

(*Paper No. 2513.*)

“Petroleum-Storage Installations at Avonmouth and at Cardiff.”

By R. PICKWELL, Assoc. M. Inst. C.E.

SCARCELY any industry in this country has grown with such remarkable rapidity as that of the import of petroleum. In 1859 it amounted to 2,000,000 gallons, and the official returns for 1889 show that in that year it exceeded 102,000,000 gallons. This enormous increase has called forth improved methods of conveying the oil and storing it. The old method of bringing it to England in barrels was successfully superseded about the year 1886, by the use of specially built steamers, provided with oil-tanks and powerful pumps. Owing to the presence in some cases of large proportions of naphtha, serious explosions have occurred, and legislative measures have been passed for the protection of the public. No oil that flashes at less than 73° on the Abel instrument is considered safe. Dr. (now Sir) Lyon Playfair, in evidence before a Parliamentary Committee, stated that he would not use oil that flashed under 120° , but would prefer 130° .

Although this substance was known to the ancients over 2,000 years ago, it has only within the last thirty years become an important article of commerce.

It is found over a wide field, including India, Persia, Peru, Java, the shores of the Caspian, the United States, Canada and South America. The chief supply at present is obtained from Pennsylvania and the Caspian Sea. The increase of the shipments from Russia is very remarkable; in 1883, 500 barrels were sent to this country, whilst in 1890 the supply was 787,529 barrels, or about 32,288,689 gallons per annum. During the same time the consignments from the United States increased from 53,000,000 gallons to 54,489,164 gallons per annum.

In this Paper it is proposed to give a description of two petroleum-storage installations, one erected at Avonmouth jointly by Mr. C. M. Jacobs, M. Inst. C.E., and the Author's firm; the other

coming under his professional notice, both of which are provided with improved machinery and arrangements that may be of interest to the Institution.

AVONMOUTH INSTALLATION.

These works were erected for the Bristol, West of England, and South Wales Petroleum and Storage Association. In the storage of so inflammable and dangerous a commodity as petroleum great care is required in the selection of a site which shall afford facilities for easy communication with the steamers and vessels bringing the oil, and at the same time be as isolated from the neighbouring property as possible, in order to avoid such disastrous occurrences as the fires at Antwerp and Rouen. The site selected for these works (see Fig. 1, Plate 7) is situated on the banks of the Avon, about half a mile from the head of the Avonmouth Dock, being outside the ancient banks of the river, on what is known as the Outstays. It possesses on two sides deep water accommodation for barges or vessels, and on a third, railway connection with the main line from Avonmouth to Bristol. The site is leased from the Bristol Docks Corporation, and contains from 4 to 5 acres.

The first contract, which was let in July, 1889, was for the construction of a sea-bank, which was thrown up all round the site to a height of 6 or 7 feet, with the double object of shutting out the high spring-tides, and of confining the petroleum in case of the accidental bursting of a storage tank. As will be seen by the cross sections, Figs. 2, the banks generally were formed with a two to one batter on the river side, and a one and a half to one batter on the back, with a 4-foot top. The seat of the bank had the turf first pared off, and was then dug up one spade deep, after which the earthwork was barrowed up and put together by chopping and ramming in the usual way. After waiting for several months any settlement was made up, the batters trimmed off, and the bank sodded over. A cess-ditch was formed at the back of the outer bank for the purpose of drainage, and provided with a small outfall clough at A, Fig. 1, details of which are shown on Figs. 3, 4 and 5. The site was then thoroughly drained into the cess-ditch, by laying lines of 3-inch agricultural drain-pipes, 2 to 3 feet deep, every 30 feet, the trenches being filled with broken stone; and the whole of the surface was subsequently covered with ballast and ashes.

At point B on the plan, a deep-water jetty was erected on the foreshore of the Avon, constructed of pitch-pine piles, ranging from 30 to 60 feet long, with timber walings, struttings, and deck, as shown in Figs. 6 and 7, where barges or vessels lie for either discharging or taking in cargo.

TANK FOUNDATIONS.

