

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
10 February 2011 (10.02.2011)

(10) International Publication Number
WO 2011/014902 A1

(51) International Patent Classification:

B29B 15/02 (2006.01) *B29C 47/10* (2006.01)
B29B 17/04 (2006.01) *B29C 47/76* (2006.01)
B29C 31/02 (2006.01) *B29C 47/92* (2006.01)
B29C 47/08 (2006.01)

Lot 2, 20 Staroderevskaya Street, Saint Petersburg,
197372 (RU).

(74) Agent: **VAINER, Michael**; VR Tek Pty Ltd, 513 Highett
Road, Highett, VIC 3190 (AU).

(21) International Application Number:

PCT/AU2010/000284

(81) Designated States (unless otherwise indicated, for every
kind of national protection available): AE, AG, AL, AM,
AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ,
CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP,
KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD,
ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI,
NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD,
SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date:

15 March 2010 (15.03.2010)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

2009903685 7 August 2009 (07.08.2009) AU

(71) Applicants (for all designated States except US): **VR
TEK PTY LTD** [AU/AU]; 513 Highett Road, Highett,
VIC 3190 (AU). **APRIL LTD - ООО «АПРЕЛЬ»** [RU/
RU]; 24 Polytechnic Street, Saint Petersburg, 194021
(RU).

(84) Designated States (unless otherwise indicated, for every
kind of regional protection available): ARIPO (BW, GH,
GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM,
ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ,
TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE,
ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV,
MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM,
TR), OAPI (BF, BJ, CF, CG, CL, CM, GA, GN, GQ, GW,
ML, MR, NE, SN, TD, TG).

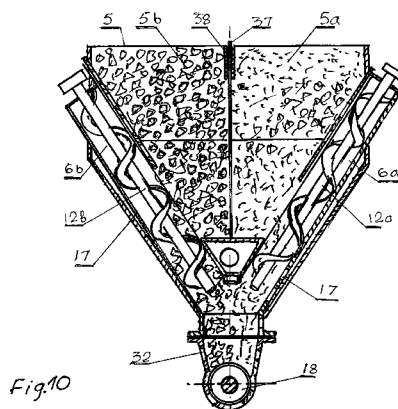
(72) Inventors; and

(75) Inventors/Applicants (for US only): **VAINER, Michael**
[AU/AU]; 194 Kambrook Road, Caulfield, VIC 3162
(AU). **ROZENBLIT, Boris** [AU/AU]; 4 Willis Street,
Hampton, VIC 3188 (AU). **SHTAK, Dmitry** [RU/RU];
Flat 141, Lot 4, 25 Tikoretsky Prospect, Saint Petersburg,
195427 (RU). **AZARENKOV, Sergey** [RU/RU]; Flat 73,

Published:

— with international search report (Art. 21(3))

(54) Title: FEEDER AND EXTRUSION DEVICE AND METHOD OF USE THEREOF



(57) Abstract: The present invention generally relates to a feeder for particulate material such as particulate polymer waste. More particularly, the present invention relates to an extrusion device including the feeder for improved extrusion of materials such as particulate polymer waste which effectively changes the quality and characteristics/properties of the polymer waste to, for example, create commercially useful products such as, for example, devulcanised rubber powders or composite materials. In a specific embodiment the method includes the steps of (1) storing one or more batches of waste polymer in one or more respective hoppers, (2) regulating the flow of waste polymer supplied to a conveyor from the one or more hoppers, (3) transporting the waste polymer from the one or more hoppers and along the one or more conveyors to an extruder such that at least some interstitial air is expelled from the waste polymer, (4) feeding the waste polymer from the one or more conveyors to an extruder, and (5) passing the waste polymer through the extruder to provide a pulverised activated and devulcanised polymer product. The present invention is particularly useful for the processing of tyres including tyre segments or shredded tyre waste.



WO 2011/014902 A1

FEEDER AND EXTRUSION DEVICE AND METHOD OF USE THEREOF

Field of Invention

The present invention generally relates to a feeder for particulate material such as particulate polymer waste. More particularly, the present invention relates to an extrusion device including the feeder for improved extrusion of materials such as particulate polymer waste which effectively changes the quality and characteristics/properties of the polymer waste to, for example, create commercially useful products such as, for example, devulcanised rubber powders or composite materials.

The extrusion device is suitable for supply of material, particularly material for the generation of highly activated, highly dispersive polymer powders.

While it will be convenient to describe the present invention with reference to processing of polymer materials derived from tyres, the invention is not limited to that application, and may be used for processing other types of polymeric or other material that can then be used in other applications. Furthermore, while the feeder will be described with particular reference to feeding extruders, the invention is not limited to use with that device and it can be used to feed other types of devices.

Background to the Invention

The discussion throughout this specification comes about due to the realisation by the inventor or the identification of certain related art problems by the inventor and, moreover, any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Australia or elsewhere on or before the priority date of the disclosure and claims herein.

It is to be appreciated that any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the present invention. Further, the discussion throughout this specification comes about due to the realisation of the inventor and/or the identification of certain related art problems by the inventor. Moreover, any discussion of material such as documents, devices, acts or knowledge in this specification is included to explain the context of the invention in terms of the inventor's knowledge and experience and, accordingly, any such discussion should not be taken as an admission that any of the material forms part of the prior art base or the common general knowledge in the relevant art in Australia, or elsewhere, on or before the priority date of the disclosure and claims herein.

Tyre waste

Polymeric waste, such as used tyres, has become a worldwide economic and ecological problem. Tyres include a wide range of polymers including natural rubber co-polymers and synthetic rubbers such as SBR (styrene butadiene rubber) and butadiene rubber, nitrile rubber, isoprene rubber, neoprene rubber and polysulphide rubber. Tyres also include metals such as zinc and steel. A large variety of other organic and inorganic chemicals are also added to tyre polymers including vulcanising agents, accelerators, retardants, pigments, fillers, reinforcing agents, softeners, anti-oxidants and desiccants.

The vast majority of current methods for disposal of end-of-life tyres not only represents economic waste of polymers as raw materials but also contributes to ecological problems associated with the practises of dumping in land and marine environments. Accordingly there are numerous methods of the prior art for disposal or reprocessing tyres including combustion, pyrolysis, and regeneration. Extrusion is processes that can be used in the disposal or reprocessing of tyres, particularly to tailor the waste to suit the requirements of downstream processes.

Extrusion generally

Extruders squeeze a feed material, applying pressure until it is ejected from the extruder. There are many different variations of extrusion equipment but most typically include a hopper for holding and feeding raw material, and a

hydraulically or mechanically driven means for applying pressure. Most extruders include a die for shaping the extruded end product.

The means for applying pressure typically include a single or twin screw auger powered by an electric motor, or a ram driven by hydraulic pressure. Screws commonly used in extruders include single flight metering screws, single barrier screws, double barrier screws, variable pitch flights, multi-start flights, slotted flights and two stage screws (for vented extruders).

Extrusion processes are usually described as 'hot', 'warm' or 'cold'. Hot extrusion is done at an elevated temperature to keep the material from work hardening and to make it easier to push the material, particularly if it is passed through a die. Warm extrusion is done above room temperature, but below the recrystallisation temperature of the material. It is often used to achieve a balance between required forces, ductility and final extrusion properties. Cold extrusion is carried out at or near room temperature. Cold extrusion has certain advantages over hot extrusion including lack of material oxidation, more precise tolerances and good surface finish.

When the feed comprises particulate material, the particles are often loaded into a feed hopper where they are loosely compacted and entrap a large volume of air. The entrapped air is often carried through from the feed hopper into the screw of the extruder which adversely affects its efficiency. Furthermore, particulate feed often has shock-absorptive and other physical characteristics that cause the particles to rebound off each other and off the surfaces of the hopper and feed lines of the extruder. This can adversely affect the extruder, its efficiency and the characteristics of the extruded product.

The production capacity of an extruder, particularly in relation to the workings of the mechanism for applying pressure, is at least partly determined by the efficiency with which it is supplied with feed material.

Accordingly, there have been a number of attempts to provide devices that optimise the feed process and thus improved the overall effectiveness of extruders. For example, in certain extruders of the prior art, supply of material to the extruder is enabled directly through a feed device having very simple construction, such as those described in RU 2325277 and US 5,284,625.

Other more sophisticated feed devices such as those described in RU 27778 incorporate additional features such as augers and shafts with vanes. JP

11349727 describes feed devices that incorporate the use of a plunger. In addition some feed devices are subjected to vibration or pulsation to assist material feeding. However the feed devices of the prior art have not significantly increased the efficiency or capacity of extruders.

Furthermore, the feeding devices of the prior art are not energy efficient, and can also be complex to manufacture.

Prior art patent RU 2329893, describes an extruder having a feeding and compacting chamber consisting of a cylindrical casing with loading and unloading ports, the chamber having its own internal auger for feeding and compacting polymeric materials into the feeding zone of the extruder's screw device.

One of the deficiencies of the extruder described in RU 2329893 include the requirement of an additional feeding vessel for loading polymeric materials into the cylindrical feeding and compacting chamber. Moreover, the feeding mechanisms of the extruders of the prior art are not adapted to regulate and control the feed of different sized and/or volumetric weight particles of feed materials. Regulation of the speed of rotation of the screw device in the feeding mechanism is not on its own sufficient to optimise compacting and extrusion.

Other processes of the prior art know use an adjunct ultrasonic process. For example the process described in WO9400497A1, is added external to the main body of the extruder and is intended to change the quality and characteristics of polymer waste. One of the deficiencies associated with the process described in WO9400497A1 is that it has no effect on the actual extrusion process which only enables pulverisation.

A further deficiency that is typically associated with feeders of the prior art is that they do not enable simultaneous feeding from separate stocks of polymeric wastes having different characteristics, such as different particle size, volumetric weight or polymer quality.

Vulcanisation and Devulcanisation

Vulcanisation is the thermo-chemical process that incorporates sulphur into polymers in order to provide properties that are desired in manufactured polymer products. It is particularly extensively used in the production of tyres. Typically, in order to use polymer waste from tyres and other sources it is first

necessary to reclaim the polymer using mechanical and thermal energy and chemicals. The principal step of reclamation is devulcanisation.

Devulcanisation is the process of cleaving the intermolecular bonds of the polymer such as the carbon-sulphur or sulphur-sulphur bonds with further shortening of the polymer chains. This is often done by chemical, ultrasonic, microwave or biological processing.

Pulverising by extrusion

Before waste polymer can be devulcanised or used in further processing, it must be reduced to small sized particles by chopping, grinding or pulverising.

