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CHAPTER 3 – THE ROYAL ARSENAL

The Royal Arsenal, Woolwich, is among Britain's most important historic sites. It played a central military and industrial role throughout the state's imperial phase, from the late seventeenth century to the early twentieth. There are many worthwhile histories, those of the institution, of war-making, of ballistics, of landscape, of labour – some have been told, others await exposition at the time of writing. In a mere chapter here it is not possible to do more than assess the site, and, through its buildings, adumbrate wider stories. Even as a topography this is only a partial account; the Arsenal grew well beyond its original enclave in the parish of Woolwich, extending eastwards to areas not covered here, across Plumstead and into Erith.^a

Lately rendered quiet and suburban, the Arsenal once thronged and thrummed with the labour and noise of heavy industry. Its fame is as a factory, but manufacturing emerged only gradually. Riverside marshland to the east of medieval Woolwich had become part of the grounds of a large Tudor house, Tower Place. From its nearby depot at Gun Wharf, the Board of Ordnance used open space east of the house, part of it a rabbit warren, for the proving of guns. A riverside battery was built to defend against Dutch

^aThe Arsenal's history is richly documented. Brigadier O. F. G. Hogg's essentially institutional and detailed document-based history, *The Royal Arsenal: its Background, Origin and Subsequent History* (1963), has been invaluable, as have numerous unpublished archaeological reports of recent years, principally those prepared by Oxford Archaeology, in particular by Rob Kinchin-Smith and Jonathan Gill. Drawings, photographs and research findings from the Royal Commission on the Historical Monuments of England's unpublished record of the Arsenal from 1994 are freely incorporated.

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invasion before the Board acquired the lands outright in 1671 for the formation of a new and larger storage depot. Before long the 'Warren' came to be used for other ordnance purposes. The making of ammunition commenced in 1696 in a laboratory relocated from Greenwich. Large-scale gunmaking came alongside in 1717 with the erection of the Royal Brass Foundry, part of a consciously grandiose round of improvements. Gun carriages were also made. From its beginnings around this time the Royal Regiment of Artillery was based here, providing a workforce at what was also a place of science and experiment; here too what became the Royal Military Academy was founded. Both these branches of the Ordnance moved up to Woolwich Common in the later Georgian period. The Board's riverside working functions developed into separate departments – the Royal Laboratory, the Royal Brass Foundry (later Royal Gun Factory), the Royal Carriage Department and the Storekeeper's Department. In the first decade of the nineteenth century vast wartime works were undertaken, including a new wharf and the complex of riverside military warehouses known, accurately enough, as the Grand Store. Lands to the east on Plumstead marshes were annexed, and in 1805 the unique and increasingly vital complex was designated the Royal Arsenal.

Another period of concentrated building activity came in the 1850s, especially in the aftermath of the Crimean War. Intensive modernization was undertaken with steam-driven and cyclopean machinery in capacious sheds for the manufacture of ever-larger guns and ever more ammunition. Subsequent development extended further and further eastwards. There were reforms, notably those instigated through the Morley Report of 1887, and the Arsenal reached its peak of production and employment during the First World War; the huge Central Offices complex of 1905–11 reflects the enormous size (1,285 acres) of the Arsenal at that time. Thereafter decline set in, and, after many re-evaluations, what had become the Royal Ordnance Factory, Woolwich, closed in 1967. Most of the eastern lands were

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given up, much to the Greater London Council for Thamesmead. The western enclave remained a Ministry of Defence facility up to 1994. Regenerative development since then has included the establishment of Firepower (the Royal Artillery Museum) and the Greenwich Heritage Centre, and a substantial housing programme has been undertaken by Berkeley Homes, involving the conversion of a number of historic buildings as well as some large new buildings.

The account of the Arsenal here presents the site's history chronologically, building by building, allowing brief accounts of alterations and additions to disrupt the temporal sequence. The chapter covers an area that extends beyond the parish boundary to take in the whole of the western enclave to which the Arsenal pulled back in 1967. This embraces all the establishment's listed buildings and its conservation area. Ministry of Defence building numbers are still in use.

The Warren

TOWER PLACE

In the 1530s, soon after the Crown had begun to build ships in Woolwich, (Sir) Martin Bowes, a wealthy goldsmith and key figure at the Royal Mint, began buying lands in Woolwich and Plumstead, taking advantage of the Dissolution to build up a riverside estate on the east side of Woolwich, within easy reach of the royal court at Greenwich. There were already houses and watermills on the land, but Bowes built anew and by 1545, when he was Lord Mayor, the mansion that later came to be known as Tower Place was standing on the site now occupied by Building 40 (the former Academy). Bowes's house was a north-south range of two storeys and garrets that was entered from the west or town side. It had a traditional kitchen-passage-hall-parlour layout, with a further and greater parlour

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under a great chamber at the upper or north end, off which a rear corner turret offered views down Gallions Reach. The east elevation had an oriel window at the end of a first-floor gallery that returned along the south or service end where, with marked asymmetry, there was an octagonal tower that rose five storeys to an ogee cap. This was probably built simply for its prospects and as an architectural statement, though one of a conservative nature. The house backed onto marshland that Bowes partially enclosed as a private garden and rabbit warren, with orchards, ponds and moats. It was more a gentleman's lodge than a country seat, though, with fifteen hearths in the 1660s, it was the largest dwelling in Woolwich.

After Bowes's death the estate came in 1569 into the possession of (Sir) George Barne, a Muscovy merchant and governor of the Russia Company, the son of a Lord Mayor of London and later himself a Lord Mayor. His grand-daughter, Anne Barne, married Sir William Lovelace, and their sons, Richard and Francis Lovelace, later to find fame as a poet and a colonial governor respectively, may have been born at Tower Place in 1618 and 1621. The estate was sold in 1638 and again several more times in subsequent decades.¹

By 1651 the Board of Ordnance, which had long had a depot in Woolwich at Gun Wharf, was being permitted by the owners of Tower Place to prove guns on the warren. Among the immediate consequences of the Dutch assault on the Medway in June 1667 was further use of the site for a substantial but temporary sixty-gun battery, hurriedly built under the command of Prince Rupert, the King's cousin and Captain-General – there may have been a precedent for a battery here from the preparations of 1588 for the Spanish Armada. Rupert's wooden platform with earthworks ran along the river bank in front of the moated orchards, facing the Gallions Reach approach to London. John Webb, concurrently engaged as the King's architect at

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Greenwich Palace, oversaw the work. This was perhaps only because Sir Bernard de Gomme, the Dutch Chief Engineer in the Ordnance office, and his close associate (Sir) Jonas Moore, the fen-drainage surveyor and mathematician whom the Board had taken on to help with wartime fortifications, were too busy elsewhere.²

(Sir) William Pritchard, an Eltham ropemaker and ordnance contractor, may also have been involved in the building of the battery; he is known to have undertaken, later and elsewhere, ordnance works and supplied building materials. In what looks like shrewd property speculation the Tower Place estate had been leased to him a few months earlier. From 1668 he held it outright, though probably not as a home. The State had not lost interest. The Board of Ordnance, reorganizing in the aftermath of war, negotiated the acquisition of the estate, which it saw as ‘a convenient place for building a storehouse for powder and other stores of war, and for room for the proof of guns’.³ Moore, appointed Surveyor in 1669, was at the centre of this. An agreement was made that year and a final deal struck in 1671 when Pritchard, on his way to prominence in London politics, relinquished the 31-acre Tower Place estate in exchange for Gun Wharf and a large cash payment.⁴

Already in 1670 the Board, through Paul Linby, its Woolwich Storekeeper (the head of the establishment), had begun building a new wharf and proof butts. A storehouse for ‘fireworks’ (ammunition), placed safely away to the south-east, followed in 1672–3 under Moore’s supervision. At the same time, after the outbreak of the Third Anglo-Dutch war, De Gomme staked out new fortifications that were probably a transformation of the former orchards into a double-moated earthwork, triangular on plan with a salient to the south where Building 22 now stands; the east side incorporated the end of the stream that elsewhere formed the parish boundary. The linear riverside

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battery was rebuilt in 1688–9, dismantled in 1714 and succeeded from 1720 by an avenue of trees that came to be known as Prince Rupert's Walk, with two small batteries projecting into the river.

De Gomme succeeded Moore's son as Surveyor in 1682 when he oversaw the division of Tower Place itself, much of it to make two dwellings, for Thomas Peach, Storekeeper, to the south, and Capt. Richard Leake, Master Gunner, in the middle. The Great Hall became Leake's kitchen, and other service rooms were created in a single-storey range west of the parlour that was probably an early addition. The large rooms to the north were kept as a Great Dining Room for Ordnance officers, under a Great Bed Chamber for the occasional accommodation of the Board's Lieutenant-General.

Between these superior lodgings and the fort, the Tower Place ordnance depot remained largely open storage ground, principally for iron cannon, behind a wharf with cranes. There was a shot-yard east of the house. Beyond were some long open sheds to house gun carriages for ships, and a gunpowder magazine in a converted dovecote; proof ranges had their butts away to the east. In addition there was saltpetre refining and storage, and firework making, for displays as well as military use. In the later 1690s a substantial ammunition factory (a 'laboratory') was built and the unused earthwork fort was adapted for a gun-carriage yard with even longer sheds. Gradually Woolwich had grown to rival the Tower of London as the country's main ordnance depot. A first brick perimeter wall was built in 1702–4.⁵

ROYAL LABORATORY

Large-scale manufacturing arrived in 1696, tipping the depot towards its future as a munitions factory. Workshops at Greenwich Palace that had

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their origins as a sixteenth-century armoury had been absorbed by the Board of Ordnance in 1671 and adapted thereafter to be a laboratory for making ‘fireworks’. Plans to convert the palace into a naval hospital, settled in 1694, meant the laboratory had to move. Its successor was formed at Woolwich, to the south-east of Tower Place. Generously laid out around two yards, the complex was built in 1695–7 to a scheme that was probably devised by Sir Martin Beckman, the Swedish and Catholic Chief Engineer for England and the Board’s Comptroller of Fireworks, under John Charlton, Surveyor-General, who gained an assistant, William Boulter, to carry the project forward. In this period the Fitch family had a lock on Ordnance building contracts, a hobble that Beckman resented. Here Robert Fitch was the master bricklayer, Henry Hayward the master carpenter, and John Young the mason; their works were overseen for the Board by William Meades. Jean Tijou supplied wrought-iron gates in 1699. In a related work, in 1695–6 a large barn in the Greenwich tilt-yard was dismantled and re-erected at the south end of the laboratory, near the road, where the Royal Brass Foundry now stands.⁶

What came to be the Royal Laboratory, sometimes Laboratory Square, was a highly rational and architectural development, thought through as a series of hipped-roofed brick ‘barns’, ranged along the sides of rectangular and triangular yards, to separate the numerous different tasks associated with the making of gunpowder, shot and shells – such as powder-mealing and fuse-driving. Between the yards there was a watch-tower and clock-house gateway for surveillance and control, an early planned instance, following the lead of the dockyards, of the co-ordinated time and work discipline that underpinned industrialization. The main enclosed quadrangle had Tijou’s gates facing the river between rusticated Portland stone piers topped by carved lion and unicorn figures, which survive at Building 40. This grand entrance opened onto a yard laid out like a parterre, with a central ‘fountain’ and ample space for making and piling shells. The perimeter buildings all

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lacked chimneys, suggesting that furnaces and associated hazards for tasks like saltpetre purification and tin-smithing were concentrated round the smaller southern yard. At the centre of each long side of the main yard there were taller ‘barns’, probably storehouses. These pavilions, of a genteel, domestic appearance, were dressed with Portland stone quoins, central bracketed doorcases and first-floor scrolled architraves with lion-mask key blocks under small pediments. Remarkably, they survive, much mutilated through nearly three centuries of industrial use, still bearing a cartouche with King William III’s monogram. As astonishing is a marvellous series of water-colour drawings from around 1750, attributed to Gamaliel Massiot. This depicts the laboratory informally at work – artillerymen and artisans working alongside each other, all male. By the 1770s women were working in the laboratory, sewing flannel cartridges.⁷

In a major transformation of 1854 the southern triangle was redeveloped, the tower taken down and the quadrangle entirely covered with an iron-framed north-lit roof to enclose a vast steam-driven ammunition factory with a grid of ninety cast-iron columns, around 500 lathes and a proudly decorative north elevation. The east pavilion’s doorcase brackets were replaced by cast-iron replicas, pierced to allow the passage of drive shafting.⁸ This factory continued as the Royal Laboratory’s ‘main machine shop’ through the First World War, but manufacturing ceased thereafter. Save the pavilions, the rest of the complex was taken down in 1950–1 and 1972–4. The pavilions stood derelict for many years. Restoration by Berkeley Homes amid redevelopment of the rest of the laboratory site is intended in 2012.⁹

BUILDING AND DESIGN, 1716–23

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The gradual increase in the importance of the Board of Ordnance presence on the Warren found strong architectural expression in a major building campaign that began in 1716. The depot no longer expanded on a domestic scale. Advantage was taken of the open site, and in a further shift towards manufacturing, unwontedly ambitious industrial buildings now arose, introducing a new Ordnance grand manner, essayed elsewhere, but nowhere so consistently and with such powerful effect. This was driven forward principally by the Board's Surveyor-General, Brig.-Gen. Michael Richards. From this time on the military significance of the Ordnance facility at Woolwich was not to be mistaken.

Part of the background to this change was a determination to reform the notoriously inefficient Ordnance department. John Churchill, the Duke of Marlborough, who had been in charge as Master-General of the Ordnance from 1702 to 1712, returned to favour and held the position again from 1714 to 1722. On his reappointment he delegated reorganization and building programmes to a new Surveyor-General, his protégé Richards, a talented artillery engineer who had become Chief Engineer of Great Britain in 1711. Richards's brother-in-law, James Craggs (the Elder), regained his old post as Ordnance Clerk of Deliveries. Col. John Armstrong became the new Chief Engineer, now made one of the Board's principal officers. Under Armstrong there were six divisional engineers, among them several foreigners; military engineering remained an expertise in which England was weak. These men were largely responsible for contracting, with some functions transferred to the Board's veteran William Meades, now titled Purveyor. The Jacobite rebellion of 1715 drew energy and engineers away, but in 1716 reforms resumed, as did discussions about bringing gun founding to Woolwich. There a key figure was Lt. Col. Albert Borgard, a Danish mercenary appointed an Ordnance engineer in 1698. He had mapped Woolwich in 1701 and was appointed Chief Firemaster, in charge of

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the Laboratory, in 1712. He was a divisional engineer under Richards and Armstrong in 1715 and early 1716.¹⁰

An accident intervened. Matthew Bagley, the Board's contract founder since 1706, invited Ordnance officials and other eminent figures to his foundry in Moorfields to witness the recasting of captured French guns on 10 May 1716. Moulds may have been damp and there was a devastating explosion of molten metal. Seventeen of the twenty-five present were killed, including Bagley and his son. Armstrong survived, as did Borgard, though badly injured. The event was a critical catalyst. Within six weeks the Board had decided to bring the manufacture of 'brass' (actually bronze) guns in-house and to Woolwich in a new purpose-built foundry. This new role for the state helped open the way to further improvements. Workshop and storage facilities were enhanced, Tower Place was rebuilt as a new headquarters, and barracks had to be built to accommodate a growing workforce of artillerymen. Funds for all this were made available up until the South Sea Company debacle late in 1720.

The project was carried through with extensive levelling groundwork and a considered layout that took its cue from the quadrangular laboratory. There was also startling architectural panache. The question of design responsibility for these works remains vexed. In principle one should look to the Board's divisional engineers (though perhaps not for panache), working under the hierarchy of Marlborough, Richards and Armstrong. But further restructuring followed the formation by this triumvirate, under a Royal Warrant of 26 May 1716, of the country's first two permanent field-artillery companies (one of them commanded by Richards's brother). This followed the peacetime 'sinking' of posts; by July new engineers, only five, were posted to forts in as many districts. Lt. John Lambertus Romer, the son of Col. Wolfgang William Romer, a Dutch military engineer who came to

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England with King William III, had responsibility for the Thames Division from a base at Sheerness. But he was in Portsmouth in late 1716 and has not been traced at Woolwich. Borgard, convalescent, was placed on the sinking establishment and appears for a time to fall out of the engineering picture. Not anyway known as a designer of buildings, he was engaged to oversee the standardization of artillery and gun carriages in a new Modelling Room at the Tower of London in July 1716. He resurfaced as Richards's Assistant Surveyor in April 1718, but by then nearly all the Woolwich buildings were underway. It may be that his engineer's post had been left vacant – if so that would explain recourse to alternative arrangements for design. One of five new sub-engineers in July 1716 was Nicholas Dubois, the Huguenot veteran of Marlborough's Flanders army who had diversified into speculative building and architecture in the West End by 1717. But there is no evidence that he was involved at Woolwich. The same goes for Andrews Jelfe, a masonry contractor who was supplying the Board with drawings for buildings from 1716 and who, in an intriguing appointment, became the first Architect to the Ordnance in 1719.¹¹

Stylistic and circumstantial pointers to the involvement of Sir John Vanbrugh or Nicholas Hawksmoor in a range of Ordnance building projects of this time, from Berwick to Plymouth and centring on Woolwich, have been noted since the 1840s and studied since the 1950s. Both architects had close connections to Marlborough and Richards, and Woolwich would not have been remote given Office of Works engagements, and Vanbrugh's Maze Hill residence, in Greenwich. The discovery of a Hawksmoor sketch of 1717 for barracks in Berwick seemed to narrow the search for the fount of the architectural originality of the Ordnance buildings, but no further such documentation has been found. Drawings in a similar though simpler style for several buildings at the Tower of London have been attributed to Richards himself, pushing the Brigadier to the fore – where he in fact was.¹²

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Richards's surveyor-generalship was no sinecure. He was hugely energetic, an able reformer as well as skilled in and responsible for building design. He certainly took day-to-day decisions about the building works at Woolwich, and lived locally at Charlton Grove (a hilltop house with a view to Woolwich). Upon his death in early 1722 he was buried at Charlton parish church. His Craggs nieces (who had inherited their father's nearby estate at Kidbrooke, south-west of Woolwich) saw to the erection of a tomb with an anachronistically armoured effigy that has been attributed to Giovanni Battista Guelfi. It evokes a Romantic sensibility rooted in militaristic nostalgia, a rhetorical outlook that has been noted in his work elsewhere.¹³

After the upheavals of mid-1716 Richards secured funding for major works and took on the revitalization of Woolwich, probably tackling design work himself, perhaps turning in 1717 to Hawksmoor, maybe also Vanbrugh, for inspiration, advice, possibly even sketches, by way of unpaid favours. But if architectural responsibility for these buildings must be assigned to an individual, it is to Michael Richards.

The Woolwich designs would have been worked up through the collaborative efforts of others in the Board's employ. William Meades, the Purveyor, had a crucial role as overseer. He was competent in building work, having prepared estimates and presented measurements for and directed Ordnance projects since at least the 1690s. He had accompanied Richards on a tour of southern forts in 1715 to view works in progress, and was thereafter told to proceed with a design for storehouses at Sheerness, with structural alterations 'as he proposes'.¹⁴ In late 1716 Richards ordered George Nicholson, a draughtsman at the Tower under Borgard, to Woolwich to work on the foundry. Much constructional initiative is likely to have devolved to

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the Board's eminent master craftsmen responsible for the actual building work, principally (Sir) William Ogbourne, master carpenter since 1700, who is known to have acted as an architect elsewhere (and who was, it seems, another of those injured at Moorfields), and Henry Lidgbird, master bricklayer since 1711.¹⁵

Royal Brass Foundry

The Royal Brass Foundry of 1716–17 was the first building on Woolwich Warren to be designed for the manufacture of guns. It was placed on the site of the old Greenwich barn, with other dangerous buildings at the back of the growing establishment, and was intended from the outset to supply forces on both land and sea. Much reconstructed, but undiminished in fabric if not in context, it survives as a powerful reminder of the scale and grandeur of operations here at this early date. It is also, a great rarity, an extant witness to significant aspects of the nascent industrial revolution.

William Meades was asked to prepare estimates in July 1716, with first designs presumably in hand. George Nicholson spent nine days in Woolwich in late 1716 preparing drawings of the foundry. Brig.-Gen. Michael Richards retained oversight of the project through its later stages which, including the building of furnaces and a boring machine, would have been undertaken in consultation with Andrew Schalch, the Swiss founder who moved from Douai to Woolwich following his October 1716 appointment to be the Board's first Master Founder. The greater part of the building work was the responsibility of William Ogbourne as master carpenter. Henry Lidgbird carried out the brickwork, largely with bricks brought by barge from Windsor. Robert Churchill was the Board's master mason, and Jane Hill, the Ordnance painter, took on the interior decoration. The Portland stone royal arms over the foundry's north entrance and those of Marlborough in

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the keystone below were carved by Thomas Green of Camberwell in 1717, his estimate approved only after Meades's intervention. The site-perimeter wall near the foundry was rebuilt by Lidgbird, also in 1717, but the building's cupola, not for a clock or bell but purely ornamental, was not complete until 1722.¹⁶

The foundry was originally entirely timber-framed within a two-colour brick shell. It was built to replace a barn that had come to be used for founding, and, barns aside, there were few domestic models for large workshops. Gunmaking, in any case, had long been a rural craft. As much as the foundry's formal origins are with barns, it can also be described as a basilica – it comprised a long tall nave with clerestory lighting flanked by continuous low aisles. These aisles housed furnaces towards their south ends, one large and one small, and had entrances in shallow porches. There were also three south entrances, close to a new triple gate in the site's boundary wall. The squat tower at the north end, timber-framed except to the north, housed a vertical gun-bore smoothing mill in which the cannon, cast hollow, were hoisted, muzzle down, on a gallows frame and lowered onto a revolving cutter-head driven by a horse gin. Either side of the tower low 'transepts' were probably a workshop for model- and mould-making and a drawing office and pattern room. As a whole, the design of the foundry was utilitarian, but an outward appearance of rusticity was disguised; confirmation that this was a barn in fancy dress comes from a remnant of Hill's work, painted *trompe l'oeil* brickwork on the once externally visible outer face of the east wall-plate. Pegs in this same length of timber confirm that there were originally posts between all the bays. A virtue was made of the prominence of the boring tower with its necessarily tall entrance, from which finished guns emerged. The embellishment introduced has a touch of Hawksmoorian eccentricity. Formerly there were rusticated pilasters (called 'rustique fascias') on all four sides of the building, and assertive impostes and corner piers rose above the cornices. Yet the Brass Foundry looks more like

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Richards's earlier buildings at the Tower than those designed in 1717 and later for both places.

