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The invention relates to an apparatus according to the preamble of Claim 1.

The prior art reveals numerous similar apparatuses of varying design, comprising a receiver or cutter compactor for the comminution, heating, softening and treatment of a plastics material to be recycled, and also, attached thereto, a conveyor or extruder for the melting of the material thus prepared. The aim here is to obtain a final product of the highest possible quality, mostly in the form of pellets.

By way of example, EP 123 771 or EP 303 929 describe apparatuses with a receiver (receiving container) and, attached thereto, an extruder, where the plastics material introduced into the receiver is comminuted through rotation of the comminution and mixing implements and is fluidized, and is simultaneously heated by the energy introduced. A mixture with sufficiently good thermal homogeneity is thus formed. This mixture is discharged after an appropriate residence time from the receiver into the screw-based extruder, and is conveyed and, during this process, plastified or melted. The arrangement here has the screw-based extruder approximately at the level of the comminution implements. The softened plastics particles are thus actively forced or stuffed into the extruder by the mixing implements.

Most of these designs, which have been known for a long time, however, are unsatisfactory in respect of the quality of the treated plastics material obtained at the outgoing end of the screw, and/or in respect of the quantitative output or throughput of the screw.

Critical to the end quality of the product are, firstly, the quality of the pretreated or softened polymer material that enters the conveyor or extruder from the cutter compactor, and, additionally, the situation at intake and on conveying or, where appropriate, extrusion. Relevant factors here include the length of the individual regions or zones of the screw, and also the screw parameters, such as, for example, screw thickness, flight depths, and so on.

In the case of the present cutter compactor/conveyor combinations, accordingly, there are particular circumstances, since the material which enters the conveyor is not introduced directly, without treatment and cold, but instead has already been pretreated in the cutter compactor, viz. heated, softened and/or partly cry-  
5 stallized, etc. This is a co-determining factor for the intake and for the quality of the material.

The two systems – that is, the cutter compactor and the conveyor – exert an influence on one another, and the outcomes of the intake and of the further con-  
10 veying, and compaction, where appropriate, are heavily dependent on the pre-treatment and the consistency of the material.

One important region, accordingly, is the interface between the cutter compactor and the conveyor, in other words the region in which the homogenized pretreated  
15 material is passed from the cutter compactor into the conveyor or extruder. On the one hand, this is a purely mechanical problem area, requiring the coupling to one another of two differently operating devices. Moreover, this interface is tricky for the polymer material as well, since at this point the material is usually, close to the melting range, in a highly softened state, but is not allowed to melt. If the  
20 temperature is too low, then there are falls in the throughput and the quality; if the temperature is too high, and if unwanted melting occurs at certain places, then the intake becomes blocked.

Furthermore, precise metering and feeding of the conveyor is difficult, since the  
25 system is a closed system and there is no direct access to the intake; instead, the feeding of the material takes place from the cutter compactor, and therefore cannot be influenced directly, via a gravimetric metering device, for example.

It is therefore critical to design this transition not only in a mechanically conside-  
30 red way, in other words with an understanding of the polymer properties, but at the same time to consider the economics of the overall operation – in other words, high throughput and appropriate quality. The preconditions to be observed here are in some cases mutually contradictory.

A feature shared by the apparatuses known from the prior art and mentioned in the introduction is that the direction of conveying or of rotation of the mixing and comminution implements, and therefore the direction in which the particles of material circulate in the receiver, and the direction of conveying of the extruder, are in essence identical or have the same sense. This arrangement, selected intentionally, was the result of the desire to maximize stuffing of the material into the screw, or to force-feed the screw. This concept of stuffing the particles into the conveying screw or extruder screw in the direction of conveying of the screw was also very obvious and was in line with the familiar thinking of the person skilled in the art, since it means that the particles do not have to reverse their direction of movement and there is therefore no need to exert any additional force for the change of direction. An objective here, and in further derivative developments, was always to maximize screw fill and to amplify this stuffing effect. By way of example, attempts have also been made to extend the intake region of the extruder in the manner of a cone or to curve the comminution implements in the shape of a sickle, so that these can act like a trowel in feeding the softened material into the screw. Displacement of the extruder, on the inflow side, from a radial position to a tangential position in relation to the container further amplified the stuffing effect, and increased the force with which the plastics material from the circulating implement was conveyed or forced into the extruder.

Apparatuses of this type are in principle capable of functioning, and they operate satisfactorily, although with recurring problems:

By way of example, an effect repeatedly observed with materials with low energy content, e.g. PET fibres or PET foils, or with materials which at a low temperature become sticky or soft, e.g. polylactic acid (PLA) is that when, intentionally, stuffing of the plastics material into the intake region of the extruder, under pressure, is achieved by components moving in the same sense, this leads to premature melting of the material immediately after, or else in, the intake region of the extruder. This firstly reduces the conveying effect of the extruder, and secondly there can also be some reverse flow of the said melt into the region of the cutter compactor or receiver, with the result that flakes that have not yet melted adhere to the melt,

and in turn the melt thus cools and to some extent solidifies, with resultant formation of a clump or conglomerate made of to some extent solidified melt and of solid plastics particles. This causes blockage on the intake of the extruder and caking of the mixing and comminution implements. A further consequence is  
5 reduction of the throughput of the extruder, since adequate filling of the screw is no longer achieved. Another possibility here is that movement of the mixing and comminution implements is prevented. In such cases, the system normally has to be shut down and thoroughly cleaned.

- 10 Problems also occur with polymer materials which have already been heated in the cutter compactor up to the vicinity of their melting range. If overfilling of the intake region occurs here, the material melts and intake is impaired.

Problems are also encountered with fibrous materials that are mostly orientated  
15 and linear, with a certain amount of longitudinal elongation and low thickness or stiffness, for example plastics foils cut into strips. A main reason for this is that the elongate material is retained at the outflow end of the intake aperture of the screw, where one end of the strip protrudes into the receiver and the other end protrudes into the intake region. Since the mixing implements and the screw are  
20 moving in the same sense or exert the same conveying-direction component and pressure component on the material, both ends of the strip are subjected to tension and pressure in the same direction, and release of the strip becomes impossible. This in turn leads to accumulation of the material in the said region, to a narrowing of the cross section of the intake aperture, and to poorer intake perfor-  
25 mance and, as a further consequence, to reduced throughput. The increased feed pressure in this region can moreover cause melting, and this in turn causes the problems mentioned in the introduction.

Co-rotating cutter compactors of this kind have had a variety of extruders or con-  
30 conveyors attached to them, the results having in principle been entirely acceptable and attractive. The applicant, however, has performed comprehensive investigations for making still further improvements to the system as a whole.

It is therefore an object of the present invention to overcome the disadvantages mentioned and to improve an apparatus of the type described in the introduction in such a way as to permit problem-free intake of conventional materials by the screw, and also of those materials that are sensitive or strip-shaped, and to permit  
5 processing or treatment of these materials to give material of high quality, with high throughput, while making efficient use of time, saving energy, and minimizing space requirement.

The characterizing features of Claim 1 achieve this object in an apparatus of the  
10 type mentioned in the introduction.

