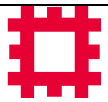

ENGLISH HERITAGE

THEMATIC SURVEY OF ENGLISH NAVAL DOCKYARDS
SUMMARY REPORT
THEMATIC LISTING PROGRAMME

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PREFACE

i. The layout of the Report

This Report consists of three sections, broken up so that users with different requirements may find information more easily. The Preface explains the previous history of conservation in the Royal Naval dockyards, and the changes which necessitated a thorough updating of the conservation regime prevailing up until now. It explains the procedure by which the dockyards were reassessed, and the geographical and typological limits to this survey.

The importance of the Royal dockyards is such that the first section of the Report has been devoted to a historical summary to establish their position as places of profound historical consequence, reflective of crucial developments in British history. The next sections consider firstly how the dockyards fit within nests of defensive works dating back to the Restoration, and how this affected them, and then the special urban development which accompanied the growth of the yards as regional centres of employment and economic activity.

In the third section, the Report examines the dockyards' specific importance as manufacturing establishments and centres of innovation; the contribution of engineers to the nineteenth century revolution in the work of the yards; relates the yard to the major phases of naval engineering; and evaluates the contribution which the dockyards made to one particular important aspect of constructional history, the evolution of structural iron.

The introduction to Section Four, which is devoted to an assessment of the surviving dockyard buildings, summarises the results of the Thematic Review. Many people involved in the work of the dockyards, or interested in the conservation of the historic environment, will be uncertain about the overall situation both before the Review, and how the recommendations will affect it. The criteria developed for assessing the dockyards are outlined. The maps which preface this section should be used for guidance only: annotated Ordnance Survey maps and full building descriptions have been included separately, and are not part of this report. Lists of recommended structures are appended to the end of this report.

In Section Four, which is the main body of the Report, the historic buildings are broken down into eight typological groups. These correspond to the main chapters in Jonathan Coad's book *The Royal Dockyards, 1690-1850*, where further information on the history of individual buildings can be found there without difficulty. In each section a list of the pertinent buildings recommended by the Review, broken down into the different yards, precedes a detailed discussion of the principal buildings and their development. This is followed by a brief assessment of their relative importance within the yards, as well their

position in a national and, in the most significant cases, an international context.

In this Report the recommended grades of listing are given in brackets; new listings or regrading are in bold, and NL means "not recommended" for Listing.

ii. Background to the Review

Serious research into the history of royal naval dockyards began in the 1960s, initially as an exercise intended to inform the Scheduling of naval dockyard buildings and structures which took place at the end of the decade. Scheduling of the most important monuments was considered more appropriate order to maintain the restricted access necessary to active defence sites.

In the 1980s, Government policy toward the naval dockyards changed, and as part of the Options for Change review of the country's defence establishment, a programme of closure and privatisation was undertaken. One of the profound consequences of this was that for this first time in four centuries the naval dockyards were to become much more widely accessible. It was no longer felt that a regime of conservation solely by Schedule of Historic Monuments was necessarily the most appropriate or the most effective, and a more structured and flexible system could be developed.

In 1991, English Heritage was asked to provide advice concerning the listing of structures within the dockyards at Portsmouth and Plymouth. It was considered, however, that any proposed new listings should rest upon a substantial body of research, not only into specific dockyard buildings but also their wider historical, architectural and archaeological context; it was also considered that a review of royal naval dockyards should inform the listing gradings (I, II* or II) for currently scheduled buildings which should be more appropriately managed under the listing legislation.

Dry docks and related harbour works form the exception to this general rule and it was considered that the most suitable options for management could be resolved by a careful appraisal during the consultation stage.

iii. Methodology

To achieve a consistent evaluation of the Dockyards, the Review was based on comprehensive listing surveys of each of the three major naval dockyards. At Chatham, Portsmouth and Plymouth they were carried out as part of larger Reviews of each District, from which the Dockyards were excepted when the new recommendations went to the Department of National Heritage in 1995/96. A draft list was submitted to the authorities at Portsmouth and Plymouth.

The most important operational aspects of the Review have been to establish what should be the most appropriate conservation regime, between Scheduling, listing and conservation area status, and to identify currently unprotected structures which were considered to be potential candidates for addition to the list. Where listing was the best approach, a substantial effort was made to determine the proper level of grade to reflect the national importance of the buildings and the international significance of the dockyards.

The assessment of the naval dockyard buildings has been heavily reliant on the large body of published research by Jonathan Coad. It has been supplemented by some primary investigation of the naval records, while a particular group of buildings, which fell outside the historical boundary (1850) of Coad's work into the era of the steam navy, were chosen for additional documentary investigation (see Sources section below).
This report provides the context within which the significance of the buildings on the royal naval yards at Sheerness, Portland, Portsmouth and Plymouth. Detailed maps and descriptions are supplied separately.

This Review has been devised and supervised by Jeremy Lake. The fieldwork and this Report has been written by James Douet and Jeremy Lake and the documentary research by David Evans and James Douet.

iv. The extent of the survey

The Royal Dockyards in England

Fieldwork has been limited to the dockyards at Portsmouth, Devonport (Plymouth), Chatham, Sheerness and Portland, and the former victualling yards at Gosport and Stonehouse (Plymouth). At the smaller yards abandoned during the nineteenth century, Deptford, Woolwich and Harwich, no features of interest, apart from those already protected, have survived. Pembroke and Rosyth are both bases which, located outside English Heritage's area, have been excluded from the recommendations resulting from this survey. However, surviving structures at the Welsh yard, particularly the slips and the officers' housing have been taken into account during the assessment of the major yards. Rosyth was begun just before the First World War, and falls geographically outside the remit of this Report. Copies will nevertheless be circulated to both Cadw and Historic Scotland.

Naval barracks and hospitals have been assessed as part of the survey of barracks buildings which has recently been completed by English Heritage (fieldworker and researcher James Douet) in consultation with the Ministry of Defence.

Naval ordnance yards

The Ordnance Yard at Morice Yard is such an integral feature of the dockyard complex at Devonport that it has been included as part of this Review, as has the Gun Wharf at Portsmouth. The ordnance depots at Priddy's Hard and Bull Point, to the west and north respectively of the dockyards at Portsmouth and Plymouth, have not been included as detailed investigation of Priddy's Hard by the Local Authority is due to be completed by the spring, while the facilities at Bull Point have not yet been researched. Both will shortly be assessed within the same broad national and typological context, when this work is available.

1.0 CHRONOLOGICAL SUMMARY

1.1 Outline

The buildings of the royal dockyards are a manifestation of three hundred years of building, equipping and maintaining the fleets of the Royal Navy. Within the yards can be found examples of almost all the types of buildings, more or less specialised in their design, which have been used over this period. They illustrate the central work of ship building and repair, as well as the numerous other crafts and trades which sustained the fleet; the vast and ever-growing appetite which the navy had for stores and equipment, as well as for food, ordnance and ammunition; the navy's own considerable manufacturing capacity inside the yards, especially of rope; and in the series of remarkably fine terrace houses of its officers, the domestic life of the yards.

Developments in ship building can be clearly seen in the docks and slips, particularly the increasing size of the navy's ships, the move to building wooden ships under the cover of great roofs, to steam-powered and then all-metal ships. Moreover, there are notable instances manifested in the dockyard buildings of developments in the history of building and manufacturing technology of international importance, notably in fireproof and metal construction, the application of steam power to manufacturing, and of standardised mass production. This is to say nothing of the historical and architectural interest of buildings dating back to the seventeenth century, both polite and industrial architecture, and of their special value in the context of places of profound national consequence.

The location and relative size of the royal yards have altered with the shifts in British naval strategic geography, and as shipbuilding technology has advanced. In the seventeenth century, Portsmouth apart, the dockyards were concentrated in the Thames estuary at Harwich, upstream at Deptford and Woolwich, at Chatham, near the mouth of the Medway, and further down the river at Sheerness. Devonport opened at the very end of the seventeenth century and Harwich closed soon after.

During the eighteenth century the relative importance of the yards shifted round to the south coast. By the nineteenth century, the two south coast yards of Devonport and Portsmouth were predominant, Chatham was used mainly for building work, while Sheerness, though rebuilt in the 1830s, remained stunted through the restrictions of its peninsular site. The Thames yards closed in the nineteenth century, Woolwich after a brief revival as a specialist steam facility while the River Thames was still a centre of marine engineering and machine tool production. Pembroke opened as a building yard in the 1820s but ceased to work within a hundred years; Rosyth, in Scotland, the last new royal dockyard

and also built for ship building, was begun in the first decade of the present century.

There were victualling yards and ordnance stores near each of the main dockyards. In the nineteenth century the work of the victualling yards, which included milling and baking on a large industrial scale as well as great storehouses, was concentrated at Deptford, Gosport and Stonehouse. The dockyard ordnance yards were primarily for storage of ordnance and powder unloaded from ships in ordinary, and for equipping those about to sail. As well as the ordnance yards at Chatham, Portsmouth and the Morice Yard at Devonport, there were stores at Upnor Castle across the Medway from Chatham, and Priddy's Hard opposite Portsmouth, as well as in the main depots at the Tower, the Royal Arsenal, Woolwich, and the large magazines out on the Thames estuary at Purfleet in Essex.

1.2 The major phases of development

War, administrative reform and technological development have been the chief influences over the way in which the dockyards have developed, and with occasional catastrophic fires, they have provided the timing of the major new phases of constructions. These are summarised below. Though the dockyards themselves trace their history back to Henry VII, the earliest structures are no earlier than the end of the seventeenth century, and we shall start this introduction to the main phases of the yards' development from there.

1690-1713

The Admiralty became a permanent bureaucracy in the last years of the seventeenth century, with the First Lord a member of the cabinet. The Admiralty retained control over the handling of the fleet at sea and of naval personnel, but devolved substantial sections of its administrative work to the Navy Board, who controlled the dockyards and ships in ordinary, to the Victualling Board, and to the Sick and Hurt Board. Ordnance for both the services was organised by the Ordnance Board.

In 1690 a site to the west of Plymouth was chosen for a completely new dockyard, providing fleet services in the Western Approaches. It was completed by the end of the decade, and consisted of a dry dock, large store, smithery, ropery and large terrace of houses for the yard officers. Its completion marked the end of this period of dockyard construction.

1713-1760

After the Peace of Utrecht in 1713, a period of little activity followed. Despite a modest reorganisation of the centre of Chatham, this was a period without major building works or reorganisation. The most significant changes were at Chatham, where a new officers' terrace, store, sail loft and guard houses were built in the 1720s, influenced stylistically by

the Ordnance Board's enormous new warehouse on its neighbouring Yard. By the mid eighteenth century Chatham had slipped from its former pre-eminence, and the centre of gravity of the country's naval works had shifted to the south coast.

1760-1815

The Seven Years War confirmed this shift, and precipitated a significant change in the planning of dockyard works. The effectiveness of the navy's administration of the dockyards can be taken from the conclusion that during the eighteenth century 'Britain prevailed by outbuilding her opponents'[1].

Successively under the First Lords of the Admiralty Anson, Egmont and Sandwich, policies of long-term reconstruction were laid down by the Admiralty, based on plans for the efficient layout of the separate parts of the yards, and programmes of costed works. These involved an unprecedented amount of rebuilding, which absorbed a very large proportion of the nation's defence expenditure. Work was concentrated at Plymouth and Portsmouth. At Portsmouth, the ropery, docks, and much of the yard's storage capacity dates from this period. At Plymouth, there were new smitheries and stores and the ropery was rebuilt to allow more effective operation of the yard. A lesser rebuilding followed at Chatham after Lord Sandwich reassessed its role, and it became the main building yard for the navy from the 1770s. There the most significant addition was the two huge warehouses which front the southern end of the quay, followed by the new ropewalk that was built to its rear.

To the continuing rebuilding work was added in the 1790s a period of sharp technological development, chiefly associated with Sir Samuel Bentham's reign from 1795 to 1807 as Inspector General of Naval Works, with a brief from the Admiralty to modernise operations in the dockyards. Bentham is associated with several highly innovative improvements to mechanised sawing and woodworking, the introduction of steam engines, and the first dockyard buildings made stronger and more fire resistant through cast iron.

1815-1889

The technical innovations of the war years were only a foretaste of what was to follow. The dockyards became geared to a technological race with the French, and to the incorporation of new industrial techniques and processes. It used to be thought that the Royal Navy had been slow to adapt in this respect, from a combination of post-Trafalgar confidence, and conservatism. The modern attitude is more sympathetic, suggesting that in view of the unproven nature of many technical 'advances', and the huge consequences which changes had for national security, the Navy Board and the Admiralty, which took over direct control of the dockyards in 1832, proceeded with a philosophy which was 'conservative but rational'.

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[1] *Oxford History of the Royal Navy*, 1995, p125

For a brief period from 1831 the Navy's steam facility was concentrated at Woolwich, close to the national centre of marine steam engineering, the commercial yards on the Thames. As a direct consequence of concern at French progress, in 1843-4 land was procured for two massive steam engine-powered engineering factories, with related basins, at Portsmouth and at Keyham, just north of the old Morice Ordnance Yard at Devonport. By the time that the watershed HMS Warrior had been launched from a private yard in 1860, these two yards had impressive capacity for fitting and servicing the growing steam-powered iron fleet. Chatham was similarly expanded to the north with the new workshops re-using the former iron slip covers dismantled and moved from Woolwich, when it closed in 1869.

A further consequence of the transition to a steam-driven fleet was the need for coaling stations around the coast. Their location was determined by both the coal-carrying capacity of the ships of the mid-century, and strategic concerns. These combined to prompt the construction from 1847 of the secure anchorage and coaling facility at Portland, conveniently equidistant between Portsmouth and Plymouth, and facing the large French naval dockyard at Cherbourg.

A third major programme of building during this period saw the complete overhaul of the Victualling Boards operation at Portsmouth and Plymouth - Deptford had been rebuilt after a fire in 1762 - and the construction of two very substantial new facilities nearby. A particular initiative of the future King William IV, both establishments were built on an unprecedentedly regal scale, and named after their royal initiator.

1889-1914

Such confidence in the supremacy of British ships as the vanquishing of the French technological threat engendered lasted a mere twenty years. By 1889 renewed anxieties over British isolation in Europe prompted further shipbuilding efforts, and a commensurate expansion and reorganisation of the dockyards to cope with the additional work. All three main yards were extended to the north with new basins and docks. From the 1900s, renewed naval rivalry with Germany and Russia, as well as the French, forced continued renewal of the fleet with improved vessels, and huge investment, under a series of Naval Loans, in the dockyards. Lord Fisher took over the Admiralty in 1904 and HMS Dreadnought was built at the new Keyham extension to Devonport the following year. Her size set a new threshold for British naval docks, and her oil-powered engines spelt the end of coaling stations and their replacement by oiling depots. In terms of the dockyard structures, however, these revolutions in shipbuilding had limited impact beyond the vast new granite-lined locks, docks and basins. The late-Victorian and Edwardian navy was largely serviced by the infrastructure which was in place at the time of HMS Warrior.

2.0 GEOGRAPHICAL SETTING

2.1 Naval dockyards and their fortifications

Further reflection of the royal yards' fundamental strategic importance can be found in their role as foci of historical as well as geographical layers of defensive works. In this respect they rank high above those of largely civil ports such as Dover, Hull and Liverpool. The fact that the Portsmouth and Plymouth regions have the finest sequences of fortifications in the country is a direct consequence of their prime strategic importance.

From Tudor times until the Second World War, the Royal Navy has been considered as Britain's first line of defence. The Government were made only too aware of the vulnerability of the dockyards to attack during the Dutch Wars of the mid 17th century, when the fleet at Chatham was attacked and the partially completed fort and dockyard at Sheerness destroyed during the raid by de Ruyter in 1667. All the major yards came to be situated within the most heavily defended towns in the country which, more than any others in England, resembled the fortified towns of Europe.

The artillery revolution of the mid 19th century, along with the development of steam-powered warships and ironclads, initiated a period of change which rendered much of the coastal crust of defence which had developed around these dockyards redundant; experience in the Crimean and American Civil Wars proved that such fortifications merely delayed the eventual and inevitable destruction of ships at anchor. Dockyards would be rendered helpless once an enemy equipped with shell-firing guns had put ashore and denied main base facilities to the fleet, a fact which spurred the Admiralty to hasten the development of the steam navy and, after the Crimean debacle and a perceived threat from the French, the War Office to construct rings of mutually-defensible fortifications around the principal dockyard towns.

In due course, dockyards became targets for attack from moored mines, torpedoes and the air: in order to deter and react to this threat, an increasingly specialised variety of measures were taken to provide an envelope of protection around these bases.

2.2 Naval dockyards and their local settlements

These fortifications, and in particular the mid eighteenth century bastioned lines which protected Chatham, Portsmouth, Sheerness and Plymouth, contributed strongly to the distinctive character of the areas around the docks. Each spawned sizeable settlements for the yard workforce and their families. Portsea grew up around the Portsmouth dockyard Lines, as did the town of Devonport, until the nineteenth century known simply as

Devonport Dock. Chatham and Brompton were distinct naval and military settlements separated from the older town of Rochester to the south. In contrast Woolwich dockyard, within the defence umbrella of London, was not encircled by defensive earthworks, and the town developed a different urban morphology to that characteristic of the other dockyard settlements.

These towns and their economies were largely dependent on the naval yards, as were all the secondary employment associated with suppliers, traders, and sub-contractors, and service industries such as inns and hotels. Their trade cycles of prosperity and decay differed from the rest of the country, being much more closely dependent upon the activity of the navy in war and peace. When Portsmouth began taking on skilled engineering craftsmen in the 1830s, for instance, there was nothing in the way of a local engineering industry from which the yard could attract workers, and it had to look in London to find suitable men.

In Plymouth, the considerable rebuilding and expansion of the dockyard from the 1760s was reflected in the development of Stonehouse as a residential area for naval officers and of Devonport for the workforce. In nineteenth century Portsmouth, shipbuilding, metalworking and engineering (concentrated in the naval yard) accounted for between 33% and 44% of industrial employment, a figure which if extrapolated from demographic statistics into households and accommodation can clearly be seen to have had a critical impact upon the topography of the town.

In none of these towns do we see the active participation of the Navy Board in providing accommodation for the workforce. This was in strong contrast to the behaviour of local entrepeneurs in speculative investment in housing which characterised industrial centres such as Manchester and Sheffield, for example. There are isolated examples of industrial housing for shipbuilding workers, like the fine tenement flats erected at Barrow-in-Furness to the designs of Paley and Austin, a celebrated Lancashire firm, or on the continent, the similar but later development at Zeebrugge.

Only at Sheerness, compelled by the need to attract labour to a feverish and insanitary location, did the Navy Board provide accommodation for its workforce, though no more than the casemates of de Gomme's 17th century fort, and the hulks of old warships used to stabilise the Medway mud. The dockyard settlement of Blue Town which grew up outside the Lines of the Ordnance Board's land was probably typical also of Devonport Dock and Portsea. Early private housing was by dock workers, on a self-help basis, using 'chips' taken from the yard. Investment was deterred by the possibility that the Navy Board might decide to extend the yard, or the Ordnance Board to realigned the defences. The limited Government accommodation at Sheerness only lasted until the 1820s, when the docks were

finally rebuilt, the hulks cleared, and new private housing began to be established in Blue and the neighbouring Mile Towns.[2]

2.3 Military Accommodation

As well as the directly and indirectly employed population of the yards, the dockyard towns were periodically swollen by soldiers and Marines entering and leaving the country, especially during war time. All the major yards were also important embarkation points. Large Royal Marines' barracks had to be provided in Portsmouth, Chatham and Plymouth from the mid eighteenth century, largely because of disciplinary problems in the town - a considerable time before such buildings were deemed appropriate for the army or for the militia. Apart from the large camps like Aldershot and Colchester, the dockyard towns remained the major concentrations of barrack accommodation in England into the twentieth century.

[2]Harris, *Archaeologia Cantiana* p259-266

3.0 THE INDUSTRIAL REVOLUTION

The primacy of British naval power from the later eighteenth century, and its importance in buttressing the rise of British mercantile wealth, underlines the importance of the dockyards in an international context. This importance is reinforced by the Royal Navy's additional position as a both a consumer and manufacturer on a scale hitherto unparalleled anywhere in the world.

3.1 The scale of industrial activity

The size of the royal dockyards, and the scale of operations conducted within them, impressed visitors from the early 18th century to the Victorian era. Visiting Chatham in the 1720s, Daniel Defoe remarked that "the streets of warehouses and storehouses for laying up naval treasure are the largest in dimension and the most in number, that are anywhere to be seen in the world".[3] A visitor to Portsmouth in 1835 wrote that "the efforts of human industry seem too weak and impotent to achieve the important works that are here displayed".[1]

The labour forces employed within the royal dockyards dwarfed those found at comparable locations in other industries throughout the period of this report. The contrast between private sector industries and the royal yards was especially extreme in the eighteenth century and in the first decades of the nineteenth. 15,648 shipyard workers were employed in 1814 and Portsmouth dockyard never employed fewer than 2,000 men (and in the 1860s over 5,000. Even the largest textile mills of this time, like McConnell and Kennedy's Sedgwick Mill in Manchester, only employed about a 1,000, many of them children. The roperies at Chatham and Plymouth employed 221 and 232 men respectively in 1821, a figure comparable with the numbers employed in an average Manchester textile mill of the period (see Section Five: Roperies). The vast scale of this government-run enterprise dwarfed that of commercial shipbuilding, Portsmouth employing 1,330 in 1813 against the largest private yard, Perry and Walls at Blackwall on the Thames, which employed 119 shipwrights in 1804. A return to Parliament in 1804 revealed that the royal yards employed no less than one third of all the 5,100 British shipwrights available.[4]

The largest comparable integrated manufacturing complex in Britain is another government-owned site associated with national defence, the Royal Arsenal at Woolwich, built up from the late 17th century. One has to look to the Continent to find anything of a comparable size -invariably state-owned, and associated with armaments production. Equivalent, though

[3]quoted in Coad J, *The Royal Dockyards, 1690-1850*, Aldershot, 1989, p4

[4]Morris p97

not larger, were the military/industrial complexes of Britain's overseas allies and rivals from the sixteenth century onwards. From the eighteenth century onwards, the naval dockyards in Britain were the largest manufacturing complexes in Europe.

European naval dockyards

For none of the Great Powers of continental Europe, with the exception of Venice, was the strategic benefit weighted so heavily toward naval as against military strength as it was in Britain. As a consequence, proportionally greater resources were directed toward constructing the fleet and keeping it at sea, and into the crucial dockyards on which naval power rested. Although the subject lacks a systematic study, the military and industrial significance of the British yards needs to be considered by comparison with their most direct parallels, the naval yards of Europe's continental powers.

The seventeenth century Dutch navy was based at Rotterdam, but the town declined in importance as a naval dockyard with the end of Anglo-Dutch rivalry after the accession of William of Orange to the British thrown in 1688. The Arsenale in Venice sustained the Venetian fleet, and remains a complex of enormous historic importance, but it did not develop after the seventeenth century in the way that the British yards grew and were adapted for changing ship design. Moreover Mediterranean shipbuilding was different to that in the northern seas. The Arsenale, the Drassanes in Barcelona, and the French Mediterranean yard at Toulon involved large covered masonry shipbuilding halls on wide arches, capable of accommodating the shallower Mediterranean vessels of the time. These yards never developed the complexes of dry docks and wet basins on which British dockyards, coping with tidal ranges of five metres and more, depended. A nineteenth century visitor from America was amazed by the miles of closed docks at British harbours.

Brest and Toulon were the principal yards of Britain's main naval rival through the eighteenth and nineteenth centuries, France, although the development of the Mediterranean yard was stifled by its poor strategic position relative to the British Isles. France made colossal civil engineering efforts in the years before the Revolution to develop Cherbourg as a naval base, close to the British coast, but it was held back until the great protective breakwater with its three defensive forts was built under Napoleon. In the nineteenth century, France established two smaller yards in the Bay of Biscay at Lorient and Rochefort. None of these was developed on the scale or industrial capacity of the three main British yards.

The other important European naval yards were in the Baltic. Kronstadt, near St Petersburg, was the base for the northern Russian fleet. Karlskrona was a very large Swedish naval base, which was rebuilt from the 1770s for Gustav III under the English master shipwright John Frederick Chapman. Samuel Bentham went there to study covered shipbuilding before it

been tried in Britain. The Prussian navy was serviced from Danzig, until a new building yard was started at Wilhelmshafen in 1860. Kiel, a German port after the annexation of Schleswig-Holstein in 1865, was developed as the main German dockyard following the establishment of the Imperial Navy in 1867. As such it has a much briefer history than all the British examples.

3.2 Planning and logistics

In understanding and appreciating the dockyards' historical importance, it is important to examine how they were ordered. Separated by gates and lodges from the outside world, the naval dockyards can be defined as very large, integrated factories, where various forms of manufacture associated with shipbuilding, ship repair and servicing were carried out, powered in turn by men, horses, steam, hydraulics and ultimately electricity.

