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Assessment

The Admiralty Experiment Works, Haslar Road, Gosport, Hampshire

Matthew Bristow

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THE ADMIRALTY EXPERIMENT WORKS HASLAR, GOSPORT

DESK BASED ASSESSMENT

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SUMMARY

The Admiralty Experiment Works (AEW) at Gosport, Hampshire is a site of unrivalled longevity and significance in the field of British naval research and development. The first experiments measuring and recording the effect of water resistance on model ship hulls were conducted on 22nd April 1887 and continue to the present day under the auspices of QinetiQ, the successor body to the AEW. In the 130 years since ground was broken on the first test building, No 1 Ship Tank, hydrodynamic experimentation has broadened to include investigations into propeller efficiency, silent propulsion systems, surface manoeuvring, submarine stability and maintenance of speed in rough seas.

The site, which is currently excluded from the Haslar Conservation Area comprises six historic AEW structures which pre-date the privatisation of the Defence Research Agency in 1995, of which No 2 Cavitation Tunnel (1955) was awarded Grade II listed status in 2014. The earliest building, No 1 Ship Tank was completed in 1887, subsequently extended in 1957 and supplemented by the larger No 2 Ship Tank, completed in 1930. No 2 Cavitation Tunnel which was removed from Hamburg in 1945 following the end of the Second World War was operational by 1955 shortly after work had commenced on a large manoeuvring tank, complete by 1959. A circulating water channel and an administration building were added to the AEW site during 1970. A number of test facilities constructed during the 1950s were demolished between 1993 and 1998 and have been replaced by buildings of the newly created Haslar Marine Technology Park or by car parks. The AEW site was also home to the Admiralty Fuel Experimental Station which became part of the Admiralty Marine Technology Establishment and a number of that department's test facilities remain.

The AEW is of national and international significance in the field of hydrodynamic research and boasts both the direct successor to the world's first hydrodynamic test facility and the exemplar on which many early model ship tanks were based.

CONTRIBUTORS

This report was drafted by Matthew Bristow and read by Wayne Cocroft and Kathryn A. Morrison of Historic England Assessment Team East.

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Historic England Archive, The Engine House, Firefly Avenue, Swindon, SN2 2EH

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LIST OF ABBREVIATIONS

ADES	Admiralty Distilling Experiment Station
AEW	Admiralty Experiment Works
AFES	Admiralty Fuel Experiment Station
ALFEE	Admiralty Liquid Fuel Experimental Station
AMEE	Admiralty Marine Engineering Establishment
AML	Admiralty Materials Laboratory
AMTE	Admiralty Marine Technology Establishment
ARE	Admiralty Research Establishment
ARL	Admiralty Research Laboratory
ASWE	Admiralty Surface Weapons Establishment
AUWE	Admiralty Underwater Weapons Establishment
DERA	Defence Evaluation and Research Establishment
DRA	Defence Research Agency
DSTL	Defence Science and Technology Laboratory
HSVA	Hamburg Ship Model Basin
NAMD	Naval Auxiliary Machinery Department
NCRE	Naval Construction Research Establishment
NGTE	National Gas Turbine Establishment
SRE	Directorate of Scientific Research and Experiment
RNPL	Royal Navy Physiological Laboratory
RNSS	Royal Navy Scientific Service

CONTENTS

INTRODUCTION

This report on the QinetiQ Haslar Marine Technology Park, formerly the Admiralty Experiment Works (AEW) Haslar has been prepared as part of a wider project being undertaken by the Historic England Assessment and Listing Team (South) to improve the understanding of inter-relationships between Gosport's built military heritage and the civil town which grew alongside these facilities.

The report presents the findings of a Desk Based Assessment carried out between September 2015 and February 2016 by the Historic England Assessment Team (East). No site visits were made, but a rapid assessment of the significance of the extant buildings was made, supplemented by contextualising research which detailed the historical development of the site and descriptions of extant and demolished structures and the potential for archaeology. A detailed examination of the available published, archival and electronic sources relating to this site was undertaken in preparation of the report. Among these published sources, the existing Historic England Research Report on the adjoining Haslar Gunboat Yard by Sarah P C Hendricks, the successful listing proposal for No 2 Cavitation Tunnel by Alex Rowse and Rob Harper and articles published by R W L Gawn (the former Superintendent of AEW Haslar) and R N Newton in the *Transactions of the Institution of Naval Architects* have proved particularly useful. The Admiralty (ADM series) records in The National Archives (hereafter abbreviated to TNA) have provided a rich source of information, in particular the ADM 226 series which contains the reports of the AEW. Drawings, plans and aerial photographs held by the Historic England Archive (HEA) and historic photographs archived at the Imperial War Museum (IWM) have also been consulted. A full list of published works and sources consulted can be found at the end of this report.

Preliminary sections of this report detail the historical development of the AEW and the Royal Navy's approach to research, including the origins of empirical testing of model ships hulls, the work of William Froude and the Admiralty's first test facility. The remainder of the report comprises detailed descriptions of the principal extant buildings and descriptions of demolished buildings known to have existed drawn from documentary and photographic sources. The report concludes with a summary of the architectural and historical significance of the site.

All building descriptions have been compiled from a combination of documentary accounts, oblique aerial photographs, satellite imagery and a limited selection of ground photography taken within the AEW site. As such the descriptions could all be enhanced and/or corrected following site visits and detailed inspection. All building dimensions drawn from documentary sources are given in imperial units with metric conversions given in parentheses. Building dimensions derived from digital mapping and GIS are given in metric units only.

HISTORICAL DEVELOPMENT

In contrast to the history of specialist sites dedicated to construction for the Royal Navy, the earliest of which in Portsmouth, a dry dock, was constructed in the 1490s, sites devoted to the empirical study of the performance of ship hulls and propulsion systems date only from the early 1870s.[1] Furthermore, systematic research into the design of ships was prompted, not by the Royal Navy whose approach to hull design had largely been dictated by the experience of master shipwrights, but by the foresight of single pioneering engineer, William Froude.[2] The first experiment tank, constructed by Froude in 1870 adjacent to his home in Torquay became known from 1872 as the Admiralty Experiment Works (Torquay), a moniker which would remain following the closure of the Torquay tank and establishment of new facilities at Haslar from 1886.[3] The Admiralty Experiment Works (AEW) was the first of the Admiralty's research establishments and of the three armed forces, the Royal Navy was arguably the first to engage in organised scientific research aimed at addressing specific issues which addressed its functioning.[4] In July 1915, the Board of Invention and Research, with its numerous sub-committees, was established to assess invention proposals from the general public and how the Admiralty might draw on the resources of private industry in much the same way that the AEW had been the product of private initiative.[5] In 1918, the Directorate of Scientific Research and Experiment (SRE) replaced the Board of Invention and Research and were tasked with co-ordinating the work of the various experimental stations which in turn led to the founding in 1921 of the Admiralty Research Laboratory (ARL) at Teddington.[6] ARL's work was intended to be more scientific in nature whereas AEW was seen to be more practical and concerned directly with producing operational equipment.[7]

In 1946, the SRE was reorganised into the Royal Navy Scientific Service (RNSS) which was comprised of four separate directorates (Operational Research, Research Programmes and Planning, Aeronautical and Engineering Research and Physical Research), each reporting to the 3rd Sea Lord, Vice Admiral Sir Charles Daniel.[8] The AEW reported to the Director of Naval Construction, while the Admiralty Fuel Experiment Station (AFES), which occupied the same site at Haslar, was the responsibility of the Engineer in Chief.[9] This reorganisation was necessitated by the establishment of the Ministry of Defence to co-ordinate the policies of the three armed services and central advice on Research & Development was provided by the Defence Research Policy Committee.[10]

After 1971, the Admiralty's Research & Development establishments such as AEW, which had previously been administered by the Director of Warship Design on behalf of the Director General, Ships, were placed under a single Controller and a greater reliance was placed on private industry for development.[11] In 1977, AEW Haslar was amalgamated with ARL Teddington, The Naval Construction Research Establishment (NCRE) Rosythe, The Royal Navy Physiological Laboratory (RNPL) Alverstoke and the Admiralty Materials Laboratory (AML) Holton Heath to form the Admiralty Marine Technology Establishment (AMTE).[12] A further merger between the AMTE, the Admiralty Surface Weapons Establishment (ASWE) and Admiralty Underwater Weapons Establishment (AUWE) to form the unified Admiralty Research Establishment (ARE) followed in 1984 which in turn saw the ARE become one of the founding members of the Defence Research Agency (DRA) in 1991.[13] In 1995 the DRA became a division of the Defence Evaluation and Research Establishment (DERA) whose research sites were split between two separate organisations following the privatisation of DERA in 2001: the Defence Science and Technology Laboratory (DSTL) and QinetiQ, with AEW Haslar and the former constituent parts of AMTE coming under the control of QinetiQ.[14]

William Froude and Model Ship Testing

AEW Haslar and the 130 years of research and experimentation into ship design and propulsion systems which followed and which continue on the site under the auspices of QinetiQ, owe their existence to the pioneering work of the engineer and architect William Froude. Froude, born the fourth son of Robert Hurrell Froude, the archdeacon of Totnes, on 28th November 1810, was schooled at Westminster School before graduating with a first-class honours degree in mathematics from Oriel College, Oxford.[15] Having worked on a survey for the South Eastern Railway in 1833, Froude joined Brunel's staff of the Great Western Railway and managed the last section of the Bristol to Exeter line, developing a new design of skew bridge and applying his mathematical training to the problem of sideways forces acting on trains entering a curve. Having retired in 1846, Froude served as a harbour commissioner, magistrate and judge of agricultural machinery before gaining an understanding of the friction of water while working on an improved supply of water to the Torquay waterworks.[16]

Froude's life defining work on the behaviour of ships at sea began in 1856 when Brunel persuaded him to undertake a study of rolling in waves which alerted the admiralty to Froude's empirical methods and began a working partnership between Froude and Brunel's son, Henri Marc Brunel.[17] Where mathematical calculation could not fill gaps in Froude's theory, he took to conducting resistance experiments both on Bassenthwaite Lake, Cumberland with self-propelled clockwork models of his own design and most notably on the River Dart above Totnes.[18] Froude's tests on different scaled models of the screw gunboats HMS *Swan* and HMS *Raven* showed that there was no universal optimum hull design, but crucially proved that it was possible to obtain accurate ship resistance data from model tests, a discovery which became known as 'Froude's Law'.[19] Later debate would focus on whether this law of comparison should be credited to Froude, or to Ferdinand Reech who had formulated the law in 1844 and published it in 1852. However what remains beyond doubt is that it was Froude's pioneering work at Torquay which showed how to apply the law of comparison in practice.[20]

In 1867 while living in Paignton, Froude began the construction of a house for himself, Chelston Cross at Cockington, Torquay. The house, in high Victorian style of local sandstone with polychromatic brick dressings, survives to the present day as the Manor House Hotel and was constructed with a small chapel as part of the service wing.[21] He continued his resistance experiments on model ships, towed by means of a falling weight in a small freshwater tank believed to have been situated within the chapel of Chelston Cross and fossilised in the footprint of the hotel swimming pool which now occupies that building.[22] The small tank and makeshift towing arrangements proved unsatisfactory and on 24th April 1868, upon the invitation of Sir Edward Reed the Chief Constructor to the Navy, Froude outlined to the Admiralty a proposal for the construction of an experiment tank for the towing of model ships.[23] After much deliberation, the Admiralty, decided in February 1870 to back Froude's proposal and allocated £2000 for the construction of a test tank to undertake rolling as well as resistance tests with the project afforded a strict two-year lifespan inclusive of the time needed to build the tank.[24]

The Torquay Tank and the Origins of AEW

William Froude was quick to respond to the Admiralty's support for his testing tank. He quickly leased land from W. Mallock in a field to the north of and separated from his house by Seaway Lane at a cost of £12 per annum.[25] Building work commenced on the site in June 1870 with the waterway excavated, puddled and surfaced with asphalt and filled with water by 21st March 1871 (Figure 1).[26]

The shape of the site which Froude had acquired dictated the tank be orientated south-west to north-east and upon completion the tank measured 278 ft (85 m) long by 36 ft (11 m) wide at the water surface and 10 ft (3 m) deep at its deepest. The water channel was formed partly by excavation and partly by building up of earth banks, giving the tank sloping sides.[27] As the facility was only intended to have a life

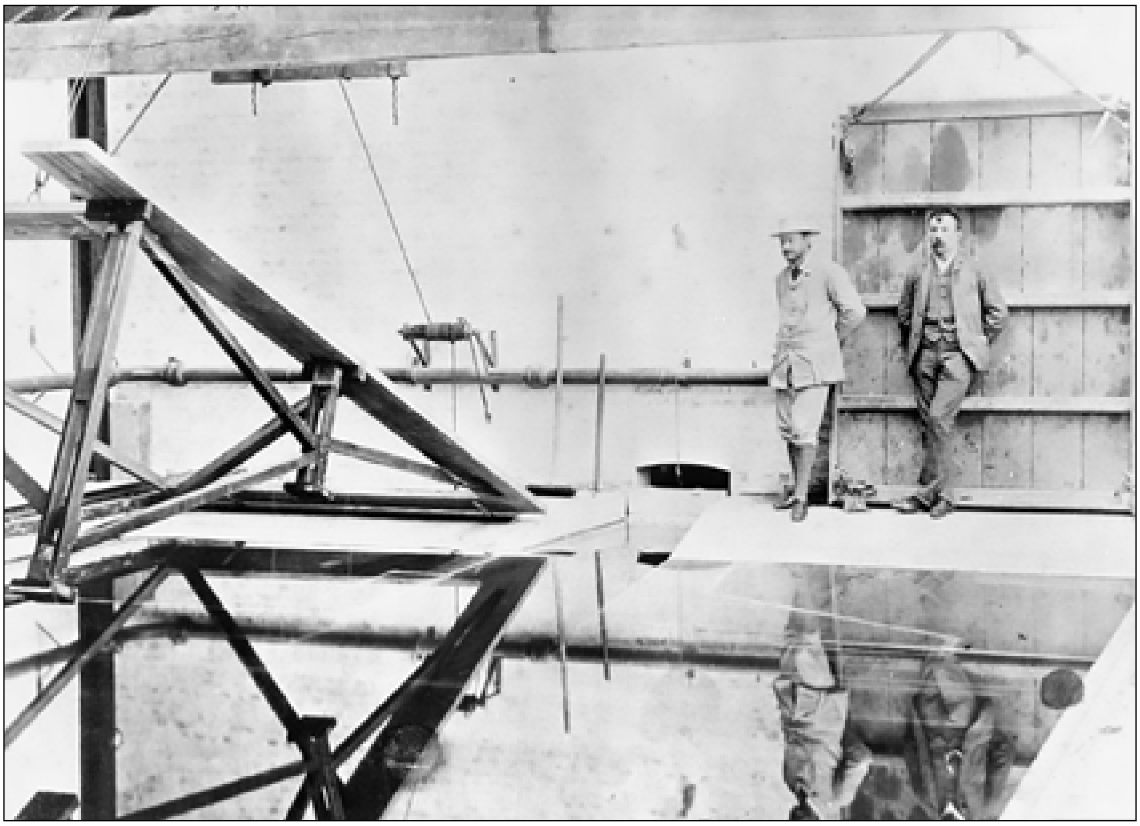


Figure 1: The civil engineer and naval architect, William Froude (left) and one of his staff photographed in the test tank at Torquay (IWM HU 82581)

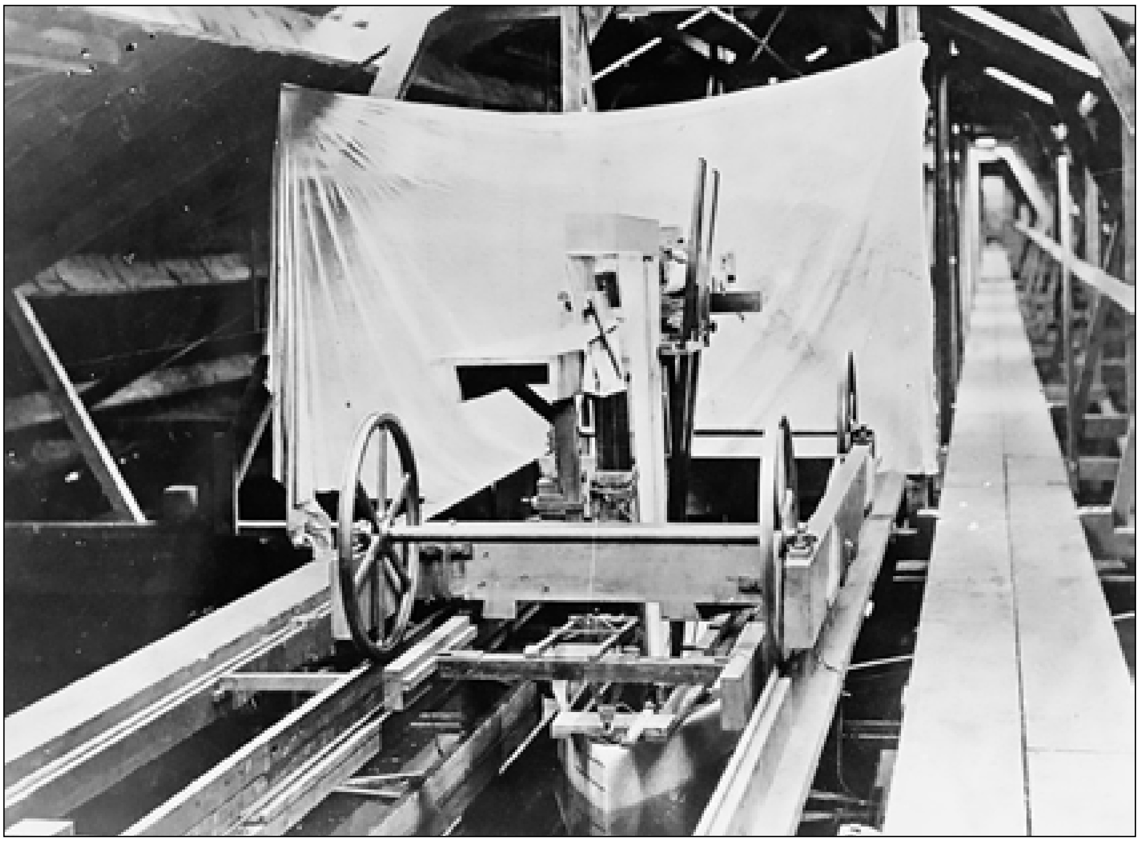


Figure 2: The resistance dynamometer on its carriage in the Torquay tank. The ephemeral nature of the tank building's timber construction is clearly visible (IWM HU 82583)

of two years, the tank building was of hastily erected timber construction and was supplemented by a brick built boiler and engine house which housed a two cylinder stationary steam engine used to haul paraffin wax models and measuring apparatus (resistance dynamometer) carriages which moved along a 3 ft 3 in gauge railway carried by the principal rafters of the roof (Figure 2).[28]

Galvanized by what he saw as the senseless and avoidable loss of life to bad ship design, characterised by the loss of HMS *Captain*, a twin screw ironclad which had turned turtle off Cape Finistere on 6th September 1870 with the loss of almost her entire 500 crew, Froude began work on the first series of experiments with a miniature version of HMS *Greyhound* that year.[29] Primarily the investigations were concerned with achieving improvements in hull and propeller design to ensure higher standards of propulsion.[30] The success of Froude's experimentation at Chelston Cross, which he supervised until his departure for South Africa in 1878, saw the first tank far outlive the two year life granted it by the Admiralty and in 1872 it was formally recognised as the Admiralty Experiment Works Torquay, eventually going on to operate at the site for 14 years.

R E Froude and the Move to Haslar

Tragically, the tank at Torquay would outlive its creator as, while holidaying in South Africa, William Froude contracted dysentery and died on 4th May 1879 at Admiralty House, Simonstown.[31] Froude's grave was initially marked with a cast iron cross which, upon its replacement with a stone, was taken to England to reside firstly in the Superintendent's office at Haslar and from 1955 in the tower of Dartington Hall.[32] A replica of the cross made in the late 1980s survives in the Haslar Manoeuvring Tank.[33] William Froude's third son, Robert Edmund Froude, (known as Eddie) had worked closely with his father at the Torquay tank and continued the programme of experimentation. Though it was not clear whether the Admiralty would accept R E Froude's succession, he was invited in 1882 to sketch out the requirements for a new facility to replace the Torquay tank which was proving to be both too small for the increased programme of testing and starting to deteriorate having never been intended to be in use for so long.[34] R E Froude proposed a new, far larger tank: 400 ft (122 m) in length and with offices and workshops at one end. His plan also dictated that the new tank be built with room for a 150 ft (45 m) extension at one end.[35]

Further validation of the value of the work at Torquay and R E Froude's expertise came in 1884 when HMS *Warrior*, originally laid down in 1859, was tested in model form at Torquay to coincide with her upgrading. Models were subjected to resistance tests and tests of screw performance with different sizes and locations of propellers and as both a twin and single screw ship. The tests found that the contemporary estimates of *Warrior's* water resistance had been over-estimated by as much as 55%.[36]

As the lease on the land at Chelston Cross approached expiration, attention turned to finding a new home for the AEW and realising R E Froude's plans for a new tank. Sites near Embankment Gardens, Charing Cross and alongside the Metropolitan Railway at Brompton Oratory were considered and rejected at an early stage as were further sites at Chiswick, Deptford and in the extension to Portsmouth Dockyard.[37] The Admiralty eventually selected an adjoining site to the west of the Victorian gunboat yard on Haslar Road in Gosport on which to locate the AEW. The site, bounded to the east by the gunboat yard, the south by Haslar Road, the Royal Hospital Haslar and the Royal Navy cemetery and to the north by Haslar Lake, was in the 1880s, remote and relatively inaccessible.[38] It did however, offer the space required by Froude for the construction of the new tank (Figure 3).

