THE SCHOOL HOUSE

MOORE

THE SCHOOL HOUSE

Its Heating *and* Ventilation

BY

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INTRODUCTION

The writer having been for the last eighteen years engaged in the inspection of public buildings in Massachusetts, and in supervising the construction of and testing the various methods of heating and ventilation, especially in schoolhouses, presents to those interested in our public schools some suggestions as to the construction and the heating and ventilation of such buildings. The class of buildings selected are those of small or moderate size, of which many are erected each year.

It is not the writer's intention to give theoretical or scientific descriptions or arguments, but simply such methods and plans as have been proved by actual experience to give satisfactory results.

Many of the plans were designed by the writer for the annual official reports of the late Rufus R. Wade, Chief of the Massachusetts District Police.

The method of setting up indirect radiators, as shown in the plans and now generally adopted in Massachusetts, was designed by the writer, and first published in drawings which formed part of the official exhibit of the Inspection Department of the Massachusetts District Police at the Columbian Exposition at Chicago in 1893, and for which an award was given.

Other plans formed part of the exhibit at the Paris Exposition in 1900, for which an award was also given, and at the Louisiana Purchase Exposition at St. Louis in 1904, for which a gold medal was also awarded the department.

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CHAPTER I.

THE SCHOOL HOUSE.

WHEN it becomes desirable for a city or town to erect a new schoolhouse, some of the first questions to be decided are: Where shall it be located, and what is to be the size and cost?

The first question, as to location, is usually decided by determining where is the most convenient place that will best accommodate the greater part of the pupils in the school district.

The size, by the number of pupils to be provided for, and the cost, by the ability or disposition of the city or town to appropriate the requisite amount of money for that purpose.

The choice of location is often a matter of considerable controversy, and it sometimes, unfortunately, depends upon the power or local strength of the contending parties.

It should, however, be determined which location will best serve the interests of the greater number of pupils, and should be where it will be free from the objections of noise or unfavorable surroundings.

A site near large manufacturing establishments, or where objectionable noises, gases or odors are produced, should be avoided, also one where unhealthy conditions may exist.

A dry and healthy location should be selected in preference to one that is low and wet, or on filled ground.

The size of the building should be determined by the number of pupils to be provided for in the district in which the building is to be located. Not only the present needs of the district should be considered, but also the probable increase in the near future.

The cost and character of the building will depend considerably upon the financial ability of the city or town. It is not true economy to attempt to build too large a building for too little money, or to reduce the cost to such a degree as will necessitate the omission of certain essential requisites for a good building.

Where this is done, dissatisfaction will be the result when the building is completed.

Erecting a large and poorly-constructed building for the sake of obtaining a large building at a low cost will in the future prove more expensive and unsatisfactory than if a smaller but well-constructed one is built, and the committee having charge of the work will eventually receive more blame than thanks for their work.

When a city or town decides to erect a new schoolhouse, it is advisable that a committee be appointed and authorized to procure plans, specifications and bona fide estimates of the cost.

Where possible, the committee should consist of one or more practical business men and builders, and also one or more representatives of the school board.

It is not advisable to appoint too large a committee, as is sometimes the case.

With a large committee the actual work is usually done by a few members, and discussions often arise which delay the construction.

A committee of three or five members will often make better progress and give better satisfaction than one that is too large.

After the committee has been appointed it is advisable for them to invite a limited number of architects who have had experience in schoolhouse construction, to submit competitive plans. The invitation should contain a brief description of what is desired; the number and kind of rooms, height and material of which the building is to be constructed, whether of brick, stone or wood, the location, and also such special features as may be desired.

The plans submitted should show the system and method of heating and ventilation. Where this is not done it is sometimes found that a suitable system cannot be installed without making changes in the building plans.

The Massachusetts law requires the plans and specifications for schoolhouses to be filed with the State "Inspector of Factories and Public Buildings" of the district in which the building is located before the building is constructed, and is as follows:

Chapter 104, Revised Laws, Massachusetts (1902).

OF THE INSPECTION OF BUILDINGS.

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Specific Requirements.

Section 22. No building which is designed to be used, in whole or in part, as a public building, public or private institution, schoolhouse, church, theatre, public hall, place of assemblage or place of public resort, and no building more than two stories in height, which is designed to be used above the second story, in whole or in part, as a factory, workshop or mercantile or other establishment and has accommodations for ten or more employees above said story, and no building more than two stories in height designed to be used above the second story, in whole or in part, as a hotel, family hotel, apartment house, boarding house, lodging house or tenement house, and has ten or more rooms above said story, shall be erected until a copy of the plans thereof has been deposited with the inspector of factories and public buildings for the district in which it is to be erected by the person causing its erection, or by the architect thereof. Such plans shall include the method of ventilation provided therefor and a copy of such portion of the specifications therefor as the inspector may require. Such building shall not be so erected without sufficient egresses and other means of escape from fire, properly located and constructed. The certificate of the inspector, indorsed with the approval of the chief of the district police, shall be conclusive evidence of a compliance with the provisions of this chapter unless, after it is granted, a change is made in the plans or specifications of such egresses and means of escape without a new certificate therefor. Such inspector may require that proper fire stops shall be provided in the floors, walls and partitions of such building, and may make such further requirements as may be necessary or proper to prevent the spread of fire therein or its communication from any steam boiler or heating apparatus.

SECTION 23. No wooden flue or air duct for heating or ventilating purposes shall be placed in any building which is subject to the provisions of sections twenty-four and twenty-five and no pipe for conveying hot air or steam in such building shall be placed or remain within one inch of any woodwork, unless protected to the satisfaction of said inspector by suitable guards or casings of incombustible material.

SECTION 24. Whoever erects or constructs a building, or an architect or other person who draws plans or specifications or superintends the erection or construction of a building, in violation of the provisions of this chapter, shall be punished by a fine of not less than fifty nor more than one thousand dollars.

SECTION 25. A building which is used, in whole or in part, as a public building, public or private institution, school house, church, theatre, public hall, place of assemblage or place of public resort, and a building in which ten or more persons are employed above the second story in a factory, workshop, mercantile and other establishment, and a hotel, family hotel, apartment house, boarding house, lodging house or tenement house in which ten or more persons lodge or reside above the second story, and a factory, workshop, mercantile or other establishment the owner, lessee or occupant of which is notified in writing by an inspector of factories and public buildings that the provisions of this chapter are deemed by him applicable thereto shall be provided with proper egresses or other means of escape from fire, sufficient for the use of all persons accommodated, assembled, employed, lodged or resident therein; but no owner, lessee or occupant of such building shall be deemed to have violated this provision unless he has been notified in writing by such inspector what additional egresses or means of escape from fire are necessary and has neglected or refused to supply the same. The egresses and means of escape shall be kept unobstructed, in good repair and ready for use. Stairways on the outside of the building shall have suitable railed landings at each story above the first, accessible at each story from doors or windows, and such landings, doors and windows shall be kept clear of ice, snow and other obstructions. Portable seats shall not be allowed in the aisles or passageways of such buildings during any service or entertainment held therein. If the inspector so directs in writing, women or children shall not be employed in a factory, workshop, mercantile or other establishment, in a room above the second story from which there is only one egress, and all doors and windows in any building which is subject to the provisions of this section shall open outwardly, and every room above the second story in any such building, in which ten or more persons are employed, shall be provided with more than one egress by stairways or by such other way or device, approved in writing by the inspector, as the owner may elect, on the inside or outside of the building, placed as near as practicable at each end of the room. The certificate of the inspector shall be conclusive evidence of a compliance with such requirements.

SECTION 26. Each story above the second story of a building which is subject to the provisions of the preceding section shall be supplied with means of extinguishing fire, consisting of pails of water or other portable apparatus or of a hose attached to a suitable water supply and capable of reaching any part of such story; and such appliances shall be kept at all times ready for use and in good condition.

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SECTION 36. The audience hall in a building which is erected or designed to be used in whole or in part as a theatre or in which any change or alteration shall be made for the purpose of using it as a theatre shall not be placed above the second floor of said building. The audience hall and each gallery of every such building shall, respectively, have at least two independent exits, as far apart as may be, and if the audience hall is on the second floor, the stairways from said floor to the ground floor shall be enclosed with fireproof walls from the basement floor up, and shall have no connection with the basement or first floor of the building. Every such exit shall have a width of at least twenty inches for every one hundred persons which such hall, or gallery from which it leads, is capable of holding; but two or more exits of the same aggregate width may be substituted for either of the two required exits. None of the required exits shall be less than five feet wide.

SECTION 37. The proscenium or curtain opening of all theatres shall have a fire resisting curtain of an incombustible material, properly constructed and operated by proper mechanism. The certificate of the inspector of factories and public buildings shall be conclusive evidence of a compliance with such requirements.

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SECTION 44. If, in the erection of an iron or steel framed building the spaces between the girders or floor beams of any floor are not filled or covered by the permanent construction of said floors before another story is added to the building, a close plank flooring shall be placed and maintained over such spaces, from the time when the beams or girders are placed in position until said permanent construction is applied; but openings, protected by a strong hand railing not less than four feet high, may be left through said floors for the passage of workmen or material.

SECTION 45. In the construction of any iron or steel framed building having a clear story of twenty-five feet elevation or more, a staging with a close plank flooring shall be placed under the whole extent of the beams, girders or trusses of such story upon which iron or steel workers are working, and not more than ten feet below the under side of such beams girders and trusses.

SECTION 46. Inspectors of factories and public buildings shall enforce the provisions of the two preceding sections, and whoever violates any provision thereof shall be punished by a fine of not less than fifty nor more than five hundred dollars for each offence.

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SECTION 51. The supreme judicial court or the superior court shall have jurisdiction in equity, upon the petition of an inspector, temporarily or permanently to restrain the erection, construction, use or occupation of a building in violation of the provisions of this chapter.

SECTION 52. The supreme judicial court or the superior court shall have jurisdiction in equity to restrain the illegal placing, maintenance or use of any building, structure or other thing. It may, upon the petition of a city or town, by its attorney, for such relief, require the removal of any such building, structure or other thing by the owner, and may authorize the city or town, in default of such removal by the owner, to remove it at his expense. The provisions of this section shall apply to such buildings, structures or other things so placed which were maintained or used prior to, as well as after, the second day of May in the year eighteen hundred and ninety-nine. Upon such petition, the defendant shall be presumed to have acted without a license or authority until he proves to the contrary.

SECTION 53. Sections fifteen to eighteen, inclusive, twenty-two to twenty-six, inclusive, thirty, thirty-one, thirty-six, thirty-seven, forty-eight to fifty-one, inclusive, and fifty-four shall not apply to the city of Boston.

SECTION 54. Cities may by ordinance provide that the provisions of sections fifteen to eighteen, inclusive, twenty-two to twenty-six, inclusive, thirty-six, thirty-seven, forty-eight and forty-nine shall apply to any building of three or more stories in height within their respective limits.

SECTION 55. Whoever, being the owner, lessee or occupant of any building or room described in section twenty-two violates the provisions of sections fifteen to eighteen, inclusive, twenty-two to twenty-six, inclusive, thirty-six, thirty-seven, forty-eight and forty-nine, shall be punished by a fine of not less than fifty nor more than one thousand dollars.

SECTION 56. Whoever violates any provision of this chapter for which no other penalty is specifically prescribed shall be punished by a fine of not more than one hundred dollars.

Chapter 106, Revised Laws, Massachusetts.

SANITARY PROVISIONS.

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SECTION 54. Every public building and every school house shall be kept clean and free from effluvia arising from any drain, privy or nuisance, shall be provided with a sufficient number of proper water closets, earth closets, or privies, and shall be ventilated in such a manner that the air shall not become so impure as to be injurious to health. The provisions of this section shall be enforced by the inspection department of the district police.

SECTION 55. If it appears to an inspector of factories and public buildings that further or different sanitary or ventilating provisions which can be provided without unreasonable expense, are required in any public building or school house, he may issue a written order to the proper person or authority, directing such sanitary or ventilating provisions to be provided. A school committee, public officer or person who has charge of, owns or leases any such public building or school house who neglects for four weeks to comply with the order of such inspector shall be punished by a fine of not more than one hundred dollars. Whoever is aggrieved by the order of an inspector issued as above provided and relating to a public building or school house may, within thirty days after the date of the service thereof, apply in writing to the board of health of the city or town to set aside or amend the order; and thereupon, the board, after notice to all parties interested, shall give a hearing upon such order, and may alter, annul or affirm it.

After the committee have decided upon the plan preferred, they can then report to the city or town and ask for an appropriation sufficient to properly construct the building.

The appropriation should be sufficient to cover the entire cost of the site, building, furnishing, grading and the architect's fee, also a reasonable allowance for contingencies. By this method additional appropriations are avoided, and the committee and architect are not obliged to revise the plans and omit essential things in order to keep within the appropriation.

The appropriation having been made, the committee should be authorized to contract for the building.

If architects, before making the finished drawings, or committees, before accepting them, would (in Massachusetts) submit them to the State Inspector for the district, the inspector will inform them as to whether or not the plans meet the requirements of law and will be approved.

Sometimes a committee will accept plans that the inspector cannot approve, and changes will be ordered which may increase the cost after the appropriation is made, or will allow the contractor to present a bill for "extras." "Be sure you are right and then go ahead."

In deciding upon competitive plans committees are often pleased with a well-drawn and colored elevation or perspective, and sometimes lose sight of the more important interior arrangement of the rooms, etc.

Site.

In deciding upon the choice of a site for a schoolhouse many different questions will arise: as to where it should be located to be near the central part of the district, the cost of the land, the nature of the soil, and the objectionable surroundings to be avoided.

A site on high, dry land where a good foundation and good drainage or sewerage can be had should be selected if possible.

If low or filled land must be used, care should be taken that good foundations are provided and supported by well-driven piling, if necessary; also that the walls and bottom of the basement are well protected and made water-tight by asphalt or hydraulic cement.

If the schoolhouse is to be built on clay or on land containing springs of water, proper precautions should be taken to provide suitable drainage by a trench outside, filled with small stones, or by drain-tile placed outside to carry off the water.

When any doubt exists as to the nature of the ground it is advisable that borings be made to determine whether there are quicksands, springs, or unstable places, also as to whether ledges are to be found in excavating. By doing this the architect and contractors will be enabled to make a better estimate of the cost, and bills for "extras" are often avoided.

A site should be selected where a good light can be had on all sides of the building, and unobstructed by trees or high buildings. High buildings or trees close to a schoolhouse often prove serious obstacles to good ventilation on account of deflection of the wind, which sometimes causes reversed drafts in chimneys and ventilating flues.

It is not desirable to place the schoolhouse where it is much exposed to very high winds.

The building should be set well back from the street and ample yard room provided.

Close proximity to manufacturing establishments, where much smoke or noxious gases are produced, should be carefully avoided, as well as a noisy location, where pupils and teachers are annoyed and their attention diverted from school work.

The Building.

School buildings should be plain, and substantially built.

The money frequently expended in the construction of towers, cupolas, and other ornamentation, can be used to much better advantage in substantial construction and convenient interior arrangements.

Not that a building should be hideously plain; but a well proportioned building, with simple and inexpensive ornamentation, can easily be designed by an experienced architect.

A schoolhouse, two stories in height, and, in large buildings, with an assembly hall above the second story, is to be preferred to one of three or four stories.

In case of fire or panic the danger is greatly increased in high buildings.

Climbing many flights of stairs, especially for girls, is not recommended.

In cities where land is very valuable it sometimes becomes necessary to have the school building more than two stories high; but where land can be obtained at a reasonable price two stories are preferable.

Construction.

When a sufficient appropriation can be obtained it is preferable that the building be of fire-proof, or at least, slow-burning construction.

After the first cost the expenditure for repairs is much less for brick than for wooden buildings.

If wooden construction is adopted on account of the first cost, care should be taken that the material is of good quality, the timber of sufficient size, and the boarding well protected with a covering of the best quality of building paper.

A loosely-constructed building requires in cold weather a constant additional expenditure for fuel to maintain a comfortable temperature in the schoolrooms. This additional expense can be considerably reduced by good construction in the first place.

Particular attention should be given to have all trusses properly designed, placed, and of sufficient strength.

The writer has found more well-founded complaints of insufficient trussing and defective roof-framing than from any other cause (exclusive of heating and ventilation) in schoolhouse construction.

It is too often the case that architects are obliged to cut down the thickness of walls and partitions and reduce the size and quality of the timber because a building committee insists on having a large building for little money. This is false economy, as will be apparent after the building is occupied. Better reduce the size of the building than cut down the material.

In brick schoolhouses an air space in the walls is advisable, and the inner walls should be of hard-burned brick with terra-cotta set to receive nailing for the finish.

The wood finish should be reduced to the minimum, and the walls smooth plastered.

In the better class of buildings Windsor or equally good cement can be advantageously used for door and window trims. Dados of gauged mortar and wood base are also used.

Oak or ash finish is preferable to white pine or whitewood, which are too soft and easily defaced. Cypress is sometimes used, and in the cheapest buildings Southern pine is frequently used.

Expanded metal is much better than wooden lathing. Stamped metal ceilings are sometimes used, but the advantage is not great when the extra cost is taken into account.

In some cases in brick school buildings the wood finish in the corridors is omitted and faced brick, carefully laid, and painted with a light-colored gloss paint, is substituted. This has proved quite satisfactory.

The upper floor-boards should be of rift Georgia or Florida pine, or of maple, and not over four inches wide. Between the upper and lower floor-boarding should be laid asbestos or other fire resisting paper or material.

Means to Prevent Spread of Fire.

The following are the requirements of the Massachusetts State Inspectors for buildings other than in the city of Boston:

General Specifications for Means of preventing Spread of Fire in Buildings, under the Requirements of Chapter 104 of the Revised Laws, as directed by the State Inspectors of Factories and Public Buildings. Special Provisions against Spread of Fire, required in Theatres, are not included in those Specifications.

1. All elevator wells and light shafts, unless built of brick, must be filled in flush between the wooden studs with fire-proof materials and lined with metal or plastered on metallic lathing, as may be directed by the inspector, and all wood-work inside of such wells or shafts, be lined with tin plate, lock-jointed.

2. Where floor beams rest on partition caps or on girders, wall girts, or on wooden sills, fill in between such beams, from the caps, girders, girts or sills, to four inches above the plaster ground solid with brick and mortar or other fire-proof material.

3. When floor beams in frame buildings rest on ledger boards, fire-stop thoroughly at each floor with brick and mortar resting on bridging pieces cut in between the studs, or, where practicable, on the ends of lining floor.

4. In brick buildings the space between the furrings on the outside walls or on brick partitions should be filled flush with mortar for a space of five inches in width above and below the floor beams of each story.

5. Where basement or other flights of stairs are enclosed by partitions of brick or wood, the spaces between the studs or wall furrings must be so fire-stopped with brick or mortar as to effectually prevent any fire from passing up between such studs or furrings back of the stair stringers.

6. The soffits of all such enclosed stairs, and also partitions on stairway side, must be plastered on metal lathing.

7. Where a building is occupied above the first floor for any purpose which renders it subject to the provisions of section 22 of chapter 104 of the

Revised Laws, and the lower story is occupied for stores, or other purposes not connected with the upper floors, the stairways leading to such upper floors must be enclosed with brick walls or with wooden partitions filled solid with brick laid in mortar, or other fire-proof material, and plastered on both sides on metallic lathing, and all doors in such partitions lined with tin plate, lock-jointed.

8. All long flights of stairs to have smoke stops in each flight, properly constructed.

9. No pipes for conveying hot air or steam can under the law be placed nearer than one inch to any wood-work unless protected to the satisfaction of the inspector by suitable guards or casings of incombustible material.

10. No wooden flue or air-duct of any description can be used for heating or ventilating purposes.

11. A space of at least one inch to be left between all wood-work and the chimneys, also around all hot-air, steam and hot-water pipes; these spaces around chimneys and pipes, where they pass through floors, to be stopped with metal or other fire-proof material, smoke-tight. Steam and hot-water pipes to have metal sleeves and collars.

All channels and pockets for gas, water and soil-pipes to be made smoke-tight at each floor.

12. The space around all metal or brick ventilating ducts must be fire-stopped at each floor with metal or other fire-proof material, as approved by the inspector.

13. All chimneys to be plastered with one good coat of brown mortar, on the outside of brick-work, from cellars to roof.

14. The ceiling of furnace or boiler and indirect radiator rooms must be plastered on metal lathing. There should be not less than one foot in height of open air space between the tops of furnace or boiler casing or any smoke-pipe and the ceiling.

15. The entire cellar ceilings of schoolhouses and other buildings used for public purposes must be plastered on metallic lathing.

So much of these specifications as applies to any building should be incorporated by the architect in his specifications for said building, and the clauses therein incorporated should be indicated by their numbers in the specification filed with the inspector.

These specifications are to be followed in every building subject to the provisions of section 22 of chapter 104 of the Revised Laws, unless omitted or changed in some part by special consent of the inspector.

Other provisions than those herein specified, to prevent spread of fire, may be required by the inspector if deemed by him to be necessary.

Means to Extinguish Fire.

Chapter 104 of the Revised Laws of Massachusetts requires that means to extinguish fire be provided in certain buildings, as follows:

Section 25. A building which is used, in whole or in part, as a public building, public or private institution, school house, church, theatre, public hall, place of assemblage or place of public resort,

* * * * * * * * *

SECTION 26. Each story above the second story of a building which is subject to the provisions of the preceding section shall be supplied with means of extinguishing fire, consisting of pails of water or other portable apparatus or of a hose attached to a suitable water supply and capable of reaching any part of such story; and such appliances shall be kept at all times ready for use and in good condition.

Although not required by the Massachusetts laws, it is advisable that each story, including the basement, should be provided with a chemical fire-extinguisher, or a stand-pipe and hose not less than two inches in diameter. Suitable and neat hose racks should also be provided in the corridors.

In order that the stand-pipe may be tested to see if it is full of water, and to do this without wetting the hose, it is advisable to place in the stand-pipe, just below the valve in each story, a small try-cock. Care should be taken that the connection with the street water main is not less in diameter than that of the stand-pipe in the building.

BASEMENT.

The basement should not be less than ten feet high and twelve feet is preferable.

It should be well lighted, and when practicable, at least five feet should be above ground.

The basement floor should be of concrete, not less than four inches thick, with a well-smoothed covering of three-quarters of an inch thick of rock asphalt or Portland cement. Rosendale or similar cement is unsuitable for the top covering of a schoolhouse basement on account of being easily worn and broken by the pupils. When so used there is complaint of the dust arising from the fine detached particles of cement.

On wet, filled or clayey ground it is advisable to cover the outside of the foundation and bottom of the basement concrete floor with boiled asphalt to prevent moisture or earth exhalations from entering the building.

The floor of the boiler, furnace and coal rooms should be paved with brick, preferably set on edge in cement mortar.

The floor of the sanitary and playrooms should be graded to some convenient point, at which a drain with a perforated cover is placed, in order that the floor may be thoroughly washed by water from a hose.

The drain for this purpose should be well trapped and not connected with the drain from the sanitary fixtures.

The heating apparatus, cold-air rooms, sanitary, play and lunch-rooms should be in the basement, and when a manual training room or gymnasium is there, the wood floor should be laid on screeds embedded in concrete, and the space between the screeds filled with cement or cinder concrete.

A chemical laboratory should never be placed in the basement.

The flooring of the rooms over the cold-air room should be well protected by some non-conducting material to prevent the cold from striking up through the floor of the first story.

This is sometimes done at a moderate expense by fastening two or more thicknesses of building or thick asbestos paper between the floor timbers, about half-way between the metallic lathing and the floor boarding, holding it in place by strips of furring nailed to the sides of the floor-beams.

A bicycle run and stalls or racks should also be provided.

Galvanized iron ash-holders should be provided for removing the ashes from the boiler or furnace room, also a convenient ash-lift or door.

Suitable soapstone or iron sinks, drinking-cups and wash-basins should be provided in the play-rooms; also in the boiler or furnace-room for the use of the janitor or engineer.

Where practicable, a janitor's room and work-bench should be provided.

Hose and pipe should also be provided for washing.

Danger from fire is greater in the basement than in other parts of the building, and as little wood finish should be used there as possible.

It is advisable that the boiler or furnace rooms should be fire-proof; or, at least, of slow burning construction, and that metal-covered doors be used for these rooms.

The basement stairways should be shut off from the corridors by doors to prevent smoke from rapidly filling the corridors and upper stairways.

Closets should not be allowed under stairways, as they frequently become receptacles for inflammable material, such as waste paper, oil-cans, etc.

Corridors.

Corridors should be wide and well lighted. Twelve feet is not too wide, and when the outer garments of the pupils are hung there fifteen feet is to be preferred.

In small schoolhouses the outer garments can be hung there, either on wall supports, or in stalls preferably made of wire grill work of about one-eighth inch diameter wire, and about two inches diamond mesh. This gives a much better chance for the air to circulate than when wood partitions are used, and the pupils, when the wire grill work is used, can be kept in view of the teachers. The top of the grill work is usually from five to six feet, and the bottom about one foot above the floor.

A shelf of wire grill, on which to place overshoes, is often put at the bottom of the upright grill. In some cases another shelf is placed near the top. Hat and coat hooks in primary schools are placed four feet above the floor, and in other schools five feet. Thirty running feet for a fifty seat room is usually the minimum hanging space.

It is advisable to run two lines of one and one-quarter inch steampipe a short distance above the floor and under the clothing, for the purpose of drying in stormy weather.

Where practicable, umbrella racks are advisable.

All corridors and clothing rooms should be well ventilated; but it is not requisite that a separate air supply should be provided, as the leakage of outside air and the frequent opening of outside doors will generally furnish the required amount of fresh air. A good exhaust duct is, however, necessary.

"Foot-warmers" should be in all cases provided in the lower corridor, in order that in cold or stormy weather the pupils may be provided with means for drying and warming their clothing and feet. The air supply for the foot warmers may be taken in through the risers in the vestibule stairs, or it may be rotated from the corridor.

In large buildings, or where the cost does not prevent, separate coat rooms may be provided.

E. M. Wheelwright, in his excellent work on schoolhouse architecture, says, "specially designed separate clothing rooms add about from four to four and one-half per cent to the cost of the building."

A hand bowl and faucet or drinking fountain should be provided in each corridor, and in some cases a mirror, soap and towels are added.

Glass panels in the class-room doors assist materially in lighting the corridors and enable the teachers to observe what is passing there. Transoms over the doors are also desirable.

In some buildings, where long and difficultly lighted corridors are designed, small windows near the ceiling of the class-rooms have been used to good advantage to assist in lighting the corridors.

Vestibules.

Vestibules are desirable for all schoolhouses. They should be well lighted and have self-closing doors.

In cold and stormy weather, where no vestibules are provided the corridors and other parts of the building are often very rapidly cooled, especially before the session or during recess, by opening outside doors directly into the corridor.

In the matter of economy of fuel, if for no other reason, vestibules should always be provided in schoolhouses.

If it is not practicable to construct a vestibule, a temporary outside storm porch should be constructed of matched boards for use in winter, and capable of being removed for warm weather.

Exits.

There should be at least two ways of exit from every schoolhouse.

The stairways and outside doors should be placed as far apart as practicable and should be not less than four feet wide. Five feet is better.

The Massachusetts inspectors require means of exit equal to twenty inches for each one hundred persons accommodated in a public building; but no stairway to be less than four feet wide in the clear. (For theaters the law requires forty inches for each 100 persons, and no exit to be less than five feet wide.)

When the expense can be incurred it is desirable that stairways in brick school-buildings be made fire-proof and enclosed in brick walls. The stairs should be of iron, and in the treads should be embedded safety treads, not less than five and one-half inches wide, and made of a combination of steel and soft metal, or rubber covering can be advantageously used.

In wooden buildings the sides of the stair-stringers should have the spaces between the studs or wall-furrings so stopped with brick or mortar as to effectually prevent fire from passing up between the studs or furrings back of the stair-stringers, and the soffits of enclosed stairs, and the partitions on the stairway-side should be plastered on expanded metal lathing. At least two cut-offs or fire stops should be put in each stairway.

Enclosed stairways should have a substantial hand-rail on each side.

Open stairways should have a hand-rail on the wall side, and especial care should be taken that the outer posts and balusters are strong enough to prevent being broken or pushed out of place should the stairway become overcrowded in case of panic.

Circular stairways or winders should never be placed in schoolhouses or places of assemblage.

In the lower grade schools, risers should preferably be six inches with twelve-inch tread; in other grades, risers not more than seven inches, with ten and one-half inches tread.

The product of the rise and run should not be less than seventy or more than seventy-five.

There should not be less than two, nor more than fifteen steps between landings, and landings not less than four feet long.

The ordinary fire-escape, such as is used on factories, hotels, tenement-houses, etc., should never be placed on a school-building unless it is impossible to provide other ways of exit.

The danger would be very great if in case of fire an attempt should be made to have a large number of children go down the narrow fire-escapes of the ordinary design.

The pupils would be very likely to become frightened when they looked down from the open fire-escape, would hesitate, stop, and be pushed by those in the rear, and a panic would ensue.

The writer has not for many years required the ordinary fire-escape to be placed on any schoolhouse. When additional means of exit from a schoolhouse must be provided, it should be by enclosed stairways with hand-rails on each side.

Outside main entrance and vestibule doors should open out or both ways.

The standing leaf of all pairs of doors leading to ways of egress should be fastened by face T-bolts, operated at top and bottom by one handle placed at a convenient height from the floor.

Edge bolts should not be used, on account of the difficulty of opening quickly.

Schoolhouse doors should never be fastened during school hours in a manner that will prevent them being quickly opened from the inside. If desirable to prevent persons from entering the building, the door-knobs may be arranged to open the door from the inside, but not from the outside. An electric bell should be provided for the use of persons desiring to enter.

Doors used as exits from the building should be at least equal in width to the stairways.

No door opening inward at the bottom of any stairway should be allowed in any public building.

Door-checks for outside doors will soon save the additional cost in the amount of fuel burned in cold weather.

From each class-room at least one door should open out, and class-rooms on the same story or side of the corridor should have connecting doors.

Windows.

Windows in class-rooms should preferably be four feet between jambs, three feet above the floor, and about six inches, or only enough for the finish, from the top to the ceiling.

Four lights of glass in each window is a desirable number.

Three windows at the rear and four at the left of the pupils give a very good light for the ordinary sized school-room, lighted from two sides.

When only lighted from the left of the pupils' desks, five windows are preferable if the construction of the building will allow it.

Arched windows are objectionable in a class-room.

Transoms may be allowed for summer ventilation where a gravity system is used; but double windows are more desirable, especially on the sides most exposed to the prevailing winter winds. A very considerable saving of fuel is made by their use, and they also to a large extent prevent the cold drafts caused by the rapid cooling of the air on the glass surface.

Double-glazed sash, that is, two lights of glass set with about one-half-inch air space between them, is sometimes used to good advantage, but is not as desirable as double run of sash.

When double glazing is used care should be taken that the glass is thoroughly cleaned and dried before setting.

When either the gravity or mechanical system of ventilation is in use all windows, transoms and doors in class-rooms should be closed in order to obtain the best results.

Windows should have an eye or a depressed piece of metal set into the upper part of the sash, by means of which they can be easily lowered or raised with a window pole or rod.

Transoms should be hung at the bottom and opened or closed by adjusting rods.

Class-room doors opening into a corridor should have a large light of heavy glass set in the center and about four feet above the floor.

Windows grouped as mullions do not give as satisfactory light as when equally spaced in the outer wall.

Basement windows should when practicable be about four feet high and correspond in width to those in the stories above.

Care should be exercised that all spaces about the window frames are caulked or made as tight as possible. Neglect of this precaution is often a cause of complaint of uncomfortable drafts.

Venetian or other blinds are very objectionable in school rooms.

Roller shade curtains, which can be adjusted to raise or lower from either the top or bottom, by means of a slide or a rod at each side of the window, and operated by a cord to hold the curtain in any position, are very desirable, and enable the teacher to regulate the light in a satisfactory manner.

Many of the modern school buildings are now provided with these adjustable curtains.

They assist in partly solving the much-discussed problem of using light from the north or other points of the compass.

Much has been written regarding the amount of light admitted to a schoolroom, and from which point of the compass it should come.

To carry out the theories of some writers would require the class-rooms to be of a height that would very materially increase the cost of the building.

By having a sufficient number of wide windows which extend nearly to the ceiling, and by the judicious use of properly colored adjustable curtains, many of the objections can be in a great measure overcome.

The theory that only a north light should be used in a school-room will often lead to objectionable conditions in the heating and ventilation.

Where a corridor is located north or northwest from class-rooms a more even temperature and better circulation of air is obtained than where the class-rooms are exposed to the prevailing winds, which in Massachusetts are from the northwest and north in the winter.

Class-Rooms.

The standard generally adopted for a class-room in Massachusetts, for what is usually called a fifty seat room, is 32 feet long, 28 feet wide and 12 feet high.

In the lower grades sometimes 56 seats are provided, but this large number is not recommended.

Grammar and the high grade rooms are commonly seated for 42, 47, 48 or 49 pupils.

Twenty-eight by thirty-two feet gives a floor space of 896 square feet, and allows 21.33 square feet of floor space for 42, 19.06 for 47, 18.66 for 48, and 18.28 for 49 pupils. Allowing one teacher per room gives respectively 20.83, 18.16, 18.28 and 17.92 square feet of floor space for each occupant.

The rooms being 12 feet high gives 10,752 cubic feet of air space. This space includes that occupied by the furniture and persons in the room. Usually this is not taken into consideration, but for accurate calculation it should be.

Allowing 42, 47, 48 and 49 pupils, this 10,752 cubic feet of air space gives respectively 256, 228.7, 224 and 219.42 per pupil, or, allowing for one teacher, we have 250.04, 224, 219.42 and 215.44 cubic feet of air space per person.

For approximate calculation we may estimate an ordinary school-room in Massachusetts as containing 10,000 cubic feet of air space.

While these amounts of floor and air space do not quite agree with the recommendations of a number of writers, yet with a properly designed system of heating and ventilation 30, 40 or 50 cubic feet of air per minute may be supplied to each occupant without uncomfortable drafts being perceived.

With wide and high windows, properly located, very little complaint can reasonably be made as to satisfactory lighting. At least this has been the experience of the writer while making many tests of heating and ventilation, and in many conversations with teachers and pupils.

Twelve feet appears to be a desirable height for ordinary class-rooms where the inlets and outlets for ventilation are of ample size and properly located.

This height will allow a good circulation of air, while a lower stud may sometimes cause uncomfortable drafts. A higher stud than 12 feet increases the cost of the building without giving an adequate return.

In rooms 14 feet high the circulation of air is no better than in those 12 feet high.

Seating.

The convenient arrangement of seats in a class-room will depend upon the number of pupils to be accommodated.

In assembly and public halls (except theaters) the Massachusetts inspectors allow six square feet of floor space for each person. This includes aisles, and the open spaces in front of the stage or platform and at the rear of the seats.

In determining the width of exits from halls or places of assemblage, divide the number of square feet of floor space in front of the stage or platform by six for the seating capacity. The width of the exits is determined by the seating capacity; allowing 20 inches for each 100 persons; but no exit to be less than four feet wide.

It is intended that the audience shall pass out in lines 20 inches wide; that is, 200 persons should have at least forty-eight inches in width of exit; 300, sixty inches; 400, eighty inches, etc.

Lecture-rooms in the larger schoolhouses are generally seated in amphitheatre form, and seats with a broad arm or small table-attachment are desirable to enable the pupils to conveniently make notes of the lecture.

In class-rooms the seats should be arranged in a manner that will allow the light to reach the pupils from the left and rear when the room is lighted on two sides, and from the left when the light is from one side only.

When the light comes from the right the effect is bad, especially when the pupils are writing, the shadow of the hand being very trying to the eyes.

Class-room seats should never be placed in a position which requires the pupils to face the windows. The teacher, not being obliged to remain in one position, can better face the light occasionally than to require all the pupils to do so constantly.

In most modern schoolhouses the teacher's platform is omitted, and a movable desk which can be placed in any desirable position is provided.

The ordinary size for a teacher's desk is about 50 inches long, 30 inches wide, and 31 inches high.

Seats and desks, the height of which can be adjusted to the size of the pupils, are much better than those which require pupils of different ages and height to have the same size desk and seat.

There are several styles of adjustable seats and desks in the market, and money expended in this manner is well invested for the health and comfort of the pupils.

The seats and desks should be adjusted to the size of the pupils at least as often as the beginning of each school term.

The old-fashioned double seats and desks occupied by two pupils should not be tolerated in any modern class-room. Seats and desks in class-rooms should be adjustable in order that they may be fitted to the needs of each individual pupil.

Ill-fitting seats and desks are often responsible for round shoulders, spinal curvature, and impaired eyesight.

There are measuring gauges by means of which the height of seats and desks may be readily adjusted.

The following show samples of adjustable and other kinds of furniture used in Massachusetts schoolhouses.

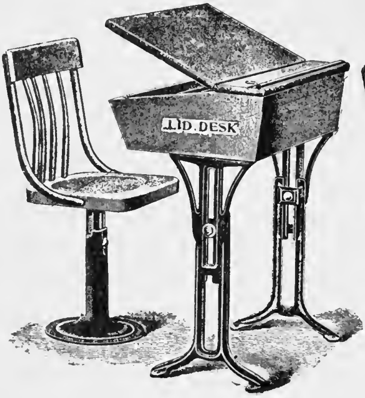


FIG 1.

FIG. 2.

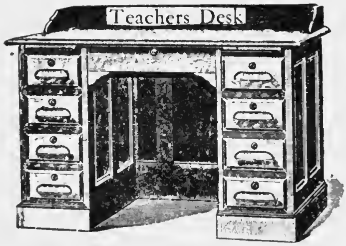


FIG. 3.

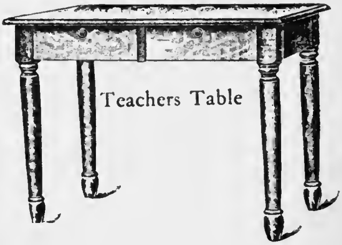


FIG. 4.

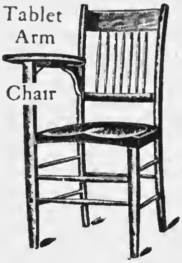
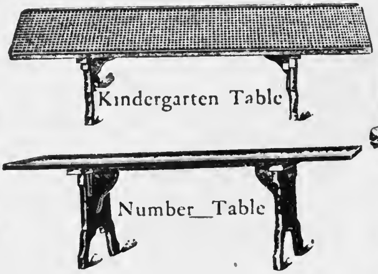


FIG. 5.



FIGS. 6 AND 7.

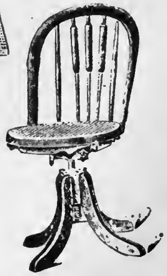


FIG. 8.

Side aisles are usually from three to four feet wide. Aisles between desks are usually 18 inches, but vary from 16 to 24 inches, according to size of the room and the number and size of desks.

FIG. 9.

In high schools the distance between rows of desks is often 30 inches, and the desk tops are 20 by 26 inches.

In schoolhouses having a room for the principal or head master there will generally be found a roller-top desk for his use, and frequently a lounge and extra chairs are provided.

A carpet and some appropriate pictures add to the general appearance of the room.

The following sizes may be considered as desirable for pupils of different ages and grades.

Ages.	Grades.	Dimensions of Desk Top in Inches	Range of Height of Adjustment in Inches.		
			Chair.	Desk.	Age of Pupil.
5 or 6 years 6 or 7 years	1 2	12 x 18	9¾ to 13½ 10½ to 15	17½ to 22½ 18 to 25	4 to 8 years 5 to 12 years
7 or 8 years 8 or 9 years	3 4	13 x 21	12¼ to 17	20½ to 29	7 and upwards
9 or 10 years 10 or 11 years 11 or 12 years	5 6 7	16 x 24	13¾ to 18¾	23 to 31	11 and upwards
12 or 13 years	8	18 x 24			
13 or 14 years	9	20 x 26			

High-school desks are usually made with tops either 18 x 24 inches or 20 x 26 inches.

Dimensions of Desk Top.	Space Occupied.
12 x 18 inches	From side to side, 18 inches From front of desk to rear of chair, 25 inches
13 x 21 inches	From side to side, 21 inches From front of desk to rear of chair, 27 inches
16 x 24 inches	From side to side, 24 inches Front front of desk to rear of chair, 30 inches
18 x 24 inches	From side to side, 24 inches From front of desk to rear of chair, 34 inches
20 x 26 inches	From side to side, 26 inches From front of desk to rear of chair, 36 inches

Allow one inch between back of desk and back of chair.

Blackboards.

Class-room blackboards should be of slate and set on the two inner walls. Where an appropriation will allow, all available space should be so occupied. Not that the space between the windows should be used for daily exercises; but exhibition drawings or artistic designs drawn there add much to the general appearance of the room.

Blackboards should be at least 3 feet high; 3 feet 6 inches or even 4 feet is not excessive in the higher grade rooms.

In primary schools they are set 2 feet 4 inches, and the other grades 3 feet above the floor.

A chalk and eraser receiver 2¾ inches wide should be set below the blackboard.

In lecture-rooms sliding blackboards set in frames that will allow two or more boards to be used in succession are advisable.

Clocks, Thermometers and Pictures.

A clock should be provided in each class-room. In many of the larger buildings electric clocks connected with a regulating one in the head master's room are provided in the several class-rooms, and indicate the time for various recitations or change of classes.

A thermometer should also be placed in each class or recitation room, and if proper attention is given to the indicated temperature more satisfactory results will be obtained, not only as to the comfort of the teacher and pupils, but a considerable saving can be made in fuel.

It is advisable to place the thermometer about on the breathing line of the pupils when in their seats, and to hang it in a location where it will be but little acted on by the rays of the sun, or by cold outside walls or drafts from windows or doors, or opposite a warm-air inlet.

On the teacher's desk or on an inside wall is generally the best location.

At least one thermometer should be placed on the outside of the building in such a position as will screen it as much as possible from the direct rays of the sun. This will be of service to the janitor in regulating his fires, and thereby controlling to a considerable extent the amount of fuel used.

Moulding for hanging pictures is often provided in schoolrooms and a few appropriate pictures add much to the general appearance of the room.

In many of the large school buildings appropriate plaster casts are provided, which with artistic pictures in various parts of the building present a fine appearance and are appreciated by teachers, pupils and visitors.

In many of the large school buildings provision is often made for additional rooms: for an assembly hall, manual training, gymnasium, chemical, physical and biological laboratories, type-writing and stenography, business course, cooking, lunch, teachers, clothing, sanitary, emergency, library, and a janitor's workroom; also book cases and storage closets.

In many schoolhouses, telephone connection is provided between the class-rooms and for the janitor and the principal's room. This is more desirable than speaking tubes, which are, however, used to a considerable extent.

In many buildings telephone connection is provided through the "central" telephone office with other buildings and with the superintendent of schools.

Fire-alarm boxes are often placed in or near schoolhouses for use in case of emergency.

CHAPTER II.

AIR.

THE atmospheric air we breathe consists of a mechanical mixture of approximately 21 parts of oxygen and 79 parts of nitrogen, and usually about four parts of carbonic acid in 10,000 parts of air.

A large number of analyses taken in different places by different persons show that when the air is not particularly contaminated by local conditions four parts of carbonic acid gas in 10,000 parts of air may be considered a fair standard.

A number of other substances are also found in air, such as ozone, watery vapor and organic matter given off by living animals, dust particles, microbes, ammonia compounds, sulphuretted hydrogen, sulphurous and sulphuric acid, nitrous and nitric acid, carbonic oxide, sewer gas and many substances produced by various sources of contamination; also some 30 species of moulds and yeasts, together with the recently discovered argon and other substances.

In breathing, the movements of respiration follow each other at the rate of 18 or 20 a minute.

Quetelet gives the respirations per minute at:

Birth, 44; five years, 26; from 15 to 20 years, 20; from 20 to 25 years, 18.7; from 25 to 30 years, 16; from 30 to 50 years, 18.1.

Dr. Edward Smith found from numerous experiments that the average depth of respiration was 33.6 cubic inches when at rest.

Different authorities give the amount of air inspired and expired as from 26 to 40 cubic inches. The movements of respiration are accelerated by muscular action.

When the lungs have been emptied by expiratory effort they still contain in the smaller bronchi and air sacs a quantity termed residual air, which cannot be expelled, and which is estimated by different authorities as from 40 to 100 cubic inches. A fair average may be taken as 75 cubic inches.

Allowing the amount of air inspired and expired to be 30 cubic inches at each respiration, and 20 respirations per minute, makes 600 cubic inches of air, or .34 cubic feet of air actually used per minute.

The air inhaled passes through the lungs and is deprived of a percentage of its oxygen, which passes into the blood, where it is taken up by the tissues, which are oxidized and carbonic acid gas and other impurities are taken away by the expired air, which, on leaving the lungs, contains about 400 parts of carbonic acid instead of the four parts in 10,000 parts of air when inhaled.

Oxygen is the life-giving element of the atmosphere and is essential for the support of life and also combustion.

In the human body there are constantly going on chemical changes which may be compared to the action of a fire. Acting upon the excess of carbon and other ingredients in the blood, chemical compounds are formed and thrown off by the breath of the individual. Thus the life-giving element of the air is reduced, and poisonous and harmful substances are introduced in its place.

The nitrogen is practically inert in the process of respiration and combustion, and is not affected by passing through the lungs or a fire. It renders the oxygen less active and absorbs some of the heat produced.

Carbonic dioxide (CO_2), or carbonic acid, is the result of combustion of carbon, and although not in itself considered a poisonous gas, yet it may cause the death of a person by suffocation for want of the life-giving oxygen.

As a product of respiration and combustion, carbonic acid is taken as an indication of the amount of other impurities present, and should not exceed eight parts in 10,000 in air intended for breathing, and in many well-ventilated buildings it is often found less than six parts.

Carbonic oxide (CO) is distinctly a poison, and has a characteristic reaction on the blood. Carbonic oxide is doubly dangerous, for, like carbonic acid it is devoid of smell.

Persons narcotized with carbonic acid may be restored to life and health by prompt removal to the fresh air, or by artificial respiration.

Poisoning with carbonic oxide is a much more serious matter, and admitting fresh air, or even pure oxygen gas, is often powerless to overcome the poison of carbonic oxide.

When the draft in a furnace or heater is insufficient the combustion is only partly complete, full oxidation of the carbon of the fuel does not take place, and carbonic oxide is formed.

The escape of this gas into a room should be carefully guarded against. Especial care should be taken that there are no open joints or cracks in the furnace or heater.

Organic nitrogenous substances exhaled with air from the lungs are poisonous, and their presence may be noted in the stagnant, vitiated air of a crowded and unventilated room.

The disagreeable odor known as the "schoolhouse smell" is occasioned by these substances and the odors given off by the skin, stomach, decayed teeth, and unclean persons and clothing.

Brown Sequard and Arsonval made extended researches into the nature of these nitrogenous poisons. They condensed the exhalations from the lungs of men and dogs and obtained a liquid with an alkaline reaction. From two to four cubic centimeters of this liquid, injected into the veins of animals, caused a slowing of the respiration, dilation of the pupils of the eyes, great muscular weakness and a very rapid pulse. When from 10 to 12 cubic centimeters were used death speedily followed, even when the fluid had been boiled.

Brown Sequard arranged eight air-tight cages, connected with glass tubes from one to the other, and by means of an aspirator air was made to pass from cage to cage successively. A rabbit was placed in each cage. The one in the first cage received pure air; the second, air vitiated by the first animal; the third, air polluted successively by two rabbits, etc. Special provisions were made for the removal of excrement. The eighth rabbit died in two days, the seventh in three days, and so on till the death of the third one, in eight days. The first and second animals remained alive.

Quantitative analysis of the air in the several cages showed the carbonic acid could not have caused the death of the rabbits. With bits of pumice stone impregnated with sulphuric acid placed in the glass tube between the sixth and seventh cages, the rabbits in the seventh and eighth cages remained well. The sulphuric acid neutralized the particular poison.

Claude Bernard made a series of experiments which tend to show that the system may gradually, in some degree, acquire a toleration of the poisonous principles in rebreathed air.

A sparrow was inclosed in a glass globe. It hopped about for an hour as actively as usual, and then gradually showed signs of suffering from rebreathing the air poisoned by its own breath. At the end of the second hour another sparrow was placed in the glass globe. It was asphyxiated by the foul air and soon died. At the end of the third hour the first sparrow became unconscious. Taken out into the open air it soon recovered; when replaced in the glass globe it died at once.

When expired, air leaving the lungs contains about 400 parts of carbonic acid in 10,000 of air, together with other impurities.

To dilute and remove these products of respiration a large quantity of pure air must be supplied.

Different writers vary as to the amount of air required for the good ventilation of occupied rooms.

Parkes fixes the amount of fresh air per person per hour

For adult males,	3,500 cubic feet.
For adult females,	3,000 cubic feet.
For children,	2,000 cubic feet.
For a mixed community,	3,000 cubic feet.

Pettinkoffer recommends 2,100.

Dr. Billings, from 850 for children 6.25 years old to 2,000 for those of 14.88.

It may be fairly considered that an ordinary adult man expires .7 of a cubic foot of carbonic acid per hour, and a person about twelve years old averages .6 of a cubic foot, and that 3,000 cubic feet of air per hour per person is required for good ventilation.

Prof. Carpenter, in his excellent work on ventilation, says, "If we take the CO_2 as an index of the character of ventilation, and consider that each person uses one-third of a cubic foot of air per minute, and that the respired air contains 400 parts in 10,000 of CO_2, while the entering air contains but 4, we can calculate the amount of air which must be provided to maintain any standard of purity desired. The formula for this operation would be as follows:

"If a = the parts of CO_2 in 10,000 thrown out in respiration, or other impurities; if b = the cubic feet of air used per minute; if n = the standard of purity to be preserved, expressed as the number of units of CO_2 permissible in 10,000, and C = the number of cubic feet of air required, we shall have

$$C = \frac{ab}{(n - 4)}$$

"For conditions considered for each adult person, $a = 400$, $b = \frac{1}{3}$, so the formula becomes

$$C = \frac{133}{(n - 4)}$$

By taking n as 8, C = 33, and n as 10, C = 22."

This very nearly agrees with several hundred tests made by the writer.

An approximate rule for calculating the amount of air required per capita per hour to keep the CO_2 down to six parts in 10,000 of air in schoolrooms and halls, is by allowing 3,000 cubic feet for this purpose.

For other ratios, divide 6,000 by the difference between normal, or four parts in 10,000, and the ratio of purity required.

Example:

$6 - 4 = 2$, $6{,}000 \div 2 = 3{,}000$ for 6 parts.
$7 - 4 = 3$, $6{,}000 \div 3 = 2{,}000$ for 7 parts.
$8 - 4 = 4$, $6{,}000 \div 4 = 1{,}500$ for 8 parts.
$9 - 4 = 5$, $6{,}000 \div 5 = 1{,}200$ for 9 parts.

$3{,}000 \div 60 = 50$ per minute for 6 parts.
$2{,}000 \div 60 = 33.33$ per minute for 7 parts.
$1{,}500 \div 60 = 25$ per minute for 8 parts.
$1{,}200 \div 60 = 20$ per minute for 9 parts.

The standard for schoolrooms adopted by the Massachusetts Inspectors of Public Buildings is a minimum of thirty cubic feet of fresh air per pupil per minute.

In many of the well-ventilated school buildings in Massachusetts from 40 to 50 cubic feet of fresh air per minute is furnished for each pupil.

Fifty cubic feet of fresh and properly warmed air per minute per person is an ample but not excessive amount for good ventilation in a schoolroom.

Humidity.

The amount of CO_2 expelled in respiration is increased greatly by external cold and diminished by heat; increased by moist and decreased by dry atmosphere.

Humidity or moisture in air has much to do with comfort and the sensation of heat or cold.

When the air is saturated with moisture water is deposited on bodies which readily conduct heat and are of a lower temperature than the surrounding atmosphere.

No evaporation from the body will take place when the air is saturated with moisture.

When the air is deprived of moisture it evaporates water from the body, causing an unpleasant sensation.

Heat increases the power of air to contain moisture, but to remove moisture from the air it must be cooled.

In schoolhouses where an ample quantity of moderately warmed air is supplied there is seldom complaint of dryness of the air.

It has been found that much better results have been obtained when the extra amount of fuel used to evaporate a considerable quantity of water has been expended in warming a larger quantity of air.

It is seldom that any special provision is made to moisten the atmosphere of schoolrooms.

Should a little moisture be desired in schoolhouses heated by steam, it can be supplied by opening an air-valve in a radiator and allowing steam to escape into the air passing over the radiator.

To feel comfortable and produce the best results in ventilation, air should be from 50 to 60 per cent saturated with moisture.

Lights.

The lights used in a room are one source of vitiation of air. An ordinary gas burner contaminates a quantity of air equivalent to that vitiated by from four to five persons, and allowance should be made for this quantity in calculating the amount of fresh air required.

In large assembly halls lighted by gas special ventilation should be provided above the clusters of gas lights to quickly remove the vitiated air and prevent it from mingling with the air of the room. Where electric lights are used it is only required to allow for their heating effect in large or crowded places of assemblage.

The size of ordinary schoolrooms should be such that a sufficient quantity of fresh air can be introduced and foul air removed without causing uncomfortable drafts.

It is the number of occupants and not the size of the room that determines the amount of air that should be supplied.

Rules calling for the change of air in a room a given number of times per hour, without regard to the number of occupants, are erroneous, and should not be adopted in designing a system of ventilation.

Testing the Purity of Air.

It is not always convenient to have a chemical test made in a laboratory of the purity of air from a schoolroom or assembly hall; but an approximate test can be made in the schoolroom by the use of a simple apparatus known as "Professor Wolpert's Air Tester," and, if carefully made, will indicate near enough for all practical purposes whether the air is contaminated to such an extent as to render it unfit for respiration.

A comparison of thirteen tests of air for carbonic acid (CO_2) made with a Wolpert air tester and of air taken at the same time and placed in glass flasks for laboratory analysis, showed an average difference of only sixty-seven one hundredths of one part in ten thousand parts of air — the laboratory analyses showing only this quantity of carbonic acid (CO_2) in excess of the amount shown by the Wolpert tester.

Care must be taken to have a saturated solution of clear lime-water and also in using the apparatus.

