Poisonous Atmospheres: Ventilation and the Late Nineteenth Century Building.

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The desire for healthy buildings and inhabitants in the late nineteenth and early twentieth century was of prime concern for hygienists, sanitary engineers, architects and regulatory officials alike. To protect inhabitants a range of technological and operational strategies were employed to prevent the air in rooms becoming foul and contaminated. At the root of this concern and resulting technology were particular concepts and theories regarding the mechanisms by which disease spread. Foul air, whether from dangerous decomposing organic matter or from the fetid breath of ordinary individuals needed dilution and deodorisation - best managed with good ventilation. Using the situation in late nineteenth century Britain and its colony in Western Australia as a case study this paper explores the way that ventilation technology at its simplest level was informed by concepts of health and disease

Introduction

In his book "Is My House Healthy? How to Find out" (1892) J. Spottiswoode Cameron a Medical Officer for Health in Leeds, England, devotes large sections to discussing the benefits of proper ventilation practices in buildings. "Far be it from me to suggest that a dirty family, living in a dark, unventilated, badly-drained hovel with a back and front entrance, would necessarily be healthier than a family living godly, wholesome, and cleanly lives in a sunny, airy back-to-back house" [1]. Spottiswoode's argument is that the former house with a door front and rear is a potentially healthy house as both doors may be opened to allow a through current of air to "sweep the apartment". Consequently, an unhealthy situation with its attendant physical and morally injurious living conditions may be retrieved. Despite wholesome and godly living the latter family may be in danger if their "cleanly" house was not properly ventilated.

This situation underscores the great concern in the late nineteenth and early twentieth centuries to provide sanitary and healthy buildings to protect the health of the population. In Britain and in Australia, laws were enacted and regulations enforced governing the siting, construction and design of buildings. Strategies for constructing healthy buildings were also promulgated through numerous publications for both professional and lay consumption. Sites of such wisdom could be found in the text of domestic science manuals as well as in "How to . . ." or self help publications and in architectural textbooks. Spottiswoode's alarm reveals a widespread anxiety about breathing unwholesome atmospheres that were possibly contaminated with disease. The technology of ventilation was a concrete strategy to lessen those dangers and improve the health of inhabitants.

This paper discusses how dwelling space and building construction in the late nineteenth and early twentieth centuries was informed and shaped by practices of ventilation and health. The desire for healthy buildings and therefore healthy inhabitants was a prime concern of hygienists, sanitary experts, architects and moralists alike. To protect inhabitants a range of technical, architectural and operational strategies were employed to prevent the air in buildings becoming foul and contaminated. While this concern was directed at the population in general, there was a tendency for discourse to focus on the poorer sections of society and therefore produce model situations and techniques for improving the health and morality of the artisan and labouring classes. At

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this time there was often seen to be a close relationship between moral issues, clean habits and good health. Incidence of disease was sometimes seen as an indication of depravity and immorality as much as of lax hygiene. Model dwellings and health bylaws promoted wholesome living though the regulation of living space, building construction and ventilation technology.

In terms of the history of building science and technology this paper demonstrates that building technology and space in dwellings in Britain and its colonies was informed by concepts of disease and health. In the late nineteenth century, regard for miasmatic theories concerned with the spread of disease resulted in building strategies and practices aimed at ridding buildings of dangerous atmospheres. These strategies revolved around the themes of control through regulation, the disconnection of the dwelling from the ground by the use of barriers and the deodorisation of atmospheres through ventilation.

To illustrate the above this study focuses on the situation in Britain and the then fledgling state of Western Australia which was a subject colony and shared empire loyalty, sentiment and laws. Referring to nineteenth and early twentieth century texts the paper discusses the concepts of disease at that time and the effect that these ideas had on building technology and space and particularly the practices of ventilation.

Concepts of Disease.

Medicine in the nineteenth century recognised two basic concepts underlying the spread of disease – contagion and infection. The key idea of contagion was that disease could be spread from person to person by direct contact with infected persons or through contact with infected goods. Contagion theories had been around since Greek and Roman times and had gained some credence in the middle ages during the time of the great plagues. Response to the aetiology of contagion generally involved a 'cordon sanitare' – a barrier or quarantine to the movement of infected people and populations. However, despite such measures, the theory continued to fail to explain the randomness with which disease was manifest. Attempts to map the spread of disease floundered as disease would often, suddenly and irrationally, strike far away from a quarantined area.

Since disease could strike from a distance it was reasonable to assume that agents beyond mere contact of infected bodies were at work. The theory of infection explained the anomalies of contagion by offering another possibility. Disease was linked to 'miasmas' – vague dangerous atmospheres that pervaded the air chiefly through the decomposition of organic matter. Both theories had their adherents and although miasmatic thought enjoyed the upper hand, both were often considered hand in glove. Delaporte shows that during the cholera epidemic in Paris in 1832 strategies for both eventualities were catered for by sanitary measures (against contagion) and health measures (against infection) [2]. Also at this time the perception arose that social conditions were linked to the incidence and spread of disease. In Paris it was the poorer and overcrowded sections of the population where the disease struck first and hardest and the notion that disease spread from the unhealthiest streets and buildings was given credence. The poor were seen as a dangerous source of infection not only for the overcrowding and accumulation of dirt and filth but also for their immoral and degenerate ways, which rendered them weakened and ripe for infection. There was a general view in the nineteenth century that environmental conditions coexisting with the incidence of the disease could be linked to the cause. As will be discussed later, outbreaks of disease were often traced back to unhealthy environments such as leaking sewer pipes, ground gases, pools of stagnant water and decomposing organic material. Moral environments were also suspect in that the deviant and degenerate – usually the poverty stricken – were more susceptible to disease [2, 3]. Moral and hygienic concern for the lower classes eventually helped to prompt middle class intervention in the form of social housing in an attempt to address lower class hygienic and moral shortcomings.

