United States Patent

[11] 3,572,646

[72] Inventor **Heinz Kocher**
Centralstrasse 41, Neuhausen, Switzerland

[21] Appl. No. **721,816**
[22] Filed **Apr. 16, 1968**
[45] Patented **Mar. 30, 1971**
[32] Priority **Apr. 17, 1968**
[33] **Austria**
[31] **A-3592/67**

[54] **APPARATUS FOR TRANSFORMING AND MIXING DEFORMABLE MEDIA**
11 Claims, 11 Drawing Figs.

[52] **U.S. Cl.** **259/25**
[51] **Int. Cl.** **B01f 7/02**
[50] **Field of Search** .... 259/7, 9, 10, 25, 26; 18/12 (SF), 12 (SE)

[56] **References Cited**

UNITED STATES PATENTS

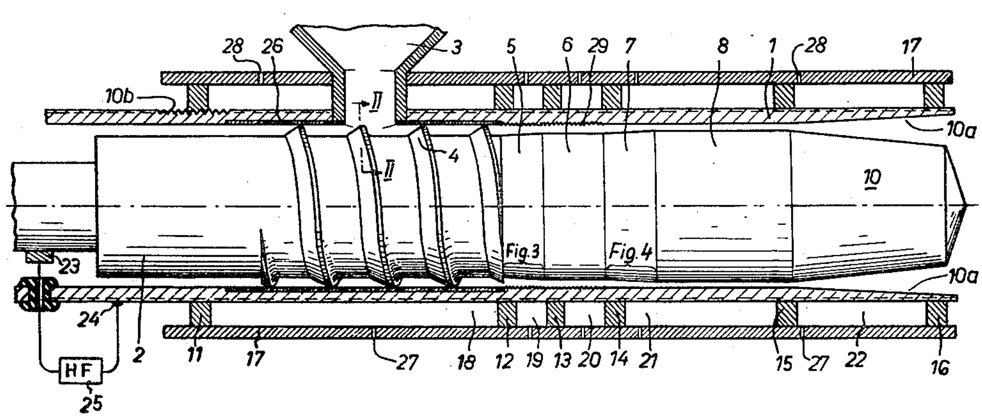
2,810,159 10/1957 Teichmann .... 18/12(SE)
3,239,882 3/1966 Yokana .... 18/12(SE)

FOREIGN PATENTS

1,007,140 10/1965 Great Britain .... 18/12(SE)
390,533 8/1965 Switzerland .... 18/12(SF)

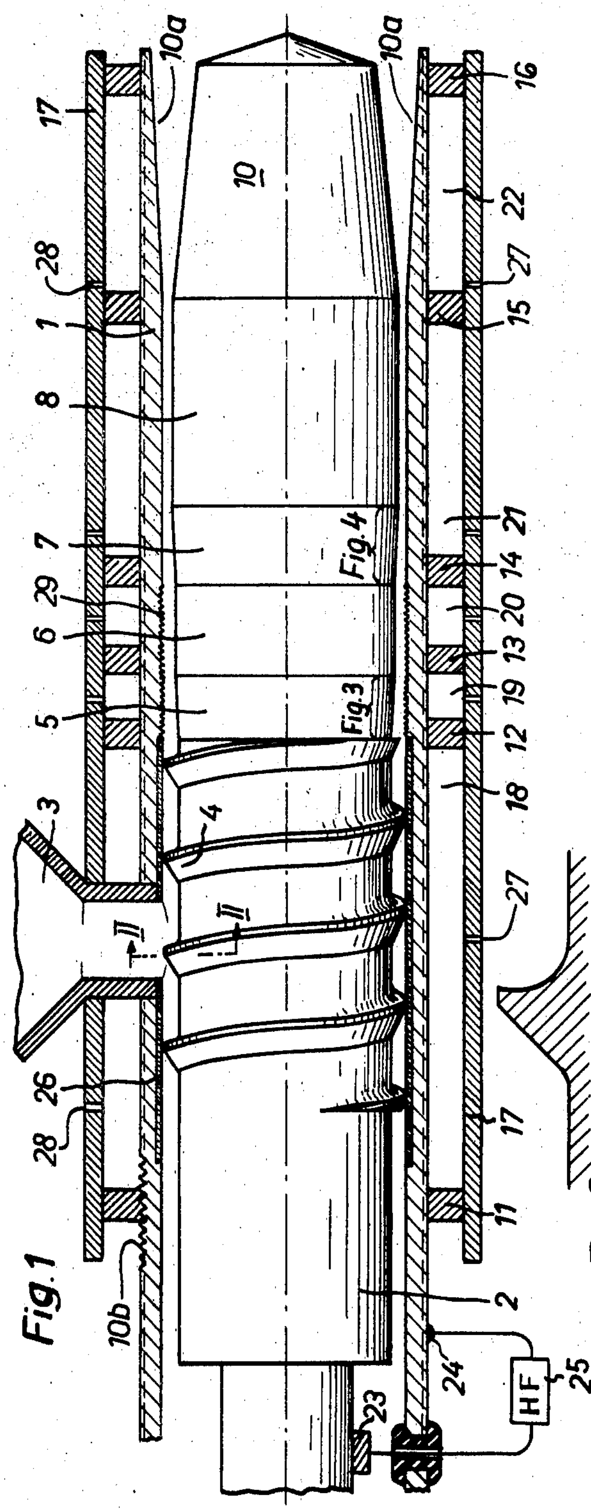
Primary Examiner—William I. Price
Attorneys—Ralph E. Bucknam, Jesse D. Reingold, Robert R. Strack and Henry A. Marzullo, Jr.

