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The Environmental Controls of the Furness Fine Arts Library

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THE ENVIRONMENTAL CONTROLS OF THE FURNESS FINE ARTS LIBRARY

by Robert Dean Nevitt

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THESIS: The environmental control system as originally designed and installed in Furness Library reflected the current theory and technology of the time and was consistant with the University of Pennsylvania's intent to build the best possible library in America.

INTRODUCTION

The Furness Fine Arts Library at the University of Pennsylvania was first opened for use as the university's main library in February, 1891. The building, designed by Philadelphia architect Frank Furness of Furness, Evans and Company, is a sandstone, brick, and terra cotta structure which was named a National Historic Landmark in 1985. Within the building there exists a number of components of the building's original steam heating system, which is still in use, in addition to components and alterations which have been added to the system since the buildings opening.

THEORIES OF VENTILATION IN THE NINETEENTH CENTURY

Exactly how the nineteenth century notion that many diseases and other physical and mental ailments were caused by interior environmental conditions that we now consider merely stuffy or uncomfortable is unknown. However, most laymen, and many of the leading doctors and hygenists of the time, considered these conditions to be grave health threats to the common man; exhaled air and the vapors from decay were thought to contain disease-causing poisons. A possible reason for their beliefs might be the lack of knowledge about the nature of many diseases and the mechanisms of transmission. This led many to believe that the foul odors and stuffy, crowded living conditions of the poor in many developing industrial cities, the damp and musky odors of swamp-like regions, and the coincidental incidences of disease and disability were directly linked in a cause and effect relationship.

Until the late nineteenth century, heating was considered a separate concern from ventilation. While the manner of providing for both were usually integrated into a single system, as heating was neccessary to moderate the temperature of the incoming air of ventilation, heating was thought to be more a matter of providing comfort for the occupants of a building while ventilation was considered to be a vital matter of sustaining life and health.[1]

Until the last generation of the nineteenth century, speculation and empirical observation made up the bulk of information on the causes of maladies which, resembling the symptoms of disease in many instances, were actually thought to be the cause of them. Hence a proper and

sufficient method of providing adequate ventilation in buildings was assumed to be neccessary to remove these perceived causes of disease.

During the early part of the nineteenth century, most doctors and hygenists -- as well as most laymen -- believed that poisons existed in exhaled air which, breathed in sufficient quantity and/or over protracted periods of time, would cause any number of diseases and mental impairments. Dr. James Johnson, M.D., warned of: "dangerous maladies that silently disorganise (sic) the vital structure of the human fabric, under the influence of this deleterious and invisible poison."[2] As late as 1885 (and in fact this issue continued to be debated until the 1920s) Charles Hood, a heating engineer, pronounced that: "experience proves that multitudes shorten their lives by breathing impure air, and many more lay the foundation of diseases, accompanied by years of pain and sorrow,...."[3] Among the maladies which were contributed in whole or in part to expired air were tetanus (associated with asphyxia), cretinism, pellegra, various epilepsies, apoplexy, fevers, agues, dysentery, and malaria, thought to be the result of hydrogen sulphide or "swamp gas".[4]

During the 1830s and 40s it was the fashion to think that "carbonic acid gas" (carbon dioxide) was a menace to good health. "Chemistry had uncovered the root of disease, and carbonic acid gas was the cause."[5] "If a room is hot or close from excess of temperature, or from a crowd of occupants, carbonic acid gas is the difficulty; if malaria is developed in a jail or hospital, or typhus or scarlet fever exist in the dwelling, carbonic acid gas in excess is the poison."[6] As the century progressed and as more came to be understood about the exact nature of

carbon dioxide and its place in human respiration, attention shifted to other supposed organic poisons which were thought to emanate from the human body, decay, and sources of combustion such as gas lighting and hot-air furnaces.[7]

Furthermore, humidity was also suspect, though not thought to be directly responsible for disease. As medicine began to unlock the mysteries of many diseases and their mechanisms of transmission, some were found to be caused by microbes which could be transmitted through the air exhaled by an infected person. Humidity was thought to be a vehicle for transporting disease causing organisms, particularly malaria which abounded in damp and humid regions.[8]

At mid-century the greatest influence in the field of published information on the subject of ventilation was a book written by Dr. David Boswell Reid, M.D., <u>Theory and Practise of Ventilation</u>, published in the year 1844. The bulk of Dr. Reid's observations on the way that air moves in enclosed spaces was generally accurate, i.e. the tendency of heated air to rise and cooled air to fall according to surface temperatures within a space, the fluid dynamics of pressure differentials caused by outside winds and warm air currents, etc..

Dr. Reid also attempted to determine the exact amount and nature of the air required for healthful and comfortable human consumption. However, his observations and experiments to determine the exact nature of requirements for human consumption are largely empirical and speculative. In one set of experiments he placed individuals in chambers into which he could control the precise amounts of conditioned air and also make adjustments to the introduced atmosphere by drying or

humidifying it, adding or subtracting other chemical substances, increasing or decreasing the amounts of oxygen or carbon dioxide or other substances, etc.. The substances and the amounts which he used were largely a matter of trial and error based on speculation, and the reactions of the subjects which he recorded were generally subjective. About their reactions he wrote:

> "There are perhaps no matters on which any two individuals are less likely to agree, than as to the precise amount and quality of air which is most suitable and agreeable to them. Age, habit, temperment, diet, clothing, previous exposure and engagements, mental excitement, and the state of the constitution at the moment, all concur to modify the impression produced by any given atmosphere upon the system.....Hence, many judging by their own sensations, do not appeal to a correct standard."[9]

Dr. Reid's observations on the relationships between air temperature, humidity, and air velocity were essentially correct as we now understand them to affect thermal comfort; however, they were made to identify the causes which altered the volume and makeup of air required for sustaining human health. He discussed a variety of factors as possibly affecting human requirements including light, electricity, and barometric pressure. He also touched on the concept of radiant heat, associated with sources of light, affecting thermal comfort; but gave too much credence to the possibility that there might be unknown physiological processes affected by daylight, and even moonlight, which affected the need for ventilation. Electricity, specifically lightning and static electricity which at the time were poorly understood phenomena, were felt by Dr. Reid to have a possible effect on respiration and metabolism. Additionally, he correctly noted the effects of barometric pressure although he overestimated its

magnitude.[10]

At the same time that the lack of ventilation was considered to have a highly detrimental effect on the health of the individual, drafts, a frequent by-product of ventilation, were considered to have an equally deleterious effect. As Dr. Reid stated: "[Vitiated air] may undermine the constitution by a slow action, but draughts and currents produce cough, colds, rheumatisms, pleurisies, and other inflammations, which not infrequently prove quickly fatal..."[11]

As to the means of providing sufficient ventilation for buildings, there were almost as many theories and techniques as there were buildings. There also existed various notions as to where the unwanted products of human respiration existed within a room. Many thought that they settled near the floor with the colder air, but to introduce warm ventilated air at the top of an occupied space in order to draw off air lower in the room meant to move ventilation in opposition to the natural tendency of heated air within a room to rise and in many instances gravity was the most efficient and dependable means of providing ventilation.[12] At the same time, removing air from the top of the room meant drawing off the previously warmed air which meant that more energy was required than actually neccessary. The ceiling heights of a room might have been lowered, however, this mechanism might be attributable to the concept of providing sufficient ventilation in an earlier era and was not the fashion of the day.[13]

HEATING SYSTEMS IN THE LATE NINETEENTH CENTURY

There were fundamentally four types of heating systems available in 1890: open fire, stoves (including hot air furnaces), hot water, and steam systems.[14]

Open fire- This oldest of systems provided direct radiant heat to very small spaces where provisions for ventilation were not considered neccessary. Fireplaces provided ventilation indirectly in the form of drafts and leaks around windows and doors and as a result of open combustion of a fuel within the space being heated. Occasionally outside air sources for combustion were provided to reduce the amount of heated air within a room which was drawn up the chimney.

Stoves- Every form from the old fashioned Franklin stove to the latest hot air furnaces were included in this catagory. This was probably the most economical means of heating but only worked well in small to moderate sized buildings. Various types included free-standing stoves, stoves placed against an opening bringing in fresh air, stoves which stood in an enclosed chamber within a room, and stoves which were placed in the basement and provided heat which was ducted to other parts of the structure.

This last system of heating, developed from older systems of stoves set within a room, includes hot air and furnace-plenum systems. The fundamentals of the hot air furnace system are little more than those of a fuel burning stove, such as a Franklin stove, removed from the room which it is heating and the heat from the stove conducted by gravity through air ducts into the room. With the addition of steam driven fans

in some instances, larger buildings could be heated using this means.

Toward the end of the nineteenth century, systems such as this went one step further in providing means of controlling the mixture of heated air and cold air from the exterior in plenums which had the advantage of providing a constant source of ventilation while allowing a greater degree of control than was available by any other system.[15] Furthermore, systems such as these were less expensive to initially install, cost less to maintain in operation, and required less skill to operate. However, these systems also had the disadvantage of being practical only in small to medium size structures where the movement of air could be more easily controlled. They also had the disadvantage of drying the air as it was heated during the colder months when a certain amount of humidity is desirable and necessary for comfort.

Hot water- Two types of this system were generally in use; high and low/no pressure systems.

The development of hot water systems came about early in the nineteenth century, but were developed primarily for use in smaller structures as the means of circulation, by convection of the heated water, was much slower in these systems and a lower capacity of the water to store and transport heat over long distances was not sufficient to make them effective in larger structures. Hot water did have certain advantages over steam in that it produces a quieter and steadier supply of heat where it could be used and it was more economical. Additionally, there was no danger of any kind of explosion or violent venting of hot gases in the event of a rupture in the system.[16]

Steam- There were two basic types in this system also, low and high pressure steam. When steam heating was in its infancy circa 1860, installations were largely confined to the better public buildings since the cost was too high for general use and there were comparatively few contractors around to install them.[17] Until late in the century, steam was seldom used in residential applications and was the primary means of heating larger institutions and workshops.[18] It was especially convenient when steam was needed for other purposes such as powering machinery.

The use of steam heating for a building was the only appropriate choice if the building was of any size; only steam methods could effectively transport heat from a central heating unit over relatively long distances.[19] Steam was in fact efficient enough at this to be generated in another building altogether and used to heat a number of buildings from one source.[20]

Two years after the library was first opened, the University first applied this principal of "district heating" by opening a steam generating plant on the northwest corner of Spruce and Thirty-fourth Streets on the current site of Irvine Auditorium. Prior to this time it is known that the Furness Library, as well as the other buildings on the campus, had their own steam boilers and thus provided their own heat. Little is known of this first boiler system for the library beyond the fact that it was fitted with a "Harrison" boiler.[21]

One of the disadvantages of a steam system was the limited control of heat which occupants had within individual spaces and the building in general. Individual control of spaces within a building was largely a

matter of opening and closing windows. The primary control of heat was affected through the sizing of radiators during construction of the system and the subsequent adjustments made to the system. Once a system was installed, steam was constantly provided throughout the heating season. Since its inception there never has been developed an effective means of thermostatic control of heat in steam systems.[22]

Also, operation of a steam system required a greater degree of skill to operate the boiler at a correct rate of combustion and to control the many valves which regulated the flow of steam to and from various parts of the building. The amount of steam admitted by the opening and closing of valves was less a matter of controlling the amount of heat as it was the prevention of condensation from accumulating in pipes leading to the various radiators and causing noisy "steam hammers".

The development of steam for heating purposes was largely due to the development of steam for powering machinery and the associated development of wrought iron piping and other fittings.[23] In fact, steam was actually developed as a means of heating before hot water systems came into use. The first practical applications of this means of heating was its industrial use in English cotton mills late in the eighteenth century where surplus steam from mill machinery was available.[24]

In addition to the two basic operating pressures of steam systems, there were also two principle means of piping, single and double systems, and several strategies for each of these. Single pipe systems provided a single riser to each radiator from a main and no return risers, the

condensed water returning to the boiler through the same pipe. Double pipe systems had separate risers for incoming steam and returning condensation to each radiator (illustration #1). Various strategies of supply and return mains and risers -- singly or separately with distribution from above or below the radiators, with return mains below the water level of the boiler reservoir, with supply and return mains provided with various slopes, etc. -- were used in commercial, industrial, and residential applications.[25]

Each of these systems had, in combination with the pressures used, advantages and disadvantages in the amount of and size of pipe needed and corresponding expense for materials and installation; and the noise, efficiency, and safety of the system in operation. Those systems with a greater number of risers and returns were normally the quietest though they were more expensive to install and maintain and were not always the most efficient. Low pressure systems were safer and more economical in terms of energy expenditures though they required larger pipes. On the other hand, low pressures were not efficient at transporting heat over long distances. Single pipe systems were the least expensive though they could be the noisiest and could not be used with long horizontal runs of mains. Thus, they were not practical for use in large structures and their use was largely limited to residential applications.[26]

There were also several ways in which the radiators of a steam system could be configured to distribute the heat.[27] In smaller rooms radiators would often be placed to heat the room air directly by convection. Control for this system was difficult because the radiator, being large enough to heat the room on the coldest of days, often gave

off too much heat on an average day.[28] There was the direct-indirect system in which the radiator was placed in a plenum either within or immediately outside of the room being heated, and through which fresh air was also introduced into the room after passing over and through the radiator. This system also had the advantage of greater control in that the incoming heated air could often be mixed at the inlet with cool air enabling the occupants to better control the temperature and rate of fresh air flow within a room.[29] A third means was the indirect system where one or more banks of radiators heated fresh air fed by fans, often steam driven using the same boiler as that which supplied the radiators, and was ducted throughout the building (illustration #2). Until the twentieth century, this third means of radiation was largely reserved for hospitals, asylums, and public buildings.[30]

For the same reasons as those discussed for ventilation, heating remained similarly a subjective matter and there were great variations in opinion as to the best temperature for maintaining health and comfort. In Great Britain seventy-five to eighty degrees was considered comfortable while Americans preferred temperatures in the sixty-five to seventy degree range. However, less importance was given to the matter as most realized that the correct temperature for comfort in any given situation would also create the least stress on the body.

RESEARCH AND STANDARDS FOR HEATING AND VENTILATION IN 1890

About the year 1880, scientists began to undertake studies of air quality in buildings in order to better understand the mechanisms of disease transmittal in indoor public places, to assess the impact of

congested public gatherings on human health, and to provide a means of creating standards for ventilation. The primary objective of these studies dealt with the conditions which existed in public schools and the perceived effects which were manifested in school age children. In 1884, John Billings, a heating engineer, exonerated carbon dioxide but indicated that its increased presence signified the buildup of other more harmful substances.[31] As a consequence, carbon dioxide, which could be measured in a particular environment, became the criterion for measuring relative hygenic purity.

By the time that Furness Library was built, much of what we today understand about the nature of heating and ventilating was already known. Though many professionals and most laymen remained skeptical, the requisite for human comfort of a constant loss of body heat to the surrounding atmosphere was known as were the transfer methods, the makeup of the atmosphere, rates and products of human respiration, and the effects of air velocity and humidity on rates of perspiration.[32] However, the results of scientific studies which presented a complete understanding of the relationships between temperature, ventilation, humidity, and air velocity would not be published until 1905 and would not become widely accepted until the 1920s.[33]

By 1890, while standards based on scientific analysis were still evolving, there did exist certain standards within the heating industry for providing sufficient amounts of heat and ventilation. While there was some latitude for various situations -- such as the number of occupants, their amount of physical activity, and the amount of gas lighting which was used -- forty to sixty cubic feet of air per minute

per person was the accepted standard of ventilation for most buildings[34] (residential units and small rooms did not require ventilation due to their smaller size and fewer occupants[35]). For low pressure steam heating systems, approximately two square feet of radiator surface per one hundred cubic feet of room space was standard -- again, this figure was adjusted with rule of thumb calculations for window area, wall materials and thicknesses, etc..[36]

The technology which provided the means for both heating and ventilating a building continued to evolve throughout the nineteenth century largely as the result of trial and error on the part of heating and ventilating firms engaged in the business of installing systems. Though the physics involved in heat transfer was well understood by scientists and engineers, making it possible to more accurately calculate the gains and losses for any particular building, much of the work of designing a heating system was done by rule of thumb.[37] Eventually, because workmen were not trained in the physics and math required for designing a heating system, and architect's concerns lay primarily in other directions, engineers of heating systems began to appear as specialists.[38]

AVAILABLE LITERATURE ON HEATING AND VENTILATION IN 1890

Hugh Barron, a heating engineer at the first annual meeting of the newly formed American Society of Heating and Ventilating Engineers in 1895, presented a paper on the available literature in the field of heating and ventilation (see appendix C). It was his opinion that the

commencement of modern literature on the subject began with "A Treatise on the Economy of Fuel and Management of Heat" by Robertson Buchanan in 1815, as he explained: "[the literature of the] art of heating...commences with Buchanan, is carried forward by Hood, and is now represented by Baldwin. The art of ventilating commences with Tredgold, is carried forward by Dr. Reid, and is now represented by Billings. The work of all the others is practically concentrated in these."[39]

At the time that the library was built, there was little else beyond the catalogs and circulars of the manufacturers and dealers; there were very few texts and virtually no space in any periodicals on the subject before 1880.[40] Baldwin's Steam Heating for Buildings, Briggs' Steam Heating: An Exposition of the American Practise of Warming Buildings by Steam, and Billing's Ventilation and Heating were the most influential at the time that Furness Library was built; however, it must be remembered that the years of experience of the engineers and workmen employed by Pancoast & Maule, the heating contractor for the building, probably had a greater effect on determining the system as it was installed.[41]

SAFEGUARDING OF BOOKS, DOCUMENTS, AND SENSITIVE ARTIFACTS IN 1890

Information regarding the proper environmental conditions for the proper disposition of library spaces and the storage of materials was first published in Europe in the thirteenth century by monastic orders. These documents contained instructions on the orientation of libraries within a building, recommendations for the exclusion of sunlight and sources of

dampness, methods for ventilation, etc..[42] By 1890, though there had been few, if any, scientific investigations into the proper environmental conditions for libraries, most librarians had a pragmatic understanding of the requirements for conserving library materials.