On the eve of Pasteur's and Koche's revelations in 1878 and 1882 regarding the links between bacteria and disease, the theories of infection and contagion existed side by side – often in vitriolic opposition but both explicit in health measures during epidemics [4]. However it was the theory of infection which held sway, chiefly since it was clearly and popularly manifest in a very conscious way – that of bad odour.

In the 'Foul and the Fragrant' Alain Corbin argues that the chief justification for miasmatic thought was odour. There was concrete danger in foul smells and the nose became the most reliable instrument in detecting 'airs' which held imperceptible viruses, miasmas and poisons [5]. The principle cause of stenches was the decomposition of organic matter including rotting vegetation, faeces and decomposing animal and human flesh. As this matter putrefied it gave off foul smelling gases and fogs signaling danger and the increased likelihood of a person being overwhelmed by disease and toxins. Throughout the nineteenth century the exact mechanisms of this process remained somewhat mysterious but dreadful smells alone were proof that something was terribly wrong – the strength of the smell an indication of the level of danger. There was also seen to be a distinct nexus between disease and dirt, as well as odour [6]. Many commentators testified to the dangers of decomposing organic material. For instance T. Pridgin Teale (1877) cites the case of fatal disease befalling children who had been standing watching as plumbers opened up a drain in their yard revealing a "mass of decomposing filth". Because of blocked drains their family had for months been living in a "tainted atmosphere" and these factors were the cause of their woes [7, 8]. As will be discussed later, commentators constantly warned of the dangers from decomposing material and often provided strategies to avoid the dangers. Even well into the twentieth century there were popular linkages between smell and disease [4, 9].

In this context vapours and smell could also penetrate and be retained in substances such as building materials to be released later. Even water could be contaminated by absorbing such gases and was also a source of danger itself if left standing or if it contained decomposing organic matter. Moisture alone could be hazard. Dampness, a constant problem in building structures, was the source of rheumatism, colds, neuralgia and consumption [10]. Even the earth hid hazards in the form of decomposing vegetable matter and, still worse, the cadaver remains and faecal deposits of past times and peoples. The leakage from cesspools was a further worry because fetid gases could rise up and infect domestic spaces. People and animals breathed out injurious gases in the form of carbonic acid (carbon dioxide) as well as dead cells from lungs which settled on furniture, walls and other domestic surfaces. Of such material Cameron (1892) warns "Dead, so far as any power of doing its own work is concerned, but not so far dead as to be incapable of further death." To combat the danger of this material, Cameron advocated constant cleaning and proper ventilation to carry away the gases of decomposition [11].

Efforts were directed at cleaning up urban environments culminating in the great sanitary reforms in Britain in the late nineteenth century.

Persistent efforts by reformers such as Edwin Chadwick were eventually augmented by health and building by-laws which sought to regulate the technology of building and the size and shape of living spaces.

The Breathing Earth

As previously discussed, the Victorians believed that the earth on which dwellings were constructed presented dangers. The earth was saturated with organic matter which putrefied and gave off various gases and miasmas. These vapours were contained in the interstices between soil particles and were in constant circulation beneath the earth's surface. Rising and falling water tables provided a pumping action which forced 'ground air' into the atmosphere and then sucked air back into the earth [12]. Other suggested mechanisms at work included rising and falling barometric pressure and temperature change [10, 11, 13]. Vapours expelled from the ground could enter dwellings causing illnesses. Moreover, the moisture in the soil also presented problems providing a situation ripe for putrefaction and dangerous gases emanating from the ground. Under certain conditions moist soil could contain such fevers as cholera and dysentery. Writing in 1905, Whitelegge and Newman introduced the dangers of bacteria in soil indicating that some were decidedly pathogenic. At face value the writings of Whitelegge and Newman represent a response to the new science of bacteriology. However they still maintain a concern for ground gas and argue that bacteria could enter dwelling structures via moisture in the ground. They still talk of 'organic impurities' and atmospheric and telluric triggers for disease. In effect, the old underpin new concepts of disease.

In the late nineteenth century a number of strategies were formulated to combat the twin evils of moisture and ground gas in dwellings. Drainage around a building helped to solve the moist building and by-laws of the time insisted that building soil be 'well drained' or that drainage strategies be employed if the soil was moist [14, 15]. Some by-laws included diagrams showing effective drainage around walls. However barriers were the most successful way of reducing the amount of moisture and ground gas entering a building. Building and sanitary texts stressed the importance of isolating the dwelling from the earth by damp proof courses and under floor barriers. Damp-proof courses of impervious material were used in walls to prevent the migration of moisture into the living spaces of the house. Cameron suggests that the practice also helped exclude ground, sewer and coal gas from entering the walls and, in the case of cavity construction, "lurking in the interval" [11]. From 1877 onwards communication with the soil was further cut by by-law insistence in that the "Whole ground surface or site of the house to be covered with asphalte or cement concrete to 6" (150mm) min" (sic) [14]. This policy was echoed by other sanitary reformers such as Russell (1879) and Buckton (1885). The latter advocated the extreme measure of completely isolating the house with a layer of concrete extending under the ground plan of the building including the footings. Despite their post bacterial status, Whitelegge and Newman were of similar mind claiming that the practice of providing impervious basements, excluded moisture and 'impure ground air' [13] (see figure 1).