A first provision here is that the imaginary continuation of the central longitudinal axis of the conveyor, in particular extruder, if this has only a single screw, or the longitudinal axis of the screw closest to the intake aperture, if the conveyor has  
15 more than one screw, in the direction opposite to the direction of conveying of the conveyor, passes, and does not intersect, the axis of rotation, where, on the out-flow side, there is an offset distance between the longitudinal axis of the conveyor, if this has a single screw, or the longitudinal axis of the screw closest to the intake aperture, and the radius that is associated with the container and that  
20 is parallel to the longitudinal axis and that proceeds outwards from the axis of rotation of the mixing and/or comminution implement in the direction of conveying of the conveyor.

The direction of conveying of the mixing implements and the direction of convey-  
25 ing of the conveyor are therefore no longer in the same sense, as is known from the prior art, but instead are at least to a small extent in the opposite sense, and the stuffing effect mentioned in the introduction is thus reduced. The intentional reversal of the direction of rotation of the mixing and comminution implements in comparison with apparatuses known hitherto reduces the feed pressure on the  
30 intake region, and the risk of overfilling decreases. In this way, excess material is not stuffed or trowelled with excess pressure into the intake region of the conveyor, but instead, in contrast, there is in fact in turn a tendency to remove excess material from that region, in such a way that although there is always sufficient

material present in the intake region, the additional pressure exerted is small or almost zero. This method can provide adequate filling of the screw and constant intake of sufficient material by the screw, without any overfilling of the screw with, as a further consequence, local pressure peaks where the material could melt.

5

Melting of the material in the region of the intake is thus prevented, and operating efficiency is therefore increased, maintenance intervals are therefore lengthened, and downtime due to possible repairs and cleaning measures is reduced.

- 10 By virtue of the reduced feed pressure, displaceable elements which can be used in a known manner to regulate the degree of filling of the screw react markedly more sensitively, and the degree of filling of the screw can be adjusted with even greater precision. This makes it easier to find the ideal point at which to operate the system, in particular for relatively heavy materials, for example regrind made  
15 of high-density polyethylene (HDPE) or PET.

- Surprisingly and advantageously it has moreover been found that operation in the opposite sense, according to the invention, improves intake of materials which have already been softened almost to the point of melting. In particular when the  
20 material is already in a doughy or softened condition, the screw cuts the material from the doughy ring adjacent to the container wall. In the case of a direction of rotation in the direction of conveying of the screw, this ring would instead be pushed onward, and removal of an outer layer by the screw would not be possible, with resultant impairment of intake. The reversal of the direction of rotation,  
25 according to the invention, avoids this.

- Furthermore, the retention or accumulation phenomena formed in the case of the treatment of the materials which have been described above and are in strip form or fibrous can be resolved more easily, or do not occur at all, since, at the aperture  
30 edge situated in the direction of rotation of the mixing implements on the outflow side or downstream, the direction vector for the mixing implements and the direction vector for the conveyor point in almost opposite directions, or in directions that at least to a small extent have opposite sense, and an elongate strip cannot



therefore become curved around, and retained by, the said edge, but instead becomes entrained again by the mixing vortex in the receiver.

The overall effect of the design according to the invention is that intake performance is improved and throughput is markedly increased. The stability and performance of the entire system made of cutter compactor and conveyor is thus increased.

The applicant has further found that a particular configuration of the mixing and comminution implements relative to the container wall and the provision of particular distances between the blades can achieve surprising advantageous effects which have a direct influence on the intake behaviour of the conveyor or extruder.

Accordingly, provision is also made, in accordance with the invention, for the radial distance ( $m_b$ ) between the implement and the inner surface of the side wall of the container, measured from the radially outermost point of the mixing and/or comminution implement closest to the base or of the implement and/or of the blades, or from the circle defined as being described by that point, to be in the range from 15 mm to 120 mm, preferably in the range from 20 mm to 80 mm.

The radial distance  $m_b$  moreover complies with the relationship  $m_b = k \cdot D_B$  where

$D_B$  ... is the internal diameter of a cylindrical container with circular cross section in mm or the internal diameter in mm of an imaginary cylindrical container of the same height with cylindrical cross section calculated to have the same volume capacity, and

$k$  ... is a constant in the range from 0.006 to 0.16.

The distance between the implements and the container wall is advantageously to be kept small, since this produces improved intake behaviour and avoids any

“pinching” of the material during intake. Nevertheless, sufficient tolerance distances must be ensured. If the distance becomes too great, the result is a deterioration in charging.

- 5 It has surprisingly been found that, because of the opposite direction of rotation of the mixing implements, the intake behaviour of the screw is not aggressive, and it is therefore possible, in the cutter compactor, to use implements that are more aggressive and that introduce more energy into the material. Accordingly, the cutter compactor can be operated at relatively high temperature, a consequence of which is in turn better homogeneity with a reduced residence time. According to the invention, particularly good and effective introduction of energy is achieved by the particular spatial relationships in combination with the reverse direction of rotation of the implements.
- 10
- 15 Another unexpected consequence of this type of combination of cutter compactor and extruder is improved melting performance of the material in an attached extruder since particles which are already greatly preheated pass into the screw. This provides compensation for possible inhomogeneity, and the material that passes from the container into the screw housing and is then compressed and melted has high thermal and mechanical homogeneity. The final quality of the plastified or agglomerated material at the end of the extruder screw or of the agglomerating screw is correspondingly also very high, and it is possible to use screws which – because of the pretreatment and the intake – treat the polymer in a non-aggressive manner and introduce a particularly small amount of shear into
- 20
- 25 the material in order to melt the same.

Moreover, the constancy of throughput over time is higher, and/or the throughput performances are more uniform, and the intake operates reliably without problems associated with the filling of the screw.

30

Further advantageous embodiments of the invention are described via the following features:

According to one advantageous development, in the container, at least one circulating implement carrier which can rotate around the axis of rotation is provided, on/in which the mixing and/or comminution implement(s) are arranged or formed. It is advantageous if the implement carrier is a carrier disc, in particular arranged  
5 parallel to the basal surface. The implements can readily and easily be mounted thereon.

In this connection it is advantageous if the mixing and/or comminution implement and/or the implement carrier comprises implements and/or blades which, in the  
10 direction of rotation or of movement, have a comminuting, cutting and/or heating effect on the plastics material.

A variant in which the blades are very easy to change provides that the mixing and/or comminution implement or implements and/or blades are arranged or  
15 formed on the upper side of the implement carrier.

It can also be advantageously provided that the implements and/or blades arranged on that, mostly vertical, external edge of the implement carrier that is situated radially outermost and that faces towards the inner surface of the side wall are  
20 incorporated or formed therein or fastened in a manner that is reversibly separable.

An advantageous development provides that the radial distance  $m_c$  between the implement carrier and the inner surface of the side wall of the container, measured from the radially outermost point of the implement carrier closest to the base,  
25 or from the circle defined as being described by that point, is in the range from 30 mm to 210 mm, preferably in the range from 40 mm to 150 mm.

It is particularly advantageous if the ratio between the internal diameter  $D_B$  of the container and the diameter of the circle described by the radially outermost point of the implement carrier closest to the base complies with the following relationship:  
30

$$D_B = k_2 * D_W$$

where

$D_B$  ... is the internal diameter of the container in mm,

$D_W$  ... is the diameter of the circle described by the radially outermost point of the implement carrier in mm,

5  $k_2$  ... is a constant in the range from 1.01 to 1.5.

According to one advantageous development, the constant  $k_2$ , in the case of containers with an internal diameter  $D_B$  greater than or equal to 1300 mm, is in the range from 1.01 to 1.12. The implements have been found to be particularly  
10 effective here, and the throughput can be kept very constant.