In addition to the injurious effects of high heat, moisture, and dryness, it was known that sulphur dioxide from gas illumination and hot air furnaces, in addition to being offensive to occupants, was injurious to books.[43] Another source of damage which we now know presents a considerable hazard to library materials is ultraviolet radiation; it does not appear in the literature of conservation until the twentieth century.

As long as a decade before the library was built, librarians themselves showed a preference for steam heating in library buildings. In a letter to the Library Journal in June, 1880, a Mr. W.F. Poole remarks on the effects of gases escaping from hot air furnaces on the deterioration of book bindings in addition to the high heat and dryness produced in the galleries of libraries where they are used. At the end of the article the Journal Editor remarks: "Thus far, all experiments agree in condemning the furnace and recommending steam."[44] In an article in the Library Journal in April, 1881, "Melvil Dui" (Melvil Dewey) made a systematic comparison of different methods of library heating and concludes: "My study leaves me a decided preference for steam. The least desirable means of heating is the most common, the hot-air furnace (see appendix B)."[45] Presumably he expressed these beliefs to Frank Furness in 1887 as a consultant on the University's Library.[46]

RECORDS OF THE ORIGINAL STEAM HEATING SYSTEM

Little direct evidence exists in the university's archives and records of the original steam heating system installed in the library. Records of the Henry B. Pancoast Company, successors to Pancoast & Maule which installed the system, do not predate the early 1970's. Early photographs of the building interiors show suprisingly little in the way of piping and radiators. Drawings and descriptions of a few alterations of the system are the only records existing which give some hint as to the original system.

EVIDENCE OF THE ORIGINAL SYSTEM BY DATING RADIATORS

By referring to trade catalogs published by various heating supply and installation companies, it is possible to determine an approximate date for all of the radiators which still exist within the building and thus it is possible to draw some conclusions about the original system and some later additions.

Those radiators such as are found in room 400 of the tower (illustration #3), the studio above the reading room apse (illustrations #4 - 6), the northwest corner of the first floor stairtower, and the direct-indirect radiators within the reading room and along the eastern side of the stacks at the first floor (illustrations #7 - 11) are representative of those in use at the time the library was built (see Appendix A for locations of all radiators and type). Additionally, sections of piping which are connected by U-joints to form radiators called 'coil radiators', such as found beneath the windows of the uppermost room of

the stairtower, just outside the studio above the apse, beneath the windows and under the stairs at the first floor level of the tower, and in the folio room at the basement level of the stacks are examples of industrial applications which were used to heat spaces about 1890.[47]

Several references exist with illustrations of the radiator which sits in the northwest corner of the tower at the entry level (illustration #12). This radiator is composed of wrought iron pipes connected by cast iron fittings in a frame of cast iron. This radiator was designed and built by the Nason Manufacturing Company of New York. One reference was in a trade catalog for Pancoast & Maule for the year 1889.[48] The others are from a Nason Co. catalog from 1895 (illustration #13)[49] and the George W. Hartman Company catalog for the year 1889 (illustration #14).[50]

Pancoast & Maule catalogs from the years 1883[51] and 1889[52] show radiators similar to those found in room 400 and in the second floor apse although they do not list those particular radiators. These radiators are similar in construction and materials to the radiator described above, although smaller, and are of a type which was no longer being installed in buildings by the turn of the century, having been replaced by sectional cast iron radiators.

There are also listings in the 1889 catalog for wall coil radiators and bracketing hardware in use within the building (illustrations #15 and #16). One example of this type with brackets similar to those found in this catalog can be found at the second floor level in the vestibule just outside of the apse (illustration #17). This type of radiator was an industrial application in use until about the turn of the century

when modular cast iron radiators similar to those in illustrations #18 & 19 found favor as they were simpler, more economical to manufacture, and can be configured in a variety of ways by connecting separate units.

On the section of wall coil radiator below the windows in the first floor stairway hall, there is stamped into the top pipe the name "BYERS". This pipe was manufactured by the A.M. Byers Co. of Pittsburgh. Furthermore, information from trade catalogs reveals that this company was still in the business of manufacturing wrought iron tubing as late as 1939, though by 1925 steel piping made up 90% of the piping which they manufactured.[53] Thus, the fact that this piping might be composed of wrought iron, rather than steel, would not help to date it to an early time in the buildings history. However, as stated above, this use of coiled sections was largely discontinued after the turn of the century.

One other interesting fact should be noted concerning Byers wrought iron tubing; a 1914 catalog for this company,[54] printed before they began to manufacture steel tubing pipe, states that their piping can be identified by the name "BYERS" rolled into the metal. Their catalog from the year 1939 states that by this time they were stamping their steel pipe "BYERS-STEEL", and their wrought iron pipe "BYERS-IRON" (illustration #20).[55] Thus this piping may have been manufactured as late as 1914, or later, but before 1939. However, lacking intermediate information, no date can be assigned to the date when this change took place.

The other existing radiators which are found within the building can be

dated to later time periods. The radiators in use at the second floor addition can be dated from the 1920s by their use in a location which did not exist at the time the building was first built, but also by the fact that they do not appear in any catalogs for the period during which the building was under construction or shortly thereafter. Examples of this type of radiator from the Henry B. Pancoast Co. (the successor to Pancoast & Maule) appears in illustrations #21 and #22.

Other radiators located throughout the building are similar to those in illustration #23 and all date from periods later than 1890, thus they were not part of the original system. Nor is it likely that they were installed as adjustments to the original system within its first decade of operation as will be explained in the section of this text on performance of the system..

DATING OTHER PIECES OF EQUIPMENT IN THE BUILDING

By examining trade catalogs it is possible reach some conclusions regarding the dates of other pieces of equipment in the building and their relation to the original system.

Steam traps are devices which are placed into the system on the return risers and allow condensed water from the system to pass back to the boiler while preventing steam from doing so. Their use greatly increases the efficiency of the system. Located in the mechanical room under the Horace Furness addition to the building there are five steam traps. Four of which bear the inscription: "McDaniels Improved Steam Trap No.13, Patented Mar 10, 1903" (illustration #24) and one: "No.2,

McDaniels Special Steam Trap, Patented Aug 19, 1890." (illustration #25) Neither of these two types of steam traps appear in the catalog for 1889, but both of them are in the catalog for 1912. (illustration #26)[56] However, it is possible that the trap No.2 was part of the original equipment installed in the building as the patent date is one year later than the date of the 1889 catalog, but predates the February, 1891 opening of the building. On the other hand, this steam trap was apparently still being marketed as late as 1912. It is most likely that the others were installed some time after the original system went into operation. Perhaps they were added as part of the contractor's or university's efforts to adjust the system to the needs of the building, or they may have been installed when changes were made in the system for the Duhring addition to the building in 1915. These steam traps are no longer in use as they have been replaced by a number of smaller steam traps throughout the system and a couple of electric pumps which perform the same function. They are needed to return condensation from radiators placed at a lower level than the return main.

The changeover from a boiler within the library building to an external district heating system would not have required any considerable changes in the equipment used. Existing equipment could have remained in place and been used without modification. The only requirement would have been the addition of a pressure reducing valve on the incoming higher pressure steam main required for district steam systems.[57]

Information on one other piece of equipment in the mechanical room has been located as well. There is a condensation meter there with the inscription: "Cadillac - Central Station Steam Co., Detroit, Michigan."

A trade catalog for this company's condensation meters printed circa 1930 relates the following information: "The Central Station Steam Co. were (sic) pioneers in the development of the rotary volumetric type of liquid meter and have specialized during the past twenty years in the field of condensation measurement."[58] While not stating specifically that the company did not manufacture their meters as early as 1891, the meters would probably not bear so similar an appearance to those manufactured in 1930. Therefore, it seems unlikely that this is an original piece of equipment (illustrations #27 - 29).

Identification and dating of many of the pipes and valves within the building in order to further delineate the original system and any early changes made to it has been complicated by the lack of documentation to changes over the years and the ad hoc nature of most of the work. A worker at the Physical Plant offices for the university stated that this has been the case for the fifteen years that he has been employed here and that additionally pipes, valves, and other pieces of equipment in servicable condition are often reused when changes are made, although they may be used in another location or be rerouted from their original configuration.[59]

FURNESS' ROLE IN THE DESIGN OF THE SYSTEM

As is still the case today, nineteenth century heating systems were usually not designed by the architect of the building. This was usually the domain of a heating engineer who was often a principal of the company which was commissioned to design and install the heating system.

However, current practise requires the integration of a heating system into a building during the design phase; during the nineteenth century, the contractor was often not solicited until the work of construction was well under way if not actually near completion.[60] From documents in the University Archives, it is known that the firm of Furness and Evans subcontracted, with the university's approval, the various building trades involved in the construction of the library and had signed a contract with Pancoast & Maule before construction began.[61] However, while there may have been a certain amount of discussion between the two as to the type of system and its general means of execution during the construction of the building, the separate concerns of Furness & Evans and Pancoast & Maule were most likely largely developed in isolation from each other.

It is unknown whether Furness had any knowledge of the problems of dryness and the emissions of sulphur dioxide gas which accompany hot-air furnaces, the most common means of heating libraries at the time. In any case, steam was more suited to the size of the building than hot-air. Therefore, the selection of steam heating was the logical choice for proper performance. Also, steam was the favored choice of Melvil Dewey who had been consulted by the University's Board of Trustees and by Furness.

The heating and ventilation system as designed and installed in the library represented the best conventional wisdom of the day for a building of its type and size. Within the larger and more public areas of the reading room, direct-indirect plenums made it possible to better control the amounts of heat and ventilation required for the varying

numbers of occupants. These radiators were distributed along the central axis of this space and at the entries of the alcoves around the perimeter for an even distribution of heat and ventilation. In other areas of the building, direct radiation located at the perimeters of the building and beneath windows moderated the effect of drafts falling from colder surfaces (a practise which is the accepted standard today, but was still debated by some at the time the library was built).

While Furness may not have been very involved in the design of the heating system, he was directly responsible for seeing that the library was adequately provided for in terms of ventilation. His general knowledge of the execution of steam systems and the requirements for ventilation of various spaces would have enabled him to realize that a number of the rooms would require no more than direct radiation. He would have also known that some means of providing ventilation in conjunction with heat would be neccessary for the reading room and stack sections, and this would require his forethought during the design phase. Direct-indirect methods provided the most logical means of providing for heat and ventilation in these spaces while a sufficient number and size of windows would be adequate for any of the smaller or larger and lower occupancy spaces.[62]

It is quite possible that the library was provided with a tall stair tower, four story space above the main reading room, and fireplace at least in part to facilitate the movement, by gravity, of fresh air throughout the building. The use of towers, domes, cupolas, and fireplaces for this purpose was common during the nineteenth century and earlier. The stair tower and reading room space as such were directly

or indirectly connected to every other sizable space within the building, and, in combination with the gravity fed direct-indirect heating system within the larger public spaces of the building, would undoubtably provide an effective means of providing for ventilation of the library.

SPECIFICATIONS FOR THE PERFORMANCE OF HEATING SYSTEMS ABOUT 1890

At the time the library was built, it was the practice of contractors for heating systems to specify that the system would heat the building to a certain temperature when the ambient temperature was of a certain temperature. The interior temperature might be specified as seventy degrees F when the exterior temperature was at zero degrees F. Often this meant that the heating contractor would have to wait until a very cold day to confirm his calculations as to the actual performance of the heating system he had installed and could get paid for his work.[63] There are no existing records as to when Pancoast & Maule were actually paid for their work which might give some hint as to testing and specifications for performance of the system.

PERFORMANCE OF THE STEAM HEATING SYSTEM INSTALLED

Prior to the opening of the Library in February of 1891, the published plans for the library met with general approval. An article in the Philadelphia Inquirer for June 20, 1888 read in part: "The building will be well lighted and will be heated and ventilated after the most approved manner. The plans have been submitted to the librarians of

Columbia College and Harvard University, and have gained their entire approval."[64] An article in the Library Journal for August 1888 on the new library listed three requirements important to a well designed library. Together with the requirements of accessibility and accomodations for study "A model library...will store books in absolute safety from fire in an accessible manner, with light, air, and an average temperature..." and proclaimed: "the new building goes nearer to meeting all three requirements considered...than any library in or out of the country whose plans have been published."[65]

Skylighting over the entire stack area of the building, in order to provide an abundance of light free from the dangers of fire which accompanied the use of gaslighting, had apparently raised the question at some point of possibly causing the stacks to overheat. The author of the article for the Library Journal, however, did not seem concerned: "access to air along the entire length of the book stack at two angles in the roof ought to make it possible to keep the temperature below the point which, in most libraries, ruins book bindings."[66] However, this did prove to be the case and those concerns for overheating due to the excessive use of skylighting were realized soon after the library was built.

Photographs from the early years of the Library, when the skylights over the book stacks were still in place, show awnings over some sections of the skylights in an effort to reduce solar gain. Furness' firm was also concerned with the problem and devising a solution. The Trustee's Minutes for 7 April 1903 read: "It was Resolved: that permission be given to Furness, Evans, and Company to make a trial, at their own

expense, of cooling the upper floors of the stack by a supply of water trickling through pipes along the roof."[67] Apparently the problem still continued as late as 1911; a letter from Morris Jastrow, the Librarian, to Mr J.G. Rosengarten, Chairman of the Trustee's Library Commitee, reads in part: "the upper floor of the stack can be used for pamphlet collections only because of the intense heat in the summer which would be ruinous to bound volumes."[68]

There were also problems of overheating in other sections of the library where skylights had been installed. A bid for work in the Archives from Gara, McKinley, and Company, architectural sheet metal workers, to Mr. Mumford of the Board of Trustees, dated 12 July 1900 reads: "As per examination by our Mr. Garraty for ventilating sky-lights on Library building as explained, five (5) lights on the east side over roof used for catalogue room, cutting glass and putting in 8 inch ventilators...".[69] Two other bids concern the alcoves in the Reading Room; from William S. Bonsall's Sons, metal and slate roofers, to Mr. Mumford, dated 6 October 1898: "We will furnish materials and labor for ventilating six alcoves and one ladies dressing room."[70], and from Andrew R. Poulson Hardware to Mr. Mumford, dated 11 October 1898: "...cut through ceilings in alcoves of Library and cut through roof...and put in fourteen 6 inch ventilators with galvanized pipe."[71]

Though there are few surviving records of the early performance of the system, there were undoubtably adjustments and alterations made to "fine tune" the system. Such alterations to steam heating systems, designed by methods less exacting than those of today, were common in the late nineteenth century. Adjustments were most likely in the form of opening

and closing valves to modify the amounts of steam to various radiators in different parts of the building and opening and closing dampers on the direct-indirect radiators. Opening and closing valves would allow for some control but was limited by the requirement that any operating radiator needed most of the eight to twelve pounds of pressure supplied to it in a low pressure system in order to prevent a buildup of condensation in the radiator and/or pipes. Radiators could be shut off entirely to reduce the heat; to add more heat, radiators had to be added.[72] No vertical wrought iron radiators seem to have been added in the early years of the building. It is more likely that wrought iron coil-tube radiators may have been added, if at all; but considering the documented problems of daytime overheating which most of the library experienced, its possible that the wrought iron vertical and coiltube radiators within the building represent the system as was in place on the day that the library opened.

