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(54) Tunnelling machine.

(57) A tunnelling machine, especially suitable for tunnelling through soft material, comprises a support (20), an arm (46) pivotally mounted on the support about a generally horizontal axis, and a rotary cutter (50) mounted on the arm for cutting a slot in a tunnel end face. The arm (46) is linearly extensible and retractable while the slot is being cut so that, for example, tunnels of non-circular cross-section can be cut if desired. The machine will normally include drive means (65,66) for moving the arm about the horizontal axis and for extending and retracting it, sensors (70,71) for sensing the pivotal position and length of the arm, and a controller that controls the drive means in response to the sensors so that the cutter (50) can be moved through a predetermined arcuate profile. The machine may include a concrete supply arrangement for supplying concrete into the slot behind the cutter.

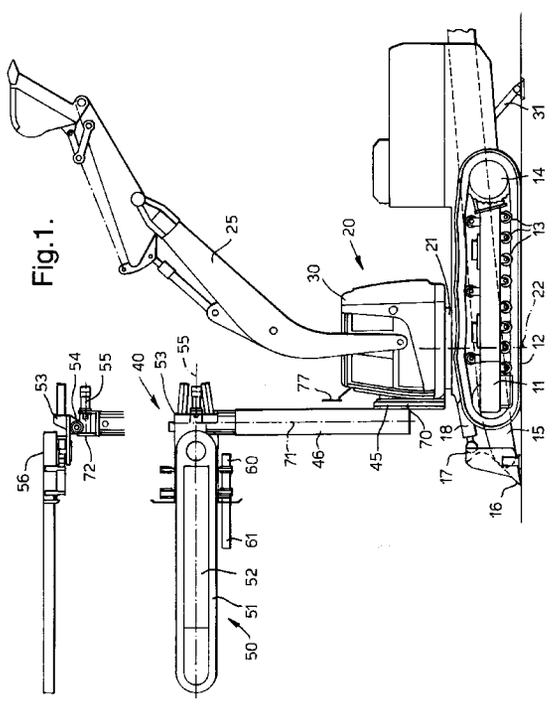

Fig.1.

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The invention relates to a tunnelling machine.

Tunnelling through soft material e.g. soft rock is best achieved by minimising the amount of ground movement towards the tunnel inwards into the tunnel, whether at the excavation face or the periphery. It has been proposed to achieve this by the process of cutting an arcuate slot into the outer perimeter of the tunnel end face and filling the slot with quick-setting concrete, prior to excavating material bounded by the slot and the resulting concrete support.

One form of tunnelling machine for cutting such a slot comprises an arcuate frame having a guide for a cutter and an arcuate rack by which the cutter is driven to cut the slot. However, this type of machine has a problem that it is capable of cutting only a single tunnel profile. It is unusual for any two tunnels to have the same profile, so the machine is usable only for cutting a single tunnel, after which the machine has to be scrapped. In addition, the guide can interfere with the efficiency of the tunnelling process and can restrict the opportunity for maximum tunnel excavation rate.

Another form of tunnelling machine intended principally for hard or stratified rock is described in European Patent Application No. 557,805 and comprises a rotary cutter that includes drive wheels that bear against the cut surface for progressing the cutting of an arcuate slot. Stresses caused by deviation from the cutting trajectory are measured and used to control guide elements in the cutter. While it is possible for such a machine to cut tunnels of different radii, it is limited to cutting tunnels of generally circular cross-section.

According to one aspect the present invention provides a tunnelling machine especially for tunnelling through soft material, comprising a support, an arm pivotally mounted on the support about a generally horizontal axis, and a rotary cutter mounted on the arm for cutting a slot in a tunnel end face, the arm being linearly extensible and retractable while the slot in the tunnel end face is being cut.

The machine according to the invention has the advantage that, since the length of the arm can be varied during the cutting operation, it is possible for the machine to be used to cut a number of profiles, including non-circular profiles. Preferably, the tunnelling machine comprises a support, an arm pivotally mounted on the support about a generally horizontal axis, a rotary cutter mounted on the arm for cutting a slot in a tunnel end face, the arm being linearly extensible, drive means for moving the arm about said axis and for extending and retracting the arm, sensing means for sensing the pivotal position of the arm and the length of the arm and control means connected with the sensing means and the drive means and responsive to the sensing means to control the drive means to effect movement of the cutter in a predetermined arcuate profile.

