Abstract: A shaft plug (11) for a mine shaft (10), the shaft plug (11) comprising an inflatable bladder adapted to be inflated by pressurised gas, the bladder being adapted to be positioned within a shaft (10) prior to inflation and to be inflated to contact the walls of the shaft (10) to thereby seal the shaft (10) and provide support to the shaft wall. A plurality of shaft plugs (11) are adapted to be linked together in a manner to provide gas communication between the shaft plugs (11) to provide a plug string (41) to enable the shaft to be substantially filled by the plug string (41) when inflated. Also defined is a method of sealing a mine shaft and supporting the shaft wall by use of a shaft plug (11) or plug string (41) described within.
"Shaft Plugging System"

Field of the Invention

The present invention relates to a means of sealing shafts in mines. It also may be used for creating shafts in a manner that is described within this specification.

Throughout the specification the term "shaft" shall be taken as including any form of underground passage, either natural or man-made, which has a significant vertical component. The invention is particularly directed for use with shafts which are vertical or near vertical, but can be adapted for use with obliquely oriented shafts, including ore passes, waste passes, disused vertical dams, tipples and finger raises and other passages.

Throughout the specification including the claims, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

Background

Shulls are provided in underground mines for a variety of reasons including access between levels and ventilation. When they are no longer required for the purpose for which they were provided, their presence becomes problematic. The shaft becomes a safety hazard for people who must work or move under or in the vicinity of the shaft at the lower level because debris is commonly dislodged from the shaft wall and it is possible for objects to fall from the upper level. In many instances it is deemed necessary to seal such shafts by filling them completely with concrete. But it will be readily appreciated that this is a very expensive solution to overcome the safety risk. In other circumstances, closure of the shaft is only required temporarily, and if it has been sealed for safety reasons, the subsequent removal of the sealing material is also an expensive task.
Disclosure of the Invention

Accordingly the invention resides in a shaft plug, the shaft plug comprising an inflatable bladder adapted, in use, to be inflated by pressurised gas, the bladder being adapted to be positioned within a shaft prior to inflation and to be inflated to contact the walls of the shaft to thereby seal the shaft and provide support to the shaft wall.

According to a preferred feature of the invention, the shaft plug provides support to the wall substantially over the full area of contact.

According to a preferred feature of the invention, the shaft plug further comprises support means to enable support to be provided to the shaft plug when it is not fully inflated.

According to a preferred embodiment, the support means comprises a plurality of anchor points secured to the bladder whereby the shaft plug may be supported.

According to a preferred embodiment, the support means comprises a harness engaged with the anchor points.

According to a preferred feature of the invention, the bladder comprises an upper and a lower end panel, at least one of said upper and lower end panels having an aperture to enable gas to be inserted into the bladder for inflation of the bladder.

According to a preferred feature of the invention, a connection means is associated with the aperture, the connection means being adapted to be connected to a corresponding connection means of an adjacent shaft plug.

According to a preferred embodiment, the connection means comprises an inflation flange comprising a flanged mouth surrounding the aperture whereby the apertures of two shaft plugs may be joined by clamping engagement of corresponding inflation flanges on the two shaft plugs.
According to a preferred feature of the invention, the pressurised gas is inserted into the shaft plug via one of the said apertures.

According to a preferred feature of the invention, the shaft plug or shaft string is re-usable.

According to a preferred embodiment, the bladder is manufactured from fibre-reinforced PVC.

According to a preferred embodiment, the bladder is manufactured from TARPOL or similar material.

According to a preferred embodiment, the bladder is manufactured from COMPLAS 300 or similar material.

According to a further aspect, the invention resides in a plug string adapted to seal a shaft, the plug string comprising a plurality of shaft plugs of the type as previously described.

According to a preferred feature of the invention, the shaft plugs of the plug string are interconnected to provide gas communication between said shaft plugs.

According to a preferred embodiment, the harness of a lower shaft plug in the plug string is adapted to be supported by the harness of an upper shaft plug in the plug string.

