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(54) **Method to dig out stone blocks and apparatus to carry out said method.**

(57) Method and apparatus for extracting blocks of stone material by means of tubular expansion devices operated at high fluid pressures. The devices are introduced at ambient pressure into cylindrical bores formed in the material to be excavated, in the region of the desired parting planes of the block from the rock. The pressure is then increased up to 100-500 bar so as to obtain parting of the block.

Each expansion device consists of a tube of plastic material with a high modulus of elasticity provided at its opposite ends with metal sealing members which are axially bored and connected to one another by a metal rod housed inside the tube.

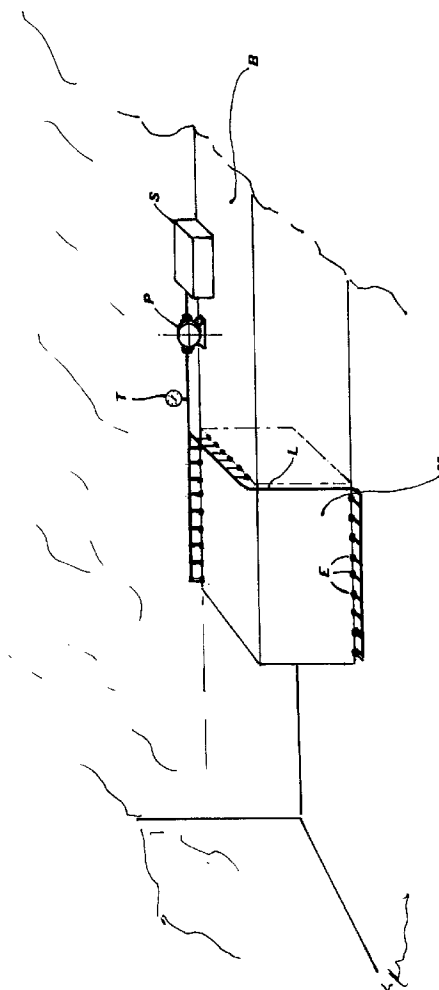


FIG.1

The present invention relates to a new method for excavating stone blocks during the mining of marble or granite or during excavation or surface-stripping works. The invention also relates to an apparatus enabling said method to be implemented.

The methods for excavating stone blocks, in particular in marble and granite mining, have over the years evolved constantly as regards the type of equipment used and hence the final excavation speed, but have nevertheless, during the course of this evolution, always been closely associated with two highly traditional excavation techniques involving the use of a wire and explosive.

According to the first technique, the block is cut from the bed with the aid of a wire or rather an annularly arranged steel cable which conveys the abrasive material (in the case of the most traditional cutting method involving water and sand) or to which the abrasive material is permanently fixed (in the case of the most recent method involving diamond-based abrasive materials in the form of small grains or beads threaded onto the wire and fixed to the latter). Nowadays the wire and sand cutting method has been more or less abandoned on account of the slowness of the cutting operation and the need to provide a fairly long section of wire which allows the latter to cool properly and have a longer service life. The cutting method which uses a diamond-coated wire, on the other hand, has spread rapidly, owing to both the higher cutting speed which is possible and the greater compactness and simplicity of the machinery compared to that traditionally used.

The cutting method which uses a diamond-coated wire, however, has several drawbacks. Firstly, from a technical point of view, it requires the availability of a certain amount of free space in front of and on the sides of the vein to be cut so as to allow displacement of the wire operating machine which must move backwards as the cutting operation proceeds; it is therefore not possible to use this method in all those excavation situations where this space cannot be easily provided. Furthermore, from a safety point of view, said method is particularly dangerous should the wire break, not so much because of the "whiplash" effect of the broken ends of the wire, whose radius of action can be predicted and limited, but more on account of the beads which come free in the breakage zone and are flung out at high speed, in some cases over a considerable distance, with the risk of causing injury and even death. Finally, from an economic point of view, said method requires a considerable outlay and repeated expenditure on account of the rapid wear of the beads made of diamond-based material.

According to the second technique, i.e. the technique which uses explosive, a series of parallel bores must be formed, at a distance of about 30 cm from one another using cutting or drilling bits, in the region of

the block planes forming an integral part of the vein; these bores are then filled with explosive which, when it explodes, causes parting of the block. This technique in fact requires an apparatus which is much more compact and has a lower cost compared to the excavation technique using a diamond-coated wire and obviously can also be used in all those less favourable conditions where there is not enough space to install the wire machine. However, this technique also has obvious drawbacks. Even though, in fact, the cost of using explosives is certainly less than that of the diamond-coated wire, this technique involves a high degree of risk both with regard to the safety of the operators concerned and the possibility of thefts and subsequent improper use of the explosive, even for criminal purposes. This has resulted in a considerable and gradual tightening of the administrative and bureaucratic laws governing the use of explosives, greatly restricting its availability.

