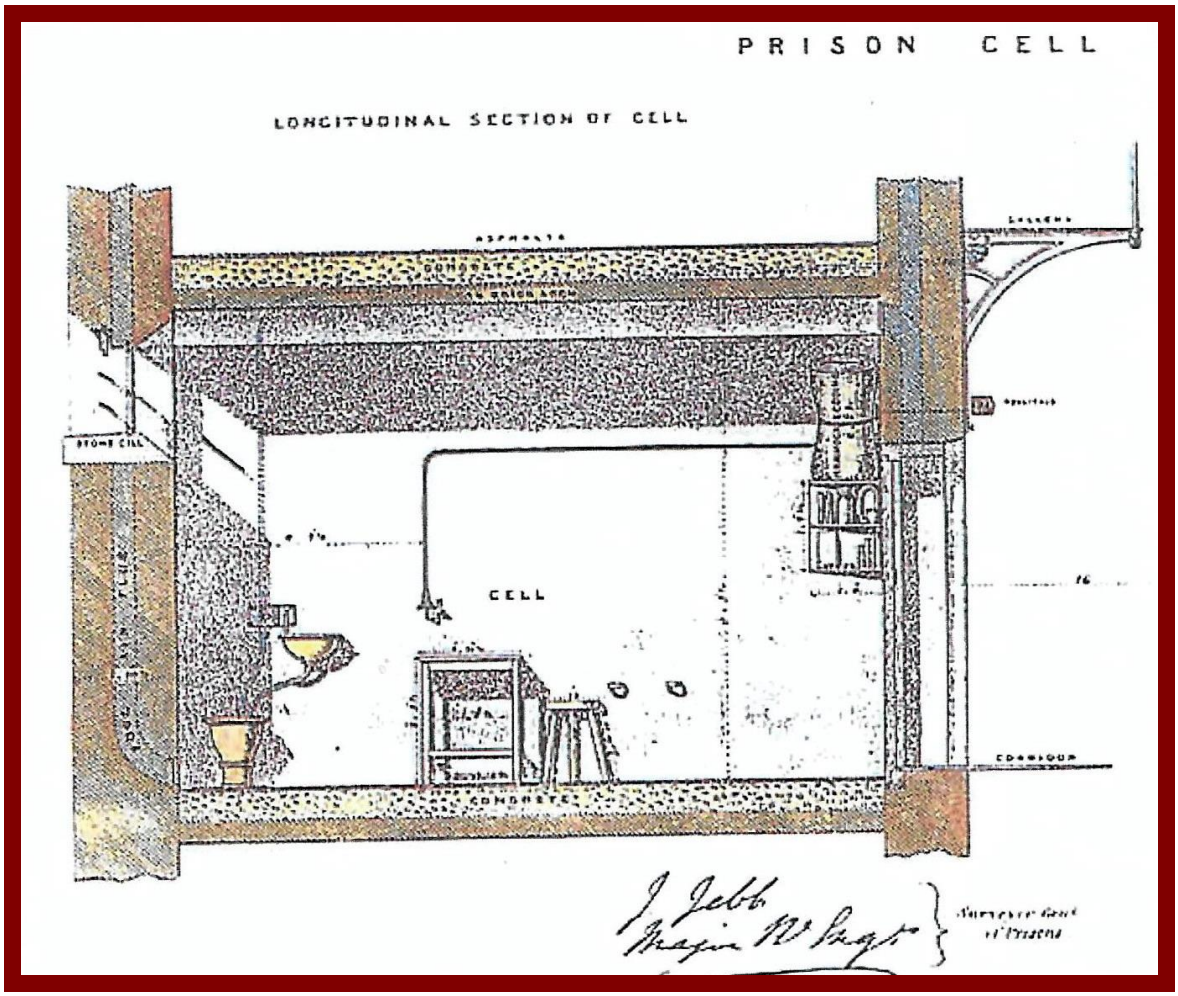


Pentonville Cell drawing (signed Major Jebb c.1840): warm air (right) and foul air flues (left) with wash basin and WC; lighting by gas.

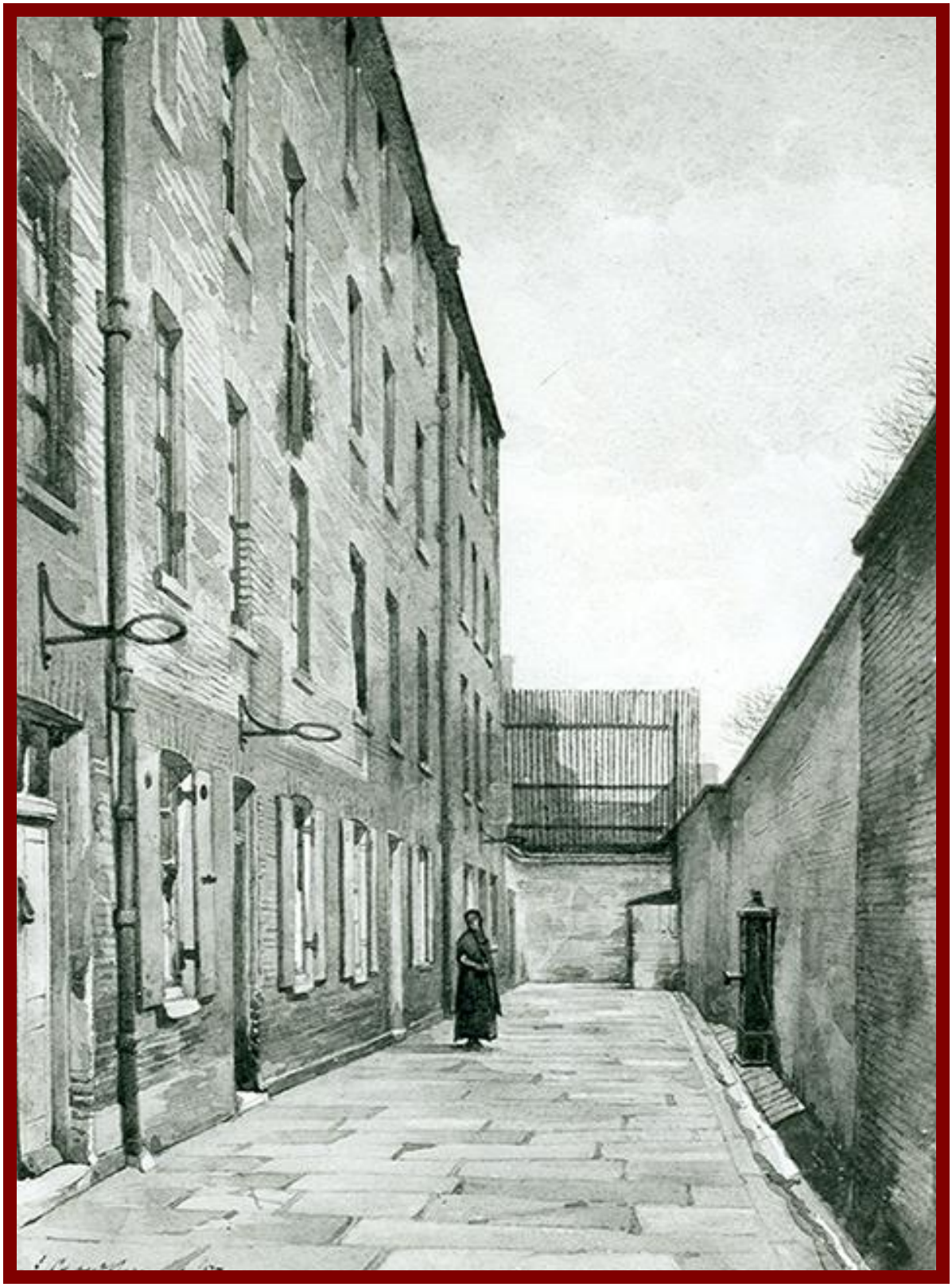
HISTORIC PRISONS

IN GREAT BRITAIN AND THE UNITED STATES

NOTES ON ENGINEERING SERVICES

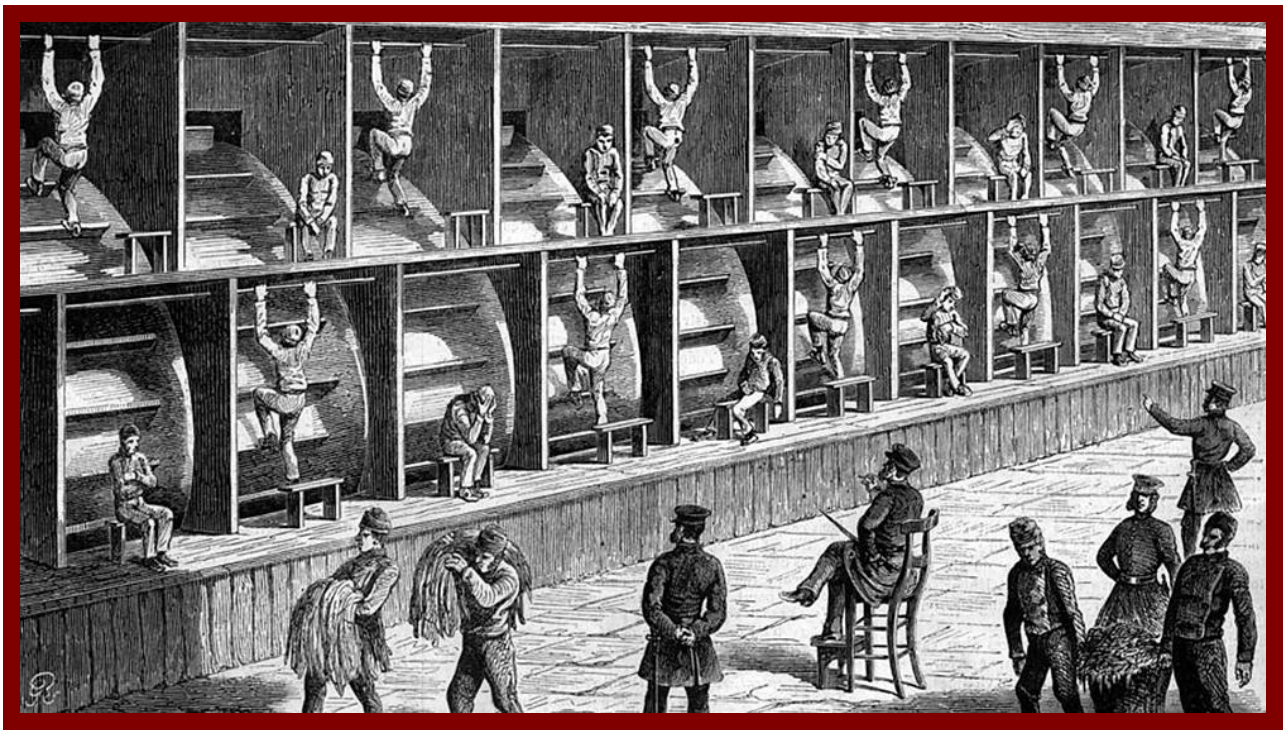
BRIAN ROBERTS

MARSHALSEA PRISON, SOUTH LONDON
BOROUGH OF SOUTHWARK



1373-1842: originally a notorious private prison subjecting debtors to an extortion racket before being taken over and closed by the Government. Demolished in 1870.

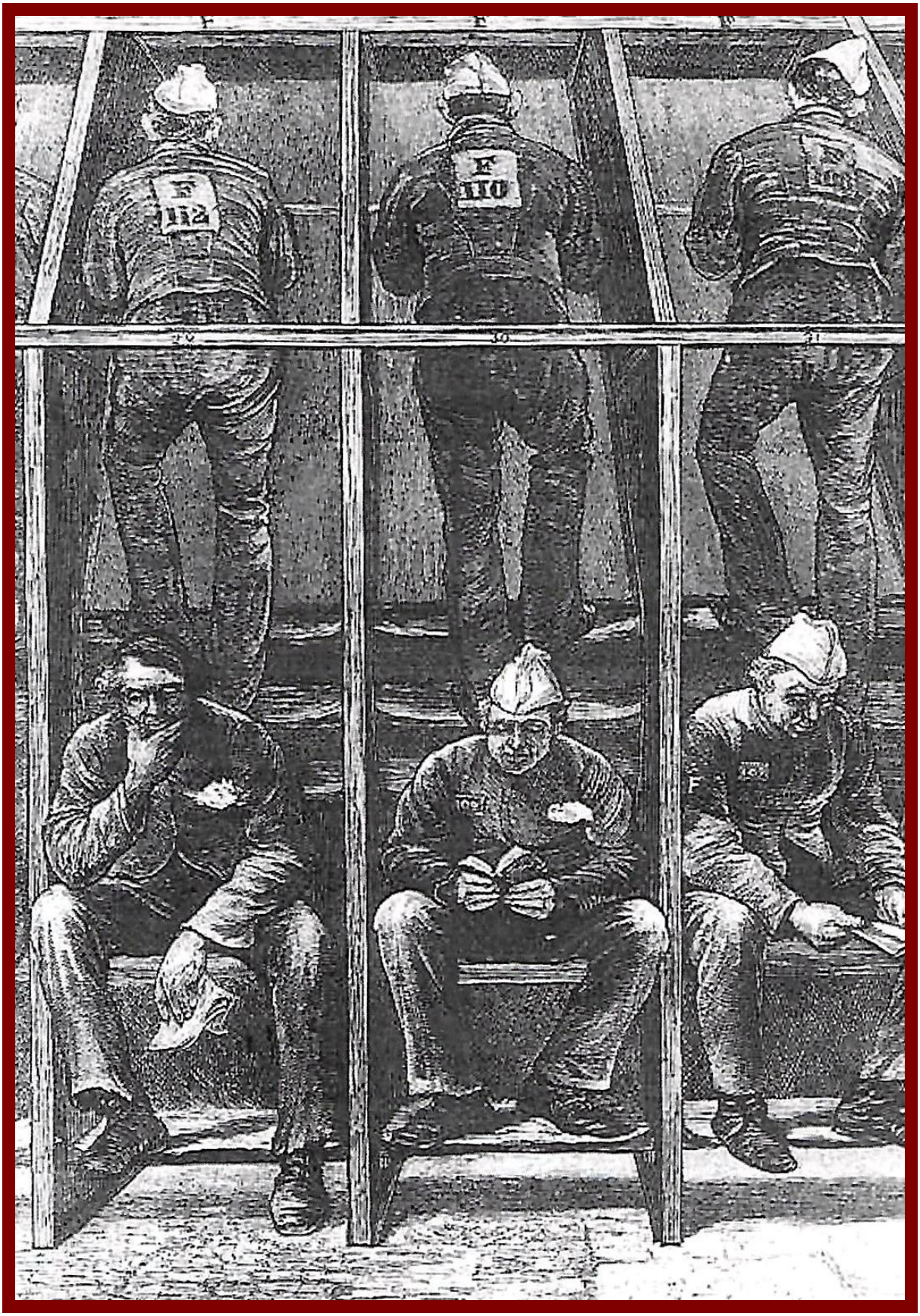
CONTENTS



Prisoners on the tread wheels at Coldbath Fields Prison in London.

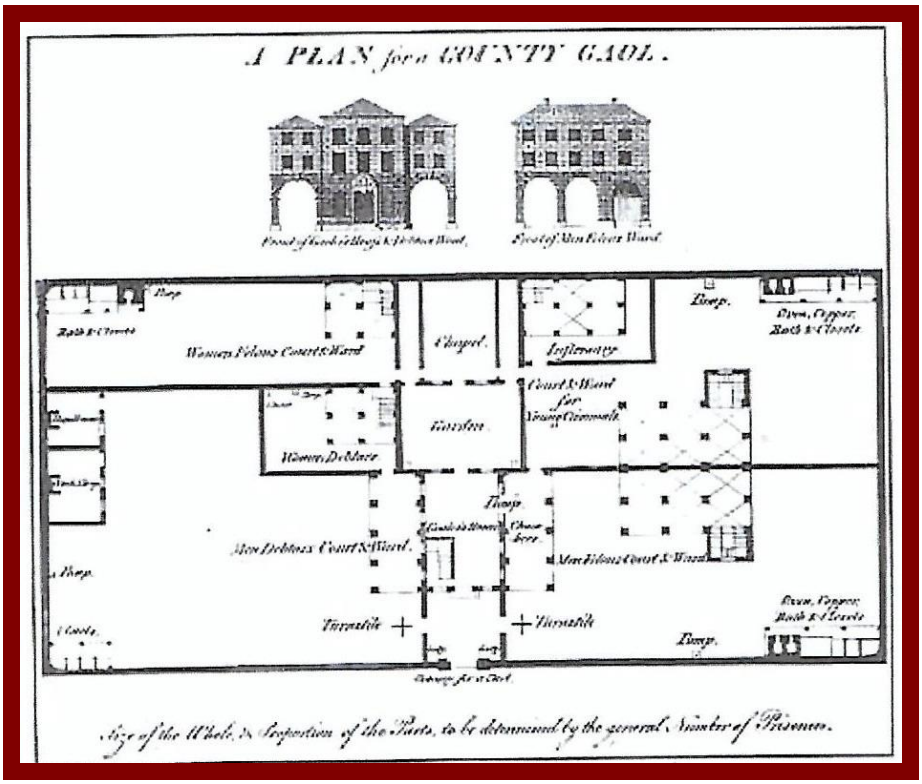
GAOLERS, NEWGATE PRISON, CITY OF LONDON

CLERKENWELL PRISON, LONDON
MIDDLESEX HOUSE OF CORRECTION



Convicts working the treadwheel, c.1870s.