The principal surviving feature of the original 'barn' interior is the framing of the roof. This structure is a notable instance of inventive carpentry to meet special demands, as the conventional forms of king-post trusses were adapted for workshop use and to serve as a gantry. The steep pitch, originally tile-covered, is one reflection of the demand for strength. The trusses over the original furnace positions are subtly modified for robustness, and heftily reinforced with extra iron straps. Bay lengths vary accordingly and horizontal cross braces at tie-beam level both triangulate the frame and offer support for ropes for heavy lifting from the floor. The south or furnace end had a gallery to permit workmen to operate above the furnace pits, in particular to work a windlass drum with tackle for lifting heavy weights. Northern areas were more open.¹⁷

In 1770 Schalch, now elderly, was pushed out of his job and home. His successor was a Dutch master gun founder, Jan Verbruggen, appointed with his son Pieter. Gunmaking processes had become more sophisticated and the Verbruggens brought modernization. They undertook an extensive reconstruction of the foundry in 1771–4, carried forth to their specifications by the Board's principal contractors, Thomas Churchill and John Groves, bricklayers, and James Morris, carpenter. The building's form and use following these changes are marvellously recorded in a series of fifty watercolour drawings which have been attributed to both Pieter Verbruggen and Michael Angelo Rooker. The work involved a rebuilding and extension of the south end of the building where the aisles were raised a storey for larger furnaces with 'quaint gun-shaped chimneys'.¹⁸ A third furnace was added in an extension up to the site boundary, finished with a blind elevation. In the nave floor in front of all three furnaces was the single 'Great Furnace Pit'

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into which molten bronze was poured into gun-moulds placed vertically. Above this the three southern bays of the original building gained a stronger and more fireproof internal structure. The timber posts between the nave and aisles were replaced by brick walls, arcaded to admit light and keep circulation free, and so reinforced by stone end piers and iron rods. The east-side internal wall incorporates part of the earlier furnace screen in its central bay, and the upper arches in both internal walls were enlarged, probably in the early years of the nineteenth century. Springing from the north ends of these walls are low elliptical arches, inserted to span the aisles. The north end of the building was also modified in the 1770s. The tower was separated from the nave by the insertion of a triple brick arch on stone piers, and from the workshops by elliptical arches, brickwork carrying up to face the sides and back of the tower, hitherto timber-framed. Cannon and mortar boring was moved to neighbouring buildings where Dutch horse-driven horizontal boring machines were installed. As the foundry's south entrance had been blocked, the space inside the north entrance became a 'vestibule', with storage above. A spiral staircase was inserted in the nineteenth century.¹⁹

The south end of the foundry was extended slightly further, probably in 1803 for John King, Master Founder, the work overseen by Capt. George Hayter. There are canted angles to another blind wall, this time with a parapet. The use of bronze ordnance was already then receding in favour of iron, and the building's primacy at Woolwich was lost in the 1850s. In 1878, no longer suitable for gun making, it was taken over by the Royal Laboratory. The north section of the west aisle was rebuilt as a broad single-storey workshop for making small ammunition castings. The equivalent part of the east aisle was raised a storey for offices in 1888.²⁰

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A stained-glass lunette had been placed above the foundry's north entrance by about 1840, perhaps in 1834 in connection with a visit by William IV. Its depiction of Edward III and his officers inspecting artillery is said to be copied from a sixteenth-century tapestry. The window was moved to the Royal Laboratory's pattern room in 1874, and then at some point after 1894 to a model room on the south side of the Royal Gun Factory's Proof Square. It was relocated again in 1908, to become the fanlight over the main entrance of the Central Offices (Building 22). Taken from there around 1990, it is now on display in the Greenwich Heritage Centre (Building 41). It is a rare survival of early Romantic-historicist stained glass.²¹

The foundry has lost its decorative fanlight, but it has gained an antique colossal statue. Outside the east 'transept' and under an awning, there is a high-relief figure of a tunic-clad oriental barbarian of the first to third century AD. It is probably of Turkish marble, perhaps made as architectural sculpture and one of a pair. It was dug up in Alexandria by British troops in 1801, shipped back to London and left at Woolwich. It stood as a 'Moon God' in the laboratory square until the yard was roofed in 1854. Cast aside, it was only re-erected, probably where it now stands, in the 1870s.²²

The former foundry became a store in 1939 and use as a garage for officers' cars followed. With the Arsenal closed, the building was sold to the National Maritime Museum in 1972. It was listed at Grade 1 in 1973. Plans for its repair and refurbishment as an archive store were prepared through the Property Services Agency by G. Alan Herbert Associates, architects and engineers. Works were not, however, carried out until the late 1970s. Accretions were removed and the east side was largely restored to its form of the 1770s, though without an entrance porch. The interior was filled with demountable storage racking.²³

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Great Pile (Dial Arch)

The biggest of the undertakings of the Richards years was the Great Pile of 1717–20, its name sufficient to convey its presence. It was a large quadrangular compound, laid out east of the Laboratory across an avenue, on a site that had once been a Roman cemetery. What survives is just the front range of a lesser forecourt of workshops at the south end, built in part to support the foundry. Behind this there were originally two great gun-carriage storehouses, one for the sea service, one for the land service. The Lidgbirds were responsible for brickwork, William Ogbourne for carpentry, and Robert Churchill for stonework.²⁴

The ‘carriage sheds’ were grandly architectural, perhaps the most Hawksmoorian of all the buildings in Woolwich. There were imposing entrances, again bearing Marlborough’s arms, though the sea-service building had only a single storey between its taller centrepiece and ends. Walls and pavilion workshops enclosed the larger warehouse quadrangle, for which a central circular basin prompted the name ‘fountain court’. The humbler southern group of six single-storey workshops in two low L-plan blocks that enclosed ‘artificers’ court’ completed the ‘Pile’. The south-west block was used for turning, washing and engraving brass cannon and was thus an adjunct to the nearby foundry. The south-east block was smiths’ workshops. These buildings could only be entered from the court, access to which was via a distinctive gable-headed and rusticated arch (later the Dial Arch) of finely gauged brickwork. The whole entrance elevation plays with military architectural forms. The central arch is flanked by battered pylons topped with pyramids of shot, and pseudo-machicolation features both here and at the gabled ends. Striking as this brown-brick façade remains, it should be borne in mind that it was conceived to be seen in front of the great warehouse that loomed up beyond. Visitors to the Warren encountered

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this view on first arriving at the site. In 1720 entrance gates were formed on the axis of the Great Pile, close to the point on Plumstead Road where there are now gates. These had brick piers, likewise topped by piles of shot, and impost-blocked arches in front of twin guard lodges (first called labourers' houses) with three-bay colonnades. This was part of a general renewal of the perimeter wall on the site's south and west sides in these years.²⁵

In 1764 the Great Pile's south entrance arch acquired a sundial to help regulate work. The gabled ends of the south front then gained segment-headed windows, probably in 1775 when the workshops within were adapted for horizontal gun boring via horse mills. The whole compound became administratively joined to the Royal Brass Foundry and the lesser court was briefly known as Foundry Square before it became Dial Square or the Dial Arch Block. By the early nineteenth century the main yard to the north, into which four carriage-making sheds had been inserted in 1758, had come to be called Basin Square.

The sea-service warehouse was adapted to house workshops for cartwrights and smiths, but otherwise the early eighteenth-century buildings were little altered until steam boring replaced the horse mills in 1842–5. The complex was further transformed in 1855–7 to provide steam-driven machine shops for what had become the Royal Gun Factory. A large single-storey boring factory had been formed, probably replacing much of the land-service warehouse, the west end of which was adapted to house engines and boilers. This factory also accounted for the north arm of the south-east workshop block; cast-iron columns that were inserted to replace the re-entrant wall survive. The rest of the south range was made offices, stores and, to the west, a school room. At the back of the central archway a decorative open-spandrel cast-iron arch was inserted, bearing the date 1780 and the names Blomefield, Dickson, Millar, MacLean, Dundas and Chalmer,

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the Inspectors of Artillery and of the Royal Brass Foundry from 1780 to 1855. The sea-service warehouse was made smiths' shops and stores, and in the built-up yard there was an iron foundry where in the 1860s a seventy-ton steam-hammer anvil was cast.

A large (north-west) section of the quadrangle was replaced around 1902 for a new brass foundry. Production here probably included parts for torpedos, made in Woolwich from 1872 and transferred across from the Royal Laboratory in 1893, but only until 1910 when government torpedo-making moved to Scotland. The last remnants of the early eighteenth-century warehouses probably disappeared during the First World War, by when the quadrangle had been filled. Other parts of the complex had become a cartridge factory in the 1890s and an erecting shop.²⁶

It was a group of engineers working in this block who, in 1886, formed Dial Square Football Club. This became Royal Arsenal Football Club in 1888 and, once the team had become professional, Woolwich Arsenal Football Club in 1891. Games were played at grounds in Plumstead parish. The name needed to be further amended to Arsenal Football Club after a move to Highbury in 1913.²⁷

The complex shut down in 1950 and was all cleared in 1969 save its south range. That was refurbished around 1984, with new cannon balls on the piers, a poorly scaled echo of the originals which had gone by the 1950s. The building was more substantially overhauled in 2009–10 to become a pub. The conversion was carried out via Berkeley Homes, by Young & Co.'s Brewery, PLC with Harrison Design Co. It involved a glass-fronted central atrium bar and a brick-faced north extension. The rest of the Great Pile site was redeveloped in 2010–11 as a block of flats.²⁸

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Building 40 (the Academy)

Tower Place was replaced in 1718–23. The new building, on a line slightly further east, was, at least initially, to be used as the house had been since the 1680s, as two dwellings and corporate space, but to more up-to-date and opulent effect. The work may have been conceived as a unity, but it was undertaken in two distinct phases, the northern and central sections first in 1718–20, to provide a new Board Room and entrance ‘saloon’, the southern section following on in 1721–3 to replace the original hall, kitchen and gallery with a second ‘great room’, to be an Academy for training the young officers of the Ordnance’s two newly formed ‘scientific’ corps, the artillery and the engineers. This institution was launched in August 1720 once funding had been arranged through a South Sea Company subscription, secured by Richards and his nephew, James Craggs (the Younger), who had risen to eminence in government. Accommodation for Ordnance officers continued in a rebuilt and enlarged west or rear range, and the totemic Tudor tower was kept to the south, standing free and now somewhat set back. Meades again acted as overseer, with William Ogbourne and Henry Lidgbird as the main builders, Robert Churchill as mason, and Jane Hill as painter.²⁹

Architecturally this is the most noteworthy survival from this period. It is both stark and symbolically ornamental. The brown-brick façade is arresting and unusual with certain stylistic features that, probably via Richards, derive from Hawksmoor: a massive projecting frontispiece with a Mannerist Serliana topped by elliptical openings under an open pediment; elongated rusticated quoins; shaped chimney stacks; impost bands to arched window openings; and plain architraved oculi. The latter, which disguise the fact that the rooms behind were full height, recall both Christ Church, Spitalfields, and Richards’s ‘Roman’ refenestration of the White Tower at the

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Tower of London of 1715–17. A large forecourt once had tall pylons at its outer corners with pseudo-machicolated heads.³⁰ The symmetry does suggest a single conception, but it could be that the centrepiece and north range were designed to be seen next to a retained south Tudor range and tower – an attempt at contextualism might help explain the oddity of the classicism.

The rebuilt and enlarged storekeeper's house to the rear is plain and functional, six bays, three full storeys and an attic. It was laid out as an L with a lower 'great kitchen' that returned to the north at the back. From the kitchen there was a three-bay arcaded 'piazza' across the side of a small yard, so that food for the Board Room did not need to be carried through the house. The kitchen was demolished around 1890, but the scar of its roofline remains visible above a blocked arch.

Inside, the main range is laid out simply, with the 'great rooms' either side of the black-dot Purbeck marble-paved entrance hall ('saloon'). The former Board Room to the north was the direct successor to Bowes's great parlour that had been adapted as a dining-room for Ordnance officers in 1682. The kitchen passage betrayed its use for dining as well as for meetings. There is a Portland stone fireplace with bold consoles, and the ceiling vault is an ellipse, another Hawksmoorian form. A full-height bow window looked across a shot-yard to the river. The former Academy Room to the south has a simpler fireplace and there are grisaille trophies on its inner wall, an early feature, interrupted by a nineteenth-century ceiling. The room was originally full-height, but unlike the Board Room, it had a gallery. This, on all sides, was supported with the help of ten twisted iron bars from the roof trusses. Elsewhere in the building there is early plain panelling and behind the entrance hall a dog-leg staircase that, though altered, goes back to 1719.

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Just as the Academy was founded the value of South Sea stocks collapsed. The institution faltered, but was relaunched in 1741, with the grant of royal warrants. Two more houses were built to the rear for its first and second masters, Dr John Muller and Samuel Derham, in an L-plan block to the south-west that was demolished around 1970. Rooms for the first drawing master, Gamaliel Massiot, and model makers, Francis Dean and William Whittaker, were fitted up in 1743 in the Tudor tower's upper rooms. It was from the Academy that John Barker, perhaps one of the Board's civilian engineers, issued his superb survey maps of Woolwich in 1749. Both 'great rooms' saw brief use as chapels and the Board Room as a theatre around 1750 as the Academy expanded.³¹

In 1764 what was henceforward the Royal Military Academy was reorganized under a Lieutenant-Governor, Lt. Col. James Pattison. It became a uniquely enlightened establishment in which training comprehended 'writing, arithmetic, algebra, Latin, French, mathematics, fortification, together with the attack and defence of fortified places, gunnery, mining, laboratory-works, fencing, dancing, etc'.³² Its First Master became the Professor of Fortification and Artillery, its Second Master the Professor of Mathematics – from 1773 the latter was Charles Hutton. In 1775 the Academy Room gallery was extended to make a floor for an upper room for models and lectures on fortifications. This work was to the plans of Thomas Powrie, Clerk of the Works, also employed as a model-maker. From 1778, when there were forty-eight gentlemen cadets, the Royal Military Academy was in sole possession of the building.³³

Paul Sandby, who had been trained as a Board of Ordnance surveyor in the 1740s and gone on to enjoy royal patronage, was appointed Chief Drawing Master at the Academy in 1768, in which year he was also a founder member of the Royal Academy of Arts. He held the post until he retired in

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1796, teaching two days a week, with morning classes in 'Landscapes and Perspective'. From 1769 to 1772 he had a house in Woolwich at Green's End, thereafter he lodged in Charlton. His students drew 'about Woolwich and other places', the empirical study of topography forming 'the eye to the knowledge of it'.³⁴ Sandby drew the Academy several times himself – one of his views was used for Charles Grignion's engraving for the title page of Capt. George Smith's *An Universal Military Dictionary* of 1779. Numerous other Sandby sketches and watercolours of the Warren and wider Woolwich survive. His assistants and students here included Michael Angelo Rooker, James Pattison Cockburn, George Heriot and William Gravatt. In 1777 Isaac Landmann, of German origin and previously professor at the École Militaire in Paris, was appointed Professor of Fortification. His son, George Landmann, who was to gain renown as an engineer, was born in 1780 and brought up here. He later recalled the demolition of the Tudor tower, deemed unsafe, in 1786.³⁵

A small and short-lived Lower Academy building was put up to the south-east soon after 1797,³⁶ but there was insufficient space for the burgeoning establishment and the Warren was thought unhealthy. The Royal Military Academy moved up to Woolwich Common in 1806. Its former home became part of the Royal Laboratory, which used the building as 'model rooms', that is as both a store and a museum for ammunition patterns, with glass-fronted display cases. In the 1840s the former Academy Room housed specimen ingredients and machines for the making of gunpowder, and on the floor and tables there were 'moulds for casting balls and bullets of various sizes; all the sizes and forms of chain, grape, and canister shot, from one to two hundred and fifty pounds in weight'.³⁷ The Board Room may have reverted to use for lectures to cadets. Offices and other support functions were placed behind, with the former storekeeper's house refitted as a chemical laboratory for Frederick Abel around 1854.³⁸

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The main windows received new sashes, probably around 1810; the oculi were reglazed around a century later. A clock, made by John Bennett of Greenwich and Blackheath with a mechanism by Thwaites & Reed, arrived in the pediment in 1837. This was moved down to block an original oculus in the last years of the nineteenth century, to make way for a weathervane, also supplied by Bennett's firm. The carved stone lion and unicorn figures came here from atop the Royal Laboratory's north gate piers, in or soon after 1854. On the outside back wall of the former Academy Room there is a tall gauge for explosives testing that is probably of the late nineteenth century. Patterns having fallen out of use, from around 1920 the 'model rooms' were converted in stages for use by the Arsenal's officers. The Royal Arsenal Officers' Mess continued here until 1994. Since a refurbishment of 2000–1, overseen by Julian Harrap Architects, the building has pertained to the Royal Artillery Museum (Firepower), and is left largely empty save for occasional hire of the grand rooms.³⁹

HOUSING

An ensemble of military accommodation, comprising artillery barracks and quarters for cadets and officers, took shape in a piecemeal manner in the south-east part of the eighteenth-century Warren. Much of this has gone, but there survives a range (Building 11) that was built as barracks in 1740 and Verbruggen's House, a detached house of 1772–3. The former was recast internally in 1787 to be four officers' houses and refaced in 1855–6.

Building 11 (1–4 Dial Square)

The two permanent artillery companies formed in 1716, each of ninety-eight men, were stationed in Woolwich Warren to carry out work that ranged from

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fuse-filling to proof-supervising, also providing a guard. For this force a barrack block (later 7–10 Dial Square) was erected in 1719 by those carrying out the other building works in the Warren at that time. The same team also built, to designs by Brig.-Gen. Michael Richards, a similarly shaped row of four houses (surviving as the Old Hospital Block) at the Tower of London in 1718–19. There were, in addition, formal resemblances with the blocks of Ravensdowne Barracks, Berwick, of 1717–21. The Woolwich building was near the south-east corner of the Great Pile, to answer the Royal Brass Foundry across what had become a rectangular parade within the entrance gates. These first artillery barracks had three storeys, garrets and basements, and comprised a large central section of open-plan barrack-rooms, implying close to fifty men in each 60ft(18m)-wide room. There were oak partition-walls to pairs of officers' houses at either end, that to the south-west occupied by Andrew Schalch, the Master Founder.⁴⁰

What had become the Royal Regiment of Artillery in 1722 under Borgard's command grew quickly and needed more housing. The block that survives as Building 11 was built in 1739–40, at right angles to its predecessor as if to suggest a square. John Armstrong, now Surveyor-General as well as Chief Engineer, helped to set out the building, and Henry Foucquet, an Ordnance engineer and Armstrong's Clerk, oversaw the work. Joseph Pratt was the master bricklayer, Roger Morris the master carpenter, and Mercer and Spriggs the masons. In scale and form this was a replica of the 1719 building. The brick block of three storeys, basement and garrets was given symmetrical eleven-bay front and back elevations. It had entrances at the centre, for central barrack rooms for some 200 more soldiers, and ends, for front-and-back pairs of officers' houses, again separated by timber partition-walls; traces of an early staircase have been noted at the centre back of the barrack rooms. The octogenarian Lt. Gen. Borgard had a house at the south end which he required to be knocked together with its pair in 1744 to create a double-sized house. There he lived until his death in 1751. By the 1770s

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about 900 artillerymen were stationed in Woolwich. Rules were abused and some wives and children probably also ended up lodging in the barracks. With great overcrowding and infestation disease was rife.⁴¹

When the Royal Artillery moved to large new barracks on Woolwich Common in 1777 pressure on these buildings was relieved. Even so, Gen. William Belford, Commandant at Woolwich, asked for a new house because he found his quarters in the Warren impossible on account of ‘the Horrid Smells from the Men’s necessary houses’.⁴² He was told that his request would be borne in mind, and in 1778 William Latimer presented plans for field officers’ houses that perhaps bore fruit on the Common. But officers continued to complain about their housing in the Warren. In 1786 James Wyatt, now the Board’s Architect, prepared a scheme for houses there. In 1787 the plans were revised and Charles Weaver, Clerk of Works, oversaw the refitting of the former barracks to be field officers’ quarters, four houses to each range. Brick party walls were inserted between the houses and to either side of shared central passages. This allowed the existing centre-front entrances to be retained, with internal access to each inner house immediately onto new back staircases. The original hipped roofs were replaced with paired M-profile roofs, with gaps in the middle. In the block of 1739–40 the larger outer houses, corresponding to the original paired officers’ houses, were given front staircases and wide three-bay back rooms with views across open ground. Two more houses (later 5 and 6 Dial Square) had been built onto the east side of the earlier building. By the 1790s coach-houses, stables and servants’ quarters formed a continuous range behind the eastern gardens.⁴³

The whole group of houses was taken over by the Royal Laboratory as official residences for that department’s senior staff and the two former barracks ranges were substantially overhauled again in the 1850s. This

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work, seemingly undocumented, almost certainly took place in 1855–6 through Col. Edward M. Boxer, newly appointed Superintendent of the Royal Laboratory, after the winding up of the Board of Ordnance had loosened purse-strings and reporting lines. It would have been overseen by Col. R. S. Beatson, RE, who was answerable directly to Boxer and the Arsenal's other departmental superintendents. It included complete refacing in brown brick with red gauged-brick window arches, continuous upper-storey string courses and cornices, and raised parapet panels for central emphasis. This left the surviving carcass of 1739–40 entirely concealed, but kept its proportions and window shapes. Symmetry was lost with the addition to the northern house of an entrance and staircase bay with a front porch. The added staircase has an ornate cast-iron balustrade identical to that in the former Royal Laboratory Offices (Building 18), also built in 1855–6. Boxer himself took this largest house (1 Dial Square), and the next largest, to the south (4 Dial Square), went to (Sir) Frederick Abel, Chemist at Woolwich from 1854 to 1888. Boxer had extra rooms added behind his staircase bay in 1862, and a successor extended further in 1875; No. 2 gained a rear wing in the early 1860s. Abel added a front porch in 1885, and there was a third porch to the centre, now removed.⁴⁴

Residence at Dial Square gradually gave way to office use, starting by 1915 at No. 1 and excepting No. 4, where later residents included Brigadier O. F. G. Hogg, the chronicler of the Arsenal's history. Nos 5–10 Dial Square, the first block of 1719 and the adjacent late eighteenth-century houses, were demolished around 1970. The surviving range stands empty under scaffolding, awaiting reconversion in 2012, with fireplaces, panelling and other joinery of the 1780s and 1850s removed to storage. Restaurant, bar and retail use is envisaged for a building that is due to find itself immediately north of the Woolwich Crossrail station.⁴⁵

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Cadets' quarters (demolished)

In 1744 the students at the Academy were formed into a company of gentlemen cadets, at first housed in the town. Discipline was a problem, so quarters were built in 1751–2, away from temptation at what was then the south-east corner of the Warren, just inside the Plumstead Road boundary wall, in Plumstead parish. Sir Charles Frederick, Surveyor-General, and Robert Hartwell, Clerk of the Works, delegated this project to John Hayter, the Board of Ordnance's first formally appointed Overseer in Woolwich, whose career had started in the Tower Drawing Room in 1733. The barracks, a two-storey eleven-bay range with a broad central pediment, comprised eight 20ft by 16ft (6m by 5m) rooms, each for up to eight young gentlemen, often two to a bed. In 1758 more accommodation was provided in two five-bay additions at either end, put up to plans by Hayter.⁴⁶

West of these barracks along the same perimeter line, a small 'grease house' of around 1710, beyond the much reconstructed 'firework barn' of 1672–3, had been converted to an infirmary for artillerymen in 1741. A larger cadets' hospital replaced this in 1756–7. Another long two-storey range, again probably by Hartwell and Hayter, it was equipped with a cold bath in 1760 and a hot bath in 1774–5. The latter was moved to the Royal Artillery Hospital that opened in 1780. Thereafter the Warren's hospital was refitted to provide more cadets' barracks. By 1797 a colonnaded hall had been put up between the blocks of the 1750s.⁴⁷

These buildings continued to house and serve some gentlemen-cadets and the Royal Military Academy until the 1860s. Thereafter they became officials' residences, except for the central hall which functioned as a school (replacing one in Dial Square) until 1890. To the west a surgery block of the 1850s expanded into a Medical Department that, in the early twentieth

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century, took over a three-storey office block of 1890 near Verbruggen's House to constitute a works hospital. To the east a library and reading rooms were converted into a Mechanics' Institution in the early 1860s. A larger reading room against the boundary wall had been adapted for lectures and concerts by 1884 to provide a galleried hall, later used as a theatre and for boxing. Beyond were a racket court and, across an internal street (later Avenue H), police barracks of the 1850s.⁴⁸ All this was cleared in 1984–5 for the widening of Plumstead Road.