The strategy of providing an impervious blanket under a building was not a salient feature of Western Australian building practice or regulations although there was a shared concern with Britain about the need to dr: and properly ventilate basements and under floor areas. Western Australian by-laws from 1887 require a layer of sand cement under a floor but only on damp ground. Through building by-laws the practice of ventilating under timber floors was vigorously advocated in Britain and Australia to reduce damp and remove gases [16]. Damp was an agent of bacterial growth and could also promote dry rot which Mrs Buckton claimed was "unhealthy" [10]. Strategies for ventilating under floor usually included the use of 'air bricks' of terra cotta or decorative cast iron grilles set into an external wall.

Measures against the migration of damp and gases into a building make sense in the light of fears about the pervious nature of building materials

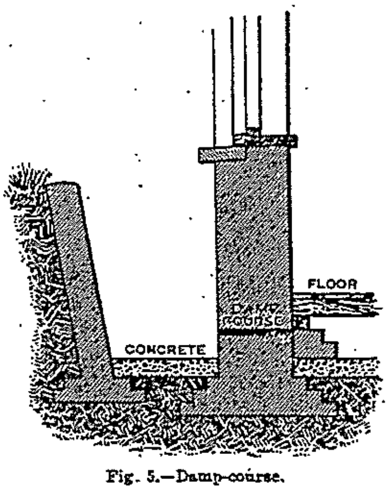

Fig. 5.—Damp-course.

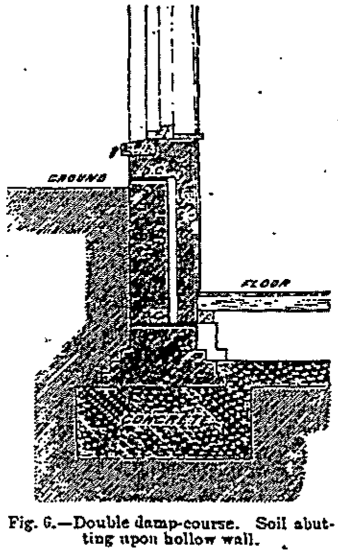

Fig. 6.—Double damp-course. Soil abutting upon hollow wall.

Figure 1: By law diagrams of wall footings showing damp course and concrete barrier. (From Whitelegge and Newman, 1905 pp. 173-174).

such as brickwork and timber. Even in times of new knowledge about bacteria there were worries that dangerous impurities could be deposited in walls by moisture and gases. These impurities would loiter in the walls and provide health hazards over a long period of time. Such "putrefying organic matters" could also filter through from outside air into a wall due to pressure and temperature differences between outside and inside a dwelling [12]. For Russell and other commentators the only effective and economic solution to the problems presented by damp, ground gas, carbonic acid and the gases from ever present microscopic decomposing materials in a home was "imperceptible renewal of the air" [12].

The Deodorisation of Spaces.

For late nineteenth century sanitary reformers there were two basic ventilation strategies: proximity to an abundant supply of pure air and control of that air around and through the spaces of the home. From 1844 onwards statutory regulation recognised that buildings needed to breathe from a reservoir of good air by regulating the space around buildings. The London Building Act of 1894 provided a sophisticated and comprehensive mechanism to ensure that buildings maintain adequate adjacent space for ventilation and light. There was particular regard for domestic buildings ensuring 100 sq ft (9.29 sq m) area of air space for habitable basements and 150 sq ft (13.93 sq m) at the rear of ground level dwellings. This concern was echoed in similar legislation in Western Australia which provided for a back yard of 150 sq ft (13.93 sq m) for access to light and air unless all rooms could be lit and vented from the street [17]. The width of streets were also regulated to ensure that air and light could reach all domestic openings, although in Australia such regulation was often limited to ratios of street widths and building heights. In London in 1894, available air for circulation around a building was also controlled by a so-called 'shaving clause' in the building regulations which stipulated that each storey at the rear of a building must be stepped back to an angle of 63 degrees. This was to ensure that windows in lower rooms of a multi-storey building had sufficient access to light and air [18].

While the abundance of air was one concern, the quality of the air was another. The rules regarding setbacks from boundaries (which also dovetailed with fire regulations) were accompanied by ordinances restricting the proximity of noxious trades, privies, cesspools and middens of filth and refuse near dwellings – particularly sleeping spaces. Once the reserves of air around a building could be regulated, attention could then be given to the spaces inside a building.

