(*Paper No. 2519.*)

“Description of a Four-Screw Hopper-Dredger, with Results of its Working.”

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THE most modern feature in dredging appliances is the combination of the dredger and the steam hopper-barge. The Author proposes to describe one belonging to the Corporation of Bristol, which has four propellers, two forward and two aft (Plate 6). It was constructed by Messrs. Simons & Co., of Renfrew, at a cost of £30,000; it steamed from the Clyde in November, 1886, and commenced working in December 1886. It has a hopper-capacity for 1,000 tons of material, which amount it is capable of dredging in one hour. The vessel is built on the ordinary frame system; it is constructed throughout of steel, and is registered in Lloyd's highest class. The four propellers necessitated the construction of shafting-tunnels through the hoppers, which have been so arranged as to add materially to the strength of the vessel. The ladder-well, situated in the after part of the vessel, also adds to the structural strength. Altogether the vessel is exceptionally strong, and is capable of grounding in safety on almost any practicable bottom. It can dredge to a depth of 36 feet below the water-line, when the vessel is light, and the ladder set at an angle of 45°; and it can also dredge a channel in advance of the bow, and therefore cut its own flotation. There are two sets of triple-expansion engines of the ordinary marine type, and they develop easily an indicated HP. of 1,300 at a piston-speed of 500 feet per minute, and with a boiler-pressure of 140 lbs. per square inch. The vessel can be propelled at 9 knots per hour when fully laden. The dredging machinery may be driven by either of the main sets of engines, and at speeds varying with the nature of the ground in

¹ The Author is indebted to Mr. J. W. Girdlestone, M. Inst. C.E., late Engineer-in-Chief to the Bristol Docks, under whose supervision and instructions the dredger was built, and to Messrs. Simons & Co., for information and assistance in preparing this Paper.

which it is working. The three boilers are of the ordinary marine type, and are fired from their after ends. The steering may be effected by hand or by steam-power, the control of the vessel being still further provided for by the four propellers, and if these break down, by the anchors and cables. This dredger in five years removed and deposited in the Bristol Channel about 1,500,000 tons of spoil from the Bristol, Avonmouth, and Portishead docks. The material dredged consisted chiefly of mud, sand, sandstone rock, concrete wall, and piles. During the five years the dredger has made about 1,390 trips. When working at Portishead in soft material, it is able to make eleven trips per week, or one each tide. A concrete wall, with its surroundings, amounting to 72,000 tons, was removed by this dredger; in which case, and also when working on sandstone rock, solid pieces weighing from 15 to 30 cwt. were brought up; and in one instance a piece of hard rock weighing 2 tons 15 cwt. was brought up by a single bucket. These pieces of solid material are not dropped into the hoppers, but are removed by a crane from the buckets. While working in the Bristol docks, the dredger removed piles over 20 feet in length, the buckets cutting into the wood, and then lifting them out of their position in the ground.

The cost of dredging for the period of five years amounted to about 5*d.* per ton, including wages, repairs, coal, grease, and sundries, together with the conveyance of the dredgings 10 miles from the Bristol docks, and also interest on the first cost of the plant. Three new sets of bucket-pins have been fitted, which are the only repairs of any importance that have been required. The cost per ton must not be compared with the cost of dredging continuously the same material, and in the same place. This type of dredger was chosen to suit the existing conditions and requirements; and it has amply fulfilled those requirements, and proved a most efficient machine. The four-screw system was adopted to enable the vessel to make equal speeds astern and ahead, as the river Avon, for the 7 miles from the Bristol docks to its mouth, is not sufficiently wide to enable a vessel of this size to turn. The Author has noticed that during dredging, it is necessary to keep the buckets well up to their work, especially in hard material; if not, they slip over their work, and bumping, or a backward and forward motion of the vessel takes place. Twenty men are required to work this vessel: viz., a captain, a mate, three engineers, four cranemen, four firemen, and seven sailors.

Hull.—The vessel has raised decks fore and aft. The three hoppers are situated in the vessel itself, and nearly amidships.

