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(54) **Method and tool for seabed excavation**

(57) For excavation of a clay seabed particularly in a coffer dam to expose a buried pipeline it is proposed to use a minimum of three water nozzles producing water jets the effects of which are indicated by the lines 16, 17 and 18. The nozzles are mounted on a disc 12 which can move horizontally and vertically and which rotates in a horizontal plane.

The effect 18 (if operated alone) would produce a trench 22 having sloping sides. The two effects 16, 17 enable a trench having vertical sides to be cut and enable the disc 12 to be moved downwardly until obstructed by the base of the trench. The three nozzles are equiangularly spaced about the axis. The rotation of the disc 12 makes the effect of the nozzles as though they were as shown in the Figures.

FIG.4.

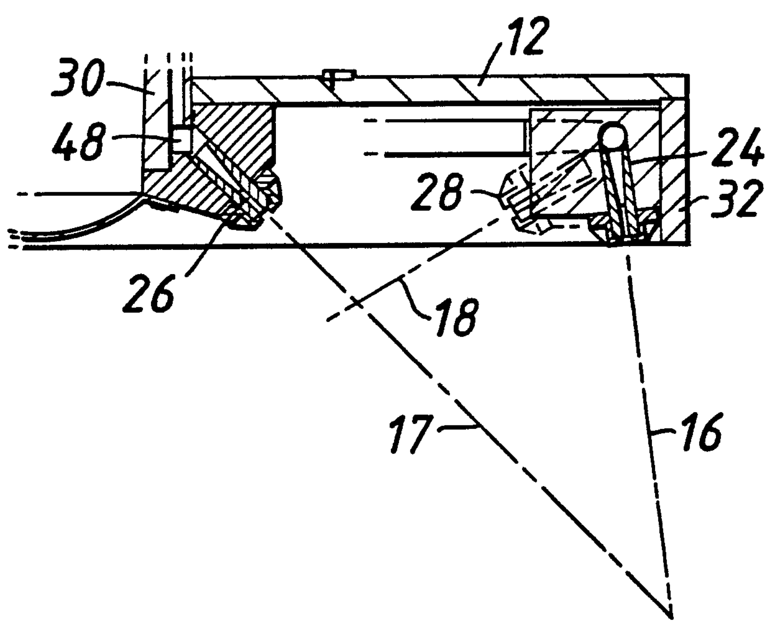

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FIG.1.

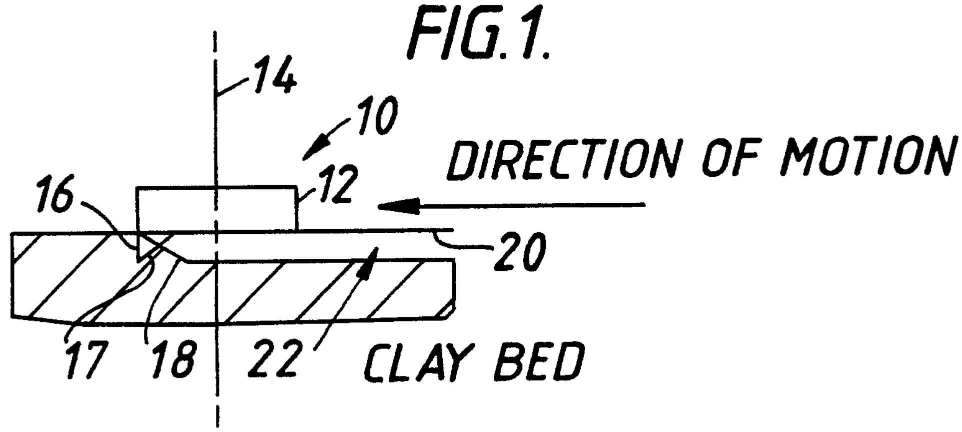

FIG. 2.

