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(71) Applicant
Howaldtswerke-Deutsche Werft Aktiengesellschaft

(Incorporated in the Federal Republic of Germany)

**Werftstrasse 112-114, D-2300 Kell 14,
Federal Republic of Germany**

(72) Inventor
Helmut Rosler

(74) Agent and/or Address for Service
**Potts Kerr & Co
15 Hamilton Square, Birkenhead, Merseyside,
L41 6BR, United Kingdom**

(54) Shield tunnelling apparatus

(57) In a shield tunnelling apparatus which includes a feed shield body (4) having a fixed bulkhead partitions (5) and a rotatable cutting wheel (6), a pressure bulkhead (10), which cannot rotate but which can be moved axially and angled, is located between the bulkhead partition (5) and the cutting wheel (6). It serves to support the face and to meter the volume of loosened material which passes between the cutter bars of cutting wheel (6) into extraction area (19) and from there is taken away by a continous conveyor (9). In the case in which the pressure bulkhead (10) is pushed up to the cutting wheel (6), the provision of service openings in the pressure bulkhead (10) also make it possible for work to be carried out in safety on the cutter bars.

In an embodiment with a hydraulic shield, which has an additional baffle and a pressurized space between baffle and pressure bulkhead, pressure bulkhead 10 is movable between the baffle and the cutting wheel.

