Some Features of Dredgers – the Crane (Rock Cutter) Dredger ________________

By Andrew C. Whyte, BSc, MSc, CEng, M.I.Mech.E.

Web site: https://acwhyte.droppages.com

1.0 Introduction. The Glasgow Museums have an outstanding collection of almost 700 ship models. As well as prestigious ships like the Queen Mary, Queen Elizabeth and the QE2 there are models of less glamorous ships. There are a range of ships (vessels), commonly called dredgers, that provide an essential role in keeping shipping lanes open, harbours free of silt and land reclamation. In the collection are 37 dredger models: 30 Dredgers proper, 2 Rock Breakers also called rock cutters or sometimes rock excavators and 5 Hopper Barges. This Research Technical Note describes one of these models, a 1/48th scale model, of a crane dredger the '*Buarque de Macedo*' (ID No. T.1956.25.c), that is currently on display at Glasgow's Riverside Museum of Transport and Travel.

The '*Buarque de Macedo*' was a twin screw, crane hopper dredger shown in use as a rock cutter. It was a multi-use vessel, as well as rock cutting, it could be fitted with a grab (ref. 5) and the pulverised rock mechanically lifted to the water surface and placed in a hopper for eventual disposal or use. This vessel was built by Lobnitz & Co. (ref. 1), of Renfrew in 1891 for use in the redevelopment of the harbour at Recife, Pernambuco, Brazil. It seems likely that the vessel's name is associated with Manuel Buarque de Macedo. Born in Recife, Brazil 1837, died Minas Gerais 1881. Engineer, journalist and politician, he was Brazil's Minister of Transport and then Minister of Agriculture 1880 to 1881, ref. 9.

> [At this date, 1891, the company name should be Lobnitz, Coulborn & Co. However, there is in the collection a nameplate for hopper barges (believed to be for T.1956.25.f) of this date and with yard numbers 361 and 362 (i.e. just before the '*Buarque de Macedo*', yard number 363) for Lobnitz & Co. In this text it is assumed that by 1891 the Coulborn name was no longer being used by the company.]

2.0 The Need to Dredge. The requirement to remove or recover material from underwater requires the use of a special vessel commonly known as a dredger. At its simplest, the dredger might be no more than a non-propelled (dumb) pontoon capable of only working in a harbour or river estuary. At the other extreme, the dredger might be a fully equipped self-propelled vessel capable of sea going voyages anywhere in the world.

There must be sufficient depth of water to allow the dredger to operate, but the material to be dredged must be at depth at which the dredger can access.

During normal dredging operations of removing obstructions to navigation, or the widening and deepening of harbours or channels, sold rock ledges or conglomerates (which consist of pebbles held together by some natural cement) are often encountered. The removal of this material would be done by mechanical hammering using a rock cutter, or by explosive blasting. The use of a rock cutter avoids the danger and inconvenience of explosive blasting. The basic principle is very simple; a heavy ram (the rock breaker or rock cutter) is lifted by means of a winch and the ram is allowed to drop by gravity onto the rock to be excavated. This operation is repeated, as many times as necessary, until the rock is sufficiently pulverised or split so that it can be brought to the surface for disposal or use.

The rock cutter itself does not do any dredging it simply cuts or pulverises the rock. Other means would be required to actually lift the rock to the water surface. This could be done with a mechanical dredger such as a grab dredger or a bucket ladder dredger.

> [In order the get a more powerful blow, rams driven by steam or compressed air have also been used, Prelini ref. 2. In other cases the rams were suspended on chains, raised by hydraulic power, and allowed to drop by gravity, ref. 7.]

3.0 The Crane (Rock Cutter) Dredger. The Main Features of the '*Buarque de Macedo*', Figures 1 and 2, are:

- Yard No. 363
- Owners: Maurice, Simon & Allain of Paris
- Length 160' x Beam 40' x Draught 14'
- Tonnage 674 tons

- Steam powered with twin screws
- Hopper with bottom opening dump doors
- Steam powered winches
- Steam powered crane
- Central well for the rock cutter ram

This vessel is provided with a hopper with bottom opening doors. The opening and closing of the doors being controlled by chains from hand operated winches Figure 3. The main propulsion would be provided by compound steam engines and has twin screws for ease of manoeuvring.

In a typical dredging operation the vessel would sail to the site to be worked on, say a rock shelf, and up to six moorings with anchors would be laid out, one mooring fore and aft and two moorings port and starboard, Figure 4. The moorings would be under control of steam powered winches, fore and aft, Figure 3. The vessel could then be accurately positioned and moved over the site by taking in the moorings on one side and paying them out on the other side. Once the rock cutter had done its work the crane would be fitted with a grab and used to lift the pulverised rock into the hopper. The vessel would then sail to the dumping ground.