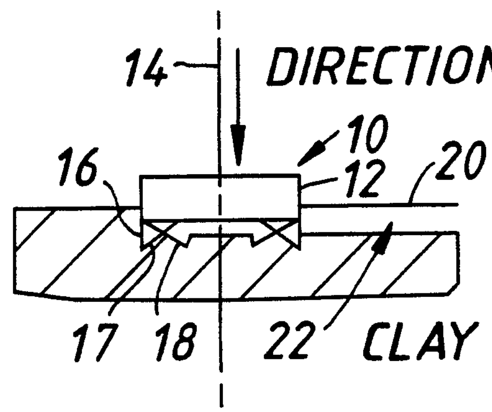

FIG.3.

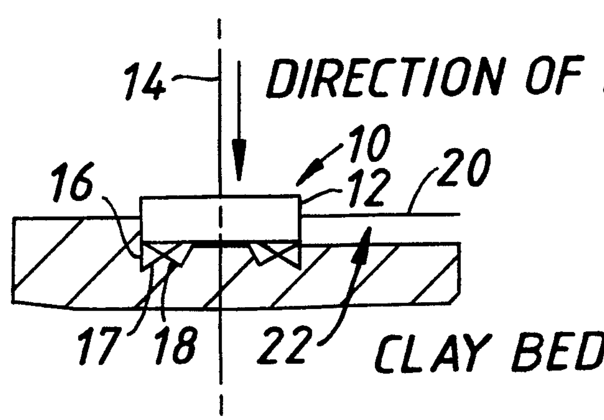

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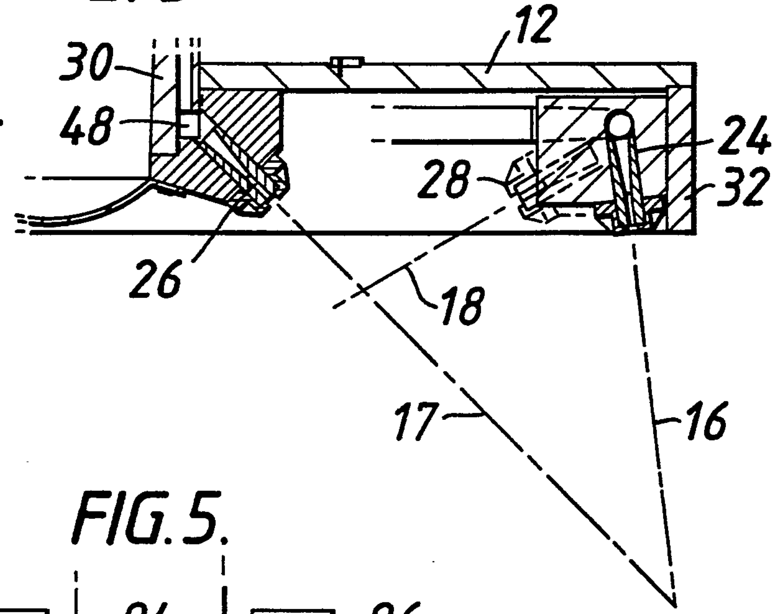
FIG.4.



12
30
48
24
28
32
26
18
17
16

FIG.5.

