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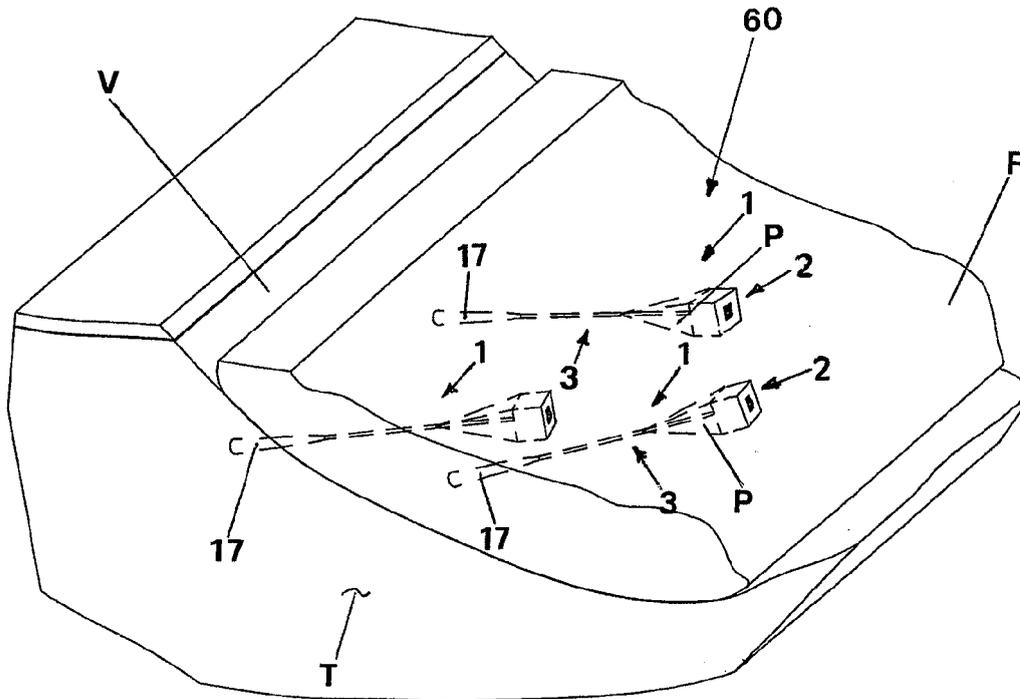
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**(54) Structures intended to consolidate and retain the grounds undergoing a movement**

(57) The invention is a consolidation and containment structure (60, 65, 70, 75) for unstable ground (F), comprising a plurality of reinforcing elements (1; 20; 30; 40; 50), all independent of each other, each one of which comprises a bulky counteracting element (2) buried in the unstable ground (F) and constrained to an anchoring

element (3) fixed in the stable ground (T) underlying the unstable ground (F), in order to allow the bulky counteracting element (2) to float in the unstable ground (F). Each anchoring element (3) has a mainly longitudinal development and comprises a first end (3a) fixed in the stable ground (T) and a second end (3b) constrained to the bulky counteracting element (2).



**FIG. 6**

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## Description

**[0001]** The invention concerns a ground consolidation, containment and stabilization structure.

**[0002]** It is known that in order to stabilize and consolidate ground subject to landslides, or to carry out hydraulic works like for example bank consolidation, construction of bridges, watercourse flow control and the like, techniques and structures of various types are currently used.

**[0003]** A known consolidation technique for ground vulnerable to landslides includes shallow and deep drainage of water from the landslide.

**[0004]** According to another known technique, in the area vulnerable to landslides the ground is moved, more precisely it is removed from the top and put back at the foot of the slope.

**[0005]** Consolidation structures are also known according to which at the bottom of the landslide area a gravity-stabilized structure is constructed, for example reinforced areas, gabions or reinforced concrete walls.

**[0006]** Another type of containment structure includes the construction of a partition made of micro piles, with reinforced concrete top strip and active tie rods or passive anchorage elements, and surrounding the area to be stabilized, thus hindering the landslide movement.

**[0007]** A further type of containment structure includes the construction of reinforced concrete walls with foundation on piles, stabilized with active tie rods or passive anchorage elements.

**[0008]** According to another known ground consolidation technique, shafts having a considerable diameter, generally ranging from 6 to 10 metres, are constructed, buried in the ground below the landslide plane and carried out using various techniques, like large piles, micro piles and reinforced concrete rings that can also be anchored by means of tie rods.

**[0009]** All the consolidation and containment structures and systems described above, however, pose some recognized drawbacks.

**[0010]** A recognized drawback concerning consolidation techniques through drainage within the landslide mass lies in the uncertainty of the result and therefore in the degree of stabilization of the landslide movement that can be achieved.

**[0011]** A recognized drawback that can be observed in the construction of the other consolidation structures mentioned above, especially when they are applied to complex landslides, is represented by the considerable design difficulties, since the available geotechnical parameters are extremely variable due to the continuous change in the hydrogeologic conditions.

**[0012]** Furthermore, the structure obtained is of the static type and the designer, in order to effectively counteract the landslide movement, will design the structure with a high safety coefficient.

**[0013]** This will result in the increased dimensions of the structure itself and consequently also in increased construction costs.

**[0014]** A further recognized drawback deriving mainly from the fact that, as already explained, said containment structures are static is constituted by the fact that if they do not achieve the result they are intended for, that is, if they do not mitigate the landslide movement, they will be destroyed by the landslide. Another drawback lies in that for making the known containment structures it is necessary to use large pieces of equipment having high operating costs, as well as high transport and site installation costs.

**[0015]** Another drawback is represented by the time required to carry out these works, which is generally rather long.

**[0016]** A further drawback is due to the fact that the presence of said structures is quite invasive for the environment.

**[0017]** Ground containment structures of known type are described in the patent documents US 4 154 554 A, US 5 017 049 A, US 3 922 864 A and CH 657 651 A and include the construction of a retaining wall arranged in front of the landslide, fixed to the ground below the landslide movement line through anchoring means.

**[0018]** Said anchoring means include a plurality of tie rods, each one of which has one end constrained to the retaining wall and the opposite end constrained to a bulky counteracting element that is buried in the ground below the landslide movement line.

**[0019]** In each containment structure the thrust force exerted by the landslide mass on the retaining wall tensions the tie rods and is discharged on the bulky counteracting elements buried in the ground below the landslide movement line.

**[0020]** Substantially, therefore, the containment action is developed by the synergy of three elements and precisely by the retaining wall that receives the thrust force of the landslide mass, by the tie rods that are tensioned by the thrust force to which the retaining wall is subjected and by the bulky counteracting elements that, being permanently buried into the ground, counteract the stress to which the tie rods are subjected.