According to a preferred embodiment, the shaft plugs comprising a plug string are supported by a composite harness.

According to a further aspect, the invention resides in a shaft sealing method, the method comprising the insertion of an inflatable shaft plug of the type as previously described into the shaft, and inflating said shaft plug.
According to a preferred embodiment, the shaft sealing method comprises the insertion of an inflatable plug string of the type as previously described into a shaft and inflation of said shaft string to thereby seal said shaft.

According to a preferred feature of the invention the shaft plug or shaft string may be removed from the shaft by deflating the shaft plug or shaft string and thereafter removing said shaft string from said shaft.

According to a preferred embodiment, shaft plugs are installed into the shaft from an upper level.

The invention will be more fully understood in the light of the following description of one specific embodiment.

**Brief Description of the Drawings**

The description is made with reference to the accompanying drawings of which:

Figure 1 is an isometric view of a shaft plug according to the first embodiment shown in an inflated condition;

Figure 2 is a schematic side elevation of a shaft string comprising a plurality of shaft plugs of the type shown in Figure 1, the string being shown prior to insertion into a shaft;

Figure 3 is a schematic side elevation of the shaft string shown in Figure 2, the shaft string being shown in position in the shaft prior to inflation;

Figure 4 is a schematic side elevation of the shaft string shown in Figure 3, the shaft string being shown in position in the shaft and in inflated condition;

Figure 5 is a schematic side elevation of portions of two shaft plugs of the type shown in Figure 1 identifying the binding of the inflation flanges.
Detailed Description of Specific Embodiment

The embodiment of the invention is directed to an inflatable shaft plug adapted to be installed in a mineshaft. The embodiment is described with reference to Figures 1 to 5.

The embodiment is a shaft plug 11 which is an inflatable bladder comprising a wall 12 of flexible, substantially airtight material which is adapted to be installed into a substantially vertical shaft. Reinforced PVC sheeting has been found to be particularly suitable for this application although other materials will also fulfil the function. One material found particularly suitable comprises a Panama woven polyester, 12 x 12 PVC coated with Acrylic lacquer on both sides. This product is marketed under the trade mark "COMPLAS 300" Fabric. An alternative material is a woven polyester 8 x 8.5 incorporating tear stop threads in both directions, PVC coated with acrylic lacquer on the top surface. This product is marketed under the trade mark "TARPOL". The material can be selected more particularly for the application according to its properties, particularly to provide suitable strength and weight characteristics.

The shaft plug 11, when inflated as described below, expands to fill a portion of the shaft 10. The majority of shafts in mines have a generally circular cross-section, due to the manner of construction and therefore, as shown in the drawings, the shaft plug 11 of the first embodiment takes a generally cylindrical appearance when inflated, having a circumferential wall 14 and being closed at the ends of the cylindrical form by an upper end panel 15 and lower end panel 16. Due to the flexibility of wall material used, the shaft plug 11 is capable of conforming generally to a shaft which is not of circular cross-section, including the accommodation of irregularities caused by the prior dislodgement of shaft wall material. It will of course be appreciated that where a shaft has a cross-section substantially departing from the circular form such as rectangular or square, it is preferable that the shaft plug is also provided with a generally conforming cross-section.
While it would be possible to construct a shaft plug in accordance with the invention that extends the full length of the shaft, such a shaft plug would be difficult to manufacture and cumbersome to transport and install. The shaft plug of the first embodiment has a length which is of similar dimension to the diameter of the shaft plug when inflated. This has been found to be a reasonable optimum between effectiveness and efficiency. Typically, mine shafts in which the embodiment would be used are substantially longer than the diameter of the shaft. For instance shafts are often between 2.4 metres and 5 metres in diameter but have a length of 20 metres or more, sometimes in excess of 150 metres. In order to function effectively, particularly in preventing wall material from dislodging from the shaft, it is necessary that substantially the full length of the shaft be filled. If a shaft plug extends from the top only partially down the length of the shaft, wall material below the shaft plug could dislodge and fall to the tunnel below. If the shaft plug is installed only in a lower portion of the shaft, wall material dislodged may acquire sufficient momentum while falling before impacting the shaft plug so that it would perforate the upper panel 15 and potentially fall to the tunnel. In order to fill a shaft with shaft plugs of the embodiment, it is necessary that a plurality of shaft plugs 11 are sequentially installed within the shaft, in a manner described below.

