

[54] PROCESS AND AN APPARATUS FOR CONTINUOUSLY CASTING A SHEET AND THE LIKE

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[30] Foreign Application Priority Data

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[51] Int. Cl..... B29d 7/14

[58] Field of Search..... 264/166, 40, 176 R, 212, 264/216, 236, 175, 347, 207, 217, 331, 218; 425/224, 150, 149

[56]

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Primary Examiner—Jeffery R. Thurlow

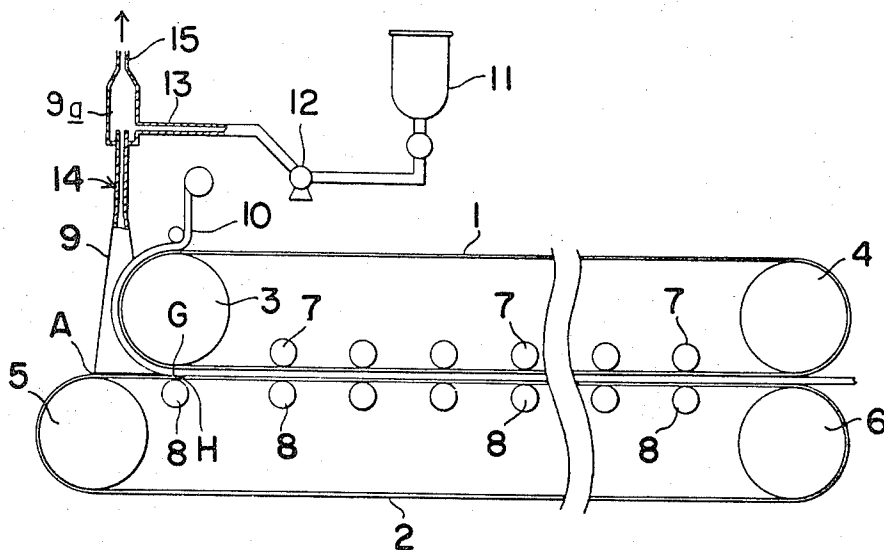
Attorney, Agent, or Firm—Kenyon & Kenyon Reilly Carr & Chapin

[57]

ABSTRACT

A process for continuously casting a polymeric sheet and the like, comprising, running two feed belts positioned in face-to-face relationship to each other, opposed belt surfaces of said belts running in the same direction at the same speed; running at least two gaskets together with the two belt surfaces at the edges thereof; maintaining the opposed surfaces rigid in the direction transverse to the running one and flexible in the running direction; supplying material between the belts from one end thereof; supporting apart the opposed belt surfaces by pressure of the material and retaining a gap of desired thicknesses between the belt surfaces at desired positions thereof; treating continuously the material between the belt surfaces and delivering treated sheet from the other end of the belts.

18 Claims, 32 Drawing Figures



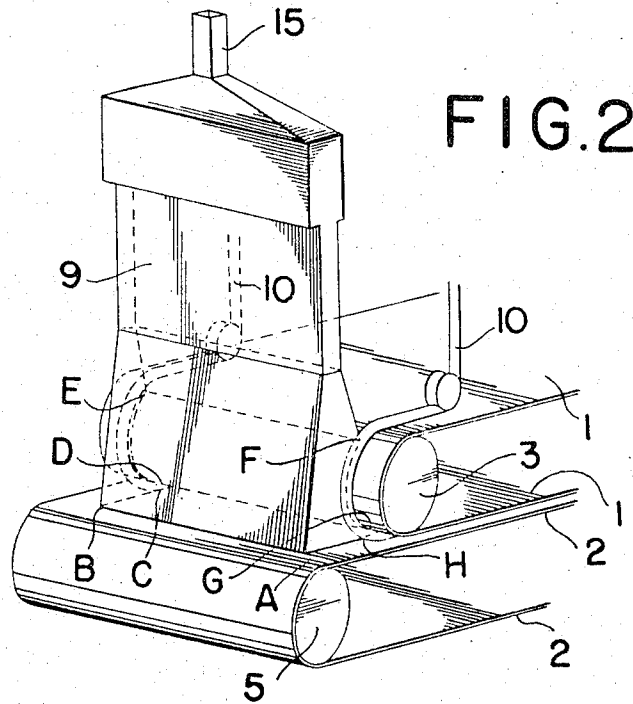
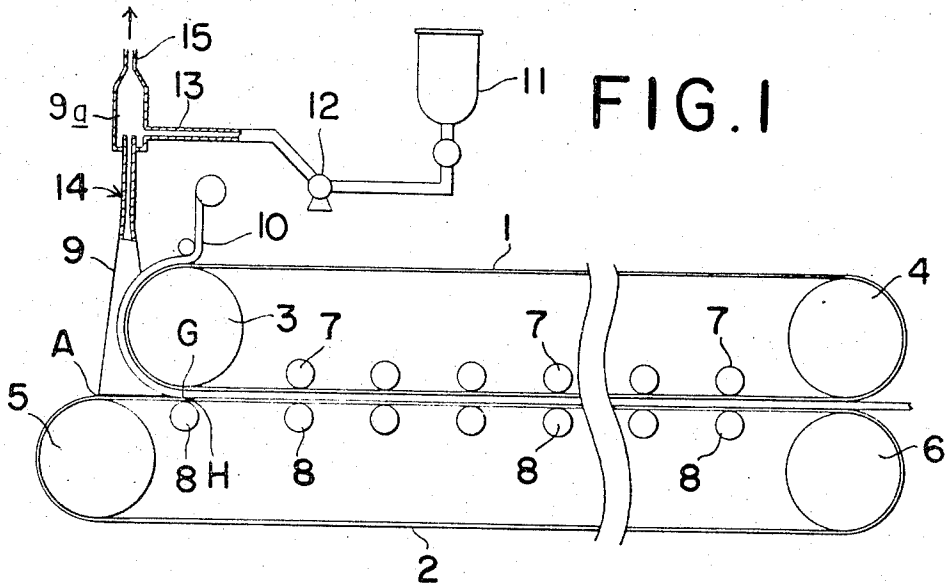


FIG. 3

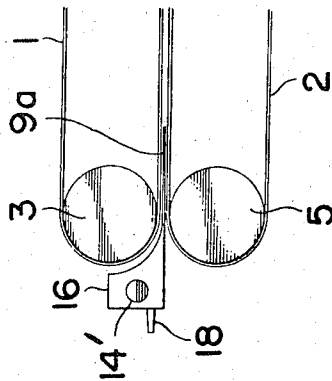


FIG. 4

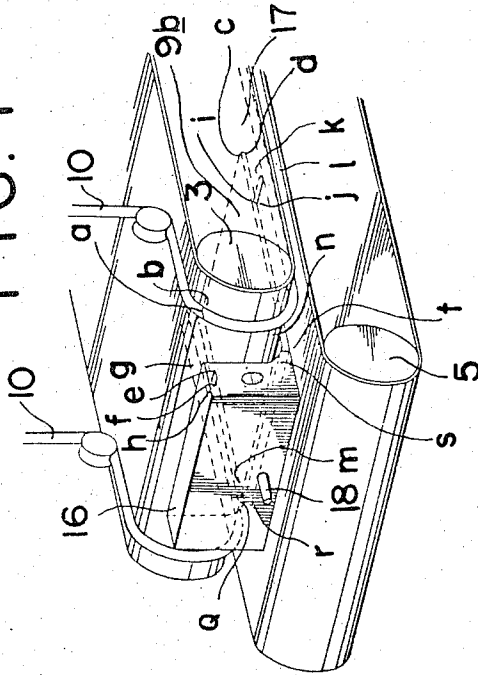


FIG. 5

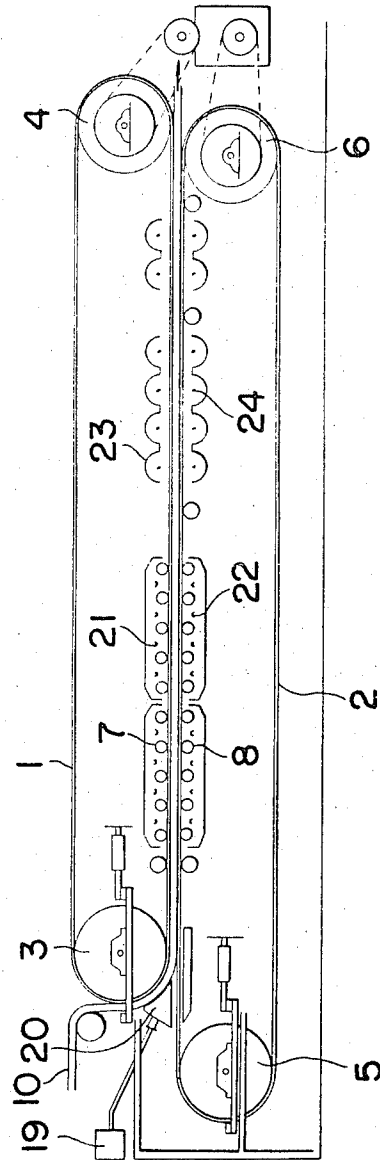


FIG. 6

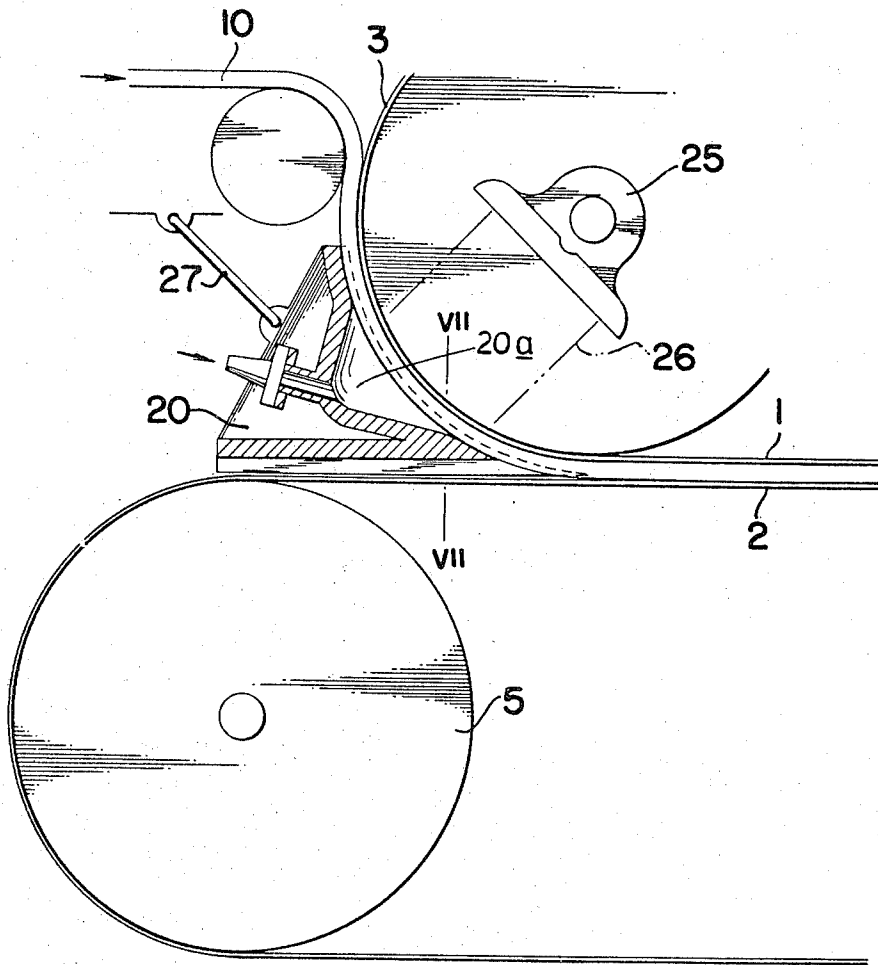


FIG. 7

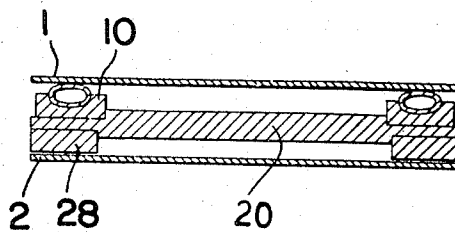


FIG. 10

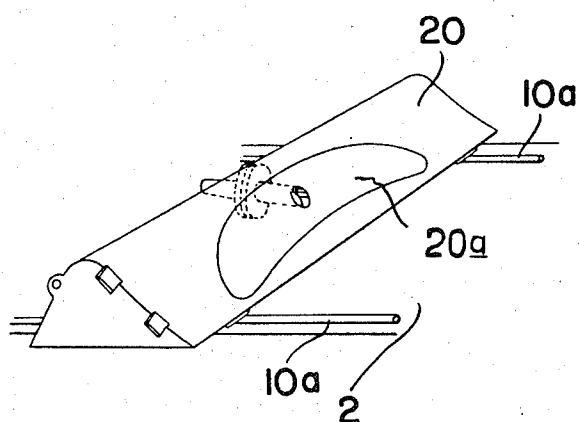
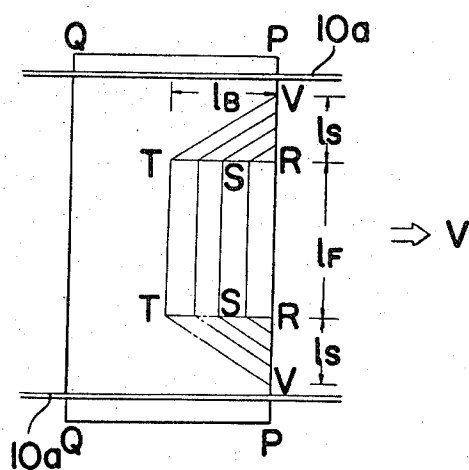