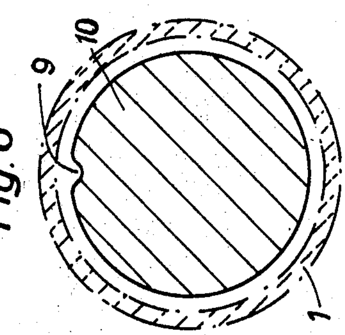
ABSTRACT: Apparatus for transforming and mixing deformable media, such as plastics, comprises a cylindrical casing having a rotor mounted for coaxial driven rotation in the cylinder which is provided with an inlet for the medium. The rotor is provided with a conveyor screw for the medium, and following the screw in the direction of flow the rotor comprises diverging diffusor portions alternating with cylindrical rotor portions. The end of the rotor adjacent the outlet of the cylinder is formed as a converging diffusor. The different rotor portions coact with surrounding wall portions of the cylinder having portions with a surface finish differing from that of the rotor portions to subject the medium flowing in the space between the rotor and the surrounding casing wall to differing frictional resistance along the external and internal layers thereof.

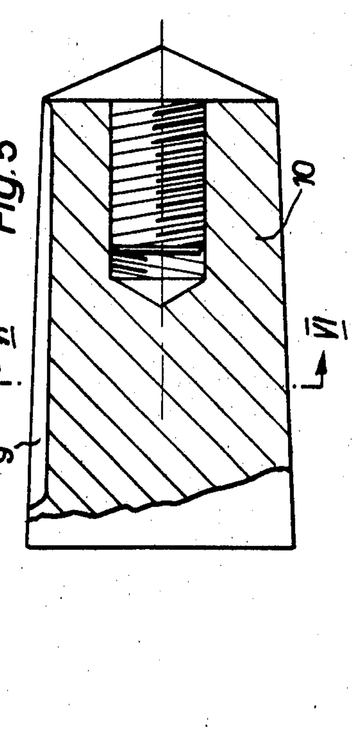


Patented March 30, 1971 3,572,646

3 Sheets-Sheet 1







INVENTOR.
HEINZ KOCHER
BY Jene D. Reingold
HIS ATTORNEY

Patented March 30, 1971 3,572,646

3 Sheets-Sheet 2

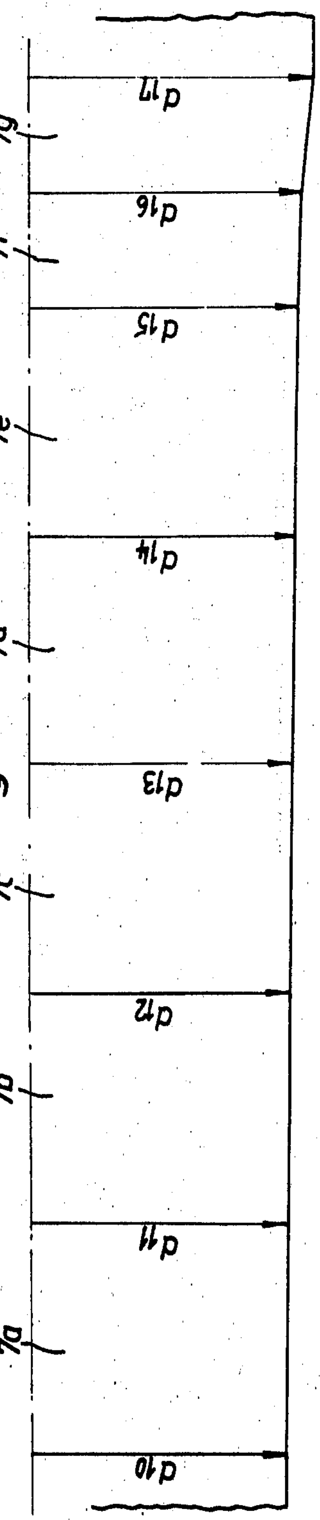


Fig. 4

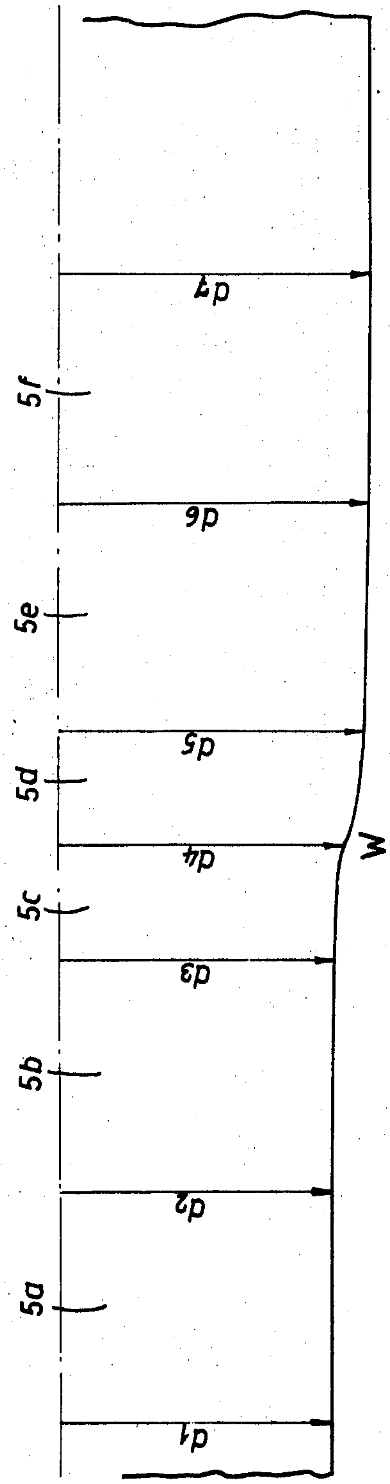


Fig. 3

Fig.11

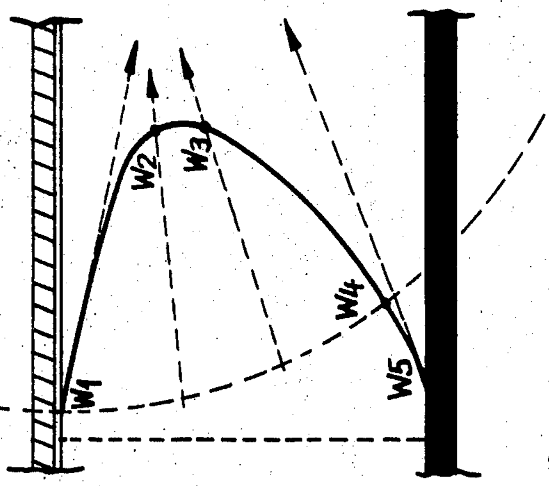


Fig.10

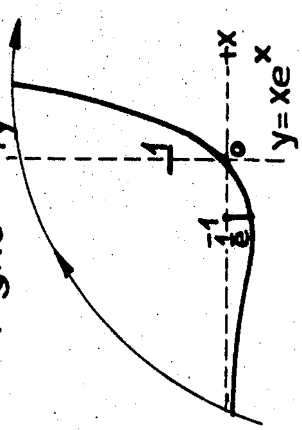
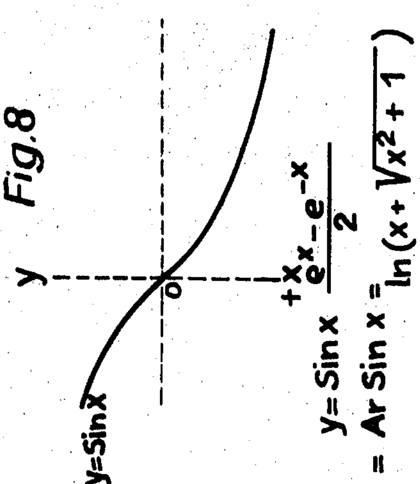


Fig.8



$y = \operatorname{Sin} x = \frac{e^x - e^{-x}}{2}$

$y = \operatorname{Ar\,Sin} x = \ln(x + \sqrt{x^2+1})$

Fig.7

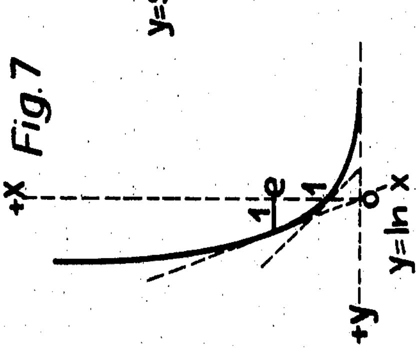
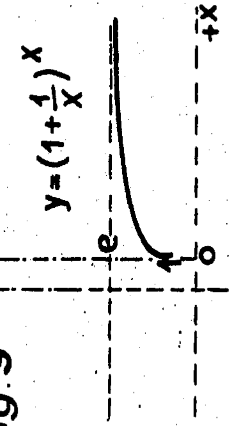


Fig.9



APPARATUS FOR TRANSFORMING AND MIXING DEFORMABLE MEDIA

The present invention concerns a method for transforming of deformable media on the basis of the double current transition, as well as apparatus for carrying out the method.

The two currents of the boundary layer physics are the laminar and the turbulent flow. In the course of a laminar flow the different molecule layers are displaced relatively to each other in plane, parallel directions. The turbulent flow is characterized by a tridimensional layer displacement in the molecular passage. The double current represents the connection of a laminar flow with a turbulent flow and the double current transition thus is the transformation or the change of a laminar flow into a turbulent flow.

With apparatus or presses for transforming of a deformable medium, which are employed e.g. for kneading and mixing of a plastic material, it is known to place a conveyor rotor in a cylindrical working space between inlet and outlet of the material. The rotor is provided with a plurality of eccentric discs in its middle portion, which are mounted close to each other or are spaced from each other with a screw thread being disposed between the discs (German Pat. No. 838,504).

Also the continuous mixing and homogenizing of plastic masses by means of a drum or a rotor revolving in the casing is known, and by which the plastic material is kneaded and externally mixed in the space between the revolving drum or rotor and the stationary casing. An improved homogenization can be obtained with this known procedure by the provision of damming means providing a pressure space in a conduit following the rotor (German Pat. No. 1,129,681, U.S. Pat. No. 2,845,656).

