PLUTO: PIPELINE UNDER THE OCEAN

In the plans finalised for the Normandy landings, fuel supplies during the initial phase (D-Day to D+21) were to go across in 4-gallon containers in 400-ton carrier vessels called 'Chants' which could ship petrol either packed or in bulk. Their American equivalent was the 600-ton 'Y' tanker which arrived in Britain in substantial numbers during the spring of 1944. Because no port facilities were likely to be found in working order for ocean-going tankers, the intention was to switch these very small tankers from packed supplies to bulk supply within 15 days of landing, with concrete barges of about 180-tons capacity towed across to provide storage. To discharge ocean-going tankers as quickly as possible from off the open shore, a system of floating or submerged pipelines code-named 'Tombola' was developed, connecting up with the vessels at moorings to be put down about a 1,000 yards out east and west of the small fishing port of Port-en-Bessin. It was planned for work to start on Tombola five days after D-Day, to be completed by D+9. Two other moorings were to be put down off Cherbourg as soon as the port was captured. Pluto (an acronym of Pipeline Underwater Transport of Oil, not the popularly-accepted Pipeline Under the Ocean) would bring across supplies to France as a direct extension of the British fuel pipeline network, linking with pipelines laid behind the advancing armies on the other side of the Channel.

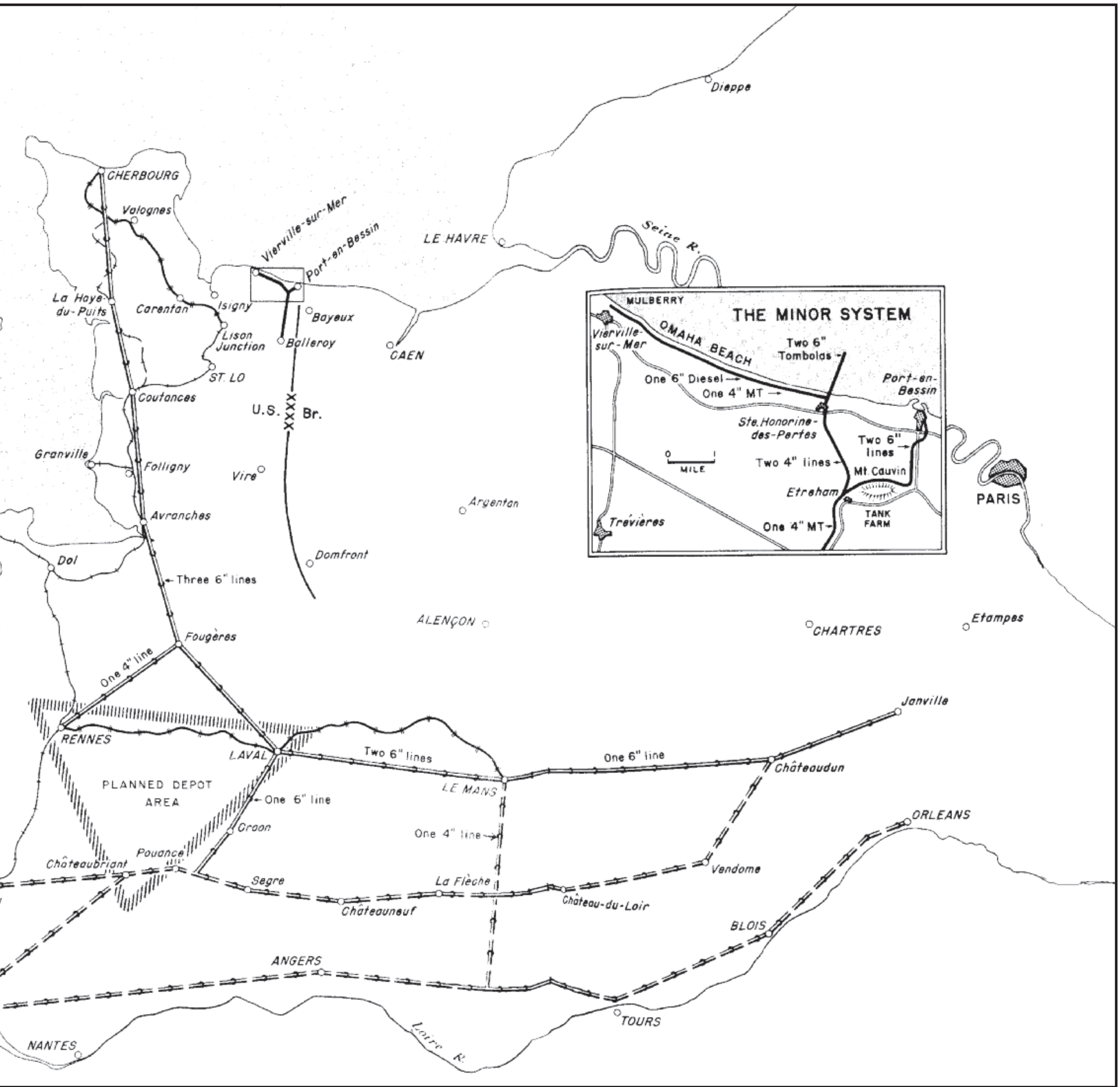
To sustain the massive invasion force when it broke out of the beach-head, it was estimated that there would be a daily requirement for 10,000 tons of fuel and it was hoped that 40-50 per cent of this might be able to be pumped across the Channel. These pictures show troops pushing forward out of the lodgement area: American troops in Montebourg ***(above)*** **and Canadians in Bretteville** ***(below)*****. (USNA/NAC)**

At the joint US-British harbour at Port-en-Bessin, which lay on the boundary between the two forces, two 'Tombola' discharge points were provided. As shown in this picture, the first pipeline was for smaller tankers which could dock against the mole while the other was buoyed 1,000 yards out to sea to permit the transfer of petroleum from larger vessels. (USNA)

TOMBOLA

The entire fuel supply plan for Operation 'Overlord' centred on the two big pipeline systems, designated as the Major and Minor Systems. The Minor System, scheduled to be constructed first, included facilities for receiving. storing and dispensing bulk petrol, oil and lubricant (POL) products in the Port-en-Bessin—Ste Honorine-de-Pertes—Balleroy area. It was to consist of tanker berthing facilities and unloading lines, onshore booster stations, inland tank farms (for storage), pipelines, pumping stations and dispensing facilities. Tanker deliveries were to be discharged through two receiving points.

Where the Western Mole (the Quay Letournier) had been damaged by landing craft during the great storm which hit the beaches on June 19, engineers improvised a suspension support to take the lines over the breach. (USNA)



Storage tanks, covered with camouflage netting, were set up beside the ruins of the town's tuberculosis sanatorium. (IWM)

Left: **Jean Paul Pallud did well to find this spot as there was no clue at all on the original caption, other than that the location was stated as being 'five miles inland'! It continued: 'The pipeline wends its way towards the storage tanks following roads and across fields'. (USNA)** *Right:* **Jean Paul: 'Another difficult research! I found that the two pictures were taken near Etréham where the pipeline ran along the D123. This shot was taken near a place called Fosses Soucy . . .**

British and American forces jointly were to use Port-en-Bessin, a British-controlled port with berthing facilities, as a discharge point for tankers carrying both motor vehicle and aviation fuel. Discharge was to be through two 6-inch lines, delivering both to the British and, through booster pumps, to the US tank farm at Mt Cauvin (near Etréham), about two miles distant from the port.

Ste Honorine-de-Pertes, two miles to the west and a convenient offshore anchorage, was to be the other receiving point, used for the receipt of motor vehicle and diesel fuel for US Army and Navy use. Discharge at that point was to be effected via two 6-inch ship-to-shore underwater lines (called Tombolas), and delivery was to be made to the Ste Honorine storage system, and by pipeline to the Navy fueling station at the site of the artificial Mulberry harbour. The Ste Honorine storage capacity was to total 20,000 barrels, the Mt Cauvin tank farm 24,000 barrels. This much of the Minor System was to be completed and in operation by D+10.

Within the next six days, pipelines were to join the Ste Honorine storage system with the lines at Mt Cauvin, and from this point a 4-inch line was to be constructed to Balleroy, about 13 miles to the south. Terminal storage tanks with a capacity of 6,000 barrels were to be erected at Balleroy, which, like Mt Cauvin and Ste Honorine, was to have dispensing facilities both for canning and for loading tanker lorries.

The entire project involved the construction of 27 miles of pipeline with the necessary booster stations and fittings, and tank storage for 54,000 barrels. Since there were no known commercial facilities in the area the entire system was to be newly constructed.

While the Minor System was designed to meet the Allies' needs for bulk POL in the intitial stages of 'Overlord', the biggest share of bulk deliveries was eventually expected to be made through the larger and more permanent system based on Cherbourg, known as the Major System. This, like the Minor, was to consist of discharge points, storage facilities and pipelines, but it was conceived and planned on a much larger scale and, when completed, was to have many times the capacity of the earlier development east of Omaha Beach. The outstanding features of the Major System were the large discharge capacities at Cherbourg, the long pipelines, and the enormous storage capacities to be developed along the pipeline route. Deliveries at Cherbourg were to be made principally via tanker discharge alongside the Digue de Querqueville. Five 6-inch lines were planned to handle those deliveries.

Modest as was the Minor System as compared with the one based on Cherbourg, it assumed enhanced importance as D-Day drew near. The change in tactical plans made only a week before D-Day not only affected the plans for the phasing in of combat and service units but also caused a revision in the estimated capture date of Cherbourg, setting it back one week to D+15. It therefore had a special significance for the supply of POL. The POL plan relied heavily on the capture of Cherbourg and the early construction of receiving and dispensing facilities there so that the scheduled transfer from packaged maintenance to bulk maintenance could be made by D+21. Any delay in the capture of Cherbourg set the POL plan back proportionately. A week's delay would cause a shortage of 31,400 tons of estimated maintenance and reserve requirements.

To make up this deficit, either additional quantities of packaged POL would have to be introduced to offset the delay in bulk deliveries, or additional bulk-receiving facilities would have to be provided. After discussing several possibilities, it was decided on May 29 that the best solution was to increase the bulk capacity of the Minor System. Meeting maintenance requirements with packaged POL would have required adjustments of the whole supply phasing programme. It was decided rather to increase both the receiving and storage capacity in the Port-en-Bessin—Ste Honorine—Balleroy area, and to make a special allocation of shipping to bring an additional 700 tons of POL construction materials over the beaches for this purpose at an early date.

Plans for the delivery of petrol and other petroleum products proved quite adequate in view of the slow rate of advance, the short lines of communications, and the resulting low consumption. Bulk deliveries of fuel were scheduled to begin on D+15, but construction of the Minor Pipeline System was delayed by difficulties in delivering construction materials, all of which had to arrive over the beaches or through Port-en-Bessin. POL construction materials were mixed with other cargo on several vessels and in the early confusion and competition for priorities, did not arrive as scheduled. A limited quantity of materials was gathered together very shortly, however, and the US 359th Engineer General Service Regiment began work on D+7, although many items were still unavailable.

Just before D-Day, when the discovery of additional enemy forces in the invasion area indicated that the capture of Cherbourg would be delayed, thus enhancing the impor-

. . . and the second picture a kilometre further west in front of the Ferme du Capitaine.' (USNA)

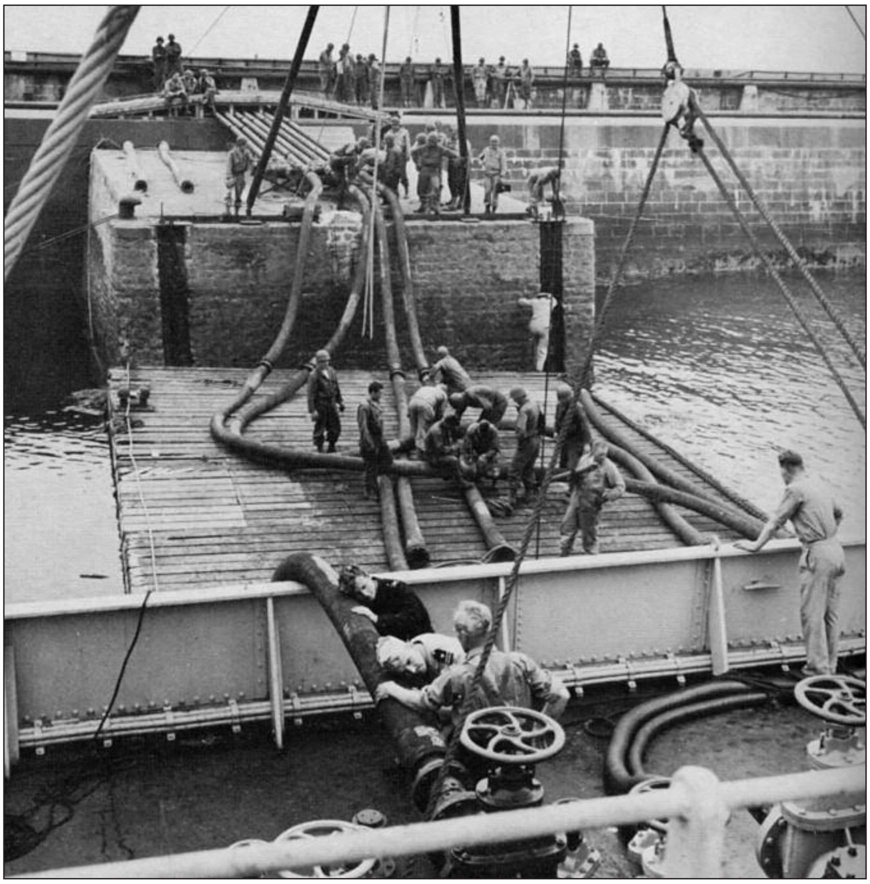
tance of the Minor System, the British 21st Army Group had fortunately made a special allocation of LCT lift to bring in additional construction materials. This cargo began arriving on D+9 and was routed to Port-en-Bessin, where it was promptly unloaded.

The POL plan benefitted by another favourable development. Previous inteligence had indicated that only the east mole at Port-en-Bessin could be used for discharge and that only small tankers of 350-tons' capacity could be handled. On arrival the Allies found that both the west and east moles could be used, one for the British and one for the Americans, and that tankers of up to 1,300-tons' capacity could be received. Eventually it was therefore possible to develop intake capacity of some 2,000 tons per day instead of the 700 originally estimated. This was most fortunate in view of the increased burden put on the Minor System during the prolonged period required to clear the port of Cherbourg.

Meanwhile construction of the facilities at Ste Honorine also proceeded, although plans for a third Tombola were cancelled because of terrain difficulties. Operation of the two underwater lines was actually restricted to fair weather because of difficulties in mooring tankers and connecting pipeheads in rough seas. Reconnaissance of the port areas shortly after the landings also resulted in some change in the siting of the tank farms. Many of the sites selected from the contour maps before the landings were unsuitable, primarily because of unfavourable gradients. The number and size of tanks placed at the ports were therefore held to a minimum, and the main storage was sited on better ground at Mt Cauvin, near Etréham.

