(19) **United States**

(12) **Patent Application Publication** (10) Pub. No.: **US 2003/0209553 A1**

Horn et al. (43) **Pub. Date:** **Nov. 13, 2003**

(54) **PLASTIC CONTAINERS WITH UNIFORM WALL THICKNESS**

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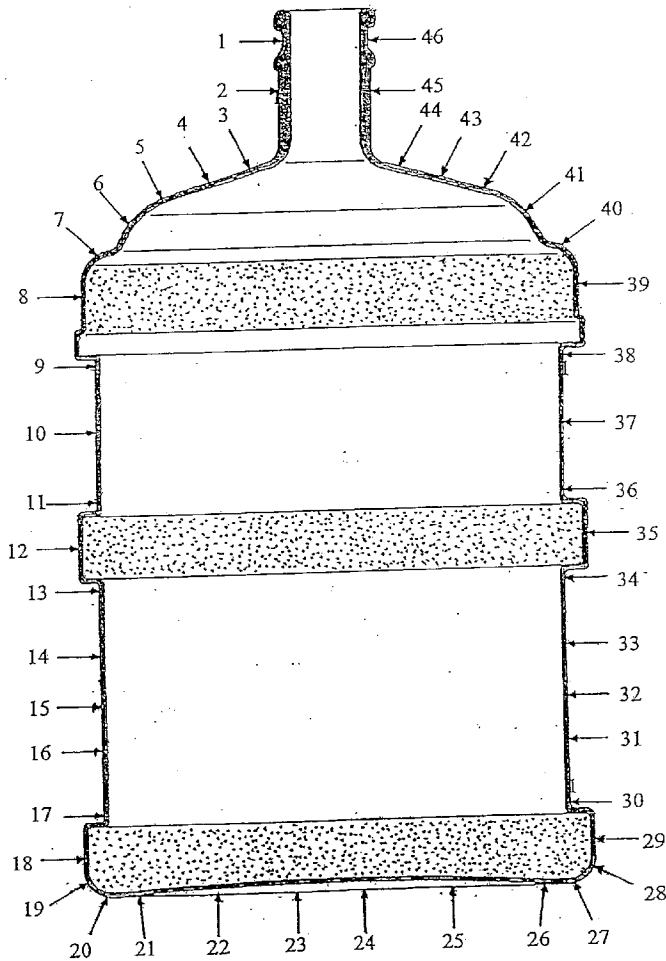**Publication Classification**