Changes in the system also took place as the functions of the library changed and expanded to include areas of the basement. In contrast to the problems of overheating and insufficient ventilation in other parts of the library, there is evidence that the basement was underheated; a letter from Mr. Jastrow to Morris L. CLothier, representative of the Library Commitee on the Finance Commitee, dated 11 November 1911, reads in part: "Two of the <u>basement rooms</u> which are used by the Library workers are <u>insufficiently heated.</u>"[73] A drawing by the Department of Buildings and Grounds of the university entitled "Direct Steam Heating Installation, New Cataloguing Rooms - Library", number 617 dated 30 June 1919[74], shows some of the changes made to improve the steam heating system for the accomodation of workers in the basement. In addition to

existing radiators under each of the windows of the east wall at the first floor level of the library, the drawing shows plans for installing radiators under each of the windows of the same wall at the basement level. The drawing also lists a number of radiators to be disconnected, without specifying their location, including: "four wall radiators in basement - three indirect stacks in basement - one pipe coil in basement - two radiators on first floor".

PRESERVATION OF THE EXISTING SYSTEM

The heating system as exists within the building currently provides heat during the colder months. Little more than this can be said in its favor as it often provides too much heat and creates a tremendous racket in the reading room due to steam hammers in the pipes overhead. Furthermore, there are currently no provisions for the control of humidity within the building nor for cooling during the warmer months, provisions which are desirable both in terms of comfort for the occupants and, more importantly, for the preservation of library materials.

While the current steam system might be renovated in order to remove the steam hammers and provide a better level of heating, it would still not provide the level of control which is desirable. Another possibility would be to convert the system to hot water. This would provide better, more consistant and more controllable levels of heating; but would probably be difficult to engineer and therefore economically unfeasible. Both of these solutions would still require additional unintegrated

systems for the control of humidity and provision of cooling.

The recommendation of the Venturi report for the current system was to "remove in entirety" the current system.[75] While it seems reasonable to expect a new environmental control system to be placed within the building, there is no reason to entirely remove the historic hardware of the old system. Radiators and piping selectively left in place will not greatly disturb any present or future functional requirements in the spaces they now occupy, and both academically and aesthetically serve to preserve the context of technology within which the building was built.

CONCLUSION

In spite of the problems of overheating caused by the skylights, a low pressure steam heating system, the costliest to install at the time, represented the best contemporary means of heating a library and a building of its size. Additionally, the use of direct-indirect radiation in the reading rooms and the stacks and direct radiation elsewhere were, by most accounts of the period, the proper and accepted method for heating the various spaces within the building. On the question of ventilation, the design of the library seems to have been configured for allowing an adequate supply of fresh air by the standards of the day and a proven means of inducing its circulation. In this regard, the environmental controls of the library were consistent with the university's intent to build the best possible academic library in America.

ENDNOTES

1. Mills, John H.. Heating by Steam (Boston: Gunn and Bliss, 1877), p. 18.

   Jacobs, Ernest H.. Heating and Ventilating (London: Society for Promoting Christian Knowledge, 1894), pp. 34-35.

2. Quotation of Dr. Johnson from "Diary of a Philosopher" quoted in A Practical Treatise on Warming Buildings by Hot Water, Steam, and Hot Air by Charles Hood (London: E. and F.N. Spon, 1885), p. 319.

3. Hood, p. 319.

4. Ibid., pp. 319-325.

5. Briggs, Robert. "On the Relation of Moisture in Air to Health and Comfort" (Journal of the Franklin Institute, Vol. 105), p. 82.

6. Ibid., p. 83.

7. Jacobs, p12.

   Hood, p. 83.

   Brabee, C.W. Heating and Ventilation (New York: McGraw-Hill, 1927), p. 125.

   Throughout the last half of the nineteenth and into the early years of the twentieth century there continued the debate as to whether carbon dioxide and other substances, some identified rather vaguely such as the "stuffy smell", were in fact poisons or not. Discussions of these arguments appear in the above cited sources.

8. Briggs, "Relation of Moisture...", pp. 83-84.

9. Reid, David Boswell Theory and Practise of Ventialtion (London: Longman, Brown, Green, and Longmans, 1844), pp176-177.

10. Ibid., pp. 184-197.

11. Ibid., p. 83.

12. Smead, Isaac D. and Co.. "The Ventilation and Warming of Buildings." (Toledo: n.p., 1889), pp.7-8.

13. Reid, p.72: "...numerous apartments are daily constructed of a much greater altitude than required ... for the purpose of giving an ample supply of air."

14. Jacobs, pp. 36-42.

15. Smead, p. 18.

16. Mills, p. 20

    Jacobs, p.42

17. Chadeayne, George D.. "Modernizing Old Steam Jobs" (The Merchant Plumber and Fitter Magazine, 25 Dec 1924), p. 432.

18. Jacobs, pp. 42-43.

19. Mills, pp. 6-8.

    In addition to these, Mills discusses a number of other points favoring low pressure steam over high pressure whenever there is a choice.

20. American District Steam Company. "History of District Steam Heating" (North Tonawanda, NY: n.p., 1925) p.1.

    The first practicle district steam heating system, according to the literature of the company which developed and installed it, was in 1877 at Lockport, New York. Other references credit the founder of this company with the invention and development of this system.

21. Trustee's Minutes for 30 June 1890, Vol. 12, p. 542, University of Pennsylvania Archives.

22. Interview with John Preite, Foreman, Steam Services, Physical Plant, University of Pennsylvania, 22 May 86.

23. Barron, Hugh J. "The Literature of Heating and Ventilating" (Transactions: American Society of Heating and Ventilating Engineers, Vol. 1, 1895), p. 186.

24. Ibid., p. 181.

    According to Barron, Buchanan stated in 1815 that a Colonel William Cooke first suggested the idea of warming rooms by steam heat in The Philosophical Magazine in 1745. Also, a Count Rumford had stated that it had been tried in England, but nothing of importance was done until it had been applied to heating cotton mills in 1791 shortly after Boulton and Watt had commenced to experiment in this area.

25. Baldwin, William J. Steam Heating for Buildings (New York: John Wiley and Sons, 1888), pp. 1-2.

26. Briggs, Robert. Steam Heating: An Exposition of the American Practise of Warming Buildings by Steam (New York: Van Nostrand Publishers, 1883), p. 39.

    Starbuck, Robert M. Questions and Answers on the Practise and Theory of Steam and Hot Water Heating (Hartford: R.M. Starbuck and Sons, 1927), pp. 60-61.

27. Jacobs, p. 43.

28. Allen, John R. and Herbert Walker. Heating and Ventilation (New York: McGraw-Hill Books, 1931), p. 34.

29. Briggs, "Steam Heating...", pp. 54 and 67.

30. Ibid., pp. 53-54.

31. Hubbard, Charles L. "Recent Developments in the Theory of Ventilation" (The Architectural Record, January 1917), p. 53.

    Anonymous. "Ventilation of Schoolrooms" (A.M.A. Journal, 6 March 1926), p. 690.

    Hubbard states: "Pettenkofer, in 1849...laid down the doctrine, accepted by sanitarians, that the percentage of carbon dioxide was only a guide to other harmful properties contained in the atmosphere." The anonymous author credits Billings in 1884.

32. Anonymous. "Heating and Ventilation" (A.M.A. Journal, 16 Sept 1911), p. 980.

    Briggs, "Relationship of Moisture...", pp. 12-15.

    Both articles seem to point to the 1880's as the period in which these relationships became known.

33. Brabee, pp. 121-122.

    Hubbard, pp. 56-57.

    Both of these articles contain a number of references to scientific studies carried out in the late nineteenth and early twentieth centuries.

34. Briggs, "Relation of Moisture...", p. 18.

35. Starbuck, p. 91.

36. Baldwin, pp. 25-26.

    Baldwin describes some of the rule-of-thumb calculations and variables for calculating radiator requirements.

37. Schumann, F.. A Manual of Heating and Ventilating for Engineers and Architects (New York: D. VanNostrand, Publisher, 1877), pp. 34-37.

38. Mills, p. 9.

39. Barron, p. 185.

40. Ibid., p. 189.

41. Ibid., p. 190.

Briggs, "Steam Heating...", pp. 30-31.

42. Interview with Paul Banks, College of Library Services, Columbia University, New York, 25 July 1986.

43. Lincoln, D.F.. "Ventilation of Libraries" (Library Journal, Vol. 4, July-August 1879), p. 255.

Poole, W.F.. "Deterioration of Bindings" (Library Journal, Vol. 5, June 1880), pp. 213-214.

44. Poole, p. 214.

45. Dui, Melvil (Melvil Dewey). "Heating Libraries" (Library Journal, Vol. 6, April 1881), p. 96.

Contained in this article is a table of various systems with a rating system for each of a number of concerns which faced librarians and comments on each.

46. Letter dated 20 April 1887 at University of Pennsylvania Archives. Cited in "A Master Plan for the Selective Restoration and Continued Use of the Furness Building", by Venturi, Rauch, and Scott-Brown Architects, April, 1986, Vol. III Historic Structures by Clio Group, Inc., p.8.

47. Allen, p. 76.

Briggs, "Steam Heating...", p. 7.

48. The Pancoast & Maule Co.. "Catalog A, Second Edition." (n.p., 1889), p. 15.

49. The Nason Manufacturing Co.. "Illustrated List of Prices." (n.p., 1895), p. 280.

50. George W. Hartman Co. "Steam and Hot Air Apparatuses." (Philadelphia: n.p., 1889), p. 20.

51. The Pancoast & Maule Co.. "Illustrated Catalog of The Pancoast & Maule Co., Second Edition" (n.p., 1883), p. 34.

52. Pancoast & Maule, 1889, p. 16.

53. Backert, A.O., ed.. ABC of Iron and Steel (Cleveland: Penton Publishing Co., 1925), p. ___.

54. A.M. Byers Co.. "The Control of Quality in Every Process." (n.p., ca. 1914), p. 1.

55. A.M. Byers Co.. General Catalog (n.p., 1939), p. 19.

56. Henry B. Pancoast Co.. "Catalog H." (Chicago: R.R. Donnelly and Sons, 1912), p. 140.

57. Interview with John Preite.

58. Central Station Steam Co.. "The Cadillac Condensation Meter." (n.p., ca. 1930), p. 2.

59. Interview with John Preite.

60. Hood, p. 317.

    Kinealy, J.H.. "Determining the Heating Power of Heating Systems" (Transactions: American Society of Heating and Ventilating Engineers, Vol. 1, 18985), pp. 56-57.

    Mills, p. 21.

    Prather, H.B.. "Heating and Ventilating of Large Churches" (Transactions: American Society of Heating and Ventilating Engineers, Vol. 1, 1895), p. 94.

    Reid, p. 78.

    Smead, p. 15.

    All the above references discuss the practise of planning and installing heating systems during the time when they were typically not designed as an intregal part of the building. Kinealy describes the process in some detail.

61. Letter from Furness, Evans, and Co. to University Board of Trustees, 28 May 1889, contained in Archives General 1888-90: Library Construction folder, University Archives; "Statement of Contracts Made and Orders Given for Library for University of Pennsylvania...Pancoast & Maule, Steam Heating, 18 October 1888, $6875.00."

Letter from Frank Furness to Rev. Jesse Y. Burk, 29 May 1889, contained in Archives General 1889: Library folder; "On all the different items for which the contracts were awarded I received in all instances at least three and in some four or five bids, all from reliable parties, the work being awarded to the lowest."

62. Lincoln, pp. 254-255.

63. Kinealy, p. 57.

64. Anonymous. "University Library" (The Philadelphia Inquirer, 20 June 1888), p. 2.

65. Williams, Talcott. "Plans for the Library Building of the University of Pennsylvania" (Library Journal, Vol. 13, August 1888), p. 238.

66. Ibid.

67. Board of Trustees' Minutes, Vol. 14, p. 212, University of Pennsylvania Archives, cited in "A Master Plan for the Selective Restoration and Continued Use of the Furness Building", by Venturi, Rauch, and Scott-Brown Architects, April, 1986, Vol. III Historic Structures by Clio Group, Inc.

68. Letter from Morris Jastrow to Mr. J.G. Rosengarten, Chairman of the Trustees Library Commitee, 9 Nov 1911, contained in Archives General 1911 - Library folder, University Archives, cited in "A Master Plan for the Selective Restoration and Continued Use of the Furness Building", by Venturi, Rauch, and Scott-Brown Architects, April, 1986, Vol. III Historic Structures by Clio Group, Inc.

69. Letter from Gara, McKinley, and Co., Philadelphia, to Mr. Mumford, Board of Trustees, 12 July 1900, contained in Archives General 1900 - Buildings and Grounds Repairs #3 folder, University Archives.

70. Letter from William Bonsall's Sons, Philadelphia, to Mr. Mumford, 6 October 1898, contained in Archives General 1898 - Buildings and Grounds #4 folder, University Archives.

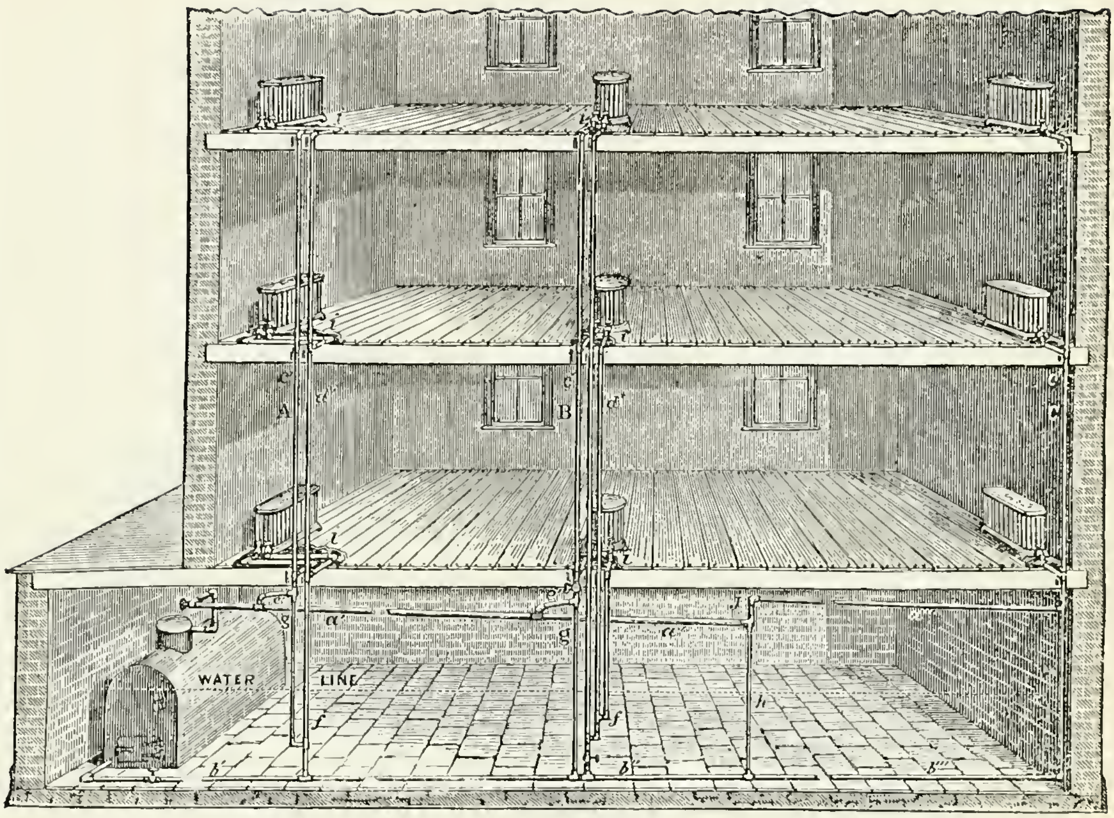
71. Letter from Andrew R. Poulson Hardware, Philadelphia, to Mr. Mumford, 11 October 1898, contained in Archives General 1898 - Buildings and Grounds #2 folder, University Archives.

72. Interview with John Preite.

73. Letter to Morris L. Clothier, Representative of Library Committee on the Finance Commitee, from Morris Jastrow, Librarian, 11 November 1911, contained in Archives General 1911 - Library Commitee Minutes folder, University Archives, cited in "A Master Plan for the Selective Restoration and Continued Use of the Furness Building", by Venturi, Rauch, and Scott-Brown Architects, April, 1986, Vol. III Historic Structures by Clio Group, Inc.

74. Drawing at Physical Plant Drawings Storage, Franklin Building, #617 dated 30 June 1919, contained in Buildings and Grounds drawers.

