangement and exposure. Between the complex problem peculiar to such a building and the simple one presented by the one-room schoolhouse at a country cross-road, there exists a range of type completely filling the interval, each step of the gradation necessitating a corresponding modification in the method of, and means for, ventilation.

Three objects sought.

Three ends are to be sought in warming and ventilating work as it relates to the maintenance of vital energy at its best by wasteless and effective means. These ends are hygienic, economic, and mechanical. The hygienic side of such a study is highly important, and deserves more than the passing notice to be here accorded. Both ventilation and warming of buildings are necessary chiefly for hygienic reasons. The economy and the mechanical efficiency of warming and ventilating methods are relatively minor and even inconsequential matters. If, therefore, less space is here given to the topic of first importance than to those which are secondary, it is because, in discussions to be found elsewhere, the hygienic side has been pressed upon public and professional notice, and the economic and mechanical aspects of the problem have been given minor attention.

Relation of pure air to vitality.

Air is as essential to the products of physical and dependent mental energy as it is to the intensity and brilliancy of a candle flame. The physical energy of the body is as much the product of the oxidation of carbon within it as the energy of the engine is the product of oxidation in the fires in the boilers. The normal brilliancy of a candle flame is obtained only in the purest air. The engine develops its greatest energy only when its fires are freely fed with air. A withdrawal of oxygen from the air in quantity equal to $\frac{1}{100}$ of the volume of the air reduces by $\frac{1}{20}$ the luminosity of a candle flame burned within it. The quantity and intensity of vital energy suffer a corresponding if not an equal or even greater change when protractedly exposed to abnormal atmospheric conditions. The breathing of impoverished air results of necessity in the dulling of the vital fires of the body and of the keen edge of the intellect. It means a weakened body and a dulled mind. A lowered vitality of the body, besides exposing it to an increased liability to communicated, contracted, or constitutional disease, also impairs its effectiveness as a vital mechanism. The aggregate of physical and mental vitality lost through ignorant or indifferent regard, and even culpable disregard, of the exact and delicate dependence of the activities of body and mind on the maintenance of a normal, including atmospheric, environment, surpasses all common conception or belief. That air quality is fully as important as food quality in the production of vital energy is a conception which has yet to be borne in upon the public, if not the professional, belief and conscience. A rule which may be safely insisted upon for general adoption and application is that pure air should be supplied to enclosures in the maximum rather than in the minimum quantity tolerable. Only two considerations should be allowed to limit the quantity of air supply: air draughts and bank drafts. Draughtiness in air currents is more dangerous to health than the ordinary vitiation of air in badly ventilated enclosures. On the other hand, the warming and, under some circumstances, the moving of air in large quantities for ventilating work is far from costless. Both draughtiness in air movement and costliness in the warming of air put, therefore, a deterring limit on air quantities to be used in practical ventilating work.

Limitations to the supply of pure air.

Draughtiness in large halls.

With a given hourly *per capita* air supply, the danger from draughtiness within an enclosure increases, approximately, inversely as the *per capita* space. Fortunately, however, the necessity and importance of ventilation are not the same for crowded as for sparsely occupied rooms, being of least account in rooms intermittently occupied, and of greatest account in those most continuously used. The length of time for which a person is exposed to the confined air of an enclosure is, therefore, an essential factor in determining the proper rate of its ventilation. The harmful effects of short exposure to impure air once a week are small when compared with those incurred by frequent and protracted exposure to such air. It is, of course, in crowded audience rooms which have a small *per capita* space, and to which a large *per capita* air supply cannot be furnished without dangerous risk of draught, that the most impure air must of necessity be found. On the other hand, such rooms are least continuously occupied. If, therefore, danger is directly proportionate to the time of exposure to impure air, the sensibly close air of a poorly ventilated church, lecture hall, concert hall, or theatre may not be productive of such harm as the purer air of a better ventilated but more frequently and longer occupied school room. By helpful coincidence, therefore, the most difficult rooms to ventilate freely are those least requiring such ventilation, inasmuch as they are least used, and when used are occupied for only short periods. In effect, the time of actual occupancy varies with the provided *per capita* space; and, for equal hygienic results, the per hour and *per capita* air supply required also vary in the same manner. Considering only permanent effects on health, an individual air supply of 1000 cubic feet per hour furnished to a crowded audience hall having but 100 cubic feet space *per capita*, may therefore be regarded as equally good ventilation with 3000 cubic feet *per capita* supply of air per hour furnished to a school room having 300 cubic feet *per capita* space. For the ventilation of crowded rooms the air volumes usable are limited by draught dangers; and for ventilating less and the least crowded rooms the quantities are limited by the cost. It is the office of the architect and the engineer to provide for the rooms of the first class a maximum air supply with a minimum of draught; and for rooms of the second class the freest ventilation consistent with reasonable expense. To produce for crowded rooms ventilation which shall be abundant and yet draughtless, and for other rooms a general ventilation which shall be effective and inexpensive, are among the most important, and often the most difficult, heating and ventilating engineering services to be rendered.

Means for reducing draughtiness.

The audience halls and larger lecture rooms of schoolhouses cannot generally be provided for as perfectly as can rooms having fixed seats or desks, the usual or specially provided surfaces of which may be utilized for a diffusive entrance of large quantities of air. The floors of these large rooms must at times be cleared for drill, dancing, and social occasions. Danger from draughts must therefore be reduced by dividing the inflow into as many and small and slow-moving currents as practicable, and by giving to the inlets such positions and formations as shall deliver the air in directions least liable to produce sensible draughtiness. The animal heat yielded by a crowded audience is frequently more than that lost through walls, windows, and other means. The effect of that heat is to raise the temperature of the auditorium air and to necessitate a temperature of air supply lower than the temperature of the room. Because of the need of this low temperature, it is desirable to give to the entering currents of air a direction which shall as much as possible prevent their dropping floorward, at least in concentrated form. If the air supply must be admitted through wall apertures, they should be elevated unless they are made so large as to reduce the rate of inflow to or below a linear rate of 30 feet per minute. Even when the wall openings are elevated, the currents should be given an initial upward direction. They will thus take a longer path before reaching the floor, and will therefore mix more thoroughly with the warm air of the room by being longer in contact with it, and by flowing more diffusively through it. If the air inlets to a room of this character can be placed in the floor and protected from infalling dirt, that position is preferable to a wall location. In general it may be said that wall inlets through which air issues with rapid or even moderate movement and at temperatures from 100° downward should be elevated well above the head plane for the purpose of giving the currents a location in the unoccupied parts of a room. By means of chutes of solid or of open material, the entering air may be given a slight or sharp upward course. By completely covering the inlet with a semi-cylindrical surface of fine wire gauze or other impervious material, of any size desired, the entering air may be made to move radially from the inlet in a more or less horizontal plane, and with a velocity varying with the extent of the diffusing surface, and with the volume of air issuing through it. By deflecting plates or blades set to separate the currents and to throw the entering air in divergent directions, the inflow may be given a radial direction from the inlet, both laterally and vertically if desired. Blades are preferable to gauze, as the meshes of the latter fill, and, even when clean, offer sensible resistance to air flow. Blades are as effective in breaking up the larger currents into a number of divergent ones, and produce a quicker and more thorough diffusion of air throughout the room. The form of diffuser must be chosen with reference to the location and surroundings of the inlet. Properly made and used, diffusers make impossible a processional of air from inlet to outlet that does no effective ventilating work. The rapidity of air flow through flues has obviously no necessary effect upon, or connection with, draughtiness in rooms. The velocity of the issuance of air into rooms has more to do with such draughtiness. By the use, however, of suitable diffusing means, air, although brought to the diffusers with a relatively high velocity, may yet by them be given such reduced velocity and dispersed movement as to remove all danger from this cause.

Diffusers.

Little draughtiness in outflowing currents.

For the protection against draught due to outward movement of air from rooms less precaution is needed. The movement of escaping air is slowly accelerative toward the location of the discharge, the velocity of the movement toward that point decreasing inversely as the square of the distance from it. The air movement, therefore, being convergent for a wide range, is the reverse of the divergent inflow produced by the use of deflecting plates or diffusing surfaces, and is wholly unlike the concentrated and continuous current projected from a supply register. It is necessary only that the area of the outlets should not be too large, the volume of air movement too great, the final velocity of air approach too rapid, and that permanent sittings should not be placed too near the outlets.

Air supply for school room.

In the case of a school room, the *per capita* floor and cubic space is generally from two to three times that common in well filled audience halls. To such a room, having a cubic space of from 11,000 to 12,000 feet, and seating from forty-five to fifty scholars, it is practicable to supply without draughtiness and without the use of exceptional precautionary means for preventing it, from 2000 to 2500 cubic feet of air per hour to each occupant, or a total hourly quantity of from 100,000 to 125,000 cubic feet, the larger quantity being more than one-sixth of the contents of the room per minute. When special means are provided for a draughtless entrance and removal of air, these quantities may be largely increased. Between 90 and 100 cubic feet per minute for each sitting have been passed through the class rooms of a schoolhouse equipped in accordance with modern methods, and there was no complaint of draughts. Usually, however, the limit of immunity from draughts is reached when the rate of air supply is brought up to an equivalent of ten changes per hour.

Cost.

The expense of ventilation properly includes the costs of all special building arrangements and construction provided; of all special equipment for heat production and air warming; of power for moving, distributing, and removing the air; of fuel for warming; and of specially skilled attendance required above that called for in ordinary heating work.

Cost: Special building arrangements.

In reference to the first of these items it may be said that the cost of adapting a building to a rigid system, or to a precise method or theory of ventilation is generally greater than that of adapting a ventilating system to a building planned with reasonable regard to heating and ventilating requirements. Flexibility and elasticity belong more appropriately to a single feature of a building than to the fundamental plan. If the plan and the ventilating system are concurrently and harmoniously developed, it is generally possible to provide at moderate cost an effective arrangement for ventilating work. If the entire scheme of the building and its system of ventilation are subordinated to rigidity in ventilating methods, theories, or notions,—such as those that fix the exact and only location for fresh air inlets and outlets, the sizes of air-ways, the means for air movement, the type, whether plenum or vacuum, of the ventilating system,—the owner may pay large sums for a slight gain or even an actual loss in the efficiency of warming and ventilating work. In general it may be said of this item of cost, as also of the efficiency in operation of the whole system of ventilation and warming, that simplicity of arrangement and compactness of plan are the characteristics most favorable to economy.

Cost: Special equipment.

The second item named as chargeable to the cost of ventilation is the increased power of the furnace, steam, or other type of plant above that required for heating alone. Limiting, for the sake of brevity, the present discussion to the use of steam for warming and ventilating purposes, it is evident that boiler capacities must be larger for warming and ventilating work than for warming alone. It is important, however, to note the fact that the needed increase in boiler power is not usually proportional to the amount of heat given to the air used for ventilating work. The fuel cost of warming and ventilation is not correctly computed by adding the cost of heating without ventilation to that of ventilation without heating. The sum thus obtained is greatly in excess of the actual cost when the heating and the ventilating arrangements are designed and operated as parts of one system. There is commonly a waste in heating alone which may be much reduced by proper and effective ventilation. By the ordinary and crude methods of heating, both the individual rooms and the different stories of a building are unequally warmed. The upper parts of rooms, especially of those in the first story, are over-heated when the lower parts are at a normal temperature. The upper stories of buildings are over-warmed when the lower stories are comfortably warmed. The average temperature of the building is thus raised above what would be required if the temperature in each room and throughout the building were uniform. The heat lost by transmission through walls is proportionally increased. As a further result, the normal loss of heat by air leakage through the top of the building is rapidly increased, both because of the higher temperature of the escaping air, and because of its increased volume of leakage due to the greater pressure producing the leakage movement. Windows in the upper stories of over-heated buildings are generally open, and this tends seriously to increase the rate of this loss. Such outflow of super-heated air at the top of the building produces a corresponding inflow of cold air on the lower floors. This in turn necessitates an increased use of heat for the proper warming of these floors. All such excessive heat loss is reduced in proportion as uniformity of temperature throughout the building is approached. The tendency of free and well planned ventilation is to produce such uniformity, both in individual rooms and throughout the building. By maintaining a plenum condition in the lower rooms without increasing that common in the upper stories, the inward leakage of cold air is reduced. If the heat required to warm a building to a uniform temperature is computed on the basis of theoretical loss by transmission through walls and by normal leakage, it will be found that the quantity required for continuous and generous schoolhouse ventilation alone is from three to four times that theoretically needed for warming alone. In practice, however, the gain made by effective ventilating work is not uncommonly such that the heat used for the combined warming and ventilating work during school hours exceeds that required for actual heating alone by not more than from fifty to seventy-five per cent. In some exceptional cases the fuel burned for the combined work has been found to vary but little from that previously required for heating alone.

Boiler power when ventilating and warming work are combined.

It is thus evident that the increase in the amount of fuel required when ventilating and warming are combined is much less than it would be if they were treated as separate items in the cost of a building. In the same proportion the additional boiler power required is also considerably less than might be expected. Assuming an average of 2 ½ boiler horse power for each class room, as necessary for warming alone,— the equivalent of other parts of the building in class rooms being also included,— then the average required for combined heating and ventilating may safely be taken as 5 horse power for each class room and its equivalent.

The additional cost of ventilating equipment used for the air warming, or for indirect radiating surface, varies greatly with the mode of such warming. A square foot of the most effective form of such surface when exposed to rapid currents of cold air passed over it, such as may be obtained by the use of a fan, may be made to yield from six to eight times the heat available from the same surface as it would usually be exposed in the quiet air of a room. If, therefore, warming is entirely accomplished by heat carried to rooms by the ventilating air as a vehicle, it is possible to effect a very considerable saving in the heating surface, and also to make the heating system so compact as to avoid the use of long and costly runs of supply and return piping. Thus, by the indirect method, the amount chargeable to heating work is considerably reduced. On the other hand, in proportion as direct heat is used and the temperature of ventilating air is reduced to that desired for rooms, the heating surface made necessary merely for air warming becomes chargeable to ventilating work. If air is passed at 70° into rooms which are kept at that same temperature, the heat given to the rooms by direct means must be not less than the theoretical quantity required for their warming under the conditions of heat loss attending uniform temperature. In general, in the matter of cost of equipment, it is true that while the plan of dealing with heating and ventilation as parts of one system undoubtedly increases the cost, it does not do so to the extent that might be supposed.

Cost: Power for moving air through ventilating system.

