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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Molding of Foamed Thermoplastic Articles

We, UNION CARBIDE CORPORATION, a Corporation organized under the Laws of the State of New York, United States of America, of 270 Park Avenue, New York, State of New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to the molding of foamed thermoplastic articles characterized by a cellular core and a substantially non-cellular, integral peripheral shell. More particularly, this invention relates to a process for molding such foamed thermoplastic articles, an apparatus for carrying out the process, and foamed thermoplastic articles so produced.

Molding processes, such as injection molding, normally are limited in the size and shape of the article which they can feasibly produce. Molds are conventionally filled with plastic in a molten state and must be free from long flow paths and sharp corners because of the flow resistance of the molten plastic material. This problem becomes particularly acute when attempting to mold high viscosity (low melt index) plastics. The problem further increases with decreasing mold temperatures because of the increasing rapidity of plastic solidification.

In injection molding, the use of molding pressures which are low can yield articles having flow marks and which are not sharply defined while the use of high pressures can yield high internal stresses and consequently low impact strength articles. Low molding temperatures can, as a further problem cause freezing of the plastic in the mold prior to complete filling of the mold as well as causing flow marks in the plastic article and low mechanical strength. High molding temperatures on the other hand, prolong molding time and can cause distortion of the finished article.

When attempting to mold articles having thick sections, molding techniques such as injection molding, tend to yield finished articles which show sink marks and warpage.

Furthermore, injection molding normally produces an article having an unsightly sprue which is formed in the feed inlet to the mold. Such sprues are removed in a subsequent operation or the feed inlet is positioned so that the sprue will not show on the finished article. To injection mold sprue-free articles, it has been proposed to make the feed inlet to an injection mold a part of the cylinder in which the injection ram travels so that the bottom of the ram can come flush with the mold cavity thereby producing a sprue-free article. This arrangement, however, has not been entirely satisfactory because when the ram is cool enough to solidify the plastic, which is necessary for part removal, freezing or sticking of the plastic to the ram occurs and, in fact, an unsightly sprue is formed. This problem is not solved by keeping the ram warm because the plastic will not solidify and will distort when removed from the mold. Furthermore, with this arrangement it is extremely difficult to mold a small part or an open structured part because of the large surface area of the face of the injection ram.

It has also been proposed to employ injection molding techniques to mold foamed thermoplastic articles. In using such techniques, particulate resin mixed with a blowing agent is pushed under pressure through a pre-injection zone where the resin is warmed but remains in the solid state. The pre-injection zone conventionally contains a solid spreader more commonly known as a torpedo. From the pre-injection zone, the warmed, solid resin is pushed under pressure to an injection zone which is isolated from the pre-injection zone when it is full of resin. In the injection zone the resin is warmed further, to a temperature to decompose the blowing agent but under

sufficient pressure to prevent foaming, until it becomes a mobile gel. At this point, a valve is opened and the gel is injected into a mold under partial vacuum where the resin foams into a uniformly porous, multicellular structure of uniform density. When the mold is full, the valve is closed and communication between the preinjection and injection zones is again established and the process repeated. The drawbacks to this process, however, are numerous. For instance, maintaining the mold under partial vacuum requires additional equipment and lengthens the molding cycle. Inherent in the injection process is the intermittent operation of a preinjection zone and an injection zone each under different pressures and temperatures and out of communication with each other for part of the molding cycle. This step-by-step, intermittent operation of these two zones requires long molding cycles, precise control and timing, and extra equipment. Practically speaking, it is almost impossible to heat resin without a blowing agent uniformly in a cylinder without adequate mixing. Where the resin is mixed with a blowing agent, this problem of obtaining proper heat transfer is only compounded. Without mixing, the blowing agent near the surfaces of the cylinder will decompose but the blowing agent remote from the cylinder surfaces oftentimes never heats up and consequently never decomposes. Also inherent in the process is the inability to admix resin and blowing agent as an integral part of the molding process. Resin and solid, decomposable blowing agent must be premixed and the use of a gaseous blowing agent, for all practical purposes, is precluded because of this inability to admix. Also, because of the uniform nature of the foamed product, its strength characteristics are seriously limited. Foamed articles produced by the injection process have generally low strengths commensurate with their density and cannot be used in load-bearing applications.

Perhaps the most serious problems met with in injection molding of foamed articles is the formation of a sprue on the uniformly porous structure and the formation in the equipment of an unfoamed slug which enters the mold on the next succeeding molding cycle creating an undesirable unfoamed, solid region in what should otherwise be a completely foamed article. This unfoamed slug is generally formed in the valve which connects the injection zone and the mold and/or in the conduits leading to and from the valve. When this valve is open, the drop in pressure allows the gas to escape from the resin but the resin does not foam because it is in a confined area, namely the flow passages in the valve and/or the conduits in communication therewith.

In an attempt to overcome the shortcomings met with in the injection molding of foamed articles, it has been proposed to use a preform injection foam molder. Such a device, however,

requires the use of a retractable mold, which seriously limits the size and shape of the foamed articles that can be produced. Generally, only very simple shapes such as cylinders and spheres can be molded. For example, this device cannot, for all practical purposes, mold a large, thin walled, open structure article such as a tote box for example. By the term "tote box" as used herein is meant an open or closed box which is used for temporarily holding and carrying or transporting various items. Moreover, this device, like the injection process, produces a foamed article of uniform density and cell distribution.

It has now been discovered, in accordance with this invention, that sprue-free foamed articles having a cellular core and a dense shell can be molded from thermoplastics, even those with very high viscosities, with more complex configuration in molds having long flow paths and sharp corners than heretofore employed with solid injection molding. Moreover, problems heretofore met in the injection molding of foamed articles are overcome. Foamed thermoplastic articles can be molded rapidly and efficiently in accordance with this invention having thicker sections, a high quality finish, and strength and weight advantages as compared to injection molded solid articles.

Accordingly, the present invention provides a process for molding foamed thermoplastic articles, which comprises fluxing a mixture of a foamable thermoplastic material and a blowing agent in an extruder at a temperature and pressure above the temperature and pressure at which the mixture foams, continuously extruding said mixture into an expanding accumulation zone while maintaining the mixture therein at a pressure above the foaming pressure thereof, the accumulation zone expanding at a rate substantially equal to the rate of extrusion, maintaining a mold remote from the accumulation zone at a pressure at which the mixture foams and expands, establishing communication between the mold and the accumulation zone, rapidly forcing the mixture out of the accumulation zone and into the mold wherein the mixture foams and expands, terminating communication between the mold and the accumulation zone at a point where the pressure is above the foaming pressure of the mixture, and thereafter removing the mixture between said point and said mold.