The technical development of the continuous processing of plastic masses has led to the fitting of conveying screw spindles rotating in a closed cylinder. The spindles comprise threaded and unthreaded sections. The conveying spindle for example is so formed that the smooth middle portion without thread is preceded by an initial spindle portion provided with a thread and is followed by a similarly threaded end portion. The plastic material fed from the initial portion of the spindle is compacted to the shape of a tube in the unthreaded intermediate portion and discharged under high pressure from the end portion. (German Pat. No. 1,019,080).

In the extruder according to U.S. Pat. No. 2,686,335 an unthreaded section of the same or a greater diameter than the shaft diameter of the spindle is mounted on centers of vulcanized rubber members in an extruder and is intended to merely satisfactorily roll out the rubber latex mixture. Therefore, the problem which shall be solved by the present invention as will appear from the following specification does not exist in this prior patent.

Also the conventional screw kneading pumps with interengaging worms or screws and coaxial rolls may not be considered as prototypes of the turbine according to the present invention, since the rolls shall serve to bring the plastic product to a uniform grain size, thus to effect a refinement of the masses (Swiss Pat. No. 232,413).

Further referring to Austrian Pat. specification No. 172,491, the latter slows an extruder having a spindle with an initial section of greater diameter and greater pitch, a terminal section of smaller diameter and smaller pitch and an intermediate section without thread. This latter section forms a chamber in which the material fed forwardly in the initial section is slowly advanced at a free cross section and a greater volume and is subjected to a potential action of heat before it is discharged in the terminal section. Also so-called torpedo formations on spindles in extruders, e.g. according to U.S. Pat. Nos. 2,719,325 and 3,026,273 are known.

In extruders having a kneading, mixing and feeding screw rotating in a closed cylinder, and comprising sections provided with screw threads and sections without screw threads, the cylinder as viewed in the direction of feed, is arranged after the inlet zone and forms together with the surface of cylinder, a restricted passage which, owing to the great shearing forces

or stress building up at this passage, produces a considerable temperature rise in the plastic mass which is prejudicial for the deformable medium.

In pertinent literature it has been explained repeatedly, that in the development of devices for plasticizing plastic materials, the difference in volume of the plastic mass to be worked as compared with that of the molten material, as well as the temperature rises in the feed path, of the plastic masses to be processed, which rises cannot be safely controlled, must be considered. Until now the opinion is advanced that for dominating the given conditions of operation, it is most useful to calculate one particular screw for each group of material.