The basic elements of flow production techniques can be seen in the yards' layout, in the placing of shipbuilding, refitting, storage and roperies through successive phases of rebuilding, and in the planning of individual buildings; the latter is most clearly apparent in the great ropery complexes built from the 1760s in Portsmouth, Chatham and Plymouth, where the raw material passes consecutively through buildings for storage, hatchelling, spinning, tarring, and laying into finished rope. (See Section 4.3)

The roperies were one of the defining factors in the organisation of the yards. With the great length of the rope walk acting as a major potential impediment to movement around the yard, Lord Sandwich's replanning of moved them to a convenient location to one side. At Portsmouth, unfortunately, two successive fires in the space of ten years forced the Navy Board to abandon the prepared plan, and build the new double ropewalk in the old position, diagonally across the middle of the yard. Ironically, it was intended for the mudflats to the north which, within seventy years, was to become the new steam yard.

The position of the dockyards with respect to the associated processes in shipbuilding and fleet maintenance can also be seen in their layout. At a convenient distance were the Ordnance Yards, where guns and powder could be unloaded, cleaned and prepared, and stored while ships were in ordinary. At Chatham, the Vanbrugh-influenced Ordnance Board built a colossal store in 1717, in terms of capacity a hundred years ahead of its time. Powder was kept across the Medway in the old Upnor Castle. At the same time a new gunwharf called Morice Yard was built just to the north of the new Plymouth dockyard, although close enough for the magazine to have to be moved further away in 1744. Powder storage was moved again up the Hamoaze first to Keyham, and finally in the mid nineteenth century to Bull Point on the Tamar. The Portsmouth Ordnance Yard also moved as the dockyard grew and the town with it. It first doubled in size in the 1770s onto the New Gun Wharf, and then moved across the harbour to Priddy's Hard, where it was accessible but a safe

distance away from the dockyard.

Victualling the fleet was the other important subsidiary activity which required substantial infrastructure close to the fleet bases, so that ships could be conveniently stocked for their voyage. Ships from the Medway yards were generally met by tenders from Deptford, close to the London meat, fruit and vegetable markets, or the Sheerness store. But the south coast yards had large Victualling Yards close by. These were intended to accommodate processing operations as well as for storage, producing principally beer, replaced from the 1830s by rum, biscuit, and meat. They were both rebuilt in the 1820s and 30s on empty, or in the case of Plymouth, expensively cleared sites. Their layout demonstrates an interest in efficient planning, but also an overriding concern to create a formal Neo-Classical order which is unique in British industry.

3.3 Dockyard engineers

The Industrial Revolution impacted comparatively late on both commercial shipbuilding, and on the royal dockyards, compared with the lead sectors of textiles, metal working and mining. However, accelerating developments in naval architecture and marine engineering in the late Georgian period required a reluctant Navy Board to admit the influence of outside experts, to assimilate personnel trained in the commercial world, and then to draw on a branch of the army, the Royal Engineers, in order to transform the dockyards from a highly organised but craft-based organisation, into integrated industrial works.

The first breach in this respect of the dockyards self-containedness was the appointment of Samuel Bentham as Inspector General. Some of his proposals and improvements were to work he carried out himself. The creation to the enlarged Great Basin at Portsmouth, and the new (now the Old) smithery in the South Yard at Devonport, show the range of his effectiveness, while the more conservative planning of other buildings built during his tenure, such as the smithery at Chatham, reflect the yard officers characteristically resisting his influence. His other contribution was in introducing outsiders. The most significant of these was Marc Brunel, whose Portsmouth block mills and Chatham saw mills are discussed in their relevant sections, and Henry Maudslay, who refined and built Brunel's revolutionary machine tools.

The Admiralty became increasingly mindful of the need to keep abreast of developments in the private sector. Private establishments were carefully studied, in order that the royal dockyards were equipped with the latest technology and worked to an optimum of efficiency. Simon Goodrich, appointed as the Mechanist under Bentham in 1799, spent a considerable amount of time touring the country and studying machinery. After a visit to the Crewe works of the London and North-Western Railway in 1848, in order to compare results with the new Steam Factory at Portsmouth, the Admiralty noted that 'A Private

Establishment ... ought not to be better conducted than a large Factory in one of Her Majesty's Dockyards and My Lords rely upon your exertions to bring matters to a similar issue'. In 1851 (when the opening of Plymouth dock's new steam factory at Keyham was in prospect) officers visiting the Great Exhibition were asked 'to bring to the notice of the several Superintendents... such inventions, new machinery, tools &c as they consider to be improvements (to those) now in use, and which might be introduced with advantage into the National Establishments'.[5]

Another important outside influence was that of the Rennies, John (died 1821) and his son, later Sir John. They were principally civil engineers, and famous for major dockworks such as Margate, and the Plymouth breakwater. Their most important civil engineering work in the royal dockyards was the reconstruction of Sheerness. In this they effectively assembled an enormous masonry platform over the estuarine mud on piles and inverted arches to support their re-planned yard.

Overlapping with Sheerness, and its opposite in terms of site conditions and engineering challenges, was the new victualling yard at Stonehouse (Plymouth), across the mouth of Stonehouse creek from the dockyard. The younger Rennie was responsible for the entire works here, from levelling the rocky promontory, laying it out to a formal grid, devising the machinery for the mill and bakery (he did the same for Deptford and Gosport), to the grand architectural expression of the main front.

The Navy Board was abolished in 1832, and G L Taylor, Holl's successor, resigned in 1837. From this date administration of the dockyards was taken over by Royal Engineer officers working at the Admiralty Works Department. The new system ensured the maintenance of a Supervising Engineer in each of the dockyards. These 'army architects', or as Pevsner dismissed one of them 'early Victorian sapper-surveyors', were at this time the only people with a systematic training in building - unlike the architectural profession. Their contribution to a wide range of improvements in both civil and military construction is today well recognised. Their impact on the dockyards was both rapid and profound. It can be summarised in two parts. Firstly their own buildings. These included the massive new steam basins and associated workshops at Woolwich (with Rennie Jnr), Portsmouth and Plymouth; the second generation of metal dock and slip covers, which presaged the railway sheds of the 1840 and 1850ss and worked through the highly significant development from braced construction to rigid portal framing; and a series of buildings of individual note such as the free-standing water tank and No 6 boat store at Portsmouth, the integrated smithery and sawmill at Devonport, and the Sheerness Boat Store (see Section 3.4).

[5]POR/P/43

The second influential aspect of the working habits of the Royal Engineers was in their cooperation with the private sector. Many of the projects referred to above were worked out in detail with iron founders and engineers such as Fox Henderson, Henry Grissell and George Baker. This cooperative practice has been called a 'collaborative genius'.[6] Undoubtedly it was at the heart of the rebuilding of the dockyards between 1840 and 1860 as logistically-efficent factories in the sense that we recognise them today.

[6]Weiler, J, 'Army Architects, the Royal Engineers and the development of building technology in the nineteenth century', unpublished PhD thesis, 1987, University of York. This carries a full discussion of the organisation of the Royal Engineers, and biographical details.

3.4 Traditional building and the evolution of structural iron

Building with timber

The methods of construction adopted on dockyard buildings in the late seventeenth and early eighteenth century fit into the mainstream of building techniques which were devised for large buildings such as theatres, chapels and larger houses: the need for clear working areas in buildings with more than one depth of span was commonly facilitated by placing wooden columns beneath the valleys - the quadrangular warehouses at Portsmouth, for example. Floor areas which could not so easily be interrupted by vertical columns were invariably spanned by queen-post trusses with raking side struts. The Mould Loft at Chatham (1753) is a good example, and the chapel at Chatham (1806-10) is another.

Many dockyard structures were intended to have a short life, and were frequently made up from reused materials including ships' timbers (the Chatham Mould Loft again). Timber weatherboarding was succeeded by corrugated iron from the 1830s, although the practice of reuse continued. Nos 5 and 7 Boathouses, Portsmouth, and especially the earlier Lower Boat Store at Chatham, are now rare examples of a building technique commonly associated with this building type.

By the mid 18th century, with a more planned programme of construction in the yards after Admiralty reforms, larger dockyard buildings, most notably warehouses and those housing processes which entailed the risk of fire, were commonly being constructed in brick and stone. Early preventative measures against fire included separating the corners of quadrangular buildings (such as the demolished Great Storehouse at Plymouth), and the storage of tar in brick-vaulted cellars, and the lining of timber beams in tin in the Ropery at Chatham in the 1770s (besides hemp, rope, tar and tallow were stored in this building).

Building with iron

The royal dockyards retain one of the best groups of structures in the country in which to trace the development of iron construction in the nineteenth century. This is a subject which deserves a systematic programme of research, but in view of the importance of iron framing to the assessment of dockyard buildings, an outline of the principal phases of development is given below.

Between the 1780s and 1850s, constructional systems went through a revolution. Iron went from being a highly experimental material forced on builders by particular specialised conditions, especially fire resistance, to a very widely employed one, for which the theoretical limits and possibilities had been established. Until the 1830s, its use was developed for primarily for textile mills, to meet the urgent need of mill owners to reduce losses through fire. From this time onwards the running was taken up by the nascent railway

industry which, particularly on bridges and wide-span sheds, forced the course and pace of development.

None of the different types of dockyard buildings, with one significant exception, went through anything approaching the evolutionary curve of either mills or railway bridges in these decades. Nor are there sufficient examples for such an evolution to be traced through the seven yards and roughly sixty structures in which iron was used. This wide spectrum covers isolated buildings erected as circumstances demanded, such as the new fireproof ropery at Devonport, or the tank for the fire main at Portsmouth, as well as the complete complexes of Sheerness and Pembroke dockyards, and the two victualling yards, Royal William and Royal Clarence, in which iron could be exploited in a more systematic manner. The exception referred to in the proceeding paragraph is in the very clearly traceable development of the wide-span slip cover. These do indeed provide a remarkably clear record of the evolution of skeletal metal structures, as has been laid out by Dr Sutherland.[7] At the end of our period the development of these two sets of dockyard buildings, one dispersed the other evolutionary, came together in the Sheerness Boat Store, among of the most significant buildings in constructional history. Here half a century of experimentation and calculation were resolved in what is recognised as the immediate precursor of the modern structural steel frame.

Opportunities for iron construction

During the first two decades of the nineteenth century, the building opportunities to use the new materials, cast and the more labour-intensive and costly wrought iron, were isolated and piecemeal. The main source for innovative building was the Inspector General for Naval Works, Sir Samuel Bentham, who in 1795 was foisted on the Navy Board by the Admiralty to update its processes. That Bentham failed to pursue structural iron in his works is surprising, since although it does occur, its use is far from the sort of policy to employ the most modern material that might have been expected of him. It is not even used in the Block Mills at Portsmouth, his most famous work.

The Navy Board, however, and its Surveyor, Bentham's erstwhile assistant, Edward Holl, were certainly aware of the progress being made in the employment of iron for fireproofing in the north of England, though geographically remote and involved in a separate field. In 1807 John Rennie, a consultant to the Board on various constructional and civil engineering matters, advised on the use of iron-framed construction 'upon the plan of the cotton and flax mills lately erected at Derby, Leeds, Manchester and Glasgow'.[8] Opportunities remained

[7]Sutherland RJM, 'Shipbuilding and the Long-Span Roof', *Trans Newcomen Soc*, 1989

[8]Johnson and Skempton 'William Strutt's Cotton Mills', *Trans Newcomen Soc*, XXX, 1955-56, p180

scarce.

From 1817 however, the possibility for a more consistent application arose through the decision to build a completely new building yard at on the west coast of Wales, at Pembroke, to rebuild the old refitting yard at Sheerness, and to reform the victualling facilities of the main fleet bases at Gosport and Stonehouse. Work began on the design of the buildings at Sheerness in 1817 and continued for some eight years. Pembroke was an almost exact contemporary. Designs were begun for the new Stonehouse victualling yard by late 1824, and Gosport was begun in 1828. All four were large works, very expensive complexes of buildings which offered the cost-saving possibility of the repetition of standardised structural or roofing units made of iron.

The four projects were carried out by a combination of Navy Board architects and draughtsmen, principally Edward Holl and his successor G L Taylor, and the Rennie family. The involvement of the commercial iron founders, who supplied all the columns, beams and trusses, is unknown; and only one has been identified, the Horsely Ironworks of Brosely in Shropshire, whose name is on some of the ironwork at Royal William. The surviving drawings are sufficiently detailed for us to assume they were merely made up by the early nineteenth century iron masters, rather than designed by them.

In the 1840s and 1850s, further building programmes were carried out at Portsmouth, Devonport and Sheerness to create large-scale steam-powered engineering facilities at the first two, and included powerful new steam-driven saw mills at the Devon and Kent yards. The iron work in these buildings falls into a different phase of more mature designs, and was by this time under the supervising engineers of the Admiralty Works Department. These officers assumed control of design and building in the dockyards in 1837. Initially local supervising engineers had responsibility for their own construction work, and worked closely with the founders and contractors who made up the components outside the yards, but after Colonel G Greene took over in 1850 as Director of Engineering and Works he centralised design under himself and his deputy, William Scamp.

The metal slip roofs were erected between 1845 and 1855 at each of the navy yards apart from Devonport, where all the docks and slips had timber roofs by the 1830s. All but the last two were designed and built exclusively by two large commercial companies, Fox, Henderson and Co, later famous for their involvement in the Crystal Palace, and George Baker and Sons. The final pair Greene took and designed himself.

Reasons for using iron.

Iron was employed in dockyard buildings almost equally for its ability to withstand heavy loads as for its fire-resistant qualities. The earliest use of cast iron that has been traced is in the New, later North, smithery the South Yard at Devonport, designed by Bentham himself and built in 1808. The material was restricted to a central aisle of tall, slender, round columns instead of conventional timber posts, to support a wooden valley and traditional wooden king-post roof. (The smithery also contains two parallel lines of lower iron posts supporting an overhead traveller crane - one of the earliest examples of a type of crane that is supposed to have been invented in 1824). Tall cast iron posts were put to the same use in the three wings of the 1811-14 Vulcan store in the Portsmouth New Gun Wharf, to support a heavy timber floor structure.

Though early, these were not pioneering uses. Iron was used in a variety of building types at the turn of the century, including Parisian theatres, non-conformist chapels and barracks, as well as the better known mills like Ditherington and Belper. More remarkable, for its sophisticated free-standing iron frame and early date, is the anchor works built by John Rennie at Woolwich dockyard between 1814 and 1816. This had a complete interconnected cast iron frame of columns bolted to arched girders in three sections, and iron trusses. These in particular bear a striking similarity to the trusses employed by Edward Holl in the generation of dockyard buildings which followed. It was six bays long and three wide, and stabilised by masonry external walls, although in its current position, as the wrought iron works at Ironbridge Gorge Museum, the frame stands on its own. Three steam engines were connected to five tilt hammers and blowing engines for the anchor forges.

Edward Holl

The spur to the development of more complete internal iron framing was the grail of a fully fire-resistant structure. In this respect, the dockyards were at the forefront of new developments. The Chatham sawmill (1812-14) employed a cast iron framing system to support two large water tanks. An identical constructional system was used for the spinning house at Devonport, rebuilt after a fire with a complete internal iron frame between 1812 and 1817, and for the highly inflammable lead and paint works at Chatham, in 1817/19. The frames of all three were designed by Edward Holl, the Navy Board's Surveyor.

The two-storey frame in the sawmill workshop consists of two lines of cast iron columns connected vertically through spigots, supporting T-section transverse beams with a lower flange and a web with an elliptically arched upper profile. The flanges extended into spanner-head ends which met one another at the column, resting on a circular bolting plate 'capital', and clasping the spigot. Along the sides of the beams were cast square sockets, to carry secondary fishbelly joists spanning the gap between the beams. These gave simple support

to a flagstone floor. This type of construction was used in 1810 at Armley Mill, Leeds (II*),[9] and by the 1830s was one of two widely-used types of iron frames in Yorkshire textile mills. (The alternative and more common system was for the floor to be formed by jack arches, springing from the bridging beams, as for example the earliest iron-framed mill, Ditherington in Shrewsbury (I), 1796-97, or Barracks Mill, Whitehaven (II*), 1809).[10] Earlier examples than Chatham are not known, and certainly there were none of the prodigious length of the Devonport ropery which, at 1200 feet in length, exceeded all the industrial structures of the age.

The roof of the spinning house was also fire-resistant. The trusses were a mixture of cast iron in compression for the principal rafters and the cruciform diagonal struts, and wrought iron in tension forming round-section king and queen rods, and square-section ties; these extended both transversely between the principals, and longitudinally along the centre of the building. The earliest known all-iron roof is the North Mill, Belper, 1803-4, and the first known use of wrought iron was at Stanley Mill near Stroud, in 1813.[11] The spinning house is clearly a very important early example of an iron roof, in which an understanding of the properties of the two materials, cast and wrought, is demonstrated. The lateral chord is an exceptionally early use of the material in tension to resist the outward thrust of the truss.

Holl's personal connection with his peers, the small set of mill wrights working on fireproof mills in the northern and midland counties, and Gloucestershire, is unknown. But he was not only up to date with the latest ideas, but a proponent of almost religious zeal. There are at least fourteen dockyard buildings with significant quantities of structural iron for which he was directly responsible between 1812 and his death in 1824.

He was certainly the author of four large multi-storey iron-framed storehouses, two at Devonport (1814), one at Pembroke (1822), and the quadrangular Great Store built erected at Sheerness (late 1820s). Only that at Pembroke is still standing. Naval stores benefited from both the compressional strength and fire resistance offered by cast iron. The earliest were the pair of ranges with which Holl divided the great rectangle of stores at Devonport, itself a wholly conventional construction built two decades before.[12] They had iron columns

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[9]Fitzgerald R, The Development of the Cast iron Frame for Textile Mills to 1850, *Industrial Archaeology Rev*, X, 2' 1988

[10]Giles C and Goodall I, *Yorkshire Textile Mills 1770-1930*, RCHME, London, 1992, p70

[11]Falconer K, 'Fireproof Textile Mills, the widening perspective'. *Industrial Archaeology Rev*, XVI, 1993, pp18-21

[12]ADM 140/271, PRO

supporting timber beams and floors, a system employed on the earliest fireproof mills, and again on the second generation of iron-framed textile mills as both the cost, and failings, of cast iron became more apparent. It is generally thought that fire-proof mills were about 25% more expensive than conventional ones built with timber, and cast iron was anyway a far from an infallible material in a fire, especially if doused with cold water. The roofs of the storehouses however were all made of iron, though at least one, the Devonport store, to a very different design to that of the contemporary ropery described above.

The reason for suspecting Holl of a pioneer's zeal in his use of iron is its occurrence throughout four houses provided for the yard officers at Pembroke. These were designed in 1817/18. They used the same system of arched-web beams to span the house as at the Devonport ropery, with iron joists and a flag stone floor, though with a spine wall rather than columns. To fit round the hearth stone, however, the joists had to be set at odd angles, and be of different lengths. The roof appears from the drawings to have been similar to the ropery trusses, with cast slots in the principals for iron slate battens.

Two late workshops of Holl's should also be mentioned. The first is the Working Mast House at Sheerness, 1823-26 (Building 26). The basic frame is derived from the Devonport ropery and Chatham lead mill, with joists slotted into beams. The unusual feature is that the columns have diagonal cruciform supports which rise from sockets midway up the sides. This detail is repeated on both floors, the upper level having three lines of columns with braces supporting trusses spanning the open floor area. The latter differ from the ropery trusses in having cast iron in tension for the tie beams spanning between the columns, an apparent reversal from the correct material, wrought iron, which is stronger in tension. The ties are supported by wrought iron king and queen ties, and I-section struts, all bolted together.[13]

Similar columns and braces were employed in another structure at Sheerness, the North Saw Pits, (Building 84). This was a light cover for a series of very late saw pits, erected in 1828. As such it is a high-tech essay on a very traditional theme, the flimsy open-fronted timber-frame sheds erected for centuries in the dockyards over the sawyers' pits. The roof trusses are also very similar to those in the Working Mast house, though without queen rods. It is possible that castings surplus to the earlier building, or thought suitable for this purpose, were adapted for the pit cover. Either way they demonstrated the adaptability of the frame for a building without restraining masonry walls.

These columns with diagonal braces were a very rare and remarkably early response to the

[13] *Sheerness, the Dockyard, Defences and Blue Town*, Royal Commission on the Historical Monuments of England, 1995

problem of achieving wide uninterrupted floor spans with cast iron. However, it was neither unique nor the first. The Skin Floor (I) of the New Tobacco Warehouse, London, assembled between 1811 and 1813. This used an even more complex castings with both columns and diagonal braces which split into two, so that the roof was supported at six separate points. It followed an earlier precedent built from timber.[14] A similar arrangement of diagonal struts was later used in erecting shops such as Stephenson's at Forth Street, Newcastle (c1830).

The Rennies and the Victualling Yards

Both John Rennie and his son (later Sir) John advised the Navy Board on civil engineering and constructional matters, the former until his death in 1821, and the latter with his brother George continuing the connection. At the Royal William Yard, Stonehouse, the younger Rennie used iron in a very specific way, which indicates both his understanding of its advantages, and awareness of its cost. He introduced iron into the mill/bakery, the brewery and the cooperage, and the Clarence and Melville stores. All had cast iron columns to timber beams and boarded floors, except where there was a particular fire risk, as in the steam engine and boiler house, in the centre of the mill, and in the separate cooper's workshop. The columns are unexceptional, with wide top plates clasping the beams, although in the granary some of these are Y-shaped where the beam pattern divides. For the fireproof areas, Rennie used the same system as Holl, with iron joists sitting in sockets cast into the sides of bridging beams, and flagstone floors.

In the Clarence store, the valley is carried by cast iron arched longitudinal girders bolted to the central line of columns. Forming rigid connections between iron columns and beams to achieve a structurally-static frame was one of the key developments in metal construction. The arched girder was one way of realising this, and was used by Rennie on his pioneering anchor forge frame at Woolwich, as well as at Stanley Mill (I) near Stroud (1813). Another way was subsequently developed at Charles Fowler's Hungerford Fish Market (1835), which was the spandrel bracket, a form of rigid brace between bean and columns. The use of the arched girder at Stonehouse makes the Clarence frame an important addition to our knowledge of the development of this significant feature, intermediate between frames with simple support, and those with rigid end connections ultimately developed on the slip roofs and Sheerness Boatstore.

One later example of the arched girder method is worth mentioning at this point, that of the Chain and Cable Testing House (1844-47), erected at Portsmouth under the Admiralty Engineer, Captain Beatson. This uses arched girders in a single-storey shed, exploiting their decorative potential by bolting them to Tuscan columns. Though archaeologically innaccurate, in the use of Greek forms with arches, the exploitation of the ease of forming decoration in cast iron with the potential of the arched form was typical of this time. (For a

[14]Tucker G, Warehousing, in Carr RJM (ed), *Docklands*, 2nd edition, London, 1987

further discussion of portal bracing, see below).

The architectonic potential of cast iron was demonstrated in a different way at the victualling yards. The fronts of the mill/ granary and the brewery on the opposite sides of the central basin at Stonehouse were flush with the quay, and stood over open ground floors so that movement along the quay was unrestricted. The upper storeys were borne on the type of heavy iron Doric columns used for the same purpose by Telford at St Katherine's Dock in London (1827/28, demolished), and by Hartley at the Albert Dock in Liverpool (I) (1841/45): impressively sturdy, they contributed to the effect on the dramatic main seaward elevation of the Yard.

The granary at the Royal Clarence Yard in Gosport adopted a similar plan. Built in 1828-32, and therefore before Rennie's granary at Stonehouse, it looms over the quay for unloading grain directly from the ships, and stands on an open ground floor. The columns along the front and sides are massive Greek Doric, but those inside are more accurately sized. They support a frame of iron beams which is almost identical to that at the Chatham sawmill, except that the longer bridging beams support fourteen joists instead of five, the more closely-spaced joists support a timber floor, and there is a longitudinal beam between the columns, rather than the wrought iron rod with which Holl made do. Internally there are iron posts to timber beams and roof.

Of the victualling yard roofs, only the cooperage and the two stores are made of metal. The trusses were almost unchanged since the Devonport ropery, with rolled flats instead of round or square rod for the tension members, and fishbelly purlins. However, Rennie's roofs were hipped, over the central Melville offices the roof is also a mansard, and in these parts the detailing becomes very complicated, not to say inelegant. They required all manner of special castings which, while fascinating to deconstruct, are inexplicable from a rationalist standpoint, and must have been adopted to keep the roof line low behind the parapet.

In the mansard Rennie, like Holl in his Devonport stores and at Archway House, used a triangular openwork cast iron beam to form the central ridge section attached to a triangulated truss for the outer sections, with diagonal cross braces. This in turn was raised to give head rooms behind the clock tower. The advantage of the mansard form at Archway House was that the tie ran under the floor beams and gave an unrestricted storage space. The roofs at Melville bear a strong similarity to John Rennie Senior's work at Custom House Docks in Dublin. All these early roofs, even if they follow earlier (and invariably demolished) precedents, are of national significance, in view of their rarity and the world importance of Britain in pioneering new constructional forms.