COUNTY GAOL, BODMIN, CORNWALL



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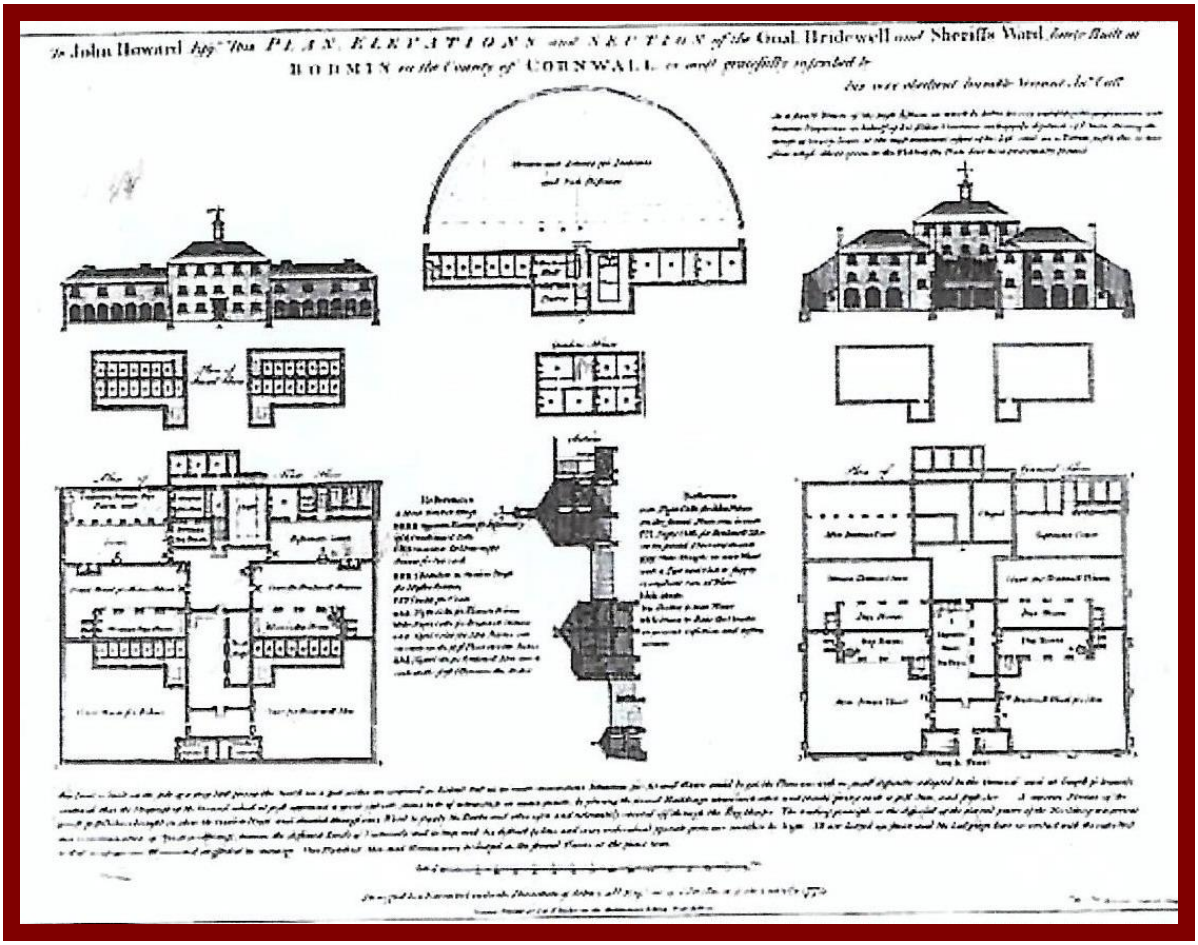
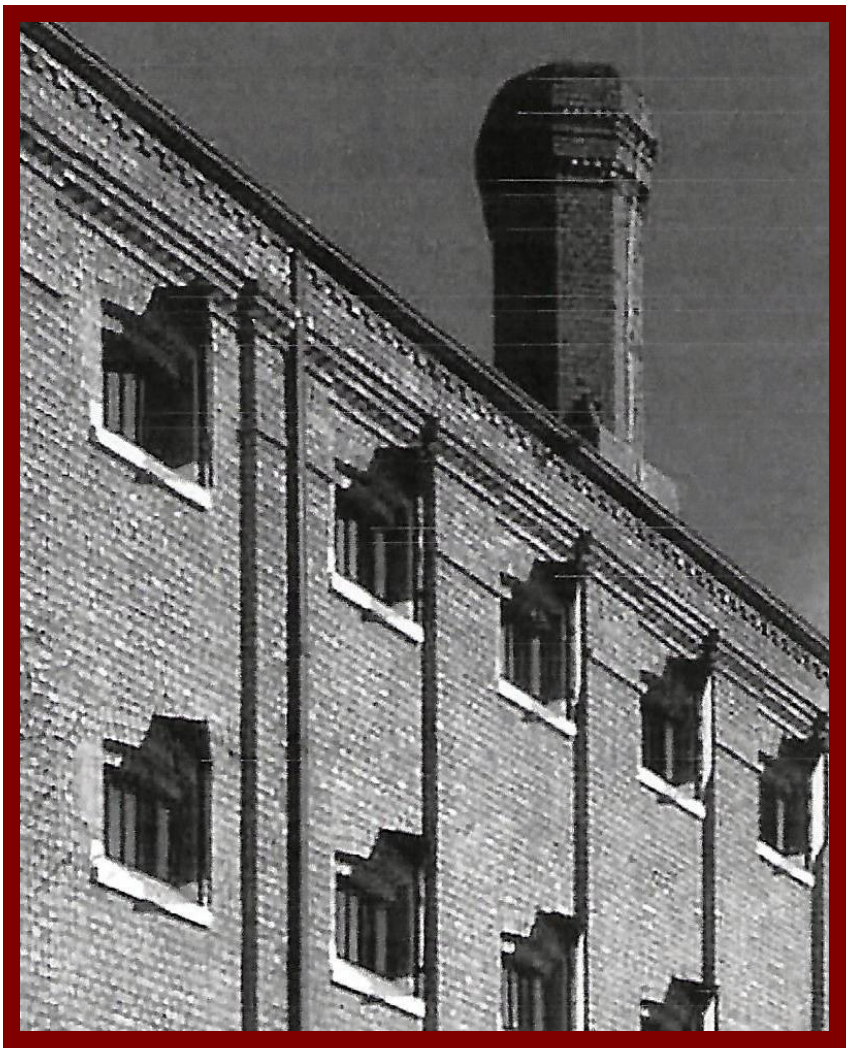


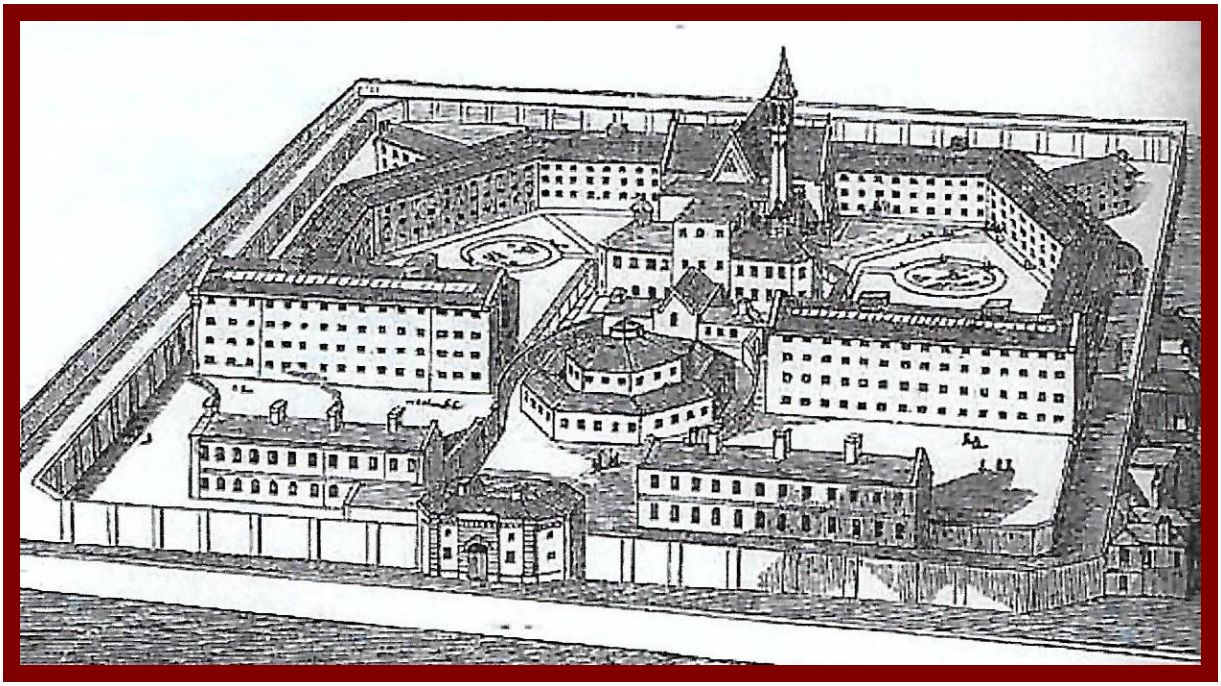
1799: John Call's early plan for a County Gaol.
Both plans show closets, baths and ovens.

HORFIELD PRISON, BRISTOL

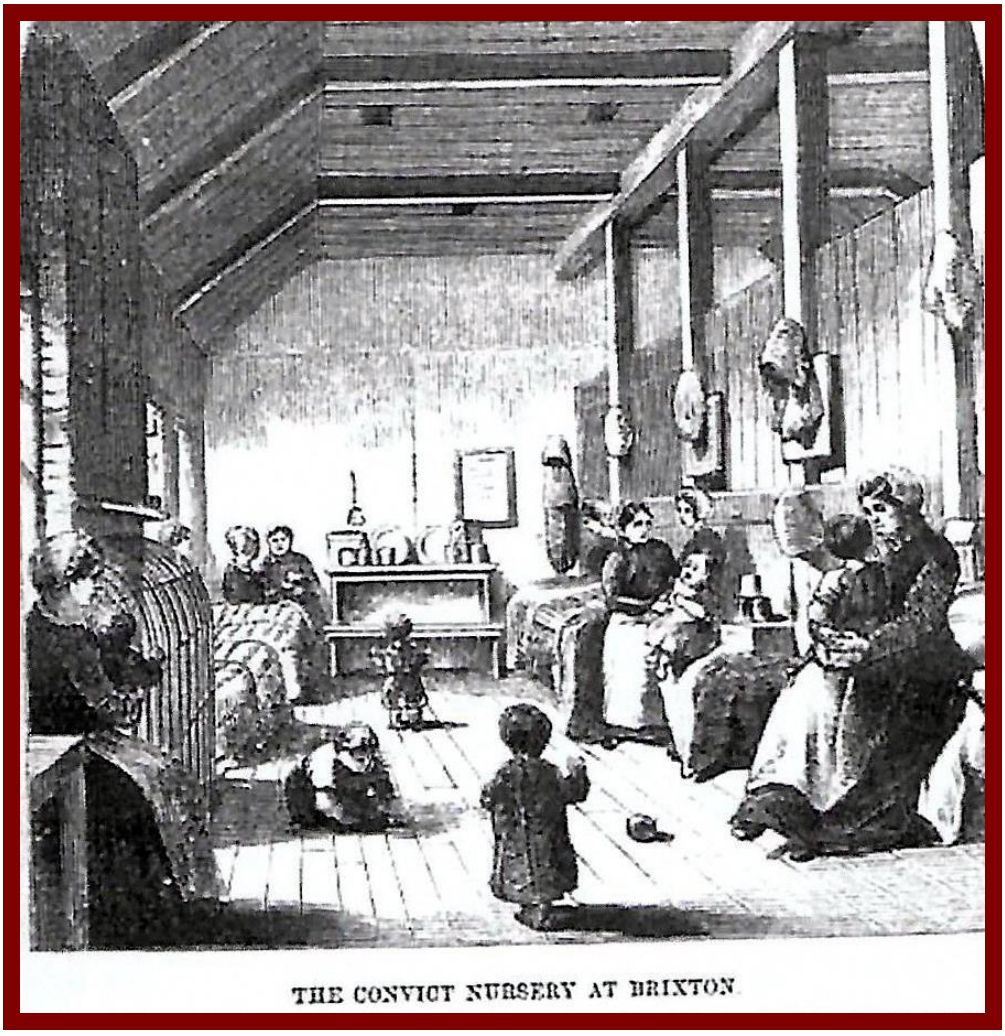


1883: Wing shown originally for women prisoners. Now Bishopston Prison.
Note the unusual external window shading devices.

BRIXTON PRISON, SOUTH LONDON



1921: Cost £52,000, 175 prisoners. Picture centre- Laundry with chimney stack.



The Nursery with heating from an open (guarded) fireplace (left).

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BRIXTON PRISON, SOUTH LONDON

Originally the Surrey House of Correction at Brixton, this prison was built by Thomas Chawner (the County Surveyor) at a cost of nearly £52,000, opening in 1821. It was designed to accommodate 175 prisoners. The governor's octagonal house is all that survives of the original, being located so as to be able to monitor the prisoners working on treadwheels

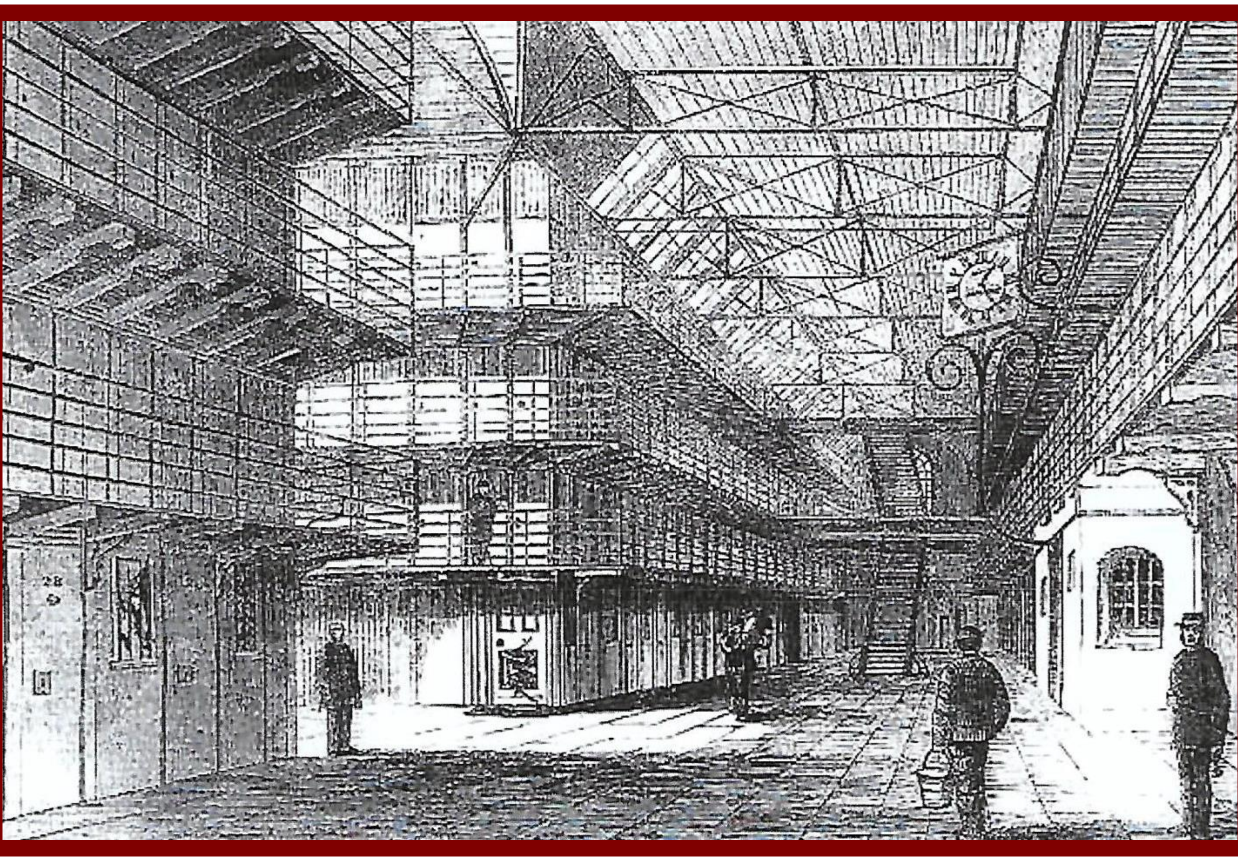
In 1853 transportation of female convicts to Australia ended. Previously they had been kept in Millbank prior to embarkation. To deal with this problem, the Government purchased the former Surrey House of Correction. Two new wings were erected, 4 storeys high, 15 window bays long, each wing containing 212 corrugated-iron sleeping cells. The cells shared one window between two, opening onto a central corridor, the upper floor being reached by galleries. Water closets and slop basins were located in the body of the cells, halfway along each side. (All this seems remarkably similar to Chatham, right down to the corrugated-iron cells).

Details of the heating and ventilating have not so far been discovered but a contemporary illustration shows a solid-fuel warm air stove on the floor of the central hall, with a number of the female convicts sitting close by.

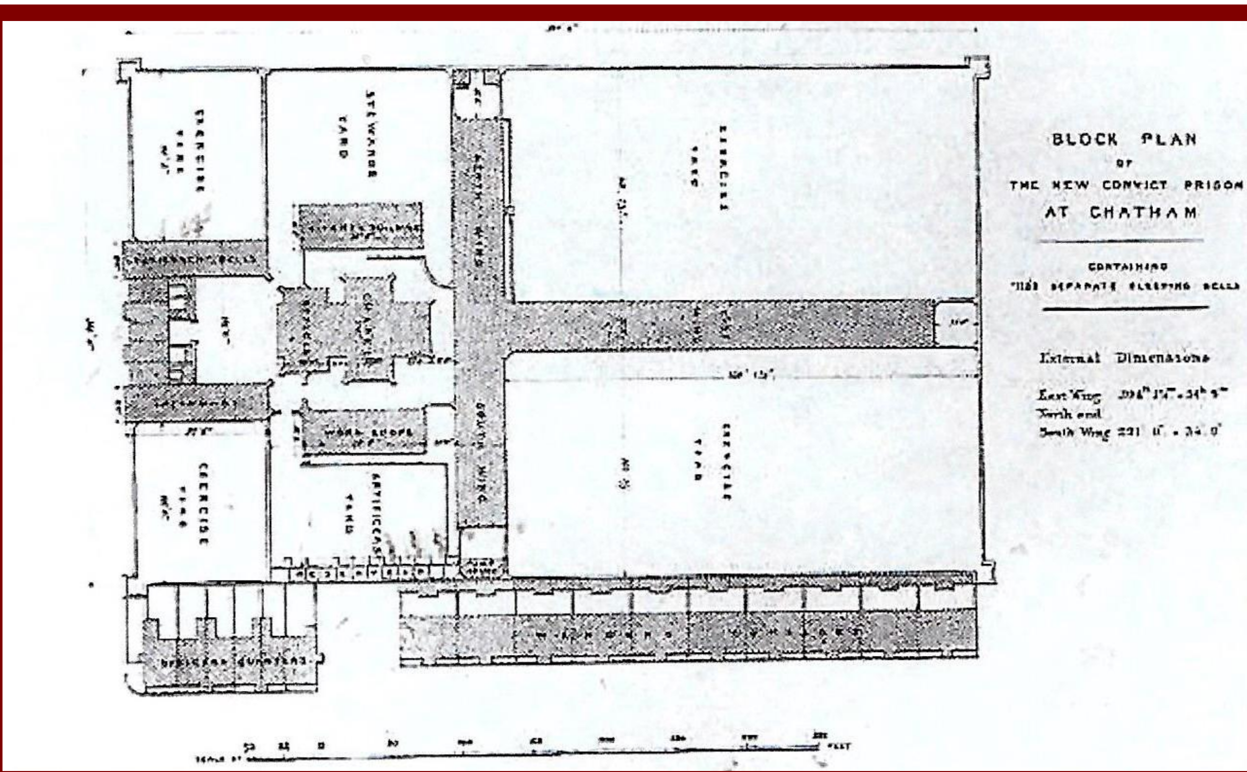
IRONING-ROOM AT THE BRIXTON PRISON.

The Ironing Room with gas lighting (right-hand wall).

CONVICT PRISON, CHATHAM, KENT

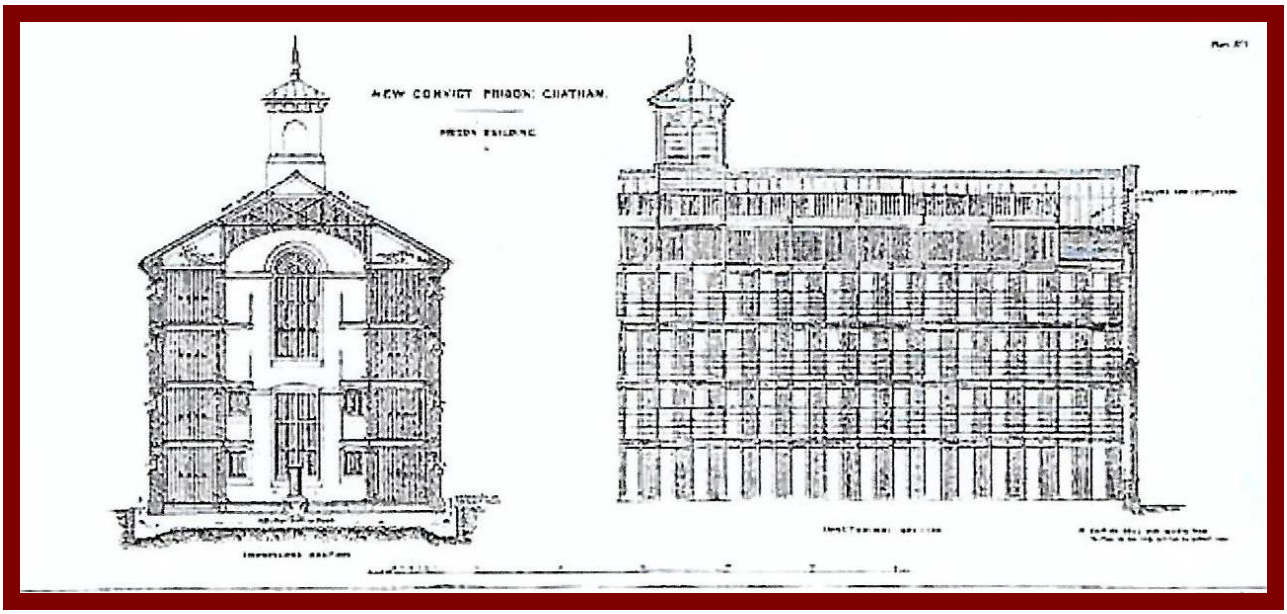


1856: Cells were constructed of corrugated iron (*The Illustrated London News*, 9 March 1861).