The apparatus consists of a simple rubber bulb (A) of a capacity of fifty-two cubic centimeters, a glass outlet tube (B) with a constriction near its extremity (E). The glass test-tube (C), which is twelve centimeters in length and twelve millimeters in diameter, has a horizontal mark (F) near the bottom, indicating the point to which it must be filled with perfectly clear lime-water to contain three cubic centimeters. The bottom of the tube has a black mark (D) made by attaching a piece of black glass. A small wooden stand, a brush or swab, a vial of vinegar for cleaning the tube, and a bottle of perfectly clear and saturated lime-water, complete the outfit, and for convenience in carrying may all be inclosed in a neat case.

Where a number of tests are to be made time may be saved by having several test-tubes and bulb outlet tubes in the case, as a clean tube should be used for each test.

DIRECTIONS FOR USING PROFESSOR WOLPERT'S AIR TESTER.

By S. W. Abbott, M.D., *Secretary Massachusetts State Board of Health.*

In order to use the instrument, the lime-water (saturated solution) should be poured into the test-tube till it reaches the horizontal mark. Press down the bulb with the thumb, so as to expel the air within it as completely as possible, and allow it to fill with the air of the apartment, insert the small tube into the lime-water nearly to the bottom, and again expel the air with moderate rapidity, so that the bubbles may rise nearly to the top of the tube, but do not overflow, taking care to continue the pressure of the thumb till the small tube is removed from the lime-water. Repeat this process until the mark upon the bottom of the test-tube is obscured by the opacity produced by the reaction of the carbonic acid upon the lime-water. the observer looking downwards through the lime-water, from the top of the test-tube.

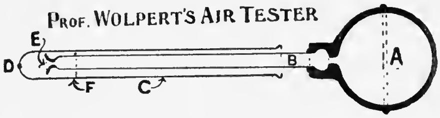


Fig. 10.

With very foul air it is necessary to examine the mark after filling and discharging the bulb a few times only; with good air it must be filled twenty-five times and upwards.

After each observation the test-tube must be washed out and wiped dry. If a white incrustation forms upon the tube, it may be easily removed with a little vinegar, after which the tube should be thoroughly washed with pure water and dried.

If the mark becomes obscured after filling the bulb ten or fifteen times only, the air of an apartment is unfit for continuous respiration.

The instrument should be used by daylight over a white ground, as a sheet of writing paper, and care should be taken not to vitiate the result by the observer's own breath.

The following approximate table is taken from the article by Professor Wolpert, the first column representing the number of fillings of the bulb, and the second column the parts per 10,000 of carbonic acid in a given sample of air.

TABLE 1.

Number of Fillings.	Carbonic Acid per 10,000.	Number of Fillings.	Carbonic Acid per 10,000.	Number of Fillings.	Carbonic Acid per 10,000.
1	200.	21	9.5	41	4.9
2	100.	22	9.1	42	4.8
3	67.	23	8 7	43	4.6
4	50.	24	8.3	44	4.5
5	40.	25	8.	45	4.4
6	33.	26	7.7	46	4 3
7	29.	27	7.4	47	4.2
8	25.	28	7.1	48	4.1
9	22.	29	6.9	49	4.1
10	20.	30	6.6	50	4.
11	18.	31	6.4	51	3.9
12	16.	32	6 3	52	3.9
13	15.	33	6.1	53	3.8
14	14.	34	5.9	54	3.7
15	13.	35	5.7	55	3.7
16	12.5	36	5.5	56	3.6
17	12.	37	5.4	57	3.5
18	11.	38	5.3	58	3.5
19	10.5	39	5 1	59	3.4
20	10.	40	5.	60	3 3

If the table is not at hand for ready reference, the approximate amount of carbonic acid (CO_2) in 10,000 parts of any sample of air may be obtained by dividing 200 by the number of fillings.

Example: $200 \div 10 = 20$ parts of CO_2
$200 \div 25 = 8$ parts of CO_2.

Preparation of Lime-Water for use with Professor Wolpert's Air Tester.

Lime-water purchased at a drug store is ordinarily worthless for testing the purity of air, and should never be used for that purpose.

Inspector John T. White and the writer prepared lime-water for use with Professor Wolpert's air tester in the following manner.

The best unslaked lime made from marble is carefully slaked in distilled water in a clean glass bottle, care being taken to put in but a small quantity at a time to prevent breaking the bottle by the heat generated during the slaking.

After the lime has settled the first water is decanted off and the slaked lime carefully washed with distilled water, allowing the lime to settle before pouring off the wash water. The bottle is then nearly filled with distilled water and shaken at intervals for several days, the bottle being carefully closed during the time with a tight-fitting paraffined cork or ground-glass stopper.

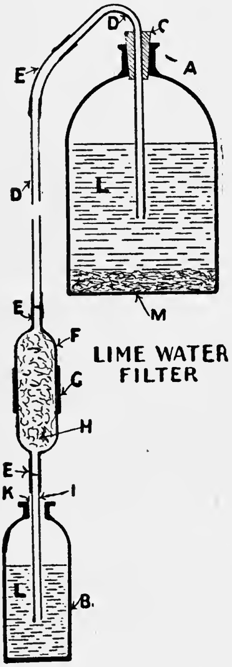


Fig. 11.

A considerable quantity, say one-half inch or more, of the undissolved lime, should always remain in the bottom of the bottle.

After the lime has thoroughly settled and the water has become perfectly clear, a sufficient quantity may be transferred to a small bottle for use with the apparatus.

The following described apparatus is used to prevent the lime-water absorbing carbonic acid from the air while being poured from one bottle to the other.

The large bottle (A) containing the clear lime-water (L), with the undissolved lime (M), in the bottom is fitted with a stopper (C), through which a glass tube (D) is passed and extended well below the surface of the lime-water, but not too close to the undissolved lime; and the glass tube (D) is connected with another glass tube (I) by the rubber tubing (E) which has inserted into it a larger glass tube or long bulb (F) consisting of two parts held together by a piece of rubber tubing (G). The larger tube or bulb is made in two pieces to allow cotton fiber as a filter (H) to be easily inserted or removed. The lower glass tube (I) passes into the small bottle (B), the mouth of which is loosely filled with cotton (K).

The larger bottle (A) being placed on a table or shelf, and the small bottle (B) on the floor or a lower shelf, the lower end of the tube (I) is placed in the mouth of the operator and the air is sucked out till the lime-water flows freely, the siphoning being continued till sufficient lime-water has passed through to clear the tubes. The lower tube (I) is inserted into the lower bottle and cotton fibre loosely placed in its mouth.

The clear lime-water will then be siphoned into the small bottle without coming in contact with the outer air.

When filled, the small bottle must be carefully closed with a tight-fitting ground glass stopper.

MEASUREMENT OF AIR.

An anemometer is an instrument for measuring the velocity of air currents. It consists of a number of blades set at an angle on a shaft and inclosed within a rim or circular casing. The blades are constructed of light-weight metal, and the shaft is provided with bearings to reduce the friction as much as possible. The movement of the air in the direction of the axis of the shaft causes the shaft to rotate, setting in motion a train of gears, by means of which the index hands indicate the number of revolutions and the velocity.

The number of index hands required depends upon the use for which the instrument is intended.

Many of those in common use have but two index hands, one index for 100 revolutions, and one for 1000.

Anemometers intended to be kept running in one place for a considerable time have more index hands, each index successively recording ten times the next lower index.

The four-inch "Byram's" with two indices has been found by the writer to be a very convenient sized and reliable instrument. Those of larger size are too cumbersome, and cannot be used to advantage in testing the velocity in different parts of a small duct or opening. The small two-and-one-half inch size, while convenient to carry in the pocket, is not usually quite as reliable as the four-inch pattern.

A correction table is usually furnished by the manufacturer for each instrument, which gives the correction to be allowed for different speeds.

For convenience it is well to have a special adjustment made, according to the work to be done, by some reliable party having the proper means for rating the instrument.

A normal rating at 300 feet per minute is a convenient speed for ordinary schoolhouse work.

Where the instrument is used frequently it is advisable to have it tested at intervals.

If a number of instruments are used by several persons who can meet occasionally at a given place, it is advisable that one carefully tested instrument be kept as a standard by which others can be tested without the expense and delay of sending them away.

A convenient way of testing by means of the standard instrument is to cover with a board an opening through which a constant current passes, preferably one through which the flow is caused by a fan. In the board cut two openings side by side, into which the two anemometers can be easily placed, but fitting reasonably tight. By changing the anemometers from one opening to the other and noting the velocity for a given time, fairly good comparisons can be had as to the running of the instruments.

The speed of the fan wheel can be adjusted by changing the angle of inclination of the blades. When the fan wheel is running too slow a greater speed will be recorded by reducing the angle or flattening the blades. If running too fast the angle should be increased.

In changing the angle of the blades care should be taken to have the pitch of each blade the same.

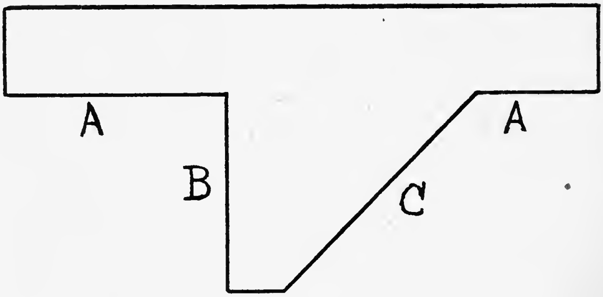


FIG. 12.

After the instrument has been tested and rated, and before using it, a template can be made of stout sheet metal or wood which will fit the pitch of the blades.

The accompanying diagram shows the form of the template.

By placing the edge A–A on the top of the casing, with the perpendicular edge B resting on the inner side of the casing, the inclined side C will give the pitch or inclination of the blades.

An accurate instrument is required to obtain correct measurements of the velocity.

In measuring the velocity of air at inlets and outlets, especially in school-rooms, care must be exercised to obtain a *correct average velocity;* also the *net available* or *working area* of the opening.

At an inlet or outlet from a room the velocity of the air currents varies materially in different parts of the opening. This variation is owing to a variety of causes, of which the form and direction of the duct or shaft is one of the principal. The ordinary inlet for

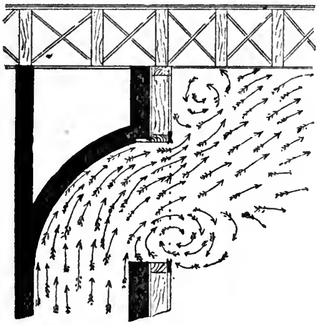


FIG. 13.

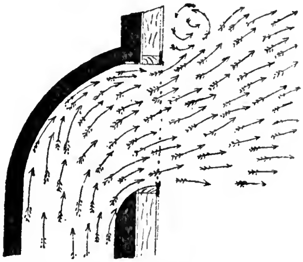


FIG. 14

supplying air to a schoolroom should have a curve at the top, and the bottom of the inlet should have the wall on the front of the duct cut away, curved, or beveled down. The tendency of the air flowing up the warm-air flue is to strike against the top of the flue and be deflected into the room. Where the top is properly curved, the direction of the warm air current is changed in a more satisfactory manner than when the top is flat. If the bottom of the opening is flat and horizontal, the current is carried up too high before it changes its direction. This is particularly noticeable in flues having walls eight inches thick with the added thickness of studding and plastering.

The available or working area of the opening is often greatly reduced from this cause, and in some cases one-third or more of the area is not available and the volume of air which should pass through the whole opening is forced into a space one-third or more smaller than it should be, thereby increasing the velocity to an undesirable point.

Upon holding an anemometer on the lowest part of the inlet opening, the fan wheel will sometimes indicate an inward or reversed current, caused by an eddy above the flat top of the front wall of the duct.

In other cases the current will be stronger at one end of the inlet opening than at the other.

Again it will be diagonally up and across the opening, or it may be in the form of an arch, or strong at one end and weak at another point in a perpendicular line.

Occasionally the lowest velocity will be in the center of the opening. These different currents are produced by offsets or changes in the form and direction of the duct before it reaches the opening.

In measuring the inflowing air the various currents and velocities must be carefully noted in order to obtain a correct average.

In the greater number of cases the velocity will be highest at the top of the inlet opening, decreasing down to a point towards the

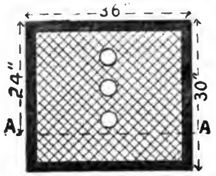


FIG. 15.

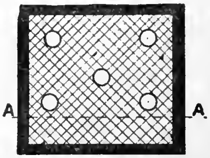


FIG. 16.

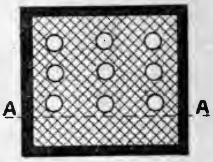


FIG. 17.

bottom, where no movement of the anemometer wheel will take place.

In measuring the amount of air coming through the inlet it is advisable to place the anemometer in front of the bottom of the inlet and gradually raise it till the top of the blades will strike the incoming current, then note this point and cover the opening below it with a piece of rubber cloth having small hooks on the upper edge to fasten to the register or grill over the opening. This will cause any incoming air below this point to be sent through the upper and uncovered part of the opening.

Then measure the length and height of the uncovered part of the opening for the effective or working area.

If a register face of any of the common cast-iron patterns is used to cover the opening a deduction of one-third should be made from the working area as found by the above measurement. With some cast-iron register faces a larger deduction will be required.

With the ordinary wire grill pattern over the opening about one-tenth will be a fair deduction. With some patterns it may be one-eighth.

Care should be taken to hold the anemometer with the edge of the casing parallel with the register face or grill. Air striking the blades at different angles will give different readings on the index.

It is usual to take three, five or nine measurements with the anemometer placed as shown in diagrams, Figures 15, 16 and 17.

If the opening is circular the anemometer may be placed as shown in Fig. 18.

If a very careful measurement of the air is required it may be advisable to construct a frame the size of the opening to be measured and one foot deep, and divide the area into squares with sides of six inches by stretching pieces of cord across the outer edge of the frame, then holding the anemometer for a given time — say one minute each — with the center of the wheel opposite the intersections of the cords.

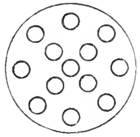


FIG. 18.

The total of the different readings of the index divided by their number will give a fair average of the velocity of the current.

The average velocity, multiplied by the net available square feet of opening, will give the number of cubic feet of air passing in a given time. If the time of each reading of the index is one minute the amount will be in cubic feet per minute. This, divided by the number of seats in the room, will give the number of cubic feet of air supplied per minute for each seat.

If the amount per hour is required, multiply the supply per minute by sixty.

The practice of moving the anemometer over different parts of the opening while taking a measurement is not a good one, especially if the lower part of the opening is not an available or working area.

If the instrument is held at the top of the opening till the fan wheel has acquired the greatest velocity obtainable in that position, and is then quickly moved to the bottom of the opening, the readings will be incorrect. The momentum of the wheel will continue it in motion till after it is gone below the available working area, and if the instrument is raised again to the top of the opening the speed will be again raised to the high point.

The writer recalls an instance in which a person who claimed to be an expert heating and ventilating engineer had installed a heating and ventilating apparatus in a new schoolhouse.

He had succeeded in securing from the building committee a contract for the work without giving any guarantee that the work should be up to the state requirements, or that it should be tested by the state inspector.

Being desirous of obtaining his pay, and being a good talker, he had induced the building committee to be present at the building on a day when the conditions of temperature and wind were favorable for obtaining good results.

His talk to the committee was like this: "Now, gentlemen, I have given you a first-class piece of work, and in order that you may see what excellent results we have obtained I have asked you to be present today and see the apparatus tested.

"To satisfy you that the test is fairly made I will ask one of you gentlemen, to give me the time by your watch, one minute, while I use this anemometer to ascertain at what velocity the air enters the room." Showing the anemometer to the committee, he explained its use and how to read the indices, and had them note the position of the hands of each index.

Holding the instrument near the top of the opening, he started and stopped it at a signal from the man holding the watch. Observing the index, the committee noted the velocity recorded to be 550 feet per minute. Then measuring the full area of the opening, which was covered by an ordinary register face, he used his pencil and paper, showing the committee the figures, of which they took a copy. "Now, gentlemen, the opening is 30 by 20 inches, which made an area of 600 square inches, or 4.16 square feet. The velocity is 550 feet per minute, which gives you 2,288 cubic feet of fresh air per minute for the 48 pupils, or $47\frac{2}{3}$ cubic feet per minute for each scholar. You will see this is very much better than I told you I would do."

The committee were satisfied, and paid the bill. After a time complaints were made of defects in the system, and the state inspector was asked what could be done to remedy them, as the contractor would not do it.

When a test was made by the inspector the committee were greatly surprised to see the report of the air actually supplied. Other defects were pointed out in the apparatus, and several hundred dollars were expended before the apparatus was made to do fair work.

The volume of air and its weight per cubic foot change with the temperature.

In measuring and computing the volume of air its temperature at the time of measurement should be taken into account.

In comparing one measurement with another the volumes should all be reduced to corresponding volumes at zero. (Absolute $T = 460°$ below zero.)

Reduce both the original and final temperature to *absolute* temperatures. Multiply the original volume by the final absolute temperature and divide by the original absolute temperature. The quotient will be the final volume.

If V = the original volume, V_1 = final volume, T_1 = original absolute temperature, and T_2 = final absolute temperature; then

$$V_1 = \frac{VT_2}{T_1}$$

Example: What will be the volume of 1800 cubic feet of air at a temperature of 100 degrees F. when it is cooled to 70 degrees F.?

$$\frac{1800\ (460 + 70)}{460 + 100} = 1703.57 \text{ cubic feet.}$$

Wind—Velocity and Pressure.

The pressure of the wind varies as the square of the velocity, or $P \sim V_2$.

The square of the velocity in miles per hour multiplied by $.005 = P$.

The square root of 200 times the pressure equals the velocity, or $\sqrt{200} \times P = V$.

To find the rate at which air is moving, divide the velocity in feet per minute by .88; the answer will be in miles per hour.

Example: 300 feet per minute $= 300 \div .88 = 3.409$ miles per hour.

To find the pressure in pounds per square foot, multiply the square of the velocity in feet per second by .0023; the result will be pounds pressure.

Example: 300 feet per minute = 5 feet per second, and $5 \times 5 \times .0023 = .0575$ pounds.

The shape of the surface obstructing the wind greatly modifies the pressure.

The pressure upon a globe, or a hemisphere with the convex side towards the wind, is only about one-half the pressure on a flat surface of equal diameter.

TABLE 2

SHOWING THE NUMBER OF MILES PER HOUR AND PRESSURE IN POUNDS PER SQUARE FOOT ON FLAT SURFACES AT RIGHT ANGLES TO THE CURRENT, AT VELOCITIES PER MINUTE.

Feet per Minute.	Miles per Hour.	Pressure in Pounds per Sq. Foot.	Character of Wind.	Feet per Minute.	Miles per Hour.	Pressure in Pounds per Sq. Foot.	Character of Wind.
10	.113	.0000		550	6.249	.1930	
20	.227	.0002		600	6.818	.2300	
25	.284	.0004		650	7.386	.2968	
30	.340	.0006		700	7.954	.3125	
35	.397	.0008		750	8.522	.3593	
40	.454	.0010		800	9.090	.4087	
45	.511	.0013		850	9.658	.4616	
50	.568	.0016		900	10.227	.5175	Gentle breeze
55	.625	.0019		950	10.795	.5763	Gentle breeze
60	.681	.0023		1000	11.363	.6384	Fresh breeze
65	.738	.0027		1500	17.405	1.4375	Light wind
70	.795	.0031		2000	22.727	2.5553	Brisk wind
75	.852	.0036		2500	28.407	3.9918	Strong wind
80	.909	.0041		3000	34.090	5.7500	Strong wind
85	.966	.0046		3500	39.772	7.8255	High wind
90	1.022	.0051	Hardly perceptible	4000	45.454	10.2202	Gale
95	1.079	.0057		4500	51.131	12.9375	Gale
100	1.136	.0063		5000	56.818	15.9709	Gale
125	1 420	.0100		5500	62.499	19.2982	Strong gale
150	1.704	.0143		6000	68.181	22.9954	Violent gale
175	1.988	.0195	Perceptible breeze	6500	73.861	26.9764	Violent gale
200	2.272	.0255	Pleasant breeze	7000	79.545	31.3020	Hurricane
250	2.840	.0398		7500	85.225	35.9375	Hurricane
300	3.409	.0575		8000	90.909	40.8868	Hurricane
350	3.977	.0781		8500	96.589	46.1554	Hurricane
400	4 545	.1021		9000	102.272	51.7500	Tornado
450	5.113	.1294		9500	107.952	57.7447	Tornado
500	5 681	.1596		10000	113.636	63.8837	Tornado

CHAPTER III.

SOME IDEAS OF VENTILATION.

THE law requiring the ventilation of public and school buildings in Massachusetts was passed in 1888.

The standard was fixed by the inspection department at a minimum of thirty cubic feet of fresh air per minute per person:

Not because that was all that is required for good ventilation; but because it would greatly improve existing conditions and would be about as much as could then be reasonably obtained without incurring considerable additional expense in a large number of school buildings.

Many persons claimed this amount was excessive and could not be supplied to the pupils in a schoolroom without creating almost a gale in the room.

Some of the heating and ventilating contractors refused to guarantee any such amount, claiming that such a quantity of air could not be properly heated.

At the present time there is no difficulty in furnishing that amount, and perhaps the larger part of the work designed for modern schoolhouses in Massachusetts now gives from forty to fifty cubic feet of fresh air per minute for each person accommodated in a schoolroom. A guarantee is required by the Massachusetts inspectors that certain results will be obtained before their approval of plans and specifications for heating and ventilating is given.

THE REQUIREMENTS OF "FORM NO. 83," INSPECTION DEPARTMENT MASSACHUSETTS DISTRICT POLICE, ARE AS FOLLOWS:

In the ventilation of school buildings the many hundred examinations made by the inspectors of this department have shown that the following requirements can be easily complied with:

1. That the apparatus will with proper management, heat all the rooms, including the corridors, to 70° F. in any weather.

2. That, with the rooms at 70° and a difference of not less than 40° between the temperature of the outside air and that of the air entering the room at the warm-air inlet, the apparatus will supply at least thirty cubic feet of air per minute for each scholar accommodated in the rooms.

3. That such supply of air will so circulate in the rooms that no uncomfortable draught will be felt, and that the difference in temperature between

any two points on the breathing plane in the occupied portion of a room will not exceed 3°.

4. That vitiated air in amount equal to the supply from the inlets will be removed through the ventiducts.

5. That the sanitary appliances will be so ventilated that no odors therefrom will be perceived in any portion of the building.

To secure the approval of this department of plans showing methods or systems of heating and ventilation, the above requirements must be guaranteed in the specifications accompanying the plans.

With a mechanical system of ventilation the allowance of 40 degrees in temperature (Section 2) should be omitted in the specifications, as it was intended to apply to gravity systems.

Many persons, some of them members of school committees, while they readily admit in a general way that pure air is essential to health, do not seem to be aware of the danger of impure air as it exists in an ordinary schoolroom. They seem to think that as some schoolhouses never have been ventilated there is no occasion for any anxiety about them now.

Many old school teachers say they never had any difficulty in ventilating their schoolrooms by means of the windows. Windows are made to admit light and not air, and except when the temperature of the outer and inner air is so nearly equal that the air can be permitted to circulate freely through the rooms they should never be depended upon for ventilation.

Besides, it costs no more to admit the same amount of air in the proper way, and warm it before it enters the room, than to let it in cold at a window and heat it after it is in.

The saving which some people think is made by admitting cold air through the windows, or by means of patented devices, is effected only so far as the amount of fresh air is restricted.

The writer remembers a hearing given by the legislative committee having the proposed ventilation law under consideration.

A man of good standing in his town, who had held various official positions, among them that of school committeeman, appeared in opposition to the bill before the legislative committee at one of the hearings. He said, "Gentlemen, this talk about carbonic acid is all humbug. We know that carbonic acid is heavier than air. You may remember what we were taught at school about putting pieces of candle on an inclined board and pouring carbonic acid out of a jar — that it would flow down the board and put out the flame of the candles. You know that a candle will not burn in a deep hole or well where carbonic acid has settled to the bottom. Now all you have got to do to get rid of this carbonic acid in a schoolroom is to cut a hole in the floor and let it run down into the cellar, and if you don't want it in the cellar just cut some holes in the outside walls at the floor and let it run outdoors."

It was quite evident that this man was not familiar with the law of diffusion of gases, or with the condition of the warm exhalations from the lungs.

Another man, talking with a friend, stated, "This matter of ventilation is all humbug. When I went to school there was no ventilation in the schoolhouse. Anyone can see I am strong and hearty, although I am well along in years." He was asked, "How many were there in your school when you went?" He replied, "About forty." How many of them are living now?" was the next question. After considerable thought he replied, "Only two, as far as I know." The friend said, "Well, the balance appears to be on the wrong side of the account, if your theory is correct."

In a small country school the inspector had induced the school committee to install a jacketed stove, build a vent shaft and put in a small heater to cause an outflow of foul air through the vent shaft. This gave fair ventilation for the number of scholars attending. Some three years later the inspector again visited this schoolhouse. The jacketed stove had been removed and an old-fashioned wood-burning stove had been substituted. The foul air outlet at the floor level had been carefully boarded up. On opening the iron feed door and looking into the vent shaft it was found that birds had used the top of the heater as a place on which to build nests. There were two nests, one upon the other, indicating that the heater had not been used for two years. When the school committee were called upon to explain their reason for making the change the reply was, "It was no use to put any ventilation in that building. When the air got bad the doors and windows could be opened. It cost more for fuel than when the wood-burning stove was in use."

I am glad to say *that* committee do not now have charge of the schools, and the town now has three modern and well-ventilated schoolhouses.

In another town a jacketed stove had been installed in a one-room schoolhouse. After a year had passed complaint was made that the system of ventilation was a complete failure, and that the schoolroom could not be heated and the air was bad. When the inspector visited the building he found that a board had been carefully fitted over the fresh-air inlet to the jacketed stove and a round hole *two inches* in diameter had been cut in the board. The cause of the failure to heat and ventilate this room was apparent.

In one city in which modern heating and ventilating had been provided in several schoolhouses, the inspector found that no heat was used in the vent shafts in any of the buildings. When the janitors were asked why they did not use the vent shaft heaters in mild weather, they gave as a reason that the superintendent of schools had given them positive orders not to use the vent shaft heaters, as *he* considered it a useless and extravagant waste of fuel.

Education is, however, reducing the number of those who oppose providing good ventilation in schools, churches and places of assemblage. The necessity of a large amount of fresh air and the practicability of obtaining it are fast coming to be universally admitted.

Nor is the fear at first entertained of an enormously increased expense likely to be realized.

Good ventilation undoubtedly costs money, but the expense of the new methods as compared with the old is more with the first cost of the appliances than with the cost of supplying and removing the air after such appliances have been put in.

Circulation of Air.

In designing a system of heating and ventilation one of the most important points to consider is the proper circulation of the air used for conveying the heat and also for removing the impurities thrown off by the occupants of the rooms, or from any other source of contamination.

For many years it would seem that very little attention was given to this matter. The only thought apparently was where the inlets and outlets could be most conveniently placed, without regard to their efficiency.

On the proper location of the inlets and outlets will depend the efficiency and economy of the heating and ventilation. A large amount of heat and air may be brought into a room, but if it is allowed to escape without proper circulation very little benefit will be derived.

We have seen schoolrooms where the warm air was brought in through a register in the floor and was allowed to escape through a register in the ceiling or side wall near the ceiling and almost over the inlet.

In other cases the inlets and outlets were placed in the outer and most exposed corners of the room, where the fresh air that leaked in around the windows was taken out through the vent ducts, having done nothing but cooled the air in the immediate vicinity of the vent duct.

Again, the warm fresh air has been brought in through an inlet properly located, but the outlet being placed directly opposite the inlet, the air would pass across the room and go out at the outlet, doing but very little good; in fact, only causing uncomfortable drafts on whoever had the misfortune to be located between the inlet and the outlet.

In many instances the warm air would be taken in at the inner or warm angle of the room while the outlet was placed near an outside or exposed wall.

Sometimes it would appear that the designer of the system had devised some scheme that would do the work in the most unsatisfactory manner.

In one "system" that was installed in many school buildings (but which is not at this time allowed in Massachusetts), the outlets were long narrow openings placed at the floor level in the outside walls and often under the windows. The air was taken across under the floors between the floor timbers and down into what was called a "foul air gathering room," and then passed over screens placed below the seats in the sanitary closets (perhaps the term *unsanitary* closets would be more appropriate). Here it was supposed to dry the excrement, which was afterwards to be burned by pouring a quantity of oil over it and then setting the oil and accumulated paper on fire.

In such a "system" the air which came into the room around the windows, or was cooled on the glass surface, would drop down to the floor, and, if there was a strong fire in the large heater in the ventilating shaft, after having been passed through the space under the "cremating closets" would be taken out of the building, while the vitiated air, especially in the inner or warm parts of the room occupied by the pupils, would remain.

By chemical tests the writer has many times found the air to be purer in the so-called "foul air gathering room" than about the seats where the pupils were located.

Another serious defect in this "system" was the danger of odors and gases being forced back into the schoolroom when there was no fire in the vent shaft heater, or where the vent shafts came through the roof in a location to be affected by adverse air currents or wind.

In addition to these defects was the danger from fire. The rough floor timbers and boards soon became covered with fine particles of lint and other material which was drawn in by the air current. If fire from any cause should get into these under-floor ducts it would spread with great rapidity through the entire building.

The Massachusetts law which prohibits wooden ducts for heating and ventilating public buildings soon put a stop to the further extension of this dangerous "system."

Another "system" was introduced into some school buildings, by means of which it was proposed to draw the air down from the upper stories through a duct which entered the bottom of the vent shaft, and which was enlarged at each story as it came down to the basement, where air was to enter the vent shaft and, after being warmed by a "stack heater," or small furnace, was to escape through the central vent shaft.

The opening from the upper story room was supposed to be sufficient to furnish the required ventilation for the room in which it was placed. The duct was enlarged at the next floor below to twice its original size, and so on.

The designer of this "system" did not take into consideration the fact that moving air will follow the line of least resistance. It was often found that, while an anemometer would show a velocity of 500 feet or more per minute at the lower opening, the movement of air at the upper opening was not strong enough to cause any movement of the anemometer wheel.

Several other "systems" were brought forward and introduced by various experimenters, who in many cases tested their theories at the expense of various cities and towns.

In 1888 and 1889 the writer, in company with State Inspector the late John T. White, made a large number of tests of the circulation of air in different schoolhouses in Massachusetts, by means of smoke and otherwise, to ascertain what should be the proper location of the inlets and outlets to secure a good circulation of the air and heat; also, to determine the proper size and form of inlets and outlets for the ventilation of schoolrooms.

It was found from these tests that the best results would be obtained by varying the location of the inlets and outlets to meet the different locations of the cold or exposed walls.

In a schoolroom having two cold and exposed walls the inlet should be placed with the lower part about eight feet above the floor (allowing the room to be twelve feet high) and in one of the warm sides, about four or five feet from a cold or exposed wall.

The top of the inlet should be curved so as to throw the air forward and across the room to the most exposed or cold angle of the two outer walls, the outlet being placed at the floor level and near the inner or warm angle of the room.

The air, on entering the room though the inlet opening (which should be covered by a grill of about one-eighth-inch wire of diamond mesh pattern, the mesh being about one and one-half to two inches long at its greatest dimension, and set in a channel iron frame) passes first forward and upward and spreads across the ceiling to the outer wall of the room, being at the same time drawn toward and down the windows by the cooling effect of the glass surface, continuing around the room with a falling spiral movement, diffusing throughout the room and gradually falling and drawing toward the outlet.

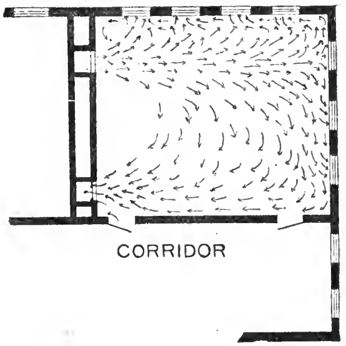


Fig. 19.

In a room considerably longer than wide and with three exposed or cold walls, the inlets should be placed at the same height above the floor as in the preceding case, but in this case there should be two inlets and one outlet. The inlets should be in the inner or warm wall, about the same distance from the cold end walls as in the first instance. The outlet should be placed at the floor level, but as near as practicable in the center of the inner or warm wall.

The entering air will spread across the ceiling to the cold walls, as in the case of the room with two cold and two warm walls, but a considerable part of the two currents will meet near the center of the longest outside wall and the whole will be drawn down and back to the outlet near the center of the warm wall.

In a room having three cold and one warm wall, but with the warm wall on one end of the room, the inlet should be placed about eight feet above the floor near the centre of the warm wall, and the outlet placed at the floor level, nearly under the inlet. The entering air will spread across the ceiling to the three outside cold walls, where it will fall and be drawn back from all sides across the room to the outlet.

In a room having one cold and three warm walls, the inlet and outlet can be placed either as in the first or last mentioned instance.

(Figures 19 or 21.) Good results will be obtained either way, and the location can be determined by considering which method will be best adapted to the construction of the building and the general location of other heat and vent ducts.

A volume of air heated from the freezing to the boiling point of water, barometer 30 inches, expands approximately 1/500 (1/490) for each degree F. it is raised.

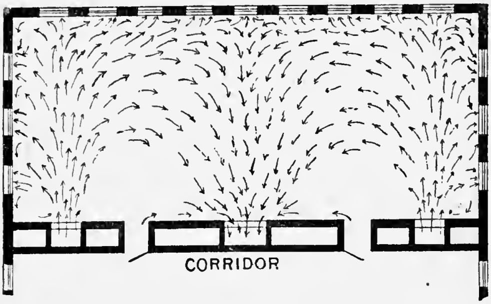


Fig. 20.

If the air of a schoolroom is 40 degrees higher than that of the exterior air its volume has been increased approximately 2/25; consequently it is lighter than the exterior air and tends to rise.

A cubic foot of air at 60 degrees F., dew point 40 degrees, barometer 30 inches, will weigh 534.27 grains.

A cubic foot of expired air at 95 degrees F., dew point 85 degrees, containing 12.78 grains of vapor, and, say, 4 per cent of carbonic acid, will weigh only 494.12 grains, or 7.5 per cent less. This tendency to rise is further increased by the heat given off by the body, which warms the air in immediate contact with it.

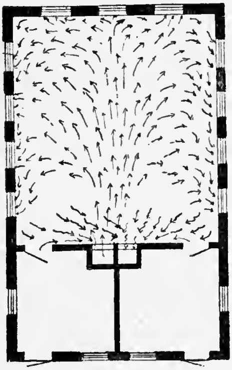


Fig. 21.

At first sight it would seem easier to ventilate a schoolroom by the general upward movement of the air, because of its tendency to rise when first exhaled from the lungs.

If the air is admitted at the floor and taken out at the ceiling there is established a current between the inlet and the outlet, leaving the foul air in some parts of the room almost unmoved, and only slowly and partly drawn into the current.

Another objection to this method of ventilation is the difficulty of properly heating a schoolroom by it. The great loss of heat necessitated thereby calls for the consumption of a much greater quantity of fuel. The hot air is drawn off rapidly from the top, while the cold air remains at the bottom of the room.

From whatever point the warm fresh air is admitted to the schoolroom, it rises at once to the ceiling, and the sooner it reaches that point without being contaminated the better it will be.

By the law of diffusion of gases the expired air would in time undoubtedly be diffused throughout the whole room, as would also the poisonous nitrogenous matter exhaled from the lungs and bodies.

By exhausting the foul air from the bottom a downward movement of the warm air entering at the top of the room is maintained, and as the poisonous products of respiration must be diluted and removed by the introduction of pure air, a circulation within the room is maintained which will produce the required results.

If we make a careful inspection of the course of hot air admitted through a register in the floor we will see that the current of hot air goes directly to the ceiling, and that a portion of the surrounding cooler air is carried up with it by friction, and that this air was drawn from near the floor. The air thus carried up was foul air, and should have been carried off through the vent duct.

The question of admitting the fresh air at the top of the room is not determined by the natural movement of carbonic acid or any other impurity, or by the gravity or weight of the air as it comes from the lungs.

In cold weather the fresh air must be warmed to a number of degrees above the temperature at which we wish to have the room at the breathing line. Heated air will go to the top of the room, no matter where we admit it, and its distribution will begin there. By leading it there in pipes or flues we avoid carrying up dust and foul air with it, and we can locate the inlets and direct the flow of air so as to distribute it more evenly than if we admit it at the floor. The air will spread over the ceiling and be drawn to the outer walls by the falling current caused by cooling on the windows and walls. It then descends to the floor, and may be best taken out at the bottom of the room.

Wherever there is any attempt at a proper system of ventilation in a schoolhouse, the walls and ceiling should be made as impervious as practicable both to air and heat.

The ceiling of an ordinary schoolroom contains about nine hundred square feet of surface, and generally consists only of laths and a coat of mortar. In the attic there is frequently only a single floor over the ceiling of the room below, and frequently no floor at all.

With the temperature of the air at the top of the room from 80 to 90° F., and that of the attic at thirty degrees, or lower, as it may be on a cold day, it is easy to see what an amount of warm fresh air is lost. This is particularly noticeable in the plenum method.

The objection has been made to the exhaust system of ventilation that the air is drawn into the room from every crevice in the walls, floor and ceiling, and also from the corridors and clothes rooms.

The objection can also be made to the plenum system that the impure air is driven out at every crevice and opening, thus possibly forming accumulations of foul matter and disease germs in places that cannot be reached to be cleaned; also that a considerable part of the warm fresh air which enters at the inlet at a higher temperature than at the breathing line escapes through the ceiling and walls before it has circulated and reached the breathing plane, thereby causing a loss of heat that could be utilized within the room.

With the plenum system there is always a leakage of air from the room, as there also is with a gravity system when the exhaust is insufficient, and if this leakage takes place from air at 90 to 100 degrees it is evident that more heat will be lost than from air at 70 degrees.

There is little difficulty in forcing 4000 cubic feet of air per minute with a plenum fan into an ordinary schoolroom when the outlet is closed and windows and doors made as tight as practicable, and hardly a perceptible rise in the barometer can be noted. This will show the effect of leakage.

In some cases, especially where fans or blowers are used, as in the plenum system, to force air into a schoolroom, and where the exhaust is very deficient, there is a tendency to force the air out of the room as it falls on the cool walls and also through the ceiling. As the warm air goes directly to the top of the room and at least three-quarters of the leakage is above the breathing plane, a large quantity of the fresh air will not reach the pupils.

As the result of many observations the writer is led to believe that a schoolroom supplied with 1,500 cubic feet of air per minute, with properly located fresh warm-air inlets and foul-air vent flues, will have the air at the breathing plane kept as pure as it will when supplied with 2,500 cubic feet per minute with no proper provisions for circulating and removing the air.

The economy of heating and forcing this extra 1,000 cubic feet of air into a room has not yet been satisfactorily explained.

Many persons who admit the necessity of supplying a large quantity of air for ventilation fail to appreciate the importance of the work done by the ventilating duct or chimney. While they acknowledge the good work done by an open fireplace in removing foul air from a room, they apparently do not appreciate the fact that the fireplace takes the air from the bottom of the room. The ventilating duct opening from the bottom of the room works in the same way, and when properly located will do the work with far less expenditure of fuel than the open fireplace.

It has been the experience of the writer that when a well-adjusted combination of the plenum and exhaust systems is installed in a school building, more economical and satisfactory results are obtained than by the use of either system independently.

When the exhaust is a little in excess of the plenum, say about five per cent, the heat that is lost by leakage by the plenum method is utilized to warm the air drawn into the room through the outer walls, but in so many small places that uncomfortable drafts are not produced.

When the corridors, clothing and sanitary rooms are properly ventilated there is little danger of foul air reaching the class-rooms from such sources. This is at variance with the recommendations of many persons, but it is the experience of the writer in making many hundred tests of the heating and ventilation of schoolrooms.

The subject of leakage of air and heat has not apparently received the attention from heating and ventilating engineers which it requires. In certain cheaply constructed buildings, where a very strong exhaust was in use, the writer has frequently found twice and sometimes three times as much air going out at the outlet as was coming in at the inlet. This is excessive, and should be guarded against by proper adjustment of dampers and heat in the exhaust flues.

In some of the mechanical systems of heating and ventilation in use in school buildings the velocity of the air at the inlets is too great and the size of the pipes or ducts is too small. Six feet velocity per second at the inlet is enough, and five feet per second, or three hundred feet per minute, is better, although in some cases, where air is brought into high-studded rooms over eight feet from the floor, a velocity of seven feet per second is not objectionable.

In arranging for an air supply for any system of heating and ventilation the number of cubic feet of air to be supplied per minute, divided by 300, will give the area in square feet for the pipe or flue.

Uncomfortable drafts will be caused if the air is brought into the room at too great a velocity, no matter whether by a gravity or a mechanical system.

Air may be forced through a main supply pipe at a velocity of 800 or 1,000 feet per minute by a fan, or at even a greater velocity by the expenditure of additional power, which, however, is not always true economy; but the risers or ducts leading to the rooms should be designed to admit the air into the room at not over 360 feet average velocity per minute.

Taking a small riser from the main duct and increasing the area at the entrance into the room will not give the best results.

There should be a steady and certain outflow of vitiated air through the extraction flues. It will not do to have back drafts. As before intimated, all ducts carrying vitiated air are likely to become coated with foul matter. There should be no possibility of any return of this matter to the rooms.

With properly constructed vent ducts or aspirating chimneys there need not be a back draft under any conditions of wind or temperature.

Every building constitutes a problem by itself, to be solved only after a careful study of all the conditions presented, and then only with a knowledge of the principles of ventilation and heating, and the mechanical skill and experience requisite for a practical application of this knowledge to the work in hand.

Every schoolhouse and public building should be planned with a view to a thorough system of heating and ventilation.

Heating and ventilation are closely connected, and should be planned at the same time.

In the construction of schoolrooms, beams or projections below the ceiling should be carefully avoided to prevent the deflection of the current of air from the inlet, and to avoid causing uncomfortable drafts. If beams project down below the ceiling and are at right angles to the entering air current the air will be deflected and strike the heads of the occupants of the seats a short distance below and beyond the beam. If the room is being cooled off or the temperature of the entering air is lower than that of the room, the uncomfortable drafts will be very apparent.

If the inlet is between two beams parallel to the direction of the current of the incoming air, or between a beam parallel with the outer wall and the wall itself, the air will pass along between the parallel beams or between the beam and the wall to the outer wall opposite the inlet without spreading across the ceiling properly. In such cases an undesirable difference of temperature will be noted in various parts of the room.

In high-studded assembly halls, usually placed in the upper story of a large school building, it is advisable that additional ventilators be placed in the ceiling to carry off an excess of heat or an accumulation of foul air at the top of the room, which is too high to be conveniently ventilated entirely by the vent openings at the floor level. These ceiling ventilators are not intended to be used at all times, but only as the special occasion may require. They should preferably pass up through the roof, or they can be connected with the ducts which take the air from the bottom of the room.

Where gas lights are used the ceiling ventilators should be placed over the groups of burners.

Placing the stacks of indirect radiators or the furnace in the basement in a wrong position, at the base of the warm air shaft, is a source of cold and uncomfortable drafts in the room.

The heating apparatus should always be placed in such a position that the warm air will pass up on the front or room side of the shaft and the cold air used for mixing will pass up on the rear side. If placed so that the warm air comes up on the rear side of the shaft cold drafts will surely be felt.

Deflectors and diffusers, which are generally useless, costly and unsightly devices, placed in front of the warm air inlets will not prevent these troublesome cold drafts.

A mixing damper, which is a device placed near the bottom of the warm-air shaft to regulate the temperature of the incoming air without materially diminishing the quantity, is of great service.

When it is desired to have an entire supply of warm air the chain leading from the mixing damper to the schoolroom is let out, and the mixing damper falls back and prevents the entrance of cold air into the shaft. When it is desirable to cool the incoming air the chain is pulled a little, and cold air is admitted to mingle with the warm air in the shaft.

This damper should not be changed from all warm to all cold, or from all cold to all warm air, by one movement. If this is done the room temperature may be too quickly changed and the room made too cold or too warm, and a constant variation of the temperature of the air in the room will follow, often accompanied by cold drafts in very cold or windy weather.

When it becomes necessary to change the temperature of the room the mixing damper chain should be gradually let out or pulled in; about one inch or less at a time will generally be sufficient.

When the heating apparatus is properly located at the base of the warm-air shaft the warm air will pass up on the front and the cold air on the rear part of the shaft, the cold air being drawn up and mixed by the ascending current of warm air. If the two currents are not thoroughly mixed in the shaft before the direction of the air currents is changed from a perpendicular to a nearly horizontal direction to flow into the room, the warm air will be on the lower side of the stratum of fresh air and will buoy up and diffuse the cold air.

If, however, the cold air is on the front side of the shaft, when the direction of the current is changed the cold air will be on the bottom of the stratum of fresh air, and being colder than the air in the room, will fall as an uncomfortable draft on the occupants of the seats in front of the inlet. These cold drafts are usually more noticeable at from eight to twelve feet in front of the inlet than in other parts of the room.

An excessive outflow of air through the outlet duct is not desirable, as the air currents are sometimes deflected or short circuited, and the heat and fresh air are wasted before having done the work required in the rooms.

This is particularly the case in very cold or windy weather. It also causes an excessive leakage of cold air into the room, and sometimes reduces the temperature of the air in the room to an undesirably low point.

Every foul-air outlet should be provided with a galvanized-iron curved damper, or at least a roller-shade curtain, to regulate the outflow of air.

Judgment must be used by the janitor and teacher in the management of these dampers. During mild weather the damper should be wide open, but during very windy or cold weather it should be *partly but never fully closed* while the room is occupied.

The proper management of these outlet dampers is a matter that should be fully and carefully explained to the teachers and janitors.

In cold weather, when the room is not occupied, the outlet dampers should be closed in order to prevent an undue loss of heat from the room. While a schoolroom should be thoroughly ventilated during school hours and after the school has been dismissed, the outlet damper should be left open long enough to flush out the room with fresh air, yet to continue the ventilation the whole twenty-four hours will cause an unnecessary expenditure of fuel which would be extremely wasteful.

In some cases gossamer rubber-cloth flap-check valves have been placed at the outlet opening. These things are, however, seldom used by the most successful heating and ventilating engineers and contractors, as they are often worse than useless. It takes a strong current of air to open them, and this means an expenditure of power, either mechanical (by a fan) or of heat, which is a needless waste. Being automatic and intended to prevent back drafts they are liable to close while school is in session and shut off the outflow of foul air, or they may open at night or when the school is not in session and cause a loss of heat from the building and an unnecessary cooling of the rooms. When a strong wind is blowing they often flap open and shut, making a noise which is very objectionable in a schoolroom. With a properly designed and located vent shaft, having either a fan or heat to cause the outflow of foul air, and with a damper to close when ventilation is not required, there should be no use for such worthless and objectionable things as gossamer flap-valves in a vent duct.

Many persons advocate the plenum system, in which the air is forced into a schoolroom and the pressure in the room is outward, rather than the exhaust system.

In factories and places where machinery and belts keep the air in motion and well stirred and mixed, and where heat is more to be considered than the amount of air for ventilation, the plenum system is well adapted to the purpose. A hot-blast system which will produce excellent results in a factory or large workshop, will not give the desired results in a schoolroom.

In school buildings and audience halls, where a large quantity of moderately warmed air is required for ventilation, it has been the writer's experience that a judicious combination of the plenum and exhaust systems gives the best results.

Where the plenum system alone is used and no heat or mechanical means employed for exhausting the foul air, the results have not been as satisfactory as where the two systems were combined.

In the plenum system the air, being under a slight pressure in all parts of the room, is forced out, not only at the vent openings but through every crack and opening, and the circulation is not as good as in a combination system, and a greater amount of heat is required.

Many heating and ventilating systems would have proven failures had it not been for the amount of air supplied by leakage into the rooms.

The writer has found, when measuring the air supply in schoolrooms, that under certain conditions from 50 to 300 per cent more air was going out at the outlet than was coming in at the fresh-air inlet, the difference being made up by the inward leakage. In many cases where a sufficient supply of air had not been provided the pupils would have suffered had it not been for this inward leakage of fresh air. Even with such a great difference between the air supplied and the air exhausted, the temperature did not vary but three or four degrees, as was shown by thermometers placed on the pupils' desks at the four corners of the room and also on the teacher's desk.

These differences have been noticed in both the mechanical and gravity systems of supply, and are not confined wholly to wooden buildings of cheap construction.

A person not conversant with the facts may well be inclined to doubt the correctness of this statement, but a series of careful tests will convince him of its accuracy.

The force and direction of the prevailing winds in the district where the building is located should also receive careful consideration from the heating and ventilating engineer and the architect. In Massachusetts the prevailing winds in winter are from the northwest.

Where air is forced by a fan through a long duct against the prevailing winds, and where there are several branches taken off, suitable allowance must be made in the size of the ducts, and at each branch where it leaves the main duct suitable adjusting switch-dampers or reducers should in all cases be provided.

Theoretically, the size of the duct to carry a certain amount of air at a given velocity to a given point may be easily calculated; but the engineer or architect must not be surprised to find his calculation considerably out of the way some day when a cold and strong wind is blowing, if the prevailing direction of the wind has not been taken into account when designing the system.

The discharge from a ventilating duct, even when a good fan is provided, should never be directly out from the side or end of a building, when it can be possibly avoided. The writer has seen cases where the discharge has been out from the side of the building against a very strong wind, and when a good fan was running at a high speed no air would be discharged from the outlet pipe. The strong wind blowing directly into the discharge pipe would more than neutralize the power of the fan.

The vent-duct opening should be up and through the top of the building whenever possible to have it so placed.

If on account of the construction of the building it is not practicable to carry the vent opening to the top, but is necessary to discharge from the side or end, a shield or guard should be provided to deflect the wind and prevent it blowing directly into the vent opening.

A strong wind blowing across the top of a chimney or ventilating duct will produce an additional outflow of air.

To illustrate this action, take a glass tube about three-eighths of an inch diameter and about five or six inches long, open at both ends; in the tube, about two-thirds of the distance from the bottom to the top when the tube is held in a perpendicular position, place a light bit of cotton fibre or similar material, then holding the tube before, but not too close to your mouth, give a strong puff from the lungs. The cotton will be forced up and out the tube and fly off in the direction of the current of air from the lungs.

To illustrate the effect of wind striking a projection on or near the top of the chimney or vent shaft, use the same tube and bit of cotton, but hold the hand or some flat article, such as a book or piece of board, in front of and beyond the top of the perpendicular tube; a strong puff from the lungs will cause the air to strike the obstruction and be deflected down into the tube, carrying the cotton out at the bottom.

It sometimes happens that one vent flue in a school building will cause trouble by having a down draft, while the other will be doing satisfactory work. If an inspection is made of the top of the flue it will probably be seen that some projection is above or against one side or end of the top, against which the wind strikes and is deflected down the vent flue.

The practice of extending the smoke flue up above the level of other parts of the same stack should be avoided. Unless absolutely called for by some special construction of the building as regards towers, etc., the top of the smoke and vent flues, if constructed of masonry, should not be capped or hooded over. The danger of water or snow going down the brick flue is very small. The bricks, being porous, absorb the moisture, which is soon evaporated by the current of warm, dry air passing up the flue.

Vent flues and chimneys should when practicable be carried well above the highest part of the ridge.

The writer recalls a building designed by a well-advertised firm of architects in which the system of heating and ventilation was designed by a heating and ventilating engineer who has frequently been quoted as an expert.

The vent shaft was of large dimensions; in it were the ventilating openings from several rooms, and there were no divisions or withes in the shaft. The top was considerably below the ridge of the building, and was capped with blue-stone flagging. There were two good-sized openings on each side under the cap.

A considerable quantity of steam-pipe was placed in a coil around the sides of the shaft and located just above the floor of the first story of the building. Flap valves were placed over the room outlets to prevent back drafts. When the wind was from a certain direction these flap valves were kept closed by the down drafts, thereby shutting off the ventilation from the schoolrooms.

Complaints of bad ventilation continued to be made. More steam pipes were put in the shaft till about 300 square feet of radiating surface had been put in the shaft.

The complaints continued, and the writer was called by the school authorities to see what was the trouble. The examination was made on a cold day when a strong wind was blowing. The steam was turned on full head in the vent-coil heaters (the boiler pressure being ten pounds by the gauge).

Commencing in the basement at the lowest opening into the vent shaft, the flap valves were found to be closed, and on lifting them and placing an anemometer in front of the opening so made, the air was found to be coming down and into the room at a velocity of over 500 feet per minute and at a temperature of 28 degrees F.

The school authorities were advised to remove the blue-stone cap, brick up the openings in the shaft, and carry it above the ridge; also to remove the flap valves. This was done, although the architects protested that it would injure the architectural appearance of the building. Galvanized iron dampers were placed at the room outlets where the flap valves had been removed, and part of the steam-pipe was taken out of the shaft.

No trouble was afterward found in having a good outflow of foul air from the schoolrooms, and no back drafts were noticed.

Where galvanized iron vent flues are used it is well to cover them with a cap which should project well beyond the sides of the duct. It is essential that sufficient clearance space be allowed between the cap and the top of the vent flue. How frequently we see flues of ample size that have a cap close down to the top of the flue with but little chance for the air to escape.

It should be remembered that the openings on all four sides are not always available, and that only about one-half of the area can be considered as effective, that is, the leeward half, or the part in the direction the wind is going.

Whether the warm-air inlets and foul-air outlets are properly located can be determined by wrapping in a piece of paper dipped in nitrate of potash and then dried, or in a piece of tissue paper, a small tablespoonful of gunpowder, placing it on a piece of sheet metal or board held about two feet in front of the warm-air inlet, setting fire to the paper and watching the circulation and diffusion of the smoke.

A sponge saturated with ammonia and held over a dish of hydrochloric (muriatic) acid will also show the circulation of air, but is not as convenient or desirable as the powder smoke test.

The down or coma of the milkweed or thistle can also be used to show the movement of air currents in a room, but not as fully as the powder smoke test.

The movement of the air currents by the powder smoke test may be best observed by taking a position at the inner angle of the room, so selected that the light from the windows in the outer walls will best enable the observer to see the movement of the smoke.

The action of open windows on the circulation of air in a room will become apparent by using the powder smoke test.

CHAPTER IV.

AIR SUPPLY FOR SCHOOL ROOMS.