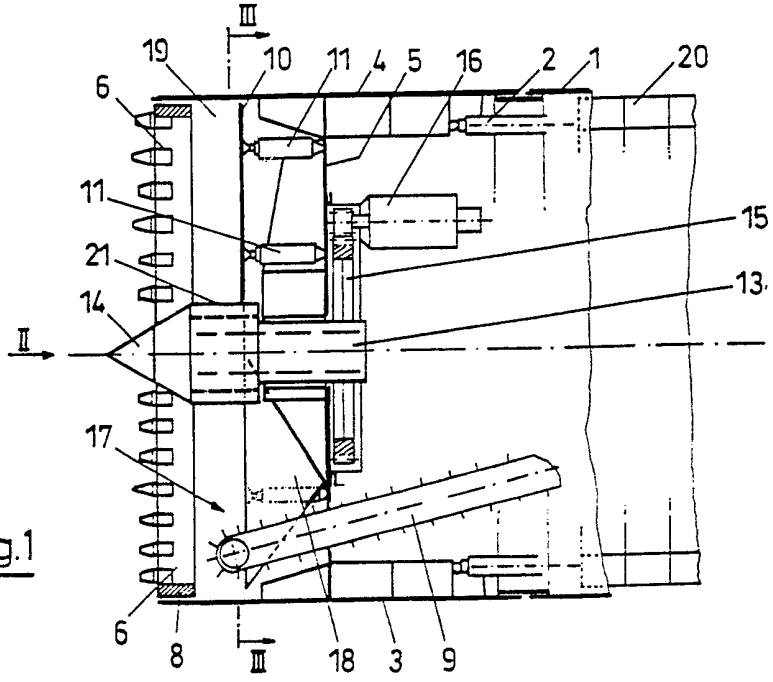

Fig.1

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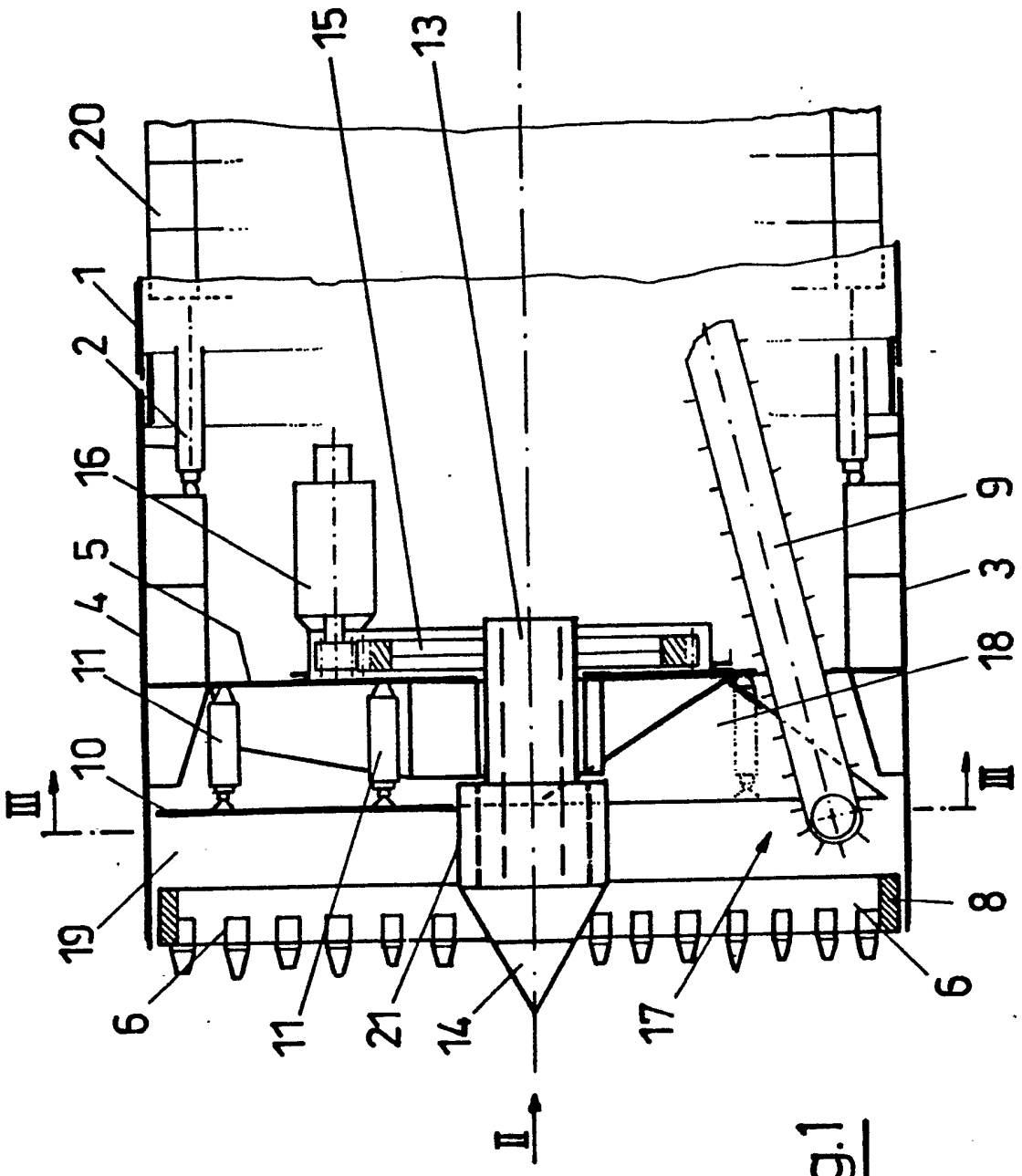