Josiah Jebb's T-shaped block plan (Extended in 1866 by addition of a new cell block).

CONVICT PRISON, CHATHAM, KENT



Section through the Convict Prison.

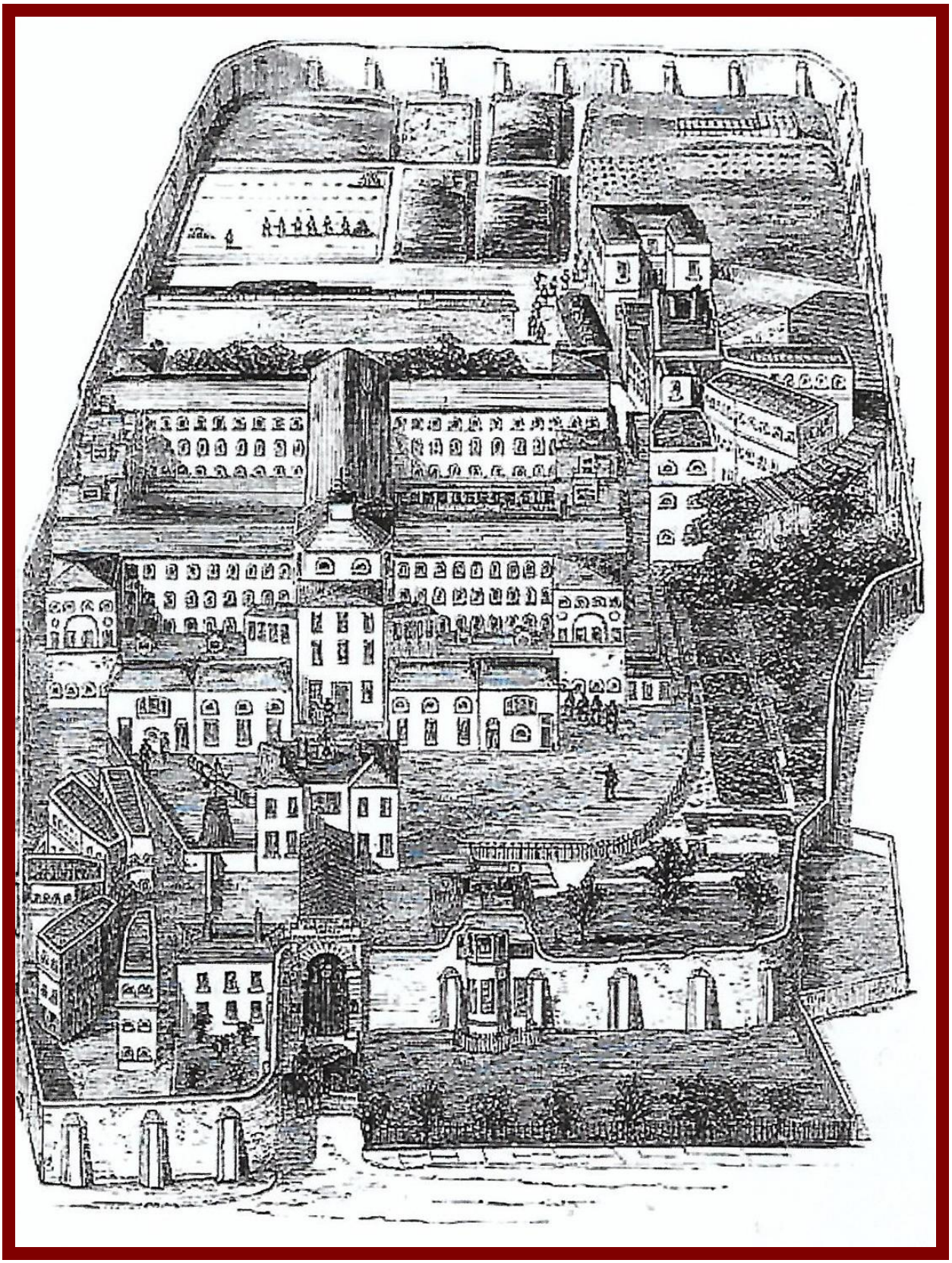
When the use of the infamous hulks (prison ships) was discontinued it more or less coincided with the introduction of penal servitude. In 1856, a public-works prison was opened on St Mary's Island at Chatham. Prisoners previously held on the *Defence* and *Warrior* hulks, who were employed in the Royal Arsenal & Dockyard at Woolwich, were transferred to the new prison.

The design of Chatham Prison is attributable to Joshua Jebb. The main building was T-shaped in plan and had 3 wings radiating from a central hall. Internally, it had 4 storeys of galleried cells capable of housing 1135 prisoners. The cells were constructed of corrugated-iron. The front elevation of the north and south wings comprised of 36 window bays in length, each window being shared by two sleeping cells. The water closets were situated midway along each wing, but on one side only.

The scheme of heating and ventilating shows some of the ideas employed by Jebb, when working with G & J Haden, on Pentonville Prison in 1840. Chatham has basement fresh air intake tunnels feeding to a heater at floor level in the main hall (the heating apparatus was in the basement at Pentonville). Warmed fresh air was drawn into the cells through low level inlets, with foul air exhausted at high level into main foul air ducts in the roof space. There are also inlet ventilation louvres shown in the longitudinal section at roof level (right) and the horizontal foul-air ducts appear to connect to the central roof exhaust tower. No fire or steam coils are shown in the exhaust system drawings, but may have been used to assist the discharge of foul air.

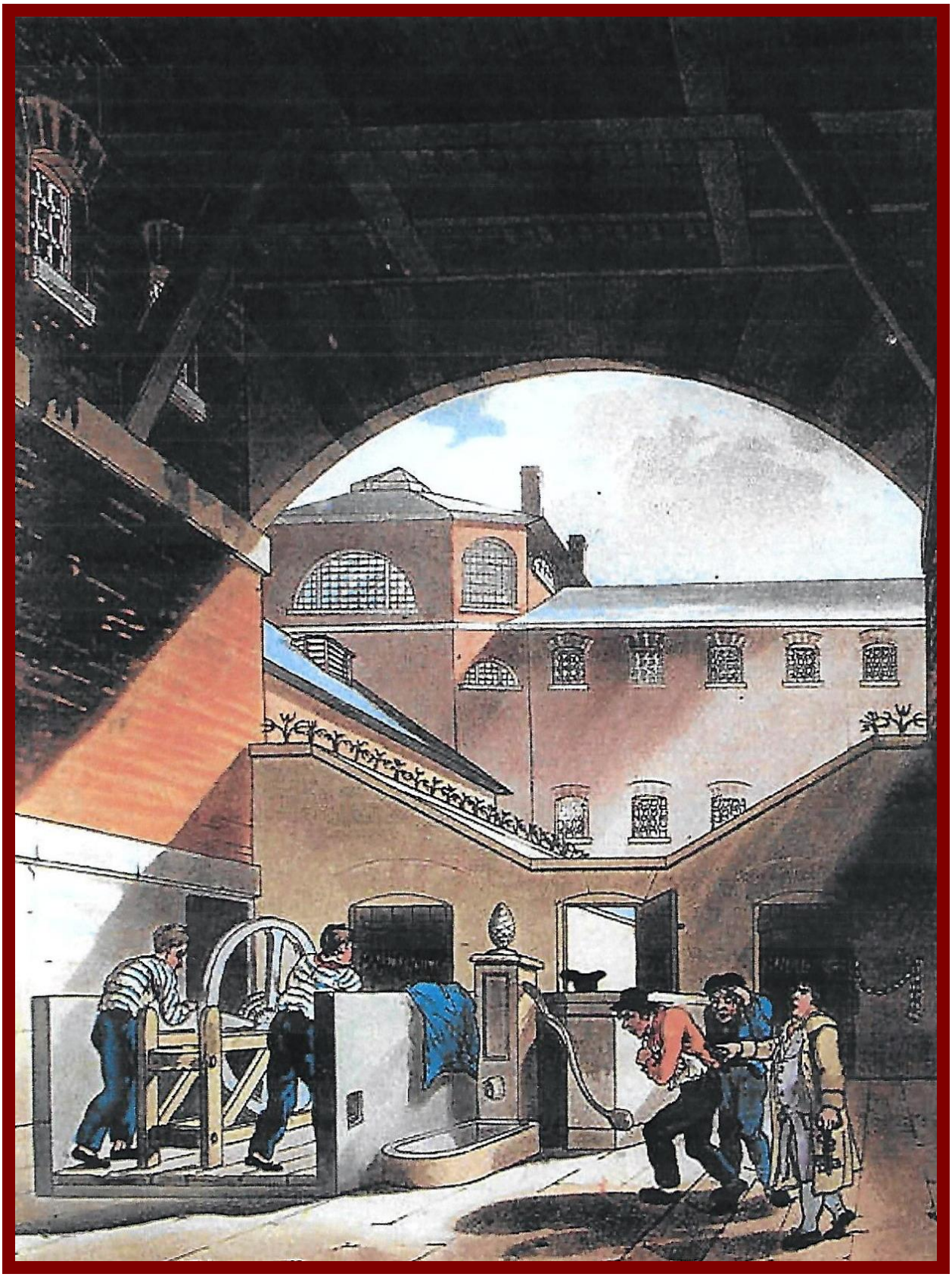
Chatham was extended in 1866 when a new cell block was added, partly employing brick in place of corrugated iron. In 1870, a further wing for an additional 250 inmates was erected.

COLDBATH FIELDS, LONDON
MIDDLESEX HOUSE OF CORRECTION



Bird's-eye view of prison in 1788 from a book of 1862.
Designed as a "House of Correction" by Jacob Leroux in 1788.

COLDBATH FIELDS, LONDON
MIDDLESEX HOUSE OF CORRECTION



Convicts at hard labour operating the water-engine, c.1810.

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HOLLOWAY PRISON, WEST LONDON

Photograph of 1896.

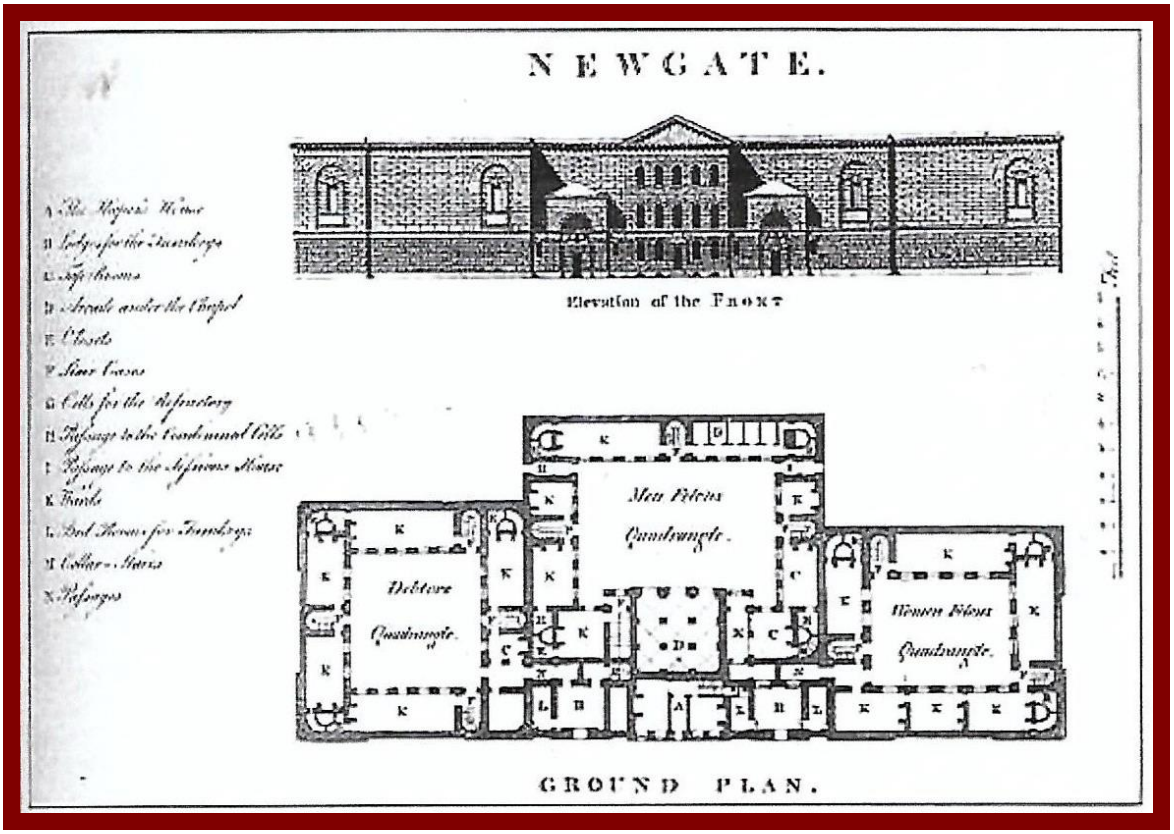
Undated Victorian photograph.

LEWES PRISON, EAST SUSSEX

View of A-Wing, built 1852-53, D.R. Hill.
"At Lewes, where four boilers were ordered in March 1852 (from G & J Haden) a total of £1814 3s was spent on ventilation and hot water apparatus". The Haden system required one or more plenum towers for the waste air flues.

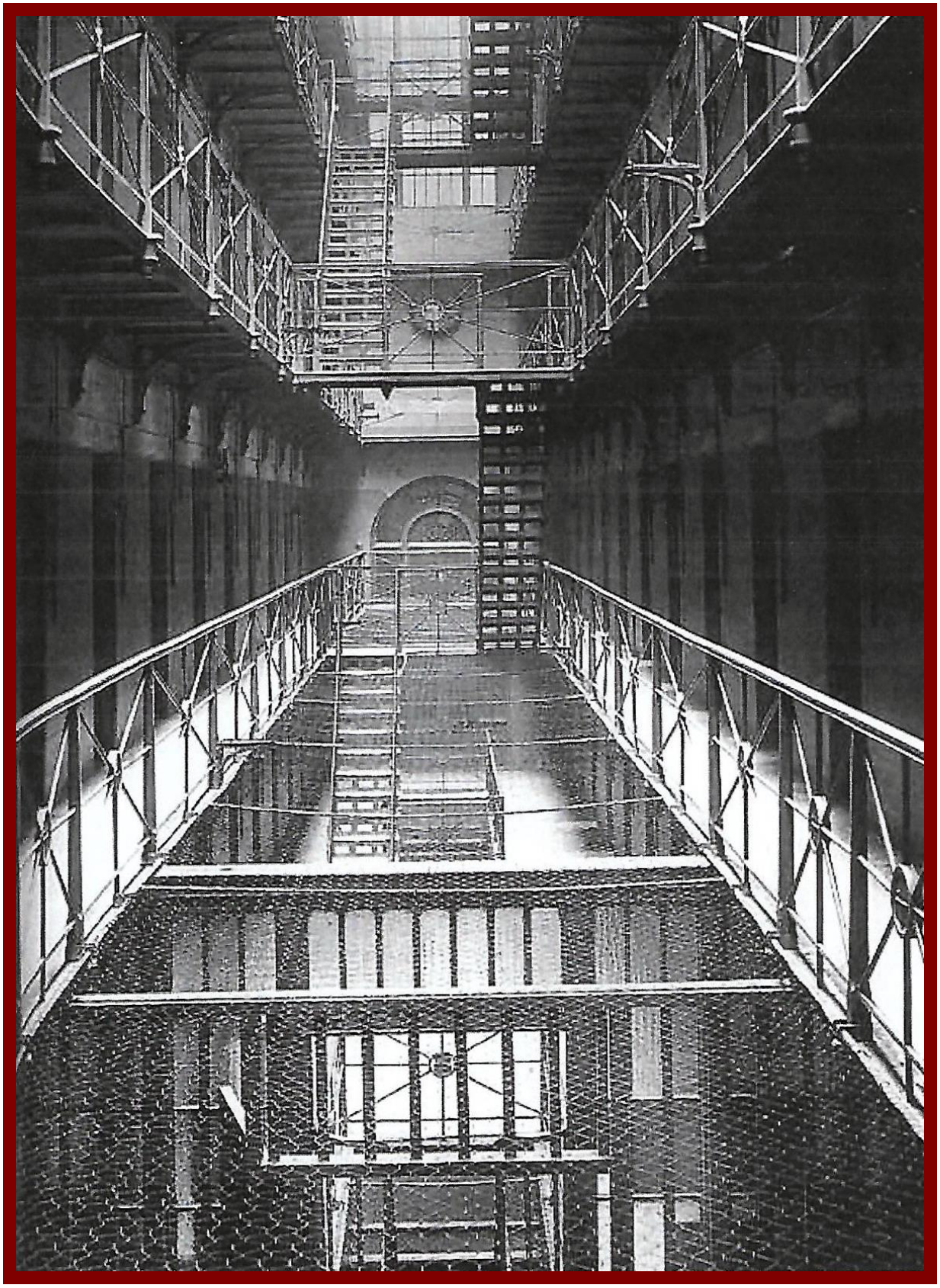
NEWGATE PRISON, LONDON
CITY OF LONDON

Drawing of 1777.



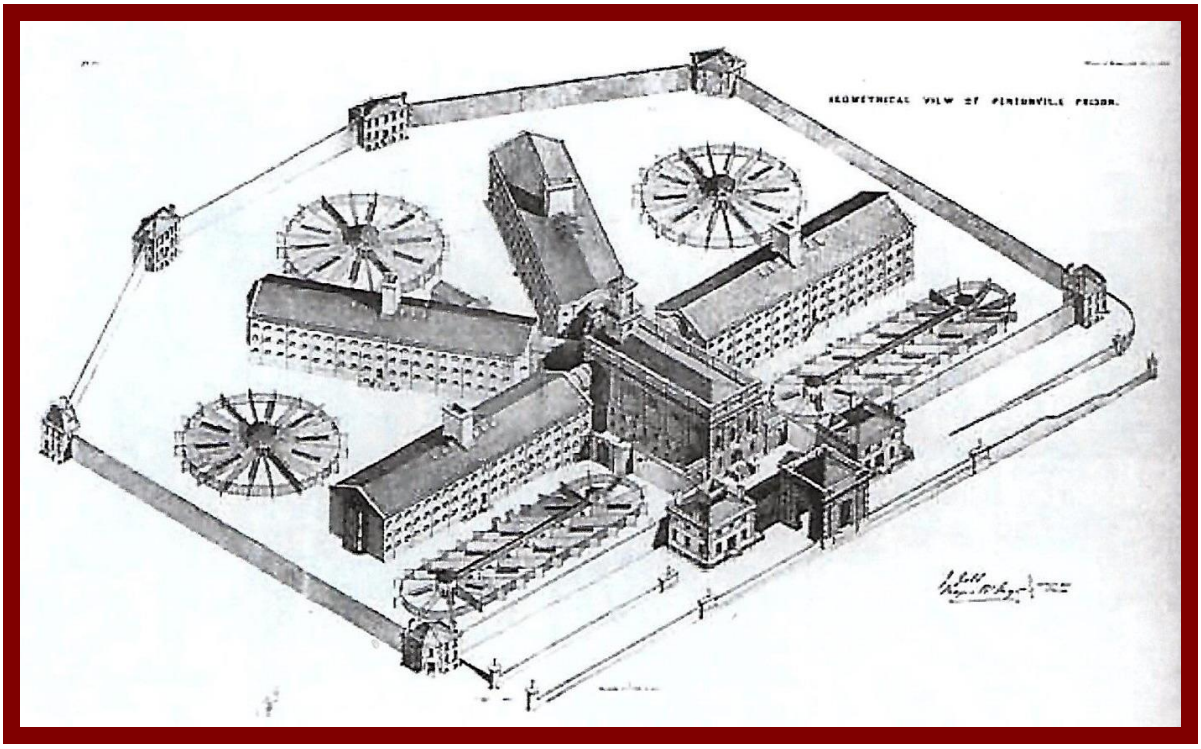
The interiors were poorly lit and badly ventilated.