The petroleum is stored in bulk in large circular iron tanks, two of which contain 2,000 tons each, and the others 1,000 tons each, and it was important that a firm foundation should be secured for them. Trial borings showed the ground to consist of about 6 feet of brown clay on the top, with 30 feet of very soft black warp below (Fig. 8). It was found that piling would be too expensive, and ultimately the Author designed the following plan, which was adopted.

After taking off the soil, a timber and concrete raft, about 5 feet larger in diameter than the tanks, was constructed; a layer of concrete, 18 inches thick, was first spread over the whole area, and upon this 12-inch by 6-inch timbers were laid across as shown, and another 18 inches of concrete put over the whole, thus forming a circular raft 3 feet thick and 68 feet in diameter for the large tanks, and 52 feet in diameter for the smaller ones (Fig. 14, Plate 7). These foundations have answered the purpose satisfactorily, and are similar to those used for the large grain warehouses at Avonmouth Dock. A gutter was formed all round the base of the tanks for collecting any leakage which might come from them. Sidings were laid from the main line of railway into the works as shown in Fig. 1, Plate 7.

The installation comprises three departments:—The storage tanks, the cooperage department, and the filling or barreling-off department.

It was desired to separate these as much as possible, keeping the tanks as well as the filling-house away from the cooperage and boiler-house to lessen the danger of fire. To maintain economical connection between these three departments, the installation is designed to work by the gravitation of both full and empty barrels from one department to another; for instance, the cooperage is connected with the filling-house by means of "barrel-runs," upon which the empty barrels, as they are turned out from the cooperage, run down to the filling-house and storing platform; empties also pass down similar runs from the jetty into the works for either storage or repairs; barrels already

filled run from the filling-house down to the end of the jetty ready for shipment. The gradient used is 15 to 16 inches in 100 feet, which is found to be just sufficient to cause the barrels to move without any tendency to run away. The runs are carried on light trestles (see Figs. 9), and consist of timbers $5\frac{1}{2}$ inches by 3 inches, fixed at about 2 feet 2 inches gauge by bolts. They are made in portable lengths of from 12 to 14 feet, and are put up where required. On reference to the general plan it will be seen that the cooerage floor is fixed at about 2 feet above the filling-house floor, and the filling-house floor a similar height above the jetty; the other runs have a similar gradient. The barrels are put on to them one after another, and close together, and as each one is taken off at the low end, the whole line moves forward one barrel. This method of dealing with them is important as regards the economical working of the installation.

STORAGE-DEPARTMENT.

A line of 6-inch wrought-iron screw-jointed filling-pipes is laid from the dock to the tanks along the surface of the ground, and is fixed upon strong wooden carriages to keep it in position. At the dock end is a stand-pipe similar to an ordinary water-main stand-pipe, or suitable bends are provided, which can be readily connected with a flexible hose-pipe from the steamer. At the other end of this main filling-pipe a branch with screw valves is taken off to each tank.

The tanks are circular and constructed of boiler-plates riveted together with lap-joints as in an ordinary gas-holder, the large ones being 64 feet in diameter and 30 feet high, the smaller ones 47 feet in diameter and 26 feet high. The bottom is made of $\frac{3}{8}$ -inch plates, with 4 inches by 4 inches by $\frac{1}{2}$ -inch angle-irons. The sides are formed of seven tiers of plates of uniform width, the first and second being $\frac{5}{8}$ inch thick, the third and fourth $\frac{3}{8}$ inch thick, the fifth $\frac{5}{16}$ inch thick, and the sixth and seventh $\frac{1}{4}$ inch full. The tops are of $\frac{1}{8}$ -inch plates, supported on angle-iron frames and principals (Fig. 10). They rise 6 feet in the middle, forming a dome, and have four raised man-holes 24 inches in diameter, provided with hinged covers which can be locked. The attachment of the side and bottom plating to the angle-iron at the base is by a double row of rivets, as is also the case with the vertical seams of the sides, but all other longitudinal seams are single-riveted. The edges of the plates both in the bottom

and in the sides are planed, and the work generally is equal to the best boiler work. All joints are made iron to iron, and caulked inside and out. Each tank is provided with a disk or false bottom, $\frac{3}{16}$ inch thick and 66 feet in diameter, which rests upon a bed of thin boards and sand, interposed between it and the foundation, in order that the tank may take an even bed (Fig. 14, Plate 7).