Fig.1

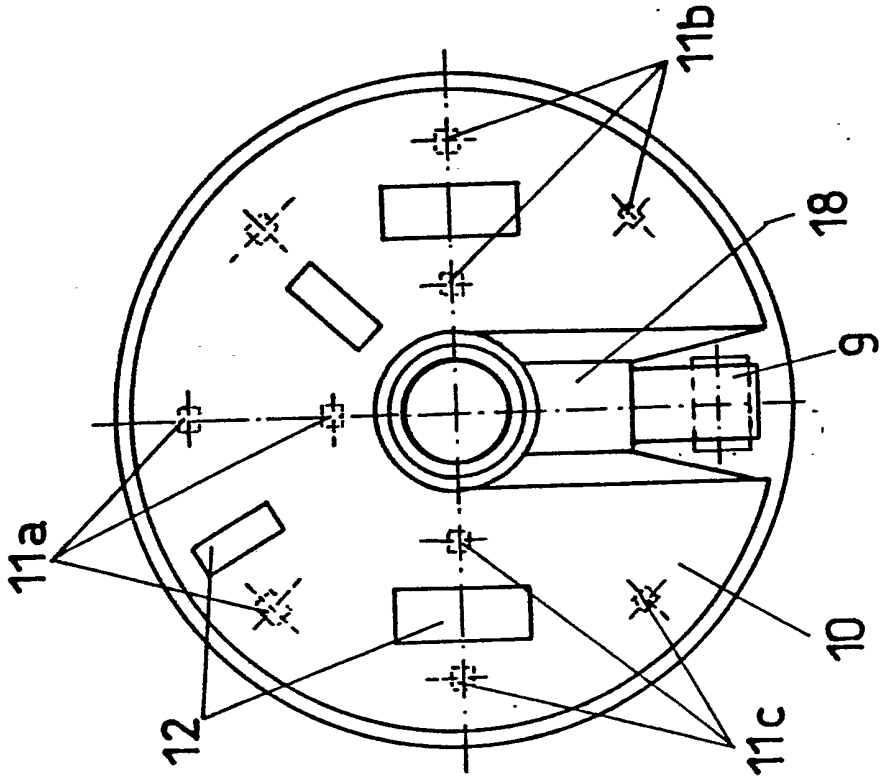

Fig.3

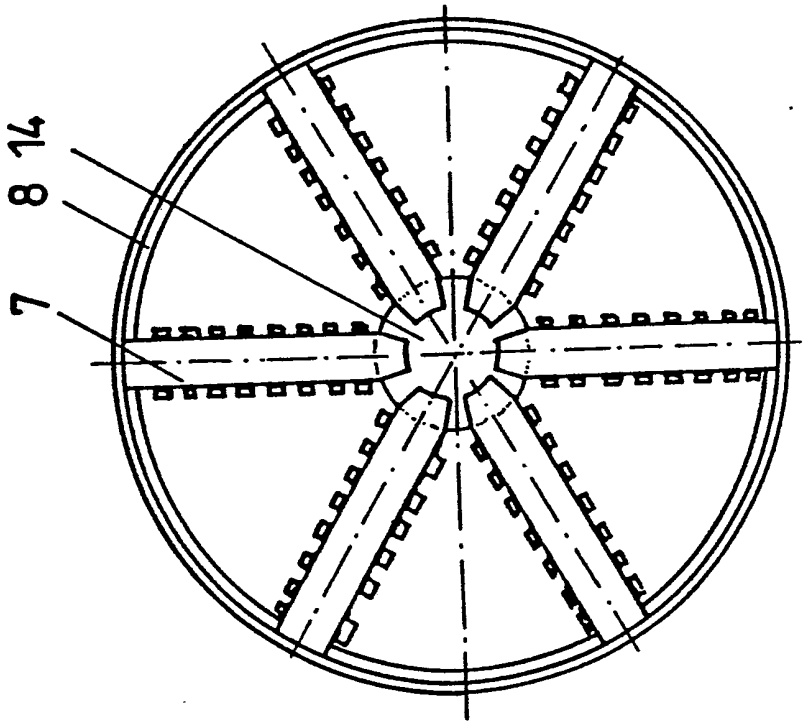

Fig.2

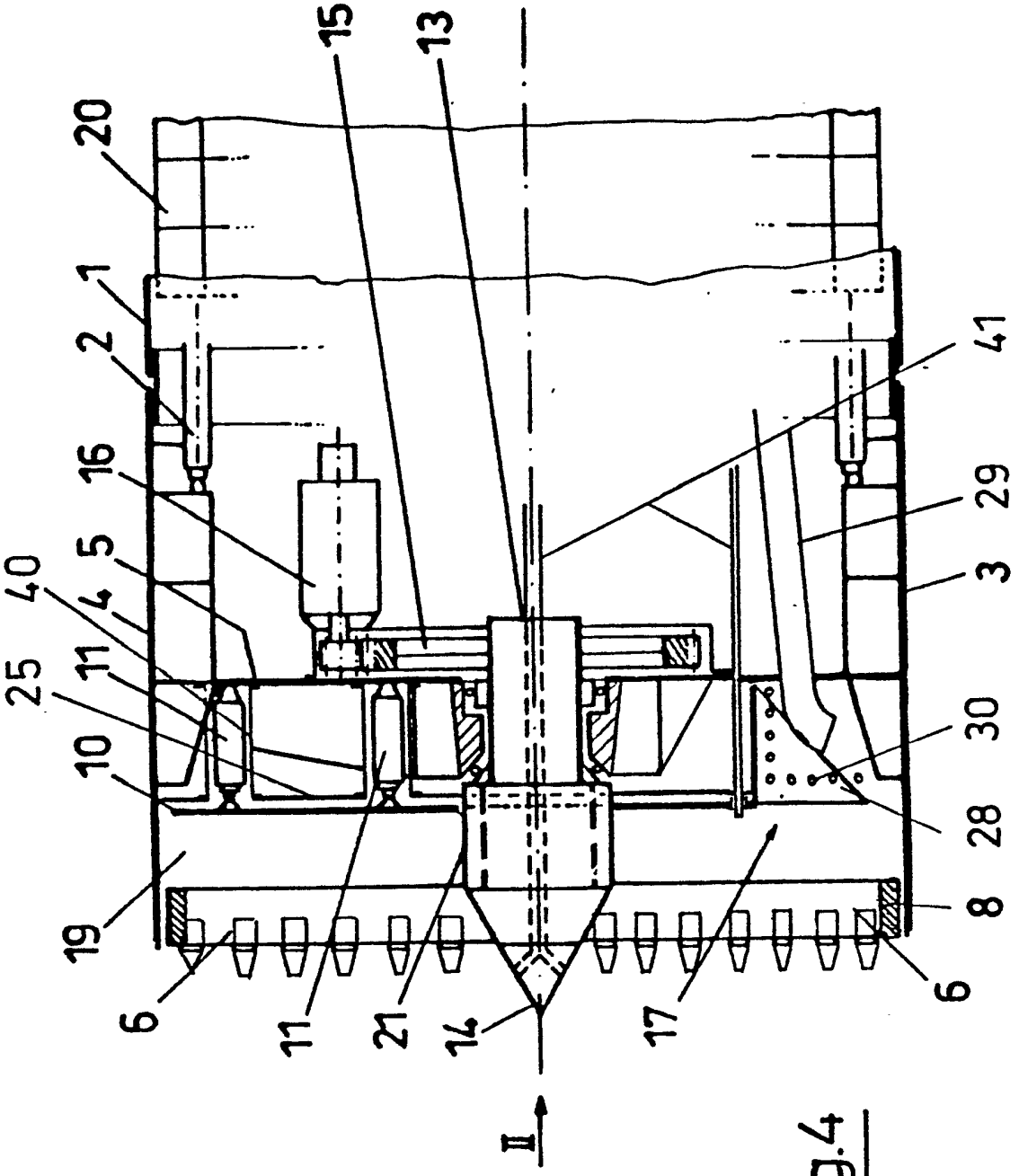

Fig.4

SHIELD TUNNELLING APPARATUS

The present invention relates to an improved shield tunnelling or advancing apparatus and refers particularly to the support of the working face.

There is known a shield tunnelling apparatus, the drilling head or cutting wheel of which has a number of radial cutter bars on which tearing or stripping teeth are located. In the case of this known drilling head, the sectors between the cutter bars for supporting the working face are predominantly closed but have variable apertures through which the loosened material is able to pass into the space behind the cutter bars, from which point it is carried away by a worm conveyor which projects approximately halfway into the said space. This space and the ring-shaped wall at its rear still form a part of the rotating drilling head, so that material falling under the worm conveyor is lifted and passes into the conveyor trough. The entire drilling head is mounted on a pressure bulkhead in the shield body, against which the tunnelling cylinders act.