It is advantageous that the radial distance  $m_c$  for the implement carrier is greater than or equal to the radial distance  $m_b$  for the implement. The implements thus projecting or protruding from the implement carrier additionally promote the effect  
15 on the material.

According to an advantageous development of the invention, the conveyor is arranged on the receiver in such a way that the scalar product of the direction vector (direction vector that is associated with the direction of rotation) that is tangential  
20 to the circle described by the radially outermost point of the mixing and/or comminution implement or to the plastics material transported past the aperture and that is normal to a radius of the receiver, and that points in the direction of rotation or of movement of the mixing and/or comminution implement and of the direction vector that is associated with the direction of conveying of the conveyor at each  
25 individual point or in the entire region of the aperture or at each individual point or in the entire region immediately radially in front of the aperture is zero or negative. The region immediately radially in front of the aperture is defined as that region which is in front of the aperture and at which the material is just about to pass through the aperture but has not yet passed the aperture. The ad-  
30 vantages mentioned in the introduction are thus achieved, and there is effective avoidance of all types of agglomeration in the region of the intake aperture, brought about by stuffing effects. In particular here, there is also no dependency on the spatial arrangement of the mixing implements and of the screw in relation

to one another, and by way of example the orientation of the axis of rotation does not have to be normal to the basal surface or to the longitudinal axis of the conveyor or of the screw. The direction vector that is associated with the direction of rotation and the direction vector that is associated with the direction of conveying  
5 lie within a, preferably horizontal, plane, or in a plane orientated so as to be normal to the axis of rotation.

In another advantageous formation, the angle included between the direction vector that is associated with the direction of rotation of the mixing and/or com-  
10 minution implement and the direction vector that is associated with the direction of conveying of the conveyor is greater than or equal to  $90^\circ$  and smaller than or equal to  $180^\circ$ , where the angle is measured at the point of intersection of the two direction vectors at the edge that is associated with the aperture and that is situated upstream of the direction of rotation or of movement, in particular at the  
15 point that is on the said edge or on the aperture and is situated furthest upstream. This therefore describes the range of angles within which the conveyor must be arranged on the receiver in order to achieve the advantageous effects. In the entire region of the aperture or at each individual point of the aperture, the forces acting on the material are therefore orientated at least to a small extent in an  
20 opposite sense, or in the extreme case the orientation is perpendicular and pressure-neutral. At no point of the aperture is the scalar product of the direction vectors of the mixing implements and of the screw positive, and no excessive stuffing effect occurs even in a subregion of the aperture.

25 Another advantageous formation of the invention provides that the angle included between the direction vector that is associated with the direction of rotation or of movement and the direction vector that is associated with the direction of conveying is from  $170^\circ$  to  $180^\circ$ , measured at the point of intersection of the two direction vectors in the middle of the aperture. This type of arrangement is relevant  
30 by way of example when the conveyor is arranged tangentially on the cutter compactor.

In order to ensure that no excessive stuffing effect occurs, the distance, or the offset, between the longitudinal axis and the radius can advantageously be greater than or equal to half of the internal diameter of the housing of the conveyor or of the screw.

5

It can moreover be advantageous for these purposes to set the distance or offset between the longitudinal axis and the radius to be greater than or equal to 7%, or still more advantageously greater than or equal to 20%, of the radius of the receiver. In the case of conveyors with a prolonged intake region or with grooved  
10 bushing or with extended hopper, it can be advantageous for this distance or offset to be greater than or equal to the radius of the receiver. This is particularly true for cases where the conveyor is attached tangentially to the receiver or runs tangentially to the cross section of the container.

15 In a particularly advantageous embodiment here, the longitudinal axis of the conveyor or of the screw or the longitudinal axis of the screw closest to the intake aperture runs tangentially with respect to the inner side of the side wall of the container, or the inner wall of the housing does so, or the envelope of the screw does so, where it is preferable that there is a drive connected to the end of the  
20 screw, and that the screw provides conveying, at its opposite end, to a discharge aperture which is in particular an extruder head and which is arranged at the end of the housing.

In the case of conveyors that are radially offset, but not arranged tangentially, it  
25 is advantageous to provide that the imaginary continuation of the longitudinal axis of the conveyor in a direction opposite to the direction of conveying, at least in sections, passes, in the form of a secant, through the space within the receiver.

It is advantageous to provide that there is immediate and direct connection be-  
30 tween the aperture and the intake aperture, without substantial separation or a transfer section, e.g. a conveying screw. This permits effective and non-aggressive transfer of material.

The reversal of the direction of rotation of the mixing and comminution implements circulating in the container can certainly not result from arbitrary action or negligence, and it is not possible - either in the known apparatuses or in the apparatus according to the invention - simply to allow the mixing implements to rotate in the opposite direction, in particular because the arrangement of the mixing and comminution implements is in a certain way asymmetrical or direction-oriented, and their action is therefore only single-sided or unidirectional. If this type of equipment were to be rotated intentionally in the wrong direction, a good mixing vortex would not form, and there would be no adequate comminution or heating of the material. Each cutter compactor therefore has its unalterably prescribed direction of rotation of the mixing and comminution implements.

In this connection, it is particularly advantageous to provide that the manner of formation, set-up, curvature and/or arrangement of the frontal regions or frontal edges that are associated with the mixing and/or comminution implements, act on the plastics material and point in the direction of rotation or of movement, differs when comparison is made with the regions that, in the direction of rotation or of movement, are at the rear or behind.

The implements and/or blades can either have been fastened directly on the shaft or preferably have been arranged on a rotatable implement carrier or, respectively, a carrier disc arranged in particular parallel to the basal surface, or have been formed therein or moulded onto the same, optionally as a single piece.

In principle, the effects mentioned are relevant not only to compressing extruders or agglomerators but also to conveying screws that have no, or less, compressing effect. Here again, local overfeed is avoided.

In another particularly advantageous formation, it is provided that the receiver is in essence cylindrical with a level basal surface and with, orientated vertically in relation thereto, a side wall which has the shape of the jacket of a cylinder. In another simple design, the axis of rotation coincides with the central axis of the receiver. In another advantageous formation, the axis of rotation or the central

axis of the container have been orientated vertically and/or normally in relation to the basal surface. These particular geometries optimize intake performance, with an apparatus design that provides stability and simple construction.

- 5 In this connection it is also advantageous to provide that the mixing and/or comminution implement or, if a plurality of mutually superposed mixing and/or comminution implements have been provided, the lowest mixing and/or comminution implement closest to the base is arranged at a small distance from the basal surface, in particular in the region of the lowest quarter of the height of the receiver, and also that the aperture is similarly arranged. The distance here is defined and measured from the lowest edge of the aperture or of the intake aperture to the container base in the edge region of the container. There is mostly some rounding of the edge at the corner, and the distance is therefore measured from the lowest edge of the aperture along the imaginary continuations of the side wall downwards to the imaginary outward continuation of the container base. Distances with good suitability are from 10 to 400 mm.

The container does not necessarily have to have a cylindrical shape with circular cross section, even though this shape is advantageous for practical reasons and reasons of manufacturing technology. When container shapes that deviate from the cylindrical shape with circular cross section, examples being containers having the shape of a truncated cone or cylindrical containers which, in plan view, are elliptical or oval, a calculation is required for conversion to a cylindrical container which has circular cross section and the same volume capacity, on the assumption that the height of this imaginary container is the same as its diameter. Container heights here which are substantially higher than the resultant mixing vortex (after taking into account the distance required for safety) are ignored, since this excess container height is not utilized and it therefore has no further effect on the processing of the material.