FIG. 11



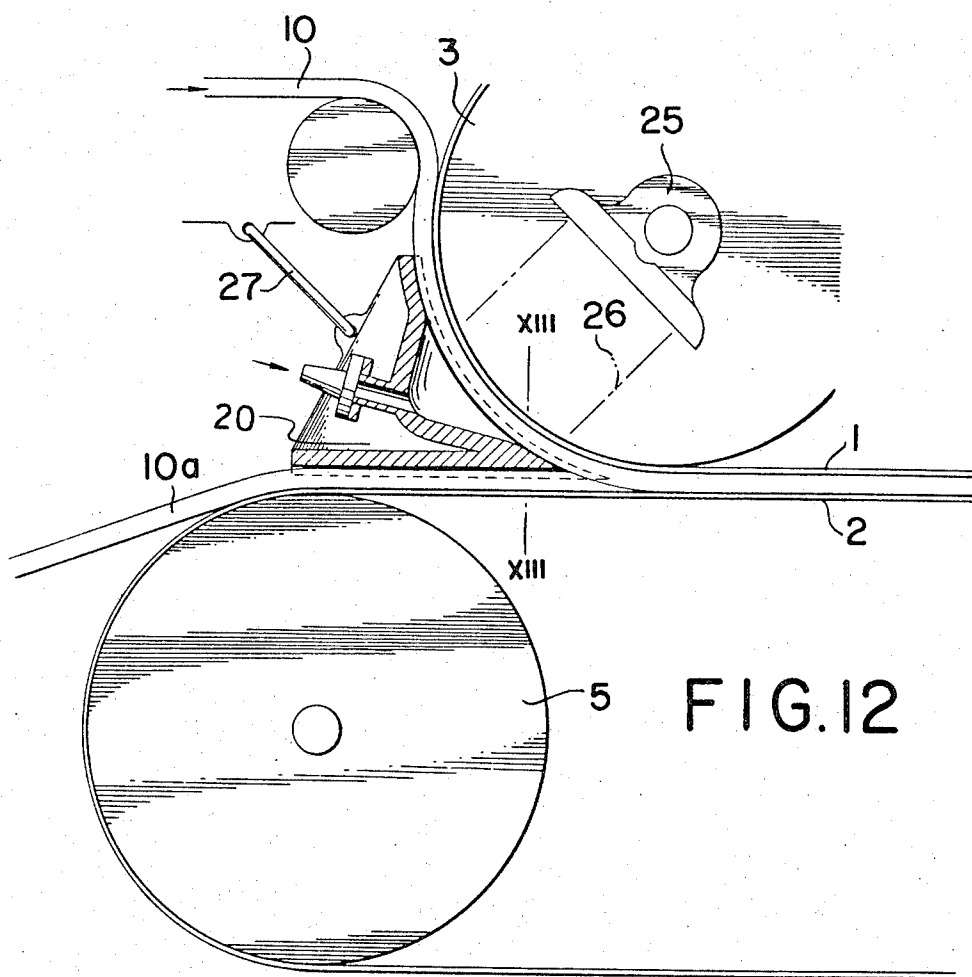
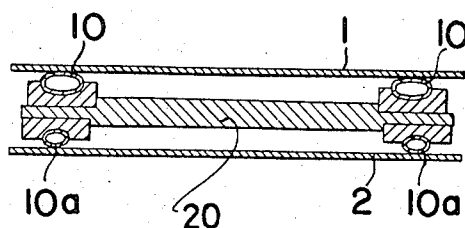


FIG. 13



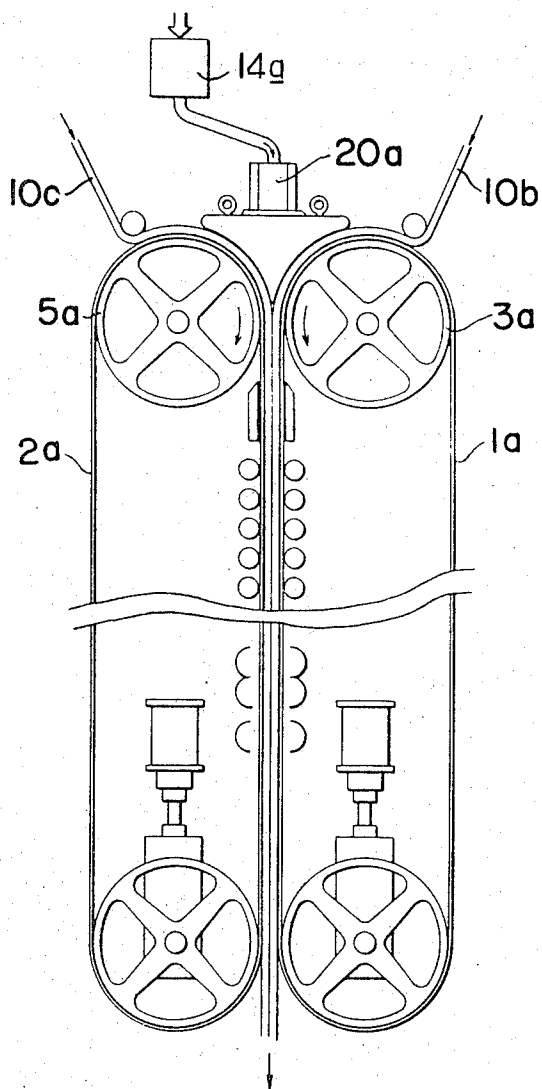


FIG. 14

FIG. 15

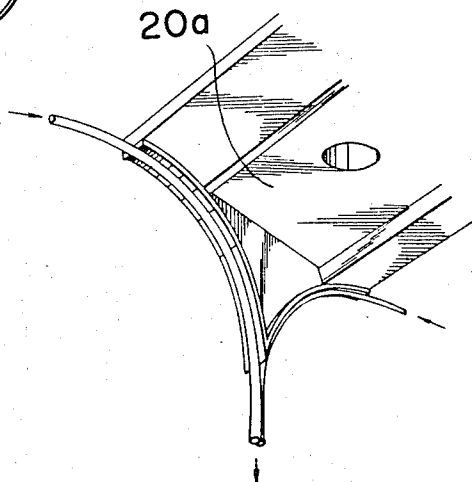


FIG. 16

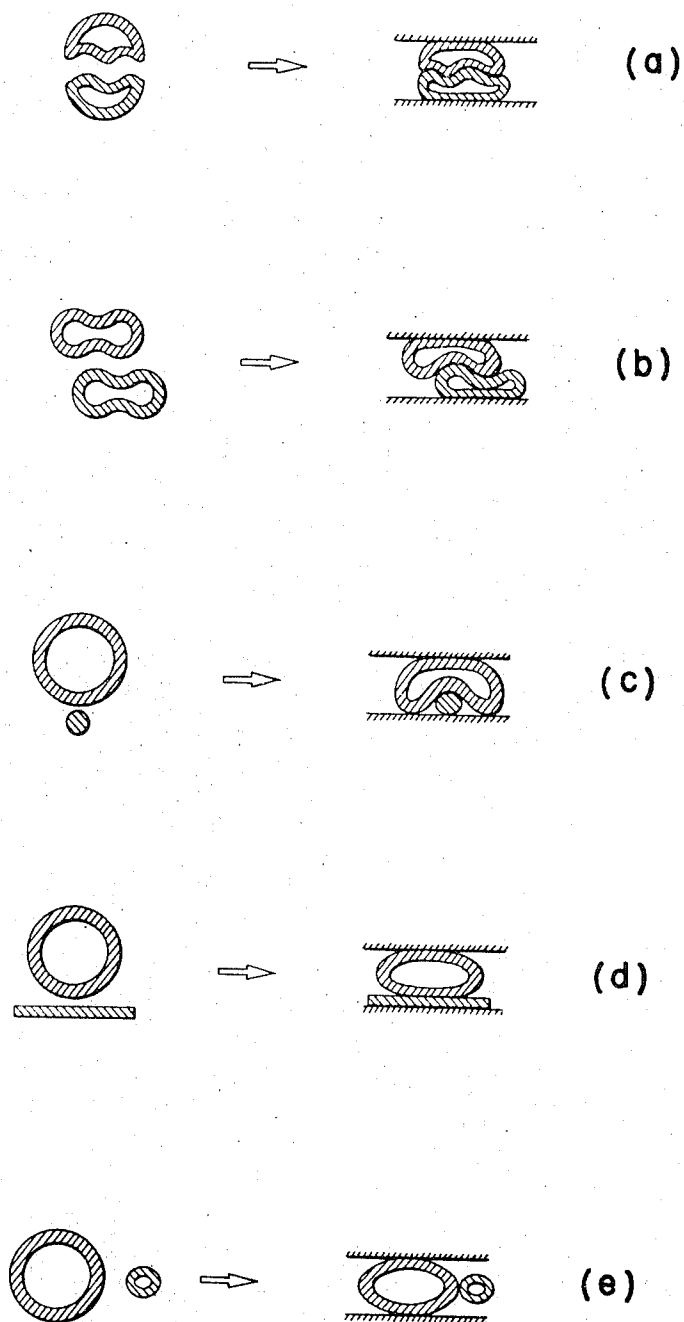


FIG. 20

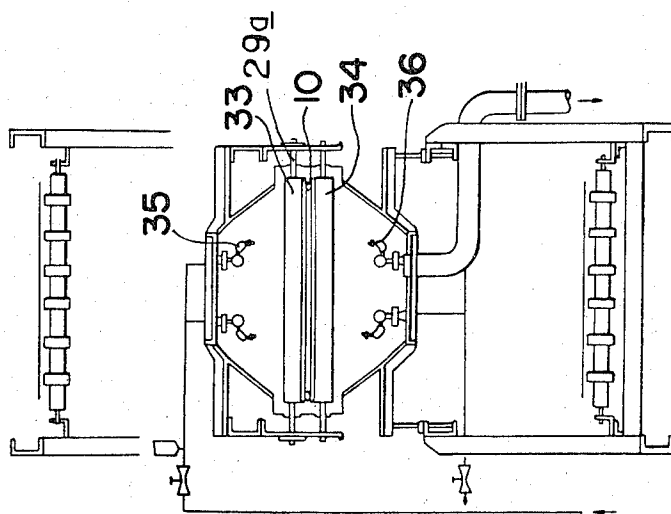


FIG. 22

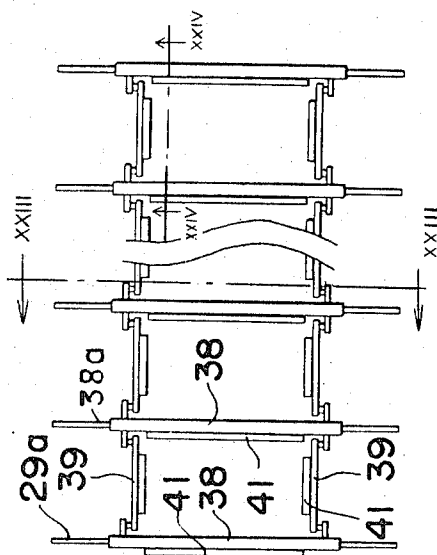


FIG. 23

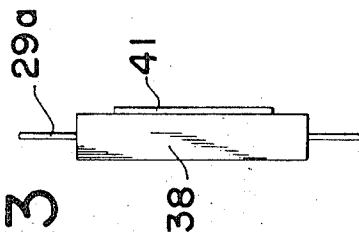
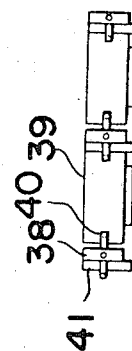


FIG. 24



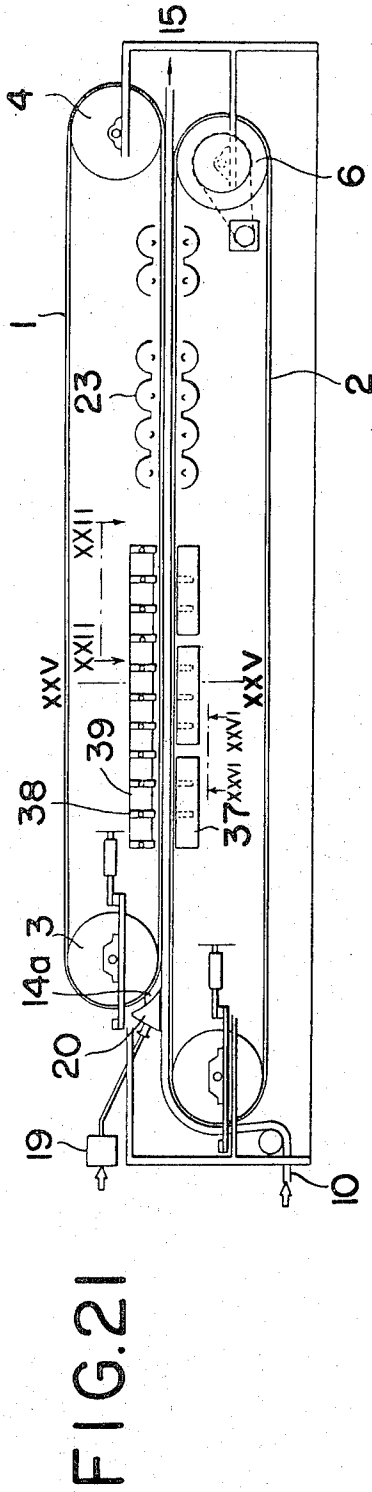


FIG. 25

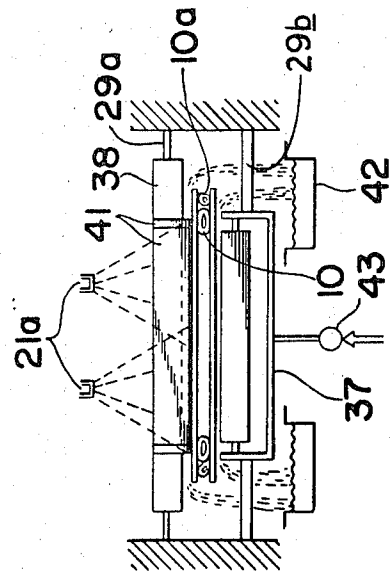


FIG. 26

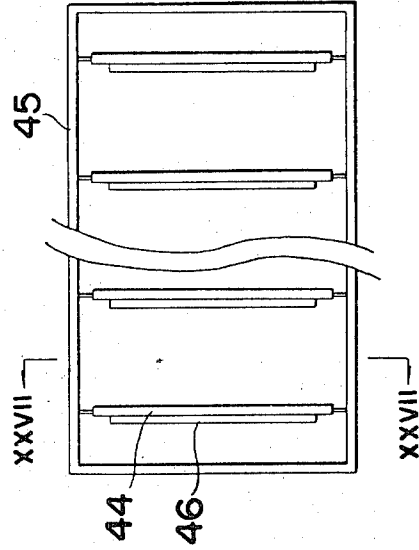


FIG. 27

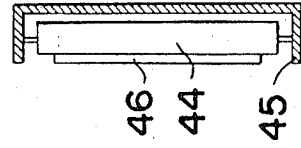
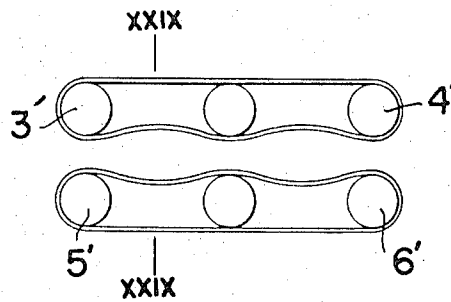
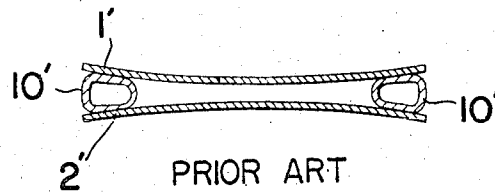