With this known apparatus, the apertures in the sector-like areas between the cutter bars have to be set in accordance with the tunnelling speed and also with the nature and volume of the loosened material. This is achieved by means of hydraulic cylinders positioned on the rear of the sector-like areas. These cylinders are constantly exposed to the material which penetrates the apertures and passes into the chamber of the drilling head and which, in the said chamber, is moved towards the worm conveyor as a consequence of the rotation of the drilling head. The dust thereby generated and also coarser pieces, ingressing water,

sludge or clay, can easily impair the operation of the cylinders to such an extent that it is no longer possible to meter the ingressing material by altering the apertures.

In EP-A1-0 299 952 a shield tunnelling apparatus is described which has a central shaft and, between the cutters and a supporting structure configured as a sealing wall, a movable and pivoting pressure dome approximate in shape to a dish. The pressure dome is moved by means of hydraulic cylinder assemblies which are supported on the basic structure and linked to pressure sensors. The periphery of the pressure dome is equipped with a circular cutter and reaches partly over the casing of the shield. The drive shaft of the cutting tools runs in an enclosure which is mounted in the sustaining structure in a manner enabling it to move and to pivot and upon which the pressure dome is similarly located. At the bottom, the pressure dome is provided with a funnel-shaped aperture for a conveyor to haul away the excavated material. The purpose of the pressure dome is to seal the extraction area, which is subjected to positive pressure, and to be pressed against the material in this area.

Various aspects of this known proposal are considered to have disadvantages for certain applications at least.

- The cutting force and the friction on the periphery of the pressure dome act in the same way as the material in the extraction area on the piston cylinder assemblies and on the pressure sensors linked to them, so that it is not apparent which supporting

pressure is actually acting on the material in the cross-section of the extraction area.

- Moreover, due to the cutting force and circumferential friction, the design of the piston cylinders has to be much bigger than would be necessary just to support the face.

- The ability to move the working tools and the pressure dome independently of each other in a longitudinal direction is limited by the fact that the pressure dome provides a link between the pressure bulkhead and the edge of the cutters, because the feed constantly affects any intended metering.

- A comprehensive sealing of the supposedly free space between the arms of the cutting wheel cannot be achieved, since the sloping walls of the pressure bulkhead cannot come into mating contact with the perpendicular working tools. Proportioning the material to be conveyed away is therefore only possible within narrow limits. It therefore appears meaningful to put pressure on, and to shift, the cutting wheel only in concert with the pressure dome and the central shaft by means of the hydraulic assemblies, which assumes a more or less constant gap between cutting wheel and pressure dome.

- The movable mounting of the central shaft must be regarded as an expensive solution, susceptible to failure.

- Though the extraction area is indeed accessible via a lock, anyone engaged in replacing the cutting tools is not protected against the ingressing material.

In DE-PS 35 33 425 a hydraulic shield is described where the size of the cavity in the extraction chamber in the direction of the cutting wheel can be varied. To this end, a ring-shaped partitioning wall, connected to a cutting edge and supported on the body of the shield, can be moved relative to said shield. However, the said partitioning wall constitutes a packwall separating the tunnel from the extraction chamber filled with fluid and adjusting the pressure of the water contained therein, such that, because of this function, it is as impossible to achieve a proportioning of the in-situ spoil unaffected by other influences as it is in the case of EP-A1-0 299 952.

The object of the present invention is to develop and improve a shield tunnelling apparatus of the generic type described so that, independently of the feed of a cutting edge, it will be particularly possible to achieve a precisely adjustable support for the face and also a precisely adjustable proportioning of the haul-away of the extracted material from the extraction chamber without exposing sensitive components, such as hydraulic cylinders, to the said material.

Particularly, it is also an object of the invention to facilitate, regardless of the effect of the water in the chamber, a support of the face and a conveying of the extracted material in the case of a hydraulic shield, in keeping with the aforementioned

improvement. It is further an object of the invention to avoid endangering those engaged in replacing tools on the cutting wheel.