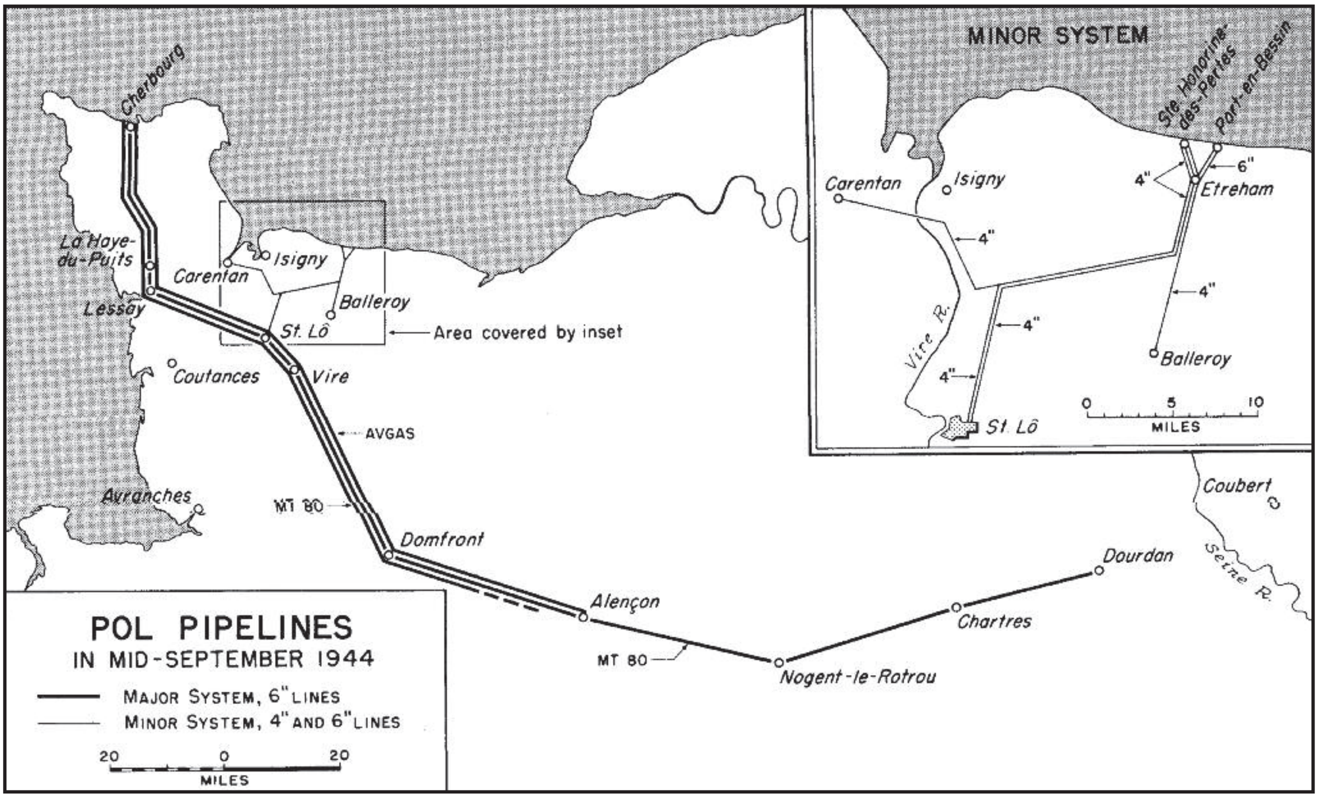
Construction of the pipeline inland from Ste Honorine was delayed somewhat by the necessity of clearing thickly-sown minefields in the area. Several casualties were sustained in this operation, but losses were undoubtedly kept down thanks to information provided by a former French Army captain on the location of mines both inland and offshore. He had witnessed the sowing from his home near the beach.

Construction of the Minor System progressed steadily and was far enough advanced for the US 786th Engineer Petroleum Distributing Company to begin operations on June 25 when the first bulk cargo of MT80 motor fuel was received, about nine days behind the planned schedule, at the Mt Cauvin tank farm. More than enough petrol in containers was on hand in Normandy to bridge the gap, inasmuch as vehicular mileage had been much less than expected in the limited area of the lodgement.



Whereas the Port-en-Bessin facilities — called the 'Minor' System — were designed to cater for the initial stages of the invasion, it was to be followed by the 'Major' System via Cherbourg but the port did not fall into Allied hands until June 27. Although work began immediately to clear the harbour, fuel was to be brought ashore via the long outer mole — the Digue running out to sea from Querqueville — and on July 3 the first ship-to-shore pipeline was brought into use. This is the *Empire Traveller* discharging on July 25. (USNA)

The pipes running at right-angles on the left lead from the tanker berth, well clear of the wreckage in the main harbour. (USNA)



Because of the delay in the capture of Cherbourg, the Minor System assumed even greater importance than expected. It was expanded beyond the original plans after the port was captured because the number of obstacles in the harbour promised to delay still further the use of the Querqueville mole for tanker deliveries.

Pipelines were extended from the Mt Cauvin tank farm to St Lô for both MT80 and aviation fuel, and a branch line for it was laid to Carentan to take advantage of existing facilities there. Eventually the Minor System had 70 miles of pipeline instead of the planned 27. Additional tankage was also constructed to give the system a storage capacity of 142,000 barrels instead of the planned 54,000. Because of rough sea conditions at the Omaha Beach fueling station, the Ste Honorine-des-Pertes installation was not used by the Navy as intended, but was turned over to the Army to be used exclusively as an MT80 receiving and storage terminal.

The Minor System was intended to deliver a total of about 6,000 barrels per day of MT80 and aviation fuel combined but by the end of July the output was double that figure. At that time the US First Army was consuming about 400,000 gallons (9,500 barrels) of motor fuel alone each day. Though originally scheduled to have served its purpose by D+41, the Minor System was compelled by tactical conditions to continue in operation at maximum capacity for many weeks to come. For a 12-day period in September its daily issues averaged 18,000 barrels.

By January 1945, millions of gallons of petrol were stored on the quayside — the supply pipelines can be seen running up from the bottom of the picture. But at this point in the story we must take a step backwards in time to look at the alternative method of supply . . . via Pluto, the code-names for the relative parts of the project conjured from Walt Disney characters too.

Although the idea of Pluto (the acronym either stands for Pipeline/s Under The Ocean or, as it appears in some sources, Pipeline Underwater Transport of Oil) may have originated with Lord Louis, its development was due to the efforts of these three men: Arthur Hartley *(left)* from the Anglo-Iranian Oil Company; H. A. Hammick *(centre)*, Iraq Petroleum Company, and B. J. Ellis *(right)* of Burmah Oil.

PLUTO

As an ambitious adjunct to the supply arrangements for the Normandy invasion — to supplement but not supplant tanker supplies — Pluto had much to commend it as an idea worth exploring; most obviously because it was less vulnerable than shipping to attack and to bad weather, while reducing dependence on vulnerable storage arrangements on the French coast and exposing fewer tankers to risk in the Channel. Underwater pipelines existed at ports and over short runs, but the distance involved in laying one across the Channel, with its tides and strong currents, placed the project in an altogether different category. The tides and the possibility of air attack meant that a pipeline would have to be laid quickly preferably overnight in a single operation, and would therefore have to be made up into a continuous length beforehand. Technically, it was a leap in the dark.

Early in the war, the idea of a cross-Channel oil pipeline from France to Britain had been regarded as impracticable. That was the general tenor of the response from various Whitehall departments to suggestions for such a pipeline which were sent in by people — mostly engineers — wishing to contribute towards the successful prosecution of the war. In fact, the earliest of these suggestions was received before the war, in October 1938. At that time, almost half of Britain's oil supplies came through the Mediterranean, the thinking behind these suggestions therefore was that by discharging cargoes at French Mediterranean ports and transporting the oil across country to the Channel ports (the idea of an overland pipeline does not seem to have been contemplated) and by pumping it by undersea pipeline to the British coast, this would safeguard fuel imports and prevent tanker losses in home waters.

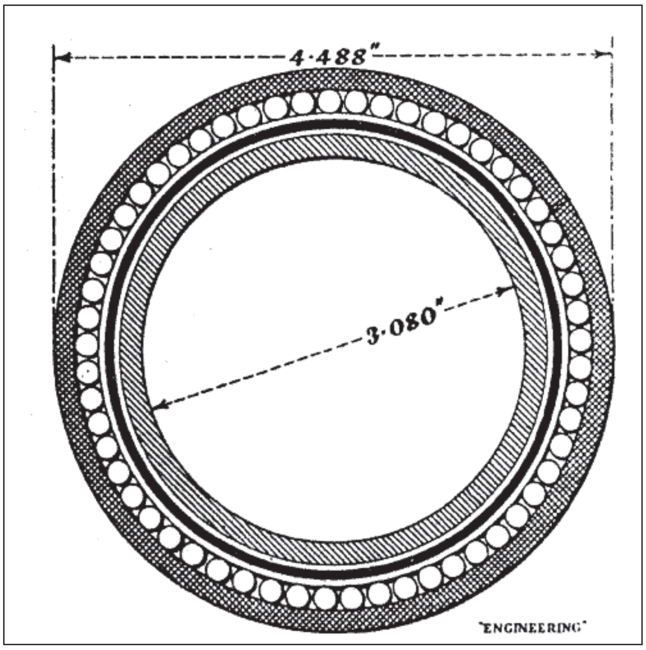
Two of the suggestions envisaged the use of a rubber pipeline, and one of these proposed that it could be laid by existing cable-laying ships, to be jointed on board and apparently looped through boosters on a stationary vessel or structure. The technical problems (though not in theory insuperable) ruled this out, apart from the difficulties of pumping low viscosity oils through narrow-bore pipes. Upkeep was another factor against a pipeline—the potential for damage included anchors fouling the line, depth-charges, friction on rocks and the sea-bed, the failure of joints, and so on. There was concern that a pipeline could easily be destroyed by the enemy should its location become known; that repairs would be difficult to carry out and considerable losses of oil could be expected beforehand; that it could be knocked out by the pump houses being bombed. The lack of enthusiasm for the idea also extended to the cost of building storage tanks in France and of transportation, rail delays were considered inevitable, and there was always the possibility of the Mediterranean being closed.

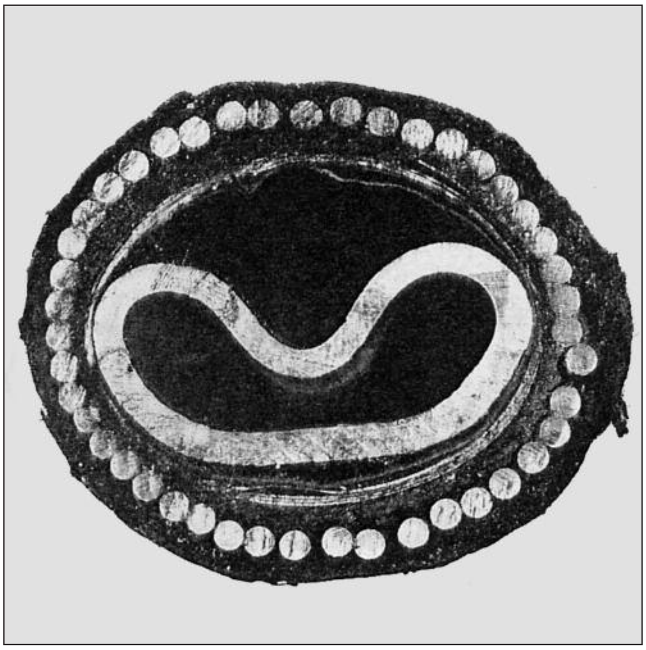
By the spring of 1942, the reversal of Britain's fortunes — the fall of France and the expulsion of the British Army from the Continent — had led to serious consideration of the idea of a cross-Channel pipeline as a means of supply for the forces which were ultimately to re-enter the mainland. Under Combined Operations Headquarters, planning for this assault embraced all manner of innovative projects for an operation that was gigantically novel. The 'Mulberry' floating harbour and the 'Pluto' undersea pipeline were to become in due course probably the most widely known, and while the credit belongs to the Chief of Combined Operations, the youthful Vice-Admiral Lord Louis Mountbatten, for enthusiastically adopting and backing new ideas certain of his staff were not slow to detect a tendency to claim them as his own!

So the story goes, as told by the head of the Petroleum Warfare Department (not to be confused with the Petroleum Department and only later involved in the project), it was at a flame-throwing demonstration at the PWD establishment at Moody Down in Hampshire that Mountbatten had turned to the Petroleum Secretary, Geoffrey Lloyd, and posed the question: 'Could you run a pipeline under the Channel to supply oil when we invade?'

Pluto (the code-name superseded the former 'Cables' and 'Eel') was developed by the Petroleum Department in conjunction with the Combined Operations Experimental Directorate, co-ordination of the project being undertaken by the department. In June 1942 this department, which was loosely subordinate to the Board of Trade, became a division of the newly-founded Ministry of Fuel and Power, with Geoffrey Lloyd as one of two Parliamentary Secretaries attached to the Ministry, and the now Petroleum Division continuing to function in virtual independence under him.

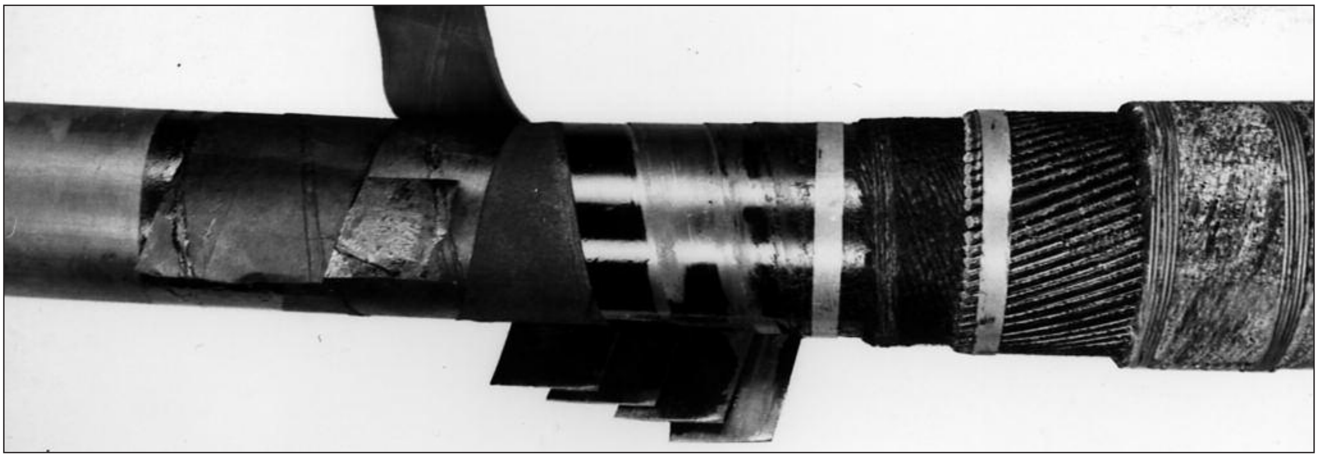
The headquarters of the Petroleum Warfare Department, under whose auspices Pluto was produced, were located in Westminster House in Dean Stanley Street, Millbank. The building is now used in part by Lloyds TSB bank.



