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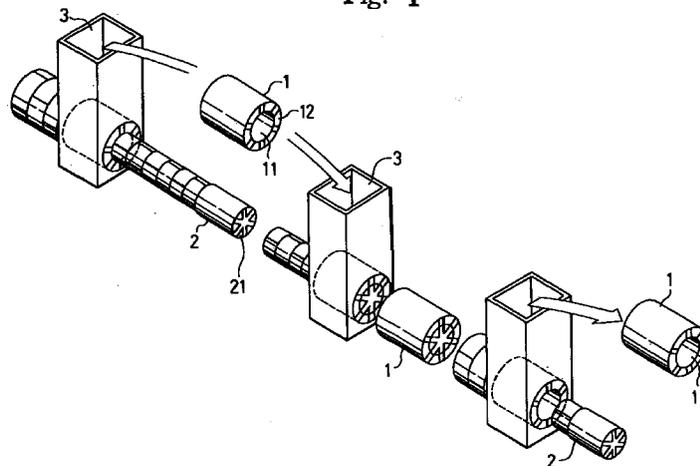
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(54) Method and apparatus of excavation for underground structures of variable cross sectional area

(57) A method and an apparatus of excavation for underground structures of variable cross sectional area are provided in which a shield excavator of large cross sectional area is used as a main machine (1), and another shield excavator of smaller cross sectional area than the main machine (1) is used as an auxiliary machine (2). That portion of the underground structure of large cross section is excavated using the main machine (1) with the auxiliary machine (2) housed inside thereof and operating jointly, and for that portion of the underground structure of small cross section, the

auxiliary machine (2) is advanced out of the main machine (1) and excavation proceeds with the auxiliary machine (2) only. Meanwhile, the main machine (1) is left on standby at the next portion of the structure of large cross section, and when the auxiliary machine (2) reaches that point, it is re-inserted into the main machine (1), and then excavation proceeds again using the main machine (1) with the auxiliary machine (2) housed inside and interlocked therewith for joint operation.

Fig. 1



Description

The invention relates to a method and an apparatus of excavation for underground structures of variable cross sectional area.

Depending on the circumstances at the respective purposes, the cross sectional area of an underground structure is not always constant and will vary at some points, for example in a subway system, underground shopping malls, underground water and sewer lines or water reservoirs. In a subway system, for example, the cross sectional area of the portion comprising the train tracks is narrow, whereas it is wider for the station concourse and then narrows again for the tracks leaving the station on the other side. This pattern is repeated over the length of a subway line. In a conventional construction method used in such a case a shield excavator is employed for the train tracks, whereas digging is used from the land surface down to the desired underground level for the corresponding stations.

In such a conventional excavation method as set forth above, the following problems arise:

- a) In order to construct a station, a continuous wall is built around the perimeter. Thereafter, the whole area is excavated and then protective plates must be laid over the excavation in order to enable traffic to pass by. This type of provisional construction entails enormous expenses.
- b) For the station portion, a huge amount of land must be excavated and removed which brings about severe limitations on construction in urban areas.
- c) When such a large amount of land is excavated, traffic is obstructed and buried facilities must be moved and/or protected. All these measures prolong the construction period and are not very economical.

The object underlying the present invention is to resolve the problems arising with conventional construction methods and to provide a method and an apparatus of excavation for underground structures of variable cross sectional area by means of which the amount of land required for excavation work is minimized in order to significantly reduce the time and expense required for provisional construction work.

This object is solved in an advantageous and satisfying manner with the method and the apparatus according to the invention as defined in the claims and set forth in the following specification.

According to the invention, a method and an apparatus are provided, wherein a shield excavator of large cross sectional area is used as a main machine, and another shield excavator of smaller cross sectional area than the main machine is used as an auxiliary machine. That portion of the underground structure having the large cross section is excavated using the main machine with the auxiliary machine housed inside

thereof, whereas for that portion of the underground structure of small cross section, the auxiliary machine is advanced out of the main machine and excavation proceeds with the auxiliary machine only. In the latter case, the main machine is left on standby at the next portion of the structure of large cross section, and when the auxiliary machine reaches that point, it is re-inserted into the main machine; thereafter, excavation proceeds again using the main machine with the auxiliary machine housed inside and propelled jointly.

While the following description relates to the construction of a subway system using the unique method and apparatus, the invention is by no means restricted to application in a subway system, but can be used to construct a large variety of constructions, including roadways, water and sewer lines, water reservoirs, shopping malls and other underground structures. Also, various shield excavators of differing shape in cross section have been developed recently and are in practical use. Hence, it should be noted that the invention is not restricted to underground structures having a circular cross section, but can be applied to various other structures comprising elliptical, oval, rectangular, and gourd-shaped cross sectional areas.

The invention will be explained in more detail below with reference to preferred embodiments and accompanying drawings which are only for the purpose of illustration without limiting the invention.

Fig. 1 a perspective and schematic view for explaining the concept of the method of excavation according to the invention;

Fig. 2 a perspective view illustrating a relative movement between a main machine and an auxiliary machine used in the method of excavation according to the invention;

Fig. 3 a sectional view of an excavation apparatus showing the main machine and the auxiliary machine in combination;

Fig. 4 a sectional view illustrating a situation in which the auxiliary machine is withdrawn from the main machine;

Fig. 5 a sectional view illustrating a situation in which the auxiliary machine is moved into the main machine provided in a stand-by position;

Fig. 6 a perspective and schematic view showing a modified concept of the method of excavation according to the invention; and

Fig. 7 to Fig. 15 various combinations of the main machine and the auxiliary machine using different geometrical configurations.

In the method and the apparatus according to the invention as shown in Fig. 1, a shield excavator with a cross sectional area virtually equal to the cross sectional area of a first portion in an underground structure, for example the station portion of a subway line, is used as a main machine 1.

The internal configuration of such a main machine 1 is virtually identical to that of a conventional shield excavator. As shown in Fig. 3, a shield jack 13 takes the reaction forces at a segment 14 assembled in the rear to propel the shield excavator forward. Also, a cutter 12 for boring into the ground is installed on the front face of the main machine 1.

Unlike conventional machines, however, the main machine 1 according to the invention is provided with a hollow cavern 11 used merely to house an auxiliary machine 2, as shown in Fig. 2. Accordingly, the hollow cavern 11 extends the full length of the main machine 1 from the front end to the tail end, wherein its inner shape is identical to the outer shape of the auxiliary machine 2. In other words, if the auxiliary machine 2 is cylindrical, then the hollow cavern 11 is a cylindrical space.

Moreover, the tube-shaped hollow cavern 11 in the main machine 1 opens at the front face of the main machine 1. Accordingly, the cutter 12 provided at the front of the main machine 1 is not a solid circular disk, rather its center is cut away to the same dimension as the cross section of the hollow cavern 11 to form the ring cutter 12. Such a component is shown, for example, in Fig. 1 of the drawings.

A shield excavator with a cross sectional area of virtually the same small cross sectional area of the underground structure, for example, the track portion of the subway line, is used as the auxiliary machine 2, as shown in Fig. 1. In other words, the outer diameter of the auxiliary machine 2 is virtually equal to the cross sectional area of this portion of small cross sectional area of the underground structure, for example the track portion of the subway; at the same time, the outer diameter of the auxiliary machine 2 is equal to the inner diameter of the hollow cavern 11 of the main machine 1.