FIG.28



PRIOR ART

FIG.29



PRIOR ART

FIG.30

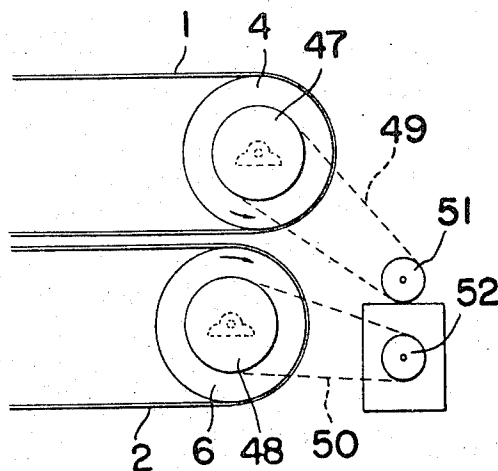


FIG.32

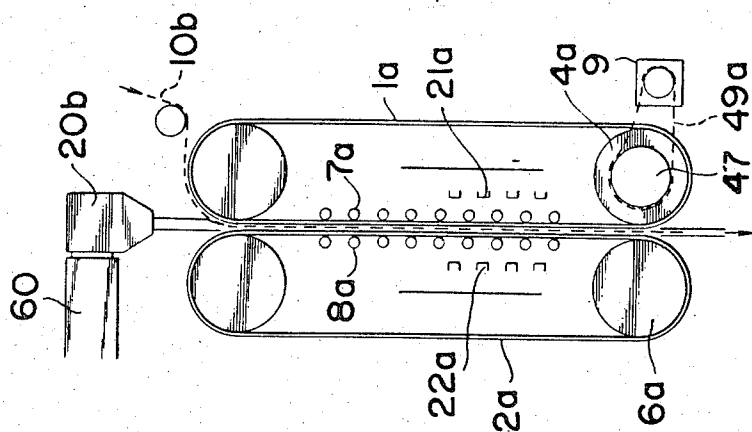
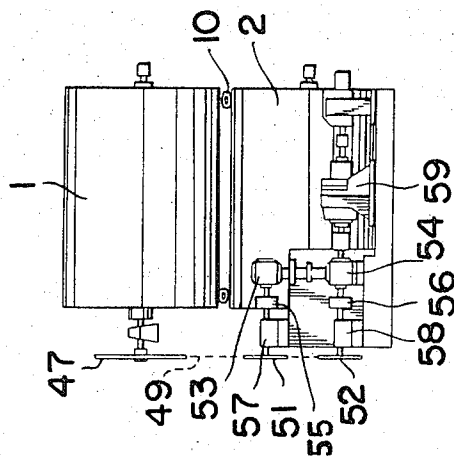


FIG.31



PROCESS AND AN APPARATUS FOR CONTINUOUSLY CASTING A SHEET AND THE LIKE

This is a continuation of Ser. No. 889,178 filed Dec. 30, 1969, now abandoned.

The present invention relates to a process and an apparatus for continuously casting a sheet and the like and in particular relates to a process and an apparatus of the belt type for continuously manufacturing a sheet form product by continuously polymerizing a liquid material of a polymerizable compound and the like or successively cooling and solidifying a melted thermoplastic polymer.

In the manufacture of a sheet form polymer by continuous polymerization of a polymerizable compound such as methylethacrylate or by solidification of melted thermoplastic compound such as polyvinylchloride a continuous casting process has been known heretofore which comprises feeding a polymer material between two endless belts located oppositely in upper and lower positions and running at the same speeds in the horizontal direction, to one end of said belts, polymerizing the polymeric compound by heating or the like the endless belts and producing a sheet form polymer product from the other end of the belts.

The continuous laminating process, in which between two opposing endless belts which are driven in the same direction at the same speed, film or sheet material and other film or sheet material on both sides or one side of the material, are supplied to one end of the belts, whereby after these materials are stuck together with proper sticking material, or without using sticking material and only adding pressure and heat as the belts run, laminated sheet products are obtained from the other end of the belts, has been already proposed. In this process a lower run of an upper belt is not supported in a horizontal state and it is lowered by its own weight, so that a sheet of uniform thickness is not produced. When the belts are narrowly spaced apart the lower run of the upper belt would contact the upper run of the lower belt, making the production of thin sheet difficult.

The liquid pressure necessary for supporting the lower run of the upper belt when a liquid material is between the opposite belt surfaces, may be 1 mm. or less water column for a plastic belt and 25 mm. or less for a metallic belt. It is difficult to maintain the liquid pressure of such order under control and also to remove air bubbles in the material.

In order to produce adequate liquid pressure when a liquid polymeric compound is between the belt surfaces, the belts may be inclined or may be vertical with a supplying device in a higher position, but such a construction is practically undesirable as it needs an extremely tall building since generally the time for polymerization is long and therefore a polymerizing apparatus is necessarily large in length.

Speaking from the viewing point of production, maintenance, and operation of the apparatus, it is preferable to position the endless belts horizontal; it is suitable to feed the liquid material forcibly by a constant flow pump and to press suitably the endless belts by a belt surface external holding mechanism. In any method for sealing between a material feeding device and the belt faces by direct contact therebetween, scratches are made on the smooth faces of the endless

belts by the relative sliding of the sealing portions, thereby the glaze and appearance of the belt faces and thus those of the product become injured. Even if a soft material would be selected as the sealing material, by dust or polymer growing gradually on the seal, the belt faces would be injured.

The gasket normally used for producing a methylethacrylate sheet according to the cell casting process has a compression strength of 1.0Kg/cm. or more at the time of compression to a sheet thickness desired at the polymerizing temperature. To form a sheet using for the cell glass having a thickness of 10 mm. or more in the cell casting method, the gasket is compressed by its weight markedly larger than the weight of a belt. Accordingly, use of a gasket smaller in compression strength will worsen the accuracy of sheet thickness. In the continuous casting process each of the belts' interspaced edge portions also require a sealing gasket, which in this case travels with the belts. The gasket is compressed while in used condition, the compression ratio gradually increasing with the contraction of volume of polymerizing material while the repelling force of the gaskets increases by compression. In case the repelling force due to compression of the gaskets is adequately large, there is produced deformation of the outer belt holding means owing to the repelling force due to compression of the gaskets, or the deformation of covering rubber of rollers, by which the space between the upper and lower belt surfaces loses uniformity in the transverse direction, that is, that the space between the upper and lower belt surfaces about the center in the transverse direction in the vicinity of the gasket on each side, becomes large. The polymer compound flows with the deformation of each belt surface. The viscosity rises as polymerization proceeds, with non-uniform distribution of thickness, finally to a degree that actually produces rigidity at polymerization temperature. That is, due to compression of the gaskets, the sheet thickness about the center in the transverse direction is small and there is produced a sheet polymer large in thickness in the vicinity of the gaskets on both sides.

To raise the fluid pressure, when using a gasket large in the repelling force due to compression, with respect to the repelling force of the gasket, means to make the pressure distribution large relative to the belt surface, and is therefore one proposal to make the sheet thickness of the polymer uniform. According to this process the upper and lower belt surfaces receive excessive pressure which makes the deflection of the outer belt holding means much larger. The excessive deflection of each surface destroys the sealing between the upper and lower belt surfaces and gaskets thereby causing leakage of the polymer compounds. In order to avoid this drawback it is necessary to make the outer holding means larger resulting in uneconomy and obstructions in the heat transmission at the polymerizing zone. Therefore, the fluid pressure may preferably be higher appropriately than the pressure equal to the weight of the upper belt surface or up to 50 mm. water column. However, the deformation of the outer holding device induced from the repelling force due to compression of the gasket cannot be solved by the method of raising the fluid pressure. To make the sheet thickness of a sheet form polymer therefore is not possible by making the repelling force (compression strength) due to compression of the gaskets, smaller. However, the gasket

has a large function to seal the polymer compound between the upper and lower belt surfaces and prevent its leaking; the compression strength of the gasket must not be too small and the contact between the upper and lower belt surfaces should not be lost. Furthermore, the gasket of small compression strength, that may not sufficiently perform its function because of deformation during its manufacture or safe keeping, is not practically adapted for use.

In the continuous casting method, it is essential to feed a corresponding amount of material polymer compound constantly between belt surfaces to obtain a sheet polymer of a predetermined thickness as a product, and in the course of running with the endless belts to secure the polymer compound against flow between the edges of the belts while the distance between the belt surfaces is strictly adjusted to follow the variation of volume of the polymer compound due to rise of temperature or polymerization. In this process, the time that the endless belt passes the polymerizing zone of the apparatus is the same in principle as the time needed for polymerizing a polymer compound. Accordingly, the production capacity of the apparatus is proportional to the product in the belt width and the length of the polymerizing zone. The industrial apparatus becomes large, using wide and long endless belts.

In this apparatus two endless belts are strictly required to be driven at the same speed. If the speed of two endless belts is different in some degree, for example, in the case of the above apparatus which manufactures sheets, it results in a bad condition of the optical feature of the products and retained internal stress in the products, and in the case of the latter half of the process it causes separation of the products from the belts. Also it gives undesirable force consumption to the apparatus especially to the endless belts.

For instance there is a method in which two main pulleys for each belt driving system are controlled automatically and strictly in order to get the same rotation speed. But in the case of this method the control apparatus and speed reduction gear box are expensive and complicated.

When two endless belts are driven by one driving motor, a big speed reduction is required, because of the speed of the main pulleys' rotation, and as a power transmission system which gives rotation to the main pulleys, very small chains, belts and worm gears are put to use in order that the positions of the two pulleys may be easily changeable. When chains are used to drive, a proper gear box is necessary in order to rotate two sprockets in the reverse direction of each other.

Now to make two driving pulleys rotate with the same speed, two pulleys must be rotated with the same speed if the two driving pulleys have the same diameters, or two driving pulleys must have the number of rotations in inverse ratio to each other if the two driving pulleys have different diameters. But though driving pulleys are made very accurately, the diameters of these two pulleys have always some errors which are due to the process of making them, or there are also some errors elsewhere in the organization. So if this equipment is driven for a long time these errors will become accumulated errors and bring about an undesirable condition in the apparatus in the end.

A torque-limit-coupling which has a slipping system in the driving axle and a front free system like a ratchet system which goes freely ahead, can be inserted into

the drive of the two belts type continuous sheet manufacturing equipment, to avoid a braking effect which comes from the condition that one pulley speeds ahead of the other pulley.

The object of the invention is to eliminate the above disadvantages.

Other objects and features of the invention will appear from the following description, reference being had to the accompanying drawings in which:

FIG. 1 is a side elevation of an apparatus according to the invention.

FIG. 2 is a perspective view of a material feeding device.

FIGS. 3 and 4 are a side elevation and a perspective view of another embodiment of a material feeding device.

FIG. 5 is a side elevation of another embodiment of the invention.

FIGS. 6 and 7 are a vertical section and a cross-section of still another embodiment of a material feeding device.

FIG. 8 is a diagram of backward flow.

FIGS. 9, 10 and 11 show another embodiment similar to FIG. 6, being an elevation, a perspective view and a bottom view, respectively.

FIGS. 12 and 13 are a vertical section and a cross section, respectively, of another embodiment of a material feeding device.

FIG. 14 is an elevation of a vertical type apparatus.

FIG. 15 is a perspective view of the feeder of the above device.

FIG. 16 a to e are cross-sectional view of various gaskets.

FIG. 17 is a cross-section showing an external belt holding arrangement.

FIG. 18 is a side elevation of a shaft used by the above.

FIGS. 19 and 20 are longitudinal and cross sections, respectively, of another embodiment.

FIG. 21 is a side elevation of still another apparatus.

FIG. 22 is a plan view taken on the line XXII—XXII in FIG. 21.

FIG. 23 is a transverse elevation view taken on the line XXIII—XXIII in FIG. 22.

FIG. 24 is a longitudinal elevation view taken on the line XXIV—XXIV in FIG. 22.

FIG. 25 is a cross section taken on the line XXV—XXV in FIG. 21.

FIG. 26 is a bottom plan view taken on the line XXVI—XXVI in FIG. 21.

FIG. 27 is a cross section taken on the line XXVII—XXVII in FIG. 26.

FIGS. 28 and 29 show a conventional type apparatus respectively in elevation and cross section.

FIGS. 30 and 31 are a side view and an end view of a belt driving device.

FIG. 32 is a view of an elevation of another apparatus.

In FIGS. 1 and 2 the endless belts 1 and 2 are provided with tension, respectively, by main rollers 3 and 4 and 5 and 6 and driven by running the rollers 4 and 6 at the same peripheral speeds. Each belt is held horizontally by the idle rollers 7 and 8. The material feeding duct 9 forms an opening ABCDEFGHA with boundary surfaces A-B, B-C, D-E, E-F, F-G and H-A of the opening on which the belt surface slide. Two gaskets 10, 10 are respectively carried along E-D and F-G

and slide with the edges C-D and G-H of the duct for making a seal. The gaskets 10, 10 may instead be delivered along A-H and B-C.

The material is fed from a reservoir or preparation tank 11 of the polymer material and fed to an upper feeding tank 9a of the material feeding duct 9 through a pipe 13 by means of a pump 12, flowing down in a thin layer on the inner surface of the duct, and forming a free surface at the location indicated at 14. The opening 15 at the upper part of the duct 9 is connected to a vacuum source device and the upper space in the duct is maintained at an adequately reduced pressure less than atmosphere.