As Alain Corbin shows nineteenth century hygienists believed that exhalations and emanations of family members in a house circulated throughout a dwelling filling the atmosphere and penetrating the structure. While ventilation could disperse atmospheric contaminations, residual emanations in the structure kept alive endemic disease. This constant "familial miasmatic intercourse" was doubly dangerous because hereditary closeness promoted "certain morbid predispositions" – certain diseases were reinforced by familial association and resulting atmospheres [5]. The problem of residual emanations could partly be solved by the use of hard or impervious surfaces such as glazed ceramic tiles. Another source of contamination was exhaled breath that contained body by-products in gaseous or vaporous form and organic matter from lungs, which decomposed and provided a breeding ground for bacteria. Insufficiently ventilated rooms smelt of effluvia and concentrated the risk of disease. In such situations breathing contaminated expired air in concentrated form facilitated transmission of infectious diseases. Concentrations of specific substances in poorly ventilated rooms could be also be aligned with specific diseases and ailments [19]. Moreover, as the ubiquitous Fletcher brothers conclude, unventilated rooms and stagnant air "produce nausea, headache and a sense of oppression, sleeplessness, lassitude, loss of appetite, and, as a rule, inability to fix the attention" [20]. Coal and sewer gases might also be present in domestic spaces despite practices designed to exclude them. As well as the threat of disease from unventilated atmospheres, there was also great importance placed on the quantity of carbonic acid (carbon dioxide) in breathed air.

From the mid nineteenth century onwards sanitary texts emphasise the importance of the levels of carbon dioxide in a room. It was high levels of carbon dioxide that caused stuffiness and poisoned the brain and the presence of carbon dioxide also signaled other dangers including the company of organic vapours and other "very poisonous organic matters". An excess of carbon dioxide gas also promoted anxieties about suffocation and the only solution was to dilute pollutants to an acceptable level by the frequent changing of air.

The Tactics of Ventilation.

There was a vast range of literary material available in the late nineteenth century and the early twentieth century devoted to the allowable concentrations of carbon dioxide, the rates of air changes possible without causing dangerous drafts and the actual mechanics of getting fresh air into a space and the expelling of "vitiated" air.

The allowable concentration of carbon dioxide was generally calculated from a standard of 4 parts of carbon dioxide to 10,000 parts of air, which was recognised as the natural proportion in ordinary fresh air. Alongside chemical analysis, the nose again became a dependable instrument for detecting the quality of air in a space. Russell claims that 6 parts of carbon dioxide to 10,000 was the limit in room atmospheres beyond which there were likely to be smells from "animal matters". From 8 to 10 parts per 10,000 rooms became close and stuffy and over 10 parts they became "foul and offensive" [12]. The healthy limit of 6 parts per 10,000 was also echoed by Cameron who used this to calculate the amount of fresh air needed by a full grown person in a room - 3600 cu ft/hour (101.83 cu metres/hour) [11]. The amount of fresh air required by a person varies somewhat from authority to authority and seems to depend on the carbon dioxide levels acceptable for various types of work. For instance Russell says that for manual work 2000 cu ft/hour (56.62 cu ft/hour) is acceptable - provided the person gets a good brisk walk in the open air at the end of the day - and calculates that 2150 cu ft/hour (60.82 cu metres/hour) was the minimum needed to maintain a person in good health. Such figures were used to calculate the size of ventilators needed to pass through external air into a room and the size of outlets expelling used air [12].

Besides an open window, practice also encouraged the manufacture and use of a range of wall and ceiling ventilators and the employment of fireplace chimneys to expel air. Russell (1878), Cameron (1892) and Wrightwick (1895) suggested calculations based on the extraction of air via a chimney where a fire was lit [21]. Provided that the cross sectional area of the chimney was equal to that of the inlet, sufficient ventilation could be maintained – assuming the inlet was spread out over a number of ventilators to reduce the risk of unacceptable drafts. Based on knowledge of temperature differences inside and outside the chimney the flow of air up the chimney could be calculated and the speed of air currents in

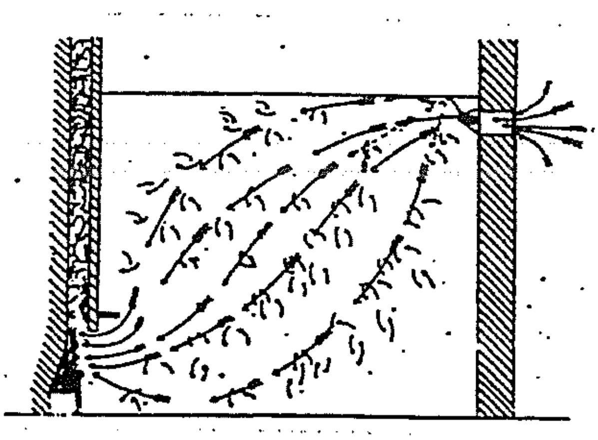

Figure 2: Illustration of air flow between a high level ventilator and a fireplace. (from Cameron, 1892 p.81)

a room determined. The use of 'aspirating' heated chimneys and ventilating stoves to encourage air movement in buildings during all seasons was a relatively old practice and numerous examples such as the House of Commons, London (1840s); Pentonville Prison, London (1840s); St Georges Hall, Liverpool (1860s); and Johns Hopkins Hospital, Baltimore (1870s) existed to show that it could be successful on a large scale [19]. Fans were also employed to force ventilation in buildings. Although there were similar aspirating and forced systems available for domestic residences, the vast majority of housing relied on cheaper passive ventilation techniques.