75. Venturi, Rauch, and Scott-Brown Architects. "A Master Plan for the Selective Restoration and Continued Use of the Furness Building", April 1986, Vol. II, section C, p.2.



SYSTEMS OF PIPING.

Fig. 1

ILLUSTRATION #1 - Three representative piping systems in use ca. 1890. From left to right: single riser and return main, single riser and sperate returns, single pipe system. from Steam Heating for Buildings by William J. Baldwin.

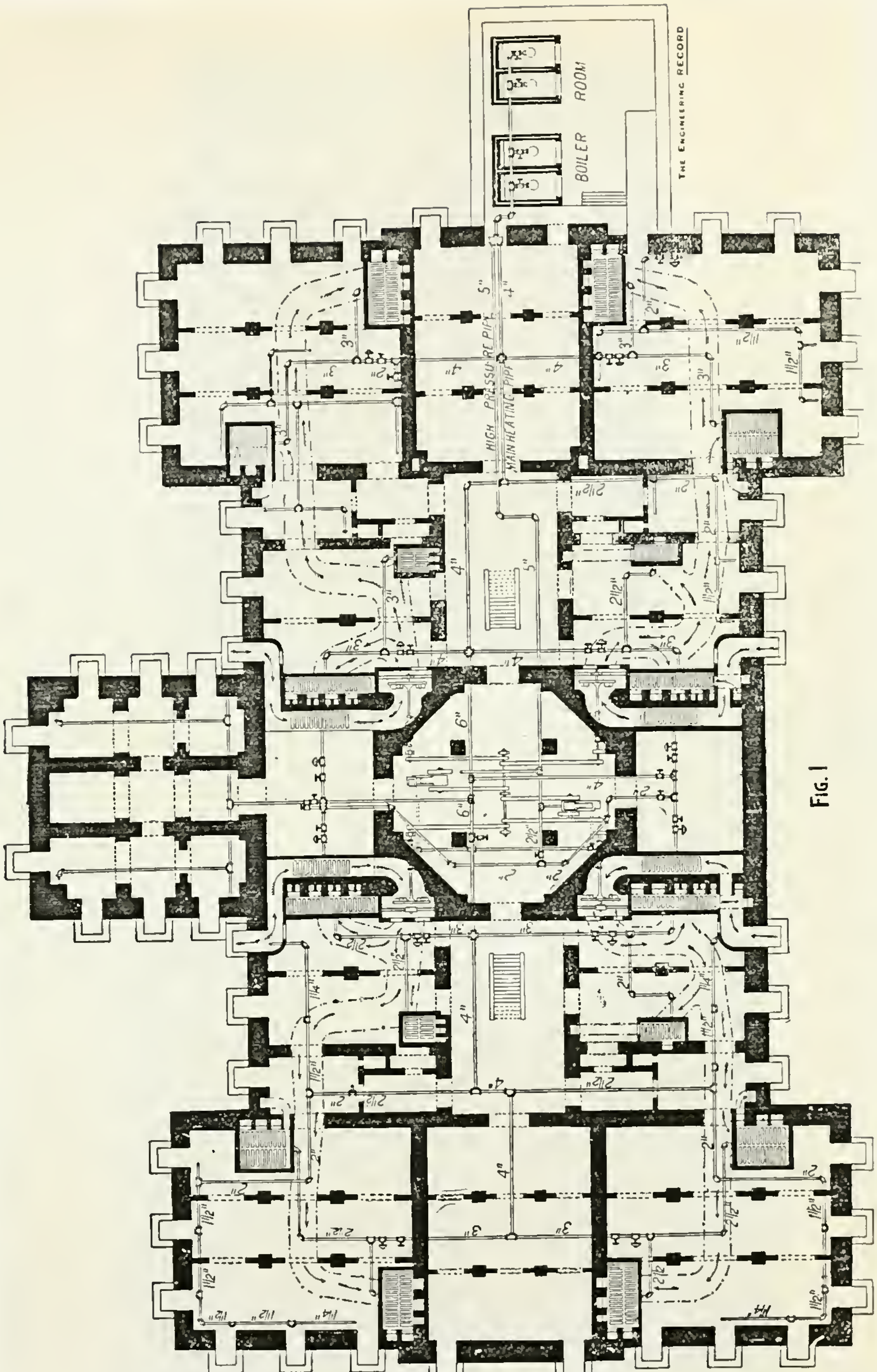


ILLUSTRATION #2 - Basement plan of an indirect system of steam heat with steam driven fans for air circulation and ventilation. from <u>American Steam and Hot Water Practise</u> by the Engineering Record, 1895.

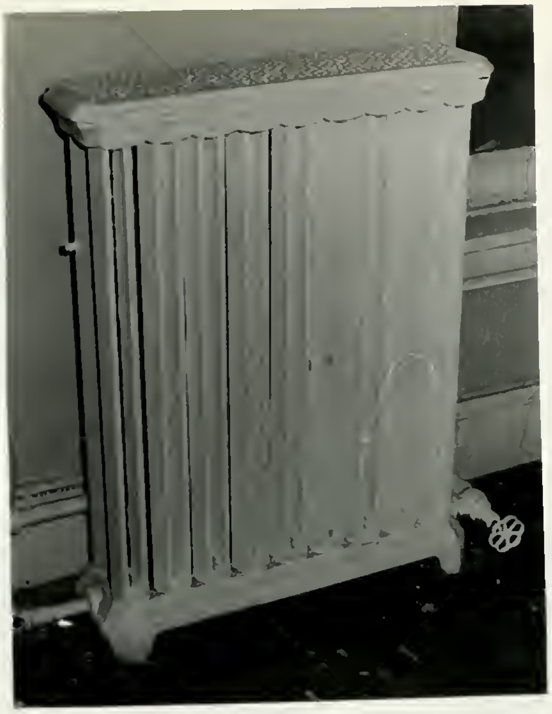


ILLUSTRATION #3 - Vertical cast iron loop radiator located in room #400 of the stairtower. This type of radiator can be dated to the original steam system.

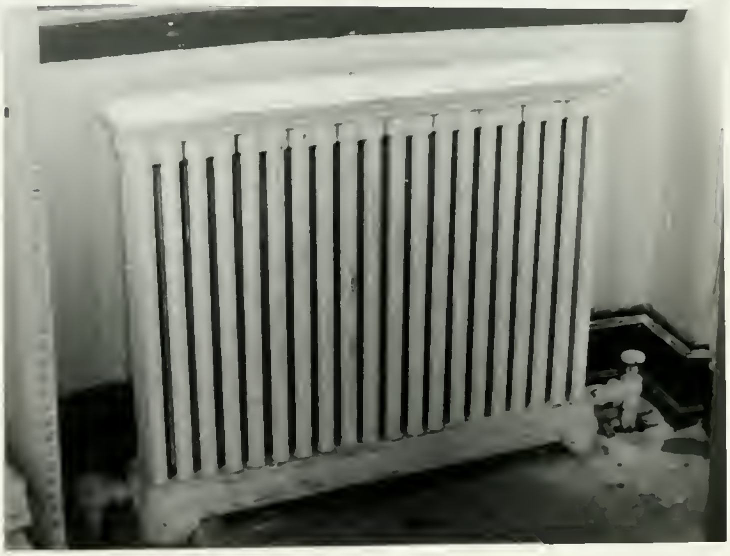
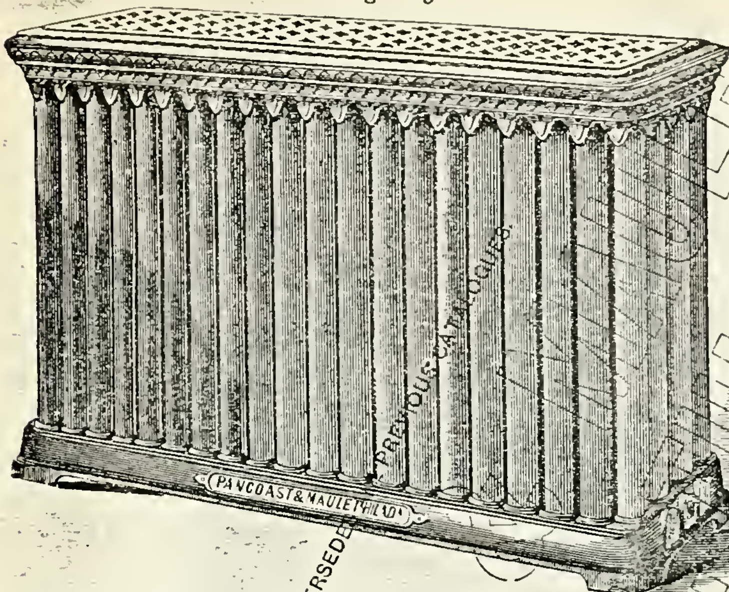


ILLUSTRATION #4 - Vertical wrought iron tube radiator located in second floor studio above reading room apse. This type of radiator is original to the heating system.

ILLUSTRATION #5 - Detail of radiator shown in illustration #4.

IMPROVED VERTICAL RADIATOR, WITH INTERNAL FEED-PIPES.

Fig. 113.

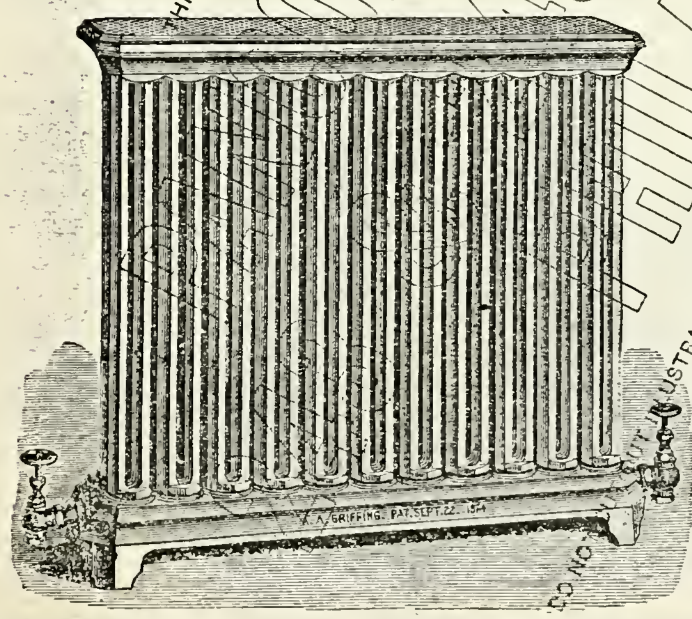


DESCRIPTION OF FIG. 113.

The hollow base has a diaphram cast in the centre, running the entire length, dividing it into two compartments, the top of the upper compartment receives the Radiating Tubes, of one inch wrought-iron pipe, each closed at the top by welding, rendering their leakage impossible. From the diaphram proper a series of wrought-iron pipes, of one-quarter inch diameter, rise inside of each Radiating Tube and constitute the steam supply. Steam being turned into the Radiator it enters the base in the lower compartment and is at once carried up each small feed-pipe and delivered at the top of the respective Radiating Tubes. By this means the air—which must be expelled before a circulation can be secured—is instantly forced, by the pressure of steam behind it, down the Tubes, until it reaches the dividing diaphram, and it then, perforce, seeks the outlet at the opposite end of the upper compartment, through which the condensation also passes off. We claim for this Radiator a perfect and immediate circulation of steam through every part, with a uniform heat at top and base. A perfect self-draining arrangement, preventing condensation from accumulating in the base and leaving the entire surface free to the action of the steam. Radiators are all tested under live steam pressure before leaving our establishment, and as the Tubes are closed at one end by welding, when once the joints are made tight they seldom become loose or leaky.

BUNDY'S PATENT VERTICAL RADIATOR.

Fig. 114.



DESCRIPTION OF FIG. 114.

Each loop is screwed independently to the base by a single joint, consequently the joint is not affected by expansion or contraction.

The loop being vertical, no accumulation of water can occur, insuring a positive, free circulation of steam. They are not liable to injury from rust or freezing.

They can be made to fit almost any place, and occupy fifteen per cent. less floor space than any other of equal radiating surface.

The design is such as not to present a corrugated or uneven surface to retain dust, and, therefore, is very easily kept clean.

Each loop contains full three square feet of radiating surface, with its proportion of base.

It has no packing of any description, and unlike others, will not leak in a short time.

It excels all in simplicity of repairing. To replace a loop occasions trifling expense or delay.

ILLUSTRATION #6 - Illustrations of radiators similar to those in illustrations #4 and 5, from "Catalog A, Second Edition." The Pancoast and Maule Co.. n.p., 1889.

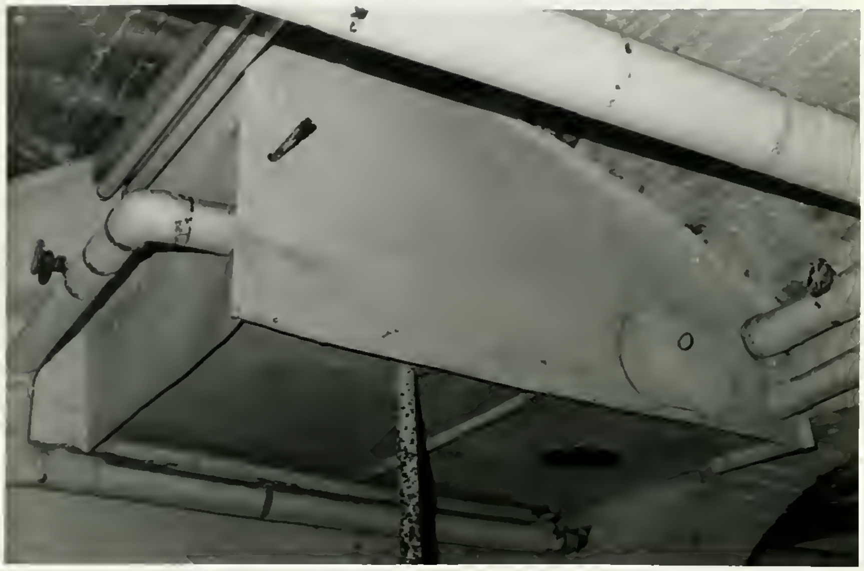


ILLUSTRATION #7 - View of sheet iron plenum for direct-indirect radiator in reading room. Flow of heat into reading room was controlled in part by opening or closing hatch at right. Another opening with hatch missing is visible on the bottom of the plenum.

ILLUSTRATION #8 - View through vent opening into sheet metal plenum of direct-indirect radiator located in basement under main reading room. Cast iron radiators specifically manufactured for this type of application were in production at the time that the library was built.

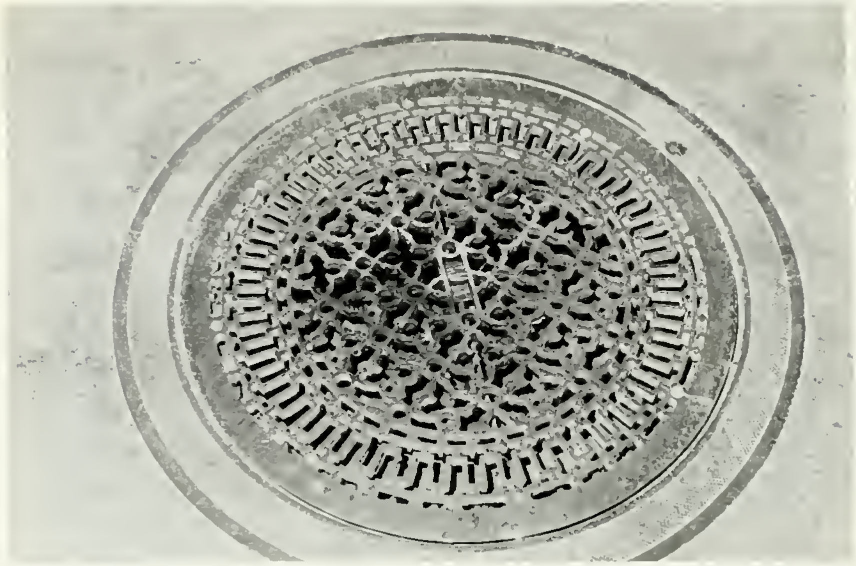


ILLUSTRATION #9 - Heat inlet grill from direct-indirect radiator located in basement into apse of main reading room at center floor (typ.). This grille is part of the original equipment. Note louver control piece at center of grill.

