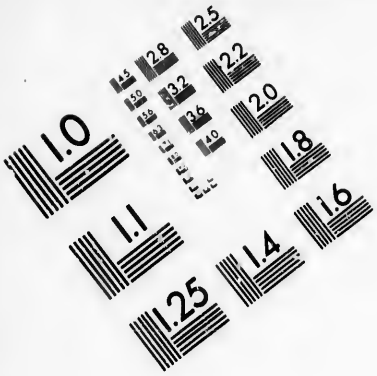

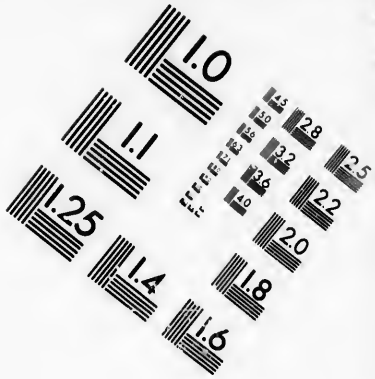

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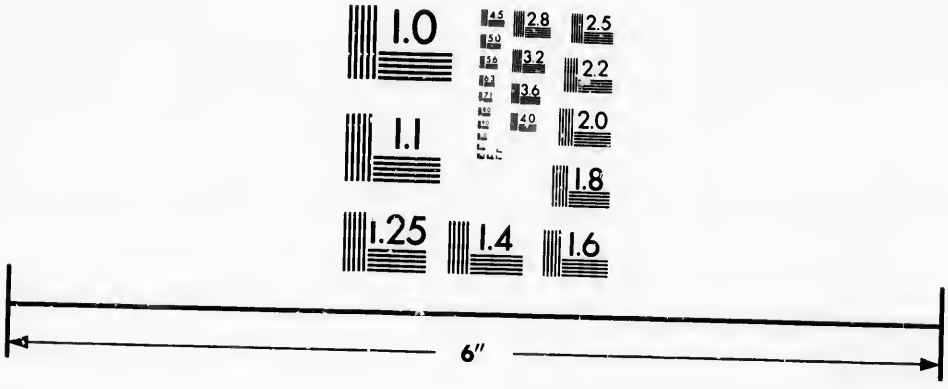

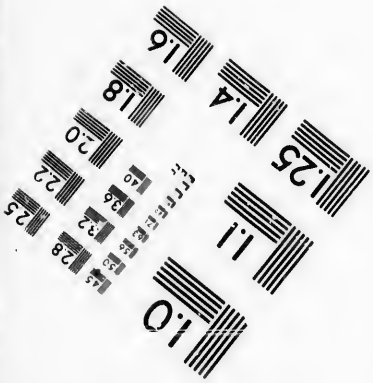

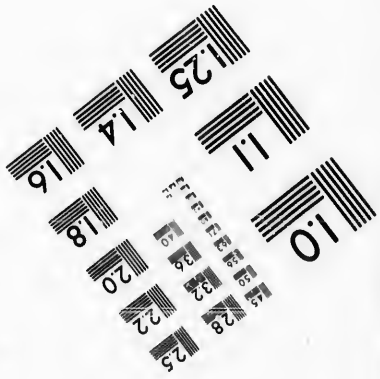

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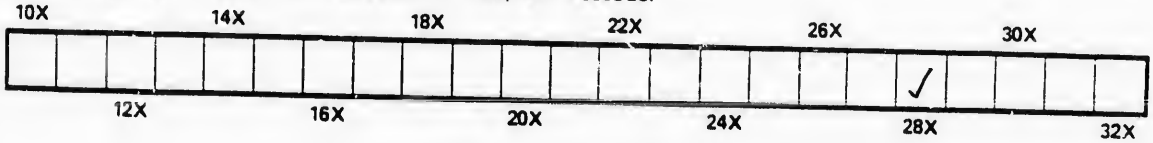

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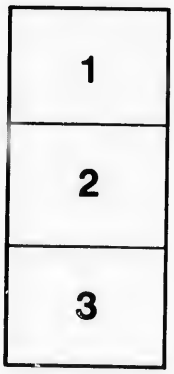

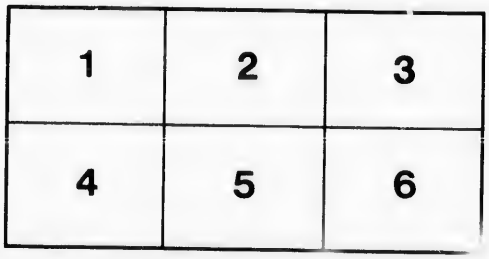

Canadian Society of Civil Engineers.

INCORPORATED 1887.

TRANSACTIONS.

THE ESQUIMALT GRAVING DOCK WORKS, BRITISH COLUMBIA.