The present invention also provides an apparatus for molding foamed thermoplastic articles, which comprises an extruder for extruding a mixture of a foamable thermoplastic material and a blowing agent, an expandable accumulation chamber for the foamable mixture communicating with the extruder and defined by the inner wall of a hollow cylindrical member and the head of a first piston in sliding engagement with said inner wall and reciprocally movable in said cylindrical member, expansion and collapse of the accu-

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10	75	10
15	80	15
20	85	20
25	90	25
30	95	30
35	100	35
40	105	40
45	110	45
50	115	50
55	120	55
60	125	60
65	130	65

mulation chamber being effected by upward and downward movement of said first piston, a filling nozzle connected to the accumulation chamber and extending to and flush with a mold cavity, a rod slidably mounted in the nozzle and attached to a second piston adapted to reciprocate within a housing, communication between the accumulation chamber and the mold being established by upward movement of the rod until the extremity of said rod reaches the point of communication of the nozzle with the accumulation chamber thereby opening a passage for the foamable mixture, termination of the communication and forcing of said foamable mixture out of the nozzle from said point of communication into the mold being effected by downward movement of the rod, movement of the second piston being responsive to movement of the first piston and thereby establishing communication when the first piston reaches the end of its upward movement and terminating communication when the first piston reaches the end of its downward movement.

In one embodiment of this invention, an accumulator device is provided which includes cylinder means having at one end thereof, communication means for the ingress of material into the cylinder from an extruder and for the egress of the material from the cylinder into a mold remote therefrom, and a piston reciprocally movable therein between a first position proximate said one end of the cylinder and a second position distant from said one end. Pressure means are also provided for applying force to the piston member in the direction of said one end. Associated with the cylinder means are valve means, described more fully herein, for establishing and terminating communication between a mold and the cylinder at a point remote from the mold and for forcing material between it and the mold into the mold. Advantageously, means are provided for automatically actuating the valve means. Further, the means can be responsive to the movement of the piston. Thus, when the piston is in the first position, the valve means can be actuated to terminate communication between the mold and the cylinder means, and when the piston is in its second position, the valve means are actuated to establish communication between the mold and cylinder means.

A mold is provided with a primary distributor channel in direct communication with the feed inlet through which the mold is filled and a plurality of secondary distributor channels in communication with the primary channel. This arrangement permits the rapid filling of a mold and results in a molded article of less weight than would be expected without any loss in strength.

The foamed articles produced in accordance with the present invention are characterized by a cellular core and a substantially non-cellular,

integral peripheral shell.

These articles have high strength characteristics but low weight. Containers can be provided having rigid walls, and which in cross-section have a dense surface zone and an integrally formed cellular interior. The rigidity of an article varies with the cube of its thickness and varies in approximately an inverse proportion to changes in density. Thus, the cellular, rigid wall has greater flexural rigidity than a non-cellular and consequently denser wall of the same weight of material. The flexural rigidity is further enhanced through the use of the dense surface zone since this configuration places more material at the surface which is the zone in which flexural stresses are the greatest.

In addition to the high strength characteristics of the dense surface area-cellular interior material, decreased heat conductivity and consequently increased insulation properties are provided due to the internal air cells.

The present invention will be further understood from the following description taken in conjunction with the accompanying drawings wherein:

Figure 1 is a side elevational view, substantially in central cross section, of a preferred apparatus of the present invention for carrying out the process of this invention;

Figure 2 is a side elevational view, partially in central cross section of an alternative embodiment of the accumulator device of the present invention;

Figure 3 is a perspective view of an article molded in accordance with the present invention;

Figure 4 is a cross-sectional view of the article of Figure 3 taken along the line 4-4; and

Figure 5 is an isometric view of a male half of a mold of this invention showing the primary and secondary distributor channels therein.

As is shown in Figures 3 and 4, foamed articles such as a tote box can be molded in accordance with the present invention having a cellular core 42 and a substantially non-cellular, integral, peripheral shell 40.

There may be a gradual transition from the cellular core 42 to the dense shell 40 and, therefore, there can be an absence of a clearly defined line of demarcation between the two zones. Moreover, the shell 40 can vary to some extent in thickness. Thus, the term "shell" refers to a general peripheral integral zone of substantially unfoamed, non-cellular material.

The stiffness of an article such as a beam, varies with the cube of the thickness of the article and directly with density or the modulus of the material employed. If the density and consequently the modulus of a material were reduced by foaming, to one-half of its original density and correspondingly increased to two times its original thickness, while main-

taining the same total weight the stiffness would be increased eightfold due to the increased thickness, but reduced by one-half due to the density decrease. A net four-fold increase in stiffness would thus be produced without the use of additional material.

The use of a dense surface zone has been found to reduce the "effective" density decrease and the modulus decrease, by placing more material in the area of greatest stress. Thus, doubling the thickness of an article can produce a net increase in the stiffness of 5 to 6 times, notwithstanding the one-half decrease in density.

The increased ratio of rigidity to weight can substantially increase the economic feasibility of producing, for example, high strength plastic containers or tote boxes, of the type employed in carrying items such as fruits or glass bottles, by decreasing the amount of plastic required and consequently decreasing the cost of the article. A further economic advantage is realized in that reinforcing ribs need not be employed for strength thus very substantially decreasing the complexity and consequently, decreasing the cost of molds.

Unexpectedly, it has been found that the process of this invention not only produces a dense shell region and a cellular core region, ~~it~~ can also produce an isotropic product free of internal stresses and distortions even in molds at room temperature, which have complex shapes and thick sections.

Foamable thermoplastic polymeric materials in general can be molded according to the present invention, as for example, polymers and copolymers of olefinically unsaturated compounds and their derivatives such as polyethylene, polypropylene, polystyrene, acrylonitrile-butadiene-styrene polymers, and vinyl resins, nylons, polycarbonates, polyhydroxyethers and polyarylene polyethers.

The mixture employed in the process can also contain conventional molding additives such as heat and light stabilizers, pigments, mold release agents, and slip agents. A conventional nucleating agent, such as calcium silicate, may be added to the mixture in order to enhance the uniformity of the cells produced by the foaming action. The ingredients of the mixture can be premixed, if desired, and charged to an extruder wherein the thermoplastic material is fluxed and mixed.