THE following tables give the average results of a number of tests of the air supply in schoolrooms made by the Massachusetts inspectors in different parts of the state in buildings of different size and construction, of wood or brick, under different conditions of temperature, wind, weather, humidity and barometric pressure.

These results are not to be considered as what is theoretically required, but such as may be expected in actual practice in schoolhouse ventilation.

The inside temperatures were taken at the breathing plane, at the four corner desks and at the teacher's desk at the same time.

TABLE 3.

AVERAGE RESULTS OF TESTS MADE IN 100 VENTILATED SCHOOLS.

Temperature, Degrees F.			Velocity at Inlet, Feet per Minute.	Net Available Area of Inlet, Square Feet.	Cubic Feet of Air Per Minute Supplied at Inlet.
Outside.	Inside.	At Inlet.			
34.26	69.69	93.78	399.39	4.439	1,772.892

TABLE 4.

AVERAGE RESULTS OF TESTS MADE IN 500 VENTILATED SCHOOLS WHEN OUTSIDE TEMPERATURE WAS BELOW 40° F. (FRACTIONS OMITTED IN THIS CASE.)

Temperature, Degrees F.			Velocity at Inlet, Feet per Minute.	Net Available Area of Inlet, Square Feet.	Cubic Feet of Air per Minute Supplied at Inlet.
Outside.	Inside.	At Inlet.			
25	70	92	377	4	1,508

TABLE 5.

AVERAGE RESULTS OF TESTS MADE IN 500 VENTILATED SCHOOLS.

Temperature, Degrees F.			Velocity at Inlet, Feet per Minute.	Net Available Area of Inlet, Square Feet.	Cubic Feet of Air per Minute Supplied at Inlet.
Outside.	Inside.	At Inlet.			
40.01	70.6	93.3	355.4	4	1,421.6

TABLE 6.

AVERAGE RESULTS OF TESTS IN 1,040 VENTILATED SCHOOLS.

Temperature, Degrees F.			Velocity at Inlet, Feet per Minute.	Net Available Area of Inlet Square Feet.	Cubic Feet of Air per Minute Supplied at Inlet.
Outside.	Inside.	At Inlet.			
37.9	70.2	93.3	369.6	4.13	1,526.488

These tests show the amount and temperature of air supplied at the warm-air inlets, but do not include the additional amount of air brought into the room by leakage through walls, ceilings, floors, or through openings or cracks around doors and windows when the exhaust through the vent shafts was greater than the supply at the warm-air inlets; neither do they take into consideration the air forced out of the room through the same places when the conditions are reversed and the supply at the inlets exceeded the exhaust at the vent openings.

In some cases the air exhausted through the vent ducts was considerably in excess of the supply at the inlets, the difference being made up by *inward* leakage. In other cases it was the reverse, and *outward* leakage accounted for the difference.

These are average tests, and do not include those cases where a *great* difference was found between the amount of air supplied at the warm-air inlet and that extracted at the vent outlet. Sometimes the amount of air is more than double at the outlet the amount at the inlet, or it may be the reverse.

These cases occur in loosely-constructed buildings, or where proper adjustment has not been made of the dampers at the outlets or of the windows admitting air to the cold-air rooms where the indirect radiation is located. They are only mentioned to show the necessity of good construction and proper regulation of the exhaust and supply openings.

From a large number of observations it appears that in order to supply a schoolroom with 1,500 cubic feet of air per minute when the temperature outside is 30 degrees F. we shall have to introduce the air at the warm-air inlet at about 93 degrees F. to keep the room at 70 degrees F., at the breathing plane of the pupils, raising the temperature of the air 63 degrees F. Fifteen hundred cubic feet of air raised 63 degrees equals 94,500 cubic feet raised one degree.

From the average tests of a large number of unventilated schools we find that to keep a schoolroom at 70° F. with the outside temperature at 30° F., supplying 500 cubic feet per minute, we shall have to send the air in at about 180° F. This is an increase of 150 degrees over the outside air.

Five hundred cubic feet raised 150 degrees equals 75,000 cubic feet raised one degree.

Assuming that it costs the same in each case to raise a cubic foot of air one degree in temperature, the increased cost of furnishing 1,500 cubic feet per minute to a schoolroom over the old method of furnishing 500 cubic feet per minute would be about 26 per cent

The cost of heating schoolrooms varies considerably in actual practice, depending upon the construction and location of the building, the system of heating and ventilation installed, and the care and judgment exercised by the janitor.

A fair average allowance of fuel for good ventilation and proper warming may be considered as ten tons of hard coal per schoolroom per year. This includes all the space within the building occupied by corridors, basement and small rooms, in addition to the schoolrooms.

The following shows the cost of heating eight schoolhouses by different methods during the winter of 1893 and 1894, and is given as showing the difference in cost that may occur under different conditions.

TABLE 7.

Building.	Kind of Heat.	Ventilation.	Number of Rooms.	Cost of Fuel per Room.
1	Steam	Combination of supply and exhaust	10	$50.50
2	Steam	Combination of supply and exhaust	16	53.31
3	Steam	Plenum supply, no special exhaust	22	106.00
4	Steam	Plenum supply, no special exhaust	12	108.10
5	Furnace	Combination of supply and exhaust	12	60.75
6	Furnace	Combination of supply and exhaust	8	63.25
7	Steam	No modern ventilation	16	90.82
8	Furnace	No modern ventilation	13	63.53

Warm-Air Ducts or Flues.

The proper location of warm-air inlets for supplying fresh air to schoolrooms is a matter that should be carefully considered by the architect who plans the building and also by the heating and ventilating engineer who designs the system of heating and ventilation. This is also referred to under the head of circulation of air. The size or cross-section of the warm-air duct is another subject for careful consideration, and is determined by the amount of air to be supplied, and should be proportioned to the number of persons who are to occupy the room.

One of the defects in the early attempts at ventilation was the small area of cross-section of the warm-air supply ducts. With the gravity system, when too small ducts were used, it was necessary that the air be heated to a very high temperature in order to give the required velocity to obtain the amount desired.

In a mechanical system, where a fan is used and the ducts are not large enough, the air will be forced into the room at too great a velocity, sometimes causing uncomfortable drafts. The fan will also require additional power in order to force the air through the small ducts at high velocity.

In a gravity system, the warm-air ducts should be of ample area to admit the air in sufficient quantity to meet the requirements of mild weather when it is only warmed to a moderate degree.

Many tests by the Massachusetts inspectors show that the best results are obtained when the warm-air ducts have a cross-sectional area of 24 by 36 inches (six square feet).

Five square feet, 24 by 30 inches, will give fair results, but 24 by 36 inches is to be preferred. This is for an ordinary schoolroom 28 by 32 by 12 feet, accommodating 50 persons.

Class-rooms a little larger or smaller than the above standard, or containing a greater or less number of persons, can have the warm-air ducts proportionally increased or diminished. In small rooms, or in large rooms having but few pupils, or where there is a large exposed wall or glass surface, or where no direct radiation is used, a liberal allowance should be made for the area of the warm-air ducts

The top of the warm-air duct, where it enters the room, should be curved to easily change the direction of the entering air from a perpendicular to a nearly horizontal direction. The interior of brick warm-air and foul-air ducts and flues should be made as smooth as practicable, and rough projections of mortar should not be allowed. Where the expense can be incurred it is advisable to cover the inside walls of warm-air ducts with a light coat of adamant plaster or Portland cement to give a smooth surface and reduce the friction.

Galvanized-iron ducts should be made as tight as practicable.

Ducts constructed of laths and plaster, or of expanded metal and plaster, should not be used, as the leakage of air through them is very great.

The inlet opening into the room should be of larger area than the cross-section of the uptake duct in order to allow for the obstruction of the register face or grill covering the opening, and also to allow for the space at the bottom of the opening where there is little, if any, inflow of warm fresh air.

If a wire grill is used to cover the opening into the room the opening should be at least 30 by 36 inches where the uptake is 24 by 36 inches.

Where cast-iron register faces are used the opening should have an area of from 33 to 50 per cent larger than the uptake, on account of the reduction of the available area and the friction of the register face. Cast-iron register faces are more expensive than wire grills, and, when placed above the floor level, cannot be recommended for covering warm-air inlets or foul-air outlets.

When two or more stories of the same building are to be supplied with warm air from the same source, and where the ducts all lead from one cold-air room, it is well to place the duct for the first story nearest the cold-air supply window. The first story duct, being of less height than the others, will have less lifting power than those to the second and third stories, and, consequently, should be placed where the supply is largest, especially if the cold-air room or duct to the heater is of limited capacity. If the duct leading to the second or third story is placed nearest the source of supply, being higher or longer than the one leading to the first story it will rob that duct of its fair proportion of air.

The opening in the duct where it receives the warm air from the heaters should be but a few inches above, or, better, on the level with the top of the indirect radiators or directly from the hot-air chamber of the furnace.

The opening for receiving the cold air for mixing and reducing the temperature of the warm air should be at the bottom of the duct and of an area equal at least to the cross-sectional area of the uptake duct.

The mixing damper for regulating the temperature should be hung at the bottom of the warm-air opening from the heater, and should incline upward toward the back of the duct. It should be operated from the schoolroom by means of a stout chain and suitable device for holding it in any desired position.

It is advisable in many cases to provide a sliding adjusting damper at the bottom of the opening where the warm air from the heater enters the uptake duct, in order that the supply of air to the different rooms may be properly adjusted.

Theoretically, the warm-air ducts leading to the upper rooms may be of less cross-section than those leading to the first story. In actual practice this is seldom done, and the adjusting damper or slide is used.

When a mechanical system is used and the air to the several rooms is forced by a blower or fan through one or more main supply ducts, and branches are taken off for the different rooms, a switch or adjusting damper should always be provided at the point where the branch leaves the main duct, and suitable means provided for holding the switch damper in any desired position.

The cross-sectional area of each branch and the reduction of area in the main duct as the branches are taken off should be calculated theoretically, making proper allowance for friction, but the switch dampers should never be omitted if proper distribution of air to the several rooms is expected in actual practice.

The writer has never seen entirely satisfactory results obtained under all conditions of wind and temperature where the switch dampers have been omitted, although the sizes of the different branches had been carefully designed according to the best theoretical rules. If a very strong north or northwesterly wind was blowing, the switch dampers could be adjusted to meet the existing conditions; but if the wind was from the south or southeast a different adjustment of the switch dampers would be required.

Where a fan or blower has been used and the ducts had not been designed of suitable size and the air entered the room at too high a velocity, causing uncomfortable drafts, the writer has in some cases to a considerable extent overcome the difficulty by placing inside and against the grill a wire screen made of ordinary iron mosquito netting. Where this is used the grill should be arranged so that it can be easily taken out to clean the screen occasionally.

Although this screen will be an obstruction and require a little more power, yet it is better than to have the uncomfortable drafts.

This mosquito-screen netting should only be used where a mechanical (fan) system is in operation, and should not be used with a gravity system.

Aspirating Chimneys and Vent Flues.

The power of an aspirating chimney or vent flue to remove a given quantity of air from a room depends upon its area or cross-section, its height, the difference between the external and internal temperature, the resistance or friction, and also the admission into the room of a sufficient quantity of air to replace that removed by the aspirating shaft.

The suction caused by a strong wind blowing across the top of the chimney is another important factor, but on account of its uncertainty is seldom taken into account in theoretical calculations.

To increase the velocity of the flow of air through an aspirating chimney or flue we must either increase the height of the chimney or raise the temperature within the flue.

As increasing the height of the chimney has the same effect as increasing the temperature in the flue, we see the advantage of having the chimney as high as practicable. The increased height costs nothing after the chimney is built, while the increase in heat is a constant expense.

In school buildings, for architectural reasons the aspirating chimney should not be too high, consequently we raise the temperature of the air in the chimney by means of heat applied there, or when a mechanical (fan) system of ventilation is used the air is forced out by means of a fan. Air expands about 1/490 of its volume for each degree of increase in its temperature, and, consequently, decreases in weight per cubic foot as its temperature is raised.

The heated column of air in the chimney, being lighter than a column of external air of the same area and height, rises, being forced up by the greater weight of the external air.

To find the *theoretical* velocity in feet per second of air in a ventilating chimney:

Let t = temperature of the external air; t_1 = temperature of the air within the chimney; T = absolute* temperature of the external air; H = height of chimney in feet, and V = velocity in feet per second;

$$\text{Then } V = 8.02\sqrt{\frac{H\,(t_1 - t)}{T}}$$

By multiplying the value of V by 60 we have the *theoretical* velocity in feet per minute.

The theoretical velocity cannot be obtained in actual practice, and a deduction of from 30 to 50 per cent (for roughly built and

* Absolute temperature = 460 degrees below zero.

crooked flues even more) should be made from the theoretical velocity for friction and eddies.

Neglect to make sufficient allowance for friction in ducts and aspirating chimneys has been the cause of partial failure in many an otherwise well-arranged scheme of ventilation.

Care should be taken that an aspirating chimney is not too large or too small.

In the small chimney the friction may be the cause of failure, and in one too large, eddies will contribute to the same result.

By standing in the bottom of an abnormally large aspirating chimney and throwing into the different parts of the chimney thistle-down or coma of the milkweed, the action of the eddies can easily be seen by watching the movement of these light substances.

It is better to provide a separate vent duct from each room than to enter the vents from several rooms into one large aspirating chimney, as the outflow of air from the several rooms can be more easily and equally regulated where separate vent ducts are provided.

The amount of heat required for each flue and the position of the damper can then be regulated to meet the special requirements of each room, especially when there is a strong wind.

At one time a very common method of heating an aspirating chimney or flue was by placing the smoke-pipe from the furnace in the center of the chimney, a cast-iron pipe being sometimes used; occasionally one made of drain-tile. When we consider the low temperature at which the products of combustion should enter such a pipe from a well-designed furnace, and the fact that the smoke-pipe was placed in the most effective and best part of the vent shaft, as well as the large increase in friction, it may well be doubted whether much was gained by this process.

Furthermore, such a pipe was of no use in mild weather, when there was no fire in the furnace or stove. In mild weather more heat is required in the aspirating chimney than when the outside temperature is low.

When several rooms are vented into one common vent shaft there will frequently be an excessive outflow from one room, while it may be deficient from others.

In one large vent shaft there are more likely to be eddies and counter currents than where several smaller vent flues are used. When the ventilation of several rooms into one large shaft is attempted, the location of the steam-pipes or radiators will sometimes be a rather difficult matter in order to obtain uniform and economical results from the different rooms.

When, however, no steam-pipes or radiators are provided in the vent shaft and a stack heater or small stove is installed, as is the case in many school buildings where furnaces are used, the large common vent shaft or aspirating chimney becomes a necessity.

In such cases the ventilation from the lower rooms is through register openings in the floor, and the foul air is taken down to the bottom of the basement and enters the common shaft *below the "stack heater."*

The air taken down from the lower rooms, being heated by the stack heater in the common shaft, rises, forced up by the denser air on the outside.

A damper should always be provided in these ducts leading from the first story rooms to the bottom of the common vent shaft.

If the ventilation from the second story rooms enters directly into the common shaft and a curved damper as a deflector is provided at the vent openings from the second story rooms, the ascending air, in passing the curved damper or deflector, will cause an induced current from the second story rooms into the common vent shaft, on the same principle as that of the steam siphon often used in removing bilge-water from vessels propelled by steam.

Many tests have shown that when this system is used the velocity of the foul air from the second story rooms is greater than from the first story, and sometimes it will be necessary to use the damper to check the outflow from the second story.

The only advantage in taking the foul air from the first story rooms down to the bottom of the common vent shaft is to have the stack heater placed conveniently near the other heating apparatus, and to avoid the dust and dirt which would be caused by placing the stack heater above the vent opening directly from the lower rooms into the common shaft.

If the air in the first story schoolrooms is 70 degrees F., and the air in the common vent shaft has been raised to 85 degrees F. by the stack heater in the lower part of the common shaft, only 15 degrees of heat are available as a motive force in the shaft at the level of the first story floor to overcome the friction and also to cause an outflow of air in the shaft at that level — 70 degrees being required to establish an equilibrium between the down and up ducts at that level. Above this level we have the advantage of the height of the column of warm air between the first and second stories.

The stack heater should *always* be placed *above* the point where the down ducts from the first story enter the common shaft.

When the stack heater is placed below this point a very large waste of fuel takes place, and satisfactory results will not be obtained.

When the stack heater is placed opposite the opening in the shaft where the down duct enters, a considerable quantity of heat is radiated into the down duct and offsets an equal amount of heat in the common shaft.

The air should pass up by and close to the heated surface of the stack heater to produce the best results.

In placing the stack heater in the vent shaft it should be so located that the air for the combustion of the fuel and the draft for the heater are taken from outside the vent shaft.

In some of the earlier attempts at ventilation by using the stack heater in the vent shaft, the heater was placed entirely within the shaft and a manhole door was provided, through which to tend the heater. This arrangement did not give satisfactory results, as the supply of air for the combustion of the fuel was considerably lessened by the suction of the current of air passing up all around the hot surface of the fire-pot and reducing the draft through the grate, in some cases causing the fire in the stack heater to go out before the fuel was consumed.

The practice of bringing a number of vent ducts together in one common chamber in the attic of a schoolhouse, and placing in this chamber a quantity of steam-pipes, is not to be recommended. It is much better and more economical to place the heating surface in the separate ducts and about one foot above the top of the vent opening from the room. In the first case we have only the lifting power of a column of warm air from the level of the steam-pipes in the chamber in the attic to the top of the vent stack, while in the latter case we have the lifting power of the longer column of warm air from the level of the radiating surface just above the opening at the schoolroom floor to the top of the vent stack, or, in other words, it would be a low chimney instead of a high one we depended upon to do the work.

A considerably less amount of heat will be required in the tall chimney than in the short one.

More even removal of foul air from the several rooms will be obtained when using separately heated vent ducts than when the common chamber in the attic is used.

When an exhaust fan is used, it is advisable to bring the separate vent ducts into one common chamber in the attic where the fan is located, and to control the flow of air from the several ducts into the common chamber by a properly arranged adjusting damper in each duct.

Theoretically, we can calculate the amount of air each separate duct should remove, but in actual practice the theoretical results will seldom be obtained, on account of the constantly varying conditions of external temperature and wind; consequently, means for adjusting the outflow from each separate duct must be provided.

In actual practice 20 square feet of steam radiation surface in the vent flue from an ordinary fifty-seat schoolroom (28 x 32 x 12 feet) placed about one foot above the opening from the schoolroom, will give satisfactory results when the flue is straight and well built and when the vent flue has a cross-section of five square feet area (24 x 30 inches). If it becomes necessary for architectural reasons to carry a vent duct nearly horizontally for any considerable distance, either under the floor or over the ceiling, before it enters the perpendicular flue, this amount of radiation may be increased.

Better results are obtained when the steam-pipes or radiators are placed with the lower part at the back of the vent flue and are inclined up and toward the front, than when an equal amount of radiating surface is placed around the sides.

The supply and return steam-pipes for supplying the vent-flue radiation should be placed at the back of the flue. If placed on the front side they will prevent the dampers being properly opened.

Where vent-flue heaters are made of steam-pipes, one-inch or one-and-one-quarter-inch pipes should be used and spaced so that they will cover the whole horizontal distance from one end to the other of the vent duct.

Where cast-iron radiators are used it is better to use radiators which are thin and wide and about 45 inches long (5 square feet per section), and space them with long nipples so that they will be evenly distributed across the full length of the duct. Do not use extended surface radiators in a vent duct, on account of the friction of the air passing over the projecting surfaces.

For the ordinary fifty-seat schoolroom (28 x 32 x 12 feet) a vent flue 24 x 30 inches or 5 square feet, one square foot to each ten persons, has been found to be sufficiently large. A larger flue than this is not required, and in some cases has been found to be detrimental.

The opening should be at the floor level and should be longer than it is high; that is, the length should be 30 inches and the height 24 inches. A curved galvanized-iron damper operated with a chain and catch should be provided in all cases.

The proper location of vent openings is described under the head of "circulation of air."

Chimneys.

In designing a heating and ventilating plant it is of the utmost importance that the chimney should be of suitable size to furnish a good draft, as on the ability to maintain a good fire depends the successful generation of heat.

In many cases an otherwise well-designed plant has proved a failure because the chimney has not been of sufficient size to furnish suitable draft for the boilers or furnaces.

The architect who designs the building, as well as the heating contractor, should see that the chimney is properly designed and located.

The location of the chimney should be carefully considered, care being taken that the top is a sufficient distance above the highest point of the ridge, and that it is not placed in a position where the wind will strike on towers or projections and be deflected down on the top of the chimney in a manner that will destroy the draft, or, as in some cases, cause a reverse draft.

The writer has in a number of cases been called upon to remedy this defect, which would not have occurred had proper precautions been taken when the building was planned.

Under some conditions the action of the wind against a tower or roof has been such as to fill the boiler-room with gas, which, escaping through an open door in the boiler-room, has passed up into the building in a quantity sufficient to make the rooms above anything but comfortable or healthful.

Different writers give different rules for the size of chimneys.

One formula is: Let H = height of chimney, T = temperature of air entering chimney, t = temperature of air at top of chimney, and V = velocity in feet per second. Then $V = 35.5 \sqrt{H\ (T - t)}$

A rule sometimes used is to allow one-eighth the area of the grate surface for area of chimney. This rule does not make any allowance for the varying heights of chimneys and is of doubtful utility.

Another rule is: Multiply the nominal horse-power of the boiler by 112 and divide the product by the square root of the height of the chimney in feet. The quotient will be the required area in square inches at top of chimney.

William J. Baldwin gives as a rule: "Having the cubic feet of air to pass through a building in an hour, and warmed 100° F., and requiring the chimney 100 feet high, divide by 500,000 and the answer is in square feet of cross-sectional area."

Thomas Hawley, late State Inspector of Boilers and Examiner of Engineers, and now principal of the "Hawley School for Engineers," used the following rule, which appears to be a safe one to follow:

"Make a chimney 81 feet high and of an area equal to the collective area of the boiler tube openings. If the chimney is higher than this, reduce the area in proportion as the square root of the height exceeds the square root of 81."

To find area of chimney, multiply the collective area of boiler tube openings by 9 and divide by the square root of height of chimney.

These last two rules are based upon the commercial H.P. and the evaporation of 30 pounds of water per hour. The coal to be burned is figured on this assumption, which is useful in determining whether the chimney is large enough, as in designing a new one, and may be used when either the area or the height is first settled upon arbitrarily, as is often the case when the architect designs a building with the chimney a given height above the ridge.

For larger powers the chimney should be higher than 81 feet, in which case the area can be less than the combined area of the boiler tube openings.

For ordinary schoolhouses two stories high, or two stories with a hall above the second story, where the area of the chimney is equal to the combined area of the boiler tube openings, satisfactory results have been obtained, and this may be considered a safe rule.

A chimney with too large a cross-sectional area may be the cause of poor draft as well as one of too small area.

The height of a chimney is figured from the boiler grate to the top.

The intensity of the draft depends upon the temperature in the flue and the height of the chimney, and the amount of air moved is controlled by the area of the chimney.

The amount of air moved will vary directly with the area of the chimney for a given velocity of flow; but the velocity of flow increases only as the square root of the height.

Doubling the height of a chimney only adds one-half to its draft power.

A square chimney is of no more effective size than a round chimney of equal diameter; that is, it is only equal to the area of a circle inscribed within the square.

The friction of a column of air is figured to take an area from the chimney equal to the area all around two inches from the sides.

This should be considered in designing a small high chimney.

Within the limits of boiler practice the influence of temperature on a chimney draft is very small. It makes but seven per cent difference whether the temperature in the chimney is 300° or 550° F.

The space occupied by a pound of air increases rapidly with an increase of temperature, and as the velocity with which it moves out of the chimney does not increase as fast, the bulk increases faster than the ability of the chimney to handle it; consequently, a temperature is reached at which the amount of air moved cannot be increased by that chimney.

A chimney that tapers at the top has its efficiency decreased.

A cap on the top of a chimney very materially decreases its efficiency.

A chimney flue should be as straight and as smooth on the inside as practicable.

All connections between the chimney and boiler or furnace should be made as straight and short as possible.

In designing a chimney it should be remembered: That the work a chimney will do should be compared upon the pounds of air it will handle.

The space occupied by a certain weight of gas increases directly as the absolute temperature. The absolute temperature is 460° added to the temperature shown by a Fahrenheit thermometer. The absolute temperature of the freezing point is $32 + 460 = 492$.

Increasing the temperature and bulk makes the air in the chimney lighter in weight and increases the difference in the weight of the column inside and a column of equal sectional area outside, and makes a higher column of the lighter air necessary to balance a given column of the colder air.

The difference in height of the two columns gives the air velocity due to this height. The difference in the height of the two columns is the moving force. Multiplying the difference in height of the two columns by 64.4 and extracting the square root will give the velocity.

CHAPTER V.

BOILERS.

A HEAT unit or British thermal unit (B.T.U.) is the amount required to raise the temperature of one pound of water one degree Fahrenheit (from 62° to 63°).

A foot pound is the unit of work done, and is one pound lifted one foot.

A heat unit, B.T.U., is capable of doing 772 foot pounds of work.

Power is the rate at which an agent can do work, and is the product of force, distance and time.

The unit of power is the horse-power (H.P.) and is the doing of 33,000 foot pounds of work in one minute.

The commercial horse-power of a boiler, as adopted by the American Society of Mechanical Engineers, is the evaporation of 30 pounds of water per hour from a feed-water temperature of 100° Fahrenheit into steam at 70 pounds gauge pressure, which may be considered to be equal to 34½ units of evaporation; that is, equal to 34½ pounds of water evaporated from a feed-water temperature of 212° Fahrenheit into steam at the same temperature, and is equal to 33,305 B.T.U. per hour.

Section 83 of Chapter 102 of the Revised Laws of Massachusetts, relative to the licensing of engineers and firemen, is as follows:

"The horse-power of a boiler shall be ascertained upon the basis of three horse-power for each square foot of grate surface, for a power boiler, and on the basis of one and one-half horse-power for each square foot of grate surface, if the boiler is used for heating purposes exclusively. The engine power shall be reckoned upon a basis of a mean effective pressure of forty pounds per square inch of piston for a simple engine; fifty pounds for a condensing engine; and seventy pounds for a compound engine, reckoned upon area of high pressure piston."

A pound of coal when properly burned gives from 13,000 to 14,000 B.T.U. In actual practice, however, only 40 to 50 per cent of this is obtainable as effective in furnaces.

In good mill practice one pound of coal, when well burned, will give from 8,000 to 9,000 B.T.U., and 12 pounds of hard coal burned per hour per square foot of grate surface is considered ordinary practice.

In schoolhouses and public buildings about nine pounds of hard coal burned per hour per foot of grate surface may be considered the maximum, while six pounds is about the average; in some cases it is as low as four pounds.

Different heating and ventilating engineers vary as to the amount of air that can be raised one degree F. by one B.T.U., the amount ranging from 48 to 59 cubic feet. A safe rule, however, is to consider one B.T.U. as capable of raising 50 cubic feet of air one degree F.

In designing a heating and ventilating system for a schoolhouse or public building it is necessary to ascertain how much air is to be supplied for the proper ventilation of the several rooms and corridors; how much heat will be lost from the building by conduction through exposed surfaces, such as walls and windows, in addition to that lost by ventilation, and how much heat will be required to maintain the desired temperature within the building; in a steam plant, how much steam will be condensed to maintain the desired temperature, and how much radiating surface will be needed to condense the required amount of steam;

How much coal will be required to be burned to produce the necessary amount of steam;

How much coal is to be burned per foot of grate surface, and how much heating surface must be provided in the boilers to generate the desired amount of steam.

Having determined the amount of coal to be burned per hour to properly heat the building, the size of the boilers can then be determined.

The size of grate is an important matter. It is seldom advisable to make a grate more than six feet long. When longer, the rear part is liable to be neglected, or the door left open long enough to produce a loss of heat by the large amount of air admitted, and also possibly causing an injury to the fire sheets.

The grate should be equal in width to the diameter of the boiler, and with its area made up as much as possible by width rather than length.

The ratio of grate surface to heating surface usual in different classes of boilers may be considered as follows:

TABLE 8.

Type of Boiler.	Grate Surface.	Heating Surface.
Horizontal tubular, burning soft coal	1	40 to 45
Horizontal tubular, burning hard coal	1	30 to 35
Upright tubular, burning soft coal	1	35
Upright tubular, burning hard coal	1	30
Water-tube, burning soft coal	1	50 to 60
Water-tube, burning hard coal	1	35 to 40
Locomotive, burning soft coal	1	35 to 60

In cast-iron boilers it will vary from 1 to 30 down to 1 to 10, according to the design of the boiler.

In schoolhouse work, with horizontal multitubular boilers burning soft coal, 1 to 35 may be considered safe practice; with hard coal 1 to 30.

The relation that the size of the tube bears to the grate surface, and also the number of tubes, have considerable influence upon the economy of a boiler. With different coals a different tube opening is necessary. On account of the large volume of gases which are generated in burning a pound of soft coal, a larger flue area is needed to carry them off and prevent the draft being choked. With hard coal a less volume of gas is produced and a smaller flue area is required.

The ratio of the grate to the combined area of the tube openings may be fixed as follows:

TABLE 9.

Type of Boiler	Area of Grate.	Area of Tube Opening.
Horizontal tubular, burning soft coal	7	1
Horizontal tubular, burning hard coal	9	1
Upright	7	1

For horizontal tubular boilers up to 48 inches diameter it is advisable to use tubes 2½ inches diameter; from 48 to 60 inches, 3 inch tubes; from 60 to 72 inches, 3½ inch tubes.

When figuring the heating surface of a horizontal tubular boiler the inside area of the tubes should be taken and not the outside, as with a water-tube boiler.

As upright tubular boilers are used in but a small number of school buildings in Massachusetts, their dimensions are not given here.

TABLE 10.

Table of Standard Boiler Tubes for Horizontal Tubular Boilers.

Outside Diameter.	Heating Surface per foot in length.	Area of Tube Opening.
Inches.	Square Feet.	Square Feet.
$1\frac{1}{4}$	.3273	.0067
$1\frac{1}{2}$	.3926	.00964
$1\frac{3}{4}$	.4589	.0133
2	.5236	.0179
$2\frac{1}{4}$	.5890	.0231
$2\frac{1}{2}$	.6545	.0284
$2\frac{3}{4}$	.7200	.0349
3	.7853	.0422
$3\frac{1}{4}$	.8508	.0494
$3\frac{1}{2}$	.9163	.0580
$3\frac{3}{4}$	.9817	.0672
4	1.0472	.0759
$4\frac{1}{2}$	1.1790	.0976
5	1.3680	.1205

That part of the shell of a boiler over the fire is the most effective, and probably three-eighths of the heat enters the boiler there. If the fuel burns with a long flame, passing the whole length of the boiler, the whole lower part of the shell will receive heat by radiation from the flame, but if there is no flame, but only a mass of heated gas, then the shell back of the bridge wall is less efficient, and only receives heat by the contact of the heated gases.

Some boiler makers and engineers add the heating surface of both heads of the boiler. This gives a somewhat larger commercial horse-power; but as the front head of the boiler receives very little heat from the escaping gases, it is safer to omit that head from the calculation. If the rear head is included only the actual heating surface exposed to the hot gases should be taken, and the area of the tube openings should be deducted from the exposed area of the head of the boiler.

To find the heating surface in a horizontal multitubular boiler.

Multiply one-half the circumference of the boiler in feet by the length of the shell in feet, for the heating surface of the shell. If there is an overhang deduct it from the length of the boiler.

To find the area of heating surface of tubes.

Multiply the circumference of the tubes (either inside or outside, according to which is exposed to heat) in inches by length of tube in inches, and reduce the product to square feet by dividing by 144. Multiply the square feet in one tube by the number of tubes for total heating surface of tubes.

Add together the square feet of heating surface in the shell of the boiler and the square feet of heating surface in the tubes for the total heating surface in the boiler.

Divide the total heating surface in the boiler by 15 for the boiler maker's commercial horse-power of the boiler.

To find area of tube surface.

Divide area of grate by 7 or 9, according to whether hard or soft coal is used — 7 for soft and 9 for hard coal.

To find number of tubes.

Divide collective area of tubes by area of sized tube used.

To find amount of heating surface.

Multiply ratio of heating surface to amount of grate surface, by the amount of grate surface.

In designing a boiler, after having found the weight of the water to be evaporated per hour or the amount of steam to be condensed, it will be necessary to find how many pounds of coal this will require to be burned per hour.

In power boilers it may be assumed that one pound of coal will evaporate from 9 to 10 pounds of water. Dividing the amount of water to be evaporated by 9 will give the pounds of coal required to be burned per hour.

Dividing the number of pounds of coal burned per hour by the number of pounds of coal burned per hour per foot of grate surface, which may be assumed as 12, will give the number of square feet of grate surface, and from this the size of the boiler can be determined.

In ordinary low-pressure systems of heating in schoolhouses it is not safe to figure as large a number of pounds of coal burned per hour, or as small a grate surface.

When the plant is poorly managed, as it sometimes is by the ordinary janitor, it is safer to estimate the amount of water evaporated by one pound of coal as not exceeding eight pounds, and the amount of hard coal burned per hour per foot of grate surface as six pounds, or even less. On this basis the grate area would be larger.

The amount of air space in a grate must be considered. If this is too small a stronger draft is required than where it is of sufficient size to allow the passage of a sufficient quantity of air when the fire is packed with ashes or clinkers, as is frequently the case near the close of the school day.

The material generally used for the shells and heads of steam-boilers is the best quality of open-hearth steel, having a tensile strength of not less than 55,000 pounds or more than 60,000 pounds per square inch, and an elongation of not less than 25 per cent, nor more than 30 per cent in a length of 8 inches; fire-box steel being used for shell plates, and flange steel for heads.

The tubes should be of the best American manufacture and the braces and stay-bolts of the best refined iron; rivets of the *best* quality. As far as practicable the man-hole frames should be of pressed steel and the nozzles of cast steel; the lugs, fronts, bonnets, doors and other castings of cast iron adapted to meet the requirements of the particular parts. The edges of shell plates are planed, and the riveted joints for the most part are calked by a pneumatic calking tool.

The circumference seams are lapped and single riveted. For boilers less than 60 inches in diameter the longitudinal seams are lapped and double riveted. Rivet holes are drilled and the riveting done with a hydraulic riveter, except necessary hand-riveting.

The drift-pin should be used as little as possible.

For boilers 60 inches or more in diameter the longitudinal seams are secured by the triple-riveted butt joint, the edges of the plate being brought together end to end, with a covering plate above and below, and riveted through the three sheets.

Where a boiler is designed for power or high pressure it is much better and safer to use the triple-riveted butt joint than to use the lap joint.

In return tubular boilers less than 60 inches in diameter diagonal braces are used, one end of each being riveted to the shell and the other bolted to a tee-bar, which is riveted to the shell, the tee-bars being laid out radially.

When the diameter is 60 inches or over, through bolts are used, running from head to head, with two nuts on each end, one inside and one outside the plate. Where the bolts pass through the plate the head is stiffened by channel-iron bars, one continuous bar being used for each horizontal row of bolts. Sometimes a combination of through bolts and diagonal bracing is used. The heads of the tubes are beaded over at both ends and secured by a roller expander. The holes in the plate for the tubes are drilled, the edges reamed, and the corners chamfered off. Where small pipes are attached to the outside shell the metal is thickened by reinforcing plates secured by rivets.

For main connections of steam-pipes and safety-valve, nozzles are riveted to the shell, the face of the outer flange being turned, and the flange drilled to receive the bolts.

The manhole frames are inside the opening of the shell. The manhole plate and yoke are of steel, and the joint packed with a lead or rubber gasket.

Steam domes are not commonly used on Massachusetts school-house boilers, as with good construction and proper management of the boilers the steam is found to be quite as dry without as with them. Mud drums are only used in exceptional cases.

The boiler maker should furnish with each boiler a cast-iron front having ash pit and fire doors protected by linings, grate bars, bearers for grates, wall binders, ash-cleaning door and frame, arch bars or back plates, cast-iron wall plates and rollers for same, anchor bolts and binder bolts; also a pop safety-valve, a steam-gauge, a water column with glass gauge and gauge cocks and a fusible safety plug; also a full set of fire tools and rack for the same. All boilers should be subjected to a hydrostatic test and examined by a boiler inspector.

In Massachusetts the use of a locked pop safety-valve, set to blow off at fifteen pounds, and of a pattern approved by the Chief of the District Police, will allow a boiler that is used exclusively for heating purposes to be operated without employing a licensed engineer or fireman.

Better service and results will be obtained if a licensed engineer or fireman is employed in addition to having the locked pop safety-valve.

An insurance policy in some standard boiler insurance company for $400 for one year is generally furnished by the boiler maker.

Horizontal multitubular return flue boilers are usually made for diameters from 24 to 36 inches with $\frac{5}{16}$-inch shell and $\frac{3}{8}$-inch heads; for 54-inch diameters $\frac{11}{32}$-inch shell and $\frac{3}{8}$-inch heads. These are for 100 pounds working pressure per square inch.

For 60-inches diameter, boilers generally have $\frac{3}{8}$-inch shell and $\frac{1}{2}$-inch heads, and for 66 to 72-inches diameter $\frac{7}{16}$-inch shell and $\frac{1}{2}$-inch heads, for a working pressure of 125 pounds per square inch.

The following table is from the Hodge Boiler Works, East Boston, Mass.

TABLE 11.

Standard Sizes of Horizontal Return Tubular Boilers.

(Externally Fired.)

Diam. of Shell.	Length of Shell.		Number of Tubes.	Outside Diameter of Tubes	Length of Tubes.	Area through Tubes.	Thickness of Shell.	Thickness of Heads.	Heating Surface.	Rated Horse-Power.	Approximate Weight of Boilers.	Approximate Weight of Castings and Fixtures.	Total Weight.
In.	Ft.	In.		In.	Ft.	Sq. Ft.	In.	In.	Sq. Ft.	H.P.	Lbs.	Lbs.	Lbs.
24	5	8	26	2	5	.43	$\frac{1}{4}$	$\frac{3}{8}$	80	5	1,040	920	1,960
24	6	8	26	2	6	.43	$\frac{1}{4}$	$\frac{3}{8}$	95	6	1,165	920	2,085
24	7	8	26	2	7	.43	$\frac{1}{4}$	$\frac{3}{8}$	110	7	1,290	920	2,210
24	8	8	26	2	8	.43	$\frac{1}{4}$	$\frac{3}{8}$	125	8	1,450	920	2,370
24	9	8	26	2	9	.43	$\frac{1}{4}$	$\frac{3}{8}$	140	9	1,575	920	2,495
30	6	9	36	2	6	.60	$\frac{1}{4}$	$\frac{3}{8}$	129	9	1,550	1,400	2,950
30	7	9	36	2	7	.60	$\frac{1}{4}$	$\frac{3}{8}$	150	10	1,750	1,475	3,225
30	8	9	36	2	8	.60	$\frac{1}{4}$	$\frac{3}{8}$	170	11	1,950	1,475	3,425
30	9	9	36	2	9	.60	$\frac{1}{4}$	$\frac{3}{8}$	191	13	2,100	1,475	3,575
30	10	9	36	2	10	.60	$\frac{1}{4}$	$\frac{3}{8}$	211	14	2,250	1,530	3.780
30	11	9	36	2	11	.60	$\frac{1}{4}$	$\frac{3}{8}$	232	15	2,400	1,630	4,030
30	12	9	36	2	12	.60	$\frac{1}{4}$	$\frac{3}{8}$	252	17	2,600	1,800	4,400
36	8	3	34	2½	7	.94	$\frac{1}{4}$	$\frac{3}{8}$	183	12	2,160	2,025	4,185
36	9	3	34	2½	8	.94	$\frac{1}{4}$	$\frac{3}{8}$	208	14	2,400	2,025	4,425
36	10	3	34	2½	9	.94	$\frac{1}{4}$	$\frac{3}{8}$	233	16	2,550	2.100	4,650
36	11	3	28	3	10	1.15	$\frac{1}{4}$	$\frac{3}{8}$	222	15	2,750	2,250	5,000
36	12	3	28	3	11	1.15	$\frac{1}{4}$	$\frac{3}{8}$	243	16	2,900	2,250	5,150
36	13	3	28	3	12	1.15	$\frac{1}{4}$	$\frac{3}{8}$	264	18	3,200	2,450	5,650
42	10	3	38	3	9	1.57	$\frac{5}{16}$	$\frac{3}{8}$	309	21	3,600	2,500	6,100
42	11	3	38	3	10	1.57	$\frac{5}{16}$	$\frac{3}{8}$	341	23	4,050	2,500	6.550
42	12	3	38	3	11	1.57	$\frac{5}{16}$	$\frac{3}{8}$	374	25	4,260	2,725	6,985
42	13	3	38	3	12	1.57	$\frac{5}{16}$	$\frac{3}{8}$	407	27	4,525	2,725	7,250
42	14	3	38	3	13	1.57	$\frac{5}{16}$	$\frac{3}{8}$	440	29	4,850	2,725	7,575
42	15	3	38	3	14	1.57	$\frac{5}{16}$	$\frac{3}{8}$	473	32	5,200	2,725	7,925
42	16	3	38	3	15	1.57	$\frac{5}{16}$	$\frac{3}{8}$	506	34	5,450	3,000	8,450
48	11	3	49	3	10	2.02	$\frac{5}{16}$	$\frac{3}{8}$	432	29	5,150	3,250	8,400
48	12	3	49	3	11	2.02	$\frac{5}{16}$	$\frac{3}{8}$	474	32	5.550	3,360	8,910
48	13	3	49	3	12	2.02	$\frac{5}{16}$	$\frac{3}{8}$	515	34	6.000	3,360	9,360
48	14	3	49	3	13	2.02	$\frac{5}{16}$	$\frac{3}{8}$	557	37	6,300	3,360	9,660
48	15	3	49	3	14	2.02	$\frac{5}{16}$	$\frac{3}{8}$	599	40	6,600	3,750	10,350
48	15	3	41	3½	14	2.36	$\frac{5}{16}$	$\frac{3}{8}$	593	40	6,750	3,750	10.500
48	16	3	49	3	15	2.02	$\frac{5}{16}$	$\frac{3}{8}$	640	43	7,000	3,900	10,900
48	16	3	41	3½	15	2.36	$\frac{5}{16}$	$\frac{3}{8}$	633	42	7,150	3,900	11,050
48	16	3	30	4	15	2.3	$\frac{5}{16}$	$\frac{3}{8}$	552	37	7,000	3,900	10,900
48	17	3	49	3	16	2.02	$\frac{5}{16}$	$\frac{3}{8}$	682	45	7,400	3,900	11,300
48	17	3	41	3½	16	2.36	$\frac{5}{16}$	$\frac{3}{8}$	668	45	7,500	3,900	11.400
48	17	3	30	4	16	2.3	$\frac{5}{16}$	$\frac{3}{8}$	590	39	7,400	3,900	11,300
54	15	3	60	3	14	2 47	$\frac{11}{32}$	$\frac{3}{8}$	725	48	7.800	4,200	12,000
54	15	3	49	3½	14	2.82	$\frac{11}{32}$	$\frac{3}{8}$	703	47	7,900	4,200	12.100
54	15	3	42	4	14	3.22	$\frac{11}{32}$	$\frac{3}{8}$	696	46	8,250	4,200	12,450
54	16	3	60	3	15	2.47	$\frac{11}{32}$	$\frac{3}{8}$	116	52	8,200	4,400	12,600
54	16	3	49	3½	15	2.82	$\frac{11}{32}$	$\frac{3}{8}$	752	50	8,300	4,400	12,700
54	16	3	42	4	15	3.22	$\frac{11}{32}$	$\frac{3}{8}$	745	50	8,700	4,400	13,100
54	17	3	60	3	16	2.47	$\frac{11}{32}$	$\frac{3}{8}$	826	55	8,650	4,400	13,050

TABLE 11. — *Continued*

Diam. of Shell.	Length of Shell.		Number of Tubes.	Outside Diameter of Tubes.	Length of Tubes.	Area through Tubes.	Thickness of Shell.	Thickness of Heads.	Heating Surface.	Rated Horse-Power.	Approximate Weight of Boilers.	Approximate Weight of Castings and Fixtures.	Total Weight
In.	Ft.	In.		In.	Ft.	Sq. Ft.	In.	In.	Sq. Ft.	H.P.	Lbs.	Lbs.	Lbs.
54	17	3	49	$3\frac{1}{2}$	16	2.82	$\frac{11}{32}$	$\frac{3}{8}$	801	53	8,900	4,400	13,200
54	17	3	42	4	16	3.22	$\frac{11}{32}$	$\frac{3}{8}$	793	53	9,150	4,400	13,550
54	18	3	60	3	17	2.47	$\frac{11}{32}$	$\frac{3}{8}$	876	58	9,100	4,400	13,500
54	18	3	49	$3\frac{1}{2}$	17	2.82	$\frac{11}{32}$	$\frac{3}{8}$	850	57	9,200	4,400	13,600
54	18	3	42	4	17	3.22	$\frac{11}{32}$	$\frac{3}{8}$	841	56	9,600	4,400	14,000
60	15	3	80	3	14	3.3	$\frac{3}{8}$	$\frac{1}{2}$	942	63	10,450	5,150	15,500
60	15	3	64	$3\frac{1}{2}$	14	3 69	$\frac{3}{8}$	$\frac{1}{2}$	898	60	10,650	5,150	15,800
60	15	3	58	4	14	4.45	$\frac{3}{8}$	$\frac{1}{2}$	931	62	11,350	5,150	16,500
60	16	3	80	3	15	3.3	$\frac{3}{8}$	$\frac{1}{2}$	1,008	67	11,050	5,150	16,200
60	16	3	64	$3\frac{1}{2}$	15	3.69	$\frac{3}{8}$	$\frac{1}{2}$	960	64	11,250	5,150	16,400
60	16	3	58	4	15	4.45	$\frac{3}{8}$	$\frac{1}{2}$	996	66	11,950	5,150	17,100
60	17	3	80	3	16	3.3	$\frac{3}{8}$	$\frac{1}{2}$	1,073	72	11,800	5,150	16,950
60	17	3	64	$3\frac{1}{2}$	16	3.69	$\frac{3}{8}$	$\frac{1}{2}$	1,022	68	12,000	5,150	17,150
60	17	3	58	4	16	4.45	$\frac{3}{8}$	$\frac{1}{2}$	1,061	71	12,700	5,150	17,850
60	18	3	80	3	17	3.3	$\frac{3}{8}$	$\frac{1}{2}$	1,139	76	12,560	5,150	17,710
60	18	3	64	$3\frac{1}{2}$	17	3.69	$\frac{3}{8}$	$\frac{1}{2}$	1,085	72	12,780	5,150	17,930
60	18	3	58	4	17	4.45	$\frac{3}{8}$	$\frac{1}{2}$	1,125	75	13,450	5,150	18,600
66	16	4	110	3	15	4.54	$\frac{7}{16}$	$\frac{1}{2}$	1,348	90	14,600	5,400	20,000
66	16	4	79	$3\frac{1}{2}$	15	4.55	$\frac{7}{16}$	$\frac{1}{2}$	1,168	78	14,600	5,400	20,000
66	16	4	62	4	15	4.76	$\frac{7}{16}$	$\frac{1}{2}$	1,073	72	14,600	5,400	20,000
66	17	4	110	3	16	4.54	$\frac{7}{16}$	$\frac{1}{2}$	1,436	96	15,500	5,400	20,900
66	17	4	79	$3\frac{1}{2}$	16	4.55	$\frac{7}{16}$	$\frac{1}{2}$	1,244	83	15,400	5,400	20,800
66	17	4	62	4	16	4.76	$\frac{7}{16}$	$\frac{1}{2}$	1,142	76	15 500	5,400	20,900
66	18	4	110	3	17	4.54	$\frac{7}{16}$	$\frac{1}{2}$	1,524	102	16,300	5,400	21,700
66	18	4	79	$3\frac{1}{2}$	17	4.55	$\frac{7}{16}$	$\frac{1}{2}$	1,320	88	16,200	5,400	20,600
66	18	4	62	4	17	4.76	$\frac{7}{16}$	$\frac{1}{2}$	1,212	81	16,300	5,400	21,700
72	16	4	140	3	15	5.77	$\frac{7}{16}$	$\frac{1}{2}$	1.689	113	16,100	5,650	21,750
72	16	4	92	$3\frac{1}{2}$	15	5.3	$\frac{7}{16}$	$\frac{1}{2}$	1,352	90	16,375	5,650	22,025
72	16	4	76	4	15	5 83	$\frac{7}{16}$	$\frac{1}{2}$	1,296	86	16,270	5,650	21,920
72	17	4	140	3	16	5.77	$\frac{7}{16}$	$\frac{1}{2}$	1,799	120	16,725	5,650	22,375
72	17	4	92	$3\frac{1}{2}$	16	5.3	$\frac{7}{16}$	$\frac{1}{2}$	1,440	96	17,000	5,650	22,650
72	17	4	76	4	16	5.83	$\frac{7}{16}$	$\frac{1}{2}$	1.380	92	16,895	5,650	22,545
72	18	4	140	3	17	5.77	$\frac{7}{16}$	$\frac{1}{2}$	1,909	128	17,450	5,650	23,100
72	18	4	92	$3\frac{1}{2}$	17	5.3	$\frac{7}{16}$	$\frac{1}{2}$	1,528	102	17,725	5,650	23,375
72	18	4	76	4	17	5.83	$\frac{7}{16}$	$\frac{1}{2}$	1,464	98	17,620	5,650	23,270
72	19	4	92	$3\frac{1}{2}$	18	5 3	$\frac{7}{16}$	$\frac{1}{2}$	1,615	108	18,750	5,650	24,400
72	20	4	92	$3\frac{1}{2}$	19	5.3	$\frac{7}{16}$	$\frac{1}{2}$	1,703	103	19,680	5,650	25,330
72	21	4	92	$3\frac{1}{2}$	20	5.3	$\frac{7}{16}$	$\frac{1}{2}$	1.790	119	20,580	5,650	26,234

These horizontal return tubular boilers have the same dimensions, whether they are set with overhanging fronts or flush fronts, and the table may be used indiscriminately for either.

The heating surface given in the table is the area which is directly exposed to the heat of the products of combustion; that is, the exterior surface, in the case of the shell and heads, and the interior surface in the case of the tubes.

The rated horse-power given is based upon 15 square feet of heating surface per horse-power.

With the draft of a good chimney 80 feet high and proper flue connections, the rated capacity can easily be produced under working conditions with good coal, it being understood that a horse-power refers to the evaporation of 34½ pounds of water per hour from and at 212° F. (A.S.M.E. standard).

Beyond the rating stated there is a surplus capacity of at least one-third when the full draft of the chimney is on and the fire is urged.

With high chimneys and the best grade of bituminous coal the boilers can be worked to much higher capacities than those noted in the table.

The thickness of boiler plates within ordinary use makes but little difference in the ability of the plate to conduct heat.

A coating or incrustation on the plates and tubes makes considerable difference in the efficiency and life of a boiler and should be carefully guarded against. This is a matter that is often badly neglected by janitors in school buildings.

The setting of a boiler is a matter to be carefully attended to in order that cracks may not appear and allow air to enter and cool the temperature of the fire and gases in the furnace.

In setting a boiler on marshy or filled ground especial care should be taken to secure a good foundation, and in some cases a thick foundation of good concrete should be put under the whole apparatus to prevent unequal settling and cracking of the walls.

Before a boiler is set the nature of the ground should be carefully investigated.

In setting the fire-brick in a furnace they should be laid with but a small quantity of fire-clay between them, but sufficient to level the work.

TABLE 12.

(*Hodge Boiler Works, East Boston, Mass.*)

DIMENSIONS RELATING TO BRICK SETTING FOR HORIZONTAL RETURN TUBULAR BOILERS; NUMBER OF BRICKS GIVEN BEING APPROXIMATE.

	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Diameter of shell		42		48		54		60		66		72
Length of shell over all	13	3	15	3	16	3	16	3	17	4	17	4
Length of brick setting over all with overhanging fronts	15	3	17	6	18	6	18	6	19	7	19	7
Length of brick setting over all with flush fronts	16	6	18	9	19	9	19	9	20	10	20	10
Width of brick setting for single boiler	7	7	8	1	8	7	9	1	9	7	10	1
Increase in width of setting for each additional boiler in a battery	5	11	6	5	6	11	7	5	7	11	8	5
Length of grate	3	6	4	0	4	6	5	0	5	6	6	0
Width of grate	3	6	4	0	4	6	5	0	5	6	6	0
Vertical distance from floor to shell	3	9	3	9	4	0	4	0	4	0	4	0
Vertical distance from grate to shell at front end		22		22		24		24		24		24
Vertical distance from floor to top of brick work	7	7	8	1	8	10	9	4	9	10	10	4
Number of red brick required for setting single boiler overhanging front		11,923		14,563		16,819		17,977		20,048		21,359
Flush front		12,860		15,568		17,903		19,110		21,245		22,624
Number of fire brick required for a single boiler		765		884		1,059		1,179		1,359		1,526
Number of red brick required for each additional boiler of a battery overhanging front		7,757		9,550		11,022		12,065		13,361		14,323
Flush front		8,335		10,174		11,695		12,773		14,109		15,116
Number of fire brick for each additional boiler of a battery		765		884		1,059		1,179		1,359		1,526
Number of red brick required for each additional length of one foot in the length of a single boiler		703		754		813		850		898		949
Number of red brick required for each additional length of one foot in the length of each additional boiler		434		468		505		531		561		595

NOTE. — When the thickness of the inside walls is 8 inches, instead of 12 inches, to which the above table applies, the number of red brick required for the various sizes of boilers given is as follows:

TABLE 13.

Single boiler, overhanging front.	10,146	12,534	14,429	15,327	17,392	18,585
Single boiler, flush front	10,962	13,412	15,383	16,331	18,458	19,713
Each additional boiler, overhanging front	5,751	7,189	8,315	8,879	10,238	11,084
Each additional boiler, flush front	6,281	7,759	8,925	9,529	10,928	11,814

Smoke Flues for Steam-Boilers.

The smoke flues connecting steam-boilers to the chimney should be constructed of iron; brick ones do not prove satisfactory.

In most smoke-flue work No. 12 tank iron is used unless otherwise specified.

The two kinds generally used are those of circular cross-section and those of a rectangular shape.