Engineering workshops in the 1840s

With the completion of the two victualling yards, over ten years passed without significant construction work in the dockyards. However, the decision to abandon Woolwich as the main steam yard, discussed during the 1830s, and to build facilities for fitting and servicing steam engines in Portsmouth and Devonport in the following decade, entailed considerable new building. In the meantime, the theoretical understanding of iron beams had advanced through the work of Thredgold, Hodgkinson, Fairbairn and others, but it is indicative of how up to date were the dockyard engieers that by this time they should be building entirely from masonry and iron.

At Portsmouth the urgency of the need and unpreparedness of the site meant that instead of one integrated works, as the yard supervising engineer, Captain Denison, had intended, the different parts were divided into four. The first, built by Denison's successor, Captain James, was the West Factory, now No. 2 Ship Shop, in 1846-49. A very high ground floor contained the various heavy forging and forming machines, while an upper floor was for lighter machine tools. The upper floor was very heavily built, with bridging girders almost 40 feet in length, a remarkable span for a cast iron beam. Corbels along the sides supported intermediate joists, from which sprung jack arches, forming a solid horizontal mass. All the beams were I-section with parabolic bottom flanges widening to the middle, the form established by Eaton Hodgkinson in 1830, and widely propagated over the succeeding ten years by William Fairbairn, as the suitable distribution of metal to resist bending in a cast beam with only simple support at the ends. The jack-arched floor was a very widely-used system of flooring fireproof mills, established at the end of the eighteenth century, and the common alternative to flagstone floors, but it seems not to have been employed in the dockyards before this point. In the corner of each section was a cast iron winder stair.

The roofs of this and James' nearby brass foundry are a mature and common roof shape using all wrought iron, rolled angle iron for the compression members and wrought iron rod for the ties. It is credited to Stephenson' Euston station (1835-9; demolished), built with Fox, Henderson. There are numerous examples in industrial buildings from the 1840s onwards.

The great size of the bridging beams and the thinking behind them is explained in the following quote from James' article for his fellow Royal Engineer. The girders were 'three feet deep, the lower web is 17 inches broad and 3 inches thick; the estimated breaking weight at the centre being about 100 tons, they are subjected to a proof of 30 tons at the centre'. He adds that given the weight of vibrating machinery, and 'the piles of iron which are laid on the floors... no greater amount of strength has been given to the girders than prudence would justify'.[15]

[15]James H, 'new works at Portsmouth', *Professional Papers of the Royal Engineers*, 1846, p59

A directly contemporary building, also in Portsmouth, shows an alternative and more experimental option for load-bearing beams at this time. No. 6 Boatstore was designed by Captain Beatson and built in 1846 as a multi-storey building in which the yard's numerous small boats could be kept. Round cast iron columns supported arched girders for the shorter spans, and trussed girders for the longer ones. These were cast iron beams with wrought iron tie bars tensioned to resist bending, and were used in both buildings and for railway bridges for about two decades.[16] Many engineers, apparently including Beatson, raised the end of the bars to the upper side of the beam in a misconceived attempt to achieve a suspension bridge effect. The earliest date for this form is uncertain, but its end is fixed by the collapse of the Dee railway bridge and the consequent enquiry in 1847. The trussed cast iron girder was discredited, and largely abandoned as a structural member, although trussed timber beams, like the purlins in the 1879 Composite Shipbuilding Shed at Devonport (II), continued to be used. The boat store is an interesting indicator of the state of structural understanding in the mid 1840s, and an example of one of the dead-ends in constructional development.

The type of frame in the No.2 Ship Shop, with parabolic beams, was used for two further dockyard buildings where its more precisely calculated strength was required. These were the sawmills designed by Greene at Sheerness and Devonport between 1856 and 1859. Each was combined with a smithery, for which the saw mill steam engine provided forced draught for the hearths; the Devonport South Smithery survives, and its very different frame is discussed below. The saw mills are two-storey structures, but unlike the Factory with internal columns. The beams have parabolic bottom flanges supporting similar joists and jack arches. Movement in the beams was resisted not by bolts through spanner-head ends, as previously, but by rings shrunk over D-shaped lugs cast at the ends. This is a method used in textile mills since the beginning of fireproof construction.

The last part of Portsmouth steam workshops was the iron foundry, which was designed by James' successor, Andrew Murray, and the Admiralty's new head engineer, Colonel G Greene. Built between c1857 and 1861, it is articulated into three sections round an open yard. The Pattern Maker's section to the west is notable for the use of rivetted wrought iron beams for the first time in a dockyard context but developed in the late 1840s. They support brick jack arch floor. In the foundry section, the roofs are a curiously old-fashioned design still employing both cast and wrought iron in a traditional form, with king an queen ties. Cruciform struts, elegantly formed with a nice entasis, radiate from the mid-point connection on the cross tie. These continued to be used in railway shed roofs throughout the later nineteenth century.

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[16]Sutherland RJM, 'The introduction of structural wrought iron', paper read at the Science Museum, 1964, p72

At Devonport, the steam engineering establishment was, in contrast to Portsmouth, a single very large building, with masonry walls enclosing a large open central area, more like a weaving shed than mill building. It is known as the Quadrangle (1852-61). The design was worked out mainly between Greene and Scamp. Its overall significance, as a massive state manufactory, is discussed elsewhere. The main central area was roofed over at a quite late stage. The roof was carried on large cast iron H-section standards laid out to a regular grid, with rigid connections to made-up cast iron arched girders in four sections, of the type discussed above at the Clarence store. This type of column, with portal or rigid bracing to the girders, is believed to have been used for the first time at Greene's No 7 slip roof at Chatham. It was being put up at the same time, 1853-55.

The wide roof trusses across the main sections are complicated to a surprising degree considering the availability of simple roofs of the sort used by James at Portsmouth. They incorporate compression struts made up of paired flat pieces held apart by short spacers. The lateral ties are in three sections with three compression struts all radiating from the mid-point connections to support the principal. This system of triple compression members was also used by Greene at Devonport sawmill, and the type of compression struts made of parallel strips of iron have been noted on much later buildings, such as the very wide trusses of the 1891 riding school at Regents Park barracks.

In the context of H-section stanchions and the evolution of rigid connections, two final buildings should be mentioned. Greene's smithery in South Yard, Devonport, was built with its associated sawmill around 1857. Square in plan, it has an inner square of H-section stanchions, connected at the top to rectangular open lattice girders, as used by Greene on the No 7 slip roof. Like the arched girder discussed above, this was a precursor to beams with rigid bolted end connections. It was used by Paxton in 1837, and brought to perfection by Paxton and Fox, Henderson, the engineering consultants and founders, on the Crystal Palace (1850). At these two Devonport buildings, the Quadrangle and South Smithery, Greene was experimenting with rigid connections to iron frames at the same time as at the slip covers at Chatham.

Greene is most famous however for the Sheerness Boat Store, designed with Scamp around 1858. Here he applied these two elements for the first time on a multi-storey building. With rigid end connections, capable of resisting tension in the upper part of the beam as well as the lower, the parabolic lower flange, arched girder and lattice girder forms were no longer needed, and equal-flanged I-beams could be used for the first time. Nothing needs to be added to Skempton's description of that important building, except to stress its historic importance as the progenitor of all the rigid metal building frames used throughout the world today.

Free-standing iron frames

Although all the iron frames discussed above had a degree of rigidity, and arched lattice girders could promote this, they were all contained within massive masonry walls. Even Rennie's anchor forge was enclosed by stone walls, although these have been dispensed within its latest incarnation, at Ironbridge Gorge Museum. The development of completely free-standing iron frames was of enormous significance in the history of construction and of architecture throughout the world. This development can also be traced in a number of key buildings erected within the dockyards during these years.

The history of the evolution of iron space frames tends to concentrate on greenhouses, leading inevitably to Paxton's Crystal Palace. In fact, many of the technical steps leading up to both the Crystal Palace, as well as to the Sheerness Boat Store, were worked through by their respective designers in the dockyards, and their thinking can be traced there like the fossil footsteps of a developing species.

The first independent iron frame was for the garden hall of Carlton House (1803), by Repton, and the form continued to be strongly developed for glass houses both in Britain and in France. These structures are however significantly different from the modern space frame, in depending for stability on the arch, an the shell effect of the glazing. Two significant dockyard buildings are rarely mentioned in accounts of this development.

The first is the North Saw Pits (Building 84) at Sheerness (1828). This has been discussed above in the context of the columns and braces supporting the roof. Its significance as a complete free-standing iron frame should not be forgotten. The stanchions forming the outer wall are T-section and bolted to deeper I-section beams running the length of the building, with thinner beams connecting the stanchions to the central columns. It appears that they are very early bolted connections made without arched braces or made-up girders like at the Clarence store and Quadrangle.

In 1843, Beatson built a multi-storeyed trabeate frame at Portsmouth to support the water tank for the fire main. This had two rows of cast iron columns connected by arched girders, braced horizontally by T-section parabolic beams. The way in which the engineers and iron founders worked collaboratively is illustrated in the wrought iron ties, which were added to stabilise the frame on the advice of Fox Henderson & Co, who supplied the iron.

Building slip covers

This brings us finally to the slip covers. Sutherland's comprehensive analysis renders only a summary necessary here. Iron slip roofs on masonry walls were first proposed by Bentham,

following his study of their value for protecting ships in foreign naval dockyards, such as Karlskrona. The first wide timber roofs were built from c1813 until 1821. Their form followed a successful early design by Sir Robert Seppings, Surveyor to the Navy, and were essentially timber trusses supported by balancing cantilevers, supported on a line of tall timber stanchions. Three survive, two at Devonport and a third, the last and largest, at Chatham.

After a gap of some years, the navy resumed covering the slips in the 1830s, starting at Pembroke, which had opened since the earlier roofing programme. This time advances in production had reduced the cost of iron, and engineers had improved methods of building large rigid frames, and they were made out of metal. Seventeen were built, five by Fox Henderson and Co, the Crystal Palace ironwork contractor and advisor to Paxton, ten by a general building contractor, George Baker and Son, and the last two by Greene and Scamp. Apart from two rather altered roofs at the former Deptford yard, all the remaining iron covers are at Chatham, including five in their original location - the last three by Baker and Greene's first - as well as the furthest developed of Fox Henderson's and Greene's designs, moved to Chatham from Woolwich. These form one of the most outstanding collection of iron structures anywhere in the country.

These were at the time the widest span roofs in Britain, and apart from isolated riding schools in Germany and Russia in the world. In his thorough analysis of the iron roofs, Sutherland saw their significance not so much for this obviously impressive statistic, but in 'the final establishment of the principle of rigid framing so as to provide large open spaces of uniform height without the encumbrance of heavy masonry walls'. He placed the last covers squarely in the line of ascent of the Crystal Palace and Greene's Boat Store, 'and the thousands of portal-framed sheds and rigid building frames which followed both in iron and steel'.[17]

3.5 Developments in shipbuilding and naval architecture

No technological changes had greater or more consistent bearing on the dockyards than the increasing size of warships. A summary of the evolution of naval architecture is provided therefore as a supplement to the discussion on docks and slips in the dockyards.

1690-1810

Shipbuilding was not the primary purpose of the eighteenth century yards, which were concerned with fleet maintenance in peace time, caring for the fleet in reserve, and repair

[17]Sutherland RJM, ibid.

and refitting during war to keep as many ships as possible in commission. In this last measure of their effectiveness, they did notably better than their French and Spanish equivalents.

The royal dockyards were responsible for building the 'Great Ships' of 90-100 guns. Smaller cruisers were built in commercial yards. This was the class of ship which increased most during the period, seven-fold over the century. Changes in ship design was in general held back between 1715 and 1749 in the long tenure as Surveyor of the Navy of Sir Jacob Ackworth.

After the appointment by Anson of Thomas Slade as Surveyor in 1755, British ship design went though a much faster development. Between 1779 and 1781 copper sheathing spread throughout the fleet; with Slade's new designs and the carronade, these innovations were the three 'most notable of the century'.[18]

From the late 18th century, the falling cost and greater availability of cast iron caused it increasingly to substitute for wood for repairing warships, replacing rotten or war-damaged beams, and other frame timbers. Such developments, still in the wooden ship era, placed increasing demand on the smitheries, and the construction of new smitheries during the pre-steam years, at Portsmouth (1795), Devonport (1776 and 1811) and Chatham (c1808) testifies to this trend. (See Section 3.4)

1810-1860

The three-decker line of battle ships designed by Seppings, whose constructional system was developed from 1811 until his retirement in 1832, and his successor Symonds have been examined thoroughly by naval historians. Superficially similar to Victory, Seppings' cross-bracing system enabled much greater size to be attained - Victory was 2162 tons, while Symonds' Queen was 3240 tons. These new types of ships also incorporated an increased quantity of ironwork in their structure, largely in the form of knees and diagonals.

All these ships were built in the Royal yards, and it was to protect them during the period of construction (an average of five years for capital ships: the Queen took seven years before it was launched in 1839) that the long-span roofs of the building slips were designed (see Section 3.4 and 4.2)

Until the advent of the ironclad all capital ships had been built in the Royal yards. However, when Warrior was laid down in 1859 they had no experience at all in the construction of iron ships, and it was built by Thames Iron Works. The Achilles, laid down in 1861, was the first iron ship to be built in a naval yard, but private yards continued to be responsible for

[18] *Oxford History of the Royal Navy*, 1995, p132

building a good deal of the iron navy. Between the Warrior and Dreadnought the numbers of ironclads (including wooden-hulled ones) and pre-Dreadnoughts built were - Portsmouth 17, Pembroke 18, Devonport 8, Woolwich 3, Chatham 26, Deptford 2. 53 were constructed in private yards such as William Beardmore and Co. Ltd and Dalmuir and Parkhead, and Vickers at Barrow.

1860-1914

This period witnessed profound changes in shipbuilding, propulsion and armaments. As the possible permutations of armour, power, size and other factors for a given displacement grew markedly, the best course for the navy became a matter of heated national debate. There was no great programme of additional buildings of the scale of the Steam Factories, most impressively displayed at Devonport and Portsmouth. The major constructional efforts from the 1860s were instead concentrated on creating the great extensions to Portsmouth, Keyham and Chatham.

These consisted almost entirely of docks and basins enclosing large expanses of water, with associated pumping stations and cranes, railways and hydraulics. New factories were not required because shipbuilding in iron and steel was to a large extent a matter of assembling components brought from elsewhere. Armour plate was supplied by private firms in Sheffield and elsewhere and shaped to fit in the yards; existing buildings could then be re-tooled and more powerful cranes and railway systems installed to handle the materials. A significant addition at Portsmouth in this respect was the Armour Plating Shop, although it survives only in fragmentary condition.

New engineering facilities were finally provided at Chatham, however. Unlike the massive masonry works of the steam engineering shops of the sister yards, the Admiralty exploited the flexibility of the disused iron slip covers at Woolwich. When the yard there closed in 1869, they were dismantled and re-erected between the Georgian dockyard and the new basins to the north, as the Machine Shop, Boiler shop and Factory.

Metal shipbuilding took place in the open, dispensing with the need for slip roofs. Shipbuilding with wood continued however at Devonport, for the composite ships built during the 1870s and 1880s for service on African or Oriental stations. Before the invention of anti-fouling paint in the 1890s, iron hulls in these warm waters deteriorated too quickly to be economic. The iron skeletons of these ships were planked with wood, to reduce maintenance costs in areas without dockyard facilities. One example of a Composite Shipbuilding Shop, connected by a plate-bending shop to a large covered slip, survives at Devonport.

4.0 ANALYSIS AND ASSESSMENT OF THE ROYAL NAVAL DOCKYARDS: CRITERIA FOR LISTING

4.1 Ship building and repair: docks and slips

Recommendations

Devonport

II* The Scrieve Board, South Yard S162
II Main Dock Pumphouse, South S087 & 89
II* No. 1 Covered Slip, South Yard S180
II Swing Bridge, South Yard
II Dock Pumping Station, North Yard
II Composite Shipbuilding Shop, South Yard (see 4.5)
II,II* Dry Docks, No. 1 Basin, South Yard

Royal William

I Dock basin walls and 6 associated bollards, Royal William Victualling Yard
I Clarence Steps, SW Quay wall and 2 bollards, Royal William Victualling Yard
I NW Quay wall and 2 bollards, Royal William Victualling Yard

Portsmouth

I Docks 1-6, Quay walls & bollards (inc N & S Camber, Mast Pond & tunnel to same)
II No. 1 Pumping Station (Building No. 2/201)
II Hydraulic engine house (Building No. 1/38) SW of No. 9 Store

Chatham

II* No. 1 Workbase
II* Nos. 2 and 3 dry docks
II No. 4 dry dock
II* Chatham Dock Pumping Station South
I No. 3 Slip Cover
I Nos. 4, 5 and 6 Slip Covers inc. No 6 Machine Shop
I No. 7 Cover
II* Boilershop
II* No. 8 Machine Shop
II Combined Ship Trade Office PP69 to rear of No. 8 Machine Shop
II Chatham Dockyard Pumping Station

Sheerness

NL Walls of the Great Basin; walls and stepped sides of 3 docks
II* Walls and gates of the Boat Basin, docks Nos. 4, 5 and slipway

Portland

II* Inner Breakwater with Coaling Shed and Inner Pierhead Fort
II* Breakwater Fort
II Outer Breakwater

Greenwich

II Pair of slip covers, Convoys Wharf

Introduction

According to whether they were for predominantly involved in building or in maintaining ships, the yards have had different combinations of docks and slips. Slips were generally ephemeral structures mostly used for shipbuilding, and often fitted in where there was suitable room. Dry docks allowed the hull to be examined; double dry docks, with space for two ships in line, were popular in the seventeenth and much of the eighteenth centuries. In wet docks and basins the level of water can be maintained relative to the quay, and can accommodate several vessels at the same time. Some basins were tidal, such as the Rennies' Royal William Victualling Yard basin and the Boat Basin at Sheerness.

Docks are the structures which define the dockyards, and formalise the relationship between land and water. The nature of this relationship has been fundamental to the history of the yards: rock to excavate at Devonport, mud and silt to consolidate or pile at Devonport and Sheerness; destructive tides and heavy seas at the maritime yards, and silting rivers at the fresh water ones. The location of the docks and slips, and the need to achieve satisfactory access for the ships, have been the major factors in the planning of the yards, and locating the stores, smitheries and workshops arranged around them. Their design, construction, maintenance and enlargement has always been one of the predominant concerns of the Navy Board and the officers managing the yard, and has absorbed far greater amounts of expenditure than any other dockyard works.

Evolution of design

Docks have evolved in their length and shape, mode of construction, and in the method of closing and emptying them. They have shadowed the growth of warships, remaining consistent during periods like the eighteenth century when the size of the ships changed little, and having to be rebuilt or relocated more frequently when ship design was developing more rapidly, as in the second half of the nineteenth century. Almost all of the entrances therefore have been altered or rebuilt at different times, the sill lowered, gates

widened, and the rounded heads of the eighteenth century docks altered to suit the sharper prows of later warships.

Dry docks were constructed of timber from 1495, when the earliest dry dock was built near Portsmouth, until the first stone-lined docks were built by Edward Dummer, Surveyor to the Navy, at Portsmouth and Devonport at the end of the seventeenth century. These revolutionised dock design, having stepped sides, or altars, from which the ship could be shored up and worked on, hinged gates, and stairs and slides for getting men and materials in and out. The bases of the docks continued to be of timber until Bentham introduced the inverted arch in 1798 at Portsmouth (now Nos 2 and 3 Docks), which had the effect of tying the two sides of the dock together and removing some of the enormous pressure imposed on the outer abutments. Bentham made use in the same docks of Aberdeen granite, which Rennie used in the 1820s at Sheerness; Norwegian granite was being used from the 1890s. The transformation of the yards to stone was gradual however, and Chatham - which had four single and one double docks in the 1690s - did not have a masonry dry dock until 1821.[19]

Water was excluded from the early dry docks by timber gates in three sections, kept closed and water tight with stones, props and clay. Dummer's masonry docks, more resistant to distortion, could be closed with more precisely-built double gates which folded back into side recesses; they were hinged at the sides, the flow of water being eased by culverts with their own sluices and pumps. Bentham introduced the first caisson gate with his inverted-arch sill in 1798. He also installed the first caissons, a hollow dam which floated when empty and could be towed to the entrance; once filled with water it was sunk into position thus sealing the dock. Caissons were strong and effective at keeping water both in or out, and they also improved ease of movement around the yard by carrying roadways across the entrance to the docks.

Wet basins facilitated the servicing and fitting out of ships at the quayside, without damage to hulls caused by falling tides and buffetting against quay walls. Dummer's development of wet dock technology at Portsmouth and Plymouth preceded similar developments in the civil field, at Rotherhithe (1697-1700), Liverpool (1709) and Sea Mills near Bristol (1710).

By the end of the eighteenth century, developments in civil engineering (both in coastal harbours and canals) had begun to eclipse the leading position held by the naval yards. By the 1830s, the Admiralty also sensed that the Royal Navy was in danger of lagging behind its Continental rivals in the provision of facilities for the longer fitting-out and servicing periods

[19]MacDougal, P, 'Granite and lime, the building of Chatham dockyard's first stone dry dock'. Archaeologia Cantiana, 1989, p173-192

which steamships demanded: "The French have had the foresight to provide ample Basins for the equipment of their Steam Navy in all their Naval Arsenals".

The docks and basins associated with the subsequent expansion of the dockyards from the 1840s into vast new areas for the building and servicing of steam ships did not represent any substantial advance in the technology employed by the Rennies, Dummer and Bentham. The earliest dry docks associated with the steam navy are at Woolwich (II), built in 1843 and now integrated into a swimming pool. No 8 dock at Portsmouth was, significantly, designed to accomodate the very different hull form of steamships, but in its method of construction differed little from earlier precedents, with the exception that the brick surrounds were this time applied to concrete and pozzolana backings.

The role of private yards, such as Barrow, became increasingly important from this period. They built 53 of the 137 ironclads constructed between Warrior and Dreadnought. Sir William White's sweeping reforms from 1884 brought shipbuilding - this time in dry docks rather than on slips - and the design of outstanding classes of warship (the Royal Sovereign and Majestic classes being the best known) back to the naval yards.

Draining the docks

Draining dry docks was a laborious process using traditional manually operated chain pumps. Dummer produced a plan for the expansion of the Portsmouth docks in 1698 which had chain pumps driven by both a water wheel and horse gin, and certainly the latter was widely used for working the pumps. It was Samuel Bentham who first introduced steam-pumping to the dockyards, as part of his integrated steam-powered woodworking shop (now the Block Mills, situated above Dummer's Upper Wet Basin). In 1799 Bentham replaced the old horse-powered chain pumps at Portsmouth by a steam-powered bucket pump.

Rennie's dry docks were drained by the first steam-powered dock pumping stations at both Chatham (1821), and Sheerness (1823, demolished). Both were symmetrical buildings combining engine house, boilerhouse and chimney, and each contained two 50 hp Boulton and Watt non-rotative beam engines working bucket pumps. The docks at Devonport continued to be served by two horse gins until the 1830s, when a steam pumping engine was introduced.

Hydraulic power was applied in the yards at a remarkably early date. It was suited to a variety of purposes, but principally for operating the lock gates and capstans. The earliest hydraulic pumping station was built in 1851 in the South Yard, Devonport, and carries the architectural hallmarks of the contemporary Keyham improvements. The first at Portsmouth was built in 1861 by the Chief Engineer, Andrew Murray, and also powered the

machinery in the Chain Testing House. The 1850s also saw some experimentation with hydraulic power for the coaling facility at Portland, reflective of the interest which many railway and dock companies had already taken in its potential. As part of the expansion of the dockyards for the iron navy, all the major dockyards had big new combined dock and hydraulic pumping stations: at Portsmouth, No 1 (1878), West (c1900) and the biggest, North Pumping Station (1913); in the steam basin extension at Chatham (1890s); and for the Dreadnought docks at Keyham (1905). These used multiple inverted vertical triple expansion steam engines, though all have been scrapped.

Building slips

The number of slips in the yards was directly related to the shipbuilding capacity of each: the great cost of building dry docks had led to the Admiralty's decision in 1764 that only slips should be used for shipbuilding. The nineteenth century building yards such as Pembroke, with eleven slips, and Chatham, with six, had more than the bases at Plymouth and Portsmouth which concentrated more of their efforts on servicing the fleet. Pembroke continued to be responsible for many of the wooden steam line-of-battle ships from the 1850s. (These break down between Portsmouth 10, Pembroke 18, Devonport 13, Woolwich 9, Chatham 17 and Deptford 4).

Slips were be built of perishable timber long after docks were stone-lined. Consequently only one complete eighteenth century slip survives, the No.1 Covered Slip at the south end of Devonport, built in 1774 and one of four built during the post-1760s expansion of the yard; a fifth, the much altered No.4 Slip, dates from 1816-21.