NEWGATE PRISON, LONDON
CITY OF LONDON

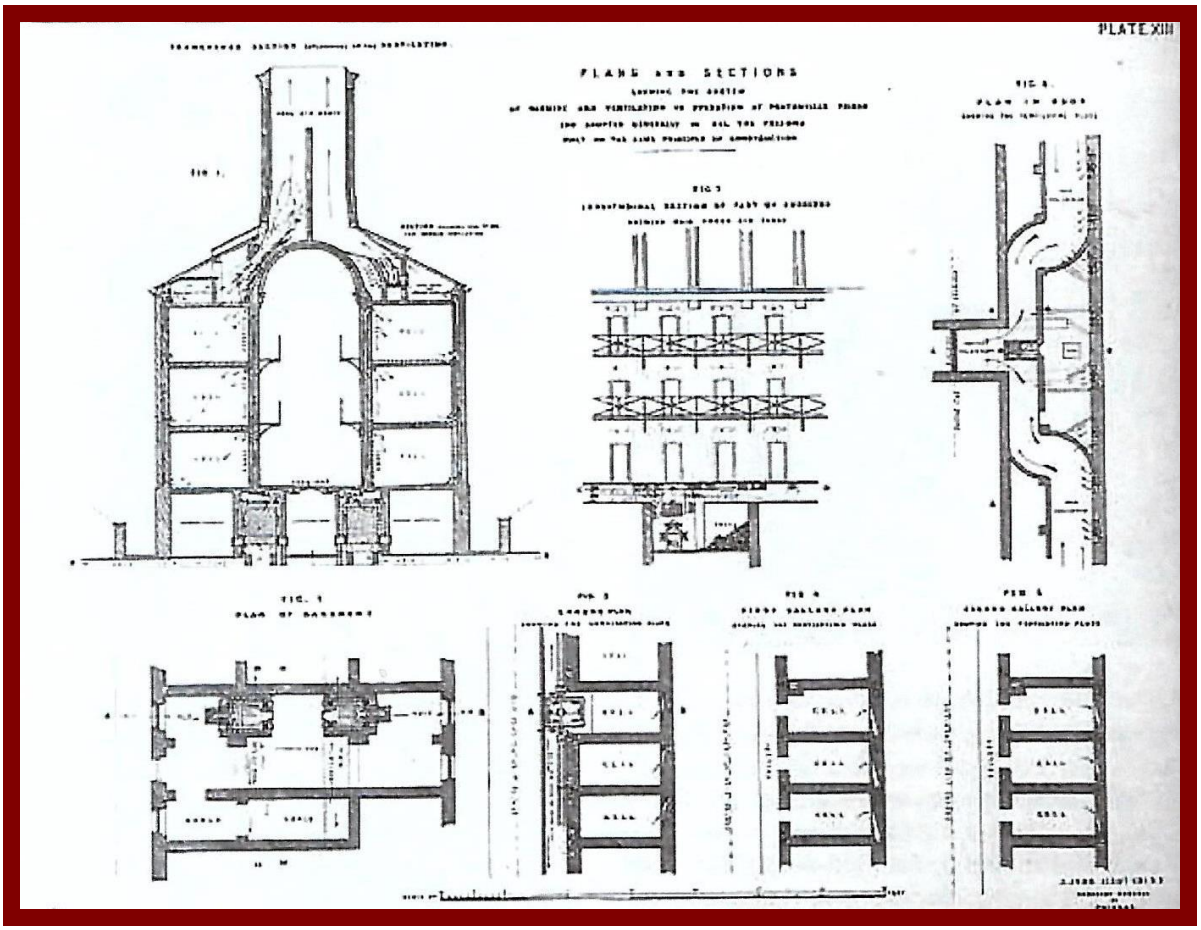


Male wing built 1859, photograph c.1900 (after prison was closed).

PENTONVILLE PRISON, NORTH LONDON

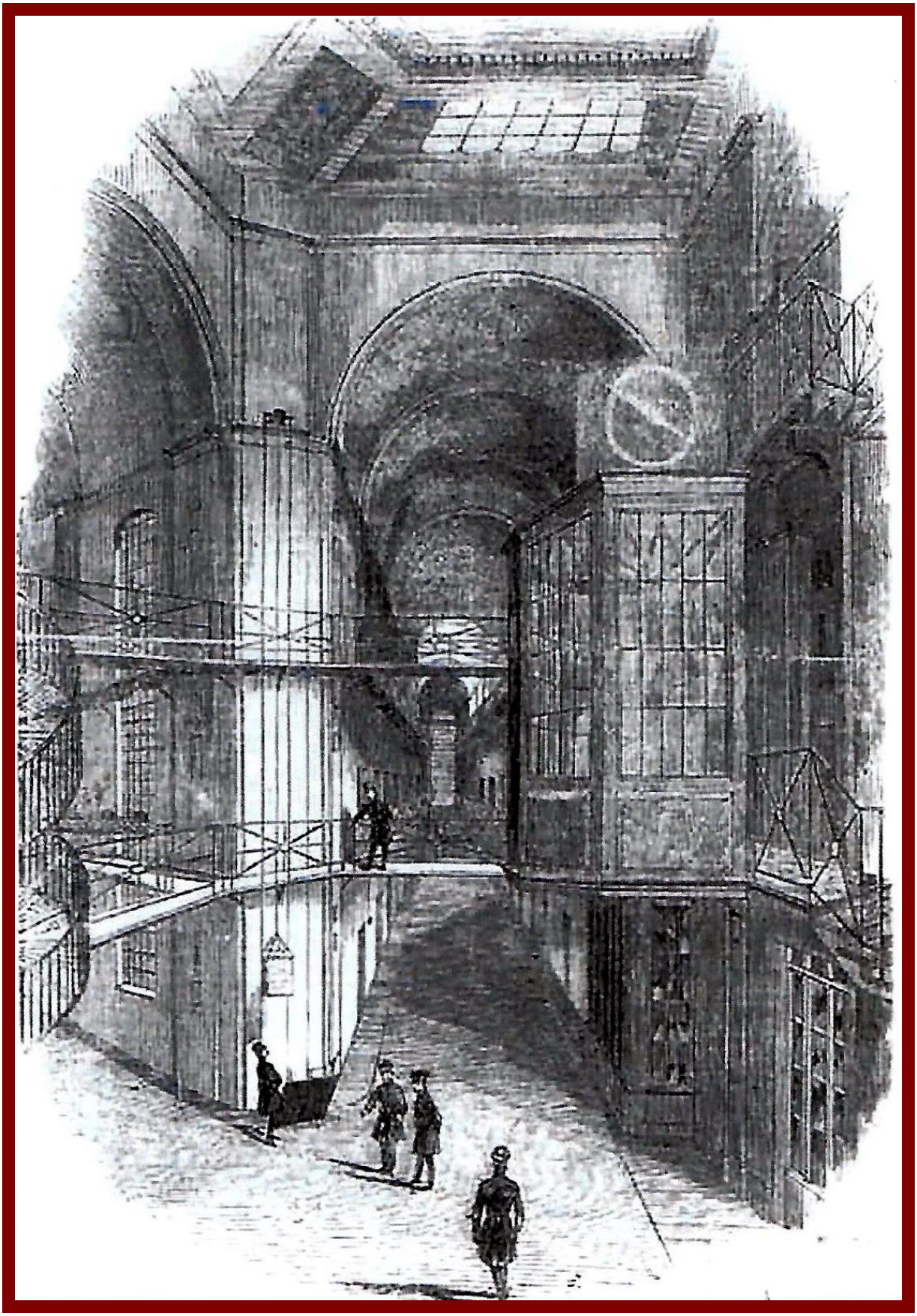


Isometric drawing, c.1844, signed by Major Jebb.



Details of the Haden heating and ventilating system.
The title block shows Jebb, now a Lt-Colonel.

PENTONVILLE PRISON, NORTH LONDON



The Central Hall (*The Illustrated London News*, 7 January 1843).

PENTONVILLE PRISON, NORTH LONDON

Within these walls

by Ken Dale

The model prison at Pentonville, built by Sir Joshua Jebb in the mid-1800s, is undergoing refurbishment. Ken Dale looks at the building services engineering of this pioneering structure.

With Christmas approaching, it may seem an inappropriate time to celebrate the 150th anniversary of the building of a prison. The excuse for doing so is to bring to the attention of present day building services engineers the work of a remarkable Victorian engineer, Sir Joshua Jebb.

The prison which he designed and built at Pentonville is still in use today. Modifications are now in progress and so Pentonville is likely to remain in use, basically as Jebb conceived it, for many decades to come.

Pentonville model prison and Jebb

Jebb, at the time a Major in the Royal Engineers, selected the site in 1840. He then produced the designs for the prison, including its building services, and supervised the construction and commissioning. The building was complete by September 1842, and was first occupied on 21 December of that year.

The 560-inmate prison became known as the Model Prison, and the model was used at home and abroad. Jebb himself oversaw the building of many similar prisons and after the first prisoners were installed at Pentonville, Jebb became chairman of directors of convict prisons. In 1859 he was knighted for his work.

Jebb's report[1] on the building of Pentonville and its first two years of operation forms the basis for this article. It was translated into French and German and was widely read by prison reformers in America.

The total area of the site was about six acres, with a garden at the rear. Four cell blocks, three storeys high, radiated from a central hall behind the chapel. Each cell was 13 x 7 feet, rising to a height of 9 feet.

A fourth storey was later added to the cell blocks, increasing the capacity to about 1150 individual cells, and clerestory lights were incorporated into the new roofs. The building works increased the extent of the site to around 10 acres.

Besides the chapel there were houses for the governor, chaplains, 19 prison officers, a schoolmaster, a clerk of works and an engineer. Eight bathrooms, a kitchen, medical facilities, offices, library, store rooms and heating plant rooms were also provided.

The whole complex cost around £90 000 which, with £1 in 1841 being the equivalent of £38.86 nowadays, works out at £3 500 000 at 1992 prices. Price per cell was £167, or £6490 per cell at 1992 prices.

The building services element of the cost of the works was somewhere between £10 500 and £11 000 (£427 500 at 1992 prices), or 12% of the total cost.

Heating and ventilation

One of the major concerns of services engineers nowadays is that of indoor air quality. Jebb was very concerned about this; he was firmly convinced that the quality of ventilation of a cell had a direct influence on the health of a prisoner, and was therefore one of the most important factors in prison design.

He also felt that the warming of cells was necessary and inseparably connected with ventilation. His peers at the time were not so convinced.

One, a certain Captain Williams, wrote a letter to Jebb[2] in which he criticised him "for applying the luxury of heat to prisoners' sleeping quarters, the more especially as the greater portion of the honest population in the country neither experience the wont nor enjoy the possession of such advantage." Jebb, however, felt that it was neither difficult nor expensive to provide warming and ventilation, and recommended it for all new prisons.

Joshua Jebb

The main objects of his design were:

- ☐ to withdraw a stated quantity of foul air from each cell – 30 cfm (14·2 litres/s);
- ☐ the supply of an equal quantity of fresh air without causing a draught;
- ☐ to find the means of warming the air when necessary without "injuring the qualities or affecting its hygrometrical condition" (52-60°F, ie 11-15°C, to be maintained in the coldest weather);
- ☐ that the air channels and flues should not be a means of communication between prisoners.

Jebb consulted Hadens of Trowbridge, and with them developed an apparatus for warming the air. A system of flues was designed (figure 1) to allow outside air, warmed or not as necessary, to be introduced into each cell at high level. An extract grille was placed at low level in each

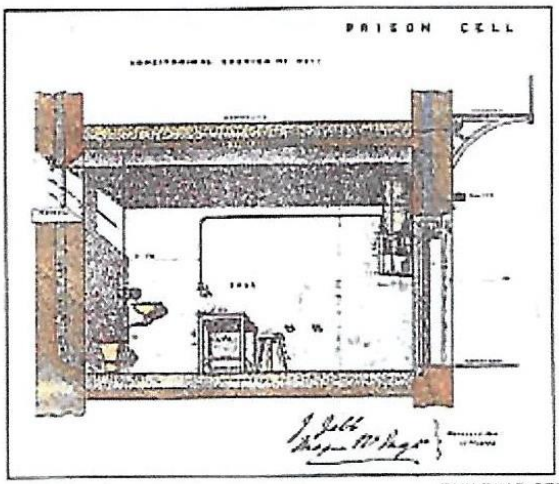


Figure 2: Each cell had its own hand basin and wa.

Author Ken Dale OBE was CIBSE President in 1974 and a member of the Heritage Group.

PENTONVILLE PRISON, NORTH LONDON

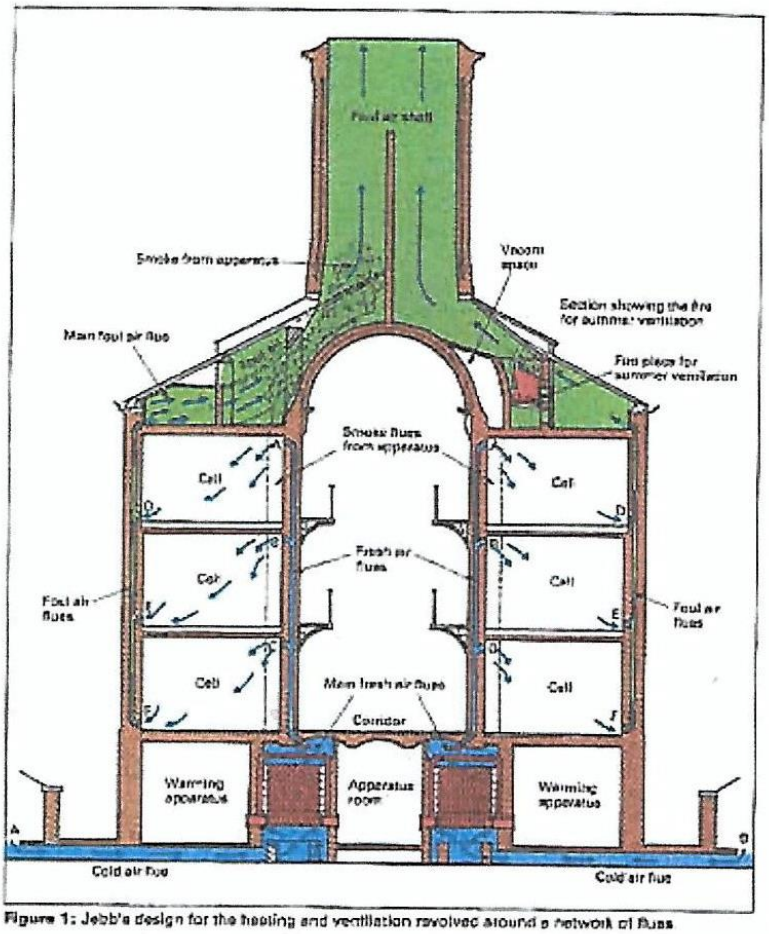


Figure 1: Jebb's design for the heating and ventilation revolved around a network of flues

cell, and was ducted to the foul air extract in the roof.

A small fire was maintained at the bottom of the vertical shaft to induce flow in the summer. Jebb remarks that the fire was needed because wind forces alone could not be relied upon to produce the necessary circulation.

Haden's apparatus was a boiler with an extended heating surface – cast iron plates in zig-zag lines in a brick work setting. It was designed to produce 60°F in outside temperatures of 32°F using water at 100-120°F. This level of heat was chosen to avoid high entering air temperatures.

Other requirements were that temperatures should be adjustable, and that the whole apparatus should be simple in its construction so there would be no difficulty in its management.

Commissioning and testing

Whether or not the system worked was not left to chance. Dr Owen Rees, the principal medical officer, was charged with conducting trials and produced a report which showed that:

- 30-45 cfm of fresh air was supplied to each with regularity (how this was measured is not clear);
- this volume could be supplied (maintaining 52-60°F in the cells during the coldest weather) at a cost of less than a farthing a cell for 24 hours;
- the same degree of ventilation was maintained in summer at half the expense.

The Surveyor General of Prisons Costs for the year 1854/5 gives the cost of fuel and light as £700 (£27 200 at 1992 prices) for the year. With 561 prisoners, this works out at three farthings per day per prisoner.

Jebb had initially cautioned against trusting temperature or fuel consumption results until all the flues and building materials had dried out.

Washing and sanitary facilities

George IV (1820-1830) required that warm and cold baths should be introduced into all prisons. Jebb provided eight baths, enough to bathe 32 prisoners in an hour. Each prisoner bathed once a fortnight.

Surprisingly, perhaps, Jebb also provided a wash hand basin and a strong glazed earthenware pan (we) in each cell. As figure 2 shows, water (six gallons per cell per day) for washing and flushing was provided from a cast iron sectionalised channel running beneath the galleries. Water from the basin drained via the soil pans so that it was not wasted.

When describing these provisions, Jebb

cautions on the need to avoid freezing, and suggests that this can be accomplished if cisterns and pipes are placed in or near to the foul air flues and kept away from the influence of outside air.

It is unclear at what point in the prison's history individual toilets were removed from cells and 'slopping out' became the norm, but it is interesting to note that it is only recently that such facilities have been reinstated as part of the programme of upgrading the prison.

Lighting and communications

Jebb employed Mr Faraday to provide gas-producing apparatus and light fittings to each cell, as well as the prison buildings. The lighting point in the cell can be seen in figure 2. Each point had a shade.

Though prisoners were not allowed to communicate with one another, it was considered essential that they should be able to gain the attention of the prison officer at any time. For this purpose, each cell had a handle attached to a spindle with a metal label at the gallery end. The label was normally horizontal but when it was turned vertically it indicated the prisoner's need for attention.

Nowadays design teams and contractors who manage to design and construct a building in 3 to 4 years talk of the project as being fast-track. Even though planners were probably not around to delay matters for Jebb, that he managed with his contractors and suppliers to build, fit-out and commission a prison for 560 offenders in 18 months was no mean achievement.

It makes you think why we, with the technology and machinery at our disposal today, take so long to produce buildings.

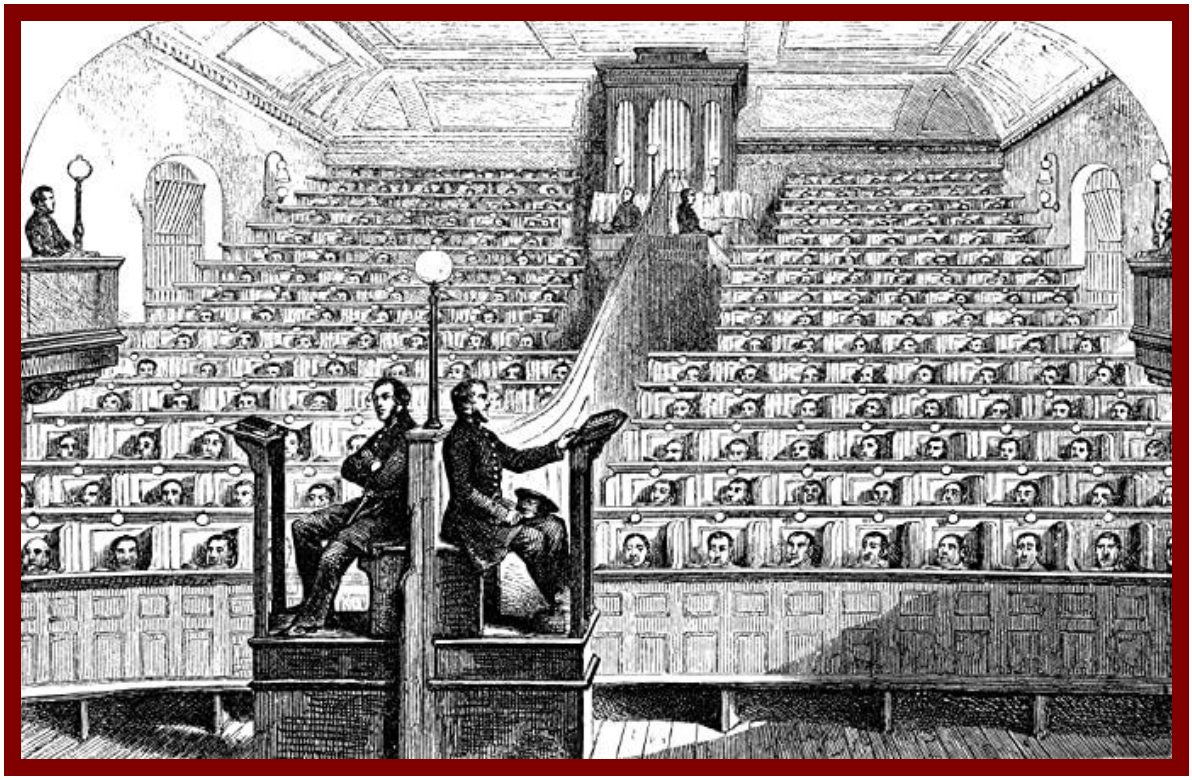
Readers will discern that Jebb was well ahead of his time in being concerned about indoor air quality, fuel consumption/energy conservation, public health engineering and the commissioning of the services he designed.