The smaller tanks, 47 feet in diameter, are made in the same manner, except that the thickness of the sides is slightly reduced. They were constructed under a guarantee for tightness, and after erection were tested by filling with water. Each is fitted with a 4-inch emptying and a 6-inch filling-pipe, with screw-valves, and furnished with a joint so that the orifice of each can be lifted up clear to the crown of the tanks by a hauling chain which passes over rollers at the top, and is brought down to the level of the ground outside, where it is worked by a small winding-gear. The orifices can thus be maintained at about the surface of the oil so as to avoid the possibility of drawing off any water that may have accidentally got into the tank, and which being heavier than oil would sink to the bottom, and also the vibration and ebullition which would occur in filling against a head of pressure. Each tank is provided with an external glass gauge from top to bottom, in lengths of about 4 feet, fitted with brass cocks, and each tube over-lapping the other so as to show the height of the oil in the tank. A light iron ladder on the outside gives access to the roof, and another is fixed from one of the man-holes to the bottom inside.

The contract was given to Messrs. Lysaght & Co. of Bristol, and the cost was about £4,000. The tanks are painted preferably white outside, and are provided with a ventilator at the top.

The operation of filling is as follows:—When a petroleum vessel arrives in port she is moored at the proper berth; her petroleum-pumps are then connected with the pipe on the quay, the valve of any particular tank required to be filled is opened, and the pumping commenced. As soon as the oil has been pumped out of the ship the valve at the stand-pipe is closed. At this stage of the proceedings the whole line of the feed-pipe from the quay to the storage tank will be full of oil. To facilitate the extraction of this the feed-pipe has a slight fall at each end to a point near the filling-house, where a small Worthington pump is attached, and the contents of the pipe are transferred into a small tank in the filling-house.

COOPERAGE-DEPARTMENT.

This consists mainly, as shown on Figs. 11, 12 and 13, of a two-storied brick building about 100 feet by 38 feet, in which the work of cooperage generally is carried on. At one end is erected the boiler-house, in which is a Cornish boiler, 26 feet by 6 feet 6 inches diameter, with the usual tanks and donkey-pumps. Adjoining the end of the boiler-house is the steaming-house, where the barrels are first steamed and then dried. At the south end of the cooperage the empty barrels are stored in the yard, from which they are taken to be cleaned and repaired prior to being sent to the filling-house. The details of the plant are as follows :—

At the end of the boiler-house, Figs. 14 and 15, Plate 8, there is a large air-heating chamber filled with a coil of small pipes supplied with steam from the boiler. This chamber is connected with the blower by the pipe A A, which enters it at the bottom and passes out at the top and down to the ground by the pipes B B B, and is connected with the main air-pipe laid underground along the side of the steaming- and drying-house. Three branches are taken from this main air-pipe at C C C, leading into the three underground pipes D D D, from which are taken short branches E E E E of 1-inch pipe, about 2 feet apart, and spaced so as to exactly fit the bung-holes of the barrels, which are placed over them in three nests of eight barrels each. The main and branch air-pipes are fitted with valves at G G G, for the purpose of shutting off either the whole or any one of the nests. Similarly steam is taken from the boiler through the pipe H into the main steam-pipe O, from which it passes into the branches P P P, leading into the branches C C C of the air-pipes. A set of barrels is taken from the empty stock and rolled on to wooden carriages with the bung-holes over the branches E E E. The main steam-valve Q and the branch valves are opened, and the steam passes along C, D and E into all the barrels for ten to fifteen minutes. It is then shut off at Q, and the main hot-air valve F and its branch valves opened, the blower set to work, so as to drive hot air through the same branches C, D, E, until the barrels are perfectly dry, after which they are rolled into the cooperage for any necessary repairs. A large steam-jacketed glue-kettle is arranged as shown in Figs. 12 and 13, Plate 7. The repaired barrels receive a charge of hot glue, and are rolled along carriages over zinc-lined troughs, laid below the floor-level, and stored over them with the bung-hole down. The surplus glue is pumped