Pulverisation techniques for polymers typically rely upon screw extruders, particularly twin-screw extruders, imposing compressive shear on the polymer at specific temperatures depending on the polymer (*Evaluation of Waste Tire Devulcanisation Technologies – Report for the Integrated Waste Management Board of the State of California*, December 2004 by CalRecovery, Inc, <http://www.ciwmb.ca.gov/Publications/Tires/62204008.pdf>). Based on this method, the solid state shear extrusion pulverisation of rubber waste using a twin-screw extruder and a single-screw extruder has also been proposed.

During this process polymers such as tyre rubber are only slightly devulcanised.

One of the problems associated with pulverisation using an extruder is that large amounts of heat are generated due to compression and shearing actions in the pulverisation zone that are difficult to control.

In particular there is a need for optimising extrusion and a process that can provide extruded product tailored to suit the requirements of downstream processes.

Detailed Disclosure of the Invention

An object of the present invention is to provide a more efficient process for supplying feed material for processing. It is a further object of the present invention to provide a more efficient device and process for feeding particulate polymer material for extrusion.

An object of the present invention is to provide a process, method and device that can provide extruded polymer tailored to suit the requirements of downstream uses.

A further object of the present invention is to provide a feeder device and method that is of reduced cost as compared with related art.

A further object of the present invention is to provide a feeder device that is more energy efficient per unit of production as compared with related art.

A further object of the present invention is to provide a feeder and associated extrusion device and method that is of reduced cost as compared with related art.

A further object of the present invention is to provide a feeder and associated extrusion device that is more energy efficient per unit of production as compared with related art.

A further object of the present invention is to enable the simultaneous feeding and processing of polymeric waste of different characteristics.

A further object of the present invention is to alleviate at least one disadvantage associated with the related art.

It is an object of the embodiments described herein to overcome or alleviate at least one of the above noted drawbacks of related art systems or to at least provide a useful alternative to related art systems.

In a first embodiment the present invention provides a feeder for a downstream process, the feeder comprising;

- one or more hoppers for storage of material,
- one or more conveyors for transporting the material from the one or more hoppers to a downstream process,
- one or more regulators for controlling the flow of material supplied to one or more conveyors from one or more hoppers, and
- multiple apertures associated with the feeder for exit of air from the material.

In a preferred embodiment the arrangement of hoppers and regulators is such that one hopper can be operated together with or instead of the other. Alternatively, the arrangement of one or more regulators is such that the flow of

material from one hopper is different to the flow of material from another hopper. The 'flow' may refer to the volume, speed or some other parameter related to the transfer of material from the hopper(s).

In another embodiment, the feeder also contains a regulating device for the alignment or displacement of pipe-sockets for the addition of solid, liquid or gaseous substances or combinations thereof, as well as the regulation of the alignment or displacement of a vibration device, such as an ultrasonic device.

Typically, multiple apertures are also provided in the casing of the hopper(s) and the conveyor(s) of the feeder.

The feeder is preferably combined with a processing device such as an extruder. The extruder may be of convenient design such as those having conventional mechanical or hydraulic drive for the extruder elements. Typically the extruder comprises a single-screw or twin-screw extruder element. The barrel housing the extruder element may be, for example, cannon barrels available as army surplus. In a particularly preferred embodiment the housing is a cannon barrel that includes rifling, which improves the rotation of the screw.

Preferably, the proximal part of the casing of the main body of extruder contains multiple apertures for the expulsion of air. Typically these multiple apertures have inclined side walls, such that the size of each aperture is greatest towards the outside surface of the casing.

It is also preferable that the said proximal part of the extruder casing has a cross-sectional diameter greater than the diameter of the rest of the casing.

In a second embodiment the present invention provides a polymer processing device comprising;

- an extruder for pulverising waste polymer in communication with a feeder, the feeder comprising;
 - one or more hoppers for storage of waste polymer,
 - one or more conveyors for transporting the waste polymer from the one or more hoppers to the extruder,

- one or more regulators for controlling the flow of waste polymer supplied to the one or more conveyors from the one or more hoppers,
- multiple apertures associated with the feeder for exit of air from the waste polymer, and
- multiple apertures associated with the extruder for exit of air from the waste polymer,

where in a preferred embodiment, the feeder exit cross-sectional area is at least 1.5 times greater than the cross-sectional area of the main body of the extruder, where in the typical case where the feeder exit cross-sectional area is circular, the cross-sectional diameter of the feeder exit is at least 1.5 times greater than the cross-sectional diameter of the main body of the extruder.

In another embodiment, the device includes a second extruder supplied with waste polymer from the feeder.

Where used herein the term 'waste' polymer is intended to be interpreted broadly, for example, to refer to polymer that is no longer required for its original application or that is created as excess or a by-product from an industrial process.

Typically the waste polymer is supplied in batches, each batch having different characteristics. For example, the batches may comprise particles of different sizes, such as 5, 10, 20 or 25 mm granules or pellets. The batches may be differentiated by other characteristics such as different volumetric weight, or polymer quality. Batches of the same or different characteristics can be processed either separately or in combination with each other, thus blending to provide an end product having desired characteristics. The polymer batches can be processed together with other solid, liquid or gaseous additives added during the feeding process.

The feeder conveyor may have any convenient conformation but typically comprises an auger or plunger located within a casing. Typically the conveyor has three zones:

1. an initial proximal zone – in this zone the flow of polymer waste from the hopper into the conveyor may be controlled. The expulsion of interstitial air from the polymer waste commences in the hopper and continues in this zone;
2. a middle zone – in this zone the polymer waste is transported, typically with some compression. The expulsion of interstitial air continues in this zone; and
3. a distal zone – in this zone there is control of flow of polymer waste into the extruder and further small amounts of air are expelled with additional compression. Solid, liquid or gaseous additives may be admitted preferably to this zone, to aid extrusion or improve product quality.

In a particularly preferred embodiment the casing for the conveyor of the main body of the extruder is a cannon barrel or similar portion of a decommissioned armament. Cannon barrels having rifling are particularly preferred because the rifling aids flow of polymer waste and the motion of any auger or screw therein. Furthermore, the cross-sectional diameter of many cannon barrels decreases from the proximal zone to the distal zone. This profile also assists in movement of the waste polymer along the length of the conveyor.

Typically many apertures will be present in the proximal, middle and distal zones and in the one or more hoppers of the feeder and the proximal zone of the main body of the extruder. The apertures permit exit of air that would otherwise remain trapped in the interstices between polymer particles. This has the advantages of;

- improving packing and flow of particles along the feeder conveyor and into the extruder with concomitant increase in efficiency and productivity,
- improving packing of particles in the extruder which reduces friction, particularly between the particles and the channels of the screw,
- improving the quality of product from the extruder, and concomitantly the quality products of downstream processes,
- minimising undesirable reactions such as pyrolysis that may occur during extrusion, particularly during high temperature extrusion.

Control of the volume of material supplied to the feeder conveyor is typically achieved by regulation at the point where a hopper communicates with the conveyor. For example, control may be achieved by regulating the size of a port, comprising an opening or conduit through which polymer material enters the conveyor. When the port is an opening in the casing of the conveyor, its size may be altered by linear or non-linear movement of an iris, plates or a hatch forming part of the casing. The casing may comprise for example, telescopic casing segments that can move to increase or decrease the size of the port. Alternatively the casing may comprise one or more slidable hatches that can move linearly to open up or close the port.

In a preferred embodiment, the feeder includes an impulse generator. The impulses may be generated by an ultrasound device or other device that creates vibration. Preferably the impulse generator comprises part of the feeder and is located in close proximity to the main body of the extruder. Typically the impulses act on the feed to improve its flow and supply from the conveyor into the extruder. The impulses typically also improve packing of polymer particles, promote the exit of interstitial air, and reduce the effect of friction. When the impulse generator is an ultrasonic generator, it may also advantageously assist in devulcanisation of the polymer. Ultrasonic waves can, at certain levels (and particularly in the presence of pressure and heat) break up the bonds in vulcanised rubber, particularly the carbon-sulphur and sulphur-sulphur bonds. The ultrasonic waves typically soften the pieces of polymer, facilitating reprocessing, shaping and revulcanisation.

The extruder typically includes a single-screw or a twin-screw. Optimisation of supply of polymer waste to the extruder is important for increasing the mass and volume of the feedstock being supplied to the extruder per operating cycle in order to increase its productivity, as well as for reduction of friction and expulsion of air.

In a third embodiment the present invention provides a method of polymer processing comprising;

- storing one or more batches of waste polymer in one or more respective hoppers,
- regulating the volume of waste polymer supplied to a conveyor from the one or more hoppers,
- transporting the waste polymer from the one or more hoppers and along the one or more conveyors to an extruder such that at least some interstitial air is expelled from the waste polymer,
- feeding the waste polymer from the one or more conveyors to an extruder, and
- passing the waste polymer through the extruder to provide a pulverised activated and/or devulcanised polymer product.

The waste polymer may also be subjected to further devulcanisation subsequent to extrusion when necessary.

Typically devulcanisation is achieved by the following methods or combinations of methods;

- Mechanical – Devulcanisation can be achieved by intense mechanical working of waste polymer, often in the presence of reclaiming oils and high temperature. In addition the action of an extruder subjects particles of waste polymer to high compressive shear and torsion due to the screw rotation, thus pulverising the waste polymer particles. They emerge from the pulverization zone with a smaller particle size, often powder, and slightly devulcanised. The particles produced typically have irregular shape, porous structure and rough surfaces. They are typically suitable for moulding into products after exposure to heat and pressure.
- Ultrasound – as mentioned above, the device of the present invention may include an ultrasound generator. Alternatively, the product from the extruder may be subsequently subjected to ultrasound treatment. The ultrasonic waves at certain power levels can quickly break up the crosslinking and devulcanise polymers. Heat and pressure can facilitate the process.

- **Chemical** – devulcanisation can be achieved by treating vulcanised polymer with chemicals, including solvents such as 2-butanol; sulphur based chemicals such as monosulphides, disulphides, polysulphides and thiols; and inorganic agents such as alkali metals, typically in the presence of an organic solvent such as naphtha, toluene, benzene or cyclohexane. The application of heat or pressure may be used to facilitate the chemical reaction. Milling may also be necessary for certain chemical devulcanisation processes. The polymer waste can be chemically treated during extrusion, but more typically the pulverised product from the extruder is supplied to a subsequent chemical treatment process.
- **Microwave** – devulcanisation may also occur due to the application of microwave energy. Microwaves create heat quickly and uniformly in the waste polymer, but usually only if the waste polymer includes polar groups. The polymer waste can be treated with microwaves during extrusion, but more typically the pulverised product from the extruder is supplied to a subsequent microwave treatment process.
- **Biological** – devulcanisation can also be achieved by biological agents such as *thibacillus* and chemolithiotrope bacterium however biological devulcanisation is typically limited to the surface of waste polymer. Biological devulcanisation is also relatively slow and would typically be applied to the pulverised product from the extruder rather than during extrusion.
- **Digestion** – devulcanisation of waste polymer can be achieved by the application of steam, or a caustic aqueous solution optionally in the presence of a reclaiming oil.