These objects are accomplished by the provision, between the rotating cutting wheel and the fixed bulkhead, of a variably adjustable and non-rotating pressure bulkhead. By means of cylinders positioned between it and the bulkhead partition and depending on the working conditions, this pressure bulkhead can be moved forward from a rearward position up to the cutting wheel. "Working conditions" are understood to mean, for example, the nature and volume of the extracted material (spoil), tunnelling speed and the required pressure on the face. In the lower region of the pressure bulkhead there is an aperture for the conveyor to remove the excavated material. In accordance with the invention, a funnel-shaped forming is provided on the essentially flat packwall which makes possible a greater feed length for the conveyor or a guiding means for the flow of material under conveyance. The cutting wheel itself consists essentially only of the cutter bars between which the sectors are open. It is driven by a central shaft which is mounted on the bulkhead partition and surrounded by a protective tube and on which the movable pressure bulkhead abuts, forming a seal. This seal largely keeps dust and overburden from the space between the pressure bulkhead and the bulkhead partition.

Preferably, sealable service apertures are located in the pressure bulkhead, through which apertures repairs can be carried out to the cutter bars. Provision can also be made for the pressure bulkhead, which is configured in the form of a bend-

resistant plate, to be guided on rails in the tunnel sidewall area of the shield body. The tunnel sidewall areas are usually described as those lateral regions of the shield body located approximately in the middle plane between floor and ceiling. In a preferred embodiment, a number of cylinders are positioned between the pressure bulkhead and the bulkhead partition, preferably in three groups, the cylinders in one group being pressurized together. This arrangement makes it possible, for example, to achieve the angled position of the pressure bulkhead, so that a certain proximity to the angle of the slope of the material and, at the same time, a greater feed length for the continuous conveyor below - which, when the tunnel section is dry, may be a drag or a worm conveyor - is maintained. With this type of tunnelling, the invention provides for the funnel-shaped forming to be so configured that the spoil can be removed across virtually the entire cutting radius. To this end, the funnel shaped forming is shaped like a shaft having an approximately trapezoidal cross-sectional area and reaching from the periphery of the pressure bulkhead to approximately the middle plane of the shaft bearing the cutting wheel. In order to prevent dust and excavated material penetrating behind the pressure bulkhead even when said bulkhead has assumed an angled position, the periphery of said bulkhead may be equipped with a suitable seal.

When it is used in a hydraulic shield, where the space between a baffle and the bulkhead partition is partly filled with water and can be subjected to an elevated pressure, the funnel-shaped forming of the pressure bulkhead is, in accordance with the invention, so configured that the suction effect of a suction conveyor can be adjusted. To this end, the funnel-

shaped forming has the shape of a shaft which, withe pressure bulkhead pulled back from the cutting wheel, reaches fully across the opening of the suction conveyor. In this position, the suction action is restricted to a relatively small volume and the suction effect is concentrated more fully. On the other hand, the suction effect is distributed over a relatively large volume. Appropriately, the aperture of the suction conveyor is equipped with a grid-type cover to withhold coarse material which might lead to the clogging of the aperture.

The present invention will be further illustrated, by way of example with reference to the accompanying drawings in which:

Fig. 1 is a longitudinal section through the leading shield of a shield tunnelling apparatus.

Fig. 2 is an end view, taken in the direction of arrow II in Fig. 1, onto the cutting wheel;

Fig. 3 is a view, taken on the line III-III of Fig. 1, onto the pressure bulkhead, and

Fig. 4 is a longitudinal section through the leading shield of a shield tunnelling apparatus, having a hydraulic shield.

From trailing shield 1, which is only outlined in Fig. 1, leading shield 3 is advanced in the working direction by means of drive cylinders 2 which are supported, for example, on tunnel lining 20. Leading shield 3 has a shield body 4, the periphery of which is sufficiently rigid and through the cross-section of which a bulkhead partition 5 extends. At the front of leading shield 3, a rotatable cutting wheel 6 is located, said wheel consisting of several

cutter bars 7 (Fig. 2), which are fitted with teeth and which may also be equipped differently. Cutter bars 7 may be connected by a ring 8 on the circumference. Preferably, said ring 8 runs, at least partially, in a projection of the jacket of shield body 4. Cutting wheel 6 is pressed against and pushed by drive cylinders 2. The sectors between cutter bars 7 of cutting wheel 6 are open. The loosened material falls through these sectors, therefore, and collects behind the cutting wheel. From the bottom of space 19, between cutting wheel 6 and pressure bulkhead 10, the loosened material is hauled away by means of a continuous conveyor 9.