In order to position the shaft plug 11 when not fully inflated, such as during installation or removal, support means are provided for the shaft plug 11. In the embodiment, the support means comprises anchor points 21 secured to the circumferential wall 14 of the shaft plug. The anchor point 21s are typically loops of the fabric material used for the wall of the shaft plug secured to the wall by adhesive, stitching, welding or a combination of these methods. Anchor points 31 are positioned in a plurality of groups 32 spaced around the circumference of the circumferential wall 14 (as considered when the shaft plug is inflated). Each group 32 of anchor points 31 comprises a plurality of anchor points positioned at spaced intervals along the circumferential wall 14 in a line parallel with the central cylindrical axis of the shaft plug 11.
A support harness 35 is adapted to be associated with the support plug 11. The support harness 35 comprises ropes or other flexible support lines adapted to engage the support means associated with the shaft plug 11. As shown in the drawings, the harness associated with the embodiment comprises a plurality of webbing strips 36 of material similar to that utilised for seat belts of motor vehicles. The webbing is provided with loops 37 at spaced intervals along its length, each loop of which is engaged with a corresponding anchor points in one group of anchor points. Engagement is provided by shackles 38 or comparable engagement means. The webbing strips extend beyond the upper end of the shaft plug and are provided with an end loop for support from above.

The upper end panel 15 and the lower end panel 16 of the shaft plug 11 are each provided with a centrally located aperture 21 and 22 respectively. Connection means is associated with the apertures to enable connection of adjoining shaft plugs and in the embodiment the connection means comprises a inflation flange 23 and 24 surrounding the respective apertures 21 and 22. As shown in Figure 5, by means of the inflation flanges, the upper end panel 15 of a lower shaft plug may be engaged with the lower end panel 16 of an upper shaft plug during installation, in a manner whereby communication of the inflation gas between the panels is enabled through the centrally located apertures 21 and 22 of each, but that the adjoining panels are held together in the vicinity of the inflation flanges. Suitable inflation flanges are commercially available in the market place. The flanges are engaged by means of a clamp 26. In this way, a series of shaft plugs 11 are longitudinally connected permitting communication of the inflation gas between them. The central aperture of the lower end panel 15 of the lowermost shaft plug is sealed. Alternatively, an adaptation of the embodiment is provided whereby the lower end panel of the adaptation is not provided with an aperture. The aperture of the upper end panel of the uppermost shaft plug receives gas, normally air, from a pressurised source via a suitable fitting to the inflation aperture. It can be seen in Figures 2, 3 and 4 that a plurality of shaft plugs may be used together to provide a plug string 41, adapted to substantially fully occupy the void of the shaft.
In use, the system is intended to be installed by being raised from the lower tunnel rather than being lowered from the upper tunnel, although the latter may be achieved with additional installation safety steps. The plug string 41 is adapted to be supported by a support cable 42 extended from a winch 43 via a pulley 44 positioned centrally above the shaft 10. The pulley 44 may be suspended from the roof of the upper tunnel 17 or alternatively mounted on a support frame positioned over the upper end of the shaft 10.