It is also striking that Jebb and his contemporaries put considerable emphasis on recording what they had done and how they did it, so that a record and guidance was available for others to follow and for us to contemplate 150 years on.

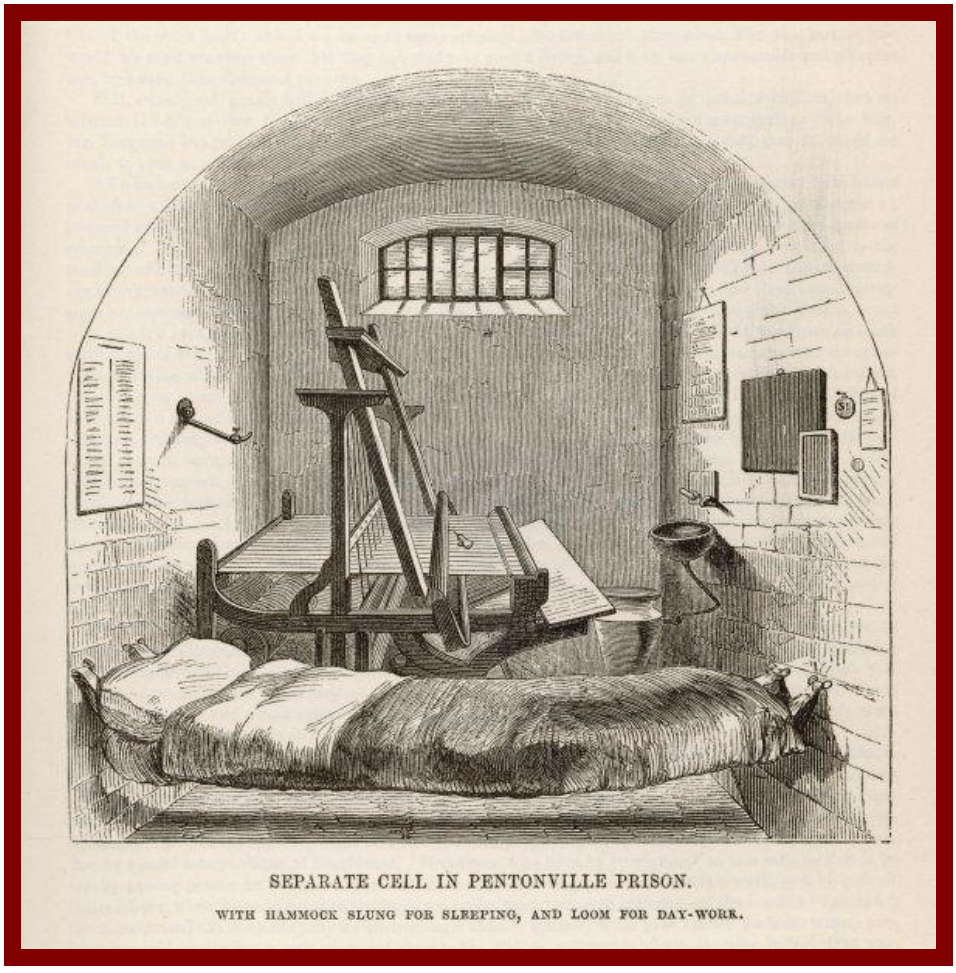
Ken Dale OBE TD CEng Hon FCIBSE Hon MASHVE is senior partner of Dale and Goldfinger Consulting Engineers.

References
1 "Report of the surveyor general of prisons on the construction, ventilation and details of Pentonville Prison", HMSO, 1844
2 "Jebb papers", British Library of Political and Economic Science

PENTONVILLE PRISON, NORTH LONDON



Prison Chapel, prisoners held in "Separate System", no communication permitted.



SEPARATE CELL IN PENTONVILLE PRISON.

WITH HAMMOCK SLUNG FOR SLEEPING, AND LOOM FOR DAY-WORK.

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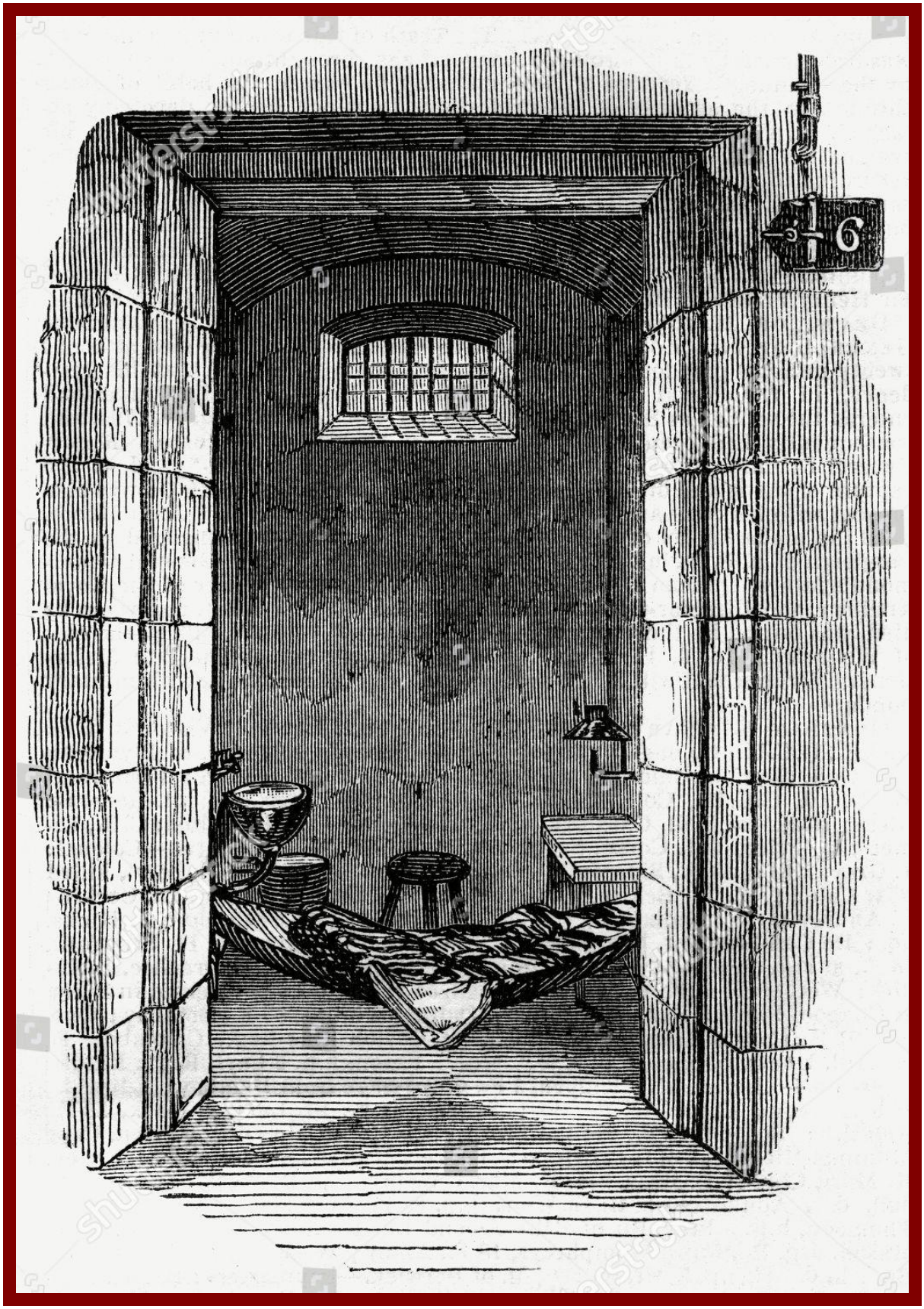
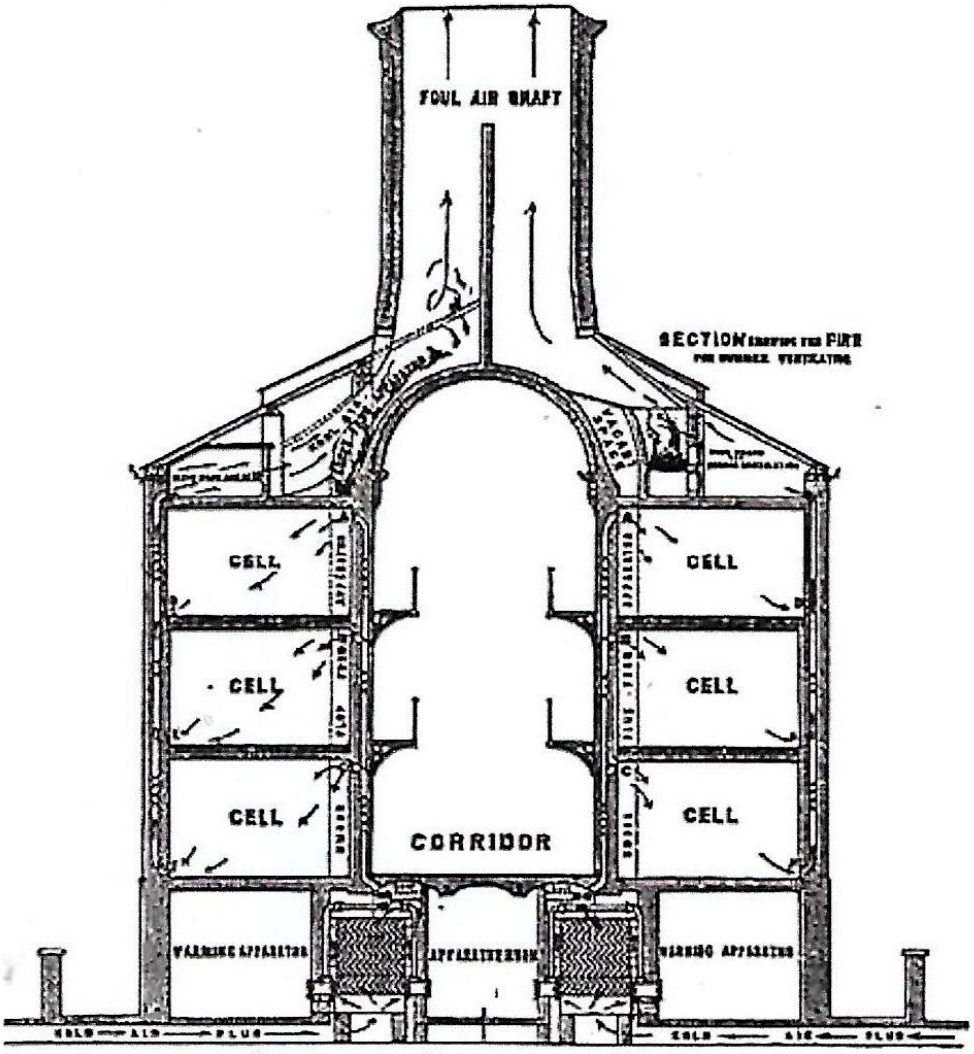
PENTONVILLE PRISON, NORTH LONDON

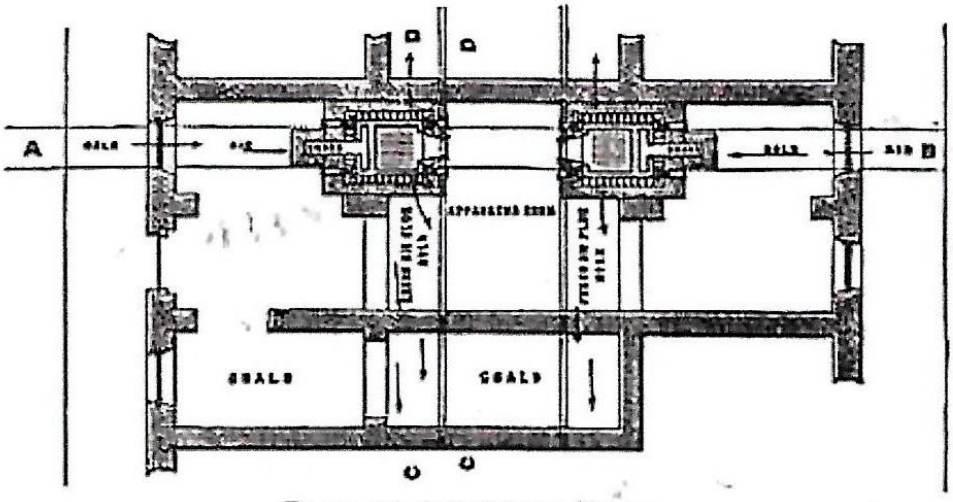


View of an empty "Separate" cell.

PENTONVILLE PRISON, NORTH LONDON



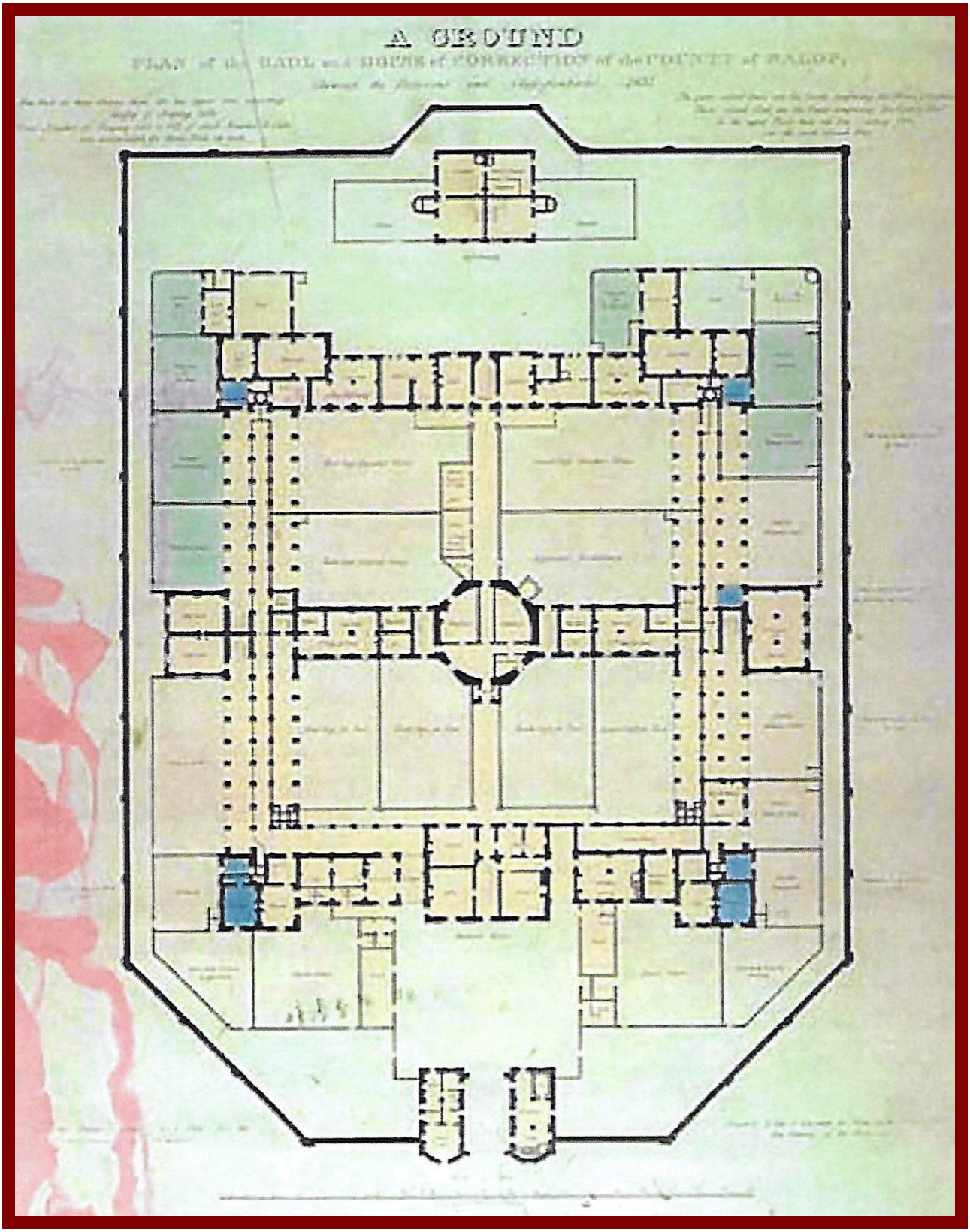
SECTION OF PENTONVILLE PRISON.



PLAN OF APPARATUS ROOM.

1840: The heating and ventilation by Major Jebb and G & J Haden.

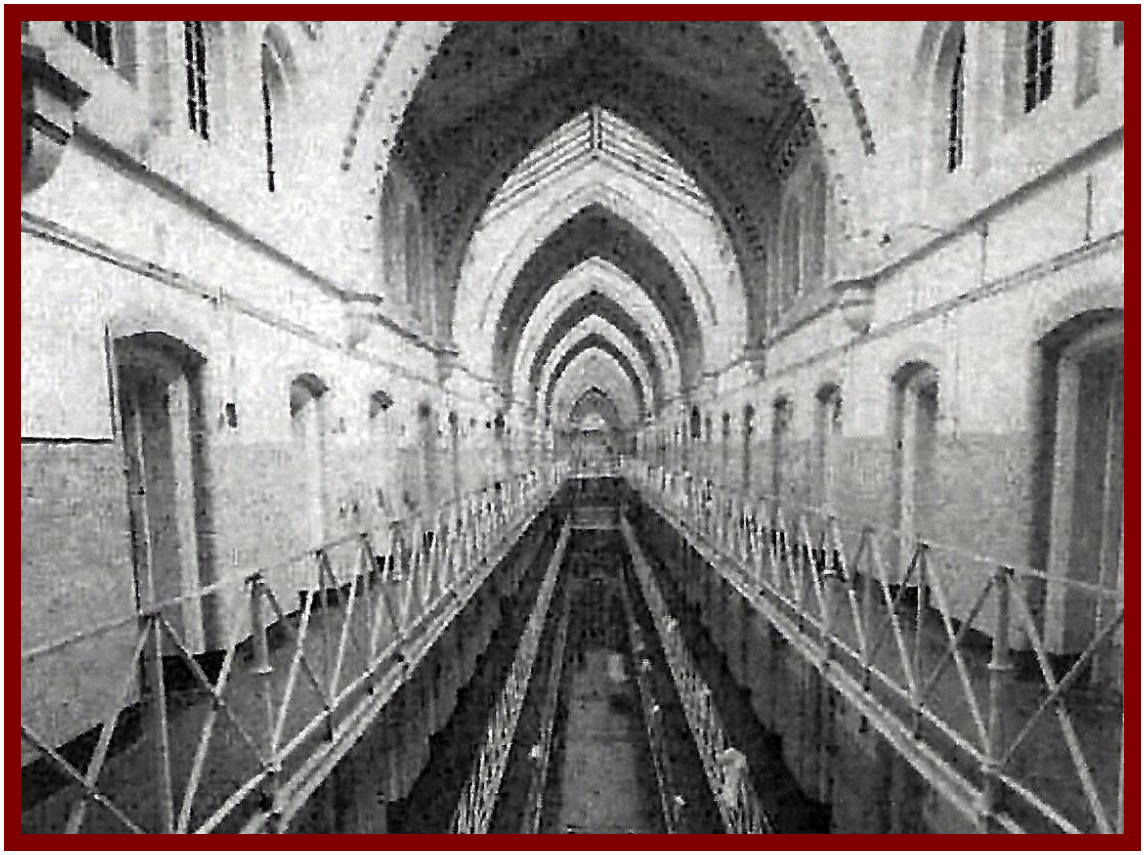
HOUSE OF CORRECTION, SALOP
SHREWSBURY COUNTY GAOL



Plan of the Goal & House of Correction (Shropshire Archives).
G & J Haden received an order for the heating system c.1842.