From a technical point of view it should be noted that the action of the explosive on the stone material cannot always be easily predicted and accurately controlled and therefore it is very difficult to prevent the force of the explosion, in addition to separating the block, from damaging to a greater or lesser extent the material still to be excavated.

For all of the abovementioned reasons there is an urgent need, in particular in the sector of the excavation of high-quality stone materials, i.e. in marble and granite mining, for an excavation method which ensures a high degree of safety for the operators concerned, which can be used even where there is not a suitable working space and which involves a low initial outlay for the machinery and low costs as regards consumable materials.

The aim of the present invention, therefore, is to provide a method of the aforementioned type, this being obtained by abandoning the traditional excavation techniques which employ a wire or explosive and by using instead, in order to effect parting of the block from the vein, the suitably controlled energy of a fluid under pressure.

A further aim of the present invention is to provide an apparatus which is simple and has a low installation and operating cost and which is suitable for enabling the abovementioned method to be easily implemented in conditions of maximum safety for the operators concerned.

According to the present invention these aims are achieved by performing excavation of a block from a vein of stone material along one or more parting planes, using a method which comprises the following steps:

- a) making one or more bores on the said parting plane or planes of the block from the vein;
- b) introducing into each of said bores a corresponding fluid pressure expansion device provided with an internal chamber for housing the fluid;

c) connecting the internal chambers of said fluid pressure expansion devices to one or more fluid pressure sources;

d) gradually increasing the pressure of the fluid inside said devices until it causes parting of the block.

Said method is preferably implemented using an excavation apparatus comprising one or more fluid pressure expansion devices with internal chambers for housing a working fluid, which are designed to be introduced into the bores formed on the desired parting planes of the block from the vein; one or more pressure sources connected by one or more pipes to the internal chambers of said fluid pressure expansion devices; a tank containing the working fluid for supplying the said pressure source.

According to a characteristic feature of the present invention, the fluid pressure expansion device advantageously consists of a tube which is resistant to high pressure, is extendable in the radial direction and is substantially rigid in the axial direction.

According to a preferred embodiment, this tube is made of plastic material with a high modulus of elasticity, provided at its opposite ends with metal sealing unions which are connected to one another by a metal rod housed inside said tube.

The invention will now be described, however, in greater detail with reference to a preferred embodiment of the fluid pressure expansion device, illustrated in the accompanying drawings, in which:

Fig. 1 is a schematic drawing which illustrates the procedure for using the apparatus of the present invention during excavation of a block of stone material;

Fig. 2 is a partially sectioned front view of a component of the fluid pressure expansion device according to the present invention, with its parts detached;

Fig. 3 is a sectioned front view of the said device illustrated in Figure 1, with its parts assembled;

Fig. 4 is a sectioned front view which illustrates the connection between two adjacent components of the type illustrated in the preceding figures; and

Fig. 5 illustrates schematically the connection of some expansion devices to a pressure source.

The method according to the present invention is now described, with particular reference to its use in marble and granite excavation mines, which represent the preferred area of application thereof. In these mines the material is normally worked in successive veins or reefs, this term referring to the actual mine working zone which generally has an elongated parallelepiped shape and is extracted with successive cuts, so that the three dimensions of the extracted block are generally between 3 and 8 metres. Figure 1 schematically illustrates a vein B from which a block M is being excavated.

The excavation method according to the invention comprises a first step during which - in exactly the same way as in the excavation technique which use explosive - the dimensions of the block to be extracted and hence the exact location of the parting plane of the block from the vein are determined, and then, using suitable cutting tools, several substantially parallel bores are made in said planes.

In contrast with what occurs in the traditional technique involving explosive, in which the bores are made with drilling bits which have gradually decreasing dimensions and which are therefore in effect conical, in the method according to the present invention the bores are suitably made with milling cutters, so that they are perfectly cylindrical. The distance between one bore and another varies according to the material to be extracted and may fluctuate between a minimum of 30 cm and a maximum of 60 cm, should it be desired to obtain a substantially flat plane for parting of the block. Beyond the figure indicated of about 60 cm, parting of the block still occurs, but with more irregular surfaces and hence greater surplus material.