The internal configuration of the auxiliary machine 2 is virtually identical to that of a conventional shield excavator. As shown in Fig. 4, a shield jack 22 takes the reaction forces at a segment 23 assembled in the rear to propel the shield excavator forward. Also, a cutter 21 for boring into the ground is installed on the front face of the excavator forming the auxiliary machine 2.

Contrary to the cutter 12 of the main machine 1, the cutter 21 of the auxiliary machine 2 is formed as a disk, in particular a circular disk. In such a construction, the outer edge of the cutter 21 can interlock with the ring cutter 12 of the main machine 1 such that the two cutters 12 and 21 rotate as a monolithic unit.

It is appropriate that the auxiliary machine 2 uses its own jack 22, and a segment 23 of virtually the same dimension as the auxiliary machine 2 is assembled at the rear of the machine. That jack 22 takes the reaction forces at this segment 23 when the auxiliary machine 2

can move forwardly independently of the main machine 1.

As mentioned above, the diameter of a station portion of a subway is larger than the diameter of the track portion; hence, the station portion is excavated by means of the main machine 1 with the auxiliary machine 2 housed inside thereof and cooperating therewith. For this purpose, the disk cutter 21 of the auxiliary machine 2 is interlocked with the inner circumference of the ring cutter 12 of the main machine 1, and the two cutters 12 and 21 rotate together as a monolithic unit.

The concept of the method and the apparatus according to the invention will be explained in more detail with reference to Fig. 1 of the drawings. At those points where the cross sectional area of the underground structure changes from the large cross sectional area to the smaller cross sectional area and vice versa, a vertical shaft 3 is pre-built at the respective end of the large cross sectional area portion, for example a station portion. That is, when excavation of the station portion with the main machine 1 is completed, it advances into the shaft 3. At this point, excavation shifts to the track portion of smaller cross section. For this purpose, the operation of the main machine 1 is stopped inside the shaft 3, and the auxiliary machine 2 is withdrawn from its hollow cavern 11. This situation is shown in a diagrammatic manner in Fig. 2 and Fig. 3 and Fig. 4 of the drawings.

As shown in the drawings, a group of segments to take the reaction force is required to launch the auxiliary machine 2 out of the main machine 1. Hence, a reaction force bearing block is set inside the main machine 1 within which the segments are assembled. The jack presses against the segments to propel the auxiliary machine 2 forward. Thereafter, only the auxiliary machine 2 is used to excavate the portion of smaller cross sectional area, for example the track portion up to the next station.

As indicated in Fig. 1 of the drawings, the main machine 1 from which the auxiliary machine 2 has been withdrawn, remains inside the shaft 3 and is then pulled up to the surface. Then, the main machine 1 is transported over land to the start of the next portion of large cross sectional area, in particular the next station portion. At that point, the main machine 1 is lowered down another pre-built shaft 3 where it remains on standby until the arrival of the auxiliary machine 2. This situation is shown, for example, in Fig. 5 of the drawings. The transport and standby action is repeated in sequence for each of the shafts 3 provided along the underground construction.

In a first embodiment according to the invention, the main machine 1 is transported in one piece as indicated in Fig. 1. However, the invention is not limited to such a concept, rather the main machine needs not be transported in one piece. It can be temporarily dismantled into several segments which are then carried to the next shaft where the main machine 1 is reassembled. This situation is shown, for example, in Fig. 6 of the draw-

ings.

In the meantime, the auxiliary machine 2 completes excavation of the portion of smaller cross sectional area, for example the track portion, and arrives at the shaft 3 of the next station, see Fig. 5 of the drawings. It is then inserted into the hollow cavern 11 of the main machine 1 which has been on standby. At this point, the main machine 1 and the auxiliary machine 2 become immediately a monolithic unit which is used to excavate another station portion of larger diameter than the portion of the tracks.

Such a configuration enables an immediate adjustment to a change in the cross section area of the portion being excavated. When the combined apparatus comprising the main machine 1 and the auxiliary machine 2 reaches the end of the station portion where the cross sectional area is reduced again to that of the jack portion, the auxiliary machine 2 is launched out of the main machine 1. These processes are then repeated over the length of the whole underground construction, for example the subway line.

The above description has been made with respect to an example of the excavation for a subway system having a circular cross section. However, as mentioned above, the cross section needs not be circular. Rather, various types of non-cylindrical shield excavators have already been developed and are in practical use, and the invention and the apparatus according to the invention can readily be applied to such shields. Also, while the above example relates to the excavation of the station and track portions of a subway, the invention is by no means restricted to a subway. Rather, it can be applied to the excavation of any other types of underground structures of variable cross sectional area.

Hence, the main machine 1 and the auxiliary machine 2 can be used in various combinations as explained hereinafter. The technology and devices used in excavating elliptical, rectangular, oval, horseshoe-shaped and other tunnels of variable cross section employ copy cutters, swing cutters, planet cutters and other cutters which are known as such so that a detailed explanation is omitted here. Such combinations and configurations will be explained shortly with reference to Fig. 7 to Fig. 15 of the drawings. In this connection, the black portions identified by the reference signs 31 in Fig. 7 to Fig. 15 represent telescopic cutters.

Fig. 7 shows a constellation using a circular main machine 1 in which an auxiliary machine 2 is housed having an elliptical shape in cross section.

Fig. 8 shows a constellation with an elliptical main machine 1 housing a circular auxiliary machine 2.

In the constellation according to Fig. 9, the main machine 1 has a circular shape, whereas the shape of the auxiliary machine 2 is rectangular.

Fig. 10 shows a configuration where the main machine 1 is of rectangular cross section, whereas the auxiliary machine 2 housed therein has a circular shape.

Fig. 11 shows a configuration where the main

machine 1 is of rectangular shape, wherein an auxiliary machine 2 of rectangular shape is housed therein.

Fig. 12 shows a configuration where the main machine 1 has an elliptical shape, and the auxiliary machine 2 housed therein has also an elliptical shape.

Fig. 13 shows a specific configuration where the main machine 1 is crescent-shaped, whereas the auxiliary machine 2 is of circular shape.

Fig. 14 shows another specific configuration where the main machine 1 is of elliptical shape, whereas two auxiliary machines 2 of cylindrical shape are housed therein.

Finally, Fig. 15 shows a configuration where the main machine 1 is of circular shape, wherein the auxiliary machine 2 is also of circular shape but mounted in an excentric manner.