30

The expression conveyor means mainly systems with screws that have non-compressing or decompressing effect, i.e. screws which have purely conveying effect,



but also systems with screws that have compressing effect, i.e. extruder screws with agglomerating or plastifying effect.

The expressions extruder and extruder screw in the present text mean extruders  
5 or screws used for complete or partial melting of the material, and also extruders used to agglomerate, but not melt, the softened material. Screws with agglomerating effect subject the material to severe compression and shear only for a short time, but do not plastify the material. The outgoing end of the agglomerating screw therefore delivers material which has not been completely melted but which  
10 instead is composed of particles incipiently melted only at their surface, which have been caked together as if by sintering. However, in both cases the screw exerts pressure on the material and compacts it.

All of the examples described in the figure below depict conveyors with a single  
15 screw, for example single-screw extruders. However, it is also possible as an alternative to provide conveyors with more than one screw, for example twin- or multiscrew conveyors or twin- or multiscrew extruders, in particular with a plurality of identical screws, which at least have the same diameters  $d$ .

20 Further features and advantages of the invention are apparent from the description of the inventive examples below of the subject matter of the invention, which are not to be interpreted as restricting, and which the drawings depict diagrammatically and not to scale:

25 Figure 1 shows a vertical section through an apparatus according to the invention with extruder attached approximately tangentially.

Figure 2 shows a horizontal section through the embodiment of Figure 1.

30 Figure 3 shows another embodiment with minimal offset.

Figure 4 shows another embodiment with relatively large offset.

Figures 5 and 6 show test results.

Neither the containers, nor the screws nor the mixing implements are to scale, either themselves or in relation to one another, in the drawings. By way of example, therefore, the containers are in reality mostly larger, or the screws longer, than depicted here.

The advantageous cutter compactor-extruder combination depicted in **Figure 1** and **Figure 2** for the treatment or recycling of plastics material has a cylindrical container or cutter compactor or shredder 1 with circular cross section, with a level, horizontal basal surface 2 and with a vertical side wall 9 oriented normally thereto with the shape of a cylinder jacket.

Arranged at a small distance from the basal surface 2, at most at about 10 to 20%, or optionally less, of the height of the side wall 9 – measured from the basal surface 2 to the uppermost edge of the side wall 9 – is an implement carrier 13 or a level carrier disc orientated parallel to the basal surface 2, which carrier or disc can be rotated, in the direction 12 of rotation or of movement indicated by an arrow 12, around a central axis 10 of rotation, which is simultaneously the central axis of the container 1. A motor 21, located below the container 1, drives the carrier disc 13. On the upper side of the carrier disc 13, blades or implements, e.g. cutter blades, 14 have been arranged, and together with the carrier disc 13 form the mixing and/or comminution implement 3.

As indicated in the diagram, the blades 14 are not arranged symmetrically on the carrier disc 13, but instead have a particular manner of formation, set-up or arrangement on their frontal edges 22 facing in the direction 12 of rotation or of movement, so that they can have a specific mechanical effect on the plastics material. The radially outermost edges of the mixing and comminution implements 3 reach a point which is relatively close to, about 5% of the radius 11 of the container 1 from, the inner surface of the side wall 9.

The container 1 has, near the top, a charging aperture through which the product to be processed, e.g. portions of plastics foils, is charged by way of example by means of a conveying device in the direction of the arrow. The container 1 can, as an alternative, be a closed container and capable of evacuation at least as far

5 as an industrial vacuum, the material being introduced by way of a system of valves. The said product is received by the circulating mixing and/or comminution implements 3 and is raised to form a mixing vortex 30, where the product rises along the vertical side wall 9 and, approximately in the region of the effective container height H, falls back again inward and downward into the region of the

10 centre of the container, under gravity. The effective height H of the container 1 is approximately the same as its internal diameter D. In the container 1, a mixing vortex is thus formed, in which the material is circulated in a vortex both from top to bottom and also in the direction 12 of rotation. By virtue of this particular arrangement of the mixing and comminution elements 3 or the blades 14, this type

15 of apparatus can therefore be operated only with the prescribed direction 12 of rotation or movement, and the direction 12 of rotation cannot be reversed readily or without additional changes.

The circulating mixing and comminution implements 3 comminute and mix the

20 plastics material introduced, and thereby heat and soften it by way of the mechanical frictional energy introduced, but do not melt it. After a certain residence time in the container 1, the homogenized, softened, doughy but not molten material is, as described in detail below, removed from the container 1 through an aperture 8, passed into the intake region of an extruder 5, and received by a

25 screw 6 there and subsequently melted.

At the level of the, in the present case single, comminution and mixing implement 3, the said aperture 8 is formed in the side wall 9 of the container 1, and the pretreated plastics material can be removed from the interior of the container 1

30 through this aperture. The material is passed to a single-screw extruder 5 arranged tangentially on the container 1, where the housing 16 of the extruder 5 has, situated in its jacket wall, an intake aperture 80 for the material to be received by the screw 6. This type of embodiment has the advantage that the screw 6 can

be driven from the lower end in the drawing by a drive, depicted only diagrammatically, in such a way that the upper end of the screw 6 in the drawing can be kept free from the drive. The discharge aperture for the plastified or agglomerated plastics material conveyed by the screw 6 can therefore be arranged at this  
5 right-hand end, e.g. in the form of an extruder head not depicted. The plastics material can therefore be conveyed without deflection by the screw 6 through the discharge aperture; this is not readily possible in the embodiments according to Figures 3 and 4.

10 There is a connection for conveying of material or for transfer of material between the intake aperture 80 and the aperture 8, and in the present case this connection to the aperture 8 is direct and immediate and involves no prolonged intervening section and no separation. All that is provided is a very short transfer region.

15 In the housing 16, there is a screw 6 with compressing effect, mounted rotatably around its longitudinal axis 15. The longitudinal axis 15 of the screw 6 and that of the extruder 5 coincide. The extruder 5 conveys the material in the direction of the arrow 17. The extruder 5 is a conventional extruder known per se in which the softened plastics material is compressed and thus melted, and the melt is  
20 then discharged at the opposite end, at the extruder head.

The mixing and/or comminution implements 3 or the blades 14 are at approximately the same level as the central longitudinal axis 15 of the extruder 5. The outermost ends of the blades 14 have adequate separation from the flights of the  
25 screw 6.

In the embodiment according to Figures 1 and 2, the extruder 5 is, as mentioned, attached tangentially to the container 1, or runs tangentially in relation to its cross section. In the drawing, the imaginary continuation of the central longitudinal axis  
30 15 of the extruder 5 or of the screw 6 in a direction opposite to the direction 17 of conveying of the extruder 5 towards the rear passes the axis 10 of rotation and does not intersect it. On the outflow side, there is an offset distance 18 between the longitudinal axis 15 of the extruder 5 or of the screw 6 and the radius 11 that

is associated with the container 1 and that is parallel to the longitudinal axis 15 and that proceeds outwards from the axis 10 of rotation of the mixing and/or comminution implement 3 in the direction 17 of conveying of the conveyor 5. In the present case, the imaginary continuation of the longitudinal axis 15 of the extruder 5 towards the rear does not pass through the space within the container 1, but instead passes it at a short distance.