The cutter is preferably a planar cutter and is tiltably mounted on the arm about an axis on the plane of the cutter. In this case the drive means preferably includes means for effecting tilting of the cutter and the sensing means includes means for sensing the tilting position of the cutter. The machine preferably includes means for supplying concrete, the means having an output nozzle adjacent to the cutter and movable with the arm in order to provide a continuous supply of concrete behind the cutter. In addition, the cutter/concrete supply means should include a mechanism for preventing concrete flowing toward the cutter and/or for preventing concrete flowing out of the slot formed by the cutter. This may be achieved, for example, by interposing a guard, preferably a flexible spring guard, between the concrete supply nozzle and the cutter, the guard having dimensions corresponding to the depth and width of the cut slot. In the case of a flexible spring guard, the guard may itself adjust to the dimensions of the slot. A further guard may be provided perpendicular to the cutter to lie over the end wall of the tunnel in the region of the cut slot and mask the slot.

The machine preferably includes equipment for excavating the tunnel endface such as a backacter road header or other mechanism so that a slot can be cut and material within the shell formed by he slot can be excavated without change of machine. This may be achieved by simple rotation fromslot cutting mode to excavation mode.

It is possible for the machine according to the invention, at least in its preferred embodiment, to be relatively manoeuverable so that it can easily be driven into and out of the tunnel and can, for example, be turned at an angle to the tnnel and used to drive an adit from the side of the tunnel. In addition, it can be used to form a tunnel with an enlarging or reducing cross-section.

Reference is now made to the accompanying drawings, wherein:-

Figure 1 is a side elevation of a tunnelling machine according to the invention, shown in a slot-cutting position;

Figure 2 is a similar view, shown in an excavating position; and

Figure 3 is a block diagram of a control system.

The tunnelling machine illustrated comprises a base 11 having ground-engageable tracks 12 running around support wheels 13 and a drive sprocket 14, whereby the machine is movable. A conveyer 15 is carried by the base and a scoop 16 is pivotally mounted at 17 at the forward end of the conveyor. A ram 18 is operable to move the scoop pivotally to deposit debris on the conveyor.

A support 20 is mounted on the base 11 by a slewing device 21, for slewing movement about a vertical axis 22. The support carries an excavating device 25, which can be positioned by the slewing device for-

ward of the machine as shown in Figure 2. The excavating device 25 may be operated to draw debris to the scoop 16 for deposit on the conveyer 15 and removal from the excavating site. Although as shown the excavating device 25 comprises a single arm, it may be preferred in many cases for it to be formed from two arms joined by a knuckle in order to enable the device to excavate material by movement in a horizontal as well as a vertical plane.

The support 20 also carries a cab 30 (or cabs in the illustrated embodiment) and a slot-cutting mechanism 40, located on the opposite side of the support 20 to the excavating device 25. In Figure 2, the slot-cutting mechanism 40 is shown in a stowed position, located over the base 11.

The slewing device 21 is operable to slew the slot-cutting mechanism 40 to the operative position, forward of the machine, as shown in Figure 1. The slewing device can be locked to position the slot-cutting mechanism in a fixed position relative to the base 11. The base can be held in a stationary position by means of stabilisers 31.

A pivot device 45 is mounted on the support 20 and carries a radial arm 46. Drive means (not shown) is provided to rotate the arm, by means of the pivot device 45, about a generally horizontal axis. The arm is telescopic and, thereby, linearly extensible and retractable. Drive means (not shown) is provided for extending and retracting the arm.

The free end of the arm 46 carries a cutter 50. The cutter is planar and elongate and comprises a continuous cutting device 51 driven around a blade 52. The cutter is mounted by means of a hub 53 on the free end of the arm 46. The cutter is pivotally mounted on the hub 53 about a transverse axis 54, permitting the cutter to be movable from a stowed position, generally parallel to the arm 46 (as in Figure 2) to an operative position, generally horizontal and generally perpendicular to the arm (as in Figure 1).

The hub 53 is swivellably mounted on the free end of the arm 45 about a swivel axis 55 transverse to the arm, perpendicular to the transverse axis 54 and generally parallel to the plane of the cutter. Drive means (not shown) is provided for swivellably moving the cutter.

The cutter can also be moved pivotally, within its plane, relative to the hub 53, about an axis 56, perpendicular to the plane.

A concrete supply conduit 60 leads to a nozzle 61 or plurality of nozzles located adjacent to the cutter 50 and carried by the hub 53, so that the nozzle 61 is movable with the hub.