The screw spindle described in the German published application No. 1,167,009 comprises a conical friction roll which, in the conveying direction of the mass, is arranged in the last one-third portion of the length of the spindle between inlet and outlet of the material. By means of the conicity the damming-up of the material shall be considerably decreased and at the same time a local overheating of the plastics shall be avoided. In this manner, a laminar parabolic distribution of velocity is imparted to the plastic mass. This velocity, however, in the region of this conical friction roll does not create any independent flow pressure.

The use of a friction roll which is arranged coaxially on a screw spindle between the inlet and the outlet of the material is applied in the form of a conical roll as well as in the form of an axially symmetrical roll, also in a double screw arrangement, In the case of a pair of conical friction rolls, this arrangement represents a known oblique roll mill. (German Pat. No. 397,961). Likewise, the manner of operation of two cylindrical roll bodies in one casing which are arranged between two screw spindles, is disclosed in Canadian Pat. No. 530,956. These conical or cylindrical roll pairs without thread do not produce any independent flow pressure. Their flow activity is determined by the portion of the corresponding spindle provided with a thread in the zone of the inlet to the casing. As it is possible to recognize in a roll mill or a calender, an exterior mixing process takes place only within a very small zone at the contacting peripheries of the roll bodies.

The rheological conditions of the mass transfer in conveyor presses studied in recent years have led to the observation of the particular behavior of plastic masses at the boundary layers. In has been basically recognized that the boundary layer phenomena are of fundamental significance. A boundary layer rupture press (system Dr. Ernesto Gabbrielli) has become known which is based on an analytical theory in which the boundary layer factor is included.

First it shall be noted that here a geometrical shape appears which can be observed over the entire working scope. It is the question of an axially symmetrical circular cylinder drawn over the full arc of the mass transfer. This mechanical working element has a function of process technique which can be well explained. The different zones of the structural arrangement, however, result in rheological difficulties.

The functional analysis of this known boundary layer rupture press is transferred in such manner into its mechanical form that a movable rotating portion of a cylindrical surface, accordingly as a circular cylinder is formed with a uniform diameter over the whole length of the axis. The internal surface of the casing also is cylindrical and is rigorously concentrical with the rotating cylinder. The real working phase in the present case comprises the entire arc absolutely axially symmetrical between a corresponding inlet or feeding zone and a scraper element, thus the "dam" at the end of the rotating cylinder i.e. the outlet of the material. The end phase of the rotating cylinder accordingly supplies a pressure chamber above, or more precisely, in front of the drawing die. This scraper element uncovers the plastic mass at the end of the working duct. In this manner the pressure over the entire arc of the working phase is rendered possible and activated. The removal of this scraper means that over the entire length of the axis of the machine, the mass is transported without any pressure in the direction towards the outlet of the material, and accordingly no plasticizing and no mixing can be obtained. It is possible that a longitudinal phase to be determined ahead of the scraper element can be formed as a lateral pressure chamber within the working range of the boundary layer rupture press. This results in a side or lateral outlet of the deformable medium. Such a lateral opening in the meaning of a drawing die for forming surface-shaped products such as sheets or plates, however, prevents even a disappearingly small action of the mixing coefficient. The perceptible outer laminar and accordingly unidimensional mixture, as it is, runs off owing to leakage current in a short zone immediately ahead of the scraper element. The scraper acts in the sense of the known Prandtl limit disc. This indicates that the plastic mass is dammed and receives a transverse impulse which acts on the flow pattern by creating a noticeable pulsation. A deflection of the tangential and radial forces thereby is rendered impossible. The current in the boundary layer rupture press is similar to an absolutely laminar pipe current according to the law of Hagen-Poiseuille having a parabolic velocity distribution. Accordingly, this distribution of velocity is independent at a small distance of the inlet of the material and no mixing occurs. Owing to a small thermal energy transformation of the laminar pipe current and in combination with the high thermal internal resistance of the plastic mass, which is to be considered, the formation of a sufficiently thick temperature boundary layer is rendered impossible.

Moreover, a feeding press according to the so-called Anger method has been developed recently. This press comprises a conventional worm or screw which only is free of thread in known manner in a middle section. Nothing is said about the required position of this middle section without thread. It corresponds to all known constructions which comprise a so-called conical or cylindrical friction roll as a middle section without thread. The difference with the present invention consists in that this middle section without thread is interrupted at a not clearly defined location by so-called "conical surfaces in the shape of rings." No analytical determinations concerning the required length of this middle section and concerning the relative position of these conical rings are made. Owing to the fact that the outlet of the material is provided with a thread, the same characteristics are formed as they have been previously exposed in relation with the boundary layer rupture press. The "conical surfaces in the shape of rings" still double this effect by the fact that the action of the Prandtl limit disc must be associated with both elements, the conical rings, as well as the screw on the side of the outlet of the material. Owing to the variable height of the chamber of this middle section without thread, there results a superposed laminar pipe current according to Hagen-Poiseuille with the same already discussed characteristics relative to the mixing and the thermodynamic effects. It is therefore superfluous to again discuss this matter. This superposed laminar pipe current divides into two independent laminar pipe currents each of which has its own parabolic velocity distribution. The smaller mass is run over by the greater mass having the greater pipe cross section. Such a laminar running over is also often observed with a torpedo head or within a metering zone of a screw. The conical rings in the claimed shape have a very small consolidating action and in no case are they flow activating, Since the flow is laminar over the whole length of this middle section without thread, also the laminar boundary layer has the same boundary layer thickness over both zones ahead of and after the conical rings. Since the masses in both zones are unequal, there result sensible thermic fluctuations which are absolutely uncontrollable. The profile of these "-conical surfaces in the shape of rings" results in an absolutely stable flow and no active movement values are obtained. Also for this reason, the mixture cannot be induced.

Essential features for the unobjectionable and rationalized transformation of the deformable media are formed by new considerations concerning the conditions of the laminar and the turbulent boundary layers and flows, of the thermodynamic phenomena in the boundary layers and in the mass volumes, and accordingly also of the mass pressures and the velocity distributions in the conveyor presses.