On the 3rd of February 1886, the lease on the Seaway Lane site expired and the process of dismantling the Torquay tank, clearing the site and transferring equipment to Haslar began. Much of the equipment used at Torquay was both highly experimental and defined by the limited expenditure afforded by the Admiralty. As such much new equipment was specially made for the new site at Haslar, although parts of William Froude's resistance dynamometer, the screw dynamometer and the square paper ruling machine designed by Froude were transferred to Haslar and remained in regular use into the 1950s.[39] No physical evidence remains of the Torquay tank nor does the tank appear on the published Ordnance Survey maps of

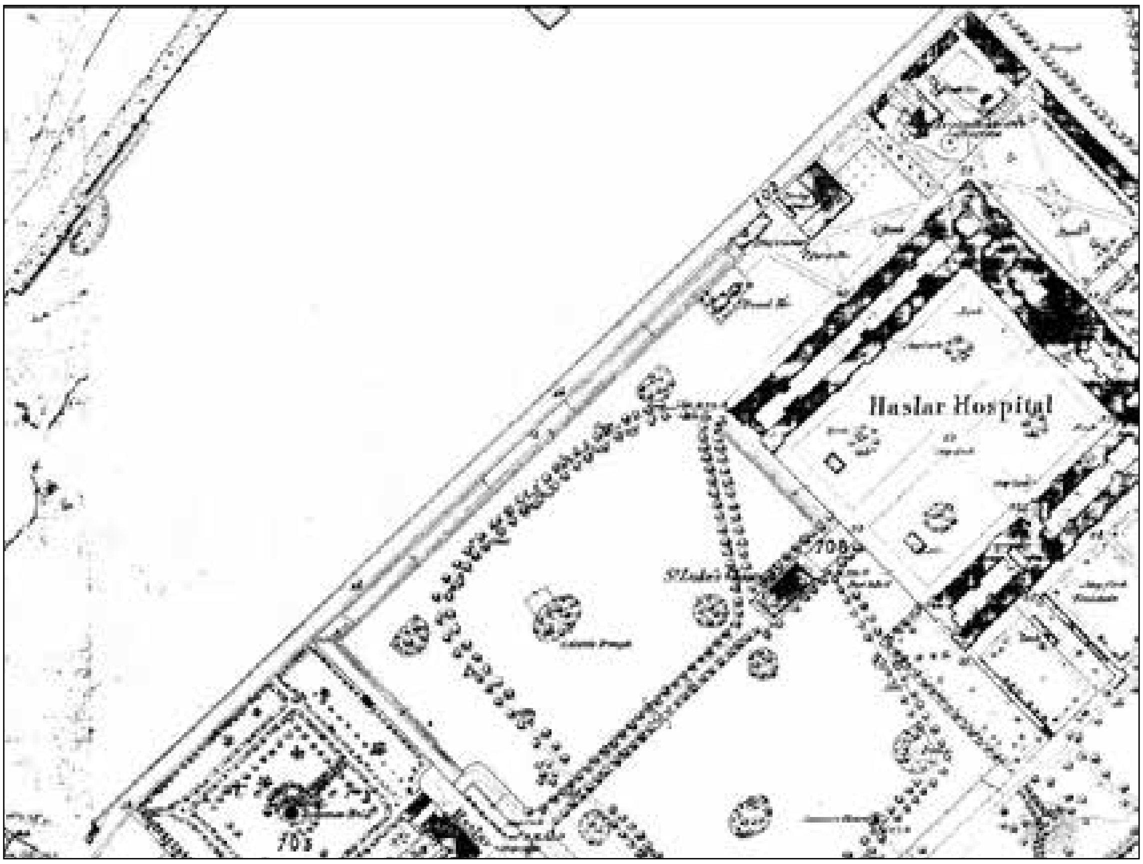


Figure 3: 1:2500 First Edition Ordnance Survey Map (1881) showing the site south of Haslar Lake chosen to house the Admiralty Experiment Works. © and database right Crown Copyright and Landmark Information Group Ltd (All rights reserved 2016). Licence number 000394

1889 or 1890, though neither does Chelston Cross which was clearly completed by those dates.[40] The Torquay tank did establish the AEW as a crucial part of the process of ship design, inspiring the construction of the UK's first commercial test tank, built by William Denny at Dunbarton in 1882 and laying the metaphorical foundations for more than a century of development at the Haslar site.

No 1 Ship Tank and Experimentation to 1919

Work on the construction of the new model towing tank began at Haslar in early 1886 and by May 15th the new tank was ready to be filled with water. Meeting the specification drawn up by R E Froude in 1882, the new tank was 400 ft (122 m) in length and was orientated roughly north-west to south-east along the western perimeter of the site. Although the Haslar tank, or No 1 Ship Tank as it would become known, followed the principles established at Torquay, it differed in a number of fundamental ways. Firstly it dispensed with the sloping sides and trapezoid cross-section of the Torquay tank in favour of a rectangular section 20 ft (6 m) wide and 9 ft (2.7 m) deep which gave the tank a flat bottom.[41] Secondly, the carriage which carried the model and dynamometers was redesigned to span the entire width of the waterway rather than a narrow carriage carried on overhead rails as at Torquay.[42] Greater provision was also given to the ancillary processes involved in the production of models and recording of test data. To the southern end of the tank a large workshop flanked by offices and a boiler house were constructed behind the three tank docks for the construction and rigging of scale models. At the northern end and to the east of the tank, a single-storey range housed the drawing office and the apparatus room.[43] Filling the new tank took 15 days in May 1886 and quickly identified leaks which saw the tank drained and repaired in August of that year. By April of the following year, work on the tank was complete and the first experiment was run on the 22nd April on a model of HMS *Iris* (Figure 4).[44] HMS *Iris* had been completed in 1877 and therefore the first test at Haslar was not of a new hull design. R E Froude however was concerned about the consistency of results being affected by the move from Torquay to Haslar and insisted on comparing the results of tests on HMS *Iris* completed immediately before the move with a similar test of the same model upon commencing testing at Haslar.[45] Froude, sentimentally, also retained a flask of water from the Torquay tank which was used to 'Christen' the new tank, a practice which was subsequently repeated both at Haslar and at other tanks around the world.

The completion of No 1 Ship Tank and the successful experiments on the model of HMS *Iris* coincided with a huge increase in the shipbuilding programme of the Royal Navy following the Naval Defence Act of 1889, and with it a dramatic increase in the

Figure 4: Plaque erected to commemorate the centenary (1887-1987) of the first test conducted in No. 1 Ship Tank, Haslar. The plaque depicts HMS Iris*, a model of which was used to ensure consistency in test results following the move from Torquay (HEA BB94/5074)*

requirement for the testing of new hull designs.[46] Models of all of the enormous ships which made up the First World War surface fleet including the iconic Dreadnought class, passed through the new towing tank at Haslar and by 1918 500 different warship models had been tested there comprising 33 battleship types, 46 cruisers, 61 destroyers and 14 submarines.[47] The testing of submarines would become increasingly central to the work of AEW Haslar and No 1 Ship Tank was utilised from the very beginning, with the Navy's first British-designed submarines, the A-class, tested in model form prior to their construction between 1902 and 1905. AEW Haslar was also called into to ascertain why HMS A8 sank with the loss of all twelve of her crew whilst conducting surface manoeuvres on 8th June 1905.[48]

Admiralty Fuel Experimental Station

In the early years of AEW Haslar, No 1 Ship Tank was joined by the Admiralty Fuel Experimental Station (AFES) which was formed in 1902 at Haslar as the Admiralty Liquid Fuel Experimental Establishment (ALFEE). Occupying a site to the west of the gunboat yard's transverse slipway, where it remained throughout its existence, AFES's activities centred on the investigations into burning oil fuels in marine boilers but later included other aspects of marine boiler design, culminating in the development of the Admiralty Three Drum Boiler (Figure 5).[49]

Figure 5: Plan of the AEW Haslar site in 1927 showing the location of the Liquid Fuel Experimental Station immediately to the north of the proposed No 2 Ship Tank highighted in orange (HEA MD95/06498)

By 1953 responsibility for the development of liquid fuels passed to the Admiralty Oil Laboratory and exacerbated by the decline in oil-fired steam plant, AFES concentrated on machinery design and testing which was reflected in the change in its name to the Admiralty Marine Engineering Establishment in 1966.[50] Further facilities were created on the northern shoreline including tidal ponds feeding piped inlets with a supply of salt water, a large boiler house and overhead pipelines connecting with storage tanks in the original AFES site. In 1974 AMEE absorbed the Admiralty Distilling Experimental Station (ADES) at Portland and in 1976 changed its name to Naval Auxiliary Machinery Department (NAMD) a department of the National Gas Turbine Establishment (NGTE) based at Pyestock.[51] The AFES continued to be known as NAMD until 1979 when it joined AEW as part of the Admiralty Marine Technology Establishment (AMTE) and when AMTE became part of the Admiralty Research Laboratory (ARL) in 1984.[52]

The First World War

Between 1914 and 1918 no additional test facilities were added to the AEW site, however the site was extensively used as a naval camp and extension of the Royal Hospital Haslar. A plan of the site made in 1917 indicates a number of temporary hutted structures were built on the Haslar Lake shoreline, in the area where the propeller and vibration laboratories would later be constructed and along the Haslar Road boundary wall adjacent to the workshop of No 1 Ship Tank. These huts were variously used as sleeping quarters, mess huts, offices, latrines and ablution rooms, while a telephone exchange and a YMCA were also provided. Although built to provide temporary wartime accommodation, the majority of these huts remained on the AEW site until after the Second World War when they were gradually removed to make way for new test facilities. The last of these First World War huts, which had begun life as a sick bay and venereal disease ward, survived on the AEW site until the early 1970s when it was removed in preparation for the opening of the new administration block. The 1917 plan also shows even more temporary accommodation in the form of a street of tents in addition to two parade grounds and a bandstand (Figure 6). Isolation camps of the naval hospital are also shown to have been created in the area to the north of the gunboat yard transverse slipway and against the boundary wall of the AEW site formed by the length of No 1 Ship Tank.[53]

Inter-war Developments and No 2 Ship Tank

The development of the Royal Navy's surface and submarine fleet during the First World War demonstrated that both the volume of investigations required by then Admiralty and the greater range of vessels to be tested would far outstrip the capacity of a single tank. It was also clear that despite the foresight of R E Froude in allowing for No 1 Tank to be extended, that a second tank would have to be far larger to accommodate models which reflected the increased size and surface speed of the Navy's ships. For example at the time of the move from Torquay, the largest ship in the Navy was HMS *Trafalgar* which was 345 feet in length, displaced 11,900 tons and could travel at 16 knots.[54] Twenty years later HMS *Dreadnought* boasted a length of 526 feet, a displacement of 18,000 tons and an unprecedented top speed of 21 knots, while by the mid-1920s, motor torpedo-boats could reach speeds of 40 knots.[55] By 2nd March 1927 plans had been drawn up for a second tank which could accommodate larger models and towing tests carried out at greater speed.[56] The addition of a wave generator also allowed for resistance experiments on surface ships in rough seas, while the greater depth of the new tank lent itself to work with submerged submarine models.

Completed in 1930, No 2 Ship Tank, also known as the High Speed Tank was orientated perpendicular to No 1 Ship Tank adjacent to the workshop at its southern end and, inclusive of its workshop, ran in a roughly north-western direction for 1024 ft (312 m) parallel to the Haslar Road. The new towing tank was twice the width

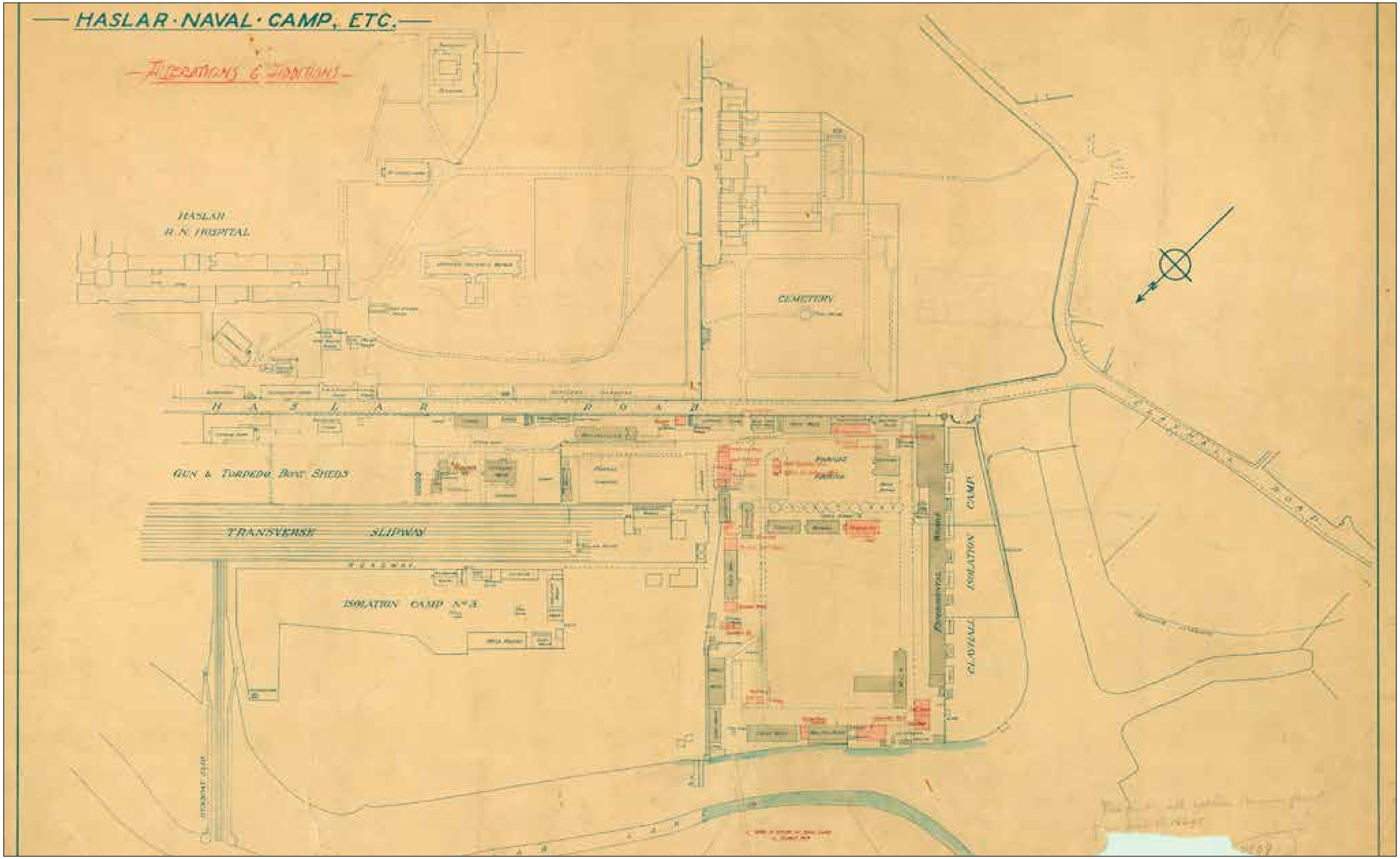


Figure 6: A plan of the Haslar site in 1917 showing the isolation wards and camps of the Royal Hospital Haslar occupying the area adjacent to No 1 Ship Tank (HEA MD95/06480)

and depth of No 1 Tank, measuring 40 ft (12 m) by 15 ft (4.5 m) and the water level of the 885 ft (270 m) waterway sat 9 ft (2.7 m) above ground level, reducing the cost of excavation during construction and raising the bottom of the tank above the level of free water in the subsoil.[57] In order to give greater scope for investigations in shallow water, a false bottom of 160 ft (49 m) was incorporated into the design of the tank allowing for adjustments in depth to be made. A large workshop was constructed to the west of the tank for the production of models and adjoined a series of offices for drawing and recording and the rooms housing the batteries and generators for powering the towing carriage.[58] The completion of No 2 Ship Tank proved very timely, given the requirement for the testing and development of new classes of ship and the increased testing of existing designs brought about by the Second World War.

The 1930s also saw AEW Haslar undertake testing for the private sector, most notably for Sir Malcolm Campbell in support of his attempts on the water speed record. Having secured the land speed record in 1935 in *Bluebird* with a speed of 301 mph, Campbell turned his attention to the water speed record which had been dominated during the 1920s by the American Gar Wood.[59] Campbell's boat, *Bluebird I*, more widely known as K3 to reflect its Lloyd's Unlimited rating, was built by Saunders Roe in 1936. A single step hydroplane powered by a Rolls Royce R aero racing engine, *Bluebird K3* was model tested in AEW's No 2 Ship Tank during 1936 where it exhibited a worrying tendency to flip over at speeds equivalent to 150 mph.[60] Although Campbell achieved the water speed record with a speed of 126.32 mph in 1937, the margin by which he beat the old record was disappointing and Campbell's attention turned to a new design on the principle of the three point hydroplane. The idea of three skimming floats, or a single hydroplane with two outlying sponsons as a method of reducing water resistance at high speeds had been proposed by William Froude as early as 1872, but the results of his tests contradicted his hypothesis.[61] Initial tank tests on the hull design of *Bluebird K4* built by Vospers of Portsmouth were similarly disappointing both with regards to speed estimates and safety, with the design showing a tendency to 'kite' upwards and flip over. Improvements were made to the design and in August 1939, Sir Malcolm Campbell smashed the water speed record, raising it to 141.38 mph.[62] Such was the importance of AEW Haslar's role in the development of *Bluebird K4* that it led Commander Peter Du Cane, the Managing Director of Vospers to remark:

> I had always viewed tank test results as regards boats, and especially where speed boats were concerned with some reserve, but I will freely admit that Mr Gawn's speed estimate in the case of *Bluebird II* [K4] was an absolute revelation.[63]

The Haslar site's association with attempts on the water speed record would continue into the 1950s and resurface again in the 21st century with $^{1}/_{8}$th scale models of the revolutionary reverse 4-point hydroplane craft *Quicksilver* tested in No 2 Ship Tank.[64]

Cavitation Research and Cavitation Tunnels Nos 1 & 2

Screw propellers had been adopted by the Royal Navy as the principal propulsion method for surface ships following the now infamous tug-of-war trial between the screw powered HMS *Rattler* and the paddle steamer HMS *Electo* in 1845. The trial in which *Rattler* pulled *Electo* backward at a speed of 2.6 knots proved conclusively that the screw propeller was the more powerful propulsion system and led to a new field of research into propulsion efficiency through the examination of model propeller designs. By the end of the 19th century screw propellers were failing to deliver the higher speeds projected by naval architects. In 1894, the torpedo-boat destroyer HMS *Daring* was only able to reach a speed of 24 knots and not the 27 knots predicted leading R E Froude the coin the term 'Cavitation' from the Latin 'cavus' meaning hollow to describe an observable phenomenon which effects propeller efficiency.[65] Cavitation generally occurs in a flowing liquid when the pressure is reduced by mechanical forces to a level near to where the liquid turns to vapour causing cavities to form either as intermittent bubbles which form on a body, implode and leave with the fluid as it passes the body; or as steady cavities which completely envelop at least part of the submerged body.[66] In the context of ship propulsion, cavitation affects the performance of pumps, turbines and propellers by causing pitting of surfaces in cavitation zones and reducing efficiency by increasing the drag on a submerged body. The imploding bubbles created by an cavitating propeller also create underwater noise and attempts to eliminate propeller cavitation would become central to research into silent running submarines after the Second World War.

Figure 7: High-speed photograph of a model propeller demonstrating the effects of cavitation (TNA ADM 226/68)

The first attempts to study the effect of cavitation on model propellers were undertaken in 1895 by Sir Charles Algernon Parsons in connection with improving the propulsion performance of his steam turbine prototype vessel, *Turbinia*. Parsons built the forerunner of the cavitation tunnel to test models of *Turbinia's* propellers, by constructing an oval conduit of rectangular section copper to form a closed circuit. The screw shaft onto which the model propeller was mounted was inserted horizontally through a gland in the upper limb and driven externally, while an arc lamp was used to heat the water to create the pressure change and a turning mirror utilised for stroboscopic photographs. This first cavitation tunnel differed only from those which followed in its absence of an impeller motor to create water circulation.[67] Buoyed by his success, Parsons constructed a larger facility at Wallsend in 1910 in which he was able to test propeller models with a diameter up to 12 inches.[68] In the years that followed the First World War, a number of cavitation testing facilities were built in Europe before AEW began to plan a facility for cavitation testing at Haslar.

In 1937 the Director of Naval Construction recommended to the Admiralty that a cavitation tunnel be built at Haslar in order to meet the requirements of the warship programme and the need for faster, larger propellers. The construction of Cavitation Tunnel No 1 was approved on the 30th October 1937 to a design which would see the facility overtake all existing cavitation tunnels both in terms of physical size, but also in terms of the power of the motors controlling the water flow and propeller and the speed of the water circulating in the channel.[69] For example, Parsons' Wallsend tunnel was 20 ft long and stood 8 ft high with a pump capable of providing 50 bhp and a propeller motor capable of 15 bhp. The Hamburg cavitation tunnel, completed in 1931 was 19.7 ft long and stood 16.6 ft high with its pump and motor providing 102 bhp and 22 bhp respectively. Haslar's No 1 Cavitation Tunnel would measure 28.3 ft in length and stand 23 ft high with the pump and motor providing 150 bhp and 50 bhp respectively, with the pump achieving a water flow of 40 ft/sec.[70]

No 1 Cavitation tunnel was completed in 1941 and housed in a building immediately adjacent and to the north of No 2 ship tank, linked to it via an elevated walkway.