The distance 18 is somewhat greater than the radius of the container 1. There is therefore a slight outward offset of the extruder 5, or the intake region is somewhat deeper.

The expressions “opposite”, “counter-” and “in an opposite sense” here mean any orientation of the vectors with respect to one another which is not acute-angled, as explained in detail below.

15

In other words, the scalar product of a direction vector 19 which is associated with the direction 12 of rotation and the orientation of which is tangential to the circle described by the outermost point of the mixing and/or comminution implement 3 or tangential to the plastics material passing the aperture 8, and which points in the direction 12 of rotation or movement of the mixing and/or comminution implements 3, and of a direction vector 17 which is associated with the direction of conveying of the extruder 5 and which proceeds in the direction of conveying parallel to the central longitudinal axis 15 is everywhere zero or negative, at each individual point of the aperture 8 or in the region radially immediately in front of the aperture 8, and is nowhere positive.

25

In the case of the intake aperture in Figures 1 and 2, the scalar product of the direction vector 19 for the direction 12 of rotation and of the direction vector 17 for the direction of conveying is negative at every point of the aperture 8.

30

The angle  $\alpha$  between the direction vector 17 for the direction of conveying and the direction vector for the direction 19 of rotation, measured at the point 20 that is associated with the aperture 8 and situated furthest upstream of the direction

12 of rotation, or at the edge associated with the aperture 8 and situated furthest upstream, is approximately maximally about 170°.

As one continues to proceed downwards along the aperture 8 in Figure 2, i.e. in the direction 12 of rotation, the oblique angle between the two direction vectors continues to increase. In the centre of the aperture 8, the angle between the direction vectors is about 180° and the scalar product is maximally negative, and further downwards from there the angle indeed becomes  $> 180^\circ$  and the scalar product in turn decreases, but still remains negative. However, these angles are no longer termed angles  $\alpha$ , since they are not measured at point 20.

An angle  $\beta$ , not included in the drawing in Figure 2, measured in the centre of the aperture 8, between the direction vector for the direction 19 of rotation and the direction vector for the direction 17 of conveying is about 178° to 180°.

The apparatus according to Figure 2 represents the first limiting case or extreme value. This type of arrangement can provide a very non-aggressive stuffing effect or a particularly advantageous feed, and this type of apparatus is particularly advantageous for sensitive materials which are treated in the vicinity of the melting range, or for product in the form of long strips.

The radial distance  $m_b$  between the implement and the inner surface of the side wall 9 of the container 1, measured from the radially outermost point or from the outermost point of the blade 14, or a circle defined as being described thereby, is included by way of example in Figure 2. This complies with the relationship  $m_b = k \cdot D_B$ .

The radial distance  $m_c$  between the implement carrier and the inner surface of the side wall 9 of the container 1, measured from the radially outermost point of the carrier disc 13, is also included. This complies with the relationship  $D_B = k_2 \cdot D_w$ .

The distance  $m_c$  is greater than the distance  $m_b$ , and the implements or blades 14 therefore protrude beyond or in front of the carrier disc 13.

Figures 3 and 4 do not include the distances  $m_c$  and  $m_b$ . These figures serve  
5 primarily for illustrating the connection possibilities of the extruder.

**Figure 3** shows an alternative embodiment in which the extruder 5 is not attached tangentially to the container 1 but instead is attached by its end 7. The screw 6 and the housing 16 of the extruder 5 have been adapted in the region of the  
10 aperture 8 to the shape of the inner wall of the container 1, and have been offset backwards so as to be flush. No part of the extruder 5 protrudes through the aperture 8 into the space within the container 1.

The distance 18 here corresponds to about 5 to 10% of the radius 11 of the con-  
15 tainer 1 and to about half of the internal diameter  $d$  of the housing 16. This embodiment therefore represents the second limiting case or extreme value with the smallest possible offset or distance 18, where the direction 12 of rotation or of movement of the mixing and/or comminution implements 3 is at least slightly opposite to the direction 17 of conveying of the extruder 5, and specifically across  
20 the entire area of the aperture 8.

The scalar product in Figure 3 at that threshold point 20 situated furthest upstream is precisely zero, where this is the point located at the edge that is associated with the aperture 8 and situated furthest upstream. The angle  $\alpha$  between  
25 the direction vector 17 for the direction of conveying and the direction vector for the direction 19 of rotation, measured at point 20 in Figure 3, is precisely  $90^\circ$ . If one proceeds further downwards along the aperture 8, i.e. in the direction 12 of rotation, the angle between the direction vectors becomes ever greater and becomes an oblique angle  $> 90^\circ$ , and at the same time the scalar product becomes  
30 negative. However, at no point, or in no region of the aperture 8, is the scalar product positive, or the angle smaller than  $90^\circ$ . No local overfeed can therefore occur even in a subregion of the aperture 8, and no detrimental excessive stuffing effect can occur in a region of the aperture 8.

This also represents a decisive difference in relation to a purely radial arrangement, since there would be an angle  $\alpha < 90^\circ$  at point 20 or at the edge 20' in a fully radial arrangement of the extruder 5, and those regions of the aperture 8 situated, in the drawing, above the radius 11 or upstream thereof or on the inflow side thereof would have a positive scalar product. It would thus be possible for locally melted plastics product to accumulate in these regions.

**Figure 4** depicts another alternative embodiment in which the extruder 5 is somewhat further offset than in Figure 3 on the outflow side, but still not tangentially as in Figures 1 and 2. In the present case, as also in Figure 3, the rearward imaginary continuation of the longitudinal axis 15 of the extruder 5 passes through the space within the container 1 in the manner of a secant. As a consequence of this, the aperture 8 is – measured in the circumferential direction of the container 1 – wider than in the embodiment according to Figure 3. The distance 18 is also correspondingly greater than in Figure 3, but somewhat smaller than the radius 11. The angle  $\alpha$  measured at point 20 is about  $150^\circ$ , and the stuffing effect is therefore reduced in comparison with the apparatus of Figure 3; this is more advantageous for certain sensitive polymers. The inner wall of the housing 16 or the right-hand-side inner edge, as seen from the container 1, is tangential to the container 1, and therefore, unlike in Figure 3, there is no oblique transitional edge. At this point that is associated with the aperture 8 and situated furthest downstream, on the extreme left-hand side in Figure 4, the angle is about  $180^\circ$ .

#### example:

25

Description of an experiment comparing a system according to the prior art (**Figure 5**) with a system according to the invention (**Figure 6**):

Both systems involve systems with a cutter compactor with a diameter of 1100 mm, with an 80 mm extruder (in principle of the structure shown in Figure 1 or 2) attached tangentially thereto. The operating parameters were identical. Material used comprised uncomminuted polypropylene foil (PP).

30



The system according to the invention differed from the known system in that the direction of rotation of the implements in the cutter compacter was reversed in a counter-rotating manner, as can be seen in Figure 2. The distance between the wall and the implements protruding beyond the carrier disc was moreover determined to be 35 mm.

Each respective lower curve shows the torque of the cutter compacter, and this reflects the energy used for cutting and compacting.

10 Each respective upper curve shows the melt pressure in front of a filtration device. This reflects the throughput or the extent to which the throughput is constant.

The throughput is clearly seen to be less constant over time in the system of the prior art than in the system according to the invention. It can moreover be seen  
15 that the prior-art system experienced at least a problem with charging of the material to the screw on at least one occasion (at about 12:30).