Verbruggen's House

When Jan and Pieter Verbruggen arrived at Woolwich in 1770 to take over the Royal Brass Foundry they were appalled at the size and state of the founder's house in the barracks' block of 1719, where Andrew Schalch had lived for fifty years. They gained sanction to build an entirely new house, put up in 1772–3 to the south of its predecessor, across the parade from the foundry. Under the supervision of Thomas Powrie, newly appointed Clerk of the Works, and to plans perhaps prepared by his predecessor, John Hempsall, it was built by James Morris, carpenter, probably with John Groves, bricklayer. It is a compact brown-brick block, with two rooms on each floor in an unconventional layout. The house was originally entered from the north, straight onto a staircase hall, and the fireplaces were at the 'fronts' of the rooms. This freed up the south and west elevations for views to the foundry and the Warren's entrance gate. On these more prominent façades there is a stone cornice and ground-floor blind arcading, later a common trope in London house-building.⁴⁹

After Pieter Verbruggen's death in 1786 the house was occupied by Capt. Michael Dorset, Inspector of the Royal Military Academy, and his successors to 1829, when Deputy Adj. Gen. (Maj.-Gen. Sir) Alexander Dickson moved

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in. It was perhaps at this point that it was extended to the east. It later came to be occupied by Gen. Sir William Cator, the only Director-General of Artillery, in 1855–9, before it was converted to use as offices and a Board Room for the Ordnance Select Committee. Extensions were demolished and the original block outwardly refurbished and internally stripped by the Property Services Agency in 1984. After standing empty for a long time the building was re-adapted for office use in 2010–11.⁵⁰

Main Guard House

The Main Guard House of 1787–8 was part of the same campaign of works that saw the former artillery barracks made into officers' houses on the other side of the entrance parade. A plan of 1781 by Powrie for a guard house for one officer and twelve artillerymen, whose housing had otherwise moved to the Common, appears not to have been carried out. Instead it was James Wyatt who designed this modest accommodation, squeezed between the earlier guard room and the Royal Brass Foundry, but made as imposing as might be. Its builder was Isaac Ashton, a bricklayer, working under Charles Weaver, Powrie's successor, who amended Wyatt's intentions for the shallow hipped roof. The plain stock-brick building is distinguished by its outsize Portland stone baseless-Doric portico, typical of Wyatt and fronting no more than shallow circulation spaces between large rooms to either side. The guard function continued through occupancy by various police forces until 1896–7 when the building was converted for record storage, with slender cast-iron columns inserted on the ground floor to take increased loads. There was office use from 1998 to 2011, for English Partnerships and the London Development Agency.⁵¹

Late-Georgian expansion and formation of the Royal Arsenal

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King George III visited the Warren three times in the early 1770s, and by the 1780s the Royal Military Repository had joined the Royal Laboratory and the Royal Brass Foundry on a significantly enlarged site offering ever more acreage to storage and to gun carriages, the latter overseen by what in 1803 became the Royal Carriage Department. When the King returned on 24 June 1805, amid unprecedentedly ambitious building works stimulated by the demands of war, he suggested that the place where around 2,000 people were now working might be more properly termed an arsenal than a warren; thenceforth the whole establishment was called the Royal Arsenal.

The name derives ultimately from the Arabic *dār sinā'a*, a house or place of mechanical industry, as applied to ninth-century facilities in Aghlabid harbours in what is now Tunisia. Muslim conquest and trade brought the term to Italian ports. Venice's shipyards and armouries, the Arsenale, formed the greatest medieval European establishment to bear the name. It spread, to Paris where the Pavillon de l'Arsenal perpetuates the name of a sixteenth-century gunpowder factory and cannon foundry. That had been wound down, its functions decentralized, by the early eighteenth century when Berlin gained its fine Zeughaus on Unter den Linden, an arms depot, but sometimes referred to as Prussia's Arsenal. Imprecise, but with grand and imperial connotations, the word came late to England where the Woolwich establishment had emerged along its own peculiar trajectories.⁵²

The land in Plumstead parish to the east of that purchased from Pritchard in 1671 had been a farm, occupied by John Withers in the early eighteenth century. The Board of Ordnance, desirous of more space for proving ranges and wharfage, extended its holdings gradually eastwards. The freeholders, Charlton's Wilson (later Maryon Wilson) family, granted leases in 1758, 1760, 1778 and 1800 for more than 140 acres. The whole was acquired outright in 1808. Small strips of property on the west side, abutting Warren Lane, were also added to the establishment in and after 1788, and the

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boundary wall along the lane was remade, completed and raised after the rebuilding of the south end of the Royal Brass Foundry in 1803 and in 1814. Much of this wall, including sections of eighteenth-century brickwork, has survived, though in 2012 it is proposed that large parts be demolished. The Arsenal's further expansion eastwards is beyond the scope of this volume, as is the acquisition of lands on the north bank of the river in association with the establishment of a military ferry in 1801.⁵³

Another important factor in the site's development was the arrival of convict labour in the late 1770s. This became a public spectacle and, amid nervousness about security engendered by riots, both in Woolwich and beyond, a wall was built round a riverside workplace. The convicts' principal achievement was an enormous new wharf, completed in 1813. Up to four convict hulks, one of which was a hospital ship, remained a part of the scene until 1857; they were the last in England. Plans for a prison in the Arsenal in 1853–4 came to nothing.⁵⁴

The management of the Board's mainstream building works changed significantly in the 1780s. In 1782 the Master-General, Charles Lennox, the 3rd Duke of Richmond, removed Sir Charles Frederick from the office of Surveyor-General and, a loyal patron, appointed James Wyatt as Architect of the Ordnance (previously a sinecure held by Frederick's son). Richmond also established the Corps of Royal Engineers in 1787–8 as a much enlarged body. In Woolwich, Col. Robert Morse was appointed Commanding Royal Engineer in charge of a Corps of Royal Military Artificers, in effect a direct-labour force of artisans. Woolwich became the headquarters of the Royal Engineers in 1795 and from 1797 Morse (later promoted General) headed up the entire Corps (becoming the first Inspector-General of Fortifications in 1802). He worked closely with Lt. Col. (later Col.) William Twiss, who had been in Woolwich since 1794 as Commanding Royal Engineer for the

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Southern District and Lieutenant-Governor of the Royal Military Academy. Twiss was closely involved with the Academy's move, but he still lived in the Arsenal in 1806. Under their command and also living on site was the local Commanding Royal Engineer – Lt. Col. Abraham D'Aubant, then Capt. Charles Holloway in the 1790s, and Capt. George Hayter from late 1801 to 1810. They were occasionally involved with design, but primarily project managers in charge of direct labour. The Duke of Richmond's system provided that 'The Plans of the Ordnance *Buildings* are prepared in some cases by the Inspector General himself, and in others by the Engineer of the station where they are to be executed; but in general they are prepared by Mr. Wyatt, the Architect of the Ordnance.' Morse observed, about Woolwich in particular, that he frequently made alterations to Wyatt's plans to save money, often simplifying or pruning decorative detail, especially at the Grand Store. Wyatt had been brought in principally to design prominent civil buildings as opposed to fortifications; he was the primary architect, and 'the style of the Building was chiefly left to him'.⁵⁵ The arrangement worked well, as Wyatt's talents were more artistic than practical; his notorious failings as an administrator were not a problem because the engineers dealt effectively with budgets and construction.

John Pitt, the 2nd Earl of Chatham, was appointed Master-General in June 1801 at the end of his brother Pitt the Younger's first Ministry. He appears to have supplied the impetus for great expenditure on major wartime building works at Woolwich up to 1813, in particular a new wharf for the monumental group of warehouses that is the Grand Store and a much enlarged Royal Carriage Factory. On Twiss's advice, Hayter gained reinforcements in early 1802 with the appointments of new staff under his Chief Clerk of Works, Charles Weaver, and Principal Overseer, Thomas Weaver, for a building workforce 300 to 400 strong. William Lunn was master bricklayer and then, from May 1804, another overseer alongside Weaver. The growing Royal Engineers' Department gained its own

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quadrangle of workshops in 1802–3 – the Corps of Artificers numbered 126 by 1806. The Arsenal's direct-labour force was reduced in 1811 to 89 artificers and 138 labourers.

By 1802 there was unprecedented demand for bricks in London, especially because of the building of the capital's first enclosed commercial docks and warehouses. But works of a military nature would have gained priority, if only by paying better rates, all the more after May 1803 once invasion became a real fear. Hayter acquired several million bricks a year from various suppliers, most based along the river: W. Attersoll and Co., of Grays in Essex, the largest supplier, who provided the best 'grey' (brown) stocks for the fronts of buildings; William Trimmer of Brentford; Taylor of Erith; and Stevens, also of Grays, as well as H. Monk of Ilford. Timber and other materials were supplied by William Adam and the brothers Alexander and Daniel Robertson. They were the rump of the Adam brothers building company, Adam & Co., effectively bankrupted by work at the West India Docks in 1801, but carrying on as what was probably London's largest firm of building contractors; they also supplied bricks to Woolwich from 1805. The otherwise hopelessly overcommitted James Wyatt found all these works for the Ordnance more than he could manage. In his late 50s and in declining health, he saw to the appointment of his nephew Lewis Wyatt as Assistant Architect in July 1804, while also securing himself a near trebling of his own salary.⁵⁶

The enormous whirl of Ordnance works in the first years of the nineteenth century, not just the massive works in the Arsenal, but also the enlargement of the Royal Artillery Barracks and the building of the Royal Military Academy all at once, was closely dependent on two men, Pitt and Hayter, at top and middle points in the hierarchy. From 1807 the Board's spending came under closer scrutiny and a Military Commission of Enquiry into

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Ordnance expenditure reported in February 1810. Pitt and Hayter were both replaced a month later. Pitt was discredited for military misjudgements, notably the disastrous Walcheren expedition. Hayter, on the other hand, who had been repeatedly rewarded for his zeal and whose efficacy seems beyond question, was court-martialled, ostensibly on account of small venalities. He found his way to Ceylon (Sri Lanka) where, by 1814, he had died.⁵⁷

Grand Store

The Grand Store of 1806–13 is an exceptionally imposing group of military warehouses. Despite a long history of problems with subsidence, its main central ranges survive in a little altered state. They have recently been converted to flats.

Built to cope with the demands of the Napoleonic Wars, the Grand Store has deeper origins in the wider site's development. At the end of the eighteenth century the Warren's riverfront was an irregular concatenation of wharves and foreshores. The main gun wharf, to the west, had been regularly mended and extended since the seventeenth century. Behind the tree-lined Prince Rupert's Walk and the triangular moated site that had reverted to being an orchard, two timber-built 'blue' storehouses had been erected for the Royal Laboratory in 1759. The moat was altered and extended to provide a rudimentary canal on the site's eastern grounds. There was little other building in this area until the late 1770s. By 1780 there was a new (east or convict) wharf. Largely of timber, this was designed by Col. James Bramham, RE, who also authored a grand but unexecuted scheme for the adjacent land in 1778, possibly working with John Smeaton to propose four tide mills to power twelve gun-boring engines. In the same years an East Laboratory quadrangle was built behind Prince Rupert's Walk, followed by

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new carpenters' shops further north-east. The moats were filled in and the convicts gained shelter sheds and a vegetable garden behind a large new eastern proof butt, the old one having been as mutable as the early wharf.⁵⁸

In 1788 Col. Robert Morse and Lt. Col. Abraham D'Aubant produced plans for a deep brick wharf for the whole Warren riverfront. Nothing was done and in 1797 Lt. Col. William Twiss put forward a scheme for the central riverside area that involved a huge inland basin and a canal with locks. This too was disregarded; thoughts were turning towards using most of this part of the Warren as a 'Store House Wharf' with six 200ft(60m)-long warehouses to be a general depot for army and navy stores.⁵⁹ Riverside storekeeping had been the primary purpose of the Ordnance presence at Woolwich from Tudor times and failings in supply chains during mobilizations for war in the 1790s brought it back into attention. John Geast, Storekeeper at Woolwich from 1798, was, by some measure, the highest paid official at the Warren – in 1801 he was responsible for about 6,000 guns and mortars. The projected storehouses were not primarily intended to house ordnance, but represented a move towards an integrated supply depot.

Before they could be built, however, the foreshore had to be reshaped. This involved reclaiming land behind a half-mile linear quay for landing and shipping goods, a huge undertaking. Alternative plans for the massive wharf were drawn up in 1801, first by Twiss and then by Morse, both proposing timber piles and a platform under a 22ft(6.7m)-tall wall. Morse's wall, which gained favour, widened from 8ft (2.4m) at the top to 12ft (3.7m) at the base and incorporated an oak platform on sleepers over the piles, and stone facing at least 2ft to 4ft (0.6m to 1.2m) thick. Hayter joined in the construction planning in 1802 and what was designated Ordnance Wharf was built from 1803 to 1813. It was 2,440ft (744m) long and included to the east a recess with canted sides for a dock, built in 1809–10. Morse laid the

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first stone and the first section was built under contract by a Mr Clark, possibly John Clark, who had part excavated the West India Import Dock in 1800–1. Later work to 1807 was overseen under Hayter by Sgt Joseph Woodhead, a mason of the Royal Military Artificers, using convict labour. Dundee gritstone for the wharf was supplied by the Mylne family, and other stone came from the Kincardine estate of Admiral Lord Keith (George Elphinstone). Timber, both Baltic softwood and English oak, was provided by William Adam and the Robertson brothers, as well as by White & Sons, and Joseph Harris. A steam engine, presumably for pumping, was used from 1804, and Lloyd & Ostell, Southwark millwrights, supplied and erected cranes on the finished quay at regular intervals; by 1812 these incorporated iron posts. In further work up to 1820 eastern ground-levels behind the wharf were raised by as much as 9ft (2.7m) using gravel from the river bed and Plumstead marshes. This was carried out by convicts supervised by contractors.⁶⁰ The wharf was refronted in granite in 1855–7, raised and refaced with rubble in 1906 and 1928, and refronted again with concrete in the 1960s, when its lower levels were built out and an additional wall was superimposed by way of flood defence. Early masonry is still visible to the east on the south and east faces of the cant-sided dock.⁶¹

Intentions for redevelopment on a cleared site behind the wharf grew more ambitious and in 1802–4 a single, long quadrangle of eight or more storehouses was projected.⁶² A different array emerged in early 1805 in James and Lewis Wyatt's designs for 'Sea Storehouses'. Absurdly grandiose for the storage of shovels, saddles and sponges, the Wyatts' plans proposed a central 'Gun Square', enclosed on all sides, with a domed and colonnaded bow-fronted riverside office block. Beyond, outer ranges were to enclose shot-yards open to the river. Altogether the scheme envisaged ten buildings, of which seven were large storehouses, ranging across about 1,120ft (342m) and back about 520ft (159m).⁶³ On this soft marshland the foundations were crucial – they cost as much as the rest of the buildings. The Wyatts intended

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inverted arches above a stone platform, but Morse, fatefully, substituted a system of fir piles with more modest brick inverts in platforms of Purbeck ashlar. ‘Having maturely considered Mr Wyatt’s designs for the new Storehouses’,⁶⁴ Hayter had in May 1805 suggested to Morse that it might be desirable to call for a less expensive design. The plans were modified accordingly and working drawings prepared by Lewis Wyatt in August. Pile-driving began in December, and Hayter saw to the commencement of work on the south range of the central group (Building 36) in 1806. Monk supplied bricks from Ilford and Purbeck stone came from Thomas Breeds and Messrs Chinchin, both of Swanage. The building work was supervised by a Mr Brock, Clerk of Works, transferred from the Brompton Artillery Barracks, Chatham. By 1808 the west side of the elongated inner quadrangle (Building 46) was well advanced and the east side (Building 49) begun. The domed office block had been dropped, leaving the square open to the river to be a shot-yard. The inner ends of the outer south storehouses were reconceived as corner pavilions or ‘towers’, one to be offices (Building 37). There were other changes too, presumably imposed by Morse to save money, though it was Pitt himself who squared rearrangement of the plans with Wyatt in early 1809. Columnar porticoes were cut back to pilasters, and internal cast-iron columns, used by Wyatt in other contexts, rejected in favour of timber posts. Riverside pavilions that were to have been linked to the storehouses were also abandoned, and the outer groupings of gun-carriage storehouses scaled down. They were begun as smaller semi-enclosed quadrangles. Rising demand for storage in 1811 prompted an extra storey to be added to the outermost ranges.⁶⁵

The complex was completed in 1813, a pale reflection of the scheme of 1805, but still palatial. This enormous storage complex was among the nation’s grandest military buildings. It remains impressive, despite later infill and the loss of the outer quadrangles. The Wyatts’ basic architectural concept was strong enough to withstand Morse’s economizing simplifications – the

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reduction of classical embellishment did not compromise the proportions that hold the overall composition together. And, even as cut back, the lavish use of Purbeck limestone for vermiculated plinths, rusticated porches and arched link bridges, Doric pilasters with fluted capitals, cornices, pediments, balustrades and an entire three-bay centrepiece, is striking and in marked contrast to contemporary plain-brick warehousing in London's commercial docks. Indeed these warehouses, their foundations and the wharf, cost at least £670,000, more than half as much as the entire West India Docks complex of 1800–06 (£1.2m) on the Isle of Dogs, which comprised two large docks, two basins, five locks and a half-mile row of nine warehouses. It is no surprise that the project drew the attention of the Commissioners of Military Enquiry appointed to look into Ordnance expenditure.⁶⁶

The main central ranges, once known as the Grand Quadrangle, survive with relatively little alteration. The two- and three-storey elevations are of stock brick under hipped slate roofs. Stone embellishment aside, ground-floor outer arches to round-headed windows mitigate plainness. There have always been timber sashes throughout, except to loading or loophole bays, now much altered. The central and taller range (Building 36) is 312ft (96m) and twenty-three bays long, the west and east ranges (Buildings 46 and 49) 213ft (65m) and fifteen bays. In structural and utilitarian terms the storehouses, seemingly used for all variety of military gear, were standard for their time, not much different to naval storehouses of the preceding century. Before 1810 structural iron was exceptional in warehouses; here the internal structure is entirely of Baltic pine. Regular grids of chamfered posts (on ground-floor stone bases) rise to queen-post roof trusses. Iron bolts tie cushion caps on the posts to spreaders and the roof trusses. Party walls were not at first used for fire-door separation, even though there were once small stoves. Some early timber double doors do survive; iron fire doors in Building 36 were introduced in 1898.⁶⁷