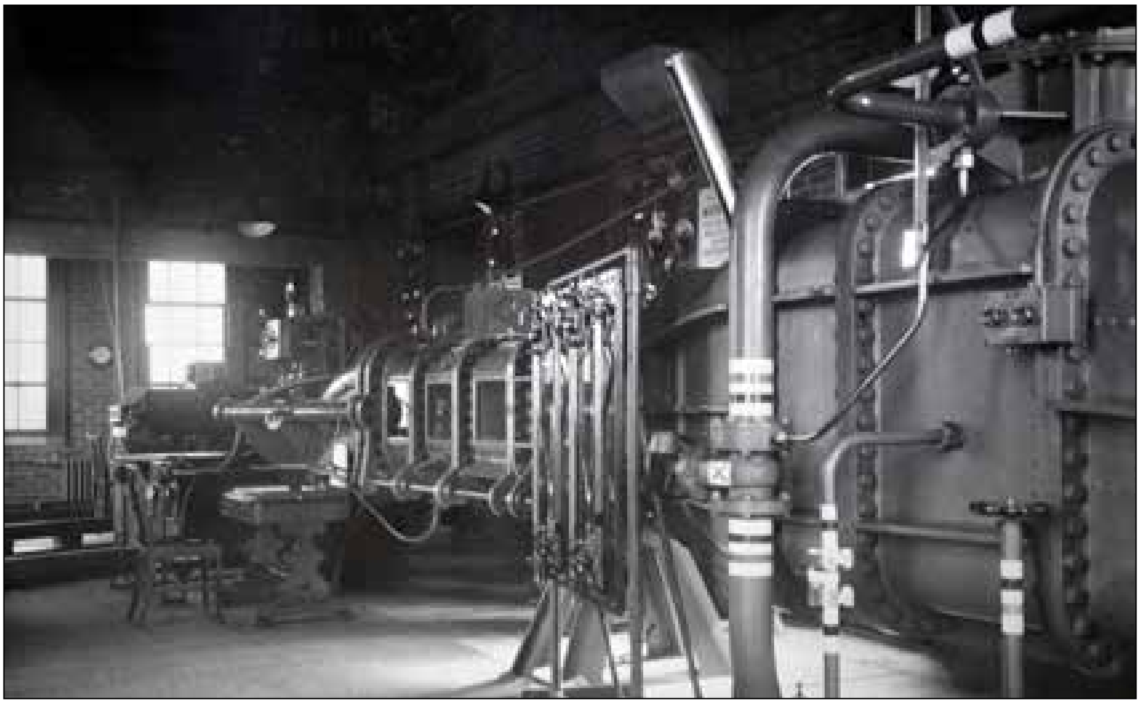


Figure 8: The upper limb and observation panels of No 1 Cavitation Tunnel (TNA ADM 1/23580)

Immediately to the west of the cavitation tunnel building, a settling tank was constructed similar to that at Wallsend, which allowed the bubbles created during the cavitation tests to be removed from the water channel. The completed tunnel had a working cross-section of 2 ft x 2 ft and a normal operating speed of 20 ft/sec (Figure 8).[71] The cavitation tunnel was used for 'open' water experiments, in that the flow upstream of the propeller was uniform and unaffected by other submerged bodies such a vessel's hull.[72] Experiments quickly showed that in addition to the propeller's diameter, blade cross-section, number of blades, speed of rotation and the power fed by the engines, cavitation was also effected by the shape of the vessel's 'after body' which defined the flow of water into the face of the propeller.[73] As such it became apparent that a larger, more advanced testing facility was required which could perform 'behind' tests and wake survey propulsion and cavitation experiments on model hull and propeller combinations.[74]

On 10th July 1945 the Admiralty wrote to Major General Anderson of the British Army regarding the acquisition of a large cavitation tunnel known to exist in Hamburg:

> The Germans constructed at Hamburg during the War a valuable experimental tank, including a cavitation tunnel. We ourselves have a much smaller cavitation tunnel at Haslar, but our experiences in the present war have brought home to us that a much larger tunnel, comparable to that of Hamburg, is required. We were planning after the war to construct a new tunnel which would have cost approximately £95,000. The shipment of the German Tunnel and re-erection at Haslar will cost something in the order of £15,000 and we are naturally very anxious to obtain it. [75]

The tunnel in question had been built by the shipbuilders Blohm and Voss of Hamburg for the Hamburg Ship Model Basin (HSVA) to a design by Dr Herman Lerbs, a leading German cavitation and propeller research scientist who had also designed the Hamburg cavitation tunnel completed for HSVA in 1931 (Figure 9).[76]

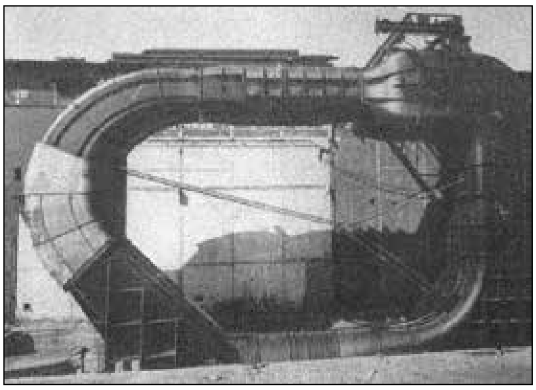


Figure 9 (left): The cavitation tunnel designed by Hermann Lerbs for HSVA in Hamburg prior to its removal to Haslar in 1945 (Dr E A Weitendorf). Figure 10 (right): Aerial view of AEW Haslar in 1947 showing the exposed shell of No. 2 Cavitation Tunnel prior to the erection of the tunnel building (HEA RAF 30054 PFFO - 0062)

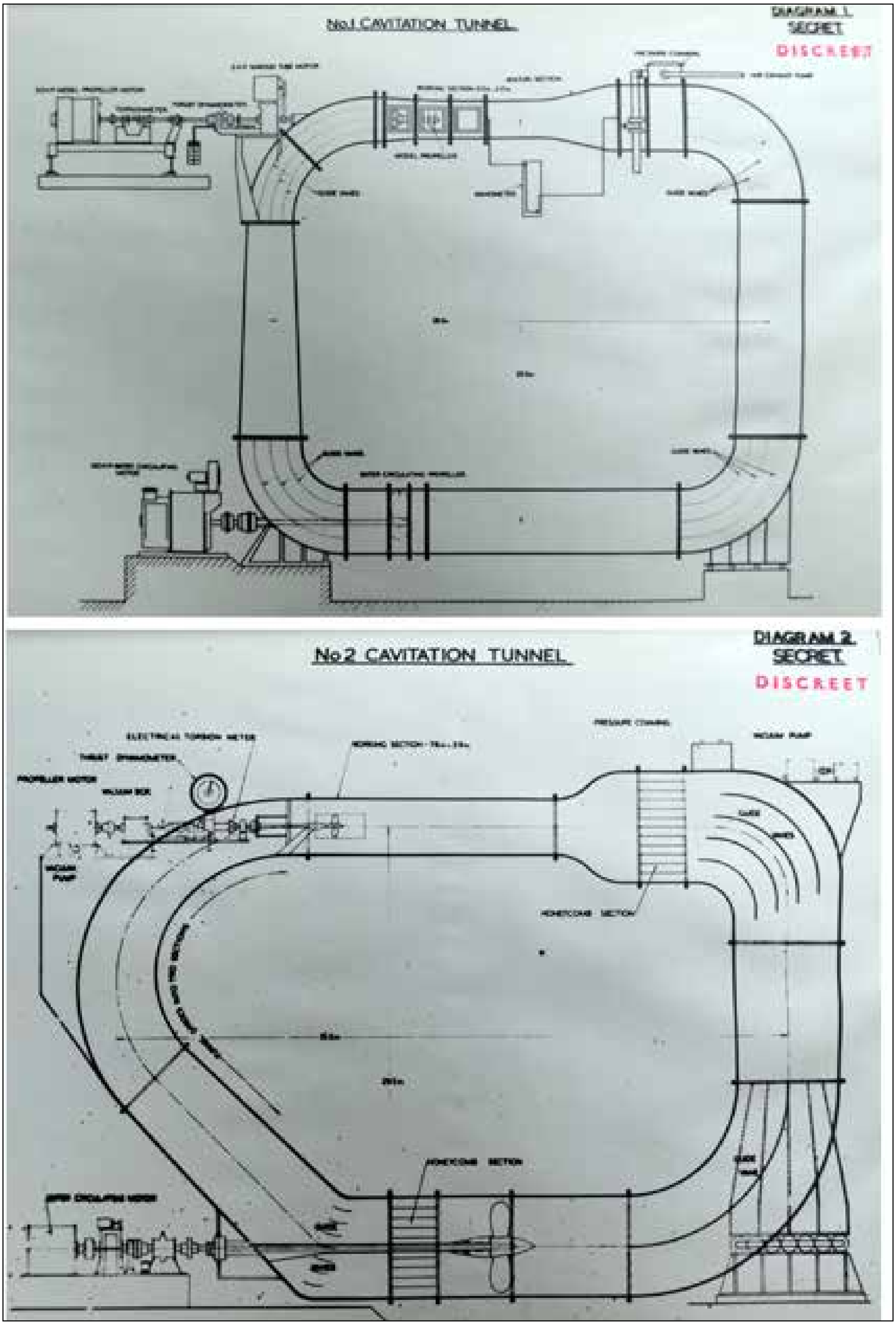


Figure 11: Sectional drawings of No 1 and No 2 Cavitation Tunnels showing the increased size and working cross-section of the tunnel removed from Hamburg in 1945 (TNA ADM 226/68)

The Admiralty's letter suggested that they believed the tunnel to have been fully operational since 1943 however it later emerged that the facility had been damaged in a bombing raid during 1943 and repairs were incomplete when the war ended in 1945.[77] A small delegation from AEW supervised the dismantling of the cavitation tunnel in Germany prior to its re-erection at Haslar which began in 1947 and was completed in 1949 following work to shot blast and zinc spray the shell of the tunnel (Figure 10). Post-war financial restrictions meant that the building to house the tunnel was not begun until 1952 and No 2 Cavitation Tunnel was finally fully operational by January 1958.[78]

Located to the north of No 1 Cavitation Tunnel and directly linked to it via an elevated walkway, No 2 Cavitation Tunnel had a significant increased working section of 8 ft x 4 ft (the largest in the world at the time of its construction) compared to the existing facility and generally worked at a slower water speed of 15 ft/sec (Figure 11). The newly erected cavitation tunnel addressed the disparity between model data gained from experiments in No 1 tunnel and full scale data from sea trials caused by the lack of a model after body and its affect upon propeller cavitation.[79] The increased size of No 2 tunnel allowed the model propellers to be run in association with a whole or part ship model to more accurately reflect conditions experienced at sea. This capability proved crucial in the development of propellers for nuclear submarines whose hull design would have a pronounced effect on the cavitation characteristics of the propeller.

Post-War Additions

In addition to a greater emphasis needing to be placed on cavitation research to develop quiet propulsion systems, the Second World War also showed that a far greater range of experimentation and testing facilities was required. The requirements of modern warships and the more diverse range of vessels which comprised the Royal Navy's fleet demanded that the scope of investigations carried out at AEW Haslar increased beyond the hull resistance and propeller cavitation tests carried out before 1945. The experience of naval combat during the Second World had brought forward a range of new naval engineering challenges such as the need to sustain higher speeds in rough seas, the capability to manoeuvre rapidly in defence and attack and the need to anchor safely when in an exposed anchorage.[80] The development of submarines capable of increasingly high speeds also required a completely new approach to testing with regards to submerged control and silent propulsion.

One of the new facilities constructed at Haslar arose directly from wartime experience and the need to develop anchors with greater holding power. During 1943 Admiral Sir Bruce Fraser initiated investigations into the possibility of improving the efficiency of anchors and arrangements were made by the Director of Naval Construction for model experiments to be undertaken at AEW. These preliminary tests were undertaken in the centre dock of No 2 Ship Tank before a purpose built steel tank measuring 20 ft by 3 ft was installed above the boiler room in the workshop of No 1 Ship Tank. Although the results of the tests were promising, better provision for observing, measuring and recording the tests was required and

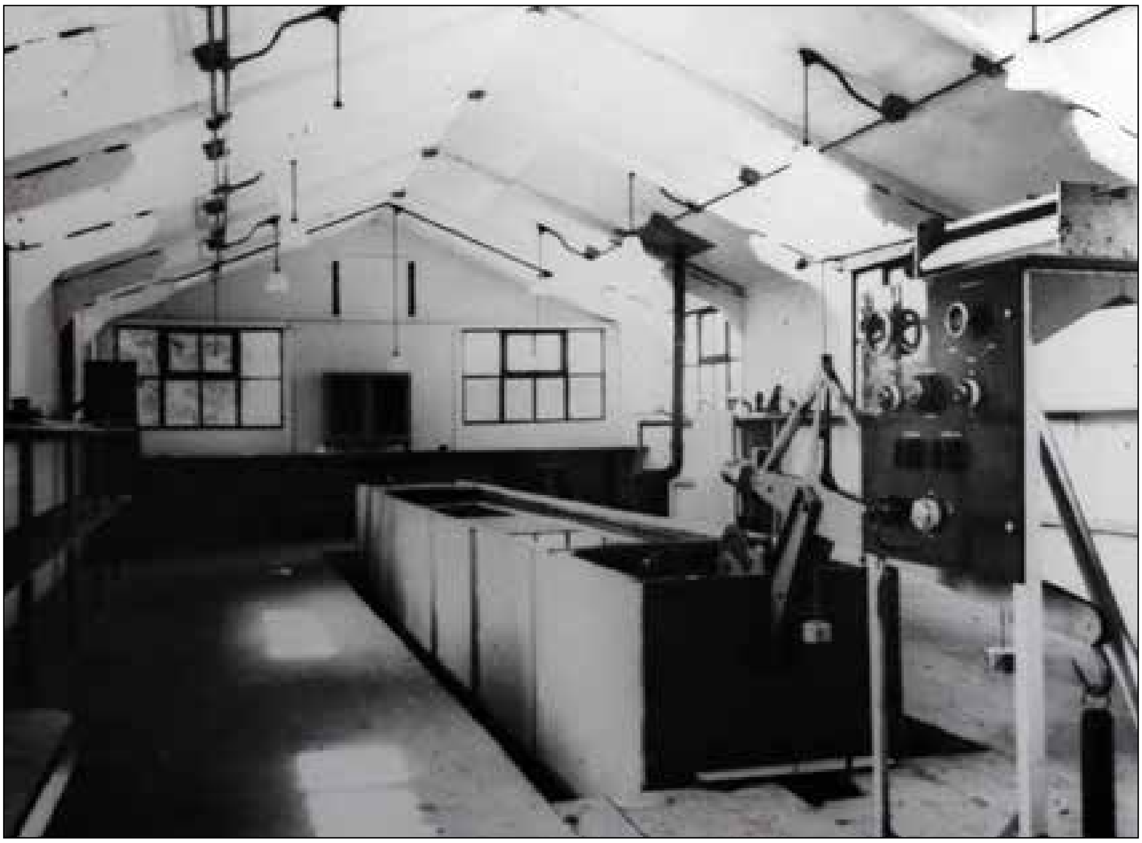


Figure 12: View of the anchor tank installed within a dedicated prefabricated building in 1947 (TNA ADM 226/59)

in 1946 a Minor Works Proposal was approved to transfer the tank to a separate, temporary building constructed at a low cost.[81] A pre-fabricated building, completed in February 1948 was authorised to accommodate the anchor tank (extended to 25 ft by 3 ft), storage space for models and measuring equipment and benches for drawing (Figure 12).[82] To conduct the tests, the tank was filled to a level of around 2 ft with silver sand and flooded with fresh water to simulate the seabed. The model anchors were hauled along the tank by a winch operated wire driven by a 2 bhp motor with a dynamometer used to measure the forces exerted on the model. In addition to experiments carried out in the anchor tank, model anchors were also tested in the mud of Haslar Creek, towed by a dinghy fitted with a dynamometer.[83]

The significantly increased programme of propeller testing brought about by the acquisition of No 2 Cavitation Tunnel and the requirement to develop more efficient and silent running propellers for high speed submarines led to the construction of a dedicated facility for the construction of propeller models. The propeller laboratory, complete by November 1951 incorporated a foundry, welding and grinding bays and a substantial workshop for the casting and finishing of the manganese bronze or aluminium-silicon alloy propellers (Figure 13).[84] The propeller laboratory was one of a number of ancillary facilities constructed at AEW between 1945 and 1960 (Figure 14). By 1950 a photographic laboratory had been added to the east of No 1 Ship Tank to deal with the increased demand for processing and printing the high speed photographs taken in the ship tanks, No 1 Cavitation Tunnel, anchor tank and on

Figure 13: Interior of the propeller laboratory (TNA ADM 1/23580)

Horsea Lake (see below). An electronic laboratory and annex was added and directly linked to No 2 Ship Tank, while a calibrating laboratory for the finishing and fitting of test models and the calibrating and assembly of testing equipment was constructed after 1952.[85] The settling tank of No 1 Cavitation Tunnel was also put to use as a wave laboratory for testing combinations of waves to replicate complex seas prior to larger scale seakeeping tests in the manoeuvring tank. Following the Second World War a greater emphasis was placed on the reduction of vibration of HM ships in order to achieve higher speeds, reduce detectable noise and to accommodate sensitive equipment such as radar and modern gunnery systems. Most vibration was caused by propellers, either hydrodynamically or from imperfections in the balance of the propeller. A small vibration laboratory was built immediately after the war in order to conduct comprehensive vibration tests using updated vibrographs during all first of class ship trials.[86]

In 1952 Ship Tank No 1, which had been in continuous use since its first test in 1887, began to demonstrate issues relating to the vibration of the wooden carriage as it passed along the length of the tank. This vibration was caused by the age and condition of the carriage, but also partly by the increased load placed upon it by the introduction of electronic measuring equipment.[87] The length of the tank also prevented constant speed being measured over a long enough test run. Between December 1956 and July 1957, No 1 Ship Tank was extended from 400 ft (122 m) to 538 ft (164 m), realising the 150 ft (46 m) extension which R E Froude had foreseen in 1882, and the dock area was modified to allow it to act as part of the accelerating run.[88] The wooden carriage was also replaced with an improved steel carriage.

Figure 14: 1:2500 Ordnance Survey map (1952) showing the development of the AEW Haslar site. © and database right Crown Copyright and Landmark Information Group Ltd (All rights reserved 2016). Licence number TP0024.

As had been the case when the tank was first commissioned, tests were run with the *Iris* model to ensure consistency and confirm that the testing equipment had been correctly configured following its reinstallation.

During this period of development at AEW Haslar, the test facilities were utilised in the design and construction of the Royal Yacht HMY *Britannia*. A replacement for the existing Royal Yacht HMY *Victoria and Albert* had been proposed by the Admiralty in 1938 with the replacement vessel designed so as to be easily converted to serve as a hospital ship during times of war.[89] The project was revived after the Second World War and in 1951 the Admiralty announced that a medium-sized hospital ship would be put into the rearmaments programme with the vessel used as the Royal Yacht in peacetime. With her role as a hospital ship in mind and the requirement for minimal vibration and the ability to reach a high speed, tank tests in rough and calm conditions were carried out at AEW Haslar on models of the hull design proposed by Messrs John Brown and previously tank tested in their own facilities. Extensive cavitation tests were also conducted in No 1 Cavitation Tunnel to determine the optimum number of blades to avoid vibration by propeller excitation, with the results indicating that four bladed propellers would reduce vibration levels in return for only a minimal reduction in speed.[90] The seaworthiness of the ship was also tested at Haslar. A $^{1}/_{32}$ scale model was towed head on at varying speeds into waves of varying sizes allowing the staff at AEW to conclude that the design had good seakeeping qualities. Following the conclusion of testing at AEW Haslar, HMY *Britannia* was built at the shipyard of John Brown & Co Ltd in Clydebank, before being launched by Queen Elizabeth II on 16th April 1953, and commissioned on 11th January 1954.

Horsea Lake and the Manoeuvring Tank

Although not physically linked to AEW Haslar, the man-made lake at Horsea Island, located immediately to the south of Port Solent and to the north-east of AEW Haslar across Portsmouth Harbour, was for a period of time during the 1950s used by AEW as an extension of its test facilities. Prior to 1889 Horsea Island had existed as Great and Little Horsea before their acquisition by the Navy in 1885 and physical amalgamation. Chalk from Paulsgrove chalk pit on Portsdown Hill was used to join the two islands and construct a torpedo testing range.[91] The land reclamation and excavation of the water range which measured 850 yards long, 100 yards wide and 30 feet deep was undertaken by convict labour and the test range opened in March 1889 as the Whitehead Torpedo Adjusting and Experimental Range before being subsequently extended to 1,115 yards (1,019 metres) in 1904 (Figure 15).[92] Between 1909 and 1960 a high power wireless station known after its 1924 rebuild as ‘Olympia’ operated on the northern bank of the water range and in 1943, concrete slipways for repairing landing craft were constructed to the south-east of the range in advance of the D-Day landings.[93]

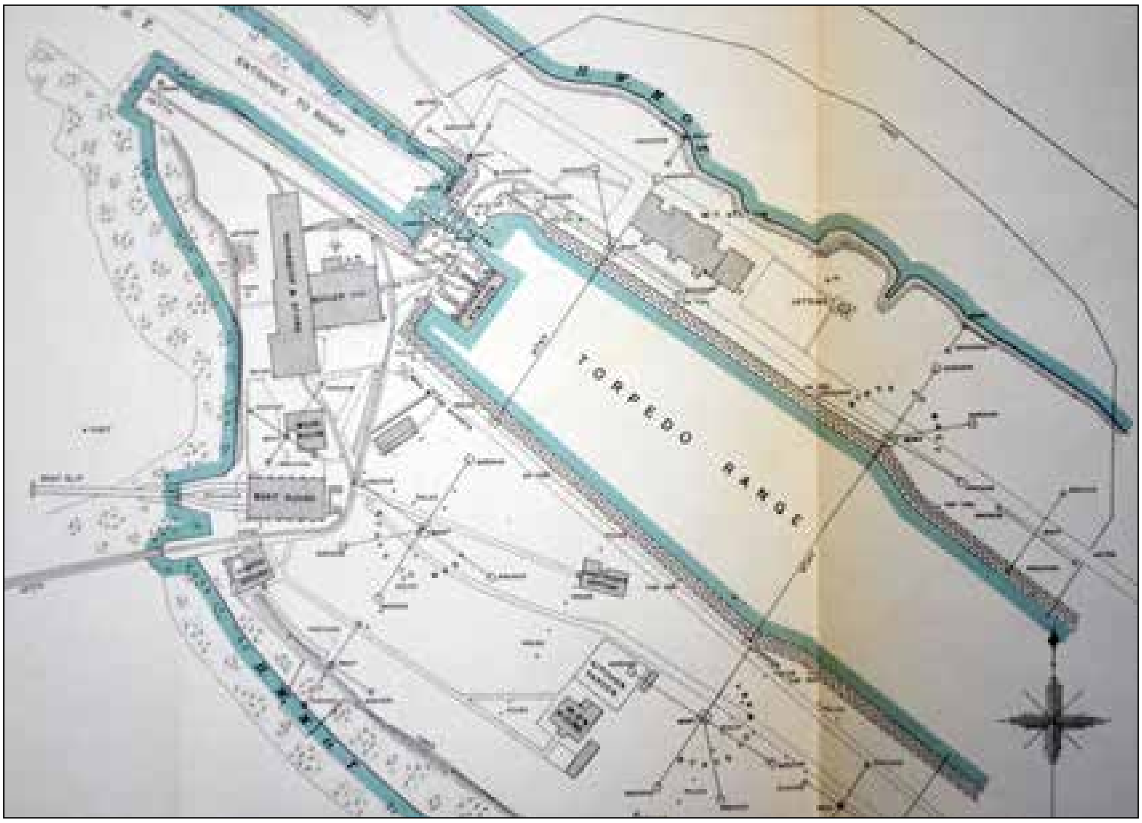


Figure 15: Admiralty plan of 1910 showing the torpedo test range on Horsea Island (TNA ADM 140/1484)

Figure 16: A model ship undergoing manoeuvring tests on Horsea Lake (TNA ADM 1/23580)

The Second World War had shown that the requirement for a ship to be able to manoeuvre rapidly in attack and defence called for more ambitious testing than could be achieved within the confines of No 2 ship tank.[94] The non-tidal waterway created at Horsea, which by the 1950s was used principally as a Navy diving facility was the obvious location to conduct steering experiments using self-propelled model ships, about 20 ft in size (Figure 16). To configure the lake for manoeuvring tests, AEW erected four 6 feet square concrete blocks on the banks of the range describing a rectangle 316 ft (96 m) by 150 ft (46 m). At the mid-length point between the blocks, opposed across the lake a white marker post and a small tower were constructed to allow accurate photography of the steering experiments.[95] Four new buildings were also constructed around the lake to complete the facility: an AEW building (35 ft x 18 ft), a drawing office (23.5 ft x 18 ft), a photographic dark room (11.5 ft x 10 ft 3 in) and an apparatus room (11.5 ft x 7 ft 9 in) in addition to a new floating dock.[96]

As the lake was uncovered to the elements, testing conditions were less easy to control and as such it was found that useful data could only be obtained on between one third and one half of all working days spent at the facility.[97] The lake however did play an integral part in the development of John Cobb's water speed record craft, *Crusader*, built by Vospers of Portsmouth. Since 1938 and instigated by Sir Malcolm Campbell, Commander Peter Du Cane, the Managing Director of Vospers and a former naval engineer, had been working in conjunction with the AEW to develop a record breaking hull based on the three-point hydroplane principal.[98] Extensive model tests were carried out in the Haslar towing tanks on different hull designs and alterations to *Bluebird K4* to accommodate a Goblin jet engine. In 1948, Du Cane switched his allegiances to John Cobb whose proposed record breaking hull received the full backing of both Vospers and the Director of Naval Construction.[99] By June 1950, 11 different model variants of the design of Cobb's craft had been tank tested at Haslar leading to finalisation of the design and a progression to propelled model testing. In December 1950, a $^1/_6$ scale model of the hull was built by Vospers and fitted with a cordite solid fuel rocket motor to replicate the intended jet engine and an AEW gyroscope to keep the model running straight and true. On the 25th January 1951, the model reached a speed of 97.5 mph on the lake at Horsea[100] A further test at Horsea on 21st February in bad weather was less successful, with the model rearing up and turning over after 200 yards of running.[101] Cobb was undeterred though and after securing a De Havilland Ghost jet engine from the Ministry of Supply, had Vospers construct the full scale craft, which he named *Crusader* and which was given the Lloyds unlimited rating, K6.[102] Tragically, Cobb's attempt on the speed record would end in disaster on Loch Ness on the 29th September 1952 when, travelling at over 200 mph, *Crusader* hit a series of rolling swells causing her to porpoise violently, destroying the craft and killing Cobb instantly as he was ejected from the cockpit.[103]