(57) **ABSTRACT**

A container having uniform wall thickness, molded of a thermoplastic composition is disclosed. The wall of the container at its thickest being at most three times as thick as at its thinnest. Also disclosed is a process for the preparation of the container. The process entails extrusion blow molding or injection stretch blow molding of a thermoplastic material characterized in that at a temperature of $200°$ C., its S value is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.0 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, and its S value is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.5 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, wherein S is $\eta_E$ divided by $3\eta$.
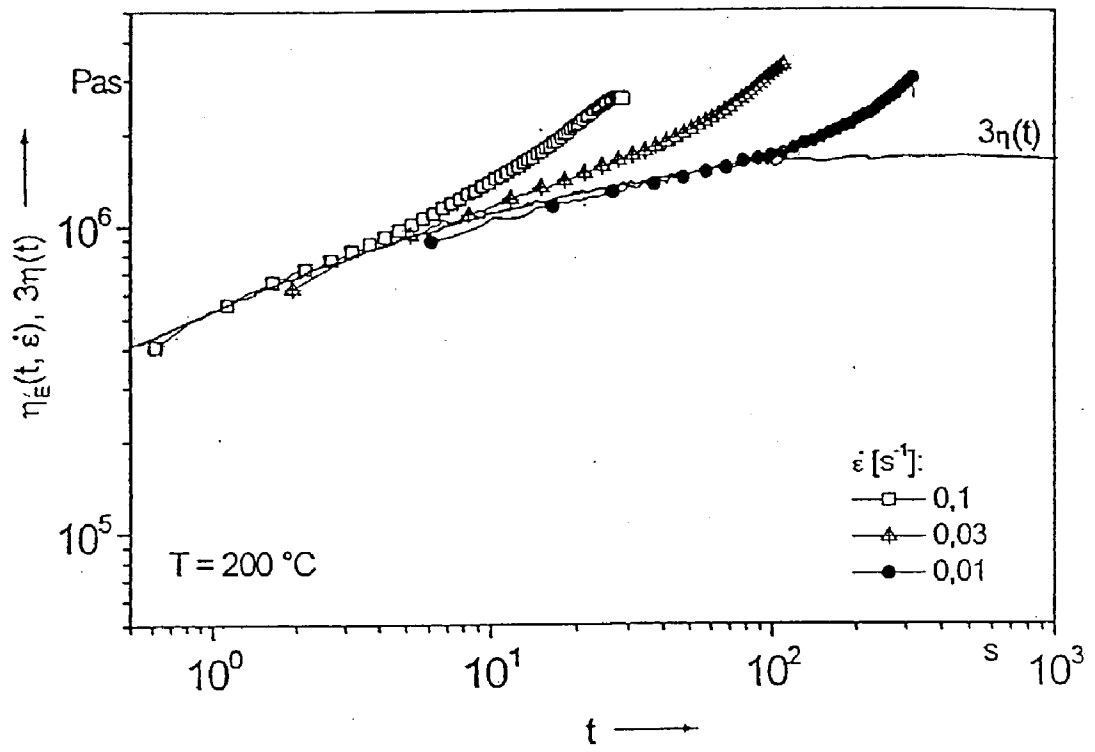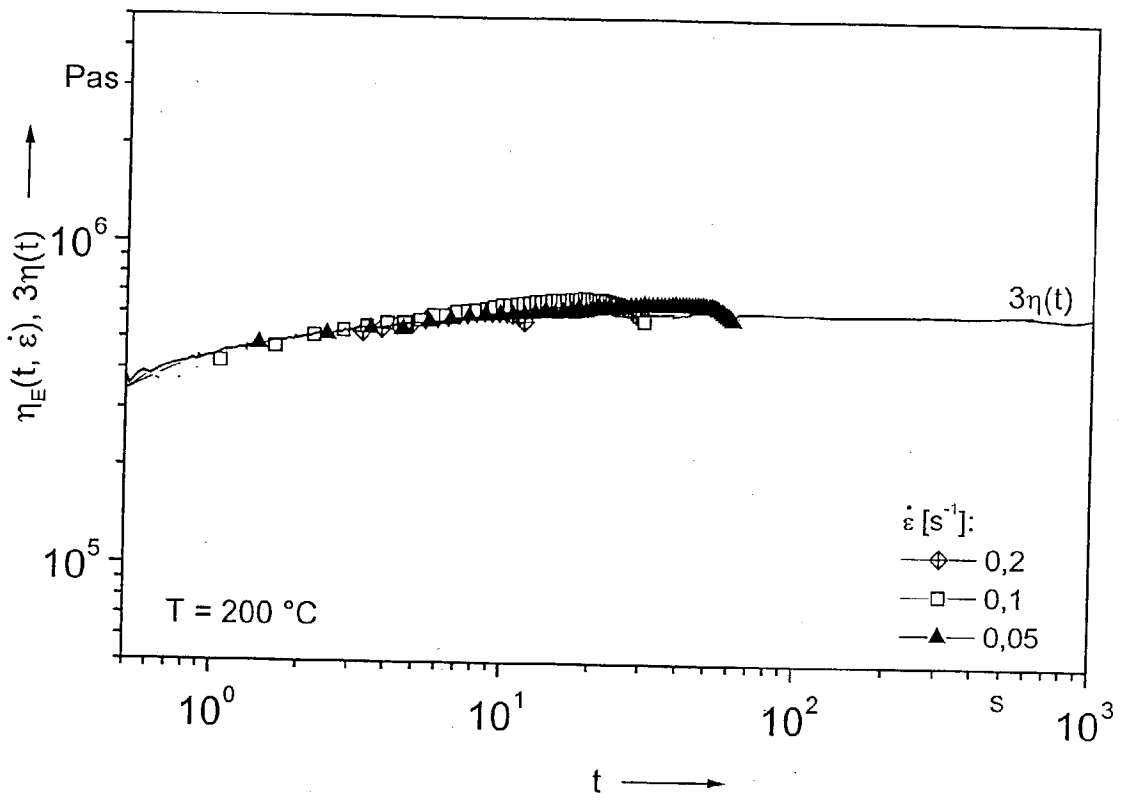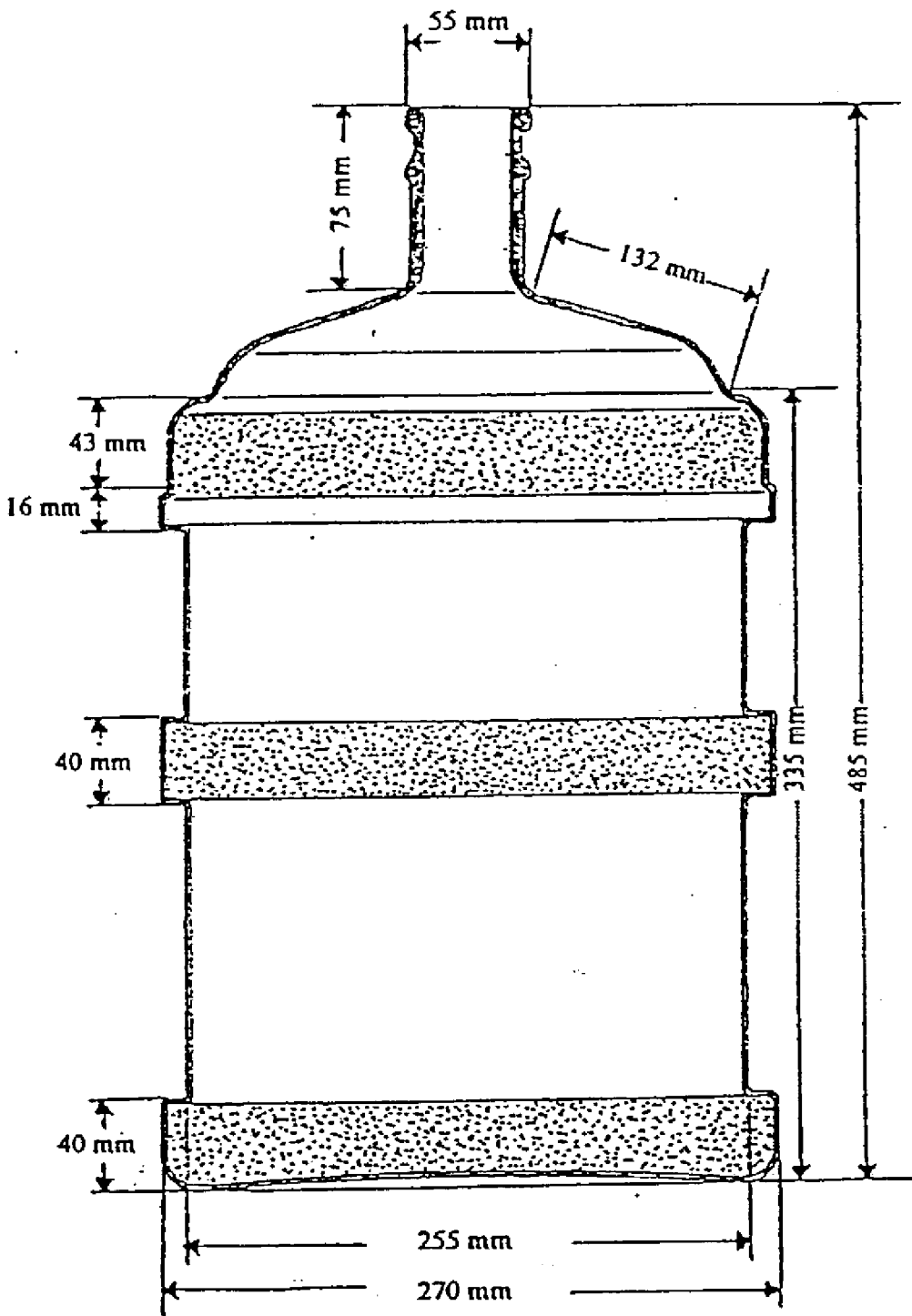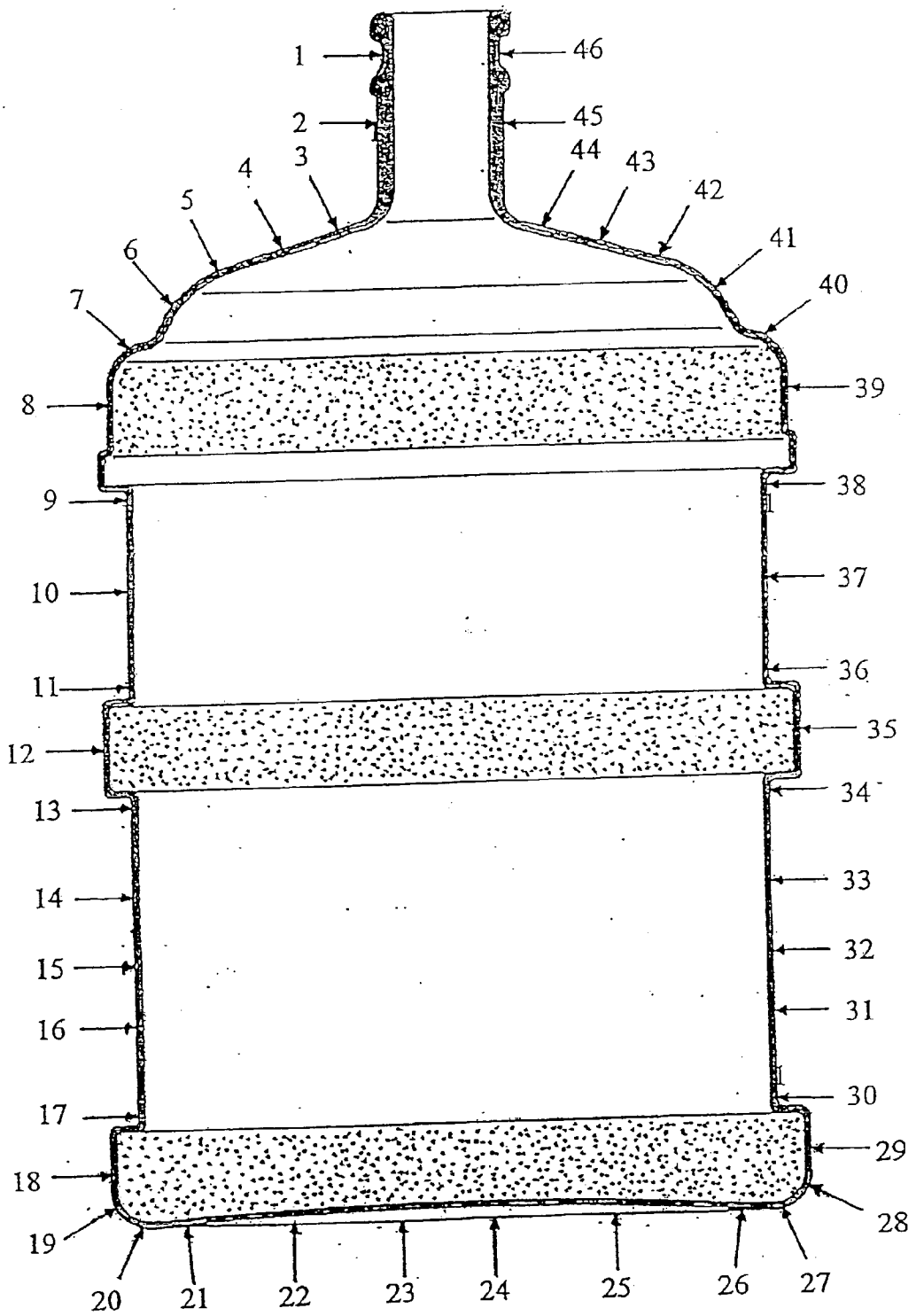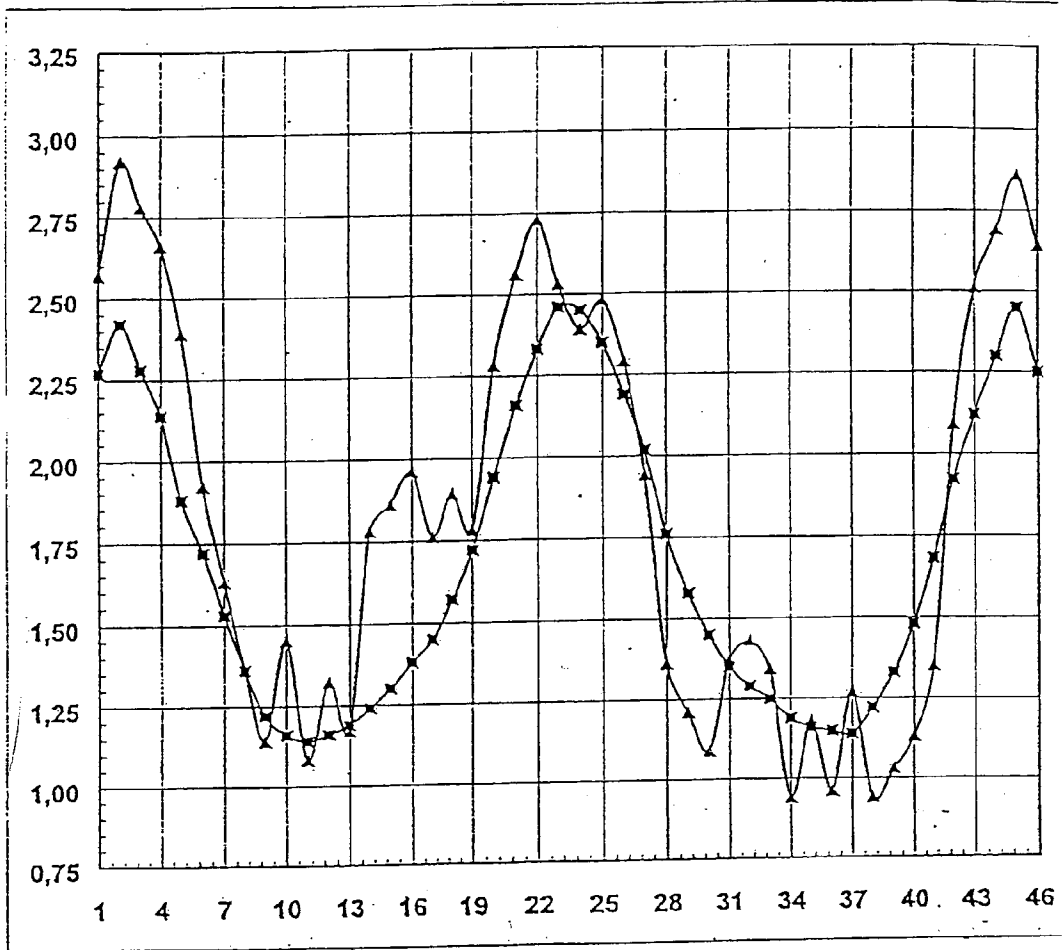
Fig. 1