**Patentkrav**

1. Apparat til forbehandling og påfølgende transport, plastificering eller agglomering af plast, især af termoplastisk affaldsplast til recirkuleringsformål, med
  - 5 en beholder (1) til det materiale, der skal forarbejdes, hvorved der i beholderen (1) er tilvejebragt i det mindste et omkring en omdrejningsakse (10) drejeligt rundtløbende blande- og/eller findelingsværktøj (3) til blanding, opvarmning og eventuel findeling af plastmaterialet,
    - hvorved der i en sidevæg (9) på beholderen (1) inden for området af højden af
      - 10 blande- og/eller findelingsværktøjet (3) eller det nærmest bunden værende blande- og/eller findelingsværktøj (3) er tildannet en åbning (8), hvorigennem det forbehandlede plastmateriale er udbringeligt fra beholderens (1) indre,
        - hvorved der er tilvejebragt i det mindste en transportør (5), især en ekstruder (5), til optagelse af det forbehandlede materiale, med i det mindste en i et hus (16)
          - 15 roterende, især plastificerende eller agglomererende, snække (6), hvorved huset (16) har en på sin forside (7) eller i sin kappevæg liggende indtrækningsåbning (80) for det materiale, som skal opfanges af snekken (6), og indtrækningsåbningen (80) står i forbindelse med åbningen (8), hvorved
            - den tænkte forlængelse af transportørens (5) eller den nærmest indtrækningsåbningen (80) værende snekkes (6) centrale længdeakse (15) fører modsat transportørens (5) transportretning (17) forbi omdrejningsaksen (10) uden at skære
              - 20 denne, **kendetegnet ved**, at transportørens (5) eller den nærmest indtrækningsåbningen (80) værende snekkes (6) længdeakse (15) på udløbssiden og i blande- og/eller findelingsværktøjets (3) omdrejnings- eller bevægelsesretning
                - 25 (12) er forsat med en afstand (18) til beholderens (1) radius (11), som strækker sig parallelt med længdeaksen (15) og er rettet udad i transportørens (5) transportretning (17) fra blande- og/eller findelingsværktøjets (3) omdrejningsakse (10),
                  - og at værktøjets (mb) radiale afstand målt fra det radialt yderste punkt på det
                    - 30 nærmest bunden værende blande- og/eller findelingsværktøj (3), eller der værende værktøjer og/eller knive (14), henholdsvis fra den ved hjælp af dette punkt

bestemte flyvecirkel, frem til den indvendige overflade på beholderens (1) sidevæg (9) ligger i området fra 15 mm til 120 mm, fortrinsvis i området fra 20 mm til 80 mm, og opfylder følgende forbindelse:

$$mb = k * D_B$$

5 hvorved

$D_B$  er den indvendige diameter i en cirkelcylindrisk beholder (1) i mm eller den indvendige diameter i mm af en til samme volumen omregnet fiktiv cirkelcylindrisk beholder med samme højde, og

k er en konstant i området fra 0,006 til 0,16.

10

2. Apparat ifølge krav 1, **kendetegnet ved**, at der i beholderen (1) er tilvejebragt i det mindste en omkring omdrejningsaksen (10) drejelig, rundtgående værktøjsbærer (13), på hvilken blande- og/eller findelingsværktøjet eller -værktøjerne (3) er anbragt eller tildannet, hvorved værktøjsbæreren (13) fortrinsvis er

15 en bæerskive, som især er anbragt parallelt med bundfladen (12).

3. Apparat ifølge et af kravene 1 eller 2, **kendetegnet ved**, at blande- og/eller findelingsværktøjet (3) og/eller værktøjsbæreren (13) omfatter værktøjer og/eller knive (14), som virker findelende, skærende og/eller opvarmende i omdrejnings-

20 eller bevægelsesretningen (12) på plastmateriale, hvorved blande- og/eller findelingsværktøjet (3) henholdsvis værktøjerne og/eller knivene (14) er anbragt eller tildannet fortrinsvis på oversiden af værktøjsbæreren (13).

4. Apparat ifølge et af kravene 1 til 3, **kendetegnet ved**, at værktøjsbærerens

25 (mc) radiale afstand målt fra det radialt yderste punkt på den nærmest bunden værende værktøjsbærer (13) henholdsvis fra den ved hjælp af dette punkt bestemte flyvecirkel frem til den indvendige overflade på beholderens (1) sidevæg (9) ligger i området fra 30 mm til 210 mm, fortrinsvis i området fra 40 mm til 150 mm.

30

5. Apparat ifølge et af kravene 1 til 4, **kendetegnet ved**, at forholdet imellem beholderens (1) indvendige diameter ( $D_B$ ) og diameteren ( $D_W$ ) i den flyvecirkel,

som dannes af det radialt yderste punkt på den nærmest bunden værende værktøjsbærer (13), opfylder følgende forbindelse:

$$D_B = k_2 \cdot D_W$$

hvorved

- 5  $D_B$  er beholderens (1) indvendige diameter i mm,  
 $D_W$  er diameteren i den flyvecirkel, som dannes af det radialt yderste punkt på værktøjsbæreren (13), i mm,  
 $k_2$  en konstant i området fra 1,01 til 1,5.
- 10 6. Apparat ifølge krav 5, **kendetegnet ved**, at konstanten  $k_2$  ved beholdere (1) med en indvendig diameter  $D_B$  større end eller lig med 1300 mm ligger i området fra 1,01 til 1,12.
- 15 7. Apparat ifølge et af kravene 1 til 6, **kendetegnet ved**, at værktøjsbærerens (mc) radiale afstand er større end eller lige så stor som værktøjets (mb) radiale afstand,  
 og/eller  
 at værktøjerne og/eller knivene (14) er anbragt, reversibelt løsbart fastgjort eller tildannet i eller indarbejdet i den radialt længst udadtil beliggende yderkant på  
 20 værktøjsbæreren (13), hvilken yderkant vender ud imod sidevæggens (9) indvendige overflade og er for det meste lodret.
- 25 8. Apparat ifølge et af kravene 1 til 7, **kendetegnet ved**, at for en transportør (5), som står i forbindelse med beholderen (1), er skalarproduktet, som dannes af omdrejningsretnings (19) retningsvektor, som er rettet ind tangentielt i forhold til den cirkel, der beskrives af blande- og/eller findelingsværktøjets (3) radialt yderste punkt henholdsvis tangentielt i forhold til det plastmateriale, som bevæges forbi ved åbningen (8) og vinkelret på en radius (11) i beholderen (1), og som peger i blande- og/eller findelingsværktøjets (3) omdrejnings- eller bevægelses-  
 30 retning (12), og retningsvektoren (17) for transportørens (5) transportretning i hvert enkelt punkt henholdsvis i hele området af åbningen (8) henholdsvis direkte radialt foran åbningen (8), nul eller negativ.