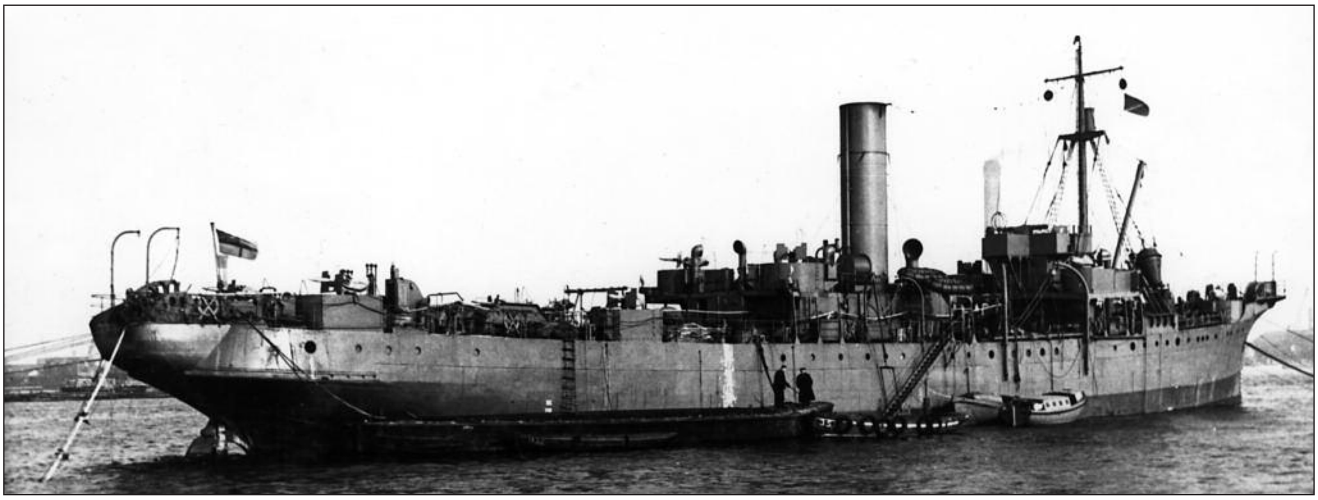


Arthur Hartley takes up the story: 'I was told of the requirement when I visited the Petroleum Department on April 15, 1942. I suggested the only chance of success would be to make a pipe in one complete length, so as to lay it across without stopping and at sufficient speed to get across the strong tidal currents. This would mean using a small-diameter pipe owing to the bulk and weight, but I then thought of the way in which a difficult pumping problem through hilly country in Iran had been solved. The unusually small internal diameter of 3 inches had been chosen, and by working at the very high pressure of 1,500lb per square inch, more than 100,000 gallons, or the equivalent of 25,000 Jerricans a day, were being delivered a distance of 40 miles from pumping station to pumping station. The next morning I saw Dr H. R. Wright, Managing Director of Siemens Bros. & Co., Ltd at Woolwich, and at once he agreed to make a trial length of cable, armoured with steel tape and wire, but without the communicating wires and conducting insulation, and it would start with the usual lead covering as an inner lead pipe impervious to petrol. It would be prevented from bursting by steel tapes and would be held together longitudinally by the steel wires. Even at this early stage, it was realised that secrecy would be essential and it was decided to use the word cable rather than pipe, and the code-name 'Hais' was chosen, standing for Hartley Anglo-Iranian Siemens. The first 200 yards were ready for test in a week but it was only 2 inches in diameter (internal) so it would only deliver about 30,000 gallons a day across the 20 nautical miles then visualised. The Anglo-Iranian Oil Company was called in to arrange the manufacture of further lengths and prepare a complete test programme. Siemens, without waiting for official orders or priorities, quickly produced more cable which was laid as a loop in the Medway at Chatham on May 10. Failures occurred on this length after two days' pumping, and the faulty portions were recovered and examined by W. T. Henley's Telegraph Works Co. Ltd of Dorking, Surrey, who had, at Siemens' suggestion, been brought in to provide more manufacturing capacity. Siemens and Henleys then combined their research and design facilities and further lengths of 2-inch cable were ordered from both makers with four layers of steel tape instead of two. Test lengths of both firms' manufacture were laid in deep water off the Clyde. Siemens' length was laid first filled with air under only atmospheric pressure. On test, after recovery from the depth of about 200 feet where the external pressure on the cable was 90lbs per square inch, the lead pipe was found to have been pressed in on itself into a kidney shape *(right)* by the external water pressure. Henleys' was laid full of water under 100lbs psi to balance the external sea pressure and was completely successful.'

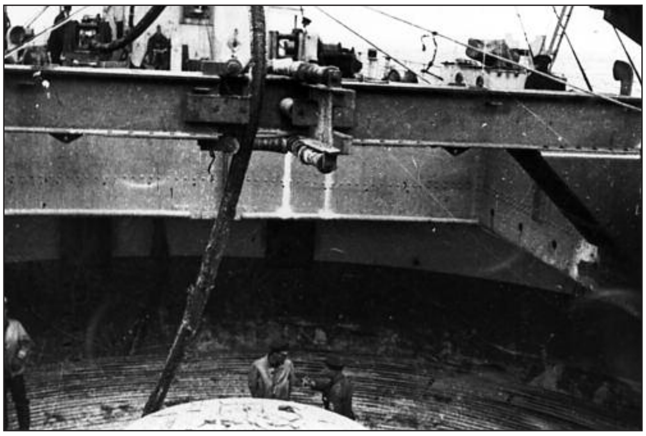
To solve the problems of laying a continuous length of underwater pipeline overnight, two solutions were adopted. The first, put forward by the chief engineer to the Anglo-Iranian Oil Company, Arthur Hartley, was for a lead cable, somewhat like a submarine telegraph cable, without the cores and insulation, to be laid from a cable ship. This was called 'Hais', a word formed from the name of its originator and the two main companies, Anglo-Iranian Oil and Siemens Brothers, which co-operated in manufacturing it.



'While the manufacture and testing of 2-inch cable had been proceeding, experiments were made with larger diameters, and it was proved that a cable of 3 inches in internal diameter (4½ inches external *(top left)*) could be made with existing facilities and could be handled by the ship's machinery with only minor modifications. A 3-inch cable would deliver about 2¾ times more petrol than a 2-inch cable, and it was therefore decided to stop the manufacture of the 2-inch and concentrate on the 3-inch. The lead wall was 0.195in thick. This was covered with two layers of paper tape coated with a petroleum compound, then overlaid with bitumen cotton tape. Four layers of mild-steel strip followed with a layer of tarred jute yarn as a bed for the outer armouring of 57 galvanised steel wires. These were finally covered with two more layers of tarred jute yarn.'

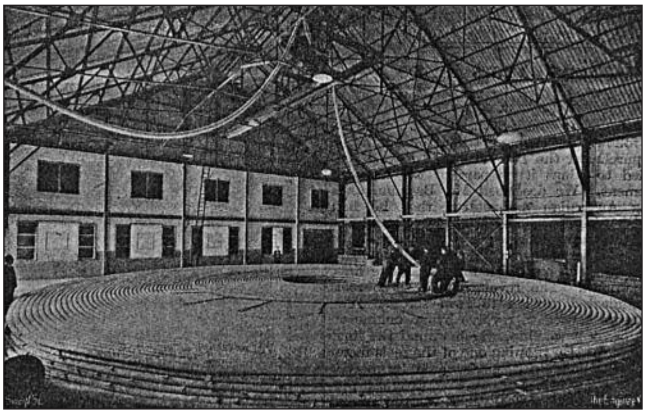


In order to retain the pressure within the pipe during handling, storage and laying, special 'bursting disks' of thin copper were incorporated in each joint. These would retain the water at up to 200psi but would burst at the operating pressure of between 750 and 1,500psi. Arthur Hartley: 'Consideration had meanwhile been given to the methods to be adopted for laying the cable in actual operation, and it was early realised that special cable ships would have to be equipped to carry a sufficient length of this unusually heavy cable, and there still remained the problem of dealing with the shore ends in the shallow water, into which the cable ship could not approach. The Admiralty and the Ministry of War Transport made available the SS ***London,*** a coaster of 1,500 tons, and she was fitted out and renamed HMS ***Holdfast*** *(above)* under direction of the Director of Naval Construction with Johnson & Phillips' cable gear.



Arthur Hartley: 'The finished cable, full of water, weighted 63 tons per nautical mile and was made in continuous lengths of 35 nautical miles.'

Johnson & Phillips' works are now no more. The pipe-handling equipment was manufactured at their Victoria Works situated at the southern end of Dupree Road in Woolwich. ***Left:*** **This is the old bricked up entrance where HRH The Duchess of Kent was greeted on March 19, 1945** ***(right)*** **by the Chairman and Managing Director Mr G. Leslie Wates, the Deputy MD and General Manager Mr W. Glass and Mr F. O. Townsend of the Factory Inspectorate.**

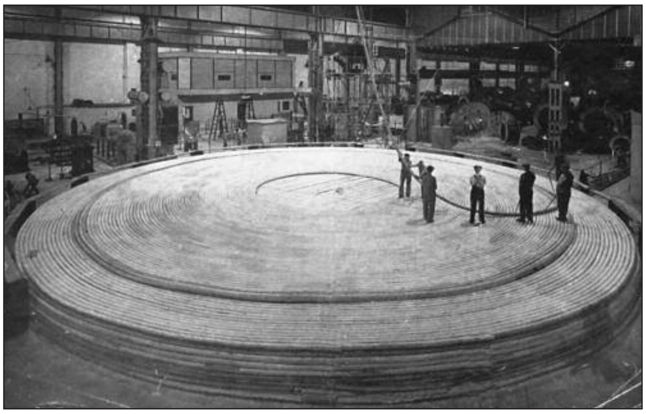


The three main cable companies used for the manufacture of Hais were all situated on the River Thames. The Siemens' factory on Harden's Manorway at Charlton still stands although the storage building ***(above left)*** **is now the print works of Campaign Posters Ltd** ***(above right).***

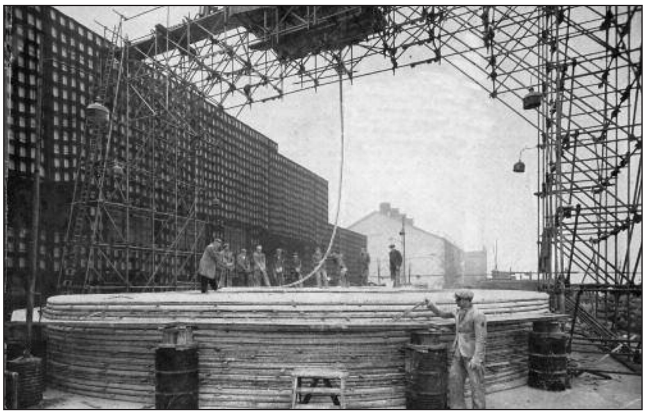
After successful initial tests carried out with a 2-inch diameter hollow cable quickly produced by Siemens, a sizeable length of Hais was experimented with as a loop in Chatham Dockyard. This revealed that under high pressure the lead tubing was pushed through the protective outer steel taping and that some of the joints fractured. The cable manufacturing firm of W. T. Henley's Telegraph Works Co. Ltd was brought in which for some time had been working on a 'straight-through' method of extruding lead pipe free of longitudinal seams. A length was laid in deep water in the Clyde with the Post Office undertaking the work, its experience and assistance proving invaluable throughout the project. Then in December came full-scale trials in the Bristol Channel.

For these, a 30-mile experimental length of 2-inch Hais cable was laid by a former cargo vessel, the SS *London,* which had been fitted out with Post Office machinery and gear, and (with a crew of mostly cable hands and merchant seamen) renamed HMS *Holdfast* by the Navy. On December 29, 1942, the ship made a successful run from Swansea, on the Welsh side of the Bristol Channel, and dropped and buoyed the line off Watermouth, on the north Devon coast, near Ilfracombe. With the help of the system's designers, the RASC brought the line ashore, and training continued in the intricacies of high-pressure pumping and storage. After the line had been brought into operation in April 1943, little did those people of Devon and the West Country possessing petrol coupons realise that their fuel had been pumped under the Bristol Channel from Wales! The line achieved an average of 125 tons (38,000 gallons) of petrol a day, at a pressure of 750lb per square inch, and led to a decision to experiment with 3-inch cable of greater capacity.

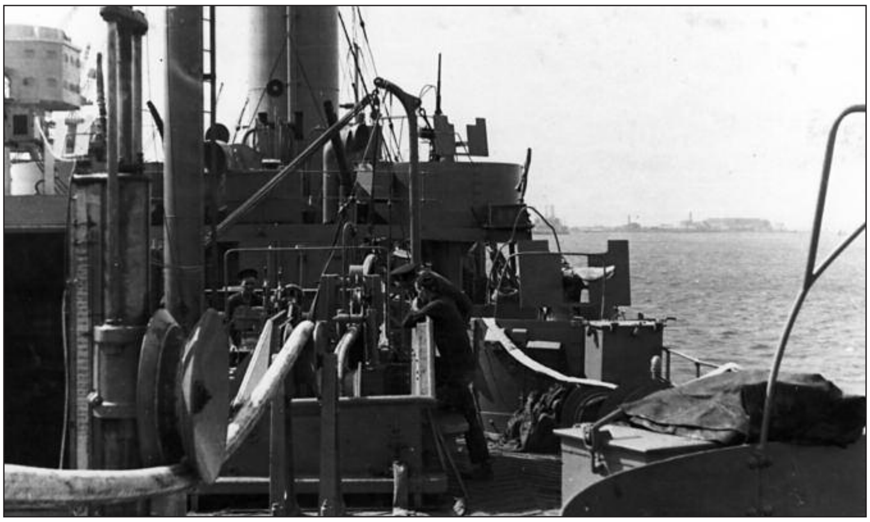
The river scene on the day the Chiefs-of-Staff came to inspect progress on Pluto — now transformed with the Thames Barrier and the skyscrapers of Canary Wharf. (MD)



On the other hand, Henleys' factory in Crete Hall Road at Gravesend is still very much into the cable-making business, albeit under a new name: AEI Cables, a subsidiary of TT Electronics. *Above:* The same manufacturing hall — then and now.



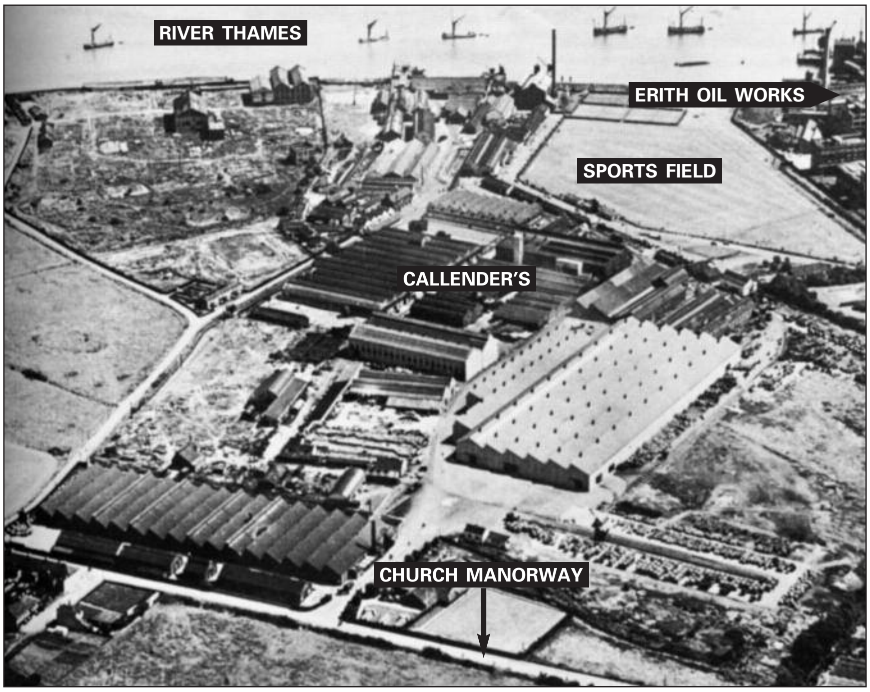
Left: The Hais cable was coiled on the river front outside the factory where a massive gantry had been erected to carry the heavy pipe to the jetty. *Right:* A modern covered cableway does the same job today . . .