In a preferred method of installation, the support harness is assembled near the shaft 10 in the lower tunnel 18 and attached to the support cable 42. The first (uppermost) shaft plug is attached to the support harness in deflated condition and then drawn partially into the shaft 10. The second shaft plug is then attached to its support harness and the harness attached to the harness of the previous shaft plug, the inflation flange of the upper end panel of the second shaft plug being engaged with the inflation flange of the lower end panel of the first shaft plug. The support cable is again raised until the second shaft plug partially enters the shaft. The process is then repeated until all shaft plugs in the string 41 are installed. The plug string is then raised so that the upper end of the uppermost shaft plug is substantially level with the floor of the upper level, as shown in Figure 3. The shaft plug string is then inflated by a convenient gas source, normally air.

Once the plug string is fully inflated, the circumferential walls of all of the shaft plugs in the string will contact the shaft wall. Although the gas pressure is quite low (typically in the order of 4 kPa (0.5 psi), the plug string is held firmly in position by friction because of the large area of contact. Due to this area of contact and the strength of the material used, it has been found that the shaft plug when inflated, provides significant support to the shaft wall, even at the low pressure mentioned. Loose wall debris or other material is held in place firmly and securely, thereby providing a safe environment below the sealed shaft. Workers may move and work under the sealed shaft secure against falling material.

Those skilled in the art will readily appreciate that, when the plug string is inflated, the end panels of the uppermost and lowermost plugs will bow outwardly relative to the planar surface transverse to the cylindrical axis of the shaft plug. At the
upper end, within reason, this is not a problem as it is not permissible to work above the shaft and the bowing out therefore does not interfere with any activities. However, at the lower end, excessive bowing out would interfere with mine operation. The shaft plug string is installed so that persons can move and work below the shaft. If the lower end panel were to bow outwards excessively, there would be a likelihood that the panel would interfere with mine operation within the tunnel, possibly being caught by a mine vehicle and damaged. This would be a safety issue. To ensure that this does not happen, the end panel is configured so that the lower end panel is tensioned sufficiently when the circumferential wall is pressed against the shaft wall when the shaft plug is inflated. In practice, bowing of approximately 0.5 metres is achieved and this is considered quite acceptable.

It is to be noted that, in joining successive shaft plugs together in the manner shown in Figure 5, a good airtight fit between the two panels is desirable but not essential. Adjoining shaft plugs are joined and inflated. Adjoining end panels will tend to be pressed together and react as a single element. If gas escapes between adjoining panels, the pressure it is at least substantially held within the confined region of the sealed shaft. Some leakage may occur into the ore, but this will generally be low. For safety, it is considered necessary to maintain a supply of air to the shaft string continuously to replenish any lost air but the air volume required will generally be very small if the integrity of the sealing is high. It may be noted that a sudden, substantial increase in air usage would indicate a fault which may require maintenance.

It should be appreciated that the scope of the present invention need not be limited to the particular scope of the embodiments described above. For instance, it would be quite possible to inflate the plug string by insertion of the pressurised gas into the inflation aperture in the lower panel of the lowermost shaft plug. A further adaptation would be to provide the harness as a single unit adapted to accommodate all of the shaft plugs in the plug string. Another adaptation would be to inflate each shaft plug in a plug string independently of the other shafts plugs in the plug string. With such a shaft plug, the inflation aperture might be
located within the side wall of the bladder rather than the end wall. An adaptation of the method of installation of the shaft plugs of a string might be to install and inflate a first shaft plug at the lower end of the shaft and then to lower a subsequent shaft plug upon the previously inflated shaft plug from above.

Successive shaft plugs would be added to fill the shaft. It is to be recognized that all such adaptations including others not mentioned are intended to be included within the scope of the invention.
The claims defining the invention are as follows:

1. A shaft plug, the shaft plug comprising an inflatable bladder adapted to be inflated by pressurised gas, the bladder being adapted to be positioned within a shaft prior to inflation and, in use, to be inflated to contact the walls of the shaft to thereby seal the shaft and provide support to the shaft wall.

2. A shaft plug as claimed in claim 1 wherein the shaft plug provides support to the wall substantially over the full area of contact by the shaft plug when inflated.