Into the duct 9, the liquid material is continuously fed from the reservoir or material preparation tank 11 through the upper feeding tank 9a, flowing down, and being fed by its weight between the two belt surfaces. The pressure in the upper space may be higher than the pressure at which the material is boiled in the tank 11 and lower than the atmosphere. For removing the gas dissolved in the material there may be adopted a pressure relatively low; otherwise there may be adopted a pressure approximate to the atmosphere but of an extent that the air bubbles floating from the material can be removed, and the relationship with the lower limit of liquid depth later described must be considered.

The liquid depth which may be preferred is in a range such that the liquid pressure caused from such liquid depth may be less than 1 kg/cm² gauge pressure between the two belt surfaces and the free surface 14 of liquid can be formed in the duct. The object of the present invention may be attained if the force acting on the upper belt surface is slightly larger than the weight of the upper belt. Therefore an excessively large liquid depth is not required. The lower limit of the liquid depth is not specifically defined but generally a limit larger than the radius of the main roller holding the upper belt surface at the material feed end is preferable because of easy removal of air bubbles.

For supplying the material into the duct it may be directly injected in the vicinity of the free surface 14 of liquid in the duct, by means of a pump or it may be flowed downwardly to the free surface in a thin layer on the inner surface of the duct from the upper part since it is easy to remove the dissolved gas which is an advantage.

The material is supplied between the belts by means of its own weight corresponding to the liquid material depth.

Main rollers for driving at both ends of the belt surface may be of a preferred curvature such that a tension within the limit of belt resiliency may be applied thereon. The surface of contact of the belt surface on the material mixture may be flat and smooth or it may be formed in a patterned sheet.

For maintaining a plane condition of the belt surface in the polymerizing zone there may be provided roller groups or other smooth belt engaging surfaces on which said belt surface may slide, and the lower belt surface may float on a fluid. In case an outer belt holding means is applied, designed so that it will deflect by pressure of the belt surface, contraction of volume by polymerization may automatically be compensated for by maintaining the distance between the belt surfaces by such means prior to deflection at a desired predetermined value of width greater than the thickness of the polymer when in sheet form and therefore it is more

preferable. According to the present invention it is possible to change the fluid pressure desired between the belt surfaces, as well as the outer holding means.

Materials of the belt surfaces according to the invention may include various films, such as cellophane, polyester films and the like while, specifically, metal endless belts made of steel or stainless steel are more favorable. The films may be used as a laminate on said belts. Plastic belts for use may be generally of a thickness less than 1 mm. which are usually sold on the market. Metallic belts may preferably be of a thickness of 0.1 to 3 mm., specifically of 0.5 to 2 mm.; the fluid pressure required for carrying the upper belt surface is less than 1 mm. water column for the plastic belts and less than 25 mm. water column even for the metallic belts. The belt surface separation distance is accomplished by slightly pressing both belt surfaces against the outer supporting device, such as roller groups, by liquid pressure. To this end a force acting on the upper belt surface by liquid pressure must produce a liquid pressure between the belt surfaces higher than the pressure equivalent to the weight of the upper belt surface. The upper limit of the liquid pressure is not specifically defined but it is generally preferable to have it in the range lower than the liquid pressure deforming the belts between the outer holding means more than 30% of the distance between the belt surfaces.

In the polymerizing area the polymerization is thermally controlled from the outside of the belt surfaces by heating and/or cooling. The heating systems include the method of applying hot air to the outside of the belt surfaces, method of dispersing warm water in a shower on the belts' outsides, method of running the belts in a water bath, method of applying infrared ray radiation, etc.

The polymerizing temperature may be a constant outside temperature over the whole area of the polymerizing zone or it may be changed by stages or continuously, and the polymerizing temperature may be dependent on the polymerization catalyst in use but it must be kept below the boiling point of the material until the polymerization is almost completed.

Gaskets are generally made of plastics in a string shape. In case a low viscosity monomer is used for gasket material it is more advantageous to use gaskets of a square or rectangular cross section for the prevention of liquid leakage at the sliding part. However, when a partly polymerized polymer/monomer solution is used, a gasket of a hollow pipe shape can prevent the leakage since the solution is high in viscosity.

For the material of a gasket, there will be used for example soft polyvinyl chloride as has been usually employed. Polyethylene and other flexible plastics, natural rubber and other rubber can be used for the gasket. By use of the gasket made of polyethylene, rubber and the like it is possible to recover the gasket and continuously reuse it. A monomer of low viscosity used as a material compound for the gasket of square or rectangular cross section is more advantageous for the prevention of leaking fluid at the sliding part. Partially polymerized polymer-monomer solution is high in its viscosity so that it can be used in a gasket of a hollow pipe shape with almost complete prevention of leakage. Flexible plastic rod or foaming plastics having individual air bubbles may be used for gaskets. The gasket's compression strength may be lessened for the hollow pipe type when using polyvinyl chloride having much plasticity

by choice of outer diameter, and wall thickness of the material. As for foaming plastics it is possible to obtain a gasket smaller in compression strength readily by raising the magnification ratio of foaming. Therefore, material, shape and dimensions of the gasket may be desirably preferred in the range to fulfill the function of a gasket corresponding to the nature, production requirements of the polymer compound, thickness of the sheet form polymer, specific object of the product, etc.

The fluid material used in the polymerizing process of the present invention includes a mixture of one or more monoethylenic unsaturated compounds which is fluid under normal pressure and/or multi-functional polymerizable compounds. These monomers may be used as a mixture of polymer in solution or suspension or partially polymerized monomer polymer mixture. For monoethylenic unsaturated compounds there are used as for example methacrylates, styrene or its halogenated or alkyl substitute derivatives, vinyl acetate, etc., or a mixture of an essential amount of these compounds and acrylates, acrylonitrile or its derivatives. For multifunctional polymerizable compounds which can be used, there are, for example, glycoldimethacrylates, diallylmethacrylate, diallylphthalate, and diethylene glycol bis allylcarbonate. The invention is particularly advantageous for casting a polymer of methylmethacrylate and a copolymer of a major amount of methylmethacrylate and a comonomer copolymerizable therewith.

The fluid material is mixed with polymerization catalysts. For polymerization catalysts there can be used for example azobisisobutyronitrile, azobisdimethylvaleronitrile, azobiscyclohexanenitrile, benzoylperoxide, lauroyl peroxide, acetyl peroxide, caprylylperoxide, 2,4-dichlorobenzoyl peroxide, diisopropyl peroxydicarbonate, isobutylperoxide, and acetylcyclohexylsulphonyl peroxide as free radical catalysts. Polymerization catalysts of oxidized reducing systems such as peroxides and amines may also be used in combination. The fluid raw material may be mixed with various additives such as stabilizers, plasticizers, polymerization controlling agents, fillers, dyestuffs, pigments, mold releasing agents, etc. Example 1

A viscous liquid of 1 poise at 25°C consisting of a solution of methylmethacrylate monomer containing 20 weight % methylmethacrylate polymer of a mean degree of polymerization of about 900, mixed with 0.05 weight % azobisisobutyronitrile as a polymerization catalyst is delivered from the reservoir 11 in FIG. 1 to the feed duct 9. Height from the free surface 14 of the mixture material in the feed duct to the upper level of the belt 2 is 3 mm, and the pressure in the upper space 9a is about 460 mmHg abs. The pressure decrease is controlled so as to have the liquid pressure on the same level of the belt 2 equal 1 cm water column. The belts 1 and 2 are the endless belts of flat and stainless steel having a thickness 1 mm and a width 1,200 mm. The distance between the upper and lower belts is maintained such that the polymerizing area may have a thickness of about 3 mm. by roller groups 7, 7 and 8, 8. Gaskets 10 are of polyvinylchloride hollow pipe of a wall thickness 0.3 mm. and an outer diameter 10 mm. The entire length of the polymerizing area is 60 m, and the front part of 40 m. is heated with warm water of 85°C from the outside of belts and the rear part is heated in the air furnace at 120°C. The belts 1 and 2 are driven at the speed of 1 m per minute. There is obtained a flat and

smooth transparent sheet of mean degree of polymerization of about 5,000, continuously.

FIG. 1 shows an apparatus in which the lower belt has a larger length than the upper belt. FIG. 3 shows an apparatus in which lengths of the upper and lower belts are equal and the material feeding duct does not have the belt surfaces sliding thereon. In FIG. 4, 16 denotes a material feeding tank, which is connected to a material feeding duct 9b at qrts and the fluid material is delivered into said feeding duct by weight of the fluid material due to fluid depth. The feeding duct 9b opens at abdc between the upper and lower belts. The upper surface amnc and the lower surface brtd of the feeding duct 9b respectively have sliding contact with the belts on the upper and lower surfaces. The right surface edts and the left surface abrq of the injecting duct 9b form passages 17, 17 to the outside between these surfaces and the gaskets 10, 10. Fluid material discharged from the opening abdc of the feeding duct 9b flows reversely by fluid pressure through said passage 17, 17 balancing dynamically with the running speed of the belt, and apparently stops at ijk and efhg; therefore, the fluid material will not leak to the outside but will produce constant fluid pressure between the upper and lower belts, it thus being possible to generate fluid pressure between and on the belt surfaces by use of a material feeding duct inserted in a proper length into the space between the belt surfaces from an opening at the material feed end and thereby prevent the leaking of polymer compound at the feeding part.

From a reservoir of a controlling tank of raw material is fed the material by a pump through pipe 18 into a material feed tank 16 to form the previously described free surface 14. The feed tank 16 is connected at qrts to the material feeding duct 9b and by weight due to fluid depth of the fluid material in the feed tank 16, the material is delivered into the material feeding duct 9b. It was found possible to have the material feeding duct between the upper and lower belt surfaces free from sliding contact by the upper and lower belt surfaces and to use the spaces between the upper and lower and left and right surfaces of the feeding duct and between the upper and lower belt surfaces and the left and right gaskets as passages to the outside. Also it is possible to permit sliding between the upper and lower surfaces of the duct and the upper and lower belt surfaces, thus to provide a space of adequate width between either one or both of the left and right surfaces to use for the passage to the outside, as well as to provide a passage having an adequate space between either one or both of the upper and lower surfaces of the duct and the upper and lower belt surfaces. The size and sectional area of each said passages defines the reverse flow speed of the fluid material which in turn is affected by the viscosity and fluid pressure of the fluid material, these being considered to determine the size and sectional area of the passage in the range controllable without leaking of the reverse flow fluid raw material to the outside. The sectional area of the passage may preferably be small, possibly when the reverse flow fluid material might adversely affect the quality of a sheet form polymer by contacting with the atmosphere.

Example 2

Methylmethacrylate monomer is mixed with methylmethacrylate polymer of about 900 mean polymerization degree, 20 weight %, and is dissolved into a solution of 1 poise of 25°C in viscosity, which is mixed with

0.05 weight % of azobisisobutyronitrile as a polymerizing catalyst. The resultant raw material mixture is delivered from the reservoir to the material feed tank 16. Height of the free surface 14 of the material in the feed tank 16 to the level of the belt 2, for the material mixture, is 10 cm. The upper and lower surfaces of the material feeding duct 9 b inserted between the upper and lower belts and connected to the feed tank 16, slides on the upper and lower belts running at the speed of 1m, per minute along a length of 40 cm. The fluid pressure at the opening of the feeding duct 9b is about 2 cm water column and the raw material mixture is delivered to the polymerizing zone between the belts, a part of which material flows reversely through passages of 5 cm. width provided between the left and right surfaces of the feeding duct 9b and the left and right gaskets 10, 10 and the back end of the reversely flowing material apparently stops in a state of rest after 10cm reverse flow.

Belts 1 and 2 are smooth stainless endless belts of the thickness 1mm. and the width 1,200 mm. The upper and lower belts are held by roller groups 7, 7, 8, 8 such that an obtained sheet form polymer may have a thickness of 3mm. For the gaskets 10 a polyvinylchloride hollow pipe of a wall thickness 1.3 mm. and outer diameter 10mm. is used. The whole length of the polymerizing zone extends 60mm; a zone of 40m. in the front part is heated with warm water of 85°C in a shower form on the outer surface of each belt and a zone of 20m in the rear part is heated in an air furnace to 120°C.

Thus there is obtained a smooth and transparent sheet of a very uniform thickness and a mean degree of polymerization of about 5,000 continuously, in a completely sealed space between the belts, without leakage.

Example 3

Methylmethacrylate polymer of a mean polymerization degree of about 900 was dissolved in a methylmethacrylate monomer to obtain a solution containing about 20 weight % of the polymer, the viscosity of which is 1 poise at 25°C, and to which is mixed 0.05 weight % azobisisobutyronitrile. This fluid material is delivered from the reservoir 11 in FIG. 1 to the feeding duct 9. Height from the free surface 14 of the fluid material in the feeding duct to the level of the belt 2 is 3 m. and pressure in the upper space of the duct 9 is about 460mmHg abs. The pressure decrease is adjusted so that the fluid pressure at said level of the belt 2 is 1cm water column. The belts 1 and 2 are smooth stainless steel endless belts of thickness 1mm. and width 1,200mm. The internal space between the upper and lower belts is maintained by roller groups 7 and 8 such that the sheet form polymer may be of a 3mm. mean thickness. The whole length of the polymerization zone covers 60 m; the area at the front part of 40 m. being heated by dispersing warm water of 80°C in shower form on the outside of each belt and the area at the rear part of 20m. heated in the air furnace of 120°C. Gaskets 10 are made of a hollow pipe of polyvinylchloride containing dibutylphthalate equivalent to 60 weight % of a polymer as a plasticizer, the wall thickness being 0.6mm. and outer diameter 6mm. The gasket has a compression strength of 0.07 kg/cm. when compressed to 3mm. at 80°C. If the belts 1 and 2 are driven at a speed of 1m. every minute there is obtained a smooth transparent sheet having a mean degree of polymerization of about 5,000 and accuracy of thickness of

3+0.3mm., continuously. Reference Data re the Above:

For gaskets, a hollow pipe of polyvinylchloride containing dibutylphthalate equivalent to 44 weight % of a polymer as a plasticizer, having a wall thickness of 1.3mm. and an outer diameter of 6mm. and exhibiting a compression strength of 0.97kg/cm. when compressed to 3mm. at 80°C. Other sheets were manufactured under the same polymerizing conditions by use of the same continuous polymerizing apparatus as in the above embodiment. The accuracy of thickness of the obtained sheet was 3+0.5mm.