Air is moved through a building and its ventilating system only by some form of power expenditure. When unconfined air is warmed, approximately one-third of the heat imparted to it has no effect in raising its temperature, and is expended in the work of expanding the air. That work put into and stored in the air is, in part at least, available for ventilating purposes. It is that which makes ventilation by gravity methods possible, and, under conditions designed with reference to that end, wholly inexpensive so far as the mechanical side of the problem is concerned. The working pressure which is due to differences in temperature and in weight between the air inside and the air outside of a building varies through a wide range. Even where that pressure is greatest it is yet so small that a close and dust-filled cobweb can resist it, and arrest air flow. When the differences in temperature between inside and outside air are trifling, and when the height of ventilating shafts is moderate, the actuating pressure becomes so small that, if full air quantities are under such conditions to be moved through them, either excessively large air-ways must be provided, or else the air of the shaft must be heated to give it the required lightness for inducing the necessary flow. When this latter practice becomes necessary, the economical use of heat and the greatest mechanical effect are secured when the air is heated at the lowest practicable point in the flue, and when heat is imparted by means which least obstruct the freedom of air flow. To heat large volumes of air while they are on the way of escape from a building is manifestly wasteful. The practice of continuously warming the air in discharge flues in order to ensure sufficient flow in cool and moderate weather, and of placing the means to secure this beyond either the control or the neglect of janitors or engineers is a costly proceeding. In usual practice the increased velocity actually gained by such means is small when measured by the heat expended. To change in 50° weather the rate of air flow from 250 to 400 linear feet through a flue 2 feet square and 49 feet high, would require an increase of 30° in the temperature of the flue air. To move 100,000 cubic feet of air per hour through that flue by such an increase in temperature would necessitate the burning of 7 pounds of coal, or approximately 50 pounds of coal per school day for each class room and all equivalent ventilating work. Such a method continuously used would increase the fuel account for the building from 25 to 30 per cent above the cost of warming the building and warming the air supplied for ventilating work. A method involving this expense is not consistent with economy. In cases, however, where a necessary contraction, contortion, or exceptional cooling of flues may jeopardize draught effects, or where for special reasons it is desired to strengthen the local draught, the heating of flue air for accelerating draught action may, in the absence of better means, become economically advisable.

Gravity ventilation.

In planning a gravity method of ventilation, both supply and discharge flues should be made large enough to move the required volume of air when outside temperatures range from 40° to 50°, and when the temperature of the discharge air is 70°. The cross-sectional area of such flues should be governed by the temperature of the air in the supply ducts; the highest outside temperatures for which the vent ducts are provided; their cross-sectional forms; the straightness and smoothness of flues; the height of the flue system; the favorable or unfavorable exposure of discharge flue tops; the freedom of air supply to the supply flue system; and the presence or absence of means for securing accelerating rather than retarding effects of wind action. Since flues constructed in accordance with all these requirements would prove excessively large as well as costly in cold weather use, means for reducing and controlling air flow in such weather should be provided. For this purpose throttling dampers should be placed at the top of vent shafts, or at room connections with such shafts, and also at fresh air intakes for the fresh air system of flues. No general rule for fixing the flue sizes for gravity work in schoolhouses of two and three stories can be given. Under the most favorable circumstances the conditions which necessarily affect flow rate are many and varied. For supply flues an area ranging from 3½ square feet in upper stories to 5 square feet in lower stories is recommended, and for vent flues an area ranging similarly from 4½ to 6 square feet. Flues of these sizes will be found better fitted for effecting desired air movement and for economic work than flues of smaller or much larger areas.

Mechanical ventilation.

The superiority of the so-called mechanical, as compared with the gravity, method of ventilation appears in the relatively small space needed for flues, both supply and discharge; in the sureness and uniformity of ventilating action through all variations of weather; and in the low cost of moving air through a ventilating system. Air-ways in gravity methods must be made from two to three times larger than those required in well arranged mechanical methods, unless the rate of flow through the flues by the gravity method is greatly accelerated by heat used for that purpose. The mechanical, and therefore the money, waste inherent in such a method appears from the fact that when escaping air is raised 30° in temperature, each cubic foot of that air carries outboard more than one-half a thermal unit,—in work equivalent, approximately 400 foot pounds. In a well designed mechanical system the average requirement of work expended on each cubic foot of air is less than 10 foot pounds. Under these latter conditions the maximum power expenditure would be 1 horse power for each 200,000 cubic feet of air moved per hour, or ½ horse power per class room and its equivalent in other air supply throughout the building. If air is propelled through a ventilating system by steam driven fans, and if the engine steam is condensed by the ventilating air which it serves to warm, the cost of the motive power used is negligible. If the exhaust steam is wasted, the cost in fuel per class room would be 2 pounds per hour. If the exhaust steam is utilized for warming purposes, the fuel cost would be reduced to from ⅕ to ⅙ pounds per hour per class room, as against the 7 pounds above found necessary for heating the discharge air in vent flues through a range of 30° in temperature. The reduction of fan work to a minimum is not under the circumstances important as a matter of economy. The main duct velocities may easily be carried to and beyond 1000 linear feet per minute, and the flow through distributing and uptake flues to 750 linear feet. Between the mains and the branches a velocity of from 1000 to 1500 linear feet can be provided for the purpose of ensuring an evenness of supply to rooms under the ordinary varying conditions of air pressure in them due to wind action. The yearly fuel cost per room for moving air by efficient fan power is, in round numbers, 150 pounds of coal, and the yearly cost amounts to three-fourths of a cent per year *per capita*. That cost may be largely increased by a mal-arrangement of system, by a contraction and contortion of air-ways and the consequent necessity for high air velocities or pressures, or by the needless multiplying of fans. One fan well placed and well proportioned, obtaining and delivering air through generously sized channels, may do effective work in the supply and removal of air for a school building of from 1,000,000 to 1,500,000 cubic feet internal capacity. When the system is planned for such work, it is essential that the flues, whether discharge or supply, in that part of the system with which the fan is not directly connected, should be given sizes but little under those required for gravity work. Neither the plenum nor the vacuum condition producible in rooms by a fan connection through one set of flues, either supply or exhaust, can be sufficient to produce in the complementary flues the velocities maintained in those immediately connected with the fan. The interposing of a room between the two systems of flues has the effect of greatly reducing the pressure available for producing air flow through that system of flues with which the fan or other motive agency is not connected. The pressure drop between the two systems not infrequently reaches 35 per cent of the initial amount, and the resulting velocity of air flow through the complementary flues falls to 60 per cent of that through the fan flues. If the system is plenum, the areas of discharge flues should therefore be made from 70 to 100 per cent larger than the supply flues, according to the plenum condition desired within the affected rooms.

Cost: Fuel for air warming.

The cost of fuel for air warming, though large in the aggregate, is small in the individual accounts. The cost depends on the manner in which fuel is burned, on the degree of completeness of the transfer of heat from combustion gases to air, on the effectiveness or wastefulness with which air is used, and on the quantity of air supplied. If fuel is so used that 8,500 thermal units per pound of fuel are made available, approximately 500,000 cubic feet of air can be warmed one degree by each pound of coal burned. When, therefore, 2,400 cubic feet of air an hour are furnished to each person for six hours during each school day, and for the one hundred and sixty school days per year when artificial ventilation is required, the total *per capita* yearly supply of air reaches 2,304,000 cubic feet. This quantity would be warmed through one degree by 4.6 pounds of coal. The mean temperature of the New England climate during the time that artificial ventilation is required (from November 1st to June 1st) is nearly 35°, and the average increase of temperature to be given the air during that time to bring it to 70°, or to the temperature required for ventilating work, is therefore 35°. The fuel required for that purpose would be $163\frac{3}{4}$ pounds, costing approximately 41 cents. This sum therefore represents the yearly *per capita* cost of generous school room ventilation. There is nothing of vital necessity or benefit which can be had in such large return for so small an outlay, and there is nothing for which the average citizen and the general public so grudgingly part with money. The yearly fuel consumption for a school room seating fifty, when the room is freely ventilated for six hours each day, should be approximately 4 tons. The cost of warming such a room without ventilation, practically through fifteen hours a day through the school year, would be between 5 and 6 tons. The same would be true for all equivalent work in a school building outside the class rooms. Experience has demonstrated the fact that, by the use of methods designed with reference to greatest economy, and by the employment of a capable engineer who is interested in rightly using the system given to his charge, the yearly fuel account per class room and its equivalent may be reduced to between 6 and 7 tons.

Cost: Skilled attendance required.

There remains to be noticed under the general head of the costs of ventilation the necessity for better skilled and higher priced service for ventilating than for simple heating work. In the heating and ventilating account the expense for fuel is the one of large proportion. The amount of that item is largely dependent on the effective or wasteful use of coal. The skilled fireman who makes 10 pounds of steam from each pound of coal burned uses only six-tenths as much coal as is heaped up under the boilers by the mere shovelman who makes only 6 pounds of steam from each pound of coal. It is the cheap and wasteful man who in the long run is costly. Well paid efficiency is here, as always, in the line of profitable economy. Furthermore, a man to whom is to be committed the duty of maintaining those atmospheric and thermal conditions upon which freshness of physical and mental activity are largely dependent should be chosen with care and paid commensurately with the importance and value of his service. So to minimize that trust as to commit it to incompetence on the specious plea of economy is to invite failure and ensure loss.

Up to this point in the discussion of the subject of warming and ventilation, the general items of cost have been dealt with. It is now intended to set forth in detail various opportunities for economy in methods as illustrated by the special characteristics of schoolhouses. The several means for special economy in the warming and ventilating of schoolhouses will accordingly be discussed under the following heads: successive ventilation, quick preparatory warming; warming by rotation; heat commonly wasted; solar heat; automatic control of temperature; double glazing; double sashing; waste of heat at night; plenum and vacuum methods; location of inlets and outlets.

Successive ventilation.

The first suggestion made in the interest of economy relates to a method for the successive use of one and the same volume of air, first for the free ventilation of the least occupied parts of a school building, and then for the ventilation of those rooms in which the vitiation of air is either excessive or else of obnoxious quality. The parts of buildings, especially in those designed for use as high or normal schools, which are not closely occupied frequently aggregate as much in space as the class rooms themselves. Such parts of a building are generally continuously ventilated, though perhaps infrequently occupied. No amount of instruction or training of janitors and engineers is likely to result in a continued practice of opening and closing dampers or registers according to the occupied or unoccupied condition of rooms. However carefully such precautions may be taken at first, they are likely to be eventually abandoned, and the ventilation of the entire building to become continuous during school sessions. It is this continuous ventilation of large parts of the building outside of class rooms which greatly increases the apparent cost of class room ventilation, and which justifies the use of economic methods for the ventilation of rooms not continuously occupied. Besides the provision to be made in school buildings of higher grade for such rooms as audience halls, lecture rooms, recitation and class rooms, gymnasiums, and laboratories,—all of which when in use require in the order given increasingly large *per capita* supplies of air,—are the coat, lunch, bath, lavatory, and sanitary rooms, and the private and retiring rooms, each requiring its own appropriate treatment. Unquestionably, a generous and continuous flushing of all these apartments with the purest air would prove hygienically advantageous and financially disastrous. In every case there is at some point of ventilating work a balance between hygienic gain and financial loss. The gain to be derived from ventilating work is not directly proportional to the air quantities employed. When no air is furnished for breathing purposes, death is immediate. An air supply of 1 cubic foot per minute would barely but uncertainly support life; 5 cubic feet per minute continuously furnished would advance such existence into the region of sustained but low vitality; 10 cubic feet would ensure more vigorous but yet curtailed vitality; 30 cubic feet would advance it to vigor and stability; while 50 cubic feet would round it into a robustness, which, if the energizing effects of the gaseous make-up of air are alone considered, would be little improved by still larger supplies of air. Only in cases of special impurities or of abnormal or disease-producing contents given to, and carried in, the air of an enclosure, or in cases of prostrated vitality requiring the utmost opportunity for recovery, is there commensurate gain in providing more than 50 cubic feet of air *per capita* per minute for breathing purposes, provided, of course, that such air is effectively used. For ordinary school room work, even that quantity cannot be safely urged unless assurance is given of the purpose and ability of its users to make ventilation draughtless.

Supply of air for rooms not frequently occupied.

The quantities of air which should be furnished by ventilating means cannot be safely based solely on the number of those to occupy the rooms to be provided for. For reasons already noted, the smaller the *per capita* space, the less the *per capita* air supply must necessarily be made. On the other hand, the larger the *per capita* space, the greater the *per capita* supply required to maintain the agreeable if not the wholesome quality of the air. The most active and dangerous impurity in the air of occupied enclosures is the matter of organic nature, called effluvia, thrown off by the body through its pores. That matter rapidly changes in character, passing through a fermenting and decomposing to a putrescent condition. The longer it is retained within a room, the worse its odor becomes and the more morbific its condition. The aims of ventilation should be, as far as practicable, to limit atmospheric impurities to the location of their origin, and to reduce the quantity and the time of retention of such impurities within an enclosure to a minimum. In proportion as the *per capita* space of an enclosure is greater, the quantity of such matter contained in it is larger, the time of its retention longer, and its character more offensive and harmful. It follows therefore that the more sparsely occupied rooms of a building are those to which the largest *per capita* supply should be furnished. Laboratories in which gas is burned and in which vapors, fumes, and gases are generated in any considerable amount outside of hoods also belong to the class of rooms needing more air per occupant than do class rooms. The same is true of gymnasiums, physical training rooms, and play rooms, for vigorous physical exercise produces a condition of the body calling for a larger air supply than the condition of repose demands.

Course of the air supply in successive ventilation.