The seams of circular flues are lap riveted, and the rectangular ones are joined together at the corners by angle irons, and where the flue is of considerable width it is stiffened by the same means. The short branch flue which connects immediately to the boiler (the uptake in a horizontal boiler) is provided with a damper. The main flue between the last boiler and the chimney is fitted with a regulating damper for controlling the entire battery of boilers. The size of the flue should be equal to the collective area of the tube openings in all the boilers to which it is connected. A clean-out which can be closed air-tight should be provided.

Flues should be as short and straight as practicable, and where a change of direction is made it should be by a curve rather than a sharp or square angle.

Rules for Determining Pressure a Boiler will Sustain:

United States Government Standard.

Divide tensile strength of metal by 6 and multiply by thickness of stock. Divide product by radius of boiler in inches. The quotient is the steam pressure the boiler will sustain.

Massachusetts Inspectors' Rule.

Multiply the thickness of sheet by tensile strength. Multiply this product by 56 per cent if single riveted, or by 70 per cent if double riveted; by 80 or 85 per cent if butt-strap riveted. The quotient is the *bursting* pressure. For *safe* pressure divide bursting pressure by $4\frac{1}{2}$ or 5, according to the condition of the boiler.

Water-tube Boilers.

Water-tube boilers are boilers in which the water is inside the tubes and the heat is applied from the outside, instead of having the water on the outside and the heat inside the tubes, as in horizontal or upright boilers.

This class of boilers is used to a limited extent in schoolhouses in Massachusetts; generally where a mechanical (fan) system of heating and ventilation has been installed, or where the architect has not provided a boiler-room of sufficient size.

They generate steam quickly and can be forced when under the charge of a skilful engineer, and have given good results, especially where a fan is used; but for ordinary small or moderate size schoolhouses the return tubular class is to be preferred.

Upright Tubular Boilers.

Upright tubular boilers have been used in schoolhouses; but to a limited extent and where it has been desired to run an engine at high pressure to drive a fan or blower.

They occupy but little floor space, but in the ordinary schoolhouse basement require that a pit be provided to keep the top of the boiler sufficiently below the ceiling.

It is generally better to use a low-pressure engine having a cylinder of large diameter and short stroke, rather than to install a high-pressure engine driven by steam at high pressure from an upright boiler.

Cast-Iron Sectional Boilers.

Cast-iron sectional boilers have been used to a considerable extent in schoolhouses, but the results obtained are not in the majority of cases as satisfactory as when the return horizontal tubular class are used.

There are many different patterns: good, indifferent and bad. Different manufacturers claim their design to be the best, and to describe them all would be beyond the scope of this book.

In many cases a higher rating for efficiency is given in catalogues than is shown in the actual work performed. If the designer of the heating system in a schoolhouse depends upon the catalogue rating of many of this class of boilers, he will be sadly disappointed in the final test.

A large factor of safety should be allowed for rating many of this class of boilers. In installing them in schoolhouses it is well to obtain from the manufacturer a good and sufficient guarantee that the boiler will do the work required.

Many of this class have a large amount of heating surface and a small amount of water and steam space, and when forced the water is carried into the heating coils or radiators and trouble is caused by low water in the boiler, melting out the fusible plug and cracking sections of the boiler.

The writer has seen many cases where this has occurred and caused the shutting down of the heating apparatus. This has been particularly noticeable in the small cast-iron sectional boilers so generally used for heating the vent shafts and for supplying direct radiation in corridors, teachers' rooms, etc., in school-houses.

Where this class of boilers is used care should be taken to select a boiler of ample size to do the work required, and one that has a proper proportion of heating surface to the water and steam space; also one that does not have a large, flat, unstayed heating surface.

REQUIREMENTS OF BOILER INSPECTION DEPARTMENT OF MASSACHUSETTS DISTRICT POLICE AS TO FITTINGS FOR LOW-PRESSURE HEATING BOILERS.

Upon all steam boilers used for heating purposes, having a grate area of over two square feet, and subject to inspection by this department, the following fittings must be provided, being deemed necessary for safety.

One safety-valve on each boiler with no obstruction between valve and boiler. If pressure carried is to be below 25 pounds, the least area of the safety-valve in inches is to be reckoned by dividing the area of grate in square feet by 2½ if a *pop* valve is used, or by two if a lever, dead-weight, or simple spring valve is used.

One steam gauge on each boiler, connected with syphon or equivalent device between gauge and boiler, to fill gauge spring with water. The supply pipe is to come from steam space of boiler.

Each boiler must have at least two try-clocks, the lower one to be placed 2½ inches above fusible plug or lowest safe water line. Where a glass is also used the lower end of glass must be above the fusible plug or lowest safe water line.

Each boiler must be provided with stop valve on main steam pipe leading from boiler. Each boiler must have check valve and stop valve on main return pipe.

Where a damper regulator is used, the pressure supply pipe must be taken from the steam space of the boiler, with proper water syphon.

SAFETY-VALVES FOR HIGH PRESSURE.

If pressure carried is between 25 and 100 pounds, the area of safety-valve in inches shall equal the area of grate in square feet divided by 3, for lever or dead-weight valves, and by 3½ for pop valves If pressure is above 100 pounds, divide by 5 for pop valves and by 4 for lever or dead-weight valves.

SECTIONS 78 TO 86 INCLUSIVE OF CHAPTER 102 OF THE REVISED LAWS OF MASSACHUSETTS, RELATIVE TO THE LICENSING OF ENGINEERS AND FIREMEN.

As Amended by Chapter 310, Acts of 1905.

Section 78. No person shall have charge of or operate a steam boiler or engine in this Commonwealth, except boilers and engines upon locomotives, motor road vehicles, boilers in private residences, boilers in apartment houses of less than five flats, boilers under the jurisdiction of the United States, boilers used for agricultural purposes exclusively, boilers of less than eight horse power, and boilers used for heating purposes exclusively which are provided with a device approved by the chief of the district police limiting the pressure carried to fifteen pounds to the square inch, unless he holds a license as hereinafter provided. The owner or user of a steam boiler or engine, other than boilers or engines above excepted, shall not operate or cause to be operated a steam boiler or engine for a period of more than one week, unless the person in charge of and operating it is duly licensed.

Section 79. If such steam engine or boiler is found to be in charge of or operated by a person who is not a duly licensed engineer or fireman and, after a lapse of one week from such time, it is again found to be operated by a person who is not duly licensed, it shall be deemed prima facie evidence of a violation of the provisions of the preceding section.

Section 80. The words "have charge" or "in charge," in the two preceding sections, shall designate the person under whose supervision a boiler or engine is operated. The person operating shall be understood to mean any and all persons who are actually engaged in generating steam in a power boiler.

Section 81. Whoever desires to act as engineer or fireman shall apply for a license therefor to the examiner of engineers for the city or town in which he resides or is employed, upon blanks to be furnished by the examiner. The application shall be accompanied by a fee of one dollar and shall show his total experience. Wilful falsification in the matter of statements contained in the application shall be deemed sufficient cause for the revocation of said license at any time. The applicant shall be given a practical examination and, if found competent and trustworthy, he shall receive, within six days after the examination, a license graded according to the merits of his examination, irrespective of the grade of license for which he applies. The applicant shall have the privilege of having one person present during his examination, who shall take no part in the same, but who may take notes if he so desires. No person shall be entitled to receive more than one examination within ninety days, except in the case of an appeal as hereinafter provided. A license shall continue in force for three years, or until it is revoked for the incompetence or untrustworthiness of the licensee; and a license shall remain revoked until a new license is granted. A license, unless revoked, shall be renewed by an examiner of engineers upon application and without examination, if the application for renewal is made within six months after its expiration. If a new license of a different grade is issued, the old license shall be destroyed in the presence of the examiner. If a license is lost by fire or other means, a new license shall be issued in its place, without re-examination of the licensee, upon satisfactory proof of such loss to an examiner.

SECTION 82. Licenses shall be granted according to the competence of the applicant, and shall be distributed in the following classes: Engineers' licenses: — First class, to have charge of and operate any steam plant. Second class, to have charge of and operate a boiler or boilers, and to have charge of and operate engines, no one of which shall exceed one hundred and fifty horse power, or to operate a first-class plant under the engineer in direct charge of the plant. Third class, to have charge of and operate a boiler or boilers not exceeding in the aggregate one hundred and fifty horse-power, and an engine not exceeding fifty horse-power, or to operate a second-class plant under the engineer in direct charge of the plant Fourth class, to have charge of and operate hoisting and portable engines and boilers. Firemen's licenses: — Extra first class, to have charge of and operate any boiler or boilers. First class, to operate any boiler or boilers. Second class, to have charge of and operate any boiler or boilers where the pressure carried does not exceed twenty-five pounds to the square inch, or to operate high pressure boilers under the engineer or fireman in direct charge thereof. A person holding an extra-first or first-class fireman's license may operate a third-class plant under the engineer in direct charge of the plant A person who desires to have charge of or to operate a particular steam plant or type of plant may, if he files with his application a written request signed by the owner or user of said plant for such examination, be examined as to his competence for such service and no other, and if found competent and trustworthy shall be granted a license for such service and no other.

SECTION 83. The horse-power of a boiler shall be ascertained upon the basis of three horse-power for each square foot of grate surface, for a power boiler, and on the basis of one and one-half horse-power for each square foot of grate surface, if the boiler is used for heating purposes exclusively. The engine power shall be reckoned upon a basis of a mean effective pressure of forty pounds per square inch of piston for a simple engine; fifty pounds for a condensing engine; and seventy pounds for a compound engine, reckoned upon area of high-pressure piston.

SECTION 84. A person who is aggrieved with the action of an examiner in refusing or revoking a license may, within one month after his decision, appeal therefrom to the remaining examiners, who shall together act as a board of appeal, and a majority of whom shall have the power to hear the parties and pass upon the subjects of appeal. The applicant may have the privilege of having one first-class engineer present during the hearing of his appeal, but he shall take no part therein. The decision of the majority of such remaining examiners so acting shall be final if approved by the chief of the district police.

SECTION 85. An engineer's or fireman's license, granted under the provisions of the seven preceding sections or the corresponding provisions of earlier laws, shall be placed so as to be easily read in a conspicuous place in the engine room or boiler room of the plant operated by the holder of such license.

SECTION 86. The boiler inspection department of the district police shall act as examiners and enforce the provisions of the eight preceding sections and whoever violates any of the provisions of said sections shall be punished by a fine of not less than ten nor more than three hundred dollars or by imprisonment for not more than three months. A trial justice shall have jurisdiction of complaints for violations of the provisions of the eight preceding sections, and in such cases, may impose a fine of not more than fifty dollars. All members of the boiler inspection department of the district police shall have authority in the pursuance of their duty to enter any premises on which a boiler or engine is situated, and any person who hinders or prevents or attempts to prevent any state boiler inspector from so entering shall be liable to the penalty as specified in this section.

[Chap. 310, Acts of 1905.]

* * * * * * * * *

Section 4. All acts and parts of acts inconsistent herewith are hereby repealed: *provided, however,* that this act shall not apply to the exemptions specified in section seventy-eight of chapter one hundred and two of the Revised Laws or that such repeal shall not invalidate any license granted under the acts repealed; and licensees holding licenses so granted shall have the powers given to licensees of the same class by section two of this act.

Section 5. This act shall take effect on the first day of July in the year nineteen hundred and five. [*Approved April 20, 1905.*]

[Amendment of 1905.]

[Chap. 472, Acts of 1905.]

An Act relative to the inspection of steam boilers.

Be it enacted, etc., as follows:

Section 1. All steam boilers of more than three horse power, except boilers upon locomotives, in private residences, or under the jurisdiction of the United States, or boilers used exclusively for agricultural, horticultural or creamery purposes, shall be inspected either by the district police or by an insurance company authorized to insure boilers within the Commonwealth. Such inspection shall be made internally and externally at least once in each year. The owner or user of any steam boiler inspected by the district police shall pay to the inspector the sum of five dollars at each internal, and two dollars for each external, inspection for every boiler so inspected.

Section 2. Every insurance company shall forward to the chief of the district police within fourteen days after each internal and external inspection a report of every boiler so inspected by it. Such reports shall be made on blanks furnished by the chief of the district police, and shall contain any recommendations that the insurance company may think it desirable to make. Notice shall be given by the insurance company or the inspector to the owner or user of the boiler inspected of the pressure at which the boiler may safely be operated.

Section 3. Any insurance company failing to make a report as above provided shall be fined not more than five hundred dollars for every such failure. Any owner failing to comply with the requirements of the insurance company inspecting his boiler, after notice by the chief of the district police, shall be liable to a fine of not more than five hundred dollars for such failure, and the use of said boiler may be enjoined in the manner provided in section four of chapter one hundred and five of the Revised Laws. The district police shall have authority in the discharge of their duty to enter upon any premises where steam boilers are located, for the purpose of enforcing the provisions of this act

SECTION 4. All acts and parts of acts inconsistent herewith are hereby repealed. [*Approved May 26, 1905.*]

REVISED LAWS OF MASSACHUSETTS.

CHAPTER 105.

Of the Inspection of Steam Boilers.

SECTION 1. The chief of the district police shall detail ten members of the inspection department of the district police, who, under his direction, shall inspect stationary steam boilers and their appurtenances, shall act as examiners of engineers and firemen and shall report to said chief.

SECTION 2. Whoever owns or uses or causes to be used a steam boiler, except boilers upon locomotives, in private residences, under the jurisdiction of the United States or under the periodically guaranteed inspection of companies which have complied with the laws of this Commonwealth, boilers used exclusively for agricultural, horticultural and creamery purposes or boilers of less than three horse power, shall annually report to the chief of the district police the location of such steam boiler.

SECTION 3. Each boiler designated in the preceding section and not therein excepted shall be inspected by the inspector of boilers for the district in which said boiler is located, and if he so orders the owner or user shall have the boiler blown off dry and the man-hole and hand-hole covers thereon removed, ready for inspection, upon the day designated by the inspector, who shall give the owner or user of said boiler fourteen days notice in writing of the day upon which he will make such internal inspection, which shall not be required oftener than twice a year

SECTION 4. If, upon examination, said inspector finds the boiler to be worthy and in safe working order, with the fittings necessary to safety, and properly set up, he shall grant to the owner or user thereof a certificate of inspection, and thereupon said owner or user may use the boiler mentioned in the certificate. If the inspector finds that the boiler is not in safe condition, or is not provided with fittings necessary to safety or with fittings not properly arranged, he shall withhold his certificate until the boiler and fittings are put into condition satisfactory to him; and the owner or user shall not operate such steam boiler or cause it to be operated until such certificate has been granted. The owner or user of such boiler shall pay to the inspector at each inspection two dollars for each boiler inspected. The supreme judicial court or the superior court, upon the application of the inspector of boilers approved by the chief of the district police, shall have jurisdiction in equity to restrain the owner or user of such boiler from operating it without certificate.

SECTION 5. If the inspector finds that the owner or user of a steam boiler is putting too much pressure upon it, he may fix the maximum pressure to be carried by it and shall prescribe a device to prevent it from carrying more than the maximum pressure designated, which shall be approved by the chief of the district police and which the owner or user shall place or cause to be placed upon said boiler. No person shall in any manner tamper with such device, or load the safety-valve to a greater pressure than that allowed by the inspector.

Section 6. Whoever violates the provisions of the preceding sections of this chapter shall be punished by a fine of not more than five hundred dollars or by imprisonment for not more than six months, or by both such fine and imprisonment.

Section 7. The mayor and aldermen of any city except Boston, or the selectmen of a town, or any person by them authorized, may, after notice to the parties interested, examine any steam engine or steam boiler therein, whether fixed or portable; and for that purpose may enter any house, shop or building; and if upon such examination it appears probable that the use of such engine or boiler is unsafe, they may issue a temporary order to suspend such use; and if, after giving the parties interested, so far as known, an opportunity to be heard, they adjudge such engine or boiler to be unsafe or defective or unfit to be used, they may pass a permanent order prohibiting the use thereof until it is rendered safe. If, after notice to the owner or person having charge thereof, such engine or boiler is used contrary to either of such orders, it shall be deemed a common nuisance, without any other proof thereof than its use.

Section 8. The mayor and aldermen and selectmen may abate and remove a steam engine or steam boiler which has been erected or used contrary to the provisions of the preceding section in the same manner as boards of health may remove nuisances under the provisions of sections sixty-seven, sixty-eight and sixty-nine of chapter seventy-five.

Section 9. No person shall manufacture, set up or use a steam boiler or cause it to be used unless it is provided with a fusible safety plug, made of lead or some other equally fusible material and of a diameter of not less than one-half an inch, placed in the roof of the fire box, if a fire box is used, and in all cases, in a part of the boiler fully exposed to the action of the fire, and as near the top of the water line as any part of the fire surface of the boiler.

Section 10. Whoever, without just and proper cause, removes the safety plug from a boiler or substitutes therefor any material more capable of resisting the action of the fire than the plug so removed shall be punished by a fine of not more than one thousand dollars.

Section 11. Whoever manufactures, sets up or knowingly uses or causes to be used for six consecutive days a steam boiler, unprovided with a safety fusible plug as described in section nine, shall be punished by a fine of not more than one thousand dollars.

Section 12. The provisions of the five preceding sections shall not apply to a boiler for which a certificate of inspection issued under the provisions of sections four and five is in force

CHAPTER VI.

STEAM-PIPES

THE success of a steam-heating apparatus will to a considerable extent depend upon the proper size, location, grading, dripping and valving of the steam-pipes.

In the earlier installment of gravity systems of steam-heating in schoolhouses trouble was often caused by the use of too small pipes, both for supply and return. At the present time larger pipes are used and much better results are obtained.

In piping indirect radiators the following may be considered a safe rule for size of supply and return pipes when a gravity system is used and steam supplied at low pressure, five pounds or less.

TABLE 14.

Square Feet of Indirect Radiators.	Supply. In Inches.	Return. In Inches.
30 or less	1	$\frac{3}{4}$
30 to 50	$1\frac{1}{4}$	1
50 to 100	$1\frac{1}{2}$	$1\frac{1}{4}$
100 to 160	2	$1\frac{1}{2}$

It is not advisable to make indirect radiator stacks with more than 160 square feet of radiating surface, and 140 is to be preferred to 160 if good circulation is expected. Three-quarter-inch pipe is the smallest that should be used for return, even from very small radiators. For indirect steam-heating the supply pipes should have double the area in cross section of those supplying direct radiators.

For direct radiation steam mains and risers the rule adopted by many heating contractors is $\frac{1}{10}$ the square root of the heating surface in square feet for the diameter of the supply pipes in inches; or, square the diameter of the pipe in inches for the number of hundred feet of direct radiation it will supply.

By using pipe one size larger than that called for by these rules better results will be obtained. Another rule is to divide the amount of direct heating surface in square feet by 100, divide the quotient by .7854, then extract the square root of the quotient ; the result will be the diameter of the pipe in inches.

As a general rule, return pipes should be one size smaller than the supply pipes, but with large supply mains this may be considerably reduced.

By using large and well-covered pipes satisfactory results will be obtained. Too frequently, in order to reduce the cost, pipes of too small diameter are used, especially for indirect steam heating.

The supply pipes in the basement of a schoolhouse should be well covered with a neat non-heat-conducting covering, and although the first cost will be increased, yet the results therefrom will fully compensate for the additional expense.

Care should be taken that the steam-pipes are properly pitched, dripped and valved in order to secure free and noiseless circulation and return ; that they are properly supported on roller pipe hangers and proper allowance made for expansion and contraction.

The main return pipes should be provided with proper check valves and shut-offs. Valves for controlling vent-flue heating should be placed in the basement. Every radiator, heating coil or stack should be fitted with a supply valve, return valve and automatic air valve properly located. Gate or angle valves are to be preferred to globe valves. Overhead pipes for heating the basement should be properly valved, pitched and of such form as to provide for expansion and contraction, and hung from the floor timbers of the first story with securely fastened roller pipe hangers about every eight feet.

Where circulation pipes are placed on the walls the pipes should be well straightened and secured to the wall by hook and expansion plates, fastened to wooden strips placed not more than ten feet apart, and ample provision made for expansion and contraction.

Rising main and return pipes should be straight and parallel, properly valved and dripped, and where pipes pass through floors they should be incased through the full depth of flooring and ceiling in tin tubes with *flanged* iron plates screwed to the floor, and with iron ring plates or flanges securely fastened to the ceiling. Where pipes pass through wooden partitions tin sleeves and flanged plates should be used and if through brick walls, metal collars should be provided. Where practicable, return pipes should be laid in a properly-graded brick trench having a covering of cast-iron plates or bluestone flagging.

Where several vertical return pipes enter the main return they should in all cases be carried well below the water-line in the boiler before they unite into one pipe.

By proper arrangement of pipes and radiators in a low-pressure gravity return system the condensation may be easily and noiselessly returned to the boiler without the use of traps or pumps.

For piping connections it is advisable to use eccentric fittings.

A two-pipe, low-pressure, gravity return system of steam-heating is to be preferred for schoolhouses of small or moderate size. In large buildings a double mechanical system (one having a fan supply and fan exhaust), or a combination of fan (or plenum) supply and gravity exhaust, is to be preferred.

Where a mechanical system is used, the exhaust from the engine should also be used for heating. A mechanical system will require the use of fans, engine, pumps or traps, governor, tanks, steam separator, reducing valves, exhaust head, vapor pipe, etc.

A blow-off tank, properly connected with a dry well or sewer and properly trapped, should be provided in all cases where practicable. A valve or cock should be provided at the lowest place in the system to draw off the water when desired.

Radiators.

In the earlier attempts to ventilate school buildings by indirect radiation many failures occurred on account of an insufficient amount of radiation and improperly locating and casing it; not allowing sufficient space between the sections for a liberal quantity of air to pass, too small steam supply and return pipes, and not providing adequate means for regulating the temperature of air passing the radiators.

It has been found in actual practice (and the schoolrooms in Massachusetts are now generally heated accordingly) that to secure the best results under varying conditions of temperature and wind 400 square feet of cast-iron radiating surface should be supplied for an ordinary schoolroom 28 by 32 by 12 feet, if situated where there are two cold exposed walls and where ample window space to give good light is provided.

This should be divided into three stacks, one of 100, one of 140 and one of 160 square feet; or one of 120 and two of 140 square feet each, each stack to be separately piped and valved, in order that one, two or three sections may be used as needed, according to the outside temperature. The 100 feet section should be placed nearest the uptake warm-air flue.

Where there is but one exposed wall, and on the southerly side, 380 square feet may be used and divided into three stacks, one of 100 and two of 140 square feet each.

Cast-iron radiators having an extended surface, and with not less than one-half-inch space between the ends of the pins or ribs of the several sections, are now generally used in Massachusetts school-houses.

While coils or radiators made of steam-pipes are the most efficient radiating surfaces, yet, on account of the cost and the facility of constructing the indirect radiator stacks, cast-iron is now generally used with gravity systems.

It is better to use a deep radiator than to double bank or place one section above another. Cast-iron extended surface radiators having 20 square feet of radiating surface per section give very satisfactory results.

The sections are 36 inches long, 15½ inches high, and connected four inches from center to center of the sections, tapped for two-inch supply and return pipes, and have right and left nipple connections. The air-valve measures $\frac{3}{8}$ of an inch.

When more than one school-room receives its warm air through radiators in the same cold-air room the radiator stacks for each room should be separated by galvanized-iron divisions extending about 20 inches below the bottom of the stacks. Where this is not done, and two or more rooms receive air from the same cold-air room, the results are very unsatisfactory, as one room may receive much more than its fair proportion of heat and air at the expense of another. The galvanized-iron casings for indirect radiators should be made on number 20 or 22 gauge iron, and be well stiffened at the edges and corners.

When rooms in different stories of the building receive their air supply from the same cold-air room the radiators for the first story should be placed nearest the cold-air window, in order that they may have an advantage in receiving air in preference to the rooms in the second or third stories.

The supply and return pipes for the indirect radiators should be well protected in all cases where they come inside the cold-air rooms with first-class pipe covering.

The valves should always be placed outside the cold-air rooms.

The air-valves give better results when placed in the quarter turn or elbow where the return changes to a downward direction than when placed in the radiator itself, as is usually done where direct radiators are used.

The bottom of the radiators should not be cased, but left entirely open, as much more even distribution of air is obtained.

In the earlier indirect radiator work it was customary to inclose the radiators on all sides and bring the air in at one end of the bottom of the casing, taking it out at the top of the opposite end. This does not give as good results, or utilize the whole of the radiator surface, as well as when the bottom is left entirely open and a cold-air room is provided. Under some conditions, when the first method is used, there is a reversed or back draft, and the writer has frequently found warm air going out of the building through what was intended to be the cold-air supply opening.

There are many patterns of direct radiators in use, each of which is claimed by the manufacturer to have various good points. Better results are obtained when a tall radiator is used than when the stack is made long and low.

In Part II. is shown a direct-indirect radiator, designed by the late John T. White, which has been successfully used where a full supply of air is not required by indirect radiators. It is cased and inclosed in a manner that insures a better utilization of heat than is possible with the common style of direct-indirect radiators.

In many schoolhouses lines of 1¼-inch steam-pipe are placed on the outside walls of the rooms, and are used at night and before the school session opens to quickly warm the rooms. In rooms occupied but a part of the time, such as assembly halls and laboratories, etc., this is a good provision and saves fuel, but they should not be used in schoolrooms while schools are in session.

Direct radiators are often used to good advantage in schoolhouse corridors and in teachers' rooms.

In basement rooms the heating should be by overhead lines of 1¼ inch pipe, unless a room is used as a manual training room or for a similar purpose, in which case a moderate supply of air from indirect radiators can be introduced near the ceiling.

In using wall or ceiling pipes special attention should be given to properly provide for expansion and contraction.

There should be at least two feet distance between the bottom of the radiators and the water-line in the boiler to secure a good return of the condensation from the radiators. If a greater distance can be had it will be better, and danger of filling the radiators with water will in a great measure be prevented. The writer has seen cases where an otherwise well-designed system of heating has been spoiled by not allowing sufficient distance between the bottom of the radiators and the water-line in the boiler.

A method is shown in Part II. of arranging radiators to be used as foot-warmers and for warming the corridors. These stacks are usually made up of 120 square feet of cast-iron extended surface radiators, cased in galvanized iron and hung from the basement ceiling.

Very satisfactory results are obtained when two lines of $1\frac{1}{4}$ inch steam-pipe are placed near the floor in the corridor and under the clothing racks.

An Approximate Rule for Estimating the Amount of Indirect Radiation

For a fifty-seat schoolroom of the ordinary size (28 by 32 by 12 feet) with a gravity system of heating and ventilation, using a good indirect radiator with ample flues, etc., and natural draft, is as follows:

50 (number of pupils) × 30 (cubic feet of air per pupil per minute) = 1500 (cubic feet of air per minute).

1500 (cubic feet per minute) × 60 (minutes per hour) = 90,000 cubic feet of air supplied per hour.

Air at zero to be warmed 105 degrees F. 90,000 (cubic feet) × 105 (degrees) = 9,450,000 cubic feet of air warmed one degree. 9,450,000 (cubic feet) ÷ 50 (cubic feet warmed one degree by one heat unit) = 189,000 heat units. 189,000 (heat units) ÷ 1,000 (heat units available per pound of steam) = 189 pounds of steam condensed to water. 189 × 2 = 378 square feet of radiation. In actual practice from 380 to 400 square feet of cast-iron indirect radiation is used per room. This allowance is made on account of overrating the square feet of surface in radiators by the manufacturers, for air leakage in rooms and to meet the requirements in exceedingly cold weather.

While this may not be an approved scientific method of calculating indirect radiation, and may by some be called a "rule of thumb," yet *in actual practice it has given excellent results* and may be considered as safe as some more scientific and theoretical formulas.

Automatic Heat Control.

Systems of automatic heat control have been installed in a considerable number of schoolhouses, especially in large buildings, and if they can give the results claimed for them they will be of great service. Unfortunately, in many cases they have not proved satisfactory, and in a short time complaints were made that the expected results had not been obtained.

The first attempts to automatically control mixing dampers were generally complete failures. A device that opens wide or closes tight the mixing damper changes the temperature from all warm to all cold air, and uncomfortable drafts are the result.

The writer has seen cases where the temperature of the incoming air was changed from over 100 degrees F. to less than 30 degrees F. in less than four minutes when the mixing damper was automatically operated. When the damper was again moved the temperature would rise to the high point in but little over five minutes. This was especially noticed when a strong wind was blowing into the cold-air room. When the mixing damper is moved to entirely shut off the warm air, except what little leaks through the narrow spaces on the sides and top of the mixing damper, the radiators, if steam is used, soon become cold, and the cold air from outside passes up directly into the schoolroom. With furnaces the results are not any more satisfactory.

When the mixing damper is moved slowly by the automatic control, but is opened wide or fully closed, the results are not satisfactory.

The managers and agents of some automatic heat-controlling systems frequently guarantee that the mixing-dampers or the valves controlling the heat supply steam-pipes will be operated by one degree or less change of temperature, as indicated by the thermometer attached to the thermostat. While this is true in many cases, yet it does not give satisfactory results at all times. When the cold air is admitted by the mixing-damper, or the steam-valves to the indirect radiators are shut, the radiators are soon cooled and uncomfortable drafts are felt, and as the thermostats are often placed where they are not easily and quickly acted on by the incoming air, the drafts continue. After the steam has been again turned on by opening the valves, time is required for the radiators to again become warm enough to give off sufficient heat to properly warm the incoming air, the cold drafts will continue until the incoming air has changed the temperature at the thermostat enough to operate the valve or damper-controlling device. This is often several minutes after the valves have been opened.

Most of the automatic heat-controlling devices are of delicate construction, and the writer has seen cases where an accumulation of lint or fine fibers has caused the apparatus to become inoperative.

Where automatic control has been used on direct radiators, or where a combination of automatic and hand-control has been used on the valves of different sections of the indirect radiators, more satisfactory results have been obtained than when used on mixing-dampers.

By dividing the amount of indirect radiation for a school-room into three sections and using hand valves on two, and automatic on one section, better results are obtained than where the automatic is used on all three sections.

Automatic control is sometimes used on the supplementary radiation in mechanical systems where fans or blowers are used. If it is to be used in a mechanical system the results will be better if the primary coils or stacks are provided with all or nearly all hand-controlled valves, and the automatic used on the supplementary coils or stacks or direct radiators or wall coils, if such are provided.

When used on hot-water radiators the change of temperature is not as rapid as with steam radiators.

CHAPTER VII.

FURNACES.

THE use of furnaces for heating and ventilating school buildings should be confined to small buildings not exceeding eight rooms.

In large buildings the number of furnaces required will occupy so much of the basement and there will be so many fires to attend to that a steam-heating apparatus can be more advantageously installed.

When furnaces are used in school buildings or places of assemblage they should be located where the warm-air flues or ducts will be as nearly perpendicular as possible. Long and nearly horizontal runs of pipe should be avoided.

It is advisable that schoolhouse furnaces should be of heavy castings having as few joints as possible. There are several makes of furnaces specially designed for schoolhouse heating and of extra large size.

A cast-iron furnace having a fire-pot of 34 to 35 inches diameter should be provided for two school-rooms of the ordinary size (28 by 32 by 12 feet).

Attempts to use smaller furnaces or to heat more than two ordinary size school-rooms from one furnace have resulted in failures to give the required amount of heat, and now it is seldom that a contractor intending to do good work will attempt to heat and ventilate more than two schoolrooms with one furnace, even if the furnace is of the largest kind manufactured.

In selecting a furnace, one with a nearly straight-sided fire-pot is to be preferred to one that has sloping or tapering sides. In the latter case the accumulation of ashes at the side of the fire-pot retards the passage of heat, and the fire is not as easily cleaned as when the sides are nearly perpendicular.

Furnaces provided with triangular revolving grates are to be preferred to those having oscillating ones, as the triangular grates will cut the ashes and clinkers and remove them more effectually than will other patterns of grates.

Wrought-iron or steel-plate furnaces with fire-brick lining have not given as satisfactory results as those of cast-iron which have a good thickness of metal.

It is claimed for wrought-iron furnaces that they do not allow gas to escape through the metal, and that it will through highly-heated cast-iron.

While it is true that under some conditions gas will to a limited extent escape through highly-heated cast-iron, yet with an ample supply of air passing to the school-rooms and a large furnace of heavy castings, not overheated, the amount of gas escaping will be so very small that it may be practically disregarded.

The escape of gas through heated cast-iron is more a matter of advertising the special advantages claimed for some furnaces than of real danger to the occupants of a school-room.

It is essential, however, that there be as few pieces as practicable, and that the joints be made as tight as possible.

By proper attention to the draft and check dampers the amount of escaping gas can be reduced to a point at which no ill effects can be observed.

If it is suspected that gas is escaping from the combustion chamber into the warm-air supply for the room, an old rubber or a leather shoe may be thrown into the fire, and when the shoe is well ablaze, all the dampers and drafts being closed, it will soon be determined whether or not gas is passing into the room. The odor of the old shoe will be noticeable at the warm-air inlet if any considerable amount of gas is coming in.

Several designs of cast-iron furnaces made of vertical sections with extended surfaces, and held together with bolts through flanges of the sections, have been used in school buildings; but they are not a desirable type, as there are too many joints, some of which may warp and open up a passage for the unconsumed products of combustion to pass through and mingle with the air supply for the schoolrooms. This class of furnace is now seldom installed in Massachusetts schoolhouses.

The writer has seen a number of these furnaces, which by excessive firing by the janitors have so warped at the flanges and where the bolts have so rusted or been destroyed by heat, that openings, sometimes one-half inch or more wide, have been made through which the unconsumed products of combustion have passed in a sufficient quantity to badly contaminate the air in the school-rooms.

Some cast-iron furnaces also have a radiator attachment of thin sheet-iron or steel which in a few years will become corroded sufficiently to open large holes for the escape of gas. Where these radiator attachments are used the sheet metal should be of sufficient thickness to last as long as the cast-iron fire-pot.

In installing a furnace for schoolhouse heating special attention should be given to having sufficient space between the heating surface and the casing to allow the passage of a large quantity of air at a moderate temperature, rather than to heat a small quantity to a high temperature.

It is advisable to use brick-set furnaces in schoolhouses instead of the metal-cased portable type generally used for dwelling-house heating, which usually have an insufficient space between the casing and the fire-pot. When the portable type of furnace is used in schoolhouses a special and large casing should be provided.

Smoke-pipes for furnaces should be of ample size and as short as possible to reach the chimney smoke-flue, having as few turns or elbows as practicable, and fitted with one or more dampers to regulate the draft.

When soft coal is burned, the ordinary size schoolhouse-furnace smoke-pipe should be at least one inch larger diameter than when hard coal is used.

Where it becomes necessary to take the smoke from two furnaces into one chimney flue, which is not a desirable arrangement, the pipes should be united by a breeches connection into one large pipe before it enters the chimney, and each furnace smoke-pipe should have its own damper.

A pit should be provided under the furnace which should be at least two feet deep and equal in width to the diameter of the furnace casing. This will allow the air to circulate around the fire-pot and will more effectively distribute it against the heated surface of the fire-pot. When, as has frequently been the case, the air is admitted through an opening in one side of the furnace casing and nearly opposite the fire-pot, the results are not satisfactory, and but part of the heated surface is utilized in the most effective manner.

The air for mixing with the air from the furnaces for regulating the temperature of the school-room should never pass under the furnace, but should be entirely outside the space between the fire-pot and casing.

When the air for mixing is taken under the furnace the result will surely be a failure to secure proper temperature for the air entering the school-room. The air will follow the line of least resistance, which is up near the heated surface of the fire-pot, and will not pass under the furnace and into the space intended for it to reach the mixing-valve.

When the warm air is shut off by the mixing-valve it will be heated and expanded in the hot-air chamber, and will back down and out into the space intended for the cold air for mixing. It will, when the mixing-valve is open for warm air, follow the line of least resistance, and the school-room will become overheated when there is a strong fire in the furnace. In moderate weather under such conditions it will be impracticable to furnish the required amount of air without uncomfortably overheating the school-room.

A furnace smoke-pipe should never pass through a cold-air room when possible to avoid doing so. In case of a smoke-pipe rusting and opening holes in the pipe, or if the pipe is not well and tightly jointed, there is liability of the unconsumed products of combustion passing into the school-rooms. The cold air also has a tendency to reduce the heat of the escaping gases and retard the draft.

The writer has seen cases where the smoke-pipe was intentionally twisted and made into what may have been intended to be similar to a trombone coil, for the purpose, as alleged, of utilizing the waste heat in the smoke-pipe for warming the air in the cold-air room.

The result was, however, that it made a good condenser, and the condensed smoke and gases dripped down through the joints in the pipe into the cold-air room and assisted in contaminating the fresh air in addition to what was done by the gas escaping from the combustion chamber through openings between sections of the furnace. The condensation also assisted greatly to destroy the iron of the smoke-pipe.

The furnace should be placed below the school-room rather than under a corridor or clothing room, in order that the warm air may pass up the front side of the heat shaft instead of on the back, and thus avoid uncomfortable drafts in the school-room.

The cold air for mixing should always pass up on the rear side of the heat shaft.

When for structural reasons the furnace must be placed other than under the school-room, the furnace should be placed low enough to enable the cold air for mixing to be taken over the top of the furnace casing or setting and to enter the heat shaft on the rear side. The proper location of the furnace is a matter that should be carefully considered, as nothing will contribute more to obtaining satisfactory results as to temperature than will its proper location with relation to the warm-air flues.

Pipes for conveying air to floor registers in corridors or clothing rooms should not be taken from the warm-air chamber of a furnace when the warm air for the school-rooms is taken into the room above the floor. Where this is done the results are not satisfactory, as the air, instead of passing to the floor registers, will frequently be carried up the warm-air flues into the school-rooms, and a reversal of the air current will result. This will happen whenever the air supply for the furnace is checked or partly shut off at the cold-air opening into the fresh-air room. The air will be taken from the corridor or clothing-room to the school-room instead of from the furnace to the corridor.

A liberal sized cold-air room should always be provided for furnaces in schoolhouses. It will to a great extent prevent back drafts by suction of the wind outside, and will give a much better supply of air under all conditions than will the ordinary cold-air box.

The windows in the cold-air room should be hinged from the top and the opening be covered with a stout wire grill or netting.

If heat is required for corridors or small rooms it is much better to provide a small and separate furnace for this purpose, providing steam cannot be used.

In the best and most satisfactory work now being done in Massachusetts, where furnaces are used for heating class-rooms, a small steam boiler is used to furnish heat for the vent-flues and also for warming the corridors and small rooms.

Twin connected furnaces are sometimes installed in schoolhouses; but the results obtained are not as satisfactory as where each furnace has an independent setting.

The distribution of air is not always good and depends upon which furnace is heated, as is the case when only one furnace is in use in moderate weather.

When a fan is used and both furnaces are heated, the results are much better than by a gravity system using only one of the twin furnaces at a time.

The use of a combination of furnace and hot-water heating is not recommended for schoolhouses. While often giving satisfaction in a dwelling-house, the conditions existing in a schoolhouse are not such as to justify the use of a hot-water attachment in the furnace.

It frequently happens that during cold weather the janitor will allow the fires to go out between the close of the Friday P.M. session and the opening of the Monday A.M. session, or that during the winter vacation the fires will not be kept up. In such cases the water attachment may become frozen and pipes or radiators burst.

Where electric power is obtainable at a reasonable price a combination of fan and furnace may be used, and excellent results obtained, especially in mild weather.

A good sized disk fan run at a comparatively low velocity, if properly located between the cold-air room and furnace, will give very satisfactory results and can quickly warm the building by rotating the air through it *before* the opening of the school session.

Where electric power is not easily obtained a gas engine, and in some cases a water-motor, has been used to drive the fan. Neither of these is as satisfactory as electric power, especially in small buildings.

The noise and the escape of the products of combustion into the building are serious objections to the use of a gas engine.

The cost of water in cities and towns having a water supply system is such as to practically prohibit the use of the water-motors for running fans.

Stack Heaters.

When steam is not available for heating vent-flues, a stove or small furnace called a "stack-heater" is used to raise the temperature in the vent-shaft and cause a good outflow of foul air. This stack-heater is usually placed in the basement so that it may be easily tended and to prevent the annoyance of ashes and dirt on the schoolroom floor. The air from the first story rooms is brought down in galvanized-iron ducts (or sometimes brick ducts) and enters the vent-shaft *below* the stack-heater.

When a stack-heater is used the foul air from the schoolrooms is taken out through one common vent-shaft having a cross-sectional area of 20 square feet for four 50-seat schoolrooms, which are as many rooms as it is advisable to vent through one shaft. The two rooms in the second story should be vented directly into the common shaft.

A stack-heater, having a fire-pot about 22 inches in diameter and grate 20 inches in diameter, is generally used to ventilate a school building where four school-rooms and two corridors are vented into the same shaft.

A stack-heater for sanitary closets in school buildings containing up to eight rooms, and with a 16-inch diameter fire-pot and 14-inch grate, is commonly used in the sanitary vent-flues. While smaller grate surface may theoretically be used in stack-heaters, yet with too small a fire-pot the fire is liable to go out for want of proper attention by the janitor.

The stack-heater should be placed so that the air for furnishing the draft for the fuel is taken from outside the shaft.

When the stack-heater is placed entirely within the vent-shaft and receives its air for draft from within the shaft and is tended through a door in the shaft, the results are not satisfactory.

Where separate vent-flues are provided from each of several rooms it is not practicable to use a stack-heater, and steam heat must be employed.

CHAPTER VIII.

JANITORS.

SUCCESS or failure in obtaining satisfactory results with a well-designed system of heating and ventilation often depends upon the care and good judgment exercised by the janitor or engineer having charge of the apparatus.

Complaints have frequently been made that the heating and ventilation of a school building were not satisfactory; that the rooms were too warm or too cold; that uncomfortable drafts were felt; that the air was bad, etc.

On inspection, these complaints were often well founded, and on looking for the cause it was very frequently discovered to be the fault of the engineer or janitor in charge, and not of the apparatus installed in the building.

A janitor or engineer who is negligent, or not informed as to the proper way of operating the apparatus under his control, can easily give a well-designed and a properly-installed system a bad name.

If heating and ventilating engineers and contractors who install systems in school and public buildings will see that the engineer or janitor is properly instructed as to his duties when first taking charge, they will find it greatly to their advantage; not only as to the reputation their work will have, but they may be saved expense in responding to calls to come and see what is the matter with the apparatus.

Printed instructions provided by the contractor or engineer who designed the work, if posted in the boiler or furnace-room, will more than pay the expense of printing and posting, and will save annoyance.

A janitor who understands the system and properly manages it will not only give better satisfaction to the school authorities, but will in many cases make a considerable saving in the expense of operation.

An incompetent or lazy janitor may cause an excessive waste of fuel and perhaps serious damage to the apparatus under his charge.

A janitor in a school or public building should be able to pass an examination as to his fitness and ability to manage the modern appliances for heating and ventilating a schoolhouse or public building.

More is required of a janitor than the ability to shovel coal into a furnace or under a steam-boiler, or to see that a proper amount of water is in the boiler. Good judgment and a thorough knowledge of the apparatus is essential.

Besides regulating the fires properly by having good and clean fires in cold weather and light fires in moderate weather, and, with a steam-heating system, seeing that the proper amount of radiation is in use, it is of the utmost importance that the inlets for fresh air, the mixing-damper for regulating the temperature of the air supplied to the class-rooms, the heat or fans for the ventilating ducts, and the dampers for regulating the outflow of foul air, should be properly understood and managed.

In a mechanical (fan) system care should be taken that the fans are run at a proper speed and at the proper time.

It is very important that the windows admitting air to the cold-air rooms, where the indirect radiators or furnaces are located, are properly opened or partly closed, as may be required by the constantly varying conditions of temperature and wind. These windows should be hinged at the top and open inward in order that the air may be deflected downward and distributed through the cold-air room.

The stacks of indirect radiators or the furnace should never be placed so close to the window that the window cannot be opened to its full capacity. When a gravity system is used the windows in the cold-air rooms should have an opening equal to the combined area of the several ducts leading from the cold-air room.

With a mechanical system in a large building the area of these windows may be less than in a gravity system.

In mild weather and when there is but little wind they should be kept wide open during the school session; in very cold or windy weather they should be partly closed; but under no circumstances should they be entirely closed when school is in session.

If opened too wide when a strong wind is blowing into the cold-air room, more air will be supplied than is required or can be properly warmed, and uncomfortable drafts will be felt in the school-rooms.

If closed too much, a sufficient supply of fresh air will not be furnished and the air in the school-rooms will be vitiated to an objectionable degree.

When on the leeward side of the building they should be opened wider than when they are on the windward side.

Each window in the cold-air rooms should be provided with a stout cord or chain and pulley and means for fastening the same, in order that the window may easily be opened or closed to any desired position.

It is also advisable to hold the window in the desired position and not allow it to fly up or down by the action of the wind. This can be done by another cord or chain.

Mixing-valves or dampers are placed in the fresh-air ducts which lead to the several rooms, by means of which the air is allowed to pass through the stacks of indirect radiators or along the heating surface of the furnace, or is caused to by-pass without going through the heaters.

By the use of mixing-dampers the temperature of the air supplied to the school-rooms can be regulated without materially reducing the supply.

When valved registers are used and the room becomes too warm the heat is shut off as is also the supply of air at the same time.

The teachers as well as the janitor frequently operate the mixing-valves and dampers, and should also be instructed in their use.

It often happens that when the school-room becomes overheated the chain operating the mixing-valve is pulled in such a manner as to almost entirely shut off the warm air and turn on the cold air. Cold air is then admitted to the room and uncomfortable drafts are caused, then when the room has become too cool the chain is moved in the opposite direction and the room is soon overheated again. If this is continued the teacher or janitor will be kept busy trying to keep the room at a comfortable temperature.

If, however, when the temperature of the room begins to rise or fall below the desired point (68 to 70 degrees F.) the mixing-damper chain is moved but a little at a time—say from one-half to one inch—there will be little difficulty in maintaining the desired temperature if the fires and the windows in the cold-air rooms are properly managed. The mixing-valve, after having been once properly adjusted, may not require to be moved during the whole or greater part of the session.

Two or three pieces of thin or narrow ribbon — about one-quarter of an inch wide and about ten inches long (red, white and blue would be appropriate colors) tied into the wire grill at the warm-air inlet, about two-thirds the distance up from the bottom to the top and in the center of the wire grill, will be of great assistance to the teacher in determining whether or not a proper amount of fresh air is being supplied to the school-room.

If the ribbon does not blow out or flutter it will indicate a deficiency in the fresh-air supply.

A metallic thermometer about four inches in diameter, which has an indicator hand, will, if placed on or in the wire grill near the ribbon, enable the teacher or janitor to place the mixing-valve in the right position.

As the outflow of air from a room through the exhaust flues or ducts is caused, in a gravity system, by the difference between the temperature of the external and internal air, and also by the force of the wind blowing across the top of the ventilating stack or flue, some means of meeting the constantly-varying conditions of temperature and wind must be provided.

In a mechanical system provision should be made for regulating the flow of air through the several ducts and flues.

In both the gravity and mechanical systems dampers should be placed at the outlet from each ventilated room.

The heat in the vent-flues should be used in a manner directly opposite from that used for warming the rooms. The greater the difference between the temperature of the outside and inside air, the less will be the amount of heat required in the vent-flues.

In very cold and windy weather no heat may be needed in the vent-flues, and the dampers in the outlets from the rooms may often be *partly but never entirely closed* while school is in session.

In mild and calm weather the dampers should be wide open and heat maintained in the vent-flue heaters. The warmer the weather, the more heat will there be required in the vent-flue heaters.

Pieces of ribbon similar to those on the warm-air inlet should be provided for the outlets, but they should be placed on the inner side of the grill. If they flutter into the duct it will indicate an outflow of air from the room. If they blow back or rest against the grill it will indicate a reversed draft or no draft.

In cold weather, after the school session has closed, sufficient time should be allowed to flush out the room with fresh air.

The dampers at the outlets should then be closed and the heat in the vent-ducts shut off.

Leaving the dampers in the vent-ducts open at night will cause a waste of fuel and unnecessary cooling of the rooms.

In warm weather, when no heat is supplied by the warm-air inlets, the dampers may remain open at night.

After school has been dismissed for the day and the class-rooms have been flushed out with fresh air from the warm-air inlets the windows admitting air to the cold-air rooms in the basement should be closed, as should also the dampers in the vent-flues. The rotating registers in the floor above the cold-air rooms, as well as the doors from the several class-rooms, should then be opened and the air rotated through the building by means of the indirect radiators or furnaces. The fires can then be banked and checked for the night.

In cold weather, if direct radiation has been provided in the class-rooms in addition to the indirect radiation, the direct radiation should be turned on and kept on till a short time before the opening of the morning session.

If plenum fans are used they should be started in season to thoroughly warm the building by rotating the air before the opening of the morning session.

The direct radiation in class-rooms should not be used while school is in session, unless the class-rooms cannot be heated without it.

The heat in the sanitary vent-flues should be kept up at all times, *except perhaps in very cold and windy weather.*

The dampers in the corridor vents should be closed at night.

Care should be taken not to open the windows in the sanitary rooms and allow the wind to blow in, as the odors may under some conditions be driven out of these rooms into other parts of the building.

It is much better to depend upon the sanitary vent-flues to properly ventilate these rooms by drawing the odors from the room through the sanitary closets and urinals.

Liberal use of water should be made for flushing the sanitary fixtures.

The janitor should be in the building in the morning in season to have the building properly heated and the ventilating apparatus in good working order before the school session opens.

After cleaning and properly starting up the fires he should open the windows admitting fresh air to the cold-air rooms and properly adjust them to meet the existing conditions of wind and outside temperature. He should then close the rotating registers, open the vent dampers to the proper degree and close the class-room doors.

When the large boilers in a steam heating system are in use the steam for heating the vent-flues should be supplied from that source; but when the large boilers are not in use, or with a furnace system of heating, the small boiler, usually called the "summer boiler," should be used.

The doors, windows and transoms should be kept closed while school is in session in order to obtain the best results from the heating and ventilating system, and to secure a proper circulation of air in the rooms.

Springs or door-checks, if provided on all outside doors, will soon repay the extra expense by the saving of coal.

Janitors should be held to a strict accountability that the heating, ventilating and sanitary appliances in the buildings under their care are managed in a manner to secure the best results.

While they should not be blamed for improperly designed or constructed apparatus, yet they should be required to secure the best possible results obtainable from the apparatus under their control and to keep the same in good condition.

The janitor should see that the boilers or furnaces are left in proper condition at the end of the school term. If a mechanical system is used all parts of it should also be attended to. If any defects develop or accidents occur to the boilers, piping, valves or other parts of a steam-heating system, or in the furnaces or stack-heaters under his charge, the proper authorities should at once be notified in order that the required repairs may be made promptly.

All accumulations of ashes or rubbish should be promptly removed from the building. No inflammable or combustible material should be placed or allowed to accumulate in any closet or near a stairway or means of exit.

Where the pupils use paper instead of slates for their work, as is now generally the case in Massachusetts schools, care should be taken that it be promptly burned or removed from the building, and not allowed to accumulate in the basement or in any closet.

All the rooms in the building should be thoroughly and frequently swept and dusted, the sanitary rooms and fixtures washed and disinfectants freely used if required.

Where outside sanitary buildings are used they are often found to be in a very bad condition. The janitor should be required to inspect all the rooms and outbuildings under his charge at least once a day and should be held responsible for their cleanliness. He should investigate all cases of misuse of the sanitaries and report to the principal of the school or the school committee.

The playgrounds or yards should be kept in a neat condition and not become the repository of rubbish of any kind. In winter the janitor should see that all walks and entrances are properly freed from snow and ice, and that the basement doors are opened a reasonable time before commencement of the school session.

The average annual amount of coal burned in well-heated and ventilated school buildings in Massachusetts is about ten tons per class-room. This includes the basement, corridors and small rooms in an ordinary schoolhouse.

Where much in excess of this amount is used, unless in a building in a very exposed location, or one badly constructed, or where the system of heating and ventilation is badly designed, it is fair to presume that the janitor has not been careful in managing the fires.

Where, as is sometimes claimed, only seven or eight tons of coal are burned per year, it will be found that the air supply has been restricted to an amount below what is required for good ventilation.

Some janitors, either to make less work for themselves, or to establish a record for economy in fuel, shut off the fresh-air supply, or fail to maintain proper heat in the vent-flue heaters.

In cities and large towns much better janitor service would be obtained if a competent "head janitor" was employed and if it was made a part of his duty to see that the other janitors were fully instructed in and properly performed their duties.

It is false economy to employ, as is often done, an incompetent or lazy janitor because he can be hired cheap.

It is not advisable that one janitor should have charge of several buildings, sometimes situated at a considerable distance from each other.

Very frequently janitors do not receive suitable compensation for their work. This is more often the case in small towns than in cities. Fair compensation should be given for intelligent and faithful service.

The following extracts from a paper read at the twelfth annual convention of the International Convention of Factory Inspectors at Boston in 1898, by Thomas Hawley, State Inspector of Boilers and Examiner of Engineers and Firemen, contain many facts which it would be advisable for school committees, superintendents and principals of schools to carefully consider:

"There is another class of boiler that has received considerable attention from the department; namely, those in schoolhouses and public buildings.