Example at compression load of less than 0.01kg/cm

The sheet was produced under the same condition of polymerization by using the same continuous polymerizing apparatus as the above embodiment except for the gasket. As the gasket a hollow polyvinylchloride tube having an outer diameter of 9mm. and a compression intensity (or resistance) of 0.008 kg/cm when compressed up to 3mm. at 80°C was used.

Since the compression load was too small in spite of the gasket having a large outer diameter, movability of the liquid material was high and leakage of the liquid material occurred between the belts and the gasket in the front half of the polymerization zone in which the liquid pressure between the belts was high. The precision of sheet thickness was reduced and at the same time the leaked liquid material was polymerized and set in the hot water; thereby smooth operations of the rollers and the hot water system were disturbed.

RESILIENT FORCE OF GASKET

Compression loads measured with some of gasket used recently were as follows.

Outer diameter (mm)	Wall thickness (mm)	DBP	Compression up to 3mm (kg/cm)	Compression up to 2mm (kg/cm)
10	0.9	44 pwt	0.39, 0.34	0.89, 0.78
10	0.6	do.	0.14, 0.15	0.34, 0.33
8	0.4	do.	0.02	0.08, 0.11
6	0.4	do.	—	0.18, 0.14

Nowadays it is optional to use a double gasket system. In this case combinations such as 9φ — 0.4t/6φ — 0.4t, 9φ — 0.4t/6φ — 0.6t and 10φ — 0.6t/6φ — 0.4t may be used. In a case of a single gasket system a gasket having an outer diameter of more than 8mm, is used.

If a gasket of 9φ — 0.4t — 44 part is used and load of roller is improperly set, then syrup may be leaked between the belts and the gasket. Therefore, it is sufficiently considered that the leakage of syrup will occur under the compression load of less than 0.01kg/cm.

When a gasket of 8φ — 0.4t — 44 part is compressed up to 3mm. at 80°C, the compression load is 0.02kg/cm. and considerably near the above minimum permissible 0.01 kg/cm. However, a gasket of less than 0.01kg/cm. has not been used. Therefore, estimation of value of the compression load with outer diameter, wall thickness and amount of DBP plasticizer specified definitely, is impossible at present.

An embodiment of the present invention will be described with reference to FIG. 5 in which case approximately horizontal endless belts are used.

Two endless belts 1 and 2 disposed upwardly and downwardly respectively are provided tension by main

pulleys 3, 4 and 5, 6 and driven to run at the same speed. Idle rollers 7 and 8 in a group and upwardly and downwardly forming a pair, carry the running endless belts horizontally and control the thickness of the distance between the belt surfaces, or the thickness of the polymer compound. The polymer liquid material is pumped by a pump 19 and fed between the belts by a material feeding device 20. Both sides between the belt surfaces are sealed with gaskets 10 having resiliency. The polymer compound is heated and polymerized by warm water spray systems 21, 22 during the running of the belts and the compound is subsequently heat treated by an infrared ray heater system 23, 24 to complete the polymerization, and a sheet polymer product is taken out.

The process according to the present invention is effectively utilized in the polymerizing zone where the thickness of a sheet polymer is determined, i.e., in a portion heated by the warm water spray systems 21, 22 in the drawing.

In case of the conventional continuous casting process, the distance between the belt surfaces in the polymerizing zone was previously set to hold a thickness of material corresponding to the thickness as predetermined for the product to be obtained. It is based on the idea inherently provided from the cell casting process, which is to facilitate the flow of the polymeric compound between belt surfaces during polymerization. In such cases also the distance between belt surfaces is set larger in the former half of the polymerizing zone than in the latter half, which has followed the contraction of volume accompanying the polymerization of the polymer compound.

According to the process of the present invention, the distance between the belt surfaces is set such that in the former half of the polymerization area where the viscosity of the polymer compound is still low, having fluidity, the distance is held larger than the thickness of the liquid material required to obtain a sheet polymer having the thickness as predetermined for the final product, and in the latter half of the polymerizing zone where the viscosity of the polymer compound becomes high as the polymerization advances, losing the fluidity, and the thickness of the polymer on the sheet is substantially determined, the distance between the belt surfaces has a thickness of a sheet form product as finally produced, whereby the time required for the passing of the endless belts through the polymerizing zone is made shorter than the time required for the polymerization of the polymeric compound, or the time of staying in the polymerizing zone is reduced, so as to elevate the productivity of the apparatus.

In the process according to the present invention, the range to the end the half of the polymerizing zone where the distance between the belt surfaces is kept large or, inversely speaking, the range to start the latter half of the polymerizing zone to set the distance between the belt surfaces so that the thickness of the sheet form polymer may become as predetermined for the sheet form product, can be respectively and experimentally obtained according to the terms of manufacturing a continuous polymer sheet, the apparatus, and, further, the precision desired for the thickness of a sheet-form product.

Where in the above described so-called range of the latter half of the polymerizing zone, irregular variation sometimes occurs in the thickness of the sheet form

product, it is for the reason that it is caused from the variation in the advance of polymerization in the former half of the so-called polymerizing zone by which if some part is advanced in polymerization excessively the viscosity in said part becomes high and in the latter half of the polymerizing zone it becomes thick without being fully levelled off. Accordingly, experiments for deciding the former half and the latter one of the so-called polymerizing zones is carried out by measuring the accuracy of thickness of the sheet form product.

Needless to say, it is an effective contrivance to continuously change the distance between belt surfaces continuously and moderately without exactly distinguishing the former half and the latter one of the so-called polymerizing zones to mitigate the influence upon the accuracy of thickness of the sheet form product.

Example 4

Two flat and smooth stainless steel endless belts respectively of thickness 1mm; width 800mm, and lengths 15.5m and 16.5m are tensioned horizontally on the upper and lower stages by use of main pulleys of a diameter 1,000mm. and driven such that the opposite surfaces thereof will run at the same speed in the same direction. The polymerizing area of this apparatus extends about 6m, 4m. in the fore part of which are disposed idle rollers of a diameter 90mm. and having flexibility, in 21 opposite sets at intervals of 200mm., in pairs upwardly and downwardly, for adjusting the distance between the positions of the endless belts and the distance between the belt surfaces. This fore part is temperature controlled by spraying the warm water of approximately 80°C on the outside of the opposite belt surfaces. In the latter half of 2m. said outside of the belt surfaces is heated with an infrared ray heater to 120°C or more for heat treatment.

A viscous liquid of about 5 poise in a solution of methylmethacrylate monomer to which is added about 20 weight % methylmethacrylate polymer as a material polymer compound, was prepared as a mixture with a proper amount of azobisisobutyronitrile as a polymerization catalyst. The solution was delivered in the material injection device by use of a pump. For sealing both sides of the belt surfaces a polyvinylchloride tube of wall thickness 0.6mm. and an outer diameter 8mm. and containing dibutylphthalate 60 weight %, was provided for gaskets running at the same speed of running as the endless belts.

1. First, the distance between belt surfaces was adjusted such that the liquid material would have a thickness adapted to obtain a product of 2mm. thickness. The endless belts were run at 10cm. per minute. The liquid material was supplied at a rate of 150cc. in every minute so that the liquid material would have a thickness of 2mm. Thus there was obtained a smooth and transparent sheet of 2+ 0.2mm. thickness.

2. Then the running speed of the endless belts was changed to 12cm in a minute and the amount of material feed to 180cc. in a minute with the distance between belt surfaces being the same and there was obtained a polymer having small bubbles dispersed in the interior. These bubbles were produced because the polymer was transferred to high temperature heat treatment without completion of polymerization at about 80°C and too rapidly polymerized.

3. The running speed of the endless belts was lowered to 10cm. per minute and the amount of material feed

to 150cc. per minute with the distance between belt surfaces enlarged to 3.5 mm. for the range of 1.5m (8 sets of rollers) at the front side or fore part of the polymerization area, and narrowed successively in stages for the range of subsequent 0.8m. (4 sets of rollers), and the same for the remaining range (9 sets of rollers). The bubbles were removed but there appeared a sheet form polymer having its thickness out of the range of 2+0.2mm. in an irregular cycle of 2 to 10m.

4. Then the running speed of the endless belts was changed to 12cm per minute and the amount of material feed to 180cc. per minute with the distance between belt surfaces being same. There was obtained a flat and smooth transparent sheet of 2+0.2mm. in thickness.

Example 5

This embodiment is an example having approximately the same construction as the described embodiment which is used in a medium-sized mill. The endless belt has a width of 1,200 mm., 1.5 times larger, and the length of the polymerizing area about 60m., 10 times larger than in the first embodiment.

The material consisted of a mixture solution of a monomer and a polymer of about 1 poise viscosity containing about 20 weight % methylmethacrylate polymer which was mixed with an adequate amount of azobisisobutyronitrile as a polymerization catalyst. In the method of determination of the belt surface distance according to conventional continuous casting process, the maximum running speed of endless belts that can obtain a polymer of 2mm. thickness as a sheet product was 1m per minute. According to the method of the present invention the distance between belt surfaces provided for the former half of the polymerizing area of 20m. which is heated with warm water spray, was set at 6mm. at the end of the material injection side, 2.1mm. at the last side, and linearly changeable at the middle part. The running speed of the endless belts was thereby raised to 1.25m. per minute.

The foregoing embodiments are the examples in which the endless belts are held horizontally. It can however be applied also in case the belt is held in other conditions than horizontal, although more description is not necessary.

FIGS. 6 to 8 show an example in which a wedge shaped feeding device 20 is not in direct contact with both belts; two endless belts 1 and 2 arranged respectively above and below are given tension respectively on main pulleys 3, 4, 5 and 6, driven to run at the same speed. Groups of upper and lower idle rollers 7 and 8 respectively disposed in a pair, support the running endless belts horizontally and control the distance between the belt surfaces i.e. the thickness of the polymeric compound, which is supplied through a constant flow pump 19 into between the endless belts with hydraulic pressure, by the material feeding device 20. Internal hydraulic pressure of the polymeric compound between the belt surfaces can be changed at will by adjusting a force for causing the opposed belt surfaces to come closer together, by the groups of the idle rollers 7 and 8. The both sides of the opposed belt surfaces are sealed by resilient gaskets 10. As the belts run, the polymeric compound is heated by hot water sprayers 21 and 22, polymerized, then treated with heat by infrared heaters 23 and 24, and polymerized completely, and the sheet product of polymer thus produced is withdrawn.

On the material feeding side, the main pulleys 3 and 5 are provided at different horizontal positions so that a part of the upper running portion of the lower endless belt 2 is exposed behind the upper endless belt. To a wedge shaped opening defined by the upper and lower endless belts, the material feeding device 20 of the corresponding wedge shape is mounted. This material feeding device for example as shown in FIG. 6, is held to float in air by using on one hand a suitable bearing device 25 suspended from a shaft of the main upper pulley 3 and two rods 26 suspended from the bearing device 25 and using, on the other hand, a rod 27 suspended from a bed to which the main upper pulley 3 is assembled. Due to this holding process, the material feeding device can cause the main upper and lower endless belts to face one to another within a wide range by keeping a suitable clearance therebetween without direct contacting with the main upper and lower endless belts, and even if the relative positions of the main upper and lower pulleys 3 and 5 would be changed by temperature raising of the device or correcting of the meandering of the endless belts, the relative positions of the material feeding device and the wedge shaped opening defined by the upper and lower endless belts are maintained constant.

Since there is a clearance between the undersurface of the material pouring device 20 and the lower endless belt 2, the liquid material 18 feeding into between the belts flows reversely, but the leading end of the reverse flow is stopped apparently in the clearance by balancing of the size of the clearance, viscosity of the liquid material, the hydraulic pressure thereof, the running speed of the belts, and etc., and thus leakage of the liquid material is prevented substantially.

When now a distance between the undersurface of the material feeding device 20 and the belt surface of the lower endless belt is expressed by C cm, the viscosity of the liquid material by ν poise, the internal hydraulic pressure at the leading end position of the material feeding device 20 by h cm. in liquid depth, and the running velocity by V cm/second, the distance L cm. from the leading end of the material pouring device 20 to the leading end of the reverse flow of the liquid material is expressed as follows.

$$L = K \cdot c^2 h / \nu V$$

The value of the constant K is 160 to 300 and is changed within a limited range according to the feeding condition. Various conditions relating to the liquid material between the belt surface of the upper endless belt along the main pulley and the material feeding device may be made in the same manner as that described above, or the liquid material may open to atmosphere to form a free surface at the height corresponding to the hydraulic pressure. As shown in FIG. 6, in order to cause the liquid material to flow to the widthwise direction of the endless belt surfaces without delaying, a space on the top surface of the material feeding device is wide near the nozzle supplying the liquid material, and of course, the both sides are formed to the wedge shape corresponding to a wedge shape defined by both of the upper and lower belt surfaces.

The sealing of the both sides is in each case carried out by supplying a tube made from soft polyvinylchloride containing a considerable quantity of plasticizer as the gasket 10, running at the same velocity as that of

the endless belts, and causing the gaskets to run in contact with the belt surfaces and in sliding contact on the material feeding device 20. In order to seal the both sides of the undersurface of the material feeding device 20, solid seals 28 (see FIG. 7) made from TEFLON is used, but injuries to the endless belts caused by the sliding movement of these portions are disposed outside of the width of the sheet product so that the sheet to be produced is not influenced by the injuries.