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The western Greek-cross corner pavilion (Building 37) was the office building for the complex. It is laid out like a smaller version of the nearby dockyard's offices of the 1780s. A central cantilevered staircase of stone treads with iron stick balusters (latterly reinforced with a brick pier and steel strings) rises around a large top-lit open hall. On its floor, once chequered black-and-white, there remains an original free-standing cast-iron dome-headed stove that worked via a sub-floor flue. There is also much early office-room joinery. On the first floor fireplaces appear to have been inserted in open arches which may originally have housed lesser stoves. Some rooms were refurbished around 1863 as higher-status offices known as 'The Duke of Wellington Suite' after a statue that once stood outside. The stone-faced links to the storehouses east and north of this pavilion were originally balustraded open-air bridges over carriage and footway openings to the shot-yard. Internal groin-vaulting survives here, but has been replaced by iron and brick jack-arching in an equivalent bridge to the east. The north-east bridge was demolished in 1888 and the others were covered. On a south-east wall of the former office block there is a pedimented stone tablet war memorial dedicated to men of the Army Ordnance Department.⁶⁸

The Grand Store was completed only two years before Waterloo, so was soon less urgently needed. It was also soon regarded as insufficiently fireproof. Worse, the buildings on made ground over marsh rapidly presented major structural problems. There was significant subsidence – cracks were first noticed in 1815 and investigations in 1822 showed that the east end of Building 36, on or close to the line of the moat, had sunk by up to more than four inches (10cm). On 15 March 1828 the north wall there suddenly settled another inch or two with a terrifying noise. It was shored up but further movement a month later, found to have been caused by the breaking up of timber sleepers above the piles, necessitated the dismantling of this

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eastern ‘tower’. It was not rebuilt until 1841 when, under the direction of Lt. Col. George Harding, CRE, the north wall was replaced with a light timber frame, with zinc in lieu of lead on the roof to minimize the structure’s weight. In a careful piece of stagecraft the new lath-and-plaster wall was painted to resemble the original elevation. The top storey was used not for storage, but as a horse-collar-maker’s workshop. Complete rebuilding, even moving of the storehouses had been contemplated, but thereafter piecemeal repair sufficed.⁶⁹

Following the abolition of the Board of Ordnance in 1855 an Ordnance Store Department was formed within the War Office and the Grand Store was made its headquarters. Improvements were initiated in 1856 under Col. R. S. Beatson, CRE. Hydraulic power was introduced – some jiggers and cranes survive in Buildings 36 and 49, and mezzanine floors were inserted either side of central aisles by D. Nicholson and Sons. The buildings had always been used to house tools (spades, shovels, axes, barrows, etc) and tack (harnesses, saddles, etc). From this point, Building 46 had tools, 36 was a ‘sea store’ and harness store, 36A (south-east) was, *inter alia*, a saddle-tree factory, and 49 a nail and harness store – the complex could accommodate up to 40,000 sets of harnesses. By the 1880s Building 36 was housing side arms and 36A was a record office.⁷⁰

The outer quadrangles of the Grand Store of 1811–13 originally comprised eleven-bay ranges to the north and south of painters’ shops, all single-storey, and two-storey outer ranges with pavilion ends, used to store gun carriages. Open-sided shedding on cast-iron posts surrounded the central shops.⁷¹ All that survives of this are the north and south single-storey ranges of the west quadrangle (Building 45), raised and altered in a complex sequence of developments, but still evident in outer elevations of round-headed windows in relieving arches on stone plinths. In 1855–7 David

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Murray oversaw removal of the intervening painters' shops block for the covering of the quadrangle's yard with a cast-iron framed roof, made by Henry Grissell to provide covered storage for shot and shells.⁷² Around 1900 the whole quadrangle was raised to be a single big three-storey carriage storehouse, entirely rebuilt internally with an eighteen-by-eleven-bay grid of cast-iron columns and steel joists. Soon after this a water tower was inserted at the centre of the building's east side and the western range of 1811–13 was demolished. Conversion to a book store in 1969–72 for what soon became the British Library saw the building further altered, its upper storey reclad and loopholes blocked.⁷³ Finally, all but the brick walls and the water tower were replaced again in a rebuilding of 2001–3 for Berkeley Homes to form 177 apartments, with the A&Q Partnership as architects. The early north and south ranges were raised again to four storeys, a new six-storey block was built where the west range had stood, and another new block of flats enveloped the water tower. Some of the century-old metalwork was reused for balconies facing an inner courtyard.⁷⁴

The Grand Store's equivalent east quadrangle had its north range and part of its east range demolished in the early 1830s because of subsidence. In 1855–6 Fox, Henderson & Co. renewed the quadrangular form by rebuilding the north side, incorporating an engine-house and accumulator towers (one incorporating a clock turret) for the Grand Store's hydraulic-power system. They also roofed over the yard.⁷⁵ This site was redeveloped for an electricity power station in 1895–6, rebuilt in turbine-driven form in 1903–8 and subsequently further enlarged. That was succeeded by an oil-fired boiler house in 1967–8, demolished in turn around 2000 to make way for the present Building 50.⁷⁶

The Grand Store's early nineteenth-century buildings gradually fell out of storage use in the twentieth century. The eastern sections were perhaps

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already empty by the 1930s and Building 46 was adapted for office use, its south section entirely rebuilt internally with a reinforced-concrete frame and steel roofing. Western parts of the complex were occupied as a book store by the Science Museum in the 1960s and, as listed buildings since 1973, the disused parts to the east were given protective sheeted-scaffold roofs in 1983.⁷⁷

Berkeley Homes took on the Grand Store in 2000. Conversion of the buildings to private apartments, begun in 2002 with underpinning work, was completed in 2006, with the A&Q Partnership as architects, RLT Engineering Consultants (for repairs) and Blyth and Blyth (for services) as consulting engineers. In a carefully conservative approach, the timber-framed section at the east end of Building 36 was repaired. There are twenty-four flats in Building 46, twelve each in 36A and 37, seventy-six in 36, and thirty-five in 49.⁷⁸

Building 10 (Royal Carriage Factory or The Armouries)

The gun-carriage factory of 1803–5, outer parts of which survive as a low skirt around tall blocks of flats, succeeded earlier buildings on its site. New Carriage Yard, an enclosed land-service carriage store was built to the east of and as a supplement to the Great Pile in 1728–9, to replace open carriage sheds on the late seventeenth-century moated fort, which then returned to being an orchard. This was a brick building, single-storeyed around a large open quadrangle. It was said to have incorporated ‘sliding gibbets’ or overhead travelling cranes.⁷⁹

Smiths’ and carpenters’ shops were added to its west in 1775–7, and a range to the east followed in 1779–81, for quite different purposes. This was

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the first Royal Military Repository, an offshoot of the Royal Military Academy established by Capt. William Congreve in the 1770s to provide training in the handling of heavy ordnance at war. Congreve's 'Repository for Military Machines', for which the King's patronage was secured, was a long two-storey range. Guns and mortars were mounted on the ground floor, with store rooms above in what was a kind of museum or teaching collection for the instructive display of large objects and models, the notion of a 'model room' deriving from the practices of the Academy. Open ground to the east was reserved for outdoor training, and it was intended in 1781 that this should be enclosed with a 10ft(3m)-high wall to prevent the soldiers 'being interrupted by the impertinence of ignorant spectators while learning the Exercises taught there'.⁸⁰

The carriage square, the workshops and the Repository were gutted by fire, probably arson, on 20 May 1802. The site, much larger than a football pitch, was cleared and replacement planning rapidly undertaken. The Repository's future lay elsewhere, on the west side of Barrack Field, but the stretched and growing Royal Engineers' Department was given a new home in 1802–3, in a quadrangle of workshops east of the cleared site, that is beyond the former Repository yard.⁸¹

James Wyatt did not include the carriage factory in his list of the buildings he designed for the Ordnance, but the Board's minutes indicate that the project did hang on his decisions. His preparation of drawings was perhaps less speedy and more perfunctory than the Board would have liked. Capt. Hayter, who may have stepped into the breach, was told to begin building the new carriage factory in early 1803 in the face of growing demand for gun carriages, for the making of which there was now no proper accommodation. At this point, in April, as war with France recommenced, the Royal Carriage Department was formed, an aggrandizement given substance, under the

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leadership of Col. Edward Fage, RA, through the rebuilding of the carriage square as a much larger factory made up of twenty-two workshops.

Completion was urged in early 1805.⁸²

The stock-brick built carriage-making complex was an exceptionally large (474ft/145m by 280ft/85m) and well-ordered group of engineering workshops for its time, its layout reminiscent of a model farm, its scale illustrative of the extent of artillery deployment during the Napoleonic Wars. But, lacking Wyatt's usual proportional sureness of touch, it presented 'rather a squatty appearance'.⁸³ The prominent (now much-altered) north elevation was given a central clock and bell turret (the clock made by John Thwaites of Clerkenwell in 1806, the bells by Thomas Mears and Son of Whitechapel), and a three-bay 'Greek' pediment over a simplified triumphal arch, as if for a stable block. The arch and the pavilions were originally blind; entrances were off centre to north and south and central on the west side. In the 1850s the entrances were remade under tall arches and panelled parapets were added. Later, probably in the early twentieth century, sections of the north-side parapet were replaced with an upper storey, and lower-level windows were inserted.

Within there was originally an outer quadrangle of single-storey workshops, mainly for wheelwrights and carpenters, with an upper-storey mould-loft and other storage at the centres of the north and south ranges and in corner pavilions. The north and south range central sheds had open colonnaded inner elevations. A few original timber king-post roof trusses still remain *in situ*. In the yard there were ample 'avenues' for circulation around three large smitheries, each with twelve forges flanked by anvils, adjacent to which there were more workshops, those for wheelwrights open-sided. Carpenters' shops on the east side were timber-framed.⁸⁴

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This factory, like the Grand Store, was in part a reprise of the large-scale organizational man-driven might that characterized England's eighteenth-century dockyards, but it also presented a small-scale opening to the mechanized future. It was here that steam power was introduced to manufacturing at the Arsenal. Joseph Bramah supplied a steam engine and planing machine in 1805. Two reverberatory furnaces and a large compass saw for circular cutting followed in 1807, and in 1809 Henry Maudslay, who had grown up in Woolwich and become Bramah's manager, sent Hayter a 6HP patent portable steam engine. The first small engine and its boiler were housed in the north-west pavilion of the quadrangle, with the machinery in adjoining ranges. The second was in the south-east pavilion. These engines were soon replaced, and all trace of this early plant has long gone.⁸⁵

The Royal Carriage Department built a sawmill in 1811–13 to the east of the carriage factory. This displaced a short-lived and mysterious Martello tower. Marc Isambard Brunel had designed the sawmill in 1808, but it was deferred. An important step in the application of steam power at the Arsenal and a substantial piece of mechanization in any context, it followed on from Brunel's experiments with sawing machinery at Portsmouth Dockyard, pursuant to his involvement with the mechanized Block Mills there, and his private sawmill in Battersea of 1806–7. The mill was designed to deal with larger timbers – Brunel later claimed 'No other Saw Mill could perform what has been done there.'⁸⁶ It was said to save £10,000 a year in labour, which helps to explain why it had its own guard room. Like that at Battersea, it comprised outer brick pavilions, for a boiler- and engine-house to the west (with a 30HP engine) and a workshop block to the east, flanking the timber-clad mill in which there were four cast-iron column frames through which whole logs could pass.

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The sawmill was used in association with a two-branched canal of 1812–16, designed by Lt. Col. Robert Pilkington, CRE, and dug under contract by William Bough and Hugh McIntosh, with aid from convicts. This, which replaced the now infilled moats and ditches, curved round to the east, providing the site with some security against pilferage and linking its wood-yards to the river. It was on the north side of the canal, well outside the present area of study, that the younger Sir William Congreve's Rocket Establishment was set up in 1814–15 with another steam-driven mill. The canal was briefly used for bathing by gunners and cadets from 1846, but there were a number of fatal accidents. In 1926–36 its western arms were filled in, otherwise it survives in Thamesmead as 'Broadwater'.⁸⁷

Steam-powered mechanization spread in the carriage factory, as it did elsewhere in the Arsenal, from the late 1840s. On the factory's east side a scrap forge of 1848–9 had the Arsenal's first steam hammers, housed under a light iron roof. Another steam engine for a third position in the main factory arrived in 1850. In post-Crimean War renewals the core of the factory was recast in 1856–7 under the supervision of David Murray, with Lucas Brothers as contractors. New workshops for fitters and metalworkers linked the inner blocks, and a machine shop replaced the east-perimeter carpenters' shops. A fourth steam engine was added at the south-east corner of the main quadrangle, reshaped to drawings by William Rickwood to be an engine-house. There were now steam engines at all four corners of the main quadrangle with a big octagonal chimney to the south. The former engineers' workshop quadrangle to the east was adapted for a steam-driven wheel factory, the engineers moving up to Mill Lane. Finally, to shelter the displaced wheelwrights and carpenters, the avenues of the main quadrangle were gradually covered, from west to east, using light composite wrought- and cast-iron trussed roofs, some borne by inserted cast-iron arches.⁸⁸ As carpentry conceded more ground to metalworking and gun carriages became ever larger, the north avenue was altered in stages in the 1870s, as was the

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east side in 1885, to provide taller erecting shops under raised roofs. The central former smitheries area became a single machine room, used for steam riveting. It contained 'a very large lathe capable of turning a circle 27ft in diameter'.⁸⁹

Sections of the south walls of the early smitheries survived into the twenty-first century, but their place and that of the west perimeter buildings were taken by a tall steel-framed and corrugated-sheet-clad central erecting shop of 1937–8, an open sky-lit floor 380ft (116m) long, roofed over with urgency in the build-up to war. This was kept active as the 'heavy machine shop' up to closure, and then reconstructed in 1967–8 as an inspection facility, around when the wheel factory to the east (the former engineers' quadrangle) was demolished.⁹⁰

On the south side of the carriage factory and extending further east there is a 27-bay brick range. This was built in 1803–4 to designs by James Wyatt as a storehouse for land-service gun carriages. Initially it was a single-storey range divided into several sections with storeyed pavilion ends and a central pediment, but its original form has been mutilated beyond recognition. It retains round-headed windows in relieving arches, stone string courses to its outer bays, and segmental heads to its former doorways. A floor was inserted, probably in the late 1850s, and a blank upper storey was added around 1890. The west part was rebuilt again in the mid-twentieth century to create a block for naval X-ray photography. The eastern parts were opened up internally for a late twentieth-century gantry crane. This storehouse, once freestanding, was joined to the carriage factory by the addition of an erecting shop in 1886–7, put up under Col. Henry Darley Crozier, RE, Inspector of Works, and given a metal-framed roof over a gantry crane for carriage assembly. By 1895 this had been extended to its east with

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a fitters' shop and further enlarged to the north of that with a tinman's workshop. These last two additions were demolished in 2007.⁹¹

Building 10 was rebuilt again in 2007–10 for Berkeley Homes, with the A&Q Partnership as principal architects for a complex, renamed The Armouries, with 455 dwellings. The main contractor was LancsVille Construction. At its centre, in place of the central erecting shop, are four seven-storey, steel-framed, gunmetal-grey blocks. They rise within outer parts of the Georgian fabric to north, south and west. A new central entrance was formed to the north. Eight hollow-cylindrical cast-iron columns with moulded capitals that had survived in place on the inner south side were moved to stand below the clock tower under composite gantry girders, also reused, but from elsewhere; the clock tower had to be reconstructed after an accident. A few trusses of the 1850s were reset over the south entrance. Royal Carriage Mews is a central north–south through route lined with new 'town houses', the west range was rebuilt behind its façade to be a row of eight more houses, and a supermarket, a gym and the Royal Arsenal Medical Centre were introduced into the north and south ranges in 2011–12. The Energy Centre was built east of the former south erecting shop to house gas-fired plant providing both hot water and electricity, and faced to replicate the former carriage storehouse that it abuts.⁹²

Building 41 (New Laboratory Square)

Unlike the other major improvements of the Napoleonic-period New Laboratory Square, at the north-west corner of the Arsenal, was an accretive development. It took in a storehouse of the 1780s and its fourth side comprises late nineteenth-century workshops.

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The sea storehouse of 1783–5, now the square’s west range, was James Wyatt’s first project for the Board of Ordnance. It was built to house supplies for the Navy and to supplement a predecessor of 1717. That was closer to the river in the extreme north-west corner of the site – a plain structure, timber-framed and gabled. A new sea storehouse had been requested in 1778, but nothing was done until Wyatt had been appointed. He prepared plans in early 1783 when contracts were settled. The storehouse was built in a rearranged shot-yard by outside tradesmen: Samuel Nicholson, bricklayer, John or Joseph Woods, carpenter, and Thomas Carter and John Blore, masons, all working under the Board’s Clerk of Works, Thomas Powrie, who was favoured over William Latimer for this task.⁹³

The elegant proportions and minimal classicism of this low-slung storehouse set a new tone on the Warren. Of fifteen-by-three bays in grey-stock brick with Portland stone dressings, it faced east with a shallow pediment over the central five bays which break forward slightly. There is fine brickwork, notably in the ground-floor relieving arches. Each five-bay section had a central entrance on both sides. Loophole or taking-in openings above the three east and the centre-west entrances are now much altered, as are the windows. Inside, outer open-well staircases and warehouse-keeper’s offices flanked eleven-bay storage areas with twin rows of timber posts. A peculiarity, though a distinctive feature of Wyatt buildings, is transverse brick vaulting below the ground floor, here possibly for heavy floor loading of stores that included rope. An office lodge was added to the north around 1812 and a short south extension came soon after, both now demolished.⁹⁴

The ‘square’ was formed in 1808–10 with the construction of originally freestanding storehouses to the east and north to create an open-cornered yard. They were built to make up for space lost when fire, again possibly

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arson, destroyed much of the 'blue' storehouses in 1805, and the Royal Laboratory's east quadrangle near the river was demolished in 1807–9 to make way for the Grand Store. Lt.-Gen. Sir William Congreve, Comptroller of the Royal Laboratory, had replacements in view from 1806. Lewis Wyatt, operating now without his ailing uncle, worked up Congreve's outline plans and Hayter saw to construction. The east range went up first, originally with office lodges at its ends. An abandoned scheme for that side had projected an engine-house of unknown type and purpose between two shorter storehouses.⁹⁵

The east range echoed as well as hid the sea storehouse, differing in small details, such as the absence of stone impost, and in bearing pediments and relieving arches on both long sides, with loopholes only to the west or yard. Some early sash windows survive, as do queen-post roof trusses from the timber interior, originally divided into three five-bay sections. The north range was similar, but only nine bays long and without pediments or loopholes. Inside it is bisected longitudinally by a thick brick wall instead of by posts. Some use other than storage may always have been intended; from around 1825 to 1856 the first floor housed offices for the Royal Laboratory.⁹⁶

Manufacturing came to New Laboratory Square with the mechanization programme that transformed the Royal Laboratory as a whole. Schemes of 1853 left the square alone, but in early 1854 they had developed to include rebuilding the north range and altering the rest to form a mechanized factory making paper cartridges for small arms. The outbreak of the Crimean War disrupted plans. The formation of the main machine factory in the old Laboratory Square was seen through by June, but the urgency of the situation demanded a temporary ammunition factory during the building works. For this the east range of the 'new' square was hastily converted – 'this well-timed exertion saved the country from impending disgrace.'⁹⁷ John

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Anderson, Maj.-Gen. E. M. Boxer, RA, Firemaster of the Royal Laboratory, and Capt. Thomas Bernard Collinson, RE, oversaw the works. Contractors for the main factory, and probably for the temporary factory as well, were Kirk and Parry, local builders, Benjamin Hick and Son of Bolton, for constructional ironwork, and John and Edward Hall of Dartford Ironworks, for steam engines. Engines and boiler houses were thrown up, probably at both ends of the east range, whose interior was reconstructed with cast-iron fittings to carry line shafting to power machines. Hollow-cylindrical columns survive *in situ*, as do some I-section longitudinal beams, spandrel brackets for the line shafting and wall-set bearing boxes.⁹⁸

A more thoroughgoing conversion of the square followed in 1856 for different purposes, to form a factory to make the packing cases and barrels for ammunition. This was done under the supervision of Col. Beatson. The east range housed a sawmill below a cooperage (which explains a surviving circular hole in the east wall, there for the direct dispatch of powder barrels); the west range had carpenters' shops and a wood store. The centre of the yard was built on to provide a desiccating house with its own engine, for drying fuses and other wooden objects. The north-eastern engine and boiler house were perhaps also rebuilt, five by three bays, and a new three-bay boiler house added to fill the gap to the north range, where the first-floor offices became a 'Military Instruction Room'. The north-east blocks survive, extensively rebuilt to the north in the early twentieth century, with those to the west raised a storey under a repositioned composite iron-framed roof. Two octagonal cast-iron columns that may have formed part of a steam engine of the 1850s have been placed where the original ground-floor north wall of the east range has been removed. Of the engine-house at the south end of the east range there remains just a part of its west wall.⁹⁹

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The south side of the square was closed with the building in 1877–8 of a carpenters' workshop with American machinery for making boxes and barrels. The large open single-storey structure, initially two ranges deep, mirrored the old Laboratory Square workshop of 1854 that it faced across the forecourt of the 'Model Room' (Building 40). Its cast-iron frame, bearing the date 1878 and the initials VR, closely followed the form of its predecessor. Only the nine-bay inner or north range was north-lit, the eight-bay outer range more exactly mirroring the earlier structure. The octagonal cast-iron columns and beams with openwork spandrels have housings for line-shafting brackets, and the lightweight roof trusses are constructed of T-section cast-iron struts and principals tied with slender wrought-iron rods. There are remnants of bearing boxes to the west. This workshop was extended to the north in 1888–9 with two similar north-lit bays, put up by George Munday and Sons, builders, to embrace the desiccating engine-house. That has been demolished save for its north wall, which persists between elevations that retain some early corrugated sheeting. The carpenters' workshop was adapted around 1900, during the Boer War, to be a factory for small-arms bullets. That use continued through the First World War, when the building was extended to the south into the forecourt. Those bays were demolished in 1999.¹⁰⁰

There were further alterations in other parts of the square. The south end of the east range was remodelled with a fireproof floor around 1890. The north range, where office use continued, was raised a storey around 1905 in a colonial hill-station neo-Tudor style, an architecturally unsettling intrusion that was removed in 1999. And around 1917 the west range was rebuilt internally with a reinforced-concrete frame and a flat roof, and thereafter converted to drawing-office use. In the years leading up to the Arsenal's closure the first floor of the east range was a firing range, and much of the rest of the square was Customs and Excise stores.¹⁰¹

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English Partnerships and the London Development Agency undertook the refurbishment of New Laboratory Square in 1999, through Llewelyn-Davies, architects, with some demolition preceding conversion of the buildings for museum and archive use. That was overseen by Austin-Smith: Lord, architects. Since 2003 the former sea storehouse to the west has housed the Greenwich Heritage Centre, which shares the southern workshops with Firepower (the Royal Artillery Museum). The latter holds the rest of the square, using parts for storage and offering other parts to let.