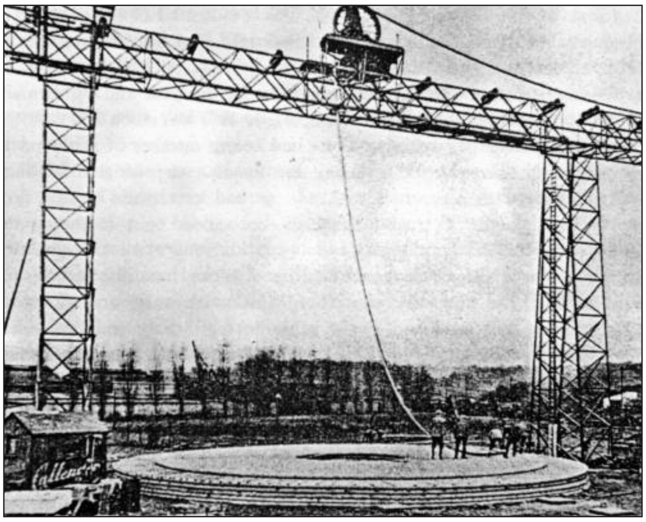


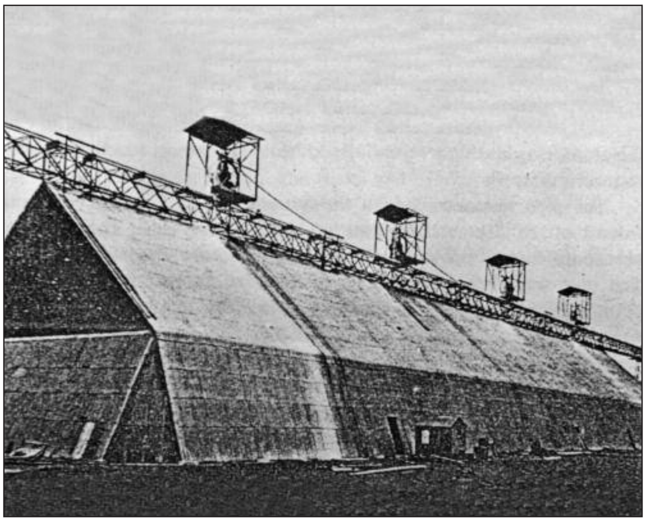
. . . but the original old jetty *(above)* still survives! *Right:* What is interesting about this shot of the cable entering the hold is that one of the Army coastal forts can be seen on the extreme left awaiting its turn to be towed out and sunk as a forward anti-aircraft battery at the mouth of the Thames (see *After the Battle* No. 4). Arthur Hartley wrote that of the 570 nautical miles of lead sheath used in the construction of the Hais cable for Pluto, 463 miles were made on the straight-through presses at Henleys and the Telegraph Construction & Maintenance Company and 87 miles on the Pirelli continuous extrusion machine by Pirelli General Cable Works Ltd, Johnson & Phillips, the Standard Telephones & Cables Ltd. and the Edison Swan Electric Co. Ltd. the balance being supplied by W. T. Glover & Co. Ltd on their 'Farmer' press. The lead sheath was manufactured in 700-yard lengths which were joined by lead burning.

Callender's Cable & Construction Company in Church Manorway at Erith were advised in May 1943 that because Siemens and Henleys were heavily engaged with producing the 2-inch pipe (at a rate of ten miles per week), Callender's were needed to produce a nautical mile of the 3-inch version for experimental purposes. Thereafter the company were asked to start armouring lengths of the 2-inch pipe which had been made by Henleys. These were supplied in continuous lengths of 30 miles which had to be loaded into the vessel moored at the nearby jetty at the Erith Oil Works. This entailed building a gantry across the sports field which was constructed using Callender-Hamilton bridge techniques.

As the extrusion of the lead pipe had to be carried out without the normal supporting core of conducting cable and its insulation, the pipe had to be pressurised to avoid collapse. Also the steel armouring tape wound around the lead sheath had to be precisely applied for a single leak would put the entire pipeline out of commission. Thirty miles of 2-inch cable weighed 1,200 tons and 3-inch 1,680 tons, necessitating a winch with a power of about three tons to haul the pipe along the gantry. Callender's, with their four armouring machines were vital to the manufacturing process and, apart from making 128 nautical miles themselves, they armoured a further 129 miles of lead pipe produced elsewhere.



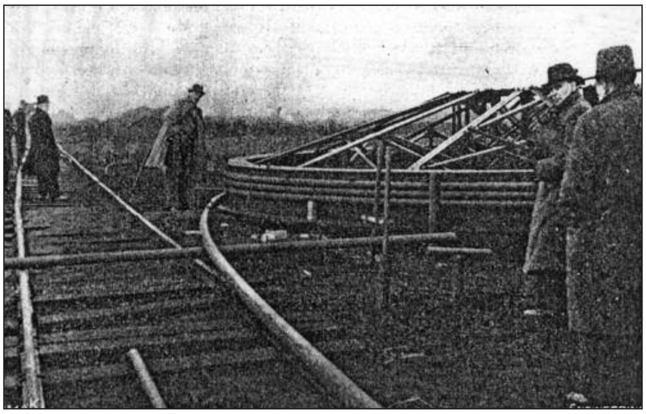




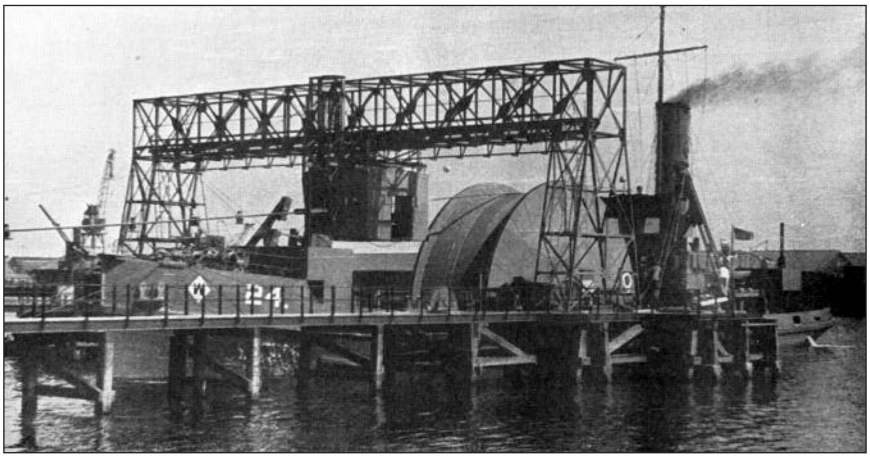
'At the commencement of the production of 3-inch Hais cable', explained Arthur Hartley, 'it became necessary to obtain much greater manufacturing capacity and therefore additional machines were brought into operation at Callender's Cable & Construction Co. Ltd, Glovers, and Pirellis. In the case of Callender's, four machines were finally brought into production, and an overhead gantry 45 feet high by 1,600 feet long with supporting towers every 70 feet ***(above left)*** **was constructed to carry cable from their armouring shop to an adjacent deepwater jetty. Eight 60-foot diameter coiling sites were situated between the supporting towers to facilitate continuous manufacture and loading; and these sites were covered by a continuous, light-framed, steel building which had to be erected due to black-out regulations** ***(above right)*****. A similar arrangement was made for two armouring machines at Glover's and for storage and loading at the Manchester Ship Canal. In February 1944, I visited the United States to arrange the manufacture of cable at four works there, to meet the increased requirements. A total of 710 nautical miles of Hais cable was produced for Operation "Pluto", of which 140 miles came from the United States.'**

After the war, Callender's merged with British Insulated Cables (which had been involved with the other Pluto pipeline — the Hamel — see opposite) to become BICC. That company was taken over in turn by another Pluto company, Pirelli Cables in August 2000. The works still manufactures cables in a modern building on the same site. In this picture we are looking back from the river towards the factory across the old sports field crossed by the wartime gantry. Today cables are fed into cable ships along the ground-level conveyor running alongside the boundary fence with the oil works on the left.

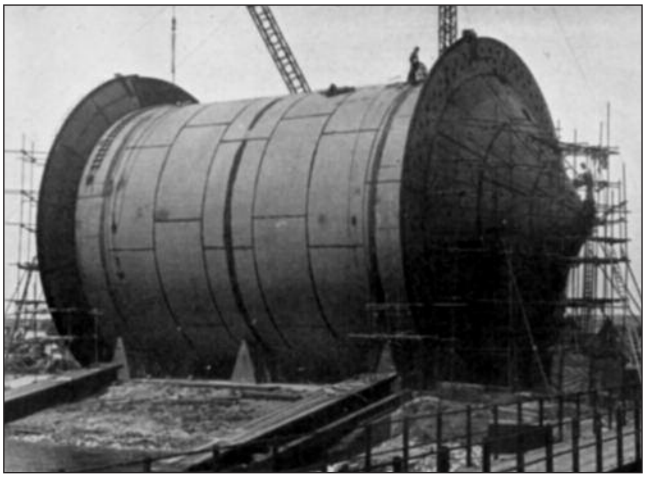
Arthur Hartley explains how the alternative type of pipeline came about. 'The second novel proposal came at the end of April 1942 from Mr B. J. Ellis of the Burmah Oil Company and Mr H. A. Hammick of the Iraq Petroleum Company. They were already dealing with the Hais cable and, when they saw how flexible it was in a long length, although extremely stiff in a short length, they suggested that steel pipe, which they had also seen to be very flexible, when handled in long lengths in the oil fields, might also be used for making long lengths of line required in one piece. With the assistance of Stewarts & Lloyds, J. & E. Hall, of Dartford, and A. I. Welding Machines Ltd. they quickly proved that 3-inch steel pipe, code-named "Hamel" after the name of its two inventors, could be bent round a wheel 30 feet in diameter, could be pulled off again relatively straight without kinking, and could be flash-welded to provide any required length. However, they realised that it could not be handled like cable in horizontal stationary coils in a cable ship because this involves a complete twist in each turn while coiling down, and its removal while uncoiling for laying.'

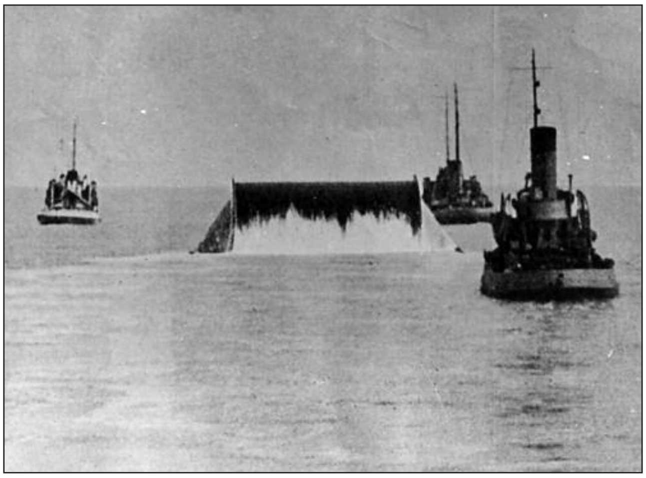


The second method employed for Pluto was for a welded steel pipe, called 'Hamel' after its two inventors, Mr H. A. Hammick, chief engineer of the Iraq Petroleum Company, and Mr B. J. Ellis, Chief Oilfields Engineer of Burmah Oil, who had now been seconded to the Petroleum Division. As the Hamel pipe was too stiff to coil in the hold of a ship, the idea was conceived of winding it round a floating steel drum and unwinding it at sea as if from a gigantic cotton reel. Tests at the National Physical Laboratory demonstrated that 3-inch steel pipe could be bent and coiled around a diameter of 40 feet, and model drums were used to act as bobbins in the trials that were undertaken. Sea trials followed, using a converted hopper barge commissioned by the Navy as HMS *Persephone*. This vessel was fitted with an enormous drum which rotated in trunnions on her deck and paid out steel pipe through her bottom. Giant floating drums 90 feet long and more than 50 feet in diameter — cone-ended, hence their being called 'Conundrums' — were constructed for towing across the English Channel.

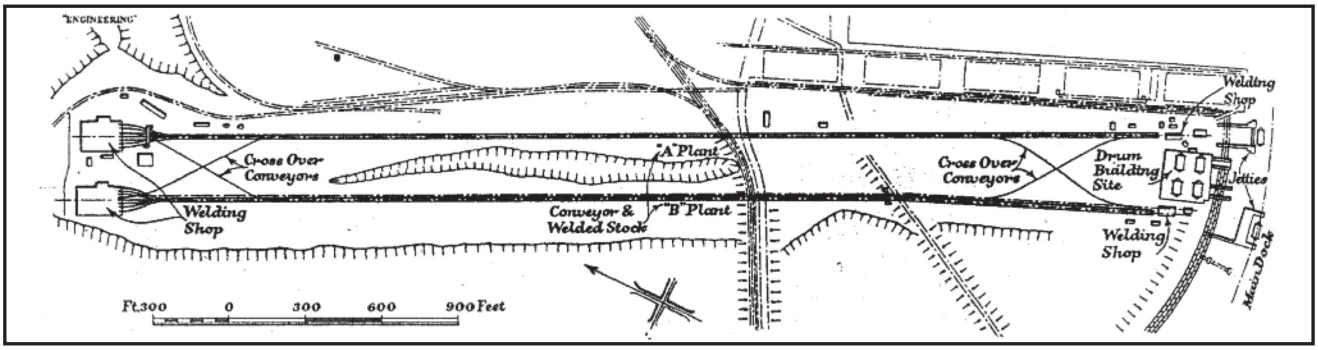


'Mr Ellis therefore suggested, the use of a large wheel mounted on trunnions on the deck of a hopper barge with its lower portion protruding into the sea through the hopper doors, and a vessel was so converted and named HMS *Persephone*, seen here taking on Hamel pipe from the gantry at Tilbury.'