The ventilation of corridors should be sufficiently free to fill them with air suitable for passage to, and use in, class or other rooms. The continuously or frequently open doors or transoms between corridors and rooms make the continuous or occasional mingling of corridor air with that of rooms probable and almost inevitable. The passage from such an accidental to an intentional use of hall-ways for fresh air reservoirs and channels is both legitimate and proper. Play rooms, lunch rooms, gymnasiums, and other rooms of their general type, though intermittently occupied and sometimes crowded, belong, because of their average condition, to the sparsely occupied class of rooms. Continuously and separately to ventilate them on the basis of the largest or the ordinary numbers occasionally occupying them would require great volumes of air. Such rooms and parts of buildings may, however, be ventilated in series, or by a successive method, which will meet the requirements of their shifting groups of occupants, and yet require the use of relatively small volumes of air. Coat, bath, lavatory, and sanitary rooms need no independent supply of purest air. Air pure enough for breathing purposes in school rooms is certainly suitable for airing wraps hung in coat rooms. The air which passes out from school rooms through discharge flues is, generally speaking, as pure as that surrounding the occupants of the rooms. Stigmatized as foul only as a matter of convenience to distinguish it from the air supply, it is popularly supposed to become so by virtue of its entrance into the way of the outcast. Lavatory, bath, and sanitary rooms are, from a hygienic point of view, most suitably treated when they are atmospherically isolated from other parts of a building, as when ventilated by strong aspirating currents which cause air to move toward and into them from adjacent apartments, and prevent air movement from such rooms to those apartments. Class rooms may be vented, in part at least, through their coat rooms. Lavatory, bath, and sanitary rooms may take their air from the supply which has done its partial ventilating work in the hall-ways, play rooms, and other permanently or periodically occupied rooms. For that purpose air may be continuously supplied in generous quantities to play rooms, lunch rooms, physical training rooms, or gymnasiums, which are in the basement, and which are occupied but a small fraction of the time. From these rooms the air may be sent to ventilate the corridors of the building rather than being immediately thrown away. The corridors are by this means flushed with fresh air which should find egress, not through the roof nor through outlets or windows on the upper floor, but rather through the lavatories and sanitaries. If the air supply is generous enough, as it may be made to be, it may be sent from the corridors to the class rooms, and thence to the coat rooms. Thus in successive ventilation the movement of air must be from locations of lesser to those of greater vitiation, as from play rooms to corridors, from class rooms to coat rooms, or as from the corridors through play rooms to sanitary rooms.

When at recess scholars leave class rooms for play or lunch rooms, the conditions described above are in part temporarily reversed. The crowds are then in the basement, and the corridor air contains impurities brought from the crowded basement rooms. Meanwhile, however, the vacated class rooms are being flushed by their independent and uninterrupted air supply, and at the same time the large volume of corridor air is so diluting the impurities carried upward from the basement that they become imperceptible, if, indeed, they are at all noticeable even in the basement rooms themselves. In this successive method, then, basement rooms and corridors, sanitary rooms and coat rooms may be effectively ventilated by moderate quantities of air as compared with the volume that would be required if each part were as effectively and continuously ventilated by independent means.

Quick preparatory warming.

The heat quantity necessary for the preparatory warming of a building varies greatly with the methods used. In the first place, the heat expenditure is approximately proportional to the time given to the warming process. The quicker the process, the less the fuel required. During the process of warming, heat is lost by its transmission through walls and by air leakage. For rapid heating the production and distribution of heat must be quick and large. A heating apparatus of low power, although economical in its first cost, is in the end expensive because it is unequal to such a demand. A heating system successfully planned with reference to maintaining both an internal temperature of 70° against an outside temperature of zero and also a generous ventilation at such times, is equal to the demands of such work. The continuous work which is demanded in the raising of large volumes of air from zero to 70°, besides furnishing heat to compensate for loss through walls and by air leakage, is no more than the work of raising that same air when in rotation from 45° to 115°. The heating surface which will raise 1,000,000 cubic feet of air an hour from zero to 70° will not, however, if filled with steam at the same pressure, raise that quantity of air from 45° to 70°. To accomplish that, either an increased steam pressure in the battery or an extension of the battery surface would be necessary.

Warming by rotation.

Next in importance to the quantity of heat produced is the method in which it is used. Relatively little heat and time are required to warm the air of a building as compared with the heat and time needed for warming walls, floors, ceilings, and contents. The surfaces about and within a room may be cool or even cold while its air is warm and comfortable. Of the heat yielded by direct radiation, approximately one-half is given to walls and other surfaces by radiation, and one-half to air by convection. Heat brought into the rooms by inflowing air warms the air first, and the warmed air then raises the temperature of walls and other surfaces by its contact with them. The same heat quantity, therefore, if delivered to a room by air currents will produce a comfortable temperature sooner than if it were yielded to the room by a radiating surface. The larger and hotter the air currents are, the more rapid the warming process becomes. The warmer the air entering the heating battery, the higher its temperature is on leaving it, and the amount of heat required to bring that air to a given temperature is correspondingly less. A considerable gain is therefore made when, for the purpose of warming a building, air is taken from the building itself rather than from the colder outside supply. The method of warming a building in this way is one of rotation,—the air is taken from the building, heated, distributed to the rooms, and, after yielding considerable of its heat to the room surfaces, is brought back to the heating battery either by means of a special arrangement of flues, or by the use of the corridor-ways and stair-wells. Warming by rotation should, of course, cease and ventilation should begin before a building is occupied. The rotary method of warming may be made possible in any warming and ventilating system by suitable provision for it in the building plans and heating arrangements. Its economic value may be roughly stated as 2 pounds of coal for every degree of difference between inside and outside air temperatures, and for every 1,000,000 cubic feet of air used in rotation. Since the mean temperature of the outside air in the early morning is much lower than the daily average of temperature, the gain to be made by rotation is manifestly large. If, for example, 35° represents the average daily temperature, then 25° may represent the average early morning temperature. If the average indoor temperature at the same hour is 50°, the gain made by warming inside rather than outside air is thus 25°. The saving of coal under these circumstances would be 50 pounds for every 1,000,000 cubic feet of air rotated. Thus if 3,000,000 cubic feet each hour were rotated for two hours, 300 pounds of coal would be saved.

Heat commonly wasted.

A continuous saving of heat commonly wasted may be made by utilizing that given off by boiler walls, the smoke flue, hot water tanks, traps, pumps, engines, and other parts of the apparatus which are steam-hot. The total heat available from such sources is sometimes large, and, in exceptional cases, has even been found to be more than 10 per cent of the average heat quantity required for warming and ventilating work. If objections are made to the husbanding and utilization of this heat because of volatile and offensive oils about engines and pumps, slovenly care of such apparatus, faulty setting of boilers, and unsuitable methods of draught control, such objections have not sufficient weight to offset the advantages gained from saving this heat usually wasted. If correct methods are employed, and if janitors are made to attend to their duties, this saving can easily be made and is of considerable value. Another form of heat usually wasted is the spare heat of boiler gases escaping through the smoke pipe. This may be used for strengthening draughts through vent stacks, and thus the making of heat especially for that purpose is rendered unnecessary. This spare heat may also be made available for strong ventilation of sanitary rooms or any other equally important work. For this purpose the chimney and the ventilating stack about it should be designed with reference to the transfer of the needed amount of heat from the combustion gases to the vent-flue air. In all such work care should be taken not to reduce the temperature of the combustion gases so as to jeopardize the chimney draught. Still another form of heat usually wasted is that of fires banked for the night, this heat being generally expended in useless steam-making in closed boilers. Such steam may be used in limited and subordinate parts of the heating system, as in the foot warmers, hall-way coils, heaters in sanitary rooms for the protection of fixtures against freezing, and for other like work. Provision for these uses may be made in any steam system through suitable supply and return pipe connections with the boiler.

Solar heat.

Solar heat is a factor to be regarded in the planning of a warming and ventilating system. It may be demonstrated by a properly protected thermometer that the average day temperature of air is higher on the south than on the north side of a building. The difference often reaches 10°. An average of 5° would make it highly advantageous to take the air for ventilating work from the south rather than from the north side of a building. If an average rise of 35° is needed in the air temperature in ventilating work, then one-seventh of the heat required for that rise could be gained by choosing a south as against a north location for the inlet. Such a location is possible only when mechanical ventilation is used, for in gravity work it is necessary to place the inlet on the side of the building toward the prevailing winds of winter.

Automatic control of temperature.

From a hygienic point of view the close regulation of the temperature of a building is important; and from an economic point of view it is even more important, when the air volumes used are large. Such regulation cannot be safely entrusted to teachers who, absorbed in their work, fail to note a change in temperature until it becomes sufficiently extreme to extort notice. A radical and speedy change being then called for, windows and doors are resorted to until rooms become chilly. The inevitable results of such methods of regulating the temperature are wasteful escape of heat and disastrous catching of colds. The heating surface for the warming of a building must be made sufficient for the demands of the severest weather. At other times only fractional parts of the heat producible from it are needed. The quantity of heat yielded by such surfaces may be closely regulated by automatic means which control either the flow of steam or hot water into the heaters, or the proportions in which cold and hot air are mixed to produce the temperatures required. Such control is as essential to the evenness of temperatures furnished by a heating system and to the economy of its working, as is a governor to the steadiness and the economy of the working of an engine. The importance and reliability of the control in these essential particulars are fully established. That reliable results are obtainable with the best forms of apparatus properly installed, cared for, and used, have been abundantly demonstrated. At the present time the cost of such apparatus for buildings of twelve rooms and more should be estimated at one-twelfth of the cost of installing the entire warming and ventilating system. Aside from the undoubted value of a reliable system for control of temperature in protecting health and in sustaining vigor, its service in economizing fuel is important. If pneumatic pressure is used for the automatic operation of valves and dampers, it will often be found highly advantageous to employ that means for actuating remote and scattered valves and dampers. That operation may be effected from some convenient point by switch valves, three-way cocks, or other means. Vent-shaft dampers located at different points at the top of a building may be opened and closed by the turning of a controlling valve or three-way cock in the basement. Steam valves controlling different parts of the distributing system may be similarly operated, and also dampers for directing air flow through flues common to several rooms or parts of a building. Remoteness, difficulty of access, number of points to be reached, and a seeming complication of arrangement are often responsible for the disuse of important parts of an apparatus. In the method described, the nearness of means and the simplicity of use of the means make it more likely that the desired results will be secured.

Double glazing.

As heat loss through the glass of windows is generally from four to six times that through walls, a double glazing in windows is advantageous. The two panes, thoroughly clean, can be puttied in, one on the outside and one on the inside of a sash, with a space between them of from ¼ to ½ of an inch. If the work is reasonably well done, the inside surfaces of the panes will remain indefinitely clean. Double glazing stands between cold temperature on the outside of a building and the desired temperature on the inside, and so is as effective upon one side of a building as another. If day and night are included, the differences in temperature between the north and the south side are not great. The saving in heat by double glazing can be made to approximate 33 per cent of the heat escaping through single glazed windows; the saving in fuel approximates 2 pounds per hour for every 1000 square feet of windows.

Double sashing.

Double windows are more effective than double glazing in preventing heat waste. They protect against both inside and outside differences of temperature, and also against the inward leakage of cold air resulting from pressure due either to inside and outside temperature differences or to wind action. They are therefore doubly serviceable. They are more effective on the prevailing windward side of a building than on its leeward side.

Waste of heat at night.

To carry over from one day to another as much as possible of the heat of a building, some of which is stored in its air and much more in its walls, the building should be closed as tightly as practicable when not in use. The in-leakage of air through walls and windows is far more rapid than is usually supposed. Recent experiments made in a building of ordinary schoolhouse construction indicate that in mildly cold and quiet weather such leakage equals the cubic contents of a room or building approximately once in each ninety minutes. In sharply cold weather it is greater, and still more so in windy weather. Air leakage is the unknown and most disturbing factor in estimating the required power of heating plants. Unless such leakage is to be relied upon as a factor in ventilation, it should be made as small as possible. To reduce loss of heat at night, and whenever the building is closed, the vent-flues or shafts should be closed by dampers at their tops.

Plenum and vacuum methods.

For the same reason discharge ventilation should not be made in excess of the supply. The supply should, on the other hand, be in sufficient excess of the discharge to produce a slight pressure or plenum condition, particularly within the lower rooms of a building. A vacuum condition within rooms augments the inward movement of cold air through walls and windows, and tends to cold floors and chilly rooms. In cold climates the proper warming of buildings in which the ventilation is strongly or even slightly vacuum is rendered more costly and more difficult than is justifiable on any other ground than that of a blindly consistent adherence to the vacuum method of ventilation.

Location of inlets.

The efficiency of a ventilating system has an important bearing on the cost of obtaining the results for which it is provided. The air quantity used does not determine the thoroughness of the ventilating work it effects. As the Gulf Stream goes through the Atlantic, so air often goes through school rooms, its ventilating effectiveness ranging as low as from 36 per cent to 40 per cent out of a possible 100 per cent. The location of outlets and the concentrated or diffused movement of air through rooms are the chief determining factors in the problem. The natural trend of air currents within a room is downward over the cooling surface of outside walls and windows. The movement of that slightly chilled air is then over the floor toward the inner and warmer walls. The trend of the ceiling air is toward the outer walls and the falling currents. The location of the fresh and warm air inlet is of less moment than that of the outlet. It is wholly unnecessary to carry the entering air by flues to the vicinity of the outer walls. No matter from what point it enters the room its warmth keeps it at the ceiling, and the ceiling currents carry it with certainty to the outer walls. If, as this air in its turn drops down those walls and then takes its course over the floor, its movement is to be even, it must from its entrance move concordantly with the ceiling currents of the room. To that end it should become a part of those currents and be thoroughly mixed with them before it reaches the outer walls. For this reason the best location for the inlet is upon the inner wall at a point that shall be central with reference to the outside wall or walls. The best treatment of the inflowing currents is to diffuse them by means of the fixtures described on page 35. To place the inlet in such a position that it shall throw its unbroken current athwart the cooling wall and windows, and then impinge upon the opposite inside or outside wall tends to leave a section of the room under the overhead current and between it and the outlet doubtfully provided for. Any arrangement of in-put or out-take producing a circling of air about the perimeter of a room from the point of entrance to that of escape is to be avoided as wasteful, however picturesque the course, as seen in smoke, may be. When ventilation is free, the volume of air used must be large and its temperature low. Under such circumstances it becomes necessary to provide an entrance for the air which shall not expose the occupants of rooms to draughts. For this reason it is advisable and generally necessary to place the inlet at such an elevation that currents produced in the rooms shall be in their upper parts. A further advantage gained is that, when the inlet is in this position, it prevents the entering air from passing through the lower strata of air, which are generally less pure than the upper strata, and from carrying a considerable portion of such air into recirculation. On the other hand, when the ventilating work is light, the air volume small, and the temperature of the inflowing air high, or when the work of warming takes the precedence of ventilation, the fresh air inlet should be placed near the floor and the entering air be given a horizontal rather than a vertical direction of flow.

Location of outlets.