While a very large number of firms and manufacturers have sadly neglected their boilers and allowed them to go without inspection, those who control the steam plants of large heating plants seem to have been more guilty in this respect Very few school boilers have been found upon which it was not necessary to order extensive changes to make them safe to be run. In some cities many of the boilers have been punctured with a blow from the light hammer each inspector uses. It has been the policy of the department to have the changes made and the boilers replaced or made safe without letting the facts be publicly known because of the possible alarming of parents, and very many boilers have thus been repaired without the pupils or parents knowing or suspecting that they had been near a dangerous boiler. The reason for this neglect seems difficult to understand. It may arise from the fact that in very many places the condition of the boilers is cared for by the public buildings department or committee of the city or town, and the boilers operated and under the care during the year of janitors appointed by the school committee. Each tries to put as much of the work as possible upon the other, or at least such would seem to be the case. I have found boilers in schools full of mud and deposits up to the hand holes, barrel staves, and bricks, tubes nearly filled up with soot, and back connections filled clear to the boiler with soot and ashes, hand-hole plates in the boiler rusted solid so they had to be broken off, showing the boilers had neither been opened for inspection nor cleaned for years. The janitors claim it is the work of the building department, and that department claims that if they give the school committee a good boiler and that committee provides the man to run it, that man should see it was run properly, and properly cared for and cleaned. Between the two, however, the boiler is not long in getting into dangerous shape; and it has been necessary to condemn school boilers entirely in some cases only after a few years' use. I have further found this condition to continue even after the inspector's first inspection, when the boiler comes to be again inspected, and it is the rule almost rather than the exception to find schoolhouse boilers in a dirty uncared-for condition, that shortens their lives, develops many defects, and in a filthy condition unfit for a proper inspection. The matter, in fact, it seems to me, has been complicated in one way, by the inspector making a third person upon whom the others rely, and they will now get only such attention as the inspector can give in his annual visit. It appears that there is claimed to be objections to having the boilers operated by persons not in the employ of the building department, it being claimed that all employees in schools should be controlled by the school committee. Of the merits of that contention I know nothing, but it does seem as though the two together could arrange that the boiler should have proper care and attention, or such an important and dangerous part of the school equipment as the boiler is should be under the responsibility of the school committee. Prior to the enactment of this law, boilers have exploded in schools in this State with disastrous results and in spite of the poor care they usually obtain, the regular inspection now made does provide a material safeguard.

"In other instances, too, heating boilers are found much neglected. The claim is made that they are run at such low pressure that they cannot explode. Yet I have pieces and sections of these boilers in my possession that have exploded and very recently, and with disastrous results. Many of these sectional boilers are of cast iron, and are bad in design, cheap in material, and improperly set up and inadequately fitted with safety appliances. They have been found with devices that bore the name of "safety-valve," but were safety-valves in name only. This most important fitting on a boiler is very frequently found altogether inadequate in size and in unfit condition. I have within a month taken safety-valves from school boilers which were stuck so solid they could not be moved with a hammer, and had become so by neglect since the previous inspection."

The following rules for janitors and firemen having charge of low-pressure steam-heating boilers are the requirements of the Hartford Steam Boiler Inspection and Insurance Company.

1. Getting Ready to Start.

The attendant should see that all joints are properly packed, and that none leak on filling the boiler with water. The gauge cocks, water gauge, and safety valve should be carefully examined that all are free and in good order. All valves in piping and radiators and air valves, should be examined and seen to be in order, and that all necessary packing or repairs have been done.

2. Condition of Water.

The first duty of an engineer when he enters his boiler-room in the morning is to ascertain how many gauges of water there are in his boilers. Never unbank or replenish the fires until this is done. Accidents have occurred and many boilers ruined from neglect of this precaution.

3. Raising Steam and Management of Valves.

All steam and return-pipes should be closed before fires are started. When steam has been raised to working pressure, the steam valves should be opened very slowly. After the boiler pressure is established in the pipes the return valves can be opened, allowing the water of condensation to flow back to the boiler. Whenever necessary to shut off at the boiler or any section of heating system, the return or drip valves should be closed first and then the steam valves. In letting on the steam the supply or steam valves should be first opened and then the return or drip valves. This caution is important.

4. Low Water.

In case of low water, immediately cover the fires with ashes, or if no ashes are at hand, use fresh coal, and shut the ash pit and open the fire doors. Do not turn on the feed under any circumstances or tamper with or open the safety valves. Let the steam outlets remain as they are.

5. Feeding.

When necessary to take fresh water the boiler should be fed as slowly as possible to avoid unnecessary contraction and leakage at joints.

6. Gauge Cocks and Water Gauge.

Keep gauge cocks clean and in constant use. Glass guages should not be relied upon altogether.

7. Safety Valves.

Raise the safety valves cautiously and frequently, as they are liable to become fast in their seats.

8. Safety Valve, Automatic Regulator, and Steam Gauge.

Should the gauge at any time indicate the limit of pressure to which the regulator is adjusted without its controlling the draft, the regulator should be examined and disconnected from the damper or draft door. If the regulator works quickly and well the trouble is in the damper or draft door, and it should at once be cleaned and made to work freely. Should the regulator fail to work, or work very slowly, the pipe connection to the boiler is choked and should be cleaned. See that pressure gauge, regulator, and safety valve agree; in case of difference, notify the company's inspectors.

9. Clean Plates and Heating Surfaces.

Particular attention should be taken to keep plates and parts of boilers exposed to the fire perfectly clean. Also, all tubes, flues and connections well swept. This is particularly necessary in many types of small heating boilers with large heating surfaces and small heat passages, as they soon foul if neglected. Strict attention to this rule is necessary for full economy and capacity of boilers.

10. Blowing Off.

If necessary to blow down during the season, the fires should be hauled and furnaces and bridge wall cleaned at least two hours before blowing down. Allow the boiler to stand until cool before filling with cold water.

11. Laying up Boilers for the Season.

Haul fires, clean furnaces, and run off the water while hot. Thoroughly clean all heating surfaces at once. Remove hand and man-hole plates, dry out water if any remains, and leave the boiler thoroughly clean and dry. Drain all water from return drip-pipes. All good systems are provided with drip-cocks at lowest point in return pipes for this purpose. During the summer see that no water can drip or moisture collect in or around the boiler.

12. Piping, Radiators, and Settings.

Mark all joints that have shown signs of leakage and need packing; also air-cocks and valves and anything that may need repairs before using another season. If repairs are needed to boiler settings see what they are and have them made while the boiler is idle.

Inspectors Will Give Special Instructions in Cases Not Covered by These Rules.

☞ *If the Boiler shows distress or unusual behavior notify the Company at once.*

A Few General Suggestions for Operating Heating and Ventilating Apparatus in School Buildings.

Furnaces.

Care should be taken not to have too deep or heavy a fire in the furnaces during Spring and Fall, as there is great danger of overheating the school-rooms.

During cold winter weather run deep, full fires in the furnaces with coal up to within three inches of the top of the fire-pot at the edges, and well crowned above that level toward the middle.

During extreme cold weather the grate-bars should be turned over at least twice each day. Ashes should not be allowed to accumulate in the ash-pits.

Fresh-Air Windows.

The fresh-air windows should be wide open daytimes in mild and calm weather, and never less than one-quarter open even in extreme weather, as judicious handling of the school-room vent-duct dampers should prevent the passage of too much cold air out of the building, thereby checking the inflow through the furnace chambers.

Always close the fresh-air windows tightly nights, Sundays and vacations, but never close the fresh-air windows entirely when school is in session.

Controlling Temperature of School-rooms.

The temperature of the air entering each school-room should be regulated by the teacher occupying the room,—this is done by pulling the warm-air chain, or the cold-air chain, as the needs of the moment may demand. The teacher should pull the necessary chain but a little way at a time,—this to prevent too sudden a rise or drop in the temperature of the air entering the school-room.

Dampers in Ventilating Ducts.

The outflow of air from each school-room is controlled by a damper, which should be adjusted by the janitor before each session of school, according to the outside conditions. In mild and calm weather, this damper should be wide open; but when the weather is cold and windy, it should be partially closed. Never should it be closed entirely when school is in session.

During extremely windy weather the vent-duct, unless controlled by the use of this damper, might take out from the school-rooms a larger quantity of air than the warm-air ducts could provide sufficiently heated,—the excess outflow finding its way *into* the school-room *cold*, through leakage around the windows and doors and through the walls.

Intelligence should be used in operating these vent-duct dampers.

Schoolroom Windows and Doors.

A much better circulation of air within the school-rooms can be obtained if the windows and doors of the school-rooms be kept closed. Windows and doors should always be kept closed when the large furnaces are in operation.

If, when the chains which allow the cool air to enter the school-rooms are pulled way down, the furnace drafts entirely checked, and it is still found that the school-rooms are uncomfortably warm, doors and windows may then be opened at discretion of the teacher.

Air Rotation.

At the close of school at night the fresh-air windows should be tightly closed and passage of air out from the building through the vent-ducts entirely checked; the rotating dampers which allow air from the school-rooms to pass back to the furnaces should then be opened, and the furnace fires fixed for the night. A circulation of air within the building will thus be established, and a reasonable temperature maintained in the school-rooms during the night, with the minimum consumption of fuel.

Stack-Heater.

When the weather is cold enough to require good fires in the large furnaces which heat the school-rooms, these furnaces will often furnish enough power to move the air required; but, on the other hand, when only low fires are needed in the large furnaces, it may be necessary to run the stack-heater in order to move the desired volume of air through the school-rooms.

In warm or muggy weather, a good fire should always be kept in the stack-heater, not only for the ventilation of the school-rooms, but for the ventilation of the sanitaries as well.

With Steam-Boiler Auxiliary.

The steam boiler supplies steam for the radiators in the corridors and small rooms, and also furnishes heat for the vent-ducts.

The steam may be supplied to the radiators in the corridors and small rooms when desired.

In warm or muggy weather the vent-flue radiators should always be kept hot, in order to secure the proper ventilation of the school-rooms.

Printed instructions (in large type) as above, if posted where they can be readily seen by the janitor, will be of great service to him when first taking charge of the heating and ventilating apparatus in a schoolhouse.

CHAPTER IX.

SANITARIES.

THE sanitary appliances in schoolhouses should receive careful attention, not only when being installed, but also from the janitor.

For buildings of large size the sanitary fixtures are generally placed in the basement, or, what would be better, in an extension in which they can be reached from the class-room floors and located where they can be properly ventilated, independently of the other parts of the building.

On account of the cost of construction, and frequently from an architectural point, this is not often done, and part of the basement is utilized for that purpose.

Where a suitable water supply is available and the fixtures are of good construction and properly placed and ventilated, the basement is not an objectionable place.

Individual closets and fixtures are preferable to those known as range closets or latrines, but where the latter are properly flushed and vented they are not objectionable and are frequently used on account of the lower cost. With individual seat bowls those having a seat vent three or four inches diameter are to be preferred. The individual bowls should be vented into a pipe increasing in size as additional vents are connected and leading to a heated vent-flue or one where a fan is provided.

In large and the best class of school buildings fans are used, but are more expensive than steam-heated flues.

The partitions between the closets should be raised on metal supports from six to ten inches above the cement floor of the basement and no woodwork on or around the bowls should be used, except such as is required for the seats. This allows the janitor to use a hose freely and prevents the accumulation of offensive matter in places not easily reached.

Each bowl should be provided with an automatic flushing device, of which there are several on the market that give good results. Apparatus is frequently used by which the whole number of bowls are automatically flushed at regular intervals.

When range closets are used they should have a large vent and flush. It is better to have a separate vent for each seat and to unite the several vents into one main vent.

Range closets should not be incased in wood on the sides or ends, and the full width between the partitions should be hinged in order that the whole length of the range can be thoroughly cleaned.

The waste-pipe should be of ample size but not too large to prevent thorough flushing.

For the main pipe six inches is a good size. Extra heavy iron pipe within the building is to be preferred to vitrified tile pipe, on account of the liability of tile pipe to become separated at the joints and allow leakage into the ground under the basement floor. The iron pipe should extend well beyond the foundation wall and in all cases should be well trapped and provided with suitable clean-outs.

The writer has seen tile pipes that had been improperly connected or not made water-tight that had leaked so badly as to saturate the ground for a considerable distance, and where it has been found necessary to take up the floor and remove a considerable quantity of earth, replace it with fresh and substitute iron pipe. Where cremating closets have been used the saturation of the earth has been more noticeable than with water-flushed fixtures.

Where there was no available water supply for flushing closets cremating closets have been used, and where the vaults were constructed of brick laid in and covered with Portland cement and a good drain provided to remove the liquid matter, and where ample ventilation into a heated flue was provided, they have not been objectionable if properly cared for by the janitor. Odors were not perceived in the building, but complaints have been made by persons residing near the buildings when the closets were burned out.

Where a water supply can be had it is better to use flushing closets.

Where a water supply is available, but no system of sewers, flushing closets or range closets can be used by constructing a double cesspool; that is, two cesspools located at such a distance from the building that there is no danger of the leakage finding a way under the building — one cesspool to receive the waste-pipe from the sanitary fixtures and to allow the heavier and more solid matter to settle, the other to be constructed of brick or field stone to allow the liquid to filter off.

The two cesspools are connected by a siphon pipe (six inches in diameter), which will, when the first receptacle has become partly filled with liquid, transfer it to the second or filtering cesspool. This arrangement cannot well be used where the ground is constantly wet or where water in the ground is much above the bottom of the cesspool, or in clay.

Each cesspool should be provided with a perforated manhole cover to prevent an accumulated gas from forcing its way through the trap and entering the schoolhouse basement.

The urinals in a schoolhouse basement, where individual fixtures are not used, should be of slate, and should have suitable divisions for the older grades of pupils. In many school buildings the divisions are omitted on account of the additional cost of construction.

A urinal has been constructed for an eight-room school building in accordance with the following specifications, and used with satisfactory results:

"A gutter slab, 8 feet long and 18 inches wide and 3½ inches thick, in one piece; one floor slab 8 feet long, 2 feet 6 inches wide and 1½ inches thick, sloped to the gutter slab; two end slabs 5 feet high, 2 feet 6 inches wide and 1 inch thick, and two back slabs each 4 feet long, 5 feet high and 1 inch thick, making the urinal when completed 8 feet long, 5 feet high and 3 feet 3⅜ inches wide, including the floor slab. The gutter is to be countersunk 2½ inches deep at the outlet and 1 inch deep at the summit; the back slants 5 inches and is to be grooved ⅜-inch into ends, and all are to be grooved ½-inch into the gutter slab; all to be strongly clamped together and bolted to the brickwork, using brass clamps and brass expansion-bolts. The floor slab laps 3½ inches on the gutter and is closely fitted to the ends; the outer or waste-pipe is a brass cesspool, having 3-inch waste trapped.

"A ⅞-inch brass flush-pipe runs the entire length, placed within two inches of the top, and perforated so as to give a uniform and even flush; this will have a controlling valve.

"The end slab near the outlet has an 8 by 10 inches opening to receive an 8 by 10 uptake vent-pipe and an 8 by 8-inch ventilating-hood which runs on top of the back slab the entire length. This connects with an 8 by 8-inch uptake vent-pipe, both of these uptake pipes and hood being made of heavy galvanized iron, properly secured in place. The uptake pipes are connected near the ceiling with the vent-duct leading to the heated brick vent-flue. All exposed parts of the slate are to be planed, rubbed smooth and well-oiled, the joints filled with slate cement in the best manner."

A better arrangement is that of a slate urinal vented at the bottom of the front slab (having at least 12 square inches of opening for each 16 inches length) into a space between the front inclined slab and a perpendicular back slab, the space at the top to be at least four inches wide and the full length of the slabs and covered on the ends and top by slate slabs, except where it is vented near the center of the top by a galvanized-iron vent-pipe four inches wide and at least 20 inches long, which changes its form into a 10 inches diameter round pipe connected with a heated brick flue.

The perpendicular back slab is grooved ½-inch into the gutter slab. The inclined front slab at the bottom projects over the gutter at least three inches.

The Boston Board of Schoolhouse Commissioners recommend, for water-closets and urinals, "Ventilation through fixtures, back of urinals, and 13 square inches local vent in water-closets.

"Water-closets. The basement water-closets for primary and certain grammar schools are, approved washout vitreous earthenware or enamel iron latrines, or short hopper closets; elsewhere a heavy wash-down closet, all as specified by the Commissioners, 13 square inches local vent from each section of closet, automatic flush.

"Slate partitions for latrines resting on top of range, 5 feet 6 inches high and about 4 feet wide; for closets 8 inches above floor, 5 feet 6 inches by 6 feet high and 4 feet wide; in both cases supported at ends with iron pipe from floor to ceiling. No doors. (These may be added later.)

"Urinals. The urinals will be of slate, floor slab and trough, the back 4 feet 6 inches high, without partitions, flushed automatically with ⅞-inch perforated pipe, vented at bottom (opening 10 square inches for each 16 inches length) into space behind back.

"Piping. Cast-iron must be in trenches in basement, running trap with direct indirect fresh-air inlets, clean-outs at every change of direction; soils and vents exposed as far as possible, no asphaltum, but oil-tested red lead and three coats paint.

"Supplies exposed as far as possible; where covered may be lead, elsewhere brass, no nickel plated. Hot-water for janitor's use in basement, and, if convenient, for master's and teachers' toilets. Supply from boiler, and from summer boiler, if any, or from a gas-heater."

All plumbing should be carefully tested to ascertain if it is tight and well trapped, especially where smaller pipes enter the main drain.

Where water-closets are provided in teachers' toilet rooms they should be well vented.

Soapstone sinks are frequently used in the basement in place of the ordinary cast-iron ones. Enameled iron is sometimes used.

Many school buildings have stream drinking founts instead of faucets and dippers.

Outside Sanitary Buildings.

The care of sanitary buildings in many towns and villages is a matter that is often neglected, and frequently they are found in a condition that does not bring credit to those who have the immediate care of such buildings.

This is something to which school boards and teachers should give more attention than they usually do. They should see that such places are kept in at least a decent condition and that the vaults are properly cleaned.

The janitor should be required to visit the sanitary building daily, cover the contents of the vault with fresh earth or ashes, and see that the seats, urinals and floors are in good condition.

In winter especially these buildings are often found in bad condition, as there is seldom any provision for heating. While a stove in such buildings would add much to the comfort of the pupils, practically it would be of little use, as the fire would not be properly tended by the ordinary janitor, and some committees would object to what they would call a needless waste of fuel.

Where outside privies are used they should be placed at such a distance from the schoolhouse that odors will not reach the classrooms when the wind is blowing from the direction of the sanitary building. When practicable they should not be located in a direction from which the prevailing winds blow.

Particular care should be taken that they are not located near the fresh-air supply for the furnaces or indirect radiators in the school building.

When such buildings are used it is advisable to provide a tight vault with the walls laid in cement and covered on the inside and bottom with cement.

A vault three or four feet deep and from four to five feet wide, extending the length of the building, will be found of ample size if cleaned out as often as it should be.

The walls should be not less than 12 inches thick (some are 16), and the bottom of cement not less than two inches thick if the ground is solid, but if the building is placed where the ground is wet or not firm, there should be below the cement a layer of concrete not less than four inches thick.

The vault should extend beyond the rear of the building and be covered with inclined and hinged doors for removing the contents. On the rear of the building, and extending not less than two feet above the ridge, should be a ventilating shaft leading from the vault.

The windows should be hinged and fitted with attachments for readily opening and closing.

Locks should be placed on the doors for closing the building when the schoolhouse is not occupied.

Where the ordinary trough urinal is used it should be well covered with sheet zinc and the floor under and at least three feet in front should be covered with sheet zinc and the joints made water-tight.

Hinged self-closing covers should be furnished for the seats.

Where it is not practicable to provide separate buildings for boys and girls, one with a partition may be used, and a board division fence or divided covered way leading from the schoolhouse to the building.

Where the sanitary building is attached to the schoolhouse by a covered way (which is not always advisable), self-closing doors should be provided at each end and ample provision made for doors or louvres in the sides to prevent odors entering the school house.

Brick piers are sometimes placed in the vault under the rear wall of the building if it is of considerable length. Three-inch iron pipe is preferable to the brick piers, as the vaults can be more readily cleaned when this is used.

Whatever class of sanitary fixtures or buildings are provided for schoolhouses it is requisite that constant supervision should be exercised by teachers and janitors to have them kept in good condition. It should be a teacher's duty to see that the janitor faithfully attends to that part of his work.

In many sanitary buildings, especially in the smaller towns, the writer has found conditions that should not be tolerated and would not have been allowed to exist if either the school committee or teachers had taken means to ascertain whether the janitor was attending to this part of his duty.

Vaults were found that apparently had not been cleaned out for years, seats and floors covered with filth, obscene writing on the walls, and doors with hinges and fastenings broken.

It has frequently been necessary to order seats and floors removed and new ones substituted in outside buildings, and in some cases new buildings were built.

Such unsanitary conditions are demoralizing, and if parents had known of the existing conditions there would have been strong protests entered with the school committee.

Where a supply of fresh earth has not been obtained, kept dry and free from freezing, in cold weather sifted ashes from the furnaces or boilers can be used to good advantage in the vaults.

In some badly-constructed cremating closets and in some of the so-called "foul air gathering rooms" with poorly cemented floors, trouble has been caused by the breaking, scaling or cracking of the cement, which allowed the liquid matter to soak into the ground under the basement floor and extensive repairs and alterations were required. Where any class of cremating closets are used in schoolhouses, *extra* care should be taken that the vaults are made perfectly water-tight, thoroughly built and well drained.

The heat in sanitary vent-shafts or ducts should be maintained at all times during the school term, except, perhaps, when there is a very considerable difference between the temperature in and outside the building, or when a very strong wind is blowing across the top of the shaft and causing an outward flow of air.

The sanitary vent-flue should never be placed in a position in which back drafts may be caused by the wind being deflected by roofs, towers or other projections.

When a contagious disease appears among the pupils the entire schoolhouse should at once be thoroughly fumigated and disinfected under the direction of a competent person.

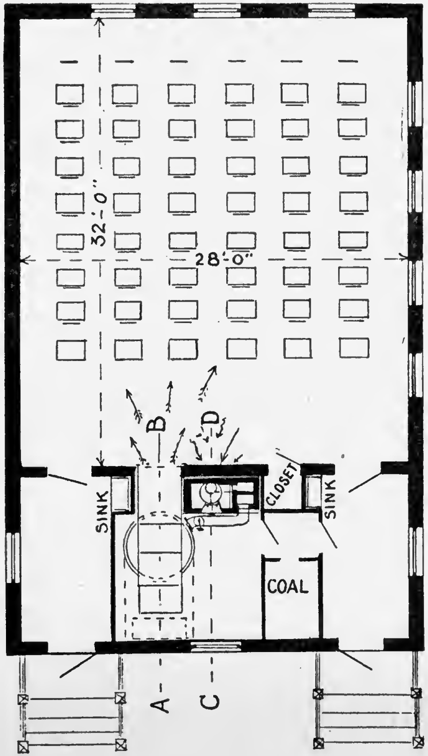
PART II

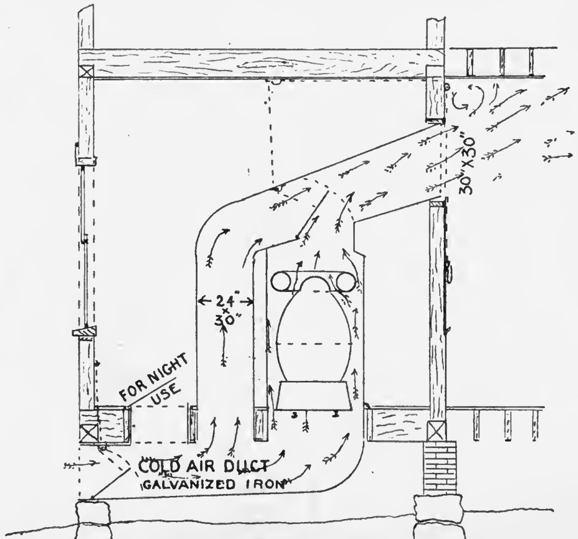
Plans and Descriptions

OF

School Houses

PLATE I.





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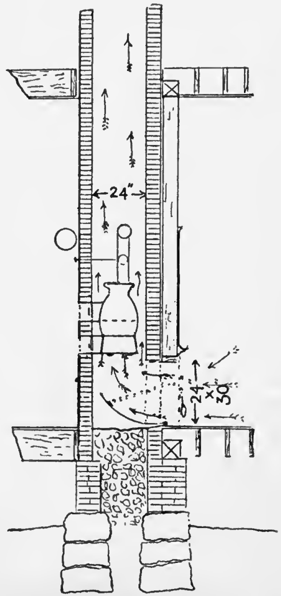


SECTION THROUGH C D

ONE ROOM SCHOOL

PLANS AND DESCRIPTIONS

OF SCHOOL HOUSES.

PLAN of a one-story, one-room schoolhouse with sections of heating and ventilating apparatus. The school-room is 28 by 32 feet and 12 feet high, with seats for 48 pupils. In front are two clothing rooms, one for boys and one for girls. A cast-iron sink is provided in each. There is a closet opening from the school-room for the teacher. Between the clothing-rooms are the furnace-room and fuel-bin.

The heating is by a medium-sized portable furnace. Fresh air is taken in through a galvanized-iron duct under the floor. This duct is 48 by 16 inches where it passes through the underpinning, and the bottom is slightly inclined toward the outside to allow rain that may be driven in to run out. The inlet is protected by a wire grill of one-eighth-inch wire set in a channel-iron frame.

A valve, with a pulley and a chain passing up into the furnace room, is provided, with a suitable catch to hold the valve in any desired position when a strong wind is blowing, or when the damper is closed at night. Before reaching the furnace the duct is tapped by a perpendicular one 24 by 30 inches, to furnish cold air for mixing with the warm air from the furnace when it is desired to reduce the temperature and yet supply fresh air to the school-room.

A mixing-valve with pulleys and chain leading to the school-room is provided to enable the teacher to regulate the temperature. A suitable catch (as shown in another plate) is provided to hold the chain and damper in any desired position.

Warm air enters the school-room through an opening 30 by 30 inches, covered with a wire grill of one-eighth inch wire, one-and-one-half-inch diamond mesh, set in a channel-iron frame. The bottom of this opening is eight feet above the floor. The warm air is thrown forward across the ceiling, spreading till it reaches the three outer or cold sides, where it is cooled and falls, and is drawn back across the lower part of the room and removed by the exhaust vent stack.

NOTE.—The method of setting up this heating apparatus was designed by the writer and has given satisfactory results where used.

In the top of the cold-air duct, before it reaches the upright part, is a trap-door covered on the bottom with galvanized iron which opens up into the furnace room. This is for rotating the air within the building at night or when the school-room is not occupied. By closing the outer damper in the fresh-air duct, closing the vent shaft opening from the school-room, and opening the doors between the school-room and furnace-room, the air is rotated through the furnace and a considerable saving of fuel is made. This trap-door should never be opened when the school-room is occupied.

The exhaust vent or foul-air shaft has four-inch brick walls, and is 30 by 24 inches inside. Adjoining, and in the same stack, are the smoke flues for the furnace and vent-shaft heater.

A small stove or "stack-heater," supported on two iron bars, is placed in the vent shaft just above the foul-air entrance.

The foul-air vent opening is 24 by 30 inches, and the bottom is at the level of the floor, being covered with a wire grill similar to that at the warm-air inlet.

A curved galvanized-iron damper is placed in the opening to regulate the outflow of air as may be desired on account of outside temperature or wind, or to close at night or when the school-room is not in use.

Plates Nos. II and III show plan and sections of what is known as the portable schoolhouse — a one-room school building for temporary use where the larger buildings are overcrowded, or for use until better accommodation can be provided.

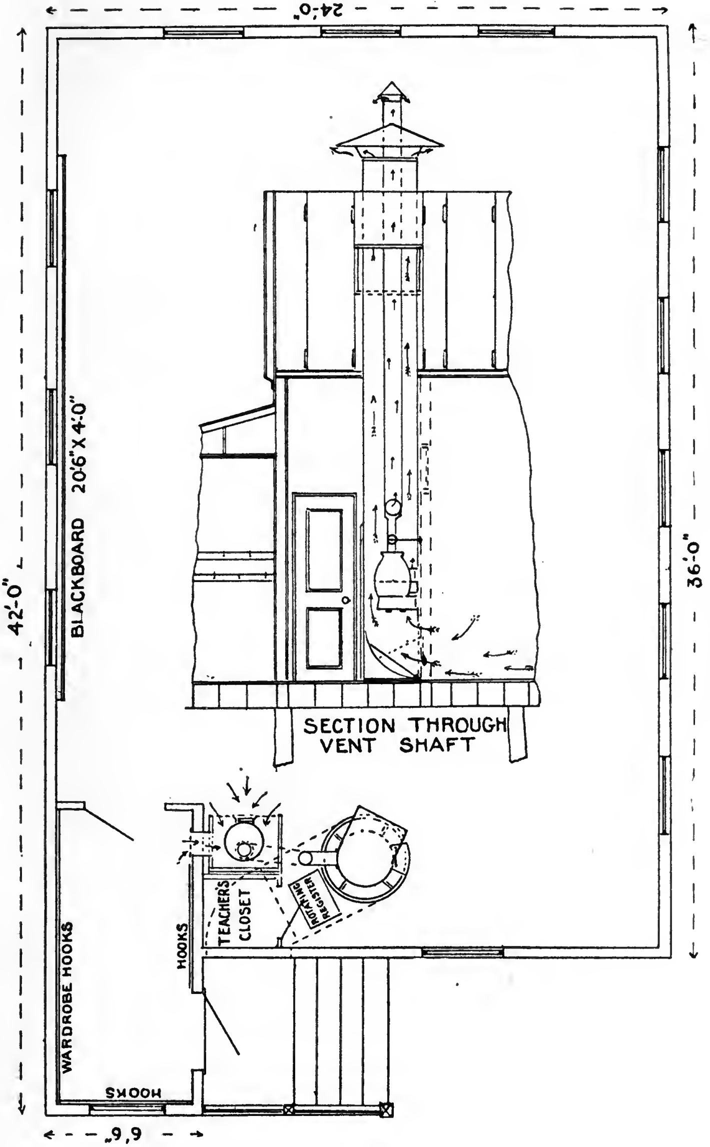
The building is constructed of light timbers and covered with matched and battened boards. The roof boards are covered with canvas, painted three coats.

The building is supported on cedar posts and the space between the floor and the ground is inclosed with two thicknesses of matched boards, the outside boarding being perpendicular and the inside placed horizontally. The inside of the building is sheathed on the sides, ends and ceiling with matched boards. Between the upper and lower floor boards are two thicknesses of heavy building paper.

The heating is by a jacketed stove or small portable furnace, which receives the air to be heated and for ventilation through a galvanized-iron duct leading from under the front platform, which is not boarded on the end, but provided with open lattice-work. A damper is provided in this fresh-air duct by which the quantity of air to be heated is regulated according to the temperature of the

NOTE.— The method of setting up this heating apparatus was designed by the writer and has given good results.

PLATE II.

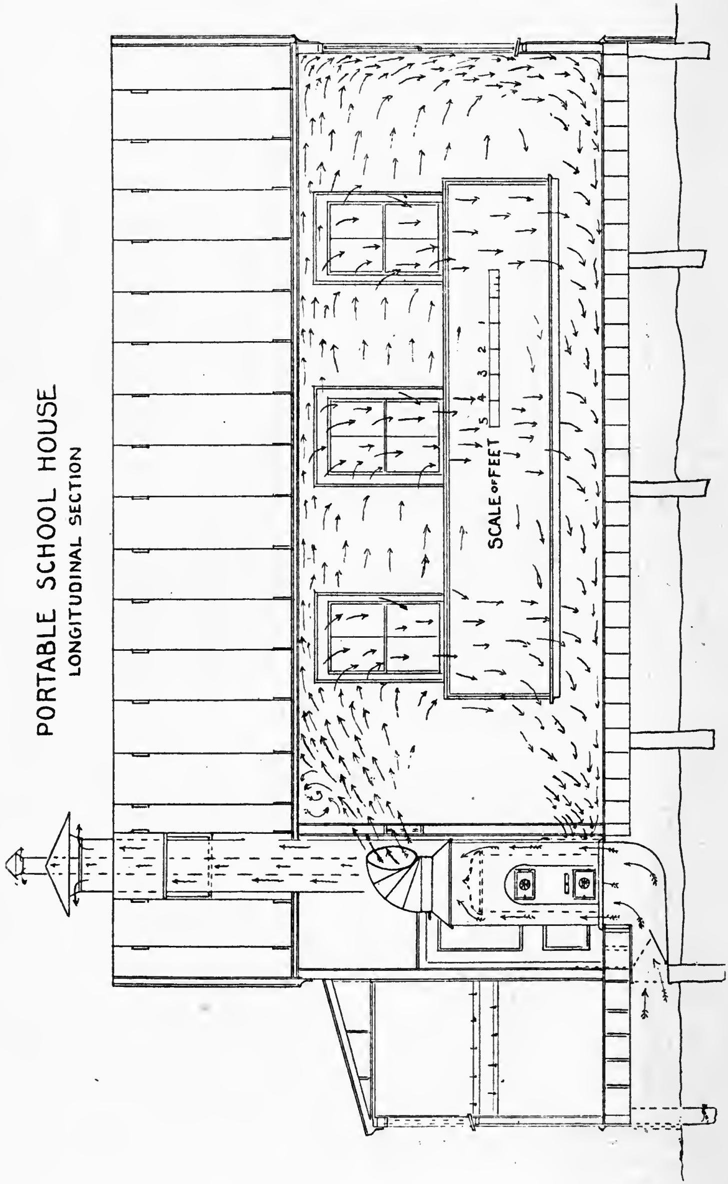


PORTABLE SCHOOL HOUSE
FLOOR PLAN

SCALE 5 4 3 2 1

PLATE III.

PORTABLE SCHOOL HOUSE
LONGITUDINAL SECTION



outside air or the force of the wind. This damper is operated by a pulley and a chain passing up into the school-room.

The air passes up between the casing and the stove and is introduced into the school-room through a curved top, which changes the direction of the current and throws the air across the ceiling to the coldest part of the room. This curved top is movable, and can be changed to throw the air against the direction of the prevailing wind when desirable, thereby securing a more even distribution of heat in the schoolroom.

In the floor of the schoolroom and behind the jacketed stove is a trap-door opening into the fresh-air duct. By closing the outer damper in the fresh-air duct, opening the trap-door and closing the damper at the opening into the ventilating shaft, the air can be rotated through the building at night. This also enables the janitor to quickly warm the room in the morning before the school session begins. The trap-door should never be opened while the school is in session.

The ventilation is by means of a galvanized-iron shaft in which is placed a small stove or "stack-heater" just above the top of the vent opening, the bottom of which opening is at the floor level.

The stack-heater is supported on two iron bars and the lower part of the ventilating shaft from the floor to above the heater is provided with a double casing, filled with an non-heat-conducting material, preferably asbestos. This vent opening is covered by a detachable wire grill.

At the vent opening is placed a curved galvanized-iron damper, operated by a chain and catch.

The smoke from the jacketed stove and from the stack-heater enters a galvanized-iron smoke-pipe which passes up near the center of the vent-shaft and above a galvanized-iron hood or cap above the top of the shaft.

The outer clothing of the pupils is to be hung on hooks in the porch clothing room, which is ventilated into the vent-shaft through a 10 by 12 inch register at the floor level, having valves.

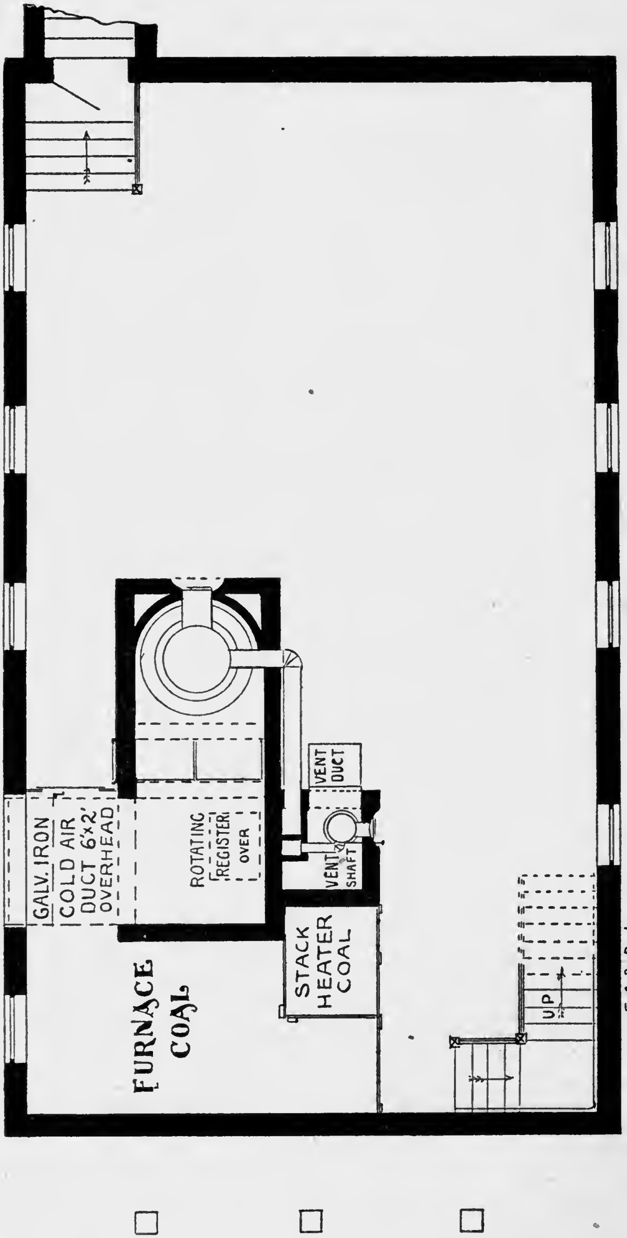
The vent-shaft is 24 by 30 inches, inside measurement. The opening from the school-room is 30 inches long by 24 inches high.

The galvanized-iron fresh-air duct is 36 by 16 inches, and the circular opening in the movable top above the jacketed stove is 24 inches diameter.

A small closet is provided for the teacher.

Plates IV, V and VI. Basement, floor plan and plan and sections of heating and ventilating apparatus for a one-story two-room wooden

PLATE IV.



BASEMENT
TWO ROOM–TWO STORY SCHOOL-HOUSE

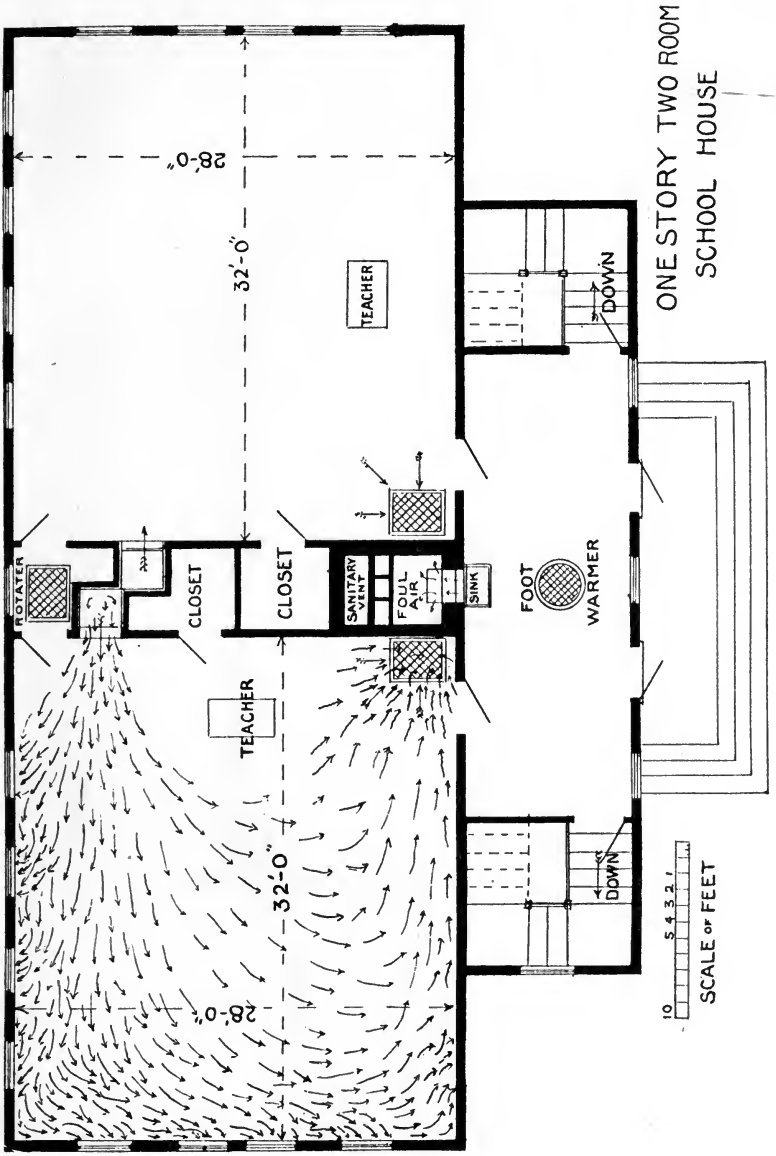
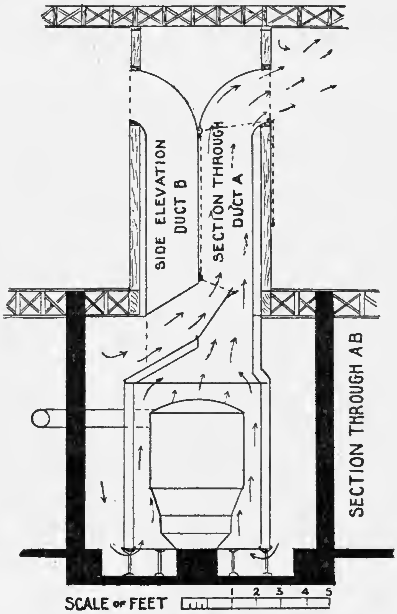
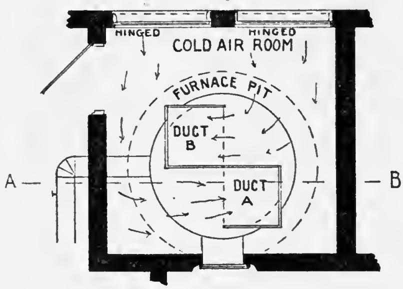

ONE STORY TWO ROOM
SCHOOL HOUSE
28'-0"
32'-0"
TEACHER
DOWN
CLOSET
CLOSET
SANITARY VENT
FOUL AIR
SINK
FOOT WARMER
ROTATER
TEACHER
32'-0"
28'-0"
DOWN
10 5 4 3 2 1
SCALE OF FEET

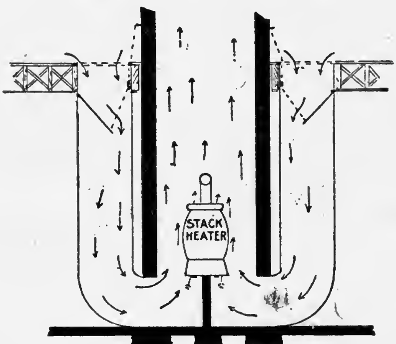
PLATE V.

PLATE VI.





PLAN



SECTION THROUGH VENT SHAFT

schoolhouse, intended to accommodate forty-eight pupils in each room.

The rooms are 28 by 32 by 12 feet, lighted on two sides from the left and rear of the pupils.

The teachers' platforms are omitted and a table-desk provided in each room.

The pupils' outer garments are hung on racks in the corridor, in which is a well-trapped sink and a looking-glass.

The basement is 9 feet 9 inches high, well lighted, the bottom concreted and covered with half an inch of Portland cement, and contains separate rooms for boys and girls, sanitary closets, coal-bins, cold-air room, furnaces and vent-shaft heaters. A well-trapped sink is also provided.

If double run of sash or outside windows are provided for the class-rooms, especially if the building is in an exposed location, a considerable saving can be made in the amount of coal required.

The school-rooms are heated by a large-size furnace encased in a double casing of galvanized iron set up inside a cold-air room, which is built of brick. If desired, an additional covering of non-heat-conducting material can be added to the outer casing of the furnace

The fresh air is admitted to the cold-air room through two windows hinged and protected on the outside by a stout wire grating, and provided with cords and pulleys for regulating the amount of air admitted.

A pit extends around and under the furnace, causing the air to be more evenly distributed than by the usual method of setting. The space between the two casings prevents the air being too rapidly cooled from the outside while and after passing the fire-pot.

Over the top of the furnace are the mixing-valves for regulating the temperature of the air for the school-rooms. The cold air for mixing passes over the top casing of the furnace direct to the mixing-valves, each of which is operated from the school-room by pulleys, chain and catch.

The warm-air ducts are 24 by 30 inches in cross-section. The warm air is admitted into each class-room through an opening 30 by 30 inches, covered by a wire grill set in a channel-iron frame. The warm-air inlets are placed on the inner or warm side of the room, but near the outer or rear wall of the building, and

NOTE. — The method of setting this furnace was designed by the writer and has given very satisfactory results where used.

the bottom of the grill is eight feet above the floor. The temperature is regulated by the mixing-valves over the furnace.

A four-inch diameter metallic thermometer with perforated back and sides, placed on the wire grill about two-thirds up from the bottom, half-way between the sides, will be of much service to the teacher in regulating the temperature.

Two or three pieces of ribbon about one-quarter inch wide and about one foot long, tied into the grill just below the thermometer, will enable the teacher to judge of the amount and velocity of the incoming air.

A thermometer, placed at about the level of the pupils' heads, when seated, and located on the partition in rear of the teacher's desk, should be provided; also one for outside use, placed where the sun will not shine directly on it, for the janitor's use.

The small supplementary heater for the corridor or hallway is intended for use in very cold or wet weather, also for drying the pupils' clothing and for a foot-warmer and drier. It also provides for moderately warming the basement. Each warm-air pipe from this heater is provided with a damper. This heater receives its air supply through a galvanized-iron duct and hinged window covered on the outside with stout wire-netting, and draws the air from under the front platform. In the stair risers in front and on each end of the outside front platform are wire-covered openings to admit fresh air to supply the heater.

A register face, 27 by 38 inches, with a hinged door underneath, is provided in the floor of the closet between the two class-rooms, and opens into the cold-air room below for the purpose of rotating the air through the building at night or when the schools are not in session.

The foul air from each school-room is taken from the floor level at the inner or warm corner of the room through a register face (without valves) 27 by 38 inches and a galvanized-iron duct down to the bottom of the foul-air shaft or stack, which it enters through an opening 24 inches high by 30 inches long. A valve or damper operated by a chain from the school-room is provided in each galvanized-iron foul-air duct.

The brick foul-air shaft is 36 by 48 inches inside, and has a brick partition extending across the narrowest way to act as a cut-off and to prevent cross drafts from the ducts. This partition extends above the top of the foul-air entrances and on top of it is placed a cast-iron stove or "stack heater" with its smoke-pipe connected with a separate smoke flue. The fuel door and draft for the stack heater are tended from outside the shaft.

A damper is provided in the smoke-pipe and operated by a rod extending through to the front of the shaft. A manhole door is provided under the stack heater and in the front of the shaft.

The foul air from the corridor or hallway is taken out through a wire grill, 12 by 12 inches, under the sink and directly into the vent shaft; a galvanized-iron deflector, hinged at the bottom and arranged to open or close by a chain and catch is placed at this opening. This vent opening is desirable for removing the foul air and odors from the clothing and preventing them from entering the school-room.

The sanitary closets in the basement are of the individual, short hopper, automatic flushing pattern, having a four-inch diameter seat vent connecting with a duct (increasing in size as each closet is added) to the sanitary vent-flue, which is 16 by 48 inches, inside dimensions.

The boys' urinal is of oiled slate, with perforated flushing pipe at the top and vented into the same vent-flue as the closets.

An underground drain-pipe is provided for the closets and urinal, and connects with a sewer or a double leaching cesspool well in the rear of the building.

No separate vent opening is provided for the basement, as it will be well ventilated through the sanitary fixtures and vent-shaft if the stack-heater which is placed in the sanitary vent-shaft is properly located and a fire maintained therein.

Hose for washing out should be provided and the underground drain thoroughly trapped.

If there is no available water supply for the sanitary fixtures they should be placed outside in a separate building and at a good distance from the school.

A matched board removable porch on the front platform is an advantage in winter and will save fuel.

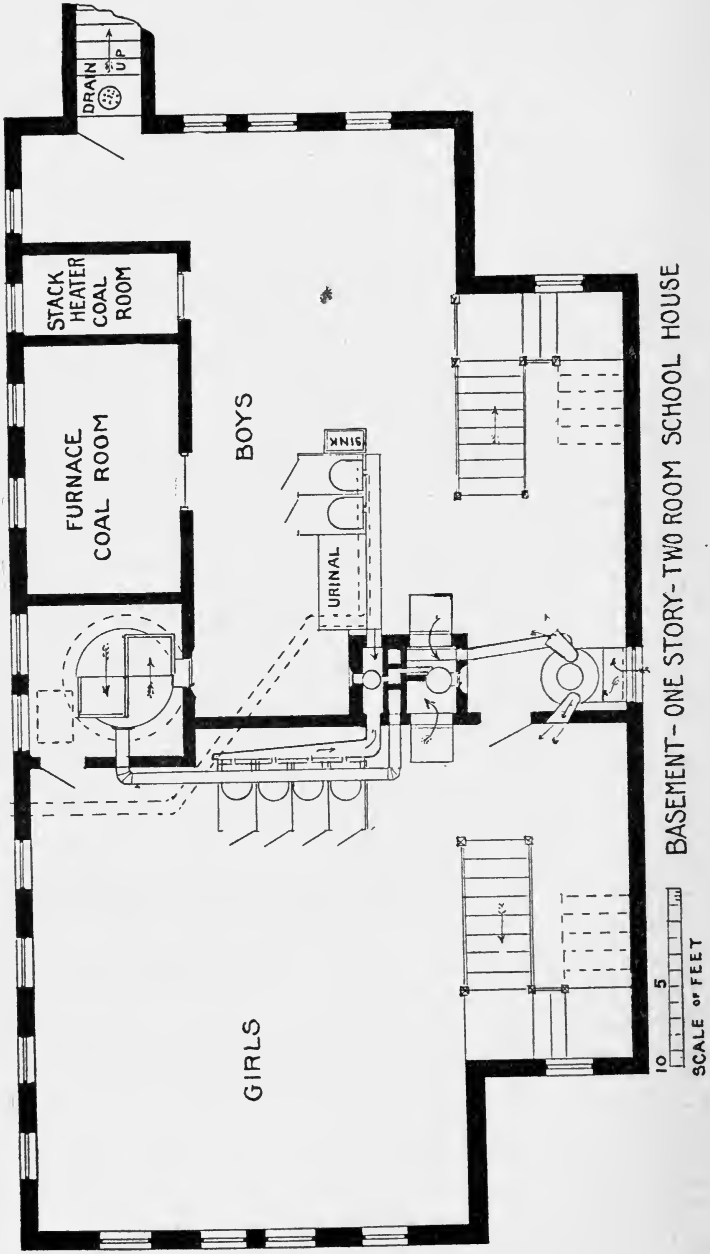
Plates VII, VIII and IX show plans of basement, first and second stories, and a section through vent-shaft for a two-story two-room schoolhouse.

This building belongs to a class of which many were built in Massachusetts some years ago and were practically without ventilation, except by means of windows and doors. They were often heated by wood-burning stoves.

The heating and ventilation of such schoolhouses may be made satisfactory if constructed as shown herein.

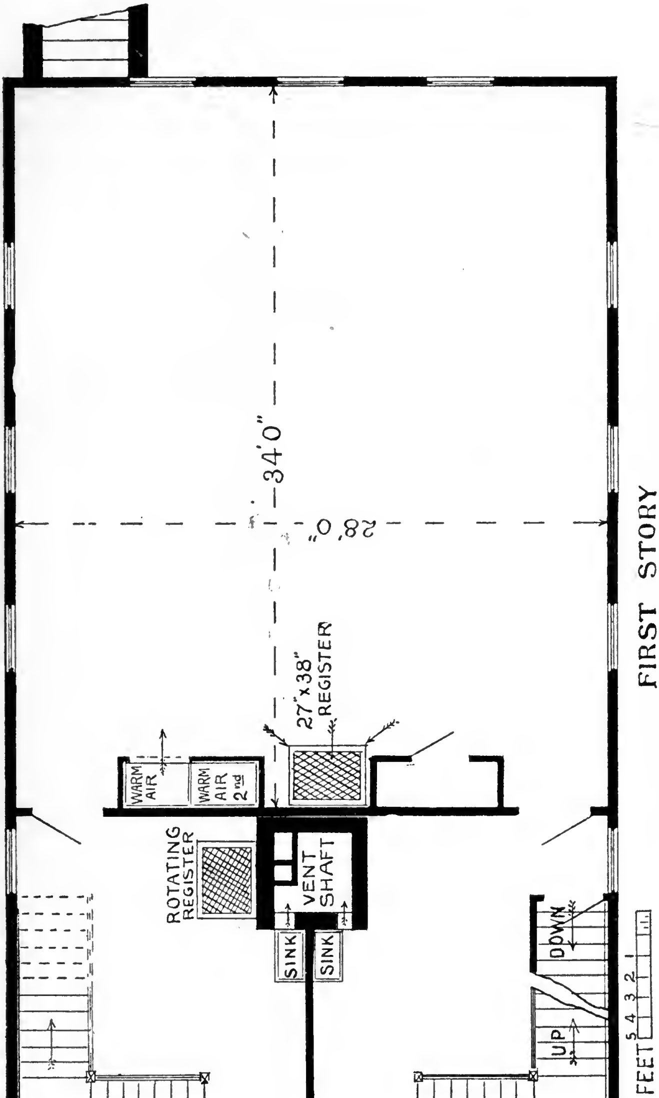
In the basement is located a large brick-set furnace with a brick cold-air room, connected with the outside air by a galvanized-iron

PLATE VII.



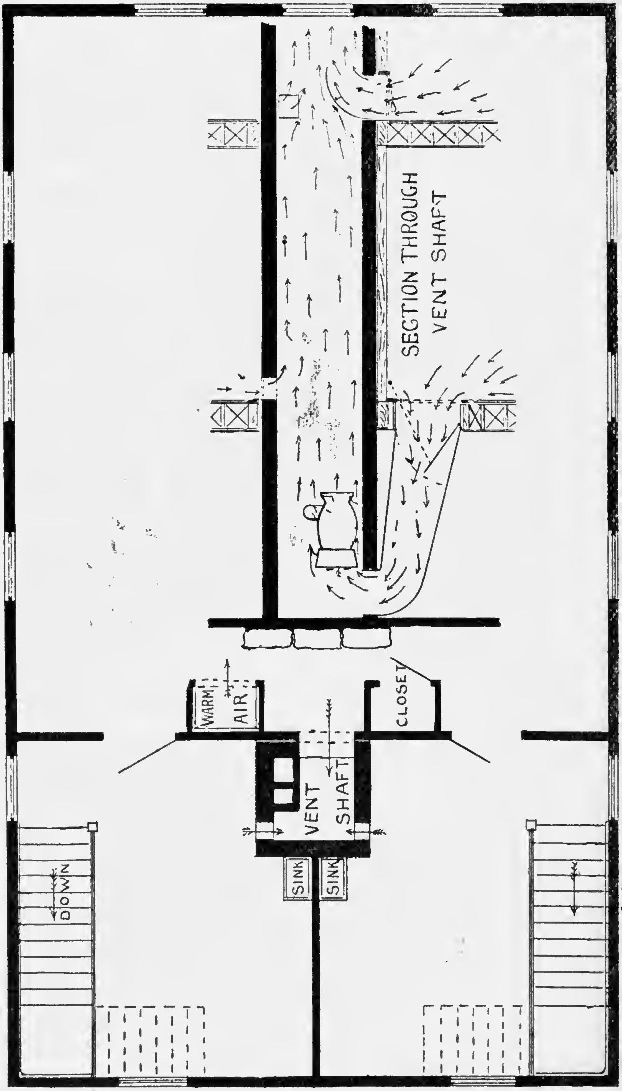
BASEMENT - ONE STORY - TWO ROOM SCHOOL HOUSE

PLATE VIII.