In use of the slot-cutting mechanism 40, the arm is angularly driven about the pivot device 45, whilst the cutter is supported in a generally horizontally projecting position, in order to cut an arcuate slot in a tunnel end face. The cutter is swivelled relative to the arm in coordination with the arcuate movement of the arm. The arm 46 will also usually be extended or retracted in coordination with the pivotal movement, in order to cut the desired profile.

Cutting is effected, so that the concrete supply nozzle 61 follows the cutter 50, filling the slot with quick-setting concrete immediately it is cut. A flexible plate parallel to the cutter prevents ingress of concrete on to the cutter. This ensures that, when cutting soft material, a concrete support is immediately formed, reducing movement of the material adjacent the slot. After setting of the concrete, the separated material within the arch defined by the slot is excavated.

The initial cut into a face may be effected with the cutter inclined downwardly from the position shown in Figure 1, about the axis 56. The pitch of the blade can beup to 15° from the horizontal. The cut may be made by driving the machine forward on the tracks 12 and may be made at one bottom end of the intended arcuate cut. After the initial cut, the cutter is extended generally perpendicular to the arm, as in Figure 1, to cut the arcuate slot.

The slot may be cut substantially in two halves, for example by starting from opposite ends of the intended slot perimeter and finishing in the middle of the intended slot or by starting in the middle and cutting in both clockwise and anti-clockwise directions.

Coordination of the various movements to effect cutting of a slot of predetermined profile is effected by a control device 80, which preferably comprises a microprocessor. A diagrammatic representation of a control system is shown in Figure 3. The practical realisation of such a control system is within the scope of a person skilled in the art.

Figure 3 show, in block diagram form, the support 20, pivot device 45, arm 46 and cutter hub 53, along with drive means 65, 66 and 67 for driving the arm rotatably, extending/retracting the arm and swivelling the cutter respectively. Also shown are sensors 70, 71 and 72, which sense the pivotal location of the arm 46, the length of the arm and the swivel location of the cutter hub, respectively.

The location of these sensors is also illustrated in Figure 1.

The control device 80 includes an output 81 connected with the drive means 65, 66, 67 to control their operation to effect a predetermined profile cut. The device includes an input 82 receiving signals from the sensors 70, 71, 72, the device operating the drive means in response to signals from the sensors.

The input to the control device also includes a signal from an inclinometer 75 provided on the support, to indicate deviation from a reference inclination, the device operating to compensate for such deviation.

An inclinometer may also be provided on the cutter 50 for controlling slight inclination from the horizontal or vertical, where this is required.

The input of the control device also includes in-

formation from a target 77 (also shown in Figure 1) mounted on the support 20. The machine is roughly lined up with the intended tunnelling line and a laser beam (90 in Figure 1) is directed along the tunnel as a reference line for the exact tunnelling direction. The support is slewed to a position in which it generally aligns with the laser beam and is then locked in position. The laser beam is intercepted by the target 77, which provides an indication of the deviation of the location of the machine relative to the laser beam. This information is inputted to the control device, via input means 83 so that the device compensates for this deviation.

The predetermined profile to be cut is fed to the control device from a profile input device 91, including an L.E.D. display. Manual override can be effected by means of a manual input device 92 including joystick control.

The machine described permits cutting of any desired profile within the limits of the length of the arm 46, including elliptical profiles. The control system permits such profiles to be cut without exact positioning of the machine.

The arm may be replaceable to permit use in excavating smaller or larger tunnels each replaceable arm being telescopic and being provided with a sensor for indicating the degree of extension of the arm.

Claims

1. A tunnelling machine comprising a support (20), an arm (46) pivotally mounted on the support about a generally horizontal axis, and a rotary cutter (50) mounted on the arm for cutting a slot in a tunnel end face, the arm (46) being linearly extensible and retractable while the slot in the tunnel end face is being cut.

2. A tunnelling machine comprising a support (20), an arm (46) pivotally mounted on the support about a generally horizontal axis, a rotary cutter (50) mounted on the arm for cutting a slot in a tunnel end face, the arm (46) being linearly extensible, drive means (65,66) for moving the arm about said axis and for extending and retracting the arm, sensing means (70,71) for sensing the pivotal position of the arm and the length of the arm and control means (80) connected with the sensing means and the drive means and responsive to the sensing means to control the drive means to effect movement of the cutter in a predetermined arcuate profile.

3. A tunnelling machine according to Claim 2, wherein the cutter (50) is planar and is tiltably mounted on the arm about an axis in said plane, the drive means includes means (67) for effecting tilting of the cutter and the sensing means includes means (72) for sensing the tilting position of the cutter.