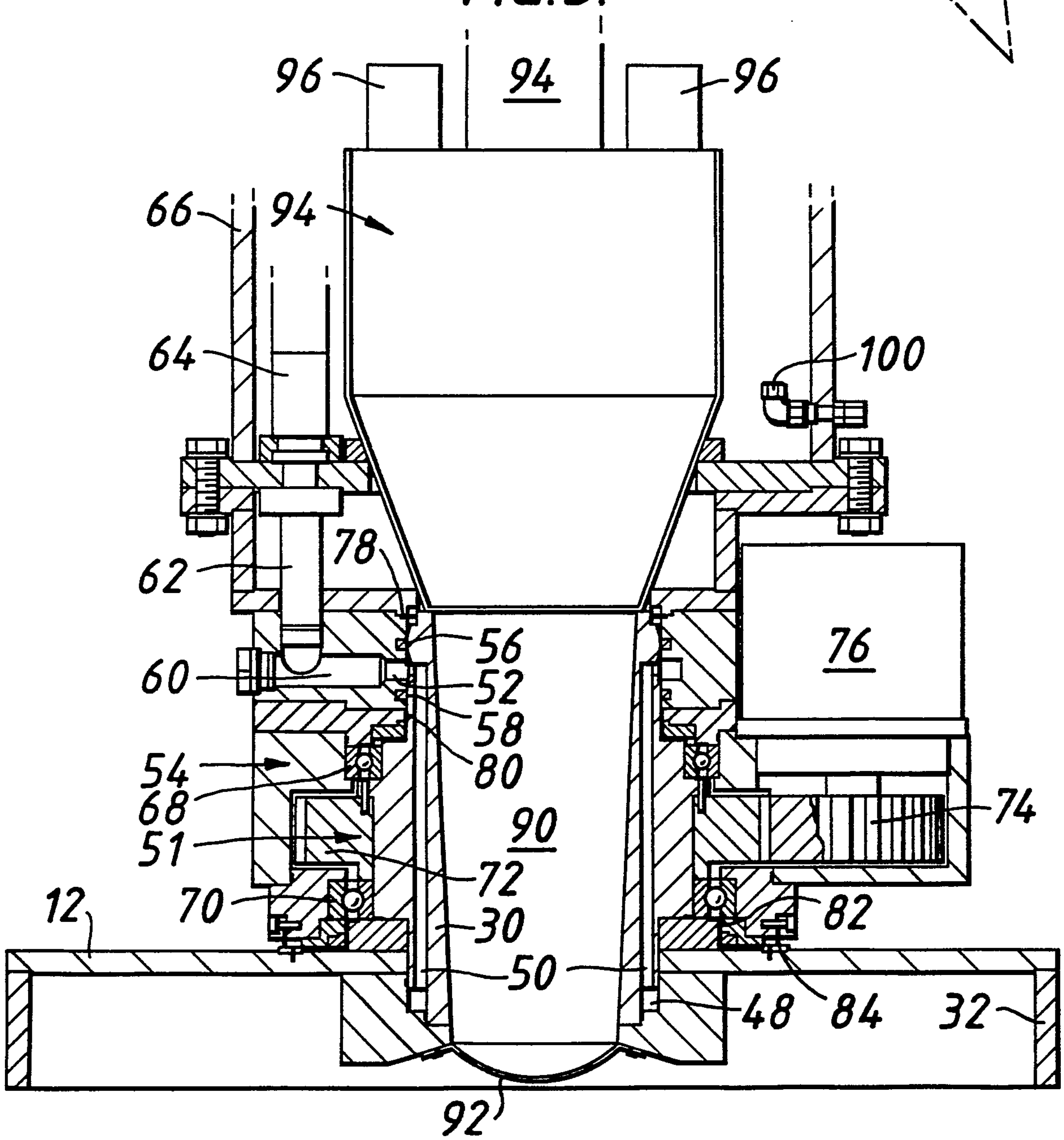


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