With the method and the apparatus according to the invention, various advantages can be achieved when excavating the ground for an underground structure of variable cross section.

a) Excavation for an underground structure for which the cross section changes repeatedly from a first shape to another shape can be performed using one main machine 1 and one auxiliary machine 2 which can be housed one inside of the other. Therefore, excavation can be carried out in an extremely economical manner.

b) Excavation in such a case requires only a narrow vertical shaft 3 to be built at those points where the cross section changes from the large cross section to the smaller cross section and vice versa. This eliminates the need of digging the portions of large cross sectional area from the surface to underground. Therefore, the method and the apparatus according to the invention are particularly suitable for urban centers where land usage is highly limited.

c) The main machine 1 can be left on standby at the shaft 3 where the auxiliary machine 2 will arrive. When the auxiliary machine 2 has arrived, it can readily be housed inside the hollow cavern 11 of the main machine 1, and immediately thereafter excavation can proceed with the main machine 1 and the auxiliary machine 2 interlocked with each other as a monolithic unit. In other words, interlocking of the main machine 1 and the auxiliary machine 2 or the separation of the main machine 1 from the auxiliary machine 2 can readily be performed, requiring no special operation and no huge space, which results in a good efficiency.

d) Excavation of the large cross section tunnel can start immediately after the auxiliary machine 2 has been inserted into the main machine 1 which is on standby. On the other hand, excavation of the small cross section tunnel can start just by removing the auxiliary machine 2 from the main machine 1. This efficiency is possible because of a configuration in which the main machine 1 is on standby waiting for

the arrival of the auxiliary machine 2. In any case, excavation proceeds by inserting the auxiliary machine 2 into or withdrawing it from the main machine 1. Due to this rapid change in operating cross section, the method and the apparatus according to the invention are outstanding over conventional techniques.

Claims

1. A method of excavation for underground structures of variable cross sectional area, in which

- a shield excavator of large cross sectional area is used as a main machine (1); and
- another shield excavator of smaller cross sectional area than the main machine (1) is used as an auxiliary machine (2);

wherein that portion of the underground structure of large cross section is excavated using the main machine (1) with the auxiliary machine (2) housed inside and operating jointly, whereas for that portion of the underground structure of small cross section, the auxiliary machine (2) is advanced out of the main machine (1) and excavation proceeds with the auxiliary machine (2) only;

and wherein meanwhile the main machine (1) is left on standby at the next portion of the structure of large cross section, and when the auxiliary machine (2) reaches this starting point of the next portion, it is re-inserted into the main machine (1), then excavation proceeds again using the main machine (1) with the auxiliary machine (2) housed inside.

2. The method according to claim 1, wherein a vertical shaft (3) is built at the respective points at which the cross sectional area of the underground structure changes, and wherein the main machine (1) without the auxiliary machine (2) is left on standby at a corresponding shaft (3) at the starting point of the next portion of the structure of large cross section, and when the auxiliary machine (2) reaches that point, it is re-inserted into the main machine (1), whereupon excavation proceeds again using the main machine (1) with the auxiliary machine (2) housed inside.

3. The method according to claim 1 or 2, wherein the main machine (1) without the auxiliary machine (2) is disassembled and transported to the site of the next portion of the structure of large cross section, where it is reassembled and left on standby at a corresponding shaft (3), and when the auxiliary machine (2) reaches that point, it is re-inserted into the main machine (1), whereupon excavation proceeds again using the main machine (1) with the auxiliary machine (2) housed inside.

4. The method according to any of claims 1 to 3, wherein a shield excavator of a cross sectional area virtually equal to the cross sectional area of a station portion of a subway system is used as the main machine (1),

wherein another shield excavator of a cross sectional area virtually equal to the track portion of the subway system is used as an auxiliary machine (2), and wherein a vertical shaft (3) is built at the respective points at which the cross sectional area of the underground structure changes,

wherein the length of the station portion is excavated using the main machine (1) with the auxiliary machine (2) housed inside,

and whereas for the length of the track portion of the subway system the auxiliary machine (2) is advanced out of the main machine (1) and excavation proceeds with the auxiliary machine (2) only, and wherein the main machine (1) without the auxiliary machine (2) is pulled to the surface, transported to the next station site at a corresponding shaft (3) and lowered underground where it is left on standby, and when the auxiliary machine (2) reaches that point, it is re-inserted into the main machine (1), whereupon excavation proceeds again using the main machine (1) with the auxiliary machine (2) housed inside.

5. An apparatus of excavation for underground structures of variable cross sectional area, comprising

- a first shield excavator of large cross sectional area forming a main machine (1),
- a second shield excavator of smaller cross sectional area than the first excavator, forming an auxiliary machine (2),
- wherein the auxiliary machine (2) is adapted to be mounted inside of the main machine (1) and to be interlocked therewith to form a monolithic unit,
- and wherein the auxiliary machine (2) is retractable from the main machine (1) so that the auxiliary machine (2) is operable as a single unit and the main machine (1) may be removed.

6. The apparatus according to claim 5, wherein the main machine (1) comprises a hollow cavern (11) with a given inner cross section and wherein the auxiliary machine (2) comprises an outer configuration complementary in cross section and adapted to be releasably insertable into the hollow cavern (11) to be housed therein.

7. The apparatus according to claim 5 or 6, wherein each of the main machine (1) and the auxiliary machine (2) is provided with an own cutter (12, 21) and wherein the auxiliary machine (2) is operable

as a single unit or jointly with the main machine (1).