[Reference 10 shows the '*Buarque de Macedo*' with masts and makes reference to a smaller crane, in the bow, with a grab for lifting the pulverised rock into the hopper. These items are not shown in the model.]

[The '*Buarque de Macedo*' was sunk in 1946, ref. 8]

3.1 Used as a Crane. The crane has three degrees of freedom – lifting, reach and swing (slewing). The crane and its superstructure details are shown in Figures 5 and 6. With reference to Figure 5 this shows the crane as a space frame diagram. It essentially consists of three pin jointed structural members: AD, AB and AC. When subjected to the action of a load W (which could be: a rock cutter ram, a hook to a load, or a grab for lifting debris) member AD is in tension and members AB and AC are in compression. Members AB and AC are connected with cross members. These cross members are essential, to provide additional strength and stability against buckling, since members AB and AC are in compression.

In operation the crane winch is powered by small steam engines commonly known as 'donkey' engines. One of the two cylinders for powering the winch, used to raise and lower the load, can be seen in Figure 6. There is no boiler on the superstructure. The steam would be supplied from a boiler within the vessel. The steam supply to the 'donkey' engines would be via piping from the centre pivot seen in Figure 6.

The swinging of the crane and the lifting and lowering of the structural members, to provide the reach, are also powered by small steam engines. The crankshaft can just be seen in Figure 7. The swinging of the crane is achieved by engaging a clutch. This allows a worm gear and wheel to drive a vertical shaft that engages a ring gear that is fixed to the deck. This allows the crane to swing about the centre pivot. The crane superstructure is supported on wheels, running on a track fixed to the deck, Figure 7.

The reach is obtained by driving end D, of member AD, along a horizontal threaded drive shaft by means of spur gearing, Figure 7. The spur gearing being engaged by means of a clutch. To help balance the reach a large balance weight is attached to the superstructure.

It is essential that the load to be lifted, the reach and the angle of swing are controlled and limited so that the transverse stability of the vessel is not compromised under any operating condition.

3.2 Used as a Rock Cutter. Lobnitz & Co. became a specialist in rock cutter dredgers. Their rock cutters were used in several important civil engineering projects including: the Manchester Ship Canal, the Channel of the Niagara Ship Canal, the Trollhattan Canal in Sweden, the Iron Gates on the River Danube, the Suez Canal, and Malta Harbour. The rock cutter use was limited to soft or friable rock (such as shales and sandstones). On hard granite the cutter would rebound without making an impression on the rock, Gillette ref. 6. The principle of operation, although simple enough, does require some expertise and trial and error in order to get the best efficiency out of the process. The following information is based mainly on Prelini reference 2, Fowler reference 3, and Gillette reference. 6.

A heavy steel rod (the ram) is lifted by the crane and positioned over a well in the vessel's hull. The ram is allowed to fall through the well onto the submerged rock by gravity, Figures 6 and 8. Above the well there is a support structure fixed to the deck. Within the support structure the ram is guided by four hardwood guides, seen in Figure 6 detail. The guides are short and loose fitting to permit some degree of freedom in an angular direction. The guides can be adjusted vertically to suit different depths of water. Some applications have renewable wearing plates and spring cushions to deaden the shock.

The top of the ram is attached to a chain (as on the model) or wire rope which is wound round a drum of a steam hoisting engine (winch). Although a chain is shown on the model, Lobnitz did use a wire rope on many of their rock cutters. The winch drum is loose on its shaft, being driven by a friction clutch operated by a foot lever, Figure 6 detail. The ram is allowed to fall by gravity and when the ram hits the rock the chain/rope slackens and the clutch is engaged to re-lift the ram.

There was a risk of the wire rope breaking unless precautions were taken. The winch should be stopped before the ram was dropped, and it was important not to suddenly jerk the rope to raise the ram. Lobnitz developed a mechanism that automatically put the clutch into gear by means of a weighted bell crank lever when the ram reached the rock. This seems to have solved some of the problems of rope breakage. When a new rope was fitted it was essential to take the twist out of the rope, before use, otherwise the rope would kink.

The required weight of ram depends on the hardness of the rock and the depth of the water. A 'rule of thumb', adopted by Lobnitz, being 1 ton of ram per 1 metre (3 feet) depth of water (Prelini ref. 2). A typical ram may weigh from 4 to 20 tons and fall from 6 to 15 feet and be dropped about four times a minute.