Example 6

1. Practical operation of the above apparatus will be explained concretely with reference to one embodiment as follows: two endless belts having a thickness of 1mm, a width of 800mm, and respectively a length of 15.5m. and a length of 16.5m. and made of smooth and flat stainless steel, are positioned by using upper and lower main pulleys of the same diameter of 1,000 mm, imposing a tension of 6.4 ton to the upper and lower main pulleys apart 550mm. in the horizontal direction. The polymerizing area has a whole length of 6m., of which a front portion of 4m. is heated by spraying hot water of 80°C on the outer surface of each belt by the sprayer, the idle rollers of a diameter of 90mm. are arranged at intervals of 200mm. and in each as pairs of upper and lower rollers, and thus the positions of the endless belts and the distance between the belt surfaces are controlled. The remaining portion of 2m. in the polymerizing area is heated to the higher temperature than 120°C on both outer faces of the endless belts by the far infrared heaters, whereby heat treatment is carried out in the material. The two upper and lower endless belts are driven to run at a velocity of 10cm./minute. As a material feeding device, that shown in FIG. 6 is provided. The length of the undersurface of the material feeding device is 400mm. The solid seals 28 on the both sides of the undersurface are adjusted so that a distance between the undersurface and the belt surface is 1.5mm. Gaskets 10 each having a wall thickness of 0.6mm. and an external diameter of 8mm. and being a tube made from polyvinylchloride containing 60 weight parts dibutylphthalate as plasticizer, are supplied from the both sides of the top surface of the material feeding device, with a distance of 750mm. between the centers of the gaskets, at a velocity of 10cm./minute. Liquid polymeric material is supplied through a tube of polyethylene by a constant flow pump at a rate of 150cc./minute, to the material feeding device. By controlling a pinching force for causing groups of the idle rollers disposed in the front portion of the polymerizing area, to pinch the endless belts towards each other so that the internal hydraulic pressure of the polymeric compound contained between the belt surfaces becomes about 2cm. liquid depth in the feeder, a distance between the leading end of the reverse flow of the liquid material on the undersurface of the material feeding device and the leading end of the material feeding device, i.e., a length of the reverse flow, is about 4cm. As a result, a smooth and flat transparent acryl resin sheet having a thickness of 2+0.2mm. and a good appearance is obtained. By increasing the pinching force for causing the groups of the idle rollers to pinch the endless belts so that the internal hydraulic pressure becomes 10cm. of depth in the feeder, without changing the material and etc., the length of the reverse flow on the undersurface of the material feeding device is increased to about 25cm. As a result, a sheet product

having the thickness of 2+0.15 mm. and improved uniformity is obtained.

II. Viscous liquid of about 12 poise is made by mixing as an additive for a milky white product, 3% of a copolymer containing a ratio of 6:4 styrene and methylmethacrylate and a very small amount of titanium oxide, to the above previously mentioned material supplied to the feeder, the pinching force for causing the groups of the idle rollers to pinch the endless belt is increased further, so that the internal hydraulic pressure may become 20cm. of the liquid's depth in the feeder, and thus the length of the reverse flow on the undersurface of the material feeding device becomes about 25cm. As a result, the uniformity of the thickness is improved further, and a milky white acryl resin sheet having the thickness of 2+0.1mm. and the good appearance is obtained. While operating the apparatus as described above, although one has been anxious about especially unusual polymerization by adherence of the polymeric compound on the undersurface of the material feeding device, even after running the apparatus for 2 months, only a thinner film like material adhered at a thickness of 0.2mm. has been found near the leading end of the reverse flow.

FIG. 9 is similar to FIG. 6 excepting that the resilient gaskets 10a are fed from below.

In FIG. 10, on the side of the upper endless belt supplied with the liquid material of the polymeric compound, there is provided in the feeder 20 a passage 20a to cause the material to flow therethrough so that flowing of the liquid material to the wide direction of the belts is carried out without delay under the hydraulic pressure of the liquid material fed into between the opposed belt surfaces, from the leading end of the material feeding device. However, this passage is constructed in such a manner that the material feeding width at the leading end of the material feeding device is narrower than the desired width of the sheet to be made i.e., a distance between two gaskets for sealing on the both sides of the belts.

Relating to the widthwise sealing of the material feeding device, on the top surface of the material feeding device, the liquid material does not essentially reach the both sides. On the undersurface thereof, the material flows into the clearance between the undersurface of the material feeding device and the lower endless belt and at the same time flows to the widthwise direction, but if the leading ends of the widthwise flow reaches only narrower portions than the width of the sheet to be made, it is unnecessary to seal the both sides of the material feeding device. In other words, the widthwise flow, considering its relation to elapsed time, starts from the leading end of the reverse flow, but if the time interval during which the belts advance along the length corresponding to that of the reverse flow is caused to be shorter than the time interval during which the leading end of the widthwise flow is displaced, as the endless belts run, and reaches the desired width of the sheet to be produced, it also follows that on the undersurface the material does not reach the both sides.

Although it might be suitable to cause the feeding width of the liquid material to be sufficiently narrow, in order to accomplish the above mentioned object, it is considered that two cases would occur as follows.

1. If the hydraulic pressure produced on the leading end of the material feeding device becomes higher es-

pecially on the center area of the belts, and thus the reverse flow caused on the undersurface of the material feeding device becomes longer, especially on the center area of the endless belts, this is disadvantageous relating to the function of the device.

2. Then, in order to relieve the hydraulic pressure on the leading end of the material feeding device, if the distance between the opposed belt surfaces is caused to be wider, for example on a front half of the device and near the feeding position, the liquid material fed into between the opposed belt surfaces flows incompletely to the widthwise direction of the endless belts and thus becomes a sheet having a thicker center area in the widthwise direction, or in an extreme case the liquid material is often polymerized before reaching the gaskets for sealing the both sides and becomes a sheet having a short width.

Accordingly, when the material pouring device according to this invention is designed, it is preferable to cause the feeding width of the liquid material to be wider, if possible, within a range bringing about the above mentioned effect i.e., a character in which the liquid material on the undersurface has a narrower width than the desired width of the sheet to be produced.

With reference to FIG. 11, it will be explained quantitatively how wide the feeding width of the liquid material can be made, as follows: FIG. 11 shows as a model picture a condition of the liquid material in the clearance between the undersurface of the material feeding device and the lower endless belt. A rectangular frame PPQQ illustrates the undersurface of the material pouring device, and a line PP illustrates the leading end of the material pouring device. A line RR illustrates the pouring width of the liquid material, and the size of the pouring width is expressed by 1F. A rectangular frame RSTTSR illustrates the range of the reverse flow of the material in a case when it is assumed that there is not any widthwise flow. Since lines parallel to the line PP illustrates equal pressure lines, the hydraulic pressure drops from RR to SS and thus TT linearly, and the hydraulic pressure becomes a zero line TT i.e., the leading end of the reverse flow. A length of the reverse flow RT is 1B. This length 1B is expressed by the following equation.

$$1B = K c^2 h / \nu v$$

where

$K = 160 - 300$ a constant

c : the clearance between the supporting side or lower surface of the material feeding device and the supporting or upper side of the lower endless belt in cm.

ν : viscosity of the liquid in poise

h : the depth of the liquid material on the leading end position RR of the material pouring device in cm.

v : the running velocity of the endless belts in cm./sec.

In this equation, the length is determined because within a practical range of the wedge shaped material feeding device the reverse flow in the clearance is a laminar flow, and from a number of experiments carried out the range of the value of constant K is determined.

On the other hand, relating to the widthwise flow, if it is assumed that the line R S T of the end of the reverse flow is a constant liquid depth source, a distance

1s is between the leading end D of the widthwise flow on the leading end PP of the material feeding device and the end R of the feeding width is expressed theoretically by the following equation.

$$1s = \sqrt{2}/2 \cdot 1_B$$

or

$$1s = K' \cdot C^2 / \nu v \cdot h$$

(3)

where

$$K' = 110 - 210$$

In practice, when there is a widthwise flow, the liquid material flowing thereto is that flowing reversely through the line RR. Accordingly, the velocity of the reverse flow on the line RR is higher than that on the line SS, and the flow velocity on the line SS is higher than that (being equal to the belt running velocity) on line TT.

Consequently, since a pressure loss caused by a resistance against flowing on the line RR may become larger than that on the line TT, the distance between adjacent equal pressure lines has a pressure difference which is smaller near the line R—R. In other words, the length 1B of the reverse flow should become smaller than the value expressed by the equation (2). This should also influence the length of the widthwise flow.

However, according to a number of experiments which have been carried out in various conditions relating to the practical device, it has been proved that the above-mentioned influence is not so large and thus the equation (3) is appropriate practically.

Double lines illustrate the gaskets 10a for sealing the both sides between the endless belts, and a distance between these two double lines is the width of the sheet to be produced. Further, these gaskets may be fed from either side of the material pouring device, since as described above it is unnecessary to seal the both sides of the material feeding device. However, since the whole width of the feeding device may be filled with the material temporarily, for example, when the belts start or stop, it is better to supply the gaskets 10a along the lower surface of the material feeding device 20 i.e., the surface of the lower endless belt 2 as shown in FIG. 10. Example 7

1. To a continuous sheet making apparatus having belts having a width of 1,200 mm and a length of a polymerizing portion of 60 m, a material feeding device constructed as shown in FIG. 10 is attached. As gaskets for sealing the both sides, tubes each having a wall thickness 0.6 mm and an external diameter 8mm and being made from polyvinylchloride containing 60 weight parts of dibutylphthalate are provided along the lower endless belt, and an inner distance between the gaskets is 1,120 mm. A clearance between the material feeding device and the lower endless belt is a constant 3mm. On an upper endless belt side of the material feeding device, there is a depression 20a serving as a passage for feeding the material to the widthwise direction, as shown in FIG. 10. The width of the depression is 920 mm, and the portion outside the depression faces the belt with a clearance of 1.5 mm therebetween.

As a polymeric compound of the liquid material, liquid is prepared by mixing azobisisobutyronitrile as polymerizing catalyzer, with a viscous liquid having 5

poise at normal temperature which liquid is prepared by dissolving polymethylmethacrylate of 20 weight parts into methylmethacrylate, and this liquid is supplied at a constant rate of 2.2 kg/minute through a constant flow pump; the endless belts are driven at a velocity of 1 m/minute, the idle rollers pressing the both endless belts on the heating area are adjusted, the length of the reverse flow of the liquid material on the undersurface of the material feeding device is controlled to be about 50 mm, and thus on the undersurface of the leading end of the material feeding device the distance from the gaskets to the position of the liquid material is maintained to be constant i.e., about 60 mm. As a result a smooth and flat transparent sheet of 2+0.2 mm thickness is obtained.

II. By increasing the supplying quantity of the liquid material to 3.3 kg/minute, on the undersurface of the leading end of the material feeding device there is maintained a small clearance between the gaskets and the liquid material without direct contact therebetween. As a result a smooth and flat transparent sheet of 3+0.3 mm thickness is obtained.

III. As a liquid material, viscous liquid of about 200 poise made by leaving the liquid material described in the above embodiments for about one day and thus promoting its polymerization appreciably, is supplied at a rate of 2.2 kg/minute, the endless belts are driven at a velocity of 1 m/minute, and thus owing to the insufficient size of the depression 20a on the top surface of the material feeding device, the width of the liquid material at the leading end of the material feeding device, becomes only about 400 mm, thereby any reverse flow of the liquid material on the undersurface of the material feeding device becomes almost not enough to be appreciated. As a result, a sheet obtained does not reach the gasket of the both sides, the width of the sheet is unstable i.e., 900 - 1,000 mm, and the thickness is thinner than 2 mm near its periphery, and is thicker than 3 mm in its center.

FIGS. 12 and 13 are views similar to FIGS. 6 and 7. In order to seal the sides of the endless belts the gaskets 10, 10, and 10a, 10a and provided on both sides of the endless belts respectively in combination so as to run at the same speed as the endless belts in contact with the belt surfaces and sliding on the material feeding device. The material feeding device and the belt surfaces do not slide in direct contact with each other in sealing.

FIG. 14 is another embodiment of an apparatus the above combination of gaskets which can be used for the process of the present invention, in which the endless belts are positioned to run in the vertical direction to feed the material from the upper part.

FIG. 15 is a fragmentary perspective view of the material feeding device of FIG. 14. In this embodiment, the upper main pulleys 3a and 5a are disposed at the same level, the axial distance of which is adjustable while the other pulleys are rigidly fixed. The material feeding device 20a here consists of side walls of the wedge shape corresponding to the wedge shape of the upper part of the belts and not directly contacted with the belt surfaces.

The gaskets 10b and 10c sealing the sides serve for cushioning the material feeding device between the edge surfaces of its side walls and the belt surfaces.

FIG. 16 shows various examples of gaskets.

The simplest shape of gasket is provided in a tube of the circular cross section. For polymerization of meth-

ylmethacrylate according to this method there is usually employed a hollow tube of a soft polyvinylchloride containing a substantial amount of plasticizer; at the side of the material feeding device, a pair of gaskets delivered along both belt surfaces contact with each other at the forward end of the feeding device and are held between the endless belts. Normally, the belt surface and the gaskets tend to intimate with each other. The material feeding device is provided with guides such as TEFLON material with grooves at a part where the gaskets run so that the gaskets in a pair are balanced in place. It sometimes occurs that such balance is broken so that the thickness of the sheet loses uniformity in that vicinity of the gasket. Particularly when a sheet of large thickness is manufactured, it is required to secure the balance of the gaskets of a pair.

FIG. 16a shows an embodiment in which one of the gaskets in a pair has a recessed groove and the other ridges. The construction has a slight difficulty for handling but it is efficient for the manufacture of a thick sheet product.

FIG. 16b is an improvement over the same type gaskets in a pair which are each formed in a cocoon shape collapsible in the middle of the circular hollow tube.

FIG. 16c shows a pair of gaskets, one of which is thin and formed as a soft hollow tube having a large diameter and the other is a narrow tube or rod considerably smaller in the diameter, the latter of which is adapted for insertion into the former so as to secure the combination. The embodiment is effective for the manufacture of a thinner sheet.

FIG. 16d shows an embodiment adapted for the manufacture of a thinner sheet, in which one gasket is formed into a film tape or ribbon shape. According to circumstance the embodiment is not suitable for a gasket of a film tape shape in the function of a gasket.

FIG. 16e shows an embodiment of a pair of gaskets which are provided for running adjacent to each other without being laid one upon another and which is most suitable for a thinner sheet product.

The rollers, previously referred to, are most effectively realized in the polymerizing zone where the thickness of the sheet form polymer is determined in the continuous sheet forming device adapted for use by the invention, for example, in a zone to which is applied heating by the warm water spray. Thickness of the sheet form polymer does not substantially vary in the heat treating zone so that the belts may well be supported from their inner surfaces in the desired way by the then substantially hardened product.