**[0021]** All the containment structures described in the patent documents mentioned above, though solving the problem of the mitigation of landslides, for which they are designed, however pose all the drawbacks and the limitations already listed above.

**[0022]** In particular, in said structures all the tie rods are connected to the retaining wall and therefore are not independent of each other. Thus, the containment structure is a rigid body comprising the bulky counteracting elements, the tie rods that pass through the landslide mass and the retaining wall, and therefore poses the already mentioned drawbacks.

**[0023]** Another drawback posed by said structures lies in that in order to bury the bulky counteracting elements into the ground it is necessary to carry out expensive and complex excavations in the area below the landslide movement line.

**[0024]** A further drawback is represented by the fact

that said excavations are made by working in the ground below the landslide movement line, thus increasing the instability of the landslide.

**[0025]** The present invention aims to overcome all the drawbacks listed above.

**[0026]** In particular, the object of the present invention is to provide a consolidation and containment structure for unstable ground in general, in particular for landslides, capable of mitigating the movement of the unstable ground, in particular of the landslide, and of stopping said movement without using retaining walls.

**[0027]** It is another object of the invention to provide a consolidation and containment structure that does not require the execution of important and expensive excavations and that therefore can be made using small equipment, easy to transport and to use.

**[0028]** It is another object of the invention to provide a consolidation and containment structure that during construction does not require works that may affect the stability of the landslide mass.

**[0029]** It is a further object of the invention to provide a consolidation and containment structure that requires shorter execution times compared to equivalent containment structures of known type.

**[0030]** It is a further object of the invention to provide a consolidation and containment structure that has a very low environmental impact, certainly lower than that of equivalent containment structures of known type.

**[0031]** It is another yet not the least object of the invention to provide a structure having a flexible configuration that therefore can be modified and integrated with further work both during construction and once construction has been completed.

**[0032]** The objects described above are achieved by a consolidation and containment structure for unstable ground having the characteristics described in the main claim.

**[0033]** Further characteristics of the consolidation and containment structure of the invention are described in the dependent claims.

**[0034]** The consolidation and containment structure that is the subject of the invention comprises a plurality of reinforcing elements, all independent of each other, constrained to the stable ground below the sliding line of the unstable ground and provided with bulky counteracting elements housed and floating in the unstable ground in order to mitigate and counteract its movement.

**[0035]** The consolidation and containment structure comprises any number of reinforcing elements, depending on the extension of the surface to be consolidated.

**[0036]** Each reinforcing element counteracts the movement of the unstable ground, exerting a predetermined counteracting force and letting the forces that it cannot oppose be discharged laterally.

**[0037]** This results in the reinforcing element remaining intact and serving its function, independently of how, when and how much the ground moves.

**[0038]** The number of reinforcing elements can be in-

creased or reduced, both during construction and after work completion, in order to vary the resistance characteristics of the consolidation and containment structure and to adapt it to any new environmental and/or use conditions.

**[0039]** When installed, the consolidation and containment structure of the invention, differently from the known containment structures, does not act as a rigid blocking element but as a flexible energy dissipating element.

**[0040]** In other words, while all the rigid containment structures block yielding ground, like for example a landslide, by counteracting its movement, the structure of the invention, being a floating structure, stops the movement of the ground through energy dissipation.

**[0041]** In particular, the use of the reinforcing element of the invention simplifies design work for consolidation of complex landslide movements, since during the design stage it will be possible to calculate and verify the behaviour of the reinforcing element that serves to mitigate the movement.

**[0042]** In particular, it will be possible to calculate the consolidation and containment structure based on the quantity of energy that it must dissipate in order to contain or even simply slow down the movement of the unstable ground.

**[0043]** It is also possible to make only part of the consolidation and containment structure and to complete and even modify the structure successively, even after years.

**[0044]** All the landslide mitigation elements will remain active, independently of how and how much the landslide moves.

**[0045]** Advantageously, therefore, it is possible to intervene on the consolidation and containment structure even after installation, in order to modify it in case of defects or even design errors.

**[0046]** Still advantageously, the consolidation and containment structure can also be modified after installation so as to adapt it to any change in the characteristics of the ground.

**[0047]** A further advantage is represented by the ease of installation of the reinforcing elements, which ensures that the consolidation and containment structures can be constructed more quickly and at lower costs compared to the prior art. In fact, contrary to the prior art described in the patent documents mentioned above, it is not necessary to make large excavations or to move large quantities of soil.

**[0048]** Still advantageously, the reinforcing elements can be integrated in the environment so that the consolidation and containment structures that are made with them have a low environmental impact, certainly lower than that of the containment structures of known type.

**[0049]** Finally, to advantage, the consolidation and containment structures of the invention are well suited to be used in hydraulic works for watercourse maintenance, for example bank consolidation and the construction of bridles, crosspieces, flow retarders and other similar works.

**[0050]** The objects and advantages described above will be highlighted in greater detail in the description of preferred embodiments of the invention that are supplied as indicative, non-limiting examples with reference to the enclosed drawings, wherein:

- Figure 1 shows an axonometric view of a reinforcing element suitable for making the consolidation and containment structure of the invention;
- Figures 2, 3, 4 and 5 show variant embodiments of the reinforcing structure of Figure 1;
- Figure 6 shows the axonometric view of the consolidation and containment structure of the invention used to consolidate slopes subjected to landslides;
- Figure 7 shows a plan view of the consolidation and containment structure of Figure 6;
- Figure 8 shows the longitudinal cross-sectional view of the consolidation and containment structure of Figure 6;
- Figure 8a shows an enlarged detail of Figure 8;
- Figure 9 shows the axonometric view of more than one consolidation and containment structure of the invention used for watercourse maintenance;
- Figure 10 shows a top view of the consolidation and containment structure of Figure 9;
- Figure 11 shows a longitudinal cross-sectional view of the consolidation and containment structure of Figure 9.

**[0051]** The consolidation and containment structure of the invention, indicated as a whole by **60**, is shown in Figures from 6 to 8.

**[0052]** According to the invention, the structure **60** comprises a plurality of reinforcing elements **1** all independent of each other, each one of which is provided with a bulky counteracting element **2** buried in the unstable ground **F** and constrained to an anchoring element **3** fixed to the underlying stable ground **T** to allow the bulky counteracting element **2** to float in the unstable ground **F**.

**[0053]** In particular, the structure **60** of the invention is arranged so as to consolidate and contain unstable ground consisting of a landslide **F** moving along a slope **V**.

**[0054]** One of the reinforcing elements making up the consolidation and containment structure **60** is shown in Figures from 1 to 5, where it is indicated as a whole by **1**.