FIRST STORY
TWO ROOM TWO STORY SCHOOLHOUSE.

PLATE IX.



SECOND STORY

TWO ROOM TWO STORY SCHOOLHOUSE

SCALE of FEET 5 4 3 2 1

duct six feet wide by two feet deep. The duct enters at the top of the cold-air room and is provided with a damper and the outer opening is protected by a stout wire grill.

Two galvanized-iron ducts, 24 by 36 inches, supply warm fresh air, one to each class-room. These ducts are provided with mixing-valves or dampers to regulate the temperature of the air for the school-rooms.

The setting of the furnace and arrangement of the warm-air ducts are as shown in plates VII, VIII and IX. In the floor of the first story is a cast-iron register without valves, but provided with a hinged door opening down into the cold-air room for rotating air within the building when the schools are not in session.

The ventilation of the building is by a brick stack, inside of which are the smoke flues. The foul air from the lower school-room is taken down through a cast-iron register face, 27 by 38 inches, in the floor and a galvanized-iron duct, which is gradually reduced in size to where it enters the bottom of the vent shaft, at which point it is 24 by 30 inches area. The register in the floor has no valves, but a damper operated by a chain and catch is provided.

In the vent shaft, placed on iron bars just above the foul-air entrance, is a stove or "stack-heater" to raise the temperature of the outgoing air and produce a good outflow up through the vent shaft.

The stack-heater should always receive its air for draft for the fire from outside the shaft. If the air for the combustion of the fuel in the stack-heater is taken from inside the stack, difficulty will be experienced in keeping the fire burning properly. The air rushing up on the outside of the heater will in a great measure destroy the draft for the fire.

The foul air from the second story is taken directly into the vent shaft through an opening 30 inches long by 24 inches high, the bottom of which is at the floor level.

A galvanized-iron curved damper is provided at this opening, and the opening is covered by a stout wire grill.

The air brought down from the lower room and heated by the stack-heater passes up on the back of the curved damper and causes a good outflow of air from the second-story room. In each clothing room is a 10 by 12-inch opening with a valved register and connecting with the vent shaft.

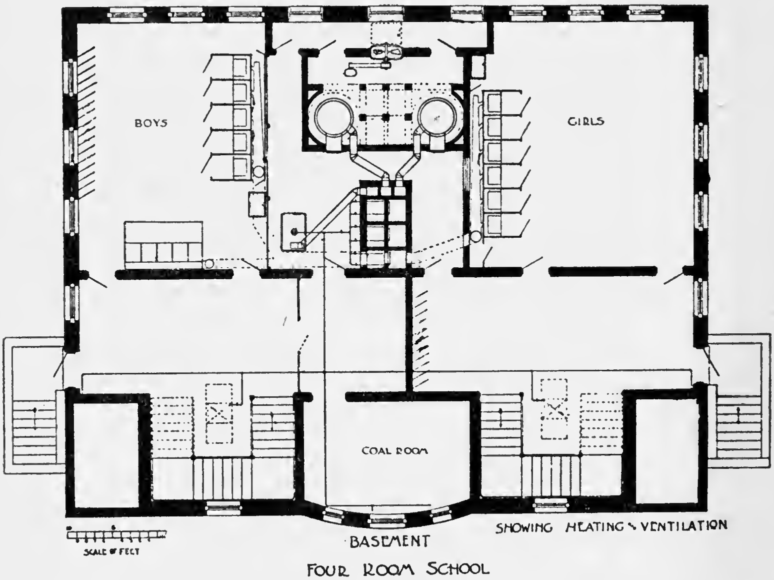
Should it be desired to provide foot-warmers and heat the clothing rooms, it is advisable to use a small furnace (set up about where the small coal-bin is located), which has pipes to the floor of each clothing-room. The supply of air for the small furnace should be taken from outside the building, preferably from under the front platform, which should have openings to freely admit air. A rotating register can also be used with the small furnace.

When an attempt is made to heat the school-rooms and the clothing-rooms from the same furnace it is hardly ever successful.

When the fresh-air supply for the large furnace is shut or partly shut off there will be a reversal of the air currents in the pipes to the lower clothing-rooms, and air will be taken down over the top of the furnace and be carried up into the school-rooms.

Two standard size school-rooms are all that should be heated by a furnace, even if it is a large one.

PLATE X.



Plates X, XI, XII, XIII and XIV.—Plans and sections of the heating and ventilating apparatus for a two-story, four-room schoolhouse, to be built of red brick with granite trimmings, slate roof, and copper gutters.

In the basement, which is 10 feet 6 inches high and well lighted, are located the heating apparatus, fuel-room, cold-air room, sanitary fixtures and rooms for boys and girls, also bicycle racks.

PLATE XI.

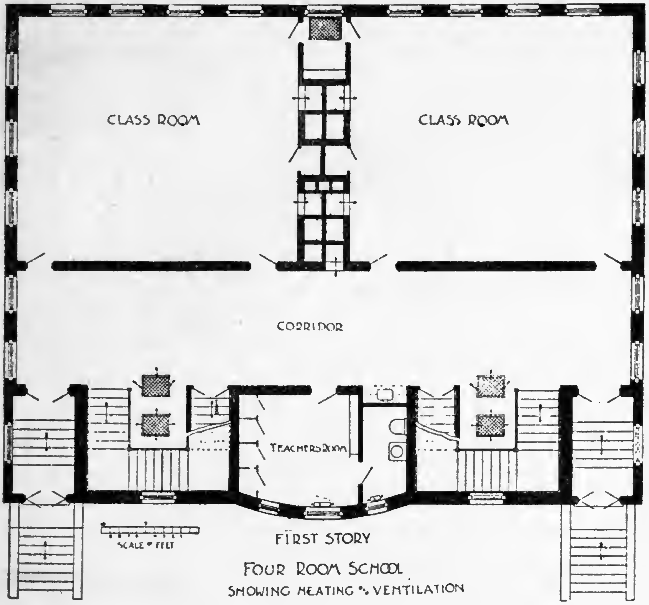


PLATE XII.

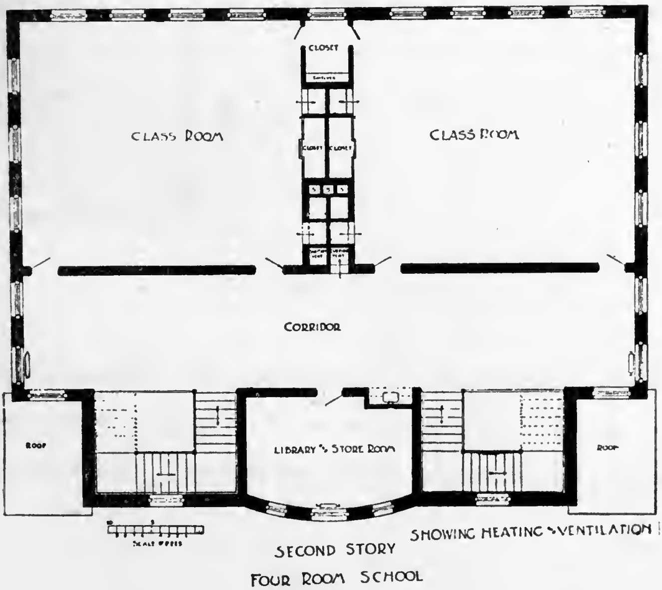


PLATE XIV.

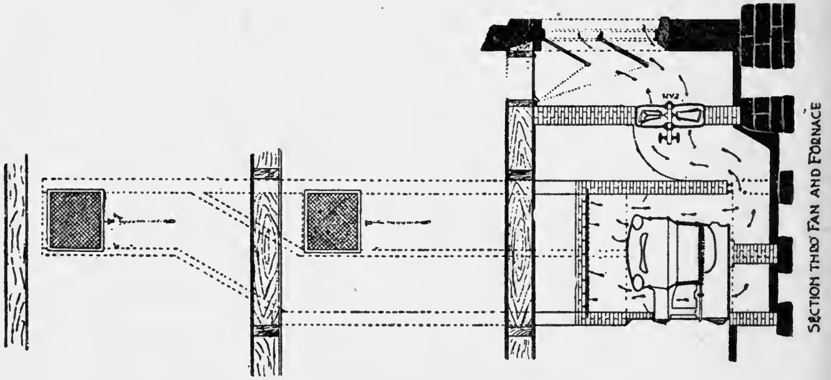
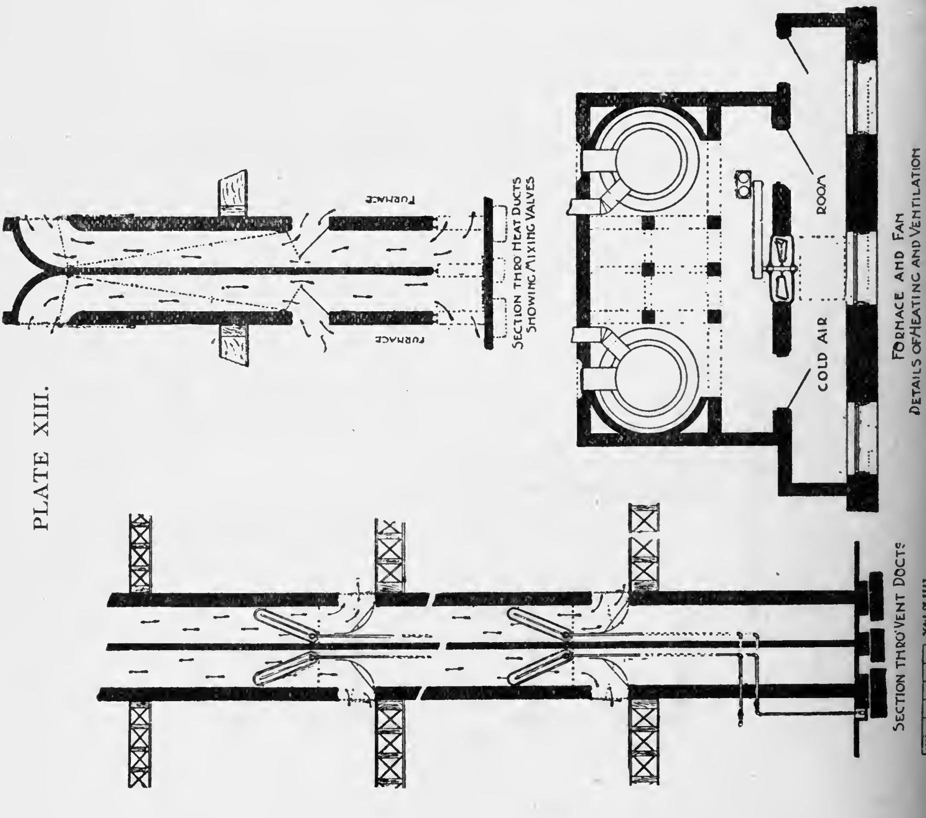


PLATE XIII.



Bicycle runs are provided at each outside basement entrance. A well-trapped sink is placed in each basement room.

The basement floor is of concrete and covered with Portland cement.

On the first floor are two class-rooms 28 by 32 by 12 feet, intended to accommodate 49 pupils each, well lighted and the seats to be so arranged that the light will come from the left and rear of the pupils. There is also a small room for use of the teachers. Suitable closets are provided in each class-room and in the teachers' room.

In the second story are two class-rooms similar to those in the first story, also a small room that can be used as a library or store-room, or as a superintendent's room.

The corridors are 15 feet wide and well lighted; clothing is hung on racks on the school-room side.

The heating for the class-rooms is done by two large-size brick-set furnaces. The corridors and two small rooms are heated by a small sectional cast-iron boiler, which is also intended to furnish heat for the ventilating flues. Foot-warmers heated by the boiler are placed in the floor of the lower corridor, for use in cold or wet weather.

A disc fan, operated by an electric motor, is provided for furnishing an abundant supply of fresh air in mild or moderately warm weather. In cold or windy weather the furnaces are to be used by the gravity system.

If electricity is not available for running the fan it can be omitted, also the partition wall in which the fan is located. In such case the furnaces can be placed three feet nearer the rear wall.

In cold weather, when it is desirable to quickly warm the class-rooms before the school session begins, the outside windows in the cold-air room and the dampers in the school-room and in the corridor vents being closed, the rotating register in the floor of the closet between the two lower class-rooms and all the doors in the class-rooms opened, the motor is started and the air is rotated through the building.

If no fan is installed, the same arrangement of cold-air windows, dampers, rotating register and doors should be made and the air rotated by gravity.

Before the school session commences or the pupils are admitted to the building, the vent-dampers should be opened, the rotating register and doors closed and the cold-air windows opened. Under no conditions should the rotation of air through the building be allowed while the schools are in session.

When using the fan during school hours, two windows and the doors in the partition in the cold-air room should be closed, the air taken in through the middle window opposite the fan and driven through the fan-opening. When using the gravity system all three windows and the two doors in the partition should be opened.

The fresh warm-air flues for the class-rooms are of brick, 24 by 36 inches (area six square feet), and have mixing-valves or dampers, operated by chain, catch and pulley, by means of which the temperature of the incoming air can be properly regulated by the teachers without materially decreasing the volume.

The vent-flues for the class-rooms are of brick, 24 by 30 inches (area five square feet). The vent-flues, with the exception of the sanitary vents, have curved galvanized-iron dampers, operated by chain and catch. The sanitary vents should not be closed at any time.

In each vent-flue, except the corridor vent, there are placed four sections, of five square feet each, of cast-iron radiators. These are placed just above the top of the inlet vent, spaced and inclined up and across the flue. In the corridor vent there are but two sections, or ten square feet of radiation.

These radiators are connected with the small boiler and separately valved on each supply and return pipe.

At night, or when the building is not occupied, the steam is shut off from the vent-flue radiators and the vent dampers closed.

In extremely cold or windy weather it will not be necessary to keep steam on the vent-flue heaters, and in some cases of this kind the dampers can be *partly* closed, but in mild, calm or warm weather steam should be kept on these heaters.

The use of unsightly, costly and often worse than useless deflectors, diffusers and flap-valves is rendered unnecessary by properly locating the supply and vent-flues and having them of ample size and properly valved.

The success of any system of heating and ventilation depends considerably on the good judgment of the janitor in operating the apparatus, and he should be carefully instructed in his duties.

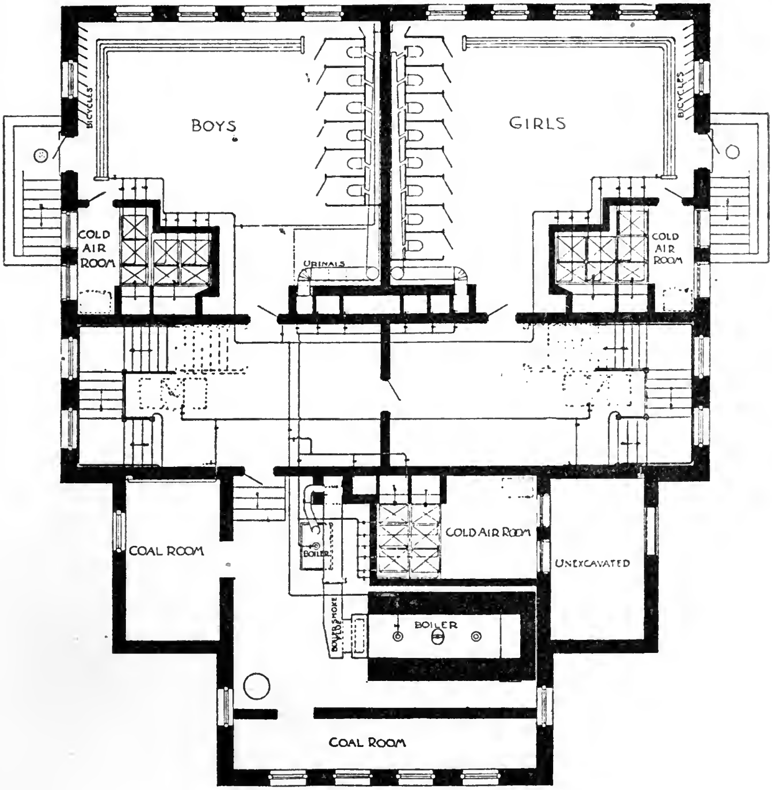
The teachers should also be instructed in the manner of operating the mixing-valves or dampers in the warm-air flues and the dampers in the vent-flues.

Plates XV, XVI and XVII.—Plans for a two-story five-room school building and for the heating and ventilation of the same.

The building is to be constructed of red brick with granite trimmings, slated roof and copper gutters.

There are four class-rooms and one large assembly-room or hall, which can, if desired, be divided into two class-rooms; also two

PLATE XV.



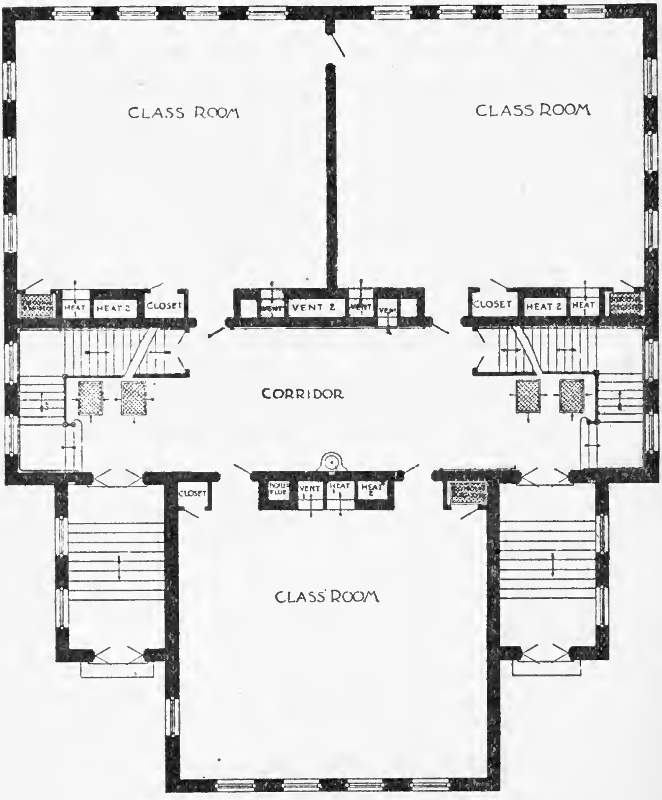
·FIVE ROOM SCHOOL BASEMENT·
·SHOWING·HEATING·AND·VENTILATION·

small rooms in the second story for the use of the teachers. In the basement, which has a concrete floor with a covering of Portland cement, are two sanitary rooms, cold-air rooms, boiler rooms and fuel rooms.

The class-rooms are of standard size, 28 by 32 by 12 feet, intended to accommodate 49 pupils each. Transoms are over each door, except in the basement. The doors from the class and assembly-rooms open into the corridors, and each has a large glass panel in the center to enable the teachers to see into the corridors.

The corridors are 15 feet wide, with special racks on the walls for clothing.

PLATE XVI.

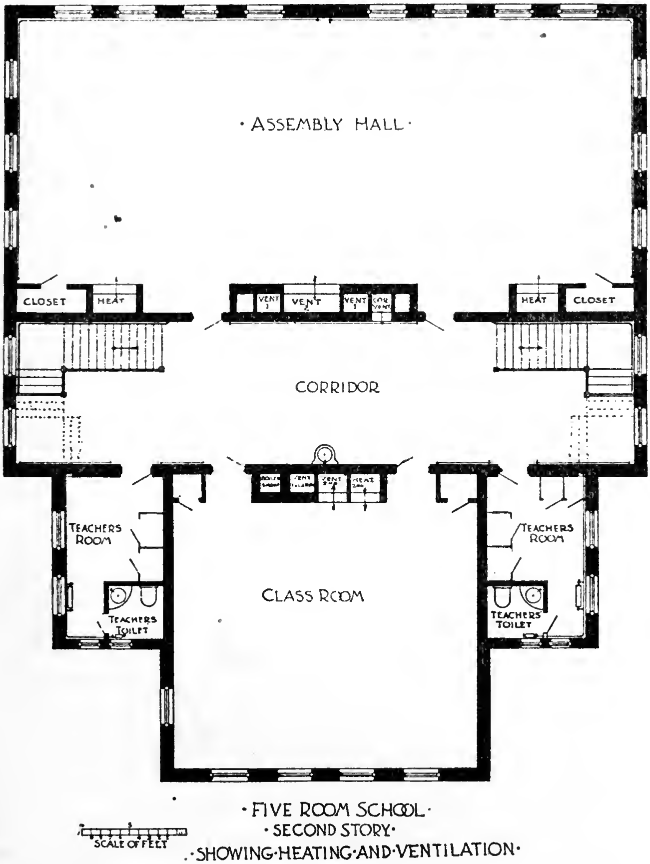


·FIVE ROOM SCHOOL·
FIRST STORY·
SHOWING·HEATING·AND·VENTILATION

The warm fresh air is admitted into the class-rooms through openings covered by wire grills 36 by 30 inches. The bottom of these openings is eight feet above the floor. In the assembly room the grills are 54 by 30 inches. The warm-air flues to the class-rooms are 36 by 24 inches (six square feet), and in the assembly room are 54 by 24 inches each. Each warm-air flue is provided with a galvanized-iron damper or mixing-valve to regulate the temperature of the incoming air without materially decreasing the supply.

The foul air is taken out at the floor level through wire grills, 30 by 24 inches (five square feet). In the assembly room the outlet grill is 72 by 24 inches (12 square feet).

PLATE XVII.



·FIVE ROOM SCHOOL·
·SECOND STORY·
·SHOWING·HEATING·AND·VENTILATION·

Each foul-air outlet vent, except the sanitary vents, is provided with a galvanized-iron damper to regulate the outflow or shut it off when the building is not occupied.

In each class-room vent-flue are placed four sections of cast-iron smooth-surface radiators, each having five square feet of radiating surface (a total of 20 square feet). In the assembly-room vent-flue are placed nine sections (45 square feet) of the same kind of radiators. These radiators are placed about one foot above the top of the vent opening from the room, evenly spaced, and inclined upward and across the flue.

A vent-flue, 24 by 24 inches inside measurement, is provided for the corridors, both corridors venting into the same flue, and 15 square feet of radiation is placed above the lower corridor vent opening.

The sanitary vent-flues are each 20 by 24 inches and contain 15 square feet of radiation.

The heating is by a horizontal tubular boiler, 54 inches in diameter, 15 feet 3 inches long, containing 60 three-inch tubes, 14 feet long, and rated at 48 horse-power.

A small sectional boiler is also provided for heating the vent-flues when the large boiler is not in use.

The piping for the vent-flues is so connected that either the large or small boiler can be used as desired. Each vent-flue heater is separately valved, both on the supply and return pipes.

The radiation for each class-room consists of 400 square feet of cast-iron indirect pin radiators, of 20 square feet per section, made into three stacks of 120, 140 and 140 square feet — one section, two sections or three sections to be used as may be required. Each section is to be separately piped and valved.

The assembly-hall has two distinct groups of indirect radiation, 480 square feet each, and each group is made up of four stacks, separately piped and valved. Around the outside walls are two lines of one-and-one-fourth-inch steam-pipe for use when the assembly-hall is not occupied.

Two foot-warmers, each of 120 square feet, of the same kind of radiation used for the class-rooms, are provided in the lower corridor.

Two lines of one-and-one-fourth-inch steam-pipe are also provided in the corridors and placed under the clothing racks for drying the clothing in stormy weather.

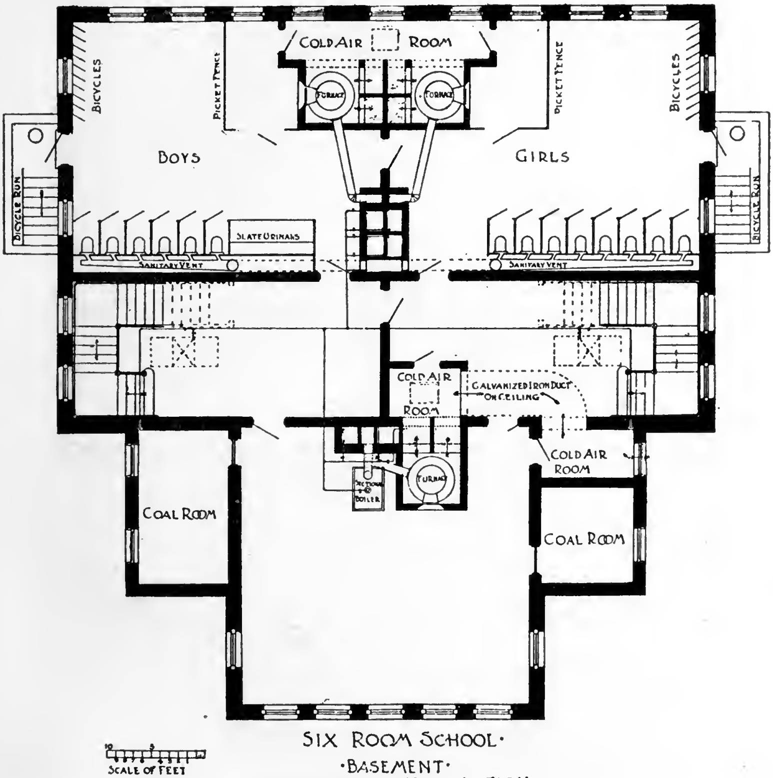
The sanitary rooms are heated by four lines of one-and-one-fourth-inch pipe, placed near the ceiling.

Direct radiators are placed in the teachers' rooms and toilets.

In the floor of a closet in each class-room is placed a register connecting with the cold-air room below. A tight-fitting shutter of galvanized iron is placed below the register to shut off the cold air from below when the register is not open. These registers, called rotating registers, are for rotating the air through the building when the schools are not in session. This is done as previously stated in the description of a two-story four-room school building.

The ventilation of the sanitary rooms and basement is through the fixtures, each closet having a four-inch diameter seat vent

PLATE XVIII.



SIX ROOM SCHOOL·
·BASEMENT·
·SHOWING HEATING & VENTILATION·

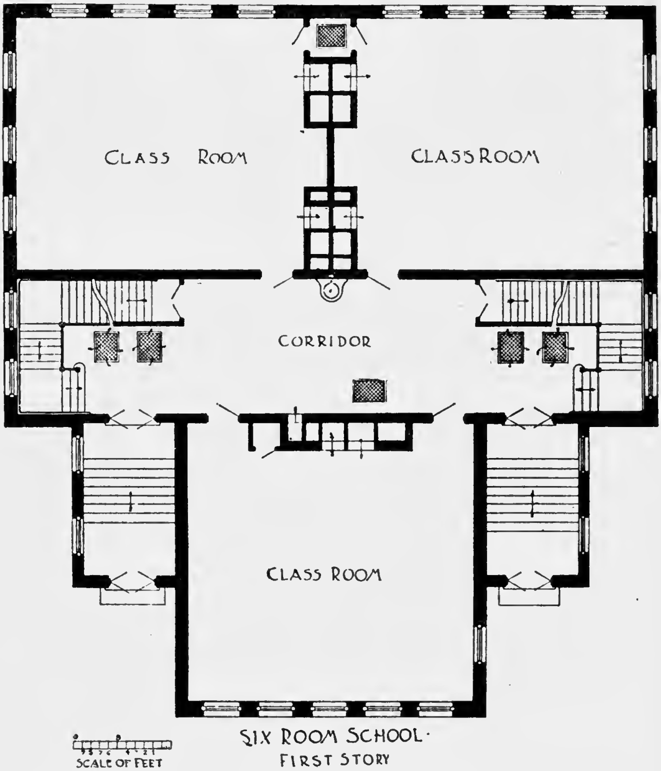
connected with a galvanized-iron duct leading from each line of closets and from the urinal to a steam-heated vent-flue.

The air from the sanitary rooms being taken out through the closets and urinal vents prevents odors passing out from these rooms up into the building, as is sometimes the case when the room is vented by an outlet separate from that provided for the sanitary fixtures, or where air is forced into the sanitary room by a fan or gravity supply from the heating system.

A plenum condition should never be allowed in such rooms. An exhaust should be used instead of a plenum.

Sufficient air will be supplied to keep the sanitary rooms free from odors, if taken into the sanitary rooms through a wire grill placed in the bottom of the doors leading from the basement corridor, and if the sanitary-vent flues are properly heated.

PLATE XIX.



SIX ROOM SCHOOL·
FIRST STORY
·SHOWING HEATING & VENTILATION·

Plates XVIII, XIX and XX. — Plans for a six-room school building and for its heating and ventilation.

The building is to be constructed of red brick with terra-cotta trimmings, slated roof and copper gutters.

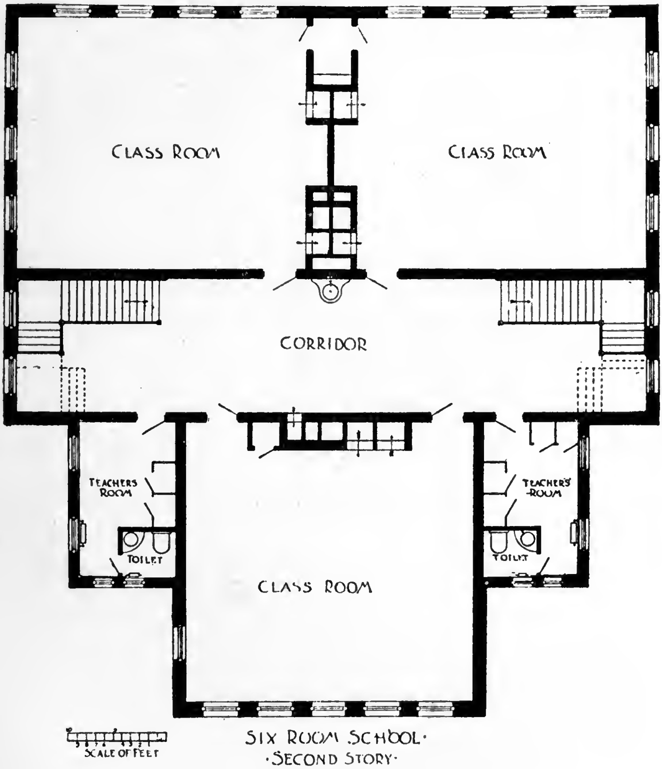
There are six class-rooms, each 28 by 32 by 12 feet and intended to accommodate 49 pupils. In the second story are two small rooms for the teachers' use.

The seats in four class-rooms are to be arranged to receive the light from the left and rear, and in two class-rooms the light is chiefly from the left.

The corridors are 15 feet wide and contain the clothing racks. Doors from the corridors to the class-rooms have each a large center panel of heavy glass, and transoms are provided over the doors.

In the basement are three rooms, a divided corridor, fuel and cold-air rooms.

PLATE XX.



SIX ROOM SCHOOL·
·SECOND STORY·
·SHOWING HEATING & VENTILATION·

The fresh warm-air flues and the vent-flues for the class-rooms are of the same size and fitted with mixing-valves, dampers and steam radiation, as previously described for a four or five-room school-house, except that the sanitary vent-flues are 24 by 24 inches area.

Rotating registers are also provided.

There are two foot-warmers in the lower corridor.

The general plan of the building is the same as that given for a five-room school, except that the assembly hall in the five-room building is replaced by two class-rooms, and the heating is by a combination of furnaces and steam heat. The six class-rooms are heated by three large brick-set furnaces, two rooms for each furnace. A cast-iron sectional boiler is provided for heating the corridors, vent-flues, foot-warmers and teachers' rooms.

If desired, the boiler may be of sufficient size to warm the basement rooms by lines of one-and-one-fourth-inch steam-pipes placed near the ceiling.

By the use of this boiler very satisfactory results are obtained, and the number of fires reduced from what would be required if coal-burning stack-heaters and an additional furnace were used to heat the corridor and vent-flues.

Plates XXI, XXII, XXIII, and XXIV. — Plans for a grammar school building.

The building is to be constructed of light mottled brick with granite trimmings and slated roof, containing six class-rooms, one recitation-room, a manual-training room, two teachers' rooms, two sanitary rooms, boiler-room, coal-room and three cold-air rooms, besides the corridors and stairways. There are four class-rooms each 28 by 32 by 12 feet, two class-rooms 29 by 32 by 12 feet, each accommodating forty-nine pupils. The basement is twelve feet high, except the boiler-room and coal-room, which are two feet deeper, or fourteen feet in the clear. The basement entrances are built with a bicycle run to take bicycles down to the places provided for them.

The corridors are fifteen feet wide, with walls of smooth water-struck brick without wood finish, being painted with light-colored gloss paint. Clothing is to be hung on special racks fastened to the walls, and there are two lines of 1¼-inch steam-pipes below the racks and near the floor for drying and warming clothing in bad weather. Two foot-warmers are provided in the lower corridor. The heating is done by a two-pipe gravity return steam system.

The two teachers' rooms are heated by direct radiators, the manual-training room in the basement by four lines of 1¼-inch steam-pipe near the ceiling and also by indirect radiators.

The boys' and girls' sanitary rooms are to be heated by four lines of 1¼-inch steam-pipe near the ceiling, and ventilated through the sanitary fixtures, the seats having 4-inch diameter vents connecting with steam-heated vent-flues, with which the boys' urinal is also connected. Air is drawn into these rooms through wire grills in

PLATE XXI.

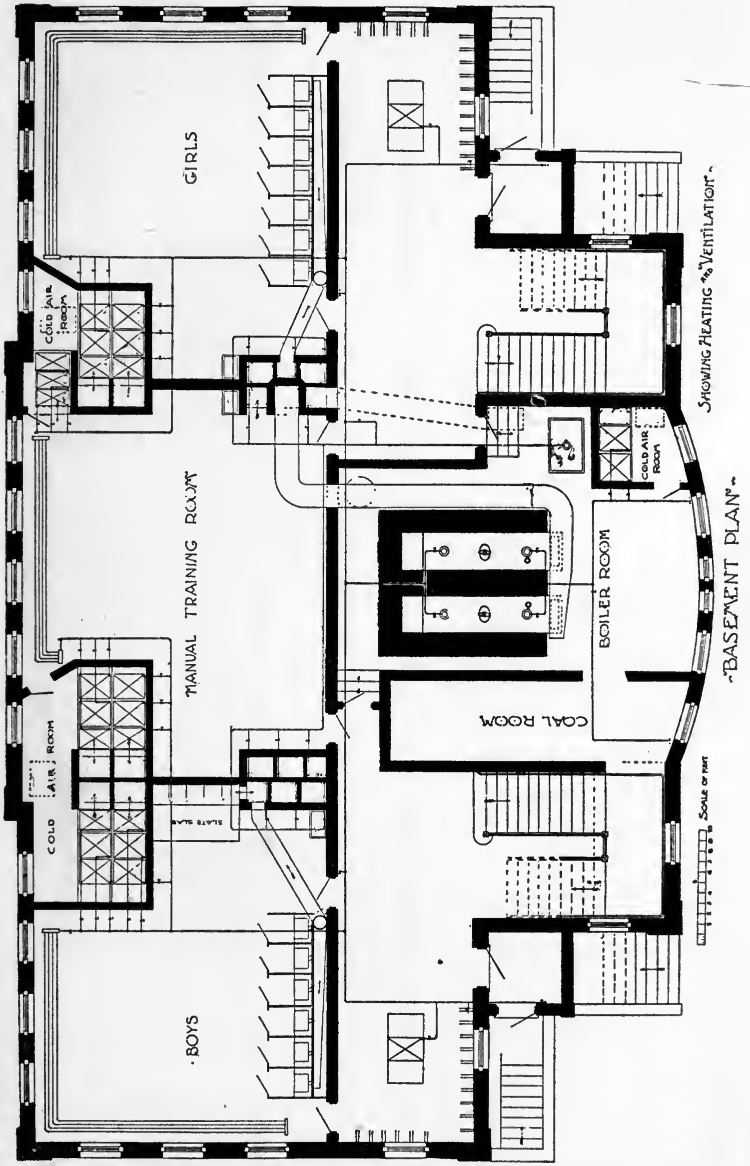
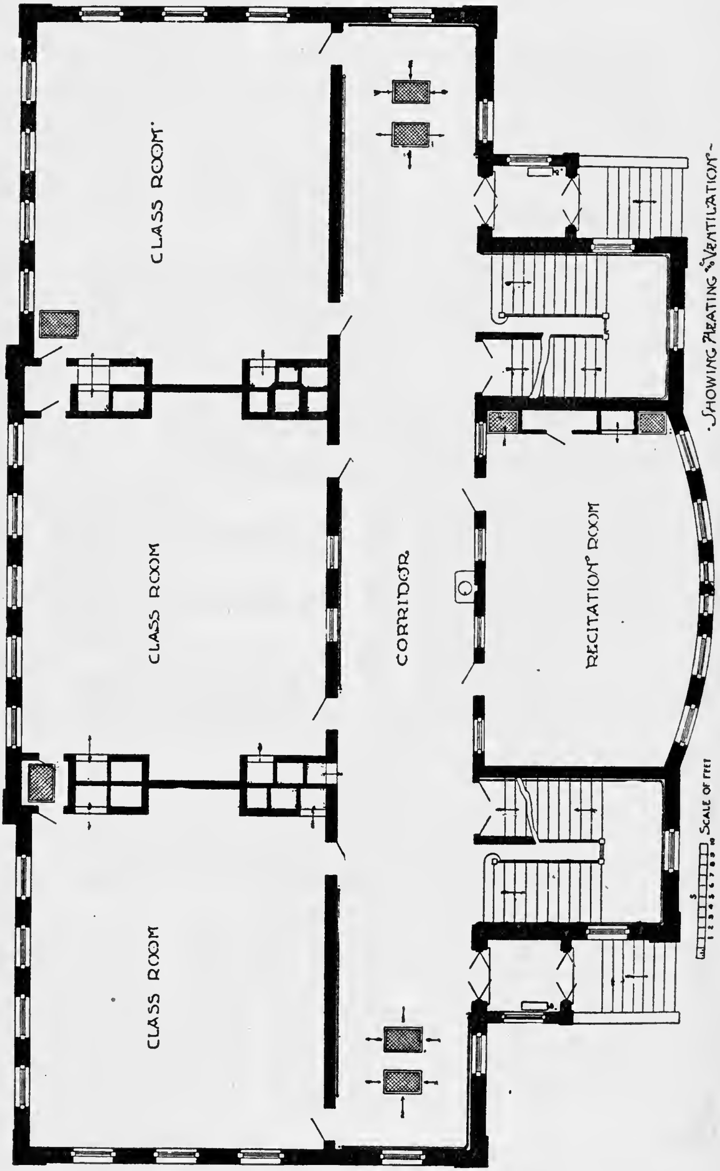
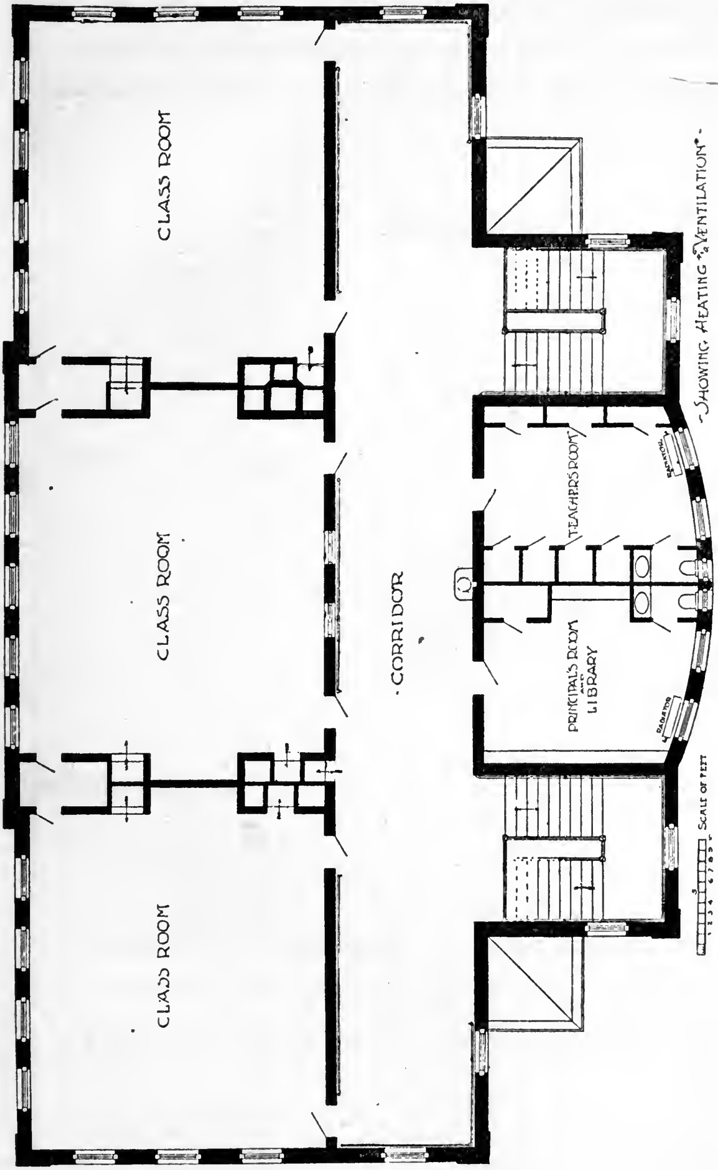

GIRLS
COLD AIR ROOM
MANUAL TRAINING ROOM
COLD AIR ROOM
BOYS
BOILER ROOM
COLD AIR ROOM
COAL ROOM
SHOWING HEATING AND VENTILATION
"BASEMENT PLAN"
GRAMMAR SCHOOL
SCALE OF FEET

PLATE XXII.



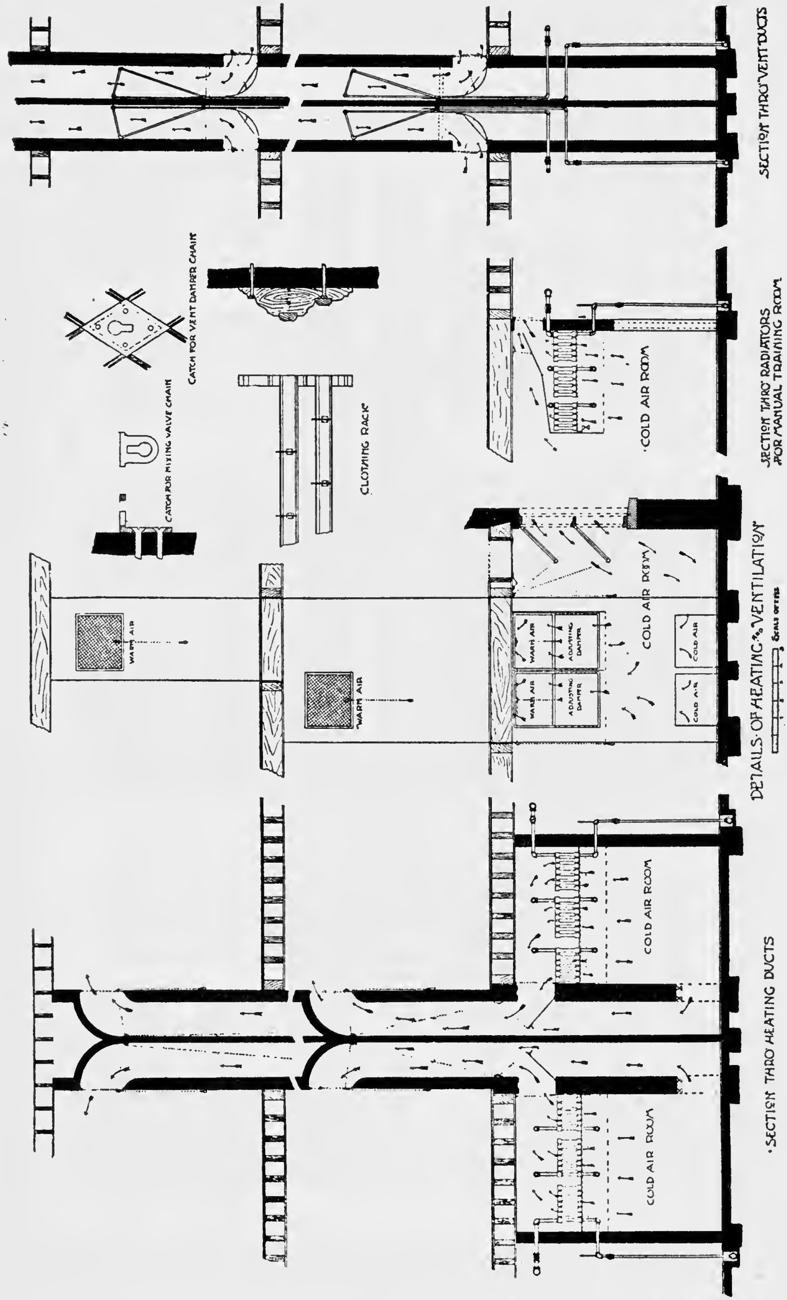
FIRST STORY PLAN
GRAMMAR SCHOOL
-SHOWING HEATING & VENTILATION-

PLATE XXIII.



SECOND STORY PLAN
GRAMMAR SCHOOL
SHOWING HEATING & VENTILATION

PLATE XXIV.


SECTION THRO' VENT DUCTS
CATCH FOR VENT DAMPER CHAIN
CATCH FOR MIXING VALVE CHAIN
CLOTHING RACK
COLD AIR ROOM
SECTION THRO' RADIATORS FOR MANUAL TRAINING ROOM
WARM AIR
ADJUSTING DAMPER
COLD AIR
COLD AIR ROOM
DETAILS OF HEATING AND VENTILATION
COLD AIR ROOM
COLD AIR ROOM
SECTION THRO' HEATING DUCTS

the bottom of the corridor doors, and the natural leakage around the windows and the removal of the foul air through the seat and urinal vents will properly ventilate these rooms and prevent odors from passing up and into the building.

In the floor of the first story are three rotating registers for rotating the air through the indirect radiators when the schools are not in session. The air for the foot-warmers is rotated from the corridor at all times. A vent is provided in each corridor, both corridors being vented into the same shaft. Direct radiation is provided in each vestibule.

The warm-air flues to the class-rooms are 24 by 36 inches in cross-section, and enter the rooms eight feet above the floor through openings covered by a wire grill 36 by 30 inches. Each warm-air flue is fitted with a mixing-valve or damper for regulating the temperature of the incoming air.

An adjusting damper is also provided for each warm-air flue for regulating the amount of air for each room, as this will vary according to the height of the flue or its location with regard to the prevailing winds.

Each vent-flue, except the sanitary, is to be provided with a galvanized-iron damper for regulating the outflow of air.

In each class-room vent-flue there is twenty square feet of radiating surface of 1¼-inch steam-pipe made into the form and placed as indicated in the section showing the vent-flues.

The vent from the recitation room is carried down and through a galvanized-iron duct (No. 24 gauge iron) on the basement ceiling to the brick vent-flue for this room, which should have twenty-five square feet of steam-pipe radiation, placed about on a level with the floor of the first story.

Each sanitary vent has twenty square feet of the same kind of radiation.

The building is to be heated by two horizontal tubular boilers of 27 horse-power each, and a cast-iron sectional boiler for heating the vent-flues when the larger boilers are not in use in moderately warm weather. These sectional boilers are generally designated "summer boilers." The boilers are to be so piped and valved that either or all of them can be used as desired.

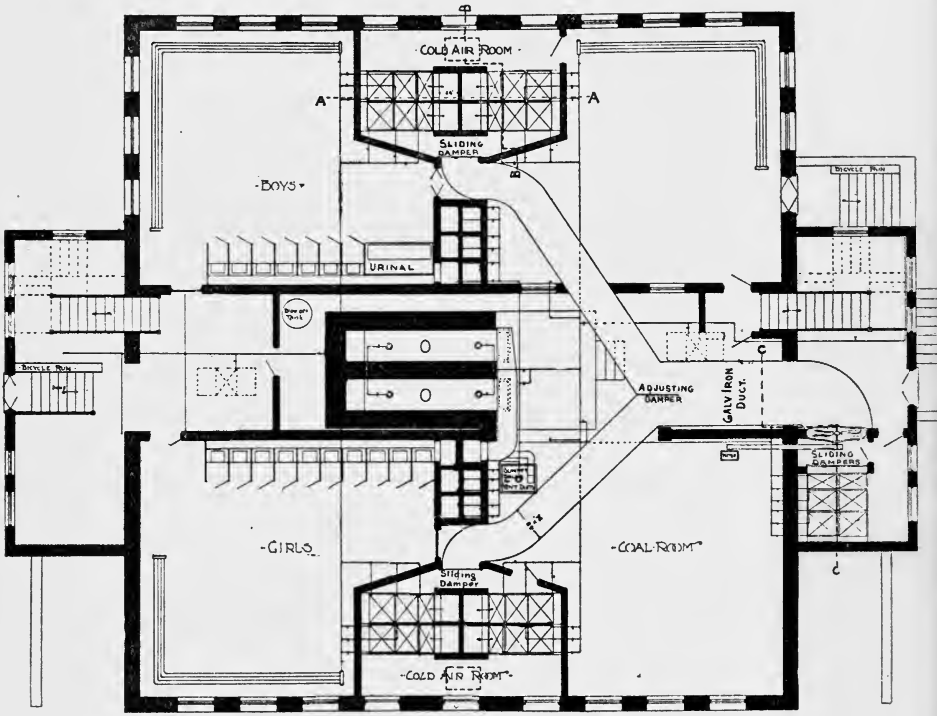
The recitation-room is to have 300, the two middle class-rooms 380, and the four corner class-rooms 400 square feet of cast-iron indirect radiation of twenty square feet per section, made into three sections for each stack, separately piped and valved, in order that the amount in use can be regulated according to the weather. The vent-flue heaters are to be separately valved and piped.

Hand bowls and faucets are provided in the first and second story corridors and cast-iron sinks in the boys' and girls' sanitary rooms, bowls and sanitary fixtures in the teachers' rooms in the second story. Mirrors are placed over the bowls and sinks for the pupils' use and in the teachers' toilets.

Hose is to be provided for use in the basement. It is advisable to install a stand-pipe and hose in the basement and each corridor for use in case of fire.

Sections are given showing the arrangement of the indirect radiators, mixing-valves and warm-air flues, the foul-air flues, heaters and dampers, adjusting dampers, rotating register and windows in the cold-air rooms, clothing racks and the catches for holding the chains for the mixing-damper and vent dampers.

PLATE XXV.



BASEMENT SHOWING HEATING & VENTILATION

Scale of Feet

EIGHT ROOM SCHOOL

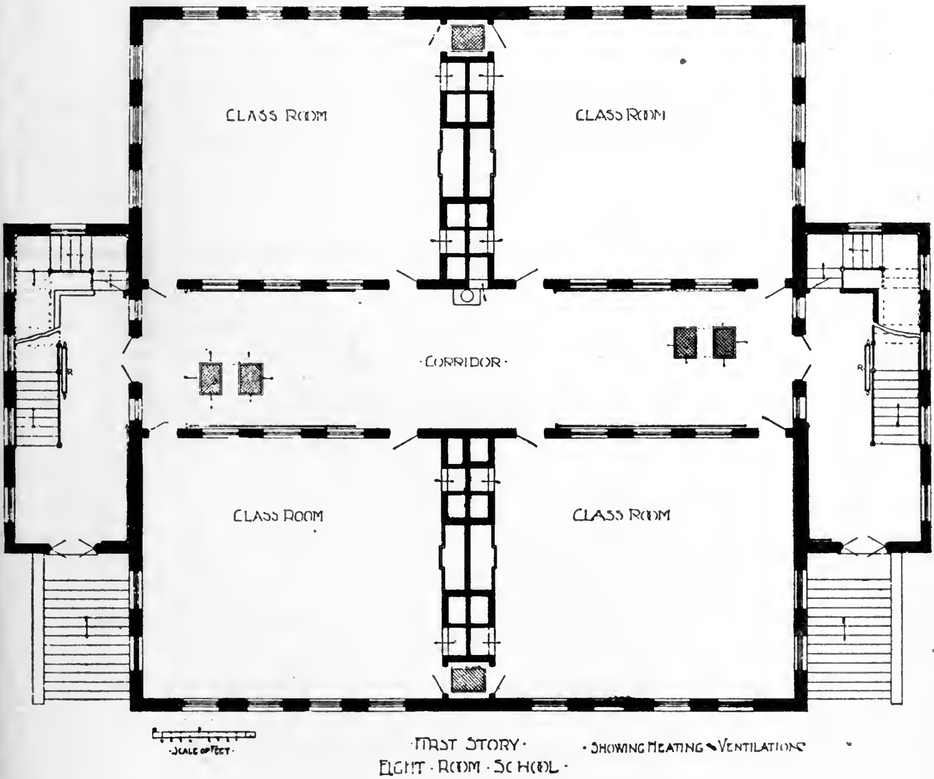
Plates XXV, XXVI, XXVII and XXVIII.— Plans for a two-story, eight-room, brick school building, showing the heating, ventilating and sanitary appliances.

A combination of the gravity and mechanical systems of heating and ventilation is used.

In the gravity system there are 400 square feet of indirect cast-iron heating surface for each school-room. This is divided into stacks of 100, 140 and 160 square feet for each class-room, separately piped and valved, in order that either a part or the whole can be used as desired, and is sufficient to meet the requirements of heating and ventilation in the coldest weather that occurs in Massachusetts.