Storekeeper's House (Middlegate House)

The move of the Royal Military Academy in 1806, and the transfer to the Royal Laboratory of the premises it had shared with the Storekeeper, prompted a decision to rehouse the establishment's senior employee. John Geast, the Storekeeper until 1823, was given an entirely new house, a stock-brick suburban villa, away in the south-east corner of the Arsenal, where he already had a garden. This had been the site of John Withers's farmhouse. Designed in 1807 and built in 1810, the new Storekeeper's House was the last of the buildings in the Arsenal for which James Wyatt claimed responsibility. Hayter would have overseen the building work.¹⁰² The house was originally just one room deep and of two storeys, with a basement for service rooms and garrets for servants. It was entered from a central Greek-Doric porch, now enclosed. The lower storeys have always had tripartite windows with cast-iron balconettes on the ground floor, but there has been renewal. Inside the front door is a hall with an open-well staircase. The house was raised a storey in 1863 for Capt. (Sir) Henry William Gordon, in charge of the Ordnance Store Department and resident here from 1858 to 1879; he was the brother of Gen. Charles George Gordon. It was converted in 1922 to be offices for the Naval Ordnance Inspection Department, which expanded in 1937–8 into a large brick-clad and steel-framed office block to

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the rear, designed in the War Office and built by Thomas & Edge. Other office uses have ensued.¹⁰³

Riverside guard rooms

Twin octagonal guard rooms, the western for officers, the eastern for artillerymen, were built at the west end of the Arsenal's riverfront in 1814–15, once the new wharf had been completed. The triple landing stairs that they complemented were an important point of access, between the Grand Store and New Laboratory Square, and at the end of the avenue from the Royal Brass Foundry. The guard rooms originally had triple open bays on their landward side. Drawings were signed off by Lt. Col. Robert Pilkington, CRE. He might have involved William Atkinson, appointed Architect to the Board of Ordnance in 1813, but is more likely solely responsible for the simple design. The open bays were closed and the west room was used as an armoury by 1864; it served as a mortuary chapel for the body of the pretender Prince Imperial of France in 1879. The central landing stairs were removed in 1931. The rooms, diminished by raised ground levels, came to be used as stores and that to the east lost its roof, replaced in 1999–2000 when a new pontoon pier was formed to project between the reconstructed outer landing stairs. The buildings were refurbished for English Partnerships to plans by Llewelyn-Davies, and Royal Arsenal Woolwich Pier was built for Greenwich Council through Posford Duvivier, engineers.¹⁰⁴

Beresford Gate

The main entrance gate of 1720 was replaced in 1828–9 further to the south-east. Beresford Gate was ordered by and named after William Carr, Viscount Beresford (1768–1854), an army officer who came to eminence under Wellington, in whose government of 1828 he was appointed Master-General.¹⁰⁵ It survives, enlarged and otherwise altered, and now isolated from

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the rest of the Arsenal across Plumstead Road, which sliced behind it in the 1980s.

There had been early nineteenth-century clearances of cottages in the town to open up the road approach to the Arsenal. Moving the entrance to face this newly formed space was justified through savings made by adapting some of the Cadet Barracks to other uses. Once Beresford had inspected the premises the new gateway was constructed under the supervision and to the designs of Col. John T. Jones, CRE, who adjusted the position of the west side of the gate to meet objections from the Woolwich Town Commissioners.¹⁰⁶

The gate was of plain yellow-stock brick with recessed panels and stone cornices, blocking courses and plinths. Its piers followed their predecessors in being topped by piles of shot. They were flanked by footway openings and the blind ends of opposed single-storey lodges, whose three-bay inner returns were arcaded. The west lodge was for porters and messengers, the east an apartment for a warden. Their front parapets were surmounted by brass mortars on richly ornamental beds. These were specially cast using condemned gun metal, as arranged through Col. William Millar, Inspector of Artillery. The Arsenal's coat of arms, the King's and Beresford's monograms and the date 1829 were also cast in plates set into the panels above the foot entrances and pier cornices. The original gates were made by John Hall of Dartford.¹⁰⁷

Policemen occupied the east lodge from 1844, and the west lodge from 1855. Col. John Walpole, CRE, was responsible for the addition in 1859 of a western superintendent's office with a bell tower above. An additional floor was inserted on the east side in 1889. By 1891 Col. M. T. Sale, RE, had

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overseen more significant alterations when three waiting rooms were built behind and above the entrance gates. To either side of a large general waiting room were smaller rooms, for officers and for ladies. A north-west stair turret left access to the lodges unimpeded. The new façade, which replaced the upper parts of the gates, was of red brick, stone dressed, with machicolated cornices and a central clock. The structure over the main arch rests on composite metal beams with arched floors. The guard's office in the north bay of the now-darkened east lodge was given a canted bay window in 1907, and the footways, through which hordes of workers passed to and fro, were widened in 1936 when the iron gates were replaced in robust spear-headed form.¹⁰⁸

The Arsenal closed and what had come to be called the Royal Arsenal Gatehouse was earmarked for demolition by 1969, to permit the widening of Plumstead Road when the Greater London Council was building Thamesmead. There were delays, the demolition was opposed, and the GLC explored options that included reconstructing the gate further north in its original (1820s) form. But the gate was then listed and so retained when the GLC's contractors, Percy Bilton Ltd, rerouted Plumstead Road to its north in 1984–6. Separated from the Arsenal, the gate passed via the GLC to Greenwich Council, which retained it as 'a backdrop to the Beresford Square market and focal point for tourist information and outdoor entertainment'.¹⁰⁹ Restoration works in 1991–2 and 1995–6, through Thomas Ford & Partners, architects, with R. R. Richardson, building contractors, included adaptation of the lodges as offices. The brass mortars, removed for safekeeping in 1985, were cleaned up and reinstated.¹¹⁰

Plumstead Road walls and gates

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The loss of Beresford Gate left the Arsenal in need of entrance gates on the north side of the widened Plumstead Road. The GLC provided these in 1985–6 with a new stretch of stone-coped boundary wall. The twin rusticated gate piers with Coade-stone urn finials are recycled from the Paragon on the New Kent Road, a development of 1789–90 by Michael Searles, surveyor. The GLC had rescued these from a road widening there in the late 1960s. The piers were raised on Portland stone plinths to satisfy security concerns and the iron railings, modelled on those at the Horse Guards, Whitehall, were designed in the GLC’s Historic Buildings Division’s Works Section by Peter Watts. The contractors, working through Greenwich Council, were Szerelmey.¹¹¹

The boundary wall thus replaced in the 1980s had its origins in a wall extending along Plumstead Road to the east about as far as where Cornwallis Road now runs. Probably first built in 1777–8, this was raised to up to 20ft (6m) and extended further east beyond Middlegate House in 1814 in works to improve security against trespass. The contemporary canal helped fulfil this purpose. A length of the later section of wall still stands to the west of an entrance formed near the Storekeeper’s House in 1830; another opening, an arch now blocked, led into a stable yard. The entrance by the Storekeeper’s House was improved in 1843 at the request of Joseph Cheetham, Storekeeper. It provided direct access to Plumstead, now growing populous. Its four tall vermiculated stone piers with bracketed cornices were designed under Col. Sir George Hoste, CRE. A third gate east of the canal followed in 1856; its predecessor thus became the Middle Gate.¹¹²

Mechanization, the Crimean War and reconstruction

The Arsenal that emerged from the Napoleonic Wars was a wonder, a vast industrial landscape that explained battlefield glory – allied sovereigns

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visiting London in 1814 were brought here to be awed. Many other visitors followed, but there were concerns about security, from espionage, arson and theft, and the circulation of outsiders was regulated in 1832. Henceforth a visitor needed permission to enter, 'readily granted at the guard-house, where he will be furnished with a ticket admitting him to all the departments'.¹¹³ In the early 1840s casual visits were stopped, gate porters were put in uniform and, after a spate of thefts, a civil police force was introduced. A visitor of social 'rank' could still be met 'by a comely policeman, so sleek and portly that his duty is evidently stationary', take a card marking a prescribed route around the outsides of buildings, and be 'struck on entering by the silence which seems to reign around him, interrupted only by the not unmusical hum of an ever-working steam-engine, and the perpetual click, click, click of light hammers, coming from the distant field of shot and shells; the slow sentry pacing up and down, with vigilant eye on each visitor as he passes; the long gravelled esplanade; the flowing river closing the view, studded with many a slowly moving sail; the convict gangs, with their felt hats, grey clothes and prison-sodden visages; the silent and unbustling look of the officials; all combine to throw a solemnity and shadow on our spirits.'¹¹⁴ After the Chartist riots of 1848 visits were stopped entirely for a time.¹¹⁵

As ever, the Arsenal subsisted to the rhythms of war and peace. There were no major building projects through the militarily quiet decades of the 1820s and 1830s, the workforce fell from around 5,000 in 1814 to around 500 in 1835 and the proportion of the nation's armaments produced at Woolwich declined. Open ground between the Royal Carriage Factory and the Grand Store continued to be used as standing space for tens of thousands of guns arrayed in rows (including those of iron, manufactured elsewhere), and millions of balls and shells stacked in pyramids, from which convicts hammered rust. Management of the site was divided between the four main departments, the Royal Laboratory, the Inspector of Artillery's Department

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(encompassing the Royal Brass Foundry), the Royal Carriage Department and the Storekeeper's Department. Building works such as there were continued to be handled by the Engineers' Department, much reduced in size.

The first works railway was built by Lt. Col. Jones in 1824–5, without steam, simply as tracks for wagons in the Grand Store's shot-yard. There was little advance on the Royal Carriage Department's pioneering initiatives with steam power and mechanization until 1840 when the rearmament of a steam-powered Navy and the improvement of coastal defences stimulated a revival of activity. The Master-General at the time, Sir Richard Vivian, perceived that the Arsenal needed modernization and resolved 'to steam we must come'.¹¹⁶ His promotion of David Napier's machinery for cutting and compressing lead rods into bullets met resistance in the Royal Laboratory, but Vivian prevailed and opened the way to change.¹¹⁷

A principal agent of that change was (Sir) John Anderson, a young Aberdonian who had joined Napier's works in 1839 and devised the bullet-making machine. On Napier's recommendation to Col. William Bolden Dundas, Inspector of Artillery, Anderson was brought into the Arsenal in 1842 to be a foreman in the Royal Brass Foundry.¹¹⁸ He found the workshops 'small and inconvenient, separated by partitions from the masters and foremen, thus affording every facility for conversation and idleness'.¹¹⁹ Anderson set about putting an end to inefficiencies and indolence and, with Napier, oversaw the introduction to Dial Square of steam-powered mechanized gun boring and of other machinery to the Royal Laboratory for a percussion-cap factory. But it was 1847 before mechanization began in earnest. James Nasmyth, another great Scottish mechanical engineer, who had learned his trade with Henry Maudslay, had gained renown in the early 1840s as the inventor and manufacturer of

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steam hammers. He was brought from Manchester to the Arsenal in 1847, when Woolwich Dockyard was being equipped with his steam hammers, and led round by Sir Thomas Hastings, the Board of Ordnance's Principal Storekeeper, responsible for the nation's supply of ammunition and carriages, and desirous of further improvements. Nasmyth found the machinery 'very interesting as examples of the old and primitive methods of producing war material', but 'better fitted for a Museum of Technical Antiquity than for practical use in these days of rapid mechanical progress. Everything was certainly very far behind the arrangements which I had observed in foreign arsenals.'¹²⁰ Through Nasmyth in 1848–9 the Royal Laboratory began to be converted to steam power, and steam hammers were introduced to the Royal Carriage Department under light iron roofs, built on his advice to span between workshops; Fox, Henderson & Co., previously active in the dockyard, were brought in for these works. Nasmyth had support on site from Anderson, as well as from senior departmental officers, Dundas, Lt. Col. Richard Hardinge and Capt. Boxer in the Royal Laboratory, and Col. James Colquhoun in the Royal Carriage Department.¹²¹

This was the beginning of a period of eager expenditure on mechanization, an 'emancipation from torpor', as Anderson had it.¹²² The enthusiasm was such that when Boxer suggested applying steam power to rocket making in 1852 Nasmyth was obliged to turn business away – 'you do not require a steam engine at all for the process in question.'¹²³ As another panic about French invasion swept England and war with Russia began to loom, the Board of Ordnance, now largely dependent on private suppliers, grew uneasy about arms' manufacturing capacity. It was recognized that the Royal Laboratory in particular would not be able to cope with increased demand. Anderson was asked to report on aspects of possible mechanization and his findings led to the appointment of a committee of senior Arsenal officers whose task was to improve the efficiency of the

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Laboratory, with Anderson, never an artillery officer, as 'Inspector of Machinery', a position created for him.¹²⁴

This committee undertook a rebuilding of the Laboratory, but war on Russia was declared in March 1854 before works had advanced far, forcing Anderson and Boxer into emergency conversion of the east range of New Laboratory Square, to keep production going while the new main machine shop was built. Completed in the summer, this, the roofed-over Royal Laboratory quadrangle, was one vast north-lit milling machinery floor. Anderson and Boxer saw to the machinery and Capt. Thomas Bernard Collinson, RE, was responsible for the building work. Collinson's prior experience of building projects was limited to a stockade and some barracks in New Zealand, and he was directed to seek help. Capt. Henry Charles Owen, RE, advised him to approach Gottfried Semper, the eminent German architect and theorist, who, a political refugee in London, had worked on the Great Exhibition where Owen had been a superintendent. Thereafter Semper had gained employment as Professor of Architecture at Henry Cole's Department of Practical Art from where he undertook to provide the Woolwich project's 'architectural elevations'. Correspondence reveals that he was responsible for the form in detail of the extensive cast-iron frame. This, supplied by Benjamin Hick and Son, provided an enduring archetype for subsequent mechanized workshops at the Arsenal. It was robustly moulded with octagonal columns, as in the Crystal Palace, which Semper knew intimately and admired, though he deprecated the spindliness of iron in other contexts. He was obliged to accommodate Collinson's ideas, which may well explain the workshop's eccentric cast ornament. This included a circle-pattern frieze with depictions of ammunition in relief, under a cornice bearing the initials of committee members. This was a demeaning assignment for Semper – Collinson altered his designs for the engine-house, expressing presumptive if not simple-minded concern for aesthetic fitness to purpose with an explanation that he wanted an elevation to be 'taken from

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the outline of a cannon, and I should like to give the chimney some resemblance to that suitable object.'¹²⁵

The pace of transformation accelerated rapidly in late 1854 under the pressure of war. There was an urgent demand from the Crimea for Lancaster shells (recently devised and made in a bottle shape from single pieces of wrought iron) and Anderson and Boxer were given primary responsibility for putting up a large new foundry as quickly as possible during a severe winter. There had been opposition to bringing more production into the state's hands, but the initiative was approved on the basis that it would provide a model for private manufacturers. This foundry, which stood to the east of Building 25, was designed by Anderson in terms of its internal workings, with Fox, Henderson & Co. responsible for the shed superstructure. It came into service in early 1855 with four steam engines, seven steam hammers and forty other machines.¹²⁶

The Board of Ordnance, long seen by some as anachronistically independent, as well as inefficient, corrupt and extravagant, came into political view. In 1855 Frederick Engels described the post of Master-General as 'a lamentable relic of the times when science was considered unsoldierlike, and when all scientific corps, artillery and engineers, were not soldiers, but a sort of nondescript body, half savants, half handicraftsmen, and united in a separate guild or corporation'.¹²⁷ Since 1852 the post-holder had been Lord Raglan. When he took command in the Crimea in 1854 he left the Ordnance in the charge of the pliable Sir Hew Dalrymple Ross, long Woolwich-based. Against a backdrop of shocking failures of supply overseas and with little fuss, Lord Panmure, Palmerston's Secretary of State for War, wound up the Board of Ordnance in May 1855. The War Office took responsibility for the Arsenal, but left the site's departmental heads to hold sway as superintendents over little-changed establishments.

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With army administration reformed, a continuing war, a determination not to be caught unprepared again and great increases in defence spending, the boom in building works at the Arsenal continued with yet greater intensity and at enormous expense, with Anderson very much in the thick of mechanization. This happened despite sustained controversy as to the appropriateness of the government being its own manufacturer and a competitor with the gunmaking trade. In 1855–6 the wholly new Shot and Shell Foundry, Paper Cartridge Factory and Royal Laboratory Offices were built. The superintendents jointly toured Continental arsenals, and a huge new cannon foundry was begun. Open ground south of the Grand Store was lost and the overall formality of the site's layout began to disintegrate. By 1858 refits and improvements had also been made at Dial Square, the Royal Carriage Factory, New Laboratory Square, the western quadrangle of the Grand Store and the Officers' Quarters. There were also new sawmills and timber seasoning sheds, a substantial pattern room south of the Royal Carriage Factory, a new four-ship T-shaped pier in the river with hydraulic cranes in front of the wharf, itself refronted in granite, new granite-paved roads and, away to the east, new storehouses, an independent gasworks and a new practice range. So much work was possible only with the help of outside contractors, principally Lucas Brothers, the Lowestoft-based builders, and in the absence of close budgetary control.¹²⁸

In the shaping of all these works, both before and after institutional reform, the Corps of Royal Engineers with its subordinate tradesmen (Royal Sappers and Miners since 1813) lost straightforward responsibility for building design, procurement and construction. At the same time as they were losing control on military sites, Royal Engineers were extending their remit to civilian jobs. In a symptomatic shift of the Corps' expertise into civil initiatives, Lt. Col. William Reid was Commanding Royal Engineer in

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Woolwich for just a year before he was seconded to chair the Executive Committee of the Great Exhibition in late 1850. In the Arsenal the rebuilding of the Royal Laboratory in 1853–4 involved Collinson only as a part of the Laboratory Committee, outside the Engineers' Department, brought Semper in, and contracted the building work to Kirk and Parry. Outside contractors had long undertaken minor building works in the Arsenal, but this was a deeper slighting of the resident workforce.^{129b}

These seemingly ad hoc rearrangements were formalized in the reforms of 1855. Capt. Roger Stewart Beatson, RE, who had been responsible for some innovative iron-framed buildings in Portsmouth Dockyard before becoming Superintending Engineer of Admiralty Works at Woolwich Dockyard from 1845–8, had returned from Canada to be seconded into helping with the Lancaster shell foundry at the end of 1854. But his intentions and the interventions of Col. Thomas Foster, CRE, were ignored by Anderson and Fox, Henderson & Co. in the interests of speed.¹³¹ Promoted Lieutenant Colonel in July 1855, Beatson succeeded Collinson as Superintending Engineer to the Ordnance Manufacturing Departments, a post lately deemed necessary because of the 'intensiveness and importance'¹³² of the works at the Arsenal. He was made answerable to the several departmental heads there, rather than to the Inspector-General of Fortifications, as Commanding Royal Engineers in Woolwich had been. David Murray, a young civilian engineer-architect, was in the same month (July 1855) moved from a post in the Engineers' Department to be Beatson's chief Clerk of the Works. Murray had spent time in the office of (Sir) William Tite, whose architectural practice was largely concerned with railways, and who was also a member of the Institution of Civil Engineers and another advocate for iron construction. At

^b Among other local builders of note whose businesses grew through work inside the Arsenal in the first half of the nineteenth century were William Spray, William Gosling, Robert Jolly and George Hall Graham.¹³⁰

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the beginning of 1856, as the war ended, the Engineers' Department moved to Chatham and Murray was promoted to Building Engineer and Inspector, taking chief responsibility under Beatson for building projects, to be carried forth through contracts. William Rickwood, an architect who went on to work privately in and around Woolwich, was Beatson and Murray's chief draughtsman. To further complicate matters, within the year a detachment of Royal Engineers was re-established in Woolwich, on Mill Hill, under Beatson's command for three months before he moved on in November 1856; his successor, Col. John Walpole, had little to do with the Arsenal.