Cameron admits that his calculations for ventilating a room contained so many vagaries that it was difficult to lay down precise rules and Wightwick echoed many others in commenting that frequently the opposing requirements for heating and ventilation were irreconcilable. What emerged from late nineteenth century debates about the clean air requirements for inhabitants of a space, is a set volume of air per person, to ensure that ventilation was adequate and that drafts avoided. This volume varied between 300 and 600 cubic feet with control often at the discretion of local boards of health in both Britain and Australia. However the regulation of the volume of rooms and minimum air requirements usually centred on stipulating room areas or minimum volume per person and a minimum ceiling height. For example London County Council Housing Regulations stipulate in 1898 that bedrooms should have an area of 102 sq ft (9.4 sq metres) room and a ceiling height of 8 ft 6 inches (2.6 metres) [14]. The Victoria Park by-laws (Perth, Western Australia) of 1902 stipulate that each person in a bedroom should have 500 cu ft (14.1 cu metres) of air available and that the minimum ceiling height should be 10 ft (3.01m) [17]. Assuming that the London bedroom caters for two people – working class bedrooms were rarely expected to house just one person - the effect on room size is similar although the more generous ceiling height would make Western Australian buildings slightly more lofty than London counterparts.

The volume of air in a room determined the number of people allowed to inhabit it and any more would be deemed 'overcrowding'. This was often policed quite vigorously by local medical officers and always frowned upon as an unsanitary evil which promoted the spread of disease. As mentioned above the chief means of getting fresh air into a room was through a window and regulations in both Britain and Australia at the end of the nineteenth century peg the minimum size of openable area of a window or other ventilation at 1/20th of the total floor area of the room. It is not clear why this figure was adopted although it is a standard that survived in Australia building codes until very recently. There were lengthy debates on the number of changes of air in a room, which needed to be balanced against the velocity of air. However a number of authorities such as Fletcher (1907), Cameron (1892) and Whitelegge (1905) advance a figure of 24 sq inches (0.15 sq m) of inlet and 24 sq inches of outlet per person for proper ventilation of a room – probably based on a figure of 3 changes of air in a room per hour [11, 13, 20]. This would result in considerably less natural ventilation than the by-law rule although it was also clear that there were myriad variables and over compensation may have been a wise course to take, particularly if the inlet mechanism could be controlled and thus reduce potential drafts.

It was important to correctly place the inlets and outlets in a room to provide adequate mixing of cold outside air and warmer inside air. Different strategies for both summer and winter ventilation were often suggested. In summer the mixing of cold air and room air was less important because of the reduced temperature difference between inside and outside. In this instance windows could be used to provide fresh air. As it was unlikely that fires would be lit in summer, the used air could be expelled through vents in the wall near the ceiling in 'foul air flues' or 'chimney flues' which were valved vents placed into the chimney flue (see figure 2). In Western Australia the preference was for both high level wall vents and vents in the ceiling itself. Ceiling vents were possible as single storey bungalow houses in Western Australia were much the rule rather than the exception. Vitiated air could be expelled directly into the roof space. In winter, windows were likely to be closed so that a strategy of providing inlets near the ceiling was advocated. This allowed cold incoming air to diffuse with warmer air and to gently descend into the room. Whatever the season, the aim of the inlet ventilators was to quickly mix in outside air to dilute pollutants. Inlets near the ceiling were sometimes arranged to shoot the air towards the ceiling to facilitate this mixing (see figure 3). Patented inlets ranged from simple

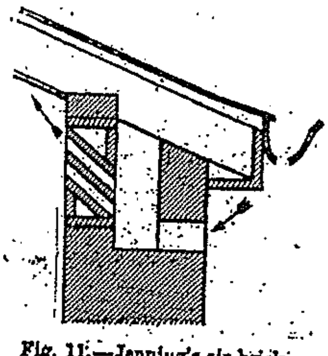

Figure 3: High level air bricks. (from Russell, 1878 p.45)

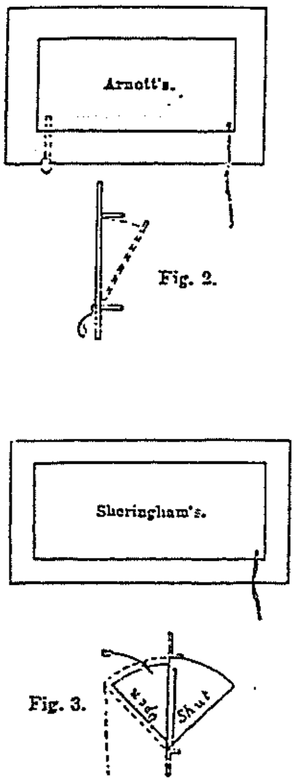

Figure 4: Patented ventilators (from The Cassell's Technical Educator, c1890, Cassell and Company Ltd. London p.22)

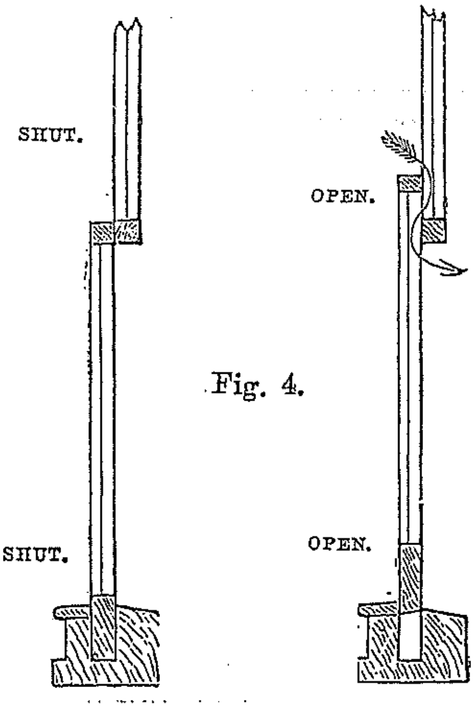

Figure 5: 'Costless' ventilation using a double hung window. (from The Cassell's Technical Educator, c1890, Cassell and Company Ltd. London p.22)