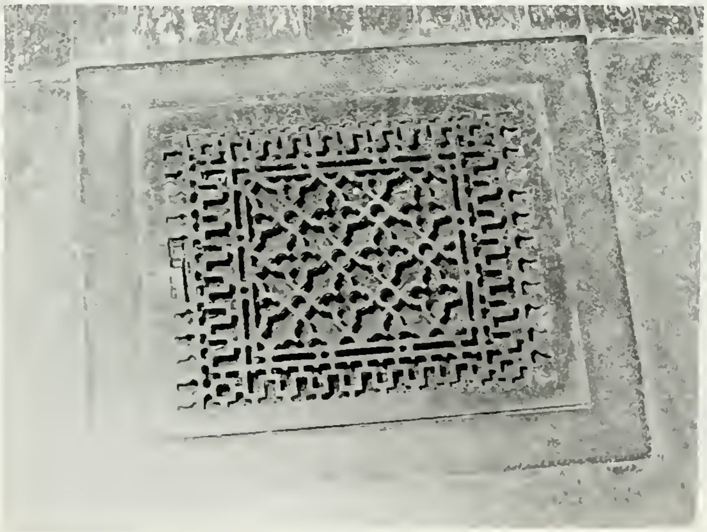


ILLUSTRATION #10 - Heat inlet grill from direct-indirect radiator located in basement into apse of main reading room at entry to an alcove in reading room (typ.). This grille is part of the original equipment. Note louver control piece at left side of grill.

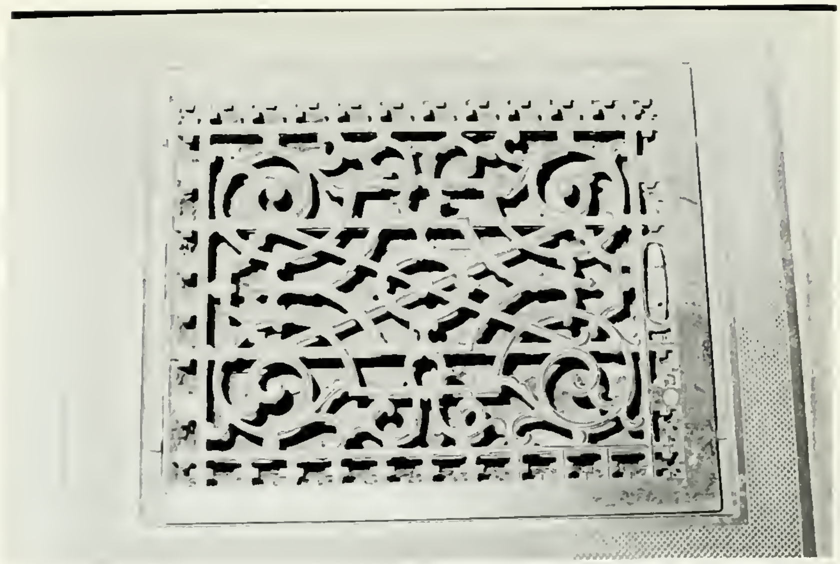


ILLUSTRATION #11 - Heat inlet grill from direct-indirect radiator located in basement into original stack area at first floor level (typ.). Four of these grills remain along the eastern side of the stacks at the first floor. The corresponding area of floor along the western side of the stack area was removed during the Furness addition to the library. Note louver control piece at right side of grill.

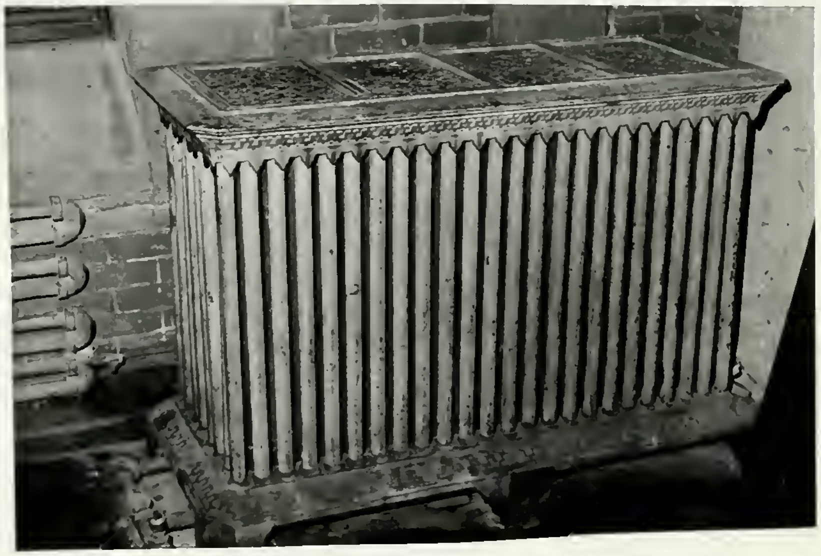
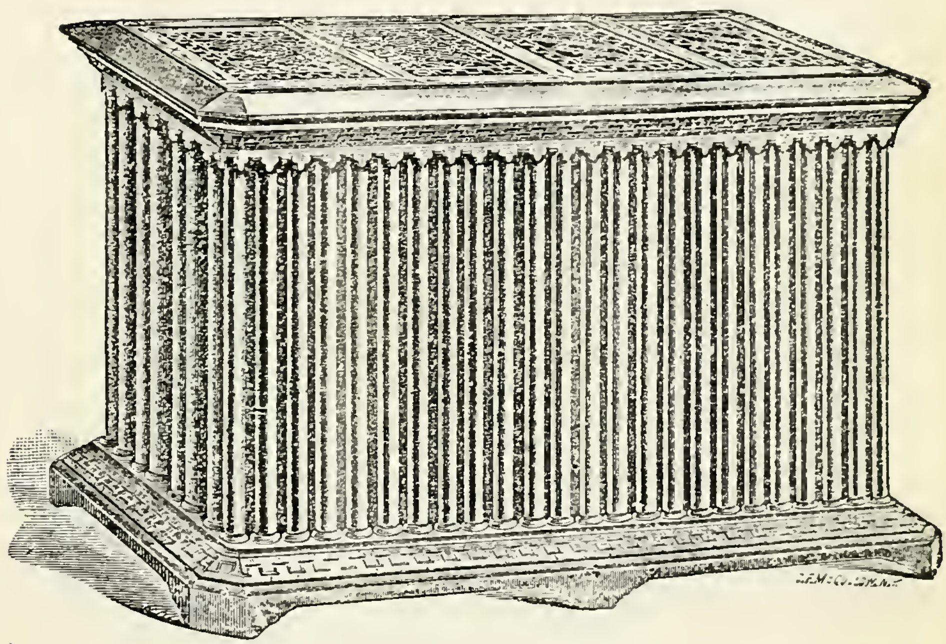


ILLUSTRATION #12 - Wrought iron tubing radiator located in the northwest corner of the stair tower at the first floor. This radiator is typical of those in production and use for non-industrial applications at the time that the library was built until ca. 1900. This particular radiator was manufactured by the Nason Manufacturing Co., New York and is part of the original heating system installed in the library.

NASON'S "DUPLEX" PATTERN.

VERTICAL WROUGHT IRON WELDED TUBE RADIATOR.



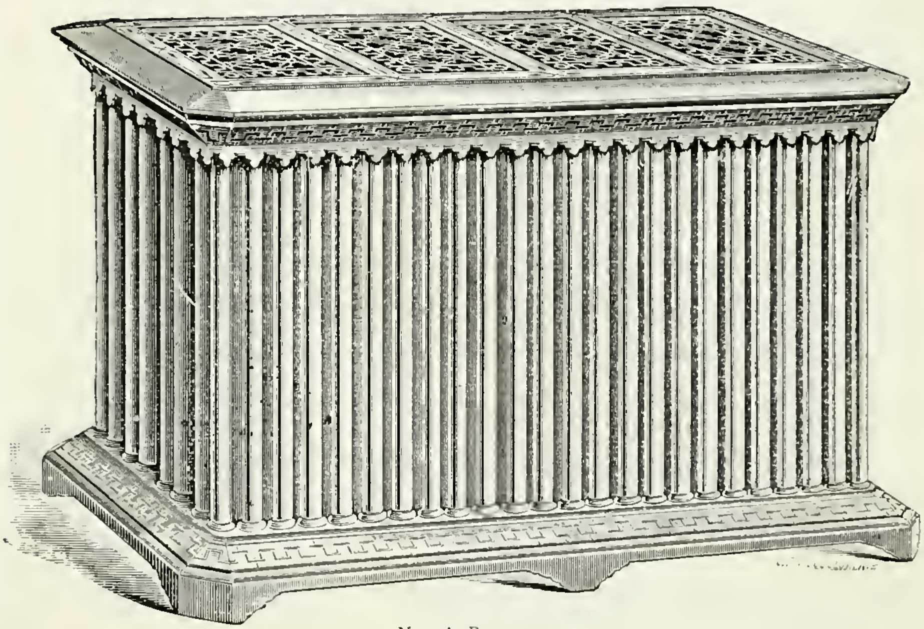
Size Tubes 8 x 24, 192 Tubes, equal to 192 Square Feet of Surface.

Outside Dimensions, Length 4 ft. 5½ in., Width, 24½ in.

ILLUSTRATION #13 - Radiator identical to that which sits in the northwest corner of the first floor stairtower, from "Illustrated List of Prices." The Nason Manufacturing Co.. n.p., 1895.

NASON'S DUPLEX PATTERN.

VERTICAL WROUGHT IRON WELDED TUBE RADIATOR.

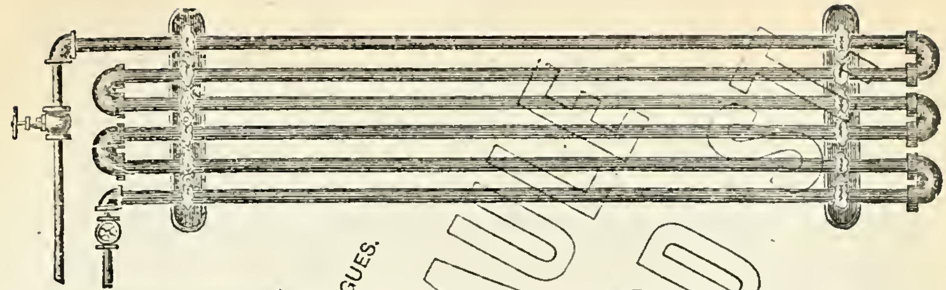


Nason's Patent

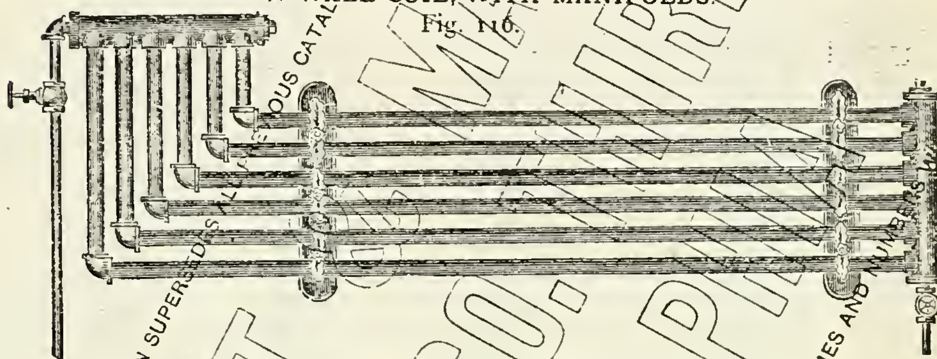
FIG. 11.

ILLUSTRATION #14 - Radiator identical to that which sits in the northwest corner of the first floor stairtower, from "Steam and Hot Air Apparatuses." George W. Hartman Co. Philadelphia: n.p., 1889.

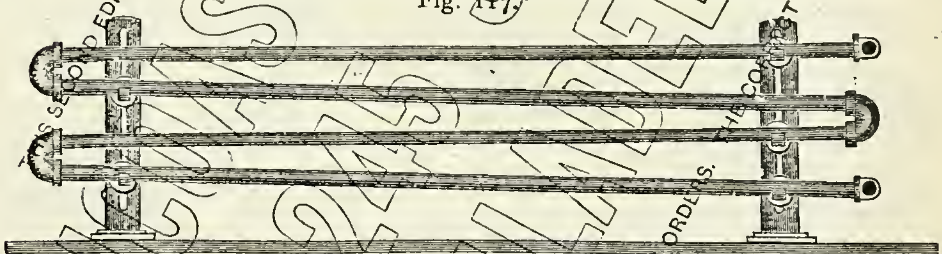
★ WALL COIL, WITH ROSETTE PLATES.
Fig. 115.



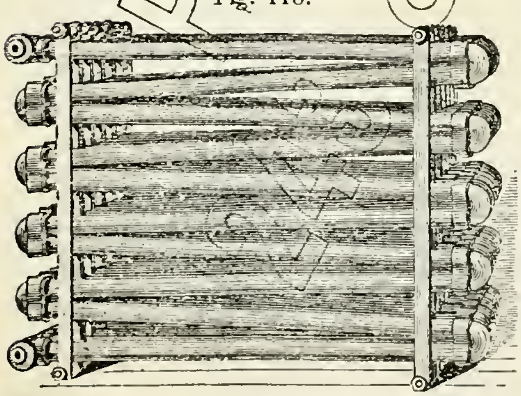
★ WALL COIL, WITH MANIFOLDS.
Fig. 116.



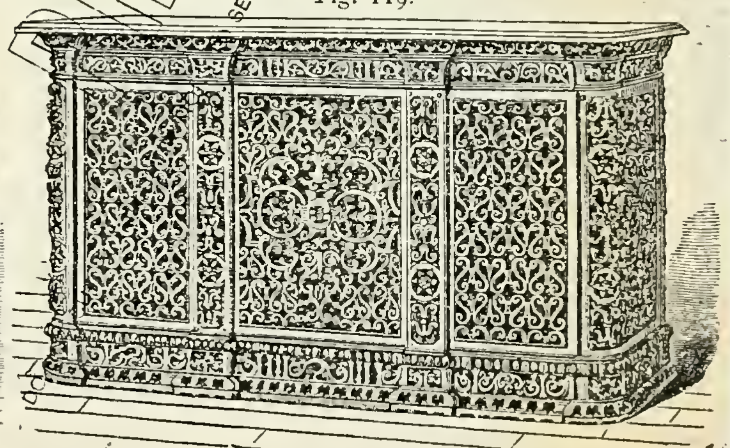
★ LAUNDRY COIL, FOR DRYING CLOTHES, &c.
Fig. 117.



★ BOX COIL RADIATOR.
Fig. 118.



★ ORNAMENTAL SCREEN FOR BOX COIL RADIATORS.
Fig. 119.



NOTE.—Figs. 115 and 116 also furnished, fitted with Hook-Plates, same as Fig. 44, when desired.

ILLUSTRATION #15 - Examples of wrought iron coil tube type radiators which can be found at a number of locations within the building, from "Catalog A, Second Edition." The Pancoast and Maule Co.. n.p., 1889.

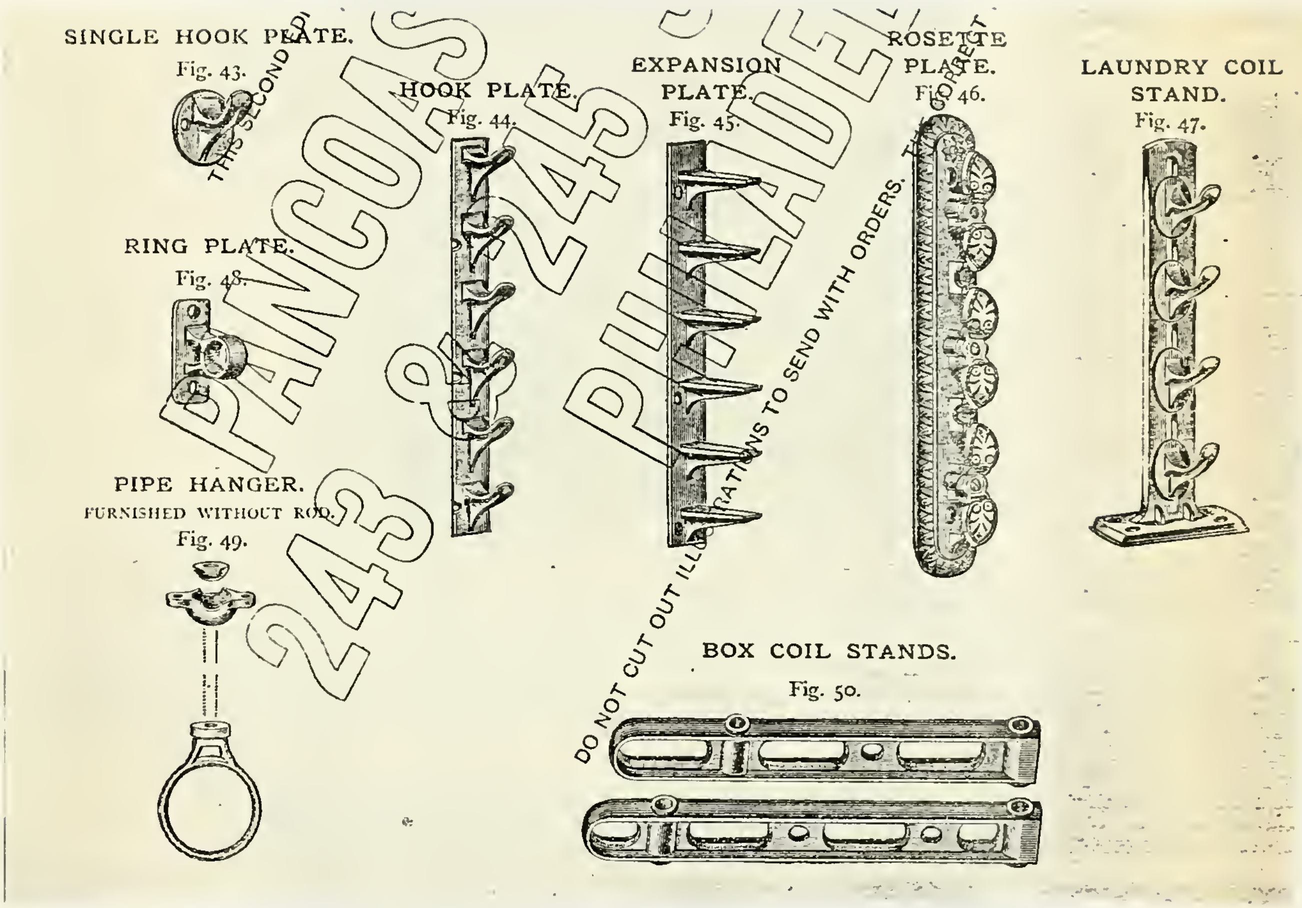


ILLUSTRATION #16 - A coil radiator pipe support similar to that described as a Rosette Plate in figure 46 of this page can be found just outside the second floor studio in the building apse. Also, brackets similar to those in figure 44 can be found throughout the building, from "Catalog A,Second Edition." The Pancoast and Maule Co.. n.p., 1889.