A more important development was that of the covers built over slips and dry docks (now involved in shipbuilding again) to protect the wooden warships during the years of construction (as much as 5 years for a First Rate). The earliest were light canopies, but from around 1814 the naval architect Sir Robert Seppings produced a timber truss design for roofs of over thirty metres span, and over the next ten years 'most of the dry docks and all the slips had graceful timber framed housings added',[20] copper being the standard roofing material used. These were the widest-span roofs in the country; one of the last survives over No. 3 slip at Chatham, erected in 1838 and spanning 28.5 metres.

A second generation of slip roofs was developed by the Royal Engineer officers appointed to the yards from 1837. Working with a small group of private sector engineering contractors, from 1845 they produced a series of wide-span iron roofs. The early ones followed the structural principles of the timber roofs, but later designs were more innovative. In particular the 1847 roof over No. 4 slip at Woolwich, built by Fox, Henderson and Co,

[20]Coad J, 1989, op cit.

established the principal of bracing by rigid joints, while Colonel Greene's roofs of 1855 at Woolwich and Chatham, more sheds than simply roofs by this time, and no longer dependent on the cantilever effect of the overhanging sides, were direct predecessors of his Boat Store at Sheerness (see Section 3.4). Development ceased with the move to metal ships which were once more built in the open.

Assessment

As indicated above, docks and slips are fundamental to an understanding of the dockyards. Their historical importance relates principally to their age and typological context, and to the degree in which their original form continues to manifest that of the ships for which they were used. Historical interest could be enhanced by association with particular ships, but there are few proveable connections as strong as that, for instance, of the dock built in 1837 for Brunel's Great Britain in Bristol (II*), and which contains the ship today, or the dock at Laird's Old Yard, Birkenhead, (II*) built in 1857 and used for the construction of Confederate ships including the famous raider Alabama. The rarity and importance of the eighteenth and early nineteenth century dry docks in the royal yards is instead underlined by their grouping in places of outstanding historical interest, and their significance within the context of naval shipbuilding and history.

Technological importance

In a number of instances naval docks have been in the vanguard of technological development. It has been seen that Dummer's invention of the wet dock - the north wall of No 1 Basin and the Upper Wet Dock (I) at Portsmouth have remarkably survived, the latter under the Block Mills - and the characteristic form of this dry dock formed the model for all subsequent developments. The establishments of other European powers have not been consistently surveyed, but one is left with the impression that these considerable engineering achievements underpinned the Royal Navy' tactical advantage over her Continental rivals in the eighteenth century. Brest Arsenal had no dry docks until the 1740s, and Toulon none till the 1770s [21] and Spain's principal naval base, at Havana in Cuba, had cranes and dry docks which were clearly modelled on British precedents.[22]

The earliest comparable examples to the dry docks in the naval yards are Nos. 1 and 2 Graving Docks, Canning Dock, Liverpool, built in 1765 and extended in 1813; there is one early nineteenth century dock in Hull and a small number of scattered mid and late nineteenth century examples. This relatively late and patchy survival in the civil field

[21] Coad, J, *Historic Architecture of HM Naval Base*, Devonport, National Maritime Museum, 1983

[22] Harbron, J, *Trafalgar and the Spanish Navy*, London, 1988, p62

illustrates the fact that English, indeed British, shipbuilding and servicing has left only fragmentary traces of its former importance.

Without regular repair, the life of a wooden ship was short: 74-gun ships, for example, the backbone of the late eighteenth century and early nineteenth fleet, had to be repaired every two and a half years and their hulls re-coppered every five. Dry docks were needed in order to facilitate the inspection of hulls and the replacement of worn copper sheets (introduced in the 1780s to combat the teredo shipworm), a process which commonly took up to six weeks to complete; further works, such as upper-deck maintenance and rigging, were performed at moorings. The fact that the most impressive sequences of stone dry docks were developed at Portsmouth and Plymouth is a direct consequence of their important strategic role in servicing the fleet. Of the 74-gun ships which needed dry dock facilities in 1804-5, for example, Portsmouth docked 50 ships, Plymouth 52, Chatham 32, Woolwich 13 and Sheerness 3; many of these were serving in the blockades of French ports.

Coad accurately describes Docks 1-6 at Portsmouth as 'the finest surviving group of such eighteenth century structures in Europe',[23] retaining as it does such important manifestatins of late seventeenth and eighteenth century engineering achievements. Dummer's Upper Wet Dock was adapted by Bentham and survives as the covered reservoir beneath the Block Mills, and there may be fragments of his work in the north wall of Basin No. 1. The docks around the Basin achieved much of their present form during the eighteenth century. Dummer's dry dock (No 5) was rebuilt in 1769, and No.4 dock replaced two building slips in 1772. The channel which separated the Upper Wet Dock from the sea was made into a simple dry dock in the 1690s, and then rebuilt as a conventional dry dock in 1737-43 (No. 6). The Upper Wet Dock was then, following a decision taken in 1764, converted into a reservoir for collecting via culverts water which remained at the bottom of the dry docks at low tide; horse-driven chain pumps were used at first, but in 1797 Bentham revived an earlier idea of Samuel Wyatt's in advocating the installation of a steam-driven pump, the engine being also used to power wood-working machinery.

In 1800, the Admiralty approved Bentham's scheme to cover the reservoir with two tiers of brick vaulting, the upper tier being flush with the yard floor and accommodating a second engine; the engines then powered the machinery in the Block Mills which still surmount Dummer's Upper Wet Dock, a remarkable and unique survival. Docks 1, 2 and 3 were built by Bentham, incorporating his invention of the inverted arch. The caissons to the docks and basin are, of course, much later replacements, although some of the penstocks and the culvert system has survived.

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[23]Coad, J, 1989, *op cit*, p97

The most important group after Portsmouth is at Plymouth, and comprise Docks 1-4 and No 1 Basin. Two eighteenth century dry docks (1758 and 1784) stand to the north of the earlier (1721) double dry dock, completely rebuilt in the 1840s; Dummer's dry dock and wet basin were rebuilt in the 1840s, the wet basin being extended to the west.

The oldest stone dry dock at Chatham, No 3, was also the first at that yard. Built by John Rennie Snr in 1821, it included upturned cannon reused as bollards when it was built. It forms an important element with Rennie's important and remarkably complete Dock Pumping Station (**II***). Rennie was working on the reconstruction of Sheerness at the time. The Great Basin and its three associated dry docks (SAM, II*), which could fit out nine ships-of-the-line and provide access to the large dry docks for First Rate (120 gun) ships, have been covered over. But the dry dock leading off the smaller Boat Basin to the north also includes a graving dock and building slip, and has survived in a remarkable state of preservation: the cast iron gates, described in Rennie's Ports and Harbours Treatise of 1851 (p.35) are the only examples of their type to have survived in any English dock, with the exception of the later II* listed dry dock at Lairds Old Yard, Birkenhead.

In using engineers such as the Rennies, the Navy Board was demonstrating its recognition of the pre-eminence of enginers in the civil field. In contrast to Portsmouth and much of Plymouth, however, the works at Sheerness and Chatham - whilst being outstanding examples representative of what is commonly known as the heroic age in British engineering - are reflective of developments perfected elsewhere. The engineering achievement at Sheerness, where Rennie used a system of hollow walls resting on inverted arches for securing the foundations onto a mixture of soft mud and quicksand, was consequent to those achieved in the civil field.

The problems of instability to harbour works presented by soft underlay had been solved in a similar fashion by John Rennie at Grimsby (Haven Lock, II*) in 1796 and was subsequently used at other ports such as the Humber Dock at Hull, 1803-9. By the 1840s and 1850s, remarkable engineering achievements such as Jessop's Floating Harbour in Bristol (II) and Rendel's Royal Dock at Grimsby (II*, which also used inverted arch foundations) had guaranteed the private sector's leading role.

The development and steady increase in the size of dock facilities, linked to the introduction of steam-powered vessels with deeper draughts for example, is best seen at Liverpool, Hull and Grimsby, where dock works can be seen to have a clear functional relationship to outstanding individual buildings or complexes. From this period, historical importance and group value become the determining factors, after completeness, in assessing the importance of the basins and dry docks of the steam navy. These expanded onto vast areas

of new land at Portsmouth, Chatham and Plymouth. Portsmouth, for example, occupied a 100 acre site into the 1860s, when it expanded onto 178 acres of mudflats and fields to the north.

The significance of later dock works is enhanced if they have a direct functional relationship to significant groups of naval buildings. The basin walls and quay walls in Rennie's remarkable planned group at the Royal William Victualling Yard (see section 4.9) are the superlative examples in this category. At Portsmouth the Steam Basin, opened in 1848, has been too rebuilt; the complete No 3 Basin at Devonport, positioned immediately to the west of the Quadrangle complex, the most outstanding industrial building associated with the Victorian navy, is recommended for statutory protection. No 8 dock at Portsmouth, to the north-east of the Steam Basin, clearly manifests through its plan and morphology the new design of steam-powered ships and stands in a clear relationship with the Iron Foundry (II*), Brass Foundry (II) and No 2 Ship Shop (II*) which were erected around the yard from the 1840s (see section 4.4).

Largely by virtue of its strategic position, the base at Plymouth had by 1914 become the largest in Europe. Five Dreadnoughts, in addition to other battleships and cruisers forming part of Fisher's expansion of the fleet, were constructed here prior to 1914. No. 8 dock, built in 1896 and extended twice prior to 1914, has been selected with its related pumping house as an example of one of the largest shipbuilding docks built during this important period in naval history.

Pumping stations

The most interesting pumping stations are those still associated with a dock, of which Rennie's at Chatham (II*) stands out. Inside the right-hand engine house is the engine's moulded iron entablature on twin round columns. The pump rods worked the well in the front end of the engine house, with the cylinder to the rear. On the beam floor above are hand-cranked hoists at each end for lifting the engine and pump parts, and it has a fireproof iron roof.

The use of steam engines for water supply was still in its infancy, and apart from the much altered engine house at New River Head, Islington, this is the oldest purpose-built steam-powered pumping station in England, containing moreover considerable archaeological evidence for its original plant. Its significance is considerably enhanced by the fact that it is also one of the engine houses in the country to have been built for machinery by the celebrated firm of Boulton and Watt.

The 1851 hydraulic pumping station at South Yard, Devonport (II), is an early surviving example of its type. Hydraulic power, experimented with by Bramah in the 1790s, had been

first used successfully by Armstrong at Newcastle docks (for powering cranes) in 1846. The Devonport example both relates to an outstanding series of docks, and predates most of the examples built in London (where railway and dock companies were particularly active during the 1850s), Hull and Liverpool. The most outstanding example of its use, both in the technological and architectural sense, was part of Rendel's work at Grimsby, where the low-pressure hydraulics were accommodated within a tower (I) modelled on the Palazzo Publico at Sienna.

Murray's pumping station at Portsmouth (II) is also a good example of its type. The hydraulic accumulator tower at Portland, used in a similar context to those built by railway and dock companies for the shipment of coal, has been too altered to fulfil listing criteria. The large pumping stations at each of the main yards form an interesting comparison with similar buildings for water supply. No.1 Pumping Station at Portsmouth (II), built in 1878 to the designs of Col Sir Andrew Clarke, RE, is the finest example dating from the expansion of the yard in the second half of the nineteenth century, and in combining architectural quality with the functional demands expressed in its plan and morphology, merits comparison with listed examples associated with urban water supply. The other examples at Portsmouth have been more altered, and do not have the same architectural merit. The 1905 station (II) in the Keyham extension at Devonport is important for its strong architectural quality and its direct association with No. 8 dock.

Slips

The earliest surviving slip in a royal dockyard is the No.1 Covered Slip at the south end of Devonport of 1774-5. It is also the most complete surviving slip in an English dockyard, the slip to the south of the Scrieve Board in Devonport being the most complete of the remainder but too altered to fulfil listing criteria. The only other complete example forms part of the Boat Basin complex at Sheerness (II*) completed around 1823. At Pembroke, only four complete examples of the original thirteen slips and a graving dock remain, dating from between 1820 and 1845 (II).

Slip covers

In the civil field, the ephemeral nature of most building slips has resulted in only one comparable survival, at Coles Yard in Cowes on the Isle of Wight (II). Many ships were simply fitted out on the foreshore, as at James Yeo's Richmond Yard at Appledore in Devon. The shipbuilding slips in the naval yards were particularly notable for their roofs, which determine their importance and places them within an international context (see Section 3.4). Stone-vaulted roofs were built to protect Mediterranean galleys and survive at Khania (Crete), Venice and Barcelona, and by the eighteenth century timber roofs were built over slips in French, Swedish and Russian yards. None of the timber roofs which Bentham saw on his visit to the Swedish yard at Karlskrona have survived, and the English timber slip covers now share the distinction of being the widest-span roofs of their date in the world, with the exception of some riding schools in France and Germany.

The significance of No. 1 Covered Slip (**II***)is thus enhanced by the timber roof of the Seppings type, the earliest example, and added around 1814. Devonport also boasts another other timber slip cover, the Scrieve Board (**II***), although the slip itself has been altered and filled in to form the former drawing floor. The 1836 timber roof at Chatham, built using the same technology but with a wide span of 28.5 metres for the protection of steam-powered ships, is described below. These three roofs are all that survive from a great many which were built over dry docks and slips during this period.

The iron roofs, as we have seen (see Section 3.4), are also of considerable significance in an international context. In terms of width of span, the slip covers exceeded the railway sheds until Lime Street Station, Liverpool, was built in 1849. Moreover, the train shed roofs relied on masonry walls to buttress the thrust of the trusses. The particular importance of the later iron slip roofs was in achieving stability by rigid portal bracing between the members and demostrating the move from empirical to calculated engineering. As such they were direct antecedents of Greene's Boat Store in 1857, and the ubiquitous metal-framed buildings of today. Greene's two structures represent the peak of a strand in the evolution of iron buildings, erected just before the launch of HMS Warrior in 1862 signalled the beginning of the new navy, and the end of covered shipbuilding.[4]

All the dock roofs at Portsmouth and all but two in the Thames yards have gone, leaving seven out of a known seventeen iron roofs to have survived. Six of these are at Chatham, which was, after Pembroke, was the navy's most productive shipbuilding yard. After Woolwich closed in 1869 Fox Henderson's 1847 roof over slip No. 4 and Greene's 1857 Slip No 5 roof were moved to Chatham to be used as engineering shops at the new steam extension there to the north of the old yard. They are now the Boiler Shop (**II***) and the No. 8 Machine shop (**II***). The old yard at Chatham has the finest collection of slip roofs, forming a remarkable "in situ" group in which the development of free-standing iron frames - a development of international significance in terms of constructional history - can be

traced. As a consequence of this, they are all recommended for listing at grade I. The earliest is over slip No. 3, built around 1836, and the last timber and largest-span slip roof erected after a gap of over twenty years. Slip Nos. 4, 5 and 6 have metal roofs by George Baker and Son, erected in 1847, and with a much wider spacing of the frames with trussed purlins carrying the loads to the frames. The roof over Slip 7 at the north end of the group was designed by Greene and erected in 1852, and is considered by Sutherland to represent the technological peak of development.[24] Another pair of Baker frames (II), more altered than these examples, survive at Convoys Wharf, Prince Street, Deptford.

[24]Sutherland RJM, 1989, *op cit.*

4.2 The Ropeyards

Recommendations

Devonport

I Spinning House, Ropery, South Yard S132
II* White Yarn House, Ropery, South Yard S135
II* Tarring and Wheel House and Tarred Yarn House, Ropery, South Yard S136 & 137
II* Tarred Yarn Store, Ropery, South Yard S138
II Master Ropemaker's office, Ropery, South Yard S097 & 98
II Master Ropemaker's House and attached railings and garden wall, South Yard S103 (see section 4.7)

Portsmouth

II* Nos. 18 & 19 Stores with linking bridge & att. bollards (Buildings Nos. 1/65 & 75)
II* No. 15 Store (Building No. 1/62)
II* No. 16 Store (Building No. 1/63)
II* No. 17 Store (Building No. 1/64)
II Chain & Cable Test Hse & Store, Chain Haulage-ways on N. (Building No. 1/41)

Chatham

I The Ropery and Spinning Room
II* Former Hatchelling House
II* Former Hemp House, Spinning Room and Offices
II* Former Tarred Yarn House

Introduction

Ropemaking was an industrial process carried out in its entirety within the dockyards. The various stages of manufacturing cordage required separate buildings through which the raw material, hemp, passed from storage on arrival in the yard to completed rigging. The ropeyard or ropery formed a distinct part of each dockyard, and was planned to facilitate as far as possible efficient production. From the seventeenth century up to the present, the processes seem to have undergone only limited development. Rising demand for rope at the end of the eighteenth century produced a degree of mechanisation, including the introduction of register plates, notably at Joseph Huddart's Limehouse ropery. Steam power was reducing the highly labour-intensive character of the work in the 1830s. However, engine houses apart, these changes had little effect on the morphology of the buildings, and a seventeenth century ropemaker would very likely have little difficulty recognising the roperies today. All three of the dockyard roperies date from the last quarter of the

eighteenth century.[25]

The most distinctive parts of the ropeyard were the laying and spinning houses which, because of the great length which their processes necessitated, formed substantial barriers within the dockyard. Their location was a central issue in the layout of the yards, and in the replanning which the major yards underwent during the 1760s and 1770s expansion and reorganisation of Devonport and Portsmouth. They needed to be close to the raw hemp stores and the tarring house, and preferably not too far from the rope and finished rigging stores. A further issue which affected the planning of the ropery was the high fire risk associated with rope making. Fires or anticipated fires played a major influence on the design of new ropery buildings, as well as on the timing of their construction.

Where possible therefore, the ropery was sited to one side of the dockyard. The ropery at Chatham has occupied the same site at the southern end of the yard since 1618, since the growth of the yard has been all to the north. When Devonport expanded to the south side of the seventeenth century ropeyard, it was demolished and rebuilt along the eastern, landward margin of the yard. A similar plan existed for the old ropery at Portsmouth, but two successive fires in 1760 and 1770 meant that rebuilding work had to take place before the land to which the ropery was intended had been reclaimed. Consequently, it too occupies the old seventeenth century site, dividing the yard into unequal halves.

Raw hemp was imported to England and arrived in the dockyard by boat. It was stored in hemp stores, of which the earliest is that at Chatham (1728). Before it could be formed into twine, the fibres of the raw hemp leaves had to be roughly drawn out, using combs or hatchel boards, and this took place in the hatchelling house.

The two processes which required very long buildings were spinning the hemp into twine and laying it into rope. The older roperies had separate spinning and laying houses, such as those at Devonport, although only foundations of the laying house exist today (SAM). The matching 1771 spinning house was gutted by fire in 1812, but rebuilt between 1813 and 1817 by Edward Holl, the Navy Board architect. It contains Holl's early fire-proof internal frame and roof (see Section 3.4).

The parallel ropehouses at Portsmouth were rebuilt as a double ropehouse - three storeys and attic with the laying on the ground floor and the spinning above - following the destruction by fire of the ropery in 1770. With the land to the north to which it was due to move still not reclaimed, the new ropery had to be rebuilt in the old position, though adopting this more space-efficient plan. It was working by 1775 but gutted by yet another

[25]Dickinson HW, 'A condensed history of ropemaking', *Trans Newcomen Soc*, XXIII, 1959/60

fire in 1776. With the ground still unreclaimed, the brick shell was re-instated the following year, though in timber - fireproof construction was yet in its infancy.

Unlike either Devonport or Portsmouth, the re-building of the ropery at Chatham was more opportunistic than planned, largely as a result of the risk of fire which the old timber ropehouses presented to the new Anchor Wharf storehouses erected alongside in 1786. The new double ropehouse was modelled on that at Portsmouth, and included vaulted cellars for storing tar barrels. It was built between 1787 and 1792, and is not only largely as constructed, but retains much working ropemaking plant. Following an initiative by Samuel Bentham, in 1811 Henry Maudslay produced more powerful forming machinery for spinning, probably designed in part by either Bentham or Marc Brunel. Several of these machines, as well as stronger ones from 1854, are still in operation.

Between laying and spinning, the twine was tarred to preserve it. This process required a store for the newly-layed twine - the white yarn store - , a tarring house containing kettles of hot tar and a winding house to draw the twine through, and a black yarn store where the twine was dried and wound onto bobbins preparatory to spinning. From here it was taken to be made into rigging.

The Navy adopted wrought iron chain cable in 1810, for which Brown, Lenox & Co in Millwall, who patented the stud link chain, remained its sole supplier until 1916. Testing machines for the cable were developed in 1813, and wire rope was being used by the Admiralty from 1838. Though not a manufacturer, the navy needed to check the condition of its metal cables. The chain and cable testing houses were a specialised facility for checking the strength, and storing, iron chains, metal cable and anchors. They were built at both Portsmouth and Devonport in the 1840s, the former under the supervision of Captain Beatson, by then the resident engineer. He designed a free-standing iron-framed building, built by Henry Grissell between 1844-47 and including space for the testing rig and chain cleaning apparatus, and a large area to store the heavy and bulky chain (see Section 3.4).

Assessment

Unlike the other dockyard buildings, the importance of the roperies need only be considered in relation to one another. The remains of commercial rope-making industry are very rare, leaving only traces in the documentation or the archaeology of town plans. In Newton Abbot a terrace of houses fronts an open-air ropewalk. A small eighteenth century ropewalk survives at Barton-under-Humber (II), and there is another example from around 1900 at Grimsby (II) for the local fishing industry. Neither of these is of the scale or completeness of the three naval roperies, which are the most important sites for this industry in the country. The lack of other roperies of the size and importance of those within Great Britain means that a meaningful assessment should consider roperies in a

European context.

No groups of eighteenth century industrial buildings in England are either individually as large, or adhere as a group to such modern concepts as process-flow planning (see 3.1-2). While obviously hugely significant in terms of the organisation layout of plant and the application of power to industrial processes, the key textile sites of the 1760s and 1770s like Cromford and Belper employed many fewer people, and were situated on comparatively compact locations. Consequently, all three roperies are considered to be of outstanding national importance and indeed, in view of Britain's world role in the 18th century Industrial Revolution, of international significance. Their grading reflects this, while acknowledging some gradation of importance resulting from different levels of completeness.

The ropery at Chatham is the most significant. It is a complete operational complex, containing all the component buildings for producing hemp rope, retaining working machinery, of international importance. All the ropery buildings at Chatham have a higher grade, reflecting their importance. There is a good group at Devonport, especially the tarring house and the spun and tarred yard stores and including the house of the Master Ropemaker, but it has lost the important laying house. The Portsmouth ropery (**II***) is the least complete of the three; while the first of the double roperies, in which the spinning and laying houses were encompassed in a single building, it was the first to cease production, in the middle of the nineteenth century, and was rebuilt internally in the 1860s.

At Chatham the 1728 hemp store (**II***) was originally a single storey building with a curved double gable, but this was lost in the extension of 1743, when a parallel building was added to the east. In the nineteenth century it was extended by a third to the south, and a second storey added in 1812. In 1830 a beam engine house was attached at the north end, the iron entablature of which survives. Of the four c1771 hemp stores at Devonport, only one survived the bombing raids of 1941 (**II**), and is substantially altered. There are three former hemp stores at Portsmouth of the same date, which were rebuilt internally in the 1960s (**II***).

Two examples of hatchelling houses survive, both built as part of the general renewal of their respective roperies, but this was not a process that demanded specialised buildings and neither contains particular process-related details. The Portsmouth hatchelling house (**II***) was built in 1771, and was connected to the neighbouring spinning house by a covered bridge by 1785. That at Chatham of around 1787 (**II***) was built as part of the rebuilding work with the yarn stores and tarring house, and was built at the north end of the great double ropehouse.

The fireproof frame with which Holl rebuilt the Devonport spinning house (**I**) followed

closely on that which the architect put into the Chatham sawmill. It was technically in advance of similar structures in textile mills of the period, which constituted the principal the testing ground for fireproof iron structural systems in the early years of the century, and the roof is particularly rare. The spinning house has a central part in the pioneering phase of iron framing with early textile mills including Ditherington Mill in Shrewsbury, (I), the Whitehaven Barracks Mill (II), Armley Mill, Leeds (II*), and Beehive Mill in Manchester (II*). Although it was shortened after wartime bomb damage, the spinning house is of outstanding interest as one of the main branches in the incomplete family tree of fireproof metal-framed construction (see Section 3.4).

The double ropehouse at Chatham is a unique instance, on this huge scale, of an unaltered late eighteenth century industrial building, containing almost original working plant, within a contemporary context (**I**). Comparisons outside rope production and the dockyards could be made with such working industrial sites as the Quarry Bank Mill, Styal, or Kew Bridge Pumping Station, both very complete sites with operational plant of international significance to their respective processes.

The earliest tarring house is that at Portsmouth built in 1747 (**II***), the only one of the old ropery buildings there to survive both fires, though it was altered later in the eighteenth century. White and black yarn were probably stored in one of the nearby 1771 stores parallel with the ropehouse, but like it, they have all been quite extensively altered this century (**II***).