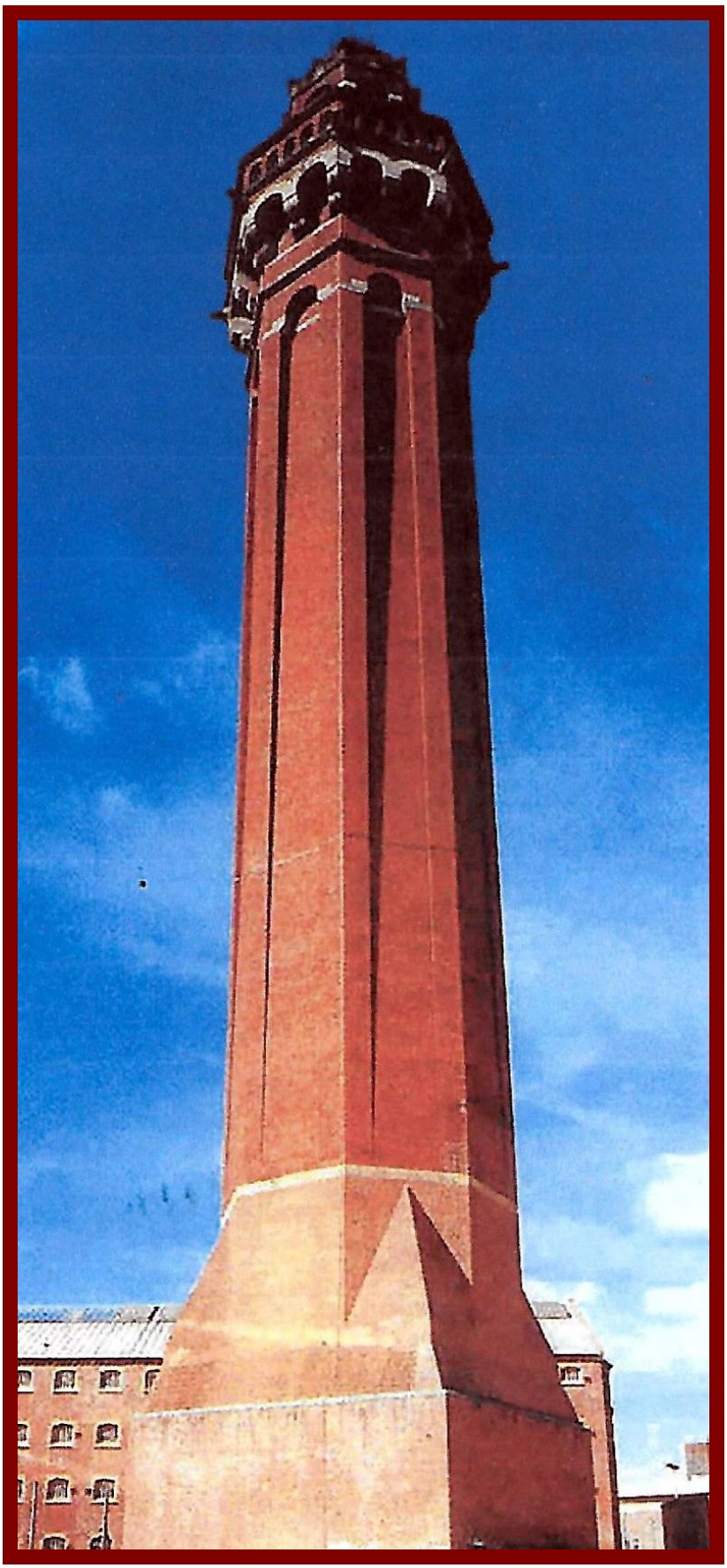
STRANGEWAYS PRISON, MANCHESTER

General view of F Wing.



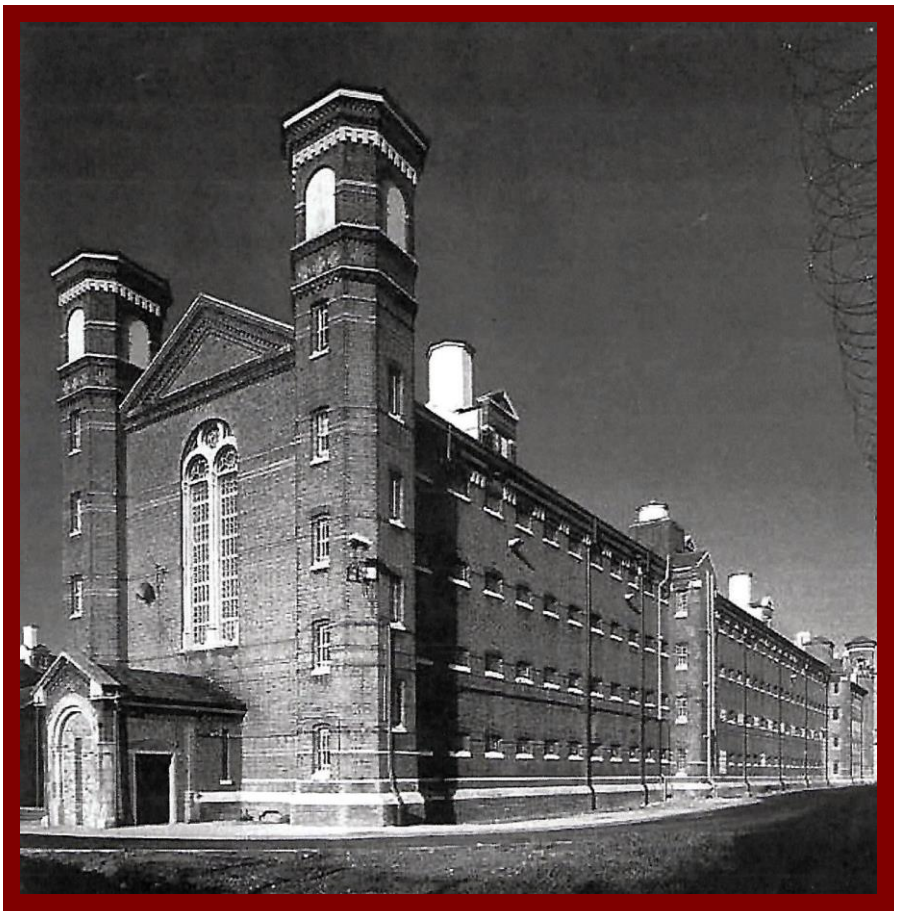
Interior view of Cell Block.

STRANGEWAYS PRISON, MANCHESTER



The detached exhaust tower for the heating and ventilating system.

WORMWOOD SCRUBS, WEST LONDON



D Wing, built 1878 by Edmund Du Cane.

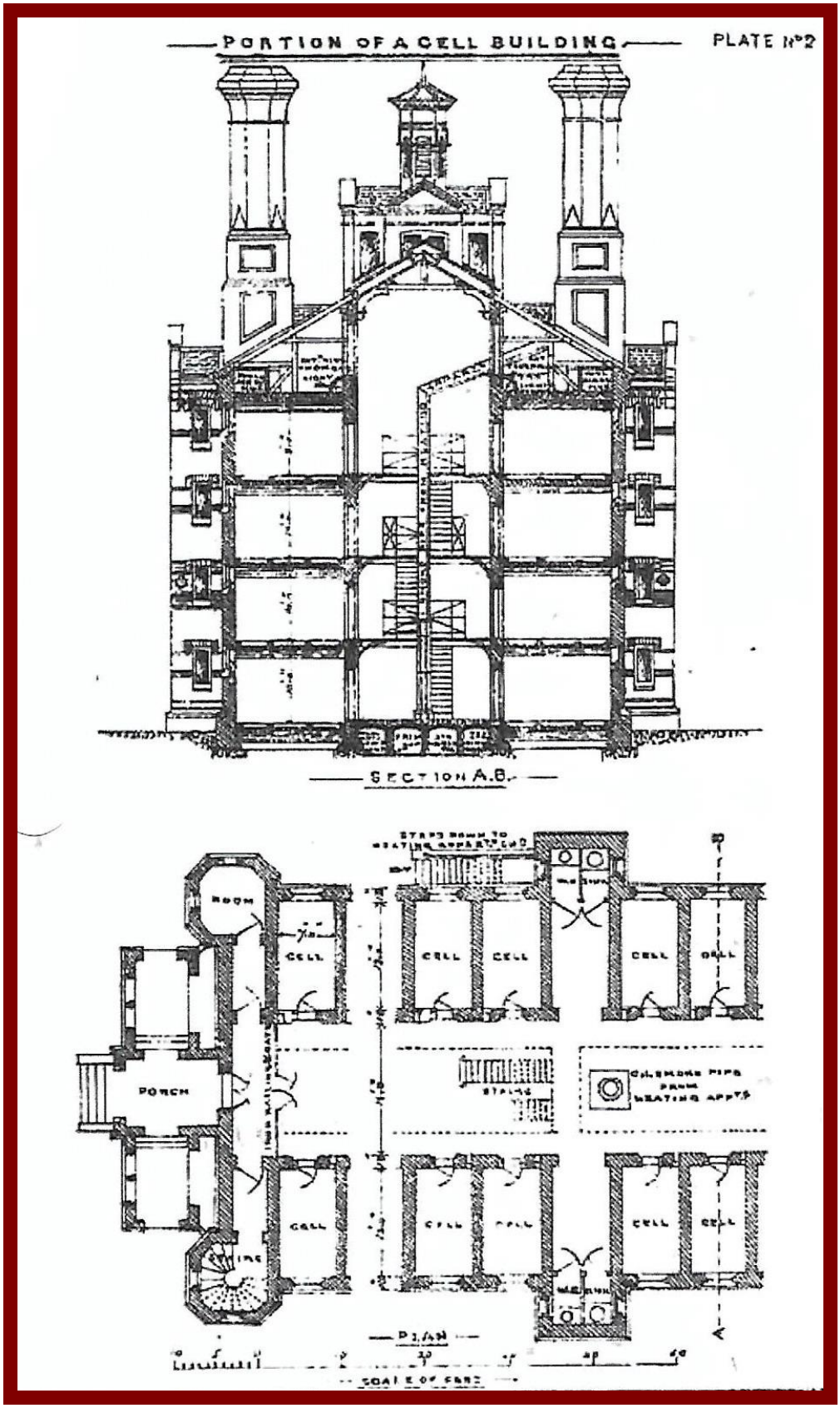
In 1863, Sir Edmund Frederick Du Cane, an officer in the Royal Engineers, was appointed Director of Convict Prisons as well as an Inspector of Military Prisons. In 1869, he became Chairman of the Board of Directors of Convict Prisons, Surveyor – General of Prisons and Inspector General of Military Prisons.

He was responsible for the building of the prison at Wormwood Scrubs in London (1874-91), the land having been obtained from the Ecclesiastical Commissioners. The prison was built by convict labour. It was based on the so-called "telegraph pole" plan, said to have originated in the layout of pavilion plan hospitals as recommended by Florence Nightingale, in particular the Herbert Military Hospital at Woolwich (designed by Captain Douglas Galton, also of the Royal Engineers).

There were cells for some 1400 convicts and the complex included a cookhouse, bakery, laundry, workshops, an infirmary, baths and an enormous chapel. The four main cell blocks were built parallel to one another, orientated north-south, with each block containing 351 cells, being linked by covered ways. Du Cane supervised the building works himself, charging a guinea (21 shillings) a day.

A description [VA, 235-37] reads, "Du Cane's scheme is remarkable for its clean, logical plans, and for the heating and ventilating system which served each cell. Staircases, vents and sanitary stacks were expressed in the building, and the completed prison combined that direct integrity familiar from early warehouse and industrial buildings." It is said that Du Cane's model plan influenced the design of prisons for many generations afterwards.

WORMWOOD SCRUBS, WEST LONDON



Heating, ventilation and sanitation (from papers of A.W. Pullan).
Shows (see Section) in attic beneath towers are (foul air flues); space between basement arches (fresh air); centre "smoke pipe from heating apparatus" connecting to right-hand tower,

SERVICES IN THE CLINK

Services in the clink

Brian Roberts outlines the development of building services in prisons, going back to the days of prison reform and beyond.

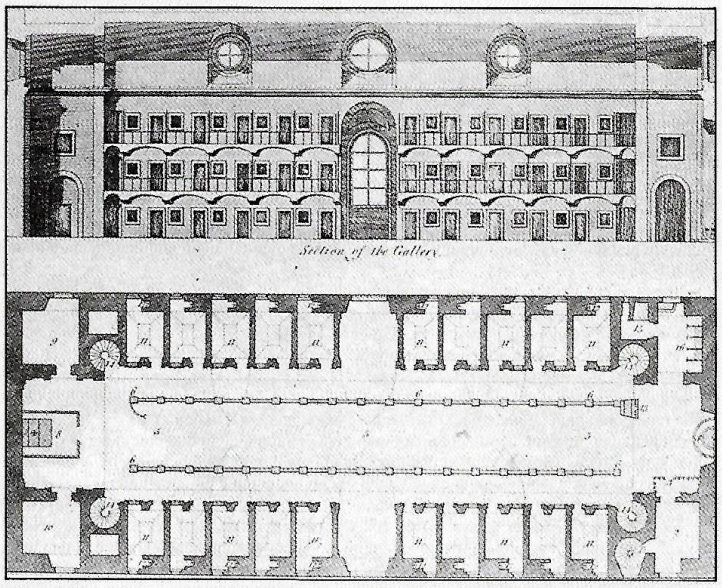
The slang expression clink, meaning prison, is derived from London's 16th century jail which used to stand in Clink Street in Southwark, and about which John Stow wrote in his *Survey of London* (1598) "...a gaol or prison.....for such as should brabble, frey or break the peace on the said bank (Bankside), or in the brothel houses". Some of the earliest and most famous dungeons to be found in Great Britain are those in the Tower of London (started in 1078) destined to become "..a symbol of authority and strength as well as a place of imprisonment, torture and execution, the name of which inspired fear".

According to the architectural historian Nikolaus Pevsner in his book *A History of Building Types*, originally imprisonment was prior to trial, or prior to execution, or for debt, or as a cruel form of revenge. Imprisonment as a form of punishment seems to have originated in the monasteries around the 11th century, where offenders were put into the carcer (hence incarcerated), this being only accessible from the top by a ladder and without a door or windows. Records from the late Middle Ages and early Renaissance illustrate a few dungeons at the bottom of round towers in castles or town walls, but prisons with cells came later. The Italian Filarete, in his *Treatise* (early 1640's), refers to a design for a large prison where the prisoners are in cells according to class or crime. Pevsner states that the building usually credited as being the first prison planned with cells and a large workroom is the S. Michele Prison in Rome (1703). It had 20 cells to each of 3-storeys and each cell had a lavatory.

In London, the Fleet was a notorious city prison from 1197 until it was demolished in 1846. It was said to be the largest brothel in the kingdom and the scene of cruelty, depravity and extortion. But it was the writings of the well-to-do Bedfordshire squire and prison reformer, John Howard (1726-90), which tell us most about the sorry state of the prisons of that period. Time and again he found prisons with no water, no sewers and no fresh air. In Warwick Gaol he talks of prisoners being "almost suffocated", but the large box bellows designed by Stephen Hales for ventilating purposes, and operated by two men working at a lever, is said to have significantly reduced the incidence of fever in the Winchester Hospital and Gaol (1744). Edwards, commenting on this (1881), wrote:

"A constant objection to the ventilating bellows was the necessity for frequent manual labour to work them. Hales sought to stimulate the men who worked the bellows by the sight of a little twirling windmill, or the sound of a tinkling bell, that they might thereby be amused, and have some evidence of their labour not being in vain".

Architecturally, many prisons followed the layout of cells on a radial plan, like the spokes of a wheel, introduced at Ghent (1775). The alternative, not so widely taken up, was Jeremy Bentham's design (1791), known as the Panopticon, with cells around the periphery of a circle with an observation post in the middle. But the most famous of the London prisons were Millbank Penitentiary (1813-21); Pentonville (1840-42) by Sir Joshua Jebb, Surveyor General of Prisons (and author of *Notes on the Construction and Ventilation of Prisons*); Holloway, built a few years later (1849-52) by Bunning; and Wormwood Scrubs (1874).



Above: S. Michele Prison, Rome (1703-4)

Jebb's scheme for Pentonville was a landmark in the heating and ventilating of prisons. A drawing of the system, shown overleaf, reveals that at the centre of the installation is a boiler and heat exchangers. Fresh air is drawn through underground ducts to the heating coils, and then passes to main horizontal warm air flues. Vertical riser ducts, with a branch leading to each cell, ascend from these flues.

Vitiated air is drawn out via low level extract grilles from each cell into a common foul air shaft which joins the boiler smoke flues at attic level. The power for foul air extraction in summer was provided by a fireplace in the attic. The firm of G N Haden sent Jebb a drawing indicating how the boiler feed water could be pumped by hand by 12 men in the cells; an arrangement later installed in a number of prisons.

Jebb noted that he had to overcome the difficulty of ventilating the prison without opening windows due to the problems of "..their being destructive of discipline (and) in favouring the transmission of sound". The principal medical officer carried out a series of tests in which he established that between 50 and 76 m^3/h of fresh air was supplied to each cell "with extraordinary regularity". It was noted that this ventilation and a temperature of between 11 and 15°C could be maintained in the coldest weather, for a cost of less than a farthing a cell a day. Jebb also discoverd a fact which is often overlooked; that since a newly-built structure has not thoroughly dried out, its initial fuel consumption is higher than normal. "Hence", he stated, "the necessity of not trusting any results in connection with the power of an apparatus until all the flues and the building are perfectly dry".

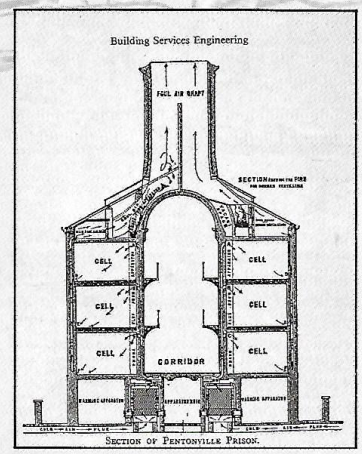
SERVICES IN THE CLINK

The French engineer Peclet, in his book *Traite de la Chaleur* (1861), makes reference to the Prison Mazas. It seems to have been common practice to appoint a commission to examine proposals for the heating and ventilating of large public buildings, not necessarily with complete success. Peclet observes: "...one knows that in France, it sometimes happens that the commissions have too little time to accomplish their task, and make their decision after an examination by, or on the opinion of, only one member". A sub-committee stated that ventilation was the principle requirement for prison hygiene, and recommended this should be at least 10 m^3/h per prisoner with the cell temperature kept at 15°C. Air was to be extracted from the cells via the waste pipes of the toilet in each cell (these were not WC's and were not trapped).