back to the glue-kettle (Fig. 12). After this the barrels are lifted on to the floor above by the elevator D (Fig. 12), which is worked by a small separate engine; there they receive a coat of paint, and are then ready for sending down the run to the filling-house. The painting is done with large flat brushes, with such expedition that a skilled man is said to be able to paint fifteen hundred barrels per day.

The boiler and steaming and drying plant were supplied by the Uskside Engineering Company, Newport, Mon.

FILLING- OR BARRELING-OFF DEPARTMENT.

This department is situated at a point near the jetty (see general plan, Fig. 1, Plate 7), and consists of a simple brick building about 46 feet by 32 feet (Figs. 16, 17, 18 and 19, Plate 8). The main floor, which is of wood, is about 6 feet above the ground, and has a 10-foot platform all round, communicating with a long platform at a lower level, about 150 feet by 30 feet. This long platform is at the level of the floor of the railway trucks, and is used for taking empties or loading up full barrels to be sent by rail. In the centre of the filling-house are two rectangular wrought-iron tanks about 12 feet by 4 feet by 4 feet, raised about 3 feet above the floor, and provided on each side with a number of 1-inch filling pipes, about 2 feet apart (Fig. 16). From the main storage-tanks to the filling-house tanks a 4-inch screw-jointed pipe is laid similar to the 6-inch main already described (Fig. 17). The arrangement of branches under the filling-house, from the 4-inch and 6-inch pipes, is as follows:—The 4-inch branch A leads from the main emptying-pipe into the two small tanks; the 4-inch branch B is carried round to the pump, and by C to pipe A; another branch D is carried from the 6-inch pipe into branch C; the main-pipe draining-branch E is carried from the point F to the pump. All these branches are fitted with screw-valves as shown at *a, b, c, d, e, f, g, h, i* (Fig. 17).

Oil in the ordinary way flows by gravitation from one of the large storage-tanks by the 4-inch pipe, and along A into the two small barreling tanks, until they are filled, the valves *e, f, g, h* being closed and the rest worked as required.

When the oil in the large storing-tank has been lowered so that it ceases to flow by gravitation, it is raised by pumping, and passes along B to the pump, and thence through C and A, into the barreling tanks, the valves *a, b, f, h* being closed, and *c, d, e, g* opened. When the main filling-pipe is being emptied, as already

described, the valves *h*, *e*, *c*, *d* are opened and *a*, *b*, *f*, *g* closed, and the remaining oil pumped along E, C and A into the barreling tanks.

As it may sometimes be necessary for repairs to take the oil out of one storage tank and put it into another, a branch D is laid from the 6-inch filling pipe No. 1 to C, and the transfer of oil from one tank to another takes place by gravitation from the tank through the 4-inch emptying pipe No. 2, along B, to the pump, and thence along C and D into pipe No. 1 passing on to the other tank, as if it was being pumped from a vessel; in this case valves *g* and *f* are opened and valves *a*, *b*, *c*, *d*, *e*, *h* and *i* are closed. It will be seen that this arrangement of pipes gives the foreman at the filling-house complete control over the direction taken. A Worthington pump is used with a cylinder 8 inches in diameter and about 10 inches stroke.

A little above the floor-level, and running the entire length of the barreling tanks, two iron waste-troughs are fixed. The process of barreling is as follows:—Empties are rolled up off the long platform into the filling-house and put on these troughs close together, as shown in Figs. 16 and 18, with the nozzles from the tanks dipping into the bung holes. When filled they are rolled down the barrel-run to the jetty, or if required to go away by rail, to the siding. To prevent barrels from being over-filled, an American automatic filler, ingeniously arranged with a pneumatic sliding piston and spring shut-off, which can be so set as to regulate the speed of filling, is attached to the nozzles of the tank by a flexible tube. The pneumatic piston rises with the oil, and when the barrel is filled, the spring shut-off is released and the supply stopped.