Fresh air is admitted through the windows in the two cold-air rooms in the basement, when the gravity system is in use (the ducts

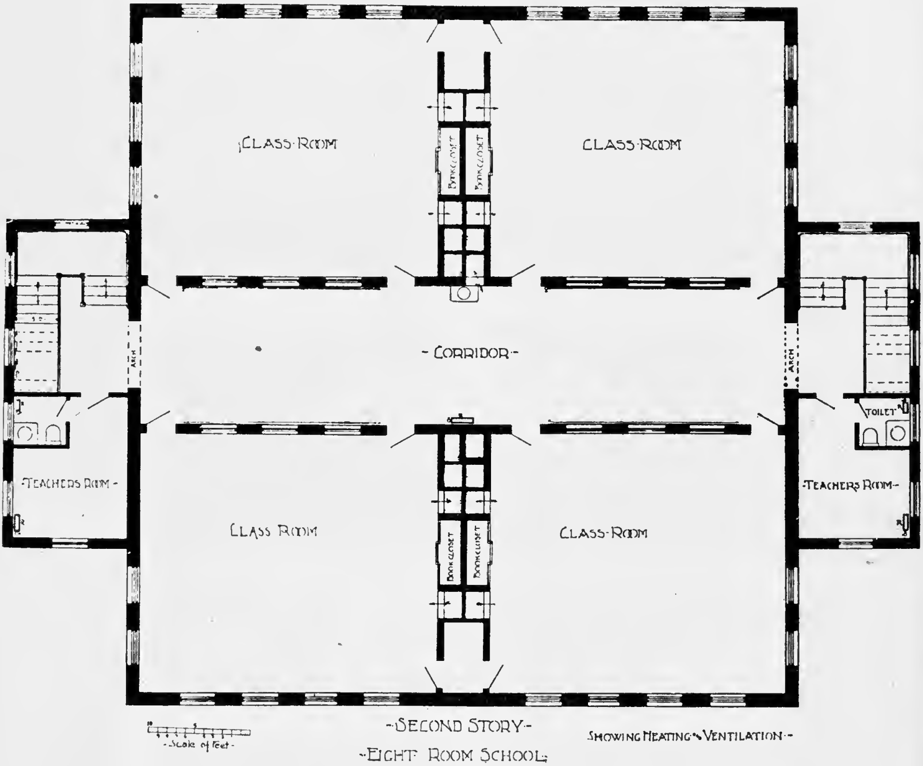
PLATE XXVI.



leading from the fan being then closed) in cold weather, when the difference between the inside and outside temperature is sufficient to furnish a full supply of warm, pure air by gravity flow.

In the floor of the closet between the rooms on each side of the lower corridor there is a rotating register connecting with the cold-air rooms below.

PLATE XXVII.

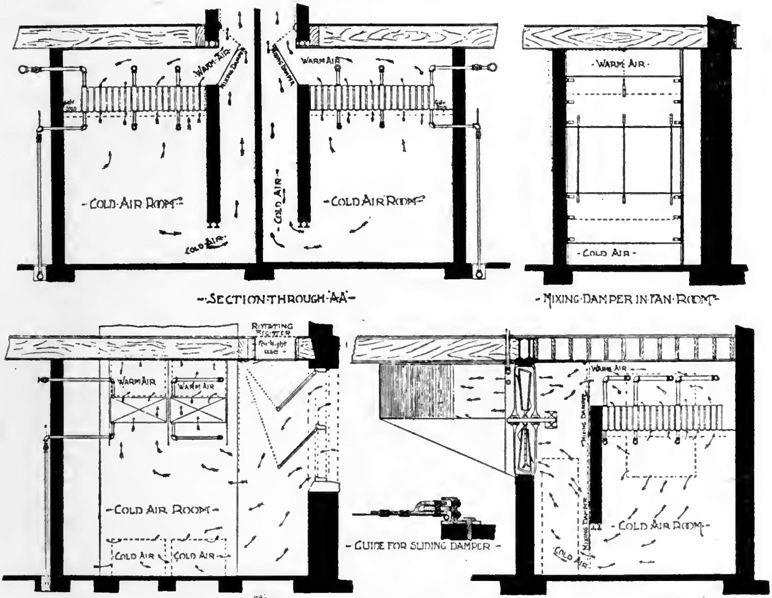


In the basement of one of the corridor extensions there is also a supplementary means of supplying air by a fan driven by an electric motor, and 800 square feet of indirect cast-iron radiation, divided into sections of 100, 140 and 160 square feet, as in the other cold-air rooms.

This part of the apparatus is intended to be used in moderate and calm weather, when the requisite supply of fresh air is not easily obtained by the gravity system without overheating, especially in the spring and fall months.

When in use the windows leading from outside directly into the gravity cold-air rooms are to be closed, and the sliding damper at the entrance of the galvanized-iron ducts into the gravity cold-air rooms opened, the windows in the cold-air corridor extension basement opened and the fan run by the motor, the air either passing through the heated radiators, or, by means of a specially designed damper, going to the fan without passing the radiators. This

PLATE XXVIII.



- SECTION THROUGH BB - DETAILS FOR HEATING & VENTILATING - SECTION THROUGH C C -
EIGHT ROOM SCHOOL

damper can be used as a mixing damper to regulate the heat and allow more or less warm or cold air to pass the fan as may be desired.

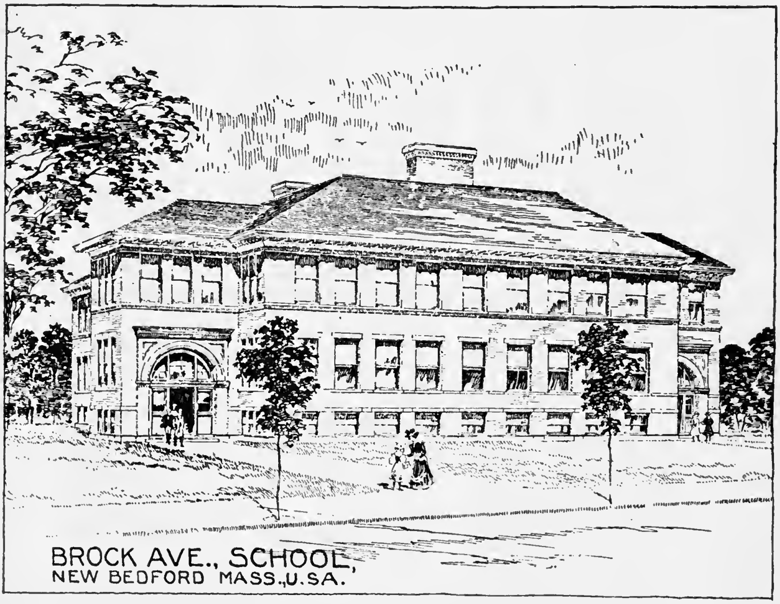
A four-inch diameter metallic thermometer, placed in the side of the galvanized-iron duct leading to the air rooms at the bottom of the warm-air flues, which go to the schoolrooms, will enable the janitor to regulate the temperature of the air sent from the fan. Should it be desired to use the fan when the air is colder than the fan radiation can properly warm, a portion of the radiation in the other cold-air rooms can be used to good advantage.

By the use of this combination system forty cubic feet of air per minute can be supplied for each pupil under all conditions of temperature.

While it may add somewhat to the first cost of the building, the effective work will more than make up for the extra first cost.

If electric power is not available, the fan may be run by an engine having a large diameter, low-pressure cylinder. This, however, will require a change in the piping and setting up of this part of the apparatus, and a small boiler of sufficient size to run the

PLATE XXIX.



engine and also furnish (at a reduced pressure) steam for the vent-flue heaters when the larger boilers are not in use.

In addition to the two horizontal tubular, a cast-iron sectional boiler is supplied for heating the vent-flues when the electric motor is used or when the larger boilers are not fired up.

The warm-air flues and the vent-flues are of the same size and location, and similarly provided with dampers and heat, as previously described for other school buildings.

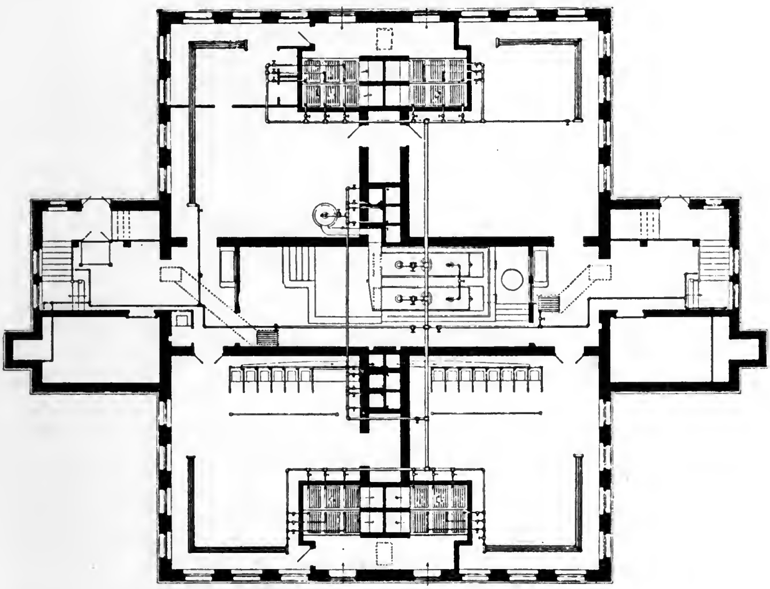
Sections are given showing cold-air rooms, indirect radiators, mixing-dampers and fan.

Plates XXIX, XXX, XXXI and XXXII.—Perspective and plans for an eight-room schoolhouse.

This schoolhouse is in the city of New Bedford, C. Hammond and Sons being the architects, and is a two-story building constructed of red brick with granite trimmings; the roof covered with black slate.

It contains eight class-rooms and two teachers' rooms, also wide corridors and vestibules. In the basement are located play rooms and sanitary rooms for the pupils, a room for the janitor, boiler

PLATE XXX.



'BASEMENT PLAN BROCK AVE., SCHOOL, NEW BEDFORD, MASS., U.S.A.

and fuel rooms, together with fresh-air chambers and the indirect steam-heating radiators and boilers.

The class-rooms are intended to accommodate 49 pupils and teacher, a total of 50. They are well lighted, the pupils' seats and desks being so placed that the light is received from the left and rear.

The blackboards are of best black slate.

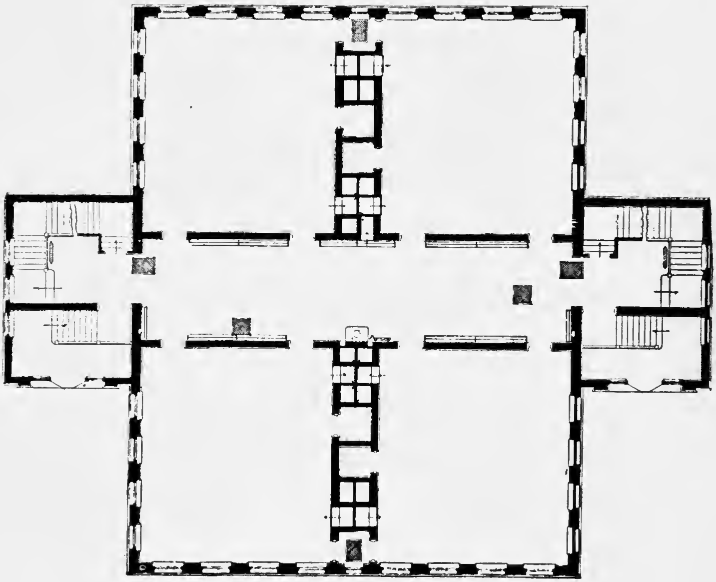
The teachers' rooms in the second story are provided with heating radiators and toilet closets.

The corridors are wide and well lighted, there being glass in the transoms over the doors and a large panel of heavy glass in each door leading from the class-rooms.

The walls of the corridors, staircase wings and vestibules are faced with selected smooth-cut brick. The vestibule floors are of tiles.

The basement floor is of concrete, well rolled and smooth. The plastering is of Windsor cement, and steel lathing is used on ceilings and wooden partitions. The plastering on the brick walls is laid directly on the brick.

PLATE XXXI.



FIRST FLOOR PLAN. BROCK AVE., SCHOOL, NEW BEDFORD, MASS., U.S.A.

The partitions around the stairways are provided with fire stops, as required by the Massachusetts building regulations.

The conductors, gutters and flashings are of rolled copper. The inside finish of the first and second stories is of selected red oak, and the floors double, the upper floors being of the best rift yellow pine, not over three inches wide.

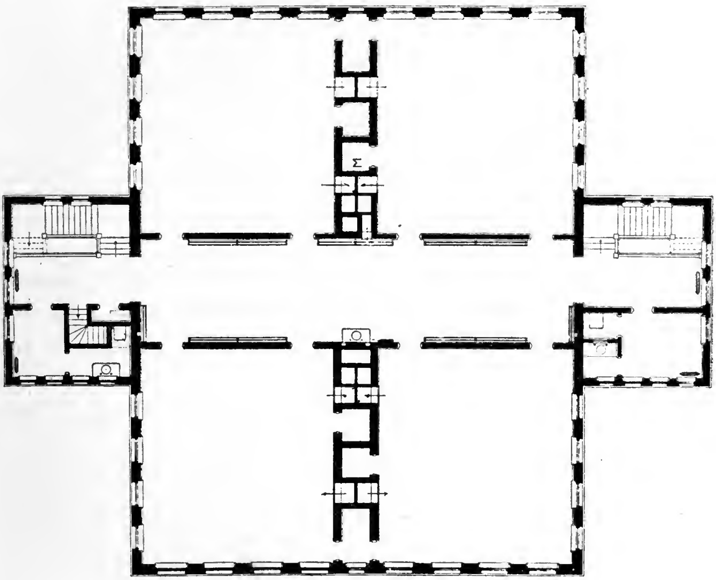
In each corridor are clothes rails with bronzed hooks for holding the pupils' clothing.

Electric call-bells and speaking-tubes are provided from each class-room to the principal's room, also to the janitor's room, and from the main entrance to the janitor's room.

The sanitary closets and urinals in the basement are provided with automatic flushing tanks, and are well trapped and well ventilated into a special vent-flue which contains steam-pipes, to cause an outflow of foul air from the basement rooms and sanitary fixtures.

In the first and second story is a galvanized-iron stand-pipe and 50 feet of hose for use in case of fire. Suitable hose racks are provided.

PLATE XXXII.



SECOND FLOOR PLAN. BROCK AVE., SCHOOL, NEW BEDFORD, MASS., U.S.A.

In the basement, corridors and teachers' rooms are water faucets and basins or bowls well trapped.

Two horizontal tubular boilers are provided for heating the building, each being 42 inches in diameter, 14 feet long, having 38 tubes three inches in diameter and 13 feet long. Each boiler is rated at 32 horse-power and tested to 150 pounds under hydraulic pressure.

Safety-valves, automatic damper-regulator, steam-gauges, water-gauges, fusible plugs, blow-off cocks and all required valves are provided.

A supplementary sectional boiler of the rated capacity of 400 square feet is also provided for the vent-shaft heaters and for use in mild weather in the place of the main heating boilers.

The piping for the vent-shaft heaters is so arranged that either or both main boilers or the sectional boiler may be used as desired. The piping in the building is what is known as the two-pipe system, with supply and return for each radiator or coil, and so adjusted that water-hammer or snapping is prevented during the circulation of the steam, and suitable allowance is made for expansion and contraction. The return pipes are not shown on the drawings, but generally follow the line of the supply pipes.

Valves are provided by which part or the whole of the heating radiators may be used as desired. The fresh air for each class-room is warmed by being passed through cast-iron indirect radiators in the basement. Four hundred square feet of indirect radiation is provided for each class-room, and is divided into three sections or stacks, so that a part or the whole may be used as desired.

In the teachers' rooms and corridors are direct radiators, and in the basement are lines of steam-pipes overhead. Radiators are also provided for bringing warm air up through two registers in the floor of the first-story corridor, the air being rotated from the corridor floor near the stairway extensions. These are designated as foot-warmers, and enable the pupils to warm their feet and hands and dry their clothing in cold, stormy weather.

In the floor of the closets between the class-rooms in the first story are what are termed rotating registers, for use at night or when the rooms are not in use. The windows in the cold-air rooms and the dampers in the vent-flues being closed, the rotating registers are opened and air is drawn down from the class-rooms, passes through the indirect radiators and is returned to the class-rooms through the warm-air flues, thereby keeping the rooms warm and saving fuel.

The warm fresh air is brought into the class-rooms through openings eight feet above the floor as shown in the drawings, and the vitiated air is removed through openings at the floor level, located as shown in the plans. The warm-air and foul-air flues are of brick, and well smoothed up on the inside.

Each foul-air flue contains 20 square feet of steam-pipe heating surface for causing an outward flow of vitiated air, and is also provided with a curved damper of galvanized iron, operated by a chain and catch, by which the amount of air taken from the rooms can be regulated or shut off when the rooms are not in use. In each warm-air flue is a galvanized-iron mixing-valve.

There is also an adjusting damper by which the supply of fresh warm air to each room may be regulated or shut off if any room is not occupied.

The direct radiation consists of vertical loop cast-iron radiators of an aggregate of 325 square feet of surface in corridors and teachers' rooms, and 280 square feet of surface of 1½ inch steam-pipe in coils overhead, in the basement.

The indirect radiators for the foot-warmers consist of 100 square feet each of cast-iron radiators.

At an inspection of this building the following conditions were found:

Weather, fair; wind north and moderate; outside temperature, 21° F.; outside relative humidity, 57 per cent; barometer, 30.32; average temperature of air at inlets to class-rooms, 87.1° F.; average supply of fresh air through inlet to each class-room, in cubic feet per minute, 2,337; average amount of air removed at outlet from each class-room, in cubic feet per minute, 2,984; average amount of air, in cubic feet per minute, supplied at inlet for seating capacity of each class-room, 47.7; average amount of air, in cubic feet per minute, removed through outlet in class-rooms, for each pupil, 60.9; greatest amount of air, in cubic feet per minute, supplied at inlet to any class-room, 3,247; least amount, 1,730 cubic feet; average difference in temperature in any room, taken at the same time at four places, at the breathing plane, 2° F.; least difference at same points, .5° F.; average temperature at teachers' desks, 69.5° F. No uncomfortable drafts could be perceived in the several rooms.

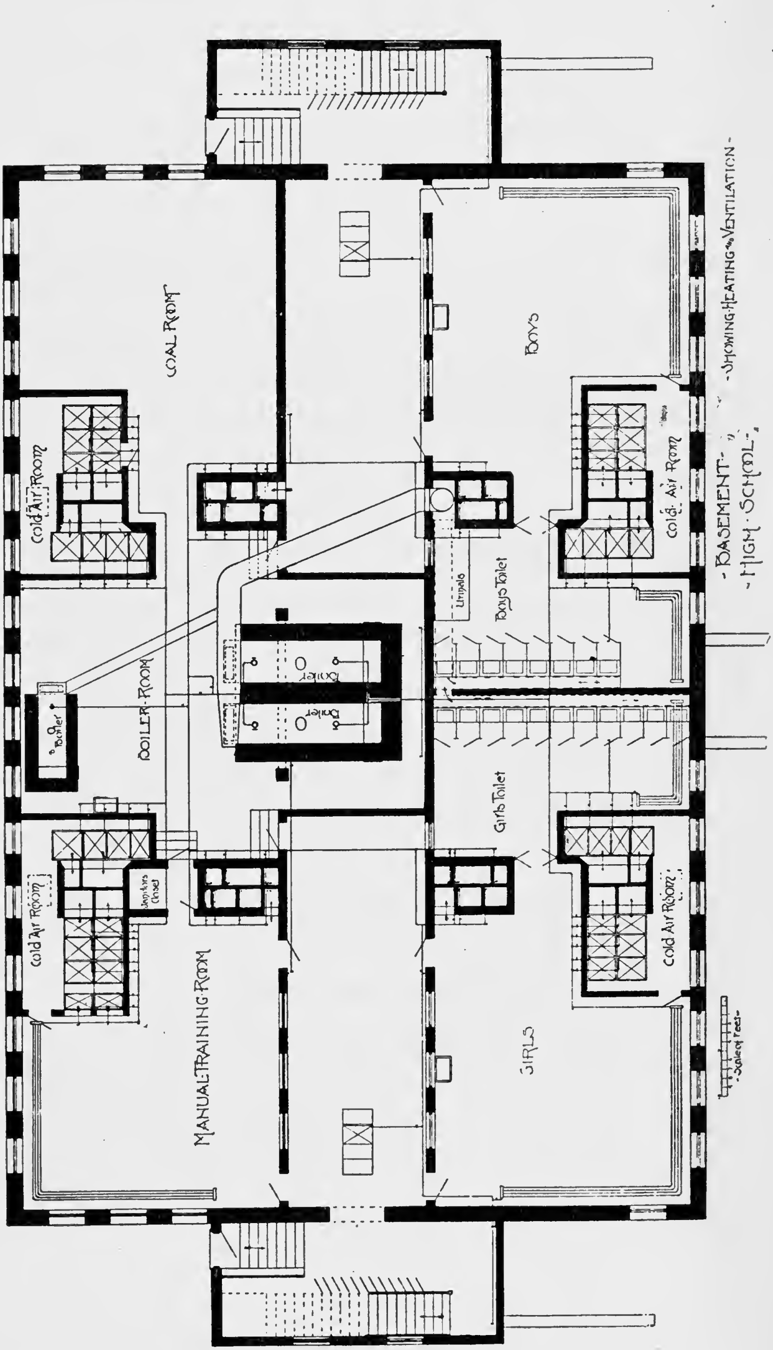
Plates XXXIII, XXXIV and XXXV.—Plans for a small high or a grammar school — a two-story building constructed of yellow brick, with yellow terra-cotta trimmings and slated roof. If used as a grammar school the rooms intended for the chemical and physical laboratories can be used as class-rooms.

In the first story are four class, two recitation, and two teachers' rooms, with toilets connected.

The corner rooms are 28 by 32 feet and 12 feet high, intended for forty-nine pupils. The recitation rooms are each 17 feet 8 inches by 28 feet.

The teachers' rooms, including toilets, are each 11 feet 4 inches by 28 feet. The center corridor is 15 feet and the front corridor 12 feet wide.

PLATE XXXIII.



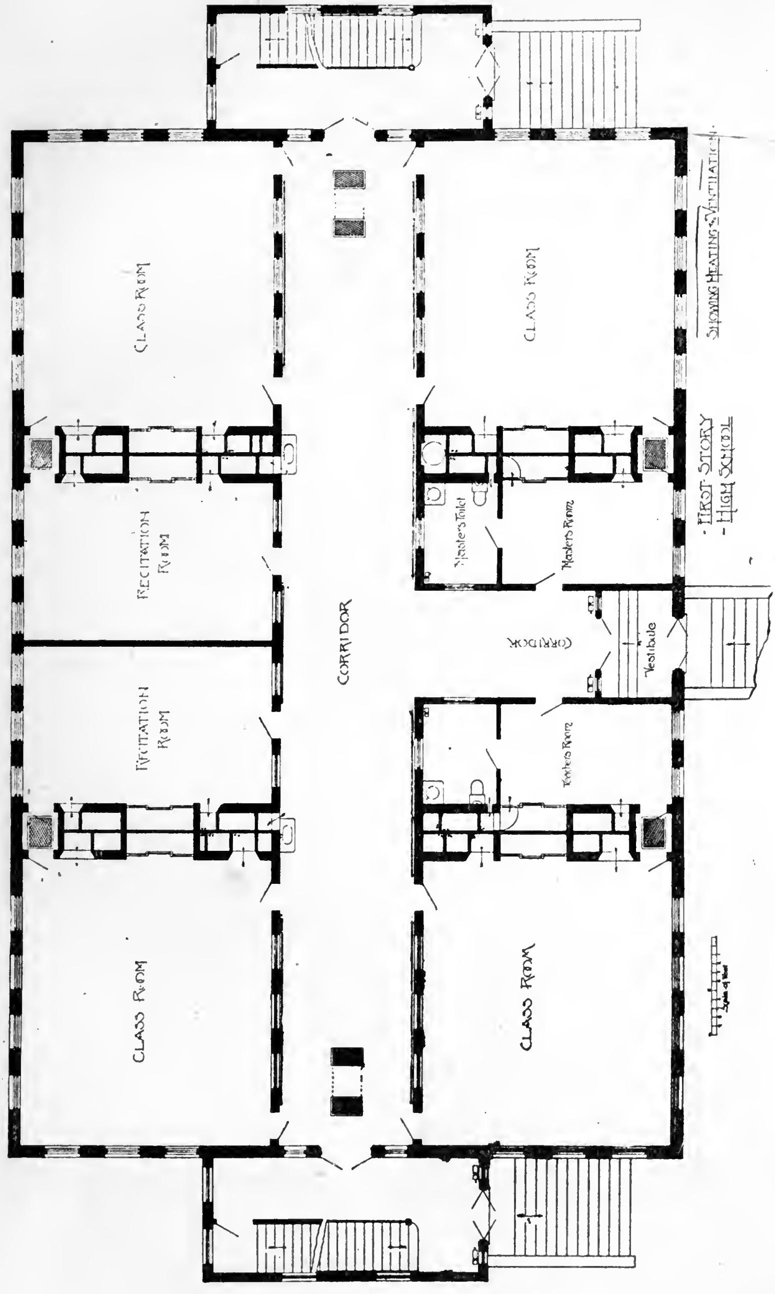
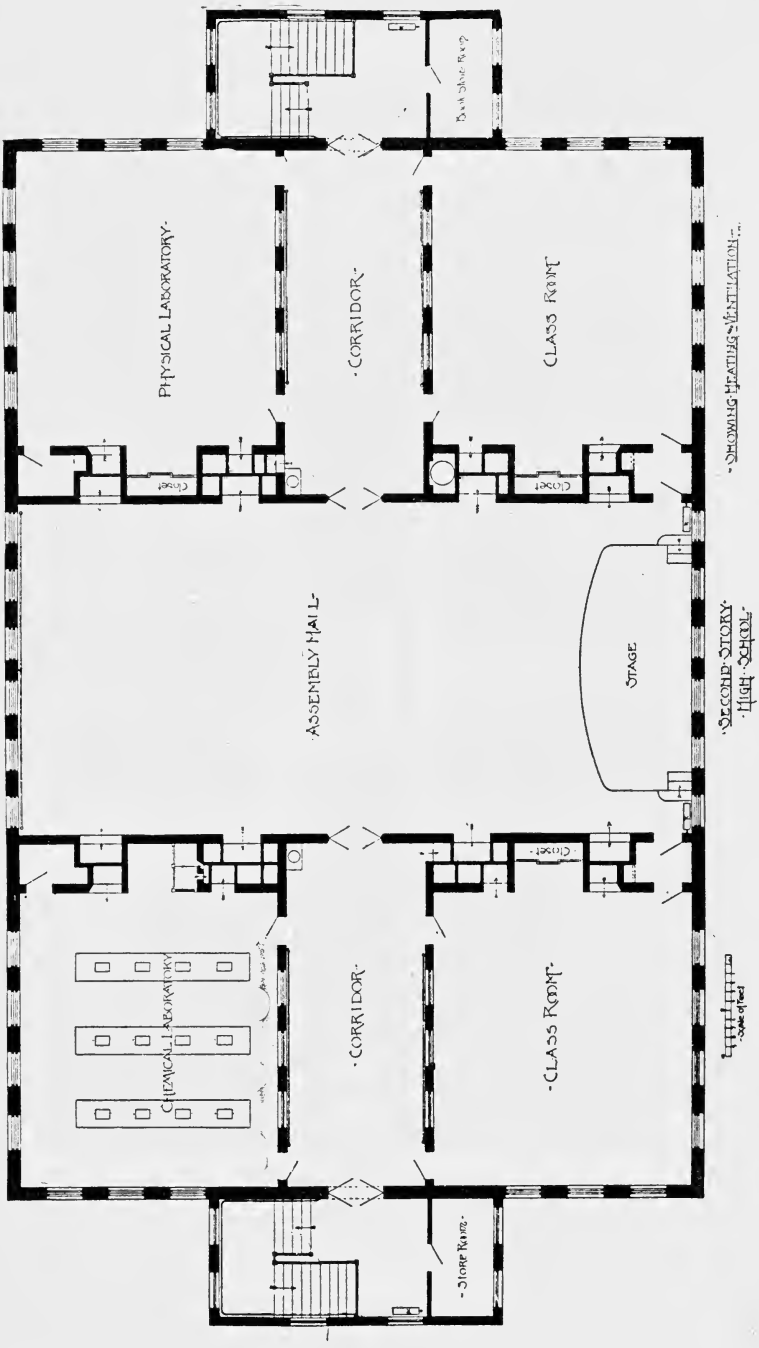

CLASS ROOM
CLASS ROOM
RECITATION ROOM
RECITATION ROOM
CORRIDOR
CORRIDOR
Master's Toilet
Masters Room
Vestibule
Teacher's Room
CLASS ROOM
CLASS ROOM
-FIRST STORY
-HIGH SCHOOL
SHOWING HEATING & VENTILATION

PLATE XXXIV.

PLATE XXXV


Book Store Room
Physical Laboratory
Corridor
Class Room
Closet
Closet
Assembly Hall
Stage
Closet
Chemical Laboratory
Corridor
Class Room
Store Room
Second Story
High School
Showing Heating & Ventilation
Scale of Feet

In the second story are two class-rooms, a chemical and a physical laboratory, each 28 by 32 feet by 12 feet high, an assembly hall 36 by 73 feet, and two storage-rooms in the stairway extension. The stairways at each end of the building are six feet wide and railed on both sides. The main doors open both ways, as do also the assembly-room doors.

In the basement, which is 12 feet high, except the boiler-room, which is 14 feet 6 inches in height, is a manual-training room, a boys' and a girls' recreation-room, sanitary rooms, boiler-room and coal-room, cold-air rooms and places for bicycles. Two stairways lead up to the first story and there are two doors from the outside to the stairway extension.

The basement floor is of concrete, with a covering of Portland cement or rock asphalt.

The interior walls and partitions are of brick, except between the two recitation-rooms, on the corridor sides of the teachers' rooms, and the small storage-rooms in the second story. Between the rooms are closets with doors connecting with the class-rooms. All wooden partitions are lathed with expanded metal lathing, which is the only kind of lathing used throughout the building. Fire stops, which are required by the Massachusetts building laws in all school buildings, are also built.

The walls of the corridors and stairway extensions have a face of good quality smooth brick, well laid and painted with light colored gloss paint but with no wood finish.

Bookcases with glass doors are placed in each class-room between the heat and the vent-flues.

The windows in the first and second story rooms have a double run of sash; the basement, stairway extension and corridor windows, single. The windows between the corridors and rooms are six feet above the floor, and each door, except to the store-rooms and teachers' rooms, has a center panel of heavy glass. There are windows over the doors leading to the front and end entrances. All inside doors have glass transoms.

The corridors in which clothing is to be hung have wooden hanging frames projecting one foot from the sides, with two pieces for hooks, the lower one nearest the wall and the upper one projecting, with hooks alternating, to prevent the crowding of the clothing.

In the basement of the stairway extensions are stands for bicycles, which are to be brought down a runway by the side of the basement steps. Gymnastic appliances are supplied in both boys' and girls' recreation rooms.

The manual-training room is fitted with lathes, grindstone, work-benches and tools.

The chemical laboratory has tables, sinks, chemical closets with glass sliding doors, water, illuminating gas, electric power and the requisite apparatus. The physical laboratory is also supplied with the necessary tables and apparatus.

The assembly hall has two large ceiling lights, connecting with skylights in the roof. The ceiling lights are fitted with roller-shade curtains. One of the ceiling lights and one skylight has a hinged section operated by chains and pulleys, which can be used for ventilation should the room become overheated in moderate weather.

The building is heated by a low-pressure, two-pipe, gravity, steam system, with two horizontal tubular boilers, each 54 inches in diameter, 15 feet 3 inches long, containing 60 three-inch tubes 14 feet long; also by a smaller horizontal tubular boiler, 36 inches in diameter, 9 feet 3 inches long, containing 34 two-and-one-half-inch tubes, 8 feet long. This small boiler is intended to furnish steam for the steam-pipes in the vent-ducts and for a low-pressure engine to run the turning lathes, etc., in the manual-training room when the large boilers are not in use. It can also be used to warm the radiators in the spring and fall months, when but very little heat is required for a part of the day. The three boilers are set, piped, valved and connected so that either may be used as desired. When it is necessary to use very low pressure in the larger boilers for warming the building in moderate weather, the small boiler can be used at higher pressure to run the engine for operating the lathes and also for heating the vent-flues. A reducing pressure-valve should be provided, also a separator, tank, pump, and pump governor.

If an electric motor is used for running the lathes, it will not be necessary to use the pump, etc., the small boiler can be reduced in size and the system can be run by gravity return. This would be advisable where electric power is to be had.

By having the boiler-room lower than the other parts of the basement a good return of water by gravity to the boiler is secured, and a complicated system of traps, pumps, etc., is rendered unnecessary. The supply and return pipes are of ample size, properly pitched, graded, dripped and valved, so as to secure a free and noiseless circulation and return to the boilers.

The class-rooms, assembly hall, recitation rooms, laboratories and teachers' rooms are heated by stacks of indirect radiators of the H. B. Smith School Pin, Bundy Newport, American Sterling, or similar pattern, placed in the cold-air rooms in the basement;

each stack being divided into three sections so that part or the whole may be used as desired.

Direct radiation is supplied in the corridor and stair extensions, and two lines of one-and-one-quarter inch steam-pipe under the clothing racks in the corridors for drying in stormy weather and for heating in extremely cold weather.

At each end of the lower corridor there are floor registers without valves for use as foot-warmers, the air being drawn down through the register nearest the door, passing through the stack of radiators, which are to be cased with galvanized iron and suspended from the basement ceiling, and coming up through the register farthest from the door. Good exhaust flues are provided from the corridors, and the leakage of air into the corridors is sufficient to keep them in good condition.

In the chemical and physical laboratories four lines of one-and-one-quarter-inch steam-pipe should be placed on the two exposed sides, to be used at night to prevent freezing in extremely cold weather when the rooms are not in use.

Direct radiation is placed in the assembly hall in addition to the indirect, to keep the room partly warmed and to heat quickly when the indirect is turned on before the room is occupied. When occupied the direct should be shut off and only the indirect used.

The manual-training room in the basement is also supplied with direct and indirect radiation. The recreation rooms and sanitary rooms are warmed by lines of overhead steam-pipes, the supply mains in the basement being protected by non-heat-conducting pipe covering.

The ceiling of the boiler-room and the cold-air rooms are specially protected by non-heat-conducting material placed between the flooring and the metallic lathing — in the case of the boiler-room, to prevent the heat passing up through the floor and over-heating the rooms above, which often happens when the boilers are located under the school-room and no protection is provided other than the wooden floors. It is advisable to construct the ceiling of iron beams and terra-cotta arches and make the boiler-room fire-proof.

If the cold-air rooms are not protected overhead the cold air chills the floor directly over them, sometimes to an uncomfortable degree in extremely cold weather. The cold-air room windows should be hung in two parts and be provided with cords and pulleys for opening and closing.

The fresh warm air is taken into the rooms through inlets of the same size and location as previously described in other plans.

The dimensions of each of the four warm-air flues for the assembly hall are 52 by 24 inches.

Tests of the best work show that by having the warm-air flues of liberal size the air is introduced into the rooms at a lower velocity and temperature than when the flues are too small. In moderate weather this is a decided advantage, as a sufficient amount of fresh air can be supplied without overheating the room, as was the case in some of the earlier work, where the temperature had to be raised too high for comfort in order to obtain the required volume of air with small ducts.

In some cases, especially where fans or blowers have been used, the ducts have been reduced in size under pretense of cheapening the cost of construction, and the air forced into the room at a high velocity, causing uncomfortable drafts and a needless expenditure of power.

Wire grills are used instead of cast-iron registers to cover the inlets and outlets. Mixing valves are supplied for warm-air flues. Adjustable galvanized-iron cut-offs or adjusting dampers are provided at the bottom entrance for the warm air to regulate the supply of air to the several rooms under the varying conditions of wind and temperature or to cut off the supply from any unoccupied room.

The use of double windows will be of great service in very cold and windy weather, and will to a considerable extent prevent too rapid cooling and precipitation of the air by the glass surface which often causes downward drafts in front of single windows. A considerable saving of fuel can be made by using double windows.

The openings from the rooms and corridors into the vent-flues are of the size and location previously described in other plans. Galvanized-iron dampers are also provided for these vent openings. Vent-flue heaters are installed.

By the use of steam-pipes or radiators in the vent-flues a good velocity is given to the outgoing foul air, back draft is prevented without the use of flap-valves, whose chief purpose appears to be to obstruct the outflow of the foul air and to cause a disagreeable noise by flapping up and down when moved by the wind.

Experience and not theory has taught that means should always be provided for causing an outflow of the foul air through the vent-flues and ducts, either by heat or mechanical means. Attempts to cause an outflow by other methods, especially when the outlets are obstructed by worse than useless flexible valves, which are liable to close when the room is occupied and ventilation required, and to open when the room is unoccupied and no ventilation needed, usually result in noticeable failures, as proved by numerous tests.

With these contrivances there appears to be no practicable way of adjusting the outflow, and in extremely cold and windy weather, when the outflow will need checking, the flap-valves will be open to their full capacity; but in mild and calm weather, when they should be wide open, they are liable to be closed.

The sanitary closets are of a pattern having an especially large local vent (four inches in diameter) and each closet is vented into an underground duct running to the smoke-flue surrounding the iron smoke-pipe from the boilers.

Each closet has an automatic flush. The divisions or partitions between the closets are raised eight inches above the floor on metal standards, which allows the janitor to use water liberally for washing the floor through a hose furnished for that purpose.

Each line of closets is connected with a well-vented and trapped soil-pipe.

The urinals are fitted with a perforated flushing-pipe, and have a liberal vent connected with the main closet vent-duct. The discharge pipe should be well trapped and vented.

The sanitary-rooms are ventilated through the closets and urinals to the space around the boiler smoke-pipe.

All plumbing should be of the open or exposed pattern and all fixtures well trapped and vented.

Plates XXXVIII and XXXIX are designs by the late John T. White, the friend and companion inspector of the writer for eighteen years.

Plate XXXVIII.—Design for a direct-indirect radiator.

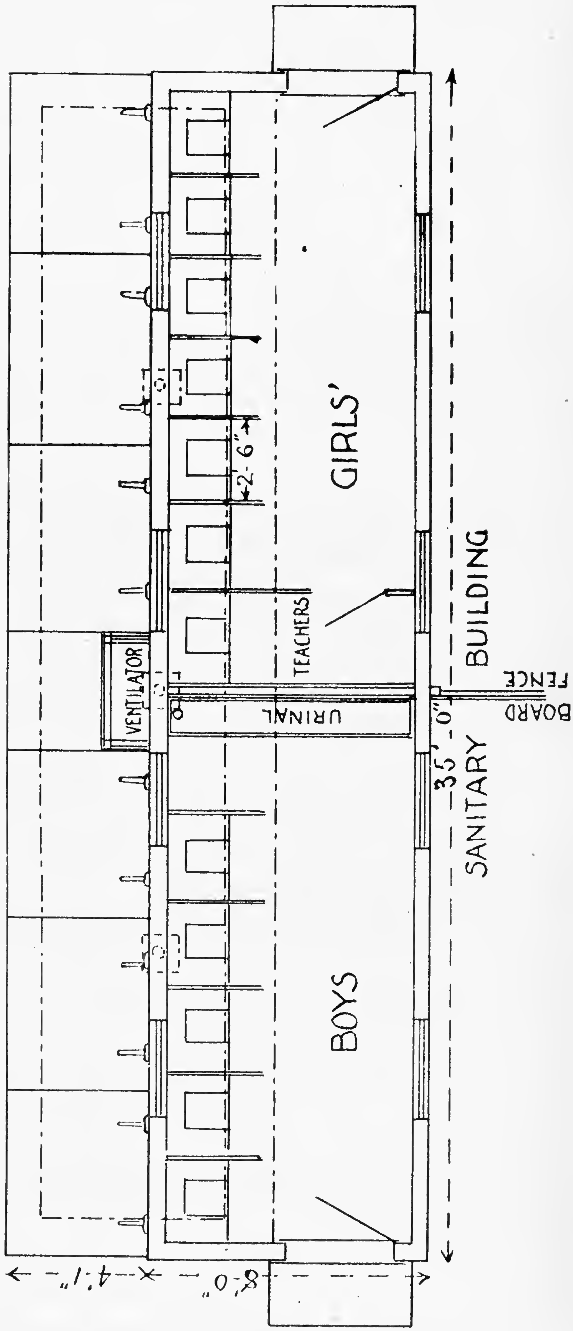
This radiator is designed to be used in small halls or in churches, where it may be easy to provide for a strong exhaust leg of a ventilating system, but difficult to arrange for a straight indirect method of heating and supplying air.

Almost any good direct radiator may be used or a coil of pipe.

The radiator is first cased in metal, and may then be finished in wood in any way desired.

The fresh-air opening has an area of two square inches for each square foot of radiation; but the supply of air from outside may be controlled by damper, as shown, which can be held in any position. The inside damper is always to be entirely open or shut. When

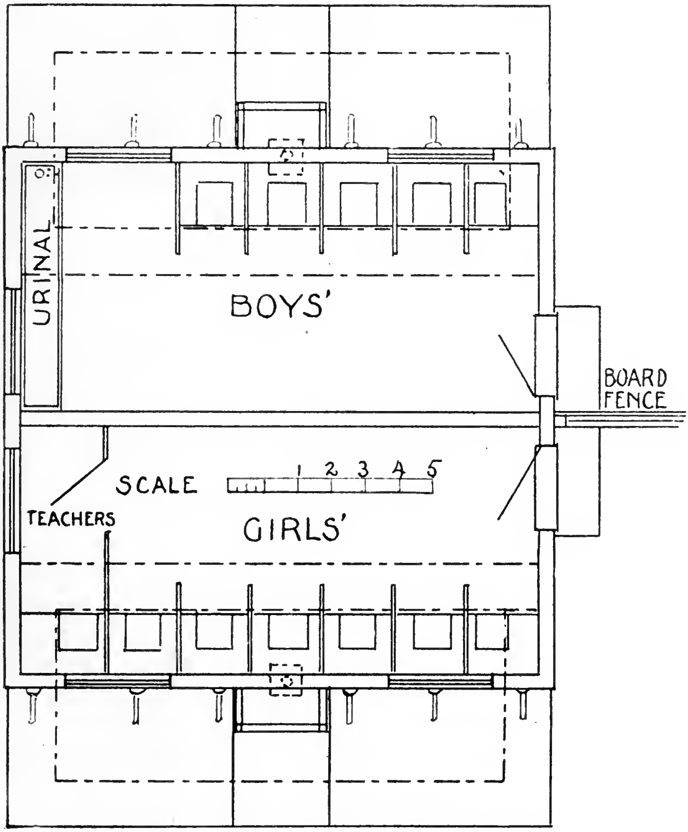
PLATE XXXVI.


GIRLS'
TEACHERS
URINAL
VENTILATOR
BOYS
SANITARY BUILDING
BOARD FENCE
35'-0"
2'-6"
4'-1"
8'-0"

open, the air is taken from the room, and the effect is, of course, nearly the same as with a direct radiator.

Such a radiator with 100 square feet of surface has been found to furnish 500 cubic feet of air per minute under *fairly favorable conditions*.

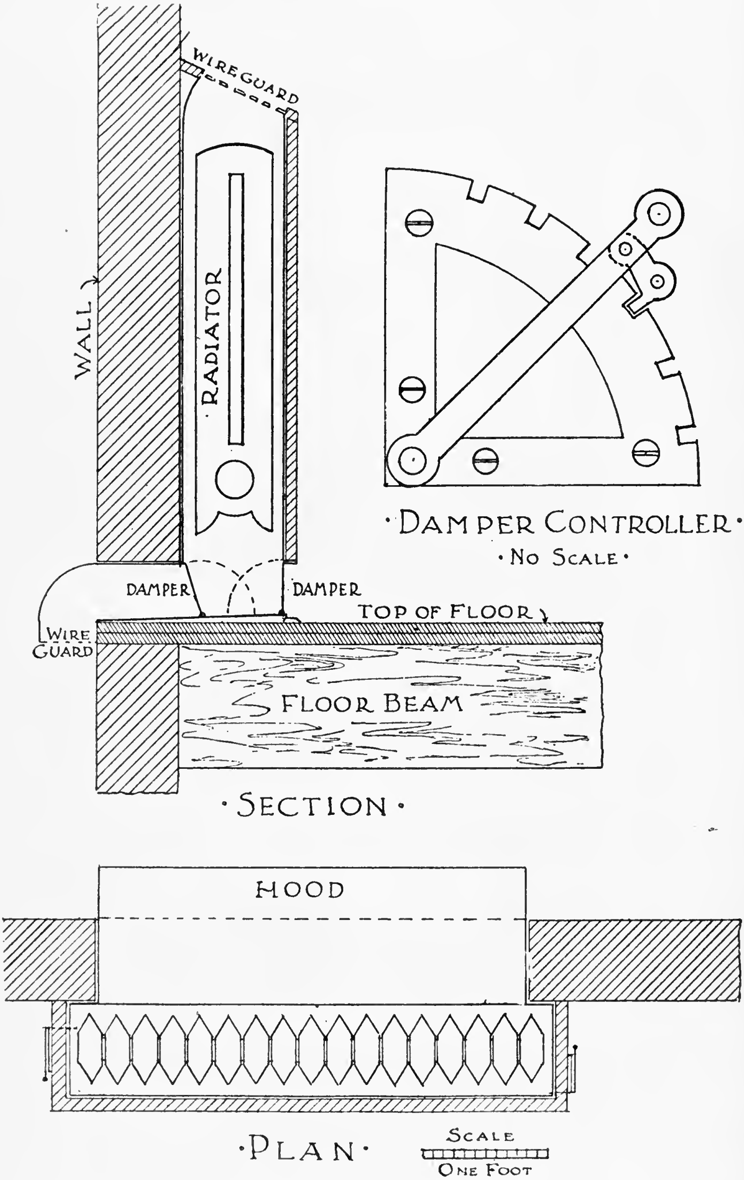
PLATE XXXVII.



SANITARY BUILDING

The fresh-air opening, extending nearly the entire length of the stack, gives a more even distribution of air to the heating surface than (as is generally the case) where the opening is near the center of the stack and the area is obtained by one which is high and short instead of low and long, as shown in this design.

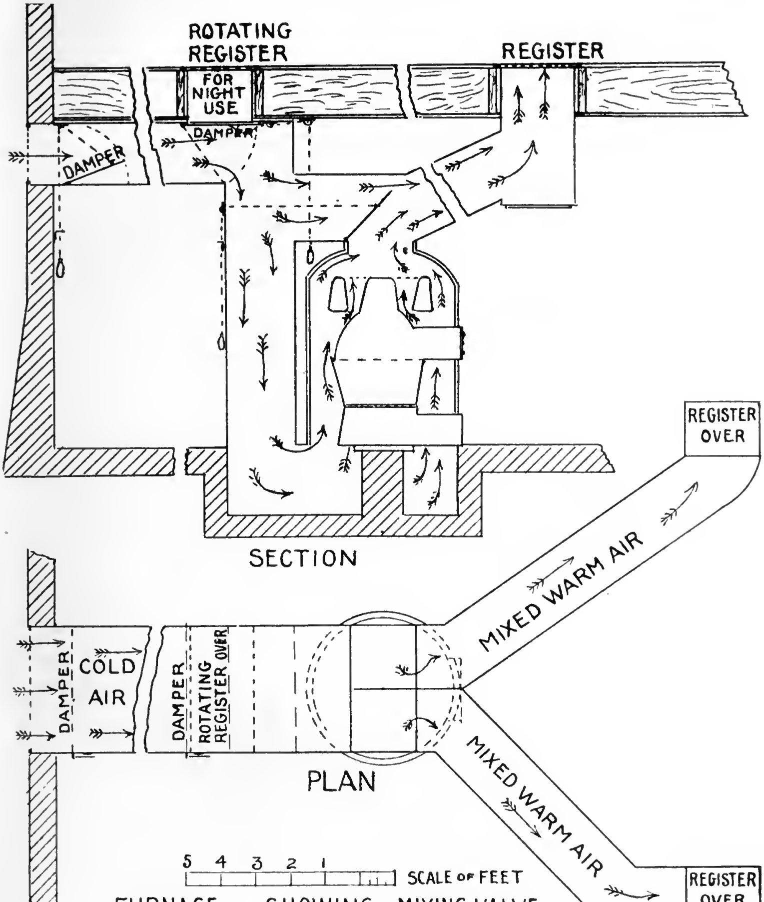
PLATE XXXVIII.



·DESIGN FOR DIRECT-INDIRECT RADIATOR·

Plate XXXIX.—Design for setting a portable furnace, showing a method of setting a portable furnace in a small hall or in a church, where the registers are necessarily placed in the floor.

PLATE XXXIX.



FURNACE – SHOWING MIXING VALVE

In such cases, when the room is too warm, the usual remedy is to close the register and thus shut off the supply of air, throwing all the heat back on the furnace, increasing the danger from fire and possible injury to the pipes and castings. The registers here shown have no valves, and the temperature of the incoming air is regulated by a mixing-valve in each duct as shown.

There is a damper for controlling the supply of outside air, and a rotating damper is provided.

The cold-air and warm-air ducts are much larger than those generally installed.

There is a pit under the furnace about two feet deep—an essential feature for good work.

If any small rooms are to be heated, branches can be taken from the large pipes with switch dampers to control the flow of air.

PLATE XL.

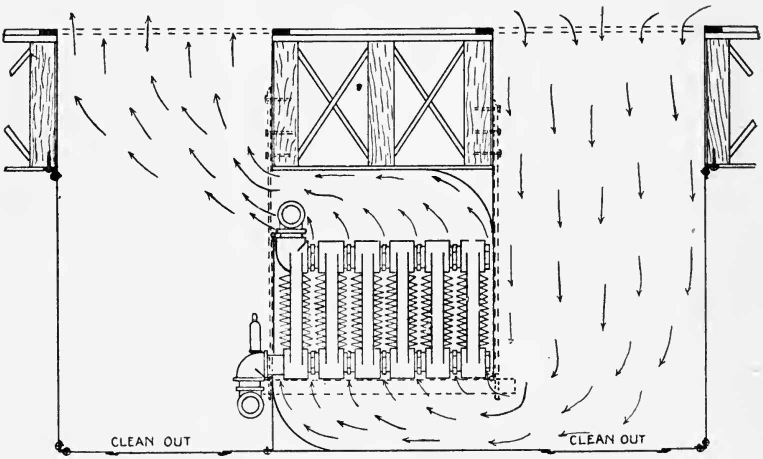


Plate XL.—Foot-warmers to be placed in schoolhouse corridors.

Six sections of indirect cast-iron pin radiators are made into a stack containing 120 square feet of radiating surface, which is suspended below the basement ceiling on two 1½-inch iron pipes, which are secured to the floor timbers above by iron hangers. The sections are 15½ inches high at their highest part and 36 inches long.

The pins are one inch long and the sections are set up four inches on centers with one-half inch space between the ends of the pins.

Two-inch right-and-left nipples are used for connecting the sections, which are tapped for two-inch supply and return. A ⅜-inch air-valve is placed in the quarter-turn or elbow of the return. This air-valve is placed in a position, where, should it be desirable to moisten the air, a small quantity of steam may be allowed to escape through the air-valve.

The casing is of twenty-four gauge galvanized iron put together with screws, nuts and angle iron, so that it may be easily removed should it be required to make repairs on the heating-stack. In the bottom of the casing are two clean-out slides for removing any dirt or substance that may fall through the register gratings in the floor of the corridor.

The air is taken from the corridor down on one side, passes under and up through the radiator-stack and ascends to the corridor through another register in the corridor floor.

This arrangement prevents the accumulation of dirt and various substances that would fall on the heated radiators through a register placed directly above the heating stack.

Covering Boilers.

Covering boilers by the use of sand is not advisable, because if cracks appear in the setting, the sand will deposit in the cracks when the wall is heated and will continue to do so and widen the cracks.

When a boiler is arched over with bricks, care should be taken that the arch does not rest on the boiler, and that at least an inch space is left between the boiler and the brick arch, which should be self-supporting.

An eighty-five per cent magnesia covering when properly applied makes a very desirable non-heat-conducting protection over the boiler and gives very satisfactory results.

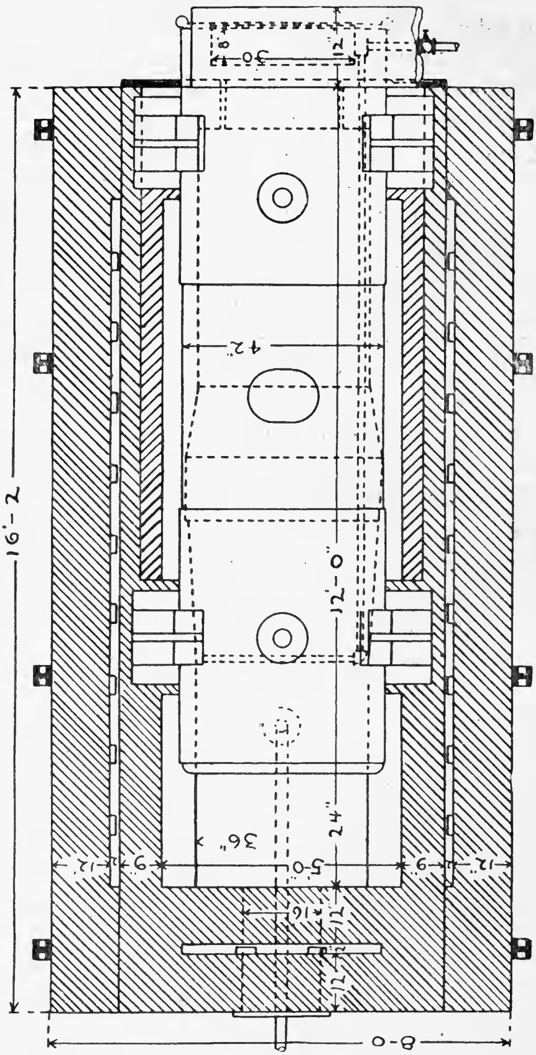
The practice of leaving a space completely bricked in around the boiler to gain additional heating surface is now but seldom resorted to, as the tendency is to burn out that part of the boiler above the water line. The returning of hot gases from the uptake, across the top of the boiler is another defect, as its efficiency is of doubtful value.