A disadvantage of early steam heating was found to be the high and uncontrollable surface temperatures in the system. To overcome this, the mixed system was developed. This used the steam to heat water in radiators or calorifiers. It was first used by Grouvelle in the Prison Mazas. The stoves each had an expansion vessel and could work at steam pressures up to 500 kPa. Steam systems required constant attendance but the mixed system used thermal storage principles: the stoves were heated by steam during the day and during the night the water was allowed to cool from around 90°C down to room temperature. Grouvelle's design used hot-water circulation to heat air by contact with pipes enclosed in a duct, which was divided into sections corresponding to the cells.

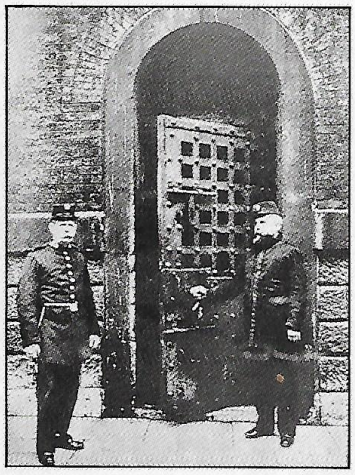
Fresh air entered the duct section, where it was warmed, escaping into the cells through low level wall grilles. Extraction was induced by a large centrally heated chimney communicating with the sewage collecting tank into which the toilets discharged. The operation was monitored for several years. The use of 13·5 kg/h of coal produced a ventilation flowrate of nearly 15000 m^3/h at a total cost of 24 francs per prisoner per year.

The Prison de Tours was warmed by Duvoir-Leblanc's system of pressurised hot water and warm-air calorifiers with ventilation (as in Prison Mazas) by extracting air from the cells through the waste pipe of the toilet in each cell. It was found that the prisoners could talk to each other by speaking down the toilets, which were probably simple pan or hopper closets. To prevent this and to preserve discipline the soil pipes were trapped in water or sand, but this also prevented the ventilation. An alternative extract was tried, failing due to insufficient pull. It was found that air was entering the cells via the cess tanks and toilet pans, due to poor building construction. Little wonder that a cholera outbreak in 1849 decimated prisoners and prison officers alike. Remedial action was attempted by Segey, the extract ducts from each cell being connected to a heated upcast shaft: this also proved inadequate. Next, a four-bladed fan (1·3 m diameter) was installed. This was turned at 2 rev/s by a prisoner, who was paid 10 centimes for 2 hours work, but satisfactory ventilation was only achieved after the toilets were altered.



SECTION OF PENTONVILLE PRISON.

Above: Jebb's heating & ventilating scheme for Pentonville Prison, London (1840)



Above: Gaolers at Newgate (about 1880)

About this time, the United States took the lead in prison design. There were two competing systems: Auburn, New York (1816-25) and the Eastern Penitentiary at Cherry Hill, near Philadelphia (designed in 1825). Auburn had cells used at night with prisoners kept in common workrooms during the day, but under strict conditions of silence. Cherry Hill operated on the principle of solitary confinement day and night with work performed in the cells.

Charles Dickens, on his American journey (1842) visited many prisons and on the whole praised America's "great wisdom, great benevolence, and exalted policy", but he found Cherry Hill "..hopeless...cruel and wrong". In spite of this, Cherry Hill was progressively equipped, for each cell had hot-water heating, a latrine and a tap; it was widely accepted as the model prison of the 19th century.

Similarly, the Victorian reformed prisons sought to impose discipline on the inmates by long periods of solitary confinement and through a rigorous programme of forced labour, such as the treadwheel installed at Coldbath Fields where "each treadmill was in its own compartment, not attached to any form of machinery, so that at the end of the day the prisoner had achieved nothing except the climbing of 8640 feet". By way of contrast, in some prisons the wheels were used to raise water.

The illustrations in Mayhew's *The Criminal Prisons of London* (1862), depict a dismal world of cage-like cells where the prisoners are separated from one another, even to the point of wearing hoods and masks. At Pentonville the water closets were removed to stop prisoners communicating with one another by tapping the pipes.

It was the Englishman, Thomas Box, who gave the symbol U to the quantity we now call thermal transmittance, in his *Practical Treatise on Heat as Applied to the Useful Arts* (1868), produced a reliable and quantitative method of pipe-sizing, and carried out studies in intermittent heating. Box developed a weight-driven fan for ventilation and heating. He describes it as being particularly suitable for prisons, where the task of rewinding the weight (1370 kg to a height of 9 m) can be carried out by the prisoners. Despite its apparent suitability, the fan seems not to have been used.

At London's Old Bailey, built on the site of the infamous Newgate Prison, the plant installed between 1904 and 1907 was a warm-air plenum system. The main heaters consisted of continuous 32 mm pipe fed with steam; there were secondary heaters at the base of each vertical supply air shaft; the condensate ran to waste. Steam was generated in a hand-fired Lancashire boiler, 2·5 m diameter and 8·5 m long. The steam was used not only for heating, but also to drive the fan engines, the centrifugal sump pump and the reciprocating boiler feed pump. In addition, racks were placed at the bottom of the main air shafts to receive ice for summer cooling. The fans were 2·5 m diameter propeller type. Fresh air was taken at high level, and before heating it was passed through a glass-tube capillary air washer and coconut matting (to wash and filter it), and then discharged to the rooms through low level outlets.

Brian Roberts FCIBSE MASHRAE MIPRP MASPE is technical director of HH Airpower Engineering Ltd and chairman of the CIBSE Heritage Group.

Picture Credits

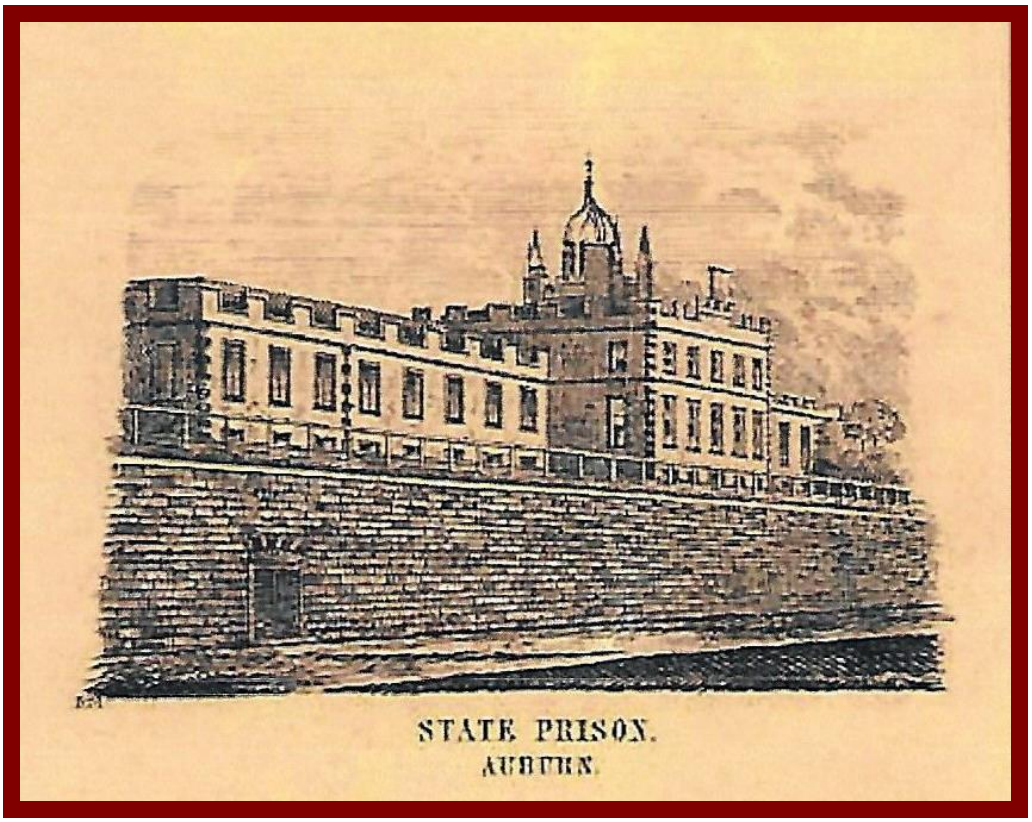
Overleaf: Howard, *Prisons*, 1777.

This page, top: CIBSE Heritage Collection.

Centre: *Victorian Life in Photographs*, Thames & Hudson, 1980.

Photographs by Zoe Roberts.

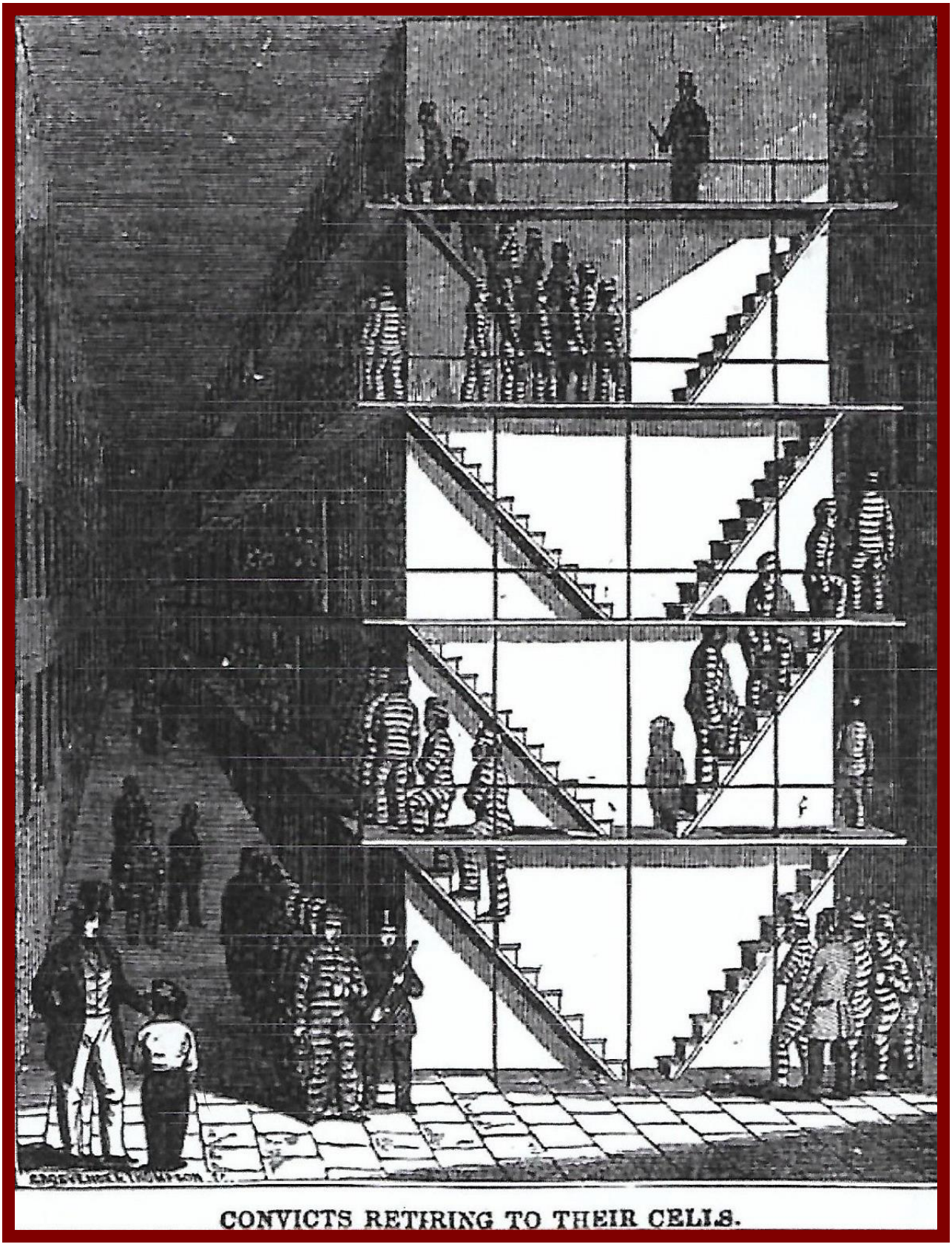
STATE PRISON, AUBURN
NEW YORK STATE



The prison was built 1816-25.

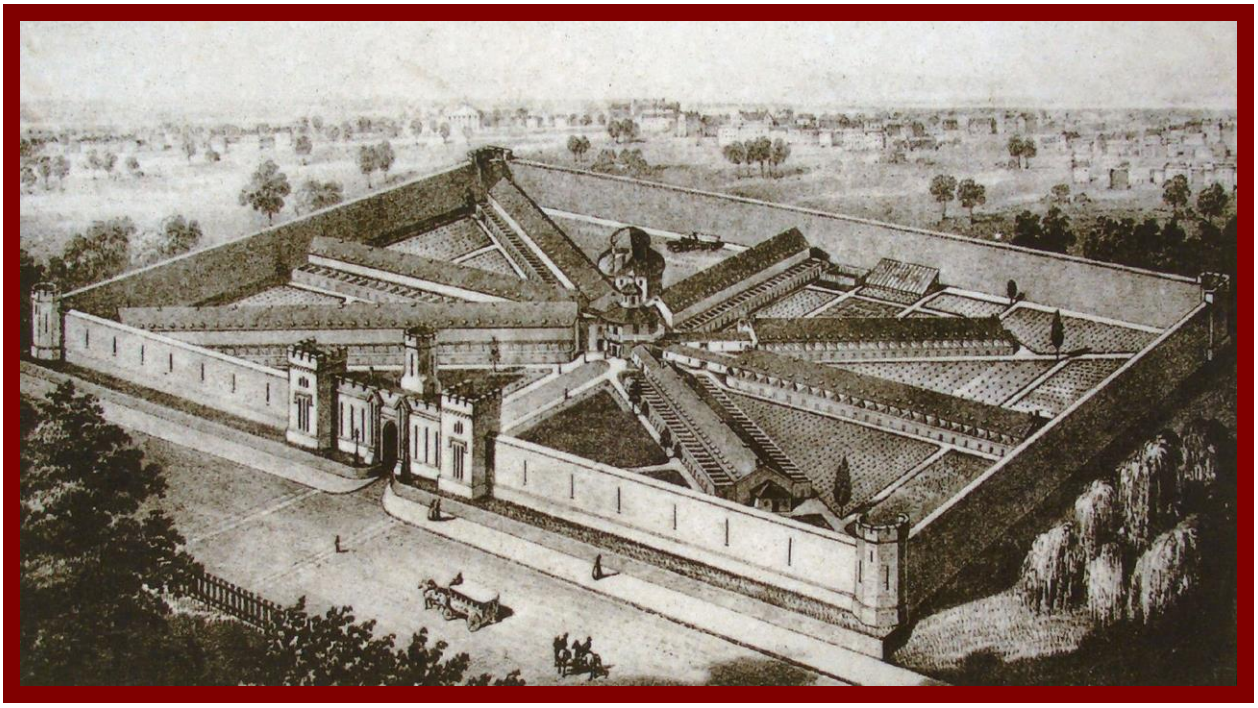
Auburn's galleried cells.

STATE PRISON, AUBURN
NEW YORK STATE



An early drawing. The prison was dark and dismal. The cells had no outer windows, receiving light from the general areas.

EASTERN STATE PENITENTIARY
CHERRY HILL, PHILADELPHIA

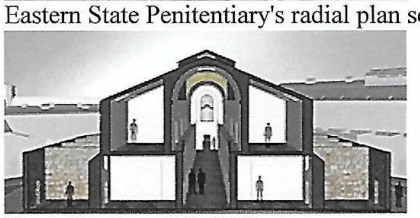


Designed 1825 by John Haviland (print of 1855).

The prison was built 1829-36 to house 450 prisoners. An early colour print.

EASTERN STATE PENITENTIARY
CHERRY HILL, PHILADELPHIA

Eastern State Penitentiary's radial plan served as the model for hundreds of later prisons.



Cross Section of Cell Block

When the Eastern State Penitentiary, or Cherry Hill as it was known at the time, was erected in 1829 in Francisville (the idea of this new prison was created in a meeting held at Benjamin Franklin's house in 1787) it was the largest and most expensive public structure in the country.[8] Its architectural significance first arose in 1821, when British architect John Haviland was chosen to design the building. Haviland found most of his inspiration for his plan for the penitentiary from prisons and asylums built beginning in the 1780s in England and Ireland.[8] He gave the prison a neo-Gothic look to instill fear into those who thought of committing a crime.[16]

These complexes consist of cell wings radiating in a semi or full circle array from a center tower whence the prison could be kept under constant surveillance. The design for the penitentiary which Haviland devised became known as the hub-and-spoke plan which consisted of an octagonal center connected by corridors to seven radiating single-story cell blocks, each containing two ranges of large single cells—8 × 12 feet × 10 feet high—with hot water heating, a water tap, toilet, and individual exercise yards the same width as the cell.[8]

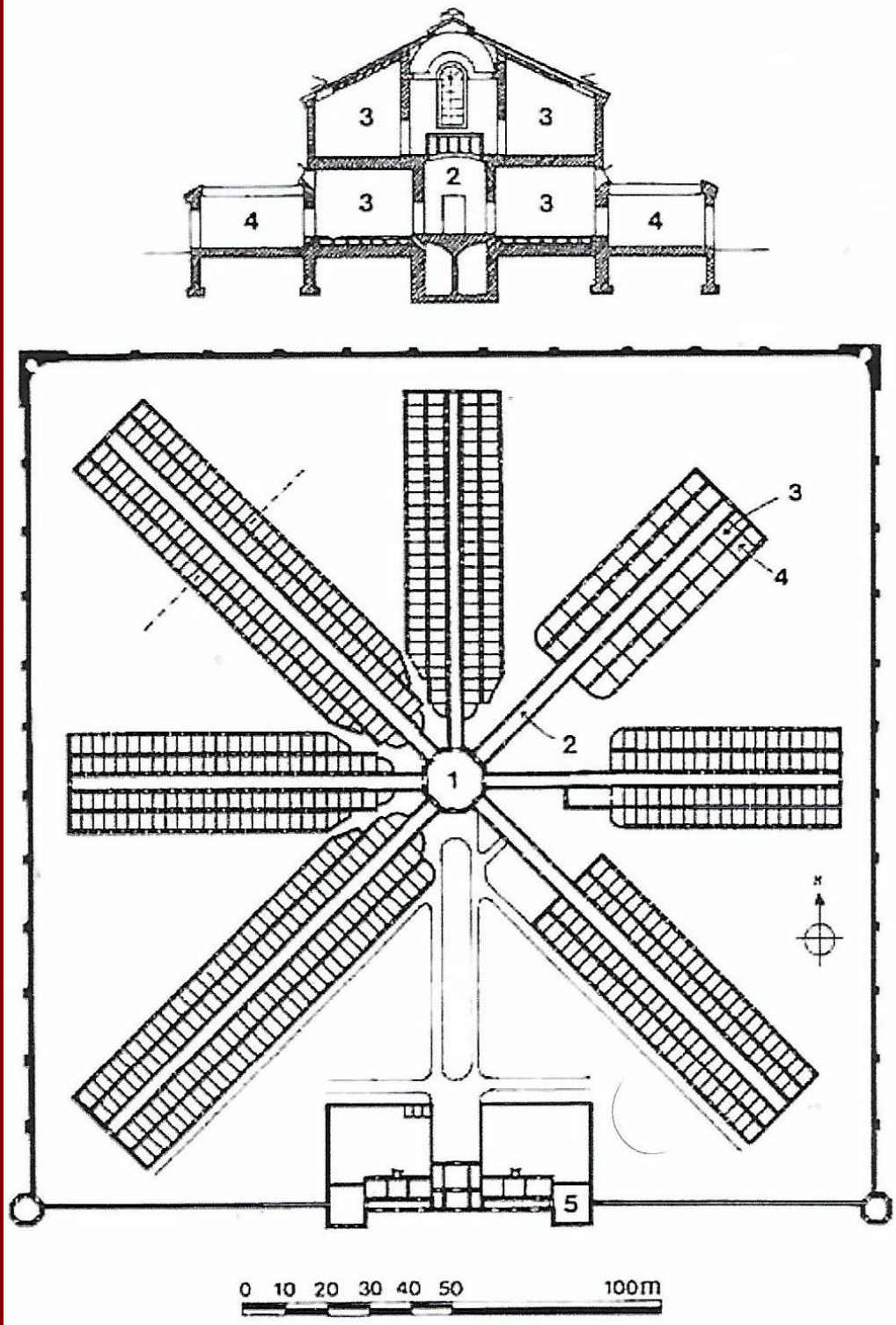
There were rectangular openings in the cell wall through which food and work materials could be passed to the prisoner, as well as peepholes for guards to observe prisoners without being seen. To minimize the opportunities for communication between inmates Haviland designed a basic flush toilet for each cell with individual pipes leading to a central sewer which he hoped would prevent the sending of messages between adjacent cells.[8]

Despite his efforts, prisoners were still able to communicate with each other and the flushing system had to be redesigned several times. Haviland remarked that he chose the design to promote "watching, convenience, economy, and ventilation".[17] Once construction of the prison was completed in 1836, it could house 450 prisoners.[18]

Haviland completed the architecture of the Eastern state penitentiary in 1836. Each cell was lit only by a single lighting source from either skylights or windows, which was considered the "Window of God" or "Eye of God". The church viewed imprisonment, usually in isolation, as an instrument that would modify sinful or disruptive behavior. The time spent in prison would help inmates reflect on their crimes committed, giving them the mission for redemption.