If the outlet is at the floor line and directly beneath the windows or the cooling walls, the falling currents of cooled but purest air in a room are withdrawn before their most effective ventilating work can be done by their passage over the floor. If, however, that air is made to traverse the lower part of the room before its escape, it is brought into a position for effecting the largest ventilating work. The outlet should therefore be on the inner or warmer wall side or sides of the room. It should be placed near or in the floor in order to remove as effectively as possible the air which traverses the lower part of the room in the floor currents, and in order to prevent its rise at the inner wall and its re-entrance into the ceiling current of warmer and purer air. If there is only one outlet, it should be located with reference to the most even movement of the ventilating current over the entire floor. In rooms having but one outside exposure, two outlets, so located as to ensure floor ventilating currents which shall actively affect the inner corners of the rooms, are preferable to a single vent centrally located.

There remain to be considered certain matters relating to the ventilating and warming of schoolhouses which are of sufficient economic or hygienic importance to warrant a brief discussion in this chapter. They are special local ventilation, air filtration, air humidity, and methods of warming.

Special local ventilation.

Strong local exhaust is required in certain parts of schoolhouse ventilation. Where ventilation can be effected by the immediate removal of atmospheric impurities, a great gain is made by doing so. Completely to remove the smoke of an open fire burned in a brazier placed in the middle of a room would require a hundred or a thousand times more air than if that fuel were burned in a fireplace. The air of a chemical laboratory may be kept as clear as that of a class room and with no greater *per capita* supply, if all fuming work is done under hoods. If such work is generally done in the open rooms, ten times that volume of air passed through them might not clear the air. The discharge from such rooms should be largely if not chiefly through the hoods; and the air-ways through and from the hoods should be designed and furnished with reference to that purpose. So also the general ventilation of sanitary rooms should be largely by means of strong local discharge through the fixtures of both closets and urinals. If the discharge ventilation is not effected by mechanical means, the vent flues of lavatories, sanitary rooms, and hoods of lunch room ranges should be made warmer than the flues of other rooms. In this way a movement of air toward and into the rooms which are to be locally ventilated is produced, counteracting and overcoming any conflicting pull of flues which discharge air from other parts of the building. The location of chemical laboratories, of kitchen school rooms, and of other rooms of similar character should be on the top floor, since the trend of air, especially in cold weather, is upward through a building. When such rooms are thus situated, fumes, gases, and odors generated within them are more completely confined to the place of their origin (see page 42, line 5) than was ever possible when these rooms were placed, as was formerly the custom, in the basement.

Air filtration.

The importance of filtering air supplied to school buildings varies with local conditions. In dusty or smoky localities such filtering may be essential to the cleanliness of buildings and to the protection of its contents. As a hygienic measure it is not generally, if ever, necessary or important. Thoroughly to clear the air supply of microbic dust by any ordinary means of filtration would be impossible in a large school building; to do so by any means whatever would be impracticable. To remove even the larger particles of dust from such large quantities of air by the ordinary or dry method of filtration makes necessary such excessively large areas of filtering cloth, or else so much fan power to force the air through the filters, that resort to the method can be advocated only with hesitancy. If such filtering is to be attempted with any thoroughness greater than that required to quiet vague apprehension or disturbing imagination, so large an area of filtering cloth should be provided that the entire quantity of air may be filtered through it with a flow rate of not more than 2 or 3 cubic feet per minute through each square foot of the filtering surface. By doubling the air pressure produced by the fan, the surface quantity may be reduced nearly one-half. In order to filter the air of a building accommodating six hundred scholars, the filtering surface to be furnished should be, under the conditions first assumed, 8000 square feet for school rooms, and some 4000 square feet for other parts of the ventilation. Any filtering device used must necessarily be made so that a compact arrangement of the surface is secured, and so that the material may be easily removed for cleansing.

Air humidity.

The moisture contained in outside air in winter weather is small. When such air is warmed to 70° without increasing the moisture which it contains, the capacity of the warm air for absorbing additional moisture is large, and evaporation from all moist surfaces becomes rapid. The skin and the mucous membranes of the mouth, throat, and nose, and the moist surfaces of the eye and the ear are more or less affected, in some persons with irritating and even serious results. Except for such consequences, dry air is hygienically advantageous, because of its effect in retarding the development and reducing the vitality of microbes, and also because it retards the decomposition and decay of organic matter. The generally fine physical appearance and evident good health and comfort of the thousands whose school life is spent in the relatively dry air of well ventilated buildings, and the general absence of complaint from them, must be accepted as evidence of the irrational position assumed by humidity hobbyists. Water cannot be evaporated either rapidly or slowly except by heat expenditure. For each pint of water evaporated at low temperatures, 1000 heat units must disappear in the process. To give an out-of-door June humidity to 1,000,000 cubic feet of air warmed through the average range of temperature required for winter ventilation, would make necessary the evaporation of 400 pounds of water, and the burning of some 50 pounds of coal. The warming of that quantity of air through the average range of 35° of temperature would require the burning of 75 pounds of coal. The cost of moistening air to that degree through the school year would therefore range from one-half to two-thirds of the cost of warming it. The comforting assurance indulged in by some persons, that the perspired moisture given to the air of well filled rooms sufficiently satisfies hygienic demands, overlooks both the quality of that moisture as dermal sewage, and also its quantity, which is but little more than one-tenth of the assumed standard requirement. The delightful and invigorating character of ideal June conditions of the atmosphere cannot be questioned. It by no means follows, however, that such conditions artificially maintained would be either healthful or satisfactory. The more moist the air, the larger the quantity needed both for comfort and for health. With outside air at 70° and at normal moisture, the supply of 2400 cubic feet of air, which is generous in winter weather, would be intolerably meagre. Such humidity to be endurable demands the open windows and the out-of-door abundance of air that belongs to June.

Method of warming.

The amount of heat required for schoolhouse work is fixed in each case. That quantity remains the same, by whatever simple or complicated form of apparatus it is generated, and by whatever form of surface it is transferred to the air of the building. Invariably, that form of apparatus by which each pound of fuel can be made to produce and yield the most heat, and that arrangement of apparatus which will insure the most effective and therefore the least wasteful use of heat, is the type of highest economy. Such considerations must, however, be balanced against those of the first cost of the apparatus itself, the cost of its maintenance, and the cost of the floor space and arrangements in the basement and in other necessary places. In this light steam plants or mechanical methods of ventilation for a one room schoolhouse become incongruous, as also do jacketed stoves for a building of twelve or more rooms. In a general way, furnaces are preferable to stoves for buildings of more than one or two rooms, and steam apparatus rather than furnaces is to be recommended for buildings of more than six or eight rooms. The economical advantage of mechanical ventilation begins when the building is large enough to make the use of steam advisable. So far as the effective and economical production and transfer of heat is concerned, it may be said that the best types of furnaces are equal to the best forms of steam apparatus. Such furnaces should have an effectively arranged heating surface not less than fifty, and, if possible, one hundred times larger than the grate surface. The "powerful heaters," with their common ratios of one of grate to twenty or thirty of heating surface, produce shell temperatures which are inversely proportional to the ratios of the grate and shell areas. Such heaters overheat the air, cook, char, or burn its dust, thus sensibly and harmfully affecting its quality, and give in return only doubtful hygienic benefits in the way of germicidal results. When steam or hot water is used, the warming may be either wholly indirect, or partly or entirely direct. The indirect method has the advantages of restricting all heating surfaces and piping to the basement; of compacting the heating system; of reducing the heating surface required, when mechanical ventilation is used, to less than half that needed for obtaining the same heat by direct radiation; of clearing the upper floors of piping and heating surface; of protecting floors, ceilings, and walls of the upper stories from damage by water-leakage; and of issuing air into rooms at a temperature which tends to reduce harmful draft effects. Direct radiation, on the other hand, when the air is warmed only for ventilation, and for this purpose is given a temperature of from 2° to 4° above that desired for rooms to prevent its falling floorward with draft effect, has the advantages of furnishing heat with sureness where wanted; of providing that heat without ventilation; of reducing the cost of maintaining the warmth of rooms when ventilation is not required; of furnishing more ready means for warming single or isolated rooms without running fans or other ventilating mechanism for the purpose; of providing compensating radiant and sentient heat for the heat lost by occupants by radiation to cold window and wall surfaces; and of counteracting the often too sharply chilled air currents from windows and wall surfaces, and so reducing their tendency to chill floors. Of these two methods the direct is to be preferred chiefly for reasons of working economy, and the indirect on æsthetic grounds and on account of the lower cost of its installation.

VI.

Main features of construction of Boston Schoolhouses.

THE schoolhouses here treated are much alike in their main features of construction. The foundations, whether built on piles or not, are in nearly if not all cases of block granite. All the brick buildings have a low underpinning of granite. The trimmings are of sandstone, white marble, or terra cotta, and the exterior steps are of North River bluestone. In three cases only is other than selected red water struck brick used for the exterior walls. These exceptions are the Gibson School, which is built of sand struck brick laid in yellow mortar, the Williams School, which is built of Scotch firebrick, and the Agassiz, which is built of red Perth Amboy terra cotta brick. In nearly every case the basements are laid in colored mortar with headers every five courses. Elsewhere Flemish bond laid in white or colored mortar is used. The Andrews School has all its floors of steel beam and terra cotta arch construction. The first floor of all the other schools, and all the floors of the Mechanic Arts School are of mill construction. With these exceptions the other floors are built of joists in the ordinary way, the roofs also being of wood. Two types of roof are used, the flat tar and gravel, and the low pitch slated roof. All flashings and gutters and, in most cases, exposed conductors are of copper. The carrying partitions are of brick or of steel columns and beams. The inner partitions when not of brick are of terra cotta lumber, except in certain of the later schools where, as will be noted in the individual descriptions, "channel iron partitions" are used. All ceilings above the basement are wire lathed. As the first floor is of mill construction, the boiler room ceiling is the only part of the basement that is plastered, except in certain cases where manual training rooms are in this story. The plastering is laid directly on the brick walls, which in every case are built with an air space in addition to a lining of hollow tile. As the partitions are fireproof and the floors either are mortar deafened or have fire stopping material between upper and lower floors, and as the ceilings are metal lathed, the construction is practically protected from internal fire. Slate blackboards are used, with the exception of a few of the earlier schoolhouses where composition is found. In the schools built after the revision of the building laws in 1892, and in some schools built before this revision, the staircases enclosed between brick walls are further protected at each story by tinned fire doors. The high school buildings have individual lockers in the basement. All the other schoolhouses have separate wardrobes adjoining the school rooms. In no case is the clothing of pupils hung in the corridors. The floors above the basement are of square edged rift Georgia pine. All plastering is finished with oil paint to the height of 7 feet 6 inches, and the wall above this height and the ceilings are tinted in water colors. With but few exceptions toilet rooms are arranged immediately adjoining the masters' and teachers' rooms. The brick latrine type of water closet is the one used for the pupils in the earlier schools;

where other fixtures were used they will be noted in the description of the individual schools. In no case are separate urinal fixtures used, all slate urinals being installed in every building. These latrines and urinals are strongly ventilated from the bottom through a duct connected with the shaft about the boiler flue. To keep the flue warm in summer and thus secure an unfailing outward draft, a small stove is placed at the base of this shaft. The systems of heating and ventilating vary considerably, and variations in method will be noted in the description of the several schools. In the large schoolhouses of the latest construction, dependence on heating by fan is abandoned, the heat being given by direct radiation; the fan is used to supply heated fresh air for ventilation only.

Cost of Boston Schoolhouses.

All the contracts for these schoolhouses were awarded to the lowest responsible bidders under advertised bids, and as there were but few extras the costs here given may be fairly considered normal for the several constructions built under the requirements of the building law and their general and special conditions. In one case only, that of the Kent School, was there a large amount of extra work not covered by the original contract. For the work uncompleted on July 1, 1895, the costs are those standing upon the books of the department at that time. They do not include any expenditures which may have been made in contracts after the work had passed from Mr. Wheelwright's control. The costs here given do not include those of grading, paving, and fencing of school yards, as no constant data can be gathered from the consideration of these elements of cost, varying as they do under the especial conditions and requirements of each case. In reckoning the cost by square foot of floor, the area is taken at the level of the basement floor, and includes the outside walls and partitions. When the cost is estimated by the number of rooms, at so much per room, the assembly hall is reckoned as the equivalent of two school rooms. In schools of the grammar grade the libraries, laboratories, etc., are not reckoned, but recitation rooms when of the area of school rooms are reckoned as such. When the cost per cubic foot is given the price will be found to vary slightly from the tables found in the Reports of the Architectural Department, as the basis of measurement adopted here is somewhat different from that followed by the City Architect. He measured the cubical contents of the building from the top of the basement floor to the top of the cornice, which has no fixed relation to the ceiling of the upper rooms. Here the cubical measurement is taken to include the contents of the building between the basement floor and the tops of the ceiling joists of the upper story, the square area being taken at the basement level. It is true that the roof, whether pitched or flat, as an artistic feature of more or less importance according to the intention of the architect, affects the cost of the building; the all-important consideration, however, in the cost of such buildings is the cubic capacity given the inmates. The method here adopted of reckoning cubical contents gives a better basis for economic comparison and a safer guide in estimating costs. This method of measurement also more readily shows how far design for architectural effect influences the total cost. The fairest criterion of cost is found in the cost per school room. Those who make use of the tables in estimating costs are advised to note carefully whether a given schoolhouse is of primary or grammar grade, and its requirements of plan should be noted before applying any of these data to a new problem. It is further advised that in such calculation an average should be struck of cost per floor area, cost per cubic foot, and cost per school room.

Classification according to date of construction.

Of the buildings here described the Blackinton, Fuller, Tweed, Williams, Wyman, Warren and Shaw Schools were begun in 1891; the Agassiz, Cudworth, Burnham, May, and Mechanic Arts High Schools were begun in 1892; and the Eustis, Weld, Kent, Morton Street, Oak Square, Gibson, Brighton High, Stuart, Bowdoin and Andrews Schools were begun in 1894. The method employed in the external treatment of the schoolhouses falls into four general classes, and on the basis of this classification the gelatine plates of these volumes will be arranged. The division is as follows: —

Classification according to architectural treatment.

1. The utilitarian, all brick buildings with flat tar and gravel roofs. These are the Warren, Wyman, and May Schools.

2. Buildings somewhat more architectural in character, but with the method of roofing of the first mentioned group. These are the Blackinton, Fuller, Tweed, and Williams Schools. The architectural character of these four buildings, while based upon classical forms, is somewhat indefinite in style.

3. Buildings designed after the style of the North Italian Renaissance, in two cases, however, the Kent and the Mechanic Arts High School, with a suggestion of the Italian Gothic. The roof of the Mechanic Arts High School is flat but has overhanging eaves. All others in this class have low pitched slated roofs with overhanging eaves. Together with the two above mentioned, the Agassiz, Shaw, Cudworth, Burnham, and Andrews Schools are in this group. To these might be added the Gibson, although the design of this building has a suggestion of the Renaissance architecture of Northern France.