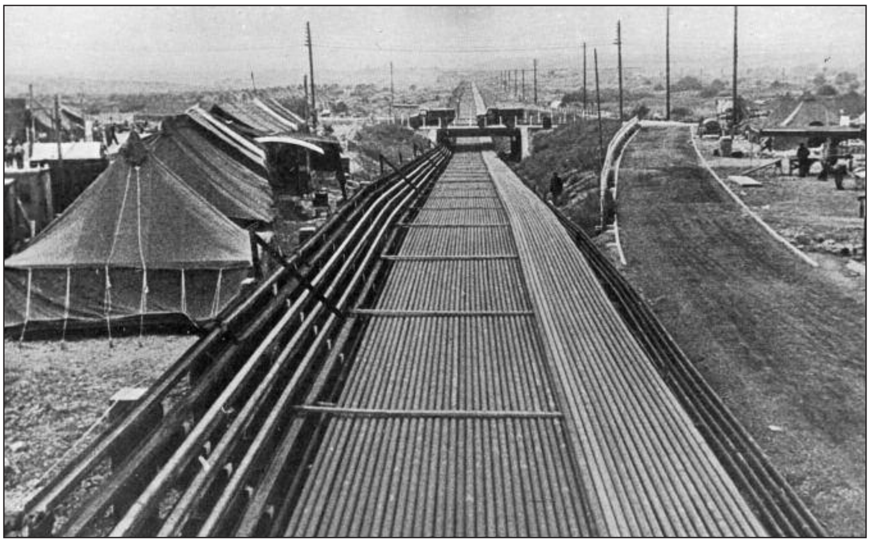


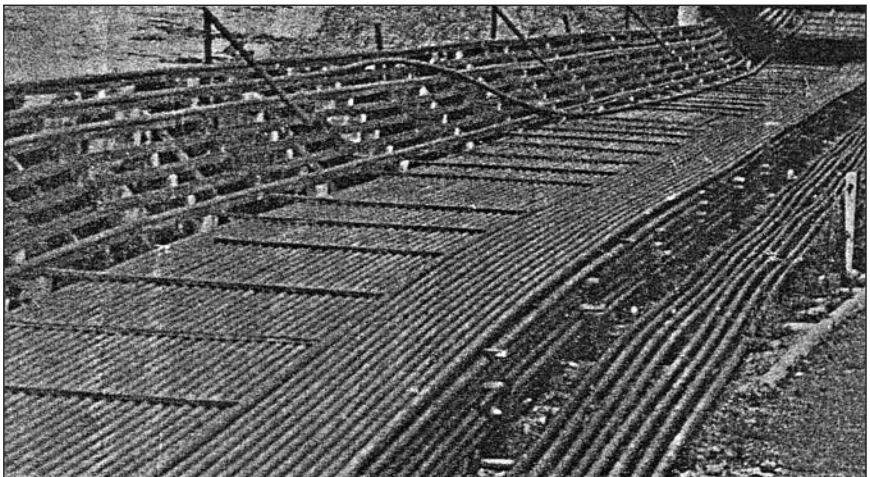
'Later, a floating drum like a gigantic cotton bobbin, capable of carrying any quantity of pipe likely to be required, was proposed', recounts Arthur Hartley. 'Model tests of the floating drum — HMS *Conundrum* or "Conun", as it came to be called — were made at the National Physical Laboratory in their Froude tank and confirmed that such a vessel could be towed at sufficient speed without yawing. Preliminary work had thus proved that the pipe could be bent and pulled off straight, that it could be welded with absolute reliability, and that it could be carried and laid by either the wheel and barge or the Conuns, but there was no previous experience as to how bare steel pipe would lie and behave on the bottom of the sea. It was felt, however, that it would have at least a six-weeks' life, and on this basis (bearing in mind that it was by no means certain there would be sufficient supplies of lead available to produce all the Hais cable required), it was decided to proceed with all speed with a factory at Tilbury to weld, store, and wind Hamel pipe and construct six Conuns. Stewarts & Lloyds Ltd undertook, in addition to the steel pipe, to act as agents of the Petroleum Division for the design, construction, and subsequently the operation, of the Tilbury factory. Pending completion of the factory, some miles of 3-inch steel pipe were hand-welded at Portsmouth Dockyard and wound on *Persephone's* wheel for preliminary trials which were, to the admitted astonishment of most of the spectators, entirely successful. This was early in April 1943, so both the Hais cable and Hamel pipe had been brought successfully through their full-scale trials, and production on a considerable scale had been organised by the Petroleum Division and Chief of Combined Operations before they handed on responsibility for the operational stage respectively to the Petroleum Warfare Department under its Director-General, Major-General Sir Donald Banks, and to Force 'Pluto' specially organised by the Admiralty under the command of Captain J. F. Hutchings. Thus, after visiting Watermouth on April 24, 1943, and seeing the Hais cable in actual operation, the Quartermaster-General was able, on April 29, to visit the Hamel factory at Tilbury, to see Hais cable in production at both Henleys at Gravesend and at Siemens at Woolwich, where he also saw HMS *Holdfast* loading cable. He decided that further lengths should be ordered at once.'



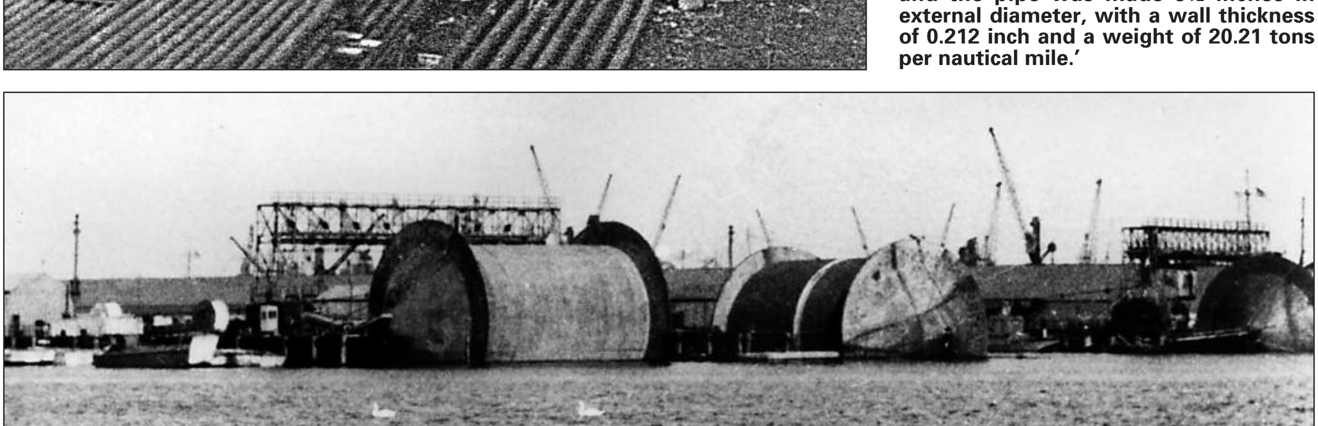
By June 1943, a factory operated by Stewarts & Lloyds had been built beside the Thames at Tilbury to receive the first lengths of pipe which arrived by rail from Corby in the Midlands. The Tilbury operation welded the pipe into sections of 4,000 feet which were progressively pushed forward down long roller ways stretching to the water's edge. For storage they were hauled off alongside by one man pulling the end of a section off the roller way — the movement communicating itself along the entire pipe. Suspended on a gantry above a slipway, the Conundrum was rotated to pull sections of pipe on to it from storage, each section being welded to the next to form a continuous line.

Arthur Hartley: 'Two factories with storage sites were erected at Tilbury, each having seven lines of machines consisting of a flash welding machine, a Taylors pipe-cutter, and a traversing machine. The standard 40-foot lengths of pipe were welded one by one to form lengths of 4,000 feet *(right)*.'





One of the most amazing sights to be seen at Tilbury during the Pluto operation occured when each length of pipe was completed. Each length comprised 100 pieces of 40-foot pipe welded together to form one 4,000-foot long. As each piece of pipe was added, the pipe moved forward towards the river gripped by spring-loaded pads which pushed it along a conveyor consisting of rolled-steel channels. Storage space was provided below the conveyors and, when each length was completed, a few yards were lifted off at one end. Due to its weight and elasticity, the rest of the pipe then threw itself sideways at around 120 mph as can be seen in the photo *(left)*. A welding machine then joined the 4,000-foot lengths as it was wound on the Conun drums. Arthur Hartley explained that 'low-carbon mild steel was used to facilitate the welding, and the pipe was made 3½ inches in external diameter, with a wall thickness of 0.212 inch and a weight of 20.21 tons per nautical mile.'

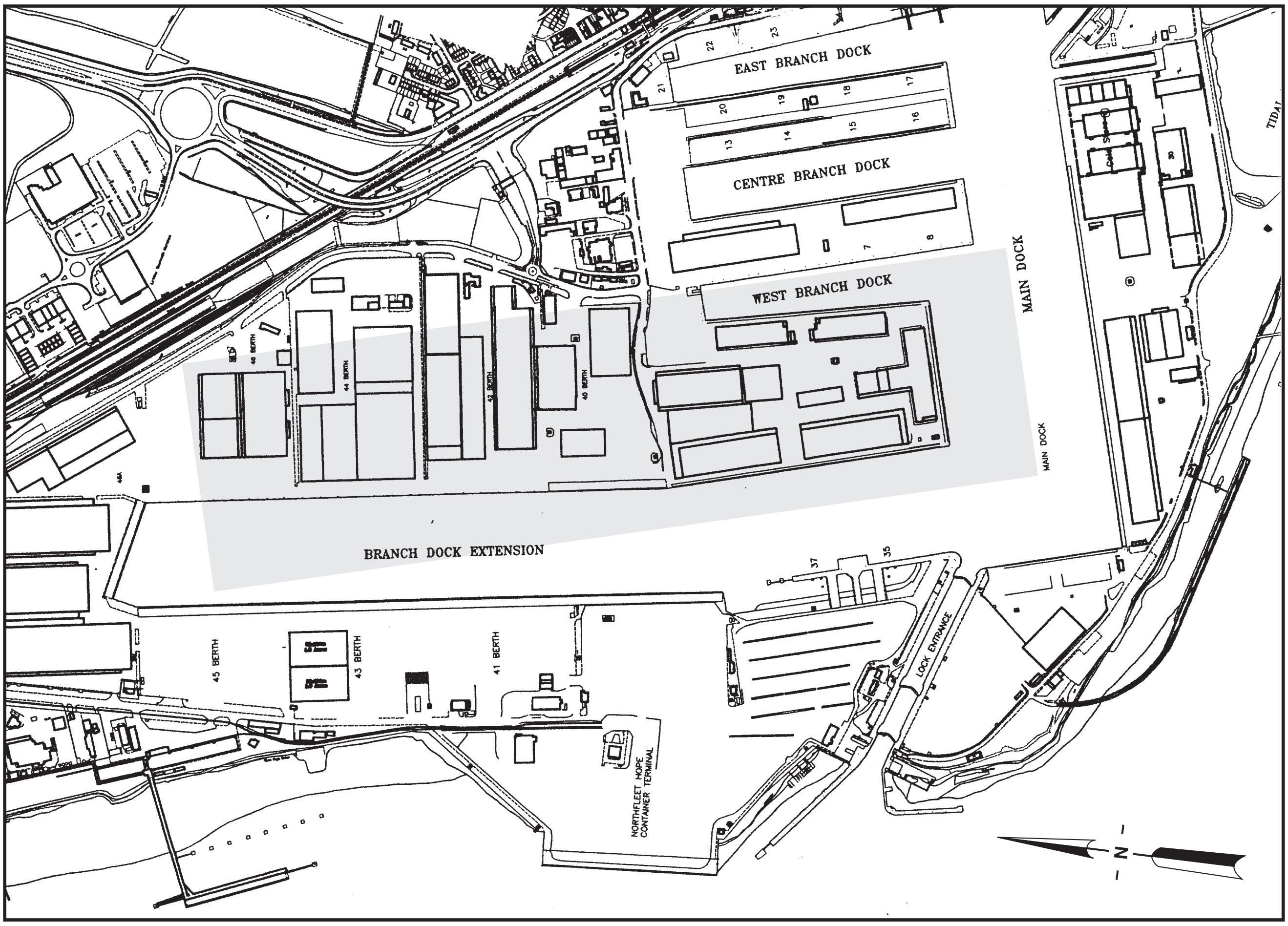


Arthur Hartley explained that 'hinged arms were provided at the end of the jetty to hold the Conun in position by its trunnions, and means were provided to ballast it with water when light to minimise wind effect.' (MD)

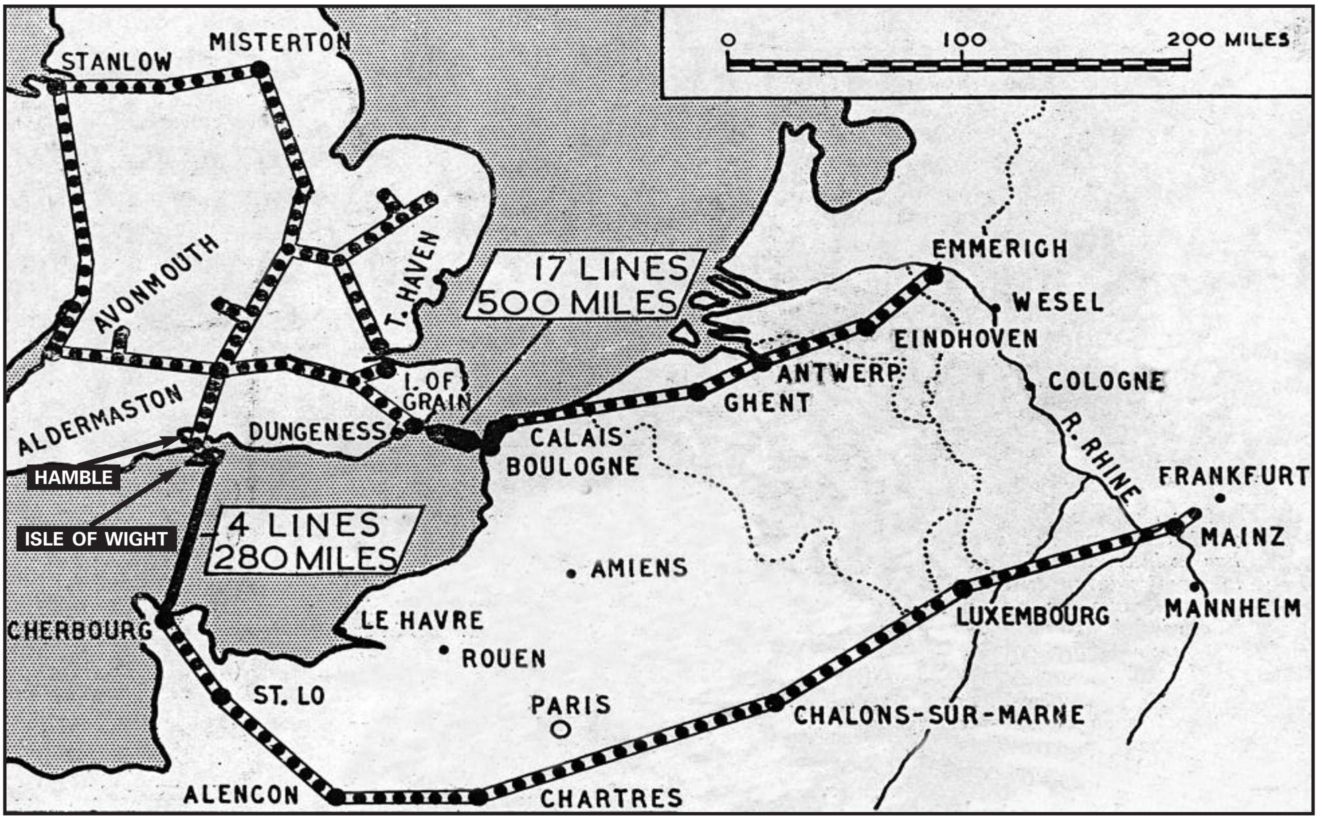
Tilbury docks pictured by the RAF in May 1946. We have arrowed the two Hamel factories.

Also in June 1943, the British Chiefs-of-Staff directed that the Pluto project should be a 'matter for immediate execution'. In April, the Petroleum Division's co-ordinating function — the responsibility for design, development and administrative work in conjunction with the services — had passed to the Petroleum Warfare Department. The change had been made by Mr Lloyd as the division was experiencing problems in its dealings with the services, and it was felt that the more services-oriented Petroleum Warfare Department would be better suited to the role. This department had been created in July 1940 under the aegis of the then Petroleum Department for the development of novel weapons and devices making use of petrol and oil, and was headed by the officer whom Lloyd had poached from the Army to 'burn the invader back into the sea', General Sir Donald Banks. Flame-throwing tanks and carriers ('Crocodiles' and 'Wasps') had since been among the ideas developed, and 'Fido' — Fog Investigation Dispersal Operation, for landing aircraft safely — was being experimented with under the direction of the department's technical director, the protagonist of Hais, Arthur Hartley, on loan from Anglo-Iranian. Mr Hammick, co-developer of Hamel also joined the department.

On the naval side, the project's fortunes were in the hands of Captain J. F. Hutchings. In the broad division of functions, the Navy was responsible for operations from high to low water marks, the Army for running the pipelines on the European mainland and the petroleum authorities for the pumping stations on British shores, to which the RASC were attached.