Fig. 2

Fig. 3

**Fig. 4**

Fig.5

# PLASTIC CONTAINERS WITH UNIFORM WALL THICKNESS

## FIELD OF THE INVENTION

[0001]   The present invention relates to plastic containers and more particularly to containers with uniform wall thickness

## SUMMARY OF THE INVENTION

[0002]   A container having uniform wall thickness, molded of a thermoplastic composition is disclosed. The wall of the container at its thickest being at most three times as thick as at its thinnest. Also disclosed is a process for the preparation of the container. The process entails extrusion blow molding or injection stretch blow molding of a thermoplastic material characterized in that at a temperature of 200° C., its S value is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.0 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, and its S value is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.5 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, wherein S is $\eta_E$ divided by $3\eta$.

## BACKGROUND OF THE INVENTION

[0003]   Containers made of plastics material, in particular of polycarbonate, are basically known. These containers are produced, for example, from compositions (also called compounds) which contain a polymer, in particular polycarbonate, and conventional additives. These compositions that include the polymer (for instance polycarbonate) and the additives are also called plastics material. The additives may include stabilizers, processing aids, etc. In addition, the plastic containers may also comprise further components, such as seals made of rubber or grips made of metal or other materials. Therefore, it is more correct to speak of "containers made of plastics material" than of "plastic containers". In addition to the plastics material, the containers may, for example, comprise the aforementioned components and/or other components. Hereinafter "plastic containers" mean "containers made of plastics material".

[0004]   Plastic containers have numerous advantageous properties, such as high transparency, good mechanical properties, great resistance to environmental influences and a long life, as well as low weight and easy, inexpensive producibility.

[0005]   Plastic containers may be produced, for example by extrusion blow molding or injection stretch blow molding.

[0006]   In extrusion blow molding the plastics material is usually melted using a single-screw extruder and molded by a die into a free standing parison. The parison generally hangs downwards from the die. The parison is then surrounded by a blow mold which squashes the parison together at the lower end. The parison is then inflated within the mold so the parison obtains the desired shaping. After a cooling period the mold is opened and the blow molded container may be removed.

[0007]   Extrusion blow molding is disclosed, for example, in Brinkschröder, F. J.: "Polycarbonate" in Becker, Braun, Kunststoff-Handbuch, Vol. 3/1, Polycarbonate, Polyacetale, Polyester, Cellulose ester, Carl Hanser Verlag Munich, Vienna 1996, pages 248 to 255).