The apparatus of the present invention imparts to the deformable medium an apparent turbulent rotary motion and produces at the same time an increasing temperature boundary layer, subsequently increasing the pressure to produce a turbulent rotary motion of the medium with a turbulent thermal energy distribution, after completion of the turbulent transformation and mixing causing the regeneration into a laminar flow of the medium by a stabilizing constant pressure and throttling of the turbulent energy distribution by cooling, and subsequently producing a final stabilization of the deformable medium by a pressure drop.

The apparatus according to the present invention comprises a cylinder, a rotor mounted for rotation within said cylinder, said rotor including in the direction of flow, (a) an unstable diverging diffusor, (b) an axially symmetrical rotor portion forming an extension of said unstable diffusor, (c) a stable diverging diffusor following said axially symmetrical rotor portion, (d) a second axially symmetrical rotor portion forming an extension of said stable diffusor, and (e) a converging diffusor following said second axially symmetrical rotor portion.

The apparatus is further characterized in that the rotor comprises a logarithmic spiral arranged in the inlet zone of the medium upstream of the unstable diverging diffusor, the thrust side of this spiral being provided with a parabolic cross section, resulting in a disappearing curvature, and that this logarithmic spiral has a counter element on the cylinder in the form of a glass sleeve.

The unstable divergent diffusor of the rotor is divided into several zones, the diameter of each zone increasing in the direction of flow, and the profile of a preselected zone comprises a reversing circle. This reversing circle produces the instability of the deformable medium and accordingly the turbulent flow. The section profile of this unstable diverging diffusor corresponds to the exponential and logarithmic function of a hyperbola.

Further, the invention consists in that the converging diffusor, the diameter of which decreases in the direction of flow, is provided with a longitudinal groove which as a transcendental curve represents the exponential function $Y=e^x$. This longitudinal groove produces the rolling of the boundary layer. The so-called rolling of the boundary layer is a phenomena of fluid physics, which is obtained by an increase of the volume of the medium and has an appreciable influence on the stability of the flow. The rolling prevents the separation of the boundary layer ahead of the entry of the medium into the tool, by effecting a limited pressure relief on the periphery of the transporting outer surface of the rotor.

A further feature according to the invention consists in that the stable diverging diffusor describes in section a transcendental curve producing the balanced pressure and the relaminar deviation of the flow which curve is represented by the function

$$y=\left(1+\frac{1}{x}\right)^x$$

A further feature of the invention consists in that the cylinder has its internal surface roughened to a certain degree in the zone of the unstable diffusor producing the turbulent flow, and the following axially symmetrical shaft. The relative roughness k/R and the admissible roughness level k_{zul} have a noticeable and accelerating influence on the transition laminar-turbulent. The velocity of growth of the boundary layer is also accelerated by the roughness level. According to the invention the admissible roughness level in millimeters in the zone of the turbulent flow shall be at least 0.1 and not exceed 0.5. The amount of 0.1 is given by the fact that passing below this value, it would be situated in the laminar lower stratum measuring only a very small fraction of the thickness of the laminar boundary layer and accordingly such a small roughness level would act hydraulically smooth.

The invention will now be more fully described with reference to the accompanying drawings, in which,

FIG. 1 is a diagrammatic sectional view of the turbine according to the invention and by means of which the method for transforming and mixing of deformable media will be carried out,

FIG. 2 is a section along the line II–II of FIG. 1,

FIG. 3 is a diagram of the profile of the unstable, diverging diffusor shown in FIG. 1.

FIG. 4 is a diagram of the profile of the stable diverging diffusor also shown in FIG. 1,

FIG. 5 is an enlarged sectional view of the converging diffusor provided with a longitudinal groove,

FIG. 6 is a diagrammatic section on the line VI–VI of FIG. 5,

FIG. 7 is an analytic section pertaining to FIG. 2,

FIG. 8 is an analytic representation pertaining to FIG. 3,

FIG. 9 is an analytic representation pertaining to FIG. 4,

FIG. 10 is an analytic section pertaining to FIG. 6,

FIG. 11 shows an analytical representation of the velocity distribution by Pascal configuration with reversing points in the region of the logarithmic spiral.

The turbine comprises a rotor 2 turning in a cylinder 1. In the region of an inlet 3 in the cylinder, the rotor 2 is provided with a logarithmic spiral. This logarithmic spiral 4 is formed on the thrust side with a parabolic section (see FIGS. 2 and 7) the course of which results in a disappearing curvature. When transforming a deformable medium having an extremely high molecular weight, for example above 1,500,000, this spiral can be replaced by a simple diffusor, e.g. a truncated circular cone having in section an oblique base surface. In the zone of these high molecular weights the boundary layer adsorption and the shearing stress, which are both influenced by the molecular weight, become so high that the presence of this spiral is no longer required, and the deformable medium can also be conveyed by the formation of a velocity distribution in the Pascal configuration with reversing points. In contradistinction with the parabolic velocity distribution of the pure laminar pipe flow according to Hagen-Poiseuille, or the helical flow, which are unidimensional and the mixing diagrams of which also are to be represented by unidimensional layers, in the method according to the invention the apparent turbulent or quasi-turbulent rotational movement of the medium is produced. This requires that in the zone of the logarithmic spiral the coefficients of friction of the internal cylinder surface and of the rotor surface differ at least by the number 0.3. This means that the internal cylinder surface must have a coefficient of friction for producing the static friction R_H, which is higher by 0.3 with respect to that of the sliding friction R_G of the logarithmic spiral. The coefficients of friction of the metals in this respect are situated too close to each other. Accordingly, a corresponding sliding friction would be obtained on the cylinder and on the rotor, which represents the parabolic velocity distribution and therefore any solid body mixing is prevented. The frictional activity of the static friction, or the coefficients of static friction without exception are greater than the coefficients of sliding friction.