The post-war expansion of Tilbury docks and the construction of the new Branch Dock Extension in 1963 has totally obliterated the Pluto workings. The area depicted on the plan at the top of the opposite page covers the shaded area on the present-day plan



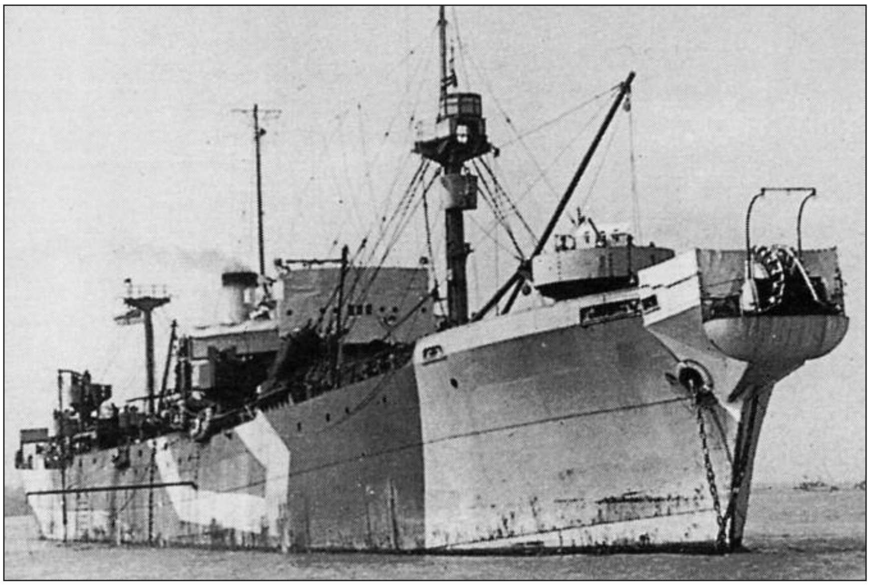
In June 1945, the *Petroleum Times* was permitted to publish for the first time a general outline plan showing the military supply pipelines, both in the UK and across the Continent. Nevertheless it was heavily censored as the spur lines for conveying aviation fuel direct to specific bases — as happens today — have been excluded.

Oil imported to Britain was mainly distributed by the railways. With the Channel closed to ocean tankers after France fell, coastal movements were also made by small vessels. Road transport carried supplies on shorter haul journeys, primarily from distribution centres to where they were needed. At the end of 1940, there were 7,000 railway tank wagons, which by mid-1944 had risen to 9,600, plus 500 from the United States used during the summer and autumn although destined for the Continent. When the war began, the petroleum authorities could call on 4,900 vehicles, a number which was to rise by only 500 by May 1944. Considerable increases were to be achieved in the railways' delivery performance; the Channel was reopened in September 1944; road tankers were to run a total of 103 million miles in 1944 compared with 64 million in 1940 — but the major scope for the expansion of long distance oil distribution was seen to lie in pipelines.

The first new pipeline of the war had been laid from the Gloucestershire port and oil storage area of Avonmouth to Walton-on-Thames in 1941 to help supply the London region from the west coast. As an important supply point for an invasion, Southampton was linked to it by a branch line from Aldermaston which was completed in June 1942. This was built in response to the question of how oil was to reach the south coast as the planners foresaw Southampton being fully occupied with outward shipping movements during a cross-Channel operation and likely also to be under heavy air attack, while the surrounding roads and railways would be loaded with other military traffic. The branch was planned to have an ultimate capacity of 120,000 tons a month, pumped from Avonmouth or, if need be, through the north-south line all the way from the Merseyside storage area of Stanlow in Cheshire. The largest scheme was for supplying the 'bomber area' of eastern England — the creation of a completely new circuit comprising new lines from Stanlow to Misterton (near Doncaster) and Sandy in Bedfordshire, connecting with an extension from Aldermaston of a second line laid alongside the first from Avonmouth. The second line improved the facilities for supplying Southampton without disrupting supplies to London; its size catered for both the 80,000 tons a month required in the 'bomber area' and the 120,000 tons a month needed to feed the branch to Southampton. By the autumn of 1943, a 70-mile link had been laid between Walton-on-Thames and the site chosen for a Pluto pumping station on the Kent coast at Dungeness. Later, two small spurs ran from this pipeline to an air force depot at Wye and a small Navy tankage at Rye. Another line was laid between Walton-on-Thames and the big oil installation on the Isle of Grain. For Pluto, this meant that the project was connected to a third main importing centre apart from Avonmouth and Stanlow.

The pipelines to Cherbourg (code-named 'Bambi') had to draw their fuel via the Isle of Wight. *Left:* **Adrian Searle pictured the remains of the 12 lines coming ashore in Thorness Bay from the mainland.** *Right:* **An old valve discovered in the BP oil terminal at Hamble-le-Rice which once fed fuel across the Solent was refurbished for the 50th anniversary of the laying of Pluto.**

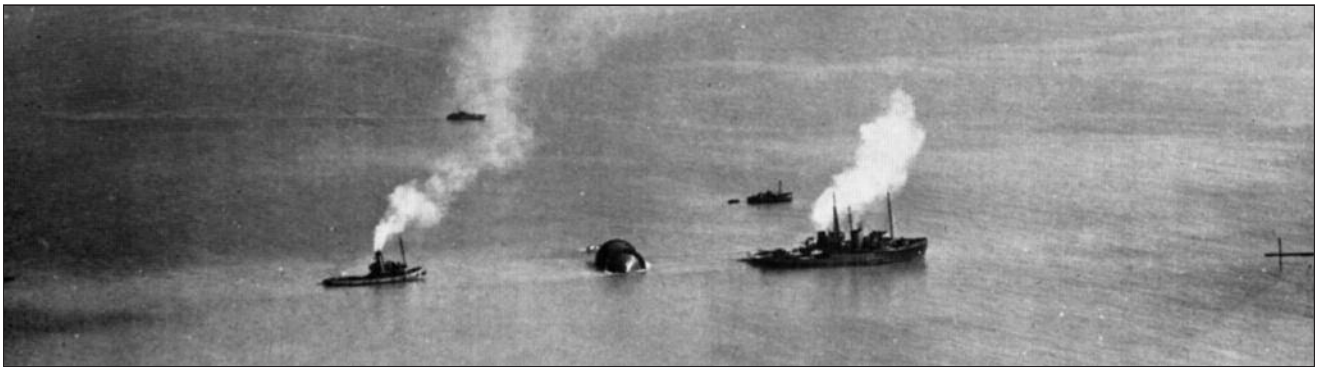
Arthur Hartley: 'During June and July, recommendations were made by the Quartermaster-General's Petroleum Committee, and confirmed by the Chiefs-of-Staff Committee, who awarded a high priority, that the English pipeline system should be extended to Dungeness and to the Isle of Wight and that pumping stations of 3,500 and 3,000 tons a day capacity, respectively, should be erected at these places. The Isle of Wight to Cherbourg crossing, then considered for the first time, involved a sea crossing of about 70 nautical miles instead of the 20 or so originally visualised, and made necessary the provision of larger cable ships and the use of the Conun loaded down till the axles were awash. Following a successful lay with 3-inch Hais cable three more ships were obtained to be converted and fitted with cable gear by the Director of Naval Construction. HMS *Algerian* was to carry 30 miles of 3-inch cable, and the other two, HMS *Latimer* (*right*), and HMS *Sancroft,* were to carry 100 miles of 3-inch cable weighing about 6,400 tons.'



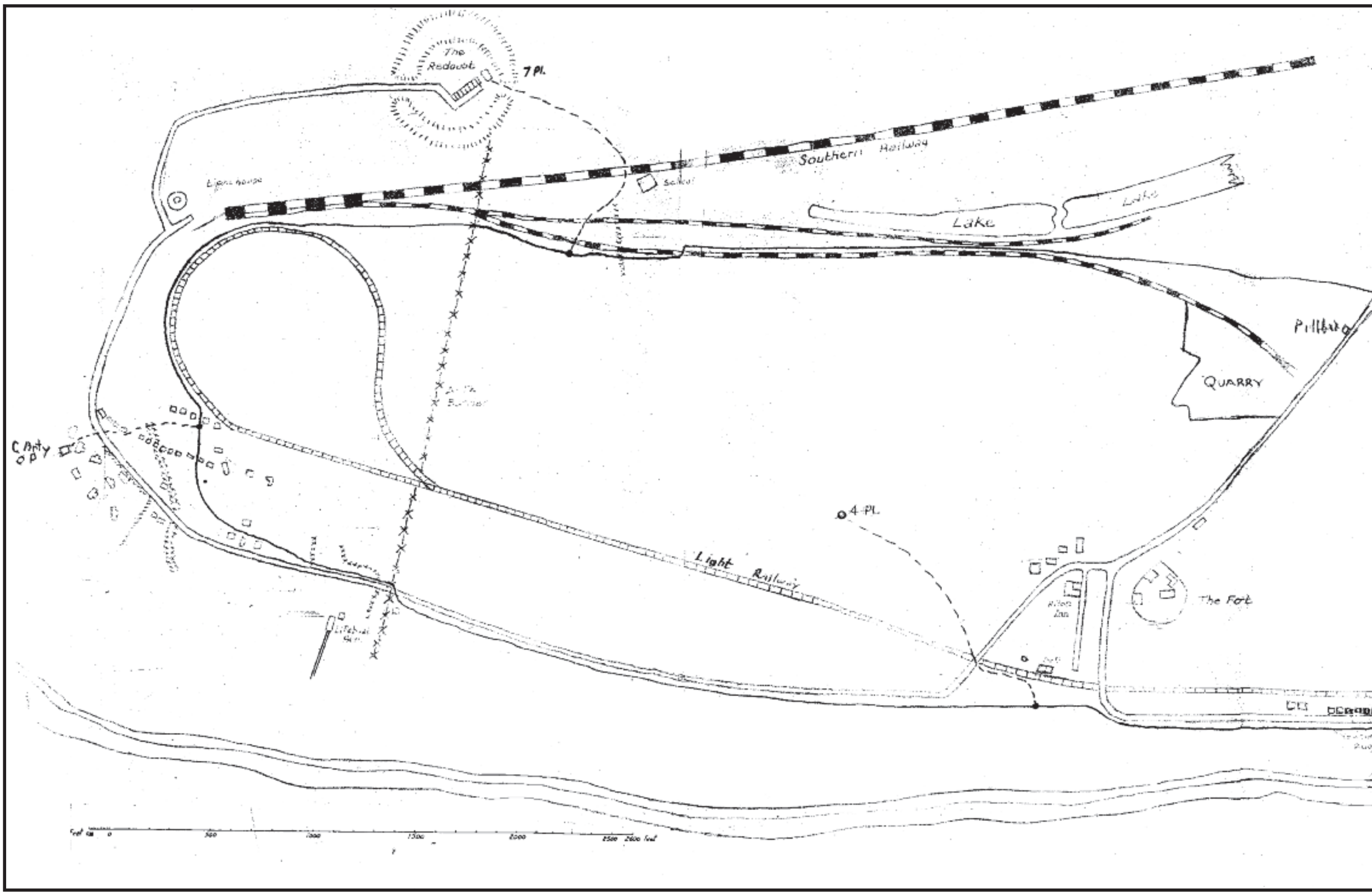
With Normandy chosen for the invasion rather than northern France, construction of the pumping station at Dungeness took second place to the two sites selected on the Isle of Wight. These were at Sandown and Shanklin about three miles apart and gravity-fed from a 620,000 gallon tank (code-named 'Toto') erected in a small wood on a hill at Shanklin. An old coastal fort at Sandown dating from Napoleonic times, already being dismantled when it was made use of as a defensive position in 1940, provided excellent cover and accommodation for the installation of pumping machinery. At Shanklin amidst a row of bomb-damaged buildings beneath the town's cliffs, a new 'wrecked' elevation was added to conceal the installations.

Hais and Hamel lines were laid across the Solent, connecting up with the storage tanks at Fawley, at the end of the Aldermaston to Southampton pipeline — all providing much-needed experience for the laying parties — and lines were laid in Sandown Bay to connect up the two pumping stations laterally. Collectively, these pumping stations were code-named 'Bambi'. The distance from Sandown Bay to Bambi's destination, the Cherbourg peninsula, was about 70 nautical miles.

'The Isle of Wight pumping installation at Sandown consisted of 18 pumps, and that at Shanklin of ten, these stations being cross-connected by two Hamel line loops laid out to sea and in again. Thus, if either of the installations had been "blitzed", the other could have taken over. The Petroleum Board constructed the land lines and a large number of Hais and Hamel lines were laid across the Solent, both to provide the link across to the Isle of Wight, and also, at the same time to train its large new force and develop and try out its ships and gear.' *Right:* **On Shanklin Chine a remnant of Pluto was left beside the path. A nearby notice tells the story: 'P.L.U.T.O. (Pipe Line Under The Ocean), one of the engineering marvels of the last World War, by which petrol was pumped by pipeline direct to the Allied Invasion Forces in Normandy, passed through this Chine on the end of its long journey across the country. From the pumping station on the Esplanade it commenced its last journey across the bed of the Channel.'**

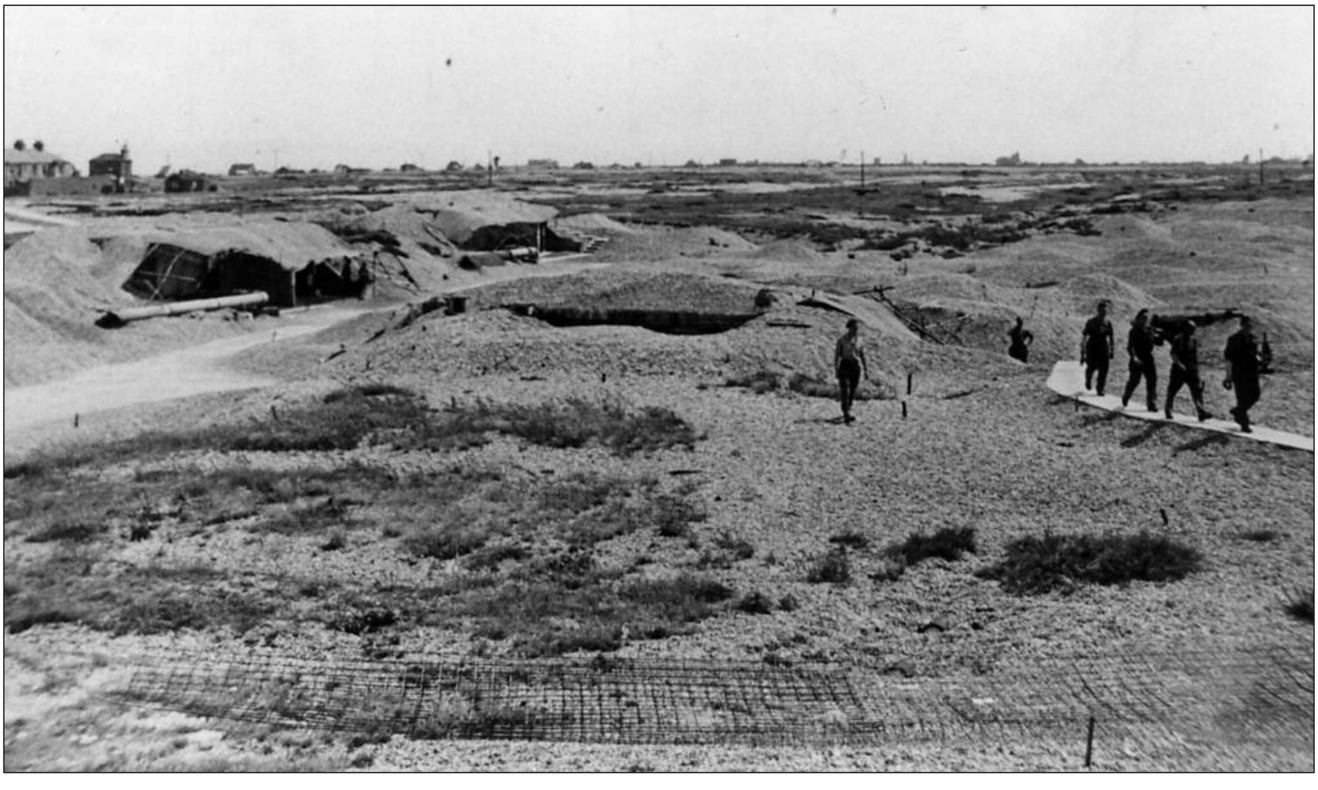


'Full-scale trials were made with the Conun in the Thames in February 1944 and in Bournemouth Bay in April', explains Arthur Hartley, 'during which the technique for towing at speeds up to seven knots was developed. It was the decision to lay Pluto lines to Cherbourg which had made necessary much larger supplies of Hais cable and Hamel pipe; and, in addition to increasing the British manufacture of Hais cable as much as possible, and starting production in the USA, the decision was taken to duplicate the Tilbury facilities for welding and winding Hamel pipe.'