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Fig. 1

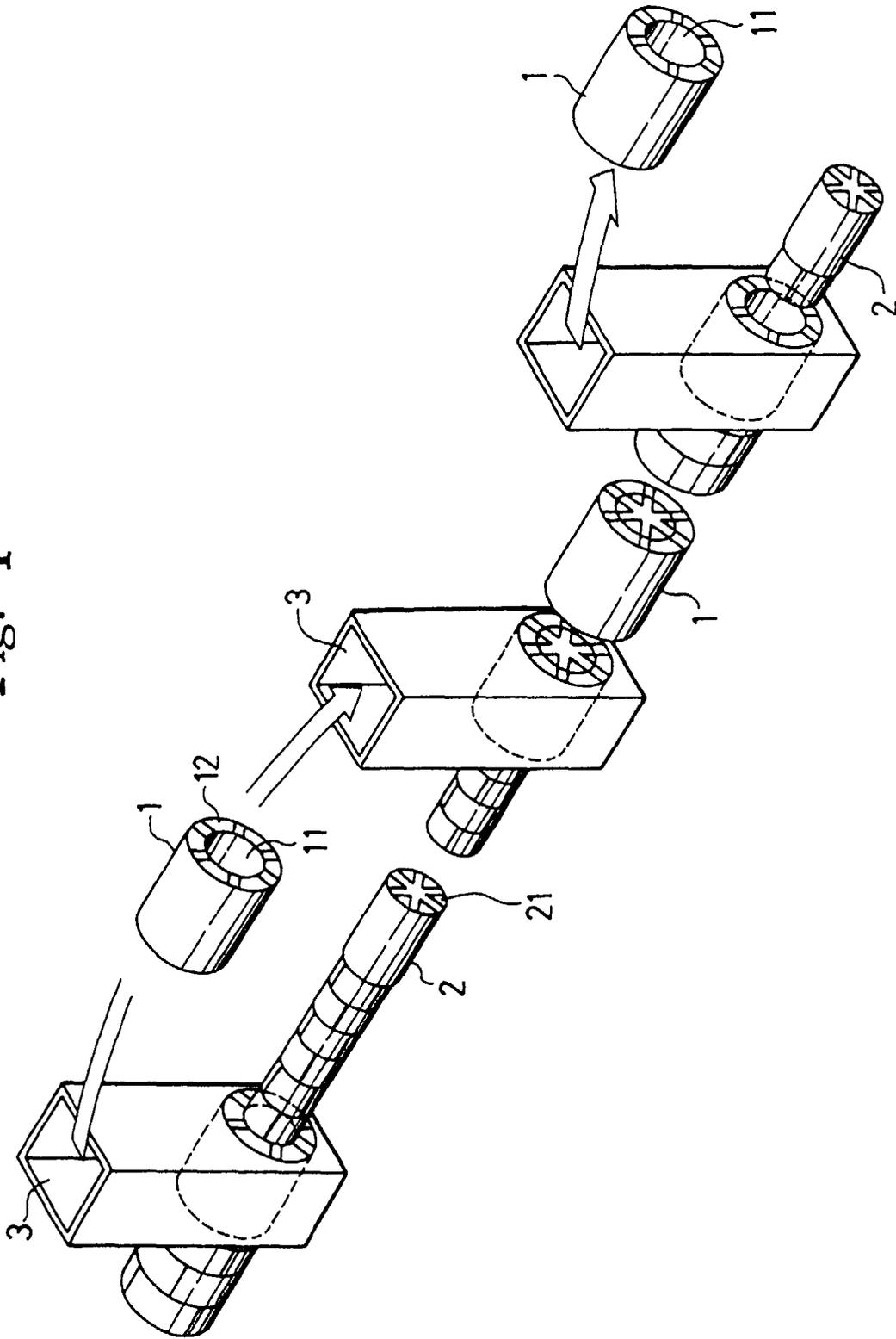


Fig. 2

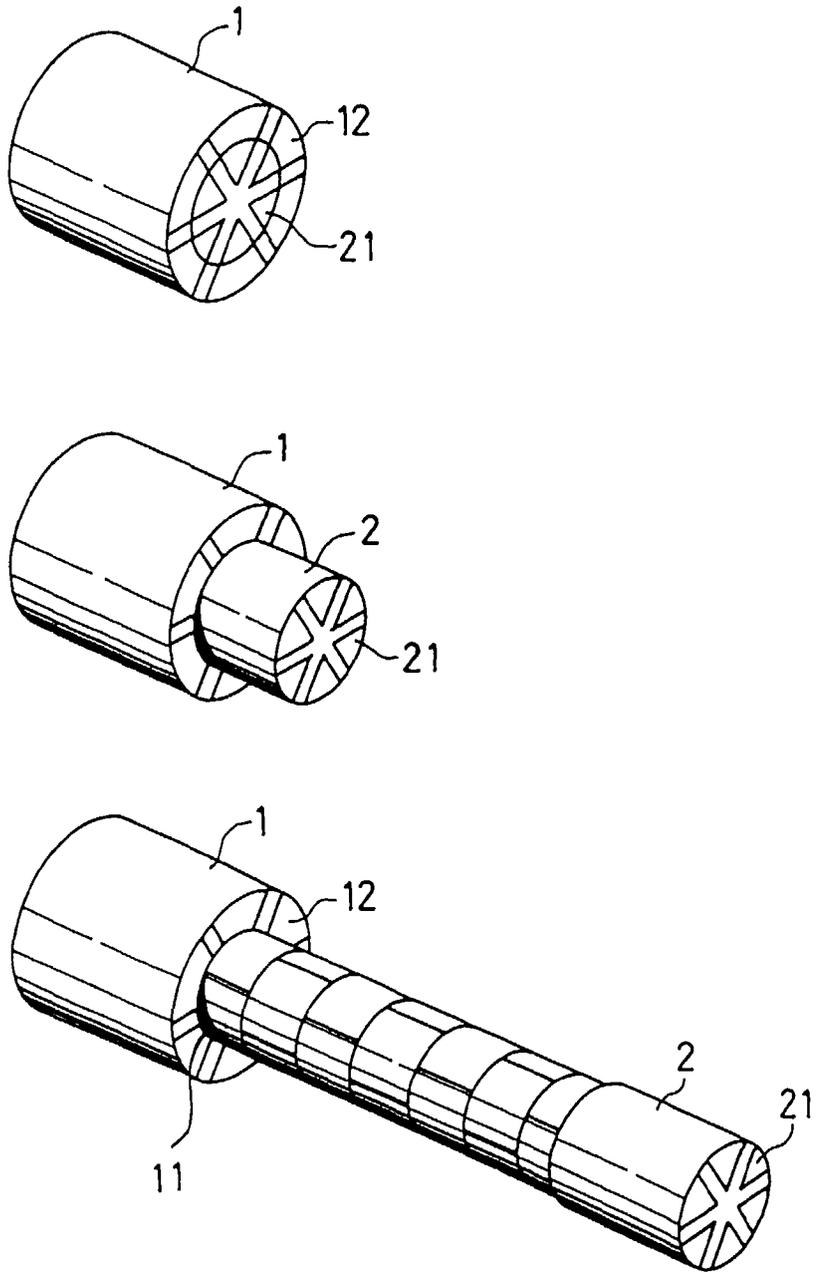


Fig. 3

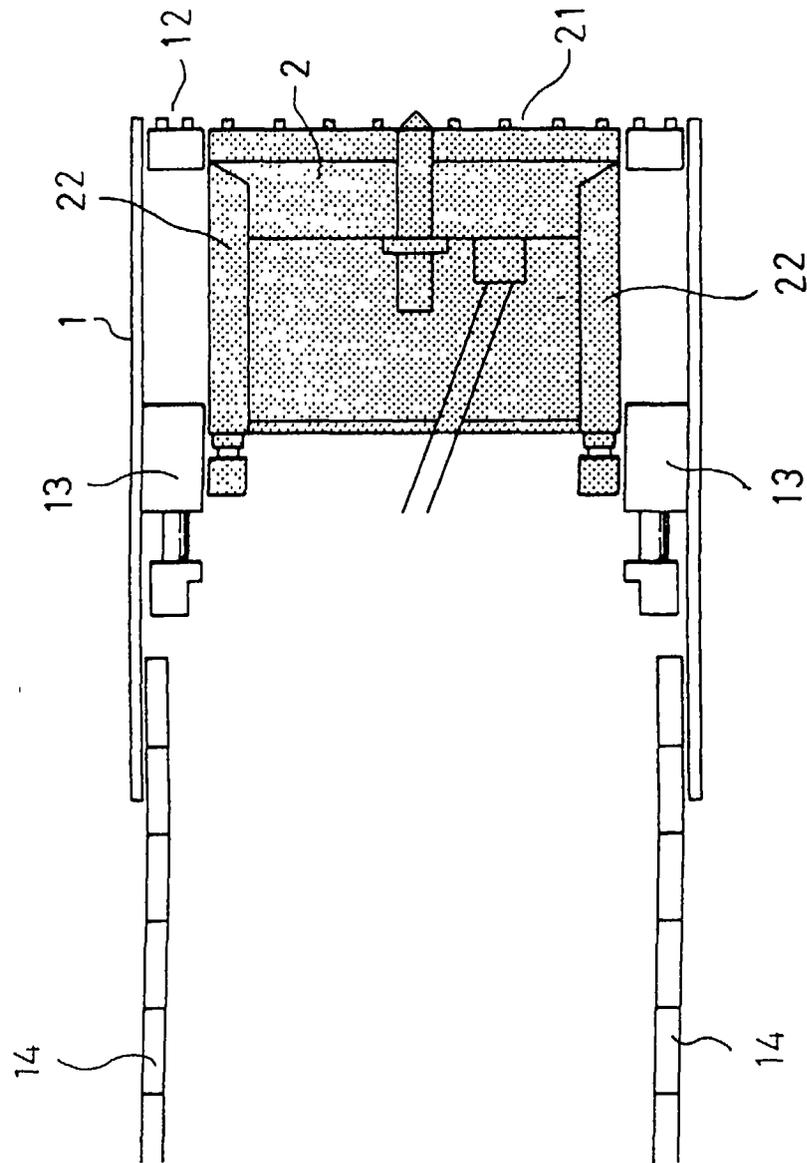


Fig. 4

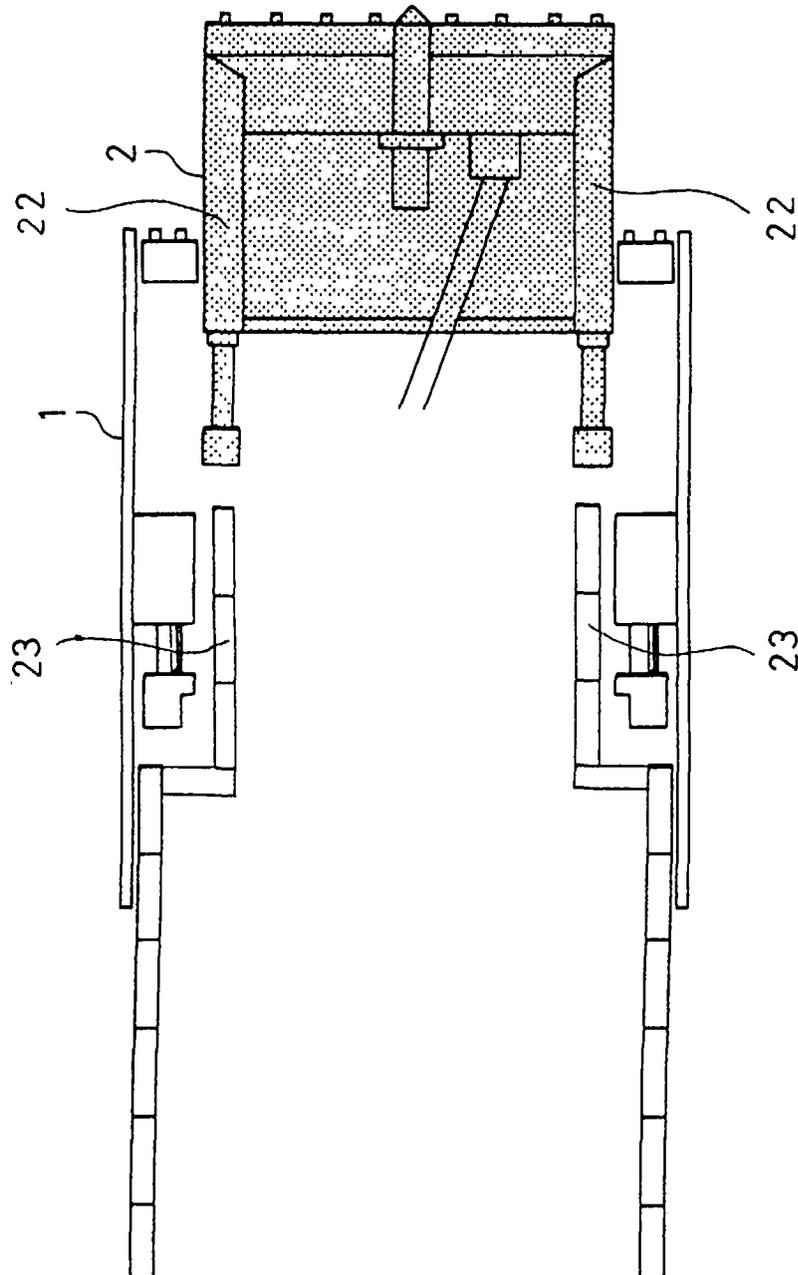


Fig. 5

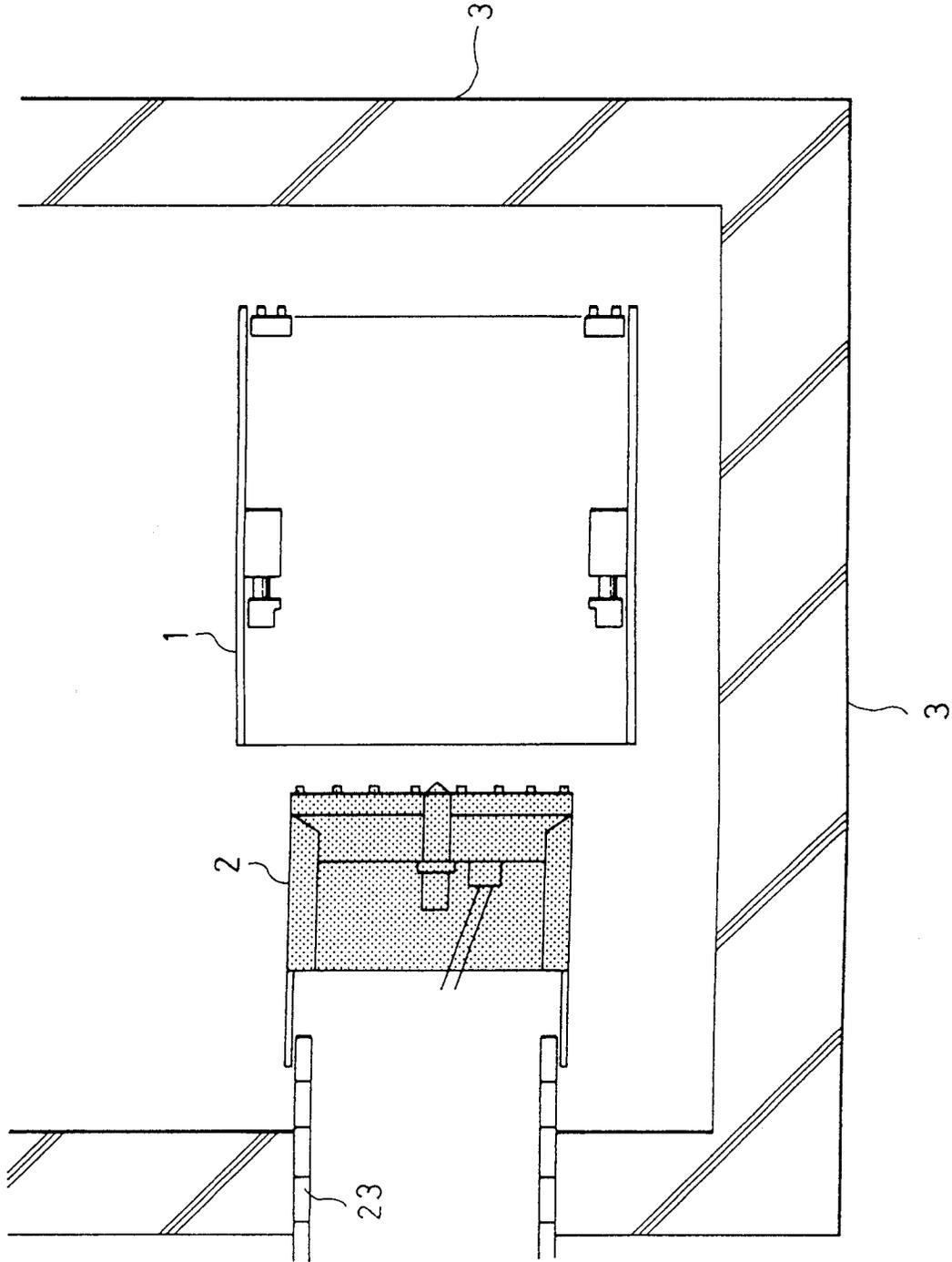


Fig. 6

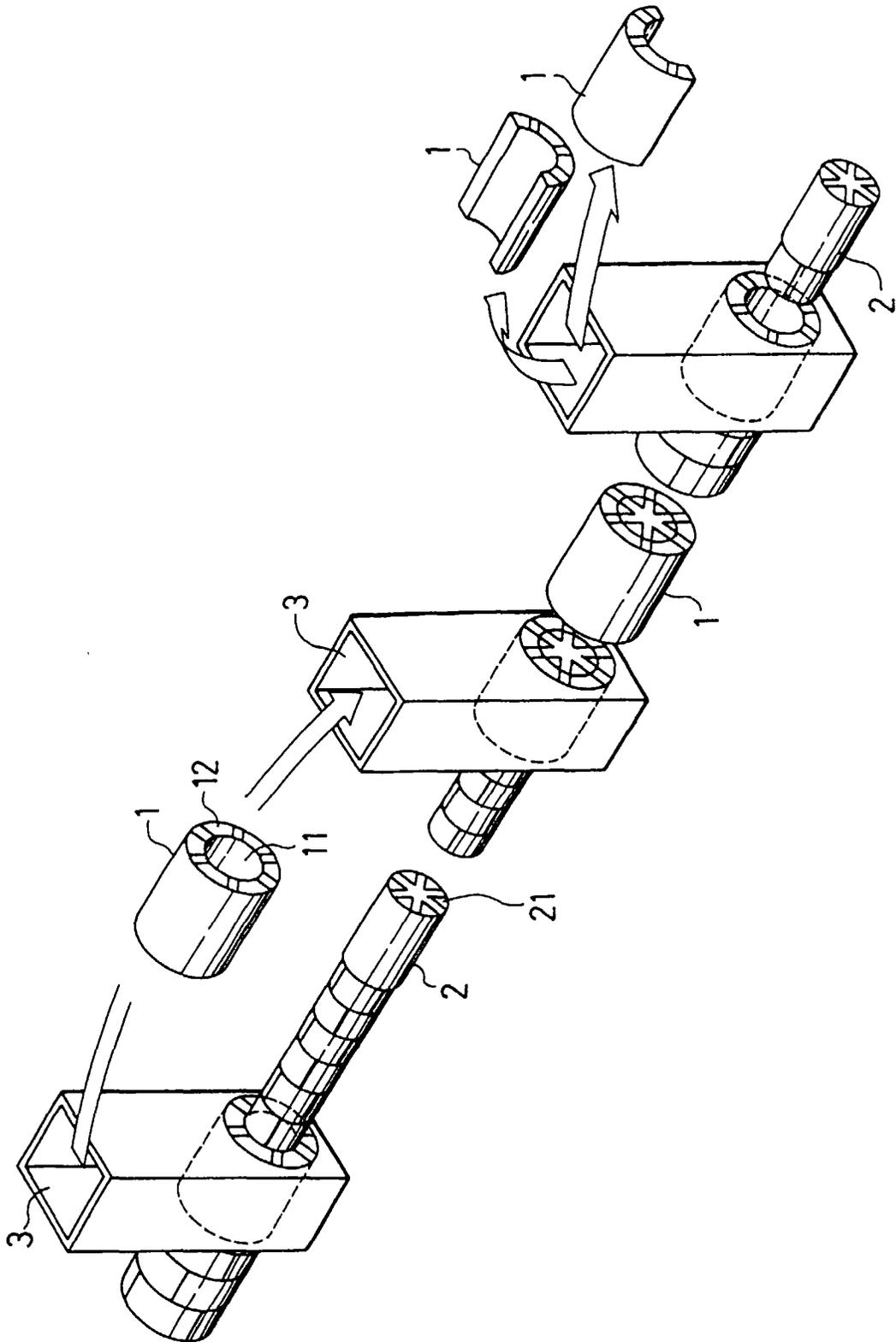


Fig. 7

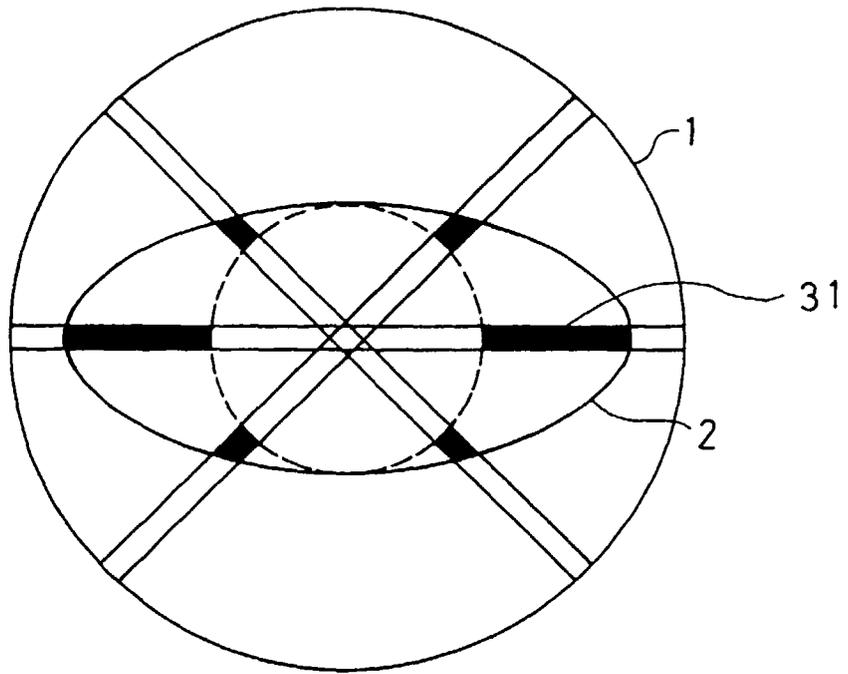


Fig. 8

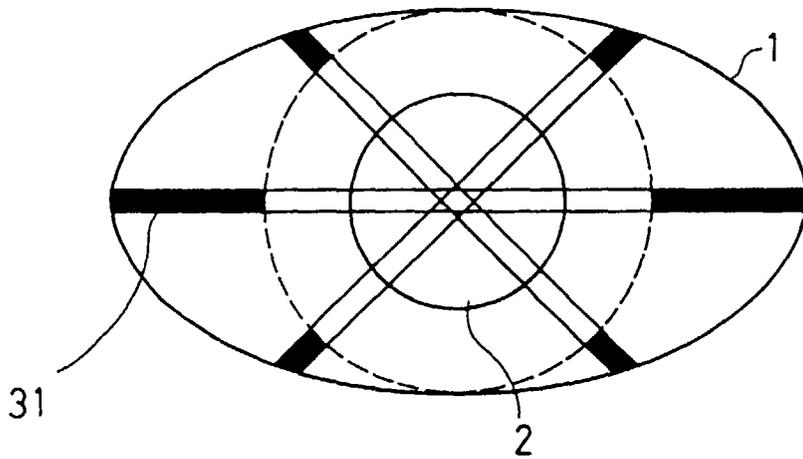


Fig. 9