[0008]   Injection stretch blow molding is a combination of injection molding and blow molding.

[0009]   Injection stretch blow molding proceeds in three stages:

   [0010]   1. Injection molding the parison in the plastic temperature range of the plastics material

   [0011]   2. Inflating the parison in the thermoplastic range of the plastics material (the core of the injection mold is simultaneously the blowing mandrel)

   [0012]   3. Stripping the blow molding and optionally cooling the blowing mandrel with air

[0013]   Injection stretch blow molding is disclosed, for example, in Anders, S., Kaminski, A., Kappenstein, R., "Polycarbonate" in Becker,/Braun, Kunststoff-Handbuch, Vol. 3/1, Polycarbonate, Polyacetale, Polyester, Cellulose ester, Carl Hanser Verlag Munich, Vienna 1996, pages 213 to 216.

[0014]   The plastic containers known from the prior art have the drawback that they do not meet certain requirements which are important for practical use of the containers.

[0015]   Therefore, great mechanical stress in the known plastic containers may lead to bursting thereof. This may occur, for example, if a container filled with liquid falls to the floor from a great height, for example from the loading area of a lorry on which the container is being transported.

[0016]   Of course the mechanical strength of the containers might be increased by using a great deal more plastics material per container so the wall is much thicker. However, this has the drawback that the material consumption increases and this inter alia causes high costs.

[0017]   The object of the present invention is therefore to provide plastic containers having high mechanical strengths with the lowest possible expenditure on material.

[0018]   It has accordingly been found that the cause of the aforementioned mechanical failure is an irregular container wall thickness.

[0019]   Known containers produced by extrusion blow molding or by injection stretch blow molding have non-uniform wall thickness.

## DESCRIPTION OF THE FIGURES

[0020]   FIG. 1 shows the uniaxial stretching viscosity and the three-fold shear viscosity as function of time for polycarbonate suitable for the purpose of the present invention.

[0021]   FIG. 2 shows the uniaxial stretching viscosity and the three-fold shear viscosity as function of time for polycarbonate unsuitable for the purpose of the present invention.

[0022]   FIG. 3 shows an exemplified bottle.

[0023]   FIG. 4 shows the locals of the measurements of the wall thickness.

[0024]   FIG. 5 is a graphic representation of the measured wall thickness.

## DETAILED DESCRIPTION OF THE INVENTION

[0025] The object of the present invention is a container made of plastics material, wherein at its thickest point the wall of the container is at most three times as thick as at its thinnest point.

[0026] At its thickest point the regular container wall is preferably at most 2.6 times as thick as at its thinnest point.

[0027] At its thickest point the regular container wall is particularly preferably at most 2.2 times as thick as at its thinnest point.

[0028] The container is preferably a bottle.

[0029] The container is particularly preferably a water bottle.

[0030] The container is preferably made of polycarbonate molding composition.

[0031] The object of the present invention is achieved by injection blow molding or by injection stretch blow molding.

[0032] Rotationally symmetrical containers are preferred. Containers with only one aperture are preferred.

[0033] Uniformity of wall thickness of the container is taken to mean the container wall at all the points at which thicker or thinner points are not intentionally provided. Such intentionally provided thicker points might be seen in **FIG. 4** in the region of the bottleneck. Under ideal conditions of producing containers the regular container wall would be uniformly thick all around.

[0034] The containers according to the invention have been produced, for example, from a polycarbonate with certain rheological properties. Therefore, the uniaxial stretching test with which these theological properties may be measured is to be described hereinafter.

[0035] The uniaxial stretching test of polymer melts and its implementation are known to the person skilled in the art. The uniaxial stretching test may be carried out with apparatuses of the Münstedt type. These are described in H. Münstedt, J. Rheol., Vol. 23, pages 421 to 436 (1979). These are also described in current text books such as in Ch. W. Macosko: Rheology, Verlag Wiley/VCH, 1994, in particular pages 288 to 297 and in M. Phal, W. Gleißle, H. -M. Laun: Praktische Rheologie der Kunststoffe und Elastomere, VDI-Verlag, 1995, in particular pages 349 to 357.

[0036] The methods for determining the shear viscosity as a function of time are known to the person skilled in the art.

[0037] Determination of the shear viscosity as a function of time is preferably carried out in a rotary rheometer at low shear speeds. Determination of the shear viscosity may be carried out in the rotary rheometer also with oscillating deformation and may be converted into a time-dependent viscosity by means of common methods.