4. Buildings designed in the manner of the Later Georgian Renaissance, a style which, after its successful adaptation in the group of buildings for the South Department of the City Hospital, Mr. Wheelwright used more than any other for schoolhouses. The schoolhouses in this style are the Oak Square, Morton Street, Eustis, Weld, Stuart, Bowdoin, and Brighton High.

Classification according to arrangement of plans.

All the plans of all the schoolhouses built in Boston during the period under consideration are here given at a scale of $\frac{1}{32}$ inch to the foot. In classifying these plans it seems desirable, as offering a more systematic opportunity for study, that the buildings should be arranged in three groups upon the basis of the number and position of the entrances, as follows: —

1. Schoolhouses with one entrance on the front, and one on either side: Fuller, Tweed, Agassiz, Cudworth, Burnham, Eustis, Weld, Stuart, Brighton High, Andrews.

2. Schoolhouses with two entrances on the front: Williams, Shaw, Kent, Morton Street, Gibson.

3. Schoolhouses with entrances otherwise arranged: Blackinton, Wyman, Warren, May, Bowdoin, Oak Square, Mechanic Arts High.

Margaret Fuller School.

MARGARET FULLER SCHOOL is on Glen Road, Ward 23 (Jamaica Plain). This building is of the primary grade and has six school rooms, three in each of the two stories. The teachers' room is in the second story. The exterior brick work is of selected water struck brick, coursed with buff terra cotta brick. The walls of the basement are laid in red mortar; elsewhere the walls are built with Flemish bond laid in yellow mortar. The window-sills are of Amherst sandstone, and the trimmings and coping of the battlement are of yellow terra cotta. The roof is flat and covered with tar and gravel. The heating is by a plenum fan run by a gas engine; in the more exposed rooms additional heat is given by direct radiation.

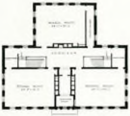
Cost.

The cost was $37,331.71, of which

$2,601.83 was for heating and ventilating. The cost per square foot of floor area was $2.81, the cost per cubic foot was $0.20, the cost per school room was $6,221.00. This building is further illustrated by Plates III. and IV.

BASEMENT PLAN.

FIRST FLOOR PLAN.



SECOND FLOOR PLAN.

B. F. Tweed School.

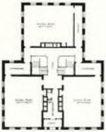
B. F. TWEED SCHOOL is on Sullivan Square, Ward 4 (Charlestown). This building is of the primary grade and has six school rooms, three in each of the two stories, and a teachers' room on second floor. The exterior walls of the basement are laid in red mortar; elsewhere Flemish bond laid in yellow mortar is used. The window-sills are of Amherst sandstone, and the trimmings and coping of the battlement are of yellow terra cotta. The heating is by indirect radiation supplemented by direct radiation.

Cost.

The cost was $36,004.05, of which $2,507.00 was for heating and ventilating. The cost per square foot of area was $3.04, the cost per cubic foot was $0.21¾, the cost per school room was $6,000.00.

BASEMENT PLAN.

FIRST FLOOR PLAN.

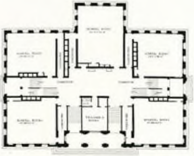


SECOND FLOOR PLAN.

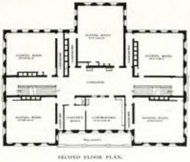
Agassiz School.

AGASSIZ SCHOOL is at the corner of Burroughs and Brewer streets, Ward 23 (Jamaica Plain). This building is of the grammar grade and has fourteen school rooms and an assembly hall. On the first story are five school rooms and a teachers' room. On the second story are five school rooms, a laboratory, and a master's room. On the third story are four school rooms and the Assembly Hall. In the basement are two manual training rooms. The exterior brick work is of red Perth Amboy terra cotta brick with red terra cotta up to impost of arches. Above this line light red brick from Epping, New Hampshire, is used, laid in a pattern of headers with ½ inch joints of white mortar. The basement and first story brick work and all the architectural features are laid in red mortar; the brickwork of the second and third stories up to arch

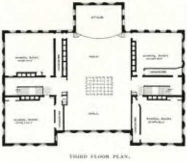
BASEMENT PLAN.



FIRST FLOOR PLAN.



SECOND FLOOR PLAN.



THIRD FLOOR PLAN.

impost course is laid in yellow mortar. The various bondings, as shown on the ¾ inch scale drawing, give this treatment of the brick work an interesting texture to the walls, and play a part in the successful color effect of the structure. The window-sills are of Longmeadow stone. The building has heavy projecting rafter ends after the Italian manner; these are of Georgia pine construction encased in copper, as required by building laws for buildings of this height. The roof is covered with light green Vermont slate. The heating is by plenum fan, supplemented in the more exposed rooms by direct heat. The cost was $90,330.93, of which $7,711.50 was for heating and ventilating. The cost per square foot of floor area was $2.32, the cost per cubic foot was $0.16½, the cost per school room was $5,020.00. This building is further illustrated by Plates XII., XIII., XIV.

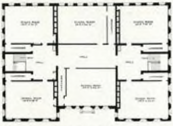
Cost.

CUDWORTH SCHOOL is on Havre, Decatur, and Paris streets, Ward 2 (East Boston). This building is of the primary grade and has eleven school rooms. Five are on the first story, which also contains the master's room and the teachers' room. On the second story are six school rooms. The building was originally designed for nine school rooms and an Assembly Hall. During the construction, it was determined by the School Committee to make two school rooms of the space originally assigned to the Assembly Hall. It is on *Cudworth School.*

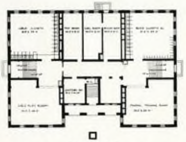
this account that one of the wardrobes in the second story has no outside window. The building is built on piles, and has block granite foundation. The exterior brick work is of selected water struck brick. The window sills are of Amherst stone. The eaves are finished open with cut rafter ends painted white. The gutter is of copper. The roof is covered with green Vermont slate. The heating is by direct radiation, with heated fresh air furnished by a plenum fan. The cost not including grading was $65,909.33, of which $9,373.00 was for *Cost.*

heating and ventilating. The cost per square foot of floor area was $2.65, the cost per cubic foot was $0.17, the cost per school room was $5,991.00. This building is further illustrated by Plate XVII.

FIRST FLOOR PLAN.



SECOND FLOOR PLAN.



BASEMENT PLAN.

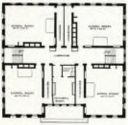
Choate Burnham School.

CHOATE BURNHAM SCHOOL is on East Third Street, Ward 14 (South Boston). This building is of the primary grade and has eight school rooms, four in each of the two stories. In the second story is also a teachers' room. The exterior brick work is of selected

water struck brick, accentuated with white terra cotta bricks, a method employed in the Southern States during the last century. The trimmings are of Indiana limestone. The eaves are finished open with cut rafter ends painted white, and copper gutters. The roof is covered with light green Vermont slate. The sign on the iron balustrade was not designed by the City Architect. The heating is by direct radiation. Fresh air is supplied by indirect radiation from a central air chamber. The cost was $53,482.55, of which $4,618.00 was *Cost.* for heating and ventilating. The cost per square foot of floor area was $3.05, the cost per cubic foot was $0.21½, the cost per school room was $6,685.00. This building is further illustrated by Plates XVIII. and XIX.

BASEMENT PLAN.

FIRST FLOOR PLAN.



SECOND FLOOR PLAN.

EUSTIS SCHOOL is on Eustis street, Ward 21 (Roxbury). This building is of the primary *Eustis School.* grade and has six school rooms, three in each story. On the second floor is also a teachers' room. The exterior brick work is of selected water struck brick. The trimmings are of white Lee marble. The cornice has a gutter of copper, with the other members of galvanized iron. The roof is covered with dark blue Monson slate. The cupola is of copper. The entrance porch is of white pine painted. Partitions where not of brick are constructed of channel irons, lathed with expanded metal and plastered with cement, finishing 1¼ inches thick. The angles of walls and ceilings are coved as in hospital construction. The iron staircases are enclosed in brick walls shut off at each story by tinned doors set in iron frames. Light is furnished to the inner hallway by a large skylight over an opening in the second floor.

The heating is by direct radiation. Heated fresh air is supplied by the indirect "natural system." Iron water closet ranges are used in the basement. The cost was $40,389.00, of *Cost.* which $4,200.00 was for heating and ventilating. The cost per square foot of floor area was $2.99, the cost per cubic foot was $0.22, the cost per school room was $6,731.00. This building is further illustrated by Plates XXIV. and XXV.

BASEMENT PLAN.

FIRST FLOOR PLAN.

SECOND FLOOR PLAN.

Stephen M. Weld School.

STEPHEN M. WELD SCHOOL is on Canterbury and Sharon streets, Ward 23 (West Roxbury). This building is of the primary grade and has six school rooms, three in each story. In the second story is also a teachers' room. The exterior brick work is of selected water struck brick. The trimmings are of white Lee marble. The cornice has a copper gutter, and other members of galvanized iron. The roof is covered with dark blue Monson slate. The architectural treatment of the principal entrance is of painted pine. The tablet was not designed by the City Architect. Partitions where not of brick are constructed of channel irons, lathed with expanded metal and plastered with cement, finishing 1¾ inches thick. In the rooms the angles of walls and ceilings are coved as in hospital construction. The iron staircases are enclosed in brick walls shut off at each story by tinned doors set in iron frames. Light is furnished to the central hallway by a skylight over a well in

BASEMENT PLAN.

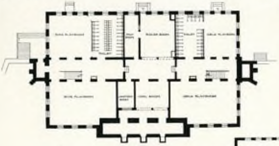
FIRST FLOOR PLAN.

SECOND FLOOR PLAN.

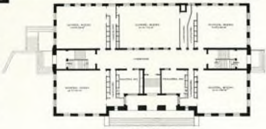
the second floor. The heating is by direct radiation, heated fresh air is supplied by indirect radiation. As there was no connection with the sewer, dry process ranges were used in the basement, and a strong ventilation provided to the space about the boiler flue. The cost was $39,531.80, of which $3,910.00 was for heating and ventilating. The cost per square foot of floor area was $2.85, the cost per cubic foot was $0.22, the cost per school room was $6,588.00. This building is further illustrated by Plates XXVI. and XXVII. *Cost.*

GILBERT STUART SCHOOL is on the corner of Richmond street and Dorchester avenue, Ward 24 (Dorchester). This building is of the grammar grade. In the first *Gilbert Stuart School.*

story are five school rooms together with the master's and teachers' rooms. In the second story are six school rooms, one of which is used as a recitation room. In the third story are four school rooms and an assembly hall. The exterior brick work is of selected sand struck brick laid in white mortar, and the first story and all the architectural features of brick, such as quoins and arches, are laid in yellow mortar. The trimmings are of Indiana limestone. The cornice has corona and coping of copper, the protected members being of galvanized iron. The roof is flat and covered with tar and gravel. The partitions are channel iron with expanded metal lathing plastered with cement. The corners of rooms and the angles of walls and ceilings are coved as in hospital construction.



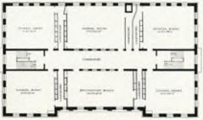
BASEMENT PLAN.



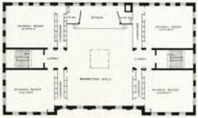
FIRST FLOOR PLAN.

Cost.

The iron staircases are enclosed in brick walls shut off by tinned doors. The heating is by direct radiation with heated fresh air supplied by plenum fan. Iron water closet ranges are used in the basement. The cost was $97,900.00, of which $9,588.00 was for heating. The cost per square foot of floor area was $2.66, the cost per cubic foot was $0.18, the cost per school room was $6,118.00. This building is further illustrated by Plates XXVIII., XXIX., XXX., and XXXI.



SECOND FLOOR PLAN.



THIRD FLOOR PLAN.

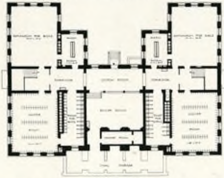
Brighton High School.

BRIGHTON HIGH SCHOOL is on Cambridge and Warren streets, Ward 25 (Brighton). This building has in the first story two school rooms, four recitation rooms, a master's room, a teachers' room, a reception room, a pupils' dressing room, and two store rooms. In the second story are two school rooms, two recitation rooms, a dressing room for girls, a lecture room with store room adjoining, and an assembly room which also serves as the library. In the third story are an assembly hall, a botany room, a drawing room, two rooms for physical and chemical laboratories, and two large store rooms. In the basement are separate gymnasiums for boys and girls, well ventilated lockers for clothing, a lunch room, wash rooms, toilet rooms, and boiler rooms. This building is designed so that when additional space is required it can be extended in the rear to form a courtyard, from which the corridors will be lighted. The extension will also give an opportunity for a drill hall on the first floor, lighted by a skylight. This building exhibits perhaps the most interesting example of Mr. Wheelwright's use of brick work. It certainly shows the most elaborate use of this material, and the result justifies the study evidently given to its design and the care given to its construction. The exterior brick work is of selected water struck brick. The basement brick and the brick architectural features are laid in red mortar; elsewhere the brick is laid in white mortar. The trimmings are of Indiana limestone. The corona of the cornice and the coping, and the back of the battlement wall are of copper. The other members of the cornice and of the balustrade are of galvanized iron, painted to match the stone work. The roof is flat and

covered with tar and gravel. Partitions when not of brick are of channel irons, covered with expanded metal lathing, plastered with cement, finishing 1¾ inches thick. The angles of rooms and corners of walls and ceilings are coved as in hospital construction. The iron staircases are enclosed in brick walls shut off at each story by tinned doors set in iron frames. The heating is by direct radiation, with heated fresh air for ventilation furnished by plenum fan. The iron range water closet system is used in the basement. The cost was $122,600.81, of which $16,264.50 was for heating and ventilating, and $1,098.00 was for exterior stone carving. The laboratory fittings cost about $4,000.00 in addition. The cost per square foot of floor area was $2.63, the cost per cubic foot was nearly $0.17. This building is further illustrated by Plates XXXVIII., XXXIX., XL., XLI., XLII., and XLIII.

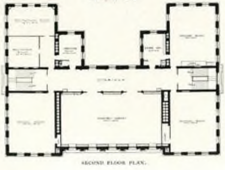
CHEMICAL LABORATORY.

Cut.

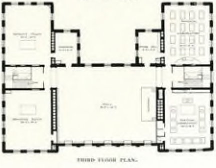


BASEMENT PLAN.