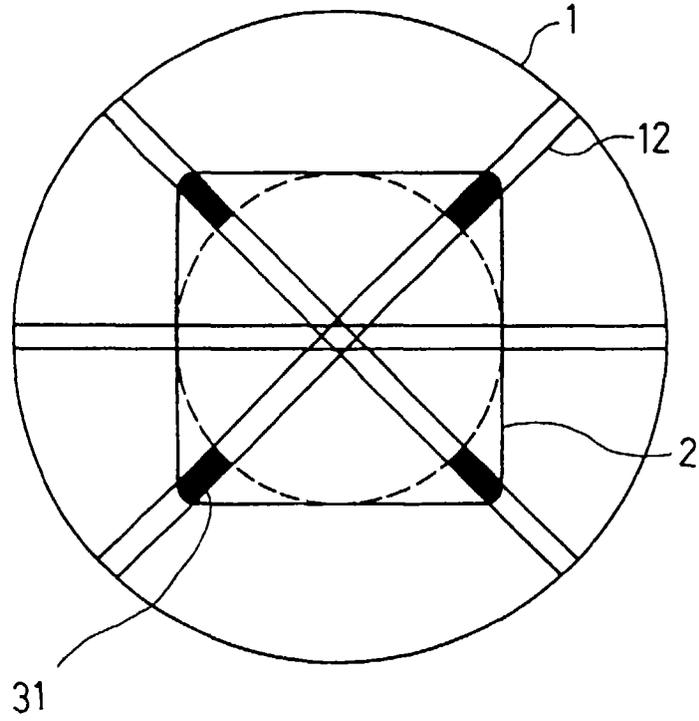


Fig. 10

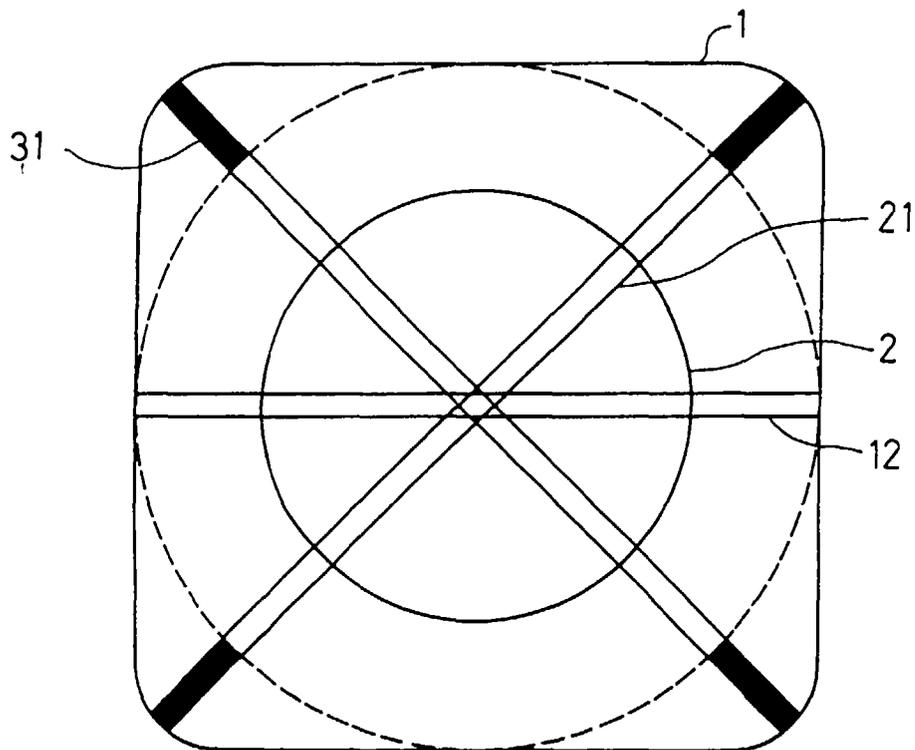


Fig. 11

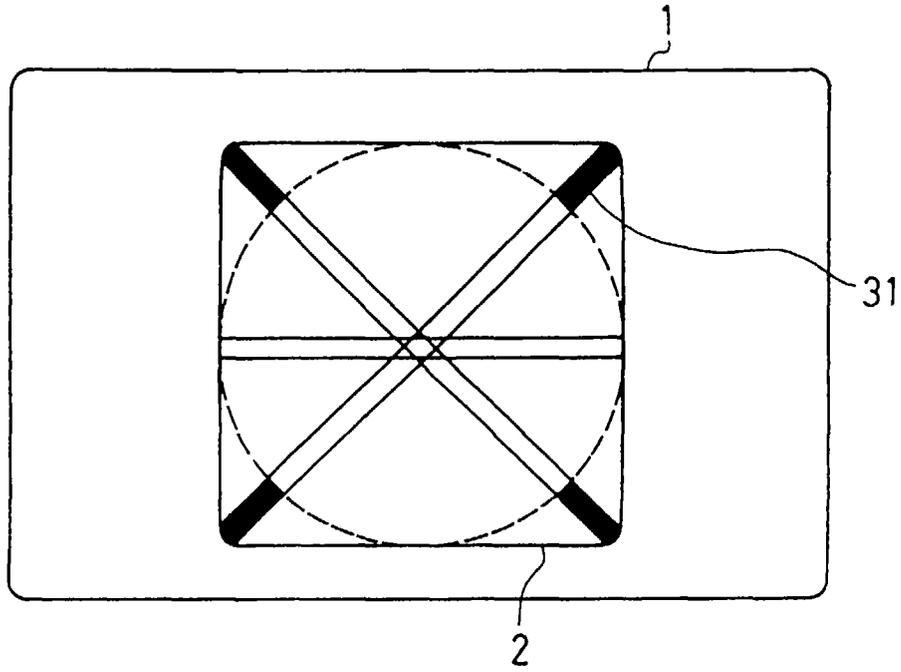


Fig. 12

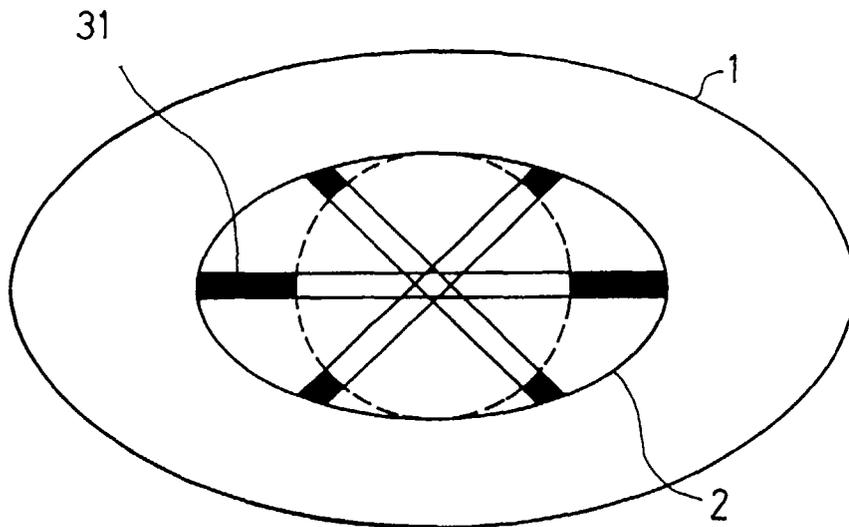


Fig. 13

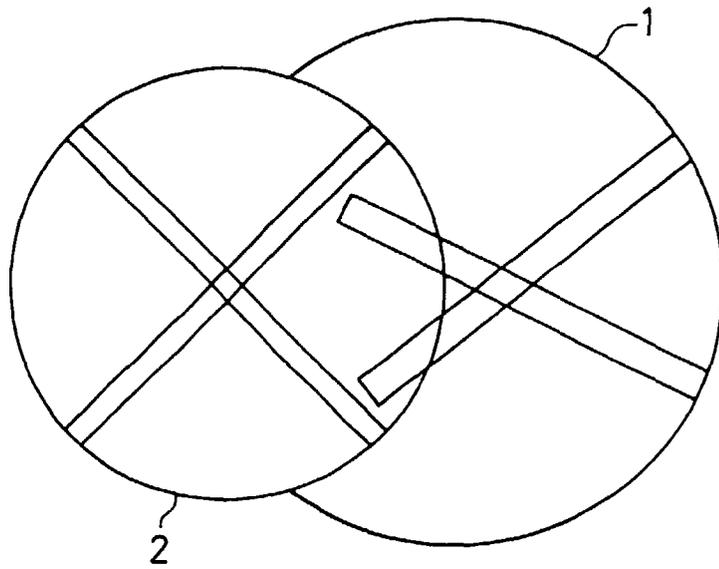


Fig. 14

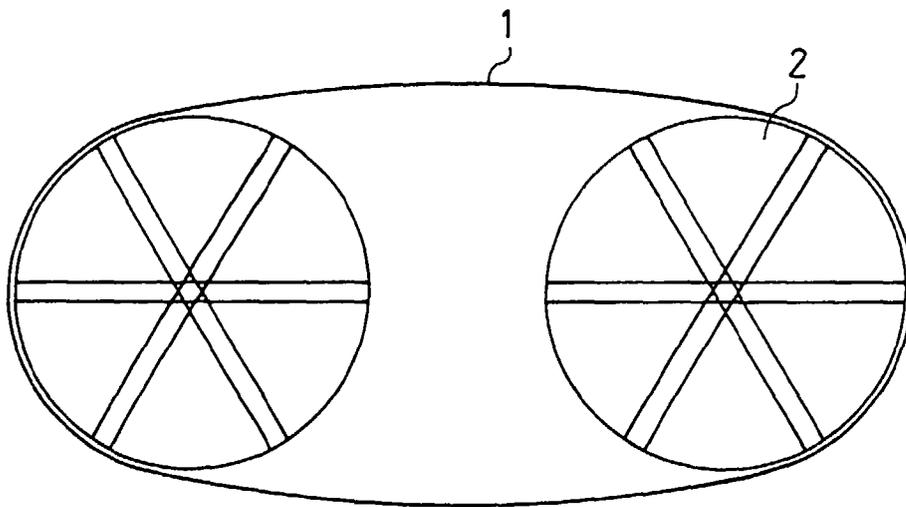
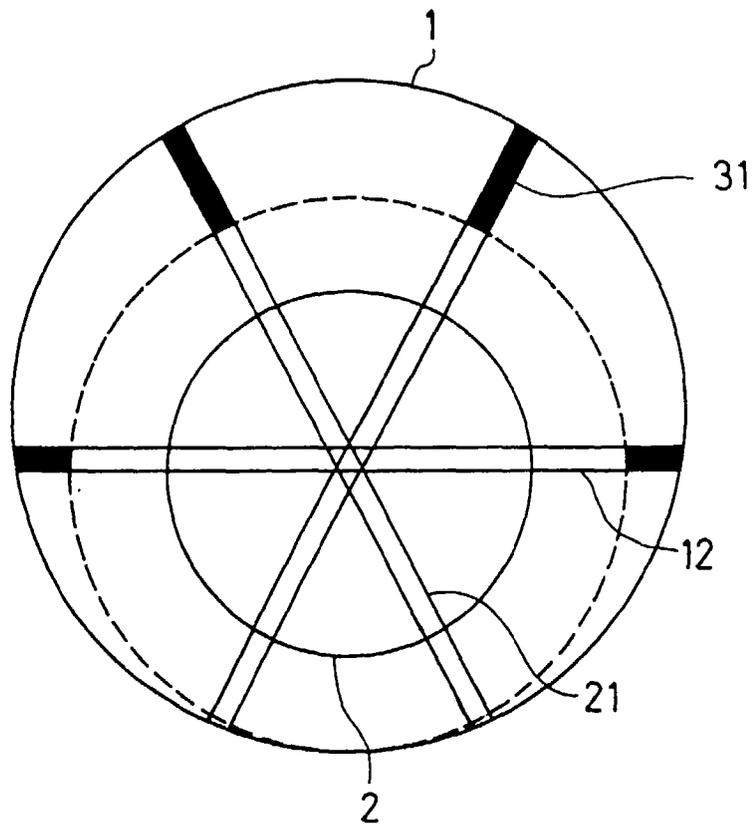


Fig. 15





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 96 11 0771

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)