During the second step of the excavation method according to the present invention, a fluid pressure expansion device E is inserted into each of the bores thus made. The device E must be able to withstand very high pressures (preferably of up to 1000 bar), have a good radial expandability (from 10 to 30 mm), a high coefficient of elasticity, i.e. a very small non-recoverable residual deformation, and finally a good resistance to axial deformation. The maximum external diameter of the expansion device must be a few millimetres less than that of the bores so that it can be easily inserted into the latter without problems of friction. Preferably the diameter of the expansion device will be between about 20 and about 50 mm and that of the bores between about 25 and about 55 mm.

A liquid or gas may be used equally well as the working fluid. From the point of view of safety, in the event of accidental breakage of the device or in any case leaks, and also from the point of view of compression costs, it is obviously preferable to use a liquid. Of the possible liquids, water is the most suitable, both because it is readily available and has a negligible cost and in particular because, in the event of breakages and other accidental spillages of liquid, it will not cause any damage to the stone materials being worked, in contrast to what would happen if traditional hydraulic oils were used. Should the excavation method be performed at external temperatures of less than 0°C, it is possible to add to the water constituting the working liquid suitable commercially available anti-freeze agents, provided that they are not oil-based and colourless.

During the third step of the method, the expansion devices E inserted into the respective bores which determine the parting planes of the block M are

connected, by one or more high-pressure supply lines L, to a high-pressure source P in turn connected to a tank S containing the working liquid.

Connection of the line L to the expansion devices E and to the pressure source P is performed in accordance with the standard practices adopted in the hydraulic sector. For reasons of operational convenience, for example the connections between the devices E and the line L will preferably be of the rapid snap-engagement type, while gate valves are envisaged for isolating the various branches of the line L or also the individual devices E, so as to facilitate the identification and elimination of any leaks. Similarly, in order to control operation of the apparatus, it will be indispensable to provide the line L with a main pressure gauge T for high pressures, as well as, where required, secondary pressure gauges situated at the inlet of the individual branches or the individual expansion devices E in order to control better the distribution and maintenance of the pressure inside them. Suitable bleeding devices, finally, shall be provided so that filling of the plant can be performed with evacuation of the air contained inside it.

During the fourth step of the process, the pressure source P is made to operate initially at a low pressure in order to transfer working liquid from the tank S to the line L and fill the expansion devices E. When bleeding has been completed, the pressure source P is brought up to operating pressure and the pressure is increased until it causes parting of the block M from the vein B, which occurs at a pressure varying from between 100 and 500 bar depending on the type of material, the distance of the bores and the size of the expansion devices.

The pressure source P used during this step of the process is preferably a pneumatically operated pump for high pressure liquids. With this type of pump, in fact, there is no need to have inside the mine (where a compressed-air supply is normally always available) an electric power point as well. An example of such a pump is that manufactured by ENERPAC and marketed under the trade name MAXIMATOR. It is obvious, however, that other types of pumps for high pressure liquids could be used, achieving the same results.

During the fifth and final step of the excavation process, after the block M has been parted, the pressure source P continues to transmit liquid at a medium pressure (30-70 bar) to the expansion devices which, expanding radially, cause displacement of the block by an amount of between 10 and 30 mm sufficient to allow the block to be gripped by conventional handling systems for further processing.

This final step involving displacement of the block is preferably performed using the devices located in only one of the block parting planes, after eliminating from the circuit and then extracting the remaining devices from the respective bores, so as to cause dis-

placement of the block in a single desired direction and so as not to damage the expansion devices - in particular those which are in the support plane of the block M - as a result of displacement of the latter.

As can be understood from the above description, the key element for the successful functioning of the method for excavating blocks of stone material according to the present invention is the fluid pressure expansion device which must be provided with very special features both on account of the type of functions which it has to perform and the extremely high pressures under which it must operate in order to perform said functions.

As a result of extensive research and experiments carried out by the inventor it has been possible firstly to identify and subsequently to develop a special fluid pressure expansion device which satisfies all the particular requirements of the process described above and which therefore forms an integral part of the present invention. A preferred embodiment of this device is illustrated in detail below.

As illustrated in Figures 2 and 3, said expansion device E comprises a tubular element 1 of elastically yielding material designed to withstand the extremely high pressures at which the excavation apparatus of the present invention operates and the abrasive action which occurs, during the excavation operation, between the internal surface of the bores formed in the stone material and the external surface of the tubular element 1. As already mentioned, the tubular element 1 must have moreover a high coefficient of elasticity and a residual deformation which is as small as possible so as to reassume substantially the original configuration at the end of each excavation operation.