Another practice not to be recommended, is that of continuing the boiler walls above the boiler for the purpose of obtaining a space above the boiler for heating air for ventilation, by utilizing the heat escaping through the boiler covering. Should cracks be made in the setting or covering, there is danger of the unconsumed gases passing into and contaminating the air intended for ventilation.

With this setting the fireman or engineer is obliged to crawl through a door and over the boiler to reach either the steam or safety-valve, and in case of the safety-valve blowing off to relieve too high pressure, the steam is carried by the warm air ducts into the school or other rooms which receive their air from this source, and possibly causing excitement or a panic among the pupils.

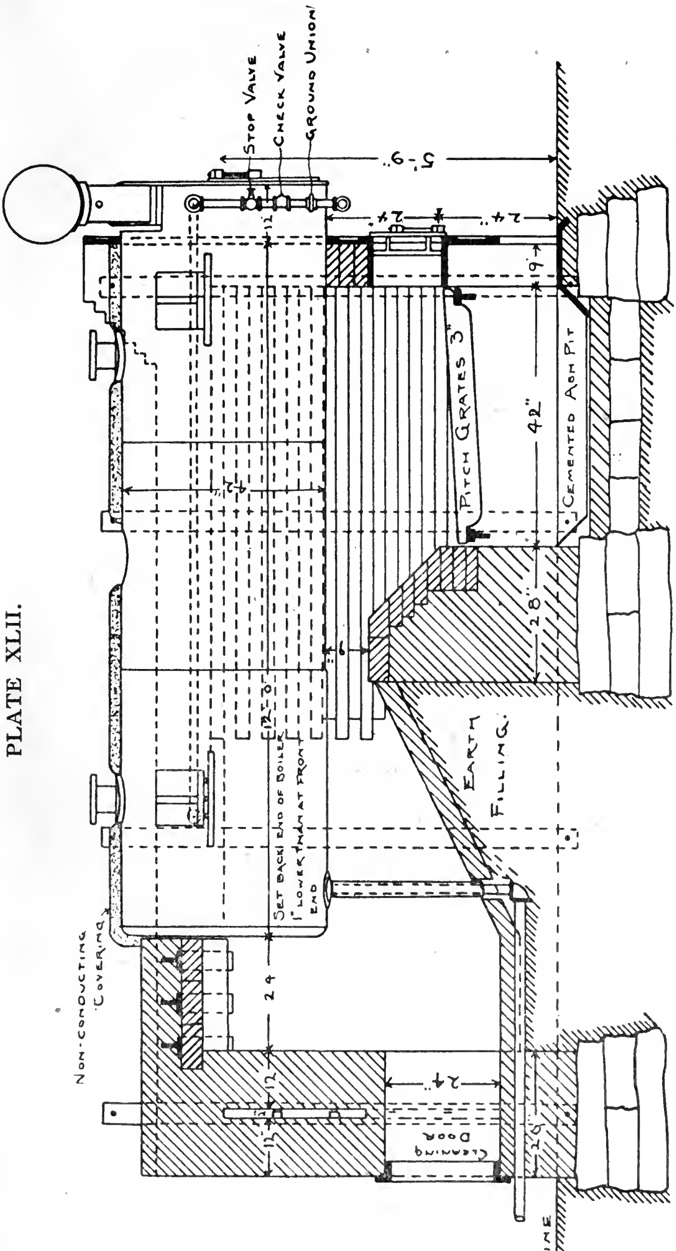
Plates XLI, XLII, XLIII and XLIV.—Settings for horizontal tubular boilers. Designed and recommended by the Hartford Boiler Inspection and Insurance Company.

PLATE XLI.



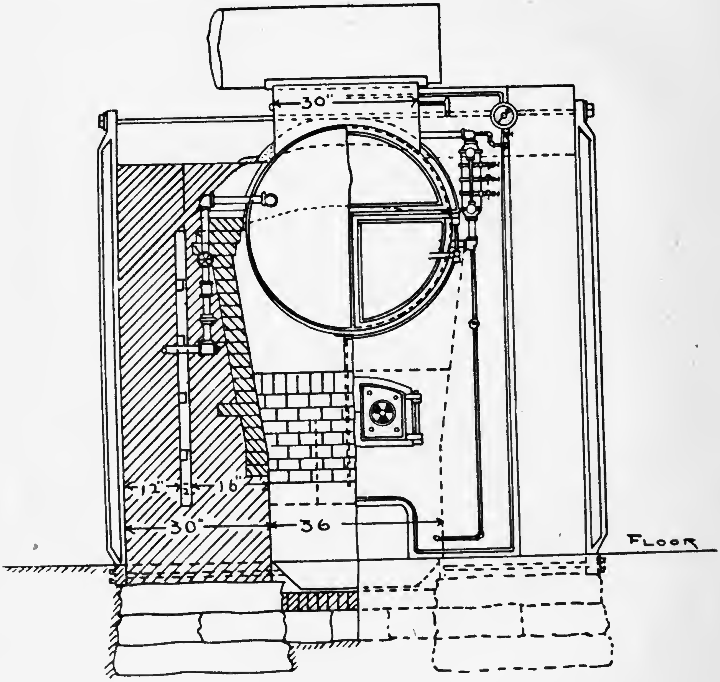
PLAN FOR SETTING ONE HORIZONTAL TUBULAR BOILER.

PLATE XLII.



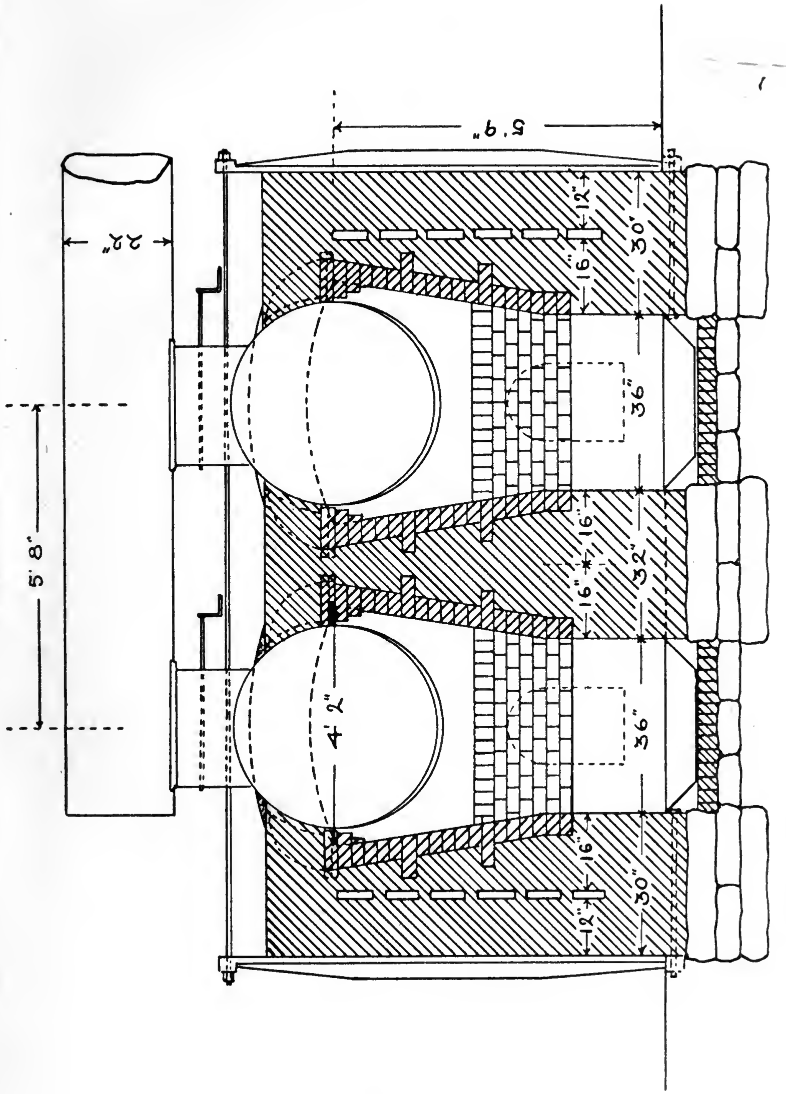
Longitudinal Section of Setting for One Horizontal Tubular Boiler.

PLATE XLIII.



Cross Section of Setting for One Horizontal Tubular Boiler.

PLATE XLIV.



Cross Section of Setting for Two Horizontal Tubular Boilers.

TABLE 15. (APPROXIMATE) AREAS

Inches	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
10	.69	.76	.83	.9	.97	1.04	1.11	1.18	1.25	1.31	1.38	1.45	1.52	1.59	1.66	1.73	1.8
11	.76	.84	.91	.99	1.06	1.14	1.22	1.29	1.37	1.45	1.52	1.6	1.68	1.75	1.83	1.9	1.98
12	.83	.91	**1.**	1.08	1.16	1.25	1.33	1.41	1.5	1.57	1.66	1.75	1.83	1.91	**2.**	2.08	2.16
13	.9	.99	1.08	1.17	1.26	1.35	1.44	1.53	1.62	1.71	1.8	1.89	1.98	2.07	2.16	2.25	2.34
14	.97	1.06	1.16	1.26	1.36	1.47	1.55	1.65	1.75	1.84	1.94	2.04	2.13	2.23	2.33	2.43	2.52
15	1.04	1.14	1.25	1.35	1.47	1.56	1.66	1.77	1.87	1.97	2.08	2.18	2.29	2.39	2.5	2.6	2.7
16	1.11	1.22	1.33	1.44	1.55	1.66	1.77	1.88	**2.**	2.11	2.22	2.33	2.44	2.55	2.66	2.77	2.88
17	1.18	1.29	1.41	1.53	1.65	1.77	1.88	**2.**	2.12	2.24	2.36	2.47	2.59	2.71	2.83	2.95	3.07
18	1.25	1.37	1.5	1.62	1.75	1.87	**2.**	2.12	2.25	2.37	2.5	2.62	2.75	2.87	**3.**	3.12	3.25
19	1.31	1.45	1.57	1.71	1.84	1.97	2.11	2.24	2.37	2.5	2.63	2.77	2.9	3.03	3.16	3.29	3.43
20	1.38	1.52	1.66	1.8	1.94	2.08	2.22	2.36	2.5	2.63	2.77	2.91	3.05	3.19	3.33	3.47	3.61
21	1.45	1.6	1.75	1.89	2.04	2.18	2.33	2.47	2.62	2.77	2.91	3.06	3.2	3.35	3.5	3.64	3.7
22	1.52	1.68	1.83	1.98	2.13	2.29	2.44	2.59	2.75	2.9	3.05	3.2	3.36	3.51	3.66	3.81	3.97
23	1.59	1.75	1.91	2.07	2.23	2.39	2.55	2.71	2.87	3.03	3.19	3.35	3.51	3.67	3.83	3.99	4.15
24	1.66	1.83	**2.**	2.16	2.33	2.5	2.66	2.83	**3.**	3.16	3.33	3.5	3.66	3.83	**4.**	4.16	4.33
25	1.73	1.9	2.08	2.25	2.43	2.6	2.77	2.95	3.12	3.29	3.47	3.64	3.81	3.99	4.16	4.34	4.51
26	1.8	1.98	2.16	2.34	2.52	2.7	2.8	3.07	3.25	3.43	3.61	3.7	3.97	4.15	4.33	4.51	4.69
27	1.87	2.06	2.25	2.43	2.62	2.81	**3.**	3.18	3.33	3.56	3.75	3.93	4.12	4.31	4.5	4.68	4.87
28	1.94	2.13	2.33	2.52	2.72	2.91	3.11	3.3	3.5	3.69	3.88	4.08	4.27	4.47	4.66	4.86	5.05
29	2.01	2.21	2.4	2.61	2.81	**3.**	3.22	3.42	3.62	3.82	4.02	4.22	4.43	4.63	4.83	5.03	5.23
30	2.08	2.29	2.5	2.7	2.9	3.12	3.33	3.54	3.75	3.95	4.16	4.37	4.58	4.79	**5.**	5.2	5.41
31	2.15	2.36	2.58	2.79	3.01	3.22	3.44	3.66	3.87	4.09	4.3	4.52	4.73	4.95	5.16	5.38	5.45
32	2.22	2.44	2.66	2.88	3.11	3.33	3.55	3.77	**4.**	4.22	4.44	4.66	4.88	5.11	5.33	5.55	5.77
33	2.29	2.52	2.75	2.97	3.2	3.43	3.66	3.89	4.12	4.35	4.58	4.81	5.04	5.27	5.5	5.72	5.95
34	2.36	2.59	2.83	3.06	3.3	3.54	3.77	**4.**	4.25	4.48	4.72	4.95	5.19	5.43	5.66	5.9	6.13
35	2.43	2.67	2.91	3.15	3.4	3.64	3.88	4.13	4.37	4.61	4.86	5.1	5.34	5.59	5.83	6.07	6.31
36	2.5	2.75	**3.**	3.25	3.5	3.75	**4.**	4.25	4.5	4.75	**5.**	5.25	5.5	5.75	**6.**	6.25	6.5
37	2.56	2.82	3.08	3.34	3.59	3.85	4.11	4.36	4.62	4.88	5.13	5.39	5.65	5.9	6.16	6.42	6.68
38	2.63	2.9	3.16	3.43	3.69	3.95	4.22	4.48	4.75	5.01	5.27	5.54	5.8	6.06	6.33	6.59	6.86
39	2.7	2.97	3.25	3.52	3.79	4.06	4.34	4.6	4.87	5.14	5.41	5.68	5.95	6.22	6.5	6.77	7.04
40	2.77	3.05	3.33	3.61	3.88	4.16	4.44	4.72	**5.**	5.27	5.55	5.83	6.11	6.38	6.66	6.94	7.22
41	2.84	3.13	3.41	3.7	3.98	4.27	4.55	4.84	5.12	5.4	5.69	5.97	6.26	6.54	6.83	7.11	7.4
42	2.91	3.2	3.5	3.79	4.08	4.37	4.66	4.95	5.25	5.54	5.83	6.12	6.41	6.7	**7.**	7.29	7.58
43	2.98	3.28	3.58	3.88	4.18	4.47	4.77	5.07	5.37	5.67	5.97	6.29	6.56	6.86	7.16	7.46	7.76
44	3.05	3.36	3.66	3.97	4.27	4.58	4.88	5.19	5.5	5.8	6.11	6.41	6.72	7.02	7.33	7.63	7.94
45	3.12	3.43	3.75	4.06	4.37	4.68	**5.**	5.31	5.62	5.93	6.25	6.56	6.87	7.18	7.5	7.81	8.12

DIMENSIONS IN INCHES. AREAS IN SQUARE FEET.

8	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	Inches
.94	2.01	2.08	2.15	2.22	2.29	2.36	2.43	2.5	2.56	2.63	2.7	2.77	2.84	2.91	2.98	3.05	3.12	**10**
.13	2.21	2.29	2.36	2.44	2.52	2.59	2.67	2.75	2.82	2.9	2.97	3.05	3.13	3.2	3.28	3.36	3.43	**11**
.33	2.4	2.5	2.58	2.66	2.75	2.83	2.91	**3.**	3.08	3.16	3.25	3.33	3.41	3.5	3.58	3.66	3.75	**12**
.52	2.61	2.7	2.79	2.88	2.97	3.06	3.15	3.25	3.34	3.43	3.52	3.61	3.7	3.79	3.88	3.97	4.06	**13**
.72	2.81	2.9	3.01	3.11	3.2	3.3	3.4	3.5	3.59	3.69	3.79	3.88	3.98	4.08	4.18	4.27	4.37	**14**
.91	**3.**	3.12	3.22	3.33	3.43	3.54	3.64	3.75	3.85	3.95	4.06	4.16	4.27	4.37	4.47	4.58	4.68	**15**
.11	3.22	3.33	3.44	3.55	3.66	3.77	3.88	**4.**	4.11	4.22	4.34	4.44	4.55	4.66	4.77	4.88	**5.**	**16**
.3	3.42	3.54	3.66	3.77	3.89	**4.**	4.13	4.25	4.36	4.48	4.6	4.72	4.84	4.95	5.07	5.19	5.31	**17**
.5	3.62	3.75	3.87	**4.**	4.12	4.25	4.37	4.5	4.62	4.75	4.87	**5.**	5.12	5.25	5.37	5.5	5.62	**18**
.69	3.82	3.95	4.09	4.22	4.35	4.48	4.61	4.75	4.88	5.01	5.14	5.27	5.4	5.54	5.67	5.8	5.93	**19**
.88	4.02	4.16	4.3	4.44	4.58	4.72	4.86	**5.**	5.13	5.27	5.41	5.55	5.69	5.83	5.97	6.11	6.25	**20**
.08	4.22	4.37	4.52	4.66	4.81	4.95	5.1	5.25	5.39	5.54	5.68	5.83	5.97	6.12	6.29	6.41	6.56	**21**
.27	4.43	4.58	4.73	4.88	5.04	5.19	5.34	5.5	5.67	5.8	5.95	6.11	6.26	6.41	6.56	6.72	6.87	**22**
.47	4.63	4.79	4.95	5.11	5.27	5.43	5.59	5.75	5.9	6.06	6.22	6.38	6.54	6.7	6.86	7.02	7.18	**23**
.66	4.83	**5.**	5.16	5.33	5.5	5.66	5.83	**6.**	6.16	6.33	6.5	6.66	6.83	**7.**	7.16	7.33	7.5	**24**
.86	5.03	5.2	5.38	5.55	5.72	5.9	6.07	6.25	6.42	6.59	6.77	6.94	7.11	7.29	7.46	7.63	7.81	**25**
.05	5.23	5.41	5.45	5.77	5.95	6.13	6.31	6.5	6.68	6.86	7.04	7.22	7.4	7.58	7.76	7.94	8.12	**26**
.25	5.43	5.62	5.81	**6.**	6.18	6.37	6.56	6.75	6.93	7.12	7.24	7.5	7.68	7.87	8.06	8.25	8.43	**27**
.44	5.63	5.83	6.02	6.22	6.4	6.61	6.8	**7.**	7.19	7.38	7.58	7.77	7.97	8.16	8.36	8.55	8.75	**28**
.63	5.84	6.04	6.24	6.44	6.64	6.84	7.04	7.25	7.45	7.65	7.8	8.05	8.25	8.45	8.65	8.86	9.06	**29**
.83	6.04	6.25	6.45	6.66	6.87	7.08	7.29	7.5	7.7	7.91	8.12	8.33	8.54	8.75	8.95	9.16	9.37	**30**
.02	6.24	6.45	6.67	6.88	7.1	7.31	7.53	7.75	7.96	8.18	8.39	8.61	8.82	9.04	9.25	9.47	9.68	**31**
.22	6.44	6.66	6.88	7.1	7.33	7.55	7.77	**8.**	8.22	8.44	8.66	8.88	9.11	9.33	9.55	9.77	**10.**	**32**
.4	6.64	6.87	7.1	7.33	7.56	7.79	8.02	8.25	8.47	8.7	8.93	9.16	9.39	9.62	9.85	10.08	10.31	**33**
.61	6.84	7.08	7.31	7.55	7.79	8.02	8.26	8.5	8.73	8.97	9.2	9.44	9.68	9.91	10.15	10.38	10.62	**34**
.8	7.04	7.29	7.53	7.77	8.02	8.26	8.5	8.75	**9.**	9.23	9.47	9.72	9.89	10.2	10.45	10.69	10.93	**35**
.	7.25	7.5	7.75	**8.**	8.25	8.5	8.75	**9.**	9.25	9.5	9.75	**10.**	10.25	10.5	10.75	**11.**	11.25	**36**
.19	7.45	7.7	7.96	8.22	8.47	8.73	**9.**	9.25	9.5	9.76	10.02	10.27	10.53	10.79	11.04	11.3	11.56	**37**
.38	7.65	7.91	8.18	8.44	8.7	8.97	9.23	9.5	9.76	10.02	10.29	10.55	10.81	11.08	11.34	11.61	11.87	**38**
.58	7.8	8.12	8.39	8.66	8.93	9.2	9.47	9.75	10.02	10.29	10.56	10.83	11.1	11.37	11.64	11.91	12.11	**39**
.77	8.05	8.33	8.61	8.88	9.16	9.44	9.72	**10.**	10.27	10.55	10.83	11.11	11.38	11.66	11.94	12.12	12.5	**40**
.97	8.25	8.54	8.82	9.11	9.39	9.68	9.89	10.25	10.53	10.81	11.1	11.38	11.67	11.95	12.24	12.52	12.81	**41**
.16	8.45	8.75	9.04	9.33	9.62	9.91	10.2	10.5	10.79	11.08	11.37	11.66	11.95	12.25	12.54	12.83	13.12	**42**
.36	8.65	8.95	9.25	9.55	9.85	10.15	10.45	10.75	11.04	11.34	11.64	11.94	12.24	12.54	12.84	13.13	13.43	**43**
.55	8.86	9.16	9.47	9.77	10.08	10.38	10.69	**11.**	11.3	11.61	11.91	12.12	12.52	12.83	13.13	13.44	13.75	**44**
.75	9.06	9.37	9.68	**10.**	10.31	10.62	10.93	11.25	11.56	11.87	12.11	12.5	12.81	13.12	13.43	13.75	14.06	**45**

NO DEDUCTION HAS BEEN MADE HERE FOR REGISTERS OR GRILLS.

TABLE 16.

Areas and Circumference of Circles.

Diam. In.	Area. Sq. Ft.	Circumference. Ft.	Diam. In.	Area. Sq. Ft.	Circumference. Ft.	Diam. In.	Area. Sq. Ft.	Circumference. Ft.
1	.0055	.2618	29	4.587	7.592	57	17.72	14.92
2	.0218	.5236	30	4.909	7.854	58	18.35	15.18
3	.0491	.7854	31	5.241	8.116	59	18.99	15.45
4	.0873	1.047	32	5.585	8.378	60	19.63	15.71
5	.1364	1.309	33	5.940	8.639	61	20.29	15 97
6	.1964	1.571	34	6.305	8.901	62	20.97	16.23
7	.2673	1.833	35	6.681	9.163	63	21.65	16.49
8	.3491	2.094	36	7.069	9.425	64	22.34	16.76
9	.4418	2.356	37	7.467	9.686	65	23.04	17.02
10	.5454	2.618	38	7.876	9.948	66	23.76	17.28
11	.6600	2.880	39	8.276	10.21	67	24.48	17.54
12	.7854	3.142	40	8.727	10.47	68	25.22	17.80
13	.9218	3.403	41	9.168	10.73	69	25.97	18.06
14	1.069	3.665	42	9.621	10.99	70	26.73	18.33
15	1.227	3.927	43	10.08	11.26	71	27.49	18.59
16	1.396	4.189	44	10.56	11.52	72	28.27	18.85
17	1.576	4.451	45	11.04	11.78	73	29.07	19.11
18	1.767	4.712	46	11.54	12.04	74	29.87	19.37
19	1.969	4.974	47	12.05	12.30	75	30.68	19 63
20	2.182	5.236	48	12.57	12.57	76	31.50	19.90
21	2.405	5.498	49	13.10	12.86	77	32.34	20.16
22	2.640	5.760	50	13.64	13.09	78	33.18	20.42
23	2.885	6.021	51	14.19	13.35	79	34.04	20.68
24	3.142	6.283	52	14.75	13.61	80	34.91	20.94
25	3.409	6.545	53	15.32	13.88	81	35.78	21.21
26	3.687	6.807	54	15.90	14.14	82	36.67	21.47
27	3.976	7.069	55	16.50	14.40	83	37.57	21.73
28	4.276	7.330	56	17.10	14.66	84	38.48	21.99

TABLE 17.

For Equalizing the Diameter of Pipes.

The number at the intersection of lines and columns, headed by heavy figures, shows the number of smaller pipes that the larger one is equal to for conveying air, etc. For example: one 14-inch pipe will convey as much air (friction considered) as 13 five-inch — 13 being at the intersection of column marked 5 and line marked 14.

1	**1**																								
2	5.7	**2**																							
3	16	2.7	**3**																						
4	32	5.7	2	**4**																					
5	56	9.8	3.6	1.8	**5**																				
6	88	16	5.7	2.8	1.6	**6**																			
7	129	23	8.3	4.1	2.3	1.5	**7**																		
8	180	32	12	5.7	3.2	2.1	1.4	**8**																	
9	244	42	16	7.6	4.3	2.8	1.9	1.3	**9**																
10	317	56	20	9.9	5.7	3.6	2.4	1.7	1.3	**10**															
11	402	71	26	12	7.0	4.6	3.1	2.2	1.7	1.3	**11**														
12	501	88	32	16	9.0	5.7	3.8	2.8	2.0	1.6	1.2	**12**													
13	613	107	39	19	11	6.9	4.7	3.4	2.5	1.9	1.5	1.2	**13**												
14	737	129	47	23	13	8.3	5.7	4.1	3.0	2.3	1.8	1.5	1.2	**14**											
15	876	152	56	27	16	9.9	6.7	4.8	3.6	2.8	2.2	1.8	1.4	1.2	**15**										
16	1026	180	65	32	18	11	7.9	5.7	4.2	3.2	2.6	2.1	1.7	1.4	1.2	**16**									
17	1197	208	76	37	21	13	9.2	6.6	4.9	3.8	2.9	2.4	2.0	1.6	1.4	1.2	**17**								
18	1375	239	88	43	24	16	10	7.7	5.7	4.3	3.4	2.8	2.3	1.9	1.6	1.3	1.2	**18**							
19	1580	275	100	49	28	18	12	8.8	6.5	5.0	3.9	3.2	2.6	2.2	1.8	1.5	1.3	1.2	**19**						
20	1797	313	114	56	32	20	14	9.9	7.4	5.7	4.5	3.6	2.9	2.5	2.1	1.7	1.5	1.3	1.1	**20**					
22	2284	398	145	71	41	26	18	13	9.3	7.2	5.7	4.5	3.7	3.1	2.6	2.2	1.9	1.7	1.4	1.3	**22**				
24	2834	493	180	88	50	32	22	16	12	8.9	7.6	5.7	4.6	3.8	3.2	2.9	2.4	2.1	1.8	1.6	1.2	**24**			
26	3474	605	219	108	62	39	27	19	14	11	8.6	6.9	5.7	4.7	4.0	3.4	2.9	2.5	2.2	1.9	1.5	1.2	**26**		
28	4165	725	265	129	74	48	32	23	17	13	10	8.3	6.8	5.7	4.8	4.1	3.5	3.0	2.6	2.3	1.8	1.5	1.2	**28**	
30	4963	864	315	154	88	56	38	28	20	16	12	9.9	8.0	6.7	5.7	4.7	4.1	3.6	3.0	2.6	2.2	1.7	1.4	1.2	**30**

TABLE 18.

Number of Gallons in Round Cisterns and Tanks.

Depth in Feet.	Diameter in Feet.																	Depth in Feet.
	5	6	7	8	9	10	11	12	13	14	15	16	18	20	22	24	25	
5	735	1,060	1,440	1,875	2,380	2,925	3,550	4,237	4,960	5,765	6,698	7,520	9,516	11,750	14,215	16,918	18,358	5
6	881	1,270	1,728	2.250	2,855	3,510	4,260	5,084	5,952	6,918	8,038	9,024	11,419	14,100	17,059	20,302	22,030	6
7	1,028	1,480	2,016	2,625	3,330	4,095	4,970	5,931	6,944	8,071	9,378	10,528	13,322	16,450	19,902	23,680	25,701	7
8	1,175	1,690	2,304	3,000	3,805	4,680	5,680	6,778	7,936	9,224	10,718	12,032	15,225	18,800	22,745	27,070	29,372	8
9	1,322	1,900	2,592	3,375	4,280	5,265	6,390	7,625	8,928	10,377	12,058	13,536	17,128	21,150	25,588	30,454	33,043	9
10	1,469	2,110	2,880	3,750	4,755	5,850	7,100	8,472	9,920	11.530	13,398	15,040	19,031	23,500	28,431	33,838	36,714	10
11	1,616	2,320	3,168	4,125	5,230	6,435	7,810	9,319	10,913	12,683	14,738	16,544	20,934	25,850	31,274	37,222	40,385	11
12	1,762	2,530	3,456	4,500	5,705	7,020	8,520	10,166	11,904	13,836	16,078	18,048	22,837	28,200	34,117	40,606	44,056	12
13	1,909	2,740	3,744	4,875	6,180	7,605	9,230	11,013	12,896	14,989	17,418	19,552	24,740	30,550	36,960	43,990	47,727	13
14	2,056	2,950	4,032	5,250	6,655	8,190	9,940	11,860	13,888	16,142	18,758	21,056	26,643	32,900	39,803	47,374	51,398	14
15	2,203	3,160	4,320	5,625	7,130	8,775	10,650	12,707	14,880	17,295	20,098	22,260	28,546	35,250	42,646	50,758	55 069	15
16	2,356	3,370	4,608	6,000	7,605	9,360	11,360	13,554	15,872	18,448	21,438	24,064	30,449	37,600	45,489	54,142	58,740	16
17	2,497	3,580	4,896	6,375	8,080	9,945	12,070	14,401	16,864	19,601	22,778	25,568	32,352	39,950	48,332	57,520	62,411	17
18	2,644	3,790	5,184	6,750	8,535	10,530	12,780	15 248	17,856	20.754	24,118	27,072	34,255	42,300	51,175	60,910	66,082	18
19	2,791	4,000	5,472	7,125	9,010	11,115	13,490	16.095	18,848	21,907	25.458	28,576	36,158	44,650	54,018	64,294	69,753	19
20	2,938	4,210	5,760	7,500	9,490	11,700	14,200	16,942	19,840	23,060	26.798	30,080	38,062	47,000	56,861	67,678	73,424	20

For tanks that are tapering, measure the diameter four-tenths from the large end.

TABLE 19.

Capacity of Pipes and Registers.

ROUND PIPES.

Diameter of Pipe	Area in Sq. Inches.	Diameter of Pipe.	Area in Sq. Inches.	Diameter of Pipe.	Area in Sq. Inches.
7 in.	38	12 in.	113	22 in.	380
8 in.	50	14 in.	154	24 in.	452
9 in.	63	16 in.	201	26 in.	531
10 in.	78	18 in.	254	28 in.	616
11 in.	95	20 in.	314	30 in.	707

REGISTERS.

Size of Opening.	Capacity in Sq. Inches.	Size of Opening.	Capacity in Sq. Inches.	Size of Opening.	Capacity in Sq. Inches.
6×10	40	10×14	93	20×20	267
8×10	53	10×16	107	20×24	320
8×12	64	12×15	120	20×26	347
8×15	80	12×19	152	21×29	406
9×12	72	14×22	205	27×27	486
9×14	84	15×25	250	27×38	684
10×12	80	16×24	256	30×30	600

ROUND REGISTERS.

Size of Opening.	Capacity in Sq. Inches.	Size of Opening.	Capacity in Sq. Inches.	Size of Opening.	Capacity in Sq. Inches.
7 in.	26	12 in.	75	20 in.	209
8 in.	33	14 in.	103	24 in.	301
9 in	42	16 in.	134	30 in.	471
10 in.	52	18 in.	169	36 in.	679

DIMENSIONS OF CAST-IRON REGISTERS.

(Tuttle and Bailey.)

Size. Inches.	Net Area. Square Feet.	Size. Inches.	Net Area. Square Feet.
10×12	.55	16×24	1.77
10×14	.64	16×26	1.92
10×16	.74	18×24	2.00
12×15	.83	18×30	2.50
12×16	.88	20×20	1.85
12×19	1.05	20×24	2.22
14×18	1.16	20×26	2.41
14×22	1.42	21×29	2.82
15×25	1.73	24×32	3.55
16×16	1.18	27×27	3.37
16×20	1.48	27×38	4.75
16×21	1.55	30×30	4.16

TABLE 20.

WEIGHTS OF ● AND ■ STEEL PER LINEAL FOOT

(Based on 489.6 lbs. per cubic foot.)

Size. Inches.	Wt. of ● 1 ft. long	Wt. of ■ 1 ft. long.	Size. Inches.	Wt. of ● 1 ft. long	Wt. of ■ 1 ft. long	Size. Inches.	Wt. of ● 1 ft. long.	Wt. of ■ 1 ft. long.
$0\frac{1}{32}$	.0026	.0033	3	24.03	30.60	6	96.14	122.4
$0\frac{1}{16}$	.0104	.0133	$3\frac{1}{16}$	25.04	31.89	$6\frac{1}{16}$	98.14	125.0
$0\frac{1}{8}$	.0417	.0531	$3\frac{1}{8}$	26.08	33.20	$6\frac{1}{8}$	100.2	127.6
$0\frac{3}{16}$	.0938	.1195	$3\frac{3}{16}$	27.13	34.55	$6\frac{3}{16}$	102.2	130.2
$0\frac{1}{4}$	.1669	.2123	$3\frac{1}{4}$	28.20	35.92	$6\frac{1}{4}$	104.3	132.8
$0\frac{5}{16}$	.2608	.3333	$3\frac{5}{16}$	29.30	37.31	$6\frac{5}{16}$	106.4	135.5
$0\frac{3}{8}$	.3756	.4782	$3\frac{3}{8}$	30.42	38.73	$6\frac{3}{8}$	108.5	138.2
$0\frac{7}{16}$	.5111	.6508	$3\frac{7}{16}$	31.56	40.18	$6\frac{7}{16}$	110.7	140.9
$0\frac{1}{2}$	.6676	.8500	$3\frac{1}{2}$	32.71	41.65	$6\frac{1}{2}$	112.8	143.6
$0\frac{9}{16}$	.8449	1.076	$3\frac{9}{16}$	33.90	43.14	$6\frac{9}{16}$	114.9	146.5
$0\frac{5}{8}$	1.043	1.328	$3\frac{5}{8}$	35.09	44.68	$6\frac{5}{8}$	117.2	149.2
$0\frac{11}{16}$	1.262	1.608	$3\frac{11}{16}$	36.31	46.24	$6\frac{11}{16}$	119.4	152.1
$0\frac{3}{4}$	1.502	1.913	$3\frac{3}{4}$	37.56	47.82	$6\frac{3}{4}$	121.7	154.9
$0\frac{13}{16}$	1.763	2.245	$3\frac{13}{16}$	38.81	49.42	$6\frac{13}{16}$	123.9	157.8
$0\frac{7}{8}$	2.044	2.603	$3\frac{7}{8}$	40.10	51.05	$6\frac{7}{8}$	126.2	160.8
$0\frac{15}{16}$	2.347	2.989	$3\frac{15}{16}$	41.40	52.71	$6\frac{15}{16}$	128.5	163.6
1	2.670	3.400	4	42.73	54.40	7	130.9	166.6
$1\frac{1}{16}$	3.014	3.838	$4\frac{1}{16}$	44.07	56.11	$7\frac{1}{8}$	135.6	172.6
$1\frac{1}{8}$	3.379	4.303	$4\frac{1}{8}$	45.44	57.85	$7\frac{1}{4}$	140.4	178.7
$1\frac{3}{16}$	3.766	4.795	$4\frac{3}{16}$	46.83	59.62	$7\frac{3}{8}$	145.3	184.9
$1\frac{1}{4}$	4.173	5.312	$4\frac{1}{4}$	48.24	61.41	$7\frac{1}{2}$	150.2	191.3
$1\frac{5}{16}$	4.600	5.857	$4\frac{5}{16}$	49.66	63.23	$7\frac{5}{8}$	155.2	197.7
$1\frac{3}{8}$	5.019	6.428	$4\frac{3}{8}$	51.11	65.08	$7\frac{3}{4}$	160.3	204.2
$1\frac{7}{16}$	5.518	7.026	$4\frac{7}{16}$	52.58	66.95	$7\frac{7}{8}$	165.6	210.8
$1\frac{1}{2}$	6.008	7.650	$4\frac{1}{2}$	54.07	68.85	8	171.0	217.6
$1\frac{9}{16}$	6.520	8.301	$4\frac{9}{16}$	55.59	70.78	$8\frac{1}{8}$	176.3	224.5
$1\frac{5}{8}$	7.051	8.978	$4\frac{5}{8}$	57.12	72.73	$8\frac{1}{4}$	181.8	231.4
$1\frac{11}{16}$	7.604	9.682	$4\frac{11}{16}$	58.67	74.70	$8\frac{3}{8}$	187.3	238.5
$1\frac{3}{4}$	8.178	10.41	$4\frac{3}{4}$	60.25	76.71	$8\frac{1}{2}$	193.0	245.6
$1\frac{13}{16}$	8.773	11.17	$4\frac{13}{16}$	61.84	78.74	$8\frac{5}{8}$	198.7	252.9
$1\frac{7}{8}$	9.388	11.95	$4\frac{7}{8}$	63.46	80.81	$8\frac{3}{4}$	204.4	260.3
$1\frac{15}{16}$	10.02	12.76	$4\frac{15}{16}$	65.10	82.89	$8\frac{7}{8}$	210.3	267.9
2	10.68	13.60	5	66.76	85.00	9	216.3	275.4
$2\frac{1}{16}$	11.36	14.46	$5\frac{1}{16}$	68.44	87.14	$9\frac{1}{8}$	222.4	283 2
$2\frac{1}{8}$	12.06	15.35	$5\frac{1}{8}$	70.14	89.30	$9\frac{1}{4}$	228.5	290.9
$2\frac{3}{16}$	12.78	16.27	$5\frac{3}{16}$	71.86	91.49	$9\frac{3}{8}$	234.7	298.9
$2\frac{1}{4}$	13.52	17.22	$5\frac{1}{4}$	73.60	93.72	$9\frac{1}{2}$	241.0	306.8
$2\frac{5}{16}$	14.28	18.19	$5\frac{5}{16}$	75.37	95.96	$9\frac{5}{8}$	247.4	315.0
$2\frac{3}{8}$	15.07	19.18	$5\frac{3}{8}$	77.15	98.23	$9\frac{3}{4}$	253.9	323.2
$2\frac{7}{16}$	15.86	20.20	$5\frac{7}{16}$	78.95	100.5	$9\frac{7}{8}$	260.4	331.6
$2\frac{1}{2}$	16.69	21.25	$5\frac{1}{2}$	80.77	102.8	10	267.0	340.0
$2\frac{9}{16}$	17.53	22.33	$5\frac{9}{16}$	82.62	105.2	$10\frac{1}{4}$	280.6	357.2
$2\frac{5}{8}$	18.40	23.43	$5\frac{5}{8}$	84.49	107.6	$10\frac{1}{2}$	294.4	374.9
$2\frac{11}{16}$	19.29	24.56	$5\frac{11}{16}$	86.38	110.0	$10\frac{3}{4}$	308.6	392.9
$2\frac{3}{4}$	20.20	25.00	$5\frac{3}{4}$	88.29	112.4	11	323.1	411.4
$2\frac{13}{16}$	21.12	26.90	$5\frac{13}{16}$	90.22	114 9	$11\frac{1}{4}$	337.9	430.3
$2\frac{7}{8}$	22.07	28.10	$5\frac{7}{8}$	92.17	117.4	$11\frac{1}{2}$	353.1	449 6
$2\frac{15}{16}$	23.04	29.34	$5\frac{15}{16}$	94.14	119.9	$11\frac{3}{4}$	368.6	469.4

These figures represent the theoretical weights of *steel*. Iron will run about 2 per cent lighter.

TABLE 21.

Standard Gauges.

U.S. Standard Gauge.					Birmingham Gauge.			
No. of Gauge.	Thickness in Inches.		Weight Square Foot.		No. of Gauge.	Thick-ness in Inches.	Weight Sq. Foot.	
	Fractions.	Decimals.	Iron.	Steel.			Iron.	Steel.
7-0's	1/2	.5	20.00	20.4	—	—	—	—
6-0's	15/32	.46875	18.75	19.125	—	—	—	—
5-0's	7/16	.4375	17.50	17.85	—	—	—	—
0000	13/32	.40625	16.25	16.575	0000	.454	18.22	18.46
000	3/8	.375	15.	15.30	000	.425	17.05	17.28
00	11/32	.34375	13.75	14.025	00	.38	15.25	15.45
0	5/16	.3125	12.50	12.75	0	.34	13.64	13.82
1	9/32	.28125	11.25	11.475	1	.3	12.04	12.20
2	17/64	.265625	10.625	10.8375	2	.284	11.40	11.55
3	1/4	.25	10.	10.2	3	.259	10.39	10.53
4	15/64	.234375	9.375	9.5625	4	.238	9.55	9.68
5	7/32	.21875	8.75	8.925	5	.22	8.83	8 95
6	13/64	.203125	8.125	8.2875	6	.203	8.15	8.25
7	3/16	.1875	7.5	7.65	7	.18	7.22	7.32
8	11/64	.171875	6.875	7.0125	8	.165	6.62	6.71
9	5/32	.15625	6.25	6.375	9	.148	5.94	6.02
10	9/64	.140625	5.625	5.7375	10	.134	5.38	5.45
11	1/8	.125	5.	5.1	11	.12	4.82	4.88
12	7/64	.109375	4.375	4.625	12	.109	4.37	4.43
13	3/32	.09375	3.75	3.825	13	.095	3.81	3.86
14	5/64	.078125	3.125	3.1875	14	.083	3.33	3.37
15	9/128	.0703125	2.8125	2.86875	15	.072	2.89	2.93
16	1/16	.0625	2.5	2.55	16	.065	2.61	2.64
17	9/160	.05625	2.25	2.295	17	.058	2.33	2.36
18	1/20	.05	2.	2.04	18	.049	1.97	1.99
19	7/160	.04375	1.75	1.785	19	.042	1.69	1.71
20	3/80	.0375	1.50	1.53	20	.035	1.40	1.42
21	11/320	.034375	1.375	1.4025	21	.032	1.28	1.30
22	1/32	.03125	1.25	1.275	22	.028	1.12	1.14
23	9/320	.028125	1.125	1.1475	23	.025	1.00	1.02
24	1/40	.025	1.	1.02	24	.022	.883	.895
25	7/320	.021875	.865	.8925	25	.02	.803	.813
26	3/160	.01875	.75	.765	26	.018	.722	.732
27	11/640	.0171875	.6875	.70125	27	.016	.642	.651
28	1/64	.015625	.625	.6375	28	.014	.562	.569
29	9/640	.0140625	.5625	.57375	29	.013	—	—
30	1/80	.0125	.5	.51	30	.012	—	—
31	7/64	.010985	.4375	.44625	31	.01	—	—
32	13/1280	.01045625	.40625	.414375	32	.009	—	—
33	3/320	.009375	.375	.3825	33	.008	—	—
34	11/1280	.00859375	.34375	.350625	34	.007	—	—
35	5/640	.0078125	.3125	.31875	35	.005	—	—
36	9/1280	.00703125	.28125	.286875	36	.004	—	—
37	17/2560	.00664062	.265625	.2709375	37	—	—	—
38	1/160	.00625	.25	.255	—	—	—	—

All sheets of iron and steel are rolled to U.S. standard gauge unless otherwise ordered.

The low temperature (as compared with iron) at which steel plates have to be finished, causes a slight springing of the rolls, leaving the plate thicker in the center than on the edge. This is especially noticeable in plates less than 3/8 inch thick and over 66 inches wide, which may be of full thickness on the edge and yet be as much as 1/8 inch thicker in the middle.

TABLE 22

Estimated Weights of Galvanized Sheets.

U.S. Standard Gauge	10	12	14	16	18	20	22	24	25	26	27	28	29	30
Weight per sq. ft., lbs	5.781	4.531	3.281	2.656	2.156	1.656	1.406	1.156	1.031	.9062	.8437	.7812	.7187	.6562
Weight per sq. ft., oz.	92.5	72.5	52.5	42.5	34.5	26.5	22.5	18.5	16.5	14.5	13.5	12.5	11.5	10.5
Size of Sheet	Weight of Sheet—Pounds													
24 x 72	69	54	39	32	26	20	17	14	12	11	10	9	9	8
24 x 84	81	63	46	37	30	23	20	16	14	13	12	11	10	9
24 x 96	93	73	53	43	35	27	23	19	17	15	14	13	12	11
24 x 120	116	91	66	53	43	33	28	23	21	18	17	16	14	13
26 x 72	75	59	43	35	28	22	18	15	13	12	11	10	9	9
26 x 84	88	69	50	40	33	25	21	18	16	14	13	12	11	10
26 x 96	100	79	57	46	37	29	24	20	18	16	15	14	12	11
26 x 120	125	98	71	58	47	36	30	25	22	20	18	17	16	14
28 x 72	81	63	46	37	30	23	20	16	14	13	12	11	10	9
28 x 84	94	74	54	43	35	27	23	19	17	15	14	13	12	11
28 x 96	108	85	61	50	40	31	26	22	19	17	16	15	13	12
28 x 120	135	106	77	62	50	39	33	27	24	21	20	18	17	15
30 x 72	87	68	49	40	32	25	21	17	15	14	13	12	11	10
30 x 84	101	79	57	46	38	29	25	20	18	16	15	14	13	11
30 x 96	116	91	66	53	43	33	28	23	21	18	17	16	14	13
30 x 120	145	113	82	66	54	41	35	29	26	23	21	20	18	16
36 x 72	104	82	59	48	39	30	25	21	19	16	15	14	13	12
36 x 84	121	95	69	55	45	35	30	24	22	19	18	16	15	14
36 x 96	139	109	79	64	52	40	34	28	25	22	20	19	17	16
36 x 120	173	136	98	80	65	50	42	35	31	27	25	23	22	20
42 x 72	121	95	71	56	45	34	29	24	22	19	18	16	15	14
42 x 84	142	111	80	65	53	41	34	28	25	22	21	19	18	16
42 x 96	162	127	92	74	60	46	39	32	29	25	24	22	20	18
42 x 120	202	159	115	93	75	58	49	41	36	33	29	27	25	23
48 x 72	139	109	79	64	52	40	34	28	25	22	20	19	17	16
48 x 84	162	125	92	74	60	46	39	32	29	25	24	22	20	18
48 x 96	185	145	105	85	69	55	45	37	33	29	27	25	23	21
48 x 120	231	181	131	106	86	66	56	46	41	36	34	31	29	

TABLE 23.

Circumferences of Circles.

Comprehending Diameters Used by Boiler Makers.

Diameter in Inches.	Circumference in Inches.	Area in Sq. Inches.	Diameter in Inches.	Circumference in Inches	Area in Sq. Inches
12	$37\frac{5}{8}$	113	58	$182\frac{1}{8}$	2642
14	44	154	60	$188\frac{1}{2}$	$2827\frac{1}{2}$
16	$50\frac{1}{8}$	201	62	$194\frac{3}{4}$	3019
18	$56\frac{1}{2}$	$254\frac{1}{2}$	64	201	3217
20	$62\frac{3}{4}$	$314\frac{1}{8}$	66	$207\frac{1}{4}$	$3421\frac{1}{2}$
22	69	$380\frac{1}{8}$	68	$213\frac{5}{8}$	$3631\frac{5}{8}$
24	$75\frac{3}{8}$	$452\frac{3}{8}$	70	$219\frac{7}{8}$	$3848\frac{1}{2}$
26	$81\frac{5}{8}$	531	72	$226\frac{1}{8}$	$4071\frac{1}{2}$
28	$87\frac{7}{8}$	$615\frac{3}{4}$	74	$232\frac{3}{8}$	$4300\frac{7}{8}$
30	$94\frac{1}{4}$	$706\frac{7}{8}$	76	$238\frac{5}{8}$	$4536\frac{1}{2}$
32	$100\frac{1}{2}$	$804\frac{1}{4}$	78	$244\frac{7}{8}$	$4478\frac{3}{8}$
34	$106\frac{3}{4}$	908	80	$251\frac{1}{2}$	$5026\frac{1}{2}$
36	113	$1017\frac{7}{8}$	82	$257\frac{1}{2}$	5281
38	$119\frac{3}{8}$	$1134\frac{1}{8}$	84	$263\frac{7}{8}$	$5541\frac{3}{4}$
40	$125\frac{5}{8}$	$1256\frac{5}{8}$	86	$270\frac{1}{8}$	$5808\frac{7}{8}$
42	$131\frac{7}{8}$	$1385\frac{1}{2}$	88	$276\frac{1}{2}$	$6082\frac{1}{8}$
44	$138\frac{1}{8}$	$1520\frac{1}{2}$	90	$282\frac{3}{4}$	$6361\frac{3}{4}$
46	$144\frac{1}{2}$	1662	92	289	$6647\frac{5}{8}$
48	$150\frac{3}{4}$	$1809\frac{1}{2}$	94	$295\frac{1}{4}$	$6939\frac{3}{4}$
50	157	$1963\frac{1}{2}$	96	$301\frac{1}{2}$	$7238\frac{1}{4}$
52	$163\frac{1}{4}$	$2123\frac{3}{4}$	98	$307\frac{7}{8}$	7543
54	$169\frac{5}{8}$	$2290\frac{1}{4}$	100	$314\frac{1}{2}$	7854
56	$175\frac{7}{8}$	2463	102	$320\frac{3}{8}$	$8171\frac{1}{4}$

Boilermakers usually add three times the thickness of the plate to length of iron for the take-up in rolling; also add for laps, single or double riveting.

TABLE 24.

Number of Tubes Usually Put in Return Tubular Boilers.

Hand-holes Under Tubes.					Manhole Under Tubes.			
Diam. Boiler.	$2\frac{1}{2}$-Inch Tubes.	3-Inch Tubes.	$3\frac{1}{2}$-Inch Tubes.	4-Inch Tubes.	Diam.	3-Inch Tubes.	$3\frac{1}{2}$-Inch Tubes.	4-Inch Tubes.
36	38	26	–	–	–	–	–	–
42	52	38	–	–	42	–	22	18
44	–	38	34	22	44	28	26	20
48	–	52	38	34	48	44	28	26
54	–	54	44	34	54	56	44	36
60	–	82	64	54	60	62	54	44
66	–	–	72	54	66	88	66	54
72	–	–	92	72	72	124	86	70
–	–	–	–	–	78	132	100	84

TABLE 25.

Dimensions of Standard Wrought Iron Pipe.

Inches.	Actual Diameter.		Thickness. Inches.	Circumference. Inches.		Length of Pipe in feet per Square Foot of Surface.		Area. Square Inches.	
Nominal Inside Diam.	Inside.	Outside.		Internal.	External.	Inside.	Outside.	Internal.	External.
1/8	.27	.40	.07	.84	1.27	14.15	9.44	.06	.12
1/4	.36	.54	.08	1.14	1.69	10.50	7.07	.10	.22
3/8	.49	.67	.09	1.55	2.12	7.67	5.65	.19	.35
1/2	.62	.84	.10	1.95	2.65	6.13	4.50	.30	.55
3/4	.82	1.05	.11	2.58	3.29	4.63	3.63	.53	.86
1	1.04	1.31	.13	3.29	4.13	3.67	2.90	.86	1.35
1 1/4	1.38	1.66	.14	4.33	5.21	2.76	2.30	1.49	2.16
1 1/2	1.61	1.90	.14	5.06	5.96	2.37	2.01	2.03	3.83
2	2.06	2.37	.15	6.49	7.46	1.84	1.61	3.35	4.43
2 1/2	2.46	2.87	.20	7.75	9.03	1.54	1.32	4.78	6.49
3	3.06	3.50	.21	9.63	10.96	1.24	1.09	7.38	9.62
3 1/2	3.56	4.00	.22	11.14	12.56	1.07	.95	9.83	12.50
4	4.02	4.50	.23	12.64	14.13	.94	.84	12.73	15.90
4 1/2	4.50	5.00	.24	14.15	15.70	.84	.76	15.93	19.63
5	5.04	5.56	.25	15.84	17.47	.75	.62	19.99	24.30
6	6.06	6.62	.28	19.05	20.81	.63	.57	28.88	34.47
7	7.02	7.62	.30	22.06	23.95	.54	.50	38.53	45.66
8	7.98	8.62	.32	25.07	27.09	.47	.44	50.03	58.42
9	9.00	9.68	.34	28.27	30.43	.42	.40	63.63	73.71
10	10.01	10.75	.36	31.47	33.77	.38	.35	78.83	90.79
11	11.00	11.75	.37	34.55	36.91	.34	.32	95.03	108.43
12	12.00	12.75	.37	37.70	40.05	.32	.30	113.09	127.67
13	13.25	14.00	.37	41.62	43.98	.29	.27	137.88	153.94
14	14.25	15.00	.37	44.76	47.12	.27	.25	159.48	167.71
15	15.40	16.00	.28	48.48	50.26	.25	.24	187.04	201.06

TABLE 26.

Expansion of Metals.

The Linear Expansion, or Extension of Metals for One Degree Rise in Temperature.

Material.	Increase of Length in One Foot for an Increase in Temperature of 1° F.	Material.	Increase of Length in One Foot for an Increase in Temperature of 1° F.
Cast-Iron	.0000740	Brass	.0001244
Wrought-Iron	.0000823	Zinc	.0001961
Steel Tubes	.0000719	Lead	.0001900
Copper	.0001146	Tin	.0001692

To find the amount of expansion or contraction of a bar or pipe of given length, which will be caused by a given change in temperature, multiply the length in feet by the number of degrees of change in temperature. Multiply this product by the co-efficient given in the table for the material employed. The result will be the change in length in inches.

Iron pipes which are used in steam and hot-water fitting expand about one and one-half inches for 100 feet in length.

In long lines of pipe this expansion must be provided for; otherwise it will make trouble by breaking connections or shoving apparatus out of place.

TABLE 27.

For Estimating Size of Coal-Bin.

Kind of Coal.	Cubic Feet in One Ton. Short Ton, 2,000 lbs.	Long Ton, 2,240 lbs.
Broken	33.	37.
Egg	33.6	37.6
Stove	34.2	38 2
Nut	35.	39.2
Pocahontas	36.	40.2

The following is from tests by Mr. D. P. Sullivan, Sealer of Weights and Measures, Boston, Mass.

Kind of Coal.	One Ton.	Cubic Feet.	Cubic Inches
White Ash	Stove	37	116
White Ash (egg)	Stove	36	36
Shamokin	Stove	37	662
Lackawanna (nut)	Stove	31	857
Franklin (Lykens Valley)	Stove	38	164
Lehigh (hard egg)	Furnace	33	576
Lehigh (free burning)	Furnace	36	62
Lackawanna (free burning)	Furnace	38	796
New River	Soft Steam	36	1295
Cumberland	Blacksmiths'	30	723

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