By W. Bennett, M. Can. Soc. C.E.

To be read on ~~Monday~~ March 28th or April 11th.

These works, which were fully illustrated in "Engineering" of the 26th and 27th of July, 1888, were originally commenced by the Government of British Columbia, and have been completed at the cost of the Dominion of Canada, the Imperial Government contributing £50,000 thereto, in consideration of which, any of H.M. ships have priority of entry and free dockage for 15 years, on payment of working expenses only. The works were designed by Mr. Kinipple, the senior member of the late firm of Kinipple & Morris, Engineers in Chief for the whole of the works.

The outer or Cofferdam works were commenced in September, 1876, and the inner or Dock works some four years later. The Earl of Dufferin, then Governor General of Canada, was present when the first pile of the dam was driven. The Dock was opened on 20th July, 1887, H.M.S. "Cormorant" being the first to enter, and followed, when her repairs were completed, by H.M.S. "Caroline."

The progress of the outer works was to a certain extent hindered by the fact that at Esquimalt the range of tide, which was supposed to be about 10 feet, is very uncertain, the tide remaining frequently at almost H.W. level for days together, which thus prevented the wales and struts of the dam being placed in their respective positions. The original drawings had therefore to be somewhat modified in order to prevent further delays in the completion of this portion of the work.

In January, 1876, the contract for the Cofferdam was given to Messrs. Reed Brothers, of Tokenhouse Yard, London, by the British Columbian Government, for the sum of £12,311. Owing, however, to the non-fulfilment of their contract in the specified and extended time, the Government, in June, 1879, after the contractors had ceased work altogether, took possession of the Cofferdam works, and completed them in the following October, under the superintendence of their Resident Engineer. (Figs. 1 to 8.)

When the water was pumped out from the area on which the Graving Dock was to be constructed, the dam was found to be perfectly tight in every respect, although for fully one-third of its total length, of upwards of 500 feet, viz., at the shore ends, the sheeting piles had to be planted on a very uneven foundation of rock, overlaid with sand, shells, and boulders, all of which, of course, had to be removed. Some of the holes for the rock pile shoes were drilled in 25 feet of water. The dam did not show the slightest strain when the full pressure, due to a head of nearly 30 feet, was brought against it, and remained intact until it was removed on the completion of the Dock in 1887. Although the dam was not removed for 7 years after its completion, no pumping whatever was required during that time beyond that which was due to percolation through the strata, or to rainfall.

The three sluices through the Cofferdam were not constructed as shown on Figs. 5, 7, and 8, as much on account of the tidal difficulties already referred to as for the avoidance of leakage, and in lieu thereof one sluice, equal in capacity to the three proposed, was built in the channel way at the back of Thetis Island (Fig. 1), and by its means the Dock was flooded at the testing of the caisson against the meeting faces.

The greater portion of the Portland cement used in the construction of the Dock was supplied by Messrs. Gibbs & Co., of Gray's Essex, and

the remainder by Messrs. Robins & Co., and other well known English makers.

In June, 1875, tenders were ordered to be obtained for the Dock pumping machinery, and Messrs. James Watt & Co., of Soho, Birmingham, secured the work at the contract price of £6300. This contract included the boilers, engines, caisson hauling gear, sluices, pumps, &c. The boilers (3 in number, one spare) are of the cylindrical and multitubular type, each 15 feet long, and 6½ feet in diameter, having 2 flues 4 feet 6 inches long, 2 feet 3 inches in diameter, a large combustion chamber, and 120 tubes 2½ inches in diameter, 5 feet in length. (Fig. 27). The boilers were tested to 120 lbs. per square inch, the working pressure being estimated at 60 lbs. The main pumping engines are capable of raising 907,000 cubic feet of water in 6 hours, with an extreme lift of 35 feet, and a mean lift of 17 feet 6 inches. These engines are of the low pressure condensing horizontal description. The cylinders, 2 in number, are 27½ inches in diameter, with a stroke of 4 feet. The main pumps are 4 feet in diameter, and 5 feet stroke, the working barrels (Fig. 24) of which are lined with brass; the pump buckets are also of brass, with india-rubber valves, and designed to discharge from 15,000 to 18,000 gallons per minute. The auxiliary engine is of the vertical direct acting description, having a cylinder 14 inches diameter, and a 12 inch stroke. This engine is used both for working the auxiliary pumps and the caisson hauling gear. The auxiliary or drainage pumps, 2 in number, 10 inches in diameter, with a 2½ feet stroke, are jointly capable of raising 600 to 800 gallons per minute, 50 feet high. (Fig. 26.)

The whole of this machinery was delivered at Esquimalt in 1876, and stored, with the exception of the auxiliary pump, which was used to pump out the area behind the Cofferdam, and also to keep down the surface drainage during the whole period that the works were under construction; thus the necessity of obtaining special pumps for this purpose was obviated.