In a fourth embodiment the present invention provides a process for at least partially devulcanising waste polymer, the process comprising;

- passing waste polymer through the polymer processing device of the present invention, and

- subjecting the waste polymer to a devulcanisation method chosen from the group comprising mechanical, chemical, ultrasonic, microwave, biological methods, digestive methods or combinations thereof,

to provide a pulverised devulcanised polymer product.

In a fifth embodiment the present invention provides a process for at least partially devulcanising waste polymer, the process comprising;

- warming the waste polymer prior to and/or whilst passing waste polymer through the polymer processing device of the present invention, and
- subjecting the waste polymer to a devulcanisation method chosen from the group comprising mechanical, chemical, ultrasonic, microwave, biological methods, digestive methods or combinations thereof,

to provide a pulverised devulcanised polymer product.

In a preferred embodiment, the water utilised for the cooling process in the main body of the extruder is also utilised for the initial warming of the feedstock in order to reduce the required energy of the extrusion process in the main body of the extruder for providing an end product with the desired characteristics.

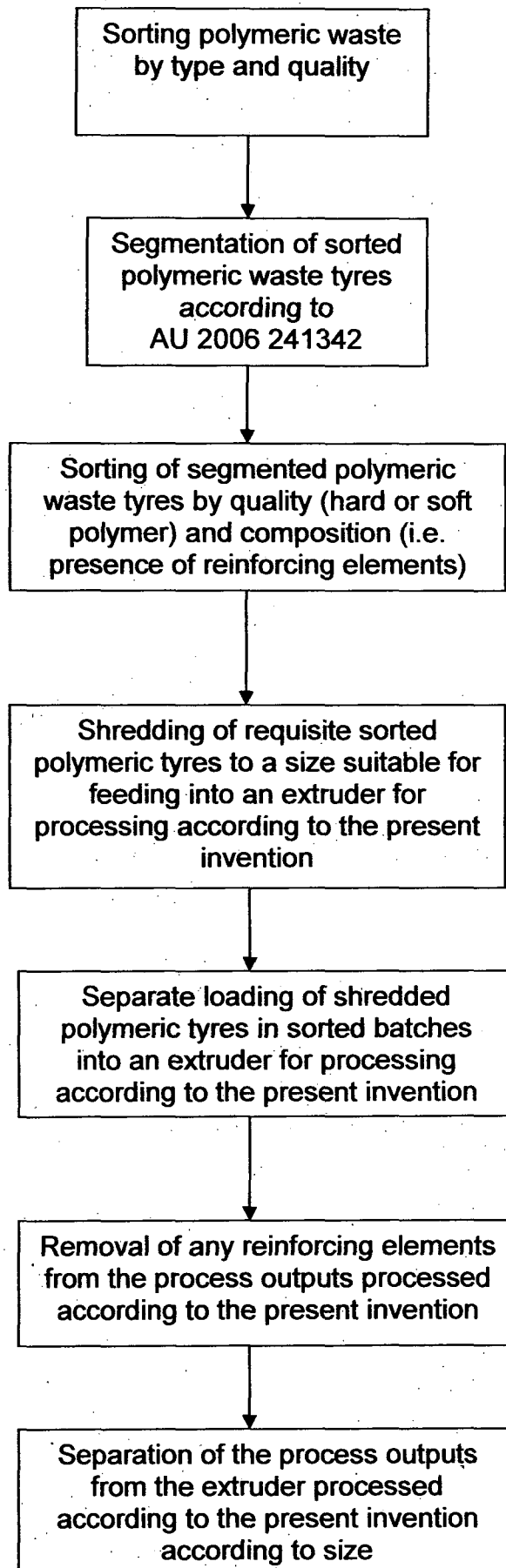
The present invention is based on the realisation that the manner in which a feed is supplied to a downstream process or device contributes significantly to the behaviour of the feed inside the process or device and the characteristics of the end product. In particular it is based on the realisation that simply controlling the speed of a conveyor is not on its own sufficient to optimise feed flow - packing and concomitant feed flow will be optimised by removal of interstitial air in combination with the control of the volume and speed of the supply of the feed to the conveyors of the present invention.

Advantages provided by the present invention include the following:

- Increased production capacity of the process;
- Improved the quality of the output of the process;
- Reduced volume of air passing into the process;
- Increased mobility and 'fluidity' of the polymer material passing through the feeder auger and downstream extrusion process;
- Reduced energy requirements per unit of product;
- Reduced the capital outlay required for the feeder;
- Reduced the servicing requirements of the feeder;
- Reduced the capital outlay required for the extruder; and
- Reduced the servicing requirements of the extruder.

The device and method of the present invention also has the advantage of being compatible with other processes relating to polymer waste, including tyre waste. For example **Scheme 1** below illustrates a preferred method for preparing batches of tyre waste for extrusion according to the process of the present invention. Waste sorted into batches (according to whether it comprises whole tyre or segmented tyre, whether it is soft polymer segment or hard polymer segment, or whether or not reinforcing material is present) can be reduced to a vulcanised or devulcanised product.

Scheme 1:



Further scope of applicability of embodiments of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the disclosure herein will become apparent to those skilled in the art from this detailed description.

Brief Description of the Drawings

The present invention will now be described with reference to the figures of the accompanying drawings, which illustrate particular preferred embodiments of the present invention, wherein:

Figure 1 is a plan view of a cross section of the feeder of the present invention adapted to transport feed material via a horizontal conveyor to an extruder shown in end-on cross section.

Figure 2 is a plan view of the top of the feeder and extruder of Figure 1.

Figure 3 is a plan view of a cross section of a further embodiment of the feeder of the present invention having a vertical conveyor to transport feed material to a horizontal extruder.

Figure 4 is a plan view of a cross section of a further embodiment of the feeder of the present invention having an angled conveyor to transport feed material to a horizontal extruder.

Figure 5 is an axonometric view of an extruder suitable for use in the present invention.

Figure 6 is a plan view of a cross section along A-A of the device of Figure 4.

Figure 7 is a plan view of a cross section along B-B of the device of Figure 4.

Figure 8 is a plan view of a cross section along E-E of the device of Figure 2.

Figure 9 is a plan view of a cross section of the casings of the feeder and the associated main body of the extruder.

Figure 10 is a plan view of a cross section of a feeder of the present invention having multiple hoppers.

Figure 11 is a plan view of a cross section of a dual hopper feeder of the present invention and associated conveyors and twin-screw extruder.

Detailed Description

List of parts

Where used in herein the reference numbers of the drawings correspond to the following:

- 1 feeder
- 2 extruder
- 3 casing of conveyor 6
- 4 driver for auger 12
- 5 hopper
- 6 conveyor of feeder 1
- 7 feed zone of extruder 2
- 8 feed zone for conveyor 6
- 9 driver for plunger 33
- 10 driver for extruder screw 18
- 11 hatch
- 12 auger for conveyor 6
- 13 feeder support
- 14 lever
- 15 feeder output opening
- 16 impulse generator
- 17 aperture
- 18 extruder screw
- 19 bottom section of conveyor 6
- 20 pivot for lever 14
- 21 pliable-resistant section of casing 3
- 22 regulator (part)
- 23 regulator (part)
- 24 connective rod

- 25 stationary component of conveyor 6
- 26 distal zone of conveyor 6
- 27 middle zone of conveyor 6
- 28 proximal zone of conveyor 6
- 29 inlet port
- 30 collector
- 31 face of plunger 33
- 32 aperture
- 33 plunger for conveyor 6
- 34 casing for hopper(s) 5
- 35 conduit for gaseous additives
- 36 conduit for solid or liquid additives
- 37 divider of hopper 5
- 38 guide rail for divider 37
- 39 casing for extruder(s) 2

Figure 1 is a plan view of a cross section of the feeder 1 of a particularly preferred embodiment of the present invention.

The feeder 1 includes a hopper 5 for storing polymer feed pieces. Typically the hopper 5 is filled with a batch of divided polymer material, such as granules or pellets of about 5, 10, 20 or 25 mm. Feed passes from the hopper 5 into the feed section 8 of the conveyor 6.

A driver 4 rotates a horizontal conveyor 6 comprising an auger 12 within a casing 3. A separate control mechanism (not shown) regulates the rotational speed of the auger 12 via the driver 4. The auger 12 transports the polymer feed pieces away from the hopper 5. The conveyor 6 has a distal zone 26, middle zone 27 and a frusto-conical shaped proximal zone 28.

The volume of polymeric pieces supplied to the auger is regulated by control devices 22 and 23 being, for example, slide devices, or alternatively telescopic pipe-sockets or the like.

The regulators, 22 and 23, can regulate the size of the opening of the open feed section 8 of the conveyor 6. For each particle size of feed there is a requirement for a different preliminary regulation of input volume via regulators 22 and 23.

Feeds of different sizes should be processed separately so that the packing of feed in the extruder screw 18 will optimise efficiency, capacity and product quality of the extruder 2.

The auger 12 feeds polymer pieces into the main body of the extruder 2, which in this view, is shown end-on in cross section.

The auger 12 includes apertures 32 and 17 for the exit of air during transport. Apertures may also be provided in the extruder 2 casing.

In this embodiment, the feeder 1 further comprises an impulse generator 16 which creates impulses, such as ultrasonic impulses, for softening of cured polymeric pieces as well as further facilitating their passage and aiding in the expulsion of interstitial air. The position of the impulse generator is chosen to optimise the passage of polymer pieces into the feed section 7 of the extruder 2. This concomitantly enhances packing, displaces air from interstices between particles and decreases friction between the feed and the screw. The expulsion of air is particularly preferred when the extruder 2 includes a high temperature zone, so as to minimise adverse effects such as unwanted chemical reactions in the said high temperature zone (not shown).

The frequency of impulses produced by the impulse generator 16 is varied according to the characteristics and size of the feed material being supplied to the extruder. The casing of the conveyor 6 may comprise a pliable-resilient section 21 that facilitates transmission of the impulses.

An inlet port 29 comprising a pipe socket is provided for the addition of additives. These processing additives may be in gaseous, liquid or solid form for improving extrusion or devulcanisation. For example, the additives may be included to establish certain characteristics and material compositions of the product from the extruder. Alternatively or in addition, the additives may be added to improve processing of the polymer feed. In particular, lubricating additives may be used to reduce friction between the compacted feedstock and the channels of the screw 18 in the extruder 2.

Figure 2 is a plan view of the top view of the extruder depicting the feeder 1 and extruder 2. **Figure 2** depicts in more detail the apertures 17 and 32 for exit of air, as well as the impulse generator 16 transmitting impulses to the feed zone 7 of the extruder 2. In this view can be seen a collector 30 for finished products from the extruder 2.