4. A tunnelling machine according to Claim 2 or 3, including concrete supply means having an output nozzle (61) adjacent to the cutter and movable with the arm (46) to provide continuous concrete supply behind the cutter.

5. A tunnelling machine according to Claim 2, 3 or 4, wherein the control means includes input means (91) for entry of predetermined profile dimensions for movement of the cutter.

6. A tunnelling machine according to Claim 5, wherein the control means includes a display device, which displays the predetermined profile.

7. A tunnelling machine according to Claim 6, wherein the control means includes manual override means (92) having joystick operation.

8. A tunnelling machine according to any one of Claims 2 to 7, including an inclinometer on the support and providing an output to the control means, which is responsive to the output to compensate for inclination of the machine.

9. A tunnelling machine according to any preceding claim, including a target (77) for indicating the location of the machine relative to a laser beam, and input means (83) for inputting this information to the control means, the control means being responsive to the input to compensate for asymmetric location of the machine relative to the laser beam.

10. A tunnelling machine according to any preceding claim, wherein the support (20) is mounted on a base (11) about a slewing axis and an excavating device (25) is mounted on the support, whereby the excavating device and the cutter can alternatively be located in operative positions adjacent a tunnel end face.

11. A tunnelling machine according to Claim 10, including a conveyor (15) mounted on the base in a location to receive material from the excavating device, with the latter in its operative position.

12. A tunnelling machine according to any preceding Claim, wherein the base has ground-engageable driven tracks (12) for moving the machine.

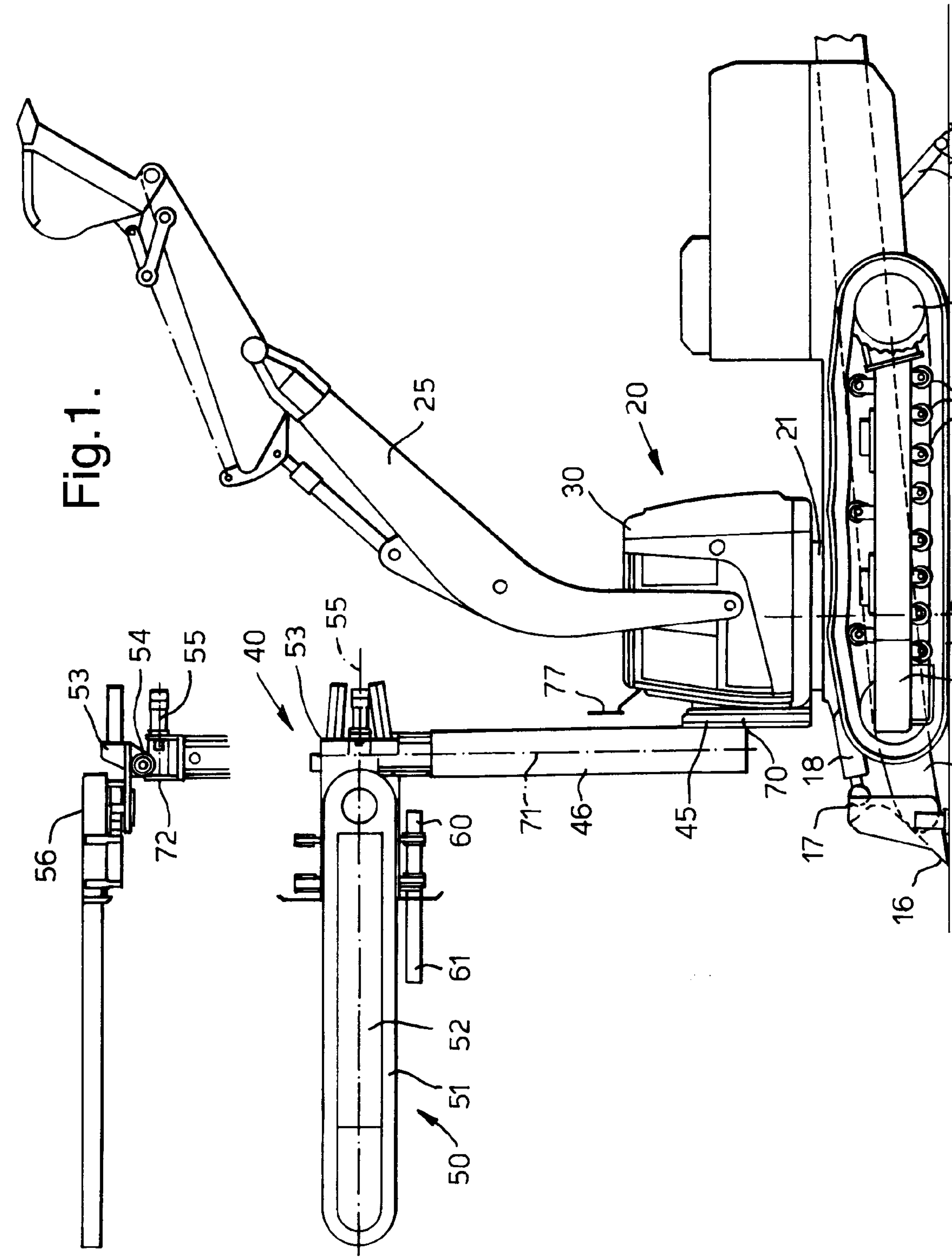
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Fig.1.