**[0055]** It comprises a bulky counteracting element **2** associated with a single anchoring element **3** driven into the ground in order to constrain the movement of the bulky counteracting element **2** only along the longitudinal direction **Y** defined by the anchoring element **3**.

**[0056]** The anchoring element **3** has a mainly longitudinal development **Y** and is inserted in a through hole **4** made in the bulky counteracting element **2** with which it is firmly connected via constraining means indicated as a whole by **5**. In particular, as can be seen, the constraining means **5** comprise a flange **6** that is fixed to the second end **3b** of the anchoring element **3** through locking means

**7** suited to keep it in position against the external surface **8** of the bulky counteracting element **2**.

**[0057]** According to the variant embodiment shown in Figure 2, the reinforcing element, indicated as a whole by **20**, has the flange **6** that is inserted in a recessed seat **9** obtained in the bulky counteracting element **2**.

**[0058]** In both the variant embodiments **1** and **20**, the bulky counteracting element **2** is constituted by a rock **10**.

**[0059]** In other embodiments shown in Figures 3 and 4, each reinforcing element, indicated as a whole by **30**, **40**, has the bulky counteracting element **2** constituted by a prefabricated block made of a cement mix **11**, preferably but not necessarily reinforced concrete, in which the flange **6** is respectively arranged so that it rests on the external surface **8** of the bulky counteracting element **2** or is inserted in a recessed seat **9** obtained in the same bulky counteracting element **2**.

**[0060]** Another embodiment visible in Figure 5 is also possible, in which the reinforcing element is indicated as a whole by **50** and wherein the bulky counteracting element **2** is constituted by a squared rock **12** that in the case shown in the figure is provided with a flange **6** positioned against the external surface **8** of the bulky counteracting element **2**.

**[0061]** Even if not illustrated in the figures, the variant embodiment of Figure 5 may also have a configuration in which the flange **6** is inserted in a recessed seat created in the bulky counteracting element **2**.

**[0062]** It can be observed that in all the variant embodiments described herein most of the length of the anchoring element **3** projects from the through hole **4** and its first end **3a**, opposite the second end **3b**, is driven into the stable ground **T** under the unstable ground of the landslide **F**, so as to constrain thereto the bulky counteracting element **2**, as shown in Figures from 6 to 8 and as will be explained in greater detail below.

**[0063]** As regards in particular the anchoring element **3**, according to a construction variant it consists of a metal bar **14** that has preferably but not necessarily a circular cross section.

**[0064]** According to another variant embodiment of the invention, the anchoring element **3** may consist of strands or metal or synthetic fibre cables.

**[0065]** In this case the flange **6** that makes up the constraining means **5** is maintained against the corresponding bulky counteracting element **2** via locking means **7** comprising a nut **15** connected to the end **3a** of the cylindrical bar **14**. According to a variant embodiment not shown in the drawings, the anchoring element **3** consists of a metal rope.

**[0066]** Regarding the installation of the reinforcing element **1**, it is constrained to the ground by inserting its first end **3a** and part of the anchoring element **3** that projects from the through hole **4** made in the counteracting element **2** into a blind hole **16** made in the stable ground **T**, as shown in Figure 8 and in greater detail in Figure 8a.

**[0067]** After insertion, a mixture preferably made of ce-

ment is injected under controlled pressure into the blind hole **16** and, as shown in particular in Figure 8a, after hardening it forms an anchorage bulb **17** that firmly constrains the bulky counteracting element **2** and therefore the entire reinforcing element **1** to the stable ground **T**.

**[0068]** According to another construction technique, it will be possible to use self-drilling hollow reinforcing bars that serve as drill rods, if necessary joined with special sleeves, to which a disposable drilling point is fixed.

**[0069]** Their main characteristic lies in that they use, as drain fluid, cement grout that, once having reached the required depth, will harden.

**[0070]** In this way, when the reinforcing element has been installed, it is constrained only along the longitudinal direction defined by the corresponding anchoring element with the bulky counteracting element that is constrained to it inserted in the landslide **F**.

**[0071]** Therefore, it is floating and free to move in any direction different from the longitudinal direction along the anchoring element.

**[0072]** By proceeding as described above and using a plurality of reinforcing elements made according to any of the variant embodiments described, it is possible to obtain containment and consolidation structures for unstable ground.

**[0073]** For example, it is possible to make the consolidation and containment structure of the type shown in Figures from 6 to 8 and indicated as a whole by **60** that, as already explained, serves to consolidate and contain the landslide movements **F** of slopes **V**.

**[0074]** In this case, by operating as described above, the procedure includes the operations of making a plurality of blind holes **16** in the ground **T**, inserting in the blind holes **16** part of the anchoring elements **3** of a plurality of reinforcing elements **1**, filling each blind hole **16** with cement mix.

**[0075]** When all the reinforcing elements have been prepared, the bulky counteracting element **2** of each one of them is substantially buried in the landslide **F** or slightly projecting from it, as shown in Figures 6, 7 and 8.

**[0076]** It can soon be observed that the bulky counteracting elements **2**, even if part of them projects from the landslide **F**, are camouflaged in the surrounding stones, thus producing a substantially negligible environmental impact or no impact at all.

**[0077]** At the level of each reinforcing element **1** and in particular at the level of the surfaces of the bulky counteracting elements **2** where the anchoring element **3** projects, a counteracting prism **P** is generated that can be compared to a cone or a pyramid whose base is the surface of the counteracting element **2** and whose vertex faces the stable ground **T**.

**[0078]** The base perimeter of said counteracting prism **P** has substantially the same shape as the bulky counteracting element **2** and substantially corresponds to a resistant area of the ground that together with the counteracting element **2** produces the deviation of the thrust forces, indicated by the arrows **S** in Figures 6, 7 and 8,

of the landslide **F** along the slope **V**.

**[0079]** Each reinforcing element **1** thus constitutes an element that is independent of the others and is floating inside the landslide **F**, in relation to which it adapts its position under the action of the thrust forces **S** of the movement of the landslide **F** that it deviates as shown in Figures from 6 to 8.

**[0080]** The bulky counteracting elements **2**, together with the counteracting prisms **P** of resistant ground, substantially behave, inside the landslide **F**, as friction elements that tend to mitigate its downward movement.

**[0081]** First of all it can be understood that the installation of the bulky reinforcing elements **1** does not require special or large pieces of equipment, since it is sufficient to use drilling means to make the holes **16** in the ground **T** for the insertion of the anchoring elements **3** and handling means to transport the bulky counteracting elements **2**.