[0038] The construction and mode of use of rotary rheometers are described in current text books. For example in M. Pahl, W. Gleißle, H -M. Laun: Praktische Rheologie der Kunststoffe und Elastomere, VDI-Verlag, 1995.

[0039] The stretching viscosity as a function of time is preferably determined by means of a Münstedt-type stretch-ing rheometer. The uniaxial stretching test may also be carried out with a range of other rheometers, for example with the commercially available Meissner-type stretching rheometer. This is described in J. Meissner, Rheologica Acta 8, Vol. 78 (1969) and in J. S,. Schulze et al., Rheol. Acta Vol. 40 (2001) pages 457 to 466.

[0040] The Hencky elongation $\epsilon$ is a non-dimensional variable. The stretching viscosity $\eta_E$ has the unit Pascal multiplied by seconds. The shear viscosity $\eta$ also has the unit Pascal multiplied by seconds.

[0041] The quotient S serves as a measure of the relevant increase in the stretching viscosity $\eta_E$. The quotient S is non-dimensional. S is the quotient from the quotient from the stretching viscosity $\eta_E$ and three-fold shear viscosity $3\eta$. S depends on the measuring temperature T, the Hencky elongation rate $\epsilon$ (unit: 1 divided by seconds) and the Hencky elongation $\epsilon$ and the time.

[0042] The following formula applies:

$$S = \eta_E(t, \epsilon) \text{ divided by } 3\eta(t)$$

[0043] The total stretching $\epsilon$ (unit: non-dimensional) depends on the sample starting length $L_0$ (unit: meters) and its length L (unit: meters) as function of stretching and the elongation rate of $\epsilon$ (unit: 1 divided by seconds) and the time t (unit: seconds) by:

$$\epsilon = \text{natural logarithm of } (L \text{ divided by } L_0) = \epsilon \text{ multiplied by } t.$$

[0044] A plastics material, in particular polycarbonate, is preferred in which, at a temperature of 200° C., the ratio S is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.0 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, and is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.5 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, wherein S is defined as $S = \eta_E$ divided by $3\eta$.

[0045] A plastics material, in particular polycarbonate, is particularly preferred in which, at a temperature of 200° C., the ratio S is greater than 1.3 at a Hencky elongation $\epsilon$ of 2.0 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, and is greater than 1.5 at a Hencky elongation $\epsilon$ of 2.5 and an elongation rate range $\epsilon$ of between 0.1 and 0.01.

[0046] The present invention relates to a container containing plastics material. This means a container made of plastics material, for example as wall material. It does not mean a container made of completely different materials and which only contains the plastics material as filler.

[0047] The present invention also relates to a method for producing this container by extrusion blow molding or by the injection stretch blow molding.

[0048] To obtain plastics materials, in particular polycarbonates, with the aforementioned rheological stretching properties the person skilled in the art may adjust various parameters of the plastics materials, in particular polycarbonates. For example, he may influence the molecular weight and the degree of branching. The choice of the monomers and comonomers or the terminal groups also has an effect on the rheological stretching properties. The person skilled in the art may also use suitable additives to obtain the desired theological stretching properties according to the invention.

[0049] The advantage of the aforementioned plastics material, in particular polycarbonate, is that it enables production of the containers according to the invention with their advantageous properties. The known and advantageous processes (extrusion blow molding and/or injection stretch blow molding) may be used.

[0050] Of course the present invention is not limited to containers containing plastics material in which the plastics material has the aforementioned rheological properties. These are only preferred as they allow the containers to be produced by simple and known processes (extrusion blow molding or injection stretch blow molding). In general it is only important for the uniformity of wall thickness to be achieved. This may also be attained by using other methods and other plastics material (for example injection molding or compression).

[0051] The containers according to the invention have the advantage that they have high mechanical strength with a predetermined quantity of plastics material per container.

[0052] The containers according to the invention have numerous further advantages. They are more resistant to mechanical stresses, i.e. resistant to breaking, and also have an advantageous range of other additional mechanical properties. They have good optical properties, in particular a high degree of transparency. They have a high heat distortion temperature. Owing to the high heat distortion temperature the containers according to the invention may be cleaned with hot water or sterilized with hot steam. They have high resistance to the conventional detergents which, for example, are used to clean reusable water bottles, a field of application of the containers according to the invention. They may be produced easily and inexpensively by known processes. The good processing properties of the plastics material, in particular polycarbonate, are thus advantageously manifested here. Their material ages slowly during use and therefore they have a long service life. For possible repeated use this means many use cycles.