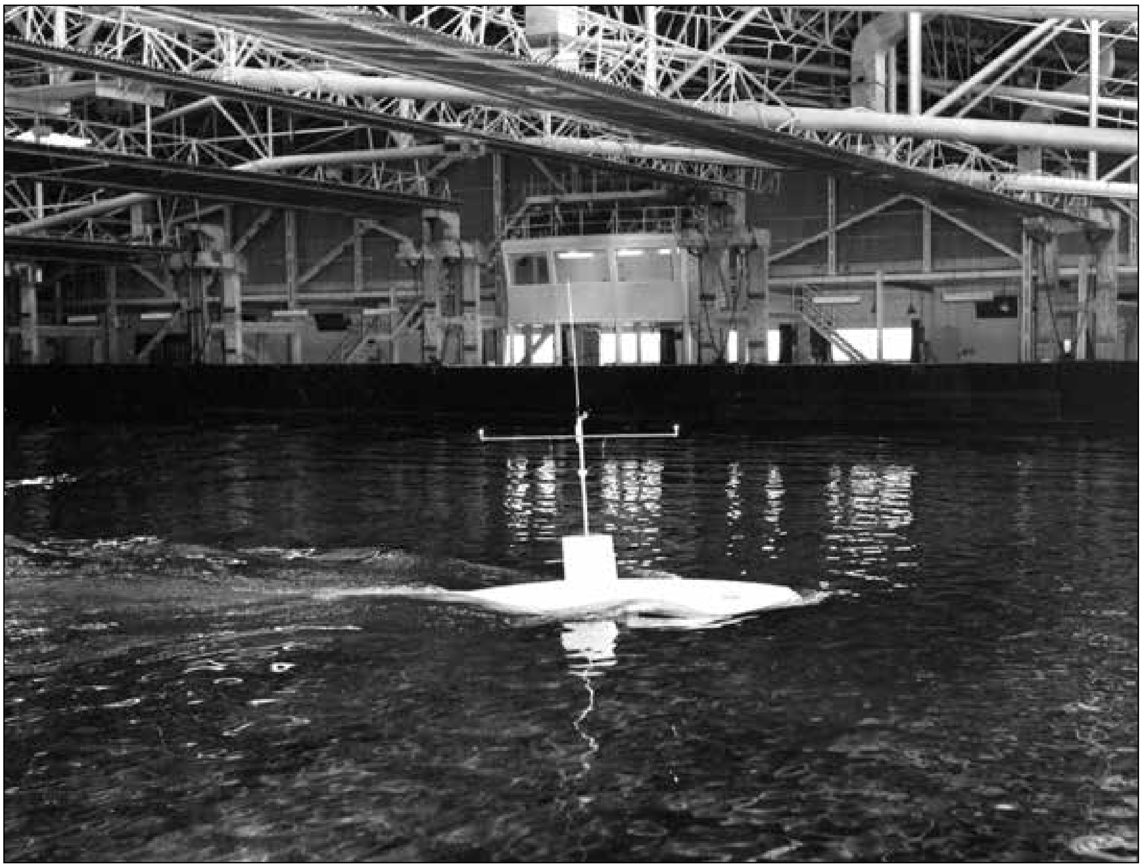


Figure 17: A self-propelled model of the submarine HMS Dreadnought *undergoing tests in the manoeuvring tank. Beyond the model is the north-western end of the tank with its bank of six wavemaking plungers and the central wavemaker control room (IWM 2005-02-20 19199)*

The experience with the second *Crusader* model test and the inconsistent data obtained in manoeuvring tests on Horsea Lake led the Admiralty to approve in 1953 plans drawn up in 1942 for the building of a large covered tank on the Haslar site.[104] The manoeuvring or ocean trials tank, as it has also been known, comprised a covered concrete pond 400 ft (122 m) by 200 ft (61 m) and 18 ft (5.5 m) deep for the testing of model ships under conditions simulating those experienced while manoeuvring in both calm water and in waves.[105] The tank also allowed applied research in new fields including directional and dynamic stability and response to rudder inputs, general seaworthiness, the ability to maintain high speeds in rough seas and the control of high speed submarines.[106] The latter became increasingly important in the post-war period when surface performance of submarines became completely subordinate to submerged speed.[107] This requirement led to the whole project being recast to include a rotating arm for testing dynamic stability at one end of the tank, 95 ft (29 m) in diameter and supported on a central concrete island 20 ft in diameter adjacent to a dry-dock which allowed for the rigging of submarine models.[108] The rotating arm was first used for model experiments in July 1960 and was used to test submarine models in both the horizontal and vertical planes to derive equations of motion and stability criteria.[109] In the opposite (north-eastern) corner of the tank to the rotating arm, two banks of five plungers with a range of stokes and frequencies were included in order to generate waves (Figure 17).

The cost of building the manoeuvring tank, which would become the biggest facility of its kind in Britain, was £700,000 exclusive of the associated machinery and a site formerly occupied by allotment gardens in the north-east of the AEW site adjacent to the gunboat yard slips was chosen.[110] Levelling of the site commenced in February 1954 by Messrs A E Farr Ltd with excavation of the tank itself by dragline undertaken by G Wimpey & Co Ltd in August 1954.[111] The contract for constructing the tank was phased in three stages: the construction of the tank floor, walls, rotating arm base and piling in the first phase, a full water test in the second phase and the completion of the building around the tank in the final phase. The work was contracted to Messrs Trollope and Colls for completion in 34 months from the 1st May 1955.[112]

The tank was designed to be flexible when settling under the weight of the water within it and to combat the rising ground water expected to be a recurrent issue as the site was only just above the high water level of Haslar Lake, and construction of the poured concrete tank was completed in July 1956. The filling of the tank with 10,000,000 gallons of fresh water for the water test was scheduled to take two weeks with a further three and a half months scheduled for the tank to stand under the load of water.[113] The existing fresh water supply to the AEW site was insufficient for the task and a new 12 inch pipe across Haslar Creek to Gosport had to be laid. The water test resulted in less settlement than had been expected and the flexible design of the structure ensured that no serious cracks or faults occurred, though sumps were hastily added around the perimeter of the structure to pump out rising ground water.

The tank, complete with its peripheral buildings for housing the staff, workshop machinery, testing equipment, electric sub-stations and necessary space for preparing the models for testing was scheduled to be in full use by 1959, though in the event the first model tests were conducted in September 1956 during the water test. The tank was officially opened by the Duke of Edinburgh on 18th December 1961 during which he performed the customary tradition of 'blessing' the tank with a small amount of the water taken from Froude's Torquay tank.[114]

In the first years of the tank's operational life, problems were experienced with the waves generated by the wave makers, with waves longer than 25 ft tending to sweep round the island created by the rotating arm's base, reform on the far side and create higher waves which crashed over the gate and into the dry dock.[115] The entrance to the dock interrupted the wooden beach created to suppress the waves which splashed into the dock making the job of rigging the models for testing quite hazardous. Tests were conducted in 1962 with a pneumatic breakwater fitted at the dock entrance which discharged compressed air from a 30 ft pipe adjacent to the dock. This method was found to be an effective way of reducing the force of the waves impacting on the dock gate.[116]

Naval Auxiliary Machinery Department

In 1966 the Admiralty Fuel Experimental Station (AFES), reflecting the change in its work away from liquid fuel research towards the testing of naval auxiliary machinery was renamed the Admiralty Marine Engineering Establishment (AMEE). The Haslar establishment became a sub-department of the National Gas Turbine Establishment at Pyestock and its work moved away from its historical role of boiler development into the broader spectrum of marine engineering and the development of turbines and diesel engines. A shoreline area of the AEW site to the west of the manoeuvring tank, lightly occupied c.1939 with a pump house to draw salt water from Haslar Lake, a condenser house and boiler house, was redeveloped between 1952 and 1969 (Figure 18).[117]

Figure 18: A view from across Haslar Lake of the buildings of the AMEE formerly NAMD (IWM 2005-02-20 1452/81)

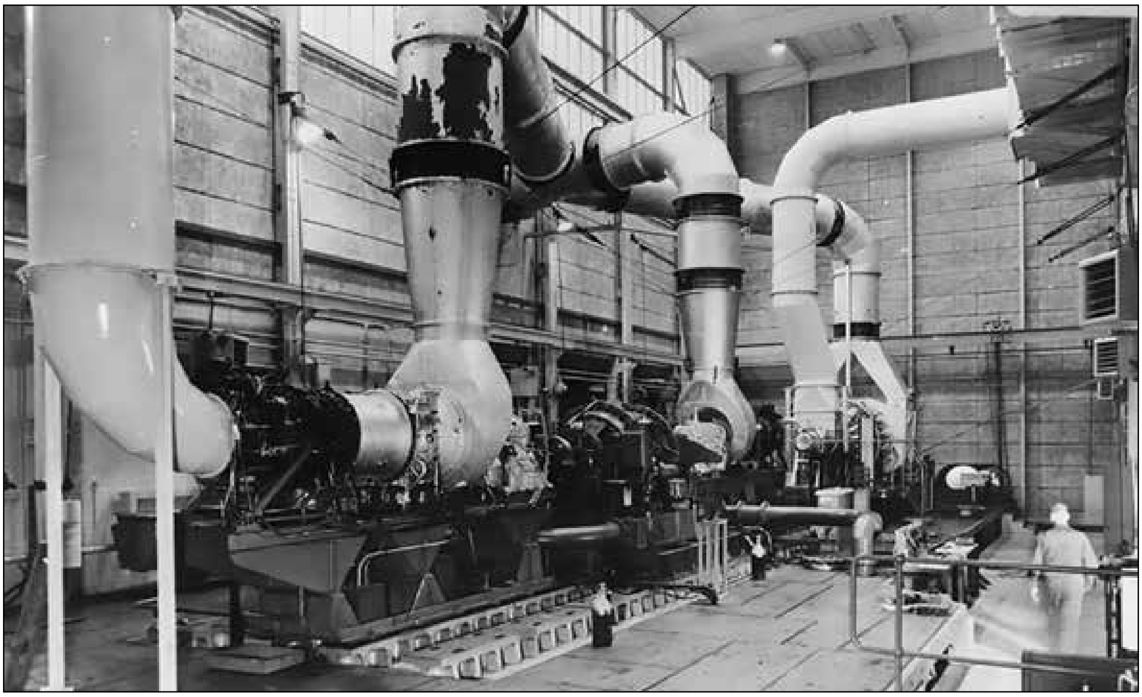


Figure 19: A marine turbine under test at NGTE Pyestock (IWM A 32455)

By 1976 the establishment again changed its name to become the Naval Auxiliary Machinery Department whose primary task was the development and testing of auxiliary machinery and components for marine engineering installations on ships and submarines.[118] Central to this was the need to simulate realistic conditions to test the effect of seawater on machinery such as propulsion auxiliaries, auxiliary boilers, air compressors, pumps, valves and flexible connectors.[119] The NAMD facilities at Haslar, which in 1979 transferred from NAMD to AMTE included a design office, materials laboratory, machine, plate and piping shops, an instrumentation workshop, steam plant with specially designed John Thompson boilers and a two large test houses for testing machinery and auxiliary boilers.[120] A series of tidal ponds had been created on the shoreline to ensure a constant supply of water from Haslar Lake even at low tide, with two submerged inlet pipes (still visible on satellite images) feeding a pump house and a condenser house. The largest of the buildings of NAMD, the Auxiliary Machinery Test House, may have served a similar function to the Admiralty Test House at NGTE Pyestock, namely the study and endurance testing of gas turbines under marine conditions (Figure 19). Admiralty Test House was equipped with its own cooling tower, water and fuel pumping stations, an arrangement which seems to have been mirrored at Haslar.[121]

Circulating Water Channel and Administration Building

By 1972 the final elements of AEW Haslar had been added to the site, firstly in the form of a large administration building to the north of the calibrating laboratory and then finally with the addition of a small circulating water channel. A building to the immediate north of No 2 Ship Tank and east of No 1 Cavitation Tunnel was constructed in 1971 to house the circulating water channel which had a working cross section of 4 ft 9 in x 2 ft 7 in. Similar in principle to a wind tunnel but filled

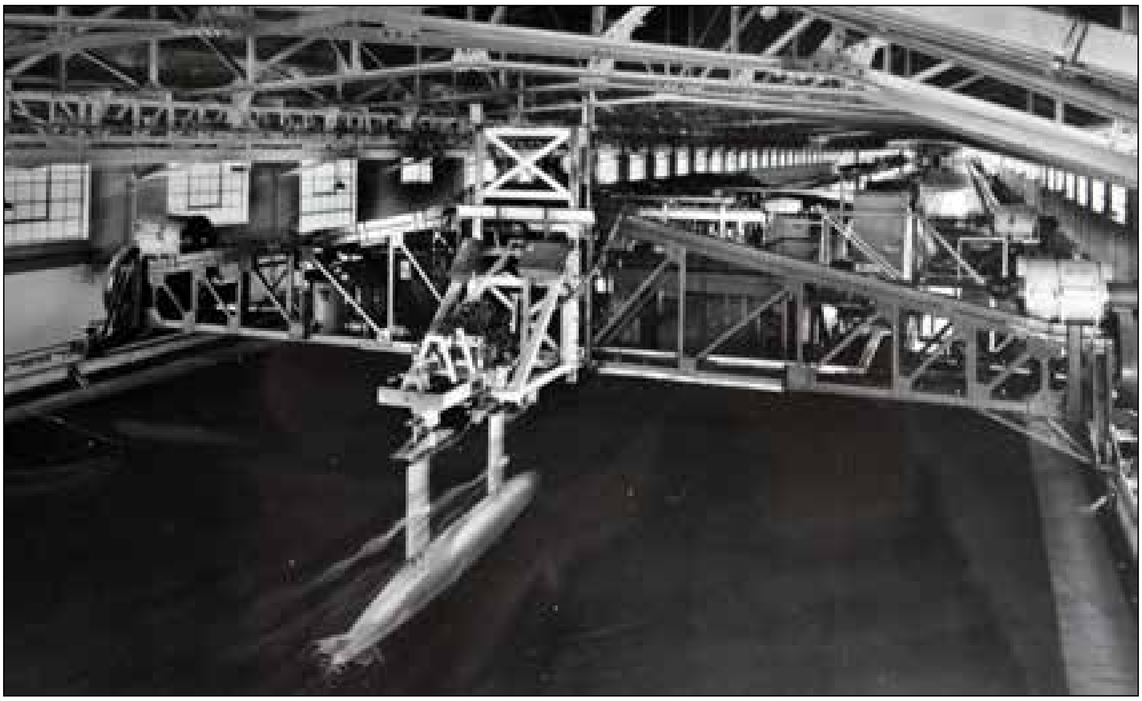
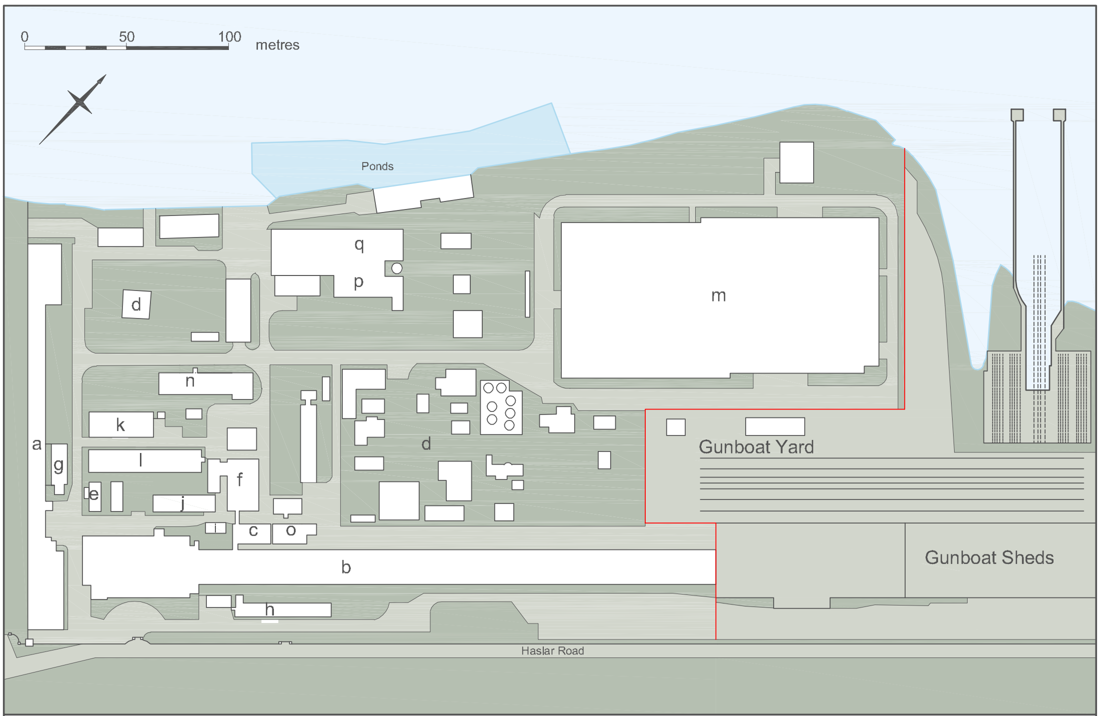


Figure 20: The carriage of No 2 Ship Tank following the addition of the Planar Motion Mechanism to allow a greater range of tests of model submarines (TNA ADM 226/1258)

with water, a circulating water channel was used to scale the Froude number and to conduct research into flow conditions over warship hulls. In that respect a circulating water channel could conduct many of the same tests as performed in No 1 and No 2 Ship Tanks but with a number of significant advantages. Principal among them were that the models and equipment remained stationary while the water moved past them which both more accurately replicated real world conditions and made photographic recording and measuring far simpler as the objects were stationary. The tests conducted in a circulating water channel were also theoretically unlimited in their duration whereas in a towing tank the length of the test was restricted to the length of the tank.[122] At Haslar tests were particularly focused on how flow conditions over ship hulls were affected by the incorporation of large sonar arrays.[123] The addition of the circulating water channel did not signal a reduction in the testing programme conducted in Ship Tank No 2, the carriage of which had been updated in 1970. The advent of high speed nuclear submarines required advances in the fields of submarine stability and control. The result was the development of the Planar Motion Mechanism for the measurement of forces and moments acting on a submarine model while running submerged at various attitudes, or when oscillated in a vertical plane.[124] Such a mechanism was fitted to the carriage of No 2 Ship Tank during the 1970 upgrade.

Privatisation and Site Clearance

The amalgamation in 1991 of AEW, or ARE as it had been from 1984, to form the Defence Research Agency (DRA) saw a streamlining of the facilities at Haslar. In 1993, R E Froude's No 1 Ship Tank was closed and subsequently converted into office space. That year also saw the beginning of the demolition of buildings on the AEW site including No 1 Cavitation Tunnel.[125] DRA's integration into DERA and the reconfiguring of the AEW site as the Haslar Hydrodynamics Test Centre in 1995 brought about further demolitions with the removal of the propeller, vibration, calibrating, wave, electronics and photographic laboratories, the anchor tank and the remnants of the AFES.[126] This process also saw the completion of a new environmental sciences building populated with staff and equipment moved from Farnborough, Holton Heath and Alverstoke and the removal from the National Physical Laboratory, Teddington, of a 30 inch section 'quiet water' tunnel to Haslar for propulsion research which opened with the environmental sciences building on 4th October 1996.[127] Site clearance continued into 1998 when the test boiler house of the Naval Auxiliary Machinery Department was demolished and the remaining pipelines removed. The most recent addition to the AEW site was made after privatisation and rebranding as the Haslar Maritime Technology Park with the opening on 25th January 2012 of the Diving and Hyperbaric Test Chamber. This facility was originally established at Alverstoke and incorporates an open water diving tank, environmental cabin, the hyperbaric trials unit and a hydrostatic and extreme temperatures tank.[128] A quiet wind tunnel was also installed at Haslar and is located in a portacabin situated between the waterway of No 2 Ship Tank and the Haslar Road boundary wall.[129]



KEY

a	No. 1 Ship Tank (Bldg 23)	g	Photographic Laboratory	m	Manoeuvring Tank (Bldg 82)
b	No. 2 Ship Tank (Bldg 101)	h	Electronics Laboratory	n	Administration Building (Bldg 145)
c	No. 1 Cavitation Tunnel	i	Wave Laboratory	o	Circulating Water Channel (Bldg 144)
d	Fuel Experimental Station	j	Vibration Laboratory	p	Auxiliary Boiler Test House (Bldg 13)
e	Anchor Tank	k	Calibrating Laboratory	q	Auxiliary Machinery Test House (Bldg 12)
f	No. 2 Cavitation Tunnel (Bldgs 46 & 47)	l	Propellor Laboratory		

Figure 21: An annotated plan of the AEW Haslar site prior to privatisation and site clearance showing the major buildings and known testing facilities (redrawn from the 1969 Ordnance Survey map)

Setting and Landscape

The QinetiQ Haslar Marine Technology Park is situated on the northern side of Haslar Peninsular, the southernmost spit of land on the west side of Portsmouth Harbour, and at the height of the AEW occupied a site covering c. 95, 863 m^2. Haslar Lake, the lowest part of Haslar Creek before the latter flows into Portsmouth Harbour, forms the northern border down to which the site gently slopes. To the south, the QinetiQ site is separated from the mid-18th century Royal Hospital Haslar by Haslar Road which runs south-west to north-east along the length of the site before crossing the Haslar Bridge to Gosport. To the west of the site is the Haslar Royal Naval Cemetery and directly to the east is the former Haslar Gunboat Yard into which the AEW gradually encroached as it expanded after the First World War. A brick wall with watchtowers and sentry walks of c.1856 encompasses the entirety of the former AEW site and gunboat yard along their eastern, southern and western extents describing a roughly rectangular site with the shoreline to the north. The site is orientated on a north-east to south-west alignment which follows the shoreline of Haslar Lake and the route of Haslar Road.

No 1 Ship Tank borders the south-western boundary of the site, orientated perpendicular to Haslar Lake to the north and Haslar Road to the South and No 2 Ship Tank is orientated parallel to Haslar Road and perpendicular to No 1 Ship Tank to the southwest. No 2 Cavitation Tunnel and the adjoining building housing its water tanks are situated to the north of No 2 Ship Tank, with the building orientated at right angles to Haslar road to the south. The largest building on the site, the manoeuvring tank occupies a position in the north-eastern corner of the site parallel to Haslar Lake and to the south-west of the jetties of the former gunboat yard and north of the site of its transverser rails. On the northern shoreline adjacent to a series of header ponds are the buildings of the Naval Auxiliary Machinery Department, while north-west and south-east of No 2 Cavitation Tunnel respectively are the administration block and the circulating water channel building. The current entrance is from Haslar Road at the south-west corner of the site and is accessed through a security control point though historic entrances are still discernable in the southern perimeter wall adjacent to the workshop of No 2 Ship Tank.