The tank steamers for conveying petroleum to England range from 2,000 up to 4,000 tons carrying capacity. The engines and boilers are usually aft, the petroleum hold occupying almost the whole of the remaining portion of the ship. The hold is divided along the centre as well as across by several bulkheads (Figs. 20 and 21). By the kindness of the builders, Sir W. G. Armstrong, Mitchell and Co., the Author has been able to give a drawing of one of these ships, which was constructed according to the design of Mr. Swan. It will be seen on reference to the cross-section, Fig. 21, that the petroleum hold is made considerably narrower above the level of the water-line, the object of this arrangement being to ensure that the main part of the hold should be perfectly full, the narrow part at the top giving ample facilities for the expansion of the oil. If the petroleum were contained in one

hold of the ordinary shape, not perfectly full, the stability of the vessel would be seriously affected. A pump is provided capable of discharging from 100 to 120 tons an hour, the suction-pipe of which has a branch fixed to each of the separate holds.

CARDIFF INSTALLATION.

This installation has just been erected by the South Wales Public Wharf, Warehouse and Transit Company, Limited, Cardiff, and is situated on a stretch of land on the banks of the Ely, and about one mile from the Bute Docks, Cardiff (Fig. 22, Plate 8). The River Ely is a small tributary running into the Bristol Channel, and joins the mouth of the River Taff in what is known as the West Muds, opposite the Port of Cardiff. The Public Wharf Company have erected upon this tongue of land extensive wharves and warehouses, which are fitted in the most complete manner with hydraulic cranes, grain-warehouses, cellars, &c. The site possesses several hundred yards of deep-water frontage to the Ely, and good railway communication.

The petroleum installation is situated at the southern end of the site. It is enclosed by an embankment of earthwork similar to that at Avonmouth.

STORAGE DEPARTMENT.

From the wharf, at the point A on the plan (Fig. 22), a cast-iron 7-inch filling-pipe is laid to the storage department with branches to the five tanks, three of which hold nearly 1,300 tons each, and the two others about 1,000 tons each.

The branches from the main filling-pipe are of copper, and are bent up in a saddle-back form to allow for expansion. The tanks are in all respects similar to those at Avonmouth, and are fitted with gauge-glasses and jointed internal feed-pipes, &c. They stand upon a concrete foundation about 3 feet thick, resting on gravel. The surface of the foundations in their vicinity is finished with a cement-rendered floor, proper facilities being provided for collecting any leakage of oil. The emptying pipe is of cast-iron, 4 inches in diameter, and is laid from the bottom of the tanks to the filling-house (Fig. 22, Plate 8). An auxiliary feed-pipe is being laid with branches into the tanks, and a portable oil-pump made by the East Ferry Engineering Company, capable of delivering 120 tons per hour, will be connected with it so as to supplement the ship's pumps and discharge the vessel in half the time. After

discharging, the ships receive their coal-supply without changing their berths. A new wharf is being constructed in a more convenient position.

COOPERAGE-DEPARTMENT.

The general arrangement of this department is shown in Fig. 22, Plate 8. It consists of a shed of corrugated iron, at the end of which is placed the boiler-house, and is fitted with a steaming and drying apparatus at C, glue-kettle and troughs at D, and a painting and branding house at E.

The empty barrels are stored in the yard at F, whence they are taken to the steaming and drying department, repaired, glued, and sent forward to the painting department. Barrel-runs are freely used, and are for the most part of a portable description.

BARRELING-OFF DEPARTMENT.

This is situated at the end of the long painting floor, which is elevated to about the level of the bottom of the railway trucks, and is arranged similarly to the one already described at Avonmouth. Two men can fill and bung 1,200 barrels per day.