**[0082]** Furthermore, also installation is quick, since it is sufficient to make the through holes **4** in the counteracting elements **2** before installation, which therefore consists in introducing the anchoring element **3** in the hole **4**, applying the flange **6** to the end **3a** of the anchoring element **3** and then injecting the cement mix.

**[0083]** It is evident that the number of reinforcing elements **1** to be inserted and their arrangement are defined through precise calculations developed on the basis of the data concerning the ground morphology.

**[0084]** After installation of the consolidation and containment structure **60**, the reinforcing elements **1**, not being constrained to each other, will allow the passage of all the stress generated by the landslide that they do not oppose.

**[0085]** If it should be observed that the number of reinforcing elements is not sufficient to contain the landslide movement, it is possible to insert additional reinforcing elements until completely counteracting the movement and consolidating the slope.

**[0086]** It can therefore be understood that even after installation of the consolidation and containment structure it will be possible to modify it in order to improve its resistance and landslide mitigation capacity compared to the design features. Furthermore, if the hydrogeological conditions of the ground should change over time, it will be possible to install further reinforcing elements in order to adapt the consolidation and containment structure to the new situations. Therefore it will not be necessary to build a new consolidation and containment structure, as it happens for the structures of the known art, and all the related costs will be avoided.

**[0087]** Furthermore, the invention overcomes all the drawbacks and the limitations that, as already explained, are observed when the consolidation, containment and stabilization of landslides are obtained by constructing rigid containment structures, for example those described in the patent documents mentioned above.

**[0088]** In particular, it is evident that the consolidation, containment and stabilization structure of the invention,

in addition to differing considerably from the known structures and in particular from those described in the mentioned patent documents in terms of construction form, differs from them also in the way it operates.

[0089] It has been shown, in fact, that while the known containment structures block the unstable ground by opposing its movement through a retaining wall, the consolidation and containment structure of the invention blocks the ground through a mitigation action and energy dissipation, with bulky counteracting elements floating in the unstable ground.

[0090] The consolidation and containment structures of the invention can be successfully used also for watercourse maintenance, as shown in Figures from 9 to 11, where said structures are illustrated by way of example all joined in the same watercourse.

[0091] One of said consolidation and containment structures is a bridle, indicated as a whole by 65, that is obtained by arranging a plurality of reinforcing elements 1 with the bulky counteracting elements 2 side by side and the anchoring elements 3 driven into the ground crosswise to the flow D' along the watercourse C.

[0092] Another of said consolidation and containment structures is a flow retarder, indicated as a whole by 70, that is obtained by arranging a plurality of reinforcing elements 1 along the banks A of the watercourse C, properly spaced from each other.

[0093] A further consolidation and containment structure is a crosspiece, indicated as a whole by 75 and constituted by a plurality of reinforcing elements 1 whose anchoring elements 3 are driven into the bottom of the watercourse C and are arranged with oblique direction D with respect to the direction D' of the current. According to the above it can be understood that the consolidation, containment and stabilization structure of the invention, in all the variant embodiments described, achieves all the set objects.

[0094] In particular, it has been shown that it is possible to make consolidation and containment structures that mitigate the landslide movements of slopes.

[0095] It is also possible to carry out watercourse maintenance work.

[0096] It has also been shown that the use of the consolidation and containment structures of the invention is more effective than the use of containment structures of the prior art.

[0097] Furthermore, their installation also allows simpler equipment to be used.

[0098] It has also been shown that the consolidation and containment structures of the invention can be modified during construction, or even after construction has been completed, in order to make up for any design error or to improve situations that change over time, with no need to dismantle the work and do it again, as required in the known art.

[0099] In the construction stage, the structures of the invention can be made and used even according to variant embodiments and with modifications that are neither

shown in the figures nor illustrated in the description.

[0100] It is understood, however, that said construction variants and modifications must all be considered protected by the present patent, provided that they fall within the scope of the claims expressed below.

[0101] Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly such reference signs do not have any limiting effect on the protection of each element identified by way of example by such reference signs.

## 15 Claims

1. Consolidation and containment structure (60; 65; 70; 75) for unstable ground (F), **characterized in that** it comprises a plurality of reinforcing elements (1; 20; 30; 40; 50), all independent of each other, each one of which comprises a bulky counteracting element (2) buried in said unstable ground (F) and constrained to an anchoring element (3) fixed in the stable ground (T) underlying said unstable ground (F) in order to allow said bulky counteracting element (2) to float in said unstable ground (F).
2. Consolidation and containment structure (60; 65; 70; 75) according to claim 1, **characterized in that** said anchoring element (3) has a mainly longitudinal development and comprises a first end (3a) fixed in said stable ground (T) and a second end (3b) constrained to said bulky counteracting element (2).
3. Consolidation and containment structure (60; 65; 70; 75) according to claim 2, **characterized in that** said second end (3b) is inserted in a through hole (4) made in said bulky counteracting element (2) with which it is associated via constraining means (5), most of the length of said anchoring element (3) projecting from said through hole (4) on the opposite side of said constraining means (5).
4. Consolidation and containment structure (60; 65; 70; 75) according to claim 3, **characterized in that** said constraining means (5) comprise a flange (6) fixed to said second end (3b) of said anchoring element (3) and placed against the external surface (8) of said bulky counteracting element (2).
5. Consolidation and containment structure (60; 65; 70; 75) according to claim 4, **characterized in that** said flange (6) is housed in a recessed seat (9) created in said bulky counteracting element (2).
6. Consolidation and containment structure (60; 65; 70; 75) according to any of the preceding claims, **characterized in that** said anchoring element (3) is a

metal bar (14).