No 1 Ship Tank (Building 23)

The oldest building on the site and the direct successor to William Froude's Torquay tank, No 1 Ship Tank, its workshop and offices, northern extension and drawing office, occupy a site parallel to the south-western boundary, extending from Haslar Road to the south to just short of the Haslar Lake shoreline. Construction began in 1886 and the original building, comprising the single range housing the waterway and the double-gabled range adjoining to the south-east which housed the model making workshop, boiler room and offices was operational by April 1887. A later 139.6 ft northern extension of the waterway and the addition of a drawing office adjoining the extension were completed in 1957. All of the ranges are English bond brick construction beneath pitched roofs of Welsh slate with skylights, save for the later drawing office and dock range which is flat roofed behind a low parapet with concrete coping stones. No 1 Ship Tank closed in 1993 and was converted into offices, necessitating the insertion of new fenestration (Figure 22). However, the test tank survives beneath the inserted floor of the new office space forming a basement for the commercial units. The survival of the tank inclusive of the stepped walls at the dock end (to supress waves created during testing) has ensured that the building has retained much of its original character and significance and that the potential for below ground archaeology related to the building's original function remains high.[130]

The principal element of the No 1 Ship Tank is the long range which housed the tank itself (Figure 23). As constructed in 1886, the waterway was 400 ft (122 m) in length, 20 ft (6 m) wide and 9 ft (2.7 m) deep, with vertical sides and a flat bottom. The single range, single storey brick structure which covered the tank was originally blind its south-western elevation. This elevation was built up from the original 1856 boundary wall of the AEW/Gunboat Yard site which extended beyond the northern end of the waterway to the Haslar Lake shoreline.[131] The north-western wall has recessed panels each around 15 ft in width and, following the conversion

Figure 22: AEW Haslar from the north in 2011. No 1 Ship Tank (right) was converted for use as offices in 1993 however the former workshop (top), waterway and later drawing office (bottom right) remain discernible elements of the building. Also pictured are the Administration Building (bottom), No. 2 Cavitation Tunnel (left) and the workshop of No. 2 Ship Tank (top left). (HEA 26941/14).

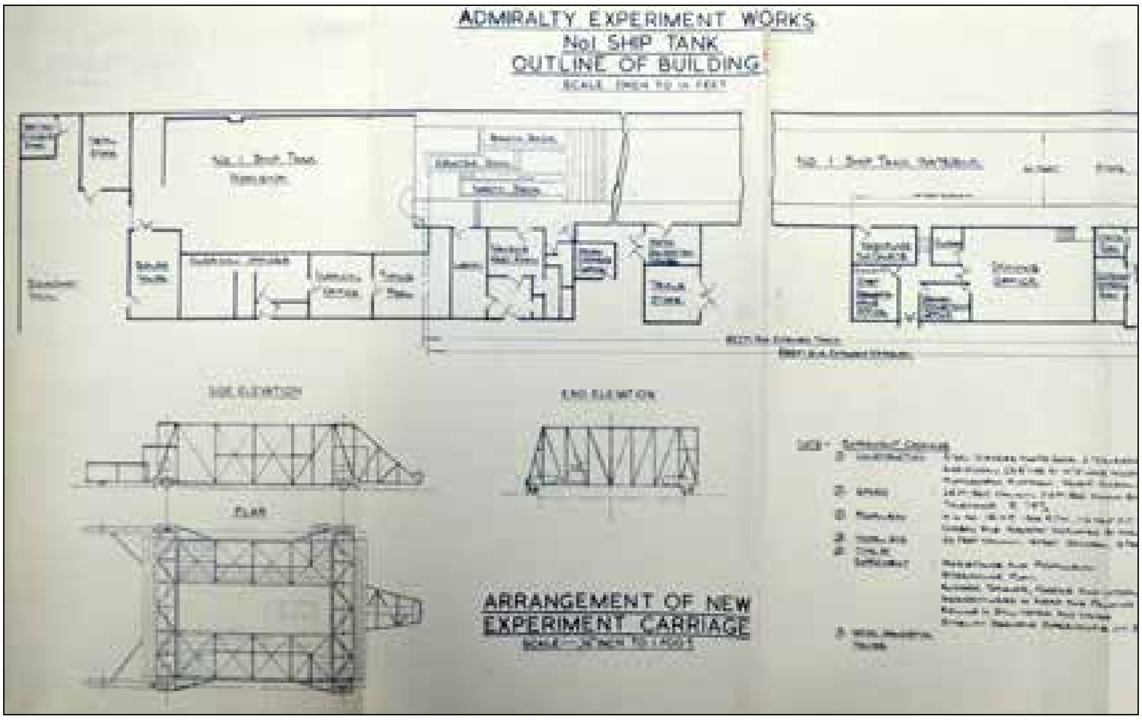


Figure 23: Plan, elevation and section of No 1 Ship Tank in 1958 (TNA ADM 226/644)

to offices, punctuated with a modern three-light windows. The panels correspond to brick pillars or buttresses visible in the interior of the north-west wall and it is possible that, in common with No 2 ship tank, the bases of these buttresses or a supporting arcade are landscaped beneath the current ground surface. The north-east elevation is of corresponding brick panels and appears to have been largely blind save for a number of small, single-pane, square windows. These windows were once fitted with pull down blinds in order to control the lighting conditions for photography of the tests. Since the conversion of the tank building to offices, modern two pane windows have been inserted into the remainder of the panels, though the small windows remain. Three new entrances have also been added to the north-east elevation in order to access the subdivided offices. The entrances are raised above ground level reflecting the inserted floor above the waterway and are housed in glazed porches. The southernmost of these porches roughly marks the location of the photographic laboratory which was directly joined to the ship tank and demolished after 1993.

The pitched roof over the waterway is of wooden boards with Welsh slate tiles. The 400 ft (122 m) long roof as constructed in 1887 was carried on 40 timber trusses of king post design with iron supporting straps. Each truss is clearly numbered, to aid operators in judging braking the carriage during experiments, and these numbers are still visible, as are the trusses within the current office configuration (Figure 24). The roof of the 1957 extension to the waterway is of narrow timber boards with matching Welsh slate tiles and is carried on steel trusses of similar design to their timber counterparts with a central strut and diagonal braces. The roof is currently punctuated by 18 pairs of skylights on either side of the ridgeline arranged in three groups, the northern group of nine pairs, the central group of three pairs and the southern groups of six pairs closely spaced. A further row of seven single lights occur on the eastern half of the roof only. Photographs taken at the time of the tank's closure show that the extension to the waterway originally had uninterrupted rows of skylights, two rows on the north-eastern side of the roof and one on the south-western. In contrast, the original section of the roof was without skylights and relied on artificial light. The alterations to the skylights of the extension and the insertion of new lights to the original section of the tank building may indicate that the roof was refreshed at the time of conversion to offices.

The interior of the waterway range has been altered to facilitate the conversion to offices, though two lengthy sections of the original waterway beneath the numbered timber trusses have not been subdivided and retain much of their original character save for the inserted fenestration.[132] The southern end of the waterway was fitted with three docks; north, south and central with the latter longer and set back. Each had a lifting steel sluice gate and steps down to allow the transfer of models to the waterway.[133] Rails on either side of the waterway for the model carriage to run on were fitted during the 1957 extension and improvements to the carriage. These rails also carried a moveable footbridge.[134] At the northern end of the extension an artificial beach of sand and gravel was created to supress the waves created by the model as it passed down the tank, returning the water in the tank to a still state to begin the next experiment.

Figure 24: View from the south along the waterway of No 1 Ship Tank in 1993 (HEA BB94/5069)

Adjoining the waterway at its southern end and contemporary in date is a single-storey double range building which accommodated the model workshop and offices. The twin rooflines give the impression of two distinct ranges indicative of a later extension however Ordnance Survey maps and the internal arrangement of the rooms suggest a single range of a single phase. The south-west elevation has nine recessed panels and was originally blind though windows have been inserted into the northern bays following the closure of the tank. The south-east elevation also has recessed panels though it appears to have been fenestrated from the start to light the clerical offices within. The roofs are both of Welsh slate with coped gables to the north-west elevation and are hipped to the south-east elevation. Within the building, a large workshop for the construction of models extended under both roofs covering approximately two thirds of the floor space. The workshop was flanked to the north-east by clerical offices and boiler house which occupied the south-east corner. The boiler house retains its tapered rectangular chimney with a stepped out stack carried on brick corbels above machicolation. A low range of service buildings between the south-eastern elevation and perimeter wall obscures the former fenestration.

The extension of the waterway to a total length of 539 ft (164 m) necessitated the extension of the tank building along the existing length of the boundary wall. The length of extension is clearly discernible inside the building by the absence of the buttresses to the northern end of the south-west elevation.[135] The extended

Figure 25: North-eastern elevation of the 1957 extension of No 1 Ship Tank and the new drawing office indicating the height of the raised dock area within (HEA BB94/5075)

waterway was supplemented by an ancillary range, 100 ft (30.5 m) in length adjoining the north-east elevation of the extension. A single-storey building with flat roof, the north-east elevation is of 13 bays, the southern ten comprising the drawing and other offices and the three wider bays to the north, the 'working space' and dock (Figure 25). The second bay from the southern end of this range forms the entrance with a pair of wooden doors within a brick porch, with the remaining nine bays of this section of the elevation each having three-pane metal framed windows. The southern-most bay of the dock and working space section of the building, distinguished as it is by a slight step out from the elevation of the offices, has a pair of wooden doors at ground level, while the central and northern bays have their respective wooden doors and metal framed windows raised off the ground indicating that the dock area within was also raised. The north-western elevation has three sets of three-pane metal framed windows with a further two sets in the pitched gable end of the waterway extension which has concrete coping to match the gables of the workshop range. Internally the ten bay office section of the flat-roofed range was divided roughly equally between the drawing office to the north and the draftsman's offices and toilets to the south.[136]

Of the buildings of the former AEW which survive in 2016, No 1 Ship Tank has been subjected to the most alteration and as a result has lost more of its original character. That ship model experiments are no longer conducted within the building, the tank has been drained, new fenestration has been insensitively added and internal sub-divisions have been inserted, dramatically alter the character of the building which was not listed prior to its conversion to offices. The alterations have not however affected the historical significance of the building which is second only to the far smaller commercial tank built in 1882 by Denny's shipyard at Dunbarton in the list of the oldest surviving ship testing tanks in the world and more significant than the tank built on the Isle of Wight in 1910 for Sir John I Thornycroft which was listed in September 2015 (NHLE 1426608). The longevity of the facility at Haslar, which was in continuous use between 1887 and 1993, save for the first six months of 1957 when it was being extended, sets it apart from other testing facilities of its type. During its 106-year lifespan, more than half a million experiments were carried out on a wide range of ship classes, playing an instrumental role in the development of warships for two world wars and the development of the modern navy after 1945.[137] The building is the direct descendant of the tank at Torquay where the AEW was formed and where William Froude made pioneering advances in the field of hydrodynamics and as such it is of international significance.

No 2 Ship Tank (Building 101)

No 2 Ship Tank was the second testing facility constructed on the AEW Haslar site. Built in response to the success of the hydrodynamic testing programme on the development of the surface fleet during the First World War and the requirement for a long tank to test at higher speeds, No 2 Ship Tank and its workshop were completed in 1930. The tank, tank building and workshop are orientated south-west to north-east and run parallel to the boundary wall which separates the AEW site from Haslar Road. The combined length of the tank building and workshops remains 1024 ft (312 m) as built and the eastern end of the waterway building adjoined the sheds of the neighbouring Haslar Gunboat Yard. Both the tank building and workshop are of English bond red brick beneath pitched roofs of Welsh slate with coped gables carried on steel principal rafters. The roof of the workshop range to the west is punctuated by skylights while the tank range has three ridge lanterns evenly spaced along its length and a short section of glazing cut directly into the roof west of that range's mid-point. The tank remains in use by QinetiQ for 'constrained hydrodynamic model tests of surface ships, submarines, off-shore structures and renewable energy devices' and retains its original dimensions and layout.[138] Approximately 30% of the tank is below ground level and the majority of the arcade piers which support the tank building (see below) are buried beneath earthen banks which flank the tank to the north and south giving high potential for archaeology.

The principal element of No 2 Ship Tank is the tank or waterway which, inclusive of its docks extends eastwards for 928 ft (283 m) from inside the workshop building. The concrete tank measures 40 ft (12 m) across by 15 ft (4.5 m) deep in internal cross-section and sits with its equator at ground level both removing the need to excavate to its full 18 ft depth (inclusive of the 3 ft. thick tank base) and raising the base of the tank above the level of ground water negating the chance of the tank base being forced upwards. The tank has gently tapered sides and a steeper batter of 1 in 12 at their bases and was originally stepped at either end to accommodate beaches with only the central section of 550 ft (168 m) the full 18 ft (4 m) depth. At 13 ft 4 in intervals,

Figure 26: Aerial view of the eastern end of No. 2 Ship Tank showing the exposed arches of the arcade which carries the tank building (HEA 26/26941/016)

horizontal limbs cast as part of the tank rest on piers of an arcade of 64 arches which extend along the length of both sides of the tank as a far as the workshop. This arcade supports both the water level walkways which extend along both sides of the tank and corresponding brick pillars along the length of the tank building which carry the principal rafters of the roof structure. Two earthen banks (most likely constructed of the spoil excavated during the construction of the tank) between ground level and tank water level obscure all but the eastern four arcades and give the tank building the appearance of a single-storey building, though the eastern gable reveals the full height of the structure.[139] The exposed arches of the eastern end of the arcade may allow access to the underside of the tank which due to the stepped base at the eastern end is above the surface of the ground. The eastern end of the tank warrants further investigation as a handwritten annotation on the 1927/8 plan indicates that the planned shelved shallow end was not constructed as designed (Figure 27).[140] Further west are a number of small adits cut into the earthen banks, presumably to afford access to valves and drains in the lower reaches of the tank.

The tank building which rises from the concrete arcade comprises 64 recessed brick panels between the brick pillars extending from the piers below. Each of the panels carries a 35-pane steel frame window with a central pivoted opening. Within the 28th bay from the eastern end, a pair of opposed brick porches, raised on plinths beneath flat roofs, both retain hoists and wide doorways for accessing the mid-point of the waterway. To the west a further 11 bays along the south-eastern elevation, a larger, two-storey porch of brick construction with a pitched roof may have served as the dining room and toilets alluded to on the 1927/8 drawings.[141]

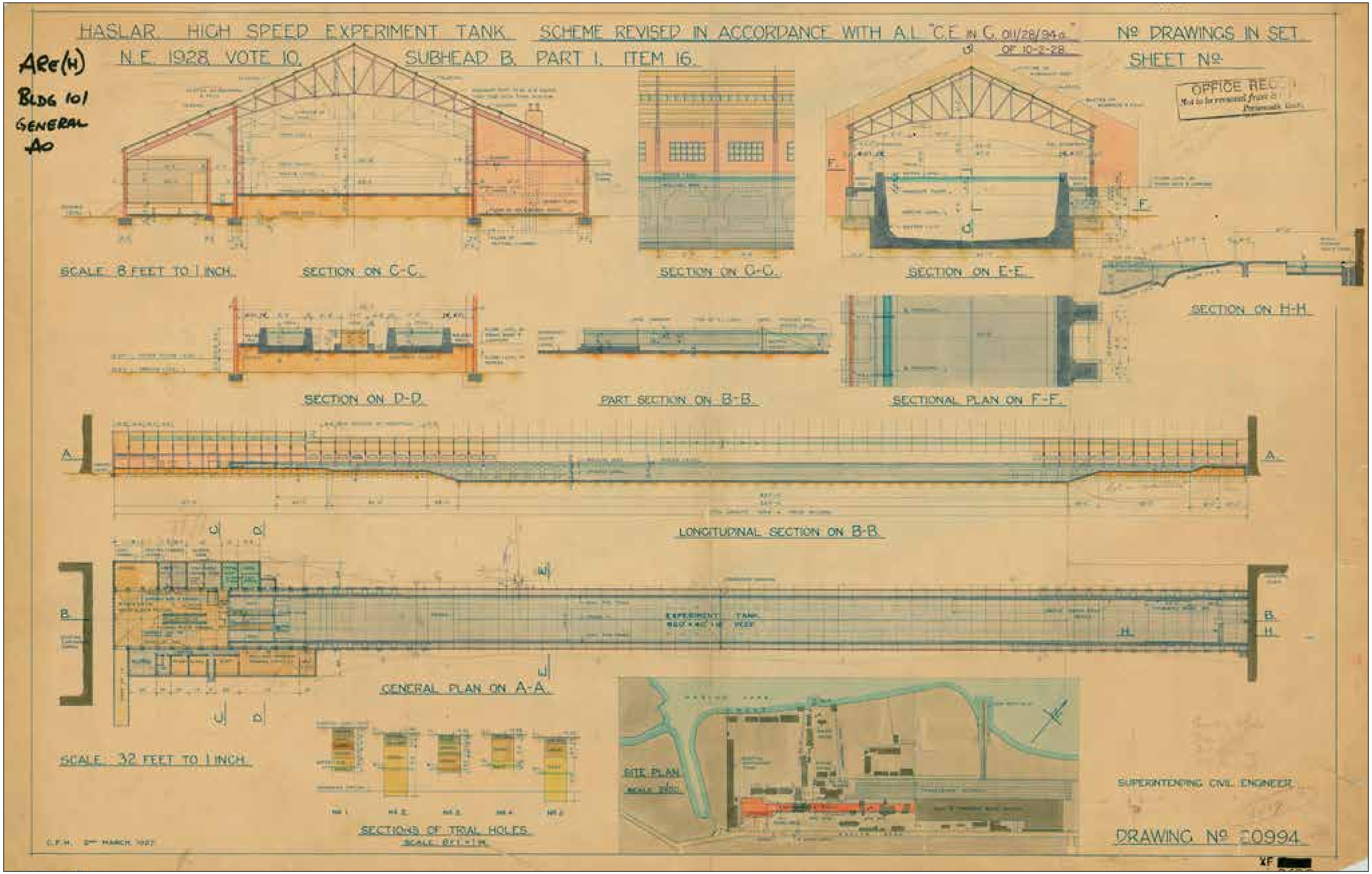


Figure 27: Plan, elevation and section of No 2 Ship Tank as proposed in 1927. The tank amd offices as built differed slightly from the plan, as indicated by various pencil annotations (HEA MD95/06498)

The roof over the tank building is carried on canted steel principal rafters 53 ft (16 m) in span seated on RSJ stanchions within the brick columns of the side walls. Each principal is 13 ft 4 in apart corresponding to the centres of the arcade piers which carry the building and support the tank. The Welsh slate roof has two rows of skylights which run between the 21st and 35th bays from the east and three raised ridge lanterns each glazed to their north and south sides with seven groups of three pane steel windows. These ridge lanterns do not appear on the architects' drawings of 1927/8 but do not appear to be a later addition. Gutters to each side of the tank building roof connect with triangular hoppers which feed tubular down pipes.

Internally the tank has traveller rails along the long walls of the waterway to carry the models and recording equipment mounted on a wheeled carriage. Either side of the waterway is a narrow walkway at water level between the waterway and the walls of the tank building. As is the case with No 1 Ship Tank, the bays of the tank building are numbered and the distance in metres from the wavemaker is marked at intervals along the length of the waterway. At the western end of the tank, a beach built on the tank's stepped base to suppress the waves created during the experiments continued a design characteristic instigated in the Torquay tank while at the eastern end of the tank a wave maker allowed for a wider range of towing tests and simulated sea conditions.[142] In 1995 a new wave maker was installed and the beaches appear to have been removed.[143] To the west of the waterway and surrounded by the rooms of the workshop range, a pair of docks with a deep central lock facilitate the launching of models into the tank's waterway.[144]

The workshop range to the west of the waterway occupies a site 175 ft (53 m) by 105 ft (32 m) and comprises a single-storey building with a pitched roof of Welsh slate and projecting gables to both the principal (south-east) elevation and the opposing north-west elevation. The south-east elevation, behind which lay clerical and drawing offices, presents a largely symmetrical nine bay façade with coped gables to the end bays which project forward of the elevation by around 2 ft. The central bay contains the entrance to the workshop range; steps to a pair of timber doors beneath a semi-circular moulded stone porch canopy carried on corbels. The entrance sits within a projecting brick panel, bearing a date stone of 1930 between coped rusticated brick pilasters (Figure 28). This neo-Georgian design was common among military buildings of the period, and is continued in the windows of the south-east elevation which are uniformally timber sashes of 12 panes arranged six-over-six set beneath flat arches with red brick voussoirs.[145] The gabled bays each have three sash windows of the above arrangement beneath a roundel window with red brick voussoirs and four keystones. The south-eastern elevation does not extend to the full length of the workshop range, stopping short of its western extent to allow for an access ramp to a pair of timber doors into the workshop. The workshop area matches the width of the waterway and extends from the dock to the western gable end. It is lit from above by four rows of skylights and two of the raised ridge lanterns which light the waterway and lit from the western gable end by five round-arched steel-frame windows of varying heights and widths and a single roundel beneath the apex of the roof. The north-west elevation of the workshop is shorter than that to the south-east and contains a single gabled porch, centrally located. This elevation, which faces into the AEW site is far more utilitarian than the elaborate Neo-

Figure 28: The neo-Georgian south-east elevation of the workshop of No 2 Ship tank bearing a date stone of 1930 to commemorate its completion (IWM 2005-02-20 2052/98)

Georgian façade which looks out to Haslar Road. Plain steel-frame windows are used throughout instead of the timber sashes and the centrally located gable houses two large openings which directly accessed the machinery control room beyond. To the west of the gable, a single door is raised above ground level and accessed via a short flight of steps to allow for a heating chamber below. In addition to the machinery control room, the north-western side of the workshop range originally housed a workshop annex, gas boiler store a fitting room and a dining room.

In contrast to No 1 Ship Tank, No 2 Ship Tank exists in 2016 in a largely unaltered state retaining its architectural character and is functional purpose through the continuation of towed model tests in the tank under the auspices of QinetiQ. At the time of its construction in 1930, No 2 Ship Tank was comfortably the largest tank of its type in the United Kingdom. A number of towing tanks have been constructed subsequently, among them those at the University of Glasgow (1963, 77 m in length), the University of Newcastle (1951, 37 m in length), the University of Strathclyde (1995, 93 m in length) and four at Westfiand Aircraft Corporation (formerly the British Hovercraft Corporation) on the Isle of Wight (1946-1972, 25 m to 196.7 m in length) but none rival the 270 m long waterway of No 2 Ship Tank. Furthermore, of contemporary European examples from before the Second World War, only the Calm Water Towing Tank at the Canal de Experiencias Hidrodinamicas de EI Pardo in Madrid built to a length of 320 m in 1934, can boast a longer waterway.[146]

No 2 Cavitation Tunnel (Buildings 46 & 47)

The two adjoining buildings which house the cavitation tunnel removed from Hamburg in 1945 and re-erected at AEW Haslar in 1947 occupy a site north of No 2 Ship Tank and immediately north-west of the site of No 1 Cavitation Tunnel. They are orientated north-east to south-west and as such are sited parallel to the boundaries of the AEW site. Their construction began in 1952 and a date stone records their completion in 1955. The buildings are regularly referred to using their contemporary site plan identifiers with the larger structure, Building 47 and the small structure adjoining to the southwest, Building 46. Building 47 contains the cavitation tunnel in addition to a workshop, boiler house and entrance lobby, staircase and lift shaft, while Building 46 houses the drainage and vacuum/pressure tanks for operating the tunnel (Figure 29). The two buildings are contemporary in their construction and are both of steel-frame construction encased in English bond red brick below flat roofs. Below ground level, a large sump beneath the cavitation tunnel provided access while pipework connecting the tunnel with the tanks in Building 46 and with No 1 Cavitation Tunnel ran in trenches below the building. The potential for surviving infrastructure is therefore high.