While at the Arsenal, Beatson had primary architectural design responsibility for the Paper Cartridge Factory along with the adjacent new offices for the Royal Laboratory and the shipping pier. Murray took the lead with the Shot and Shell Foundry and the Gun Foundry (Building 25), and was left in charge of these and numerous other continuing works at the end of 1856. Amid all the urgency, over-commitment and administrative restructuring some basics were forgotten. These major projects went ahead without proper estimates or specifications, simply on the understanding that there was 'plenty of money' and because nobody above Beatson had general oversight of the building programme. Murray, whose 'youth and inexperience are perhaps his best excuse',¹³³ carried the can in 1857 when excess expenditure on the previous year's building works was found to be almost £40,000. After the supposedly economizing reforms of 1855 Panmure could not but stop the party.¹³⁴

In a tumultuous decade of rapid technological change initiated by military demands the Woolwich arms factory and its working practices had been thoroughly transformed. In 1857 the Arsenal had nine iron-framed buildings, sixty-eight steam engines, eighteen steam hammers and 2,773 machines for every conceivable process previously done by hand – cutting,

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turning, boring, sawing, moulding, creasing, compressing, forging, rolling, haunching, piercing, welding, grinding, sifting, mixing, planing, shaping, drilling, slotting, punching, shearing, screwing, grooving, polishing and knitting: 'ten thousand times ten thousand wheels, all in rapid motion'.¹³⁵ Anderson claimed that no other wood or metal factory in the country could rely so heavily on unskilled labour. Where before in a week just seven or eight brass guns could be made, now there was capacity to produce fifteen brass guns, and thirty iron guns.¹³⁶ All the mechanization was, of course, labour-saving. Even so, expansion had been such that the Arsenal's workforce had risen back above 2,000 in the early 1850s. Numbers soared to more than 10,000 at the height of the Crimean War, and the working week was fixed, for the first time, at fifty-six hours in 1855. With all its new factories, the Arsenal of the 1860s was said to have 'a power, stability, and security, calculated to inspire the mind of every true British subject with sentiments congenial to the love of home, country, and constitution, while he chronicles the Victorian age as the most brilliant on the page of history'.¹³⁷

Building 17 (Paper Cartridge Factory or Firepower)

In 1853 John Anderson suggested adapting a new process for making seamless conical paper sugar bags, whereby pulp was shaped using a vacuum, to the manufacture of small-arms bag cartridges. It was deemed preferable to make these at the Arsenal, rather than buy them in, partly on account of the volume required, but also because they were very delicate and unsuited to packing. Machinery to make 400,000 paper-cartridge bags a day (each cartridge used two bags) was destined for the north end of New Laboratory Square in early 1854 when the outbreak of war disrupted reconstruction plans. A wholly new building for making the bags was first proposed in early 1855. In the new War Office hierarchy it gained the sanction of Col. Boxer, Superintendent of the Royal Laboratory, though he

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was not closely involved as, by his own admission, he did not understand the process. The open site east of New Laboratory Square and north of Dial Square was chosen and Col. Beatson began to prepare plans for a building soon after his arrival in July. Anderson and a Royal Laboratory employee called Mackintosh oversaw the mechanical aspects of design and fitting out. Beatson's first scheme had to be modified to accommodate details from Benjamin Hick and Son, contractor for the ironwork, steam engine and boilers. Machinery was supplied by Fairbairn and Co. of Leeds, and Blaikie Brothers of Aberdeen. Building work, probably the last job for the on-site Engineers' Department, finished in April 1856 and the factory, intended to employ around 800, was in use by 1857 with a rag boiler, four rag engines, a rag-cutting machine, two pulp reservoirs, a knitting machine, and five sets of cartridge-bag moulding machines.¹³⁸

The building is a two-storey block, entirely iron-framed within a rectangle of two-colour brick walls that were extended down to broad footings in a gravel layer to address the difficult ground conditions. It has a prominent but plain nineteen-bay south front with a slightly projecting central entrance bay marked by key-blocked stone architraves. This composition was probably designed to echo that of the facing sea-service carriage storehouse of 1717–20 which, by this time, had been attributed to Vanbrugh. Nine-bay returns have similar articulation, though there was no entrance to the west, where many openings were blind – the engine-house was within to the north. The elevational treatment continued on a five-bay north-east block that housed a rag store. A north-west boiler house was lit by oculi above blind arcading, another reflection of the early eighteenth-century buildings, and flanked by a tall octagonal chimney. Of the boiler house little more than the east wall survives. Further north low walls enclosed yards, for coal and other storage, up to the new Royal Laboratory Offices.

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The iron-framed interior of the Paper Cartridge Factory has considerable structural interest. As a piece of structural engineering it reflects developments in textile mills and dockyard buildings, notably Beatson's own, and the ironwork is striking for forming a fully storeyed frame, as well as for its robust elegance and degree of survival. The ground floor was originally divided into four aisles by three rows of tapering octagonal columns that followed the form of those Gottfried Semper had designed eighteen months earlier for the Royal Laboratory's main machine shop. Cast I-section beams and joists with parabolic lower flanges framed the upper floor. The beam ends are extruded to clasp octagonal connecting blocks between the lower column caps and upper column bases, with half-round lugs from the ends of the clasping sections that meet to allow linkage by means of wrought-iron shrink rings. Flooring was evidently fixed directly onto the beams and joists. It was probably timber (possibly beneath a concrete layer); 'fireproofing' was perhaps not an over-riding concern in a building that housed a process that required volumes of water. An elegant arcade of slender columns to arched beams with open spandrels divided the upper storey under the central valley. Twin hipped roofs over the main block have composite trusses made up of wrought-iron ties and rods under cast-iron principals with integral openwork circle struts and ridge plates linked by octagonal honeycomb fittings. There were originally louvred vents along the ridges.

The revealing nature of the ironwork and an early descriptive account provide an indication of the original processes and layout. Rags, the major raw material for paper making, were collected in the rag store and then cut and boiled, perhaps in the room above the store, which, supported by two columns, may have housed machinery. The paper-cartridge-bag machinery was at ground level in the main block. A design drawing shows denser columniation to the north-west, probably to support pulp reservoirs. A network of sub-floor channels may have fed the pulp tanks that stood under

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the cartridge-bag moulding machines. The centre-row columns have oval openings below their caps through which pipes could have carried water back. The main drive shaft from the steam engine ran along the south side of the northern row of columns, where bolting faces for brackets survive. Multiple secondary shafts extended southwards, as reflected by similar bolting faces on the central row of columns. The lower flanges of many beams have grouped bolt holes that suggest further brackets for drive shafting and the support of pipes. The former engine-house retains rocking-beam bearing boxes in its side walls and prior to conversion there were also traces of its north-eastern flywheel, as well as of a staircase to a beam gallery and a high-level water tank. The main upper-storey space was a large workshop for the manual assembly of other paper cartridge-bags.

Advanced technology and intense child labour co-existed here side by side.

The visitor, as he mounts the stairs to the upper floor . . . , finds that he is in the midst of a little army of urchins, varying from eight to fourteen years of age, seated at long benches rolling up paper cartridge-bags. This process requires some little nicety, as each bag is made up of three distinct papers of different sizes and shapes, which have to be neatly adjusted round a roller one upon another. . . . In the room below we note as we descend strange wheel-like frames revolving horizontally, and others working up and down into tanks of paper pulp. Circles of brass tubing have short upright tubes inserted into them at regular distances. These upright tubes, or fingers, are pierced with fine holes, and the whole apparatus is attached to an exhausting-pump. Worsted mittens are fitted to the fingers, and when all is ready, the Briarean hand is dipped into the bath of pulp, the air in the tubes is withdrawn, the liquid necessarily rushes towards the fingers, and the water passing through, leaves the pulp adherent to the mitten. The process is instantaneous, hand after hand drops into the trough,

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gloves its fingers with pulp, and rises with a thousand cartridges in its grasp, quicker than one of the boys up stairs has finished a single bag. The process is not complete, however, until they are dry. Each mitten is removed from its metal finger, and placed on a similar one heated with steam. In ten minutes the desiccating process is finished, and the cartridge-bag is removed, a far more perfect instrument for its deadly purpose than that which is made up stairs by hand.¹³⁹

On Saturday evenings the upper storey was used for penny lectures to the Arsenal's artisans and labourers (average attendance 1,600). Percussion-cap making had been introduced to the upper storey by 1864, and to the lower by 1866. The whole factory was converted to the making of percussion-cap components within another decade. Another conversion for the making of metal cartridge cases followed around 1884. Rolling mills and annealing furnaces were introduced, the upper storey was fitted with drive shafting and light machinery, the yard was gradually built over and, around 1890, a second engine-house was added to the west. In the late 1920s the building was adapted for use as an RAF bomb shop. Yet more conversions followed the Second World War, initially for electroplating small gun barrels. Parts of the iron frame and most of the upper-storey floor were removed and gantry cranes were inserted, one as late as 1986 when the building was in use as a Quality Assurance Directorate metrology laboratory.¹⁴⁰

The former Paper Cartridge Factory was once again adapted in 1999–2000 in a conversion to museum use for the Royal Artillery Museum (Firepower), with Austin-Smith: Lord as architects. Twentieth-century ancillary structures to the north of the original main building were replaced and elements of the original iron-framed boiler house roof were retained in an altered position to provide a museum entrance hall on the west side.¹⁴¹

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Building 18 (Royal Laboratory Offices or James Clavell Library)

An office building for the rapidly expanding Royal Laboratory was part of the Paper Cartridge Factory development of 1855–6. This was placed immediately north of the factory's yard, and designed by Col. Beatson as a simple seven-bay pedimented 'villa' with a pilastered stone porch. It was extended, by six bays to the east and eight to the west, between 1869 and 1877. Inside it retains an original staircase with stone treads, a wreathed rail and an ornamental cast-iron balustrade, with further early staircases in the extensions. The building was converted in 1999–2000 as part of the Firepower project, to house museum offices and the Royal Artillery Historical Trust's collection, what was the Royal Artillery Institution Library, latterly renamed after James Clavell, a benefactor.¹⁴²

Building 23 (Shot and Shell Foundry)

The Lancaster shell foundry that was put up in great haste in 1854–5 proved a success. But private foundries were not meeting demand for shot and shells. While the country was still at war Anderson and Boxer gained approval for the Royal Laboratory to build an even larger foundry with huge capabilities. A rectangular swathe of the storage grounds south of the Grand Store was cleared and the Shot and Shell Foundry was built between February and September 1856. David Murray designed the building, Lucas Brothers were the building contractors, Hick and Son supplied machinery, and Henry and Martin Grissell of the Regent's Canal Iron Works were responsible for iron columns and roof trusses as well as ornamental cast- and wrought-iron gates. The latter were separately designed by Charles Baily, the son of a successful ironmonger, who, as an antiquarian architect, studied the history of English ironwork; he was himself a member of the Ironmongers' Company.¹⁴³

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The single-storey foundry, the west front of which was more than 400ft (120m) long, was made up of three internally iron-framed workshops, from south to north a moulding ground, the foundry and a turning shed, with several subsidiary spaces – ‘save the lurid glare of the molten metal streaming in cataracts from the furnaces, or, in seething cauldrons, borne through the gloomy shades of this Inferno, scattering their dross in brilliant fiery stars over the iron floor, all is black as night.’¹⁴⁴ Concrete foundations were 23ft (7m) deep, to support machinery that included steam hammers. Beyond the foundry cupolas to the east a chimney rose 224ft (68m). Outwardly the foundry was of red brick and Portland stone, with pilasters and round-headed windows, reminiscent as a whole of railway-station classicism. All that survives is the lavishly ornamental two-storey gatehouse, which housed offices to the north and stores to the south. It is more stone than brick, with Ionic over Doric Orders in which engaged columns are paired. Magnificent wrought-iron gates fill the central entrance arch, standing 14ft (4.3m) tall. Originally finished with bronze and gold enamel, they incorporate the royal arms and monograms, the arms of Lord Panmure and numerous lit shells around a warrior’s mask in the arch. There are flanking thistle- and rose-patterned window grilles and, to the rear, cast-iron plinths with moulded shot and shell patterns. The committee appointed to look into excessive expenditure at Woolwich may have had the gatehouse in mind when its report commented that expense ‘could have been reduced by the adoption of a simpler style of architecture’.¹⁴⁵ It is certainly the best surviving witness to the extravagance of the mid-1850s.

The workshops were extended to the east in 1876–7 and all demolished when the Arsenal closed, giving way in 1967–8 to another large block of single-storey workshops, of plain Modernist character. The gates were removed and re-erected at Royal Ordnance Factory Patricroft. The gatehouse

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was listed in 1973 and its refurbished gates returned in 1991 after urgings from English Heritage.¹⁴⁶ The workshops of the 1960s were demolished around 2000, and the gatehouse was converted in 2001 as a marketing suite for Berkeley Homes, then, from 2005, to provide offices for a concierge and estate management as well as a gym for residents of adjoining developments, functions that moved to Building 10 in 2011.¹⁴⁷

Building 25 (Cannon Foundry or Cannon House)

The Inspector of Artillery's Department had in 1810 leapfrogged the Arsenal from its Royal Brass Foundry base to establish a Proof Department near the river and far to the east, beyond the Grand Store. On the west side of what became Proof Square a large open-sided iron store was built in 1853, entirely iron-framed within brick perimeter walls, and the Lancaster shell foundry went up to its south in 1854–5.¹⁴⁸

The Crimean War exposed shortcomings not just in the supply but also in the engineering of artillery. Weapons were criticized as heavy, unreliable and inaccurate, and ordnance design became a matter of feverish debate, investment and invention. The Government was cautious about putative technological breakthroughs, but, so long as it did not make its own iron guns, was forced to continue to pay the high prices private manufacturers demanded for outmoded weaponry. The contentious decision to bring iron-gun manufacturing in-house for the state to develop its own designs, purloining ideas from those being independently submitted, was taken in early 1855 shortly before administrative reform created the Royal Gun Factory at the Arsenal. Col. Frederick Marow Eardley-Wilmot, who had proven himself an effective administrator at the Royal Military Academy, was its first Superintendent.

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To make the Arsenal's first iron guns a large new cannon foundry was built in 1856–7 on the west side of the former Lancaster shell foundry, now reconstructed to be a forge, north of which a dependent boring mill was formed. In the post-war ferment of patriotic technical innovation outside contractors had submitted tenders to build the foundry to their own plans. Instead, keeping close control, Eardley-Wilmot himself determined on an H-shaped layout and relied on David Murray to design elevations. A tower was originally intended, but never built. Lucas Brothers were the building contractors, chosen by competitive tender, and Fairbairn and Co. of Leeds supplied tanks for casting pits in the concrete floor.¹⁴⁹

The foundry survives, a tall single-storey building with polychromatic brick elevations and a central entrance porch that emphasizes an Italianate railway idiom, another reflection of Murray's background. This character in his buildings was noticed when they were new – 'these spacious factories present more the appearance of first-class railway termini than of ordinary workshops.'¹⁵⁰ Large round-headed windows are linked by corbelled brick bands at impost level where there are numerous massive cast-iron plates, to strengthen internal buttresses that supported gantry girders. The interiors, once large open floors, are longitudinally divided by cast-iron arcades with substantial panelled stanchions carrying hollow-cylindrical columns upon which sit open-spandrel beams. These support twin-span roofs with composite iron trusses above which there were louvred lanterns. The H-plan gave the building three distinct sections. The western nine-bay cross range (180ft/55m long) was the moulding division, with four fifteen-ton travelling cranes. The inner gantry girders were carried by the central arcade piers and bolted to the column bases, and also rested on their own intermediate octagonal piers. The thirteen-bay centre range (220ft/67m long) was the casting division, with ten wrought-iron casting pits up to 20ft (6m) deep under two 25-ton travelling cranes. An iron-framed shed to the rear housed twelve furnaces. The other cross range was where moulds were broken up

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for recycling, and the guns trimmed and centred in readiness for the boring mill. A steam engine may have been housed here.¹⁵¹

Eardley-Wilmot courted Henry Bessemer, allowing the Royal Gun Factory's rolling mills to be used for experiments in steelmaking. Bessemer's process was set to be adopted for making steel guns,¹⁵² but the new foundry, opened in 1858, had scarcely begun production before it came under new and celebrated management that spurned steel in favour of wrought iron. The most significant upshot of post-Crimean artillery science was the development by William George Armstrong, with help from I. K. Brunel and Nasmyth, of a new kind of gun at his Elswick, Northumberland, factory in 1854–5. Its revolutionary design (to a great extent pirated from Capt. Alexander Theophilus Blakely, RA) combined a rifled barrel with breech loading and the use of coils of white-hot wrought-iron made tubular and heat-shrunk together under a steam hammer. By 1858 this was accepted as a breakthrough. These guns were available only from Elswick, potentially marketable internationally, and the Royal Gun Factory had failed to identify a cheaper way of producing them. Further, after the spending debacle of 1856–7, there was a shift in favour of civilian oversight of manufacturing at the Arsenal at the expense of artillery officers. Armstrong agreed in January 1859 to give his patents to the Government and to move to Woolwich as Engineer of Rifled Ordnance, to act part-time as Eardley-Wilmot's successor as Superintendent of the Royal Gun Factory, with John Anderson as resident Assistant Superintendent, though not without ensuring further business for Elswick. Armstrong was knighted and hailed as a national hero. His guns were carefully guarded – 'A gentleman who was detected in the act of taking a pencil sketch of the gun was immediately arrested and called upon to forfeit his unfinished production.'¹⁵³

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The guns were in production in Woolwich by August 1859, at the height of another invasion panic, but the completion of a new Rifled Ordnance Factory east of the forge was held up when Lucas Brothers' workmen went on strike. Royal Engineers were brought in and work finished in 1860. Demolished in the late 1960s, this was another inwardly fully iron-framed two-storey building, conceived, perhaps by Capt. Thomas Inglis, RE, as resembling an early eighteenth-century church, though the tower facing east to the marshes was probably never built. The gun foundry was remodelled to accommodate the later stages of Armstrong's manufacturing process (it has latterly and misleadingly been known as the Armstrong Gun Factory). The iron shed to its rear became a shrinking and tempering department, the east cross range a turnery with powerful lathes, and the west range and part of the centre range a sighting room, altogether 'an immense place, where, though everyone is busy, the light and quiet are a relief after the sombre glare and dreadful uproar of the foundry beyond'.¹⁵⁴

While Armstrong worked on further innovations, Anderson saw to manufacturing. But Anderson also helped Armstrong's rival, Sir Joseph Whitworth (who had supplied machinery to the Arsenal in the early 1850s), to make a gun at Woolwich using Armstrong's principles. In 1862 this proved more powerful than Armstrong's own. Armstrong, an opportunistic opponent of the patent regime, was hoist on his own petard. He resigned his Woolwich appointment in early 1863 whereupon the Government decided simply to carry on making guns at the Arsenal based on refinements by Anderson and others of Armstrong's original invention, presented as cheaper than buying from Elswick or other contractors. Armstrong's successor as Superintendent of the Royal Gun Factory was an artillery officer, Col. Sir F. A. Campbell. The Deputy Assistant Superintendent, Robert S. Fraser, a civilian engineer, now modified Armstrong's coil construction. The result was standardized in 1868 as the Fraser or Woolwich gun and proved genuinely cheaper. A heavier successor of 1870 was known, ironically, as

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the 'Woolwich Infant', and the factory building of 1856–7, still used as turneries or a finishing or erecting shop, was dubbed the 'infant school'.¹⁵⁵

There were further adaptations. In 1875 the shrinking department was altered and raised to include a heavy boring mill. By 1891 'wire coiling' had been introduced in the centre range of the foundry – gun barrels were strengthened by encircling steel wire (better understood as tape) while turned in a huge lathe. The former shrinking department became another turnery. Wrought-iron gunmaking continued and was not finally scrapped in favour of steel until 1902. Following this shift the central range of Building 25 was raised in height in 1911–12 in works carried out under Col. N. H. Hemming, RE, with Matthew T. Shaw and Co. as contractors. The south wall was replaced by 37ft(11m)-tall lattice-steel stanchions and a new gantry to support a full-width 130-ton capacity travelling crane under steel-frame roofing.¹⁵⁶

After gunmaking ceased floors were inserted in 1967–9 and a three-storey steel and glass office block, now demolished, was added to the south.¹⁵⁷ The former foundry was leased to the British Library in 1994, and its south and east sides have been sheet-clad. Berkeley Homes took possession in 2011, and the building was named Cannon House prior to another conversion.