The blowing agent can be selected from chemical compounds such as azo, N-nitroso, carbonate and sulfonyl hydrazide compounds which are heat decomposable to yield a gas such as carbon dioxide or nitrogen. The blowing agent can also consist of normally gaseous agents such as methyl chloride, propylene, butylene and gaseous fluorocarbons, as well as gases such as nitrogen, carbon dioxide or air. Volatile liquids such as pentane, water and liquid fluorocarbons can also be employed in the foaming of the polymer.

While the various types of blowing agents which can be employed to produce a foamed product can be mixed with the plastic material at various stages in the process, it is advantageous to add liquid or gaseous agents directly to the polymeric material in the extruder, while the thermoplastic material is in a molten state in order to obtain a uniform dispersal of the agent within the molten plastic without employing additional mixing apparatus. Similarly, a decomposable chemical blowing agent is advantageously premixed with the polymer prior to the charging of the polymer into the extruder.

Careful consideration should be given to the means of obtaining a homogeneous distribution of the decomposable chemical foaming agent in the plastic compound. This can be conveniently achieved by adding the foaming agent in the form of solid particles or in the form of a dispersion in a vehicle compatible with the basic resin. The mixing is then carried out in conventional equipment such as a churn, colloid mill, three-roll mill, or Banbury, the choice of which depends upon the viscosity of the plastic compound. Alternatively, to obtain uniform dispersion, pellets of plastic resin can be coated with the blowing agent by tumbling. Regardless of the method used, the foaming agent must be incorporated below its decomposition temperature to prevent the possibility of gas losses taking place in the plastic mass prior to expansion.

In the case of chemical blowing agents premixed with the polymer the time-temperature relations within the extruder must be adequate to decompose the blowing agent to release the gas within the extruder. The extruder pressure must then be maintained uniformly high at least until the mixture is transferred into the high pressure accumulator in order to prevent premature expansion of the cells.

The decomposition of the blowing agent can be delayed through the proper control of the extruder operating temperature and/or through the proper selection of the blowing agent. Thus, for example, diazoaminobenzene can be employed for decomposition at 95°C. to 105°C. while azodicarbonamide can be employed for decomposition at the higher temperature range of 160°C. to 200°C.

Referring now to Figure 1, the preferred apparatus of this invention for carrying out the present method is shown to include an extruder 6 having attached thereto a line 7 for feeding a liquid or compressed gas blowing agent directly into the barrel of extruder 6. A valve 8 is provided on line 7 to control the feeding. Line 9 connects the extruder 6 to the internal conduit 19' of a base member 19 which is shown resting on a support member 20. Extending upward from the base member 19 is an accumulator device which includes a cylinder 10 and a piston 11 reciprocally movable therein. The piston 11 is shown having a frus-

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to-conical head 11¹ and a conventional O-ring 38 positioned around the piston 11 to provide a seal between the cylinder 10 and the piston 11. Attached to the rear of piston 11 and extending upward therefrom is a shaft 12.

A flange member 13 is attached to the other end of the shaft 12 and a piston 14 is located on the shaft at a position intermediate the piston 11 and the flange 13. The piston 14 is adapted to reciprocate within a piston housing 32. It should be noted that flange 13 is located at the uppermost functional end of the shaft 12 and need not be located at the actual physical end thereof. The configuration of the flange 13 is critical only to the extent that it must extend from the shaft 12 and contact switches 16 and 17 during the reciprocal movement of the shaft 12.

Alternatively, photoelectric type switches can be employed if desired, thus eliminating the need for a projecting member on the shaft 12. A pair of photoelectric units can be positioned such that shaft 12 blocks the light path of lower unit when the shaft moves upwardly from its lowest position and blocks the light path of an upper unit when it reaches the desired upper position.

Leading from the internal conduit 19¹ of the base member 19 is a line 21 which is connected to an internal conduit 22¹ of a second base member 22 which is also resting on the support member 20. Extending downward from the base member 22, and through the support member 20 is a filling nozzle 23. It should be evident that a plurality of filling nozzles can be employed to mold one or more foamed articles. The lower end of the nozzle 23 extends to and is flush with a mold cavity defined by a male mold half 25 and a female mold half 24. Mold half 24 is conveniently affixed to the support member 20 and the mold half 25 is supported by a reciprocating bed 26 adapted to provide for easy separation of the mold halves 24 and 25 to facilitate product removal. Slidably mounted in the nozzle 23 and the base member 22 is a rod 27. The upper end of the rod 27 is provided with a piston 28 which reciprocates within a piston housing 33. The housing 33 is provided with a pair of conduits 29 and 30 which are alternately connected to a source of gas under pressure.

The operation of the preferred apparatus shown in Figure 1 is as follows. Thermoplastic material is fluxed in the extruder 6. A fluid blowing agent is admitted under pressure directly into the barrel of the extruder by means of line 7 and is admixed therein with the melted thermoplastic. The mixture which is extruded from the extruder 6 is at a temperature above the foaming temperature of the blowing agent and under a pressure substantially above the foaming pressure thereof. The extruder 6, which is in continuous communication with an expanding accumulation zone 35

defined by the cylinder 10, the piston 11 and the base member 19, continuously extrudes the mixture of thermoplastic material and blowing agent through line 9, into the zone 35, and against the piston 11. As the mixture is fed from the extruder into the zone 35, the piston is forced from its lower-most position to an upper, predetermined position. In Figure 1, the lower-most position of the piston 11 is reached when the piston 11 comes in contact with the base member 19. The upward travel of piston 11 and piston 14 is resisted by means of a gas under pressure in the region 15 above the piston 14 in the piston housing 32. The phrase "gas under pressure" is intended to include any suitable hydraulic fluid conventionally used in such apparatus. In addition, the region 15 in the piston housing 32 is provided with a conduit 31 which is in communication with a source of gas under pressure. As the material from the extruder forces piston 11 upward, and at the same time forces piston 14 upward, the gas in region 15 is compressed. Since the charging of the zone 35 is opposed by the piston 11, the filling of the zone 35 cannot start until the extruder pressure exceeds the back-pressure of the piston 11. As the piston 11 moves upward, the gas volume in region 15 is decreased and the gas pressure is increased. The extruder pressure must continuously exceed the increasing piston pressure during the expansion of the zone 35. Alternatively, during the expansion of the zone 35, the pressure of the gas in region 15 can be regulated so that a substantially constant force is applied to the piston 14. In any case, the mixture being charged into the expanding zone 35 must be maintained at a pressure above the foaming pressure thereof. While a pressure of as low as about 500 psi will normally prevent premature foaming of the mixture, pressures of at least 1500 psi have been found to give best results. Pressures in excess of 10,000 psi are usually not required for proper operation of the accumulator device and normally should be avoided because operating expenses increase with increasing pressures.