A	PATENT ABSTRACTS OF JAPAN vol. 014, no. 510 (M-1045), 8 November 1990 & JP 02 210189 A (SHIMIZU CORP), 21 August 1990, * abstract *	1-7	E21D9/10 E21D9/08
A	PATENT ABSTRACTS OF JAPAN vol. 016, no. 487 (M-1323), 9 October 1992 & JP 04 179796 A (TEITO KOUSOKUDO KOUTSUU EIDAN), 26 June 1992, * abstract *	1,5	
A	US 3 480 327 A (MATSUSHITA KUNIJIRO) 25 November 1969 * the whole document *	1,4-7	
A	US 5 221 160 A (AZUMA YOUJI ET AL) 22 June 1993 * figures 1-3 *	1,5	
A	EP 0 384 065 A (ZAIDAN HOHJIN DOBOKU KENKYU CE ;KOBE STEEL LTD (JP)) 29 August 1990 * figures 1-13 *	1,5	TECHNICAL FIELDS SEARCHED (Int.Cl.6) E21D
A	US 2 864 600 A (M.B. KIRKPATRICK) * claim 1; figures 1,2 *	1,5	
A	GB 2 001 684 A (MOWLEM & CO LTD J) 7 February 1979 * abstract; figures *	1,5	
A	GB 961 295 A (BADE & CO GMBH)		
A	US 3 639 006 A (STEIFMEHL WILLI) 1 February 1972		
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 25 March 1997	Examiner Fonseca Fernandez, H
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	



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Application Number
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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)
A	US 3 643 998 A (T.N. WILLIAMSON) -----		
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	25 March 1997	Fonseca Fernandez, H	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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