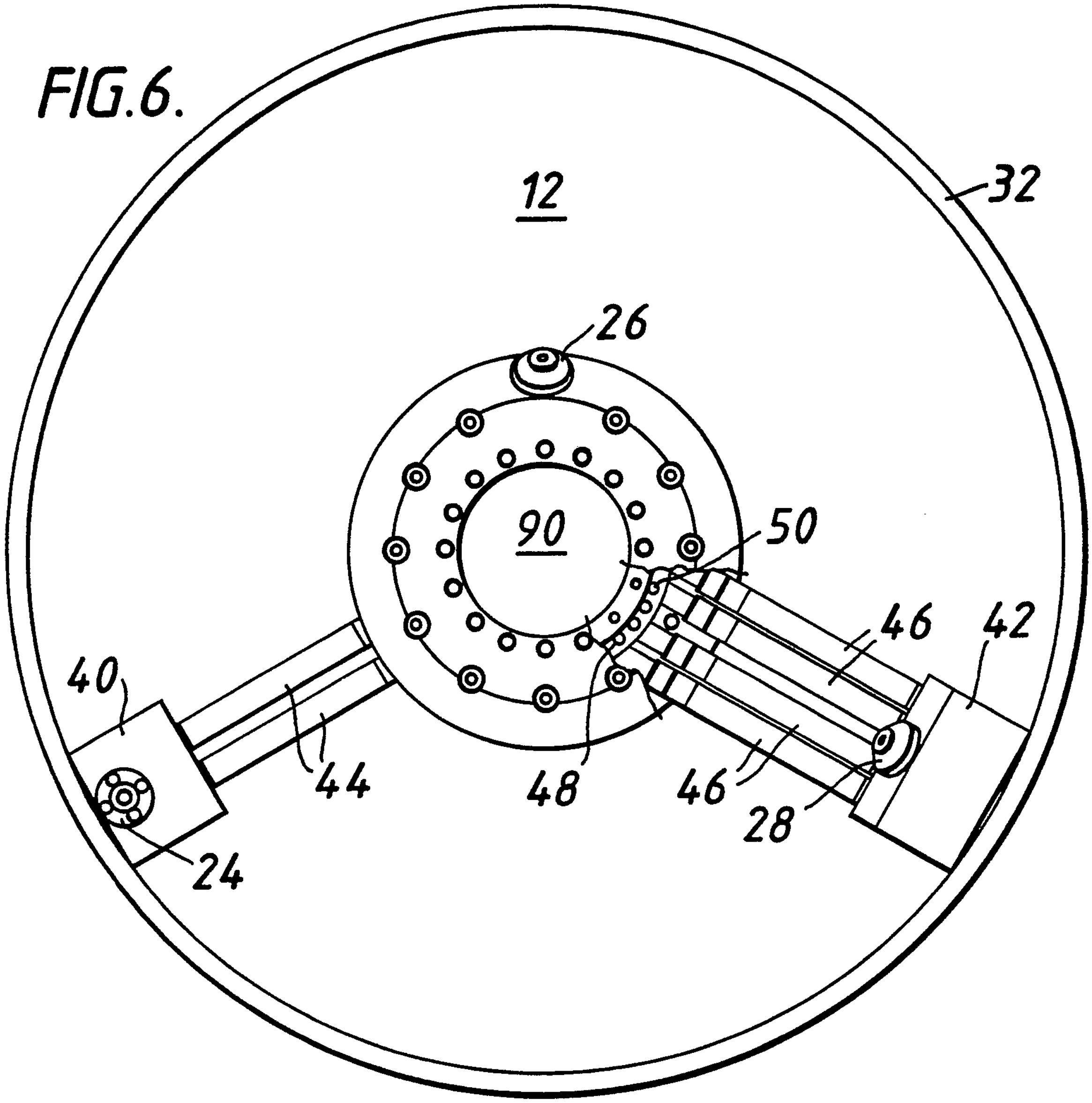
FIG.6.



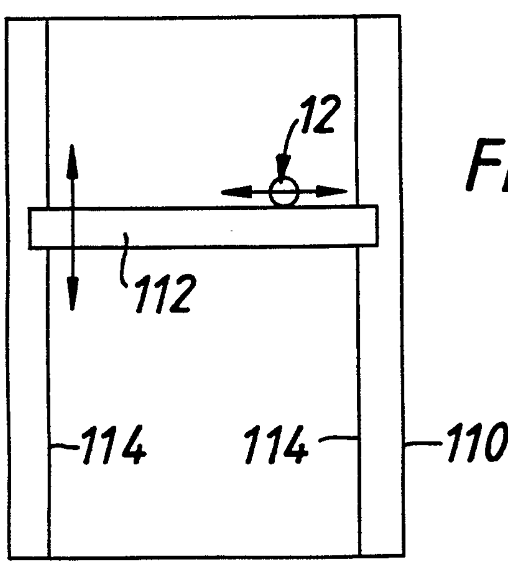


FIG.7.