In addition, if necessary, the cylinder 10 can be provided with heating means, not shown, to prevent solidification of thermoplastic material therein. It should be noted, however, that no additional heating of the molten mixture while it is in the cylinder 10 is required. Heat is applied to the material in the extruder 6 to melt the same and is only maintained in the molten state in the cylinder 10.

The piston 11 travels upward until the flange 13, carried by the shaft 12, contacts the switch 17 located at a predetermined position. In a manner well known in the art, the activation of the switch 17 causes gas under pressure to enter piston housing 33 through conduit 29 and produces an upward motion of the piston 28. The lower end of the rod 27 is thereby withdrawn from the nozzle 23 until it reaches

a position indicated by the reference numeral 37. Communication between (1) the mold defined by mold halves 24 and 25 and (2) the zone 35 and the extruder 6 is thus established.

5 As the instant communication is established, the mixture is forced from the accumulation zone 35 into the mold because the pressure within the region 15, which has now become greater than the pressure within the zone 35, causes the downward motion of the piston 11 until it reaches its lower-most position. If necessary, the line 21 and the base member 22 can be provided with heating means, not shown, to prevent solidification of thermoplastic material therein. Normally however, the short molding cycles used in the present invention eliminate the need for any additional heating.

20 When the piston 11 reaches its lower-most position the zone 35 is essentially collapsed and the flange 13 contacts the switch 16, and in a manner well known in the art, gas under pressure is caused to enter the piston housing 33 through conduit 30 thereby producing a downward movement of the piston 28 and the rod 27. At the instant the rod 27 enters the nozzle 23 at the point 36, communication is terminated between (1) the mold and (2) the accumulation zone 35 and the extruder 6 at a point remote from the mold where the pressure is above the foaming pressure of the mixture. As the rod 27 travels downward it forces the mixture in the nozzle 23, that is, between the point 36 and the mold, into the mold and the bottom of the rod 27 comes flush with the molded article 34. In this manner, a sprue-free molded article is produced and the formation of an unfoamed slug in the system is prevented. The mold halves 24 and 25 are separated and the sprue-free molded article 34, in this case a tote box, shown in Figures 3 and 4 and previously described, is removed. It should be evident that foamed articles can be molded according to the present invention having either a sprue or a depression simply by adjusting the rod 27. While it is preferred to mold sprue-free articles, the configuration of certain molded articles will be able to tolerate a sprue or a depression. It should also be evident that the apparatus of this invention can be employed to mold solid thermoplastic articles.

55 Because of the pressure differential between the mold and the accumulation zone, the mixture rapidly foams and expands in the mold. The filling of the mold, which is caused by the action of the piston 11, the rod 27, and the expansion of the mixture in the mold, should preferably involve a period of approximately 1 to 15 seconds.

60 The flow of gas under pressure through conduits 29 and 30 is controlled by means of a valve system actuated by the switches 16 and 17 in a manner well known in the art.

65 The switch 17 is positioned in accordance

with the amount of material which is required to be charged into the mold. The greater the distance between the switches 16 and 17, the greater will be the upward travel of the piston 11. Consequently a larger amount of material will be stored in the accumulation zone 35 and subsequently forced into the mold. Conversely, decreasing the space between the switches 16 and 17 decreases the amount of material which will be forced into the mold.

While lowering the temperature of the mold decreases the time required for cooling the thermoplastic material in the mold and consequently decreases the time required for the molding operation, when employing high density polyethylene for example, high mold temperatures of at least about 265°F. can produce a smooth glazed surface, which is desirable in many applications. Lower mold temperatures; on the other hand, tend to produce a grainy surface texture similar in appearance to the texture of wood.

Low mold temperatures can be employed without interfering with the flow of plastic in the mold and without producing internal stresses.

The ability to fill a cold mold (e.g. at room temperature, about 70°F.) without encountering problems such as incomplete filling due to premature solidification of plastic and high residual internal stress due to flow resistance would at least in part seem to be due to the fact that the molten polymer, when suddenly transferred from the high pressure accumulation zone to the low pressure mold, "explodes" into small particles and fills the mold while in this form. The particles fuse together once in the mold, thus forming a resultant article which is substantially free of orientation and internal stresses (isotropic).

The outwardly acting pressure of the expanding particles apparently forces the outermost mass of polymer against the surface of the mold, thus destroying the cell structure of this mass of material. This serves not only to form a dense peripheral shell, but also serves to produce a finished article which accurately conforms to the configurations of the mold.

The degree to which the plastic "explodes" as well as the rapidity of filling the mold and the degree of foaming increase with increasing quantities of blowing gas in the molten plastic. However, particularly in regard to density, the size and configuration of the mold influences the effect of the blowing gas.

Molds which cause sharp pressure drops to take place therein, due to a complex configuration, or sharp corners, for example require the use of a greater amount of blowing gas in order to achieve a particular degree of foaming than a mold which has, for example, a simple configuration like that of a bowling pin and which produces a more gradual pressure drop. It would appear that the complex mold configuration, and the consequent sharp change

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in pressure which the mixture undergoes cause a substantial loss of gas from the mixture. This gas leaves the mold through the vent openings conventionally employed in molds, and thus is unavailable to produce a foaming action.

From the foregoing description, it is evident that the process and preferred apparatus of this invention can be employed to rapidly, efficiently, and automatically mold foamed thermoplastic articles on a batch, semi-continuous or continuous basis.

Figure 2 illustrates an alternative embodiment of the accumulator device of this invention. In this embodiment, the piston 11 and the shaft 12 are shown co-axial with the rod 27 thus providing a more compact equipment arrangement. The piston 11 and the shaft 12 are provided with a centrally positioned internal bore in which the rod 27 reciprocates. Migration of material between the rod 27 and the internal bore of the piston 11 and the shaft 12 is prevented by providing a slip fit between the rod and bore and/or providing conventional sealing rings therebetween. The piston housing 33 for the piston 28 is mounted above and is co-axial with the piston housing 32 for the piston 14. The operation of the accumulator device shown in Figure 2 is the same as has been described previously for the apparatus of Figure 1.