The invention is described first with reference to FIG. 17. Idle rollers which are the outer supporting device for the belt surfaces of the endless belts, are constituted by center shafts 29 and drums 31 and 32 supported on the shafts by bearing units 30 and 30, at two intermediate points X and X. End portions Y and Y of each center shaft are supported by brackets 30a for the adjustment of the distance L between the shafts of the upper and lower idle rollers. Between the upper and lower endless belts 1 and 2 are disposed gaskets 10 and 10 for sealing at the sides of said endless belts. Surrounded by said parts is the polymeric compound. The endless belts 1 and 2 receive the internal liquid pressure of the polymeric compound, and a repelling force due to compression of the gaskets, respectively on the upper and lower belts, as a load to expand or separate the endless belts. This load acts to produce a roller de-

flection, for example, in the drum 31 of the two rollers. It is provided that a diameter D of the drum 31 may be sufficiently large to have the deflection substantially negligible, and therefore the thickness of the polymeric compound between the belt surfaces may not be excessively thick in the middle part of the polymeric compound in the transverse direction. The described load acts as a load W concentrated symmetrically with respect to the center shaft 29 through the bearing units 30 and 30. The center shaft 29 has produced therein a deflection by the load W applied at the Y points and the reactionary force W produced in the support X at the shaft end. At this instant the deflection of the center shaft 29 is symmetrical with the shaft so that the drum 31 remains horizontal and the drums 31 and 32 of the upper and lower rollers are parallel to each other. Therefore, the distance between the belt surfaces, or the thickness in the transverse direction of the polymeric compound, is held uniform. Assuming that W is a concentrated load applied at points X , X of the center shaft and that there is a repelling force produced at points Y , Y on the shaft end l_1 distances between X , Y of the center shaft; l_2 a distance between X , X of the center shaft; d_1 a diameter between X , Y and d_2 a diameter within or between X , X on the central portion; the deflection δ between X , Y may be expressed in the following formula;

$$\delta = 32 W l_1^2 / 3 \pi E (2 l_1 / d_1^4 + 3 l_2) / d_2^4$$

where π is circular constant and E Young's modular of the center shaft.

As shown in Formula (4) it is seen that the rollers are as much deflectable as is large l_1/d_1 or l_2/d_2 specifically. Further, assuming that D is a diameter of a drum; t thickness of a belt; L a distance between axes at a point B on the center shaft, the distance between belts or the thickness of the polymer compound is as follows:

$$\epsilon = 2\delta + L - d - 2t$$

In case a drum is covered with rubber the deformation of the rubber due to compression is to be well considered.

Contraction in volume, or the so-called polymerizing contraction produced with the progress of polymerization, is automatically corrected with the decrease of the belt interspacing distance ϵ and the reduction of the deflection of the roller, even though the distance L at the shaft end of the roller is constant. When it is desired to change the internal liquid pressure exclusively in a zone of polymerization to its end, it is possible to vary the deflection of the elastic center shafts 29 accordingly the internal liquid pressure in said zone by changing the axial distance L at the shaft end of the roller, since the polymeric compound is substantially non-compressive and its viscosity is high with the progress of polymerization, so the distance between the belt surfaces ϵ can hardly change without substantially causing the flow to raise the level in the feeder and therefore the liquid pressure between the belts.

In order to provide the sheet form polymer the thickness desired, the material polymeric compound is constantly supplied by the pump. Therefore, the thickness of the polymeric compound during polymerization or

the distance ϵ between the belt surfaces is provided at every point of advance of the belt. The polymeric compound is substantially assumed as the non-compressive fluid, so that setting of the axial distance L at the shaft end of the idle rollers disposed opposite to each other, is to determine the deflection δ of the roller and accordingly the internal liquid pressure between the belts.

With the axial distance L being the same the amount of material feed may be changed, and accordingly the axial distance ϵ between belt surfaces will change correspondingly, and accordingly the deflection δ of the roller as well as the internal liquid pressure. In this case, use of deflectable rollers can make the change of the internal liquid pressure small relative to the change of distance between the belt surfaces and accordingly the change of deflection δ of the roller. It is, therefore, possible to obtain the sheet form production in the thickness of a broader range only by changing the amount of material feed without changing the distance between roller shafts at the points W .

Extraordinary volume expansion such as foaming due to abnormal polymerization, can be easily ascertained.

It will be easily seen that if the rollers are used on only one belt as the outer supporting device for that belt surface, although the other outer supporting device is a construction of high rigidity used for the other belt, there will be obtained a polymerizing apparatus having the described characteristics.

If rollers are made integral with a drum shaft as by making the shaft diameter d equal the roller diameter D , suggestively shown in FIG. 18, the deflection δ is different from the formula (4) and may be expressed in the following formula:

$$= 64 W / 3 \pi E \cdot l^3 / d_1^4$$

(6)

Example 8

FIGS. 19 and 20 are cross sections of an embodiment of a polymerizing apparatus having such roller means. In this example, endless belts 1 and 1' of two smooth endless stainless steel each of thickness $t = 1$ mm and width 800 mm are run in the horizontal direction at a speed of 0.1 m per minute. For the supporting devices are used deflectable rollers 33 and 34 each constituted of a drum with the center shafts of both upper and lower drums each at two interspaced points. The drum is made in each instance of a stainless pipe. Dimensions of these parts are as follows:

Drum Diameter $D = 88$ mm	Length 800 mm
Center shaft $d_1 = 16.5$ mm	$l_1 = 150$ mm
$d_2 = 19$ mm	$l_2 = 750$ mm

Intervals in the spacing of rollers are 150 mm or 300 mm in some portions and 200 mm in other portions. The polymerizing zone extends about 6 m in full length, a first half of 4m being heated at 80°C by being sprayed with warm water with sprays 35 and 36, and a second half is heated at above 120°C with infrared ray heater systems. Said rollers are used for polymerization in the first half portion.

A solution of 1 poise at 25°C was prepared consisting of methylmethacrylate monomer containing 20 weight % methylmethacrylate polymer of a mean degree of polymerization about 900 and 0.05 weight % of azobisisobutyronitrile. The solution is normally fed between the

belt surfaces through a material feeding device using an adequate sealing process, by means of a pump. For gaskets are used polyvinylchloride hollow pipe of a wall thickness 1mm and an outer diameter 10mm. The axial separation distance at the shaft ends of the rollers is 92 mm for the first half 1.5m, and 91.5mm for the latter half 2.5 m. The amount of material feed was adjusted so that the sheet thickness was 2mm for a finished product, and thereby was obtained a smooth transparent sheet of mean degree of polymerization about 5,000 in which the sheet thickness precision = maximum deviation in sheet thickness divided by the mean thickness $\times 100$, was 10% or less in the longitudinal direction, and 5% or less in the transverse direction. Sheets having thicknesses of 3mm and 4mm were manufactured by increasing the amount of material feed under the same condition, in which it was found that the internal liquid pressure in the material feeding part increased respectively by 8cm and 15cm in liquid depth in the feeder as compared with the manufacture of the 2mm sheet, but there was obtained in each case a transparent sheet of mean degree of polymerization about 5,000 and better thickness tolerance.

The foregoing description relates to a liquid material which is a polymeric compound which is polymerized and solidified with the advance of the belt surfaces to obtain a sheet form polymer. The invention can be applied also for obtaining a sheet form product by cooling and solidifying a melt of thermosetting polymer continuously with the advance of the belt surfaces.

In FIG. 21 a pair of endless belts 1 and 2 are tensioned by main pulleys 3, 4 and 5, 6 respectively, and driven by the main pulley 6 for their opposed runs to travel at the same speed. The lower endless belt is horizontally maintained by frame constructions or beds 37 and the distance between the opposed belts, namely thickness of the polymeric compound, is regulated by frame constructions for supporting the upper endless belt comprising bars 38 and side bars 39.

The term of "frame constructions" used herein mean such constructions comprising bars of a cubic body as a member and serving to support the endless belt longitudinally and widthwise by said bars. Therefore they contact slidably with the endless belts.

The polymeric compound of liquid material is fed by a metering pump 19 and supplied between belts by a material feeding means 20, under pressure. The free surface of the liquid material is indicated at 14a. The opposed sides between the belts are sealed off by resilient gaskets 10. As the endless belts run, the polymeric compound is heated by the surfaces of the opposed belts and polymerized by spray water beds (see FIG. 25 in which the lower endless belt runs as if it floats on a hot water bed) and discharged as a sheet product of the polymer after said polymerization is completed, by an infrared ray heater system 23. An outer supporting mechanism for each belt surface is effectively used at the polymerizing zone in which the thickness of the sheet polymer is determined i.e., the portion of the beds 37 and 38 heated by the hot water. Since the thickness of the sheet polymer is not substantially changed in the heat-treating zone 23 the endless belts may be supported at their outsides by any suitable means.

The frame constructions for supporting the upper endless belt according to the present invention, comprise bars 38 to support transversely the belts and side

bars 39 to suppress the repulsive force of the gaskets (FIG. 22).

Two adjacent bars may independently move relative to each other by being mounted by bearing mechanisms 40 for sufficiently following the contraction of polymerization.

Also the bars 38 and the side bars 39 are provided with sliding members 41 respectively for reduction of frictional forces between them and the belt surfaces. As materials of the sliding members TEFLON in which glass-fiber, powders or the like are added for increasing the mechanical resistance or the like, having a low frictional coefficient and a good hot water proofness are preferably selected. The bars must be designed for their portions contacting with the endless belts, to be little flexed (their maximum amount of flexure is less than 0.05 mm). This is easily achieved by use of metal material. If the material, size and distance between fulcrum-cra of shafts 29a on which the bars 38 are mounted (one end of each shaft 29a forms an end portion of each bar) are properly selected, the shafts may be flexed with flatness of the belt surface maintained, as if springs mounted both ends of the bars, so that the bars move up and down. That is to say by the flexure of the shafts 29a with the flatness maintained, the contraction of polymerization may be automatically followed, by the distance between the opposed belt surfaces.

FIG. 25 shows a heat transfer system in which a hot water is used as a heat medium. In this system the upper endless belt 1 is heated by the hot water sprayed by sprayers 21a, the hot water staying for the moment on the upper endless belt for increase of the heating effect, and then falls from joints between the bars and the side bars into reservoirs 42 and is recovered. With the lower endless belt the hot water is supplied at a controlled rate to the lower bed 37 through a valve 43 and sweeps the lower endless belt. The excess hot water is overflowed through the gaps between the lower endless belt and the lower bed and recovered in the reservoirs 42 for re-use.

Moreover the hot water contributes reduction of the frictional force between the frame constructions and the endless belts.

FIGS. 25, 26 and 27 show details of the lower bed 37. A group of the bars 44 in a rectangular box are provided, the construction of which bars is almost the same as the supporting bars for the upper endless belt. The bars serve to maintain horizontally the lower endless belts.

The lower bars 44 are arranged coplanarly with the lower bed and the frame 45. In the sliding area between each bar and the endless belt an antifriction member is provided in the same manner as the frame constructions for supporting of the upper endless belt. A reference numeral 46 indicates a sliding member which is the same as the sliding member 41 in the frame constructions for supporting the upper endless belt.

Features and advantages of the foregoing outer supporting mechanism for each belt surface, are now described as follows.

A. The side bars 39 and the frame 45 for the lower bed will operate to control perfectly the resilient force of the gaskets (via the side bars 39) and to eliminate effects of the gaskets on the thickness of the sheet produced.

In other words sheets of polymer having uniform thickness will be obtained, the thickness of which corresponds to one in a case of manufacture of sheet in which gaskets having no resilient properties are used, and sealing of the polymeric compound is effected perfectly.

In order that this effect might be more understood the flexure of the endless belt where a group of rollers are used as the outer supporting mechanism for the belt surface, is now described with reference to FIGS. 28 and 29.

In FIG. 28 the maximum flexure of belts 1' and 2' by an inner liquid pressure and a resilient force of the gaskets is in the middle line XXIX — XXIX between the rollers 3', 4', 5' and 6'. As seen in FIG. 29 this flexure is distributed across the width and is maximum near the gaskets 10'. Thus in particular the precision of sheet thickness is poor in the longitudinal direction. Said precision is shown by a percent value of (deviation in the sheet thickness/the means sheet thickness) X100.

B. Selection of the gaskets is possible in a wide range. Requirement for the characteristic of the gaskets is only the resilience for sealing.

C. Contact with the endless belts is a surface contact, and thus the longitudinal flexure of the endless belts may be more finely regulated as compared with a line contact of the roller.

D. The polymeric compound contracts in the progress of the polymerization. However with each bar 38 the distance between the opposed surfaces of the belts may be adjusted in response to the contraction. That is to say, said distance may follow automatically the contraction in the polymerization, with the mounting shaft 29a flexed.

E. Damage of the endless belts by entry of any impurity will little occur. For example, with the rollers, if impurities are present between the endless belts and the rollers, the impurities will be positively entered between the rollers and belt by rotation of the rollers, so the endless belts will be damaged. This is a fatal trouble.

On the one hand, when the frame constructions are used as an outer supporting mechanism for the surfaces of the belts, each bar serves as a scrapper able to eliminate the trouble of entry of impurities.

Example 9

Flat stainless steel endless belts 1 and 2 of thickness of 1.0mm and width of 800mm were run in the horizontal direction at a speed of 0.1m/min. and the frame constructions according to the invention were used as upper and lower outer supporting mechanisms for the surfaces of the belts. Dimensions were as follows:

Bar for the upper bed:	
material	SUS 27 Stainless Steel
width	10mm
height	60mm
length	870mm
Side Bar:	
material	SUS 27 Stainless Steel
width	10mm
height	60mm
length	160mm
Bar for the lower bed:	
material	SUS 27 Stainless Steel
width	10mm
height	40mm
length	730mm
Sliding members:	
material	sheet of phenol resin
thickness	10mm

-Continued

Mounting shaft 29a:
material
diameter
length

SUS 27 Stainless Steel
16mm
80mm

Moreover distances between adjacent bars in the upper and lower frame constructions were 200 mm. With reference to the flexure of the bars 44 for the lower bed, they were more flexible since their height was less, but for an inner liquid pressure of 10cm water column, the flexure of the bars 44 was in the order of 0.02 mm, while the flexure of the bars for the upper bed was less than 0.01mm (this flexure may be easily calculated as flexure of a beam having a rectangular cross section on which a load is evenly distributed). The inner liquid pressure under operation was in the order of about 5 cm water column and in fact the amount of said flexure was about half said value.

The polymerization zone was about 6m in overall length. In the front half zone of 4m length the outer surfaces of the upper and lower belts were sprayed with the hot water at 80°C, or contacted with the beds for heating and cooling. In the rear half zone of 2m length the heat treatment was effected at more than 120°C by the infrared ray heater system 23.

The frame constructions are to be used in the front half polymerization zone.