Building 46 is of two storeys and is connected to Building 47 by an enclosed angled bridge between the second storey of Building 46 and the third storey of Building 47.[147] The remainder of the north-east elevation is blind, with the bridge the only feature, while to the north-west elevation a pedestrian access door sits beneath a single first floor window. The south-eastern elevation retains a pair of part-glazed double doors raised above ground level with no access steps. To the west of these doors, a blocked opening at ground level may indicate a point of access to and from the vibration laboratory which stood directly to the south. The principal fenestration is located on the south-western elevation and retains its original character. Six elongated windows covering both floors and arranged 1: 1: 2: 1: 1 sit within concrete surrounds which stand proud of the brickwork around them. The windows themselves are steel-framed casements of 18 panes arranged nine-over-nine. Above the windows a concrete plat band delineates the roof line which is hidden behind a parapet. The interior of Building 46, as constructed in 1955, was occupied by four pieces of plant (now reduced to three tanks) and a number of transfer pumps and compressors which operated the tunnel. The principal pieces of equipment, listed from north to south were the deaerator vessel for removing the cavitation bubbles from the tunnel following each experiment, the upper limb drain tank for removing the water around the model propeller, the vacuum pressure tank and water cooler for ensuring the water conditions were conducive for simulating cavitation. Building 46 was open to the full height of its two storeys, exposing its concrete beam roof with an upper metal grill platform running along the north-east wall at second storey level creating a mezzanine and facilitating access to the tops of the tanks and to the bridge with Building 47 at its southern end (Figure 30).

Building 47 is of four storeys and rises to 18 metres in order to accommodate the 40 ft (12 m) tall cavitation tunnel. The principal elevation is to the north-east and is of seven bays with those to the northern and southern ends elevated above the level of the roofline and stepped out beyond the footprint of the building to give the

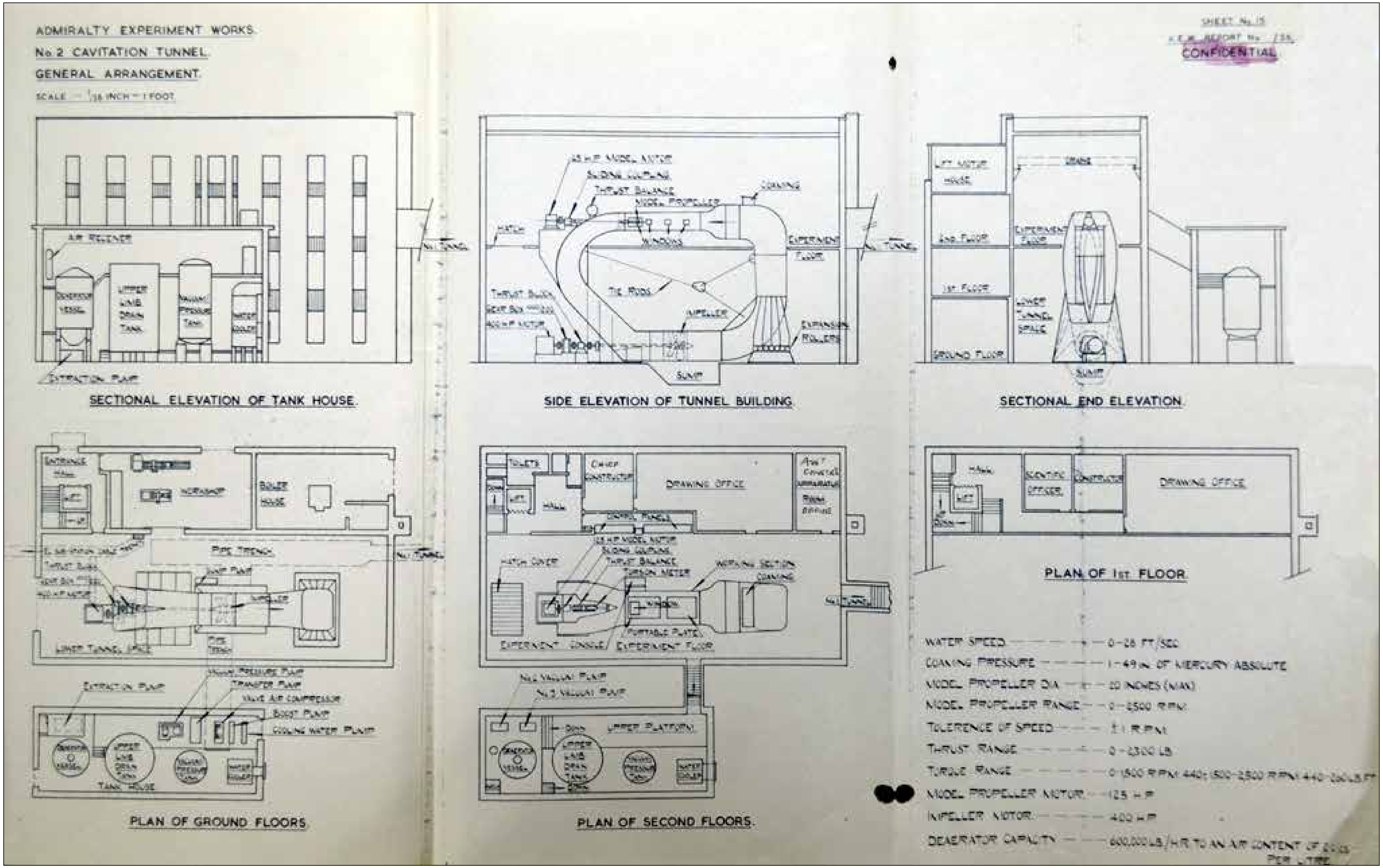


Figure 29: Plan and elevation drawings from 1958 of Buildings 46 & 47 showing the internal arrangement of No 2 Cavitation Tunnel (TNA ADM 226/644)

appearance of turrets. As with Building 46, the windows (which unlike Building 46 are no longer the original small-pane steel-framed casements) are set within cement surrounds and elongated across all floors with the exception of the southernmost bay which extends only as far as the first floor. The windows of the central bay are of a different nature having triple lights above a large machine-bay door of a wooden folding, half-glazed type which gave access to the workshop behind. The northernmost bay has a pedestrian door (a modern replacement within an original opening) set beneath a concrete rain hood above which a decorative date stone with an anchor and rope commemorate the date of the building's completion, 1955. The north-west elevation has a modern roller-shutter door within an original opening which directly accessed the lower space around the tunnel located below a beam for lifting machinery. The interior stair which occupies the northern corner of the building is lit by a triple arrangement of elongated windows. The south-west elevation mirrors the south-east with seven bays punctuated by full-height, elongated windows and the bridge to Building 46 which adjoins this elevation at third storey

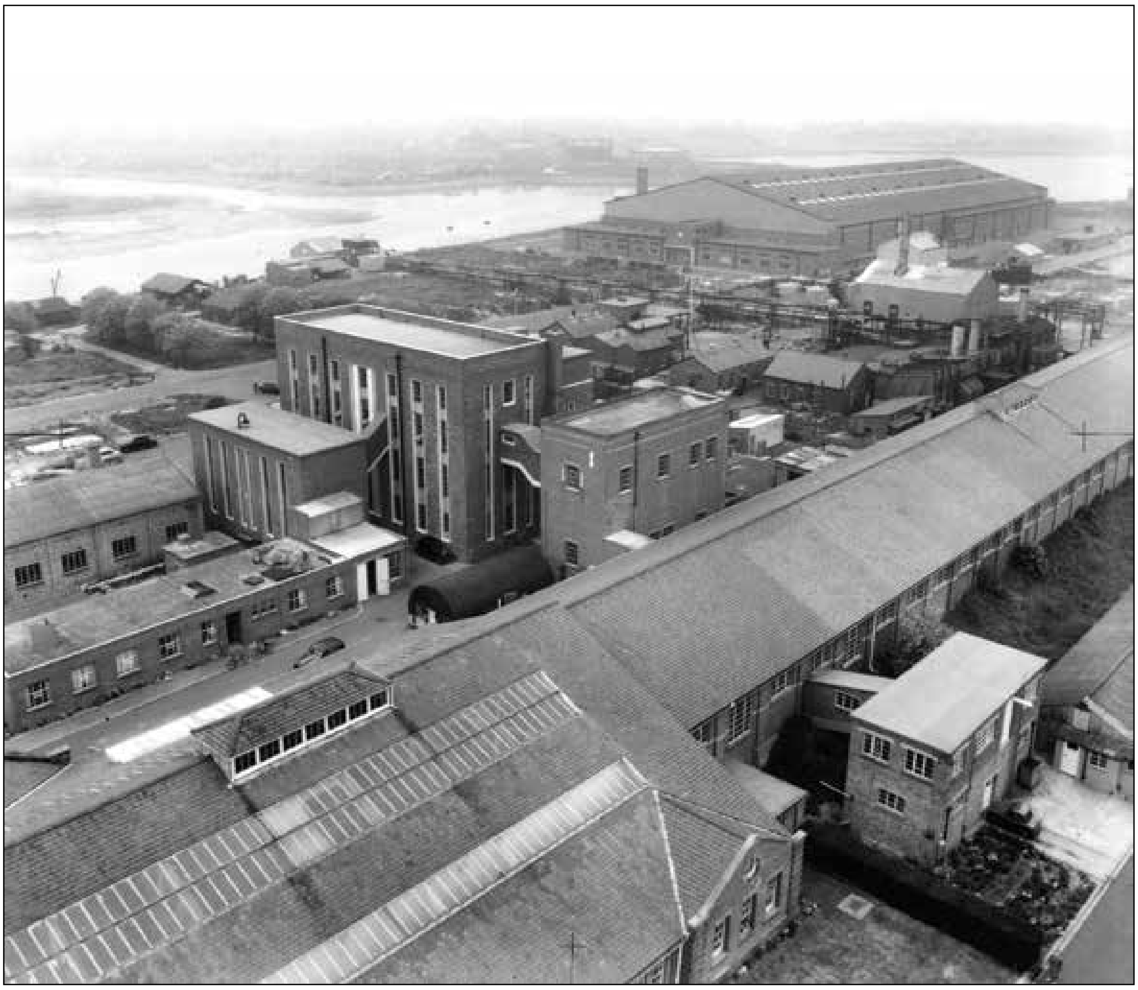


Figure 30: Aerial view of No 1 Cavitation Tunnel (centre) and Buildings 46 & 47 housing No.2 Cavitation Tunnel, (left of centre) from the south. The settling tank of No 1 Cavitation Tunnel was reused as a wave laboratory and housed within the Nissen hut beyond the waterway of No 2 Ship Tank (IWM 2005-02-20 19388)

level in the third bay from the southern end. A circular steel fire escape extending from the ground and intersecting with an inserted third-storey door within the windows of the southernmost bay is a later addition. The south-eastern elevation is asymmetrical in character with three elongated windows to the western half, the middle of which being wider than those outside it and interrupted at third storey level by a blocked opening indicating the location of the former stepped bridge which linked the building to No 1 cavitation tunnel directly to the south-east. The eastern half of the south-east elevation presents a pair of elongated windows and a folding, part-glazed door.

In plan, the ground floor interior of Building 47 is divided into four rooms. The largest of these extends along the entire width of the south-west elevation and for more than half the depth of the building and contains the cavitation tunnel itself.[148] The tunnel is a vertically mounted, asymmetrical but broadly ovular tube made up of eleven welded mild steel plate sections with heavy steel joint flanges and two cast-iron bends, with the whole mounted on two large pedestals. To the north-west, motors power two drive shafts which enter the horizontal elements of the tunnel respectively at ground floor level to power the impellor which creates the circulating channel of water and at second-floor (third-storey) level to drive the propeller motor which spins the model under test. The tunnel is punctuated on both sides in its upper horizontal element by observation windows of toughened glass, while the control panels occupy the second floor which wraps around the top of the tunnel. The three remaining rooms of the ground floor extend along the north-eastern elevation and comprise the stairwell which wraps around a central lift shaft, to centrally positioned workshop with door through to the cavitation tunnel and the boiler house to the eastern end of the building. At second floor, a drawing office occupied most of the space above the boiler house and workshop with an adjacent office for the Chief Constructor.[149]

Buildings 46 and 47 have received only minor alterations, with Building 46 retaining its original windows and character. Alterations to Building 47, including the addition of a fire escape, the replacement of its small-pane steel-framed windows and a number of its doors, have made only minor alterations to the character of the building as the replacement doors and fenestration have been (for the most part) set within original openings and surrounds. The significance of these buildings is given by the largely unaltered cavitation tunnel contained within building 47, one of only two extant in the UK and both larger and older in its entirety than the Emerson Cavitation Tunnel in Newcastle, which was not originally a cavitation tunnel at all. When No 1 Cavitation Tunnel was completed at Haslar in 1941, it was the largest facility if its kind but No 2 Tunnel, once operational in 1955, had eight times the capacity. The design of the tunnel by German scientist Dr Hermann Lerbs and its acquisition and relocation to Haslar as part of war reparations give the tunnel and its purpose-built buildings international significance and in 1995 Haslar's No 2 Cavitation Tunnel was one of only 5 extant cavitation tunnels that was built before 1950.

Manoeuvring Tank (Building 82)

The manoeuvring tank or Ocean Basin as it has become under QinetiQ, with its associated peripheral buildings and ancillary accommodation occupy a large site parallel to the Haslar Lake shoreline, south-west of the gunboat yard jetties and north-west of the rails of the gunboat yard transverser. The building is orientated roughly south-west to north-east and is defined by the concrete tank which describes a rectangle of 400 ft (122 m) by 200 ft (61m). When full the tank holds 40,000 tonnes of fresh water making the Haslar Ocean Basin one of the largest hydrodynamic test facilities in the world.[150] The tank, which was completed in 1956 and officially opened in 1961 comprises a sectional concrete tank, constructed with expansion joints to address issues of settling and movement caused by the tank's location close to the high water line, surrounded by a two-storey building of aluminium ribbed panelling beneath a pitched roof of ribbed steel sheets carried on tubular steel trusses. Surrounding the tank building on all four sides are the buildings which provide the ancillary accommodation which are variously one and two storeys high and of cavity brickwork construction using local, red facing bricks. Around 25% of the tank's 18 ft (5.5 m) depth lies below the level of the surrounding site's ground surface and a new 12 inch pipeline was laid between the tank and a suitable public main on the other side of Haslar Lake to provide a supply of fresh water suggesting that there is archaeological potential in and around the Ocean Basin.

The principal element of the Ocean Basin facility is the large concrete tank constructed by Messrs Trollope and Colls.[151] The tank was constructed of reinforced concrete, pumped on site into a configurable shuttering system which allowed for variations in the lengths of bays and different buttress designs, with the largest of the forty-four bays of construction weighing approximately four tonnes. Before work commenced on the tank itself, the 20 ft (6 m) diameter concrete base to support the 95 ft (29 m) rotating arm and central post was constructed on 50 ft (15 m) reinforced concrete piles 100 ft (30.5 m) from the south-western end of the tank (Figure 31). The tank was designed to be flexible when settling under the load of water contained within it and was designed with a number of expansion joints along each of its four sides to allow this. Twelve pairs of opposed buttresses along the two long walls of the tank support the 20 ft (6 m) high walls whilst also carrying the walkways around the tank. Expansion joints are located within the third and seventh, fifth and eleventh buttresses with the southern wall supported by two additional buttresses. The north-eastern wall of the tank has six equally spaced buttresses with expansion joints in the second and fifth buttresses. The south-western wall has eight buttresses, unevenly spaced with expansion joints between the second and third and sixth and seventh buttresses, with a centrally located dock between two lifts. The buttresses in this wall also provided recesses for the double slatted wooden beaches which, like those in the towing tanks were installed to minimize the reflection of waves created by models during still water experiments and to suppress waves generated to replicate sea conditions in seakeeping experiments. The floor of the tank was also designed to allow for settling and movement with the two 6 inch thick layers of reinforced concrete, laid in 62 ft by 62 ft squares and separated by a layer of bitumous felt, abutting rather than adjoining the heels of the walls.

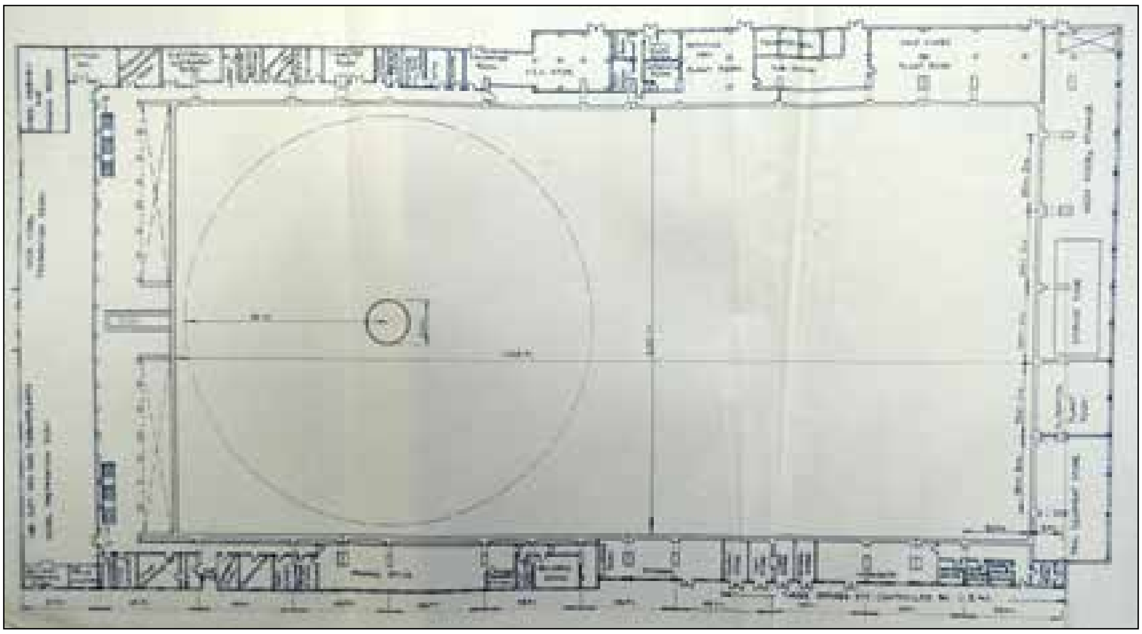


Figure 31: Plan of the manoeuvring tank in 1958 showing the location of the rotating arm, wave makers and ancillary accommodation (TNA ADM 226/644)

To allow for experiments into the dynamic stability of surface ships and submarines, the manoeuvring tank was designed with a massive steel rotating arm to subject 16 ft models to 360 degree turns in controlled conditions to measure resistance, side force and yaw. The arm is constructed of tubular steel and driven by an electric motor and carries a testing carriage which can move along the length of the arm to vary the radius of the experiments between 7.5 m and 27.5 m.[152] In order to simulate open water conditions and conduct experiments into maintaining surface vessel speed in rough seas, two banks of six plunger type wave makers with a range of stroke and frequency were incorporated along the north-east end of the tank and halfway along the north-west side. These wave makers were capable of producing waves between one and 12 metres in length and up to a height of 0.6 m.[153] In 2014, the wave makers underwent a major programme of upgrades, having been previously refitted in 1980, and now the entire wave making plant is situated along the north-eastern wall of the tank. The dock area for the rigging of the ship models adjoins the south-western wall of the tank and is separated from the main body of water by a dock gate.[154] Above the central dock area, raised on a steel frame is the glass-fronted control room from which the rotating arm is operated.

The roof over the manoeuvring tank is constructed of tubular steel forming a series of nine main trusses carried on the buttresses extending from the long walls of the tank. The main and tertiary trusses support a shallow pitched roof of galvanized, ribbed interlocking 20-gauge steel sheets, covered in a thin sheet of roofing felt with cork insulation and finished with green mineralised felt. Four rows of glazed panels, two either side of the ridgeline, run longitudinally for the entire length of the building. Four corresponding lines of corrugated aluminium sheets supported by steel frames are suspended from the main trusses throughout the length of the building to break the light entering from the roof light panels. The two gable ends and the upper sections of the side walls which rise from the wrap-around ancillary buildings to the roofline are formed of ribbed aluminium 'Q' deck panelling backed by light steel sheeting to form a cavity filled with glass wool insulation. The majority of the windows are located within the adjoining ancillary buildings which rise to near the roofline at the north-eastern half of the building. However seven pairs of windows are cut directly into the aluminium panelling at second-storey level in the south-western end of both the north-west and south-east elevations.

The lower sections of the tank building walls beneath the aluminium panelling are of red brick cavity wall construction and form both the lower sections of the tank building and the adjoining wall of the ancillary buildings which wrap around the tank on all four sides. The south-west elevation presents a deep single storey with mezzanine building of 13 bays, the wide central bay of which contains the principal entrance to the test tank. The entrance comprising a pair of double doors with side windows beneath a canopy sits below an aluminium panelled clerestory with a glazed front. This feature is a later addition replacing a flat-roofed brick clerestory lit from each side by three groups of three pane windows.[155] The flat roof is punctuated with eight skylights which provide large quantities of natural light to the model preparation and assembly workshops below. The workshop range was originally blind to the two outer bays and fenestrated to the remainder with groups of five-pane steel-frame windows to the ground floor with corresponding rows of five small windows above to light the mezzanine. The ranges adjoining the north-west and

Figure 32: Oblique aerial photograph of the manoeuvring tank from the east showing the workshop range and adjacent boiler house. In the foreground and right of picture, the inlet pipes of the pumping house are clearly visible as are the initials of the Admiralty Fuel Experimental Station. © IWM 2005-02-20 19426

south-east walls of the tank are of a similar type, with a low single-storey range extending to just short of the mid-point of the tank before rising to two storeys from the remainder of the elevation. The single storey ranges of the south-east elevation are fenestrated with 12-pane casements with concrete sills and lintels, whereas the two storey ranges have metal-framed windows.[156] The windows of the north-west elevation all appear to be steel framed. The flat roofs of the long ranges carry drainpipes which connect via downpipes with the guttering of the tank building roof above and with downpipes along the length of the long ranges. The single-storey ranges provided office accommodation and computer and instrumentation rooms, with a large drawing office sited within the south-east single storey range. The two-storey range to the south-east elevation housed a small workshop and various materials stores, while the corresponding range on the opposite side of the tank was considerably deeper and provided accommodation for the rotating arm and wave maker plant and a transformer sub-station. The two storey range to the north-east elevation was used principally for storage and appears to have been designed to be open to the testing tank.[157]

To the north of the manoeuvring tank stood a rectangular brick boiler house, two storeys high with attic above and a principal elevation of four bays facing south-west. Each of the four bays contained a 24-pane window to light the ground floor with smaller eight pane windows to light the upper storey beneath porthole windows in the eaves of the shallow pitched roof. A single-storey, flat-roofed range adjoined to the north and tapered rectangular brick chimney occupied the northern corner of the boiler house (Figure 32). The boiler house is no longer extant and its former site is concealed benath a tarmacked car parking area, however there is potential for archaeological deposits in the form of this building's foundations and the pipework which once connected it with the adjacent manoeuvring tank.