Figure 3 is a plan view of a cross section of a further embodiment of the feeder 1 of the present invention. In this embodiment the conveyor 6 is vertically oriented and transmits polymer feed pieces into a horizontal extruder 2. This view clearly shows the output opening 15 of the feeder 1 where it joins the extruder 2 at the feeding zone 7.

The conveyor 6 is supported within the hopper 5 of the feeder 1 by a support 13. The conveyor 6 is rotated by the driver 4. The hopper 5 includes a hatch 11 for cleaning and clearing of polymer pieces and sediment.

The volume of polymer pieces transported by the conveyor 6 is regulated by a lever 14 operating about a pivot 20 which moves telescopic slides 22 and 23 over the casing 3 of the conveyor 6.

A pliable-resilient section 21 of the conveyor casing 3 connects the bottom section 19 of the conveyor to the extruder 2. The connector 21 includes apertures 17, for the exit of air. The section 21 is in the shape of a truncated cone.

Inlet 29 permits the addition of various other additive substances in gaseous, liquid or solid form, as required.

The extruder 2 has a screw 18 which is rotated by driver 10.

Figure 4 is a plan view of a cross section of a further embodiment of the feeder 1 of the present invention having an angled conveyor 6 comprising a plunger 33. The plunger 33 is moved by a hydraulic driver 9. The face 31 of the plunger has a flat or curved profile as appropriate for the angle of connection between the conveyor 6 and the extruder 2. Whether the conveyor 6 comprises an auger or a plunger or other device for transportation will depend on the properties of the polymer feed. For example, certain feedstock materials require a pulsating feeding action to optimise their delivery into the screw 18 of the extruder 2. In this case a conveyor 6 comprising a plunger 33 which may be pulsed during its action would be the preferred.

The conveyor 6 has an initial distal zone 26, middle zone 27 and proximal zone 28 in proximity to the extruder 2. The plunger 33 may have a continuous up and down movement or discontinuous, providing a pulsating delivery of polymer feed from the hopper 5 to the extruder 2.

Figure 5 depicts an axonometric view of the casing 3 of the conveyor 6 showing the telescopic sliding movement of regulators 22 and 23, which

regulates the size of the opening to the feed zone of the conveyor 8. This controls the volume of the polymeric materials that can enter the conveyor and be transported to the extruder 2.

Inlet port 29 in the form of a pipe socket allows the addition of various substances in gaseous, liquid or solid form, as required to aid processing.

The conveyor 6 can be placed in any convenient orientation from vertical, to angled, to horizontal relative to extruder 2.

The feed zone 8 incorporates connective rods 24 in connection with the stationary component 25 which give internal support to the casing 3 as well as providing a sliding mechanism to regulator 22.

Figure 6 is a plan view of a cross section along A-A of the device of **Figure 4**. In this view the plunger 33 can be seen filling the casing 3 of the conveyor. Regulator 22 with apertures 17 is also depicted.

Figure 7 is a plan view of a cross section along B-B of the device of **Figure 4**. In this view the face 31 of the plunger 33 is shown.

Figure 8 is a plan view of a cross section along E-E of the device of **Figure 2** showing the hopper 5 and the casing 3 of the conveyor. A hatch 11 opens into the hopper 5 for cleaning, clearing or purging of polymeric materials, sediments, and the like from the hopper 5. Apertures 32 allow the exit of air that can be trapped amongst pieces of polymer feed when the conveyor is in an angled or horizontal orientation.

The conveyor 6 of the feeder 1 depicted in the drawings preferably has a diameter that is at least 1.5 times greater than the diameter of the screw 18 of the extruder 2 in order to optimise processing and production capacity of the extruder. More preferably the conveyor 6 has a diameter that is 2 to 2.5 times greater than the diameter of the screw 18 of the extruder 2.

Figure 9 is a plan view of a cross section of the casings of the feeder and the associated main body of the extruder of the present invention showing the hopper casing 34 and extruder casing 39 along their longitudinal axis depicting multiple apertures 17 and 32 through which air can escape from the hopper(s) 5 and the extruder(s) 2.

Figure 10 is a plan view of a cross section of a feeder of the present invention. In this embodiment the feeder 1 includes a hopper 5, partitioned by a divider 37 to form two smaller hoppers 5a, 5b. In other embodiments, the

divider 37 is made mobile. Also, in other embodiments the hopper 5 could be further partitioned to form yet more hoppers. Each of the smaller hoppers 5a and 5b, store batches of polymer particles of different size and/or different quality.

The polymer particles pass from hopper 5a into feed section 8a of conveyor 6a and are pushed along the conveyor 6a by an auger 12a. Similarly, polymer particles of a different size and quality pass from hopper 5b into feed section 8b of conveyor 6b and are pushed along the conveyor 6b by an auger 12b. Separate regulators can be used for respective hoppers 5a and 5b. One regulator can be non-operational, or operated at a different rate to the other. In this manner blends of the different qualities of polymer can be conveyed to the extruder and the composition of the extruded product thus controlled.

Conduit 35 allows for the addition of gasses, and conduit 36 allows for the addition of solids and/or liquids. A vibration device 16 is utilised to for softening of cured polymeric pieces as well as further facilitating their passage and aiding in the expulsion of interstitial air as necessary. Guide rail 38 allows for the controlled movement of the mobile divider 37 to determine its end position and the relative positions of its associated elements. Apertures 17 and 32 in the casing of the conveyors and the extruder permit expulsion of air.

Thus, in this embodiment, the two different batches of polymer are transported in separate conveyors to an extruder 2 having a single screw 18.

Figure 11 is a plan view of a cross section of a dual hopper feeder of the present invention and associated conveyors and twin-screw extruder. In this embodiment the feeder 1 includes a hopper 5, partitioned by a divider 37 to form two smaller hoppers 5a, 5b. Each of the sub-hoppers 5a and 5b, store batches of polymer particles of different size and/or different quality.

Regulators 23a, 23b control the flow of polymer particles from respective sub-hoppers 5a, 5b by adjustment of the position of a slidable member and concomitant adjustment of the size of the opening between each sub-hopper and respective conveyors 6a, 6b. One regulator can be non-operational, or controlled differently to the other. In this manner blends of the different qualities of polymer from hoppers 5a and 5b can be conveyed to the extruder and the composition of the extruded product thus controlled.

The polymer particles pass from the sub-hoppers 5a, 5b into feed sections 8a, 8b of their respective conveyors 6a, 6b. Augers 12a, 12b push the polymer particles along the conveyors 6a, 6b. Separate regulators can be used for respective hoppers 5a and 5b. An ultrasonic impulse generator 16 assists feeding of the polymer particles as necessary. The relative positions of the impulse generator 16 and the regulators 23a, 23b can be adjusted by a mobile alignment device (not shown) which drives the mobile divider 37 to which these elements are connected.

In this embodiment, the two different batches of polymer are transported in separate conveyors to an extruder 2 having twin screws 18a, 18b. This embodiment of the feeder and extruder includes a conduit 35 for gaseous additives and a conduit 36 for solid or liquid additives which may be worked into the particulate polymer.

As the polymer particles pass from the sub-hoppers 5a, 5b and along the conveyors 6a, 6b, apertures 17 permit expulsion of air. These apertures 17 may be provided in any appropriate locations such as in the regulators 23a, 23b in the casing of the conveyors 6a, 6b.

In a particularly preferred embodiment the batches of feed for the device and process of the present invention are derived from tyres segmented according to the method of AU 2006 241342. The segments consist of:

1. the crown, which is the part of the tyre that contacts the road and provides grip and cornering stability. It typically includes a tread made of thick, hard polymer composition to resist abrasion, cutting and impact as well as withstanding high temperatures encountered on the road surface and due to friction. The tread is integrally bound to a belt made of steel wire or textile fabric. It acts as a reinforcement, reducing the impacts sustained from the road and helping to maintain stability by widening the tread in contact with the road. The inner surface of the crown (and side wall) is lined by a special air-tight polymer lining which substitutes for a tube;
2. the sidewall, which protects the carcass, which is the inner cord of the tyre that supports the weight and absorbs impact. The sidewall is

often made of a different polymer composition to the tread. It is thinner and designed to allow the tyre to expand and compress in response to the nature of the terrain to maintain good ride quality. The inner surface of the sidewall (and crown) is lined by a special air-tight polymer lining which substitutes for a tube; and

3. the bead, which is composed of a bead wire and a polymer core. The bead fixes the tyre to the wheel rim and secures the end of the cord.

Once they are separated these segments can be sorted according to whether or not they include hard polymer or soft polymer, and further, whether reinforcing elements are present. Once sorted into batches according to these qualities, they are typically shredded before the batches are processed separately according to the method of the present invention, or at least loaded into separate hoppers of the extrusion device for co-processing.

While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

As the present invention may be embodied in several forms without departing from the spirit of the essential characteristics of the invention, it should be understood that the above described embodiments are not to limit the present invention unless otherwise specified, but rather should be construed broadly within the spirit and scope of the invention as defined in the appended claims. The described embodiments are to be considered in all respects as illustrative only and not restrictive.

Various modifications and equivalent arrangements are intended to be included within the spirit and scope of the invention and appended claims. Therefore, the specific embodiments are to be understood to be illustrative of the many ways in which the principles of the present invention may be practiced. In the following claims, means-plus-function clauses are intended to

cover structures as performing the defined function and not only structural equivalents, but also equivalent structures.

“Comprises/comprising” and “includes/including” when used in this specification is taken to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components or groups thereof. Thus, unless the context clearly requires otherwise, throughout the description and the claims, the words ‘comprise’, ‘comprising’, ‘includes’, ‘including’ and the like are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense; that is to say, in the sense of “including, but not limited to”.