In one embodiment of this invention, it has been found that the use of a primary distributor channel in the mold in conjunction with a plurality of secondary distributor channels permits rapid filling of a mold and results in a molded article of less weight than would be expected without any loss in strength. This embodiment is illustrated in Figure 5 wherein the male half of an open structured tote box mold is shown. A female mold half, not shown, is adapted to fit over the male half, in an arrangement similar to the mold halves shown in Figure 1, thereby forming a mold cavity and the distributor channels described below. Such distributor channels may be employed in molds for producing open structures such as "tote" boxes for tomatoes or eggs for example, or for producing closed structures such as a storage battery casing. The primary distributor channel in the mold is in direct communication with the feed inlet through which the mold is filled while the secondary distributor channels are in communication with the primary distributor channel. For purposes of this invention, it is preferred to employ a plurality of primary distributor channels arranged in an equally spaced radial pattern about the feed inlet or inlets through which the mold is filled with at least one of the primary channels having a plurality of secondary distributor channels in communication therewith.

As is shown in Figure 5, it is even more preferred to employ a plurality of primary distributor channels 51, 52, 53, and 54 arranged in an equally spaced radial pattern about the

feed inlet through which the mold is filled, the position of which in the female half (not shown) is indicated by the dotted circle 50 on the male half, with the primary channels 51 and 53 each having at least four equally spaced secondary distributor channels 55 in communication therewith. Thus, it is possible to employ two or more radially spaced primary distributor channels (52 and 54) in a mold without any secondary distributor channels in communication therewith with two or more radially spaced primary distributor channels (51 and 53) each having two or more secondary distributor channels in communication therewith. With such distributor channels, a mold can be filled so rapidly that the molded article weighs less than would be expected but, because of the unique rigidity to weight ratios obtainable with the process of this invention, does not exhibit any decrease in strength as would be expected from the reduction in weight.

A wide variety of useful foamed articles can be molded in accordance with this invention. Illustrative, but by no means limiting of such articles are shoe lasts, bowling pins, containers, particularly fluid-tight and/or thermally insulated containers, such as storage battery cases, farm product containers such as asparagus and tomato boxes, poultry coops, milk cases, other containers such as bomb fin, shell and soda cases, battery trays, shopping cart baskets, gun stocks, paint brush handles, broom and shovel handles, kitchen drawers, car seats, seat and back pans for children's car seats, highchairs, frames for baby recliners, top and storage bins for baby dressers, wardrobes and bathinettes, furniture drawers, take-or-leave pallets, lawn mower housings, conduits, and articles having the appearance, sound and weight characteristics of wood.

It is to be understood that while the mixture in the accumulation zone is maintained at a substantially constant pressure, this pressure being greater than the pressure at which the blowing agent causes the foaming and expansion of the foamable material, pressures which would absolutely prevent foaming are unnecessary in the present invention for minor bubbling is not significant and is not detrimental to the resultant product.

The phrases "melt index," "melting temperature," and "foaming pressure," as used herein are defined as follows:

"Melt index" is an indication of molecular weight and viscosity and is determined in accordance with ASTM Test D-1238-57T.

The phrase "melting temperature" refers to the general temperature range at which the material becomes sufficiently fluid to be processed in the manner heretofore described. Thus the material would thus be about sufficiently soft or fluid to flow through an extruder, an accumulator or a mold, or be foamed and expanded by an internally contained gas.

The phrase "foaming pressure" refers to the pressure at which an internally contained gas can produce the substantial foaming and expansion of the plastic material within which it is contained.

The following examples are intended to further illustrate the present invention without

limiting the same in any manner.

EXAMPLE 1

The equipment shown in Figure 1 was used to mold seat and back pans for an infant car seat from polyethylene having a density of 0.96 and a melt index of 4.0 under the following conditions:

Extruder RPM's	16
Temperature of material in extruder	515° F.
Nitrogen injection pressure, Fig. 1, line 7	2400 psi
Accumulation zone pressure	2800 psi
Accumulation zone temperature	350° F.
Mold pressure	Atmospheric
Mold temperature	45° F.

The molded pans had a slightly grainy surface and had a cellular core and a non-cellular skin in cross section.

EXAMPLE 2

The equipment shown in Figure 1 was used to mold child's safety car seats from polyethylene having a density of 0.96 and a melt index of 4.0 under the following conditions:

Extruder RPM's	17
Temperature of material in extruder	540° F.
Nitrogen injection pressure, Fig. 1, line 7	2400 psi
Accumulation zone pressure	2800 psi
Accumulation zone temperature	350° F.
Mold Pressure	Atmospheric
Mold Temperature	50° F.

The mold seats had a cellular core and a non-cellular skin in cross section. No voids were present in the molded parts.

EXAMPLE 3

The equipment shown in Figure 1 was used

to mold sprue-free kitchen cabinet drawers from a blend of 25 lbs. of polyethylene having a density of 0.96 and a melt index of 4.0 and 5 lbs. of medium impact, free flowing polystyrene under the following conditions:

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Extruder RPM's	25
Temperature of material in extruder	530° F.
Nitrogen injection pressure, Fig. 1, line 7	2800 psi
Accumulation zone pressure	2800 psi
Accumulation zone temperature	350° F.
Mold pressure	Atmospheric
Mold temperature	~60° F.

The molded drawers were sprue free, had a slightly grainy appearance and a cellular core and a non-cellular skin in cross section. The Izod impact (ASTM D-256) of the drawers was 1.06.

EXAMPLE 4

Example 3 was duplicated using instead a blend of 25 lbs. polyethylene and 1 lb. polysty-

rene. Results were the same and the Izod impact was 1.26.

EXAMPLE 5

The equipment shown in Figure 1 but with the accumulator device of Figure 2 was used to mold sprue free rectangular containers from polypropylene under the following conditions:

Temperature of material in extruder	400° F.
Nitrogen injection pressure, Fig. 1, line 7	600 psi
Accumulation zone pressure	2000 psi
Accumulation zone temperature	350° F.
Distance between switches 16 and 17	6-3/4"
Mold pressure	Atmospheric
Mold temperature	70° F.

A shot weight of 3.93 pounds was obtained having an overall density of 0.66 and the material completely filled the mold leaving no voids in the mold. The molded article was sprue free and in cross section had a cellular core and a substantially non-cellular, integral peripheral shell.

EXAMPLE 6

Example 5 was duplicated but the distance between the switches was 6-1/2" and the injection pressure of the nitrogen was increased from 600 psi to 1500 psi. The container had a shot weight of 3.80 pounds and an overall density of 0.64. The material completely filled the mold.

EXAMPLE 7

Example 5 was duplicated with the switches 6-1/4" apart and the nitrogen pressure maintained at 1500 psi. The shot weight of the container was 3.68 pounds and the overall density was 0.62. The mold was completely filled with material and no voids appeared.