It is possible - particularly when the earth is loose - for a fairly large quantity of material to ingress through the gaps between the cutter bars, causing material to be loosened which does not need to be extracted in front of the cutting wheel above the profile of the tunnel under construction. In accordance with the invention, therefore a movable pressure bulkhead 10 is positioned between bulkhead partition 5 and cutting wheel 6. Said bulkhead 10 exerts a certain pressure on the loosened material in front of it and this supports the face. It also meters the volume of the available extracted material in front of it for hauling away from the extraction area 19 by continuous conveyor 9. The position of the pressure bulkhead can be varied by means of cylinders 11 and adapted to suit the prevailing working conditions. Cylinders 11 are preferably distributed in three groups - 11a, 11b and 11c - on the rear of pressure bulkhead 10 (Fig 3). This makes it possible to incline pressure bulkhead 10. Service openings may be provided in bulkhead 10 through which access can be gained to the space in front of bulkhead 10 and, particularly, to

cutting wheel 6. The parts of the cutting wheel to be serviced are each rotated into a position in front of one of service openings 12, so that work can be carried out safely under the protection of bulkhead 10. In this respect, the configuration according to the invention is particularly advantageous, because service work can also be carried out on the very tip of drill 14 as pressure bulkhead 10 is also close to the cutting wheel 6 in this region. There is at least one access opening in bulkhead 5 which is not shown.

Cutting wheel 6 is mounted on a central shaft 13, which neither swivels nor is axially movable, and is driven thereby. The front end of shaft 13 may be configured as a drill tip 14 with cutting teeth. A protective tube 21 is located in the region of extraction area 19 between cutting wheel 6 and the bearing of shaft 13 in bulkhead 5. Pressure bulkhead 10, preferably with an elastic seal, is so adjacent to this, if necessary, replaceable protective tube, that spoil is largely prevented from penetrating behind pressure bulkhead 10. At the rear end of shaft 13 the drive for cutting wheel 6 is located in the form, for example, of a gearwheel 15 rotated by a drive motor 16 with gearbox. In the lower section of pressure bulkhead 10 there is an aperture 17 for continuous conveyor 9. Since pressure bulkhead 10 can be pushed up to cutting wheel 6, it is appropriate to provide at aperture 17 a bell-mouth 18, which ensures an adequate length of feed for continuous conveyor 9 even in the most advanced position of bulkhead 10. Bell-mouth 18 extends from the periphery of pressure bulkhead 10 to its approximate centre. This also means that a long feed length is achieved. This configuration of bell-mouth 18 also enables even the material extracted at the centre of cutting wheel 6, or in situ there, to

fall directly onto the conveyor. Any build-up of material in the extraction area is thereby avoided if it should occur and the flow of conveyed material is essentially restricted to the working range of the continuous conveyor due to its lateral guidance in the bell-mouth. The configuration of conveyor 9 is such that it can remove spoil even when material pressure is relatively high. The conveyor shown in the drawing is a drag conveyor 9, but a worm conveyor may also be used.

Fig. 4 shows an exemplary embodiment of the pressure bulkhead of a hydraulic shield. In known manner, a baffle 25 is situated in front of bulkhead 5. Baffle 25 is connected to bulkhead partition 5 by means of distance pieces or spacers 40 in which cylinders 11 are housed. Pressure bulkhead 10 is located between baffle 25 and cutting wheel 6. Funnel-shaped forming or bell-mouth 28 is fitted to aperture 17. Said bell-mouth has, for example, vertical side-walls in the form of approximately equilateral right-angled triangles connected at the top to an approximately square horizontal area. Forming 28 is so configured that it can be pushed with the pressure bulkhead across a grid-type cover or screen 30 and across the aperture of suction conveyor 29, thereby making it possible to adjust the suction action and range of suction conveyor 29. Drilling water lines 41 lead into drill tip 14 via hollow shaft 13. Further drilling water lines 41 can lead through baffle 25 up to a point in front of pressure bulkhead 10.