Claims defining the invention are as follows:

1. A feeder for a downstream process, the feeder comprising;
 - one or more hoppers for storage of material,
 - one or more conveyors for transporting the material from the one or more hoppers to a downstream process,
 - one or more regulators for controlling the flow of material supplied to one or more conveyor from one or more hoppers, and
 - multiple apertures associated with the feeder for exit of air from the material.
2. A feeder according to claim 1 wherein at least one regulator comprises means for altering the size of a port between a hopper and a respective conveyor.
3. A feeder according to claim 1 or claim 2 wherein at least one conveyor is supplied by two or more hoppers.
4. A feeder according to claim 1 or claim 2 wherein the feeder additionally includes an impulse generator.
5. A feeder according to claim 1 or claim 2 wherein the feeder additionally includes conduits for solid, liquid and/or gaseous additives.
6. A polymer processing device comprising;
 - an extruder for pulverising waste polymer in communication with a feeder, the feeder comprising;
 - one or more hoppers for storage of waste polymer,
 - one or more conveyors for transporting the waste polymer from the one or more hoppers to an extruder,
 - one or more regulators for controlling the flow of waste polymer supplied to the one or more conveyors from the one or more hoppers,
 - multiple apertures associated with the feeder for exit of air from the waste polymer, and

- multiple apertures associated with the extruder for exit of air from the waste polymer.
7. A polymer processing device according to claim 6 wherein the conveyor of the feeder has a cross-sectional area greater than 1.5 times the cross-sectional area of the extruder.
 8. A polymer processing device according to claim 6 wherein the feeder conveyor casing comprises a cannon barrel.
 9. A polymer processing device according to claim 6 wherein the casing of the extruder comprises a cannon barrel.
 10. A polymer processing device according to any one of claims 6 to 9 wherein the regulator comprises one or more means for altering the size of a port between a hopper and a respective conveyor.
 11. A polymer processing device according to any one of claims 6 to 10 wherein the feeder additionally includes an impulse generator.
 12. A polymer processing device according to any one of claims 6 to 10 wherein the feeder additionally includes a plunger within the feeder conveyor which operates as an impulse driven device.
 13. A polymer processing device according to any one of claims 6 to 12 wherein at least one conveyor is supplied by two or more hoppers.
 14. A polymer processing device according to any one of claims 6 to 13 wherein the feeder incorporates a mobile divider with associated guide rails that controls the position of the hoppers in relation to the conveyors and the feeding zone of the extruder.
 15. A method of polymer processing comprising;
 - storing one or more batches of waste polymer in one or more respective hoppers,
 - regulating the flow of waste polymer supplied to a conveyor from the one or more hoppers,
 - transporting the waste polymer from the one or more hoppers and along the one or more conveyors to an extruder such that at least some interstitial air is expelled from the waste polymer,

- feeding the waste polymer from the one or more conveyors to an extruder, and
 - passing the waste polymer through the extruder to provide a pulverised activated polymer product.
16. A process according to claim 15 wherein the waste polymer comprises tyres.
17. A process according to claim 16 wherein the tyres are chosen from the group comprising whole tyres or segmented tyres.
18. A process according to claim 15 wherein each respective batch is chosen from the group comprising tyre tread, tyre sidewall and tyre bead, or combinations thereof.
19. A process for at least partially devulcanising waste polymer, the process comprising;
- passing waste polymer through a polymer processing device according to any one of claims 6 to 14, and
 - subjecting the waste polymer to a devulcanisation method chosen from the group comprising mechanical, chemical, ultrasonic, microwave, biological methods, digestive methods or combinations thereof,
- to provide a pulverised devulcanised polymer product.
20. A process for at least partially devulcanising waste polymer, the process comprising;
- warming the waste polymer prior to and/or whilst passing waste polymer through a polymer processing device according to any one of claims 6 to 14, and
 - subjecting the waste polymer to a devulcanisation method chosen from the group comprising mechanical, chemical, ultrasonic, microwave, biological methods, digestive methods or combinations thereof,
- to provide a pulverised devulcanised polymer product.

21. A process according to claim 20 wherein warming the waste polymer prior to and/or whilst passing waste polymer through a polymer processing device utilises heat from the cooling system of the extruder.