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METHOD AND TOOL FOR PERFORMING SEABED EXCAVATION

The invention relates to methods of performing seabed excavation and to a tool for performing the method.

The method is particularly suitable, for example, for excavating the seabed beneath a frame to enable isolation valves to be installed or in a coffer dam in order to expose a buried pipeline. In these instances the seabed is more or less horizontal. However, the method has other applications including those in which the seabed in non-horizontal, so that the array of water jet nozzles has to be operated in a plane other than horizontal. For that reason, the term 'depth of cutting' as used herein is not to be limited to a vertical direction.

According to the invention, a method of performing seabed excavation comprises rotating an array of a minimum of three water nozzles about a axis of rotation and moving said axis parallel to itself in at least one direction, the effect of the jet from a first nozzle which lies nearer to said axis intersecting at a first depth of cutting the effect of the jet from a second nozzle, which lies further from the axis, the third nozzle being further from said axis than said first nozzle and the effect of its jet intersecting at a second depth of cutting less than said first depth, the effect of the jet from said first nozzle, and removing debris from the result of action of said jets.

According to the invention, a tool for performing the method comprises a rotatably assembly comprising a generally planar member supported by a hub, the plane of the member being at right angles to the rotational axis of the rotatable assembly and the hub forming an inlet for debris, the tool being movable parallel to the said axis in at least one direction, and an array of a minimum of three water nozzles mounted on said planar member, the effect of the jet from a first nozzle which lies nearer to said axis intersecting the effect of the jet from a second nozzle, which lies further said axis, at a first depth of cutting, the third nozzle being further from said axis than said first nozzle and the effect of its jet intersecting the effect of the jet from the first nozzle at a second depth of cutting less than said first depth, and a jet pump in a conduit for removing debris through said inlet from the result of action of said jets.

An example of the method and an example of a tool for use in performing the method will now be described with reference to the accompanying drawings in which:-

Figures 1 to 3 show modes of cutting the seabed using the tool in the course of excavating the seabed using the method,

Figure 4 is a scrap vertical section through an array of nozzles and part of a disc supported on a hub on which the array is mounted,

Figure 5 is a vertical diametric section through the tool showing the disc and hub shown in Figure 4 but not showing the array of nozzles, and

Figure 6 is a view, looking upwards, of the tool shown in Figure 5.

Figures 1-3 show modes of operation of the tool 10 shown in Figures 4-6. The tool 10 consists of an array of three nozzles mounted on a circular disc 12. The disc 12 is rotatable about an axis 14 normal to the disc 12. The tool 10 is movable from right to left as shown in the Figures (and back from left to right). The tool 10 is also movable in both directions transversely to the plane of the Figures and can also move up and down in the plane of the Figures as shown.

Each nozzle emits a jet of high pressure (eg 3000 pounds per square inch) water and the effects of these jets are shown by three lines 16, 17, 18 in the figures. The tool 10 is designed to cut and excavate a seabed consisting of clay, for example the boulder clay encountered in the Morecambe Bay zone of the North Sea. Such excavation is required to enable buried pipelines to be exposed, for example, within a coffer dam.

Figure 1 shows the mode of operation when the tool 10 advances at a constant height above the seabed 20. A shallow trench 22 is cut out. The sides of the trench are vertical owing to the effect 16, together with the effect 17, which enables the segment of clay to be detached. The nozzle producing the effect 16 is angled very slightly to point outside the periphery of the disc 12 as described below.

If the array consisted of only the nozzle producing the effect 18, the sides of the trench would be sloping, at the angle of the effect 18. The forward motion of the disc 12 would repeatedly strip off sections of clay at that angle thus producing the trench 22.