The Prison building: "Considered to be of Architectural significance".

EASTERN STATE PENITENTIARY
CHERRY HILL, PHILADELPHIA



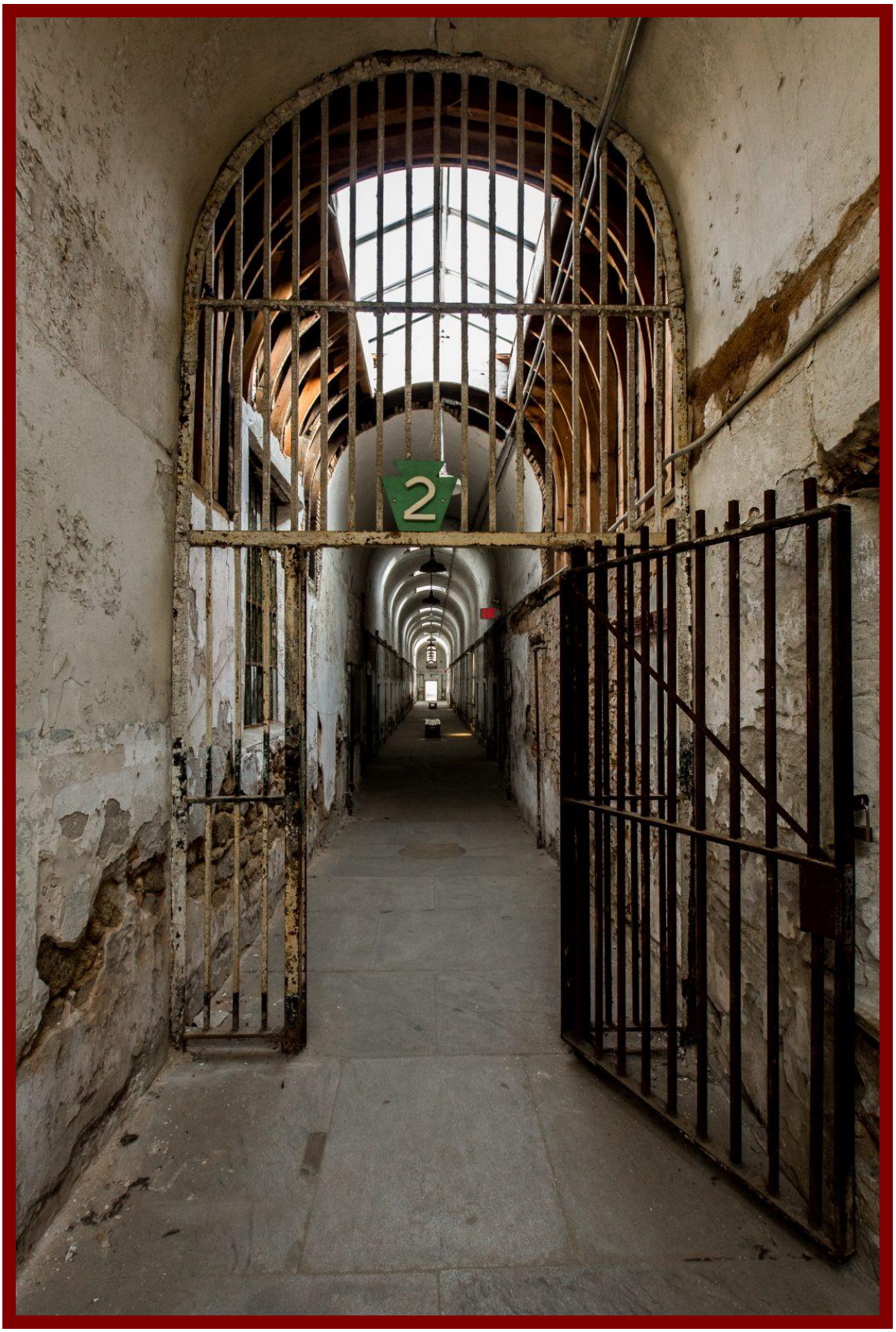
366 Cherry Hill prison (Eastern Penitentiary), Philadelphia, Pa.: section and plan; John Haviland, 1823–9. 1 warders' room; 2 corridor; 3 cells; 4 small courtyard; 5 heating ducts; 6 administration.

Section and Plan.

EASTERN STATE PENITENTIARY
CHERRY HILL, PHILADELPHIA

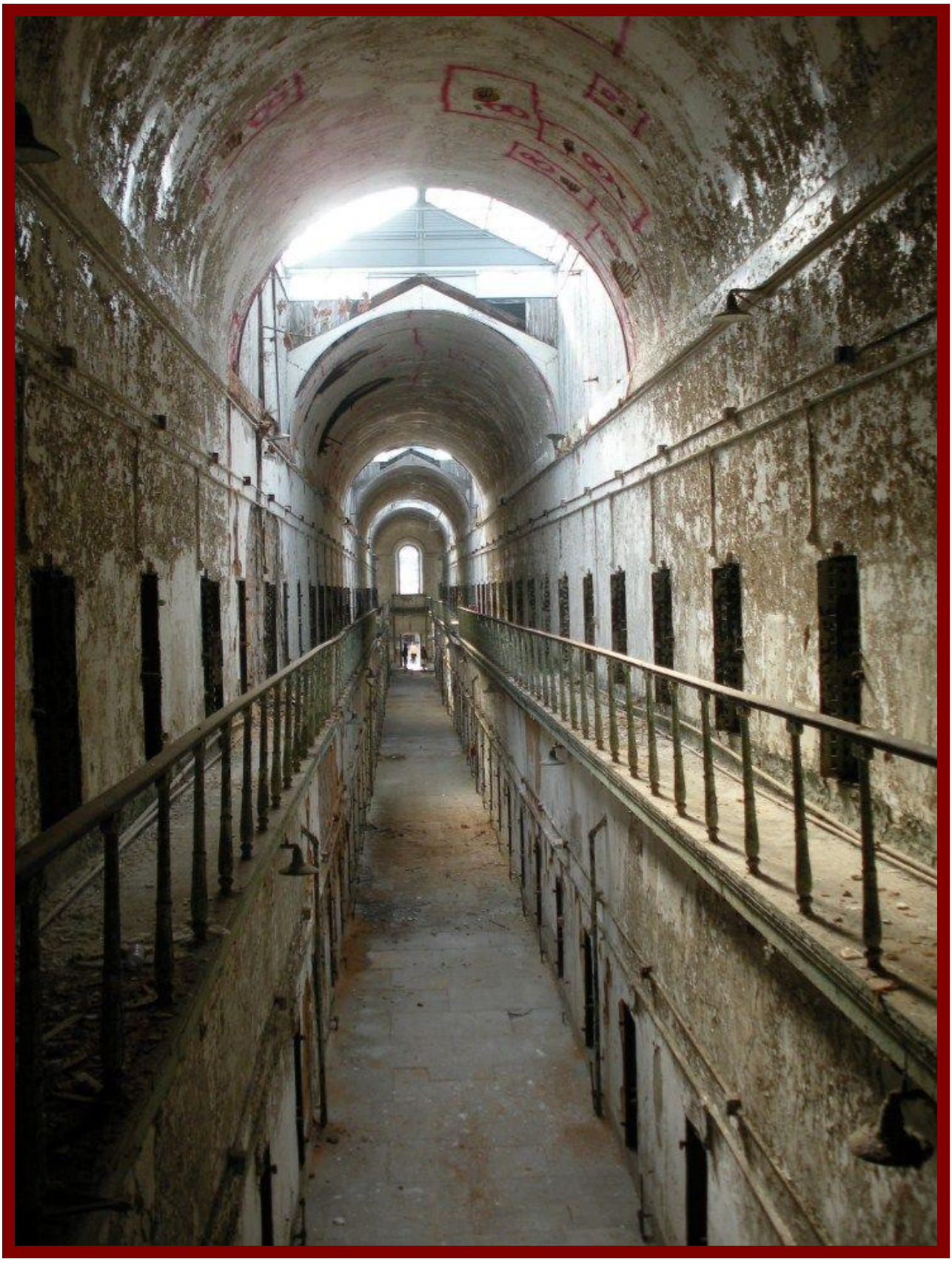
Now derelict and unused, but open for tourists.

EASTERN STATE PENITENTIARY
CHERRY HILL, PHILADELPHIA



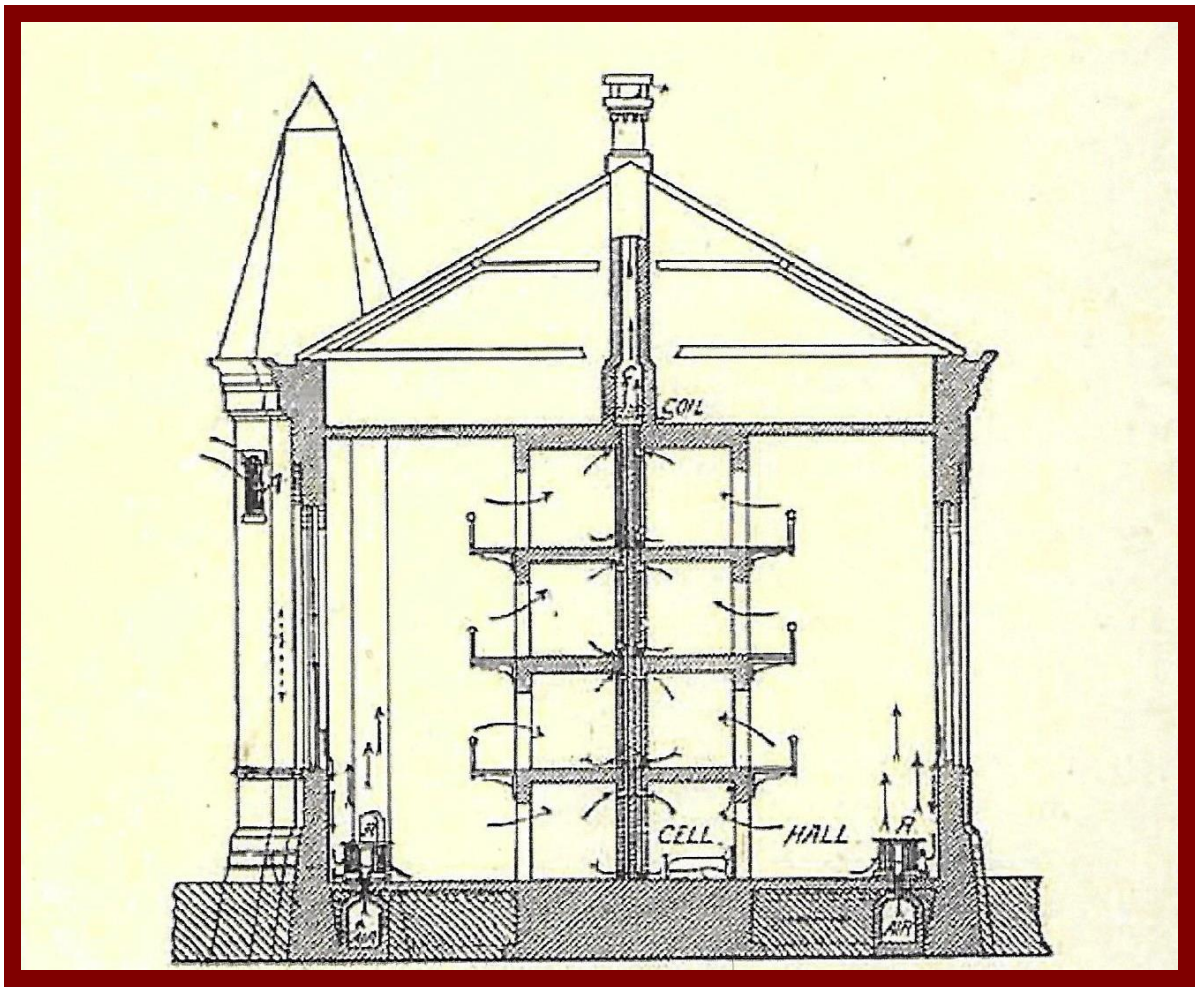
A crumbling corridor.

EASTERN STATE PENITENTIARY
CHERRY HILL, PHILADELPHIA



Remains of a radial cell wing.

ELMIRA REFORMATORY
NEW YORK STATE



Section showing heating and ventilating arrangements, The design is modelled on the Pentonville system (*The Sanitary Engineer*, 26 April 1883).

An early drawing.

ELMIRA REFORMATORY
NEW YORK STATE

"The Elmira Reformatory, or Penitentiary, is modelled on the Pentonville (or Auburn-the American equivalent) system where the cells are arranged in blocks of several tiers in height, this block being surrounded by an outer building. Between the walls of the outer building and the doors of the tiers of cells and their walkways is an open hall, stretching in height from the lowest to highest levels of the tiers of cells.

Heating is provided by round, vertical tube steam radiators set under the windows, with openings in the centre of the bases. In corresponding openings in the stone flags are set strong cast-iron pipes, with flanges built into the masonry. These pipes extend up through the openings in the bases of the radiators which they fit closely, connecting the fresh-air ducts with the radiators and preventing water (when washing the floors) from entering the ducts.

The number of concentric rows of tubes in the radiator is four. The two outer rows are separated from the inner pair by a galvanized sheet-iron partition, the object being to divide the inside rows from the outer ones so as to make each radiator practically an indirect heater, the air from the duct coming only in contact with the inner rows, while the outer rows warm the air already within the halls and give direct radiation.

Elmira has 500 cells, each with two 4x4-inch flues, one near the ceiling, the other in a cast-iron niche near the floor. The one near the ceiling is fitted with a heavy cast-iron frame built into the walls, while the lower one connects with the top of the "night-bucket" niche. The flues are separate their whole length, each terminating in and main exhaust chamber. There are no means of closing them. Steam coils of $1^1/_4$-inch tubes within the exhaust chamber extend over the upper ends of all the flues, providing heat-assisted ventilation This exhaust air is discharged through a series of roof chimneys (aspirators).

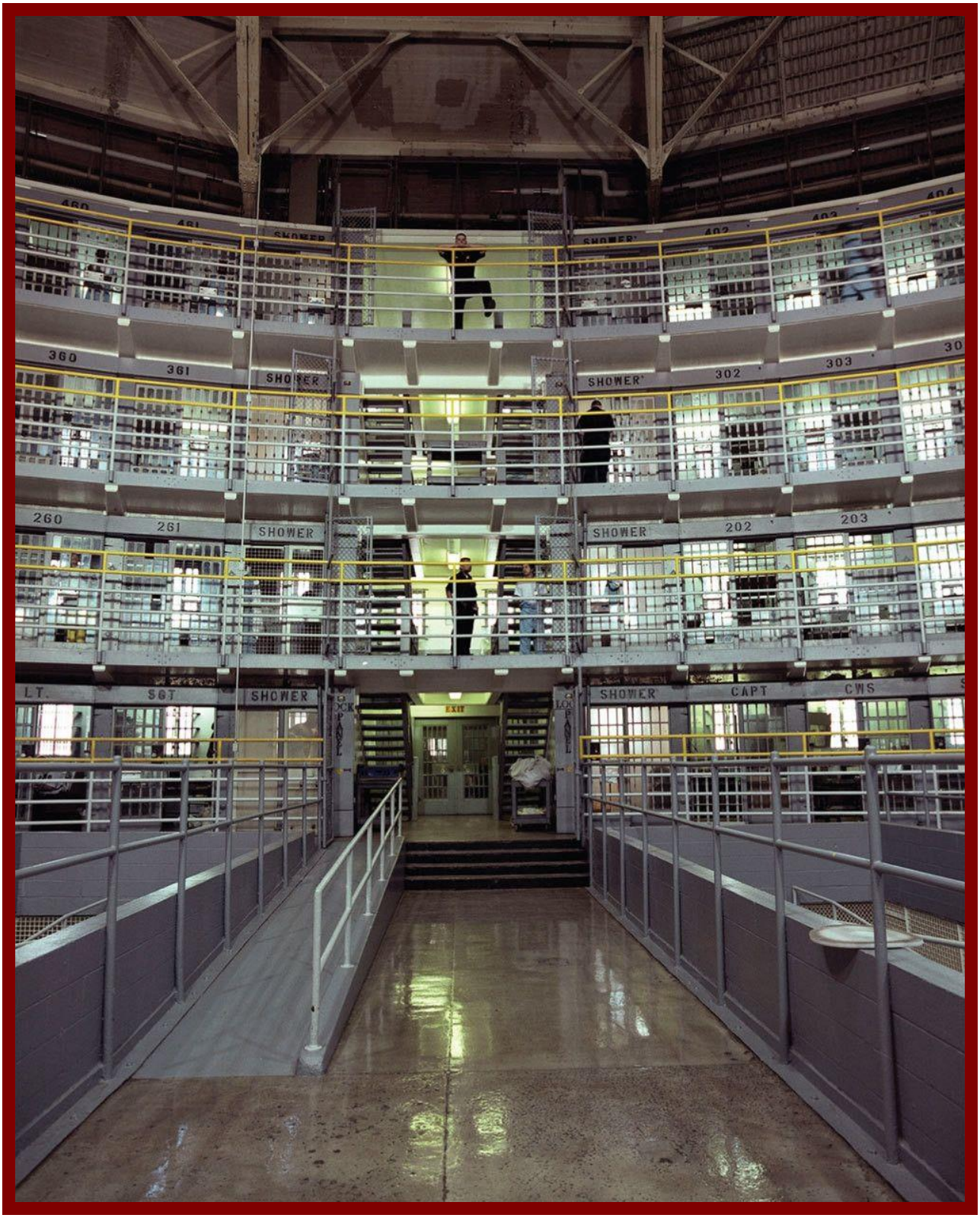
Fresh air is drawn in near the top of a ventilation intake tower (left on drawing) and descends to basement tunnels where it is discharged upwards through the under-window radiators into the hall, being drawn through the cells by the action of the independent flues and out through the aspirator. The aspirator steam coils are on a separate steam system to enable summer ventilation where the radiator system is off. It is recorded that this system caused difficulties in cell temperature control, either overheating the upper cells, or underheating the lower ones."

STATEVILLE PRISON, CREST HILL
NEAR CHICAGO, ILLINOIS

Opened 1925, 1500 inmates. The exercise yard with circular prison blocks behind.

Central guard tower in open internal space surrounded by tiers of cells.

STATEVILLE PRISON, CREST HILL
NEAR CHICAGO, ILLINOIS



Built on the Panopticon system, a design for prisons proposed by the British Prison Reformer Jeremy Bentham.

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Includes **Auburn, Eastern State,** and many others such as Folsom, Leavenworth, Sing Sing.