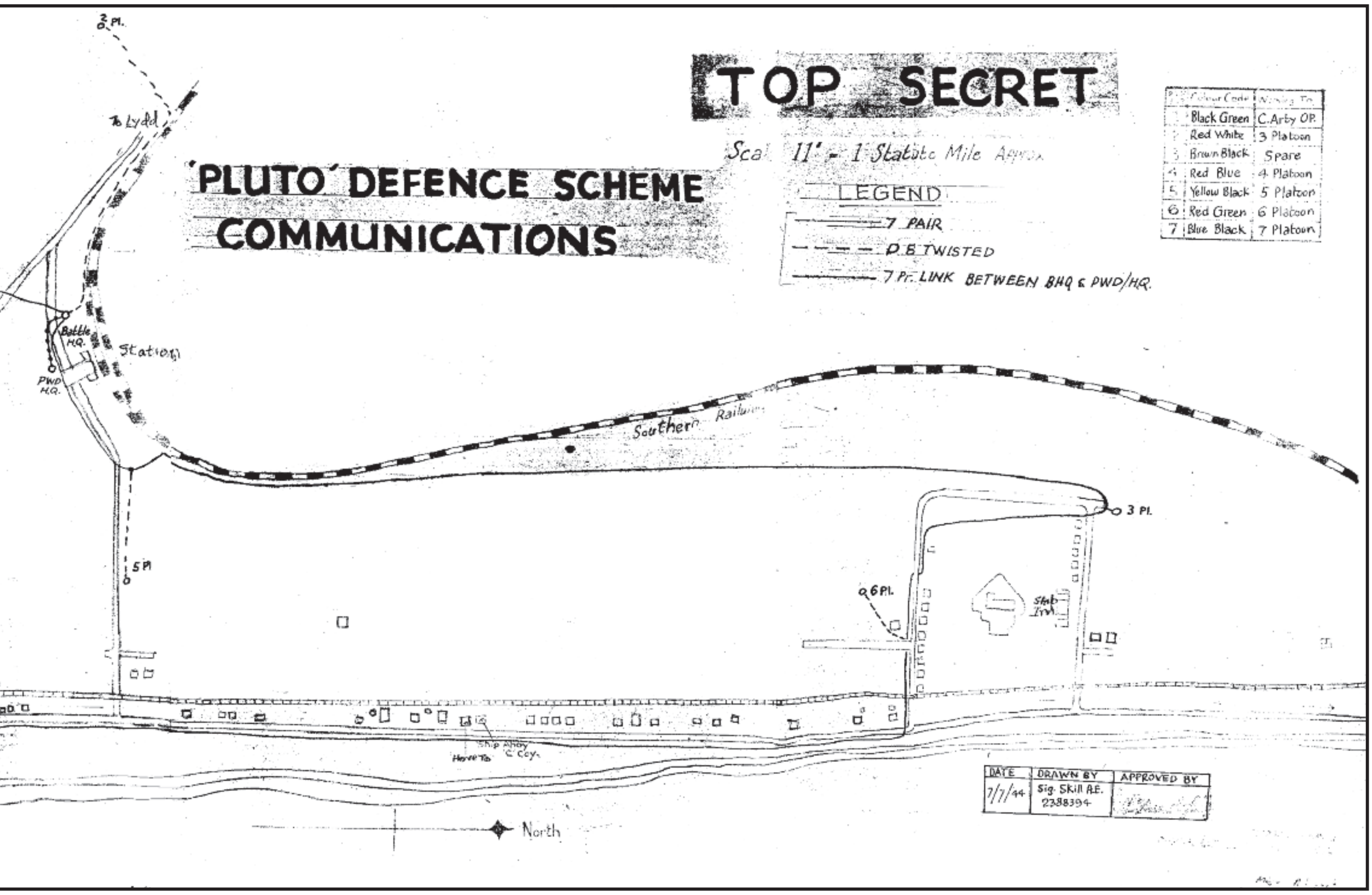


The secondary station at Dungeness, 'Dumbo', lay on the shingle of the flat bleak Kent promontory, back from the shore where a ribbon of little holiday villas faced the sea. Into a number of these were crammed pumping machinery and controls. All telltale signs were camouflaged; shingle was heaped over the end of the inland pipeline; and before it reached the area, it was made to look from the air as if it led to the beaches at Hythe and Folkestone and might have something to do with preparations for an assault across the Straits of Dover.

The aim was for Pluto to provide a cross-Channel capacity of 4,000 to 5,000 tons a day — 40 to 50 per cent of the expected requirements of all oil products. Bambi would consist



The installations at Dungeness were camouflaged beneath the shingle which covers the bleak and windswept promontory.



'At Dungeness', wrote Arthur Hartley, '30 reciprocating and four centrifugal pumps, designed for 1,500lb per square inch pressure, were installed at three well-dispersed sites along the coast and were fed from the land-line system. The reciprocating pumps were manufactured by Frank Pearn Ltd. and delivered approximately 40 Imperial gallons of fuel per minute, when running at a speed of 45 rpm. They were driven by 60 hp Caterpillar engines. The centrifugal pumps were manufactured by Mather & Platt Ltd and delivered 214 Imperial gallons per minute, and were driven by 500 hp motors. The Anglo-Iranian undertook the supervision of the erection of the pumping terminals and tankage by civilian contractors and RE, RASC and Pioneers.'

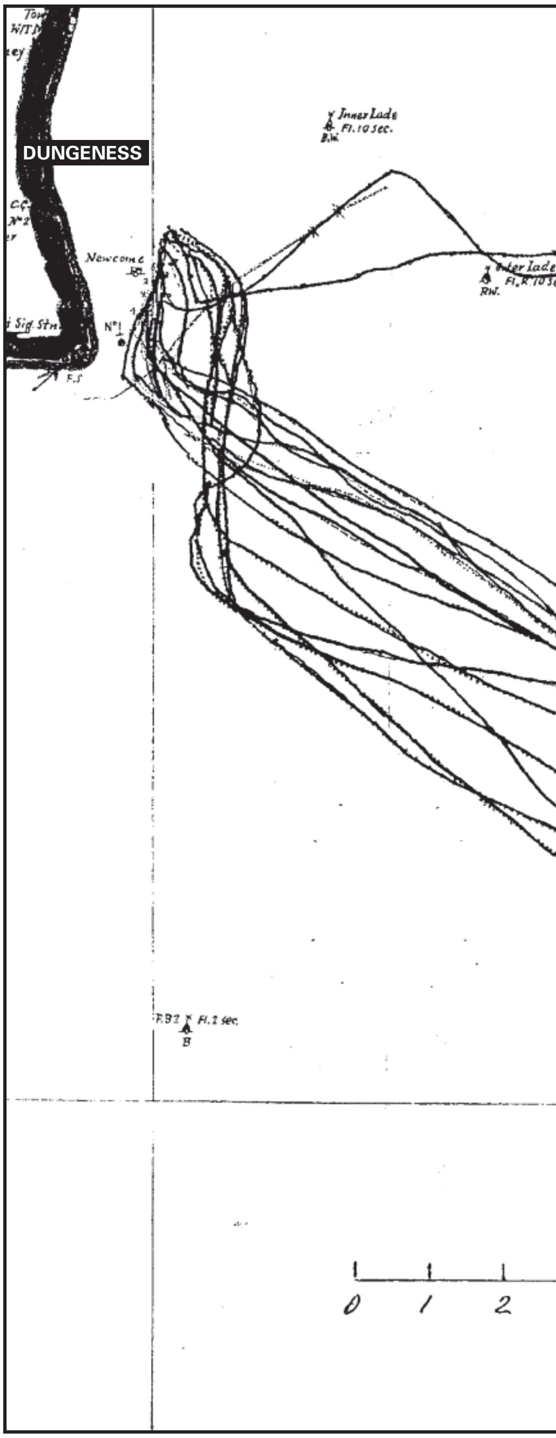
Save for the erection of the nuclear power station in the far distance, time has stood still in this corner of Kent.

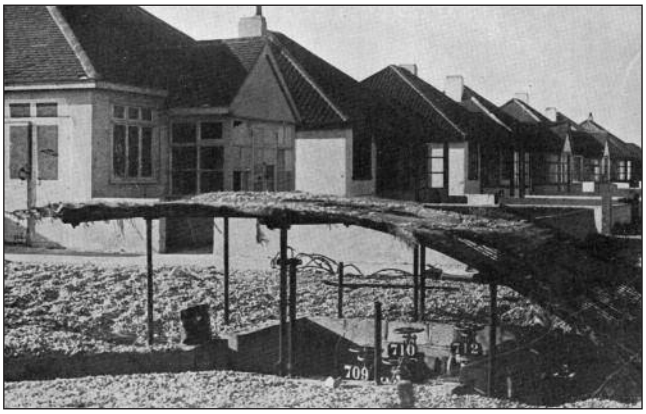
Left: **The main pumping control for the British end of 'Dumbo' — the code-name for the Dungeness operation — was located in 'Hove to' on Coast Drive at Lydd-on-Sea (see plan pages 20-21).** *Right:* **The same house has now been renamed Fort George.**

of six 3-inch lines of Hamel pipe and four 3-inch lines of Hais cable, and was intended to have a throughput capacity of about 3,500 tons a day. Dumbo, running from Dungeness to northern France, would make use of the pipe and cable left over plus all the 2-inch cable that had been manufactured before the change to 3-inch and that was of too small a capacity to make it worth laying all the way across to Normandy. Throughput capacity was envisaged as about 3,000 tons a day. The first of the Bambi pipelines was intended to be laid 18 days after D-Day (on to the open shore if necessary) and the others by D+75. The Dumbo system, with its far shorter run, obviously could not come into operation until a later stage.

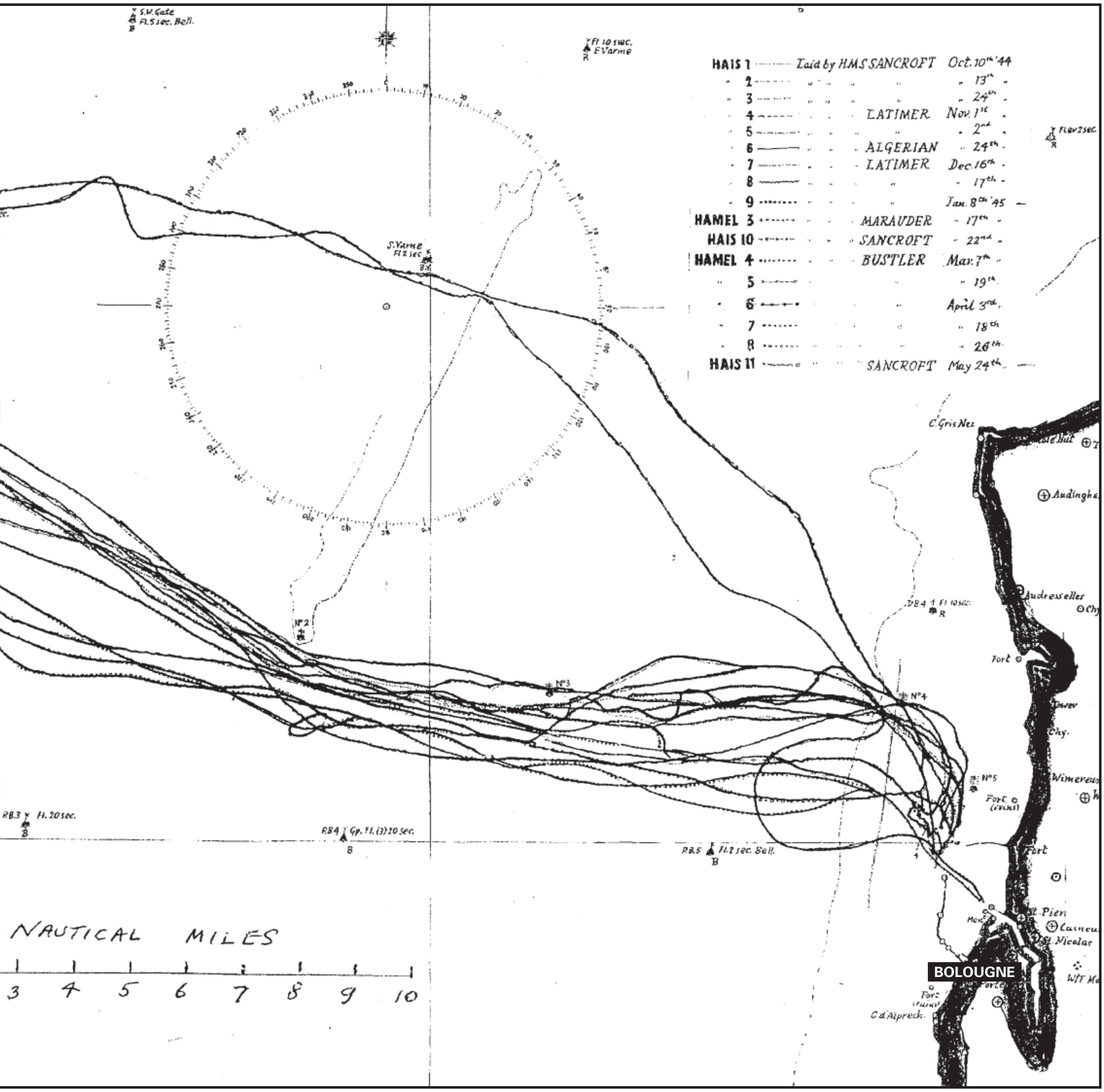
The control team at Dungeness. L to R: Lieutenant H. Begg, Lieutenant E. Moody, Lieutenant D. Stirling, Captain E. Cobbold, Captain A. Gordon, Major F. Dagger, Mr. J. Len, Mr. W. Woods, Lieutenant W. Frost, Lieutenant E. Hughes, Captain D. McLeod plus their mascot.

Captain J. F. Hutchings — the commander in charge of the naval side of Pluto — inspects the control board which indicated the flow rate of fuel in each pipeline to France. With him are Major Dagger and Captain Gordon. (IWM)





The pumps were hidden inside bungalows along Coast Drive. In this shot, Nos. 30, 31 and 33 were pump houses with No. 32 a billet for army personnel. Camouflaged corrugated iron sheds protected the valves in their sunken chambers.



Undoubtedly remnants of the Pluto workings still exist below ground at Dungeness. Relics visible on the surface include smashed concrete and pipe clamps *(below left).*

Below right: **A section of Dumbo pipe protrudes from the shingle. A mouse has now made it home although we could not tell if it was Minnie or Mickey!**

While the Navy and Army parties strived to get to grips with the laying, bringing ashore and connecting up of Hais, in September 1943 the first Conundrum was launched at Tilbury. It was some months, however, before initial winding problems could be overcome. In fact, the Conundrum was overloaded, carrying some 70 miles of pipe for the run from the Isle of Wight instead of some 30 miles for the run from Dungeness. With a spindle 60 feet long and 40 feet in diameter, this entailed 17 layers of pipe being wound around it, which made its overall weight some 1,600 tons.

The Navy acquired one of the most powerful tugs available, HMS *Buster,* but she could only manage three knots towing the Conundrum. Mulberry and the invasion were in the offing, and to obtain another powerful tug when they were in such demand required an approach to Churchill's Chief-of-Staff, General Sir Hastings Ismay, for it was said that the Prime Minister kept a list of these vessels in a locked desk drawer and sanctioned their use personally. Ismay was the key to the problem (if not the supposed drawer!), producing HMS *Marauder.* Her four knots with the Conundrum in tow were an improvement, but hardly enough. The National Physical Laboratory went back over their calculations and the Navy sought to come up with an answer. Then someone suggested that perhaps it was worth considering spacing out the tugs so that their wake flowed past outside the drum, not against it as this was merely pushing the drum backwards in inverse proportion to the effort to pull it forward! Thus, another 3 or 4 knots were achieved — enough to surmount the crisis.