ILLUSTRATION #17 - Detail of "coil tubing" radiator located in alcove just outside of second floor studio above main reading room apse section. The decorative brackets which are used here to attach the radiator to the wall are similar in appearance to those found in the Pancoast and Maule catalog for the year 1889.

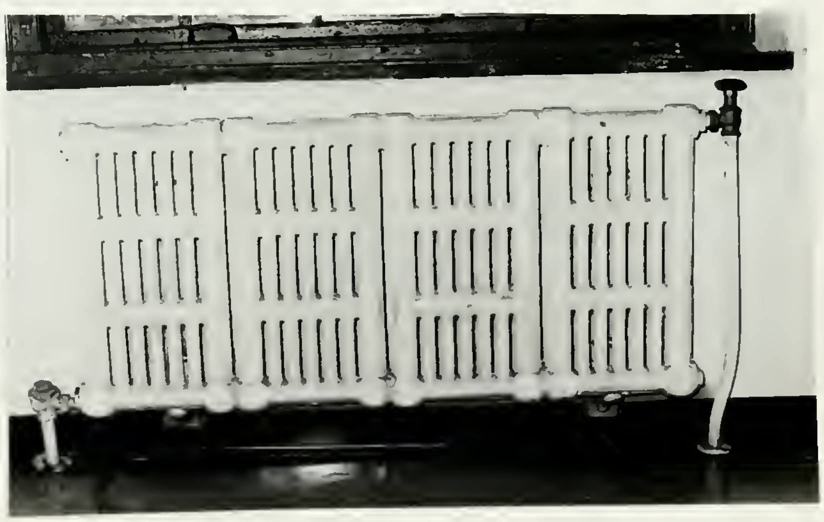
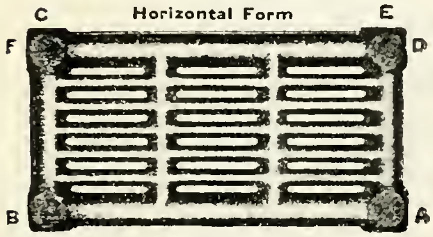


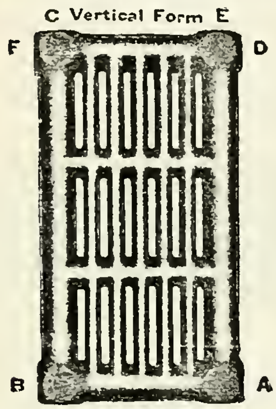
ILLUSTRATION #18 - Radiator located below basement window in Lea addition to library. Typical of industrial type in production after ca. 1910.

WALL RADIATORS AND HANGERS

WALL RADIATORS



G Fig. 7222A H



G Fig. 7222B H

VERTICAL AND HORIZONTAL, PLAIN PATTERN ONLY

10 square foot section; 24x13¼x3⅝ in.

VERTICAL AND HORIZONTAL, PLAIN AND ORNAMENTAL PATTERN

9 square foot section, 24x13x3¼ inches 7 square foot section, 24x12½x3 inches. 6 square foot section. 21x12½x3 inches. 5 square foot section, 17x12½x3 inches. 3¾ square foot section. 17x9½x3 inches.

The 3¾ square foot section is furnished in single sections both vertical and horizontal, but assembled in vertical form only.

Prices upon application.

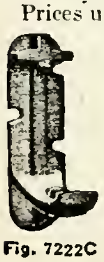


Fig. 7222C

No. 18 CAST IRON WALL HANGERS

For all size sections excepting the 10 square foot which requires a modified type, similar to cut, but with longer hook, and listed as No. 18X.

Prices on application.

No. 33 WROUGHT IRON ADJUSTABLE HANGERS

PATENTED

Fig. 7222D

Expansion and contraction of the radiator is provided for by the rotation of the hook upon the bolt.

Vertical adjustment of 1 inch is obtained by turning the bolt.

Lateral adjustment of ⅞ inch is possible by moving the bolt in the slots in upper and lower saddles of the plate, to locate the hook in its proper position between the tubes of the radiator.

Length over all, 9¾ inches. Distance from wall to back of radiator, 2 inches. Distance from wall to centers of tapping: 7-foot sections, 3¼ inches; 9-foot sections, 3⅝ inches; 10-foot sections, 3⅞ inches.

Prices upon application.

No. 30 CAST IRON ADJUSTABLE HANGERS

Fig. 7222E

The supporting hook swings freely in a socket, providing for expansion and contraction of the radiator, and has a vertical adjustment of one inch, by means of a set screw, such adjustment being possible after radiator is erected.

The top is cross slotted for head of tie bolt, accommodating both horizontal and vertical radiators and all size sections.

Length, 17¼ inches. Distance from bottom of hanger to bottom of radiator, when hook is at lowest point, 4½ inches. Distance from wall to back of radiator, 1⅜ inches. Distance from wall to center of tappings—10-foot sections, 3⅛ inches; 9-foot sections, 3 inches; 7-foot and smaller sections, 2⅝ inches. Prices upon application.

ILLUSTRATION #19 - Cast iron radiators top left of this page are similar to those in illustration #18, from "Catalog H." Henry B. Pancoast Co.. Chicago: R.R. Donnelly and Sons, 1912.

IDENTIFYING MARKINGS

Byers Tubular Products

TO FACILITATE inspection of pipe and tubular material on the job, all Byers Products are clearly marked at the mills. Different markings are used on Byers Genuine Wrought Iron and Steel Products to make it easy to distinguish between the two types of material.

GENUINE WROUGHT IRON PRODUCTS

For permanent identification all butt-welded pipe, excepting the 1/8" size, and all lap-welded pipe has the name "BYERS IRON" rolled in raised letters on the surface of the pipe every few feet.

In addition to the roll markings, all sizes of Byers Genuine Wrought Iron Pipe and Tubular Products have a RED SPIRAL STRIPE painted on every length (unless otherwise ordered) to provide for quick identification on the job.

All Byers Genuine Wrought Iron Nipples, excepting Close Nipples, are machine the center, it being impractical to stamp on the threads.

ILLUSTRATION #20 - Top illustration shows Byers Company identification markings of its wrought iron pipe in the year 1939. Steel pipe was stamped with the words "BYERS - STEEL" as described in the text on a following page, from General catalog. A.M. Byers Co. n.p., 1939.

ILLUSTRATION #21 - Radiator located in second floor addition studio above main reading room. This type of radiator is typical of a type manufactured after ca. 1910 and is located in a section of the building which was not original to the building, thus it is certainly not a part of the original steam heating system.

HENRY B. PANCOAST CO.

CAST IRON RADIATORS

THREE COLUMN—FOR STEAM OR WATER

PEERLESS

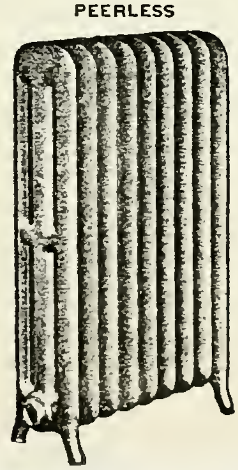


ILLUSTRATION #22 - Radiator similar to those which can be found at the east wall of the second floor addition above the main reading room, from "Catalog H." Henry B. Pancoast Co.. Chicago: R.R. Donnelly and Sons, 1912.

ILLUSTRATION #23 - Radiator located at the first floor of the stair tower near the entry to the library. This radiator is typical of segmental cast iron radiators which were manufactured circa 1900.

HENRY B. PANCOAST CO. 229

CORTO RADIATORS

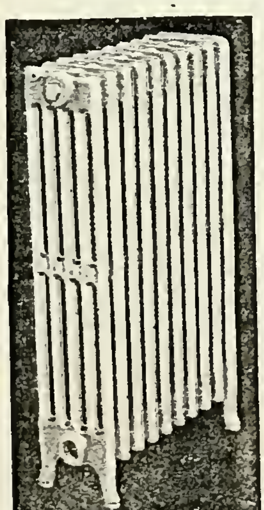


Fig. 29196A

The series of columns that constitute this radiator make it unparalleled for resisting high internal pressures. The internal area of its tubes in relation to the heating surface has been reduced to about one-quarter of that now generally in use. Not only has this invention greatly increased the pressure-resisting ability of the Corto Radiator, but in reducing the internal area the water or steam contents are likewise decreased.

The water content of the Corto is equal to three-fourths of a pound per square foot of heating surface, or about one-half the water content of the average radiator; this assures quick and positive venting for all kinds of steam and vapor systems, while in water installations it provides a rapid circulation, causing the radiator to respond more quickly to the immediate heating needs.

The symmetrical spacings between the tubes and the decreased size thereof permit of obtaining approximately 30 per cent more heating surface in a given area of floor space than with any other type of radiator.

Irrespective of height, a series of six sizes ranging from two to four and one-half feet of heating area have been produced, and the surface of each additional size will be increased by one-half square foot, thus abandoning the cumbersome method of increasing heating surface by irregular fractions.

ILLUSTRATION #24 - Cast iron radiator similar to that in illustration #23, from "Catalog H." Henry B. Pancoast Co.. Chicago: R.R. Donnelly and Sons, 1912.

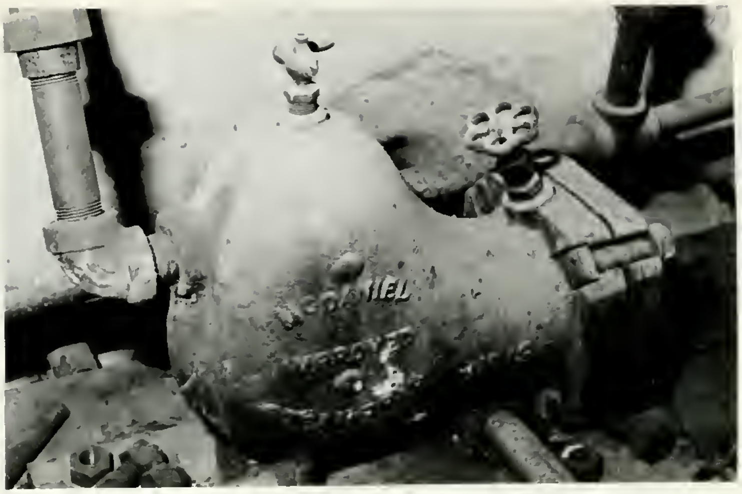


ILLUSTRATION #25 - Steam trap located in the mechanical room for the building. This "boot type" steam trap is imprinted with "McDaniels Improved Steam Trap No. 13, Patented Mar 10, 1903".

ILLUSTRATION #26 - Steam trap located in the mechanical room for the building. This type of "float" steam trap is imprinted with "No. 2, McDaniels Special Steam Trap, Patented Aug 19, 1890."

STEAM TRAPS

McDANIEL IMPROVED

EXTERIOR SECTIONAL

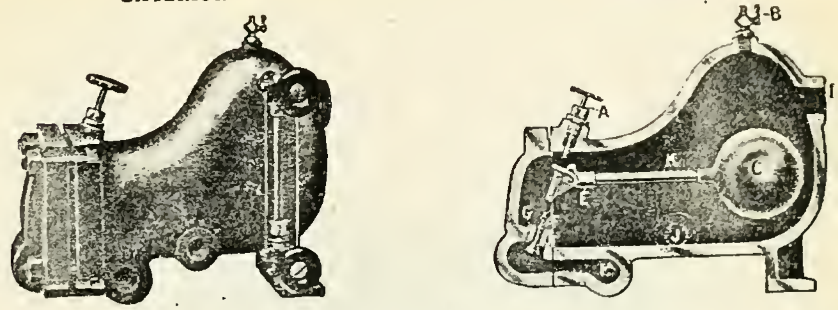


Fig. 22115A

The new model embodies all the desirable features of former patterns, but is made more compact and easier to get at if a repair is needed. Regular pressure, all sizes, to work from 1 to 125 pounds steam pressure, low pressure, all sizes to work from 1 to 20 pounds steam pressure, when not otherwise specified, regular pressure traps will be sent. State highest steam pressure in ordering.

Number	12	13	14	15	16	17	18
Capacity, Lineal Feet of 1-inch Pipe	500	1500	4000	8000	15000	20000	25000
" Radiation....square feet	166	500	1333	2666	5000	6666	8333
Size, Pipe Connections.......inches	½	¾	1	1¼	1½	2	2½
Price.......each	12.00	18.00	30.00	40.00	60.00	80.00	100.00

McDANIEL REGULAR

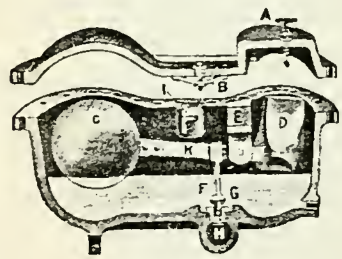


Fig. 22115B

STANDARD

Fig. 22115C

McDANIEL REGULAR

Adapted for either high or low pressure. Is automatic in discharging condensation and requires no attention. The trap has a counter balance weight which gives it a great lifting power and allows a large valve area. All parts can be lifted out together on removal of cover. Regular pressure, 1 to 100 pounds, low pressure, 1 to 20 pounds.

Number	1	2	3	4	5
Size, Inlet and Outlet.......inches	1	1¼	1½	2	2½
Drainage of 1-inch Pipe.......feet	3500	7000	14000	20000	25000
Equivalent in Heating Surface....sq. ft.	1166	2333	4666	6666	8333
Price.......each	30.00	40.00	65.00	75.00	100.00

In ordering, always state the highest steam pressure.

STANDARD

Diameter.......inches	12	15	18
Capacity, Lineal Feet of 1-inch Pipe	1500	3500	5000
Price.......each	23.00	36.00	54.00

ILLUSTRATION #27 - Upper two illustrations are those of the four McDaniel's No. 13 steam traps pictured in illustration #25 which are still in place (though no longer in use) in the mechanical room. Bottom left illustration is a cut-away view of the McDaniel's steam trap pictured in illustration #26 which is also still in place in the mechanical room (also no longer in use), from "Catalog H." Henry B. Pancoast Co.. Chicago: R.R. Donnelly and Sons, 1912.

ILLUSTRATION #28 - Condensation meter found in the mechanical room for the building. This condensation meter, which measures by returning condensation the amount of steam used in the library heating system, was manufactured by the Central Station Steam Co..