The tarring process is most clearly manifested in the yarn stores and tarring house at Devonport, which are much as they were when completed in 1771. Parallel to and close beside the spinning house, they are arranged in a sequence determined by the tarring process, so that spun twine could pass from the white yarn store, be drawn through the tar boiler, and continue on to be dried and wound, in preparation for laying into rope. They include windlasses in the roof of the black yarn house for drawing the tarred yarn, as well as a nineteenth century execution cell with trap door in the tarring house (**II***).

The Chatham tarring and yarn houses were originally separate, and the 1787 buildings have been amalgamated into one (**II***). Before the introduction of steam engines, the tarring house was the only dockyard workshop with other than manual power, having a horse gin in the basement turning the tarring windlass.

Beatson's chain and cable testing house (**II**) has a complete iron frame and roof, travelling crane and archaeological evidence of the testing machinery for which it was designed. The frame is part of the evolution of structural ironwork in which Beatson was closely involved, and in which the dockyards were an important area of innovation (see Section 3.4). The

most famous testing house is Kirkaldy's Testing and Experimenting Works in London (II), established in purpose-built premises in 1864.

4.3 Metal working: smitheries, foundries and factories

Recommendations

Devonport

II Composite Shipbuilding Shed, South Yard
II* The North Smithery, Building SO 23, South Yard
II* South Smithery, South Yard
I The Quadrangle, North Yard N173-178, 187-191, 203-205

Portsmouth

II* No. 2 Ship Shop (Building No. 1/208)
II Brass Foundry (Building No. 1/142, E end (PSTO(N) 34 Store
II* Iron Foundry (Building No. 1/40)
II Boiler Shop West (Building No.1/84)
II* South Office Block (Building No. 1/88)

Chatham

II Former Galvanising shed
II* No. 1 Smithery
II* No. 1 Workbase

Greenwich

Deptford
II Former Steam Factory and Chimney

Introduction

With the transition between sail and steam during the first half of the nineteenth century, and from wooden to iron ships during the second half, the dockyards were expanded and radically altered in character (see 3.5). This process began with Sir Robert Seppings' structural improvements to battleship design from 1811, which involved the increased use of iron largely in knees and diagonal braces. By the 1870s, the old Thames yards had closed for good, Portsmouth had a large extension, and Chatham and Devonport were developing distinct new areas for steam-powered metal ships. Within the yards, many of the old smitheries and forges became redundant, and new types of engineering workshops, some pioneering novel construction systems, were replacing them. With engineering processes and techniques changing and increasing in scale, the few surviving drawings show many changes of use. These are reflected in alterations to the fabric of the buildings themselves, especially the earlier smitheries. Bentham's North Smithery at Devonport is notable in retaining its external walls almost intact except for the intrusion of the railway line in the

1860s.[26]

Wooden ships needed a variety of iron fittings, from small castings up to very substantial wrought iron anchors. In the usual uses of the terms, iron is cast in a foundry, and wrought iron worked in a forge or smithery, though it appears that in the dockyard smitheries iron was both founded and forged. Neither material was made within the naval yards. The Old Smithery in the South Yard, Devonport (1776), the oldest in a naval yard, and the New Smithery at Chatham (1809) both had a courtyard plan with forges in the side ranges and casting in the open central yard. Bentham's South Smithery at Devonport (1808) was solely for forging, and like Rennie's demolished smithery at Sheerness (1813-21) was rectangular in plan. They were all single storey structures with steep roofs carrying raised louvred clerestory ridges to let out the smoke and steam.

Internally, individual furnaces were arranged at intervals and served by hand bellows which occupied a considerable amount of room inside the smithery. At Chatham there were twenty-six small furnaces in pairs, and fourteen larger furnaces, each with a brick chimney. Bentham's slightly earlier smithery at Devonport had two parallel ranges rather than a courtyard, with eighteen furnaces in the east range and five larger ones in the west, each with chimneys passing through the roof.

The principal innovation to these traditional craft processes came through the greater power made available by the application of steam. In 1808 Bentham suggested that the Chatham smithery, then in construction, should use steam-powered blowing engines, even though they do not seem to have been a part of his own design at Devonport. The Chatham yard officers resisted, and the Navy Board consulted John Rennie. He approved the use of steam for blowing as well as for working the tilt hammers, but pointed out the consequences for employment among the smiths. In the end manual power prevailed until steam engines were finally introduced in the 1840s.

Rennie was more positive in introducing steam into smitheries of his own design. The earliest use of steam other than for pumping in the navy yards was in Rennie's anchor forge and smithery of c1814 at Woolwich (see Section 3.4). This innovative workshop had three steam engines working blowing engines for the anchor forges and five tilt hammers. It has been moved to the Ironbridge Gorge Museum for the reconstructed wrought iron works

[26]Evans D, The Buildings of the Steam Navy, unpublished report for English Heritage Listing Branch, 1994. This includes a detailed account of the design and construction of the steam engineering shops at Portsmouth, and of the Quadrangle, Devonport, with transcripts of many of the important documents. It is lodged with English Heritage, but has been published as David Evans, *Building the Steam Navy Dockyards, Technology and the Creation of the Victorian Battle Fleet 1830-1906*, English Heritage, 2004

there. Rennie's smithery at the new Sheerness yard (1813-21) was also equipped with a steam engine.

Unlike the other yards, metal-working capacity at Chatham was improved in a piecemeal fashion, additional sections being added to the smithery until the end of the century. Boulton and Watt engines were installed in 1841 and 1842 for blowing and working tilt hammers. In common with the other yards, Nasmyth steam hammers were added in 1844, and new foundry space provided in 1855. The construction of the Achilles at Chatham between 1861 and 1863, the first ironclad built in a royal yard, contributed to pressure on the existing forge and smithery capacity, and the courtyard was roofed over in 1865. The last major alteration before the new workshops on the St Mary's Island steam extension came into operation was a completely new iron roof in 1888, with brick gables to front and rear.

The Navy Board's response to the challenge of fitting steam engines to the navy's ships was a decision in 1829 to build repair facilities in the dockyards. Facilities for installing and repairing engines were concentrated at Woolwich, which was close to the important shipbuilding and engineering yards at Millwall, from whence both machinery and expertise was being sought by the navy. In 1831, Rennie Jnr designed the first naval steam yard there, with a steam basin and new building slips, and this was expanded in 1838-45. Various new processes were involved that demanded new buildings. Boiler shops were for shearing and punching sheets of wrought iron into boiler plates, and rivetting them into steam boilers. ('Boilermakers' was a condescending term applied by craftsmen building traditional wooden ships to those building iron vessels). Several brass foundries were built at this time, though they may have actually been making copper pipes for boilers, rivets, etc. The many castings for steam engines were assembled in erecting shops. The construction of distinct iron foundries apart from general smitheries marks the increasing specialisation of processes, and illustrates the wide range of uses for cast iron in both engineering and building construction during the first half of the century. The word factory came to be applied from the early 1800s to large buildings which combined a number of different processes in one large, steam-powered unit.

The new steam yard at Woolwich was the responsibility of Captain William Denison RE, who was Superintendent there until he exchanged appointments with Captain Beatson, who was formerly at Portsmouth, around July, 1845. The Woolwich steam yard contained a smithery, erecting shop and brass foundry, with a boiler shop designed by Denison in 1843 with sixty-two feet wide wrought iron trusses (II). A large chimney at the south side of the yard drew all the forges and furnaces (II).

Slightly later than Woolwich, which only operated until 1869, a new steam basin and

associated engineering shops were started at Portsmouth in 1845. They were planned by Denison and Andrew Murray, who as Assistant Chief Engineer at Woolwich (a civilian post) had prepared a report on smitheries in the dockyards. He followed Denison to Portsmouth in 1846. The design was taken over by Captain Henry James, who replaced Denison when the latter went off to be Governor of Van Dieman's Land later the same year. The buildings for which they were responsible at Portsmouth, all fireproof structures with iron frames, were a fascinating combination of strong, permanent structures, and temporary iron buildings using re-used materials, indicative of the urgency with which the Admiralty viewed the creation of new capacity for its steam-powered fleet.

Denison and Murray had already prepared plans and won approval for several new buildings, which James reworked when he took over. The two permanent buildings were the Steam or West Factory, now No. 2 Ship Shop, and the Brass Foundry, both built in 1847. The former was a long, comparatively narrow building, the plan forced on James by the limited space then available beside the new steam basin. It combined space for boilermaking, punching and shearing (cutting iron sheets and making rivet holes), heavy turning on large lathes, and assembling engines. The floor above was for light engineering and making casting patterns. The Brass Foundry was actually used initially for iron, and was not dissimilar to the early smitheries, though square in plan. Both are substantial red brick buildings with Portland stone dressings, and heavy cast iron internal members (see Section 3.4).

To meet the rising demand for iron, a temporary smithery, designed by James, was built entirely of iron, much of it re-used from material which James found available in the yard. It had round-arched iron windows like those in the Brass Foundry, and was clad in corrugated iron. It lasted until 1866.

In 1850 Colonel Greene was appointed Director of the Admiralty Works Department, and later in the year James left to head the Ordnance Survey. He left plans in preparation for a new Smithery, which was developed by Greene and Murray and put up between 1852 and 1855. This was very different to those of the previous generation of metal-working shops. More innovative for a permanent building, it was an all-metal construction, square in plan with chimneys in each corner and an even larger one in the centre.

Greene continued to expand the casting capacity of the yard with an iron foundry, which was working by 1861. In contrast to James' No 2 Ship Shop and Brass Foundry with their careful architectural detailing, Greene's work, at Portsmouth and elsewhere, is more functional. His Iron Foundry forms a roughly L-shaped range, with the main foundry building on the front and a trimming shop with machine tools for working the castings along one end, enclosing a yard with a rotating crane.

Demand for armour plating for warships increased sharply in the 1860s. It was manufactured at specialist works like the River Don foundry in Sheffield. This increase can be traced in another extension to the smithery at Chatham, but at Portsmouth it resulted in the construction of a new and very large armour plate shop, which replaced an iron shed in 1867. It was designed by another engineer officer, Colonel Sir Andrew Clarke. The plan has some similarities with that of the South Smithery, with four large corner chimneys. Little more than their stumps and sections of heavy brick walls survive of the original structure (NL).

At the same time Greene, having seemingly centralised design away from the individual yards, was building combined smitheries with saw mills at both Sheerness and in the South Yard, Devonport. Both smitheries were extensions to those already in operation. That at Sheerness has gone, but the Devonport South Smithery survives, attached to the remains of the 1776 courtyard block. It is similar in plan to Greene's Portsmouth smithery, square with corner chimneys and an internal frame of H-section columns forming a central square, although the walls are of masonry (see Section 3.4). The saw mills and their relationship with the smitheries are discussed under Section 4.5 on woodworking.

Unlike the circumstances of the steam engineering works at Portsmouth, described above, both Chatham and Devonport had completely new steam yards built apart from the older areas, which radically altered the role of both. However, the Admiralty's approach to the two extensions was completely different. At Devonport the Keyham steam factory was planned carefully over about five years. The plans were forwarded to a nationally renowned architect, Sir Charles Barry, for him to prepare a suitable architectural clothing. His son noted wryly that is was 'the only example of his treatment of a class of buildings which it has been common to despair of architecturally, and to surrender to the domains of plain and even ugly utilitarianism'. Keyham was omitted from Barry's obituary article in the RIBA Journal. This building was clearly considered a major work, and one on a different scale to the already over-stretched steam factories at Woolwich and Portsmouth. While Barry's involvement was both unprecedented and unrepeated in a naval context, the division between architect and engineer on major industrial complexes was well established by the 1850s.

An early general plan for what is now called the Quadrangle consisted of separate buildings around a large yard, but it was reorganised by Greene and his deputy William Scamp, who roofed the yard over to create an undivided, flexible workshop. It was completed by around 1864. Within the one building, connected by an internal railway and with two huge chimneys drawing all the furnaces, were large storehouses facing the steam basin, a central iron foundry at the rear flanked by the chimney towers, with brass foundry and pattern shop either side, and steam engines connected to shaft drives in both rear corners; boiler shop

and heavy turning shop were along the sides; and within the adaptable quadrangle itself varying uses included areas for coppersmiths, armourers, platers, millwrights, and engineering students. For its date, this represents a revolutionary concept in factory planning. The scale and inherent flexibility of the building has meant that it has been adapted to numerous new uses since its completion.[27]

At Chatham the approach could not have been more different. The new yard was built north of the old yard as at Devonport, and with it Chatham took on a new lease of life as a building yard for iron ships. For its three main engineering buildings, rather than build an ultra-modern integrated works enhanced by the architect of the Palace of Westminster, as at Keyham, the Admiralty moved three of the recently erected slip covers from Woolwich, soon after it closed in 1869. The earlier two had been designed by Fox, Henderson and built at Woolwich in 1845 and 1847. They became the No 8 Machine shop and Boiler shop, while the 1855 slip cover by Greene was the Prom EW Factory (demolished). In 1880 a further metal-framed building was added, now called the Combined Ship Trades office (II). This is a complex and interesting structure which illustrates the development of metal frames in the generation since the slip covers (see section 4.1).

The transformation in warship design between 1850 and 1861 meant that Devonport was excluded from the construction of first-class warships until 1900, and many of the new metal ships, starting with HMS Warrior, were built in private yards such as at Barrow, Teeside and Clydeside. Specialist engineering and metal working buildings were added during the later years of the century, but metal shipbuilding, in the open, consisted largely of assembling components brought in from elsewhere, and existing buildings could be re-tooled to cope with changes.

Assessment

The significance of metal-working buildings within the royal dockyards is underlined by a swift comparison with the very scant survival of the navy's commercial counterparts, from forges and foundries to the large-scale engineering sheds of the later nineteenth century. Naval metal workshops dwarf in scale the small craft-based workshops that have sporadically survived in villages and farms. Larger foundries, for servicing agricultural implements, were built in country towns throughout England. The only extant examples which retain working machinery are the Long Shop at Leiston in Suffolk (II*) and Sara's Foundry (II*) at Redruth in Cornwall. The Long Shop was built in 1852 as a purpose-designed structure for the assembly of portable engines, and survives as the most outstanding industrial building representative of large-scale agricultural engineering. Comparisons can also be drawn with the early development of metalworking on an industrial scale: the grade I listing of Abbeydale Industrial Hamlet in Sheffield serves as an

[27]Evans D, 1994, *ibid*

indication of the importance and extreme rarity of these. Very little now remains of one of the most important metal-working centres in the world during this period, at Sheffield: the works which developed along the Lower Don Valley produced massive forgings and castings, armour plate, and armour-piercing gun shells. Other larger scale forges and smitheries, like the old Carron works in Glasgow, have also gone.

Of commercial shipbuilding, only isolated fragments remains of the early iron shipbuilding industry on the Thames. These include Rennie's Quadrangle building of 1824 (II). Equally little can be found of the later nineteenth century shipyards along the Wear, Tees and Tyne. Of the larger engineering shops of the mid-late nineteenth century, the very large Fairfield works at Govan (II*), designed in 1869, the Linthouse marine engine works at Glasgow of 1872 and the boiler shop of 1888 are of comparable interest, though from a slightly later phase than the Navy's examples. The large Heavy Engineering Shop of Vickers in the centre of Barrow (1900; II) may include an erecting shop of c1875. From around 1900 this type of building was replaced by standardised steel structures of less archaeological interest.[28]

Of related metal-working industries, the most important single building is the Brass Foundry (I) at the Woolwich Arsenal, built in 1717 and altered later in the seventeenth century, for casting and boring canon. The Arsenal remains the only industrial works in the country of comparable scale and historical interest to the royal dockyards. The large engineering works there have been much more extensively altered than those at Devonport, Portsmouth or Chatham. The building closest in character to the navy's works is the Armstrong Gun Factory (II), an H-shaped range with an iron internal frame which is an almost exact contemporary of the Keyham Quadrangle. Despite its importance in the production of gun barrels, it was built on a much more restricted scale, and is without the remarkable level of architectural attention which distinguishes the naval factory.

The dockyards smitheries merit a superifical comparison with the foundries built for the armaments industries of eighteenth century Sweden and France (the latter benefitting from imported talent of British ironmasters). None of them have retained original machinery.

The comparatively small size of the earlier generation of naval smitheries and their usually central location meant they were vulnerable to redevelopment, and all were rebuilt during the eighteenth century. The oldest example is at Portsmouth, built in 1794 but long since converted to the North Office Block (II). Given the change in scale of metal-working during the following century, it is remarkable to find two examples from this period which maintain their original morphology. Although the old layout of the 1776 Devonport Old Smithery (NL) can be traced, but it is very fragmentary. It has been so much changed that not enough remains of the historic fabric or plan to convey anything of the processes which went on

[28]Hay G and Stell G, *Monuments of Industry*, RCHME, Edinburgh, 1982, p121-125

within, and it is not therefore listable.

The North Smithery, Building SO 23, (**II***) designed by Bentham at Devonport, is especially interesting as an example of the Inspector General's influence in the yard, and because apart from the intrusion of the railway in the 1880s the fabric is much as he designed it. Further examination of both fabric and documentary evidence will no doubt throw more light on his thinking. The South Smithery (**II***) was part of the joint metal and timber complexes which Greene conceived for Sheerness and Devonport, sharing steam power, and as such it is largely complete, although the corner chimneys have been altered. The open plan exemplifies the changes which steam-powered plant such as Nasmyth's steam hammer had imposed by the 1850s. Though altered, it has no parallels outside the navy yards.

At Chatham the No. 1 Smithery (**II***) shows how metal working developed over some seventy five years, and was indeed still in use when submarines were being built at the yard in the 1960s. The courtyard plan laid out by Edward Holl responded to the need for an open space for the largest processes, such as anchor forging, which were carried out within the smithery at that time. Although it is roofed over, it is significant that this layout is still apparent in the building today. Its various alterations and additions clearly indicate how the original concept was adapted and modified to meet changing demands imposed by a modernising navy.

Steam engineering

The steam workshops built at Portsmouth during the 1840s and 1850s, Devonport in the 1850s and Chatham from the 1870s, are without parallels outside the dockyards, and offer striking contrasts in their approach to planning. The three principle surviving engineering workshops at Portsmouth, the No. 2 Ship Shop (**II***), Brass Foundry (**II**) and Iron Foundry (**II***) were built under pressure of time, preventing a single integrated building being deployed such as the Quadrangle (**I**) at Keyham represents. For its scale and advanced planning, this qualifies as one of the most remarkable engineering buildings in the country. It combined within a single space all the various crafts which needed to be integrated for assembling and maintaining steam plant, with scope for these arrangements to be adjusted as required: boiler shop and plate-forming shop; fitting, turning, and erecting shop, smithery, foundry, brass and copper shop. Two steam engines for the machine tools and furnaces, stores and office space were included, and a leading architect (Charles Barry) employed to dignify the exterior.

In contrast to Keyham, most factory complexes of the period had their separate functional components individually expressed, as at the Vickers and Co Atlas Works in Sheffield with its palace front, or the classical facade of the Fairfield Shipbuilding yard and Engine Works (1869) in Glasgow, which conceals the machine halls behind. Moreover, any comparable

examples which exhibit this unity and completeness have gone. Complete factory complexes of the period are extremely rare (for example, the Jackfield Tile Works, now museum, at Coalport in Shropshire (II*)). Factories of the scale and completeness of the Quadrangle simply do not exist. Some front ranges, for offices or pattern shops, are all that remain of large nienteenth century foundries like the Sheepcote Street Brassworks, Birmingham, or the Globe Works in Sheffield (c1825, II*). Even if one seeks examples from other industries, such as textiles, the Quadrangle is a remarkably early and successful case of the unified approach to factory design, anticipating by several decades the early twentieth century automobile industry.

All the naval engineering structures are greatly enhanced by their context beside their respective steam basins. At Portsmouth, where the new steam yard was built alongside the old Georgian dockyard, the sharply increasing scale of dockyard buildings can be clearly seen. Keyham was a new and distinct yard with its own impressive entrance. Two pair of houses for its own officers formerly stood to the rear of the Quadrangle, which was formally situated squarely overlooking the nine acre No. 3 Basin (**II***). At Chatham, on the other hand, the resited slip covers used for the engineering workshops have been completely decontextualised. Their significance rests much more on their position in the technical development of metal space frames and wide-span roofs discussed in Section 3.4. The one exception at Chatham is No. 1 Workbase (**II***), built as an an engineering workshop next to No. 2 dry dock and in association with the building of *Achilles*.

4.4 Woodworking and manufacturing

Recommendations

Devonport

II* South Saw Mills, South Yard S128, 148-150
II Composite Shipbuilding Shop, South Yard
II House Carpenters' Shop, South Yard

Portsmouth

I The Block Mills and Nos 35&36 stores (Building No. 1/153)
II No. 33 Store, North-west building (Building No. 1/150) See 4.6
II* No. 25 Store (Building No. 1/118) See 4.6
II No. 24 Store (Building No. 1/117) See 4.6

Chatham

I Brunel's Saw Mill
II* Clock Tower Building (see 4.6)
II* Timber seasoning store, North
II* Timber seasoning store, South
I Lead and Paint Mill
II* Joiners' Shop
II Former House Carpenter's Shop
II* Former Wheelwright's Shop
I Former Mast House and Mould Loft
I Sail Loft

Sheerness

II* Archway House, Building 23
II* Former North Saw Pits, Building No. 84
II Building No. 86
II Former Sawmill, Building No. 105-107
II* Former working mast house, Building 26

Introduction

This section is composed of a heterogeneous group in which the buildings themselves only weakly manifest the nature, scope and development of the work carried on within them. All were devoted to the processing of a raw material. Timber was the most important of the various materials worked in the yards, and the numerous different processes and crafts were carried on both in more or less specialised workshops, and in the open. Hemp in the

ropeyards and iron and other metals in the smitheries are covered in previous sections. Other significant raw materials included canvas for sails, paint, varnish and tar, and glass. The last three were delivered to the dockyards ready to be used, but making sails and paint were specialist manufacturing operations for which dedicated buildings were usually provided.

A large proportion of the shipwright's workshops were ephemeral, clustered around building slips, and have left no traces. Many other crafts were carried on in non-specific buildings which have been since used for other purposes. The semi-quadrangular storehouses at Portsmouth for instance, designed in 1786, included space for shipwrights, wheelwrights, house carpenters and joiners, craftsmen producing capstans, blocks and trenails, as well as for clerks. Many of these crafts have been obsolete for a century and a half, and have left scarce archaeological evidence of their former centrality to the work of the yards.

Converting felled trees to beams and planks was an exclusively manual process in the dockyards until steam-powered sawing was introduced in 1812, but timber continued to be planked by hand into the second half of the nineteenth century. Logs were cut over saw pits by pairs of sawyers using double-ended saws. Because these were below ground and lined with brick, saw pits have a strong archaeological potential. The sawyers were protected by open timber sheds which have not survived. A related but more permanent form of construction was adopted at Rennie's model yard at Sheerness. Of the North Saw Pits, built in 1828 and now called Building 84, each bay formerly covered a pair of saw pits. The structure is one of the earliest known free-standing iron frames, - the brick infill is later -, in which additionally the connections between the columns and beams are made without arched connections or braces (see Section 3.4).

A related structural system was employed for what is now the most complete and unaltered workshop for forming timber in the dockyards. Archway House was built in 1825 to the rear of the three main dry docks at Sheerness. It was a long single-depth range articulated into five sections carefully separated by stone stair wells in bays with firebreak walls. It formed an integrated carpentry shop containing saw pits in three sections - probably the last built in the navy yards - separated by timber seasoning sheds, with carpenters' shops, timber stores and mould loft on the first floor, and more storage space in the attic. Its specialised cast iron fireproof frame, fireproof and with castings in the columns for the seasoning racks, is discussed in the Section 3.4.

Many saw pits were incorporated into other buildings. The former Present Use store at Chatham, now the Clocktower Building, originally had an open ground floor on timber posts with six saw pits at the northern end, and there were saw pits in the masthouses,

including that at Chatham.

Mechanised and powered sawing

The mechanisation of woodworking was slow in Britain, and the application of water power to sawing lagged well behind the continent, in both the naval dockyards and commercial industry. The introduction of steam-powered saws was one of Samuel Bentham's first innovations to the yards following his appointment as Inspector General of Naval Works in 1795. Bentham had a specialist interest in this field, and lodged key patents in the early 1790s. His steam-driven saws were installed at Portsmouth in 1798, followed five years later by the forming machinery for the Block Mills. These were pioneering applications of steam power and machine tools, of which 'the technology and working methods... heralded a new era in the manufacturing of wood products'.[29]

He helped to justify the high initial cost of the steam engine by combining it with a pump to empty the docks at Portsmouth. The engine was placed within one of a pair of three-storey brick buildings which contained the pumps and woodworking machinery, built over the dock sump, formerly Dummer's Upper Wet Dock. Two years after steam-powered sawing had begun, Marc Brunel offered his patented block-making machinery to the Admiralty. Supported by Bentham, the machines were made by Maudslays, and installed in a single-storey shop fitted into the space between the two earlier ranges at Portsmouth. They were in operation by 1803, powered by a larger engine bought from Boulton and Watt in 1800. The buildings themselves are traditional in construction. Inside power was transmitted by overhead shaft drive with belts to individual machines. Brunel installed a more advanced steam-driven system at the Royal Arsenal at Woolwich in 1814.