FIRST FLOOR PLAN.



SECOND FLOOR PLAN.



THIRD FLOOR PLAN.

Andrews School.

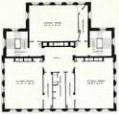
ANDREWS SCHOOL is on Genesee street, Ward 16. This building is of the primary grade and has nine school rooms. There are three rooms on each floor. On the second and third floors are teachers' rooms. It is built on piles and has block granite foundations. The exterior brick work is of selected water struck brick laid in yellow mortar. The trimmings are of Kibbe sandstone, red moulded brick, and terra cotta matching the color of the brick. The cut rafter ends are of copper on iron frame, painted white. The gutter is of copper. The roof is flat, and covered with tar and gravel. This schoolhouse being three stories high, and in a crowded part of the city, all the floors are of steel beam and terra cotta arch construction. The roof is constructed of wood. Partitions where not of brick are constructed of channel irons, lathed with expanded metal, and plastered with cement, finishing 1¾ inches thick. In the school rooms all the angles of walls and ceilings are coved as in hospital construction. The building is heated by direct radiation, heated fresh air being supplied by a plenum

Cost.

fan. Iron water closet ranges are used in the basement. The cost was $59,520.25, of which $3,101.22 was for heating and ventilating. The cost per square foot of floor area was $3.15, the cost per cubic foot was $0.22¾, the cost per school room was $6,614. This building is further illustrated by Plates XX. and XXI.

BASEMENT PLAN.

FIRST FLOOR PLAN.



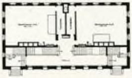
SECOND FLOOR PLAN.

THIRD FLOOR PLAN.

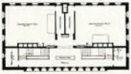
Williams School.

WILLIAMS SCHOOL is on the corner of Harold and Homestead streets, Ward 21 (Roxbury). This building is of the primary grade and has two school rooms on each floor, and a teachers' room in the second story. The exterior brick work is Carteraig Scotch fire brick with buff terra cotta trimmings and Amherst stone window-sills. The cornice is of buff terra cotta. The roof is flat and covered with tar and gravel. The heating is by indirect radiation supplemented by direct radiation. The cost was $35,212.90, of which $1,625.00 was for heating and ventilating. The cost per square foot of floor area was $3.32, the cost per cubic foot was $0.25, the cost per school room was $8,803.00. This building is further illustrated by Plates V., VI., and VII.

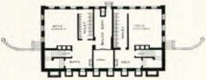
Cost.



FIRST FLOOR PLAN.



SECOND FLOOR PLAN.



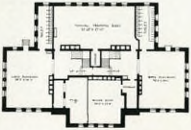
BASEMENT PLAN.

Robert Gould Shaw School.

ROBERT GOULD SHAW SCHOOL is on Henshaw street, Ward 23 (West Roxbury). This building is of the grammar grade. In the basement is a large manual training room wholly above grade. In the first story are five school rooms. In the second story are three school rooms, an assembly hall, and master's and teachers' rooms. This is the first schoolhouse in which the Italian treatment of overhanging eaves was used. The exterior is of selected water struck brick, with red terra cotta trimmings and Longmeadow stone window-sills. The basement and the architectural features are laid in red mortar, elsewhere the mortar

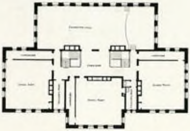
Cost.

is white. The heavily projecting rafter ends are of Georgia pine. The roofing is of light green Vermont slate. Heating is by a plenum fan supplemented in the more exposed rooms by direct heat. The brick latrine system is used in the basement toilet rooms. The cost was $54,815.59, of which $5,641.98 was for heating and ventilation. The cost per square foot of floor area was $2.42, the cost per cubic foot was $0.17, the cost per school room was $5,463.00. This building is further illustrated by Plates XV. and XVI.



BASEMENT PLAN.

FIRST FLOOR PLAN.



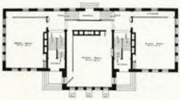
SECOND FLOOR PLAN.

William H. Kent School.

WILLIAM H. KENT SCHOOL is on Moulton street, Ward 3 (Charlestown). This building is of the primary grade and has six school rooms, three on each floor. The teachers' room is on the second floor. The exterior brick work is of selected Eastern face brick. Trimmings are of white Lee marble. Panels over the entrances are "Red of Levanto" marble. The eaves are open exposed cut rafter ends, with copper gutter. The roof is covered with green Vermont slate. Partitions where not of brick are constructed of channel irons, lathed with expanded metal, plastered with cement, finishing 1¾ inches thick. The iron staircases are enclosed with brick walls and are shut off at each story by tinned doors set in iron frames. The heating is by direct

radiation, with heated fresh air for ventilation supplied by a fan. Iron water closet ranges are used in the basement. The cost of this building was increased above a normal rate because the conditions of the site required foundations of great depth. This additional cost for foundations was $7,485.43, and to furnish a guide as to the probable cost of a similar structure built under ordinary conditions this sum in the data here given has been deducted from the total cost. The cost, after this deduction has been made, was $45,181.77, of which $4,082.00 was for heating and ventilating. The cost per square foot of floor area was $3.24, the cost per cubic foot was $0.24, the cost per school room was $7,530.00. This building is further illustrated by Plate VIII. *Cost.*

BASEMENT PLAN.



FIRST FLOOR PLAN.

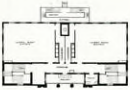
SECOND FLOOR PLAN.

MORTON STREET SCHOOL is on Morton street, Ward 25 (Dorchester). This building is of the primary grade and has four school rooms, two in each story, and a teachers' room in the second story. Neither this nor the Oak Square School, the only other wooden schoolhouse of which plans are here shown, is relatively as successful in execution as the brick schoolhouses. It is evident that the detail of these two buildings was not given the careful personal consideration which is generally evident in this work. It is a frame construction fire stopped. The walls are clapboarded, and the roof is shingled. The exterior finish is of white pine. Heating is by indirect radiation. The staircases are of iron, and one of them, as required by the building laws, is enclosed in brick walls. The *Morton Street School.*

dry latrine system was used in the basement, as there was no sewer to which a plumbing system could be connected. *Cost.* The cost was $22,203.51, of which $2,772.00 was for heating and ventilating. The cost per square foot of floor area was $2.40, the cost per cubic foot was $0.18, the cost per school room was $5,550.00.

BASEMENT PLAN.

FIRST FLOOR PLAN.

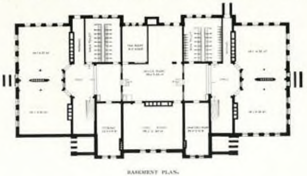


SECOND FLOOR PLAN.

Christopher Gibson School.

CHRISTOPHER GIBSON SCHOOL is on Bowdoin avenue, Ward 24 (Dorchester). This building is of the grammar grade and has in the first story seven school rooms, a library, a reception room, and a master's room. In the second story are five school rooms, a teachers' room, and an assembly hall. The schoolhouse is built on a sharply sloping hillside,

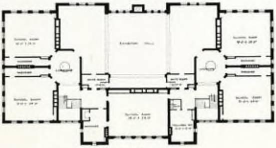
which leaves the rear rooms in the basement free from the ground. This is a case where the boilers might well have been in an outside building, so that these basement rooms could have had fresh air supplied by the fan, and thus been used as school rooms. The exterior brick work



BASEMENT PLAN.

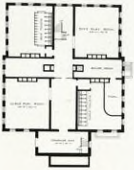
is of selected sand struck brick laid in yellow mortar. The trimmings are of terra cotta and Amherst sandstone. The eaves are open with exposed cut rafter ends. The roof is covered with light green Vermont slate. The iron staircases are enclosed in brick walls shut off at each story by tinned doors set in iron frames. The central corridor is lighted by skylights over wells in the second story. The heating is by direct radiation, with heated fresh air furnished by a plenum fan. Iron water closet ranges are used in the basement. The cost was $99,800.44, of which $12,927.20 was for heating and ventilating. The cost per square foot of floor area was $2.87, the cost per cubic foot was $0.18¾, the cost per school room was $7,128.00. This building is further illustrated by Plates XXII. and XXIII. *Cost.*

FIRST FLOOR PLAN.

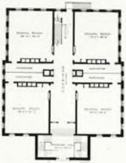


SECOND FLOOR PLAN.

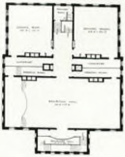
BLACKINTON SCHOOL is on Leyden street, Orient Heights, Ward 1 (East Boston). *Blackinton School.* This building is of the grammar grade and has on the first floor four school rooms, and on the second two school rooms, a teachers' room, and an assembly hall. It is built on a very awkward site and has little architectural distinction. It is of interest as being the first schoolhouse designed by Mr. Wheelwright. The exterior brick work is of selected water struck brick laid throughout in red mortar. The window-sills are of Longmeadow sandstone. The trimmings and cornice of the battlement are of red terra cotta. The roof is flat and covered with tar and gravel. The heating is by a plenum fan supplemented by direct radiation. The cost was $50,472.11, of which $2,507.00 was for heating and ventilating. The cost per square foot of floor area was $2.70, the cost per cubic foot was $0.18, the cost per school room was $6,309.00. This building is further illustrated by Plate II. *Cost.*



BASEMENT PLAN.



FIRST FLOOR PLAN.



SECOND FLOOR PLAN.

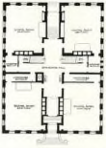
Wyman School.

WYMAN SCHOOL is between Bowe and Wyman streets, Ward 23 (Jamaica Plain). This building is of the primary grade and has six school rooms, of which four are in the first story, and two in the second, where is also the teachers' room. Although the school contains only six school rooms, the construction is so arranged that at any future time two additional rooms may be built in the second story. The exterior brick work is of selected water struck brick, laid throughout in red mortar. The window-sills are of Longmeadow sandstone. The cornice of the battlement is of brick. The roof is flat and covered with tar and gravel. The heating is by the plenum fan supplemented in the more exposed rooms by direct radiation.

Cost.

The cost was \$36,521.69, of which \$3,010.00 was for heating and ventilating. The cost per square foot of floor area was \$2.55, the cost per cubic foot was \$0.22, the cost per school room was \$6,086.00.

BASEMENT PLAN.



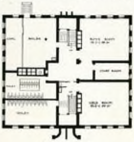
FIRST FLOOR PLAN.

SECOND FLOOR PLAN.

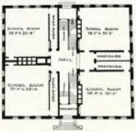
WILLIAM WIRT WARREN SCHOOL is on Waverley street, Ward 25 (North Brighton). This building is of the grammar grade and has six school rooms and an assembly hall. In the first story are four school rooms, in the second two school rooms, an assembly hall, and rooms for master and teachers. The exterior brick work is of selected water struck brick laid throughout in red mortar. The window-sills are of Longmeadow sandstone. The cornice of the battlement wall is of brick. The roof is flat and covered with tar and gravel. The heating is by the plenum fan supplemented in the more exposed rooms by direct radiation. The cost was $38,978.83, of which $3,372.00 was for heating and ventilating. The cost per square foot of floor area was $2.09, the cost per cubic foot was $0.14¾, the cost per school room was $4,874.00.

William Wirt Warren School.

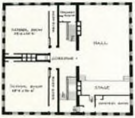
Cost.



BASEMENT PLAN.



FIRST FLOOR PLAN.



SECOND FLOOR PLAN.

ABBY W. MAY SCHOOL is in a block lying between Thornton and Fulda streets, Ward 21 (Roxbury). This building is of the primary grade and has six school rooms, three in each story. In the second story there is also a teachers' room. The exterior brick work is of selected water struck brick. The brick work in the basement arches and in the cornices is laid in red mortar, the rest of the brick work is laid in white mortar. The window-sills are of Indiana limestone. The cornice of the battlement wall is of brick, and the coping and the back of this wall are covered with copper. The roof is flat and covered with tar and gravel. The building is heated by direct radiation, with a fan supplying heated

Abby W. May School.

Cost. fresh air for ventilation. The cost was $36,292.95, of which $4,650.00 was for heating and ventilating. The cost per square foot of floor area was $2.73, the cost per cubic foot was $0.19, the cost per school room was $6,048.00. This building is further illustrated by Plate I.

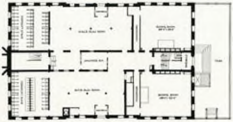
FIRST FLOOR PLAN.

SECOND FLOOR PLAN.

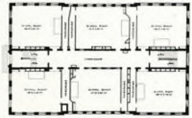
BASEMENT PLAN.

Bowdoin School. BOWDOIN SCHOOL is on Myrtle, Irving, and South Russell streets, Ward 8. This building stands in part on the site of the house in which Charles Sumner was born, and the architect has commemorated this by a bronze tablet set in an outer wall. The school is of the grammar grade. Its site on the sharply sloping north side of Beacon Hill admits of two school rooms entirely above grade on the basement floor. In the sub-basement is the boiler room, etc. On the first floor are six school rooms. On the second floor are four school rooms, a library 28 feet by 37 feet, and the master's and teachers' rooms. On the third floor are four school rooms and an assembly hall. The exterior brick work is of selected Eastern brick. The trimmings are of Indiana limestone. The cornice has corona and coping of copper and the protected members and balustrade of galvanized iron. The roof is covered with light green Vermont slate. The partitions are of channel irons and expanded metal plastered with cement. The corners of rooms and angles of walls and ceilings are coved as in hospital construction. The iron staircases are enclosed in brick walls and shut off by tinned doors. The heating is by direct radiation, with heated fresh air supplied by plenum fan. Iron water closet ranges are used in the basement lavatories.

Cost. The cost was $104,866.99, of which $9,825.00 was for heating. $3,000.00 of this expense might have been saved if the building had been built as a whole and not in two sections. This, however, was rendered necessary since the building was designed to occupy in part the site of an old schoolhouse which had to be used until the first section of the new schoolhouse was built. The normal cost of the building was therefore $101,866.99. Upon this basis the cost per square foot of floor area was $2.74, the cost per cubic foot was $0.19, the cost per school room was $5,659.00. If the two basement school rooms are not counted as such, the cost per school room would then be $6,366.00. This building is further illustrated by plates XXXII., XXXIII., XXXIV., XXXV., XXXVI., XXXVII.

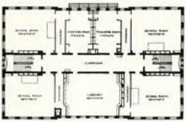


BASEMENT PLAN.



FIRST FLOOR PLAN.

SUB-BASEMENT PLAN.



SECOND FLOOR PLAN.