Under the present system of distribution by barrels great loss is incurred, not only in filling and in carriage, but also from the large waste of space between the barrels when loaded, the expense on the returned empties, and the necessary repairs and cooperage. To avoid this loss this company have adopted the use of 10-ton tanks, mounted on railway trucks, which are filled and consigned direct to the dealers, carriage being paid only on the net weight of the oil. The dealer can either retain the tank in his siding until emptied, or he can have his own small storage tank into which the oil is discharged, the portable tank being consigned back to the depot. It is probable that this system of distribution will shortly become general.

The Author expresses his thanks to Mr. Robert Johnston for supplying him with information concerning the Cardiff installation.

The Paper is accompanied by six tracings, from which Plates 7 and 8 have been prepared.

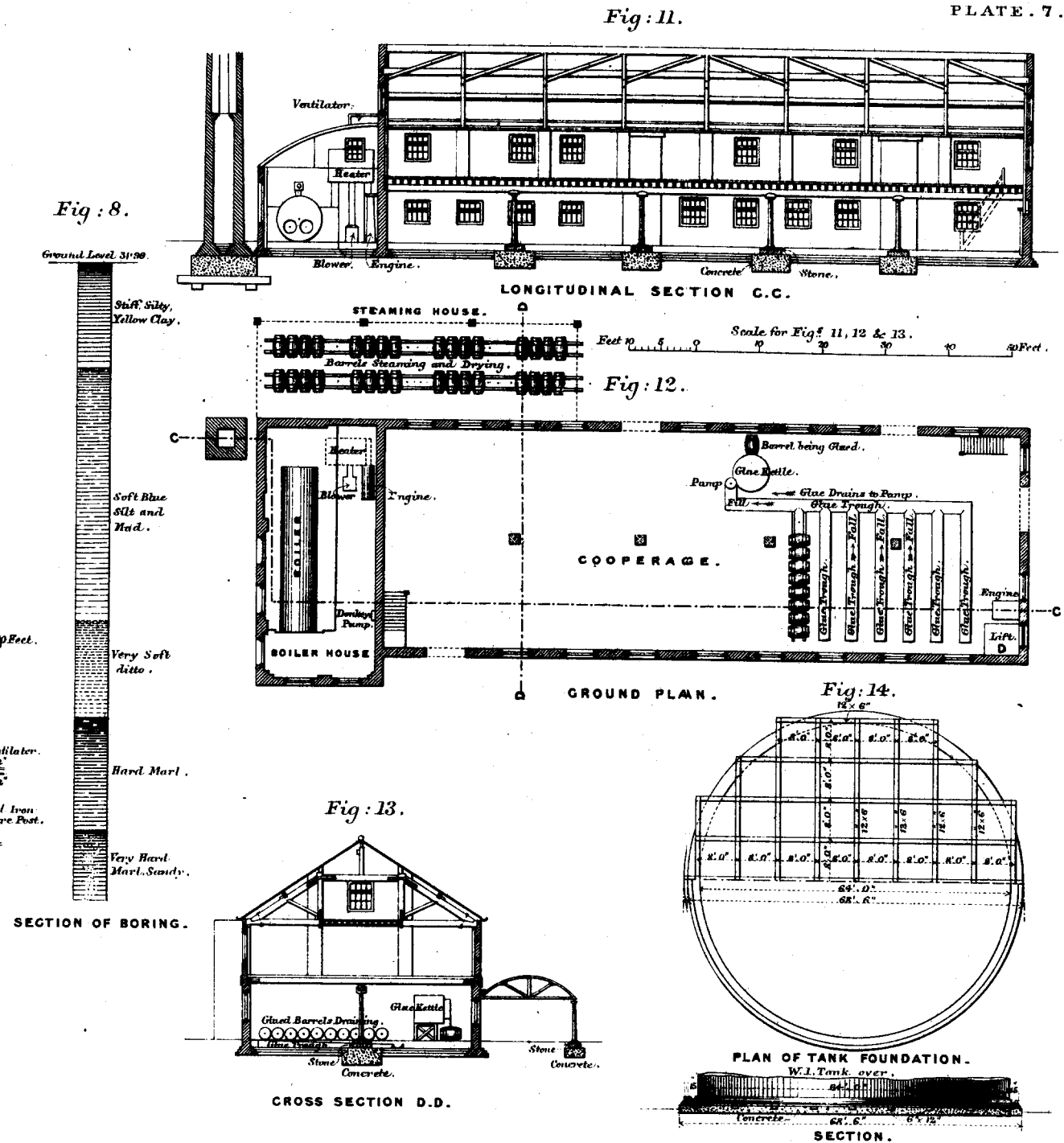


Fig : 17.