The main hopper is placed immediately ahead of the side hoppers. The length of the vessel on the deck is 218 feet; the draught is 14 feet 6 inches when fully laden, and 10 feet 6 inches when light. The hopper capacity is 25,000 cubic feet, or about 1,000 tons at a specific gravity of 1.44. The frames are 22 inches apart; all joints are made over the keel, where doubling pieces 3 feet in length are used. The centre keelson, forward of the hopper, is 15 inches by $1\frac{1}{8}$ inch. Sister keelsons run fore and aft as far as possible. The whole of the frames, keelsons, and stringers are exceeding strong. The vessel is divided longitudinally towards its after end, so that the buckets may dredge in advance of the stern, the vacant space being called the well. The two parts or wings are strongly connected towards their after extremities by bridging over the interval between them. A cut-water is fitted at the fore and aft ends of the well, to throw a current of water under the vessel's bottom, and to diminish the resistance when steaming astern. There are three complete bulkheads extending across the vessel, and one across each section of the vessel, running on each side of the bucket-well. The bulkheads, which are $\frac{1}{2}$ inch thick, are well stiffened with angle-bars. The main framing, and the framing for carrying the engine-shafting and the upper tumbler, which rests on the keelsons, are exceedingly strong. The frames for carrying the upper tumbler and gear are box-shaped, 14 inches by 12 inches by $\frac{7}{8}$ inch plate; the angle-bars are 3 inches by $2\frac{1}{2}$ inches by $\frac{7}{8}$ inch thick. The hopper-doors are formed of $\frac{7}{8}$ -inch plates, lined inside with $3\frac{1}{2}$ -inch elm; and they can be opened either by steam or by hand. A neat arrangement of worm-gear, consisting of chains, barrels, clutches, trigger-bars, and a powerful brake, is fitted for opening the doors. The bunkers hold about 90 tons of coal. Comfortable accommodation is provided for the officers and crew, the cabins being thoroughly well fitted. The bottom of the vessel is protected from injury when grounding by four outside bilge keels. With a view to protect the vessel from injury on coming into contact either with wharf walls, or with another vessel, she has been surrounded by a steel-faced fender of American rock-elm at a suitable distance above water-line. The vessel is steered from the bridge by steam-power. The bridge is fixed on the top of the dredging frame, which permits the steersman to overlook the gear. The deck plates are made of Coalbrookdale rolled chequered iron. The vessel is constructed throughout of "Hallside steel, brands S.B.X.X. and S.B.X."

Dredging-Machinery.—The dredging-machinery is adapted for

dredging readily at least 400 tons of stiff clay, mud, silt, free sand, or gravel, at a depth of 36 feet below the water-line. The machinery is fitted with Brown's patent traversing gear, to allow for dredging in advance of the bow. Steam-winchs for mooring the dredger are placed fore and aft. The cylinders of each winch are 9 inches in diameter, and have a stroke of 12 inches. The gearing is arranged for a speed of either sixteen or eighteen buckets per minute, with a piston-speed of 340 feet per minute. Suitable clutches are provided, so that the engines may readily be engaged with, or disengaged from, the propeller shafting. On each crank-shaft, strong spur-wheels are fitted for giving the necessary motion. The port and starboard engine gears, which are of different velocity-ratios, can be brought into gear separately or together as may be required. Power is transmitted to the top tumbler by means of an almost vertical steel shaft of 9 inches diameter. The gearing for driving the top tumbler, and for traversing the carriage, is capable of being readily and independently disengaged. The top tumbler shaft is driven by a surging wheel, 10 feet in diameter. All the gearing wheels are made of cast-steel. The hoisting and lowering of the bucket-ladder is effected by means of chain-tackle suspended from the shears. The purchase-gear consists of four upper, and three lower iron sheave-blocks; the pulleys are about 20 inches in diameter. The hoisting chain is wound on a barrel, which is driven by a separate donkey-engine, and is so arranged that the lower tumbler may be raised or lowered at a rate of 7 feet per minute. The barrel is under the control of a friction-brake and compound lever. The handles for working the gear are actuated on deck. The shears for hoisting the ladder are of box section, measuring 16 inches by 12 inches, and consist of $\frac{3}{8}$ -inch plates. The bucket-ladder, which is built in the best style of girder work, consists of a plate-girder 85 feet between centres of tumblers, and measures 57 inches in depth at the centre, and 27, and 30 inches in depth at the upper and lower ends respectively, the web being $\frac{7}{16}$ inch thick. The two girders are strongly united by cross ties. The upper and lower ends of the bucket-ladder are fitted with strong cast-steel brackets for the reception of the tumblers. The tumblers are of hard-wearing steel with strong flanges at the ends, the upper tumbler being five-sided, and the lower tumbler six-sided.

The bucket-chain passes over, and is supported by cast-iron rollers, 12 inches in diameter. The thirty-six buckets weigh $23\frac{3}{4}$ cwt. each with their links and pins; and each one is capable of containing $17\frac{1}{2}$ cubic feet of material. The buckets are made

of mild steel $\frac{7}{16}$ inch thick, and are furnished with a mouth or lip of harder steel. The links are made of cast-steel, and are 5 inches by 3 inches; the eyes of the links are bushed with hard steel. The pins are $3\frac{1}{2}$ inches in diameter. The shoots are so arranged as to ensure convenience in discharging, either into the main hoppers, or into hopper-barges, when the side shoots would be used. A derrick crane is also provided to lift 4 tons, and is worked by hand.

The power absorbed during dredging operations varies from 120 indicated HP. to 150 indicated HP., depending on the nature of the material. Probably 70 per cent. of the power is required to drive the machinery, showing the low efficiency of the bucket-ladder dredger as a machine. Practically this low efficiency is not of much importance, as the power at the disposal of the machine is very large.