7. Consolidation and containment structure (60; 65; 70; 75) according to any of the preceding claims from 1) to 5), **characterized in that** said anchoring element (3) is a metal rope. 5
8. Consolidation and containment structure (60; 65; 70; 75) according to any of the preceding claims, **characterized in that** said bulky counteracting element (2) is a rock (10; 12). 10
9. Consolidation and containment structure (60; 65; 70; 75) according to any of the preceding claims from 1) to 8), **characterized in that** said bulky counteracting element (2) is a prefabricated block made of cement mix (11). 15
10. Consolidation and containment structure (60) according to any of the preceding claims, **characterized in that** said unstable ground is a landslide (F) that develops along a slope (V). 20
11. Consolidation and containment structure (65) according to any of the claims from 1) to 9), **characterized in that** it is a bridle positioned in a watercourse (C) according to a direction (D) crosswise to the direction (D') of the current. 25
12. Consolidation and containment structure (70) according to any of the claims from 1) to 9), **characterized in that** it is a flow retarder arranged along the banks (A) of a watercourse (C). 30
13. Consolidation and containment structure (75) according to any of the claims from 1) to 9), **characterized in that** it is a crosspiece positioned on the bottom (F) of a watercourse (C) and defining an inclined direction (D) with respect to the direction (D') of the current of said watercourse (C). 35  
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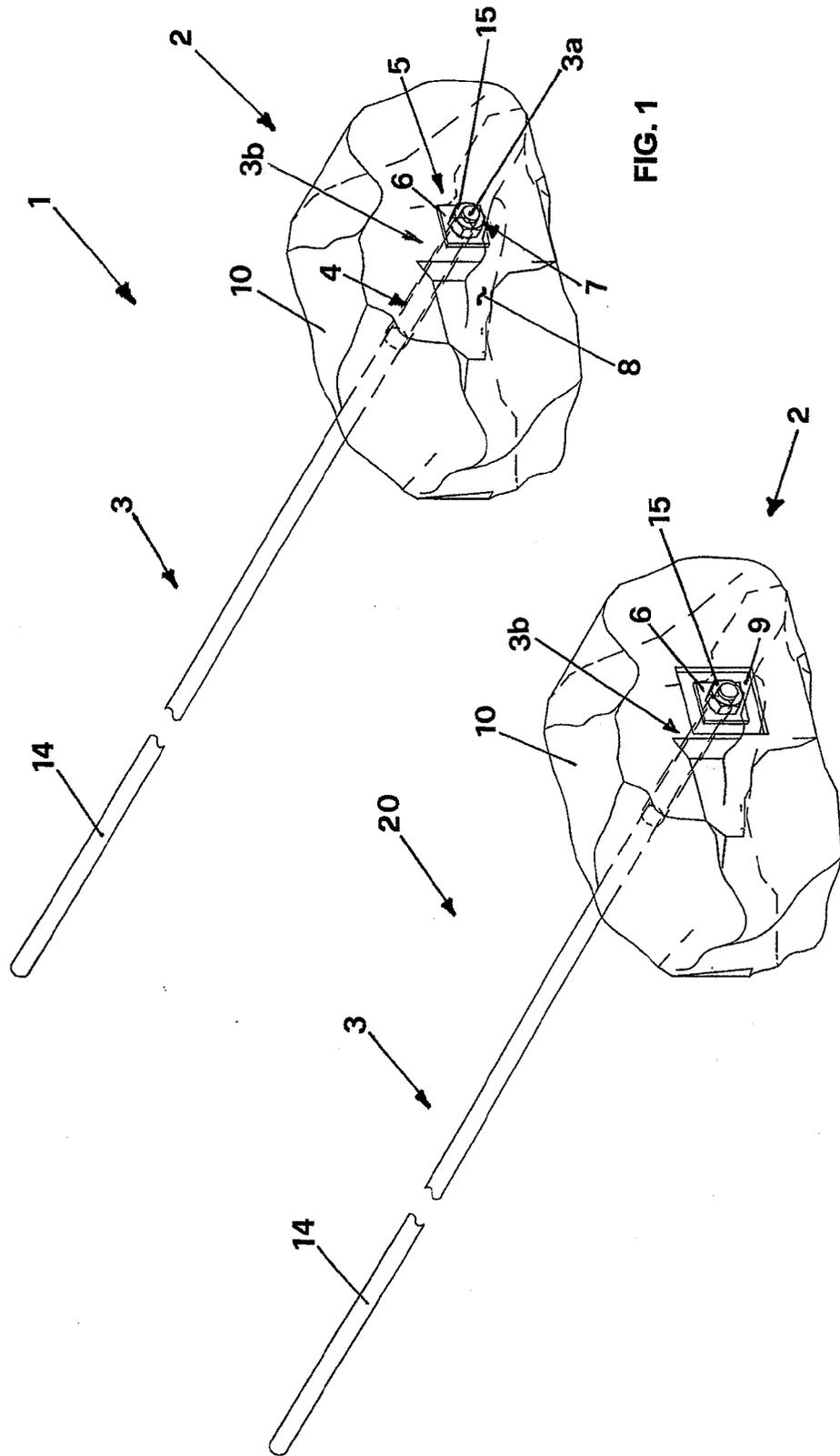