Numerous tests carried out by the inventor demonstrated that polyurethane resin based materials formed into thick-walled tubular elements were particularly suitable. Tubular elements of this type, used as springs for moulds, are commercially available, such as, for example, those marketed under the trade name ADIPOL by A.E.M. of Modena. The external diameter of the tubular element 1 is preferably between about 20 and about 50 mm, with an internal diameter correspondingly varying between about 8 and about 20 mm.

The tubular element 1 has housed inside it a solid steel tie-rod 2 with an external diameter slightly smaller than the internal diameter of the tubular element 1, so as to form with the latter a cavity which constitutes an internal chamber of the expansion device for housing the working fluid. The two ends of the tie-rod 2 are threaded and also have longitudinal grooves 2a cut in its surface so as to allow the working fluid to pass through, as described in more detail below.

Two steel sleeves 3 are fitted and then screwed onto the opposite ends of the tubular element 1 and, for this purpose, have a threaded internal surface 3a

with a wide pitch and large thread, which is designed to engage with and fit tightly onto the external surface of the tubular element 1.

The sleeves 3 also have a second threaded internal surface 3b with a diameter which is smaller than that of the preceding one, but which is distinctly greater than the diameter of the tie-rod 2. When the sleeves 3, therefore, are fully screwed onto the tubular element 1, the tie-rod 2 is still completely free and, if necessary, can still be removed from the tubular element itself.

The tie-rod is fixed and at the same time the tubular element 1 is tightened with respect to the sleeves 3 so as to form a sealed connection by means of a pair of male/female unions 4M and 4F, both provided with an axial through-bore, which are respectively mounted at either end of the tubular element 1. The male/female unions 4M and 4F each have an elongated end 5 directed towards the tubular element 1; said end 5 is formed by a conical external surface and a cylindrical internal surface provided with a thread 5a designed to engage with the corresponding threaded end of the tie-rod 2.

The unions 4M and 4F are also provided, at the base of the elongated end 5, with an external thread 4b designed to engage with the thread 3b of the sleeves 3, said thread 4b having a pitch identical to that of the thread 5a described above.

During assembly, the unions 4M and 4F are first screwed onto the opposite ends of the tie-rod 2 until the thread 4b of each union starts to engage with the corresponding thread 3b of the sleeves 3. Screwing is then continued on both pairs of threads until the shoulder 6 of each union 4 comes up against the corresponding sleeve 3, with the arrangement in between of suitable sealing gaskets 7. At this point, final tightening of the device is performed, so that the arrangement shown in Figure 3 is obtained. As can be clearly seen in this figure, the unions 4M and 4F are provided, in addition to the threads already described above, with a third thread, respectively a male thread 4am and a female thread 4af, for effecting the series connection of identical devices, with the arrangement in between of a suitable gasket 8, as shown in Figure 4.

With the assembly described above the expansion device E ensures perfect hydraulic sealing of a working fluid which is injected under pressure inside the cavities of the unions 4M or 4F. The conical shape of the elongated ends 5 of the said unions in fact causes the ends of the tubular element 1 to be pressed against the surface 3a of the sleeves 3, resulting in secure hydraulic sealing of the fluid which, after being injected inside the unions 4, penetrates, via the groove 2a, into the cavity existing between the tubular element 1 and the tie-rod 2. The sealing action is also further guaranteed, on the inner side of the tubular element 1, by gaskets 7.

The expansion device E described hitherto may be constructed so as to have any length desired. For the sake of transportation, easy assembly and convenient fitting, it is preferably constructed in relatively short sections, of modular length, for example 50, 100, 150 or 200 cm, which may be varyingly assembled at the time of use, with the aid simply of a pair of spanners, so as to form the expansion device with exactly the length required. As can be clearly seen in the left-hand part of Figure 2, in fact, both the sleeves 3 and the unions 4 are provided externally with four orthogonal planes 9 suitable for gripping with conventional mechanical workshop spanners.

Figure 5, finally, shows in greater detail a section of the line L supplying a plurality of expansion devices E. Said line is closed at one end by a stopper Q, preferably provided with a bleeding device, and is connected at the other end to the pressure source S. The individual devices are linked to the line L by means of high-pressure pipes 10 which are connected to the line L preferably via unions of the rapid snap-engagement type and are advantageously provided with a gate valve and pressure measuring devices.