Moreover, the static friction slightly increases with increasing temperature, while no such interrelation exists with the sliding friction. According to the invention the difference of 0.3 of the coefficients of friction is obtained by means of a quartz glass sleeve 26 shown in FIG. 1. The extremely high coefficient of viscosity as well as the deformation stress damping out in small periods of time (Maxwell's relaxation time) are acting in the boundary layer on the sleeve 26 in the manner of the critical case of a "liquid having a very high viscosity." The principal reversing point of the velocity distribution is displaced towards the wall of the cylinder and the resulting flow has angularly displaced axes relatively to the axially symmetric walls of the cylinder and the rotor, which denote the apparent turbulent flow. These angularly displaced axes are intercepted by the thrust side of the logarithmic spiral profile according to an optimum angle nearly always measuring 90°, whereby a three-dimensional mixing of the solid body agglomerates, exempt from pulsations, is obtained.

The rotor 2 further comprises an unstable diverging diffusor 5 extended by an axially symmetrical shaft portion 6. The profile of this diffusor 5 is represented diagrammatically in FIG. 3 and analytically in FIG. 8. The profile of the diverging unstable diffusor 5 has the shape of a transcendental curve of the hyperbolic function

$$y=\sin X=\frac{e^x-e-^x}{2}$$

which is subdivided into six sections 5*a*, 5*b*, 5*c*, 5*d*, 5*e*, 5*f* (FIGS. 3 and 8). Moreover, the profile of the diffusor between the sections 5*c* and 5*d* comprises a reversing circle which kindles the instability of the medium or the turbulent flow and which, in the boundary layer physics, is designated as the circle of indifference or neutral circle.

Following the axially symmetrical shaft portion 6 (FIG. 1) the turbine comprises a second diverging but stable diffusor 7 which again is followed by an axially symmetrical shaft portion 8. The stable diffusor 7 the profile of which is diagrammatically represented in FIG. 4 and analytically in FIG. 9 also is divided into seven section 7*a*, 7*b*, 7*c*, 7*d*, 7*e*, 7*f* and 7*g*. The diameter of the diffusor increases in the direction of flow and in the analytical representation of the diffusor, its profile describes a transcendental curve having the function

$$y=\left(1+\frac{1}{x}\right)^x$$

This function of the curve produces the stability of the medium or the laminar flow. The axially symmetrical shaft portion 8 is followed by a conveying diffusor 10 having the shape of a truncated circular cone. This diffusor as represented in FIG. 5 is provided with a longitudinal groove 9 which produces the unrolling of the boundary layer of the medium. An additional diffusor 10*a* is provided in the region of the diffusor 10 and is obtained by continuously increasing the internal diameter of the cylinder 1. The diffusor 10*a* in cooperation with the longitudinal groove 9 of the diffusor 10 produces an additional stabilization of the flow of the medium at the outlet of the turbine. FIG. 6 represents a transverse section through the diffusor 10 of the rotor 2.

In the region of the unstable diffusor 5 and the following axially symmetrical shaft portion 6 the surface of the cylinder 1 (FIG. 1) is roughened to a predetermined degree of roughness.

The outer surface of the cylinder 1 is provided with a screw thread 10*b* on which are threaded a plurality of rings 11, 12, 13, 14, 15 and 16. A second cylinder 17 is placed over the rings. These rings are distributed in such manner as to provide annular chambers 18, 19, 20, 21 and 22. The chamber 18 extends over the axial length of the logarithmic spiral 4, the chamber 19 over the length of the unstable diffusor 5, the chamber 20 over the length of the shaft portion 6, the chamber 21 over the length of the diverging stable diffusor 7 and the shaft portion 8, and the chamber 22 over the length of the converging diffusor 10 and the diffusor 10*a*. Each chamber is provided with inlet and outlet openings 27 and 28, respectively for circulation of a fluid for independently controlling the temperature of each chamber.

Owing to the supply of thermal energy from the wall of the cylinder 1 into the deformable medium, a temperature dependent boundary layer is formed. The dissipation, i.e. the transformation of shearing stress into heat is the greatest within the boundary layer of a current flow. The thickness of the temperature dependent boundary layer has the same value as the thickness of the flow boundary layer. In the zones of the laminar flows the temperature boundary layer is determined by direct action of the molecular viscosity, while in the zone of the turbulent flow the temperature-boundary layer builds up by withdrawal of energy by which the fluctuation or secondary movement of the mean or principal movement is effected. The energy transformed by the fluctuation movement into heat is the turbulent dissipation.

The fluctuation movements superposed to the principal movement produce or effect the mixing. Hereby indirect effects are obtained which increase the stress in the turbulent flow in the same manner as if its viscosity would be highly increased. The mixing path expressed as an ordinal index of boundary layer physics (Prandtl group) is determined by this movement condition. The turbulence whirls progressively mix with the surrounding turbulent media and continuously form new whirls of various sizes. It is essential that the dissipation of energy takes place mostly in the small turbulent whirls or balls, accordingly in close proximity of the walls. This phenomenon is energetically similar to the formation of spherulites in the crystallization of deformable media. The turbulence whirls or balls, as well as the spherulites have a substantially higher energy density than their environment. For their formation, however, they also require a high energy. For this reason a continuous thermoenergetic conversion must be ensured. The continuously progressing mixing process accordingly also is a pure energy transformation. The heat of transition developing upon a change in size of the turbulent whirls or balls corresponds to the continuous thermodynamic transformation of mass volumes. The stress principally is transmitted by the bigger turbulence whirls, thus, in contradistinction to the dissipation of energy, in the principal movement or nearer to the middle of the mass of the deformable medium. It is to be attributed to this comprehensive procedure that the frictional resistance and also the distribution of the mean velocity within the turbulent flow which energetically performs the main work for the transformation of the deformable media only depend to a very small degree on the Reynold's number.

This principle of continuous transformation of energy is realized according to the invention by the combination of a variable temperature boundary layer with the thermodynamic-capacitive volume energy of the medium. The essential deformable media and also their considerable thermal resistance require a cooperation of the temperature-boundary layer with the turbulence. These required high thermal energies cannot be supplied merely by convection from the wall into the flow. They are transformed by the medium without reaching the bigger turbulence whirls or even enabling their formation. On the other hand, the radiation losses and energy losses in the exterior current layers would be too great, if no temperature-boundary layer would be present. This means that by the assistance of the temperature-boundary layer the loss angle and the dielectric constant or coefficient of the medium, and therefore the flow must be brought to a certain value in order to obtain a dissipation of the energy into the principal and mean movements of the flow. Further, a too high value of the temperature-boundary layer would have the effect of an immediate disintegration of the molecule chains.