Brunel, Bentham and Holl then went on to design a steam-powered saw mill which was built between 1812 and 1814 at Chatham, then the main shipbuilding yard. It had a symmetrical I-shaped plan consisting of an engine and boiler house at one end and a joinery shop at the other, separated by a single-storey mill divided into nine open-ended bays. Each one contained a reciprocating frame saw, the type most used for cutting beams and planks, mounted on the basement floor, with the frames, rising up to the ground floor level, connected to a drive shaft in the basement by belt drive. Timber was fed through the frames by railed trolleys. The fireproof frame in the workshop is the earliest example of the system used by Holl, and discussed in the section 3.4.

Brunel also devised an extraordinary mechanised system to transport sawn and unsawn timber to and from the mill. Logs were floated through a tunnel from the mast pond to the base of a vertical shaft beside the mill, up which they were raised by a lift worked by a

[29]Lowe H, 'The mechanisation of architectural woodwork in Britain from the late eighteenth to the early twentieth century and its practical and aesthetic implications. Part 1: the period c1790-c1860' *Construction History*, vol.8, 1992, p64

counter balance tank filled by condensate from the steam engine. This further powered an overhead gantry crane which moved the baulks of timber between the mill and a storage area to the north. All of this conveyancing system has gone, although the tunnel and shaft survive below ground.

Although sawmills were proposed in 1812 for Devonport, Portsmouth, Chatham, Sheerness, Woolwich and Deptford, only that at Chatham appears to have been built. Indeed, new manual saw pits were provided by Rennie at Sheerness after the Chatham mill had been working for some years. This is surprising given Rennie's pioneering use of steam power for pumping both at Chatham and at Sheerness and in the bakery and mill at the Royal William Yard, Stonehouse. At Portsmouth, sawing was mechanised around 1850, the new reciprocating saws with their 'six blades could get through eight to ten logs daily, doing the work of sixteen pairs of sawyers'.[30] New sawmills were finally built at Sheerness between 1856 and 1858 and at Devonport around 1860 to the designs of Colonel Greene. They share close similarities in their planning and internal construction, and in being jointly built with new extensions to the smitheries alongside. At the Devonport South Smithery (see above) and probably also that at Sheerness smithery (now demolished), the saw mill engines also acted as blowing engines for the furnaces, and may have supplied steam for Nasmyth hammers.

Greene's sawmills worked in a similar way to Brunel's. At Sheerness, a pair of beam engines at one side was connected by drive shaft to four frame saws mounted centrally across the square mill. Logs were introduced and planks or beams passed out through wide entrances to front and rear. The floor above was used as a joinery shop. On the opposite side from the engine and boiler houses was a large 'junk store', two fire engine houses and workshops.

The Devonport South Sawmill is similar, though architecturally more unified and built of ashlar rather than brick, and without the large store. It had a pair of engines which drove a drive shaft off a spur wheel, as well as fans for the furnaces and possibly other plant in the adjoining South Smithery. The internal iron frame was similar to that at Sheerness (see section 3.4).

There is clearly a question of why the Admiralty were investing in large new sawmills, not to mention hand-operated sawpits, just at the dawn of iron naval shipbuilding, with the Achilles, the first iron warship in a naval yard, being laid down in 1861. Obviously, the Navy anticipated continued strong demand for sawn timber, even if the mills were built in conjunction with large expansions to the iron working facilities at both places. The South Smithery at Devonport was on the site of a carpenter's shop which may have been moved

[30]Field, 1994, p5, *op cit*

into the new South Sawmills. Land occupied by the ranges of sawpits was also made available by the new mills.

Construction in timber continued at Devonport, which was excluded from building iron ships until the end of the century. It was involved in building composite ships, which for a period in the second half of the nineteenth century continued to be employed by the navy. They had iron frames and wooden hulls. A Composite Shipbuilding Shop was built at Devonport in 1878-82, between the building slips, Scrieve Board and bending shop and the new saw mills. This also had a combined iron and timber frame, with trussed timber purlins and H-section stanchions, and was clad with corrugated iron. It is comparable to shipbuilding sheds commonly seen in civil dockyards.

Paint and lead

The other process to which steam power was applied early was the rolling of lead, which was used both for plumbing and in paint. The latter was both an expensive commodity and an inflammable one. After considering an extension to the Chatham sawmills for a lead rolling mill, a site some distance to the east of the ropery was chosen, and a combined lead and paint mill designed by Edward Holl. Chatham supplied all the paint for the Navy. This integrated works contained a beam engine and boiler in the single storey shop linked directly to a double rolling mill, and with a line shaft into the adjoining paint shop with bevel gearing to nine paint mills. It included a furnace for melting and casting lead, oil tanks, offices and room for painting oars and other items. On the floor over the paint mill was a large room with iron frames for stretching and painting canvas. The fireproof iron frame was identical to that which Holl had used for Brunel's saw mill, an almost contemporary work, and for the slightly later spinning house at Devonport, rebuilt between 1813 and 1817.

Paint stores at Portsmouth exist from around 1869; and from the 1890s, when Murray, the yard engineer, built one across the Camber, on the west side of the yard. It stood on iron columns above the water, so that if fire broke out, it would collapse into the water.

Masts

Masthouses are another of those classes of building which were once numerous but are now reduced to one or two examples. Typologically they were lengthy timber sheds often built in groups, in which the long timbers for the masts could be cut, assembled and stored. Alongside the workshops, known as the working masthouses, were masthouses used for storage, mast ponds where timber could be stored under water to prevent them cracking, and mast locks in which masts could be kept completely submerged.

The only surviving example of the traditional type of masthouse is the 1753 masthouse at Chatham, which consisted of eight parallel masthouses. It was constructed in the dockyards

building vernacular using old ship's knees and other timbers, covered with weatherboard. A mould loft was built over the central two bays in 1755 by raising the roof; it was in this wide space, spanned by large queen post trusses, that HMS Victory was laid out. The only other example is the Scrieve Board laid inside one of the old covered slips at Devonport. The name was given to the drawing floor on which finished outlines were 'scrieved' full size, for finished sections of steelwork, as opposed to the earlier work on a new design which was worked on in the mould loft. The Scrieve Board was conveniently located next door to the bending slab and adjoining Slip No. 4.

The masthouse at Sheerness was in sharp contrast to this traditional arrangement at Chatham, as befits that carefully laid out yard. Rennie planned a complex consisting of a working mast and boathouses and matching mast store, separated by a mast pond, and connected by a tunnel under the working masthouse to the river. The mast store was built over a vaulted mast lock with individual chambers fitted with gates and capable of being pumped out as necessary. The surviving working masthouse (Building 26) was designed by Holl and built between 1823 and 1826. It had a very unusual iron internal structure designed to achieve wide working areas for shaping masts (see section 3.4)

Like mould lofts, sail lofts required unobstructed spaces in which canvas could be stretched out, cut and stitched. This necessitated the use of upper storeys without obstructing columns, and sometimes the sail makers were put into the top floors of the storehouses. Purpose-built sail lofts such as that at Chatham, the only remaining example, included considerable storage space for canvas and finished sails. An early drawing shows a crenellated parapet similar to that on the contemporary Officers' Terrace. The existing building was built in 1723. It had a semi-basement and ground floor for storage, and an open first floor sail loft with timber posts set into the side walls to provide rigidity and stiffen the floor of the attic above. A wide stair flight led down at one end to the dispatch door.

Assessment

The highly specialised nature of some of the structures listed in this section, such as paint mills, and the high rate of loss experienced by others, like the seasoning sheds, has resulted in the fact that few comparisons can be drawn. Hardly any of these building types are to be found outside the royal dockyards, and thus their assessment is solely dependent upon their historical significance within the content of the navy yards.

Two other factors add value to the buildings in this section. The first is their place in the forefront of the application of steam engines to processing and manufacturing, and the second the development of iron constructional systems. These issues are more fully considered in the Section 3.4.

Brunel's block mills (I) are so well known they require little further assessment to be made here than to repeat that of Cossons, that they are 'perhaps the first installation in the world in which machine tools were used for mass production'.[31] The historical significance of the site is compounded by its archaeological value, containing not only substantial pieces of machinery and parts of the power transmission, but also situated above the former Upper Wet Dock built by Dummer in the late seventeenth century (see 4.1).

As in mechanised woodworking, the navy was the earliest organisation to develop steam-powered sawing. Estate saw mills are much more modest affairs, usually forming part of planned, model farmyards. There are no saw mills outside the navy yard which even superficially merit comparison with the large and complete examples at Chatham, Sheerness and Devonport.

The Chatham saw mill (I) was not the first to be powered by a steam engine, but was certainly one of the earliest. The first in London was built in 1806-7, and Brunel himself apparently had an engine in his own workshop. The State, in royal dockyards and at Woolwich were, under Bentham's impetus, at the forefront of the application of steam to sawing and woodworking. The Chatham saw mill is the most complete early example in the country, containing as it does parts of the frames of the reciprocating saws, as well as the original fireproof beam floor of the engine house. There are very few manufacturing building of this period so complete. The interest of Brunel's extravagantly sophisticated lumber handling system also makes the area of the lift and tunnel of archaeological interest, one that should be recognised through its status as a Scheduled site.

Evaluating Greene's two mills is less straightforward, since they are essentially the same design, though interestingly adapted to the materials and architecture of their respective yards. Both have passed through further uses, and appear to have lost all evidence of their original role. The slightly earlier one at Sheerness (II), investigated by the Royal Commission in 1995, while little altered apparently contains no evidence of the mill's work, and the basement has been infilled. The smithery with which it operated has been demolished.

The Devonport South Sawmill (II*) possesses an important contextual relationship with the neighbouring South Smithery, sharing architectural details and a unique functional connection. There is further group value with the Composite Shipbuilding shop (II) just to the west. Large sheds of this type for shipbuilding do not exist in the old civil yards except at Glasgow, where the almost contemporary Govan works is a listed example. Building composite ships was a requirement forced onto the navy by the change to iron ships at the same time as the country had extensive warm-water colonial obligations, of the 'send a

[31] Cossins N, *The BP book of Industrial Archaeology*, Newton Abbot, 3rd edition, 1989, p135

gunboat' kind. This shed has therefore a particular historical resonance which distinguishes it from large industrial sheds of this period.

Evidence of woodworking outside the navy yards is again very scarce. The quadrangular plan workshops and stores at Portsmouth have been described in the Section on stores (see 4.6). Open-fronted seasoning sheds are commonly illustrated and documented from the medieval period onwards, but those at Chatham are the only surviving examples. Saw pits can be traced, but there are no sufficiently distinctive surviving examples which merit listing. The North Saw Pits (**II***) at Sheerness, however, are outstanding in a national and typological context for their introduction of a free-standing iron frame with rigid, unbraced end connections (see 3.5).

Carpenters' shops survive in rural areas and some towns, occasionally with nineteenth century machinery. These have not been quantified, but all are modest in scale and architecturally undistinguished. The House Carpenters' Shop at Plymouth is an architecturally modest but rare and significant surviving example of this type (II). The contrast with Sheerness is marked. The woodworking buildings at Sheerness are an unrivalled complex, including an integrated carpentry shop with seasoning sheds, sawpits and stores, a steam-powered sawmill, and a free-standing iron sawpit cover. In the former, Archway House (**II***), Holl (probably) attempted to bring together the various carpentry crafts into a rationalised building which would improve their efficiency, a notable example of industrial production planning. Like the North Saw Pits, it is another outstanding example of iron-framed construction (see 3.5).

The evidence for mast making has disappeared completely from both Devonport and Portsmouth, although they both had substantial capacity in the mid nineteenth century. No generic buildings survive outside the royal yards. The two surviving examples are contrasting in their building technology and organisation. The Chatham masthouse (**I**) is a magnificent example of the traditional type, built in the dockyard vernacular re-using timber from dismantled ships, with the mould loft above with its own strong historical associations, and facing across the extant South Mast Pond. Rennie's combined mast- and boathouse (**II***) at Sheerness on the other hand carries the imprint of his re-thinking of the organisation of the yard to try and improve the efficiency of its operation, forming part as it did of a complex of working mast and boat houses, mast stores, ponds and locks, linked to the yard pumping station, and built to a unitary plan from repetitive prefabricated iron units (see 3.5). This framing system with its diagonal braces is related to the remarkable New Tobacco Warehouse of 1813 in the London Docks, which has bifurcating struts rising from the columns in the same way, to support wide timber trusses.[32]

[32]Tucker G, in Carr RJM, 1987, *op cit*, p27

Holl's lead and paint works at Chatham (I) had sufficient capacity to supply all the yards with paint and rolled lead. It contains one the first of the fireproof iron frames which Holl developed for the navy, with other specialist fittings for paint manufacture and canvas painting. There are no other known paint works, and industrialised paint production almost certainly did not exist anywhere else in Britain at this time, and as an early and almost entirely complete example of a specialist manufacturing building of the late Georgian period is of great importance.

The Chatham sail loft (I) is now the only one of its type in the dockyards, or in the country. It is particularly notable since it is still in a use related to its original one, and forming a central part of the historic Georgian yard. Some examples of sail lofts have been identified in small ports, associated with warehouse buildings of comparatively modest size, and predominantly of nineteenth century date. Substantially complete ones such as at Topsham and Penryn have been listed, but none compare for scale of historical significance with that at Chatham.

4.5 Stores and storehouses

Recommendations

Devonport

II No. 3 Store, Morice Yard M066
II* No. 2 Store and former Furbisher's Shop, Morice Yard M067 & 68
II* No. 12 Store III 3 (The Painted Canvas Store), Morice Yard M046
II* No. 16 Store, the Powder House, Morice Yard M042
II No. 17 Store, Morice Yard M037
II* No. 4 Store, Morice Yard M070
II No. 8 Store, Morice Yard M055
II No. 5 Store, Colour Loft, Morice Yard M056

Portsmouth

II No. 33 Store, North-west building (Building No. 1/153)
II* No. 25 Store (Building No. 1/118)
II No. 24 Store (Building No. 1/117)
I No. 9 Store (Building No. 1/35)
I No. 10 Store (Building No. 1/58)
I No. 11 Store (Building No. 1/59)
II* South Office Block (Building No. 1/88)
II No. 5 Boathouse (Building Nos. 1/27 & 1/28)
II No. 7 Boathouse (Building No. 1/29)

II No. 3 Store (Building No. 1/39)
II* No. 6 Boat Store (Building No. 1/23) and slipway to front

HMS Vernon
II Vulcan block (Building No. 21) and attached bollards, HMS Vernon
II Buildings Nos. 47 and 92, HMS Vernon

Chatham
I Former Storehouse No. 3 and Former Chain Cable Store
I Former Storehouse No. 2 and Former Rigging Store
I Sail Loft
II* Lower Boat Store
II* Clock Tower Building

Sheerness
I The Boat Store, Building 78

Introduction
Storehouses were an important part of the victualling yards, were the commonest class of building in the dockyards, while in the ordnance yards almost every structure was used for storage.

Sailing ships, largely made from perishable organic materials, were constantly in need of repair to replace worn out timbers, sails and rigging, and large stocks had to be maintained at the principal yards, particularly during wartime. The predominance of storehouses in the dockyards declined with the advent of iron ships, but many have survived, often with new uses.

Naval storehouses divide between those for general stores, including the Present Use stores which kept material about to be issued to ships, and specialised stores such as those for hemp (discussed under the Ropeyards), paint or masts. Many buildings which were primarily workshops also included storage space: in the ropeyards for instance, workshops also acted as stores for tar or yarn. Others included office space for administering the in- and out-flow of materials.

The naval store houses differ typologically from the type of mercantile waterside warehouse common in ports such as Hull, Great Yarmouth or Penryn, and which from the later nineteenth century lined the south side of the Thames below Tower Bridge. These are effectively a type of transit warehouse, receiving goods directly from the ship, storing and in some cases processing them, before dispatching them, sometimes from the opposite side of

the building. The late eighteenth century warehouses along the High Street in Grimsby (II) are excellent instances of this type. None of the naval warehouses loaded directly from the quay except the two 1720s stores at the Morice Yard, around the end of which curved small embayments of the dockwall.

The Great Storehouses

The biggest storehouses, and the largest dockyard buildings after the ropewalks, were the general stores, referred to in most yards as the 'Great Storehouse'. These fall into two typological groups, those with a quadrangular plan, and those forming a simple rectangular plan. The first great quadrangular storehouse was built at Devonport in the early 1690s, eleven bays wide with a central archway through to the courtyard. (It is significant to note in passing that there was a clock displayed in the exterior, a remarkably early attempt to formalise the working day and the practices of an industrial workforce). Coad relates the planning to the precedent of the Amsterdam Arsenal Zeemagasijn of 1656,[33] and its main operational advantages as a plan form were compactness and security.

The Devonport storehouse was replaced with a much larger double quadrangle between 1761 and 1817. The matching elevations of the side ranges had pedimented centres, an almost ubiquitous feature of late eighteenth century institutional buildings, with comparatively small dispatch doorways. The sides were separate, and linked to each other at the corners by an archway with a first-floor bridge. The two cross ranges were inserted to separate the courtyards into two in 1814, and had iron columns to timber joists, and an iron roof. All were was destroyed in 1942. A similar arrangement is found on the Grand Store at the Royal Arsenal, Woolwich (1807-14) (II*). This is a three-sided quadrangle with linking bridges, open to the river to achieve a picturesque architectural effect, probably the work of James Wyatt. Separating the sides lessened the likelihood of a fire spreading between them, a constant anxiety for the dockyard officers.

A large quadrangular Great Store was built in the late seventeenth century at Deptford, although architecturally very much in the massive, sturdy manner associated with Board of Ordnance architecture of this period. The quadrangular plan was revived for two almost contemporary stores at Sheerness (1822-31) and the Melville store at the Royal William Victualling Yard (1823-32), both with a single dispatch archway leading from the inner court. Sheerness was the plainer of the two; Melville forms the centrepiece for Rennie's dramatic seaward front at Royal William. The last example of the Great Store was built at Pembroke around 1822. In their time among the most imressive buildings in the dockyards, and after the officers' houses the focus for much of the architectural attention given by the yard officials, all but the Pembroke and Melville stores have been either destroyed or demolished. For a discussion on the planning and framing of the fireproof Great Stores, see

[33]Coad J, 1989, o*p cit* , p123

Section 3.4.

More usual than the quadrangle were simple rectangular ranges to which light was admitted from both sides, usually with one or two rows of timber posts supporting cross beams. The oldest existing naval storehouse is the Present Use store set back from the quay at Chatham, (now the Clocktower Building), which dates from the reorganisation of the yard in the 1720s. In scale if not architectural refinement it is more like the stores of the Stuart yards. It originally had an open ground floor over saw pits.

The rebuilding of Portsmouth in the 1780s included a line of three imposing new stores. Nos. 9, 10 and 11 were divided internally into three with a heavy, wide central stair, and a pediment to the central section which makes them almost indistinguishable from contemporary offices. In contrast, the two storehouses built at the same time at Chatham are plain, functional buildings though their enormous length has an imposing effect. Nos. 2 and 3 Anchor Wharf are each around 200 metres long, set back from the quay and separating it from the ropery. They are comparable in size and architectural treatment to the large early nineteenth century stacks of the West India docks (1802/6) and London docks (1805), now demolished, but which they pre-date by two decades.

The Surveyor and consultant engineers employed by the navy were well aware of the potential benefits which the use of iron conferred in buildings for storage, and cast and wrought iron were deployed in naval stores from the first decade of the nineteenth century (see Section 3.4). Iron conferred a degree of fire resistance, could admit greater unobstructed spaces in which materials could be stacked, and had greater compressive strength than timber posts, which tended to either split if overloaded or punch through the floor. The oldest surviving instance of iron in a naval store dates from 1811, the simple cast iron posts at the Vulcan store, New Gun Wharf, but Edward Holl was using more sophisticated iron columns and a cast iron roof in large stores within the Devonport quadrangle at the same year. By the 1830s more complex structural arrangements which dispensed with the use of timber altogether were being tried out at Sheerness Great Store, the granary and Clarence store at Royal William Yard, and the granary at the Royal Clarence Yard. All involved collaborations between the Rennies and Edward Holl or his successor, G L Taylor, though the balance of responsibility for design varies in each case.

Workshop stores

The manufacturing sections of the dockyards mostly included dedicated storage space within workshops. The ropeyards usually stored highly inflammable tar in basement vaults, and had specialist stores for the raw hemp. Finished rigging was stored in rigging stores such as No. 3 Storehouse, Anchor Wharf, at Chatham. Two of the three floors in the 1723 sail loft at Chatham were for storing canvas and completed sails, and the smitheries had space nearby -

usually in the open - for storing coal and iron.

Unsawn timber was also kept in the open air, but sawn timber waiting to be seasoned was laid in racks in special ventilated seasoning sheds. To improve the quality of seasoned timber going into the ships, in 1771 the Navy Board established a standard, unitary design of seasoning shed. These were once very common in all the yards: at that time Chatham, Devonport and Portsmouth were expected to each need over 1500 feet of seasoning sheds, Deptford and Woolwich over 1200 feet each. Only two short examples of this once-important component of the Georgian dockyards survive today, both at Chatham.

Woodworking shops were combined with stores in four quasi-quadrangular plans of a 1786 design at Portsmouth. They had parallel pedimented ranges not dissimilar to the contemporary Nos. 9, 10 and 11 Stores, with pediments, separated by narrow open yards.

Masts were stored in underwater mast locks, such as that beneath the Working Mast House at Sheerness, a series of vaults with racks, connected by a gated tunnel to the river. It is not known if this still survives beneath the Mast House. An even more specialised type of store was that for boats. These were used to keep the numerous small boats which the navy needed dry and secure. Because of the difficulty of lifting boats, boat stores were typically single-storey buildings built of timber. At Portsmouth, the mid nineteenth century Nos. 5 and 7 Boathouses are weatherboarded sheds built over the Boat Pond. The double-storey Lower Boat House at Chatham of 1844 is of the same type, a significant and rare manifestation of a tried and tested technique of building construction in the navy yards.

Such vernacular buildings are in striking contrast to the No. 6 Boathouse at Portsmouth and the Boatstore at Sheerness. These stand out as examples of the innovative, experimental designs produced by the Royal Engineers. No 6 Boathouse (1845-48) was designed by Captain Beatson during his spell at Portsmouth, when he was thirty three. Its heavy iron frame is significant for the use of very large trussed cast iron beams to carry the boats on the upper floors. The Boatstore must be among the last and largest instances of their use in building (see Section 3.4).

Even more revolutionary was the Sheerness Boatstore (1858-60), designed by Colonel G T Greene and his assistant William Scamp with the iron founder Henry Grissell.[34] This used a trabeated multi-storey frame made from repetitive units of cast iron columns and cross beams and rivetted wrought iron longitudinal girders, with rigid bolted connections at the ends. In plan there was a central aisle open to the roof, spanned by a hoist and by travelling platforms at each level to carry boats to the storage bays either side. As well as its

[34]Skempton AW, 'The Sheerness Boat Store', *Trans NewcomenSoc*, XXX, 1956/57

structure, celebrated for its pioneering use of the portal-braced frame, Greene and Scamp were also very progressive in devising a largely mechanised system for moving the boats around the store. Handling of stores was almost entirely by hoist and manual labour, even with the development of hydraulic lifts and cranes in the 1860s. The Boatstore has a materials handling system much in advance of those available in other warehouses in the dockyards or outside.

Ordnance stores

The Ordnance Board had yards close to all the major dockyards where it could keep and maintain the arms and gun powder used by the navy. Armaments were the property of the Boards, were issued to ships when they were ready to leave the dockyards, and were returned while the ships were 'in ordinary'. The Ordnance occupied deep water sites close to the dockyards, containing stores for gun carriages and associated materials, workshops for smiths, carpenters and painters, and accommodation for officers and sometimes for a small garrison as well. Cannon and cannon balls were stacked in the open. Magazines were usually removed as far as was practicable to limit the effect of a catastrophic explosion.

Nothing remains of the ordnance yard stores at Chatham. Unlike the others it had one enormous storehouse, built in 1717 for both naval and army ordnance, and which when built must have been among the largest warehouses in the country. It shared the massing and some of the architectural devices that connect the generation of Ordnance buildings built between 1714 and 1720, during Marlborough's period as Master General, when both Hawksmoor and Vanbrugh were involved.

The contemporary Morice Yard at Devonport is on a far smaller scale and largely complete, although there are architectural similarities which connect it with Chatham. The original buildings are distinguished by the use of the local shaley iron-rich rubble stone which was excavated to make the gun wharf. Two parallel stores stood with their end gables to the quay, and there was a magazine in between, replaced by one a little further away in 1744. Apart from the great Victualling Board granaries at Gosport and Stonehouse, these are the only naval stores built directly on the quayside. Further stores were added of a similar scale and plan in the 1770s and 1840s. The early eighteenth century buildings have a spine wall, and were fitted with wooden rails for trolleys to handle the stores. The later ones have timber posts supporting the upper floors. No. 2 Store is a particularly little altered example, with boarded linings to the walls and a wide central dogleg stair.