On the 5th of September, 1879, tenders were advertised for the main works, and Messrs. F. B. McNamee & Co., Montreal, were the successful contractors.

The works, however, were not commenced before the 13th of September, 1880; but progress was slow, and in April, 1882, the contractors stopped work, and consequently, in June, 1882, possession of the works was taken by the Government of British Columbia. The works were carried on for the following 12 months by day labor, and again under the direction of their Resident Engineer. On the 24th of August, 1883, the works were handed over by the Government of British Columbia to the Dominion Government, under the terms of the Settlement Bill, one of the terms of which Act provided for the repayment of all sums expended on Dock account by the Federal to the Provincial Government.

The Dominion Government thereupon advertised for tenders for completion of the works, but it was not until November, 1884, that the tender of the well-known firm of Messrs. Larkin, Connolly & Co., of Quebec, was accepted, and they afterwards prosecuted the works to completion with great energy and ability.

The Dock is 450 feet in length (Fig. 9) from the inner face of the caisson, when in its ordinary berth, to the base of the circular head, and has a width at the entrance of 65 feet. (Fig. 10.)

The walls of the Dock are parallel for the entire length, and the width across the floor is 41 feet. The top inside width of the Dock at coping level is 90 feet, and the depth on sill at ordinary H.W. is 26½ feet, occasionally, however, the tide rises from 2½ to 3½ feet higher.

The excavation for the Dock, which was commenced in 1880, was mostly in sand and shells for a depth of about 3 feet over the entire area of Thetis-Cove. Below this level very stiff brown and blue clay was encountered (with occasional boulders imbedded), with the exception of an out-cropping of rock, which occurred about half way up the Dock, continuing to the end, and under the caisson chamber and engine house foundations.

The whole of the foundations of the entrance works are of cellular brickwork, laid in 3 to 1 Portland cement compo, and the pockets filled in with concrete.

The walls and Dock entrance are 7 to 1 rubble concrete, faced with sandstone in 2 feet courses. The sandstone facing of the Dock, according to the contract drawing, was in 1 foot courses; but as good stone was easily obtainable of large size in the district, it was ultimately decided to adopt 2 feet courses. The sandstone was obtained from Salt Spring or Admiralty Island, and the granite from Nelson Island, respectively distant from Esquimalt, 50 and 100 miles. A skin of 9 inches in thickness of 5 to 1 Portland cement fine concrete was introduced into the bottom of the whole of the foundations, against the backs of all the walls, and also behind the brickwork and stone facing work, and generally throughout the works.

The whole of the Dock-side walls are built vertical, the upper portions being carried by rubble concrete arches. Under the bottom of the Dock there are 6 arterial box drains, laid in 5 to 1 Portland cement porous concrete, which are connected with the rubble drains running behind the walls in each arched recess, the whole of which discharge into the drainage pump well.

The inverts are 112 feet radius, the outer being 15 feet wide, and the inner 20 feet, both of which are faced with sandstone with a hearting of brickwork and 7 to 1 concrete. (Figs. 10, 11.) The caisson berth meeting faces and quoins of the Invert are of granite, which are very fine-axe dressed for 12 inches in width, and which have a projection of $\frac{3}{4}$ of an inch. (Fig. 10.)

The invert at the bottom of the caisson chamber is of brickwork set in 3 to 1 Portland cement compo, and founded on 7 to 1 concrete, and the walls of the chamber are of hammer-dressed sandstone, in 2 feet courses, with 5 arched recesses on each side. The chamber is provided with stop quoins (Figs. 13 to 17) at its entrance, and by means of balks of timber inserted therein, can be converted into a dock for painting or repairing the caisson.

The cast-iron boxes carrying the rollers on which the caisson travels are set in brickwork on the bottom of the chamber and berth. At each end of the caisson chamber pathway there is a scouring culvert, which can be used, when desired, to clear the roller pathway of any mud that may accumulate. (Fig. 10.)

The Dock is provided with four timber slides and stairs, of finely dressed masonry, two at the head and two at the stern, there are also twelve cedar double fenders, with ladders in them of 4 feet in width, six patent hand power capstans, and the necessary mooring posts, a powder magazine, all necessary lavatories, &c., 3 hydrants on each side of the Dock, with a first-rate water supply. Outside the entrance to the Dock are two wrought-iron buoys attached to screw moorings by a $2\frac{1}{2}$ inch stud cable, for the purpose of facilitating the docking and undocking of vessels. The works are now lit up at night by electricity. The engine and boiler house and chimney shaft are faced with hammered dressed ashlar, backed with brickwork in Portland cement. The chimney shaft is 90 feet 9 inches above coping level; it was found necessary to go to 45 feet below coping for foundation for the same.