Upon transformation of the deformable media the value of the dielectric loss factor as matter constant varies and increases linearly with the value of the temperature-boundary layer. Thereby the heat resistance also is molecularly reduced. The deformable medium then is subjected at the same time as a dielectric to a capacitive current combined with an ohmic current component at an alternating voltage. These two current components are in phase quadrature and are directed at right angles to the flow of the medium. The dielectric constant of the medium is independent of the frequency. However, the loss angle increases with increasing frequency. This thermal molecular movement or Brownian motion is permanently accelerated in the direction of flow. The length of the particle trajectories become progressively shorter in a kind of zigzag motion and the particles combine or ball up to other formations, i.e. the turbulence whirls or balls, or spherulites. This constitutes the energetic mixing (Boltzmann constant). Due to the conglomeration of the particles the volume of the deformable medium is reduced and a higher density is obtained. The laminar flow as well as the turbulent flow participate at this procedure. This means according to the invention the coupling or combination of the laminar correlative boundary layer association with the turbulent autocorrelative boundary layer association in the molecular range.

With the increase of density of the medium by acceleration of the potential of the Brownian motion as thermal energy of the molecules in the volume by the value of the thermodynamic-capacitive volume energy, the loss factor of the medium increases with an absolutely constant velocity, but in dependence of the frequency and the temperature in the medium. Accordingly, a relation is obtained between the thermal acceleration of the quasi-turbulent flow and the turbulent flow. The quasi-turbulent temperature-boundary layer and the thermal energy of the quasi-turbulent flow are transferred by the variation of the loss factor until a given critical value. This critical value represents the thermoenergetic neutral value which initiates the transition into the turbulent energy dissipation. According to the invention, besides the double current transition, there also exists a double transition of the thermal energy. Owing to the Pascal's distribution of velocity of the quasi-turbulent flow, the ratio of growth of the thermal energy in the range of the quasi-turbulent flow has the same value in all molecular layers of the medium at a point of the axis as seen in the direction of flow, thus correlative with time, and this growth, when the neutral value is attained, will undergo a transition into the turbulent energy dissipation, the thermal energy dissipating in the zone of the turbulent flow, owing to the action of the turbulent fluctuation movement and principal movement and to the high energy of the turbulence balls, this dissipation occurring with an increasing ratio as seen at a point of the axis in the direction of flow at different times, thus autocorrelatively. The frequency of the energy supply by the high frequency alternating field remains constant during the whole period of the double transition of the thermal energy.

The procedure of crystallization, the conservation of the spherulites of the energy-rich turbulence balls occurs by removing thermodynamic capacitive energy from the turbulent energy dissipation by cooling of the walls and by a drop in pressure. The frequency of the HF alternating field hereby is not displaced.

In the same manner as the polymerization, also the polycondensation and the addition polymerization occur according to the same principle of the double transition of the thermal energy. For example, the polycondensation of the polyamides takes place over a large number of molecule chains as seen in the direction of flow, whereby decomposition products in the form of water, alcohol or ammonia are set free. By transition of laminar correlative growth of the thermal energy into autocorrelative growth of the turbulent thermal energy dissipation and the subsequent stabilization by wall cooling and pressure drop, the polycondensation balance is obtained and then trimmed.

The addition polymerization also is controlled by the double transition of the thermal energy. This is obtained by initiating the migration of hydrogen for the continuous formation of new principal valence compositions by the correlative growth of the laminar thermal energy, whereafter the transition away from the thermoenergetic neutral value into the autocorrelative turbulent energy dissipation occurs and finally within this turbulent energy dissipation the hydration and dehydration is effected, whereafter finally the addition by heteratoms is reactively interrupted by wall cooling and pressure drop.

By means of the double transition of thermal energy the inherent low conductivity of the deformable media is modified and increased, particularly in the correlative, laminar temperature-boundary layer, without a decomposition of the molecule chains being obtained already in the boundary layer by overstrain. The tendency of overstrain will become more noticeable, as the thermal conductivity almost proportionally decreases with the increase of the molecular weight of the deformable medium. The lower is the thermal conductivity of the medium, the higher are the energy and the shear force required for its transformation. With the decreasing conductivity of the medium also the speed of propagation of the Brownian motion decreases proportionally, thus requiring the thermal double transition. The laminar stabilization occurring at the outlet of the turbine can be effected in one or two stages, within certain values of the molecular weight of the medium a one-state stabilization by means of the converging diffusor 10 being sufficient. In the extreme cases of a high molecular weight, i.e. high shear stresses and high energy of the turbulent dissipation, two-stage pressure relief is required. In this case the initiating points of the two-stage stabilization, on the rotor 2 and on the cylinder 1, are peripherally superposed. The diffusor 10 of the rotor, together with the longitudinal groove 9 forms the first stage of stabilization, while the diffusor 10*a* formed by the cylinder portion having a gradually increasing internal diameter in the direction of flow, constitutes the second stage.

The pressure relief produced by the converging diffusors 10 and 10*a*, while conserving the size of the turbulence whirls or balls and the number of spherulites occurs simultaneously with the cooling of the wall, i.e. with the passage of thermal energy from the medium into the wall. This thermodynamic procedure acts highly stabilizing. The supply of the thermodynamic-capacitive volume energy, i.e. of the capacitive and the ohmic current components of a determined frequency from an alternating current generator, occurs via the capacitive mass of the rotor 2 and the capacitive potential of the cylinder 1. For this purpose the rotor 2 is provided with a sliding contact 23 and the cylinder 1 with a terminal connection 24. This latter and the contact 23 are connected to a HF generator 25, and the energy of a preselected frequency supplied to the rotor 1 and the cylinder 2, for example between 13.6 and 27 MHz, is insulated immediately behind the beginning of the logarithmic spiral by means of a loss-free shield of ceramics. The sleeve 26 of quartz glass, already mentioned, is engaged by a press fit into the cylinder 1 and extends over the length of the logarithmic spiral 4.