HMS *Conundrum I* was brought from the Thames through the Straits without causing the Germans to sit up and take notice and eventually arrived at Bournemouth Bay for Hamel's dummy run. A 12-mile lay was accomplished, in a loop, the ends being brought ashore, connections made and petrol pumped through.

The one that got away! Walt Disney finally comes to grief at Greatstone — Clement Atlee being the Deputy Prime Minister before the election in July 1945. The two swimmers give a good idea of the size of the Conundrums, six of which were constructed to float the Hamel pipe across to France. 'However, the method of pulling in the Hamel shore ends from the Conun proved difficult and involved the loss of one Conun', explains Arthur Hartley. 'In the end a solution was found by winding turns of Hais cable at the beginning and end of each length of Hamel, followed by a special floating wire. The Conun could then be handled like the cable ship, laying each end on the bottom for the barges to pick up and connect to the shore ends in the same way as for a complete Hais. This technique enabled the first Hais-Hamel line to be commissioned in January 1945.'

Not until three months after D-Day did petrol finally arrive in Cherbourg through the first Bambi pipeline but far too late to influence the battle for by then Allied forces had reached the Pas-de-Calais. Bambi was therefore shut down and priority given to Dumbo which came ashore at Boulogne. It had been intended to make landfall at Ambleteuse but to save time clearing the heavily-mined beach there, another location was chosen inside the outer harbour at Boulogne.

IN RETROSPECT

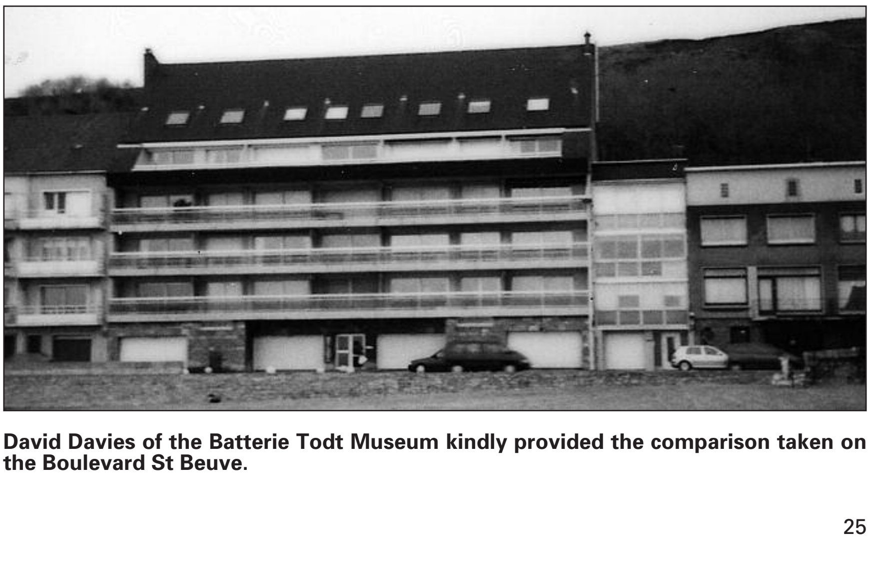
Like the Mulberry harbour, the Pluto pipeline was lauded as a unique achievement when its existence was revealed at the end of the war, and the project has since been invariably regarded as an ingenious idea successfully implemented for the benefit of the advancing Allied armies. Ingenious it undoubtedly was, not to mention ambitious and spectacular. But it was of course the fate of all such Miracles of Modern War — as they were referred to in print during the post-war decade — to come in for later, more critical appraisal; and, without being needlessly disparaging, it is instructive to contrast the legacy of that era with the assessment of the actual performance of Pluto that appears in the volume on the subject of oil in the British official history series.

In the five months after D-Day (between June and October 1944), Pluto delivered only 3,300 tons of petrol to the Continent. The target dates of D+12 for the first line and D+75 for the completion of the Bambi system came and went. Even after Cherbourg had been taken on July 1, a whole month lapsed before the first cable lay was made by HMS *Latimer* while it was considered whether the pipeline should terminate outside or inside the harbour (outside making discharge more difficult, inside endangering the harbour) until nearby Naqueville Bay was decided upon. The first attempt, on August 12, went wrong in Sandown Bay when the 3-inch Hais cable was snagged by an escort vessel's anchor while preparations were being made to bring the end of the return line ashore. Two days later, HMS *Sancroft* set out for Naqueville with the second cable only to face problems when the cable became wrapped around a ship's propeller. There were difficulties in effecting the connection ashore and also leaks were detected.

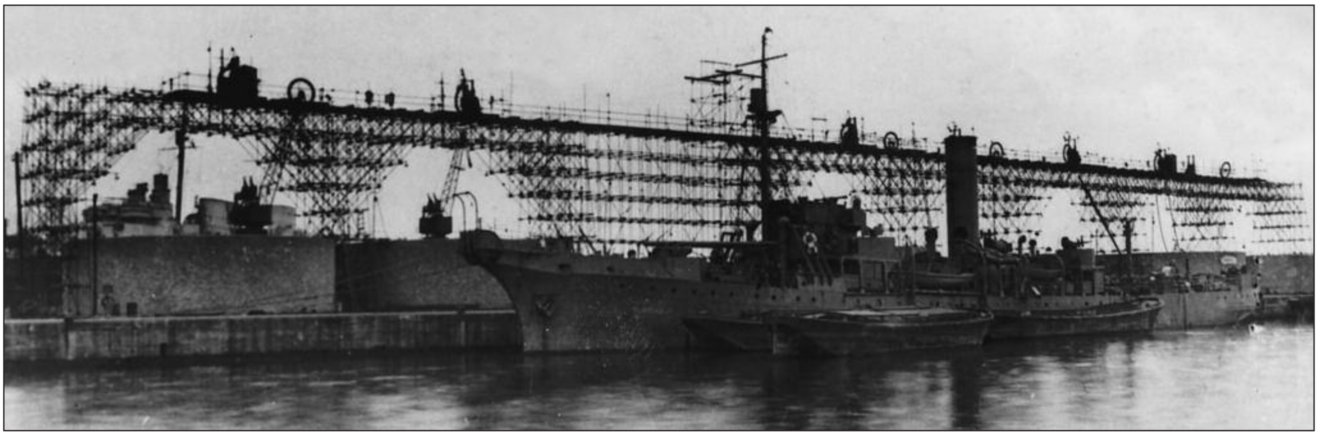
On August 27, the first Hamel pipe was unwound across the Channel from its Conundrum, which by now rested still lower in the water with the addition of tons of barnacles. It was a failure; so was the second attempt; and on the third the pipe broke about 30 miles off the Cherbourg peninsula having probably fouled the drum. It caused great damage to the drum and a replacement, aptly called *Conundrum II*, had to be launched before a new attempt with Hamel could be staged.

Eventually, on September 18, a Hais cable was successfully laid, brought ashore and connected up. Water was pumped through for testing and on September 22 the line was brought into commission, delivering 56,000 gallons of petrol a day at 750lb per square inch. On the 29th a Hamel pipe was successfully laid, tested with water and came 'on flow'. However, neither of them operated for long. During the night of October 3 when it had been decided to increase the pressure on the Hais cable, the pressure indicators suddenly went wild — from registering over 1,000lb per square inch they dropped to almost zero and the line had to be shut down. Later, it was discovered that the trouble lay with one of the couplings. That night, pressure was lost on the Hamel pipe too.

With Le Havre in Allied hands by then, as well as Cherbourg, the effort of continuing with Bambi hardly seemed worth it. The Bambi operation was closed down and, since the Pas-de-Calais had been overrun and the German cross-Channel guns silenced, attention was switched to the Dungeness system, Dumbo. As soon as the approaches to Boulogne had been cleared of mines, HMS *Sancroft* made the first run with Hais on October 10 and pumps started on October 27. Other lays were made by *Sancroft* and *Latimer,* but once more, progress was slow. Problems continued to arise in bringing the ends of cables ashore, and, to begin with, these were exacerbated by the shallow beach at Dungeness which made it difficult for the Navy to deliver the cable to the Army at the high-water mark. The weather too caused delays — rough seas and gale warnings obliging the laying ships to run for shelter, and fine days were lost when the ships were unable to get back into position quickly enough to take advantage of them. There was much changing of plans and waning of enthusiasm. By mid-December, Dumbo consisted of just six Hais cables (four 3-inch, two 2-inch), four of them in operation at low pressures of 350 to 400lb per square inch. Daily deliveries amounted to no more than 700 tons of petrol (the plan to pump aviation spirit from Wye was not implemented) and the total for the 88 days to January 20 was only 62,000 tons.



David Davies of the Batterie Todt Museum kindly provided the comparison taken on the Boulevard St Beuve.



Back in Britain, storage of the Hais pipe at the factories along the Thames was proving a real problem so additional space was found in London's East India, Surrey Commercial and King George V docks *(above)* even though this involved double handling. At first, cable was just piled on open ground but in view of the risk of damage by bomb splinters, protective walls of brick were built. And, of course, it involved the erection of an elaborate gantry to unload and load the cable vessel.

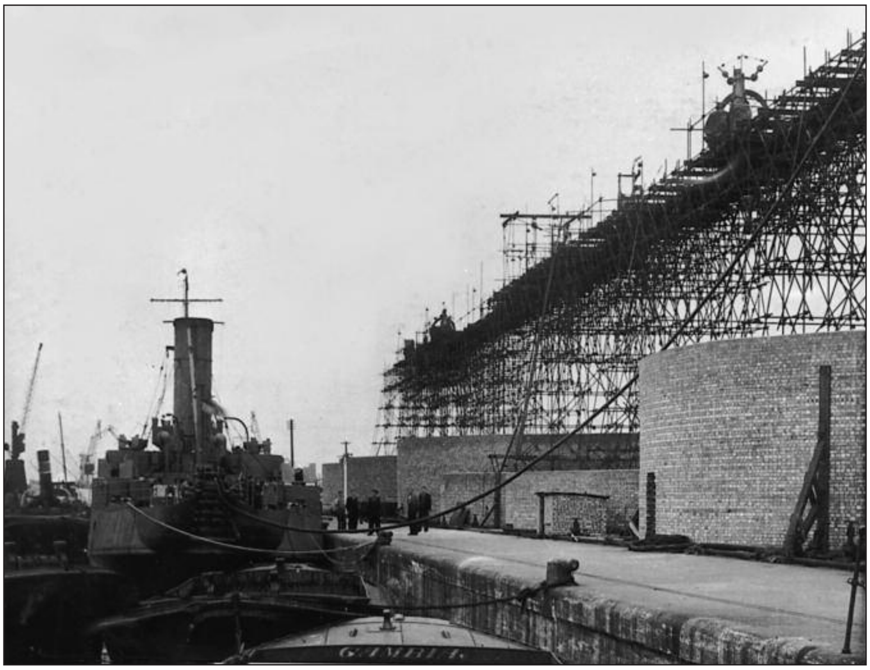
The Navy questioned whether it was worth going on with Pluto in view of the number of ships and men involved. A committee of the Joint Administrative Planning Staff ruled that it was. To put the question into context, Antwerp although under bombardment from flying bombs and rockets, was receiving one ocean tanker a day, while Ostend and Le Havre were each receiving small tankers bringing in some 2,500-3,000 tons a day. Cherbourg and Antwerp alone were capable of taking ocean-going tankers, but supplies could not be stepped up through them; Cherbourg was already working flat out and Antwerp could not be risked further. Small tankers were needed for the Far East and had to be conserved.

The planners' intention was for all the Hais cable to be used up for Dumbo. (In all, 710 miles of Hais had been produced, 140 of which by cable factories in the US.) The system still lacked Hamel, as the steel pipe had proved impossible to lay successfully until a new technique to land it was used in January 1945. This consisted of coupling a length of Hais cable to the end of the relatively inflexible pipe at the start of the lay, the Conundrum being towed at the French end right into Boulogne harbour for the pipe to be cut and drawn off while the drum was moored alongside the jetty. Subsequently, Hais was used at the finishing end as well, so that there was no need to berth the drum. This adaptation was called the Hais-Hamel system. Another five Hamel lays were authorised by the planners in mid-February in order to achieve the maximum saving of small tankers.

Thus, Dumbo pipelines continued to be laid during the final months of the war (one 3-inch Hais cable being laid as late as May 24, three weeks after the Germans had surrendered, as the quickest way of clearing the cable ship in which it was wound). By then, 16 lines ran from Dungeness: eight 3-inch and two 2-inch Hais cables and six 3-inch Hamel pipes.

'Each 3-inch line at Dungeness', wrote Arthur Hartley after the war, 'could deliver about 400 tons a day, or 120,000 gallons, and lines were laid quickly enough to keep ahead of the capacity to pump beyond Boulogne. Eventually 11 Hais and six Hais-Hamel lines were laid with a capacity of more than 4,500 tons or 1,350,000 gallons a day; and 1,000,000 gallons a day were pumped across for many weeks.

'No Hais cable which had been satisfactorily laid and commissioned failed; and the post-war recovery operation to clear the beaches showed the cable to be in good and usable condition. The Hamel pipes, on the other hand, while more than fulfiling the original estimate of six weeks of useful life, did fail successively in 77, 52, 55, 112, 55, and 60 days. However, in spite of these failures the loss of petrol between tanks at Dungeness and at Boulogne was less than 1.1 per cent for the whole operation.'



Seven brick storage chambers at the King George V dock were built on No. 1 Berth.

No trace of the Pluto constructions today. In the background the eastern end of the runway to London's City Airport built in 1986-87.

In this early post-war shot of the King George V dock, the storage chambers on No. 1 Berth, just to the right of the lock, still appear to contain unused cable. On the left one can see the bomb sites of Silvertown hit on Black Saturday (September 7) in 1940. In the foreground repairs are taking place on the bascule bridge on Woolwich Manor Way struck by a flying bomb on February 10, 1945 (see *The Blitz Then and Now,* Volume 3, page 525). (MD)

In July, Dumbo was closed down to save technical manpower. In the words of the volume of the British official history on the subject of oil: 'Perhaps the most trenchant epitaph on Pluto is provided by a few figures of comparative achievement. Down to the end of German resistance on May 10, 1945 about 5.2 million tons of oil products were delivered to the SHAEF area through the ports of North-West Europe. Of this, about 826,000 tons came direct from across the Atlantic and 4.3 million tons, or 84 per cent, was delivered across the Channel from England. Pluto's contribution was only 370,000 tons, less than 8 per cent of the cross-Channel supplies. This was the equivalent to an average daily rate of under 1,800 tons a day from the time when pumping began.'

Nevertheless, the Supreme Allied Commander, General Eisenhower, described Pluto in his report as 'second in daring only to the artificial harbours projects', and wrote: 'This provided our main supplies of fuel during the winter and spring campaigns'.

In all, Pluto delivered 172 million gallons to the Allied armies of liberation, the fuel at Boulogne eventually being pumped on through Ghent, Antwerp, Eindhoven and across the Rhine — a distance of 200 miles. After the war, there was a desperate requirement in Britain for raw materials — notably lead — so salvage work began to recover the pipeline, an operation that lasted until July 1949. ***Left:*** **Of the original 23,000 tons of lead in the Hais pipe, 22,000 were recovered and of the 5,500 tons of steel used in Hamel, 3,300 tons were lifted from the seabed** ***(above).*** **Coming at a time of strict petrol rationing, the discovery that the recovered pipework still contained some 75,000 gallons of fuel was a real bonus!**