The manoeuvring tank is significant in terms of its scale – more than fifty years after its construction it remains one of the largest hydrodynamic test facilities in the world but also in terms of its complexity as a civil engineering project. The manoeuvring tank also enabled a significant increase in the number and range of tests which could be performed related to seakeeping in rough seas and allowed greater use to be made of self-propelled, remotely controlled models, playing a direct role in the development of the Navy's submarine fleet.

Administration Building (Building 145)

The administration building at AEW Haslar was constructed during 1970 and 1971 and occupies a site north-west of No 2 Cavitation Tunnel adjacent to the site of the former calibrating laboratory. Orientated south-west to north-east, the building is comprised of two ranges both of English bond brick construction. The range to the north-east is roughly square in plan, single storey, largely without fenestration, and its flat roof is railed to form a veranda accessed from the second storey of the main range. The main range rises to two storeys beneath a flat roof, is rectangular in plan and presents its principal, symmetrical 11-bay elevation to the north-west.[158] Each of the bays of the north-west elevation, save for the central bay, are punctuated by metal framed windows to each storey, elongated to the full height of each storey to include a blind panel below. The central bay carries a projecting two-storey brick lobby, glazed to the majority of its height with narrow windows in surrounds, with entrance to the building gained via double doors to the north-eastern elevation of the lobby.

Circulating Water Channel (Building 144)

The circulating water channel test facility was installed at AEW Haslar between February 1970 and February 1971 and was housed in a newly constructed building to the immediate north-east of No 1 Cavitation Tunnel and north of the waterway of No 2 Ship Tank. In common with the majority of the buildings on the Haslar site, the water channel building is orientated south-west to north-east and in width the building matched the adjacent building housing No 1 Cavitation Tunnel. The building is of steel-frame construction with English bond brickwork and pressed corrugated steel panelling (Figure 33). The building comprises three distinct ranges beneath flat roofs and the principal elevation is to the north-west.[159] It is highly likely that the water channel shares a piped source of water with No 2 Cavitation tunnel and that there is some potential for archaeological deposits. The construction of the circulating water channel building also necessitated the excavation of the sloping earthen bank which separates its south-east elevation from the waterway of No 2 Ship Tank. These excavations exposed the arched arcades which support the long wall of the ship tank. In 2007 the circulating water channel was not in use due to low demand, but was identified as an important element of the proposed Solent Ocean Energy Centre (presumably due to the rarity of that type of facility) and the prevention of its destruction was identified as a recommendation of a feasibility study prepared by Marine and Technical Marketing Consultants.[160]

The central and largest range rises to three storeys and is of five equal bays which correspond to the vertical beams of the steel frame.[161] The height of this central range mirrors that of the former No 1 Cavitation tunnel building and it is within this central section that the water channel is housed. The north-west elevation has an entrance to the west of the central bay with corrugated cladding rising from the top of the doorway to the roofline which continues to all four elevations.. Each of the five bays are lit with elongated metal windows of four panes end-on-end which straddle the first, second and third storeys indicating a-typical internal levels dictated by requirements of accessing the water channel (Figure 34). The south-east elevation of the main range is entirely blind.

The south-western range is of traditional brick construction and does not have the internal steel frame of the main range. It is of two storeys and three bays, the wider south-western bay of the north-west elevation containing a recessed porch. This range is fenestrated with metal framed windows to each of the bays, save for the first storey of the end bay which is occupied by the porch. The windows to the ground floor are elongated whilst those to the upper storey have narrow 'letterbox' panes above them. The corrugated panelling of the central range does not continue onto this range, though there are panels above each of the windows and the porch. The arrangement of the windows is repeated to the south-east elevation. The range to the north-east is of a single bay and rises to two storeys. It is also of English-bond brick construction and is only half the depth of the other ranges of the circulating water

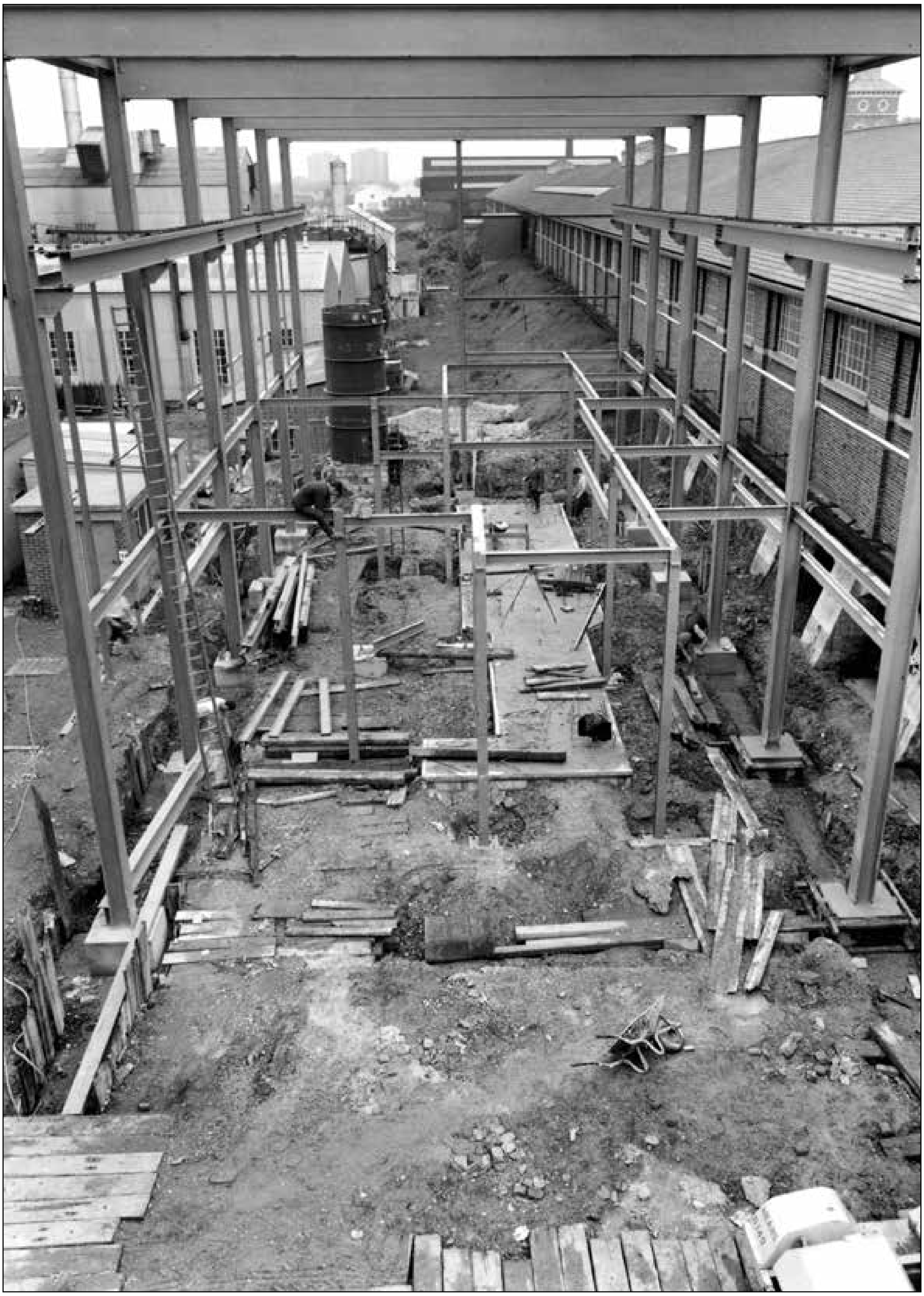


Figure 33: The building to house the circulating water channel under construction in 1970. The buttressed piers of the arcade which carry the tank building of No 2 Ship Tank were exposed during the work and can be seen in the right of the picture. The tank which supplied the water channel can also be seen at the far end of the building (IWM 2005-02-20 468/70)

Figure 34: The circulating water channel building from the north in 2011. The adjacent building is Building 47 which houses No 2 Cavitation Tunnel (HEA 26941/15)

channel building. This building housed the tank which supplied the water channel and it is connected to the main range via an internal door at ground floor level.[162]

Internally, the central range housed the circulating water channel which is similar in proportion and appearance to the cavitation tunnels. Square in cross section, the upper horizontal limb of the water channel rises through a mezzanine floor level carried on steel joists between the second and third storeys accessed via a steel staircase.[163] A photograph taken in January 1971 shows rails running along the length of the central range which supported a motorised hoist, though it is possible that this was a temporary installation needed to position the water channel during construction.[164] The lower horizontal limb of the water channel is circular in section and can be accessed at ground-floor level with the whole length of the channel above ground level. The range to the south-west, photographed under construction in 1970, is sub-divided into smaller rooms indicating that this range provided ancillary office and model preparation areas.

The circulating water channel is significant as it marked the development of resistance testing from towed tests within a static body of water to static model tests within a circulating body of water and as such forms part of a direct lineage from Froude's original Torquay tank. That this facility is currently mothballed while tests continue in No 2 Ship Tank suggests that the results achieved in the circulating water channel did not represent an improvement on the data produced by traditional towed tests in the ship tanks.

Buildings of AMEE and NAMD (Buildings 12, 4, 147 & 142)

The renaming of the Admiralty Fuel Experimental Station (AFES) as the Admiralty Marine Engineering Establishment (AMEE) and the shift away from fuel research to research into auxiliary machinery after 1966 saw large-scale development of the area adjacent to the Haslar Lake shoreline west of the manoeuvring tank. Likely constructed in 1966/67 and extant by the time of the 1969 edition of the 1:2500 Ordnance Survey map, the new buildings covered a roughly rectangular site which extended along the shoreline from the manoeuvring tank but stopped some way short of the northern end of the extension to No 1 Ship Tank. This site had previously been sparsely populated with huts of the AFES and stores used by the AEW. Of these new buildings the largest is the former Auxiliary Machinery Test House (Building No 12) which occupies the centre of the site, is aligned south-west to north-east and in plan measures approximately 65 m by 23 m.

The test house rises to two storeys and a single storey range with a further lean-to extension wraps around the north-eastern and north-western elevations. The windows to the south-east elevation comprise a single row located just below the eaves of the pitched, corrugated cement roof indicating that internally the building is open to the roof in order to accommodate large test rigs and that there was no ceiled ground floor space (Figure 35). These windows only extend for just over half of the south-eastern elevation indicating the point at which the former auxiliary boiler test

Figure 35: The Auxiliary Machinery Test House and Boiler Test House from the south (IWM 2005-02-20 1014/93)

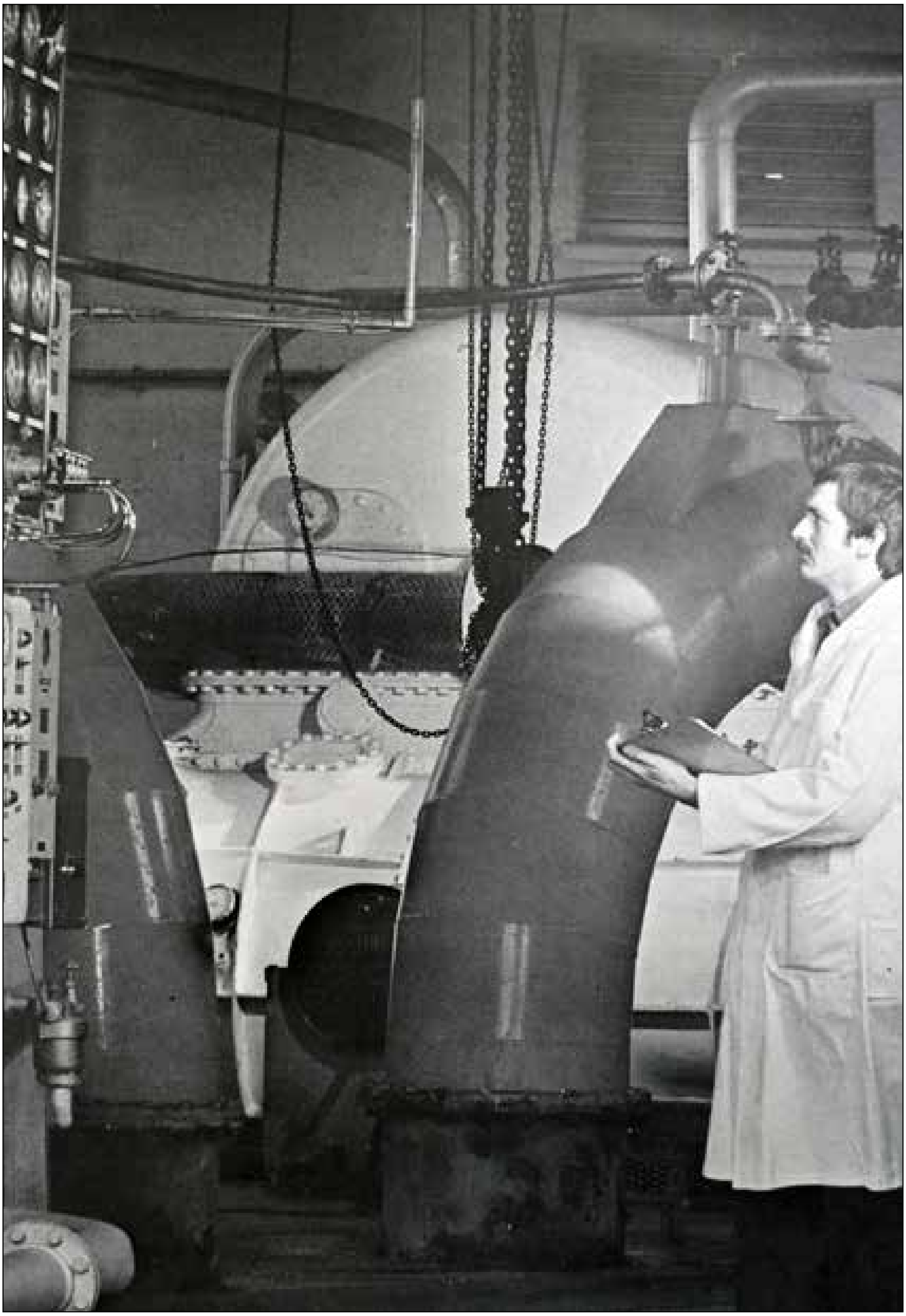


Figure 36: Auxiliary machinery testing in Building 12 at AMEE Haslar in 1979 (TNA ADM 341/5)

house adjoined to the south-east. The machinery test house is likely of steel frame construction and in 2016 is clad in aluminium panelling. This exterior cladding was fitted to the building after June 1998 when a planning application was filed with Gosport Borough Council, and replaced the original walls constructed using steel tracking in filled with small rectangular panels possibly of asbestos board.[165] The alteration to the exterior walls of the machinery test house also saw the removal of the original fenestration to the south-east elevation which comprised six elongated 50-pane steel-frame windows with horizontal pivot openings.[166] The south-west gable end of the building has a large entrance with roller shutter to facilitate the movement of large pieces of equipment and further supporting the supposition that the building is without internal divisions (Figure 36). To the south of the test house are a number of large fuel storage tanks providing liquid fuel for the turbine, boiler and machinery test rigs. This system for storing and moving fuel once connected to the network of overhead pipelines and below ground pipes which drew salt water from the ponds on the Haslar Lake shoreline. As a result there is potential for archaeological deposits and evidence of former infrastructure in this part of the site.

Immediately to the west of the Auxiliary Machinery Test House is Building 4, a three-storey, flat-roofed building approximately 30 m by 10 m. The ground floor of the building is of brick construction with the upper floors formed of heavily glazed steel-frame walls with panelling beneath the windows. A photograph taken from Haslar Creek in 1980 (see figure 18) shows that the upper storeys of Building 63 were once entirely glazed save for small GRP or asbestos panels at beneath the windows. It is most likely that this building was originally the materials laboratory of Admiralty Marine Engineering Establishment, later the Admiralty Marine Technology Establishment.[167]

To the east of the Auxiliary Machinery Test House, the use of two further buildings of the AMEE can be stated. Building 147, a tall, aluminium panelled, single-storey hut approximately 11 m by 6 m was the Condenser Test House and relates directly to the two pump houses on the shoreline.[168] The larger, (28 m x 14 m) two storey brick structure aligned north-west to south-east adjacent to the manoeuvring tank, was Building 142, the instrumentation workshop.[169]

Boundary Walls

The site, inclusive of the former Haslar Gunboat Yard is bounded by a red brick wall of Flemish bond with recessed panels along the length of its Haslar Road frontage which dates from c.1856. A two-storey watch tower of Flemish bond red brick with single-light round-headed windows to the ground and first floors of the south-east elevation and the first floor of the south-west elevation and a hipped Welsh slate roof above machicolation, marks the southern corner of the site. On the Haslar Lake shoreline, a low boundary wall with a corresponding watch tower remained until after the Second World War when the shoreline was developed for use by the AFES.[170] The south-western wall of the site which extended from Haslar Road to Haslar Lake, did form part of the c.1856 boundary and it was raised and modified when No 1 Ship Tank was built into it. A short section of wall running north-west between the watch tower and the workshop of No 1 Ship Tank is of the c.1856 boundary. To the south-west of the watch tower, a short section of curved walling with recessed panels and coped gate piers was the gateway and flanking walls to a 'New Burial Ground' constructed as an overflow for the Haslar cemetery in 1857/58. The section of the boundary wall north-east of the watch tower was reconstructed in the late 1880s when the pump house for Haslar Hospital was removed. The reconstructed section included a pair of gate piers of the same character as those to the new burial ground and formed the original entrance to the AEW site after the construction of No 1 Ship Tank. This entrance is now bricked up and two pairs of brick gate piers with folding wooden doors adjacent to the workshop of No 2 Ship Tank provided the direct access to the AEW yard. The western boundary of the site is no longer marked by the wall of No 1 Ship Tank but by a wire fence further to the west bringing the whole of the new burial ground within the AEW site. Access to the QinetiQ site is gained via a gate and security post adjacent to the workshop building of Ship Tank No 1 at the southern end of Froude Avenue, a newly created road through the former burial ground.

IDENTIFIABLE DEMOLISHED BUILDINGS

No 1 Cavitation Tunnel

Of the test facilities and buildings demolished after the creation and subsequent privatisation of DERA, the most historic and significant was No 1 Cavitation Tunnel. Situated parallel to No 2 Ship Tank to which it was linked via a bridge, No 1 Cavitation Tunnel was later supplemented by No 2 Cavitation Tunnel to the immediate north-west and the circulating water channel to the immediate north-east. No 1 Cavitation Tunnel stood 23 ft high and was accommodated in a brick building 48 ft (14.5 m) by 18 ft (5.5 m) in plan and 40 ft (12 m) high across three storeys beneath a flat roof with a low parapet.[171] The building, which was likely of a similar steel-frame construction as No 2 Cavitation Tunnel and the circulating water channel building was completed in 1941. Unlike the later No 2 Cavitation Tunnel, contemporary plans do not suggest significant below ground structures or a sump, though there was certainly pipework which linked the tunnel with the settling tank to the south-west that was converted for use as a wave laboratory during the 1950s.

The building which housed No 1 Cavitation Tunnel was orientated south-west to north-east with the principal elevation of three bays to the north-west. The windows were 16-pane steel windows beneath lintels and lit the first and third storey of the north-east, north-west and south-west elevations. An elevated bridge which linked with the walkway of No 2 Ship Tank entered the westernmost bay of the south-east elevation at second-storey level while the corresponding bay of the north-west elevation was linked to No 2 Cavitation Tunnel via a stepped bridge.[172] To the north-east of the building, a single storey, single bay lean-to building accommodated the boiler house and battery store (Figure 37). This north-east elevation differed from the rest of the building in that it had a window at second storey level.

Although rising to three storeys in height, internally the No 1 Cavitation Tunnel building was largely open with a platform at second-storey level to access the measuring apparatus creating the only floor. This access platform housed the control panel for operating the equipment and a small turntable for manoeuvring the measuring table.

Anchor Tank

Within the square formed by the workshops of the two ship tanks, the anchor tank, competed in February 1948 was the first new building completed on the AEW site after the Second World War (Figure 38). Built to accommodate the steel anchor tank which had previously been situated in No.2 and then No 1 Ship Tank, the anchor tank building was orientated north-west to south-east immediately to the south of the propeller laboratory. The building, which was 48 ft (14.5 m) long by 18.6 ft (5.7 m) wide and 12 ft (3.7 m) high was a type of Ministry of Supply pre-fabricated hut with single skin courses of bricks laid between 16 pre-cast concrete pillars. The roof and end gables were constructed of corrugated asbestos sheets supported on pre-cast concrete pillars to which they were through bolted.[173] A double timber door below louvered ventilation panels in the south-east elevation provided access to the

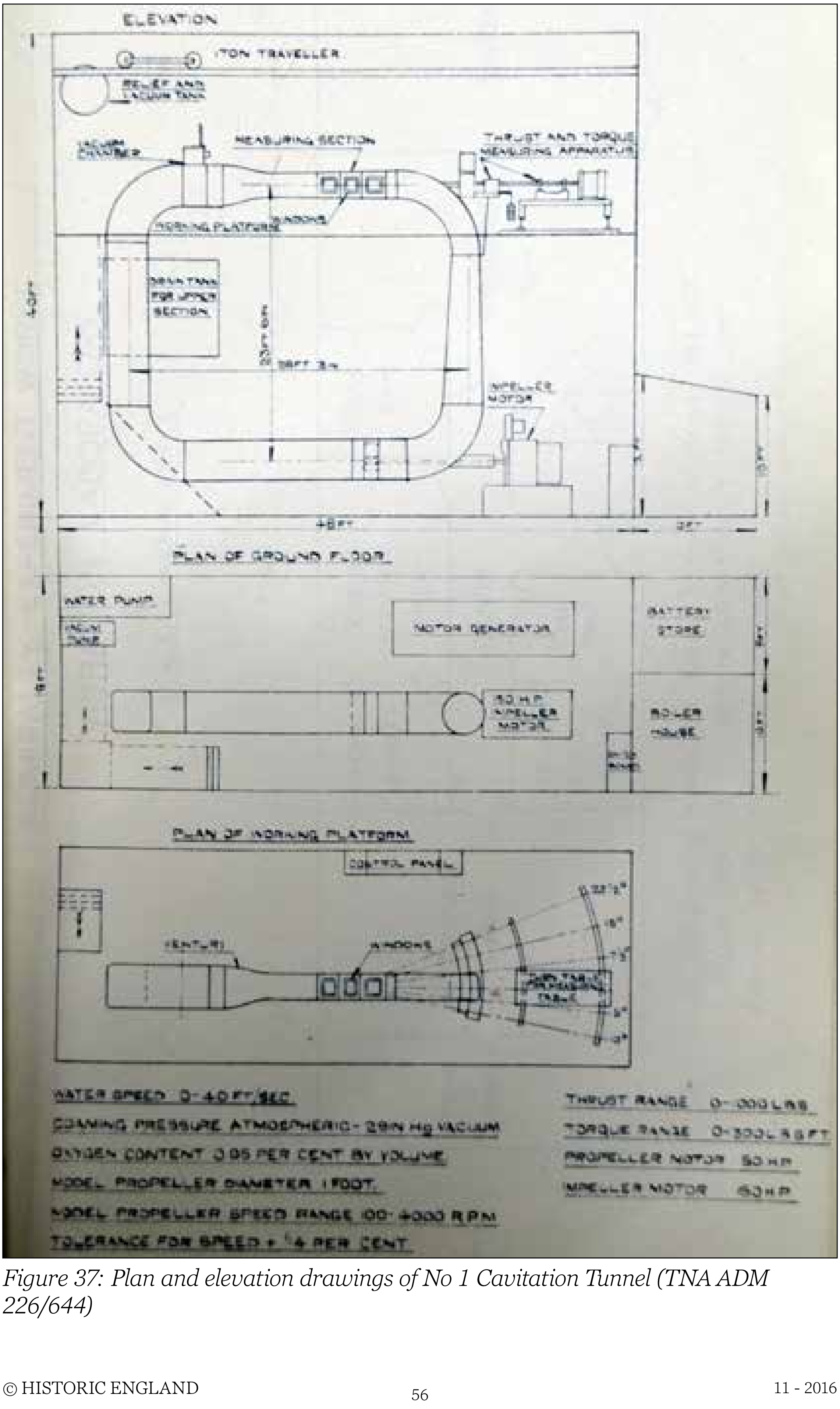


Figure 37: Plan and elevation drawings of No 1 Cavitation Tunnel (TNA ADM 226/644)

Figure 38: The newly completed anchor tank building in 1948 (TNA ADM 226/59)

anchor test tank and the building was fenestrated with eight pane steel windows to the remaining elevations. The 25 ft by 3 ft by 3 ft test tank was situated in the centre of the building with shelves for storing model anchors along both of the longer walls and a drawing bench situated in the eastern corner. A track was suspended from the ceiling down which a light trolley carrying a camera could run to record the tests. The base of the tank was located slightly below ground level, however it is unlikely that any potential for archaeology exists following the removal of the anchor tank in 1993.