The ram cutter on the model is chisel shaped, but Lobnitz also favoured a cylindrical ram with a renewable projectile shaped ogival cutter head. This cutter head had a centre harder than the outside. The head was thus made self-sharpening the softer outside being worn away more rapidly than the harder centre, Figure 9. The normal life of the point depended on the nature of the rock and the amount of working. On very abrasive rock the life could be as low as about one month, night and day working, Gillette ref. 6.

In operation the ram would be dropped onto the same spot repeatedly (from 10 to 20 blows would be required) splitting or pulverising until the required depth of disintegrated rock was obtained, Figure 10. Usually a layer of about 3 feet thick is broken up and a mechanical dredger would remove the disintegrated rock before another layer is started. The final depth should be about 9 inches more that the depth of excavation to allow the dredge buckets or a grab to remove the debris without obstruction.

It is important that the ram should repeatedly fall on the same spot. The system is best suited to harbours and sheltered regions, it was not suited to work in rough water or exposed situations, Gillette ref. 6.

The dredge requires to be accurately positioned. One method was by the use of sighting rods, which are collimated with base lines on land. The operator in charge would be required to continually keep an eye on the position by use of the sight rods. Bray in Chapter 8, reference 4 discusses several alternative methods of accurately positioning the dredger. The dredger would be moved, over the site, by means of mooring chains or ropes operated by the steam winding gear, Figures 3. In practice it was found that a move of about 3 feet spacing was required to completely pulverise the rock, Figures 4 and 10. Any wider spacing would not completely break up the rock while closer spacing would lead to unnecessary pulverising, in either case the dredging would be uneconomic. The costs involved in the rock cutting process are briefly discussed in references 2, 3 and 6.

4.0 Summary. The crane (rock cutter) dredger is one item of dredging equipment that is often overlooked compared to other more imposing equipment. Lobnitz & Co. was one of the Clyde shipyards who made an important worldwide contribution to this area of specialisation.

5.0 References.

1. Lobnitz Marine Holdings Limited, publicity material for: Seadrec Ltd., Fleming & Ferguson Ltd., Alluvial Dredges Ltd, and Sir J.H. Biles &Co. Ltd. Web site information: www.lobnitz.com
2. C. Prelini, *Dredges and Dredging*, Published by: Crosby Lockwood & Son, London 1911
3. C. E. Fowler, *A Practical Treatise on Sub-Aqueous Foundations, including the Coffer Dam process for Piers, and Dredges and Dredging*, 3rd edition, Published by: John Wiley & Sons, 1914
4. R. N. Bray, *Dredging: A Handbook for Engineers*, Published by Edward Arnold, 1979
5. Glasgow International Exhibition, Official Catalogue, 1901
6. H. P. Gillette, Handbook of Rock Excavation, Methods and Cost, Published by Clark Book Co., New York, 1916.
7. Web Site: www.chestofbooks.com/crafts/scientific-american/sup7/Demolition-Of-Rocks-Under-Water-Without-Explosives-Lobnitz-System.html
8. Web Site: http://www.clydesite.co.uk/clydebuilt/viewship.asp?id=7251
9. Wikipedia: Manuel Buarque de Macedo.
10. The Engineer, January 1, 1892, Vol. LXXIII. Pages 2, 3 and 6.

Figure 1. Starboard side view of Model (ID No. T.1956.25.c) of Crane Hopper Dredger, the '*Buarque de Macedo*', in Rock Cutter mode of operation, built in 1891 by Lobnitz & Co. of Renfrew for use in the redevelopment of the harbour at Recife, Pernambuco, Brazil.

Figure 2. Port side view of Model (ID No. T.1956.25.c) of Crane Hopper Dredger.