EXAMPLE 8

The equipment shown in Figure 1 but with the accumulator device of Figure 2 was used to mold sprue-free rectangular containers from polyethylene having a density of 0.96 and a melt index of 4.0 under the following conditions:

Temperature of material in extruder	400° F.
Nitrogen injection pressure, Fig. 1, line 7	1800 psi
Accumulation zone pressure	2000 psi
Accumulation zone temperature	350° F.
Distance between switches 16 and 17	5—3/4"
Mold pressure	Atmospheric
Mold temperature	70° F.

5 The mold was completely filled and the containers were sprue-free and had a cellular core and a non-cellular skin in cross section. A container weighing 3.33 lbs was obtained having an overall density of 0.56. The mold was completely filled with material and no voids were present in the mold.

EXAMPLE 9

10 Example 8 was duplicated using a nitrogen injection pressure of 1500 psi. The distance between the switches was 6-3/4". A container

weighing 3.97 lbs and having a density of 0.67 was obtained. The mold was completely filled with no voids noted.

EXAMPLE 10

The equipment shown in Figure 1 but with the accumulator device of Figure 2 was used to mold sprue free two cell battery casings and covers from polyethylene having a density of 0.96 and a melt index of 4.0 under the following conditions:

Extruder RPM's	12
Temperature of material in extruder	600° F.
Nitrogen injection pressure, Fig. 1, line 7	2800 psi.
Accumulation zone pressure	2800 psi
Accumulation zone temperature	350° F.
Mold pressure	Atmospheric
Mold temperature	~60° F.

25 The molded casing was sprue free and had a wall thickness of 190—205 mils and required no further finishing. In a manner well known in the art, a two cell, 3 volt battery was constructed using the molded casing and cover with carbon-zinc electrodes and an alkaline electrolyte. The dielectric strength of the casing walls was found to be above 80 volts/mil. After one month, a weight increase of less than

1% was noted and the strength of the casing was substantially unchanged.

EXAMPLE 11

The equipment shown in Figure 1 but with the accumulator device of Figure 2 was used to mold sprue free kitchen cabinet drawers from a medium impact, free-flowing polystyrene under the following conditions:

L.C.

Extruder RPM's	22
Temperature of material in Extruder	550° F.
Nitrogen injection pressure, Fig. 1, line 7	2800 psi
Accumulation zone pressure	2800 psi
Accumulation zone temperature	350° F.
Mold pressure	Atmospheric
Mold temperature	~80° F.

The mold was completely filled and the molded drawers were sprue free and had a cellular core and a non-cellular skin in cross section.

EXAMPLE 12

The equipment shown in Figure 1 but with

the accumulator of Figure 2 was used to mold milk carton tote boxes from acrylonitrile-butadiene-styrene resin under the following conditions:

Extruder RPM's	15
Temperature of material in extruder	450° F.
Nitrogen injection pressure, Fig. 1, line 7	2800 psi
Accumulation zone pressure	3000 psi
Accumulation zone temperature	355° F.
Mold pressure	Atmospheric
Mold temperature	~60° F.

The mold was completely filled and the molded article had a cellular core and a non-cellular skin in cross section.

EXAMPLE 13

The equipment shown in Figure 1 but with

the accumulator device of Figure 2 was used to mold lawn mower housings from polyethylene having a density of 0.96 and a melt index of 0.2 under the following conditions:

Extruder RPM's	15
Temperature of material in extruder	515° F.
Nitrogen injection pressure, Fig. 1, line 7	2700 psi
Accumulation zone pressure	3000 psi
Accumulation zone temperature	350° F.
Mold pressure	Atmospheric
Mold temperature	~60° F.

The mold was completely filled and the molded article had a cellular core and a non-cellular skin in cross section.

EXAMPLE 14

5 The equipment shown in Figure 1 but with

the accumulator device of Figure 2 was used to mold battery casings from a polyethylene-ethyl acetate copolymer containing 18 per cent by weight of ethyl acetate under the following conditions:

10

Extruder RPM's	19
Temperature of material in extruder	405° F.
Nitrogen injection pressure, Fig. 1, line 7	2850 psi
Accumulation zone pressure	3000 psi
Accumulation zone temperature	350 °F.
Mold pressure	Atmospheric
Mold temperature	~60° F.

The mold was completely filled and the molded article had a cellular core and a non-cellular skin in cross section.

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EXAMPLE 15

The equipment shown in Figure 1 but with

the accumulator device of Figure 2 was used to mold battery casings from a polyethylene-vinyl acetate copolymer containing 28 per cent by weight vinyl acetate under the following conditions:

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Extruder RPM's	18
Temperature of material in extruder	385° F.
Nitrogen injection pressure, Fig. 1, line 7	2800 psi
Accumulation zone pressure	2800 psi
Accumulation zone temperature	350° F.
Mold pressure	Atmospheric
Mold temperature	~60° F.

25 The mold was completely filled and the molded article had a cellular core and a non-cellular skin in cross section.

EXAMPLE 16

The apparatus of Figure 1 but with the accumulator device of Figure 2 was employed. One hundred parts of grey pigmented polyethylene pellets having a density of 0.96 were charged into the extruder. The polyethylene was worked and heated in the extruder until the material attained a temperature of about 420°F. Nitrogen was slowly fed into the barrel of the extruder and therein mixed with the molten polyethylene. The extruder 6 charged material to an accumulation zone 35 maintained at 350°F. and under a pressure of 2300

psi. The mold was maintained at about 70°F. and at atmospheric pressure.

40

The mold design used was an open structure for a rectangular tomato tote box having eight equally spaced voids (or slots in the molded box) parallel to each other and running the length of the bottom of the mold. The feed inlet through which the mold was filled was located centrally of the bottom of the mold (outside bottom of the molded box). Four tote boxes molded using this mold had an average weight of 3.82 pounds and an average tensile strength of about 1200 psi.

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The mold design was then modified to provide a distributor channel running diagonally from one corner in the bottom of the mold to the other. Thus, the modified mold was pro-

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vided with two primary distributor channels in communication with the feed inlet and arranged in an equally spaced radial pattern about the feed inlet with each having a plurality (ten) of secondary distributor channels in communication therewith. Two tote boxes molded using the modified mold had an average weight of 3.61 pounds and an average tensile strength of about 1200 psi. The average weight here was 0.21 pound less than the boxes molded with the unmodified mold yet the tensile strength remained substantially the same. This was quite unexpected because in adding a diagonal distributor channel, it would be expected that weight would be added to the molded box rather than a decrease in weight as was actually discovered.