9. Apparat ifølge et af kravene 1 til 8, **kendetegnet ved**, at retningsvektoren for omdrejningsretningen (19) af blande- og/eller findelingsværktøjets (3) radialt yderste punkt og retningsvektoren (17) for transportørens transportretning danner en vinkel ( $\alpha$ ) på større end eller lig med  $90^\circ$  og mindre end eller lig med  $180^\circ$
- 5 målt i de to retningsvektorer (17, 19) skæringspunkt ved den ved åbningen (8) værende kant, som befinder sig opstrøms i forhold til blande- og/eller findelingsværktøjets (3) omdrejnings- henholdsvis bevægelsesretning (12) og på tilgangssiden, især i det længst opstrøms beliggende punkt (20) på kanten eller åbningen (8).
- 10
10. Apparat ifølge et af kravene 1 til 9, **kendetegnet ved**, at omdrejnings- eller bevægelsesretningens (12) retningsvektor og retningsvektoren (17) for transportørens (5) transportretning danner en vinkel ( $\beta$ ) på imellem  $170^\circ$  og  $180^\circ$  målt i de to retningsvektorer (17, 19) skæringspunkt i åbningens (8) midte.
- 15
11. Apparat ifølge et af kravene 1 til 10, **kendetegnet ved**, at afstanden (18) er større end eller lige så stor som den halve indvendige diameter i transportørens (5) henholdsvis snekkens (6) hus (16) og/eller større end 7%, fortrinsvis større end eller lig med 20%, af beholderens (1) radius, eller at afstanden (18) er større
- 20 end eller lige så stor som beholderens (1) radius,
- eller
- at den tænkte forlængelse af transportørens (5) længdeakse (15) modsat transportretningen er anbragt som en sekant til beholderens (1) tværsnit og passerer i det mindste afsnitsvis igennem beholderens (1) indre rum,
- 25 eller
- at transportøren (5) er tilsluttet tangentielt til beholderen (1) eller strækker sig tangentielt i forhold til beholderens (1) tværsnit, eller at transportørens (5) længdeakse (15) eller snekkens (6) længdeakse (15) henholdsvis længdeaksen i den snekke (6), som ligger nærmest indtrækningsåbningen (80) eller husets (16) ind-
- 30 vendige væg eller snekkens (6) indkapslingsende, strækker sig tangentielt i forhold til den indvendige side af beholderens (1) sidevæg (9), hvorved fortrinsvis snekken (6) på sin frontside (7) er forbundet med et drev og ved sin modsat be-

liggende frontende transporterer til en på husets (16) frontende anbragt udløbsåbning, især et ekstruderhoved.

12. Apparat ifølge et af kravene 1 til 11, **kendetegnet ved**, at åbningen (8) er  
5 forbundet direkte og uden nogen væsentlig afstand, især uden nogen overgangsstrækning eller transportsnekke, med indtrækningsåbningen (80).

13. Apparat ifølge et af kravene 1 til 12, **kendetegnet ved**, at de på materialet virkende i omdrejnings- henholdsvis bevægelsesretningen (12) vendende forreste  
10 områder eller forkanter (22) på blande- og/eller findelingsværktøjerne (3) eller knivene (14) er tildannet, indstillet, krummende og/eller anbragt forskelligt i forhold til de, set i omdrejnings- eller bevægelsesretningen (12), bag ved liggende eller efterløbende områder,

og/eller  
15 at beholderen (1) er tildannet i det væsentlige cirkelcylindrisk med en plan bundflade (2) og en i forhold hertil lodret oprettet cylinderkappeformet sidevæg (9) og/eller blande- og/eller findelingsværktøjernes (3) omdrejningsakse (10) falder sammen med beholderens (1) centrale midterakse og/eller omdrejningsaksen (10), eller den centrale midterakse er rettet lodret ind og/eller vinkelret på bundfladen (2).  
20

14. Apparat ifølge et af kravene 1 til 13, **kendetegnet ved**, at den nederste nærmest bunden værende værktøjsbærer (13) henholdsvis det nederste af blande- og/eller findelingsværktøjerne (3) og/eller åbningen (8) er anbragt nær bunden i  
25 en lille afstand fra bundfladen (2), især inden for området af den nederste fjerdedel af beholderens (1) højde, fortrinsvis i en afstand til bundfladen (2) på fra 10 mm til 400 mm.

15. Apparat ifølge et af kravene 1 til 14, **kendetegnet ved**, at transportøren (5)  
30 er en enkelt-snekke-ekstruder (6) med en enkelt komprimerende snække (6) eller en dobbelt- eller flerdobbelt-snekke-ekstruder, hvorved de enkelte snekkers (6) diameter d er indbyrdes lige store.