THE CADILLAC CONDENSATION METER

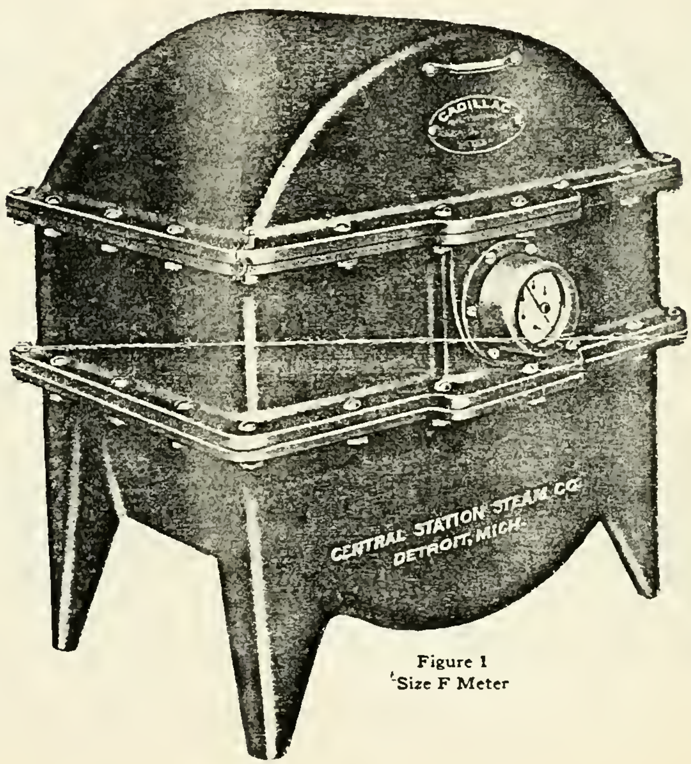
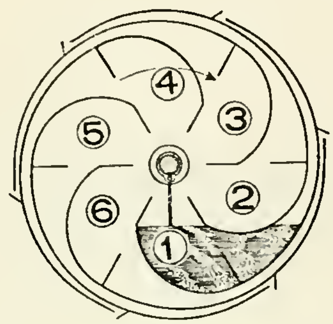


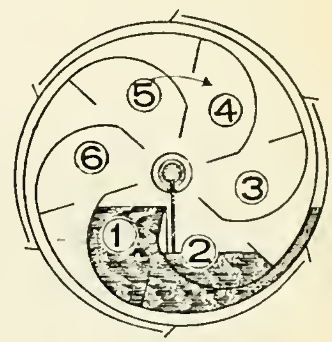
Figure 1
Size F Meter

CENTRAL STATION STEAM CO.
DETROIT, MICHIGAN

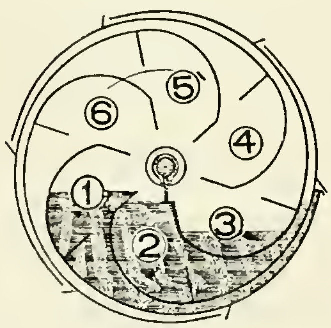
ILLUSTRATION #29 - Cadillac condensation meter located in the mechanical room, from "The Cadillac Condensation Meter." Central Station Steam Co.. n.p., ca. 1930.



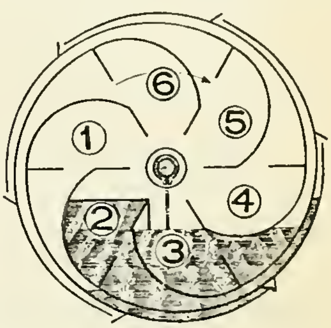
A
Compartment No. 1 filling. Water extending to right of center turns drum in direction of arrow



B
Compartment No. 1 filled and overflowing into Compartment No. 2



C
Compartment No. 1 ready to empty. Compartment No. 2 full and overflowing into Compartment No. 3



D
Compartment No. 1 nearly empty. Compartment No. 2 overflowing and Compartment No. 3 nearly full

Figure 7
Diagrams showing Principle of Operation

ILLUSTRATION #30 - Illustration showing the action of the Cadillac condensation meter, from "The Cadillac Condensation Meter." Central Station Steam Co.. n.p., ca. 1930.

Appendix A:

The following floor plans note where existing radiators within the building are located and their type. Those denoted by capital letters indicate those types which are probably part of the original steam heating system. Those in lower case are more likely to have been added some time, no less than ten years, after the building was built.

A - Wrought iron tube radiators. See illustrations #4, 6, 12 - 14.

B - Direct-indirect radiator grille locations with radiators sheet iron plenums below floor. See illustrations #7 - 11.

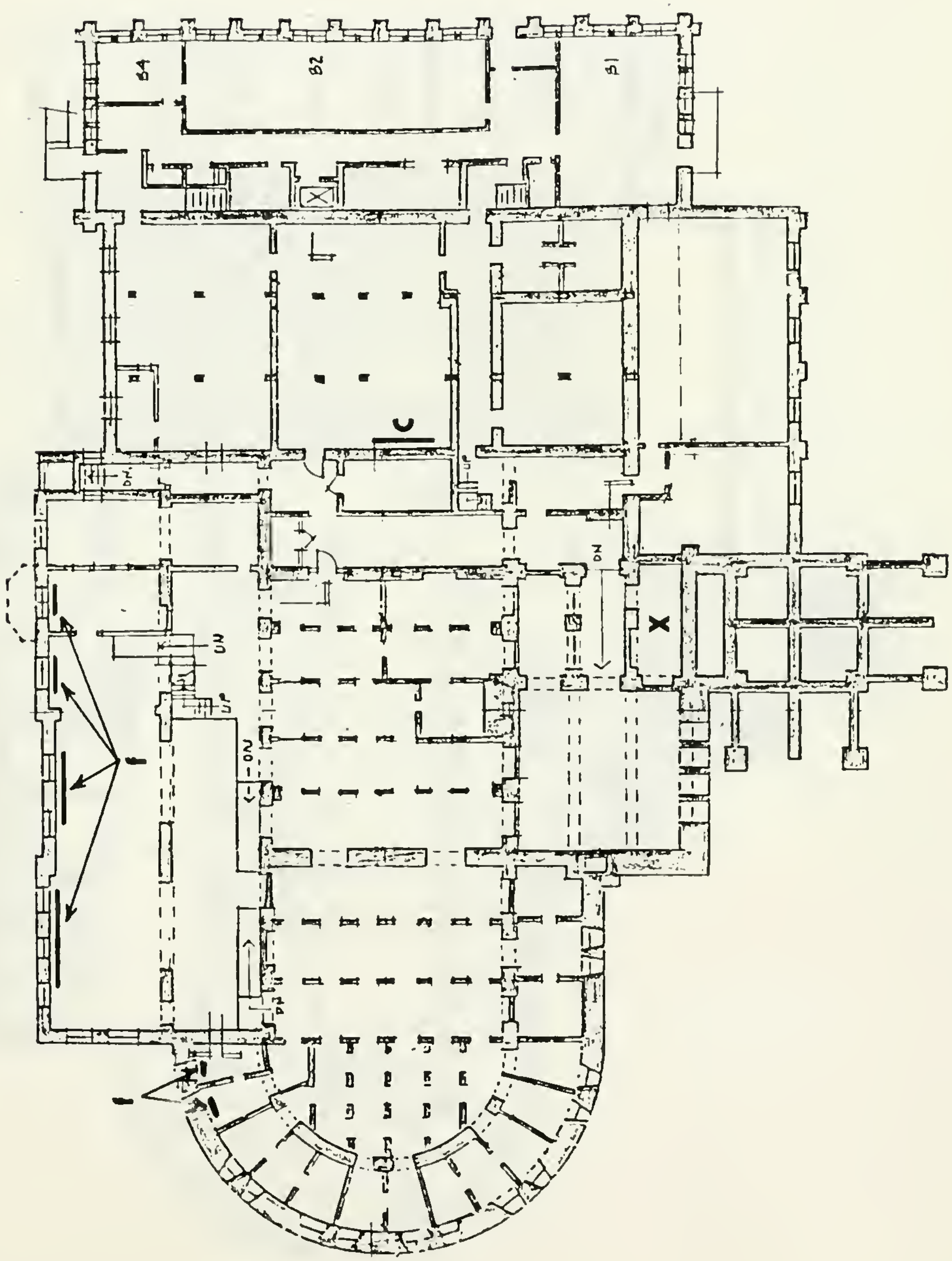
C - Wrought iron pipe coil radiators. See illustrations #15 - 17.

D - Vertical cast iron loop radiator. See illustrations #3 & 6.

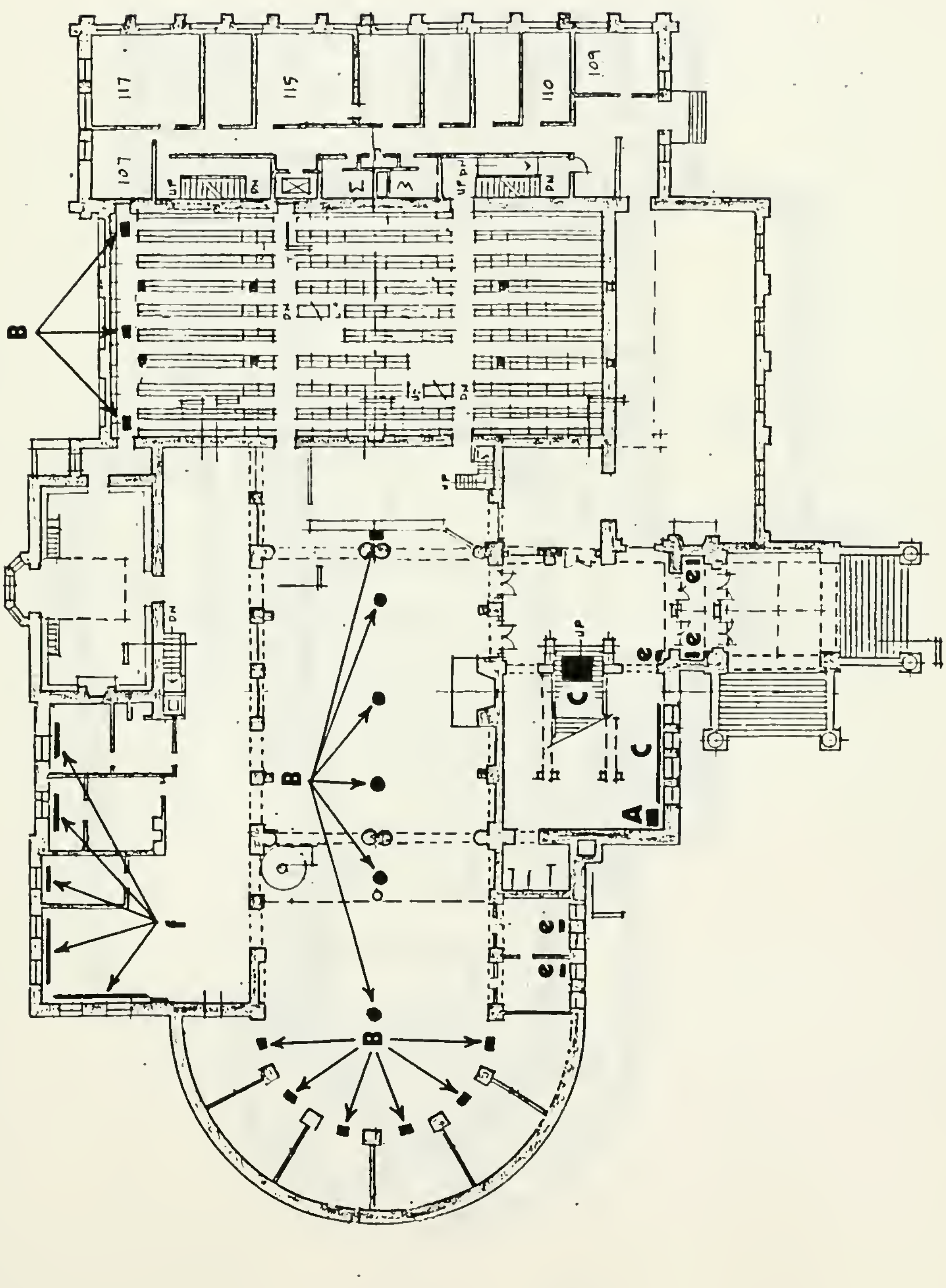
e - Cast iron tube radiator. See illustrations #23 & 24.

f- Industrial type cast iron unit radiator. See illustrations #18 & 19.

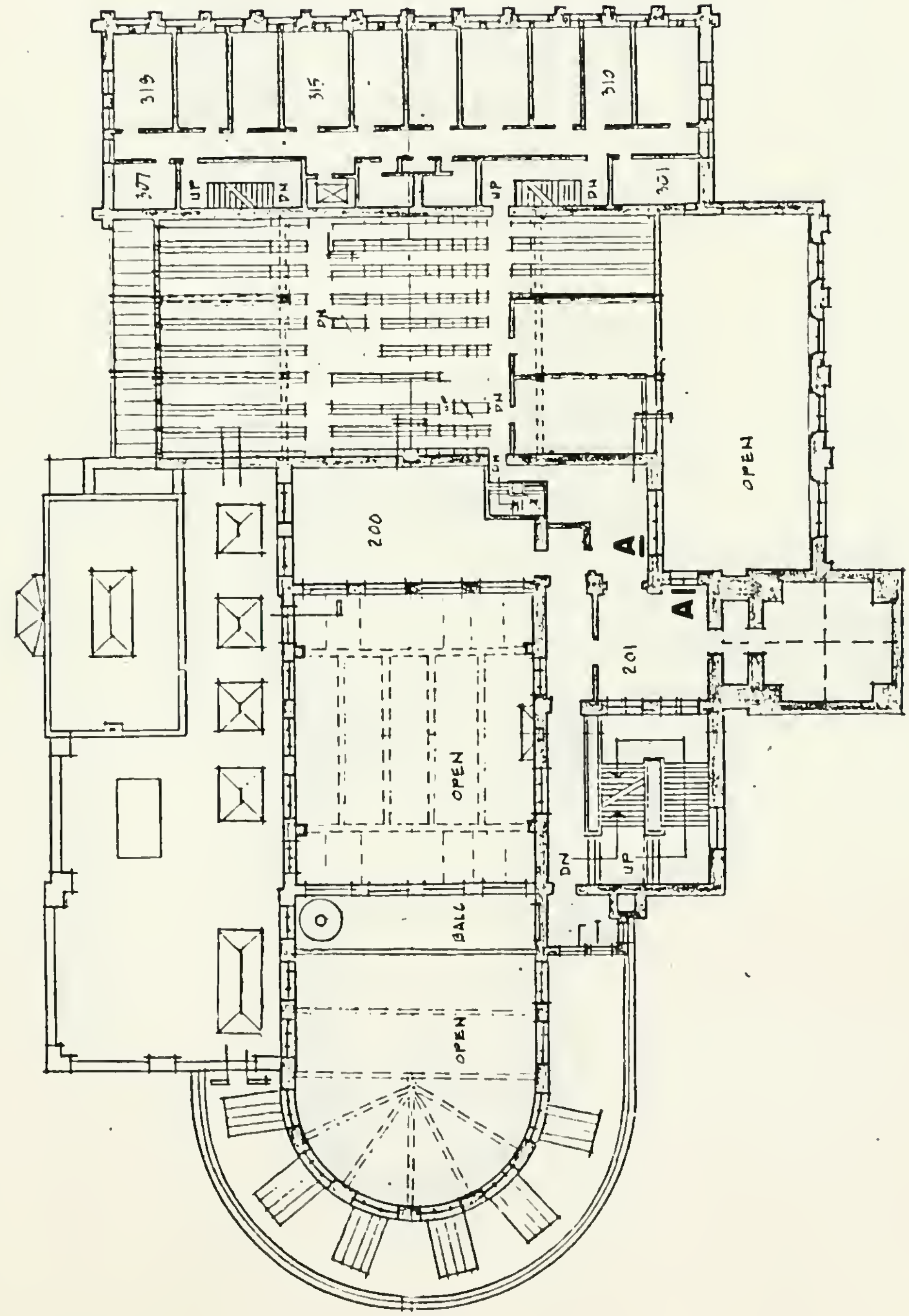
g - Cast iron column radiator. See illustrations #21 & 22.