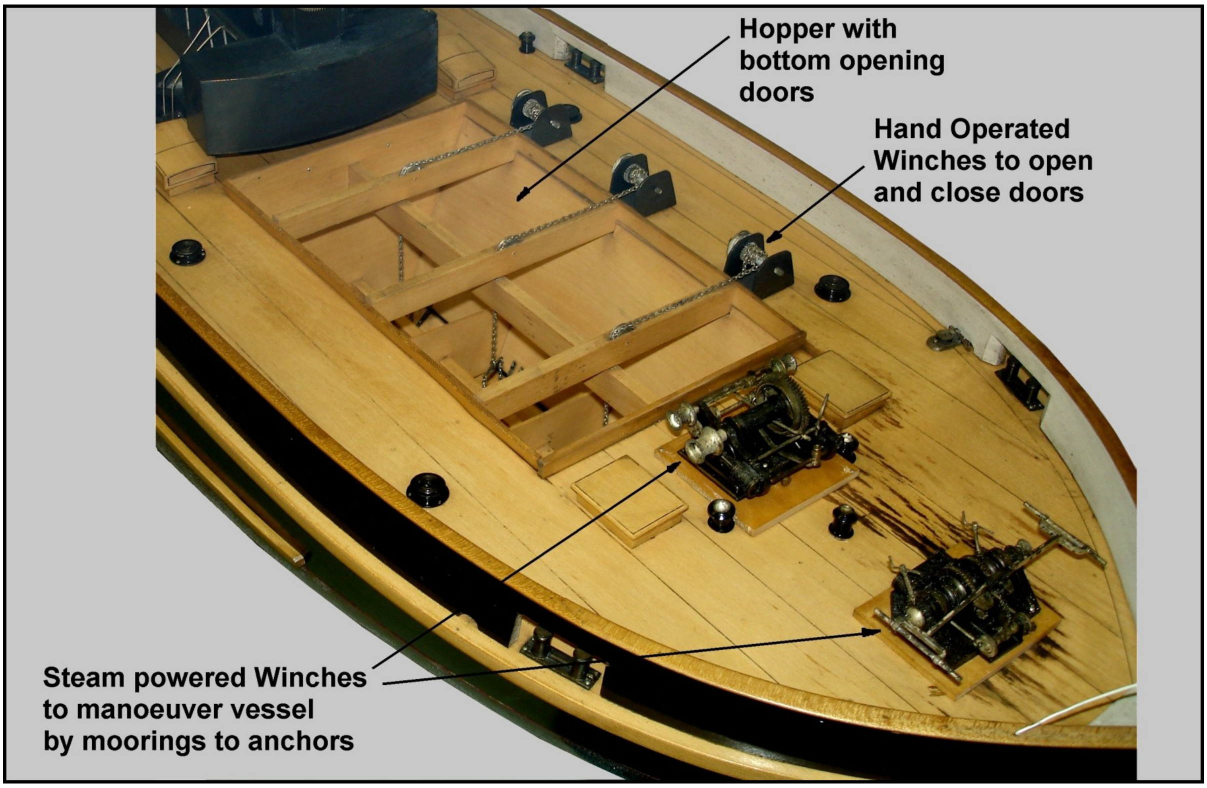

Figure 3. View showing the hopper and forward steam powered winches.