Propeller Laboratory

The propeller laboratory was completed during early 1950 and occupied a location adjacent to No 2 cavitation tunnel and perpendicular to No 1 Ship Tank, orientated south-west to north-east.[174] The propeller laboratory was demolished between 1993 and 1995 and its former site was covered in tarmac for use as a car park. 180 ft (55 m) by 32 ft (9.8 m) in plan, the propeller laboratory was a single-storey brick hut beneath a pitched roof of corrugated asbestos cement panels. The long walls had recessed brick panels defining the bays, each of which housed 20-pane steel windows. The principal entrance to the laboratory was on the south-east elevation and was closed by a large roller shutter. A small brick chimney to the northernmost corner of the building served the foundry within.

The interior of the hut was open to the apex of the roof which was carried on steel trusses and the interior space was divided into three main rooms. The eastern end of the building contained a small foundry for casting the model propellers to be used in the cavitation tunnels while the largest room, occupying the central space provided a general workshop for the preparation of the models with discreet areas for welding, grinding and measuring. To the west of the workshop and separated from it by a corridor with external doors at either end were the drawing, tracing and draftsman's offices.[175]

Calibrating Laboratory

The calibrating laboratory was the only post-war ancillary building not shown on the Ordnance Survey map of 1952 though it was likely completed shortly after. Situated to the immediate north of the propeller laboratory and perpendicular to it, the calibrating laboratory comprised a row of four interconnected, prefabricated huts each 43 ft long, with the two outer huts in the row 24 ft 11in wide and the two middle huts 26 ft 5 in wide (Figure 39). The huts were single storey with pitched roofs clad in corrugated asbestos cement and all bar the westernmost

Figure 39: Aerial view showing (clockwise from the bottom left), the wave laboratory, the vibration laboratory, the propeller laboratory, the calibrating laboratory, No 2 Cavitation Tunnel, the officers' mess (formerly the sick bay of the 1917 naval camp) and No 1 Cavitation Tunnel (IWM 2005-02-20 19382)

hut were accessed via double timber doors on their south-east elevations. From aerial photographs it is difficult to ascertain whether these huts were of the same prefabricated method of construction as the anchor tank, or whether they were made up of pre-cast concrete panels. The nature of the activities undertaken in the calibrating laboratory, namely the finishing and fitting of models and calibration of testing equipment, required large amounts of natural light and as such the huts were fenestrated to both the south-eastern gable ends and to the long walls of the outer huts. To the north-east of the row of huts was a small, square brick boiler house.[176] The calibrating laboratory, like the propeller laboratory, was demolished between 1993 and 1995 and the site converted to use as a car park. There is little or no potential for archaeological deposits.

Moving south-west to north-east, the first hut of the calibrating laboratory was divided into three rooms, the largest of which formed the trials section drawing office with the offices of the Constructor and the Constructor's Assistant beyond. This hut had no large south-eastern doorway and was accessed via a single door and lobby to the north-west elevation. The second hut formed the ship trials apparatus calibrating and assembly room, an undivided single room hut fitted with overhead traveller rails aligned to the large double doors on the south-eastern elevation. The third hut contained the confidential apparatus room and the model finishing room. These rooms were not connected and the apparatus room was accessed via doors in the north-east elevation. The fourth hut was similar in character to the second hut, providing a single room for the fitting and assembly of models and overhead traveller rails capable of carrying one and a half tonnes.[177]

Electronics Laboratory and Annex

The electronics laboratory and its annex were extant by January 1946 and located parallel and to the south of the dock area of No 2 Ship Tank on the narrow strip between the tank's waterway and the Haslar Road boundary wall.[178] The electronics laboratory was a two storey brick structure beneath a flat roof which measured 41 ft (12.5 m) by 15 ft (4.5 m) in plan and was connected to the walkway of No 2 Ship Tank by an elevated walkway from its second storey.[179] The laboratory was accessed via a single door in the second bay of its south-eastern elevation and fenestrated with steel frame casement windows. At second storey level, a doorway beneath a hoist boom within the third bay indicates that sizeable equipment and components were once located at first-floor level.[180] The adjacent annex, a prefabricated hut originally 18 ft 6 in by 48 ft beneath a pitched roof of corrugated cement was likely of the same design and construction of the anchor tank which was of identical proportions. By 1950, the annex had been extended through the addition of another hut which more than doubled the length of this range. It would appear that initially the second hut stood apart from the annex, separated by several feet, but by the end of the decade they had been joined, the union clearly visible through a change in the colouration of the corrugated cement roof sheets.[181] As with the majority of the ancillary support buildings constructed after the Second World War, the electronics laboratory and the adjacent annex were demolished between 1993 and 1995. However, satellite imagery indicates that the foundations of the laboratory survive (at least in part) as does a section of the foundations for the annex huts as their site was returned to grass and not covered over for car parking. As such there is potential for archaeological remains associated with these buildings.

Internally, the electronics laboratory comprised a single room without divisions used for the assembly and testing of electronic measuring apparatus. A small dark room, presumably in use before the construction of the photographic laboratory in 1949, occupied the north-eastern corner of the building. The annex was primarily used as office space and for storage.[182]

Vibration Laboratory

The vibration laboratory was extant by January 1946 when it was recorded in an RAF aerial photograph and it is possible, given the wartime experience of the detrimental effects of vibration on the maintenance of speed at sea, that this facility was built during the later months of the war.[183] Located north of the workshop of No 2 Ship Tank and aligned, like the majority of the buildings on the site, south-west to north-east, the vibration laboratory was a low, single-storey building 101 ft (30.8 m) by 26 ft (8 m) beneath a flat roof of corrugated asbestos cement sheets.[184] Originally of nine bays, an annex was added to the eastern end of the building between 1950 and 1955 to connect with Building 46 of No 2 Cavitation Tunnel. The annex bay had a pair of timber doors to its south-east elevation and the principal entrance to the building was also to the south-east in the form of a single door set back from the façade to create a shallow porch. As with the propeller laboratory which stood to the north, the site of the vibration laboratory now forms part of a car park and archaeological potential is low.

Internally the vibration laboratory was divided into a number of small offices arranged either side of a central corridor with larger, double aspect rooms to the eastern and western ends. To the western end, a drawing office and linked analysis room adjoined the corridor which accessed the offices of the experimental officers, Principal and Senior Scientific Officers, a store room, a toilet and a small dark room. A large experiment room which presumably housed the vibrographs, occupied the eastern end of the building prior to the addition of the annex. It is noteworthy that this building was supplied with A C and D C 220 volt mains with a special 220 volt 60 amp D C connection provided for the heavy electrical machinery needed for vibration testing.[185]

Photographic Laboratory

Photographic recording of the tests and experiments conducted at the AEW had been established at an early stage in the history of the department and became increasingly crucial in recording cavitation tests where high speed photography was used to record the bubbles generated during experiments. Prior to the construction of a photographic laboratory, small dark rooms existed within the vibration and electronics laboratories to process film, but in 1950 they were supplemented by a building dedicated to the production of photographs. Built to the east of, and adjoining, the waterway of No 1 Ship Tank, the photographic laboratory was a single-storey brick built building 73 ft (22 m) by 25 ft (7.5 m) in plan beneath a

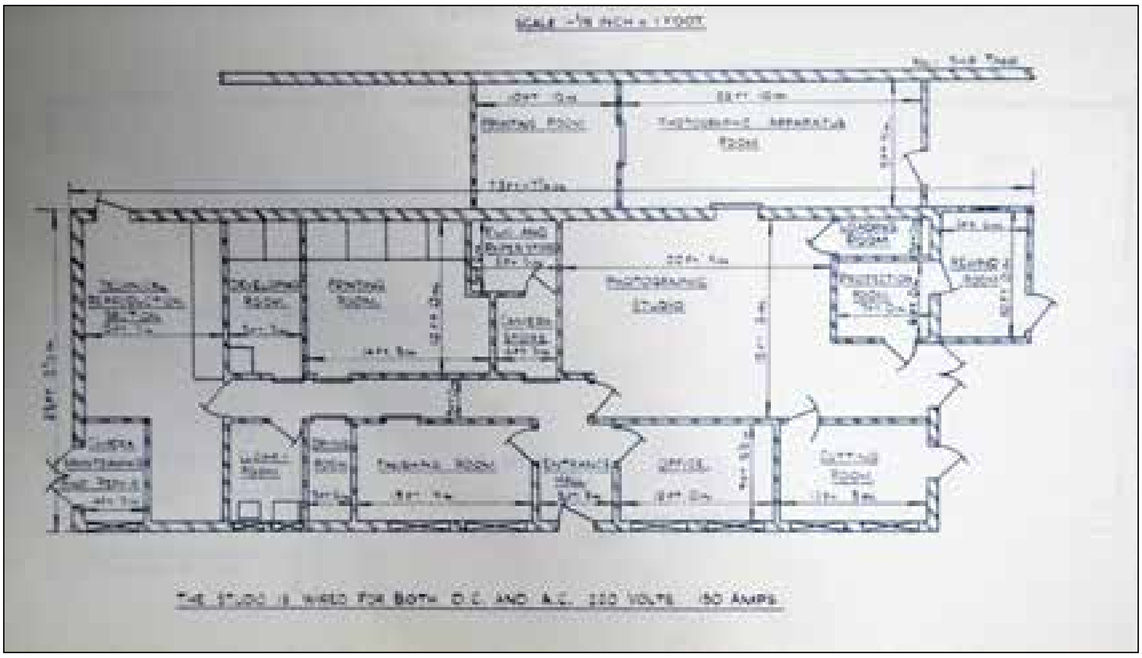


Figure 40: Plan of the photographic laboratory in 1958 (TNA ADM 226/644)

pitched roof. The photographic laboratory was originally separate from No 1 Ship Tank, however at an early stage, the 9 ft 9 in gap between the ship tank and the laboratory was walled and roofed forming a covered link 32 ft (9.8 m) in length.[186] The photographic laboratory with its dark rooms and finishing rooms was largely without windows, with only the north-east elevation fenestrated. Demolished after 1993, there is no visible evidence of building foundations or record of below ground structures and there is little potential for archaeological remains.

The largest room within the laboratory was the photographic studio which was accessed via a pair of double doors to the north-west elevation. Adjoining it a small projection and rewind room shows that moving film as well as stills photography was being recorded at AEW. A central corridor divided the offices and cutting, drying and finishing rooms to the eastern half of the building from the printing and development rooms to the west while there were also rooms devoted to camera maintenance, storage and repair and to the Technical Reproduction Section (Figure 40). Two further rooms where created by the addition of the covered link: a second printing room and a larger photographic apparatus room.[187]

Wave Laboratory

Immediately to the south-west of No 1 Cavitation Tunnel lay a small, slightly raised, open water tank 19 ft (5.8 m) by 10 ft (3 m) in size and approximately 7 ft (2 m) deep. This settling tank was directly linked to No 1 Cavitation Tunnel and allowed for the removal of cavitation bubbles created during experimentation to leave the water channel in advance of the next experiment, an arrangement which Charles Parsons had adopted in his 1910 cavitation tunnel. The reduced testing programme in No 1 tunnel brought about by the completion of the larger No 2 tunnel in 1955 saw the settling tank repurposed as a wave laboratory. The tank was covered with a standard small span (16 ft) Nissen hut, comprising corrugated steel sheets (10 ft 6 in by 2 ft 2 in) bent around a series of eight T-shaped ribs. Wave generating machines were fitted to the north-east and north-western sides of the tank in an arrangement which mirrored the location of the wave makers in the manoeuvring tank and a scale replica of the manoeuvring tank's rotating arm was installed at the south-western end of the tank. The wave laboratory served as a scale model of the waterway of the manoeuvring tank and allowed for experimentation in the making of waves and in the combination of waves to produce complex seas. The wave laboratory was directly linked to No 1 Cavitation Tunnel and had a valve chamber to its northernmost corner. There was below ground pipework which linked this facility to No 1 Cavitation Tunnel, however the potential for archaeology beneath the present car park surface is low.

Admiralty Fuel Experimental Station

Figure 41: Aerial view looking west towards No 2 Cavitation Tunnel. The group of buildings to the right were of the AFES as was the cuboid building in the distance. To the left of No 2 Ship Tank and linked with a bridged walkway are the electronics laboratory and annex (IWM 2005-02-20 19382)

The buildings of the AFES, later the ALFEE and ultimately the AMTE were among the oldest on the AEW site with the earliest of them dating to 1902. Originally concerned with research into liquid fuels and boilers, the AFES occupied two sites at the AEW, the largest being to the north of No 2 Ship Tank and immediately to the west of the transverse slipway of the Haslar Gunboat Yard (Figure 41). Labelled on a plan of 1927 as the 'Oil Fuel Works' the buildings of AFES were generally single storey, pitched roof huts of traditional construction. The largest building in the group was of two storeys with a mono-pitch roof and several chimneys. This building was directly linked to ponds and a pumping house on the shoreline of Haslar Lake via an overhead pipeline described as the 'condenser main' and it is likely that this building was the site of research into marine boiler design. By 1953, the buildings on this site declined in use with the responsibility for research into liquid fuels passing to the Admiralty Oil Laboratory and most of the buildings of the oil fuel works had been demolished or remodelled by the time of the 1969 Ordnance Survey map. Although this part of the AEW site is now covered by car parks and later buildings, the previous existence of boiler houses, an engine house, fuel tanks and below and above ground pipework means the potential for archaeological discovery should not be eliminated.

A further AFES facility was constructed between 1933 and 1950 on a site to the east of the later extension to No 1 Ship Tank. A flat roofed, largely windowless cuboid structure supported by a single buttress to its eastern elevation, this building was photographed in late 1963 emitting dark smoke suggesting that it was an extension of the liquid fuel research facilities.

Auxiliary Boiler Test House

Also known as Building 13, the Auxiliary Boiler Test House formed part of the complex of buildings built on the Haslar Lake shoreline between 1952 and 1969, most likely c.1966 with the formation of the Admiralty Marine Engineering Establishment. Adjoining the Auxiliary Machinery Test House, primarily used for testing marine turbines, the Auxiliary Boiler Test House continued the work of the AFES in marine boiler design. Four storeys in height and of brick construction, most likely around a steel frame beneath a shallow pitched roof of corrugated asbestos cement, the main range was largely windowless and had an entrance closed by a roller shutter in the centre of the south-east elevation which rose to second storey height.[188] At the western end, a two storey flat-roofed range likely provided the ancillary office accommodation while the test house itself was probably without internal floors to accommodate the large boilers. Surmounting the test house were two tapered chimneys of sectional concrete construction, though whether these corresponded directly to two separate boilers is unclear. To the west of the test house, a number of large storage tanks held the liquid fuel to feed the boilers under test. In early 1998 the chimneys of the Auxiliary Boiler Test House were removed and the building was demolished shortly after, save for the two-storey range which stood at the western end of the test house, which remains in situ.[189] The slab foundations and footprint of the former test house are also clearly visible on satellite imagery.

CONCLUSION

Following the creation of the DRA in 1991 and its subsequent privatisation, the former AEW site has been subject to extensive alteration and demolition of test facilities to create Haslar Marine Technology Park currently operated by QinetiQ. However the major historic elements of the AEW (with the exception of No 1 Cavitation Tunnel) remain and No 2 Ship Tank and the manoeuvring tank (Ocean Basin) continue to be used for hydrodynamic research. No 1 Ship Tank was converted for use as offices following the cessation of testing in 1993 resulting in windows being cut into the walls of the tank building and the tank itself covered over with a false floor which has preserved the tank structure *in situ* below. Internal divisions have been inserted into the tank building and workshop during the conversion, however the buildings retain their original plan form and the 1957 extension to the 1887 tank building is still clearly discernible. No 2 Ship Tank, completed in 1930, continues to be operated by QinetiQ as a towed model testing tank. The beaches of the original waterway have been replaced and the wave maker updated, but the building retains its original plan form, character and architectural detailing such as the neo-Georgian workshop façade and raised clerestory skylights. No 2 Cavitation Tunnel was afforded Grade II listed status in 2014 and the two buildings which house the test facility retain their original plan and character, although the windows of the larger building are not original and an elevated walkway which linked the building with the adjacent No 1 Cavitation Tunnel was removed when that building was demolished in 1993. Like No 2 Ship Tank, the manoeuvring or Ocean Trials Tank remains in use as a testing facility for self-propelled remotely operated models and for models fitted to the large rotating arm. The original wave making plungers have twice been updated, but the tank and building which surrounds it remain largely unaltered. None of the other facilities constructed during a phase of increased testing following the Second World War remain, although the circulating water channel, currently in mothballs, and the administration building remain in an unaltered state. On the Haslar Lake shoreline, a number of buildings of the NAMD, later AMTE, survive in a more altered state.

In addition to the surviving buildings it is likely that below-ground evidence of former structures and ancillary services may survive. Elements of a number of demolished buildings were sited below ground level and were connected by below-ground pipework. Satellite imagery also suggests that the foundations of a number of demolished structures including the electronics laboratory and the auxiliary boiler test house also survive. The 1857/8 extension of the Haslar burial ground lies beneath No 1 Ship Tank, its northern extension and the QinetiQ site's internal road, Froude Avenue. Human remains were discovered in August 1885, presumably during preliminary excavations for No 1 Ship Tank, and the potential for similar archaeological discovery must remain high in the western part of the site.

The AEW, including as it does the site of the former AFES and NAMD is unique in the history of the research and design of surface and submarine warships. Far greater in scope and scale to comparable facilities at ARL and NPL Teddington, the AEW Haslar built on the pioneering work of William and R.E. Froude at Torquay to embed empirical experimentation into the process of ship design and directly influenced the design of every class of warship operated by the Royal Navy during the late 19th and 20th centuries.

Each of the surviving buildings of the AEW are physical manifestations of the response to naval engineering challenges which arose over the course of the last 130 years. From the need to accurately model test ships capable of far greater speeds than their Victorian predecessors and the challenge of producing propellers free from the inefficiency and noise emission effects of cavitation to the requirement of modern warships to be able to turn sharply at speed and to maintain that speed in rough seas, the history of Royal Navy research and development can be read through the remaining buildings of the AEW. The remaining hydrodymanic test facilities, which for the most part, continue to be used for their intended purpose, are highly significant and survive as a working memorial to the pioneering work of William and R E Froude.

SIGNIFICANCE

The former Admiralty Experiment Works is situated on the Haslar peninsular adjacent to the Victorian Haslar Gunboat Yard and the Royal Hospital Haslar and is an important site within the wider naval settlement of Portsmouth, Gosport and Alvestoke. Ship model basins, or sites with both towing tank and cavitation tunnel test facilities exist around the world, however the Haslar site has no governmental or private sector parallel in the UK either in terms of its early date or its scale and range of test facilities.

The significance of the AEW Haslar site goes beyond its national context or even its context in the field of British naval architecture. Haslar's No 1 Ship Tank is the direct descendant of the first ship model testing tank, constructed by William Froude in Torquay and where Froude refined the calculations needed to 'scale up' the resistance results from model tests to apply to full size craft and where he first applied the technique of attaching the models and measuring implements to a carriage rather than towing a free model with a cable.[190] Furthermore, as first William and then R E Froude's work at Torquay and Haslar gained wider recognition, No 1 Ship Tank Haslar became the exemplar for similar facilities being constructed around the world. In 1891, Grekhnev, a representative from the facility which would become the Krylov Shipbuilding Research Institute in St Petersburg, was sent to Haslar to study the tank with a view to replicating it, which the Russian's duly did to within a few feet of Haslar's No 1 tank.[191] Further copies of the Haslar tank were made at La Spezia in Italy and at Washington by David Taylor who, like Grekhnev had visited Haslar and the Denny tank at Dunbarton before designing his tank, so that by 1900 there were eight tanks in six countries inspired by Haslar. Before the First World War, the Imperial Japanese Navy established its own tank at Tsukiji, designed by Suzuki who had been trained at Haslar and in 1906, the French built an enlarged version of the Haslar Tank at the facility now known as the Bassin D'Essais des Carenes.[192] In addition to No 1 Ship Tank, No 2 Ship Tank, the manoeuvring tank and No 2 Cavitation Tunnel are also internationally significant structures in terms of their scale, and the latter as a surviving example of a cavitation tunnel designed by the German scientist Dr Hermann Lerbs.

Beyond their significance within the context of international hydrodynamic research, the buildings of the former AEW are significant in terms of their contribution to the development of the Royal Navy's surface and submarine fleets. Speaking in 1941, Vice Admiral Sir Bruce A. Fraser, then Third Sea Lord and Controller of the Navy remarked that: 'In a large measure the Navy owes the performance and speed of its ships of all descriptions to the experimental work carried out at Haslar'.[193]

When it closed in 1993, No 1 Ship Tank had been in continuous operation for 106 years making it the world's longest continuously-serving laboratory and during that time more than half a million experiments were conducted there.[194] The research into hull design and propulsion efficiency which has continued at Haslar for 130 years has been directly responsible for the design of every class of ship used by the Navy during that period and it is difficult to overstate the AEW's significance. The longstanding and direct association between AEW Haslar and British attempts to break the water speed record with iconic craft such as *Bluebird K4* and *Crusader* also adds to the significance of the surviving test facilities.

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