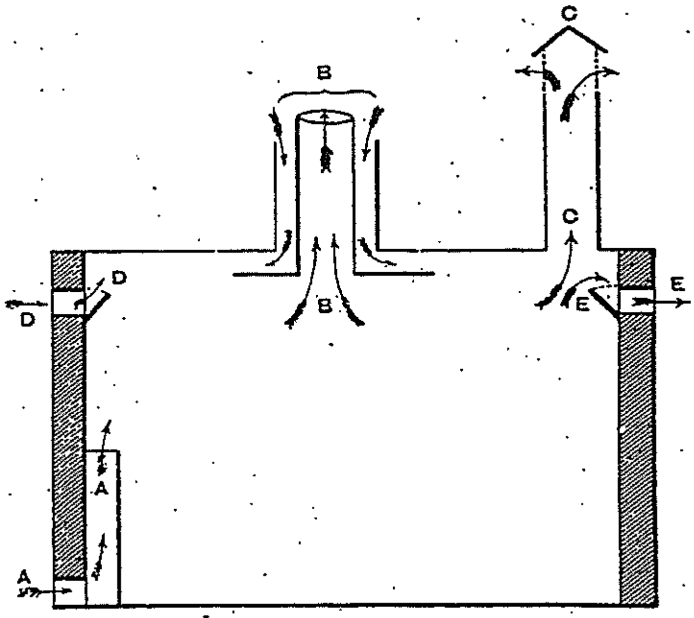

Fig. 7.—Ventilators.
A A, Tobin's; B B, McKinnell's; C C, simple ventilating shaft, with cap; D D, Sheringham's (acting as inlet); E E, Sheringham's (acting as outlet).

Figure 6: Illustration of various types of ventilators and their effect (from Whitelegge and Newman, 1905, p.189)

air-bricks to ornate cast iron devices which allowed adjustment of air flow (see figure 4). Other inlet types filtered air through cotton wool or horsehair or 'washed' air with water as it entered a building in an attempt to remove pollutants before entering the room. Any outlet other than the fireplace opening usually incorporated a valve of sorts - usually a mica flap - to ensure that expelled air could not re-enter the room.

By far the cheapest form of ventilation equipment was the window, which was arranged to "...take advantage of wind and sweep out the air in a room" [12]. Of all window types the double hung sash was favoured as an opening top and bottom could be created, allowing air to flow in at the bottom and flow out at the top. Further, a cheap method of winter ventilation, known as 'costless ventilation', could be obtained by attaching a block of wood to the bottom sash preventing it from closing fully and creating a gap between the meeting rails of top and bottom sashes. Great play was made of this method as a way of continuously venting rooms in lower class housing. (see figure 5) To the chagrin of hygienists, people in poor homes were wont to stop up all openings, including the chimney in summer, to preserve warmth [22]. Other suggested modifications, included increasing the height of the bottom wind mould, allowing a double hung window to be left partially open without creating drafts. Sanitary and architectural texts stressed the importance of positioning ventilating appliances so that all parts of a room were properly aerated (see figure 6). Most commentators suggested arrangements that involved the delicate positioning of a window or wall ventilator so that air currents would circulate a room before being expelled through a chimney. Russell suggested an arrangement involving a window, a ventilator and a fireplace (see figure 7). Although this arrangement might be efficient (in his mind at least) his positioning of the fireplace would be impractical unless the chimney breastwork was angled across the corner. Russell also preferred to ignore the effect of internal doors, which was a consideration for other commentators. Buckton (1885) included doors "especially of bedrooms and workrooms" to provide fresh air – either by natural leakage or opening the door [10].

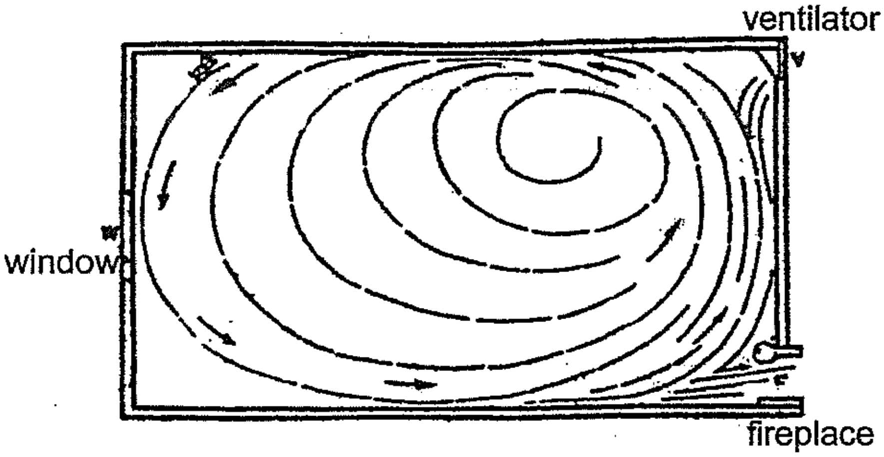

Figure 7: Plan of probable air movement between an air ventilator, window and a fireplace - names added for clarity. (from Russell, 1878, p.52)

The relative positions of the window and the fireplace was of prime consideration. For example placing a fireplace and widow opposite each other could promote good ventilation but would also produce drafts directly across a room. These could be unacceptable and difficult to counter if the room was used as a dining room or a sitting room. Hermann Muthesius (1904) indicates that the positioning of the fireplace in British homes was a compromise between conviviality and comfort. Great skill was needed in positioning windows doors and fireplaces to avoid drafts. The flow of drafts required plotting before decisions on positioning these elements were made. He did however admit that it was nearly impossible to prevent all drafts and he reported that large protecting armchairs overcame some of the problems [23]. Economic considerations also demanded attention and favoured combining the stacks from a number of fireplaces that meant locating it on internal walls shared with other rooms an practice often at odds with the reduction of drafts. Although practices aimed to reduce unhealthy drafts but permit frequent changes of air, the location of ventilation equipment was a minefield of health imperatives, custom and economic necessity.