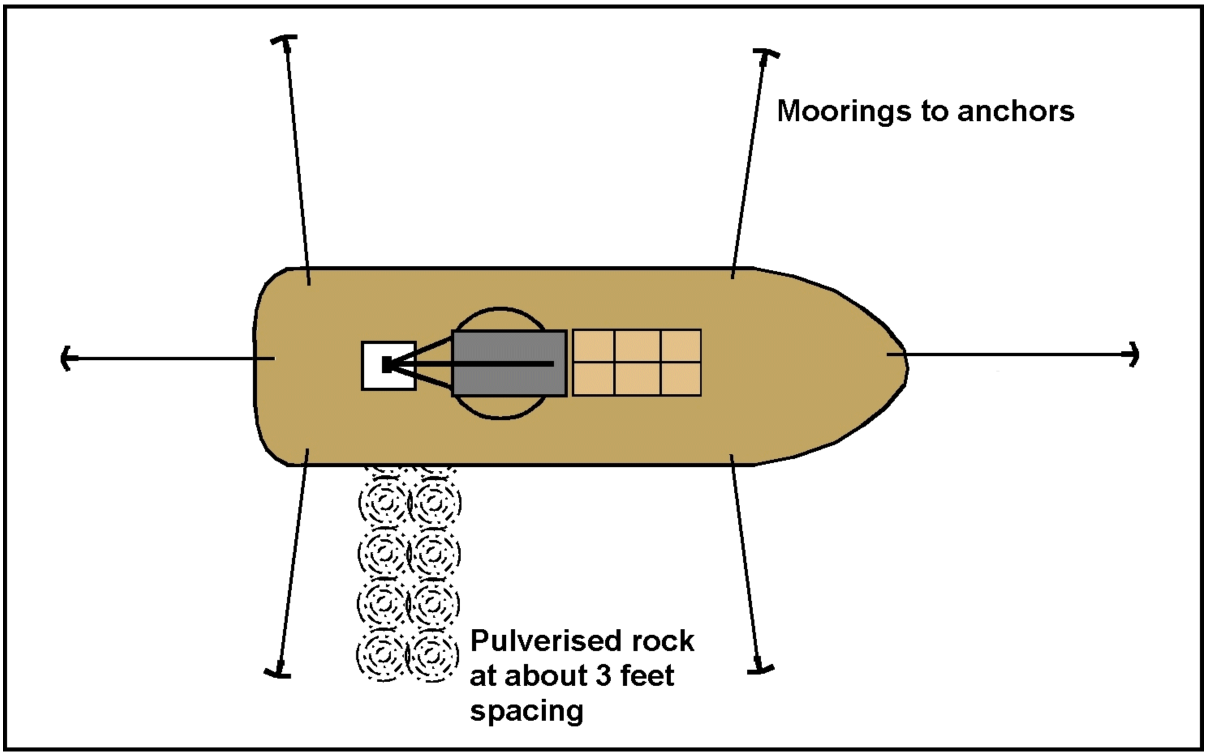

Figure 4. The dredger would be moved over the site by taking in moorings on one side and paying them out on the other side.

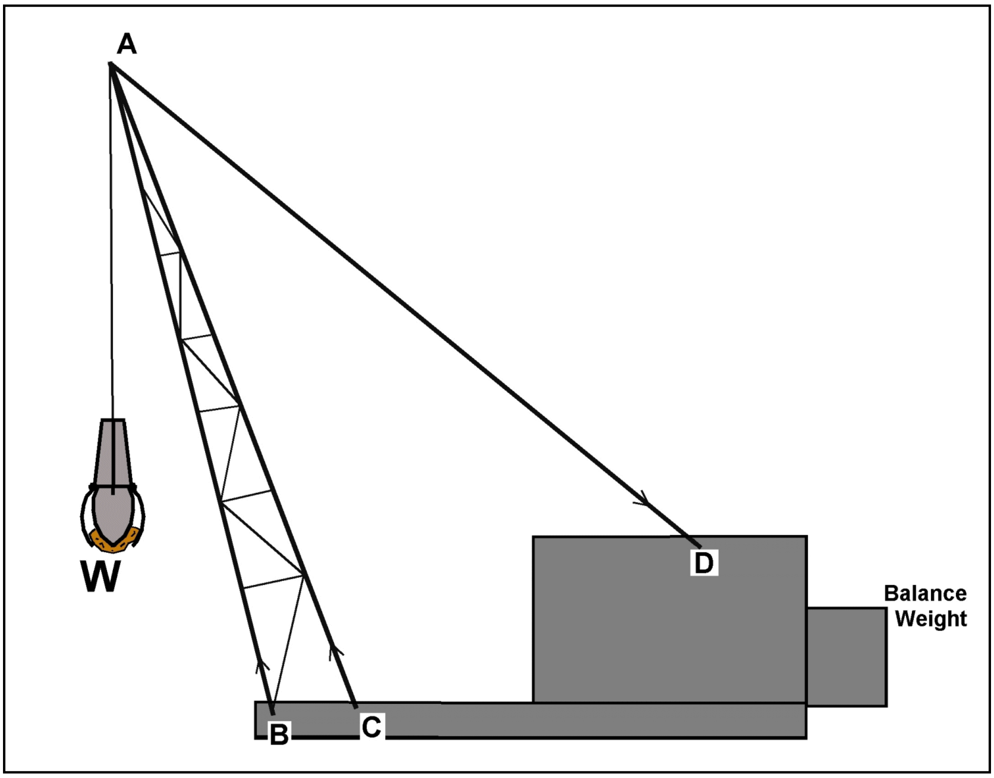

Figure 5. Space frame diagram of the crane.