FIG. 1

FIG. 2

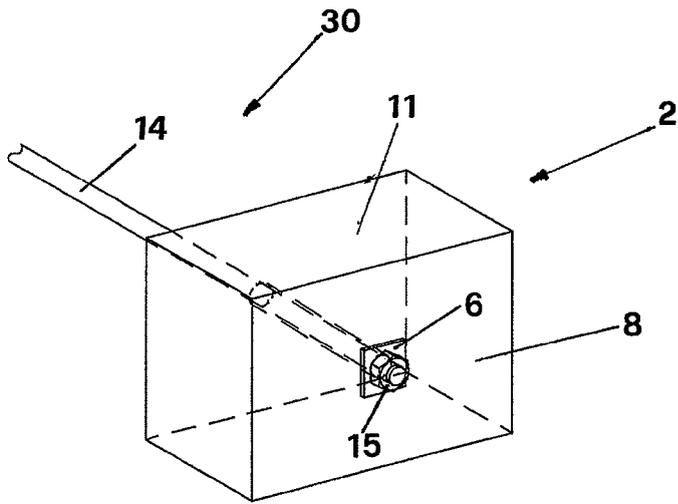


FIG. 3

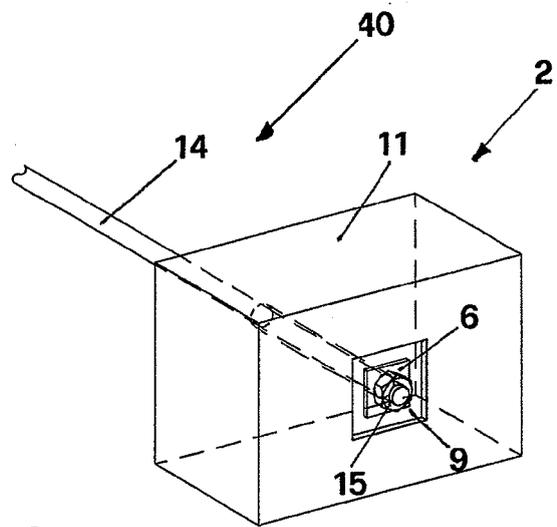


FIG. 4

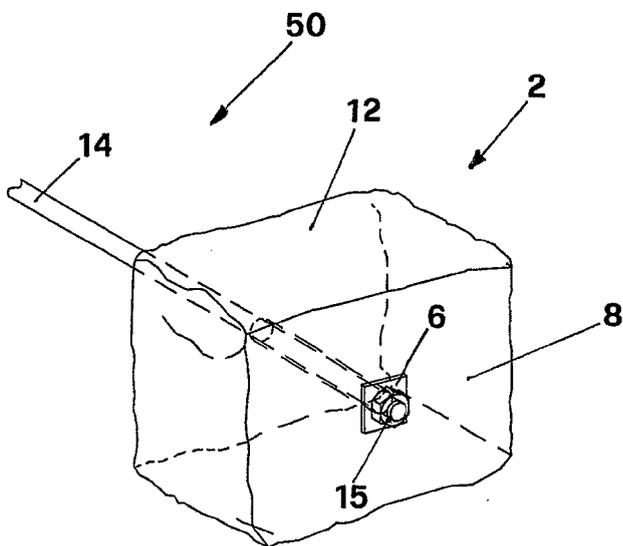


FIG. 5

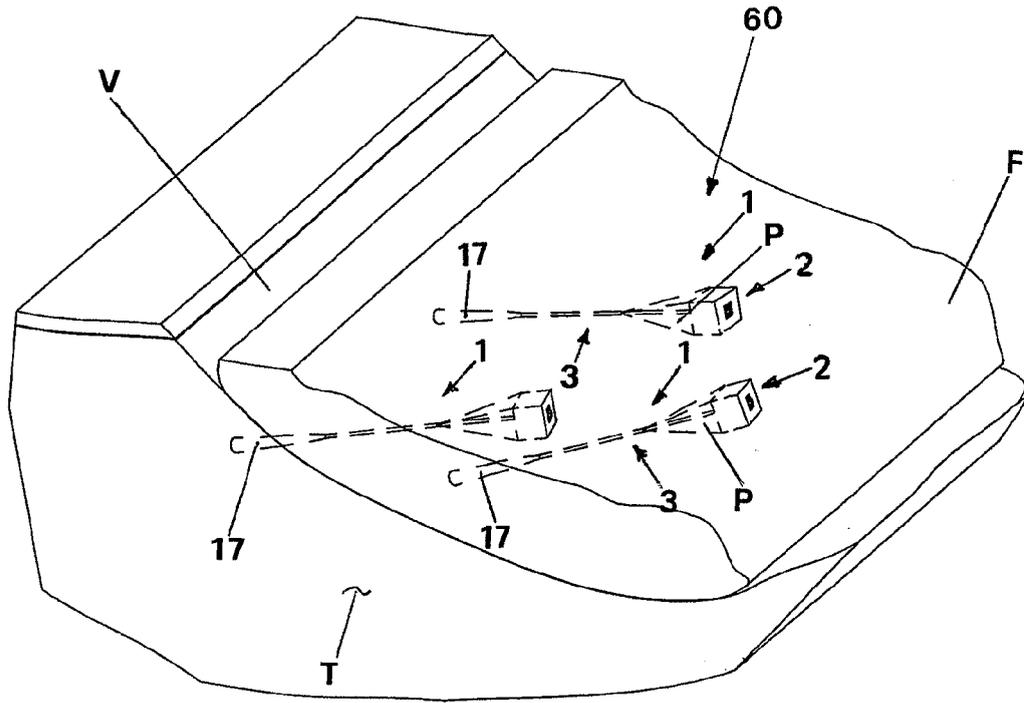


FIG. 6

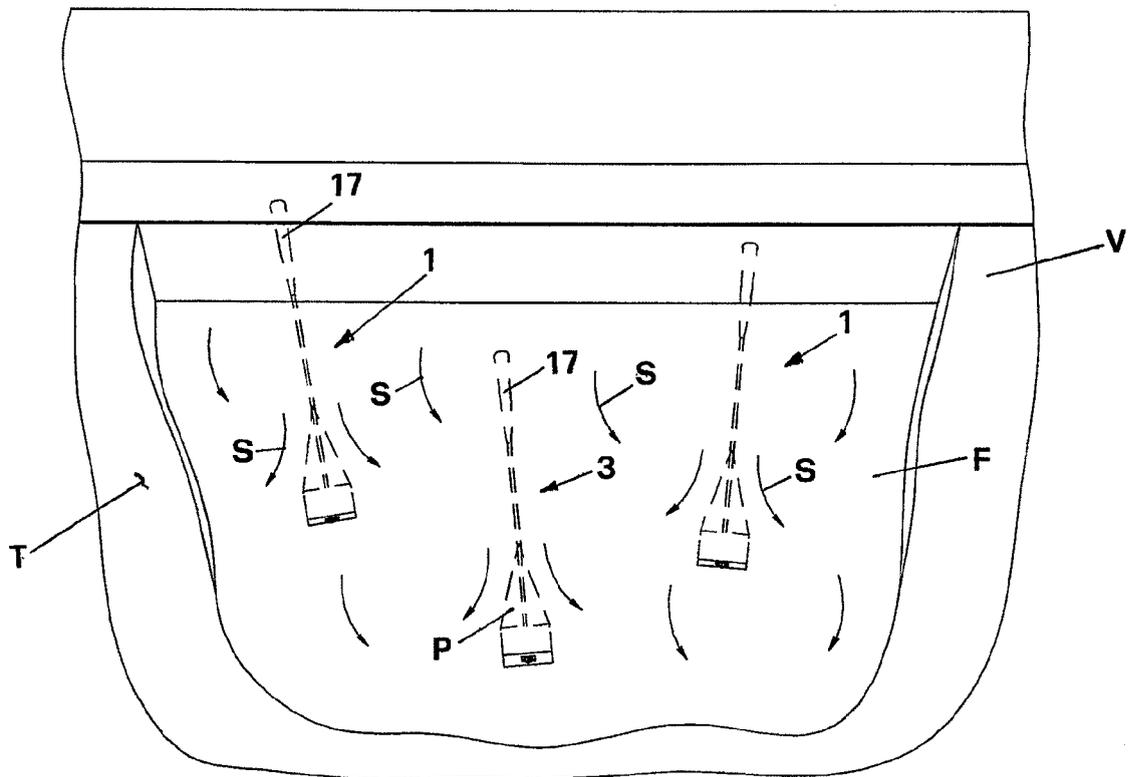


FIG. 7

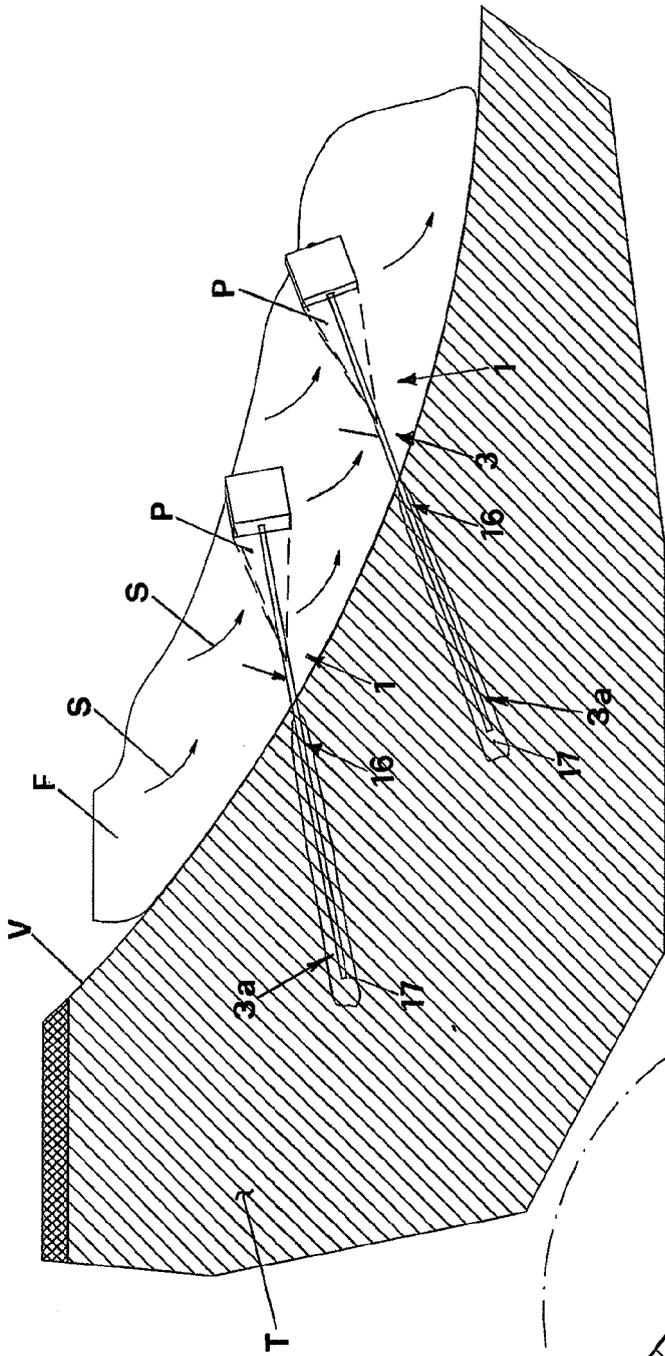