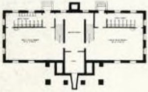
THIRD FLOOR PLAN.

Oak Square School.

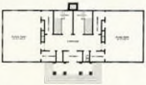
OAK SQUARE SCHOOL is on Tremont and Nonantum streets, Ward 25 (Brighton). This building is of the primary grade and has two school rooms on its single floor. It is of frame construction thoroughly fire stopped. The walls are clapboarded and the roof is shingled. The exterior finish is of white pine. The heating is by indirect radiation. The dry latrine system was used in the basement, as there was no sewer to which a plumbing system could be connected.

Cost.

The cost was $14,970.28, of which $1,570.00 was for heating and ventilating. The cost per square foot of floor area was $2.49, the cost per cubic foot was $0.20, the cost per school room was $7,485.00.



BASEMENT PLAN.



FIRST FLOOR PLAN.

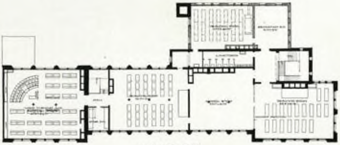
Mechanic Arts High School.

THE MECHANIC ARTS HIGH SCHOOL is on the corner of Dalton and Belvidere streets, Ward 11. The description of the interior finish and fittings of the building here given is taken, through the permission of Dr. Charles W. Parmenter, Head Master of the School, from his report for the year 1897. This report is quoted from liberally, in the hope that its full account of the methods of manual training and of the plant necessary for such work may assist in the establishment of similar schools. The distinctive character and purpose of the school are explained as follows: "It is an institution of high school grade whose curriculum provides for thorough training in drawing and the elements of the mechanic arts, in addition to many of the branches usually taught in high schools. Its subjects of study and methods are

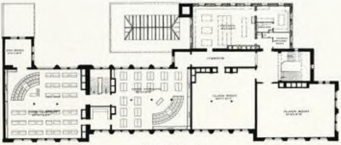
chosen solely on account of the superior educational results which they are adapted to yield. It educates boys not primarily to become mechanics, but to become men of intelligence and skill."

Main features of construction.

The purpose of the school is expressed in the design of the building, which has the character of a factory or work shop with architectural treatment. Ornamental detail derived from the early brick architecture of Northern and Central Italy is sparingly used; and the tower, suggested by that of St. Antoine in the South of France, harmonizes well with the design both in general character and in detail. The roof was originally intended to pitch toward the eaves, but just before the completion of the design a change was made in the building laws by which, on account of the proposed thickness of the walls, the height had to be restricted. The open eaves treatment was retained, as a heavy shadow at the eaves was desirable, but the roof was pitched to the rear and covered with tar and gravel. The roof of the tower is covered with red slate. The main portion of the building is of deep red water struck brick laid in red mortar. The screen walls between the piers are of the same brick laid in yellow mortar; the cornice and the surface between the archivolts of arches are of a yellowish red sand struck brick laid in white mortar with wide joints. The headers with which the wall is bonded are laid in a pattern which, while not apparent to the casual observer, gives texture to the brick surface. The trimmings are of terra cotta and Kibbe stone. The building has pile foundations. The heating is by direct radiation, with heated fresh air supplied by a plenum fan. Water closets are used in the basement. The interior walls are unplastered, the brick work being treated in color. The blackboards are of slate. Separate well ventilated lockers for clothing are placed in the basement. By the instruction of the School Committee this building was built with exposed mill construction floors, which, by the requirements of the building laws, were mortar deafened. The result of the experience in this school as to the possibility of deafening mill construction is like that of the Institute of Technology in one of its buildings so constructed. In the one case one inch of mortar deafening was used; in the other four thicknesses of Beaver Brand sheathing felt, two thicknesses of tarred paper, and two thicknesses of asbestos paper, were laid between the lower and the upper floors. In neither case was the transmission of sound between the floors sufficiently prevented. In the Mechanic Arts building, although the precaution was taken of laying two thicknesses of paper on top of the planking before the mortar was laid, there was trouble from the sifting of dust through the ceilings. To meet this difficulty the ceilings of the school rooms have lately been plastered, and those of the machine rooms have been covered with embossed steel ceilings, in each case a satisfactory remedy. As originally constructed the upper story finished up into the roof, but provision was made for an attic floor, which was put in in the summer of 1897. The cost, not including cost of tower above ceiling of third story, or the cost of furnishings, machinery, tools, etc., was $143,149.31, of which $16,608.42 was for heating. The cost per square foot of finished floor area was $3.00. The cost per cubic foot was $0.20. In computing cubical contents, the area of the tower, above the top of third story ceiling, was not included. The cost of tower was about $6,000. The cost of furnishings, machinery, tools, etc., has been about $44,000.



THIRD FLOOR PLAN.



SECOND FLOOR PLAN.

FIRST FLOOR PLAN.

BASEMENT PLAN.

The report of the Mechanic Arts High School for 1897 gives a full description of the equipment of the school, including complete lists of tools used in the several departments. This description is here quoted, with the omission, however, of the lists of tools:—

Arrangement of rooms.

The rooms are large and well lighted, and peculiarly attractive on account of their evident fitness for their specific uses.* The rooms in which machinery is run are separated from the rest of the building by heavy double brick partitions on each side of a stairway. The tint chosen for the steel ceilings and the brick walls of the rooms and corridors is agreeable to the eye, and adapted to diffuse light freely.

On the basement floor are the boiler room, forge shop, coal bunker, engine room, engineer's store-room, sanitary appointments, and dressing rooms containing 258 lockers, each 23 in. long, 18 in. wide, and 5 ft. high, fitted with combination locks.

On the first floor are two school-rooms, each of which accommodates seventy pupils, the machine shop, the tool-room for metal-working tools, the storage room for metal stock, the office for the instructors in the metal-working departments, and a large room originally designed as a finishing room for the various mechanical departments, which has been divided by temporary partitions, so as to furnish a physical lecture room, a recitation room, and a small office for the principal. It must be remembered that the present structure is only the main portion of the original design. The rear wing, which will contain the library, principal's office, physical and chemical laboratories, a drawing room and a recitation room, has not been erected.

The second floor provides for two school-rooms, identical with those on the first floor, two wood-working rooms for first-year pupils, the tool room for carpenters' tools, and the room devoted to the preparation of stock for exercises in wood-working.

On the third floor are two drawing rooms, a school-room, lavatories, a room for the storage of drawing materials, and the room devoted to wood-turning and pattern-making. The drawing room at the east end of the building, and the adjacent school-room are separated by flexible doors. When these doors are opened, the two rooms furnish a tolerably good assembly hall for occasional use.

The Drawing department.

Each of the two drawing rooms has accommodations for six classes of thirty-six pupils. The drawing tables (Fig. 1) provide conveniently for the storage of all materials used in class exercises; consequently pupils obtain the articles needed at the beginning of the lesson, and restore them to their proper places at its close, with little loss of time. Each table is fitted with a locker which holds six half imperial (17 in. x 24 in.) drawing boards. The six individual drawers on the right contain the note books, pencils, needle points, erasers, etc., the personal property of each pupil. The drawer over the locker holds the other drawing tools and materials, with the exception of the T square, which is used in common by members of different classes.

In addition to the slate blackboard over the teacher's platform in each room, is a set of three movable blackboards (54 in. x 83 in.) placed one directly in front of another, each counterbalanced by weights like an ordinary window sash, so that it can be easily moved

* Experience has proved that the school-rooms should be either of the size customary in high schools or even smaller, and that several small recitation rooms should be provided.

upward to expose the board behind it. In the rear of the larger room is the apparatus for making "blue prints," which consists of a very convenient device for holding the prints while they are exposed to the sunlight, together with soapstone sinks and racks, of special design, which furnish excellent facilities for washing and drying the prints.

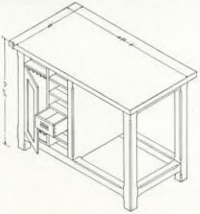


FIG. 1.

The adjoining supply room is furnished with cases designed to hold paper, models, and the numerous miscellaneous articles used in the drawing department. Provision has been made, in one of these cases, for filing the drawings of four hundred pupils so that any plate can be readily examined.

The Wood-working department.

Two adjoining rooms on the second floor are assigned to the department of wood-working with hand tools. This department is equipped to accommodate daily six classes of thirty-six pupils. Each room is furnished with eighteen double benches, 57 in. long, 45 in. wide on the top, and varying in height from 29 in. to 33 in. On each side of these benches is a tier of three drawers, one of which is assigned to each pupil. In this drawer he stores the set of cutting tools with which he is supplied, together with his apron and unfinished work. Upon the vertical tool board, 9½ in. high, which divides the top of the bench in the centre, and upon hooks and shelves at the ends of the bench, are kept the measuring and miscellaneous tools used in common by members of different classes. The individual sets are kept in the drawers. Each pupil is also supplied with a tray, 26½ in. long, 13¾ in. wide, and 1¾ in. deep, divided into compartments adapted to receive a set of Buck Brothers' London style carving tools. Suitable cases are provided, at one end of each room, for the storage of these trays when they are not in use. Two Brown & Sharpe grindstone troughs, fitted with stones and truing devices, furnish facilities for keeping cutting tools in order.

The tool-room, which contains a variety of minor supplies, together with a large collection of miscellaneous tools for occasional use, is located between the two wood-working rooms, and is conveniently entered from either of them. Many of the shelves in this room are divided by narrow strips of wood in such a way that each tool has its appropriate compartment. Each pupil is supplied with three brass checks bearing his shop number, one of which will be received by the person in charge of the tool-room in exchange for any desired tool. The check is placed in the compartment from which the tool is taken, where it remains until it is redeemed by the return of the tool.

Opening out of one of the wood-working rooms is a small room which contains a Colburn double arbor bench-saw, a Dover band-saw, with 36-in. wheel, and a Moseley jig-saw. This room is devoted to the preparation of stock for models, and to special work which demands the use of these saws. All pupils are taught to use the jig-saw, but the other machines are reserved for the instructors, and for pupils who prove to be particularly careful and skilful. The location of these saws in a separate room makes it possible to use them at any time without disturbing class exercises.

The Wood-turning department.

The room devoted to wood-turning and pattern-making is equipped with thirty-six benches. One side of each bench supports a Putnam 11-in. speed lathe, while the other side is adapted to all the processes of pattern-making that require the use of hand tools. These benches, as well as those in the other wood-working rooms, are fitted with 9-in. Wyman & Gordon quick action vises. Beneath the lathe is a tier of three drawers, each containing a set of turning tools. On the opposite side, under the work bench, is a tier of four drawers. The top drawer in this tier is devoted to the measuring and miscellaneous tools used in common by members of different classes, while each of the three others contains an individual set of cutting tools.

Conveniently located in the centre of the room are two grindstones and a Putnam pattern-makers' lathe having an 8 ft. bed and, with open slide, capable of doing work 36 in. in diameter. This lathe is fitted with the most approved devices for doing all kinds of work, and is designed to be used only by the instructor and by pupils who develop special skill and demonstrate their ability to do a high order of work. Near at hand is a small tool-room which contains a large variety of minor supplies, and all miscellaneous tools likely to be needed. The loft above this room furnishes adequate storage for a year's supply of lumber.

In one corner of each of the three wood-working rooms is an amphitheatre in which the entire class may be seated so that each member can see plainly the work done by the instructor at the demonstration bench. The space behind the amphitheatre has been utilized to provide a convenient place for sinks and mirrors. Each room is also furnished with large cases which provide convenient storage for prepared stock and finished work. The frames of drawing tables and work benches, and all exposed parts of tables, benches, and cases, are ash; the sides of drawers, interior of cases, and tops of drawing tables are white pine; the tops of work benches are of narrow strips of maple glued together to prevent warping. All drawers and compartments of cases are fitted with locks, no two of which have the same combination, but all are operated by a master key. The tables and benches have been constructed in the most thorough and substantial manner, and no pains have been spared to make every part of the equipment illustrate excellence of design and workmanship.

The Forge Shop.

The forge shop is a brick structure, 50 ft. long, 29 ft. wide, and 20 ft. high, lighted both by windows in the walls and by a large skylight. It is separated from the main building so that the noise incident to the work causes no disturbance in the class-rooms, but pupils can enter it through the basement without passing out of doors. It contains all needed appliances for the instruction of classes of twenty-four pupils. In the centre is a row of three four-fire forges, and on each side are three two-fire forges, all made by the Buffalo Forge Company. Upon a post conveniently located with reference to each of these fires is an Eagle anvil weighing 130 lbs., near which is placed a tool-bench (Fig. 2) supplied with tools.

One of the three drawers in this tool-bench is assigned to each boy for the storage of the models which he has completed, or on which he is engaged. Each of these individual drawers is furnished with a 1½-lb. ball peen hand hammer.

Eleven blacksmiths' vises are attached to benches 21 in. by 30 in., and 34 in. high, built in convenient locations about posts firmly fixed in the masonry of the floor. Fans of ample size produce blast for the forges, and carry away the foul air and products of combustion. The instructor's forge, located at one end of the room, is supplied with a hand blast, for use when the engine is not running, and his tool-bench is furnished with a variety of tools for occasional use in addition to those above mentioned. Behind the instructor's anvil is a large slate blackboard for use in demonstration lessons; and near at hand is a 75-lb. Laird & Sweeney power hammer, which has proved very useful in making and re-dressing tools, and in a great variety of constructive work. Attached to the wall, near the power hammer, is a Goddard drill press, No. 3, furnished with all needed accessories. At the opposite side of the room, resting on a heavy iron bracket securely bolted to the wall, is a Diamond grinding machine, No. 4, which carries, at each end of the spindle, a 12-in. by 1½-in. Hart emery wheel. At the end of the shop, opposite to the instructor's forge, are two large cases for the storage of supplies and special tools. A Cleveland shear, capable of cutting 1¼-in. round iron, a Boynton & Plummer bolt-heading machine No. 1, an oil tank, a brine tank, a swage block, and numerous minor tools complete the equipment.

FIG. 2.

It is believed that the equipment of this shop is admirable in every respect, with the exception of the forges, which are not to be commended. Experience has shown, also, that a larger shop is highly desirable, for more ample space is needed between the anvils to insure each pupil against annoyance from the necessary movements of his neighbor. Nevertheless, in spite of the disadvantages under which they have labored, the classes have been able to execute very creditable work.

The Machine Shop.