The largest surviving ordnance store is the Vulcan Store of 1811-14 at the New Gun Wharf at Portsmouth. Like a number of Ordnance buildings in Portsmouth it has walls of patterned brick with black headers laid in Flemish bond. Its elevations are those of the late eighteenth century naval stores at Portsmouth, though the pediments are carried round to the ends of

the main range, but in plan it formed a three-sided quadrangle. The north wing was destroyed by bombing. Internally it contains only the third recorded use of cast iron as a structural element in a naval building. The other large store built at the same time is more conventional, with joists supported centrally by a large brick stack which rises through the building.

Assessment

With the houses of the yard officers, storehouses present the fewest problems of assessment among dockyard buildings. Their function is clear, they are of a type widely found in other industrial contexts, and little affected by considerations of architectural quality. Their historical interest is not diminished by the loss of machinery, since apart from hoists and lifts they generally had none. Indeed, since the activity of storage changed so little, they are often the least altered buildings in the yards, sometimes containing original stairs, horizontal wall boarding, and wooden rails. The recent examination of the railway warehouse at the Liverpool Road Station, Manchester (II*), shows that the archaeological potential of this class of building is considerable, and much information on the construction and operation of these buildings may be contained within them.

In a national framework, the dockyard storehouses of the eighteenth century are among the most important in the country. They are practically without parallels in the civil sphere. The fifteenth century Hanseatic League warehouses at Kings Lynn (I) and the 1670s Ordnance Board store in the Plymouth Citadel (II*) emphasise, by their uniqueness, the importance of the few buildings of this type which survive. A recent discovery of a seventeenth century warehouse at Exeter, with its projecting wharfage area over the river, was deemed to be such a rare survival that it was listed at Grade I. In terms of scale, comparisons can be drawn at an international level, most notably with the surviving 1770s warehousing facilities at Karlskrona, in Sweden.

Few late eighteenth century warehouses on the size of those in the naval dockyards were built for commercial stores. In conservative Bristol, the country's second port at the start of the eighteenth century, merchants continued to store goods in medieval cellars. Separate warehousing on a substantial scale did not appear until the canal basins of the later eighteenth century, such as Castlefield Basin in Manchester. Examples as early as the 1790s Cutler Street warehouses in the City of London stand out (II, demolished behind the facades). The group of Nos 1 and 2 Warehouses and their associated office at West India Dock (I) of 1802/3 are the outstanding commercial warehouses of this date in the London docks.

In their plan form, as discussed above, the naval storehouses differed from commercial dockyard warehouses, typically consisting of large store rooms with integral stairs, on two

or three floors. Clearly the commercial pressures of space that forced merchants to build tall, narrow warehouses weren't felt in the more rationally-planned dockyards.

The longevity of the Georgian stores, and the growth of much larger commercial warehouse complexes in London, Liverpool, Glasgow and elsewhere after the 1803 and 1823 Warehousing Acts, mean that Victorian naval stores generally do not have the same importance. The features that give some of the dockyard storehouses special interest are their early date compared with those in most other industries, as discussed above, their unaltered context within the yards, and their position within the evolution of modern iron-framed structural systems.

The stores at the Morice Yard and those at Chatham are of special interest by virtue of their setting within the eighteenth and early nineteenth century yards. The original Morice Yard storehouses Nos. 4 (**II***) and 8 (**II**) are rare Board of Ordnance stores, the latter rather modified, and with intact later storehouses such as Store No. 2 (**II***), the Officers' housing and the perimeter walls, part of an almost unaltered gun wharf. At Chatham, the much larger former Present Use store (Clocktower Building, **II***), also of the 1720s, is at the heart of the Georgian yard and an example of the combined workshops and stores of the period, as is the 1723 Sail Loft (**II***), the only surviving example for this important craft. The enormous Anchor Wharf stores (No. 2, the Fitted Rigging Store, and No. 3, **I**) form part of the complete ropeyard at the south end of the yard. They are the largest set of eighteenth century warehouses in Britain, anticipating the scale of the large warehouses being built in London and Liverpool after the 1803 Act.

The late eighteenth century warehouses at Portsmouth are typologically in two groups, the pedimented row of the South, Middle and Present Use Stores, Nos. 9, 10 and 11 (**I**), and the former set of four quasi-quadrangular stores. The former are the finest group of pre-nineteenth century warehouses in Britain, remarkably complete with their elegant pedimented fronts, and wide flights of timber stairs. Of the four combined stores and workshops at Portsmouth, Building 25 (**II***) retains the plan and internal fixtures of the original, a unique example of a combined workshops and store. Buildings 24 and 33 (**II**) retain the important courtyard plan which distinguishes these buildings from either workshops or offices in other commercial contexts, as well as the New-Classical planning of the four stores, themselves marking the corners of a large courtyard, which was a direct consequence of the more controlled development of the dockyards from the 1760s.

The only surviving example of the concept of the 'Great Storehouse' is the Melville store at Royal William Victualling Yard (**I**). The last of the large quadrangle stores, it forms the centrepiece of Rennie's magnificent yard, laid out on a grid and a rare example of a state enterprise to compare with the great royal industrial works on the continent. The

comparable quadrangle store at Sheerness, built by Rennie and Holl and completely fireproof (Melville unaccountably has timber floors) has been demolished, but Holl's store at Pembroke (II*) is an example of the iron framing system which he probably used at Sheerness.

Of the more specialised stores, those in the ropeyards have been discussed above. Magazines are outside the remit of this Report, but falling within the Devonport Yard, we may mention the Morice Yard magazine, Store No.16 (**II***), one of the last built within a dockyard before they were relocated to more isolated locations. Eighteenth century powder stores used by the army are found at Berwick-on-Tweed (II*) and Tilbury Fort (SAM), but they are otherwise rare, especially since the clearance of the ordnance depot at Purfleet.

The boat stores present a group of particular historical importance. The three traditional examples, the Lower Boat Store, Chatham (**II***) and the much later Nos. 5 and 7 (**II**) at Portsmouth are rare examples of a vernacular timber building practice which was squeezed from other parts of the dockyards by fear of fire and the advent of cast and corrugated iron. Both occupy situations within the yards, close to the mast ponds, which reinforce their value. The No. 6 Boatstore at Portsmouth (**II***) has a wider significance outside the dockyard for its position within the development of iron structural members. The Sheerness Boatstore (**I**) is of international significance, standing at the conclusion of an evolution of iron structures within the dockyards, and prefiguring the development of one of the two predominant structural systems of the twentieth century. The failure of architects to take up the innovation highlights the way in which in the second half of the nineteenth century they chose to ignore the potential of the utilitarian iron frame in preference for the more familiar architectural vocabulary provided by masonry.[35]

4.6 Officers' houses, offices and chapels

Recommendations

Devonport

II*	The Terrace and attached basement railings & rear walls, Morice Yard	M063
II	Steps and dwarf walls to gardens fronting Officers' Terrace, Morice Yard	
II*	Officers' Terrace and attached basement area railings, South Yard	S059
II	Terrace Walls and associated steps and railings, South Yard	
II*	Dockyard Museum, former Pay Office, South Yard	
II	Rose Cottage, South Yard	
II	Police Offices (former Dock Entrance Gatehouse), North Yard	N223
II	North Yard Offices and attached front walls, North Yard	
II	Master Ropemaker's House and attached railings and garden wall, South Yard	S103

Royal William

II*	Officer's House No. 1, attached walls & railings, Royal William Victualling Yard	
II*	Officer's House, No. 2, attached walls & railings Royal William Victualling Yard	

Royal Clarence

II	Residence 6, Royal Clarence Victualling Yard	
II	Superintendent's House, attached walls & rails, Royal Clarence Victualling Yard	
II	Deputy Superintendent's House, walls & rails, Royal Clarence Victualling Yard	

[35]Skempton AW, 1956/57, ibid

Portsmouth

II* The Parade 1-9
II* Long Row (Spithead House) (Buildings No. 1/124-132) and attached walls
II North Office Block (Building No. 1/44)
II* Former Royal Naval Academy (Buildings Nos. 1/14, 16, 17, 18, 18 (& att. railings)
II* Admiralty House (Building No. 1/20)
II Building No. 1/121, former Commissioner's stables
II Pair of lamp standards approx 5m west of entrance to the Commissioner's House
II Former School of Naval Architecture (Building No. 1/22)
II* Short Row 10-14 and attached railings and walls (Buildings No. 1/68-72)
II Church of St Ann (Building No. 1/65)
II Former Pay Office
II Dockyard Offices

HMS Vernon

II Ordnance Board office, Building No. 58, HMS Vernon

Chatham

II* Former Cashier's Office
II* Main Gate and attached Dockyard perimeter wall to south west
II* Former Captain of the Dockyard's House and attached front area railings
II* Former Admirals's Offices and forecourt walls and attached iron railings
I Former Officers' Terrace and attached front area walls and overthrows
II* Front and perimeter walls to raised gardens to rear of former Officers' Terrace
II* The Royal Dockyard Church
II* Wall surrounding garden to rear of former Commissioner's House
I Former Commissioner's House
II Former Police Offices
II* Front railings and lamps to Commissioner's House
II* Former Assistant Queen's Harbourmaster's Office
II The Cottage and attached front garden walls
II Dockyard Cottage and attached garden wall and basement railings, Medway Docks
II Former Stables to rear of Dockyard Cottage

Sheerness

II Former Pay Office, Building No. 104
II Main Road 1 and 2
II South Gate House
II* Regency Close 1-15
II Walls extends approx 200m enclosing garden to rear of Nos. 1-15

II* Dockyard House and attached front basement area railings
II Wall, approx 200m enclosing garden to rear of Dockyard House
II* Naval Terrace, attached basement railings, front walls, coach house & stables
II Railings to S side of green to E of Naval Terrace
II* Former Royal Dockyard Church and attached wall and railings
II* Nos. 1-15 Regency Close

Portland
II Dockyard Offices

Greenwich
Woolwich
II Clock House
Deptford
II Master Shipwright's Apartment, Convoys Wharf
II Office Building, Convoys Wharf

Introduction
The inclusion of substantial, good quality housing (albeit for the officer class) within the dockyards emphasises both the isolated locations which the yards often occupied in their early days, and their enclosed and introspective character. The presence of chapels is a further indication both of the yard's relative isolation, especially Devonport and Portsmouth which were the first to have them, and the self-contained nature of the dockyard communities. Senior officials' houses routinely included space for administration and paperwork, as did stores and workshops, and the lack of distinct office buildings in the early yards is one of the major differences to their modern counterparts. In these, specialist office buildings as well as those converted from stores and foundries occupy large areas. Houses, offices and chapels are today among the best preserved of dockyard buildings, often having remained in the same use continuously.

The officials who were housed within the yard were first of all the Commissioner, followed by between eight to twelve senior officers including the Master Shipwright, Master Caulker, Master Storekeeper, Master Attendant, Clerk of the Cheque, Clerk of the Survey, First and Second Assistants, Surgeon and Boatswain. After Chatham was rebuilt in the early seventeenth century, the officers lived in part of the long semi-quadrangular range that enclosed the dry docks and which included stores and workshops. As improved accommodation was provided in the yards in the late seventeenth and early eighteenth centuries, the custom of the officers living together in what became a terrace was maintained.
It is notable that the plan form and elevational treatment adopted for this new housing, in

which the apartments of the commissioner (though apart from Devonport they later had their own houses) and other senior officials were combined, was that of a terrace behind a unified facade, known as a palace front. This was a remarkably early appearance of this important technique for handling long terrace facades, especially so given the functional, rather than fashionable, character of the dockyards. The earliest was the former Devonport Officer's Terrace, (now part of South Yard and largely destroyed by bombing), which was built between 1692 and 1696 under the direction of the Surveyor, Edward Dummer. It contained a central house for the Commissioner with six officers either side. The central and outer pairs of houses were accented by pediments and set slightly forward, as became customary in the eighteenth century to achieve the impression of a single palatial building as opposed to an agglomeration of separate houses within a row. Above the heavy dentil cornice of this impressive facade was a steep old-fashioned roof with dormers. Each house was two rooms deep with a through passage to a rear central stair, had service rooms and long gardens behind, and a deep terrace in front set high above the yard.

Unlike other early English terraces such as those round Covent Garden (1630s, largely demolished) or Grosvenor Square (1725-53), this was not an attempt to achieve unity as part of a larger urban plan, but was a free-standing piece of architecture. As such the Officers' Terrace at Devonport preceded Queen Square in Bristol (almost entirely rebuilt, and a much less sophisticated design), as the earliest instance in Britain of a palace front terrace. Furthermore it predates Mansart's Place Vendome in Paris, finished in 1698 and usually credited as the first full development of the palace front in Europe.[36] (Interestingly, the Devonport terrace with its centre arched pediment and end pavilions bears more than a slight resemblance to seventeenth century building in the French naval dockyard of Brest). Only the inaccessible nature of the dockyards accounts for its absence from the standard works on the subject.

Three further impressive early terrace designs were built at Portsmouth, Chatham and the Morice Ordnance Yard, just to the north of the original Devonport dockyard, between 1715 and 1731. Portsmouth was the first, probably designed by the master shipwright and completed in 1719 for nine officials (the Commissioner stayed for the time being in his own house), and now known as The Parade or Long Row. As at Devonport, each house had a central passage leading to a rear stair, but with a second lateral stair to one side with corner fireplaces in the rooms each side, deep service buildings round a small rear courtyard, and long gardens. The main differences were the almost complete disappearance of the roof, now in three shallow pitches behind a parapet, and the strikingly calm facade in which the much reduced palace effect was achieved through no more than a slight emphasis of the central and end houses, and the proportioning of the openings. In this respect it has more in common with Regency terraces of a hundred years later.

[36]Gomme A, Jenner M, and Little B, *Bristol, an architectural history*, 1979, p99

The Chatham officers were rehoused in a new terrace built between 1722 and 1731 so that the area around the dry docks occupied by the old ranges of houses and workshops could be redeveloped. It accommodated twelve officers - the Commissioner had already moved into a new house some twenty years before - and as at Devonport stood away from the river with a deep promenade enabling a fine view over the dockyard. Again the centre and ends were emphasised, with pairs of houses were set forward rather than individual ones, and given distinction by a heavy crenellated parapet with raised rounded panels in the middle.

This military decoration, and the date of the Chatham terrace, naturally associates it with the Ordnance Board buildings of the period of Marlborough's Surveyor Generalship, and of Hawksmoor's supposed design influence.[37] This influence would have been readily felt at Chatham, where the Master Shipwright presumably designed the terrace and would have had plenty of opportunity to study the enormous Grand Storehouse which the Ordnance Board built in the adjoining Ordnance Yard between 1717 and 1720. The plan of the houses was almost identical to those at Portsmouth, with rear service areas surrounding a small courtyard, and the long officers' gardens behind separated by a roadway.

The fourth major terrace from this period, much more closely linked with the Hawksmoor strand of Ordnance design, was built between 1720 and 1723 in the new Morice Ordnance Yard just to the north of the original Devonport dockyard. The scheme by the Divisional Engineer Colonel Lilley was superseded by a different scheme for the site sent from the Board in London. These were quite different from the standardised designs which the board had evolved in the days of de Gomme, and include a strongly mannered terrace for the officers.

The terrace was situated on the rise above the excavated gun wharf overlooking the Hamoaze, and was constructed from the shaley brown rubble quarried from the site. The central house for the senior official was set back slightly with a taller pair of houses either side, and stables at the ends. A wide terrace extended in front with a dramatic flight of steps down the carefully-cut cliff face to the wharf below. The facade has several architectural details such as the lunettes set in small gables and the curious flat-headed dormers rising above the parapet, which link it with the Ordnance building most strongly associated with Hawksmoor, the Berwick-on-Tweed barracks.[38]

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[37]Barker N, 'The building practice of the Board of Ordnance, 1680-1720, in Bold J and Chaney E, *English Architecture, Public and Private*, London, 1993, p199

[38]Hewlings R, Hawksmoor's brave designs for the police, in Bold J and Chaney E, 1993, *ibid*, p215

Apart from an additional short row at Portsmouth for the surgeon, master ropemaker, clerk of the ropeyard and boatswain, completed by 1780, these buildings were sufficient for the officers' accommodation. The only dockyard housing built during the nineteenth century was that at Rennie's model yard at Sheerness and at the new building yard at Pembroke. Sheerness was an unpopular yard because of its isolated and insalubrious location, and more living space, in the garrison and in hulks, was provided than was usual in the other yards. In the rebuilt yard, housing was concentrated in the landward eastern corner, and was largely designed by George Ledwell Taylor, the Navy Board architect who succeeded Holl after his death in 1823. Two comparatively plain Regency terraces were built for the senior offices (1824-27) and for 'Inferior Officers' (1829-1833). The former stood alongside the chapel facing way from the yard, and consisting of eight substantial houses with gardens and stables to the rear. The slightly later terrace for the lesser officials was behind and facing in the opposite direction. It had five principal entrances, but contains fifteen separate apartments, a division which may be original.

These were the last naval terraces to be built, though a number of detached houses were built. At the smaller yards within reach of the Navy Board in London, Woolwich and Deptford, much more limited accommodation was provided. There were houses for two officers at Woolwich in 1753, and seven officers' apartments are marked on a map of the same date of Deptford. One of these survives, that of the master shipwright, which is probably an early eighteenth century remodelling of an older structure. Later in the eighteenth century the master ropemakers were given their own houses at Devonport, as part of the rebuilding of the ropeyard and within it, and at Portsmouth. At Pembroke, Edward Holl built a detached house for the master warden and a semi-detached pair for the master shipwright and clerk of the cheque in 1818. These are of particular interest for the extensive use of cast iron, not only for floor beams but in the roof also. While expensive iron internal framing is generally accounted for by the needs of fireproofing, as it was widely used by Holl in the Devonport ropery, Chatham lead mills and elsewhere, its employment in a domestic building is very unusual.

The Commissioners of all the yards except Devonport had their own residences apart from the officers. The oldest Commissioner's house, and the oldest intact building in any dockyard, is Medway House at Chatham. The Commissioner was the first to move out of the old seventeenth century workshop range, and occupied the new house around 1703. At Portsmouth the Commissioner remained in his 1664 Jacobean house years after the officers had moved into their new terrace. He was eventually rehoused in 1787. In a rare instance of an outside architect working in the yard, a design proffered by Samuel Wyatt was accepted. It originally had a pedimented porch with pedimented outer pavilions, possibly offices, linked by single-storey ranges with balustrades.

Neither of Holl's designs for Commissioner's houses at Pembroke or Sheerness were carried out, although the Captain-Superintendent's house at the Welsh yard, built in c1832, follows his earlier officers' housing there. His successor Taylor built the Commissioner's house at Sheerness to match the officers' terrace, and it was occupied by 1830.

Offices

Clerical and accounting work in the dockyards was limited by modern standards, and space for record keeping was accordingly limited. The Commissioner and senior officers had rooms within their residences for meetings, interviews and for storing records in. At Deptford the master shipwright had access to a building adjoining his apartment, now the oldest surviving dockyard office, dating from the early eighteenth century, although little is known about how it was used. The Devonport officers' terrace had lower projecting wings at the ends in which each had a room. Edward Dummer, who laid out the yard, suggested in 1694 that the wide terrace fronting the houses and overlooking the yard would be used for conference among the officers, as indeed could those at Chatham and Morice Yard with similar panoramic views. The ground floor of the Chatham officers' terrace was used as offices; it backs onto a slope and the domestic rooms were above. The large porches which were added to the front are a characteristic of all of the terraces except that for senior officers at Sheerness, and appear to be an early nineteenth century innovation. They are reported to have been for messengers waiting outside the ground-floor office for instructions.

Despite the presence of space within their houses for administrative work, five of the Chatham officers had a new block of offices built for themselves in 1750, the earliest recorded purpose-built office. The master shipwright had the central rooms behind a pedimented section, with the first and second assistant, clerk of the cheques, storekeeper and clerk of the survey either side. Curiously, each had its own entrance and there were no internal doors between. It was rebuilt by Edward Holl in 1808 with a similar pedimented elevation, though with deep bows at either end. Internally a more commodious plan included spinal corridors and a large central stair hall. This had been the design and layout in the 1786-1789 block of offices built at Portsmouth, now the South Office Block and the work of the master shipwright. The plan of the 1770s offices at the former Portsmouth Gun Wharf, HMS Vernon, has been altered, but it remains the oldest example of an Ordnance yard office. The Ordnance was early to develop standard designs for its magazines and barracks.

The offices at Sheerness have gone, but those of the senior officer at both Woolwich and Pembroke survive. The Admiral- Superintendent at Woolwich, Clock House, had a large square office building with a pedimented front, with a pair of porches raised above the semi-basement approached by a central flight of steps, and a clock tower. At Pembroke, Holl

included a two-storey office building of c1822 not dissimilar to the now demolished range at Sheerness, plain with round-arched lower windows. A combined Captain Superintendent's Office and Surgery, was added in 1848, intriguingly by the engineering company Fox, Henderson.

The pay department was the only section to be provided with dedicated space. The pay offices form an interesting class of building, of which examples survive in all the major yards. The earliest is at Devonport, built during the late eighteenth century rebuilding. The Portsmouth Pay Office is a design by Samuel Bentham of c1808, and at Sheerness the 1828 Pay Office is by William Miller, Taylor's successor as the Navy Board architect. All three are fireproof structures, the earlier two with vaulted ground floors, Sheerness with what remains of an internal iron frame of the Holl type, though ironically it was destroyed by a fire above the ground floor in the 1980s. All of the pay offices had separate flights of stone stairs, a large hall, strong rooms and guard house, suggesting that the work of the pay office was a strongly formalised activity, to which the plan of the buildings was closely related. The structure and layout of the pay offices suggests that a degree of risk and insecurity was attached to its work which is not immediately apparent in the histories of the yards. The exception was at Chatham, where the Cashiers Office by Holl was a traditional building built in 1808 between the Officers' terrace and the Commissioner's house.

At Devonport, the movement of work northwards into the North Yard and the Keyham extension necessitated the building of a large block of offices in between the entrance, now the Police House, and the retaining wall behind the Quadrangle. Though rather old fashioned architecturally, the North Yard Offices are a handsome block, part of the cliff of silvery Plymouth limestone which lines the back of the Yard, and an integral part of the growth of shipbuilding-capacity at the Devon dockyard in the feverish arms race leading up to the First World War.

Chapels

The first dockyard chapels were built in the early eighteenth century for the isolated communities at Portsmouth and Devonport, and paid for by voluntary subscriptions within the yards. During the latter part of the century, the Navy Board assumed more responsibility for the chapels. That at Portsmouth was replaced by the current building in 1784, after it was demolished to make space for the Commissioner's house. Devonport chapel was rebuilt in 1816, though destroyed by bombing. The Board finally built new chapels at Chatham, where the local church had previously been used, and as part of the wholly new yards at Sheerness and Pembroke in the 1820s and 1830s.

The consistency of the planning of the chapels suggests a need for capacious buildings providing a clear access for the congregation. All were simple single-volume buildings with

shallow gable ends either made into pediments or in the case of Sheerness with a pedimented portico in front. Inside the box-like interiors, galleries on cast iron columns provided additional seating space - in fact typical Georgian preaching boxes. Holl was responsible for the similar chapels at Portsmouth and Chatham, while his successor Taylor built the Sheerness and Pembroke buildings a few years later.

Assessment

The obvious point at which to begin an assessment of the domestic, religious and administrative buildings of the dockyards is by comparison with contemporary examples outside. The feature that sets apart the naval buildings is their being part of a planned industrial enterprise, rather than of the fabric of a town. For this reason their setting and context are quite different to what it would be for comparable buildings in an ordinary urban setting.

As discussed above, the development of palace-front terraces within the dockyards is of considerable significance in the evolution of English architecture. This form of unified planning was widely used during the eighteenth century and in the first half of the nineteenth century, and is considered one the country's particular contributions to European architectural history. Moreover, its appearance within the dockyards was not a one-off occurrence. Four examples were built over little more than thirty years, using similar ground plans but with facades varying from the vigorously articulated terrace at Morice Yard (**II***) to the calm and restrained front of the Long Parade, Portsmouth (**II***).

Outside the dockyards, the palace front arose out of the late seventeenth century interest in Renaissance urban planning, with rows of similar houses around a piazza. The earliest instance of the piazza terrace Inigo Jones' Covent Garden of 1630, but in the early eighteenth century, uniform rows began to be accented at the centre and ends to create an impression of a single palace, notably at Bedford and Grosvenor Squares in London, and Queen Square in Bath (I). The naval terraces were free-standing buildings, and obviously not designed to form part of a larger urban concept in this way. As such they predate the first individual palace-front terraces, arranged by Nash around Regent's Park, by a hundred years.