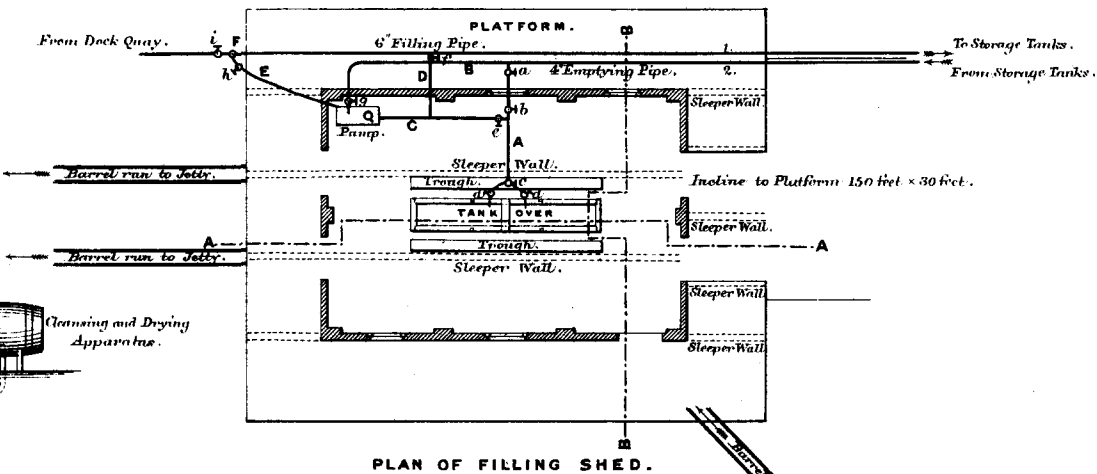


Fig : 16 .

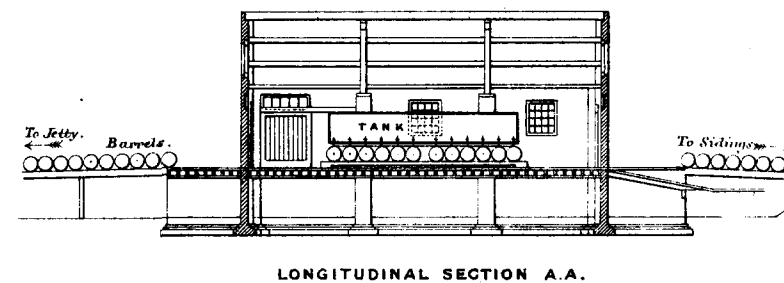


Fig : 18.

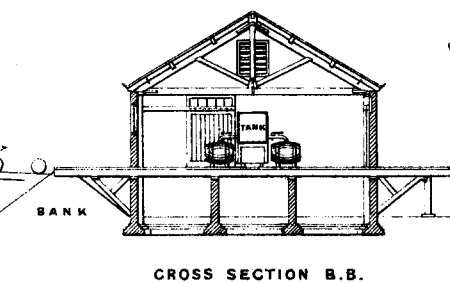
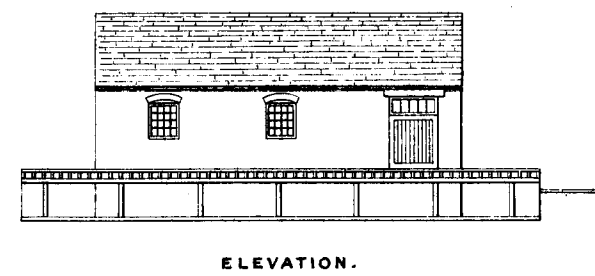


Fig : 19.