Ventilation practice as described above was essentially a series of strategies to remove odour and provide continual regulation of the agents which affected health and caused disease. Moreover, sanitation measures employed to accommodate the miasmatic theory served equally well for the updated contagion theory [3]. Equipment such as patent ventilators, chimneys and windows provided an automatic surveillance of odours. Fresh air could sweep out these agents or at least dilute them to reduce the danger. Statutory deference for ventilation practices was reinforced by policing by health officers in both Britain and Western Australia, who inspected, reported and enforced regulations. From mid–nineteenth century, health laws in Britain made provision for local boards of health to appoint medical officers and inspectors who could enforce health regulations. The establishment and effectiveness of these boards was patchy and slow but with continuing amendments to health legislation they became an established feature of local government by the end of the century. In colonial Western Australia the situation followed a similar pattern but at a slovenly rate. The first Board of Health established in 1852 had advisory powers and little authority to enforce sanitary standa This situation lasted until the Municipal Act of 1871 which gave powers to local authorities but remained silent about ventilation other than to prohibit 'overcrowding'. The first Western Australian Public Health Act (1896) was modelled on the English Public Health Act of 1875 and gave local councils the authority to appoint Boards of Health and make health laws. These worked in tandem with local building regulations but were - in comparison with British counterparts - tardy in proscribing building standards and were largely silent about ventilation except in relation to privies and the policing of the (vaguely defined) overcrowding of rooms.

Conclusion

In 'Lessons on Domestic Economy', Joseph Hassell (1873) teaches school girls of the dangers of domestic atmospheres and how decaying organic matter and carbon dioxide charge the air in houses. "There must, therefore, be provision made in all our rooms for this dirty air to escape and fresh air to enter. This admission of fresh air is called ventilation and should be attended to by all persons. Every girl should understand th subject" [24]. Hassell provides a number of lessons on air composition, gas and dust pollutants and the correct use of windows and ventilators to provide fresh air. He is particularly respectful of vegetable and animal refuse and their correct disposal lest they contaminate the atmosphere. His book, aimed principally at young girls about to enter domestic service, indicates the seriousness of the subject of ventilation in the late nineteenth century and the emphasis placed on knowledge of principles and the operation of ventilation equipment. Good ventilation diluted the poisons that caused disease and death. Pure air helps to purify the blood, which invigorates the body "and enables it to work better, enjoy life more, and so tends to make men both useful and happy" [24].

Of course, practices of using the equipment would have varied enormously. Ventilation equipment was clearly proscribed by the early twentieth century but Western Australia does not seem to have adopted the more rigorous demands of British by-laws except in relation to privies and human waste. Local councils did insist on under floor ventilation, minimum size windows and brick vents directly to outside air for all habitable rooms. Double hung windows were also a popular type until outmoded by aluminum sliding windows in the mid twentieth century. Chimneys were a solid feature of domestic construction in principal rooms until the twentieth century. They started to lose favour in the early twentieth century after which they were generally reserved for lounge and kitchen areas. The reasons for initial tardiness in framing and enforcing regulation is hard to pin point but may have something to do with the perception of the climate, the small population and a general unwillingness of public authorities to spend money on public works. Council aldermen, often local businessmen, were unwilling to enact laws that were seen as detrimental to development interests. The climate of the Swan River Colony, as Perth was known, was touted as a very healthful environment and "...takes a good position among the communities of British origin for its salubrity, and prospect for producing a future healthy race" [25]. Living conditions in such a healthful climate did not require the same intervention as in the crowded centres of Britain and Europe. The population was small - 48,500 in 1890 - scattered over 2,500,000 sq kilometres - and, in 1891, only 9500 were concentrated in the capital Perth. The gold rushes of the 1890s massively increased the population of Western Australia (250,000 by 1905) and also precipitated disastrous epidemics – principally typhoid. This had the effect of finally stimulating more careful health and building regulation although, still not as rigorous, in building terms, as those in Britain.

We have seen how the notion of ventilation was generated by concepts of health and disease in the late nineteenth century. Evidence of the presence of disease could be detected in the smells emitted from decaying vegetable and animal matter privileging the miasmatic idea of the spread of diseases. These dangers reached a peak in the closed atmospheres of buildings and rooms and could be reinforced though familial associations. Deodorisation of these atmospheres through the constant introduction of fresh air and the exhaust of 'poisoned' air was a solution to these problems. As Corbin (1986) explains the process of deodorization had its equivalent in the process of disinfecting in as much as the removal of the smell had the effect of removing the danger [5]. The concentration of carbon dioxide (carbonic acid) became the measure of the health of a closed environment and the stimulus for the calculation of the volume of rooms and the size and positioning of openings. Even with the advent of bacteriology the techniques and technology devoted to miasmas and vapours served the same purpose – the techniques of deodorization were simply shifted to bacteria infested air with high concentrations of carbon dioxide as a sure sign of an unhealthy environment and potential poisoning. The idea that smell signaled danger still claimed consideration in many sanitary texts well into the years proceeding 1900. The technology of ventilation as practiced in most homes in Britain and Western Australia was simple but effective and its use was widely promulgated and taught though texts and in schools.