The machine shop, like the forge shop, is equipped for classes of twenty-four pupils. The benches, 20 in. wide and from 32 to 36 in. high, which extend along three sides of this room are divided into twenty-four sections, each provided with a vise and a tier of four drawers. One of the three lower drawers is assigned to each pupil, but the top drawer is reserved for the tools used in common by members of different classes. In his individual drawer the boy stores the work upon which he is engaged, together with about a dozen files and a set of chisels and lathe tools. At the beginning of a lesson each pupil obtains from the tool-room a tray adapted to fit a compartment either in the upper drawer at his bench or on the tool-board of his lathe. This shop is equipped with the following machine tools: Three 14-in. engine lathes, 5-ft. beds, each having a compound rest and one a taper attachment, built by the Fitchburg Machine Works; sixteen 12-in. engine lathes, 5-ft. beds, with elevating rests, built by the F. E. Reed Co.; two 12-in. engine lathes, 5-ft. beds, with plain rests and taper attachments, built by the F. E. Reed Co.; one 20-in. planer, built by the Fitchburg Machine Works, supplied with a 10-in. Skinner vise with square base; one 14-in. pillar shaper, built by the Pratt & Whitney Co.; one No. 2 universal milling-machine, built by the Brown & Sharpe Mfg. Co.; one universal hand lathe, built by the Brown & Sharpe Mfg. Co., supplied with shell chucks $\frac{1}{8}$ in., $\frac{3}{16}$ in., $\frac{1}{4}$ in., $\frac{5}{16}$ in., and $\frac{3}{8}$ in.; a Whiton geared scroll chuck, 2½ in., and an Almond drill chuck, No. 2; four 10-in. hand lathes, 3 with 3½-ft. beds, 1 with 4-ft. bed, built by the Putnam Machine Co.; one Walker universal tool and cutter grinder, complete with attachments, built by the Norton Emery Wheel Co.; one 20-in. standard upright drill, built by Prentice Brothers, fitted with Pratt drill chuck, No. 2; one upright drill, built by Sigourney Tool Co., fitted with Almond drill chuck, No. 2; two grindstone troughs, built by Brown & Sharpe Mfg. Co., each fitted with a 39-in. stone and truing device; one Challenge wet and dry grinder, No. C, built by Appleton Mfg. Co.; one Greenerd arbor press, No. 3; one Miller's Falls power hack-saw.

The following chucks are fitted to the engine lathes: 1 Westcott scroll combination, 10 in., three jaws; 2 Standard independent, 10 in., four jaws; 3 Union combination, 6 in., three reversible jaws; 5 National independent, 6 in., four reversible jaws; 10 Skinner independent, 6 in., four jaws; 1 Whiton geared scroll, 4 in.; 1 Pratt, No. 1. The following chucks are fitted to the Putnam hand lathes: 4 Whiton geared scroll, 3 in.; 1 Whiton geared drill; 1 Little Giant drill, No. 0. Each engine lathe is furnished with a tool board of special design, adapted to receive the tool tray, and to provide a convenient place for cutting and miscellaneous tools. Upon pegs in a vertical board fastened under the bed of each lathe are kept the face plates, change gears, back rest, chuck drill rest, and a set of dogs, ½ in., ¾ in., 1 in., 1½ in., and 2 in. There is no available space for an amphitheatre similar to those in the woodworking department. During the demonstration lessons pupils occupy tablet arm chairs grouped about the instructor's bench, which is placed in front of a large blackboard in the rear of the room. Near at hand is the tool-room, furnished with shelves and cases for the numerous tools required for the various kinds of work. One of these cases, which stands near the door, contains the small tools likely to be needed frequently, and the tool trays previously mentioned. An attendant delivers these trays to the pupils at the beginning of the lesson, and is always ready to furnish any desired tool in exchange for a pupil's check. The universal tool and cutter grinder and the power hack-saw are located in this room.

The stock-room is furnished with shelves, compartments, and racks adapted to provide convenient storage for the many varieties of supplies, castings, and prepared metal stock that are needed by the classes. No pains have been spared to provide a convenient place for all of the numerous articles used in every department of the school, and it is an invariable rule that every article must be kept in its proper place. It is deemed as important to establish orderly habits as to teach mechanical principles.

This building is further illustrated by Plates IX., X., and XI.

Table of Costs of Schoolhouses.

PRIMARY GRADE.

School.	Number Rooms.	Number Floors.	Material.	Total Cost.	Cost of Heating.	Cost per Sq. Ft. of Floor Area.*	Cost per Cub. Ft.	Cost per School Room.
Oak Square . . .	Two	One	Frame	$14,970.28	$1,570.00	$2.49	$0.20	$7,485.00
Morton St. . . .	Four	Two	Frame	22,203.51	2,772.00	2.40	.18	5,550.00
Williams	Four	Two	Brick	35,212.90	1,625.00	3.32	.25	8,803.00
Fuller	Six	Two	Brick	37,331.71	2,601.83	2.81	.20	6,221.00
Tweed	Six	Two	Brick	36,004.05	2,567.00	3.04	.21¾	6,000.00
Wyman	Six	Two	Brick	36,521.69	3,010.00	2.55	.22	6,086.00
May	Six	Two	Brick	36,292.95	3,372.00	2.73	.19	6,048.00
Eustis	Six	Two	Brick	40,389.00	4,200.00	2.99	.22	6,731.00
Weld	Six	Two	Brick	39,531.80	3,910.00	2.85	.22	6,588.00
Kent	Six	Two	Brick	45,181.77 †	4,082.00	3.24	.24	7,530.00
Burnham	Eight	Two	Brick	53,482.55	4,618.00	3.05	.21½	6,685.00
Andrews ‡	Nine	Three	Brick	59,520.25	3,101.22	3.15	.22¾	6,614.00
Cudworth	Eleven	Two	Brick	65,909.33	9,373.00	2.65	.17	5,991.00

* The costs are based upon the area of all floors including basement and with walls and partitions also included.

† The costs of extra foundations is deducted. See description page 65.

‡ This building had steel and terra cotta arch floors.

GRAMMAR GRADE.

ALL WITH ASSEMBLY HALL.*

School.	Number Rooms.	Number Floors.	Material.	Total Cost.	Cost of Heating.	Cost per Sq. Ft. of Floor Area.	Cost per Cub. Ft.	Cost per School Room.
Blackinton	Six	Two	Brick	$50,472.11	$2,507.00	$2.70	$0.18	$6,309.00 †
Warren	Six	Two	Brick	38,978.83	3,372.00	2.09	.14¾	4,874.00
Shaw	Eight	Two	Brick	54,815.59	5,641.98	2.42	.17	5,463.00
Gibson	Twelve	Two	Brick	99,800.44	12,927.20	2.87	.18¾	7,128.00
Agassiz	Fourteen	Three	Brick	90,330.93	7,711.50	2.32	.16½	5,020.00
Bowdoin	Fourteen	Three	Brick	101,866.99 ‡	9,825.00	2.74	.19	6,366.00 §
Stuart	Fourteen	Three	Brick	97,900.00	9,588.00	2.66	.18	6,118.00

* In the cost per school room assembly halls are counted as the equivalent of two school rooms.

† The condition of the site increased the cost of this building above a normal rate.

‡ $3,000.00 is deducted from the actual cost as this amount would have been saved if building had been built as a whole and not in two sections.

§ If two school rooms on basement level but wholly above ground are considered the cost per school room would be $5,659.00.

HIGH SCHOOLS.

School.	Number Stories.	Total Cost.	Cost of Heating.	Cost per Sq. Ft. of Floor Area.	Cost per Cub. Ft.
Mechanic Arts	Three	$143,149.31 *	$16,608.42	$3.00	$0.20
Brighton	Three	122,600.81	16,264.50	2.63	.17

* This cost does not include cost of tower above roof ($6,000.00) or cost of equipment ($44,000.00).

Plate I. Abby W. May School.

Plate II. Blackinton School.

Plate III. Margaret Fuller School.

Plate IV. Margaret Fuller School—Detail of Entrance.

Plate V. Williams School.

Plate VI. Williams School.

Plate VII. Williams School—Detail of Entrance.

Plate VIII. William H. Kent School—Detail of Entrance.

Plate IX. Mechanic Arts High School.

Plate X. Mechanic Arts High School—Detail of Corner Pavilion.

Plate XI. Mechanic Arts High School — Tower.

Plate XII. Agassiz School.

Plate XIII. Agassiz School — Detail of Entrance.

Plate XIV. Agassiz School — Detail Working Drawing.

Plate XV. Robert Gould Shaw School.

Plate XVI. Robert Gould Shaw School—Detail of Entrance.

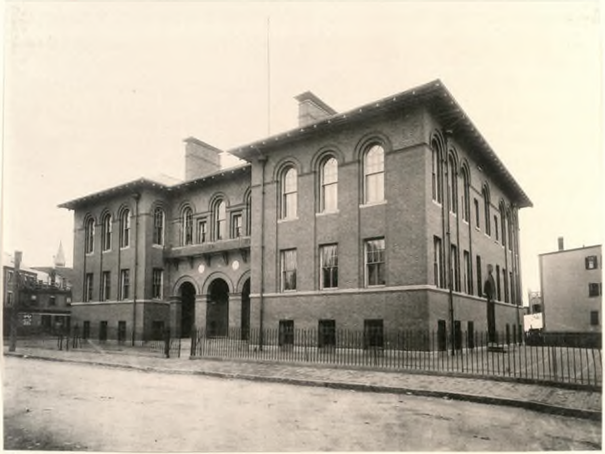


Plate XVII. Cudworth School.

Plate XVIII. Choate Burnham School.

Plate XIX. Choate Burnham School—Detail of Entrance.

Plate XX. Andrews School.

Plate XXI. Andrews School—Detail of Side Entrance.

Plate XXII. Christopher Gibson School—Detail of Front.

Plate XXIII. Christopher Gibson School—Detail of Front.

Plate XXIV. Eustis School.

Plate XXV. Eustis School—Detail of Entrance.

Plate XXVI. Stephen M. Weld School.

Plate XXVII. Stephen M. Weld School—Detail of Entrance.

Plate XXVIII. Gilbert Stuart School.

Plate XXIX. Gilbert Stuart School—Detail of Entrance.

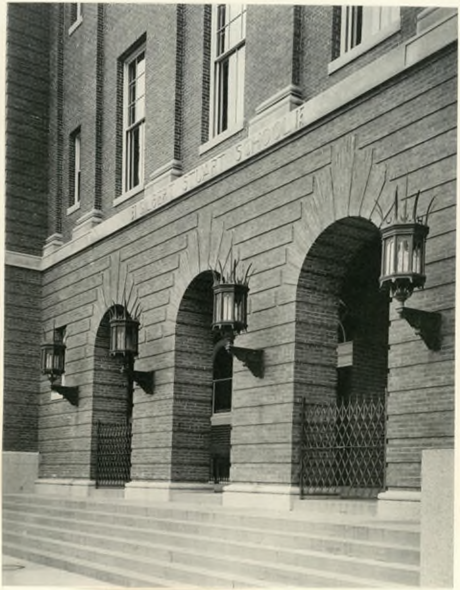


Plate XXX. Gilbert Stuart School — Detail of Entrance.

Plate XXXII. Bowdoin School—Perspective Study.

Plate XXXIII. Bowdoin School.

Plate XXXIV. Bowdoin School—Detail of Entrance.

Plate XXXV. Bowdoin School—Detail of Side.

Plate XXXVI. Bowdoin School—School Room.

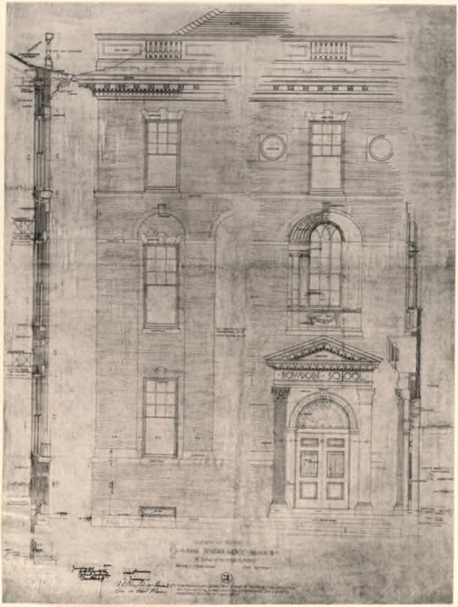


Plate XXXVII. Bowdoin School — Detail Working Drawing.

Plate XXXVIII. Brighton High School — Perspective Study.

Plate XXXIX. Brighton High School.

Plate XL. Brighton High School—Detail of Entrance.

Plate XLI. Brighton High School—Detail of Entrance.

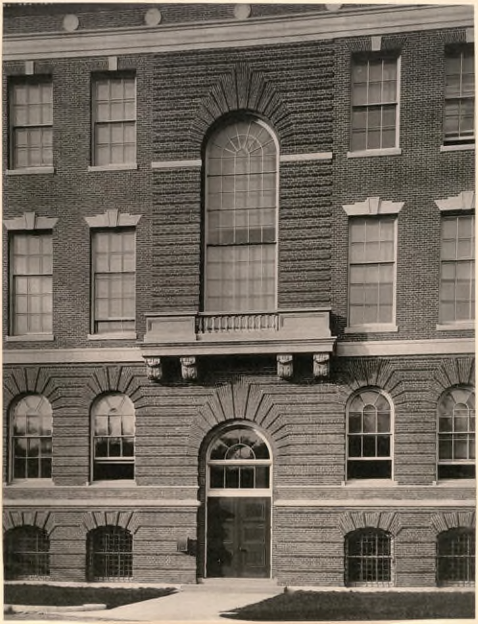


Plate XLII. Brighton High School—Detail of Side.

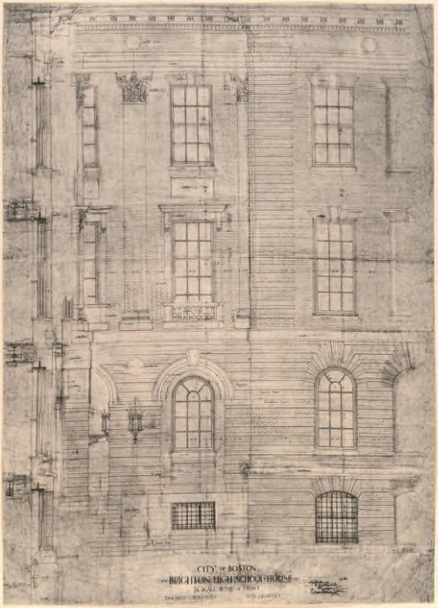


Plate XLIII. Brighton High School—Detail Working Drawing.