Buildings 4–7 (including Gunnery House)

The south-eastern site now occupied by Gunnery House, between Arsenal Way and Cornwallis Road, first became available for development through the removal of an early proof butt. Eight long weather-boarded timber-framed sheds, six of them parallel, were built here in 1777–80. Initially these were partly used for storing and seasoning timber for making gun

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carriages, but with the addition of another shed they soon all simply sheltered the made-up carriages and wagons. They came to be known as the Cross Blue Storehouses (blue on account of the colour they were painted). Plans for their replacement in 1829–30 and 1846–8 came to nothing.¹⁵⁸

East of the storehouses, the Royal Carriage Department replaced Brunel's 'almost worn out'¹⁵⁹ sawmill on the same site in 1855, to designs by Hick and Son, the contractors for its machinery. Land to the north stayed open as timber fields. Plans to build more seasoning sheds south of the sawmill for the sawn timber, deferred in the 1840s, were taken up again. What became Building 5 took shape in 1856–7 as three cast-iron framed seasoning sheds (extended to the south in 1860) with a long thin brick-built pontoon storehouse to the west. David Murray was probably the architect, and Fox, Henderson & Co. the contractors for the iron framing that included light and largely wrought-iron trussed roofs. The pontoon store became a fitters' shop around 1867 and by 1877 the sheds had also been adapted as a woodworkers' factory, housing wheelwrights, carpenters, collar makers, forgers and fitters. Around 1880 an open-sided iron-framed waterproofing shop was added alongside to the east. Steel-framed machine shops for making Navy guns replaced the three seasoning sheds in 1917–18. Further east the Ordnance Store Department had around 1856 put up a cast-iron-framed open-sided shed for its own timber storage. This (Building 4) had typically Semperian octagonal columns, cast with pockets to receive rails that probably supported racking and similar light trusses. In the 1960s it was occupied by the UK Atomic Energy Authority, which also had significant post-war laboratories in the Arsenal's more eastern parts. Buildings 4 and 5 were demolished in 2001.¹⁶⁰

What survives as Gunnery House (formerly Building 7) was once a larger and complex aggregation of carriage-completing workshops under a variety

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of late nineteenth-century lightweight-iron roof trusses. The block began to take shape in 1860–2 when the Royal Carriage Department and Capt. Inglis replaced a north-west section of the eighteenth-century seasoning sheds with a two-storey range of ‘completing shops’, a fourteen-bay iron frame inside stock-brick walls. This had become a turnery by 1877. The southern parts of the old sheds were replaced with a large single-storey forgers’ shop in 1871–2, when Col. Peter Scratchley, RE, was in charge of works. This ‘great smithery’, which aimed to be ‘the largest and most complete smiths’ shop in the world’,¹⁶¹ had sixty forges, eight steam hammers, three furnaces and a machine that could punch a hole in a sheet of iron 1.5in. (4cm) thick. Paired east and west gable ends had half-round windows in relieving arches. Inside a big open floor lay under twin lightly framed trussed-purlin roofs on an open cross-braced girder over a central row of columns. It was demolished in 2011 to provide storage space for works on Crossrail. Further north, a second and similar forgers’ shop of about 1877 stood until 2001. A turnery block replaced the northern and last parts of the old sheds in 1883–6, in two phases of works overseen by Col. H. D. Crozier. An earlier painters’ shop originally screened the plain brick north elevation. The turnery, twelve bays by four, has a single-height cast-iron frame to north-lit saw-tooth roofs. There are octagonal columns and perforated beams to composite roof trusses. By the 1890s there had been infill between the forgers’ shops, giving the east side of the complex a deceptively regular five-gable façade; the west side was not filled out until the mid-twentieth century. Around 1900 there was further enlargement to the south and rebuilding to the north-east. The block was refurbished to be a large tool-room for the Arsenal in the 1960s and again in 2002–3 by the io Group to provide nineteen light-industrial workshops.¹⁶²

Later developments to 1918

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In the later decades of the nineteenth century the Royal Arsenal was among the world's largest depots for army stores, and an arms factory without parallel, except perhaps at the Krupp works in Essen. It deployed the heaviest and most sophisticated machine tools invented, to devastating effect on many distant parts of the world. But growth was not uninterrupted. Thousands of men were thrown out of employment in 1857, many expatriated at public expense to Canada and Australia. About 5,000 more were discharged after defence spending was cut in 1868 and more emigration ensued. The number working at the Arsenal rose again in the early 1880s, almost doubling back up to 10,000. Thereafter there were steady increases to about 20,000 around 1900 during the Second Boer War. After decades of pressure the 48-hour week (42 for clerical workers) was introduced in 1894, permitting half-day Saturdays. The scale of operations had become such that one of the last pieces of open ground in the Arsenal's western parts was taken for a capacious Central Offices block. And from the great works other great institutions emerged – the Royal Arsenal Co-operative Society in 1868 and what was to become Arsenal Football Club in 1886. But the workforce declined from 1902, again causing great local hardship and a campaign for 'bread not bullets', spearheaded by Will Crooks for Labour. The First World War caused numbers to swell extraordinarily, from a base of around 10,000 to about 75,000 in 1917, men working up to ninety-six hours a week; about 28,000 women, 'Munionettes', were taken on in 1915–16 to work twelve-hour shifts – all were dismissed at the war's end.¹⁶³

The western parts of the complex had been built up by the 1880s. Expansion to the east, already substantial, continued and building there gathered pace. There was even expansion to the west in 1915 onto what had been Kirk and Randall's wharf. The internal railways, made more extensive in 1854–5, had been reconstructed as the narrow-gauge steam-powered Royal Arsenal Railway in 1868–73, modelled on Crewe's railway works, and

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seen through by Royal Engineers working under Maj. Peter Scratchley. This system, suitable for the tight spaces within the built-up Arsenal, was supplemented from 1876 by standard-gauge lines with links to outside lines further east. The internal railway closed and began to be dismantled in 1923. Electric lighting was introduced in the 1870s, and electricity began thereafter to replace steam in the driving of machinery, only about forty years after horse-power had been abandoned. The Arsenal's own generating station was built in 1895–6.¹⁶⁴

Guns, particularly those for the growing Navy, became ever larger, and their production engineering increasingly complex. By the 1870s steel was gaining favour elsewhere, following the deployment of Krupp steel guns in the Franco-Prussian war. But, after the false start with Bessemer and the Armstrong interlude, there was little capacity for steel gunmaking at the Arsenal. To catch up with technological change in the context of an international arms race, the Royal Gun Factory set about building a steel mill in 1884, but Government cancelled this in favour of buying from private trade, turning back to Armstrong and Elswick because Woolwich was deemed too far out of date and private manufacturers' techniques were thought too sophisticated to steal. By 1886 Col. Eardley Maitland had defiantly expanded the Royal Gun Factory's steelmaking capacity in an attempt to outmanoeuvre both politicians and private manufacturers. Government arms manufacturing retained advantages, not least the breaking of price cartels, but the blithe independence of the Arsenal's separate departments, each run by military superintendents with civilian managers, was a problem. Attempts at rationalization met strong opposition, both military and political. In 1868, for example, Brig.-Gen. Sir John Henry Lefroy was appointed Director-General of Ordnance and Commandant of the Royal Arsenal, a new co-ordinating office. It was abolished after less than two years.¹⁶⁵

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Concerns about the way the Arsenal was run led Government to appoint a committee of enquiry in 1886, chaired by the Earl of Morley. Its report a year later noted egregious instances of disconnection between the factories – for example, the patterns of guns were changed without telling the Royal Carriage Department, which therefore continued to manufacture mounts for obsolete guns. The Morley Committee recommended setting up a central authority, opening up senior appointments to civilians, introducing independent inspection, leaving steelmaking to private factories, and constraining any further enlargement of the Arsenal’s factories. These reforms were to take effect in 1888, in the face of bitter opposition from the Army. To some extent they were dodged, for example the first Director-General of Ordnance Factories was not a civilian but Maj.-Gen. Maitland, promoted from the Royal Gun Factory. However, he was succeeded a year later by (Sir) William Anderson, a civilian engineer who had established himself at Erith through the firm that became Easton and Anderson. Taking charge at the Arsenal until his death in 1898, he brought commercial probity, as well as important civil links. He had connections with the co-operative movement and was also a key figure in the founding of Woolwich Polytechnic. But Anderson achieved less than he hoped by way of centralization, amalgamation and the streamlining of production, and Elswick increased its dominance of ordnance manufacturing.

One important successor of Anderson’s was Sir Hay Frederick Donaldson, the son of the first premier of New South Wales. He had come to the Arsenal in 1898 after a period as London’s leading dock engineer to be Anderson’s deputy and the site’s first Chief Mechanical Engineer, which post he combined from 1903 with that of Chief Superintendent of Ordnance Factories. Under his leadership the Central Offices were built to provide strong physical assertion of the administrative unity that had been intended

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since Morley. He remained in charge until 1915, a year before he died on board HMS *Hampshire* (with Lord Kitchener) after it struck a mine. After the Second Boer War government policy favoured a shift in the balance of the nation's armaments production towards private trade, keeping the Arsenal as more of a repair shop. Vigorous opposition to the loss of jobs in Woolwich to the 'armaments ring' prompted investigations in 1907 into the scope for using the Arsenal's workshops for other kinds of manufacturing. This was held at bay, but there were some other reforms; the Royal Carriage Department and Royal Gun Factory were amalgamated and a centralized research department was formed. Torpedo-making and its 700 jobs moved to Greenock. Governments tiptoed gingerly, trying to keep balance between maintaining the Arsenal, in case of war or popular agitation, and encouraging private manufacturing. The result was that when war did break out in 1914, the Arsenal was congested, inefficient and no longer innovative. Yet, at huge cost, it was mobilized, and feminized, into exceptional productivity.¹⁶⁶

Intense industrialization and the absence of vacant ground left the tradition of a military architectural aesthetic in the dust – there were to be no more gun-shaped chimneys. However, inside the buildings, engineering developed its own constructional aesthetic, particularly in the development of metal framing, most notably in lightweight roofs on single-storey, sometimes, north-lit sheds; upper storeys were avoided in most manufacturing buildings. Structural ironwork derived from the prototypes introduced by Fox, Henderson & Co. and Semper in the 1840s and 1850s steadily evolved towards lighter forms. There was some technical virtuosity in wrought-iron composite trusses, using rods for tension members and T-sections for compression members. Thereafter there was conservatism, buildings of the 1870s and 1880s not being readily distinguishable from those of the 1850s. By the 1890s there was a shift to steel, as at the Mounting Ground and in

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new warehouses in front of the Grand Store. There were still elegantly formed roofs, but those from after 1900 were more crudely constructed.

After the extravagant fiasco of 1856–7 works management had reverted to Royal Engineers, initially under the charge of Lt. Col. Thomas Inglis as Inspector of Works of the Manufacturing Departments, at first in the office of the Inspector General of Fortifications and from 1865 at the Arsenal with a Works Department of Royal Engineers. The retained building contractor for the site in this period was John Kirk of Kirk and Parry, which firm held a wharf to the west and reconstituted itself as Kirk and Randall in the 1870s. Part of the post-Morley reorganization in 1888 was the formation of a new Building Works Department. Its first superintendent was Col. M. T. Sale, RE, who was permitted to bring back direct labour in 1891. This department survived into the 1950s.¹⁶⁷

Building 20 (Chemical Laboratory)

(Sir) Frederick Augustus Abel, born in Woolwich in 1827, came to work at the Arsenal in 1854 as Ordnance Chemist (a lapsed post then revived), having succeeded Michael Faraday as lecturer on chemistry at the Royal Military Academy two years previously. At this pivotal moment in the technological development of arms and ammunition, Abel, given charge of a new Chemical Department, was close to other innovators, including Armstrong. Initially accountable for the examination of metal from the gun foundry, his responsibilities expanded into research, ranging from the purifying and stabilizing of guncotton in the 1860s to the development of cordite in the 1880s. A leading authority in the science of explosives, Abel worked and lived in the Arsenal until 1888. At first he had a laboratory in the back parts of Building 40, but in 1864 his department, which had grown to have ten subordinates, gained its own purpose-built headquarters. These

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filled a gap south of the Grand Store's west quadrangle, close to the Royal Laboratory Offices. The design of this, in parochial terms, Murray-esque building was probably overseen by Col. Inglis, with Abel closely engaged in the specifications. Originally the building was symmetrical, eleven bays by three, in polychromatic brick with round-headed windows. The laboratory itself lay at the west end and rose to full height, with a balcony at upper level and a ventilated roof carried on arched ribs with open spandrels. Balcony and roof alike were of cast iron, as were two external balconies projecting at the ends of the front. All these features were planned with the dispersal of noxious fumes in mind. A furnace was housed in a single-storey space to the north. Abel's photographic section was housed to the east and there were offices flanking a central stone staircase with decorative cast-iron balusters. The building was thrice extended to its north and east, in 1885, 1903 and 1913, always closely in keeping with the first build. From 1936 the Armament Inspection Division occupied the premises, and use as offices ceased only in 1994. Berkeley Homes converted the building in 2002–4 to provide ten flats.¹⁶⁸

Enlargement of the Royal Gun Factory

The Royal Gun Factory had spread across a huge area east of the Grand Store by the end of the 1860s. To trans-ship its heavy iron guns, the Arsenal's second river pier was built in 1869 and extended by 1875 to be 328ft (100m) long to support an 80-ton Armstrong crane. Initial designs by Inglis and his successor, Scratchley, were modified at first by Lt. J. W. Grover, RE, with a later piling system by John Gibson. The pier was made by the Hamilton's Windsor Ironworks of Liverpool, and extended by the Fairbairn Engineering Company. Reconstructed more than once, in 1921–2 it was modified to accommodate a monstrous 200-ton crane. Just east of the study area, it survives, semi-ruinous, still bearing some mixed-gauge railway track, as do the remnants of a third, coaling, pier of around 1915,

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constructed of reinforced concrete by Edmond Coignet Ltd using Arthur Williams's patented piling system. The T Pier of the 1850s near the Grand Store was extended in 1881 and demolished around 1990.¹⁶⁹

The large area south of the Royal Gun Factory that had been a timber field (now bisected by Armstrong Street) was taken over and built on in the early 1870s in a project overseen by Col. F. A. Campbell, who remained the factory's Superintendent, with his subordinates Maj. Eardley Maitland and R. S. Fraser. Scratchley, who went on to advise on the defences of Australia, was in charge of the works. By 1874 there were three buildings across the north part of the ground – from west to east, a forge, a boiler house (with twenty-four boilers) and a rolling mill. The 'south forge' had two unprecedentedly large reverberatory furnaces and a 45ft(14m)-tall steam hammer, claimed to be the world's most powerful, with a falling mass of forty tons to flatten ingots of reprocessed scrap iron. Made by Nasmyth, Wilson and Co., it had an anvil, cast on site in 1872 by a Mr Vinnicombe, that weighed 103 tons. It was first used in the presence of Tsar Alexander II of Russia in 1874 and for some time remained a marvel. It was decommissioned in 1914, overtaken by hydraulic-press technology. Its anvil was excavated by Pre-Construct Archaeology in 2004 and moved to the corner of Wellington Avenue and Arsenal Way where it is on display.¹⁷⁰

The rolling mill opened in 1875 for the production of wrought-iron bars that were to be forged into coils in the making of the large guns. It had a tripartite arcaded cast-iron frame clad with corrugated-iron sheeting. Massive wrought-iron lattice girders that spanned about 100ft (30m) supported the roof of the taller central section. The west section came down around 1970, the rest stood until 1998, when it was dismantled and its parts were placed in store.¹⁷¹

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Of even greater volcanic grandeur was a radial steam crane. This was placed west of the south forge in 1876 by Campbell's successor, Gen. C. W. Younghusband, with Scratchley still in charge of works. It was for shrinking and tempering – the crane, which had a capacity of 250 tons, lifted hot gun barrels of up to twenty-five tons into and out of underground oil pits. In 1891–2 Col. Sale and John Lysaght Ltd of Bristol, contractors, roofed it on an enclosing 72ft(22m)-tall free-standing steel frame with wrought-iron cross bracing; this was replaced in 1939. Latterly called the Rink or Roundhouse, it was demolished in 1966.¹⁷²

The adjacent South Boring Mill was begun in 1882 by Col. Maitland as Superintendent, with Col. William Hatt Noble, RE, signing drawings. These sheds had more arcaded cast-iron frames and wide-span lattice-girder roofs over huge lathes. They were enlarged in phases up to 1914 to fill all the remaining open ground. Parts for locomotives were built here after the First World War.¹⁷³

Additional stores buildings

The quay in front of the Grand Store was given two long cast-iron framed open-sided shipping sheds in 1860–1, to provide cover for imports and exports in transit. These were raised a storey along most parts in 1889–90 and around 1900. The eastern shed was mostly demolished around 1970, and the western dismantled in 1999; parts are held in store.¹⁷⁴

In the late 1880s the Grand Store remained the British Empire's great central depot for receiving, inspecting, keeping and issuing Army stores. It housed 'guns and gun-carriages; shot, shell and cartridges; waggons, carts

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and harness; barrack and stable furniture; tents and tables; brooms, brushes, pails and all the paraphernalia of a soldier's equipment'.¹⁷⁵ But, even with its inserted mezzanines, it was insufficient to meet demand. The Morley reforms re-established the Ordnance Stores as the Central Stores Branch and the big central shot-yard, long since lined with railways, was built on to increase storage capacity, probably for small arms. This impeded views to and from the Grand Store. A 'sea store' (Building 48) was built first, in 1889–90, towards the east, under Sale's direction, though it had apparently been designed in 1886 under his predecessor, Col. H. D. Crozier. On concrete-pile foundations, this handsome three-storey stock-brick range, of seventeen bays by three, had large windows and columns of cast iron (supplied by John Lysaght), I-section joists, timber floors and an iron roof, hipped and slate-covered. A similar storehouse (Building 47) was added at the centre of the yard around 1897, with Sale still in charge. One bay wider with gable ends, a steel frame and part-concrete floors, it had a double-height entrance hall with a gantry crane.¹⁷⁶ Two slightly smaller ranges were built to the west around the time of the First World War, more or less filling the yard, but these have been demolished. Buildings 47 and 48 were occupied as bookstores for the British Museum's libraries from 1962. They were then converted again in 2003–4 by Berkeley Homes despite being unlisted; they were readily convertible, each to provide forty-eight apartments.¹⁷⁷

Immediately east of the former Chemical Laboratory there is a free-standing three-storey block, closely similar to its neighbour. This was built in 1890–1, under Sale and in association with post-Morley reorganizations and expansions in the Arsenal's storage capacity, as offices for the Naval Ordnance Department (Building 21), newly formed in a restructuring of the Ordnance Store Department. The upper storey was added in 1903, incorporating the original lightweight iron roof with coupled struts. Building

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21 was converted for the Arsenal's telephone exchange after 1967 and again in 2002–4, as five flats.¹⁷⁸

Building 19 (Mounting Ground)

By 1810 an open site north of the Royal Carriage Factory was known as 'the mounting ground' – it was here that guns were placed on their carriages. To cover this activity an iron-framed and corrugated-sheet clad 'perfect crystal palace',¹⁷⁹ was built in the early 1860s, perhaps following the example of erecting shops at railway engineering works. To its east, on the shot-yard in front of the Shot and Shell Foundry (where the Central Offices now stand), small offices for the Royal Carriage Department and for drawing were put up around 1868.¹⁸⁰ The mounting shed was destroyed in a snowstorm and replaced with the present larger and more durable erecting shed in 1887, exactly when the Morley Committee reported failures of co-ordination between the departments. It was built for the Royal Carriage Department, the work of which here met that of the Royal Gun Factory, so the timing was perhaps not coincidental. The drawings were signed off by Col. H. D. Crozier and by George Munday and Sons, building contractors. Cast-iron components were supplied by John Lysaght, and steelwork came from Stockton-on-Tees. The little-altered and functionally simple building is a shed of three parallel ranges, the northernmost shorter and perhaps used for storage. Its stock-brick exterior has round-headed windows in relieving arches, pilaster strips and gable-end oculi. An off-centre south entrance was positioned to align with an entrance to the Royal Carriage Factory. Inside, the ranges are separated by tall cast-iron columns with composite I-section wrought-iron valley-girder trabeation to roof trusses that incorporate steel principals and span about 53ft (16m). Under these roofs the two main ranges retain original gantries for the travelling cranes that were used to mount the heavy guns. These are made up of robust openwork cast-iron stanchions with composite I-section wrought-iron girder rails. The cranes

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themselves were renewed in 1916 and 1958 and use for weapons-testing continued into the 1990s. Both standard and narrow-gauge railway lines crossed the building's wood-block flooring and some narrow-gauge track survives outside to the north.¹⁸¹ In the early years of the twenty-first century the building has been a works depot for Berkeley Homes's projects on adjacent sites. Longer-term conversion is intended.

Building 22 (Central Offices or MyHQ)

An office building for central staff was built south of Verbruggen's House in 1888–90, but the separate departments continued in their own offices. In 1902 an Ordnance Factories committee was set up to enquire into cost accounting, a matter that concerned H. F. Donaldson as Deputy Director-General. One of its recommendations in 1904 was that the offices of the Arsenal's departments should be brought together. Donaldson evidently anticipated this conclusion, as designs for central offices were being made in 1903. Government approval was obtained and a massive office complex went up in 1905–11 in front of the Shot and Shell Foundry, displacing the Carriage Department offices. The partially completed building first came into use in 1908 to serve as the administrative centre of the entire Arsenal, then about three miles long. An outside architect, James Osborne Smith, perhaps best known for the London Library in St James's Square, had been brought in to design what is, progressively for its date, a wholly steel-framed building. Earlier in his career Osborne Smith had been engaged in the Office of Works on the fitting up of the Natural History Museum and he was a close friend of Sir Henry Tanner, a structural innovator. Col. Arthur Henry Bagnold, RE, was responsible for supervising the works at the Arsenal, and steel was supplied by Dorman Long & Co. of Middlesbrough. It may be that the building was structurally up to date in another respect – Hennebique-system reinforced-concrete foundation piles were supplied to the War Office

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in Woolwich in 1905. They were probably for this project; poor ground conditions would have been a concern.

The offices are a loosely rectangular aggregation of blocks around an internal service courtyard, rising three storeys above a basement, with some attics. The internal frame carries elevations of stock brick, dressed with red brick and stone, in a heavy neo-Georgian style with Baroque touches. The main southern part of the entrance front to the west is symmetrical with projecting ashlar to its centre and ends. There is rustication around the main central entrance arch which bears the date 1908. Above, a pediment carries the Royal Cypher of King Edward VII. Another stone entrance bay to the north has Royal Arms in its pediment. The plainer east side has a nearly flat elevation of thirty-four bays. In the courtyard cream-glazed brick elevations were linked by a covered bridge at first-floor level in latticed steelwork, an early addition that was removed around 2005. Inside, along with the steel frame, there were concrete floors above the lower storeys and internal walls of concrete poured *in situ*. The main entrance hall had a coffered ceiling with marbled columns and pilasters. It led to the principal staircase which rose round a lift well with ornamental iron balustrading. Other staircases were lined with glazed brick. The best offices, for the several superintendents, were on the first floor in the main part of the west range. On the top floor there was a drawing office, the superintendents' mess, and, from 1917, a telephone exchange. The basement was reinforced for use as an air-raid shelter in the Second World War. The building did suffer a direct hit and its southern parts had to be reconstructed. Attics were extended to the south in 1967–8 when the complex became a headquarters for defence inspection (quality assurance) directorates. In 2004–7 Berkeley Homes replaced those additions and added a further additional set-back storey in a conversion to provide 388 flats, with a shop in the northern entrance archway. For this Broadway Malyan were

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architects, and the building, thoroughly refenestrated, was renamed 'MyHQ'.¹⁸²

Decline and closure

When the First World War ended, activity in the Arsenal was drastically scaled back. There were no more significant new building projects in the site's western parts (those to the east are not described here) and inquisitive visitors were no longer tolerated. Committees of review, already a commonplace in the life of the factory, now proliferated.