From the above description it is immediately obvious that the method and apparatus of the present invention have fully achieved the aims set. In fact, with them, it is possible to perform fast and perfectly safe excavation of blocks of stone material with a low-cost apparatus which is practically devoid of operating costs, apart from the very small amount of power required for compression of the working fluid. The method moreover is extremely simple, does not pose any danger for the operator, and does not require any precautions, interruption of operation or screening off of areas, as is required, however, in the case of the conventional excavation techniques using either wire or explosive.

Finally it is understood that the present invention has been described with particular reference to a preferred embodiment of the fluid pressure expansion device, but that there may be numerous other variations differing therefrom in terms of the materials used, the structure of the unions or the ways of achieving hydraulic sealing, without thereby departing from the protective scope of the invention itself, as defined in the following claims.

Claims

1. Method for excavating a block from a vein of stone material along one or more parting planes, characterized in that it comprises the following steps:
 - a) making one or more bores on the said parting plane or planes of the block from the vein;
 - b) introducing into each of said bores a corresponding fluid pressure expansion device

- provided with an internal chamber for housing a working fluid;
 c) connecting the internal chambers of said fluid pressure expansion devices to one or more fluid pressure sources;
 d) activating said pressure sources so as to increase gradually the pressure of the fluid inside said devices until it causes parting of the block from the vein along the said parting plane or planes.
2. Method according to Claim 1, comprising moreover, after completion of step d) involving parting of the block, the following step:
 e) keeping the pressure of the fluid inside said expansion devices at a value lower than that reached during the parting step, but sufficient to cause gradual expansion of the said devices and consequent displacement of the block, after removing, where necessary, some of the devices used during the aforementioned step d).
 3. Method according to Claim 1 or 2, in which the bores formed during the aforementioned step a) are cylindrical and are made by means of milling cutters.
 4. Method according to Claim 3, in which said bores have a diameter of between 25 and 55 mm.
 5. Method according to Claim 1 or 2, in which said fluid pressure expansion device consists of at least one tubular means which is resistant to high pressures, extendable in the radial direction and substantially resistant to deformation in the axial direction and has a negligible residual deformation.
 6. Method according to Claim 5, in which said tubular means consist of a tube made of plastic material with a high modulus of elasticity, provided at its opposite ends with metal sealing members which are axially bored and connected to one another by a metal rod housed inside said tube.
 7. Method according to Claim 6, in which said plastic material is a polyurethane resin based material.
 8. Method according to Claim 6, in which said metal sealing members comprise a sleeve screwed onto said tube of plastic material and a union, respectively a male union and female union at either end, screwed onto said sleeve and onto the metal rod so as to force with its conical end which penetrates inside the tube the tube itself against the walls of the sleeve.
 9. Method according to Claim 8, in which said tubular means can be joined to one another by means of screwing of the male/female unions of adjacent tubular means, with the arrangement in between of a sealing gasket.
 10. Method according to Claim 1 or Claim 2, in which said pressure source is a pneumatically operated pump for high pressure liquids.
 11. Method according to Claim 1, in which the pressure of the working fluid during the step d) involving parting of the block increases up to a maximum value of between about 100 and about 500 bar.
 12. Method according to Claim 2, in which the pressure of the working fluid during the step e) involving displacement of the block is maintained at a value of between 30 and 70 bar.
 13. Apparatus for excavating a block from a vein of stone material, characterized in that it comprises:
 - one or more fluid pressure expansion devices with internal chambers for housing a working fluid, designed to be introduced into bores made along the desired parting planes of the block from the vein;
 - one or more pressure sources connected by one or more pipes to the internal chambers of said fluid pressure expansion devices;
 - a tank containing the working fluid for supplying said pressure sources.
 14. Apparatus according to Claim 13, in which said fluid pressure expansion device consists of at least one tubular means which is resistant to high pressure, extendable in the radial direction and substantially resistant to deformation in the axial direction and has a negligible residual deformation.
 15. Apparatus according to Claim 14, in which said tubular means consists of a tube made of plastic material with a high modulus of elasticity, provided at its opposite ends with metal sealing members which are axially bored and connected to one another by a metal rod housed inside said tube.
 16. Apparatus according to Claim 14, in which said material is a polyurethane resin based material.
 17. Apparatus according to Claim 14, in which said metal sealing members comprise a sleeve screwed onto said tube of plastic material and a union, respectively a male union and female union at either end, screwed onto said sleeve and

said metal rod so as to force, with its conical end which penetrates inside the tube, the tube itself against the walls of the sleeve.