CARDIFF PETROLEUM INSTALLATION.
SECTION C.

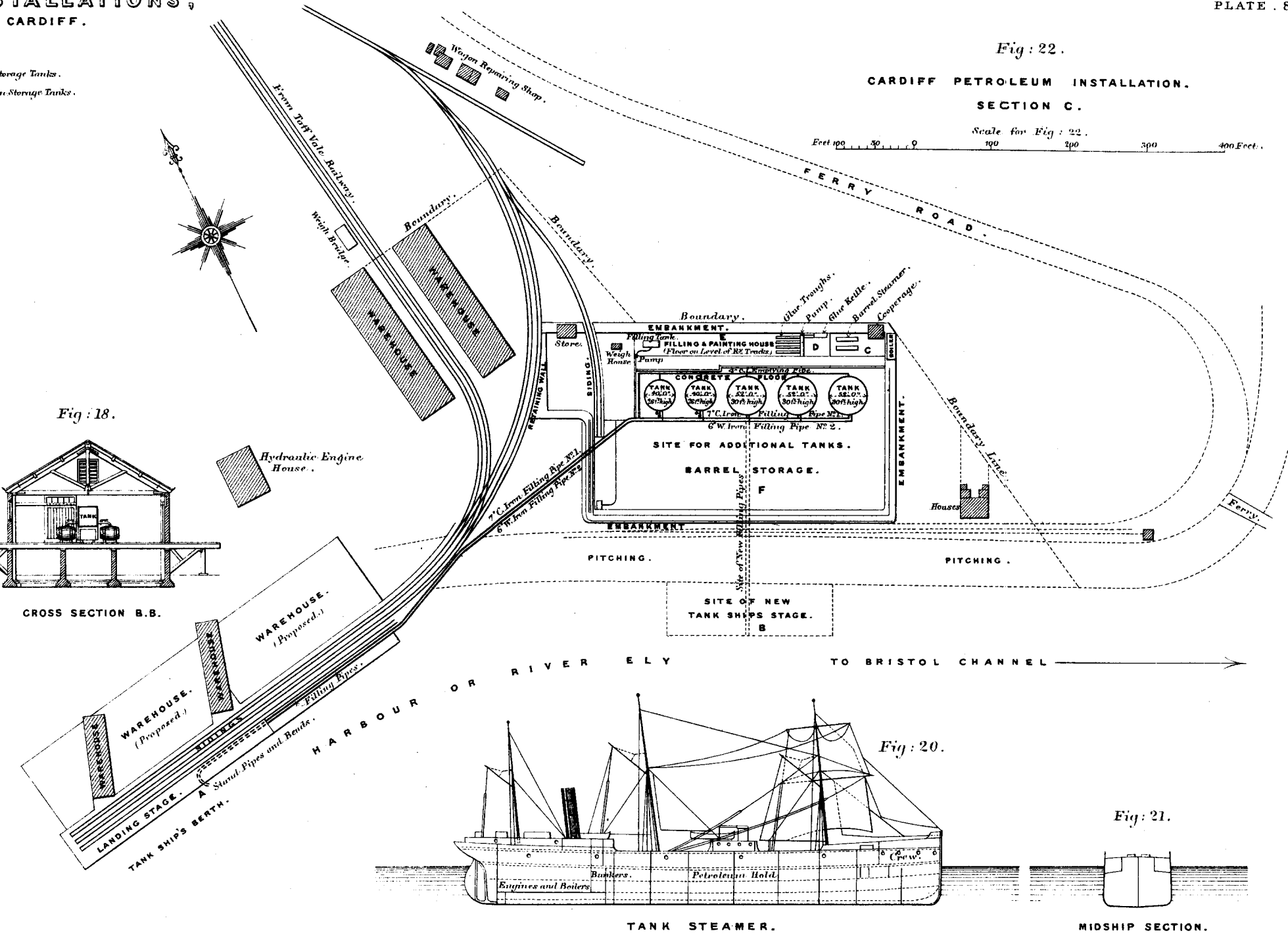


Fig: 21.