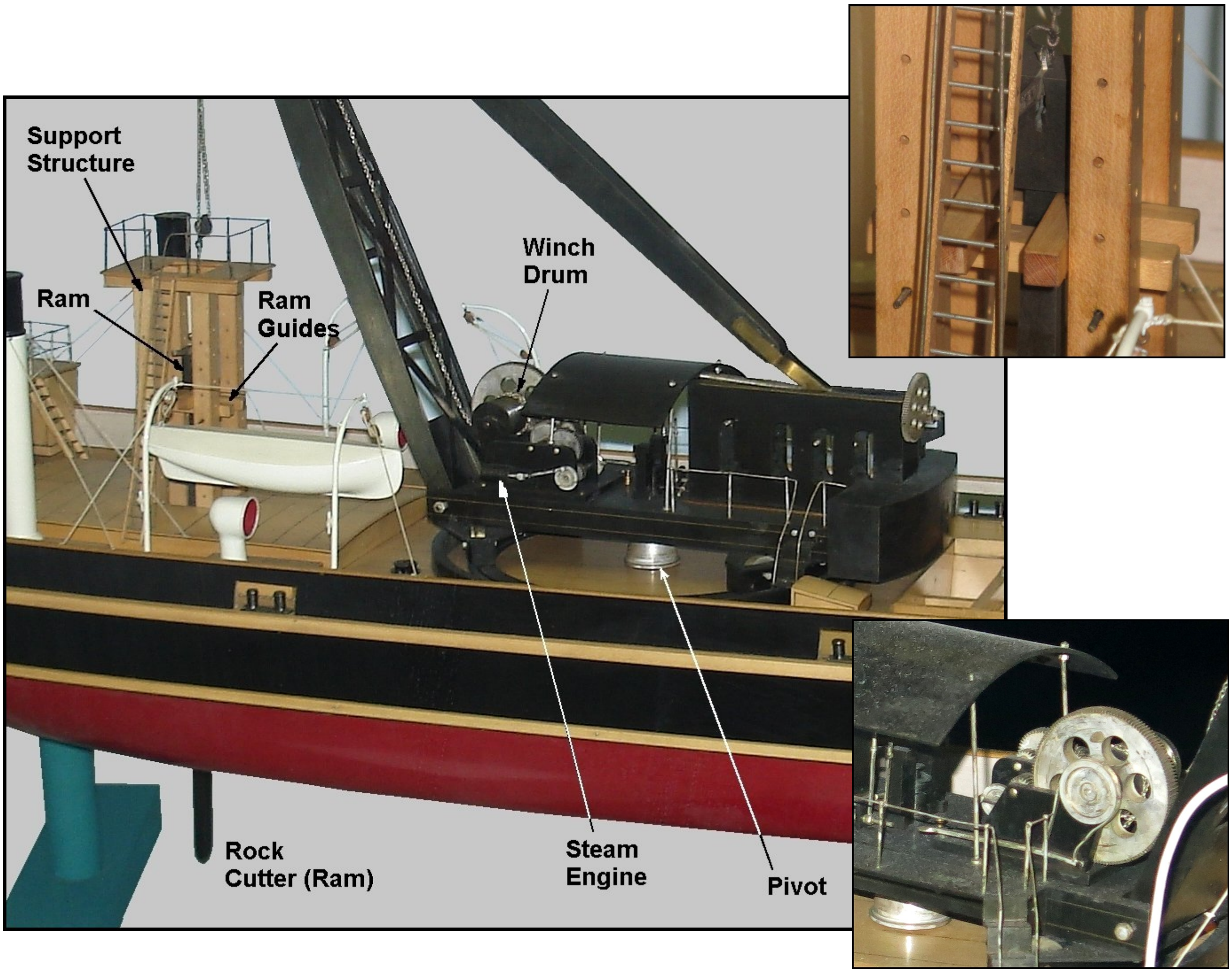

Figure 6. Starboard side showing: (1) rock cutter support structure and detail of the ram hardwood guides, (2) crane steam winch drive with port side details of the friction clutch and foot lever.