The further functions of pressure bulkhead 10 are retained even in the case of a hydraulic shield. Thus, in spite of drilling with drilling water and of ingressing ground water, it is possible to support the

face and it can be appropriate to set a certain distance between the cutting wheel and the pressure bulkhead, which distance limits the quantity of loosened solids or slurry-like materials penetrating into the extraction area through cutting wheel 6.

In the case of a hydraulic shield, service openings 12 (Fig. 3) can be used - for example, for working on the cutter bars - if the pressure bulkhead is pushed up close to cutting wheel 6. Since positive air-pressure prevails in the upper part of the space between bulkhead partition and baffle 25, which prevents the water in the lower part of this space rising as far as the bearing of the shaft 13, a lock (not shown) is used for passage through bulkhead partition 5 and a sealable entrance is also provided in the baffle 25, in order to gain access into the upper part of the space (also pressurized for this purpose) between the baffle 25 and the pressure bulkhead 10.

CLAIMS

1. A shield tunnelling apparatus having a rotating cutting wheel on the feed shield body of the leading shield and a fixed bulkhead partition located behind the cutting wheel, which partition has an aperture through which the extracted earth is removed from the extraction area by means of a conveying device, the cutting wheel being attached to a shaft mounted in the bulkhead partition, and having a pressure bulkhead which can be moved in relation to the bulkhead partition in the direction of the axis of the shield, which regulates the pressure of the incoming earth in the extraction area, which is of a configuration resistant to turning and bending and which, in its lower region, has an aperture with a bell-mouth for a conveying means, the shaft mounted in the bulkhead partition being surrounded by an enclosure to which the pressure bulkhead is adjacent, in which the pressure bulkhead, having the configuration of a flat plate, can be moved to alter the extraction area and also relative to the cutting wheel and the casing of the leading shield and also to increase the feed length of the conveyor, and can be advanced up to the cutting wheel and in which the shaft near the extraction area is surrounded by the protective tube to which the movable pressure bulkhead lies closely adjacent.

2. A shield tunnelling apparatus as claimed in claim 1, in which, at the aperture for a continuous conveyor, a bell-mouth is situated which extends from the periphery to approximately the centre of the pressure bulkhead, extending in the conveying direction over the conveyor.

3. A shield tunnelling apparatus as claimed in claim 1, in which, a baffle is located between the pressure bulkhead and the bulkhead partition and to which a bell-mouth is situated at the aperture for the suction conveyor of a hydraulic shield, which bell-mouth extends from the edges of the pressure bulkhead through a cut-out in the baffle across a grid-type cover of the suction conveyor to a point approximately over the entire aperture of the suction conveyor.

4. A shield tunnelling apparatus as claimed in claim 1, 2 or 3, in which the pressure bulkhead has a single-piece or uniform configuration and is in the form of a bend-resistant plate and, in the tunnel sidewall areas of the shield body, is guided in rails.

5. A shield tunnelling apparatus as claimed in any preceding claim, in which as the apparatus approaches the natural slope of the material, it can be angled to increase the feed length of the conveyor.

6. A shield tunnelling apparatus as claimed in any preceding claim, in which the cylinders between the bulkhead partition and the pressure bulkhead are located in preferably groups of three in each area, the cylinder pressurizing one group simultaneously.

7. A shield tunnelling apparatus as claimed in any preceding claim, in which the cutting wheel consists only of radial cutter bars, between which the area sectors are open.

8. A shield tunnelling apparatus as claimed in any preceding claim, in which sealable service openings are located in the pressure bulkhead, through which

openings access can be gained to the cutting wheel for the purpose of repair or tool replacement.

9. A shield tunnelling apparatus as claimed in any one of claims 3 to 8, in which the bulkhead partition has a pressure lock and to which the baffle is provided with a sealable opening.

10. A shield tunnelling apparatus, substantially as hereinbefore described with reference to the accompanying drawings.

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