EXAMPLE 17

A mixture comprising 100 parts by weight of polyethylene and one quarter of 1 part by weight azodicarbonamide were charged to a Banbury mixer and mixed at a temperature below the decomposition temperature of the azodicarbonamide. The polyethylene employed had a density of 0.96 and a melt index of 0.2. The mixture was charged to the cylinder of a screw extruder wherein it was thoroughly worked and fed therealong by means of a screw. The cylinder was heated to a temperature of 400°F. to cause the dispersed azodicarbonamide particles to decompose. The extruder charged material to an accumulator maintained at a temperature of 330°F. and at a pressure of 1740 psi. The pressure exerted on the composition by the screw and the back-pressure exerted by the accumulator was such as to substantially prevent the gas resulting from the decomposition of the azodicarbonamide particles from expanding. The pressure on the accumulator continuously increased as the extruder operated indicating that material was being charged to the accumulator. When a pressure of 3200 psi was reached the rotation of the screw of the extruder was stopped and thus the extruder ceased to charge material to the accumulator. With the pressure on the accumulator stabilized at about 3200 psi a valve between the accumulator and a bowling pin mold was rapidly changed to establish communication between the accumulator and mold. The material rapidly transferred into the mold which was maintained at atmospheric pressure and a temperature of 320°F. After a few seconds elapsed, the mold was rapidly cooled and then opened and the resultant bowling pin weighed. The bowling pin had a weight of 3.05 pounds and had a glazed, polished-like surface. The bowling pin was cut in half, and was seen to have a dense outer shell and a cellular core. At a distance of about one quarter of an inch from the surface, the density of the material substantially decreased.

EXAMPLE 18

Employing the process of Example 17, a bowling pin was formed in a mold maintained

initially at 265°F., and then a few seconds after the filling operation, rapidly cooled in order to reduce the cycle time. The surface of the pin was glazed in appearance and the internal structure was similar to that of the pin of Example 17.

EXAMPLE 19

The process of Example 17 was employed to produce a bowling pin in a mold maintained at 235°F. prior to filling and rapidly cooled a few seconds after filling. The resultant bowling pin had a rough, grainy surface, similar in texture to wood.

A comparison of bowling pins made in accordance with Examples 17—19 and coated wooden pins yielded comparable results with regard to impact response, impact sound and center of gravity. The surface hardness and impact strength of the foamed high density polyethylene bowling pins exceeded that of the coated wooden pins.

The bowling pin of Example 19 was provided with an ethyl cellulose coating, in order to provide a finished appearance. Although adhesion to polyethylene is normally difficult, the coating was found to tenaciously adhere to the grainy surfaces of polyethylene. The surfaces of the bowling pins of Examples 17 and 18 were adequate in appearance without the use of a coating.

Because of the ability to accurately measure the amount of plastic which will be charged to the mold, greater exactness of weight can be attained in the foamed pins of the present invention, than is attained in wooden pins.

Conventional stains of the type employed in staining wood, when applied to conventionally molded or extruded polyethylene articles can be rubbed off the surface of polyethylene after the stain has been fully dried. The foamed article of Example 19, however, retains stains without the need of further surface treatment. The use of wood colored stains yields an article which, because of its grainy surface texture, has the appearance of wood. Since, as previously noted, the foamed articles can also have the sound, impact response and weight characteristics of wood, wood substitute articles can be produced by the process of the present invention. Of particular significance, is the ability to produce a molded plastic cabinet having the aesthetically desirable wood-like appearance in addition to the characteristic acoustical properties of wood. Moisture resistance and high impact resistance can thus be built into a speaker cabinet without a sacrifice in fidelity.

EXAMPLE 20

A mixture of 100 parts of 0.96 density polyethylene and one quarter part azodicarbonamide were premixed in the manner set forth in Example 17. The extruder temperature was maintained below about 300°F. and employing the process of Example 17, the mixture was charged into an accumulator initially maintained at 1450 psi and below about

300°F. The accumulator was heated to 400°F. and the material which was heated to 375°F., in the accumulator and maintained at a maximum pressure of 3000 psi was released into a 70°F. mold, having the shape of a shoe last. The shoe last weighed 3 pounds, and had a density of 0.73. Under internal examination, the same cellular core-solid outer skin structure produced by the processes set forth in Examples 17—20, was found to have been formed. The shoe last was found to hold nails even after repeated nailing and extraction of nails. The extremely fine cell structure of the core section was also noted to have adequate nail holding power.

WHAT WE CLAIM IS:—

1. A process for molding foamed thermoplastic articles, which comprises fluxing a mixture of a foamable thermoplastic material and a blowing agent in an extruder at a temperature and pressure above the temperature and pressure at which the mixture foams, continuously extruding said mixture into an expanding accumulation zone while maintaining the mixture therein at a pressure above the foaming pressure thereof, the accumulation zone expanding at a rate substantially equal to the rate of extrusion, maintaining a mold remote from the accumulation zone at a pressure at which the mixture foams and expands, establishing communication between the mold and the accumulation zone, rapidly forcing the mixture out of the accumulation zone and into the mold wherein the mixture foams and expands, terminating communication between the mold and the accumulation zone at a point where the pressure is above the foaming pressure of the mixture, and thereafter removing the mixture between said point and said mold.

2. A process as claimed in claim 1 wherein the communication between the mold and the accumulation zone is terminated at a point remote from the mold where the pressure is above the foaming pressure of the mixture, and thereafter rapidly forcing the mixture between said point and said mold into the mold.

3. A process as claimed in claim 1 or claim 2, in which the foamable thermoplastic material is a polyolefin.

4. A process as claimed in claim 3, in which the polyolefin is a high density polyethylene.

5. A process as claimed in any one of claims 1 to 4, in which establishment and termination of communication between the mold and the accumulation zone is determined by the expansion and collapse of said accumulation zone.

6. A process as claimed in any one of claims 1 to 5, in which the mold is maintained at a temperature below the melting temperature of the foamable thermoplastic material.

7. A process as claimed in any one of claims 1 to 6, in which the mold is at atmospheric pressure.

8. A process as claimed in any one of claims

1 to 7, in which the mixture is forced from the accumulation zone into the mold and from the point remote from the mold into the mold in a time of from 1 to 15 seconds.

9. A process for molding foamed thermoplastic articles substantially as hereinbefore described and with reference to any one of the Examples.