Engines.—The two sets of propelling engines are in all respects similar, and of equal dimensions; and they are arranged so that either set, or both sets simultaneously, may be utilized for the purpose of driving the dredging-machinery or propelling the vessel. The working pressure is 140 lbs. per square inch, which gives an indicated HP. of 1,300 at a piston-speed of 500 feet per minute. The engines are adapted for working at a pressure of 150 lbs. per square inch, which gives an indicated HP. of 1,500; and in special cases these engines have indicated 1,600 HP. The diameters are 17 inches, 27 inches, and 43 inches, for the high-pressure, intermediate, and low-pressure cylinders respectively, with a common stroke of 30 inches. Each bed-plate is made of cast-iron, of ample thickness and strength, securely bolted to the keelsons. The standards, six in number, are of cast-iron, and are as nearly symmetrical as possible. These engines are of the latest design in marine practice, and give very good results, the coal consumed being 1.6 lb. per HP. per hour. All glands are readily accessible. The slide-valves, which are single ported, are of the ordinary pattern. Relief-valves, spring-loaded with casings to prevent spouting of water, are fitted at each end of each cylinder. A safety-valve, loaded to 25 lbs. per square inch, is fitted to each low-pressure valve-chest. The pistons are fitted with Mather and Platt's metallic packing. The connecting-rod, which is made of forged scrap-iron, is two and a half times the length of stroke. Each valve is fitted with the ordinary link-motion gear, and double eccentrics. The eccentric sheaves are of cast-iron, with gun-metal straps. The reversing-gear may be worked by hand or by a small engine.

There are two surface-condensers for each set of engines. The condenser tube-plates are made of rolled brass; the tubes are of brass, solid drawn, $\frac{3}{4}$ inch external diameter, and No. 18 standard B.W.G. in thickness; they are packed by means of the ordinary screwed glands. The usual air- and circulating-pumps are fitted to the condensers. The pump-rods are of solid Muntz metal; and all bolts, nuts, and studs exposed to the action of the water are of Muntz metal. Each engine is fitted with one feed-pump and one bilge-pump. All the stuffing-boxes are bushed with brass, and the glands are made of brass. The feed-pipes are of copper, No. 8 B.W.G. The bilge-pipes are $2\frac{1}{2}$ inches in diameter, and are made of lead. An ordinary donkey-pump and a hand-pump are also fitted. Sensitive governors are fitted to each set of engines; and a balancing fly-wheel is fitted at the ends of the main crank-shafts. The crank-shaft is made of scrap iron. The cranks are forged solid, and set at angles of 120° . The bearings of the main shafts and of the thrust-blocks are of the usual marine type. The stem and stern tubes, which are of cast-iron, are fitted with brass bushes, $\frac{1}{2}$ inch thick, and lignum vitæ strips, $\frac{3}{4}$ inch thick.

Each of the four propellers has three movable blades, made of cast-steel, and bolted on to a cast-steel boss. The blades are secured in position by Muntz metal bolts and nuts. The blades are curved, to allow of sufficient blade-area with the small draught of the vessel. The diameter of each propeller is 8 feet 4 inches.

All steam-, feed-, air-, and circulating-pump discharges, all bilge, surface, and bottom blow-down pipes, and all internal pipes are made of copper. The bilge suction-pipes are made of lead. The thicknesses of all pipes fully comply with the requirements of the Board of Trade. An ample water-service is fitted to all bearings on the crank shafting, thrust-blocks, and motion-shafting; the pipes are of copper, with brass telescopic directors and universal joints. Telegraphs, gauges, counters, and the usual fittings, of the most approved type, are provided. The engines throughout are in accordance with the rules adopted by the Board of Trade.

Boilers.—There are three boilers, which are placed aft of the engines, and are fixed from their after ends. They were designed and made in accordance with the rules of the Board of Trade, as applied to steel boilers intended to work at a pressure of 150 lbs. per square inch, and are of the plain cylindrical form. Each boiler is fitted with two of Fox's patent corrugated furnace tubes, and with one hundred and fifty-six tubes $3\frac{1}{2}$ inches in diameter. The tubes are made of steel, lap welded. The mean diameter of the shell is 12 feet, and its length 9 feet 6 inches; and the

diameter of the furnaces is 3 feet 4 inches. The boilers are arranged so that any one of them may be worked independently of the others. The longitudinal seams are of double strap, and treble riveted; and the circumferential seams are lap-jointed and double riveted. The shells, $1\frac{3}{8}$ inch thick, combustion-chambers, doors, &c., are of steel, and were made by Messrs. Colville, of Dalzell. All cocks are made of gun-metal, each being submitted to a hydraulic test of 400 lbs. per square inch. The uptakes are fitted with hinged doors, $\frac{1}{4}$ inch thick, to allow for cleaning or the withdrawal of the tubes. The steam-piping is of copper. The boilers were tested by hydraulic power to 300 lbs. per square inch.

The communication is accompanied by a drawing, from which Plate 6 has been prepared.

FOUR-SCREW HOPPER-DREDGER

PLATE . G .

BELONGING TO THE BRISTOL CORPORATION.

DECK PLAN.

Scale: 32 Feet = 1 Inch.

Feet 10 5 0 10 20 30 40 50 60 70 80 90 100 Feet.