The paving at the centre portion of the Dock bottom, for a width of 10 feet, consists of two courses of stone 2 feet in depth and 1 foot 9 inches in width, and filled in between with 5 courses of 18 inches in depth, and the remaining portion of the Dock bottom is paved with 20 courses of stone 2 feet in depth by 18 inches in width, the whole being laid in Portland cement compo.

The discharge pipe from the auxiliary drainage pump is carried through the quays, and across the caisson chamber immediately under the surface of the quays, and down the face of the Harbour quay wall.

There are also two culvert mouths, 4 feet in diameter, in the faces of the Harbor or quay walls. The one on the west side is the discharge from the main pumps, and the other for scouring the caisson berth at its eastern end.

One of Mr. Kinipple's patented Travelling and Folding Bridge Caissons was constructed and erected for this Dock, by the Dominion Bridge Works Co., at Lachine, Quebec, and transported in pieces by the Canadian Pacific Railway to Esquimalt. The caisson herein illustrated is provided with keels, which travel on two lines of rollers placed on the bottom of the chamber and caisson recess. (Fig. 19.)

The folding Bridge on the top of the caisson is supported by levers having adjustable tail weights, which together form a parallel motion. The rising and lowering of the platform is affected by rollers on the nose of the platform against curved plates placed in the abutment.

The caisson, which is hauled by steam power, may be drawn in or out of its recess in less than five minutes, and in any weather. It is divided into two parts, the lower being an air tight chamber of sufficient capacity to reduce the weight of the caisson on the rollers to a minimum, and the upper a flotation chamber, from which the water is pumped out by means of a Pulsometer whenever it is necessary to float the caisson out of its berth. Abrasion of the meeting faces of the caisson and granite cills and stop quoins is prevented by the keels having "swells" in them, as illustrated (Fig. 23), which ensures a clearance of all such, or more, between all the meeting faces, when the caisson is being hauled into or out of its recess.

The sides of the caisson are vertical, but are bevelled horizontally, the inner face being of less width than the outer, in order that by moving the caisson a short distance back into its chamber, and allowing the caisson to float high enough to clear the invert or cill, the caisson may be turned round and floated out, when necessary, for repairs, &c. The caisson, when afloat, can also be berthed against the outside meeting face of the outer invert, and by this means the available length for dockage would be increased by 31 feet, and the length of the dock from the inner face of the caisson to the base of the circular head would then be 481 feet.

By constructing the caisson as above described, the usual battered sides are dispensed with, and a saving of about 10 feet in width of the entrance is thereby effected.

The caisson is constructed of a series of horizontal and vertical angle and T irons, with cross diagonal bracing 4 feet 6 inches apart. The outside plating varies from $\frac{1}{2}$ inch to $\frac{1}{4}$ inch in thickness. A teak meeting face or rubbing piece 1 foot 3 inches wide is attached to the inside and outside faces of the caisson, following the vertical sides and radius of the invert.

The displacement of this caisson is 530 tons, and its entire weight equals 294 tons, made up as follows:—Cast iron, 63 tons; brass, 4 tons; wrought iron, 199 tons; teak face and other iron work, 28 tons; the weight of the concrete ballast, over 180 tons.

The width of the rising and falling platform is 10 feet, the height of the caisson from the inner side of the keels to the coping level is 34 feet 10 inches, the length 67 feet 2 inches on the inner or dock side, and 71 feet 2 inches on the outer or harbor side. The keel blocks are of cast iron, in three pieces, wedge shaped, the lower piece is checked into the stone paving, each block is provided with a hard wood and cap and a rubbing piece on top.

The dockage rates are at present as follows:—

Gross Tonnage of Vessel.	For the first day of docking.	For each following day, including the undocking day.
For all vessels up to 1000 tons . .	$400 00	10 cents per ton.
From 1000 to 2000 " . .	500 00	8 " "
" 2000 to 3000 " . .	600 00	6 " "
" 3000 to 6000 " . .	750 00	5 " "

It may be of some interest to mention that the above rates are slightly less than those at Yokohama, Japan, and from 100 to 300 per cent. less than those at San Francisco, U.S.A., should a vessel occupy the dock from 7 to 10 days.

The Royal Naval Dockyard is adjoining the Graving Dock property, and to the westward thereof, thereby affording great facilities for repairs to any of Her Majesty's ships.

The total cost of the Graving Dock Works, inclusive of the site, the cofferdam works, as well as the engine and boiler houses, pumping machinery, and caisson, amounted to about £180,000.

Mr. William Bennett, M. Inst. C.E., M. Can. Soc. C.E., was the Resident Engineer from 1875, until the completion of the works in 1887, and Mr. Francis O'Reilly was for two years his assistant.