By adding the two nozzles producing the effects 16 and 17 the disc 12 has the ability to cut downwardly until it is obstructed by the base of the trench 22 as shown in Figure 3. Figure 2 shows an intermediate stage.

The disc 12 can thus cut clay right up to a vertical boundary in any plane. Further progress in cutting, now at the new depth of cutting shown in Figure 3, can be made by advancing the disc 12 from left to right back along the route of the trench 22, if desired. Of course, the whole of an area (for example the rectangular area within a coffer dam) can be cut at the depth of cutting shown in Figure 1 before any sinking of the disc 12 is attempted. Then, a new first trench is cut from the position shown in Figure 3 and, using cuts at the same depth, the whole area is again cut. Thus, progressively, the whole area may be excavated to any depth.

Figure 4 shows the three nozzles 24, 26, 28 producing the effects 16, 17, 18 just referred to. The nozzles 24, 26 28 form an array mounted on the disc 12 supported by a hub 30, part of which is shown in Figure 4 but which is ;better shown in Figure 5. The disc 12 has a downwardly extending peripheral circular flange 32. the angle of inclination of the nozzle 24 produces an effect 16 which intersects with the effect 17 from the nozzle 26 at a point close to or on the notional cylinder, the continuation downwardly of the flange 32. This means the effect 16 excavates a vertical wall which just clear the flange 32.

Figures 1 to 4 shown the lines 16-18 or the three nozzles 24, 26 and 28 in an idealised manner, all lying in the same vertical plane. In fact, the three nozzles are distributed about the centre of the disc 12 ad 120 degree spacing, as shown in Figure 6. Each nozzle 24, 28 is mounted in its own manifold 40, 42, respectively, and is fed by tubes 44, 46, respectively, from a water distribution annulus 48 (Figure 5). The nozzle 26 is mounted on the hub 30 and communicates directly with the water distribution annulus

48 (Figure 4). The effect of rotation of the disc 12 makes the effects of the nozzles as explained with respect to Figures 1 to 4.

The water distribution annulus 48 is fed by a plurality of drillings 50 which extend longitudinally within the wall of the hub 30, which with the disc 12 forms the rotatable assembly 51 of the tool. The drillings 50 are fed from a water feed annulus 52 machined in the non-rotatable assembly 54. High pressure water seals 56, 58 are positioned in the non-rotatably assembly 54 on each side of the water feed annulus 52. The water reaches the feed annulus 52 through three cross-drillings 60 in the non-rotatable assembly 54, three water transfer tubes 62 and three hoses 64 extending downwardly within a tubular mast 66. The water fed to the nozzles 24, 26, 28 is supplied from a point remote from the vicinity of cutting effected by the nozzles 24, 26, 28.

The hub 30 is rotatably mounted in two sets of ball bearings 68, 70 and carried a gear 72 which meshes with another gear 74 driven by a hydraulic motor 76.

A brush seal 78 engages the upper end of the hub 30. A lip seal 80 engages the hub 30 beneath the high pressure seals 56, 58. A lip seal 82 and a brush seal 84 are also provided.

Debris is removed from the seabed, resulting from the effcts of the jets 16, 17, 18 upwards through the inlet 90 formed by the bore of the hub 30. The entrance to the inlet has a coarse mesh grid 92 placed over it. Upflow through the inlet 90 is produced by a jet pump located at 94 and the debris is ejected through a conduit 94 leading to a remote point of disposal. Water flow hoses for the jet pump are connected at 96.

A supply of hydraulic fluid (and a return path not shown) for the hydraulic motor 76 is fed by a hose through the centre of the mast 66 to the bulkhead connector 100. From there another hose connects with the motor 76.

In this example, the tool is part of an arrangement for excavating the seabed within a coffer dam 110 (Figure 7). The apparatus shown in Figure 5 includes the lower end of a mast 66 which is mounted on a gantry 112 movable along the coffer dam 110 on a pair of rails 114. The mast 66 is mounted so as to be traversable along the gantry 112 and also so as to be movable towards and away from the seabed.