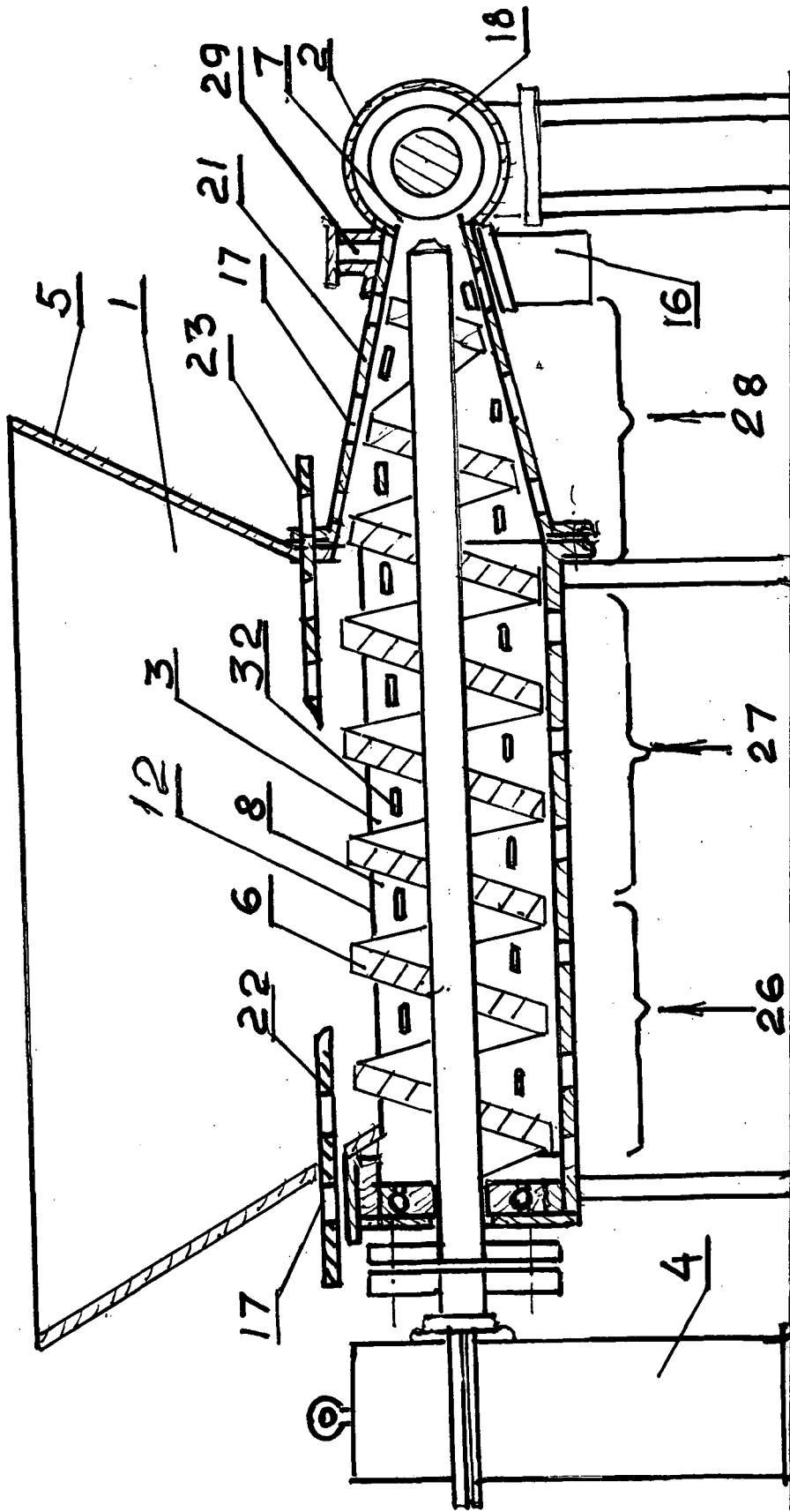


Fig. 1

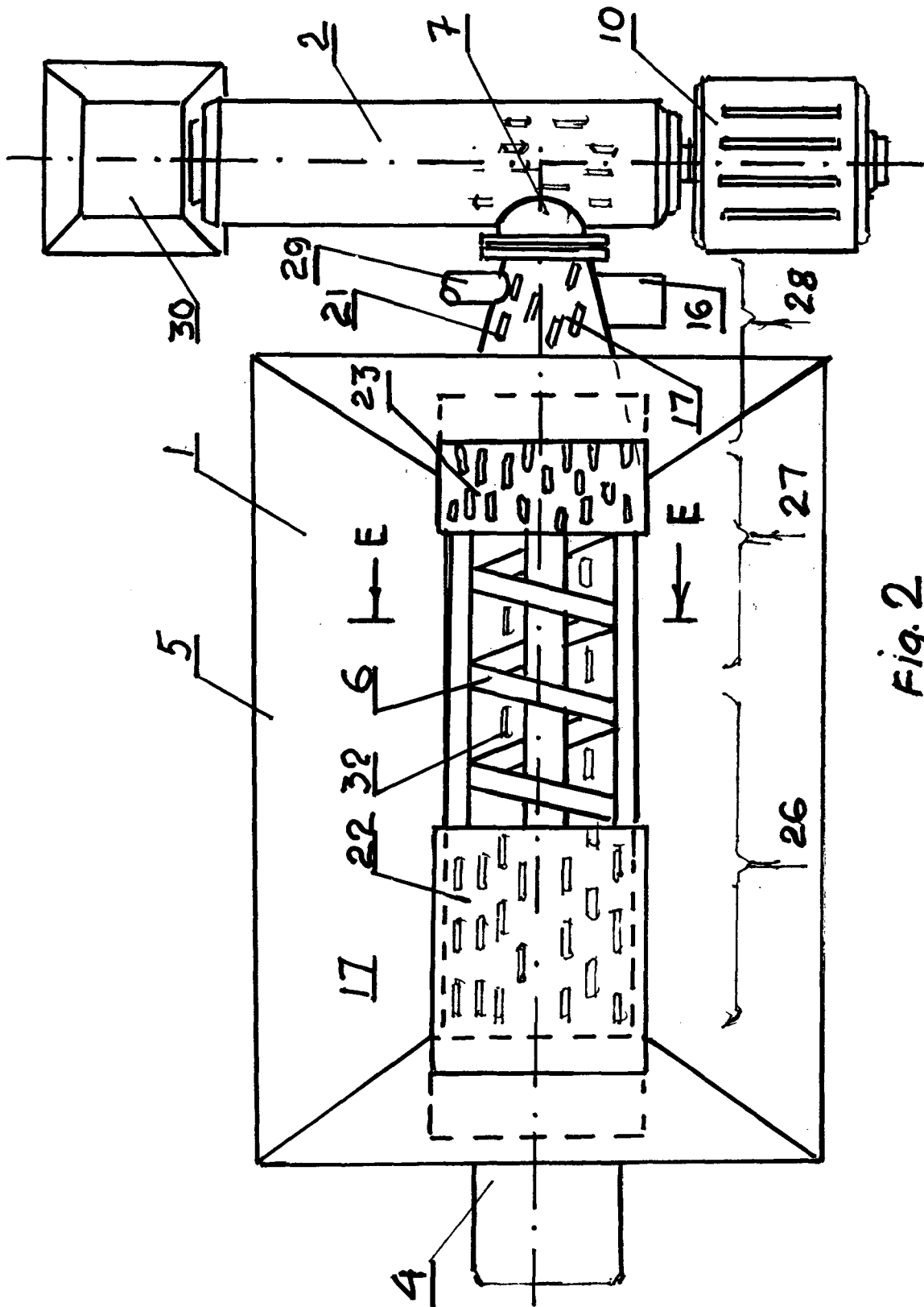


Fig. 2

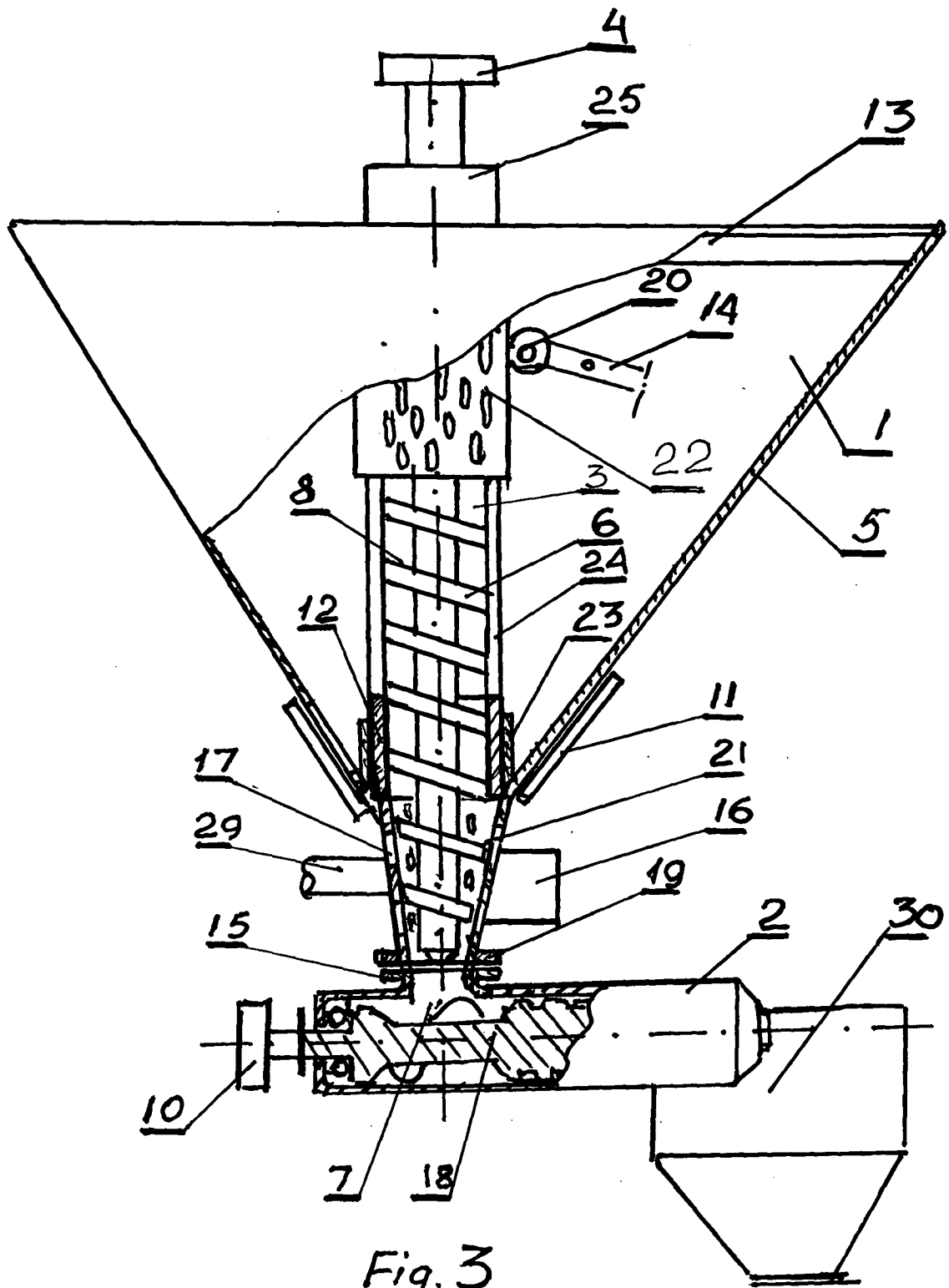


Fig. 3

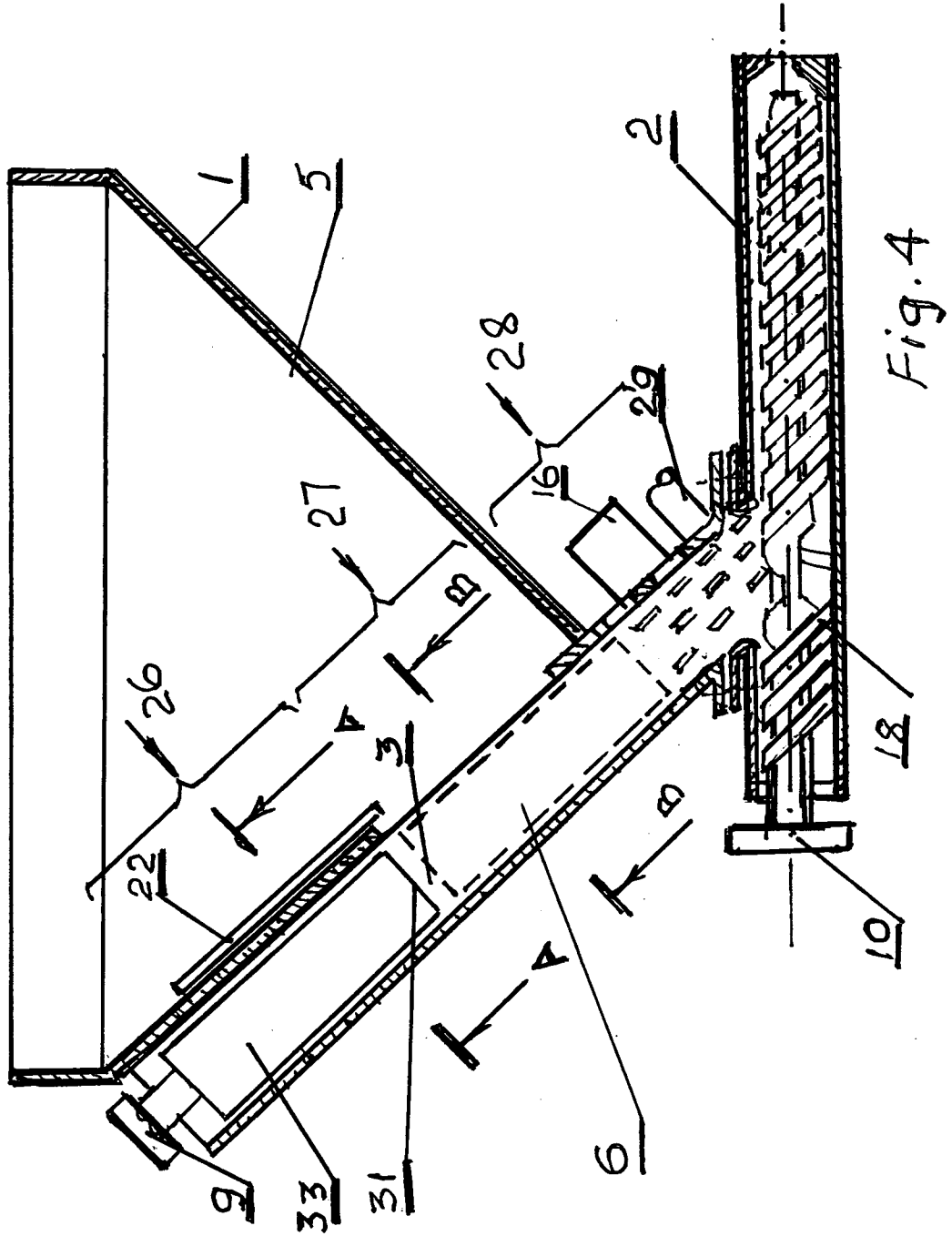


Fig. 4

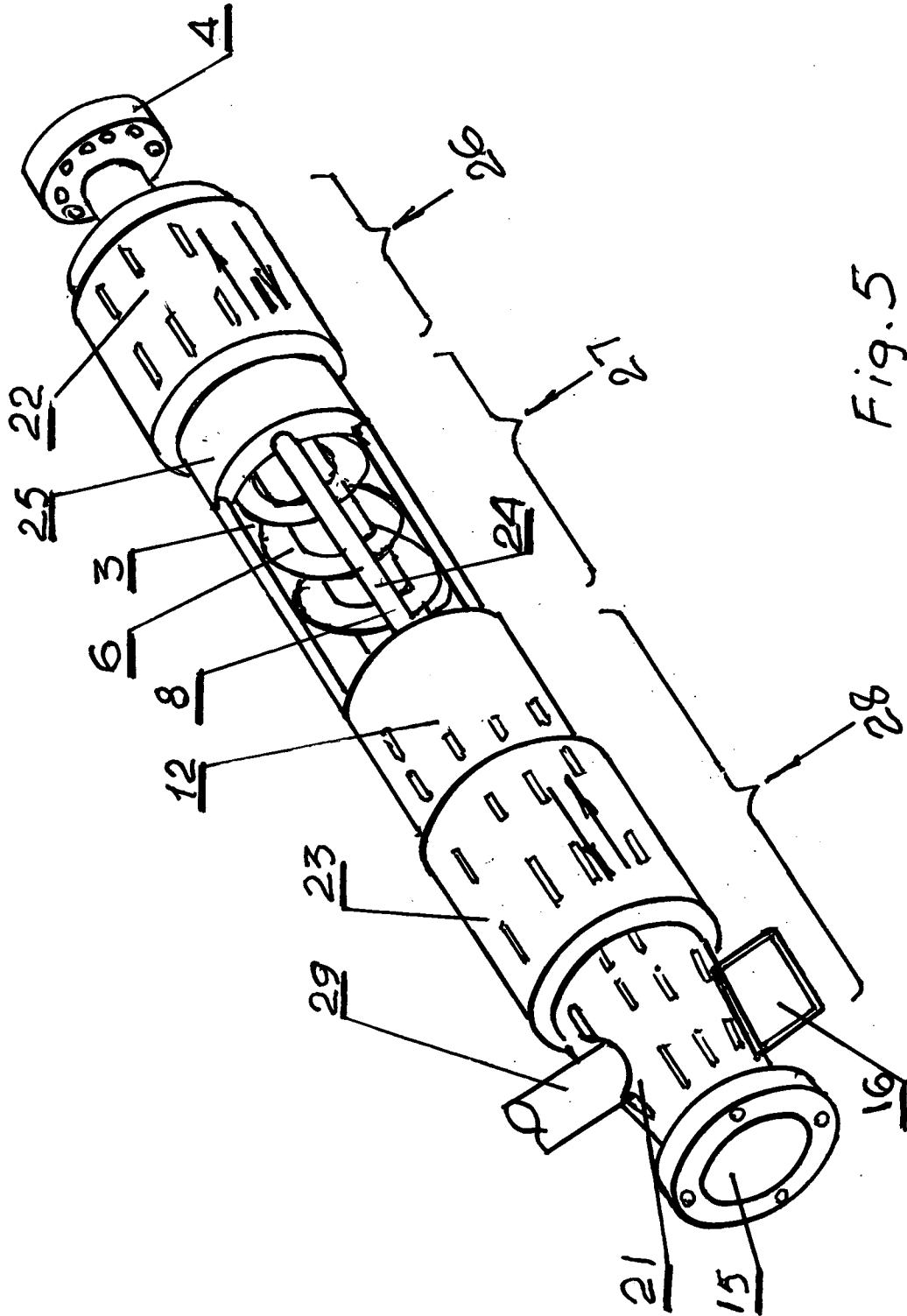


Fig. 5

B-B

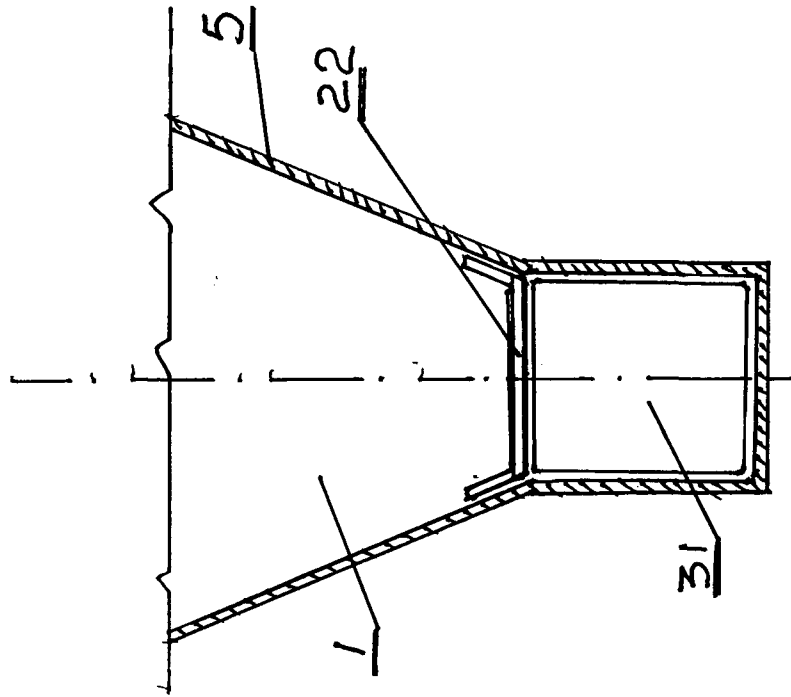


Fig. 7

A-A

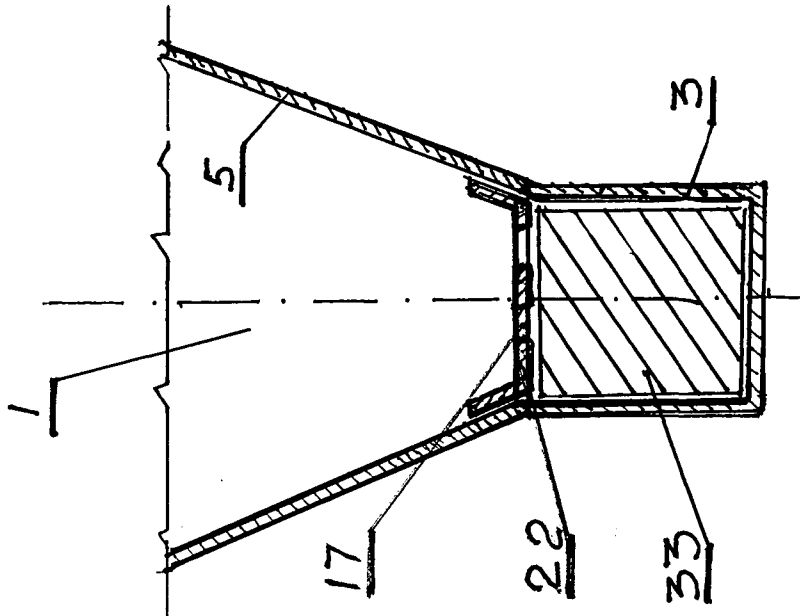


Fig. 6

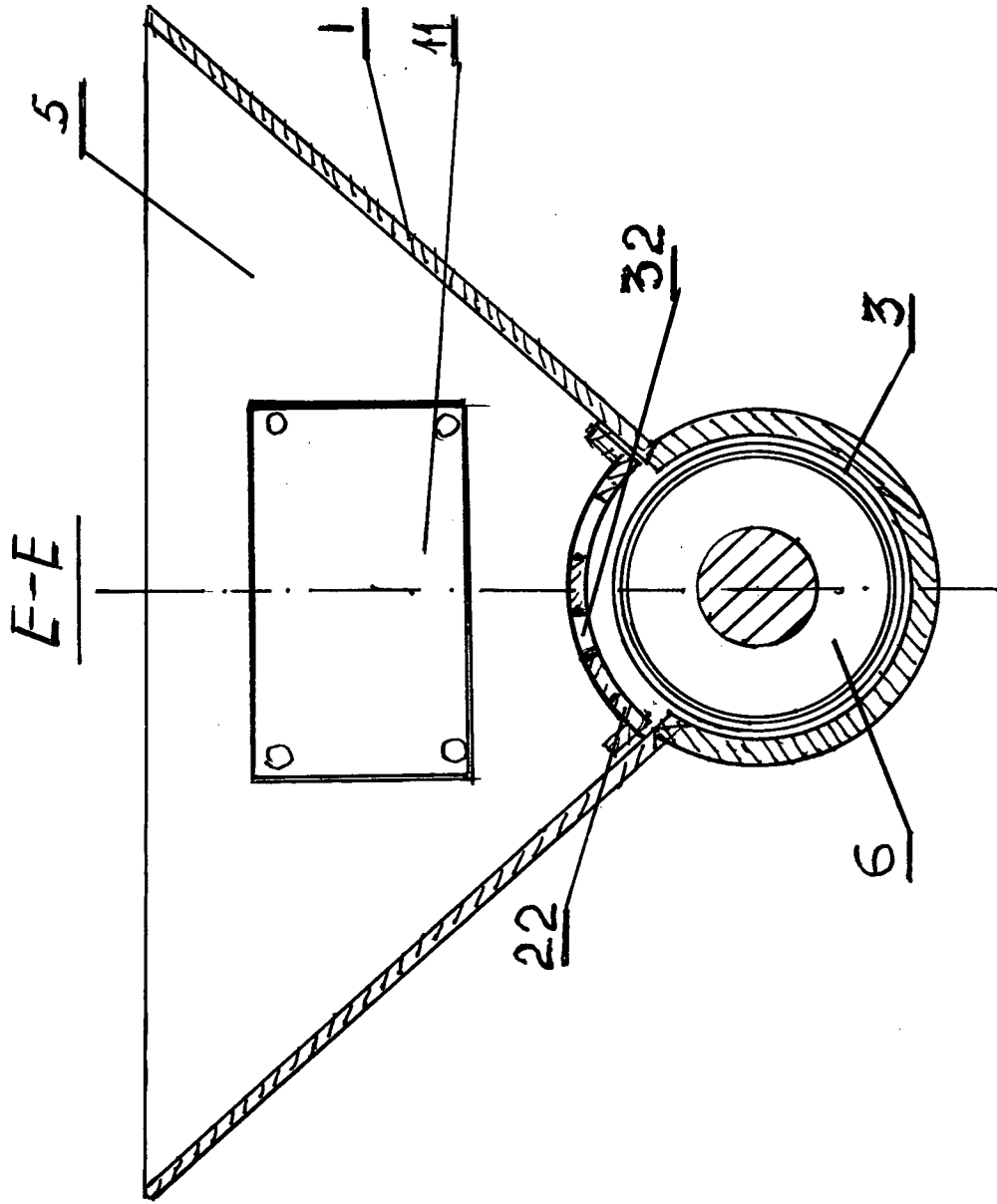


Fig. 8

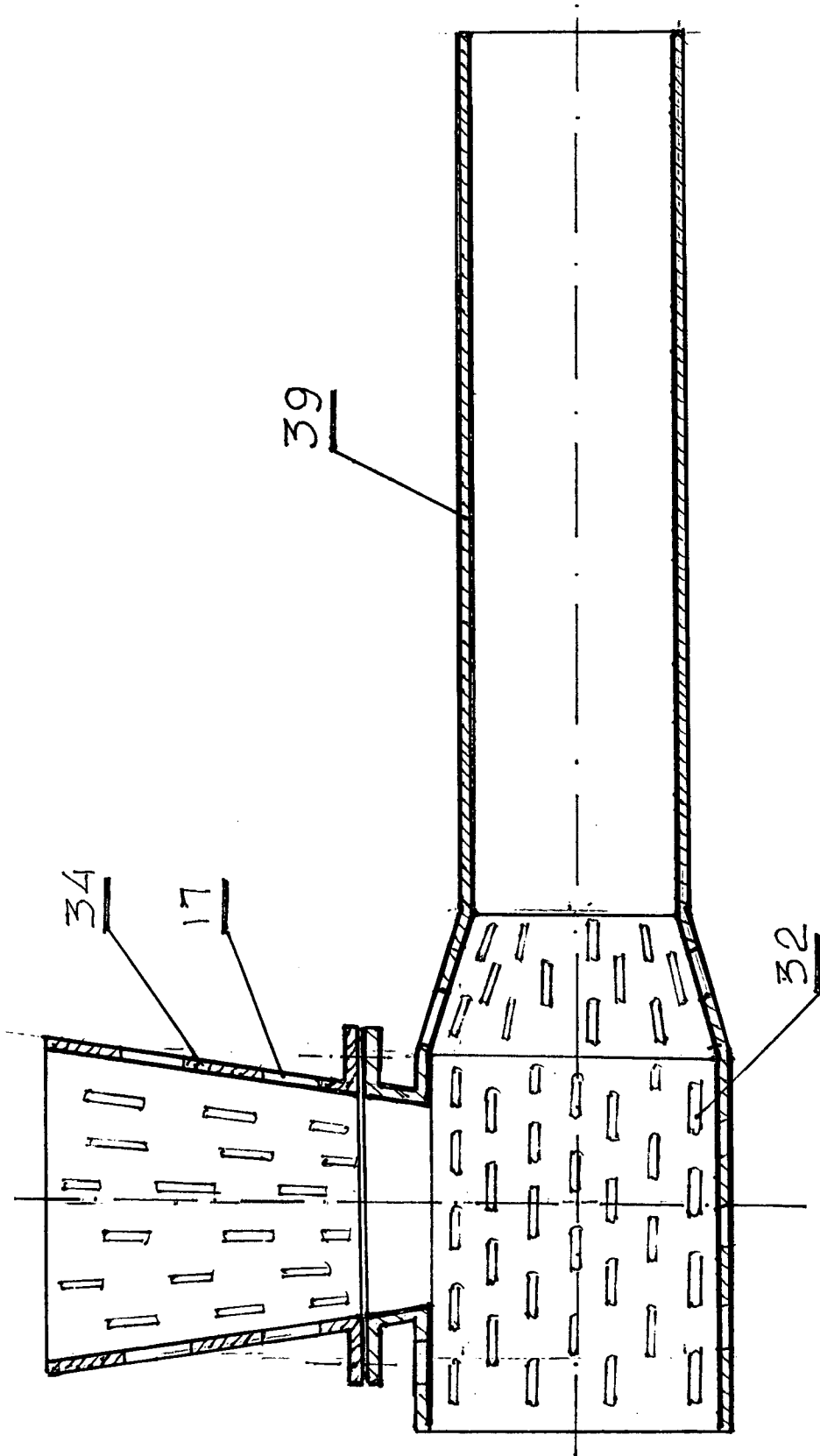


Fig. 9

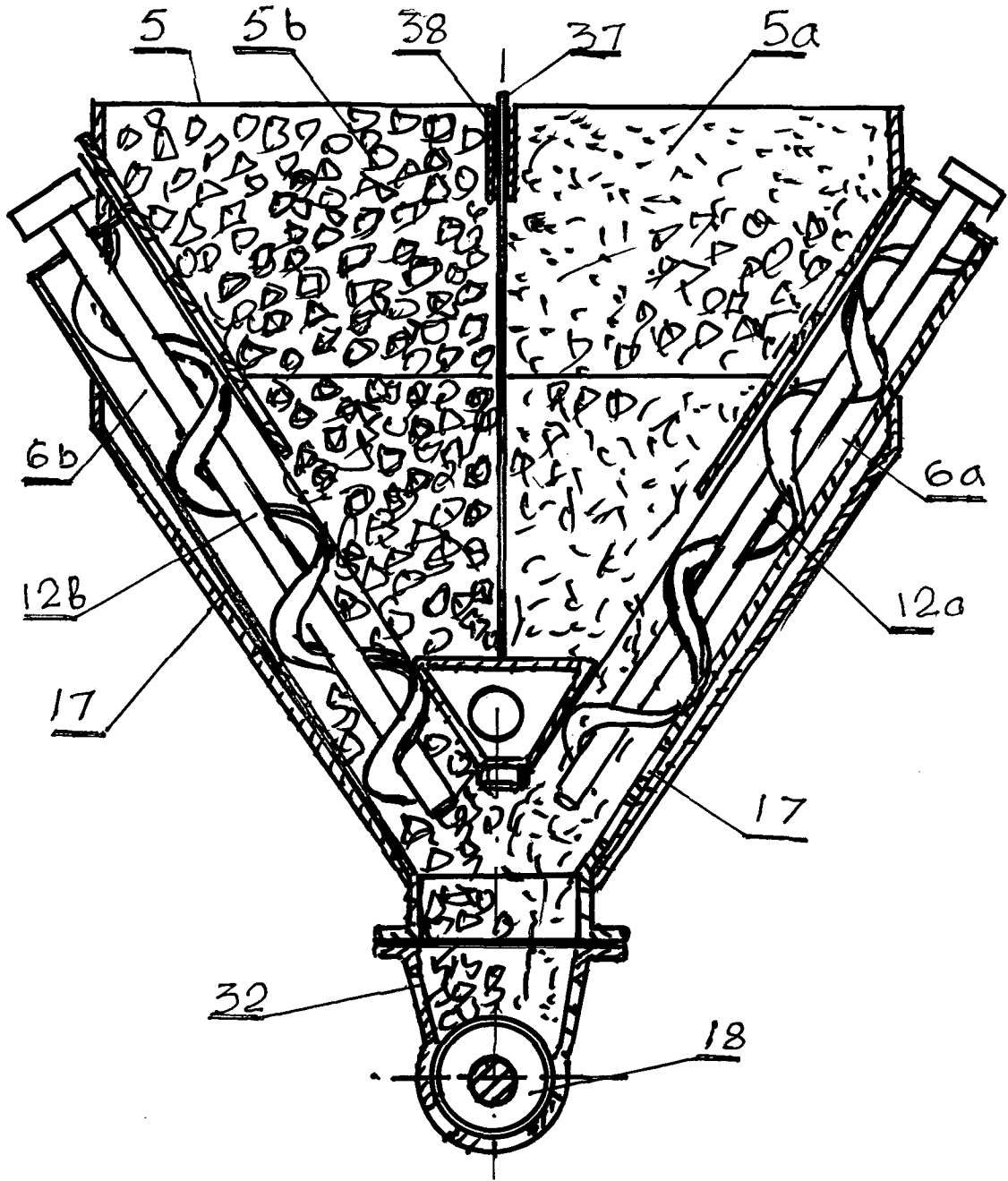


Fig.10

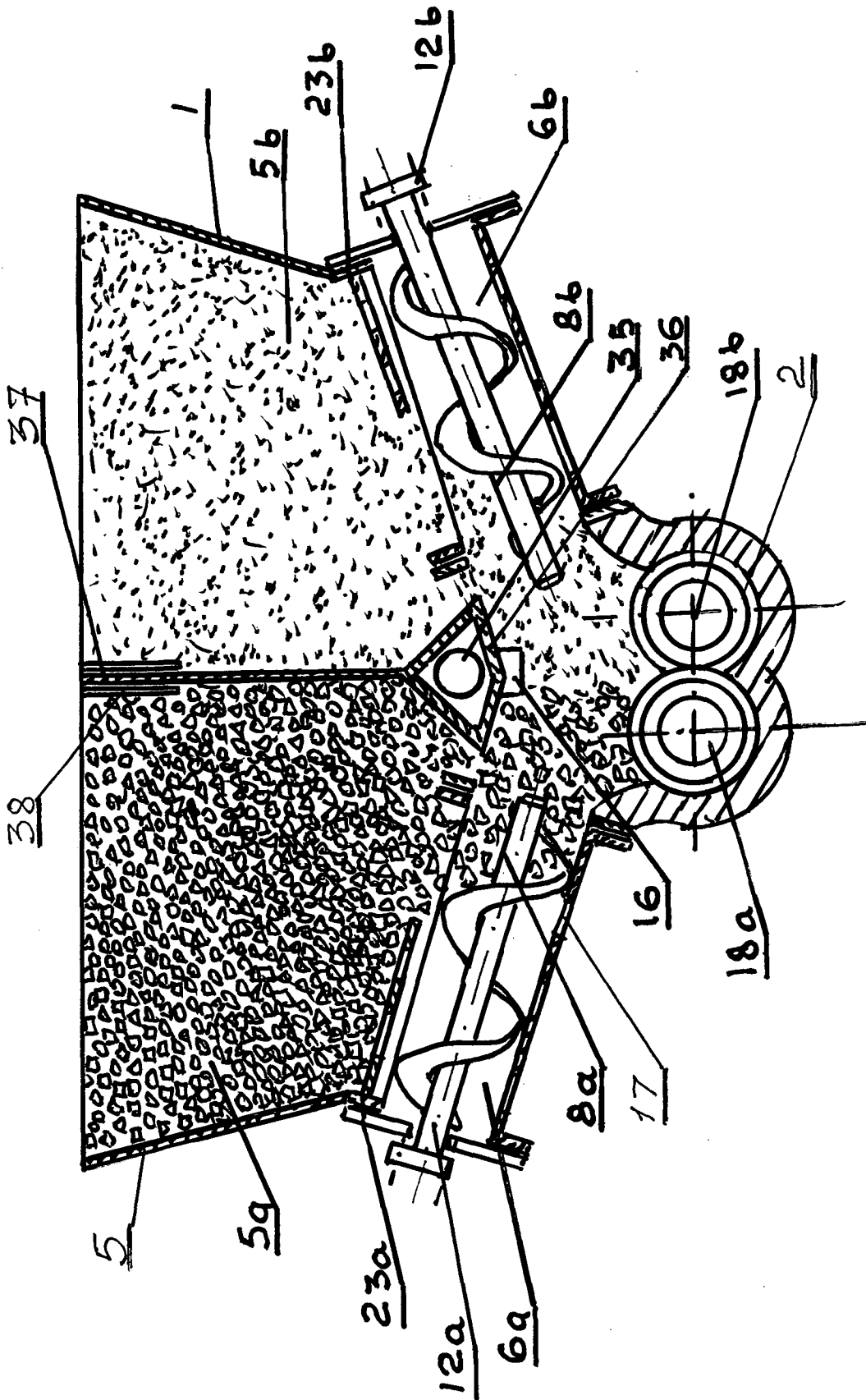


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2010/000284

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B29B 15/02 (2006.01)

B29C 47/08 (2006.01)

B29C 47/92 (2006.01)

B29B 17/04 (2006.01)

B29C 47/10 (2006.01)

B29C 31/02 (2006.01)

B29C 47/76 (2006.01)

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)