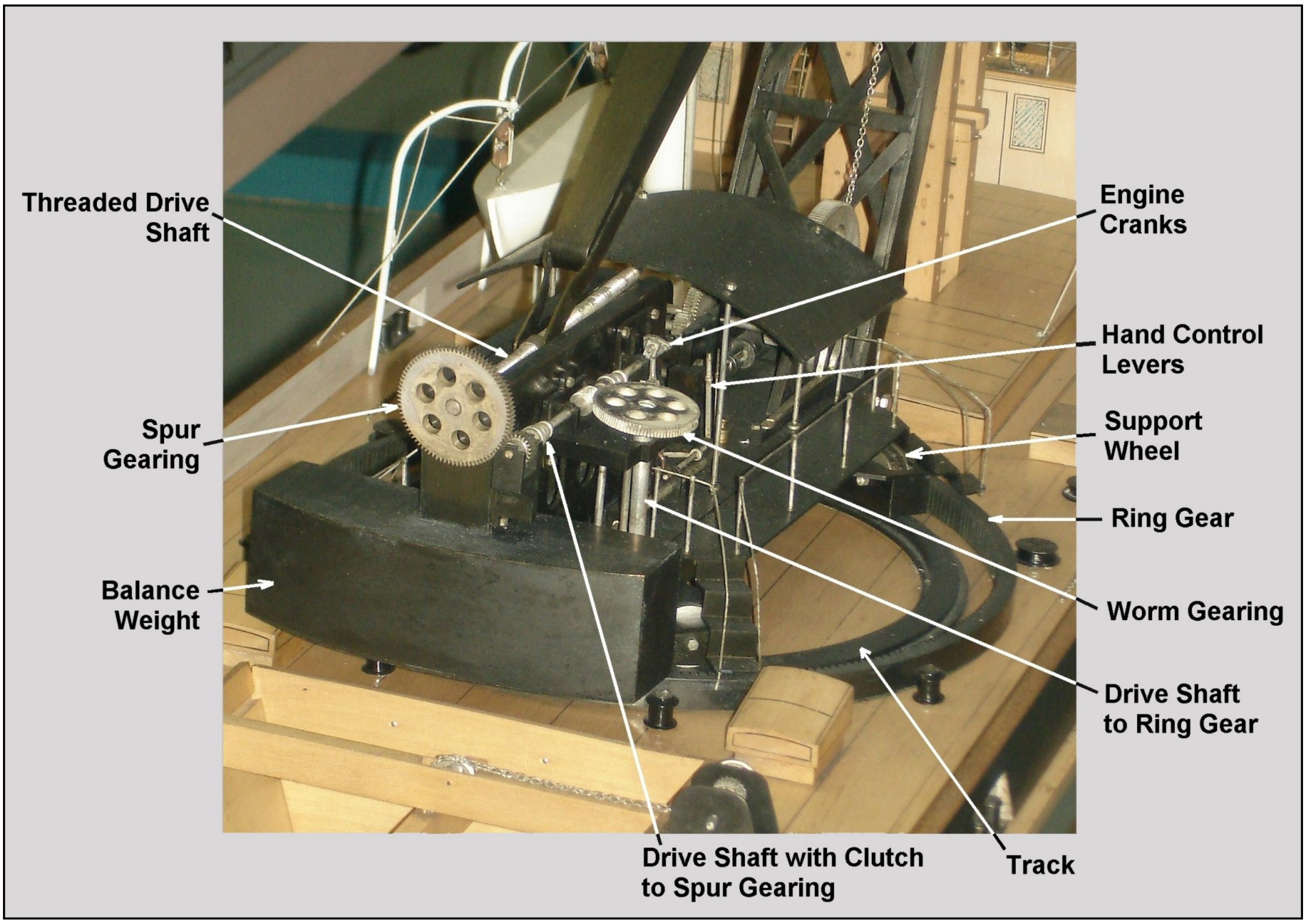

Figure 7. Crane manoevering, reach and slewing, machinery.