An investigation of 1919 (the McKinnon Wood Committee) concluded that the Arsenal should continue to supply arms at reduced levels and, in response to a reiteration of a case put in 1907, engage in alternative work to maintain no fewer than 10,000 employees. This was a concession to the vigour of local labour. A workers' committee had gained post-war and pre-election assurances from both Lloyd George and Winston Churchill that jobs would be protected. The repair of railway wagons and lorries, and making of GPO carts, telephone apparatus, milk churns, even parts for locomotives, all began, but the Conservative government backed away from the pre-election assurances. (Sir) Holberry Mensforth, who had handled labour difficulties and increased munitions output for Westinghouse in Manchester during the war, was appointed Director-General in 1920. He cleared out the last military officers from the management of ordnance factories, and lower-level layoffs continued apace – among those affected were war veterans, many disabled. The locomotives failed to sell, discrediting the alternative-work programme, and from 1919 to 1922 numbers employed in the Arsenal declined from more than 24,000 to about 6,000. Meanwhile the Air Staff and others in the War Office pointed out that Woolwich was vulnerable to air attack and urged closure. A memorandum of 1921 reported that 'additions

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to plant and buildings have resulted in a vast network of structures, mostly unsuitable for present day requirements. A clan of work people has grown up in the district which generation by generation has found, or hopes to find, its way into the Arsenal . . . The prevalence of unemployment today provides perhaps the best opportunity that has yet arisen for making an excuse for demolishing Woolwich.¹⁸³ After another committee (Stevenson) was appointed in 1922, more cautious counsels prevailed, not least because of the great cost of a move.¹⁸⁴

The question of the Arsenal's vulnerability to air attack and the advisability of closure resurfaced in 1934. A new committee (Hacking) noticed that anywhere else might also be subject to air attack, found that the Navy, in particular, remained highly dependent on the guns and ammunition made in Woolwich, that the factories would still be very expensive to move, and that dispersal of the Arsenal's interlocked functions would increase overall costs. It recommended the gradual phased removal of the factories, but in 1935, as rearmament began, the Government concluded that Woolwich could not be dismantled until there was sufficient productive capacity elsewhere.¹⁸⁵

At the outbreak of the Second World War there were once again about 20,000 employed at the Arsenal, but, with the deliberate dispersal of numerous new ordnance factories, the place was far less significant to the conduct of war, the number of its workers scarcely rising above 30,000. Yet, while there had been little bomb damage in 1914–18, there were twenty-five air raids in 1940–5, causing death and destruction, though comparatively little in the older western parts. After the war, alternative or peace work made a return; railway wagons, knitting frames and oil-field equipment were made in the late 1940s. Armament production resumed in 1950, but it was

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soon clear to a new Conservative Government that the Arsenal had become 'something of a white elephant'.¹⁸⁶

Appointed Minister of Supply, Duncan Sandys set up a committee (Perrott) in 1953 that led to further shrinkage via the merger in 1957 of the heretofore still separate factories to form the Royal Ordnance Factory, Woolwich, all concentrated to the west. Eastern lands were to be sold to the London County Council in what were seen as steps in an inevitable long-term withdrawal. The surrender of the Beresford Gate area for road-building began to be considered. Numbers employed dwindled gradually down from about 9,000 and buildings were progressively deserted. Yet there were also modernization projects – electric steel furnaces in the former Shot and Shell Foundry, new machinery for turning and boring gun barrels in the east range of Building 25, and concentration of heavy welding in Building 10. It had been hoped that other parts of the estate would find other defence uses, but, as force levels declined generally, this failed to happen. On this account, and with only slow progress towards the reconfiguration of manufacturing, it was apparent that the Arsenal's future was less secure than ever. Another review in 1959–60 (Hutchinson) encouraged a more open approach to new uses, if not new employment, in the western areas, which Government was to retain. The Pakistan Government moved a few people into buildings west of the Chemical Laboratory, but there was no other advance until 1962 when tenancies for the British Museum were arranged in Buildings 47 and 48 for remote book storage for the National Central Library (the inter-library lending branch). The idea was floated that the Royal Brass Foundry, already listed and recognized as the site's prime historic building, might be made a museum just inside a new gate. As for eastern parts of the site, numerous options were rather despairingly considered – a helicopter port, car parking and unspecified 'comprehensive redevelopment'.¹⁸⁷

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The loss to the private sector of a large contract for making armoured personnel carriers in 1962 was a major blow. As redundancies escalated in early 1963 John Profumo, the Conservative Government's Secretary of State for War, continued to pursue reorganizations and, for an independent view, called in Sir Eric Mensforth, the chairman of Westland Aircraft who (as the son of Sir Holberry) had begun his own career at the Arsenal in the 1920s. Mensforth reported confidentially that the Royal Ordnance Factory was too inefficient to be allowed to continue and, Profumo having departed in scandal, James Ramsden announced in the House of Commons on 4 December 1963 that, facing great over-capacity in its ordnance factories, the Government had decided that the Arsenal would be closed. Charles Pannell, Labour MP for Leeds West, commented 'Woolwich Arsenal probably means more to Woolwich, and has meant more to Woolwich, than almost any other factory has meant to any other constituency in the country.' The new Labour Government in 1964 granted a temporary reprieve, but then upheld the decision.¹⁸⁸

The closure was of the Royal Ordnance Factory; manufacturing was to cease. By 1966 it had, and formal closure came on 31 March 1967. Many buildings were demolished, but, in a rearguard manoeuvre by the military and civil servants, a 'Woolwich Review Committee' of 1964 had ensured that there would be a continuing defence presence in the western enclave. This was largely devoted to the inspection of armaments, vehicles and other equipment, and it brought together units from other sites, such as the Red Barracks. As a consequence there were significant new building works in 1967-70, with A. W. Aveston as project manager for the Ministry of Public Buildings and Works, and Holland, Hannen & Cubitts as contractors. The Central Offices were enlarged to become the headquarters of defence inspection, and the site of the Shot and Shell Foundry was given new

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workshops for the Royal Air Force. There were also a new boiler house, photographic laboratory and tank-testing ramps. Nothing of substance from this phase of the Arsenal's history survives.¹⁸⁹

During this transformation there were discussions between government departments and Greenwich Council about the preservation of some of the Arsenal's more historic buildings, and disputes, as over the removal of the Shot and Shell Foundry gates. The south-western eleven acres of the site remained destined for sale to the council to permit road widening. This was delayed, by haggling between the Ministry of Defence, Greenwich Council and the GLC, which eventually acquired the land, and by planning complications, including the listing of more buildings in 1973. Meanwhile, museum schemes for the Royal Brass Foundry and Dial Square area continued to be explored and a short-lived supermarket scheme was fought off in 1978. No. 1 Avenue through the centre of the site was renamed Wellington Avenue, and other numbered roadways were given names deriving from the Ordnance past. The Royal Arsenal Conservation Area was declared in 1981 at the west end of 'a vast deserted area scattered with the half-used remnants of later structures, an eerie and desolate scene'.¹⁹⁰ When the Plumstead Road was finally widened in 1984–6 the Falklands War had given defence work at the Arsenal an extended life in naval-weaponry research. What had become Ministry of Defence Quality Assurance Directorates continued, diminishingly active, at what had become Royal Arsenal West, but, in 1989, before post-Cold War 'peace dividend' cuts, it was decided that the whole operation would move to Teesside. Final and almost full withdrawal came in 1994; the Royal Regiment of Artillery occupied south-eastern parts of the site until 1998.¹⁹¹

Regeneration

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The Arsenal had already begun to attract attention as both a major development opportunity and a conservation challenge. In 1992 the Crown Estate, advised by Hillier Parker, promoted a planning strategy that zoned uses, residential to the north-east, retail to the south-east, employment to the centre, and heritage and leisure to the west. The London Planning Advisory Committee, operating in the absence of London-wide local government, identified Woolwich more generally as a ‘regeneration area’ within the East Thames Corridor (later Thames Gateway) ‘assisted area’. To assess the ‘brownfield’ that the Arsenal had become and produce a development plan, a newly formed national urban-regeneration agency, English Partnerships, was brought in to work with the Ministry of Defence and Greenwich Council which had, through the Greenwich Waterfront Development Partnership, secured European Union funding for the rehabilitation of former defence sites. English Heritage affirmed the importance of conservation and an evaluation of the site’s buildings by the Royal Commission on the Historical Monuments of England supplemented a suite of surveys in 1994–5. Future use was addressed by Inner City Enterprises; the condition of the buildings by Alan Baxter and Associates; archaeology by the Mills Whipp Partnership; and site contamination by the Royal Ordnance. This and what followed was orchestrated for English Partnerships by John Anderson – by a coincidence, two fundamental transformations of the Arsenal have been catalysed by men with the same name.

Ministry of Defence plans for piecemeal disposal were halted and it was agreed that continuing public-sector ownership was essential to oversee the reuse of buildings and the formation of links to integrate the site with the rest of Woolwich across the Plumstead Road. The widening of that road only a decade earlier was bemoaned as a disaster for regeneration. Beresford Gate was refurbished in 1995–6 as a nod towards ‘civic linkage’ and occasional public access followed. Plans for a museum complex on the

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western part of the site had simmered gently until 1994 when the Royal Artillery Museum at the Rotunda, wanting for space, launched a fund-raising appeal under the leadership of Gen. Sir Martin Farndale. This posited an ambitious move to the former Academy, New Laboratory Square and Paper Cartridge Factory (Buildings 17, 18, 40 and 41), all now peremptorily 'requisitioned'. With the thought that museums might lure other development, Greenwich Council also decided to bring its borough museum and local-history library together at the Arsenal. There were further hopes that the University of Greenwich (formerly Woolwich Polytechnic) might relocate to the Grand Store until it opted instead for the even grander former Greenwich Hospital. Tesco intended a supermarket and petrol station south of the Royal Carriage Factory, but this was firmly resisted by English Heritage which gained a stronger foothold in wider discussions through new listings. The Ministry of Defence disposed of the whole site to English Partnerships for £1 in 1997.¹⁹²

A year later the Arsenal's new owners mounted a competition to amend the development proposals of the early 1990s as a masterplan for regeneration. The winners, Llewelyn-Davies, refined the initially pragmatic zoning to present a simple and clear separation of four broad and flexibly projected uses, divided into twenty-two sub-zones incorporating as many listed buildings. The zones were identified as residential to the north-east, heritage to the north-west, mixed heritage-leisure to the south-west, and employment to the south-east, where road links were best. Museum building work in the heritage area began in 1999, but progress elsewhere depended on further preparatory work. The Oxford Archaeological Unit was brought in to deepen historical understanding, with English Heritage in close supervisory attendance. In parallel, Greenwich Council secured government funds for clearance and landscaping across the site, carried out by Mowlems to designs by Llewelyn-Davies and completed in late 2000. English Partnerships was then able to transfer control of the Arsenal to the

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London Development Agency, set up to work under the new Greater London Authority. With the site primed through all this public investment, the LDA selected private-sector developers for the next stages – in 2000 Berkeley Homes Ltd embarked on the residential zones; in 2001 the io Group, specialists in multi-let industrial and business property, took on the employment zones. The public authorities made planning permissions contingent on the provision by these developers of further public amenities.¹⁹³

Heritage, landscaping and public art

The Royal Artillery Museum project aimed to ‘break the mould of regimental museums’. With a grant from the Heritage Lottery Fund, secured after a first application was turned down as overambitious, Royal Artillery Museums Ltd built the new museum in 1999–2001 through Austin-Smith: Lord, architects, and Wates Construction, contractors. The museum opened as Firepower in Building 17, expanding in 2004 into Building 41, premises it shares with the Greenwich Heritage Centre. Formed with the aid of a grant from the European Regional Development Fund, the centre opened in 2003 as a long-desired amalgamation of Greenwich Council’s formerly separately located museum and archives.¹⁹⁴

In the infrastructure work of 1999–2000 clearances happened quickly, in some cases cutting across the findings of as yet undigested archaeological investigations. Aggressive resurfacing and street clutter tended to separate the listed buildings, as if to form a tidy suburb. In keeping with the plans of 1994 cross-axes of circulation were reinforced: east–west – along the river with new foot and cycle paths, and along Wellington Avenue; and north–south – on No. 1 Street, the avenue between the Royal Brass Foundry and the river, now paved with granite setts and lined with trees as a pedestrian

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route, with a new river pier to encourage improvements in transport links. The masterplan intended these linked ‘civic spaces’ in the ‘public realm’ to provide ‘a sense of place’ and ‘to introduce vitality’. ‘Assembly’, a group of sixteen cast-iron standing figures, made by Peter Burke in a style reminiscent of Antony Gormley, but not with this site in mind, was acquired through the planning-gain process and placed by Greenwich Council at the river end of No. 1 Street in 2004. At the east end of the riverside walk, north of Armstrong Road, is ‘spiral of steel’, a blue footbridge over the flood wall, put up for Sustrans by Gerry Judah, sculptor, also in 2004. A year later a stone ‘tribute plinth’ with a bronze football was put up in front of Dial Arch Square to commemorate the origins of Arsenal Football Club.¹⁹⁵

Another part of the development plan of 1994 was a small park. This was modified in the masterplan, and made larger thereafter through Berkeley Homes to form Wellington Park, which has occupied most of the site of the Shot and Shell Foundry since 2004. Designed by Broadway Malyan, it is a landscaped roof over a semi-sunken car park. There is a pergola and, at the park’s centre, a marble statue of the Duke of Wellington on a Portland stone plinth. This was commissioned by the Board of Ordnance in 1848, made by Thomas Milnes and erected at the Tower of London. The uniformed figure holds a sword (now broken) and a roll of plans, with pieces of ordnance at his feet. The statue was moved to the Arsenal in 1863 and set up south of the Grand Store offices. There it stayed until 1974 when it was made the centrepiece of a Wellington Memorial at the south end of the present park site, placed in front of a low brick wall with raised flowerbeds, an ensemble that incorporated cannon and ironwork of 1854 from the then recently demolished main machine shop of the Royal Laboratory. The statue was moved again in 2005.¹⁹⁶ At the south-west corner of Wellington Park there are three steam-hammer anvils placed here in 2004, representing archaeological salvage as public art, a token of the heritage-based approach to regeneration. A massive sandstone steam-engine base of the early 1840s

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from the Dial Arch workshops was also excavated and moved north of New Laboratory Square to be a 'focal historic artefact'.

Another small green was laid out in 2004, in front of the Royal Artillery Museum's offices and library (Building 18) where a War Office police section house of 1963 had been demolished in the clearances of 1999–2000. This was named James Clavell Square and given an array of mounted guns in 2009–10. Additionally, parts of the boundary wall along Plumstead Road were demolished in 2005 with a view to opening up the Arsenal to the town.¹⁹⁷

Early twenty-first century housing and sheds

In the north-eastern residential zones Berkeley Homes was initially responsible for 711 housing units, pushed up from 595 in the masterplan. John Anderson moved across from English Partnerships in 2000 to see this through. Plans for the housing anticipated other new housing on former Arsenal lands to the east in Thamesmead. The Southern Housing Group, a housing association, was the registered social landlord for the project's 'affordable' elements, originally twenty-nine per cent (206 units), in a mix of social-rented, shared-ownership and key-worker housing. Beside the constraints thus presented, this was for Berkeley Homes less a new-build project than a comparatively unprofitable matter of converting listed buildings, notably the subsided and semi-ruinous Grand Store. The refurbishment work gained recognition as model regeneration, won awards and enabled expansion in more profitable directions. Initially Llewelyn-Davies were commissioned to design housing, but the architectural baton quickly passed to Broadway Malyan, a firm that had worked with Berkeley Homes on luxury-flat regeneration conversions in the 1990s, and thence, in 2001, to the A&Q Partnership, for whom Keith Cowell took the lead.¹⁹⁸

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The first phase of 2001–4 generated nearly 400 dwellings. On land to either side of Building 25 ‘affordable’ terraces and small blocks of flats went up quickly, along and behind Hastings Street and then around Hardinge Crescent, altogether about 160 units of which around three quarters were houses. Designed by the A&Q Partnership, these simple red-brick buildings are in a flat, suburban neo-Georgian style, scarcely lifted by white quoining on more prominent elevations. Through the same years Building 45, west of the Grand Store, and the smaller buildings to its south, were rebuilt and converted to provide 187 apartments. Here and at the Grand Store itself Broadway Malyan secured planning submissions and the A&Q Partnership took over thereafter. A new six-storey west range to Building 45 stepped out in a more adventurous style that was developed with greater freedom and confidence by the latter architects in Building 50 of 2003–5, on the other side of the Grand Store. This block, aimed at a wealthier market, is a six-storey quadrangle faced with yellow brick; it contains 322 flats with balconies, overlooking the river and a central-courtyard ‘lagoon’ above a basement with parking for 183 cars. A district-heating system was formed and the Grand Store itself was refurbished in 2002–6. This was a remarkable rescue from dereliction and a conservation triumph, but the great quadrangle was formed into a gated community, a spearhead for gentrification, and privatization of some of the Arsenal’s best architectural space. Berkeley Homes and Broadway Malyan also took on an extra building, the former Central Offices (Building 22), reprieved from the demolition for which the masterplan had earmarked it, and converted to flats as ‘MyHQ’ in 2004–7, with the Couture Food Hall (the only food shop in the Arsenal until 2011) – all overtly aimed at well-to-do young professionals. By 2007 Berkeley Homes had built 1,250 homes for a resident population of around 4,000, with 128 families in ‘affordable’ accommodation. The work was blandly welcomed, the Commission on Architecture and the Built Environment (CABE) commenting that ‘overall, a positive balance has been

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struck between extracting maximum value out of a very complex series of existing buildings and creating new contemporary blocks and traditional style terraces, while retaining the overwhelmingly historic feel of the whole.¹⁹⁹

In the employment zone to the south-east are the industrial and warehouse units that are known as the io Centre. The io Group worked with Swallow Construction on the first phases in 2001–3. Buildings 4 and 5 were replaced with ten units in three steel sheds. Nineteen more units were provided through the refurbishment of Building 7 as Gunnery Terrace (now House), for which Hamilton Associates were architects. That firm was also responsible for more plain steel sheds on the site of the South Boring Mill, and, finally, for small office buildings near Middlegate House that were completed in 2007. Uses in this commercial area range from printing to joinery, office furniture, medical equipment and Premier Prison Services.²⁰⁰

Royal Arsenal Riverside

Intentions for a south-west leisure zone had been vague, envisaging a cinema, restaurants and other facilities that would unify the Arsenal with the rest of Woolwich. But a developer did not surface. John Anderson stepped forward for Berkeley Homes (East Thames) Ltd and, with a buoyant and buy-to-let housing market, proposed taking on more of the site and cutting through the constraints of the original masterplan. By 2004 a new masterplan had been prepared, initially by the architectural firms Sergison Bates and East, then by Broadway Malyan working through the Barton Willmore Planning Partnership. It covered not just the problematic south-west area, now relabelled the Warren, but also extended west to embrace an additional twenty-five acres, taking in all the land north of Beresford Street (denominated the ‘Teardrop’) and the riverside up to the Waterfront Leisure

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Centre. This, it was argued, was a way of breaking down the isolation of the Arsenal, of improving its ‘permeability’. But CABA criticized the scheme as too dense and insensitive to the site’s historic buildings. It was called in for a Government decision so Berkeley Homes and the London Development Agency together engaged Allies and Morrison Architects, via a competition, to prepare revised plans. These promulgated numerous seven-storey blocks, rising higher to twenty-two storeys to the far west, largely for residential use (2,517 more units of which thirty-five per cent would be ‘affordable’) with limited commercial space in a pervasively mixed-use approach that included a cinema, a hotel, shops, restaurants and bars.²⁰¹

An underlying factor in the vagaries of the regeneration project as a whole had been improved transport links and associated uncertainties. The extension of the Docklands Light Railway was a boost when it opened in 2009; there is a cylindrical riverside shaft for access to the line’s tunnel near the north-east corner of Building 50. Additional connection had arrived through commuter-boat (Thames Clipper) services from the pier, subsidized by Berkeley Homes, and an internal bus service is intended. All this is insignificant beside Crossrail. The possibility of a Crossrail station lay in the background during the revision of the masterplan, but Woolwich was cut from the rail scheme in 2006 for want of money. Berkeley Homes then took a further bold step, reversing the model that held public infrastructure to be a catalyst for private investment by offering to pay for the building of the shell of the station, subject to securing planning consents for its wider scheme. On this basis, and following a campaign led by Greenwich Council and the local MP, Nick Raynsford, Woolwich was reinstated as part of Crossrail, with a station to be sited between the Plumstead Road and Building 11. The masterplan was revised in 2007–8 to accommodate the rail line under a reoriented riverside park, and more towers, eight in all, of up to twenty-five storeys, were projected for the east and west ends of the development. This went forward despite continuing doubts from CABA and

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English Heritage about density and impact. Weston Williamson Architects were appointed to design the Crossrail station. Work began in 2011 when Hochtief Construction AG, and J. Murphy and Sons Ltd contracted to build the tunnel under Woolwich. The station is scheduled to open towards the end of the decade.²⁰²

Meanwhile, Berkeley Homes advanced steadily westwards, building what had been branded Royal Arsenal Riverside. Early on there were hopes of finding a leisure use for Building 10 (the Royal Carriage Factory), but this proved impossible and preservation was reduced to a gesture. It was transformed into The Armouries in 2007–10, through designs by the A&Q Partnership that had their origins in Broadway Malyan’s masterplan, with input from Allies and Morrison. Four seven-storey residential towers with inner water courts are encased by low early nineteenth-century walls, providing 455 dwellings of which about two thirds have been made ‘affordable’, twice the amount first intended in a shift that reflected the collapse of the housing market in 2008 and enabled construction to continue. The early eighteenth-century south range of Dial Arch Square was made a ‘gastropub’ called Dial Arch in 2009–10, followed, on the rest of this site, by The Warehouse (2010–11), a seven-storey quadrangular block in two tones of brick that comprises 298 apartments and some shops. For this Stephen Marshall Architects won a competition and designed the building with the A&Q Partnership. Principal contractors were Morrisroe. Plans for redevelopment of the former Royal Laboratory site to designs by CZWG Architects were brought forward in 2011. The proposals for ‘Laboratory Square’ have the seventeenth-century pavilions restored as trophy fragments flanked by blocks for 234 more flats to complete a battery of seven-storey buildings across the middle of the proportionally diminished historic Arsenal. By 2011 the LDA’s assignment was complete, and its role increasingly peripheral. With its closure impending, the freehold of the whole site was transferred to Berkeley Homes.²⁰³

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At the beginning of the regeneration process prospects seemed weak, so concessions to generic planning and the banality of speculators' architecture were made, and aspects of the site's robust historic character were lost. Within a decade the strength of the housing market had over-ridden employment and other desiderata, and forced further compromise, this time over heights and density, up to the precipice of the credit crunch of 2008. By then the prospect of a Crossrail station encouraged an acceptance of seven-storey permeability and other planning considerations were overwhelmed. At the time of writing the Royal Arsenal is beginning to emerge from a period as a sterile dormitory framed by museums and sheds. Commitment to Crossrail seems to ensure continuing transformation.