The described turbine operates as follows: The deformable medium to be processed is fed through the feed hopper 3 and is conveyed by the logarithmic spiral 4 towards the diffusor 5 in an apparent-turbulent or quasi-turbulent stream. In the zone of the reversing circle W provided on the unstable diverging diffusor 5 the quasi-turbulent flow of the medium is transformed into a turbulent flow. Over the length of the logarithmic spiral, the apparent turbulent temperature boundary layer with the correlative thermal energy is transmitted to the medium and transformed in the diffusor 5 and the following axially symmetrical shaft portion 6 into the turbulent energy dissipation with an autocorrelative rise in intensity. Due to the presence of the roughened zone 29 in the cylinder 1 extending over the length of the diffusor 5 and the shaft portion 6, the unstable, turbulent condition of flow is induced or kindled also in the cylinder. In the zone of the stable diffusor 7 the turbulent flow is stabilized and by cooling on the wall, while conserving the frequency, the intensity of the turbulent energy dissipation is restored, so that the laminar condition of flow is obtained. The longitudinal groove 9 provided in the diffusor 10 enables the rolling of the boundary layer and thereby prevents the separation of the laminar flow, and the diffusor 10*a* formed in the cylinder 1 produces a further relief of pressure, leading to a supplementary stabilization of the medium. The medium thus leaves the turbine in a stabilized laminar flow of high density or crystalline condition and with aligned energy centers or mass balls.

I claim:

1. Apparatus for transforming and mixing deformable media, comprising a cylinder, means for feeding a deformable medium into said cylinder, a rotor mounted for rotation within said cylinder, said rotor including in the direction of flow, (a) an unstable diverging diffusor, (b) an axially symmetrical rotor portion forming an extension of said unstable diffusor, (c) a stable diverging diffusor following said axially symmetrical rotor portion, (d) a second axially symmetrical rotor portion forming an extension of said stable diffusor, and (e) a converging diffusor following said second axially symmetrical rotor portion, said rotor, in the zone of the inlet of said cylinder, being provided with a conveyor screw in the shape of a logarithmic spiral arranged upstream of said unstable diverging diffusor, the thrust face of said conveyor screw being of parabolic cross section forming a transcendental curve provided with a disappearing curvature in its course.

2. Apparatus according to claim 1, in which said unstable diverging diffusor is divided into a plurality of axially successive zones of increasing diameter in the direction of flow, the profile of a preselected zone including a reversing circle which induces the instability of the medium or the turbulent flow.

3. Apparatus according to claim 1, in which said stable diffusor is divided into a plurality of axially successive zones of continuously increasing diameter in the direction of flow, for producing the stability of the medium or the laminar flow.

4. Apparatus according to claim 1, in which the converging diffusor having a decreasing diameter in the direction of flow is provided with a longitudinal groove for producing the rolling-off of the boundary layer.

5. Apparatus according to claim 1, in which said cylinder is provided with a roughened internal surface in the zone of said unstable diverging diffusor and said axially symmetrical rotor portion forming an extension thereof.

6. Apparatus according to claim 1, in which said cylinder is provided with a plurality of axially successive annular chambers arranged for circulation of fluid for the temperature control of the medium supplied to the cylinder.

7. Apparatus according to claim 6, in which one of said annular chambers substantially extends over the axial length of said logarithmic spiral, another of said annular chambers extends over the axial length of said unstable diverging diffusor, a third annular chamber substantially extends over the axial length of said axially symmetric rotor portion following said unstable diffusor, a fourth chamber substantially extends over the length of said stable diverging diffusor and said axially symmetrical rotor portion following the stable diffusor, and a fifth annular chamber extends over the length of said converging diffusor.

8. Apparatus according to claim 1, in which the internal surface of said cylinder is provided with a quartz glass sleeve, substantially extending over the length of said logarithmic spiral formed on the rotor.

9. Apparatus for transforming and mixing deformable media, comprising a cylinder, a rotor mounted for rotation within said cylinder, said rotor including in the direction of flow, (a) an unstable diverging diffusor, (b) an axially symmetrical rotor portion forming an extension of said unstable diffusor, (c) a stable diverging diffusor following said axially symmetrical rotor portion, (d) a second axially symmetrical rotor portion forming an extension of said stable diffusor, and (e) a converging diffusor following said second axially symmetrical rotor portion, said cylinder being provided with an additional converging diffusor formed by a length of the cylinder of gradually increasing internal diameter in the direction of flow, said additional diffusor being situated in the zone of said converging diffusor formed by the rotor.

10. Apparatus for transforming and mixing deformable media, comprising a cylinder, a rotor mounted for rotation within said cylinder, said rotor including in the direction of flow, (a) an unstable diverging diffusor, (b) an axially symmetrical rotor portion forming an extension of said unstable diffusor, (c) a stable diverging diffusor following said axially symmetrical rotor portion, (d) a second axially symmetrical rotor portion forming an extension of said stable diffusor, and (e) a converging diffusor following said second axially symmetrical rotor portion, said cylinder being provided with a terminal and the rotor with a sliding contact, said terminal and sliding contact being connected with a high frequency generator.

11. An extruder for transforming and mixing of plastics material on the basis of laminar-turbulent and turbulent-laminar transition of the flow of material and of the transition of the thermal quasi-turbulent energy exchange into turbulent energy dissipation, comprising a cylinder, a rotor rotatably mounted in the cylinder, said rotor comprising a first flow cone having a diverging profile in the direction of flow of the material for producing flow disturbances, said flow cone being

extended by an axially symmetrical shaft portion followed by a second flow cone having a diverging profile in the direction of flow of the material for stabilization of the flow, said second flow cone being extended by a further axially symmetrical shaft portion of greater axial length than said first and second

flow cone, and a truncated circular flow cone having a convergent tapering profile in the direction of flow and forming the rotor end portion of greater axial length than said first and second flow cone.