As a polymeric compound of liquid material, a mixture was used which was made in such a manner that methylmethacrylate polymer of about 20% at volume having mean polymerization degree 900, was dissolved in methylmethacrylate monomer and azobisvaleronitrile of 0.05% by weight, was mixed, with said solution having a viscosity of 5 to 10 poise at 20°C. The mixture was supplied at predetermined rate and constantly between the surfaces of the belts through the material pouring means 20 by the metering pump 19 with a proper sealing means used.

As the gaskets hollow polyvinylchloride tube was used which has the wall thickness of 1mm and the diameter of 10mm and the resilient force of which was 0.5kg/cm when compressed to 2mm (this means that the gaskets have relatively large resilient force). The distance between the opposed surfaces of the belts was adjusted so as to obtain products having sheet thickness of 2mm, and the supply amount of the material was set so that the sheet thickness became 2mm.

In this way a sheet polymer of mean polymerization degree about 5,000 having precision of sheet thickness of $\pm 5\%$ both in widthwise and longitudinal direction was obtained.

The precision of sheet thickness, in particular in the longitudinal direction, was improved by about ten percent as compared with a case in which as an outer supporting mechanism a group of improved rollers were used and gaskets having relatively low resilient force were used for improvement of sheet thickness (the resilient force was about 0.05kg/cm when compressed to 2mm).

In the same way sheets of 3mm and 4mm were also obtained.

Now FIGS. 30 and 31 show the well-known equipment to make two main pulleys rotate with the aid of chains from a driving system in order that the upper and lower endless belts can be driven in the same direction with the same speed. Two upper and lower endless belts 1, 2 are tensioned by main pulleys 4, 6 of which

the diameters are the same. Chain sprocket wheels 51, 52 of the driving equipment are rotated to drive through chains 49, 50 and chain sprocket wheels 47, 48 which have the same axles with main pulleys. Gear boxes 53, 54 are used in order that rotations of the two main pulleys 4, 6 rotate in opposing direction to each other. 55 and 56 are front free systems, 57 and 58 are torque detectors which measure driving power or brake power, and 59 is a motor.

When this apparatus is being driven, for example, polymeric compounds or plate-like polymer between the belts operates on the surfaces of the belts as if they are sticking materials which stick the surfaces of the belts together according to their sticking nature. Therefore if only one of the two endless belts is driven, both two belts can run with the same speed together and nothing does harm the apparatus and quality of the products. In case no polymeric compounds are between the belts, for instance at the beginning of driving or at running idle, gaskets which are set continuously as seals at both sides of the surfaces between the two belts can maintain considerable power transmission. In case that power transmission by the gaskets is not enough, another assistant gasket or some assistant gaskets, can be set in the middle part of the endless belts, or in case of adjusting the works, a sticky film for protection of the mirror surface, cloth, polyurethane foam sheet or other buffer materials can be inserted between the opposing belts, and if only one of two endless belts is driven, the other belts gets power to drive itself through the gaskets or buffer materials and both surfaces of the two belts can run with same speed.

Example 10

FIG. 5 shows the example of continuous polymerized sheet manufacturing apparatus of the opposing endless belts type, of methylmethacrylate, which takes this driving process. Stainless steel endless belts 1, 2, which are 1mm in thickness and 1,200mm in width and are given the finishing touch of a mirror surface, are strained in parallel by two main upper and lower pulleys 4, 6 of which each diameter is 1,000mm. The first tension of the belts is decided to be 12 ton respectively, that is to say 5 kilogram per mm², by oil pressure tensioning apparatus. Material liquid is consisted of sticking liquid, in which methylmethacrylate monomer and polymerized methylmethacrylate 20 percent in weight are dissolved, with a proper polymerizing catalyzer. This liquid must be fed to the material feeding device by a pump, and moreover be fed between the belts. At the same time for sealing the both sides of the belts surfaces, hollow pipe made of polyvinylchloride which has considerable plasticizing materials in it is inserted as gaskets between the opposing surfaces of the belts. The polymerized zone is 60m long. In the first 40m of the zone idle rollers are placed at intervals of 300mm and control the distance between both belts' surfaces, and heat is applied by spraying water which is at about 80°C on the belts' outsides. In the latter 20m idle rollers placed at intervals of 2m to support and space the endless belts and the two endless belts are heated up to about 120°C by the infrared rays heaters forming the heat furnace. Through this process sheets of good appearance and of good precision are made. The endless belts are driven with the speed of 1m per minute, but directly, only the lower belt is driven by a main pulley. The upper belt is driven by the medium, which makes the driving speed of two endless belts accord with each

other. Now during the normal driving the torque for driving the apparatus is under 40 kilogram-meters.

At the time of driving, before feeding of materials, some polyvinylchloride hollow tubes, which are usually used for the seal of both sides of the belts surfaces, are driven between the belts' surfaces. According to this process direct contact of both surfaces of the upper belt and lower belt will be avoided in order to guard the belts' surfaces. The gaskets work for power transmission which drives the upper endless belt. In case that running idle is taken place because of adjusting work, a sticking film of polyvinylchloride will be stuck on both belts' surfaces for guarding their mirror surface, and moreover polyurethane foam or flannel cloth is sandwiched between the film and surfaces, as buffer materials. Such buffer materials work for driving transmission to drive the upper endless belt.

Now let's take an example. When the upper belt and lower belt in this apparatus are independently driven, imperceptible difference of either of two main pulleys will bring about the above mentioned difference of rotation. It causes tension on the losing side of the chain which is strained to drive the main pulley which has the smaller diameter and is also caused to brake. This torque of braking amounts to 500 kilogram -m. If the chain and the chain sprocket slip one link in this condition, the big shock will be given to all the apparatus and the appearance of the sheet part of which sheet products are peeled off will remarkably go wrong, or the shock may sometimes deform the endless belts partly. Example 11

FIG. 32 shows continuous sheet manufacturing apparatus of polyvinylchloride and using this driving process.

Polyvinylchloride of extruding grade is made to melt by extrusion machine 60 which has a 60mm screw diameter, and a fixed quantity of polyvinylchloride is fed to die 20b which is 800mm in width and heated up to about 240°C. After the above process polyvinylchloride is extruded downwards as sheet form from the die. There is a polished belt system which runs vertically under the die and the extruded sheet is cooled between two endless belts 1a, 2a. After the above treatment good sheet which has 2mm in thickness and 700mm in width will be produced. Belts 1a, 2a are 0.6mm thick, 800mm wide and 6m long and have been made of stainless steel with as a finishing touch a mirror surface. Each belt is strained with first 4.8 ton tensile strength, that is 5 kilogram/cm² per belt cross section, by each main pulley 4a 6a of which each diameter is 600mm. Opposing driving parts of the two endless belts, are sandwiched from both sides at intervals of 200mm, by idle rollers 7a and 8a of which their diameters amount to 80mm. These rollers serve to maintain well-balanced thickness of sheet. In order to cool the outside of the belts, nozzles 21a, 22a are installed in this apparatus. In order to seal both sides of the two belt surfaces, polyvinylchloride made as hollow tubes which have considerable plasticizing material, are inserted as gaskets. The gaskets are not always necessary according to manufacturing conditions to make sheets, but the gaskets serve to transmit power to the driving side of the endless belts at the beginning of driving. The endless belts are forced to be driven only by driving the lower main pulley 4a of the one endless belt 1a directly with the air of a chain 29a and chain sprocket wheel 47. That is to say, the other endless belt is driven by the medium of the inter-

mediary between both belts' surfaces. In case that these endless belts are driven with a speed of 200mm per minute, the required torque amounts to 2 to 4 kilogram -m.

Example 12

In a laminating apparatus two stainless steel endless belts, which are 1mm thick, 800 wide and 5.5m long, are pulled horizontally with a main pulley of 1,000mm diameter and the opposing part of the driving belts' surfaces is sandwiched between idle rollers of 90mm diameter which are placed at intervals of 200mm. In the first half of this driving part an infrared rays heater is installed to make a heating zone of maximum 220°C temperature. In the latter half of this driving part a cool zone is formed. Soft polyethylene sheet of 3mm thickness whose both sides were covered by soft polyethylene film of 0.4 thickness was sandwiched between these two belts. The above sheet was examined, after making the whole sheet by adding pressure and heat and by cooling in accordance with the described driving of the endless belts. In this case all the apparatus could be driven all right by driving one endless belt directly.

Many variations may be effected without departing from the spirit of my invention. It is to be understood that these, together with other variation in details, are defined by the appended claims.

What we claim is:

1. A method for continuously casting a liquid having a viscosity rendering it flowable under the force of gravity and which hardens with changing temperature and time, in a traveling casting space having casting and discharging ends, said space being defined between two opposed, vertically interspaced, externally restrained, horizontal upper and lower, elongated, flexible belt spans having side seals and traveling at the same speed and in the same direction and formed by endless flexible belts each running around horizontally interspaced cylindrical rolls forming each belt into a loop having semi-cylindrical ends; wherein the improvement comprises continuously casting said liquid into said casting end by flowing the liquid into contact with said belts while controlling the traveling speed of said belts so that by the belts' engagement with the liquid the latter receives therefrom a forwardly directed force, said liquid hardening as it travels through said space and the latter being long enough to permit said hardening, said force being greater than the force of gravity on the liquid to a degree preventing the latter force from causing said liquid to flow reversely out of said casting end far enough to fall from said lower belt, and the total of said forces producing a pressure on the liquid cast in said casting space, prior to the liquid hardening therein, which is at least sufficient to hydraulically support said upper span.

2. The method of claim 1 in which said liquid is flowed into contact with said belts via a column of the liquid having a free upper surface.

3. The method of claim 1 in which said lower belt span is extended backwardly from said upper belt span to form a forwardly moving horizontal belt surface on which the liquid forms backwardly extending body of liquid terminating where said forwardly moving force received from this belt surface is adequate to hold the liquid body against extending further backwardly.

4. The method of claim 3 in which said liquid body is maintained in a laminar condition.

5. The method of claim 3 in which said liquid is flowed into contact with said belts in the form of a flow of less width than the width of said casting space so that this flow spreads laterally while moving into said casting space under said forwardly moving force, said flow being at a rate filling said space.

6. The method of claim 3 in which said liquid is flowed down a surface declining towards said casting end of the casting space and terminating above said forwardly moving horizontal belt surface, said surface being spaced from the semi-cylindrical end of the upper belt at said casting end.

7. The method of claim 6 in which said liquid is flowed onto said surface with a flow width less than the width of said casting space.

8. The method of claim 3 in which said body of liquid is confined in a space formed between said traveling horizontal surface and a static non-traveling, flat surface spaced thereabove free from contact with said belts.

9. The method of claim 8 in which said liquid is cast in the form of a laterally confined column of continuously fed liquid having a free upper surface and a forward side contacting the adjacent cylindrical end of said upper belt, said column extending above the level of said lower span and communicating with said space in which said body of liquid is confined and by its height above said level hydrostatically placing said casting liquid under pressure.

10. The method of claim 1 in which said belt spans are externally restrained by resilient forces.

11. The method of claim 1 in which one of said belts is driven by a power source and the other belt is driven by this powered belt via said side seals.

12. The method of claim 10 in which said resilient forces permit said belt spans to separate different distances with changes in the rate said liquid is cast in the casting end of said casting space.

13. The method of claim 1 in which the viscosity of said liquid is not materially less than 1 poise.

14. The method of claim 1 in which said liquid is flowed into contact with said belts at said casting end from a level below the axis of the roll around which the belt forming said upper belt span runs at the casting end.

15. The method of claim 10 in which said liquid is flowed into contact with said belts at said casting end from a level below the axis of the roll around which the belt forming said upper belt span runs at the casting end.

16. A method for continuously casting a liquid having a viscosity rendering it flowable under the force of gravity and which hardens with changing temperature and time, in a traveling casting space having casting and discharging ends, said space being defined between two opposed, vertically interspaced, externally restrained, horizontal upper and lower, elongated, flexible belt spans having side seals and traveling at the same speed and in the same direction and formed by endless flexible belts each running around horizontally interspaced cylindrical rolls forming each belt into a loop having semi-cylindrical ends; wherein the improvement comprises continuously casting said liquid into said casting end by flowing the liquid into contact with said belts while controlling the traveling speed of said belts so that by the belts' engagement with the liquid the latter receives therefrom a forwardly directed

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force, said liquid hardening as it travels through said space and the latter being long enough to permit said hardening, said force being greater than the force of gravity on the liquid to a degree preventing the latter force from causing said liquid to flow reversely out of said casting end far enough to fall from said lower belt, and the total of said forces producing a pressure on the liquid cast in said casting space, prior to the liquid hardening therein, which is at least sufficient to hydraulically support said upper span; said lower belt span being extended backwardly from said upper belt span to form a forwardly moving horizontal belt surface on which the liquid forms a backwardly extending body of liquid terminating where said forwardly moving force received from this belt surface is adequate to hold the liquid body against extending further backwardly; said liquid being flowed into contact with said belts in the form of a flow of less width than the width of said casting space so that this flow spreads laterally while moving into said casting space under said forwardly moving force, said flow being at a rate filling said space; said belt spans extending from said casting end and towards

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a location within said casting space where said liquid has substantially hardened, being externally restrained by resilient forces reacting against the hydraulic force of said liquid between said spans, said spans being held against separation to provide the casting thickness desired at least while adjacently approaching said location, and said resilient forces being proportioned relative to said hydraulic force to permit the latter to hold said belt spans apart for a distance greater than said thickness and controlling the lateral spread of said flow to cause the latter to completely fill said cast space at a location within said casting end but adjacent thereto.

17. The method of claim 16 in which said liquid is flowed down a surface declining towards said casting end of the casting space and terminating above said forwardly moving horizontal belt surface, said surface being spaced from the semi-cylindrical end of the upper belt at said casting end.

18. The method of claim 6 in which said liquid is flowed onto said surface with a flow width less than the width of said casting space.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 3,872,197
DATED : March 18, 1975
INVENTOR(S) : Tetsuji Kato et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, line 66: Change "not" to --only--.
Col. 4, line 67: Change "surface" to --surfaces--.
Col. 19, line 16: Change "supplying" to --suppling--.
Col. 24, line 7: Change "bara" to --bars--.
Col. 25, line 8: Change "flexture" to --flexure--.

Signed and sealed this 20th day of May 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents
and Trademarks