10. An apparatus for molding foamed thermoplastic articles, which comprises an extruder for extruding a mixture of a foamable thermoplastic material and a blowing agent, an expandable accumulation chamber for the foamable mixture communicating with the extruder and defined by the inner wall of a hollow cylindrical member and the head of a first piston in sliding engagement with said inner wall and reciprocally movable in said cylindrical member, expansion and collapse of the accumulation chamber being effected by upward and downward movement of said first piston, a filling nozzle connected to the accumulation chamber and extending to and flush with a mold cavity, a rod slidably mounted in the nozzle and attached to a second piston adapted to reciprocate within a housing, communication between the accumulation chamber and the mold being established by upward movement of the rod until the extremity of said rod reaches the point of communication of the nozzle with the accumulation chamber thereby opening a passage for the foamable mixture, termination of the communication and forcing of said foamable mixture out of the nozzle from said point of communication into the mold being effected by downward movement of the rod, movement of the second piston being responsive to movement of the first piston and thereby establishing communication when the first piston reaches the end of its upward movement and terminating communication when the first piston reaches the end of its downward movement.

11. An apparatus as claimed in claim 10, in which the first piston is adapted to move upwardly at a rate substantially equal to the rate of extrusion.

12. An apparatus as claimed in claims 10 and 11, in which upward movement of the first piston is controlled by a gas under pressure in a housing for said piston.

13. An apparatus as claimed in any one of claims 10 to 12, in which the first and second pistons are coaxial.

14. An apparatus as claimed in any one of claims 10 to 12, in which the filling nozzle is connected to the accumulation chamber through a conduit.

15. An apparatus as claimed in any one of claims 10 to 14, in which the mold is provided with a plurality of primary distributor channels in direct communication with a feed inlet through which the mold is filled, said primary channels being disposed in an equally spaced radial pattern about said feed inlet, at least



300°F. The accumulator was heated to 400°F. and the material which was heated to 375°F., in the accumulator and maintained at a maximum pressure of 3000 psi was released into
5 a 70°F. mold, having the shape of a shoe last. The shoe last weighed 3 pounds, and had a density of 0.73. Under internal examination, the same cellular core-solid outer skin structure
10 produced by the processes set forth in Examples 17—20, was found to have been formed. The shoe last was found to hold nails even after repeated nailing and extraction of nails. The extremely fine cell structure of the core
15 section was also noted to have adequate nail holding power.

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1. A process for molding foamed thermoplastic articles, which comprises fluxing a mixture of a foamable thermoplastic material and
20 a blowing agent in an extruder at a temperature and pressure above the temperature and pressure at which the mixture foams, continuously extruding said mixture into an expanding accumulation zone while maintaining the
25 mixture therein at a pressure above the foaming pressure thereof, the accumulation zone expanding at a rate substantially equal to the rate of extrusion, maintaining a mold remote from the accumulation zone at a pressure at
30 which the mixture foams and expands, establishing communication between the mold and the accumulation zone, rapidly forcing the mixture out of the accumulation zone and into the mold wherein the mixture foams and expands, terminating communication between the
35 mold and the accumulation zone at a point where the pressure is above the foaming pressure of the mixture, and thereafter removing the mixture between said point and said mold.

40 2. A process as claimed in claim 1 wherein the communication between the mold and the accumulation zone is terminated at a point remote from the mold where the pressure is above the foaming pressure of the mixture, and
45 thereafter rapidly forcing the mixture between said point and said mold into the mold.

3. A process as claimed in claim 1 or claim 2, in which the foamable thermoplastic material is a polyolefin.

50 4. A process as claimed in claim 3, in which the polyolefin is a high density polyethylene.

55 5. A process as claimed in any one of claims 1 to 4, in which establishment and termination of communication between the mold and the accumulation zone is determined by the expansion and collapse of said accumulation zone.

60 6. A process as claimed in any one of claims 1 to 5, in which the mold is maintained at a temperature below the melting temperature of the foamable thermoplastic material.

7. A process as claimed in any one of claims 1 to 6, in which the mold is at atmospheric pressure.

8. A process as claimed in any one of claims

1 to 7, in which the mixture is forced from the accumulation zone into the mold and from the point remote from the mold into the mold in a time of from 1 to 15 seconds.

9. A process for molding foamed thermoplastic articles substantially as hereinbefore described and with reference to any one of the Examples.

10. An apparatus for molding foamed thermoplastic articles, which comprises an extruder for extruding a mixture of a foamable thermoplastic material and a blowing agent, an expandable accumulation chamber for the foamable mixture communicating with the extruder and defined by the inner wall of a hollow cylindrical member and the head of a first piston in sliding engagement with said inner wall and reciprocally movable in said cylindrical member, expansion and collapse of the accumulation chamber being effected by upward and downward movement of said first piston, a filling nozzle connected to the accumulation chamber and extending to and flush with a mold cavity, a rod slidably mounted in the nozzle and attached to a second piston adapted to reciprocate within a housing, communication between the accumulation chamber and the mold being established by upward movement of the rod until the extremity of said rod reaches the point of communication of the nozzle with the accumulation chamber thereby opening a passage for the foamable mixture, termination of the communication and forcing of said foamable mixture out of the nozzle from said point of communication into the mold being effected by downward movement of the rod, movement of the second piston being responsive to movement of the first piston and thereby establishing communication when the first piston reaches the end of its upward movement and terminating communication when the first piston reaches the end of its downward movement.

11. An apparatus as claimed in claim 10, in which the first piston is adapted to move upwardly at a rate substantially equal to the rate of extrusion.

12. An apparatus as claimed in claims 10 and 11, in which upward movement of the first piston is controlled by a gas under pressure in a housing for said piston.

13. An apparatus as claimed in any one of claims 10 to 12, in which the first and second pistons are coaxial.

14. An apparatus as claimed in any one of claims 10 to 12, in which the filling nozzle is connected to the accumulation chamber through a conduit.

15. An apparatus as claimed in any one of claims 10 to 14, in which the mold is provided with a plurality of primary distributor channels in direct communication with a feed inlet through which the mold is filled, said primary channels being disposed in an equally spaced radial pattern about said feed inlet, at least

two of the primary channels each having a plurality of secondary distributor channels in communication therewith.

5 16. An apparatus for molding foamed thermoplastic articles, substantially as hereinbefore described with reference to any one of Figs. 1, 2, and 5 of the accompanying drawings.

10 17. Foamed thermoplastic articles whenever obtained by the process claimed in any one of claims 1 to 9.

18. Foamed thermoplastic articles, substantially as hereinbefore described with reference

to the Examples and as illustrated in Figs. 3 and 4 of the accompanying drawings.

19. Foamed thermoplastic articles when produced by the use of apparatus as claimed in any one of claims 10 to 16. 15

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