The source of the plan and consequent facade design probably lies in the particular working relationship of the officers with one another, and within the social fabric of the dockyards. It must also have reflected the attitude of the Navy Board toward its officers, since houses arranged in terraces were also provided by the Board for the officers at its hospitals. These usually numbered four, the Physician, Surgeon, Agent and Steward, but from 1795 residences were also provided for the resident Commissioners, newly appointed to the hospitals. Stonehouse had a four-house terrace built around 1765. The new terrace built in 1796-98 at Haslar Hospital, in Gosport, followed the dockyard model in placing the

commissioner in the central apartment of the terrace, and was designed by the Board's architect, Samuel Bunce.

Another obvious connection can be made with the large planned industrial enterprises or colonies built during the nineteenth century, such as Saltaire in Lancashire, the textile *colonia* in Catalunya, and elsewhere. In these, housing is typically provided for the workers rather than the owner, who was more likely to live at some distance. The early dockyards were perhaps unique instances of large industrial enterprises where senior officials with the highest status and power lived on the site.

Of the Commissioners' houses, Medway House at Chatham (I), and Admiralty House Portsmouth (**II***) are both very impressive domestic buildings which also demonstrate the particular planning developed to suit the requirements of senior naval administrators. The significance of the former is enhanced by its beautiful internal decorations, including the painted ceiling over the stair thought to have been taken from the Royal Sovereign. This is the oldest unaltered building in an English dockyard. Admiralty House has a more articulated plan than the Chatham Commissioner's residence, with the separation of administrative space under Wyatt's classical composition. It is possibly the grandest of the dockyard houses, suitable for its use as a home for the monarch when visiting Portsmouth.

The housing for the senior officials at Sheerness was not as grand as in the older yards, the terraces fairly typical late Georgian stock brick rows, but they form the most complete and unaltered part of Rennie's model layout there. The eastern corner of the compound contains the gatehouses (**II**) (the linking Doric colonnade of the entrance has gone), Commissioner's house (**II***) and the two parallel terraces for the yard officials (**II***), as well as the chapel (**II***), with stables, railings, and the various perimeter and garden walls that separated them. All are the work of George Ledwell Taylor, the Navy Board architect, and are directly comparable with his predecessor Holl's work at the contemporary dockyard at Pembroke, (mostly **II***).

Chapels

The five dockyard chapels was very similar. Morphologically they were functional meeting houses, in the simple Italian classicism widely used for such buildings, and their planning had no complex liturgical arrangements. They were used by a community accustomed to religious services on board ship or in converted hulks. St Ann's at Portsmouth (**II**) is the earliest but had to be shortened and the front rebuilt after bomb damage. Holl's Chatham chapel (**II***) occupies a strong position facing the entrance to the yard, and is complete inside with galleries on three sides on iron columns. This is one of Holl's earliest works, and show him already pioneering the use of this material in the navy yards. Sheerness (**II***) is architecturally the grandest with a tall Ionic portico, though it had to be rebuilt internally after a fire. In a unique reversal of the usual dockyard planning it and the neighbouring officers' terrace face out of the yard, creating a polite face to the Kentish marshes.

These all reflect mainstream developments in eighteenth century non-conformist and Anglican chapels and churches, with wide plans and fittings which maximised sight of the pulpit through galleries and the use of slim iron columns.

Offices

The two surviving office blocks, the South Office at Portsmouth (**II***) and Admiral's Offices at Chatham (**II***), are rare examples of purely administrative buildings from a time when office and clerical work was limited, and in a commercial context, took place at the home or workplace of the merchant or industrialist.
The external architecture of the dockyard offices is indistinguishable from contemporary buildings of many types, from textile mills to barracks. Their internal planning suggests rather more specialised activity, with central spinal corridors with entrances at either end connecting the officers' rooms showing an awareness of the functional requirements of the yard administration.

Comparable examples outside the yards are very rare. Harbour towns often provided very early specialist office buildings connected to the administration of the harbours in the Customs House, of which fine late seventeenth century examples can be found at Kings Lynn and Exeter (I). Specialised state office buildings in England date from the construction of the Admiralty (I) in 1723, and other large suites followed for different offices, culminating in Somerset House (I), in 1776-1801. Their plans however failed to realise a new building type. They were usually little different from domestic houses, and often owed more to external effects than internal convenience. Specialised offices of a more modern kind developed in the early nineteenth century, associated with emerging professions and financial services like banking and insurance. Offices of industrial enterprises were traditionally included within either the domestic property of the owner, or space for administration was allowed within the concern itself. No existing early industrial sites include separate administrative accommodation.

The evolution of a distinct typology for naval pay offices is interesting, overlapping as it does with the search for an effective method of fireproof construction. At Devonport (**II***) and Portsmouth (**II**) this takes the form of a massive construction with vaulted ground floor. By the time the Sheerness pay office (**II**) was built in 1828 more sophisticated methods were available, and the surviving parts appear to be related to the fireproof system employed by Holl (see Section 3.4).

4.7 Gateways, boundaries, and ancillary buildings

Recommendations

Devonport

II The Muster Bell, Morice Yard
II* Steps and dwarf walls to gardens fronting Officers' Terrace, Morice Yard
II* Morice Gate, two gatehouses and attached dockyard walls, Morice Yard M039 & 65
II North Gate and attached dockyard walls, Morice Yard
II Former Fire Station, South Yard S032
II Dockyard Wall, South Yard
II Former Devonport Market House, South Yard S053
II* Kings Hill gazebo, South Yard S186
II* Railings, piers and gateway to King's Hill Gazebo, South Yard S186
II Wall, piers & steps, extend approx 200m E of Tarring and Yarn Houses, South Yard
II Wall, piers and steps, approx 300m long all with Spinning House, South Yard
II Walls and railings around reservoir, South Yard

Royal William

I Police buildings, Royal William Victualling Yard
I Main Gate, Royal William Victualling Yard
II* Dockyard wall, extends approx 100m to NE side, Royal William Victualling Yard
II Reservoir and enclosing iron railings, Royal William Victualling Yard
II Rear retaining wall extends approx 400m, Royal William Victualling Yard
II Firestone Bay sea wall, Royal William Victualling Yard

Royal Clarence

II Main gate and 2 lodges, Royal Clarence Victualling Yard

Portsmouth

II* Victory Gate and Dockyard Wall
II* Fire Station (Building No. 1/77), Portsmouth

II The Unicorn Gate
II Dockyard Extension Wall
II The Lion Gate
II Whitley Rooms (Building No. 1/138) and attached bollard
II The Royal Railway Shelter (Building No. 1/45)
II Former Railway Station and Waiting Room (Building No. 1/47)
II R.N. Detention Quarters (Building No. 2/44)
II Former Detention Centre (Building No. 1/2)
II Fredericks Battery
II Round Tower

HMS Vernon
II HMS Vernon, former Gunwharf Gateway & walls of approx 3m to N, 38m to S
II HMS Vernon, perimeter walls with gateways including former main gate

Chatham
I Main Gate
II* The Bell Mast
II Police Section House
II* Former Guard House
II* Customs House
II* Former Police Offices (Guard House)
II Queen's Stairs overthrow arch
II* Stables, north range, SE of Sail Loft
II* Stables, south range, SE of Sail Loft
II The Stables
II* North Tower House and attached perimeter wall to the south
II* South Tower House
II North Gate House
II* Guard House West and store

Sheerness
II Boundary wall, extends from Main Gate round S and E sides of former Dockyard
II Boundary wall, extends from Main Gate along N and NE side

Greenwich
Woolwich
II Police building at east side of entrance gateway
II Entrance gateway piers and abutting walls
II Former Police Station

Introduction

All the naval yards were enclosed and protected by perimeter walls, and access restricted through imposing gateways. Theft from outside and pilferage from within were the main reasons, but security became an increasing consideration in the nineteenth century as the naval technology advanced more rapidly. Porters and later the dockyard police usually had rooms and guard houses close to the gateway, and the Royal Marines, established formerly in 1755, had guardhouses after they took over responsibility for security in 1764.

Most of the perimeter walls and some of the dockyard entrances have been altered to accommodate expansion or improved access, but enough survive to make an important contribution to the landscape and character of the yards.

Least survives at Devonport. Although the yard had a high wall from its formation in the 1690s, with a main gate with rusticated piers and ball finials, the imposing walls which survive in sections today date from the rebuilding of the ropeyard in the 1770s. The oldest gate is the Victory Gate at Portsmouth, a plainer version of the original Devonport entrance with a tall coped wall attached. The porter's house inside is a handsome domestic building built just after the gate, around 1712. A later entrance was built to the north steam yard extension in the mid nineteenth century, with a guard house, now known as the Whitley Rooms, in a style to match the new brick engineering workshops recently established in that part of the yard.

The arrangements for Chatham were on a completely different scale, and the contrast between the entrance there and that at Portsmouth mirrors that between the officers terraces at the two yards, built at the same time. Chatham is in the Ordnance Board style long associated with Vanbrugh, and with Marlborough's tenancy of the Master Generalship, discussed above. The forbidding entrance towers with blank oculi flank a wide archway beneath a large coat of arms of George III, cast from Coade stone. The towers contained apartments for the yard porter and boatswain, and latterly the chaplain. The high walls extended north and south with four square crenellated watch towers with battered bases and more oculi.

Just inside the gateway a guard house was built for the Marines in 1764, with a long colonnade to the front. This anticipated the similar designs for the victualling yards of the 1830s.

The wall enclosing the Morice Ordnance yard is one of the most complete, though the northern section was lost when the yard expanded. It and the pair of surviving gate lodges were shown on the Ordnance Board plan sent from London in 1721 with the revised and

strongly mannered designs which were subsequently adopted. The lodges are plain, however, with heavy piers capped by mortars as was customary with Ordnance Board sites. The heavy wall was built from the excavated rubble stone, vertically bedded. When the wall was extended to meet the new Keyham yard, a further north gateway was built, with an iron overthrow.

The entrance to Keyham itself confirms the Admiralty's intention that the new yard be special. Colonel Greene's assistant, William Scamp, who had much of the responsibility for the planning of the Quadrangle, designed an impressive Italianate gateway consisting of a police house and office set a ninety degrees from one another with a curved gateway in the angle. Both sections had tall square clock towers framing the entrance to the navy's new facility.

As at Keyham, where one of the two entrance blocks has gone, the entrance to Sheerness has been partly destroyed. It originally included the existing matching porter's buildings containing offices, linked by a severe granite wall with a central gateway beneath an overthrow lantern. Behind the wall were guard houses surrounded by a Tuscan colonnade. Just inside the entrance was the tall iron shaft which carried the muster bell, a relic now only found at Morice and Chatham yards.

Somewhat unaccountably, considering the nature of their traffic, the grandest of the navy yard entrances were those for the victualling yards. At the Royal Clarence yard in Gosport, a Roman triumphal arch carrying a royal coat of arms gave on to a wide space leading to the brewery and bakery. Either side and facing inwards were colonnaded porters' lodges. It was built between 1830 and 1831. The Royal William at Stonehouse was built at much the same time, but was a much more grandiose concept, and had an entrance to suit. A much larger triumphal archway in deeply rusticated granite had heavy pilasters with bull's heads beneath the cornice, and an oversize statue of King William in Roman garb on the top. Inside, matching colonnades faced each other across the avenue leading into the yard, one for the porters and the other a blind facade to the slaughterhouse.

Assessment

Entrances and walls had an important practical purpose in controlling the movement of people and materials in and out of the yards. This grew more important during the nineteenth century, although naval yards never had the degree of inbuilt security that commercial dockyards with their forbidding external warehouse walls achieved. Walls are of interest as important ancillary elements which define a site and establish some cohesion, and entrances for the symbolic role which they play in informing the visitor of the nature and importance of the site. The scale of dockyard entrances increased in the nineteenth century as security was raised, with police houses, porters lodges and guard houses incorporated.

The increase in the scale of gatehouses also reflects changes in the relationship between the yards and the outside world. It is notable that Keyham with its strong and consistent architecture and dramatic entrance was the first yard planned after the demise of the Navy Board and establishment of direct control by the Admiralty.

Commercial dockyards experienced even greater problems with loss through pilferage, and whole docks were designed to limit the flow of material out. The most impressive commercial dock walls are undoubtedly those designed by Jesse Hartley around the Liverpool docks, from his appointment as dock engineer in 1828. The blunt morphology of the gate lodges and the Incan granite masonry of the walls are as eloquent in an industrial situation as much more 'polite' architecture would be.

The section of high walls (**II**) behind the ropeyard at Devonport form the backdrop to the spinning house and yarn tarring complex, and extend down to behind the No. 1 covered slip. At Morice Yard, the walls and gatehouses (**II***) enclose the tight enclave of the Gun Wharf and officers' terrace. These are a notable instance of walling involving vertically-bedded rubble, a rare and skilled piece of work.

The source for the particular style of the Chatham gatehouse (**II***) has been repeatedly analysed and the attribution to Vanbrugh widely debated. The brickwork with its arched frieze compares for instance with one of the houses be built for himself, Vanbrugh Castle in Greenwich, built between 1717 and 1726. Not only the style but the scale of the entrance set it apart from other naval yards.

There are an interesting collection of gateways, lodges and guard houses around Portsmouth dockyard, some of them relocated, and others still watching over entrances long absorbed by the growing yard. The Victory Gate (**II***), is the oldest of the dockyard entrances, and moreover forms a part of the yard dominated by the contemporary porter's house (**II***). The Unicorn gate (**II**) of 1779 which opened toward Portseas has been resited. The later Whitley Rooms (**II**) is recommended along with the nearby Iron Foundry and No. 8 dock.

The role of the old muster bells in regulating the working day is clear from their position, mounted on tall masts, close to the entrances at both Chatham (**II***) and in the Morice Yard (**II**).

Complete sets of mid eighteenth century stables for the horses and carriages of the officers occupy a corner of the dockyard wall in Chatham (**II***), and the commissioner's stables of the same age at Portsmouth (**II**), closely associated with his house, are another example. The south stables and the guardhouses most clearly related to the ropery and entrance

complex at Chatham are all graded at II*, by virtue of their integral association with Late Georgian dockyard and factory complex in Britain, and one of the most significant in the world.

Although the two grand entrances to the Royal Clarence and William victualling yards stand out among naval buildings, they correspond closely to similar archways into military barracks of almost the same period. The most impressive of these were the Marines barracks built by Captain William Denison at Woolwich in 1845, and the Raglan infantry barracks built in 1855 by his fellow engineer officer Captain Francis Fowke at Devonport. Both used the triumphal arch as the emblematic gateway into the barracks square in the way Taylor and Rennie already had done. The first victualling yard archway at Gosport (II) is restrained, with paired pilasters and modelled lion and unicorn on top. Although the overall coherence of the yard has suffered from bombing and demolition, the immediate group of officers' houses and porters lodges, to which the entrance leads, is intact. At Royal William, the archway (I) is not only itself a forceful piece of Baroque modelling, it is the formal entry into the best planned industrial complex in England. As an industrial monument it is to the food industry what the lost Euston arch was to british railways.

4.8 The Victualling Yards

Recommendations: note that other recommendations can be found under sections 4.1, 4.6 and 4.7.

Royal William

I Slaughterhouse and attached Yard wall, Royal William Victualling Yard
I Mills and Bakery, Royal William Victualling Yard
I Brewhouse, Royal William Victualling Yard
I Old Cooperage, Royal William Victualling Yard
I Clarence Store, Royal William Victualling Yard
I Melville, Royal William Victualling Yard
II Street lamp approx 30m SE of the Mill & Bakery, Royal William Victualling Yard
II Street lamp at N corner of the Clarence Steps, Royal William Victualling Yard
II Street lamp approx 20m S of No. 1 Officer□s House, Royal William Victualling Yard
II* Swing bridge, Royal William Victualling Yard
II Pair of bollards in front of Melville, Royal William Victualling Yard
II New Cooperage, Royal William Victualling Yard
I Dock basin walls and 6 associated bollards (see section 4.2)
I Clarence Steps, SW Quay wall and 2 bollards (see section 4.2)
I NW Quay wall and 2 bollards (see section 4.2)
II* Officer's House No. 1 (see section 4.7)
II* Officer's House No. 2 (see section 4.7)
I Police Buildings (see section 4.8)
I Main gate (see section 4.8)
II* Dockyard wall extending 100m to NE side (see section 4.8)

II Reservoir and enclosing iron railings (see section 4.8)
II Firestone Bay sea wall (see section 4.8)

Royal Clarence

II Slaughterhouse, Royal Clarence Victualling Yard
II* Granary and bakehouse, Royal Clarence Victualling Yard
II* Cooperage, W range, Royal Clarence Victualling Yard
II* Cooperage, S range, Royal Clarence Victualling Yard
II* Cooperage, E range, Royal Clarence Victualling Yard
II Pump house, Royal Clarence Victualling Yard
II Residence 6 (see section 4.7)
II Superintendant's House (see section 4.7)
II Deputy Superintendant's House (see section 4.7)
II Main gate and 2 lodges (see section 4.8)

Introduction

Until the early nineteenth century, the victualling yards as such were fairly ad hoc collections of cooperages, bakeries, breweries and stores, scattered near the dockyards. Many were rented, or converted, and buildings were transferred between victualling and other uses such as for barracks. The major yard was at Deptford which was close to the big London food markets and could supply the eastern yards. Very little of these older yards remains - only the former entrance at the old Royal Victoria yard in Deptford - although former Victualling Board buildings may survive in later uses.

At Plymouth part of the cooperage, reservoir and quay walls of the victualling yard remain at Millbrook, on the Cornish side of the Tamar, from what was a massive complex. It included a brewery on a different scale to any eighteenth century commercial works. In 1822 the Board decided to centralise victualling at Plymouth in a new yard, and in 1827 a similar decision was reached with respect to Portsmouth. The Navy Board was given responsibility for building work, thereby bringing the younger John Rennie forward as the consultant for the challenging work at the Stonehouse site, across the river south-east of Devonport. The Portsmouth site at Gosport presented fewer topographical obstacles, and although there are similarities in the internal details and planning of the buildings there, they were the responsibility of the Navy Board architect, G L Taylor. Rennie acted as a consultant on the plant.

Stonehouse included a large granary and bakery, a similarly-sized brewery, and the Melville grand storehouse discussed above, a large cooperage, a slaughterhouse and further stores, as well as a small dock basin, quay, officers' houses, entrance and reservoir.[39] Rennie's layout

[39]Keystone Consultants, The Royal William Yard, Stonehouse, Report K/438, Vols 1 & 2,

was even more rigidly symmetrical than his father's for Sheerness, and the size of the major buildings was dictated by the grid which he imposed on the site. The vocabulary of the architecture varied between the buildings but was consistent. The planning and design of the yard therefore is subordinated to a surprising extent to the grand aesthetic effect which the hug complex would create.

A cooperage had existed at Gosport since 1766, and a large brewery was built around 1820. The new works there combined the brewery with a large granary and bakery, the former modelled on Royal William and like it overhanging the quay, and the latter fitted with steam and production plant by Rennie. It formed a long symmetrical range recalling the impressive seaward view of Stonehouse.

Assessment

Royal William Yard (I) is a unique concept in English industrial history. As a planned state manufacturing complex, on such a lavish scale, it is without comparison. In the private sector, no commercial factories as large as this were built until the 1850s, when textile colonies like Saltaire were first laid out. In the quality of the architecture applied to an industrial building, the planning of the site and use of cast iron, they are directly comparable with the biggest commercial dockyards such as St Katherine's Dock, London, built by Thomas Telford, with the public elevations enhanced by Philip Hardwick, between 1827-8. This is the period during which the Stonehouse site was being prepared.

No commercial organisation had the capacity or finance to build so large a works, on such a difficult site and to so lavish a standard. This was royal naval architecture in the direct line from Wren's Royal Naval Hospital at Greenwich. The only state organisations in England which operated on this scale were the Office of Works, the Navy Board and the Ordnance Board. That Rennie subordinated the functional utility of the new yard to its architectural consequence is apparent from the way in which the plans of the major buildings are determined by a formal grid, with a major axis through the centre of the basin and the elevation of the Melville store, containing the yard offices. This is a notable feature of nineteenth century industrial enterprises established by central state agencies in Europe. A well-known example is La Saline Royale, the French state salt works designed by Ledoux, but others were built by European powers whose governments were struggling to encourage domestic efforts to keep up with British industrial expansion. Examples of this grandiose approach to industrial enterprises are very unusual in laissez fair England.

Iron was used in a precise and rational way. This suggests both Rennie's appreciation of its properties, and of its cost: wrought iron especially was still a much more expensive material

than timber. Fully fireproof sections were concentrated where fire was a serious risk, in the mill engine room and cooper's workshop. Otherwise cast iron was used for its compressive strength, and wrought iron in the roofs of the stores and cooperage. Nor was Rennie especially innovative in his design of the iron components, most of which related back to Edward Holl's work, and to structural ironwork in textile mills. However, the arched girders in the roof of the Clarence yard are among the earliest uses of this type of beam.

The historic interest of the site rests on the relationship between victualling and the Royal Navy, and on Royal William's position in the history of industrial food production. Of the Navy's other victualling yards, nothing related to production survives at either Deptford or the early nineteenth century yard at Haulbowline, near Cork. Victualling is represented in England by Royal William and its sister Royal Clarence Yard, at Gosport. Comparisons between them are interesting. Although on a similar scale, the mill/bakery (**II***) at the Portsmouth yard is much more utilitarian in its architecture. Both employ a water-side granary, raised so as not to block the quay, but Rennie's is a more compressed design, squeezed within his grid. At Gosport, the designer responded to the waterfront location by incorporating the yard stores as a matching wing on the opposite side of the central granary to the bakery, to create the maximum elevational width. But Clarence has nothing of the completeness of William in terms of its component buildings, and retains no more of internal process details than can be found at Stonehouse.

The only naval victualling building to compare for historic and architectural importance with Royal William is the mill and bakery at Malta (1845). This was designed by William Scamp, one of the leading Royal Engineer architects. It would be interesting to know how Scamp addressed the planning of his mill; architecturally it is as grand as that at Royal William, though displaying an appropriate Mediterranean influence.

In the context of the food industry, Royal William is important because the Navy was such a large processor of food, on a scale unrivalled in private sector, and because little else from this early period survives outside the Yard. Large steam-powered mills were being built in the late eighteenth century - the disastrous Albion Mill was a pioneering example - but little remains. Industrial bakeries weren't developed commercially until the late 1840s, and mechanised baking techniques were a late nineteenth century innovation. It is not known wether they followed Rennies machinery installed at the three big naval bakeries for mixing dough. Food warehouses, less use-specific than breweries or bakeries, are more common, and the two big examples at William are of interest in this context for the planning of Melville, and for the attempts at fireproofing in both.

At Gosport the cooperage (**II***), and the yard where barrels were stored which it enclosed, is the last run by the navy, and closed with the ending of the rum ration in 1970. Furnaces

for heating staves survive in sections of the building. The destruction of the brewery has spoiled the fine symmetrical range developed by Taylor (**II**), though the view from the sea is still impressive. Like Royal William, the granary/mill and bakery are on a scale unknown in commercial industry, and contain much evidence for the methods of mechanised production devised by Rennie.

5.0 SOURCES

Jonathan Coad has been involved in the study of naval dockyard facilities for nearly thirty years, and the great bulk of information relating to specific buildings, within this report and in the list descriptions, is indebted to his research. An introduction to the subject was published in 1983, followed by a series of three articles on Portsmouth, Plymouth and Chatham published by Mariners Mirror (Vols. 67, 68 and 69). The RCHME cooperated in the publication of the definitive work The Royal Dockyards 1690-1850: Architecture and Engineering Works of the Sailing Navy. This includes a helpful guide to the primary material in the Public Record Office at Kew, and at the National Maritime Museum in Greenwich.

Naval administration is a subject which has only recently received the attention it has deserved, of which the most thorough and relevant research has been conducted by Roger Morris (1983). The industrial archaeology and engineering achievements of the naval dockyards have not been as closely examined as those within the private sector, largely because of the inaccessibility of the sites. Notable exceptions are Professor Skempton's investigation of the Sheerness Boatstore (1959) and R.J.M. Sutherland's comprehensive paper on shipbuilding and the long span roof (1989). The Royal Engineer architects of the mid 19th century are thoroughly catalogued in Weiler's comprehensive PhD thesis (1987). The most useful guide into the Victualling and Ordnance Yards is included within Coad (1983). However, the Keystone Consultancy Report on the Royal William Yard includes much material on victualling in the nineteenth century, as well as a full analysis of that important complex.

Journals and papers

The Portsmouth Papers series represent the finest local research into a naval dockyard (Riley 1976, Laing 1985 and Field 1994). County archaeological publications such as Archaeologia Cantiana contain articles on dockyards in their areas. The Newcomen Society Journal has quite a lot of material on specific buildings or processes within the dockyards.

Additional detailed sources are referred to in the text. Unpublished sources include the following:

Pembroke Dock, Cadw, List of Buildings of Architectural or Historic Interest, 1994
The Royal William Yard, Stonehouse, Keystone Consultants, Report K/438, Vols 1 and 2, 1994
The Buildings of the Steam Navy, Evans, D, report for English Heritage, 1994
Sheerness, the Dockyard, Defences and Blue Town, RCHME, March 1995

Please note that individual list descriptions include specific statements on historical importance, and provide key references.

[1]quoted in Field, 1994, p3