3. A shaft plug as claimed in claim 1 or claim 2 wherein the bladder comprises an upper and a lower end panel, at least one of said upper and lower end panels having an aperture to enable gas to be inserted into the bladder for inflation of the bladder.

4. A shaft plug as claimed in claim 3 wherein the pressurised gas is inserted into the shaft plug via said aperture.

5. A shaft plug as claimed in claim 3 or claim 4 wherein a connection means is associated with the aperture, the connection means being adapted to be connected to a corresponding connection means of an adjacent shaft plug.

6. A shaft plug as claimed in claim 5 wherein the connection means comprises an inflation flange comprising a flanged mouth surrounding the aperture whereby the apertures of two shaft plugs may be joined by clamping engagement of corresponding inflation flanges on the two shaft plugs.

7. A shaft plug as claimed in any one of the previous claims wherein the shaft plug is re-usable.

8. A shaft plug as claimed in any one of the previous claims wherein the bladder is manufactured from fibre-reinforced PVC.
9. A shaft plug as claimed in any one of claims 1 to 7 wherein the bladder is manufactured from TARPOL or similar material.

10. A shaft plug as claimed in any one of claims 1 to 7 wherein the bladder is manufactured from COMPLAS 300 or similar material.

11. A shaft plug as claimed in any one of the previous claims wherein the shaft plug further comprises support means to enable support to be provided to the shaft plug when it is not fully inflated.

12. A shaft plug as claimed in claim 11 wherein the support means comprises a plurality of anchor points secured to the bladder whereby the shaft plug may be supported.

13. A shaft plug as claimed in claim 11 or claim 12 wherein the support means comprises a harness engaged with the anchor points.

14. A plug string adapted to seal a shaft, the plug string comprising a plurality of shaft plugs of the type as claimed in any one of the previous claims.

15. A plug string adapted to seal a shaft, the plug string comprising a plurality of shaft plugs of the type as claimed in claim 13 wherein the harness of a lower shaft plug in the plug string is adapted to be supported by the harness of an upper shaft plug in the plug string.

16. A plug string as claimed in claim 15 wherein the shaft plugs comprising a plug string are supported by a composite harness adapted to support all shaft plugs in the plug string.

17. A plug string as claimed in any one of claims 14 to 16 wherein the said plurality of shaft plugs are interconnected to provide gas communication between said shaft plugs.

18. A plug string as claimed in any one of claims 14 to 17 wherein the plug string substantially fills the shaft when inflated.
19. A plug string as claimed in claim 18 wherein the plug string provides support to substantially the whole area of the shaft wall covered by the plug string.

20. A shaft sealing method comprising the insertion of an inflatable shaft plug as claimed in any one of claims 1 to 13 into the shaft, and inflating said shaft plug.

21. A shaft sealing method comprising the insertion of an inflatable plug string as claimed in any one of claims 14 to 19 into a shaft and inflation of said plug string to thereby seal said shaft and provide support to the shaft wall.

22. A shaft sealing method as claimed in claim 20 or claim 21 wherein the plug string is installed by drawing the plug string up from a lower level by lifting means located at an upper level, the shaft interconnecting the lower and upper levels.

23. A shaft sealing method as claimed in any one of claims 20 to 22 wherein the plug string may be removed from the shaft by deflating the plug string and thereafter removing said plug string from said shaft.

24. A shaft sealing method as claimed in claim 20 or claim 21 wherein shaft plugs are installed into the shaft from an upper level.
INTERNATIONAL SEARCH REPORT

International application No

PCT/AU2005/000957

A CLASSIFICATION OF SUBJECT MATTER

Int Cl 7 E21D 7/00, 1/00, E21F 15/00, 15/08

According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable search terms used)

DWPI : E21D 7/00, 1/00, E21F 15/00, 15/08, 17/00 and Keywords (inflat+, bladder, plug, string, seal, pressur+, gas and like terms)

C DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C

X See patent family annex

* Special categories of cited documents

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This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

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