18. Apparatus according to Claim 17, in which said tubular means can be joined to one another by means of screwing of the male/female unions of adjacent tubular means, with the arrangement in between of a sealing gasket. 5
19. Apparatus according to Claim 13, in which said pressure source is a pneumatically operated pump for high pressure liquids. 10
20. Apparatus according to Claim 13, in which said connecting pipes comprise gate valve means for isolating the expansion devices or groups thereof. 15
21. Apparatus according to Claim 13, in which said connecting pipes comprise measuring means for measuring the pressure value in the region of the pressure source and/or the expansion devices. 20

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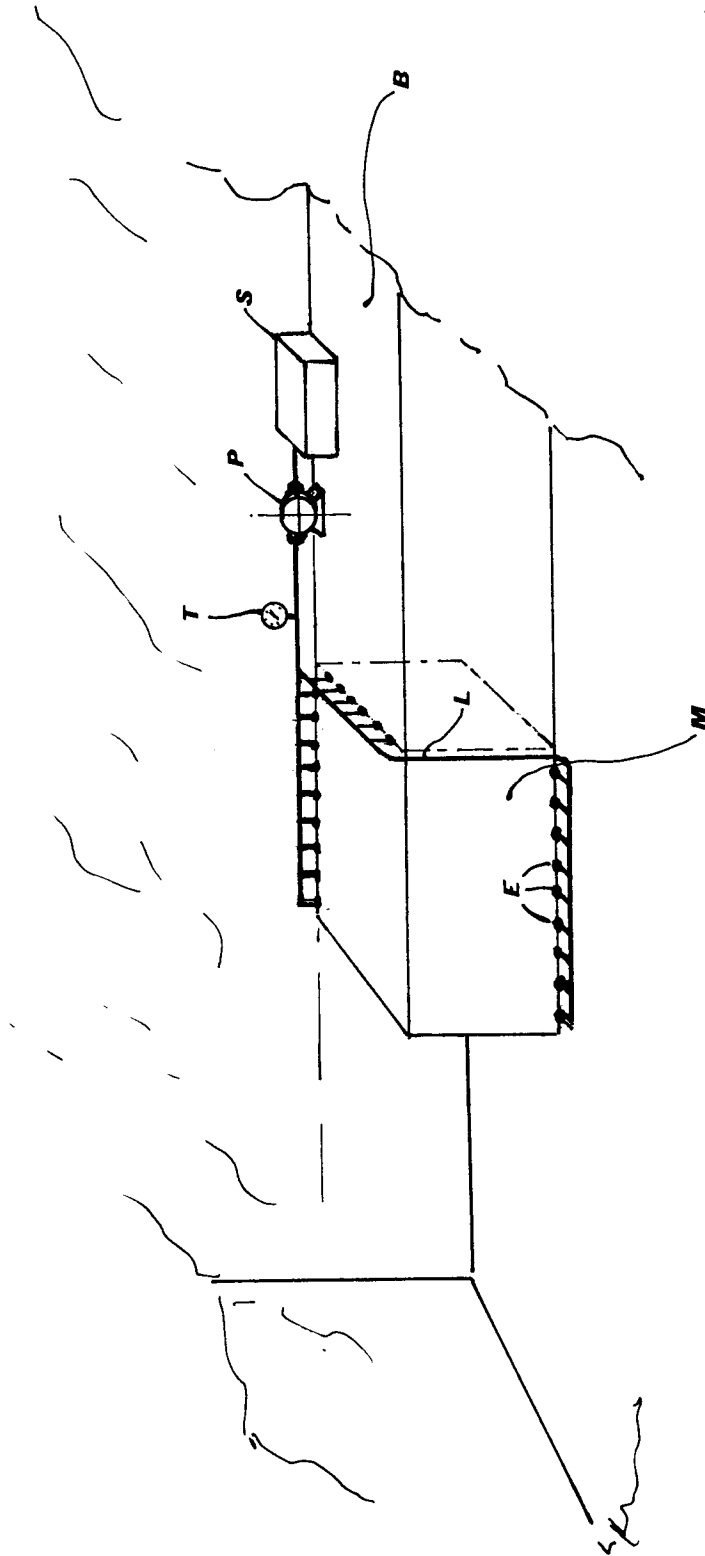