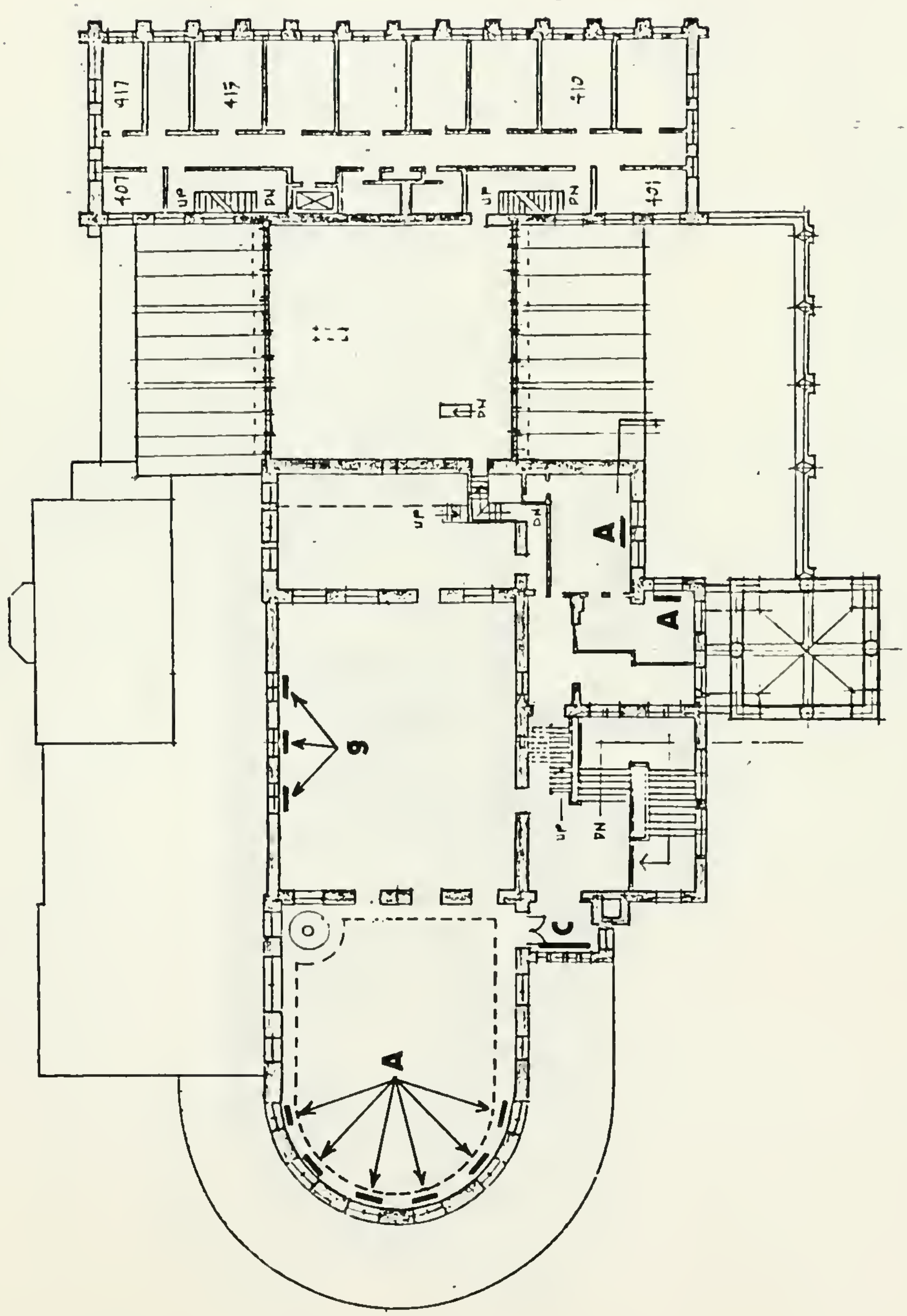
BASEMENT



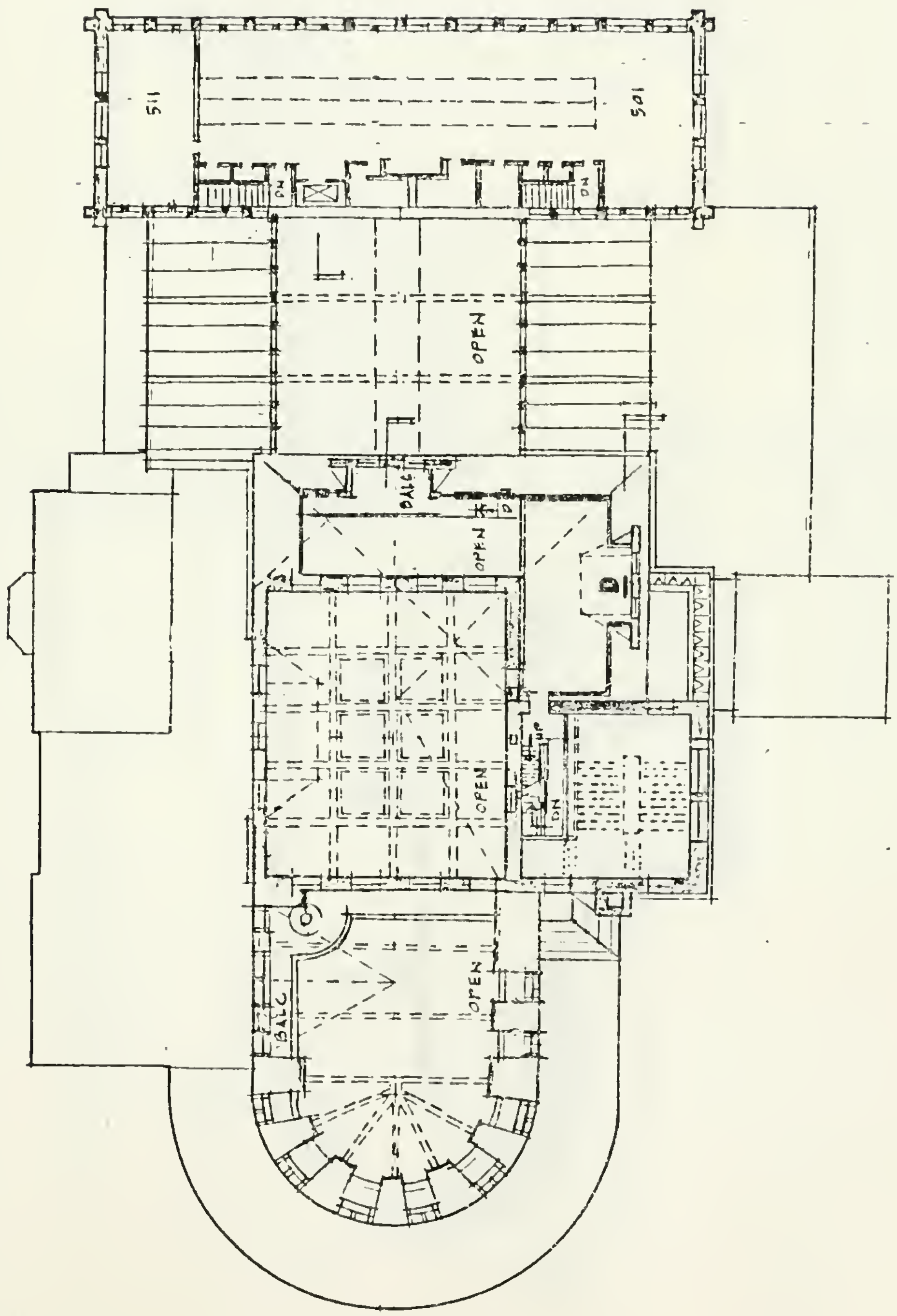
MAIN FLOOR



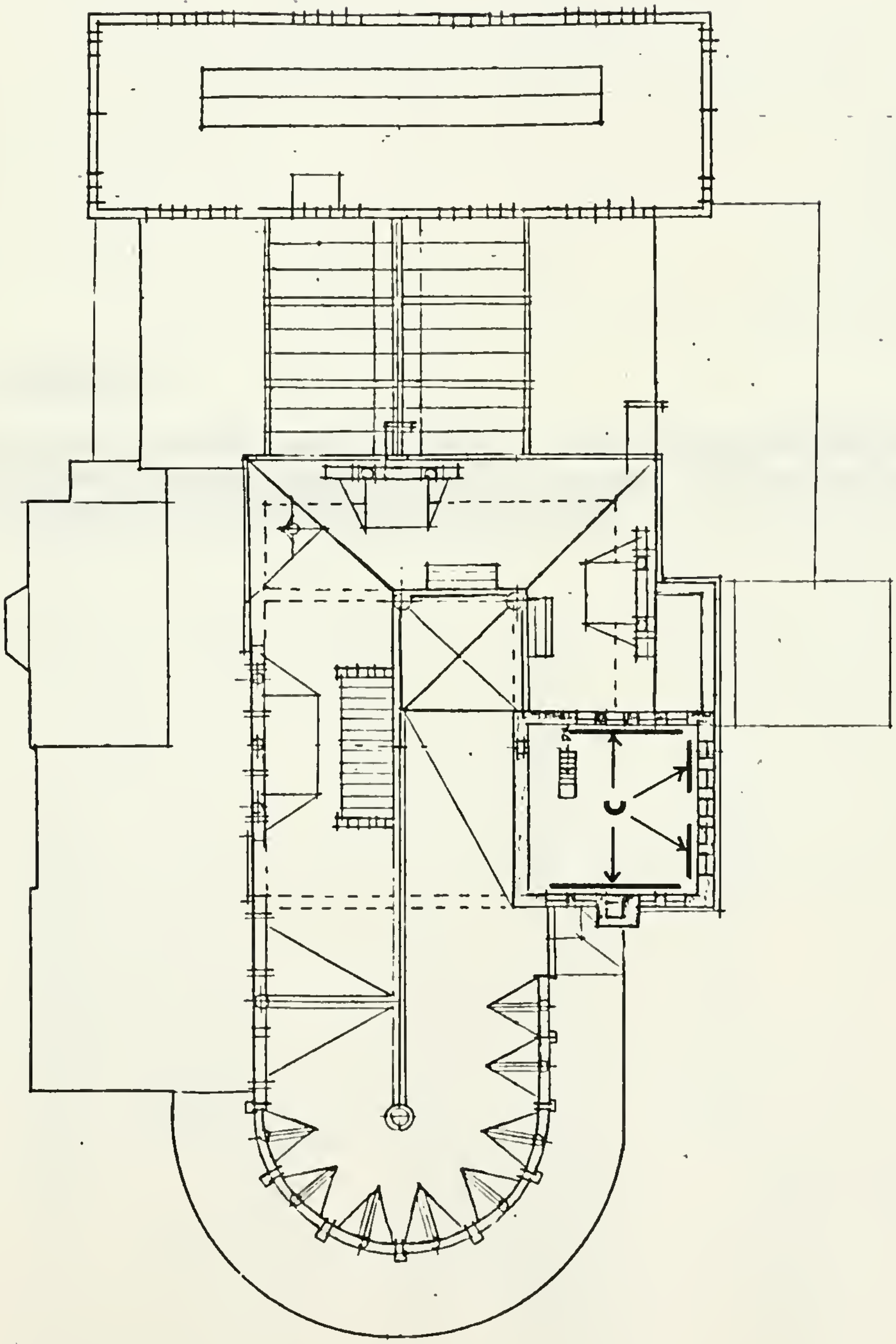
ENTRESOL



SECOND FLOOR



THIRD FLOOR



TOWER & ROOF

Appendix B:

On the following page is a copy of a Matrix photocopied from the Library Journal, Vol. 13, April 1881, pp. 94-95. Its purpose was to evaluate various heating systems for library use.

	1. Open fireplace.	2. Open stove.	3. Close stove.	4. Hot-air furnace.	5. Low-pressure steam.
a. **Safety against fire.** 5, 1, 2, 3, 4.	a1 — Very safe. No smoke oor hot-air pipes. Defective flues daogerous with large fires. Sparks snap out from some wood. Coal safe.	a2 — Better than close stove, as outside is not so hot.	a3 — Smoke pipes set many fires.	a4 — Worst. Hot-air pipes set most fires.	a5 — Safest. With right apparatus explosions are impossible or harmless.
b. **Freedom from dust, dirt, gas, smoke, and noise.** 5, 4, 1, 2, 3.	b1 — Very dusty, dirty, and smoky. Noise of fire-irons and soapping of fuel.	b2 — Less than 1, but bad. Noise added.	b3 — Same as b2.	b4 — Gas, dust, and noise. Hot-air pipes are simply great speaking-tubes to carry every sound.	b5 — Nearest perfect. Poor piping will cause great noises; but it is noiseless wheo properly put in.
c. **Quality of heat.** 1, 2, 5, 3, 4.	c1 — Best. Direct radiation from flame. Like beat of suo.	c2 — Next best. This is part 1 and part 3, and combines their qualities.	c3 — Apt to be bad.	c4 — Usually worst. May be improved, but heat rays, not bot air, is best.	c5 — Direct radiatioo. With proper attachmeots can be made best.
d. **Influence on ventilation.** 1, 2, 5, 4, 3.	d1 — Best koown if properly combined with air supply.	d2 — Little inferior to fireplace.	d3 — Worst.	d4 — Usually very bad. Can be made fair.	d5 — Usually bad. Can be made best.
e. **Ease of distribution to different rooms, or parts of rooms.** 5, 4, 2, 3, 1.	e1 — Practically impossible to distribute.	e2 — Circulates air in same room best. Can beat room above with dummy.	e3 — Worst except 1.	e4 — Easiest except steam-pipes. Take room aod are dangerous.	e5 — Best known. Small pipes go anywbere aod caooot set fires.
f. **Space occupied by apparatus, 1, 2, and 3 beiog in each room.** 5, 4, 1, 2, 3.	f1 — More than furnace or steam.	f2 — Same as stove.	f3 — Most.	f4 — Least except steam.	f5 — Vastly least. Boiler smaller thao furoace, aod pipes much smaller.
g. **Economy in fuel.** 5, 3, 2, 4, 1.	g1 — Least. Costs most for beat given. Chimney sucks life out of the fire.	g2 — Good. Little inferior to close stove. Four times the fireplace.	g3 — Good.	g4 — Worst after fireplace.	g5 — Best for large rooms or buildings.
h. **Ease of running, 1, 2, and 3 beiog in each room.** 5, 4, 3, 2, 1.	h1 — Hardest.	h2 — Harder than stove 3. Easier than 1.	h3 — Easiest in each room.	h4 — Easier than 1, 2, or 3 in each room.	h5 — Same as h4.
i. **Ease of keeping in order.** 1, 5, 4, 2, 3.	i1 — Easiest.	i2 — Next to close stove, hardest.	i3 — Hardest. Lioings, pipes, drafts, etc., need frequent care.	i4 — Easiest after fireplace.	i5 — Same as furnace.
j. **First cost.** 1, 3, 2, 4, 5.	j1 — Cheapest if built with building. Otherwise costs most.	j2 — Cheap.	j3 — Cheapest.	j4 — High.	j5 — Costs most.
k. **Durability.** 1, 5, 2, 3, 4.	k1 — Greatest.	k2 — Neat to fireplace and steam.	k3 — Greater than furnace.	k4 — Least.	k5 — Greatest except fireplace.
l. **Appearance.** 1, 2, 5, 4, 3.	l1 — Best.	l2 — Next to fireplace.	l3 — Worst.	l4 — Bad.	l5 — Good.

Appendix C:

The following pages are photocopies of a bibliography included in the article: "The Literature of Heating and Ventilating", an address given by a Mr. Hugh Barron before the first meeting of the American Association of Heating and Ventilating Engineers, and reprinted in Transactions: American Society of Heating and Ventilating Engineers, Vol. 1, 1895, pp. 176-180.

In the development of the arts no work of man is to be despised; even the most rubbishy is interesting as a milestone on the march of human progress. Philosophers now generally realize that the histories of nations are in their arts and their literatures. The true history of this special art is in its literature, and when that is carefully examined it will be found that its development has been due to the thousands of unknown workers who have been engaged in it, and that any one man's share in the advancement has been very small indeed.

BOOKS.

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Warming, Ventilation, and Sound. W. S. Inman. London, 1836.

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Walker's Hints on Ventilation. London, 1845.

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Robertson Buchanan notes that a certain M. Bonnemain exhibited at Paris, in 1777, an incubator heated by a coil containing water under pressure, thus anticipating Perkins' invention of high pressure hot water heating by 40 years, and the Baker car heater by 80 years. (See page 163 Tomlinson's "Warming and Ventilation.") Bonnemain's system was introduced into England in 1816 by the Marquis de Chabannes, who was long regarded as the inventor. In 1822 Messrs. Atkinson, Barrow, and Turner, and Mr. Baker introduced modifications of the apparatus, working at low temperature, and open to the atmosphere, in contrast to Perkins' high temperature. (See Dr. Reid, page 252.) (Perkins' distinctive features were in working at very high temperatures and using a water tube or coil boiler and a closed system.) He also refers to a certain M. Gauger's treatise on fire places, stoves and chimneys, published during the 17th century, and the translation of this work by Dr. Desaguliers in 1715 (the inventor of the fan blower—died 1749), and the treatise of our own Dr. Benjamin Franklin on chimneys, published in 1785, and to the Essay of Count Rumford on the same subject, published in 1796; but before proceeding to examine Robertson Buchanan's treatise I wish to note that his works are

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