1

Fig. 1

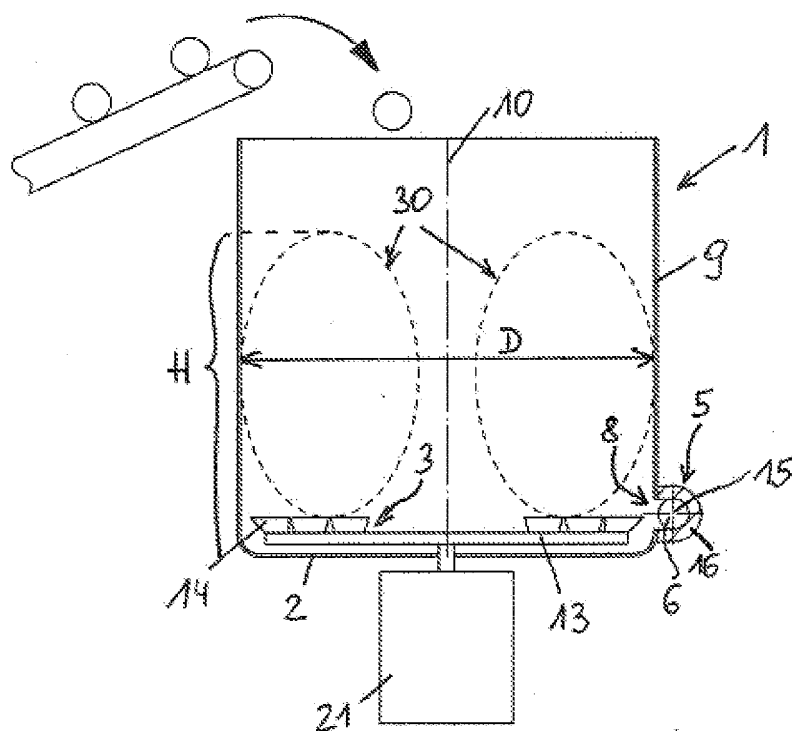


Fig. 2

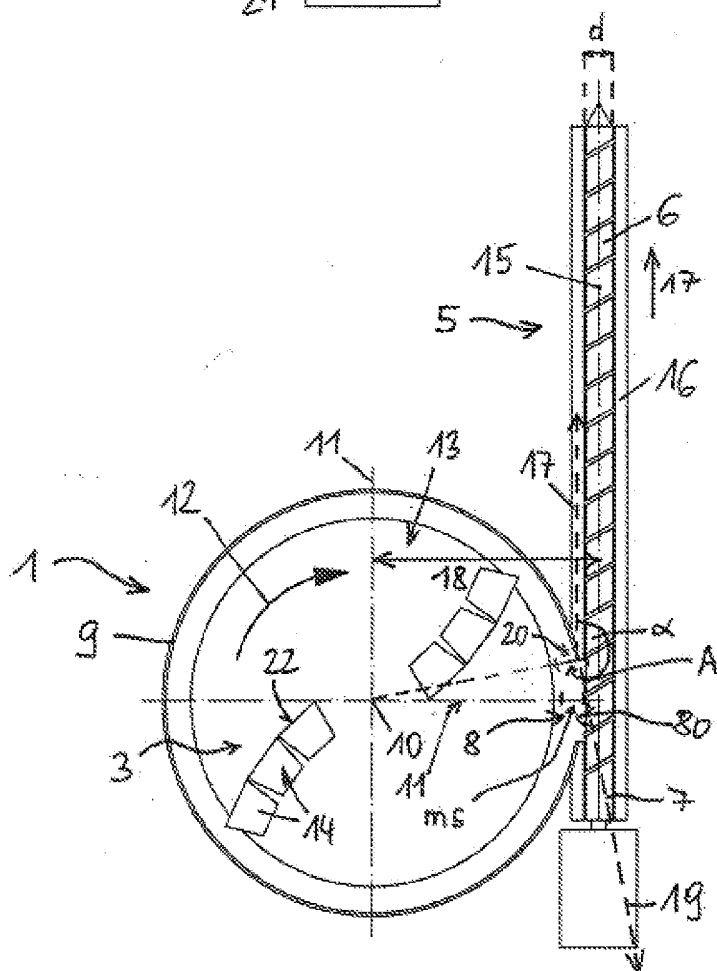


Fig. 3

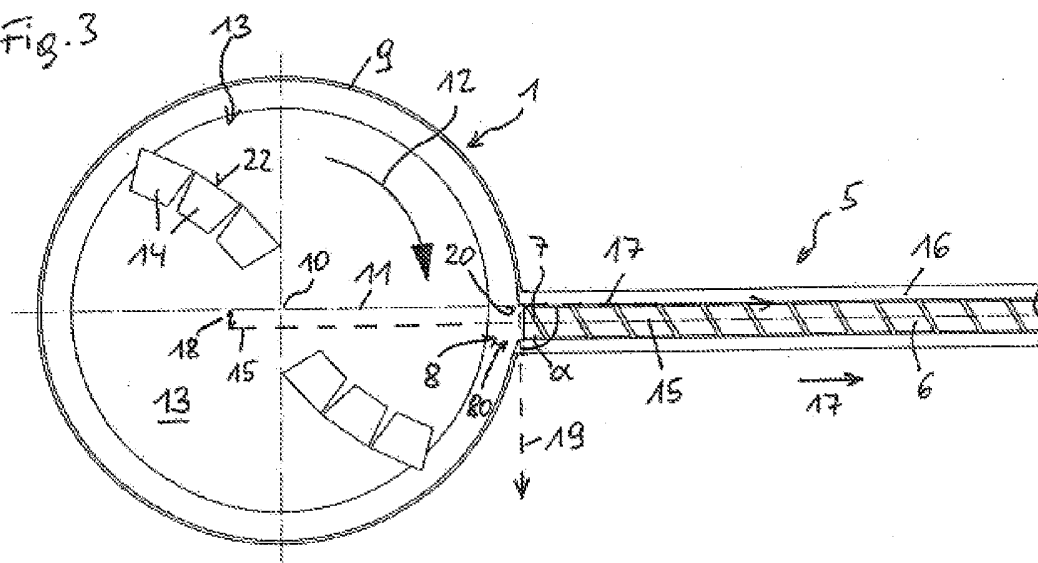
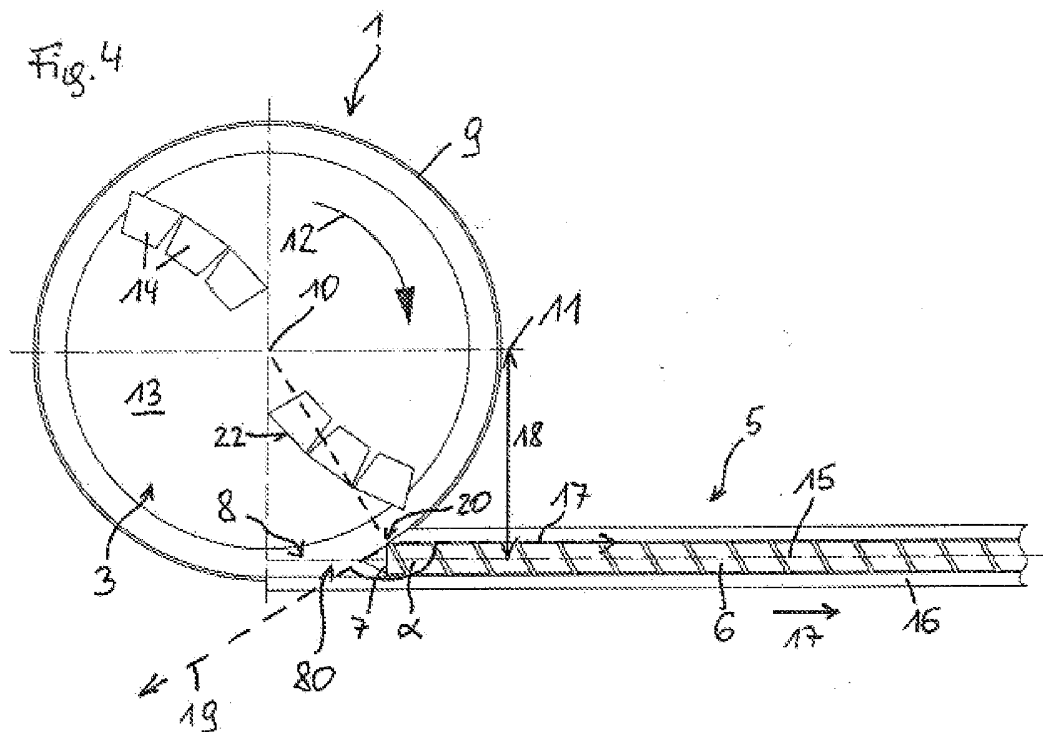


Fig. 4





10-408/3/5

Fig. 6

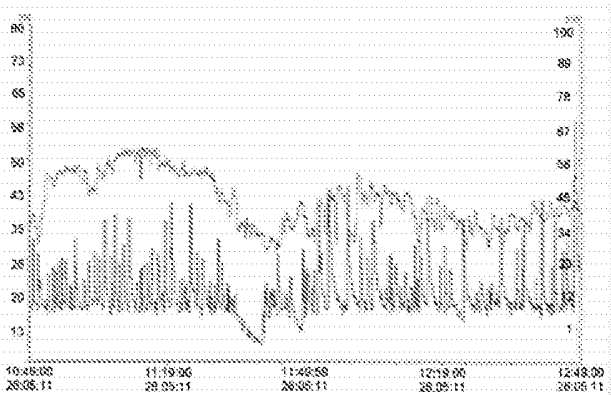
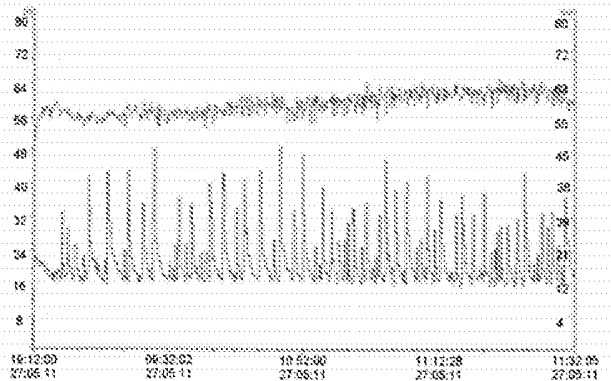


Fig. 6



Each lower curve: Actual torque of cutter compactor [%]  
Each upper curve: Actual metal pressure 1 in front of SW