Although in this example the seabed is considered to be horizontal, in other applications the array of nozzles 24, 26 and 28 may be operated in a plane which is other than horizontal, for example where a sloping seabed is being excavated or where a vertical wall is to be excavated. The depth of cutting is not limited to a vertical direction, for that reason.

Further nozzles can be used in modifications. For example, further nozzles on the same pitch circle as the nozzle 28 can be used. This will have the effect of deepening the trench 22 but reducing the rate of advance. Further nozzles corresponding to the nozzles 24 and 26 can be used but in all cases more water power must be provided or else, or in addition, some control of the period during which the nozzles are 'on' will be needed.

The mast 66 described above may, in a modification, be mounted on a frame instead of being mounted in a coffer dam. Such an arrangement is suitable for digging foundations for sub-sea isolation valves. The mast would be movable along the frame and also movable across the frame as well as being movable vertically. In another modification the tool may be mounted on a tracked sub-sea vehicle. For example, the vehicle may have a plunge arm on which the tool is mounted.

In all such modifications and in the example desribed above with reference to the drawings the tool can be remotely operable from a surface vessel or platform.

CLAIMS

1. A method of performing seabed excavation comprising rotating an array of a minimum of three water nozzles about an axis of rotation and moving said axis parallel to itself in at least one direction, the effect of the jet from a first nozzle which lies nearer to said axis intersecting at a first depth of cutting, the effect of the jet from a second nozzle, which lies further from the axis, the third nozzle being further from said axis than said first nozzle and the effect of its jet intersecting, at a second depth of cutting less than said first depth, the effect of the jet from said first nozzle, and removing debris from the result of action of said jets.

2. A method according to claim 1, the debris being removed by being drawn through an inlet at the centre of said array.

3. A method according to claim 1 or claim 2 performed in a coffer dam the array being mounted for movement along and across said dam and also up and down.

4. A seabed excavation tool for performing the method according to claim 1, comprising a non-rotatable assembly and a rotatable assembly, the rotatable assembly comprising a generally planar member supported by a hub, the plane of the member being at right angles to the rotational axis of the rotatable assembly and the hub forming an inlet for

debris, the tool being movable parallel to the said axis in at least one direction, and an array of a minimum of three water nozzles mounted on said planar member, the effect of the jet from a first nozzle which lies nearer to said axis intersecting the effect of the jet from a second nozzle, which lies further from said axis, at a first depth of cutting, the third nozzle being further from said axis than said first nozzle and the effect of its jet intersecting the effect of the jet from the first nozzle at a second depth of cutting less than said first depth, and a jet pump in a conduit for removing debris through said inlet from the result of action of said jets.

5. A tool according to claim 4, said nozzles being connected by tubes to a water distribution annulus in said hub, s aid annulus being fed by a plurality of drillings extending longitudinally through said hub and communicating with a water feed annulus formed in the non-rotatable assembly, high pressure water seals being located at each side of said water feed annulus.

6. A tool according to claim 4 or 5, said nozzles being spaced at 120 degrees around said array.

7. A tool according to claim 4, 5 or 6, said array being mounted on a disc mounted on said hub.

8. A tool according to claim 4, 5, 6, or 7, said hub being rotatably mounted in bearings in said non-rotatable assembly and having a gear around its circumference drivingly connected to a second gear, being the output gear of a motor mounted on the non-rotatable assembly.

9. A method according to claim 1 substantially as hereinbefore described with reference to Figures 1 to 3 of the accompanying drawings.

10. A tool according to claim 4 substantially as hereinbefore described with reference to Figures 1 to 3 of the accompanying drawings.

11. A tool according to claim 4 substantially as hereinbefore described with reference to Figures 5 and 6 of the accompanying drawings.

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