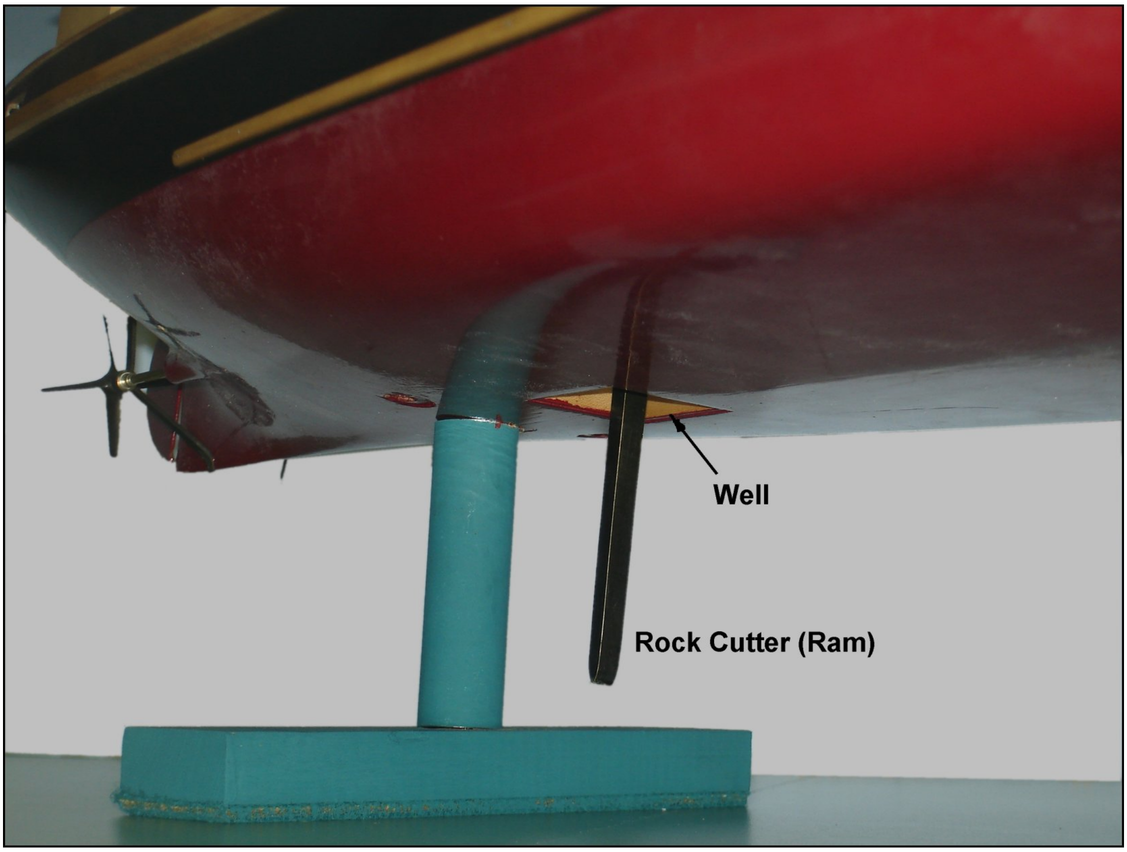

Figure 8. The rock cutter ram passes through a central well in the vessel's hull. Note the ram has a chisel point.

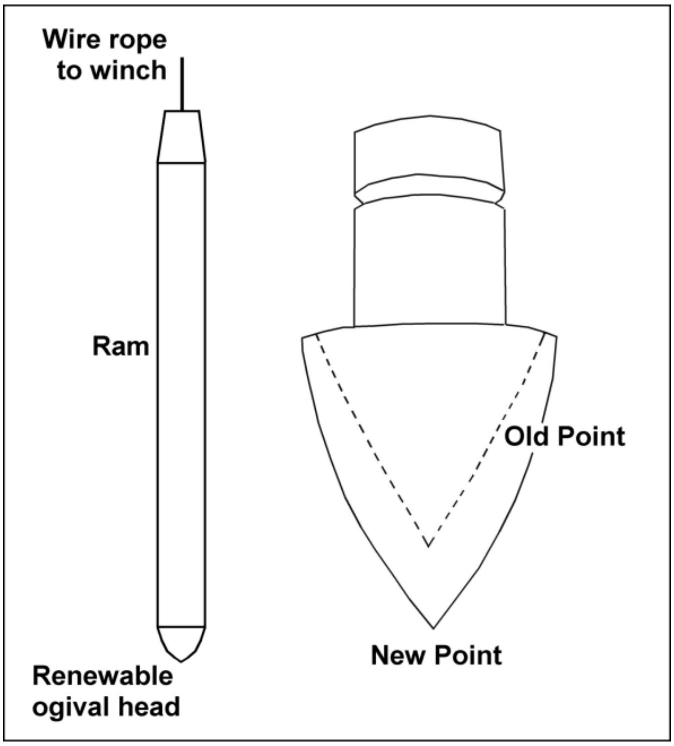

Figure 9. The Lobnitz renewable ogival rock cutter heads, based on Fowler ref. 3. The centre of the pointed head was harder than the outside and so the head was self-sharpening.

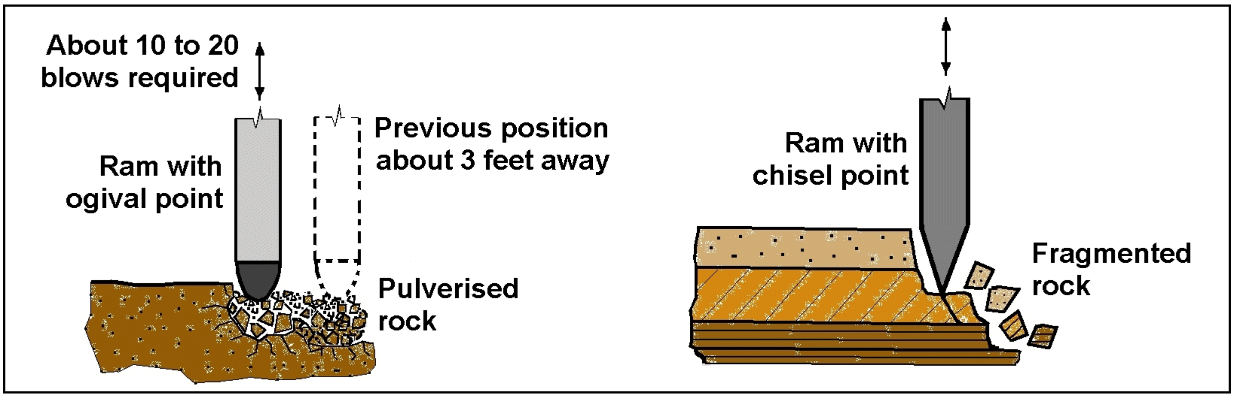

Figure 10. Pulverising or splitting of rock depends on the nature of the rock being excavated.