FIG.1

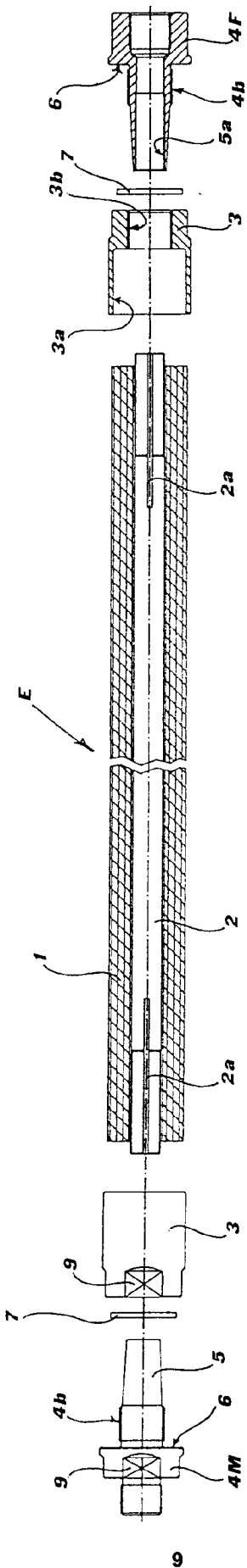


FIG. 2

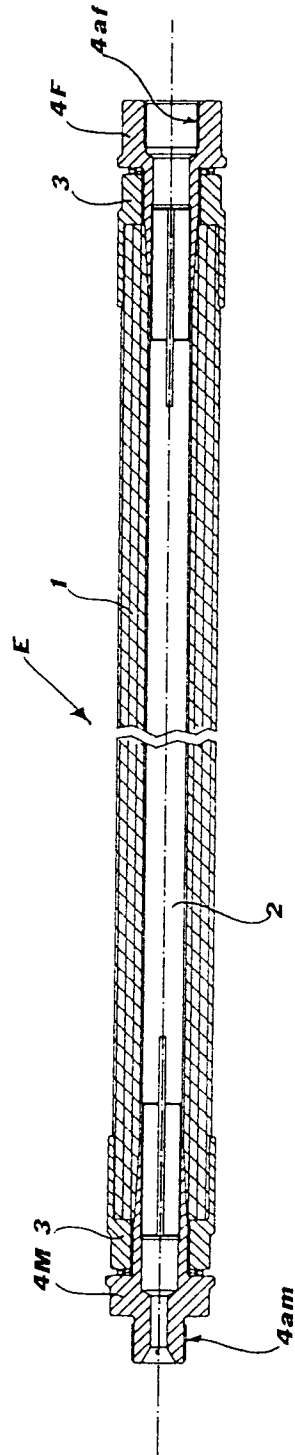


FIG. 3

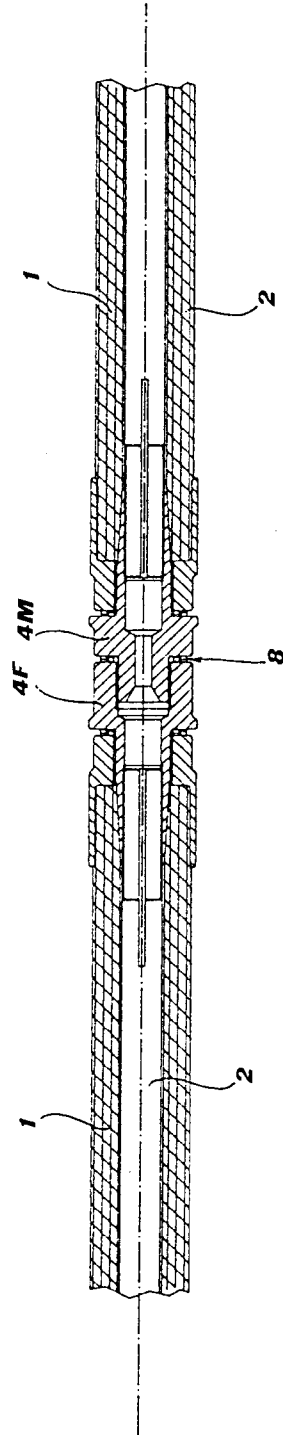


FIG. 4

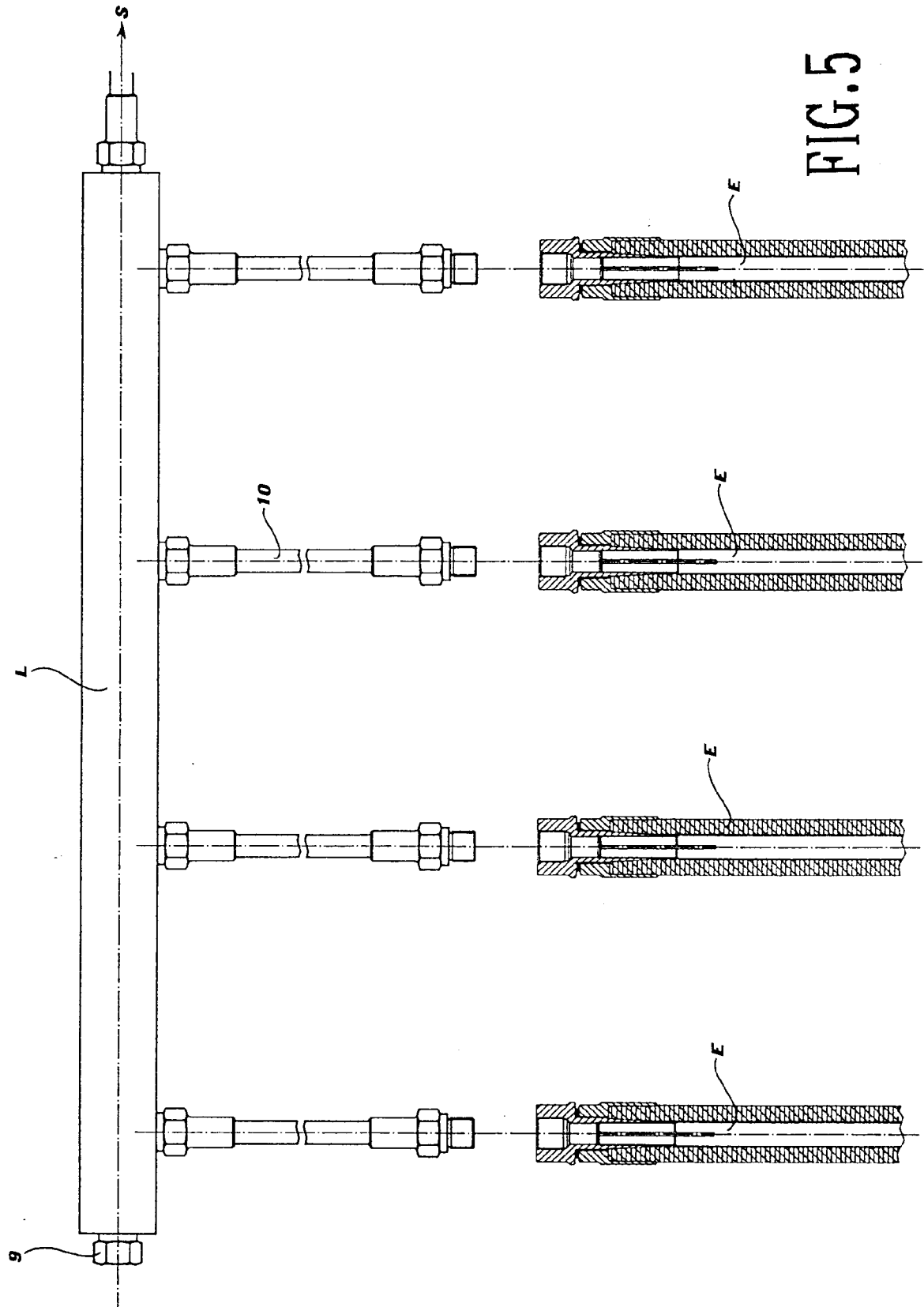


FIG. 5



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 94 10 5189

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.5)
X	FR-A-2 671 376 (BRÛLE)	1,3,5,6,8	E21C37/10
Y	* page 7, line 25 - page 8, line 24 * * page 9, line 24 - page 10, line 23; figures 7-12 *	7,9,10,14,15,17	
X	EP-A-0 182 510 (OKUMURA)	13,19-21	
Y	* page 6, line 10 - page 8, line 19; figures 1,2 *	10,14-18	
Y	GB-A-2 131 854 (KAJIMA) * abstract * * page 2, line 20 - line 27; figure 1 *	7,16	
Y	WO-A-86 02404 (DERMAN) * page 6, line 25 - page 7, line 15; figures 1,2 *	9,18	
X	US-A-1 630 470 (CLIFFORD)	1,3,5,6	
A	* page 1, line 87 - page 2, line 39; figures *	8-10,13-15,17-21	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			E21C
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 5 July 1994	Examiner Fonseca Fernandez, H
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