The discourses of ventilation perceived space as system of benign and dangerous air currents and as a juxtaposition of inlets and outlets. Through the measurement of cross-sections, air flow and impurity, health could be calculated. Although the claim that ventilation practice and regulation directly generated the shape of space could be contested, it certainly impacted on the volume of rooms, on ceiling height and the insistence on windows of a certain size on walls adjacent to external air. Certainly some British regulations insisted on minimum size rooms but the design options for any room, if driven purely by economics, could be severely limited just by regulating ceiling heights, volume per person and size of window to outside light and air. Furthermore the position of windows, fireplaces and doors might be determined by their role in the proper ventilation of a room. The introduction of patent ventilators changed the surface texture of walls and provided concrete evidence of the ability of a room to rid itself of smells and disease. A room or building could be adjudged 'healthy' by its adherence to good ventilation practice.

In terms of the late nineteenth century building in Britain and in colonies such as Western Australia the technology of ventilation and its effect on the design and operation of inhabited spaces can be better understood through reference to the concepts of disease and health. This paper offers an insight into the simple practices and technologies of ventilation employed to service those concepts.

Notes

1. J. C. SPOTTISWOODE: *Is My House Healthy: How to find out*. Simpin, Marshall, Hamilton, Kent & Co Ltd., London, 1892.
2. F. DELAPORTE: *Disease and Civilisation*. The MIT Press, Cambridge, Massachusetts, 1986.
3. B. LUCKEN: in *Urban Disease and Mortality in Nineteenth Century England* (R. Woods and J. Woodward, eds.). Batsford Academic and Educational, London, 1984.
4. J. H. L. CUMPSTON: Health and Disease in Australia: A History. A.G.P.S., Canberra, 1989.
5. A. CORBIN: *The Foul and the Fragrant*. Berg Publishers Ltd., Leamington Spa, 1986.
6. D. LUPTON: *The Imperative of Health*. Sage, London, 1995.
7. T. P. TEALE: *Dangers to Health in Our Own Houses*. J & J Churchill, london, 1877.
8. For Teale it was enough that the children had been present at the opening of the drain and had breathed the contaminated air arising from the rotting material.
9. Cumpston was Australia's first Commonwealth Director-General of Health and completed the manuscript for Health and Disease in Australia in 1929 but could not publish it because of financial restrain at the onset of the Great Depression. Cumpston made comment in this book about the popular connection between odour and disease. As a child in Western Australia in the 1950s the author of this paper was given iodine throat lozenges to prevent throat infections when smells arose from overflowing septic tanks.
10. C. M. BUCKTON: *Our Dwellings Healthy and Unhealthy*. Longmans, Green, and Co, London, 1885.
11. J. S. CAMERON: *Is My House Healthy?: How to Find Out*. Richard Jackson, Leeds, 1892.
12. J. A. RUSSELL: *Sanitary Houses: Two Lectures to Plumbers and Builders*. Maclachlan and Stewart, Edinburgh, 1878.
13. A. WHITELEGGE and G. NEWMAN: *Hygiene and Public Health*. Cassella and Company Ltd., London, 1905.
14. R. H. HARPER: *Victorian Building Regulations*. Mansell Publishing Ltd., London, 1985.

15. In Britain such clauses appear from about 1844 onwards usually targeting cellars or the 'lowest room' in the house. R.H. Harper, (1985). Victorian Building Regulations, London, p. 59. Western Australian regulations offer similar clauses but these do not appear until 1887, 51 Vict. No 17, The Building Amendment Act 1887. p. 276.

16. In Britain concern for such ventilation seems to have come about in 1840. Harper, Victorian Building Regulations, p. 3. Western Australia lagged well behind and did not regulate under floor ventilation until 1887. 51 Vict. No17, p. 276.

17. VICTORIA PARK MUNICIPAL COUNCIL: *General and Building By-laws of the Victoria Park Municipal Council: and By-laws of the Victoria Park Local Board of Health*. Perth, 1902.

18. B. FLETCHER: *The London Building Act, 1894*. B.T.Batsford, London, 1901.

19. C. ELLIOT, D: *Technics and Architecture: The Development of Materials and Systems for Building*. The MIT Press, Cambridge, Massachusetts, 1994.

20. B. F. FLETCHER and H. P. FLETCHER: *Architectural Hygiene: or Sanitary Science as Applied to Buildings*. Whittaker and Co., London, 1907.

21. G. WIGHTWICK: *Hints to Young Architects*. Crosby Lockwood and Son., London, 1895.

22. Buckton relates the sad tale of two young sailors aboard a ship who closed every crack in a cabin to keep out the cold and in the morning were found dead. p88

23. H. MUTHESIUS: *The English House* (Das Englische Haus). Wasmuth, Berlin, 1904.

24. J. HASSELL: *Lessons in Domestic Economy*. William Collins, Sons and Company, London, 1873.

25. J. BONWICK: (ed.), *Climate and health in Australasia: to which is added a chapter on the laws of the colony, Western Australia*. Street, London, 1886.