FIG. 8

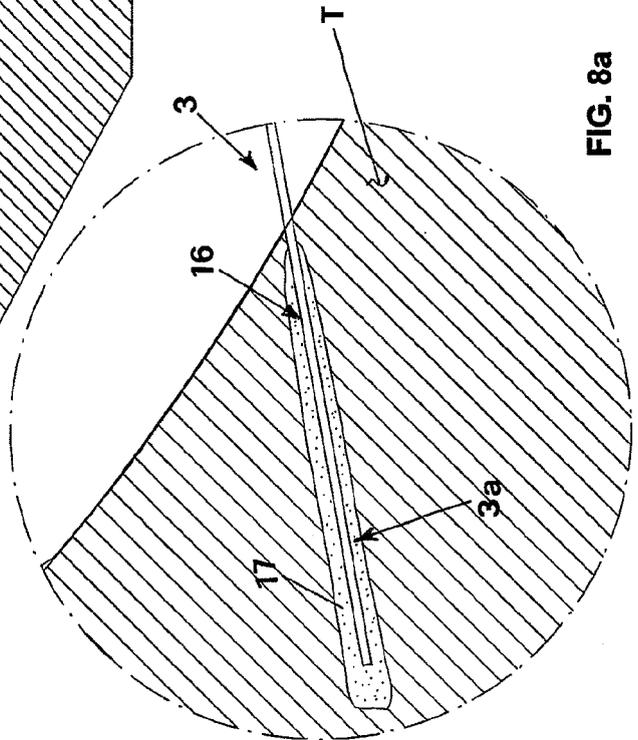


FIG. 8a

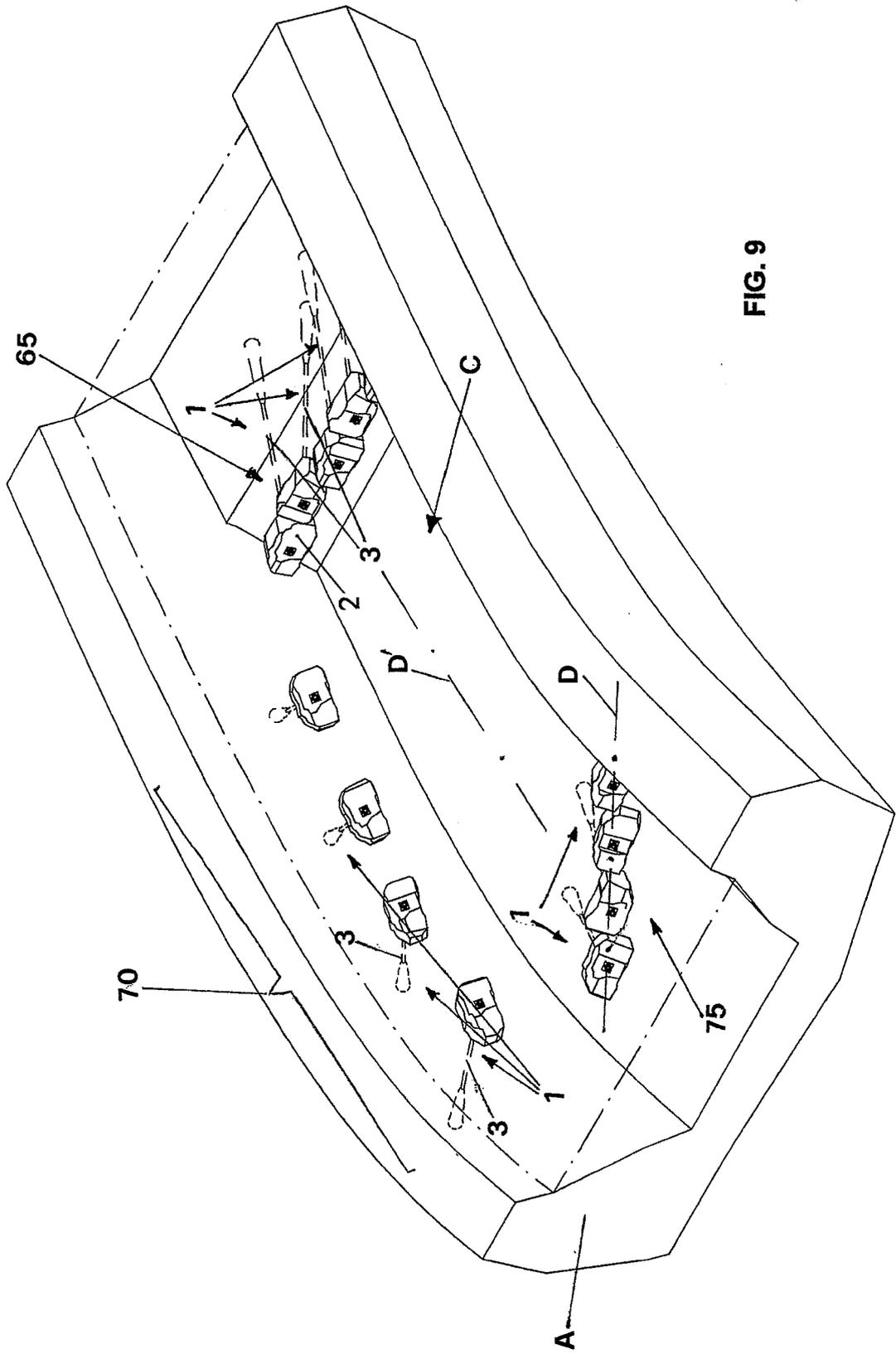


FIG. 9

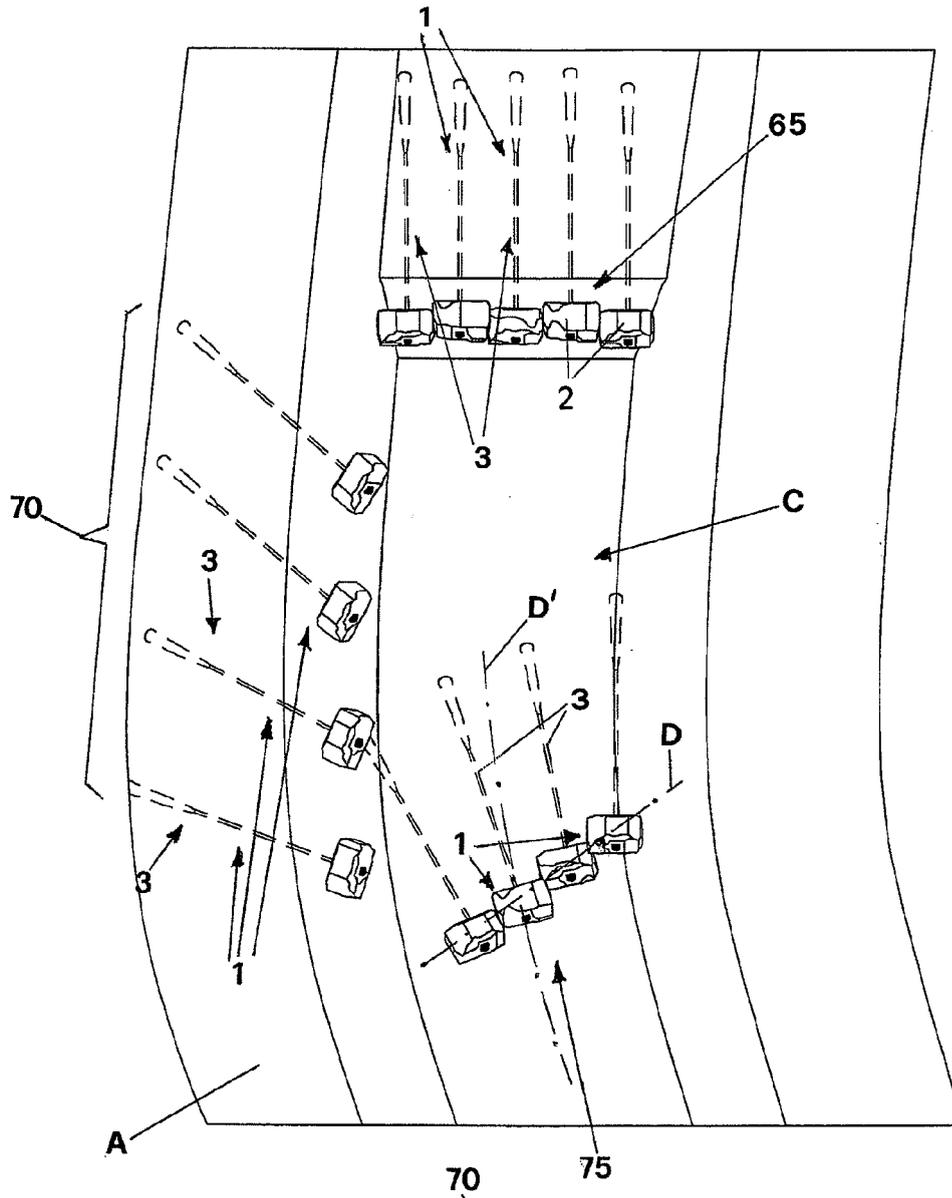


FIG. 10

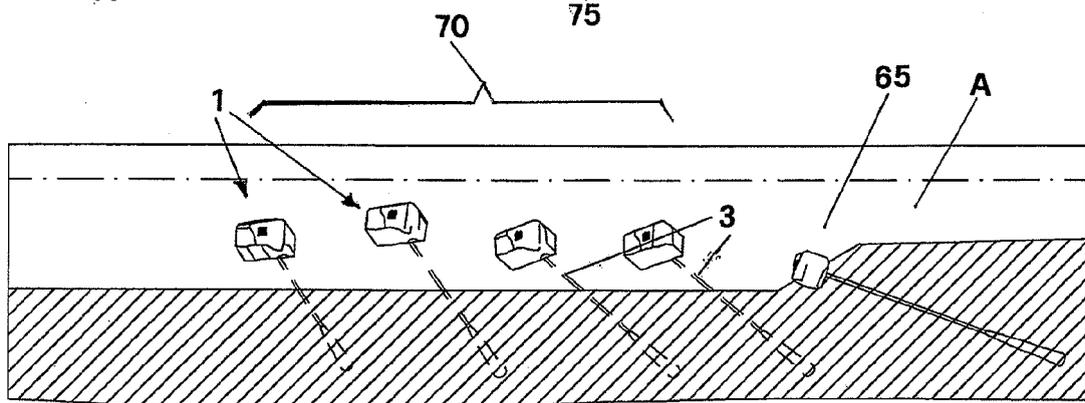


FIG. 11



EUROPEAN SEARCH REPORT

Application Number  
EP 11 15 3454

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Place of search		Date of completion of the search	Examiner
Munich		6 June 2011	Geiger, Harald
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06-06-2011

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**REFERENCES CITED IN THE DESCRIPTION**

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