Fig.2.

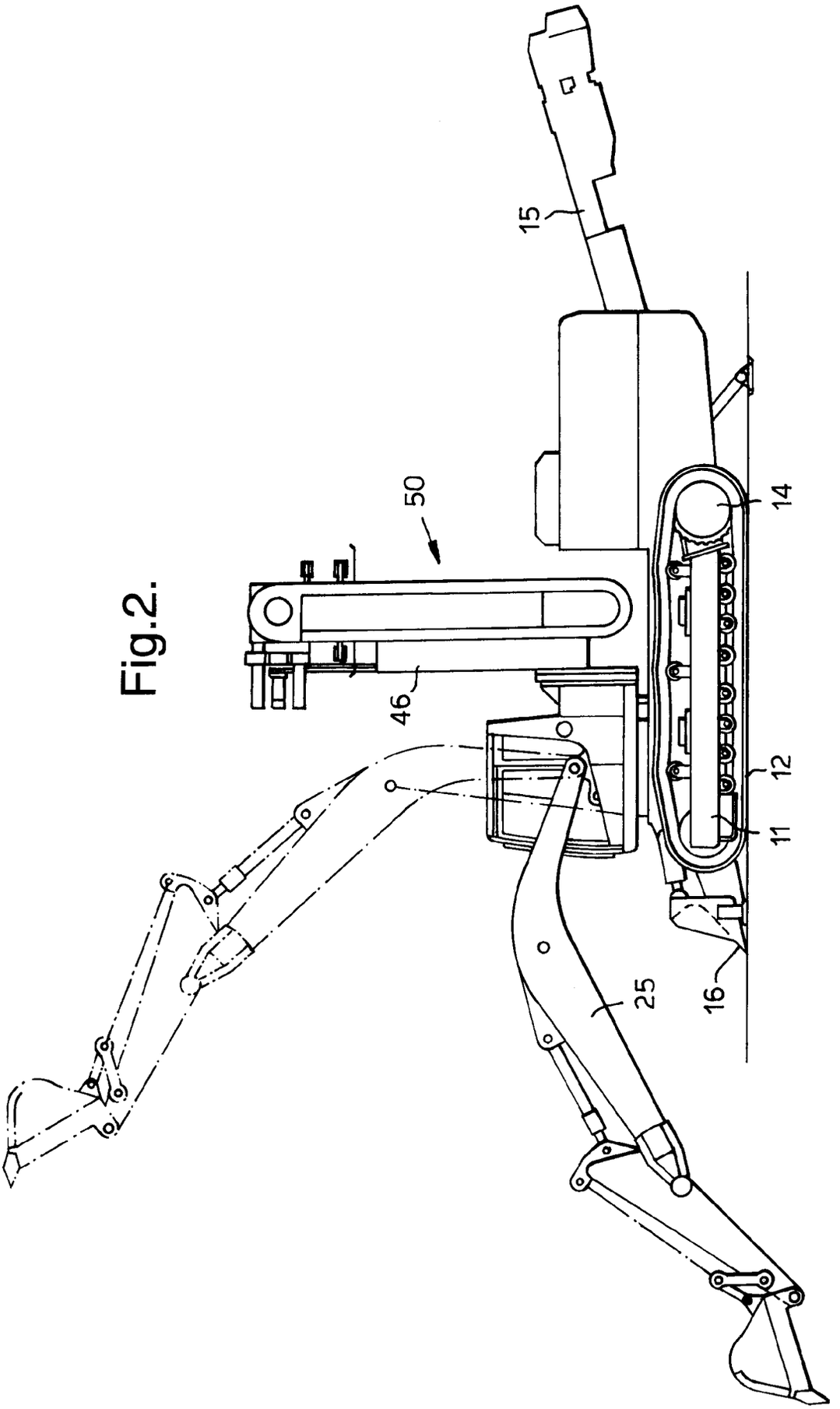
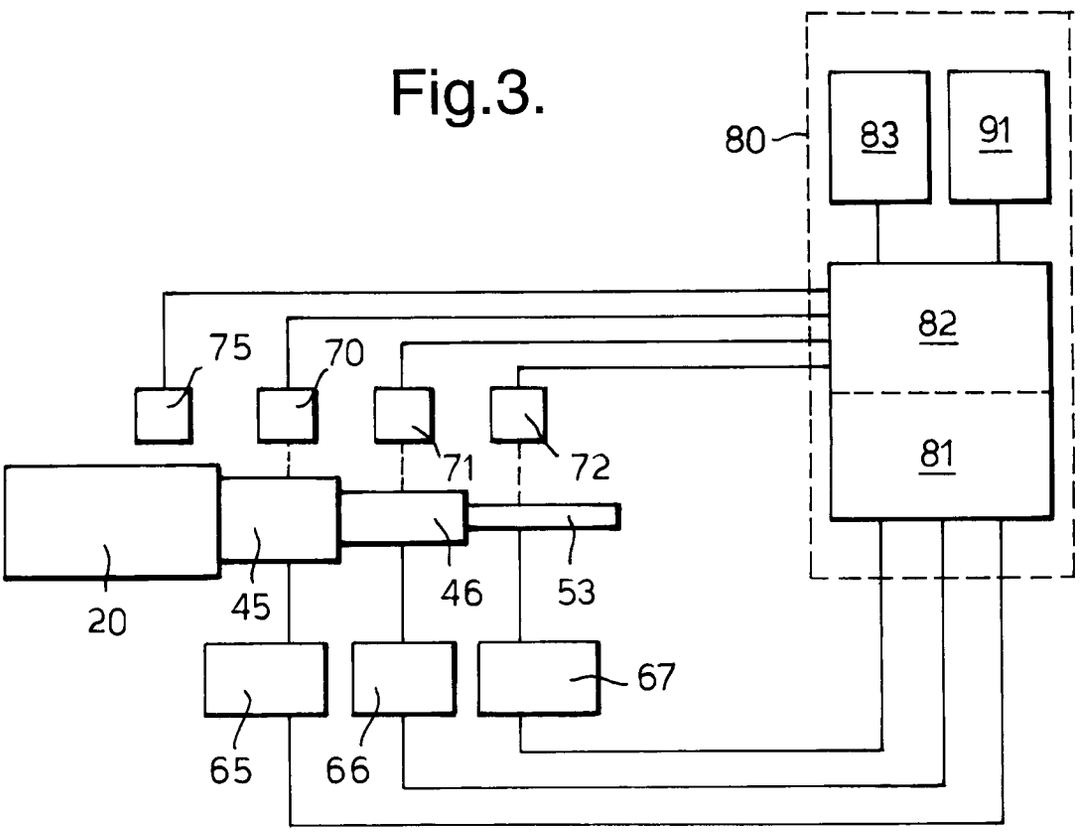


Fig.3.



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EUROPEAN SEARCH REPORT

Application Number
EP 95 30 0801

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X Y	FR-A-2 123 846 (F.. PERRIER,F. LONGELIN) * the whole document *	1,10,12 2-9	E21D9/10 E21D9/04
Y	GB-A-2 124 407 (ZED INSTRUMENTS) * claims; figures *	2,3,5-8	
D,Y	EP-A-0 557 805 (TREVI) * column 5, line 13 - line 30; claim 5; figures *	4	
Y A	FR-A-2 543 612 (H.CIZERON) * claims; figures *	9 2,3,5-8	
X A	EP-A-0 394 806 (TREVI) * the whole document *	1,10-12 2-5	
X	DE-B-10 08 681 (M.KORFMANN GMBH) * column 4, line 15 - line 35; figure 1 *	1	
A	FR-A-2 559 541 (EISENHUETTE WESTFALIA) * claims *	5-9	
A	DE-A-36 24 962 (GESTEINS UND TIEFBAU)		TECHNICAL FIELDS SEARCHED (Int.Cl.6) E21D E21C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 May 1995	Fonseca Fernandez, H

CATEGORY OF CITED DOCUMENTS

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