EPODOC and WPI with KEYWORDS (POLYMER+, PLASTIC+, EXTRUD+, PULVERIS+, SHRED+, AUGER, EXPEL+, VENT+, REGULAT+ AND SIMILAR TERMS), GOOGLE PATENTS with KEYWORDS (AIR, VENT, SCREW, EXTRUDER, POLYMER, WASTE)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5503788 A (LAZARECK ET AL) 2 April 1996 Figure 4; column 12 line 46 – column 13 line 65; column 14 lines 61 – 63	1, 3, 6 – 9, 13, 15 – 18
Y	Figure 4; column 12 line 46 – column 13 line 65; column 14 lines 61 – 63	4, 11
X	US 4110844 A (NAKAMURA) 29 August 1978 Figures 1 – 14; column 3 line 5 – column 10 line 4	1 – 3, 5, 6, 8 – 10, 13
X	US 6129873 A (SHELBY ET AL) 10 October 2000 Figure 2; column 3 line 23 – column 4 line 64; Examples 1, 2	1, 6, 8, 9
Y	US 5468429 A (LI ET AL) 21 November 1995 Column 3 lines 31 – 60	4, 11

 Further documents are listed in the continuation of Box C See patent family annex

* Special categories of cited documents:		
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family	
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

13 May 2010

Date of mailing of the international search report

17 MAY 2010

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaustalia.gov.au
Facsimile No. +61 2 6283 7999

Authorized officer

MILKA WENAS
AUSTRALIAN PATENT OFFICE
(ISO 9001 Quality Certified Service)
Telephone No : +61 2 6283 2593

INTERNATIONAL SEARCH REPORT

International application No.

Information on patent family members

PCT/AU2010/000284

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.

Patent Document Cited in Search Report		Patent Family Member					
US	5503788	CA	2153450	EP	0692356	JP	9085212
US	4110844	NONE					
US	6129873	NONE					
US	5468429	NONE					

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

END OF ANNEX