[0053] Containers in the sense of the present invention may be used for packaging, storing or transporting liquids, solids or gases. Containers for packaging, storing transporting liquids (liquid containers) are preferred, containers for packaging, storing or transporting water (water bottles) are particularly preferred.

[0054] Containers in accordance with the invention are preferably blow moldings with a volume of 0.1 1 to 50 l, preferably 0.5 l to 50 l, with volumes of 1 l, 5 l, 12 l and 20 l being particularly preferred.

[0055] 3 and 5 gallon water bottles are most particularly preferred.

[0056] The containers preferably have an empty weight of preferably 0.1 g to 3,000 g, more preferably 50 g to 2,000 g and particularly preferably of 650 g to 900 g.

[0057] The wall thicknesses of the containers are preferably 0.5 mm to 5 mm, more preferably 0.8 mm to 4 mm.

[0058] Containers in the sense of the invention preferably have a length of preferably 5 mm to 2,000 mm, particularly preferably 100 mm to 1,000 mm.

[0059] The containers preferably have a maximum circumference of preferably 10 mm to 250 mm, more preferably of 50 mm to 150 mm and most particularly preferably of 70 to 90 mm.

[0060] Containers in the sense of the invention preferably have a bottleneck of a length of preferably 1 mm to 500 mm, more preferably of 10 mm to 250 mm, particularly preferably of 50 mm to 100 mm and most particularly preferably of 70 to 80 mm.

[0061] The wall thickness of the bottleneck of the containers is preferably between 0.5 mm and 10 mm, particularly preferably of 1 mm to 10 mm and most particularly preferably of 1 mm to 3 mm.

[0062] The diameter of the bottleneck is preferably between 5 mm and 200 mm. 10 mm to 100 mm are particularly preferred and 45 mm to 75 mm most particularly preferred.

[0063] The bottle base of the containers according to the invention has a diameter of preferably 10 mm to 250 mm, more preferably 50 mm to 150 mm and most particularly preferably 70 to 90 mm.

[0064] Containers in the sense of the present invention may have any geometric shape, for example they may be round, oval or polygonal with, for example, 3 to 12 sides. Round, oval and hexagonal shapes are preferred.

[0065] The design of the containers may be based on any surface structure. The surface structures are preferably smooth or ribbed. The containers according to the invention may also have a plurality of different surface structures. Ribs or beads may round the periphery of the containers. They may have any spacing or a plurality of spacing which are different from one another. The surface structures of the containers according to the invention may be roughened or integrated structures, symbols, ornaments, coats of arms, manufacturer's emblems, trademarks, signatures, producer's details, material characteristics and/or information on volume.

[0066] The containers according to the invention may have any number of handles which may be located on the sides, at the top or at the bottom. The handles might be on the outside or integrated into the contour of the container. The handles may be foldable or fixed. The handles may have any contour, for example oval, round or polygonal. The handles preferably have a length of 0.1 mm to 180 mm, preferably 20 mm to 120 mm.

[0067] In addition to the plastics material according to the invention the containers according to the invention may also contain small amounts of other substances, for example seals made of rubber or handles made of other materials.

[0068] The containers according to the invention are preferably produced by extrusion blow molding or by injection stretch blow molding.

[0069] In a preferred embodiment for producing the containers according to the invention, the plastics materials according to the invention are processed on extruders with a smooth or grooved, preferably a smooth, feed zone.

[0070] The drive power of the extruder is selected in accordance with the screw diameter. By way of example it is mentioned that, with a screw diameter of 60 mm, the drive power of the extruder is approximately 30 to 40 kW, and with a screw diameter of 90 mm, approximately 60 to 70 kW.

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[0071] The universal three zone screws conventional in the processing of industrial thermoplastics are suitable.

[0072] To produce containers having a volume of 1 l a screw diameter of 50 to 60 mm is preferred. To produce containers having a volume of 20 l a screw diameter of 70 to 100 mm is preferred. The length of the screws is preferably 20 to 25 times the diameter of the screw.

[0073] In the case of blow molding the temperature of the blow mold is preferably adjusted to 50 to 90° C. to obtain a sparkling and high quality container surface.

[0074] To ensure uniform and effective temperature adjustment of the blow mold the base region and the other regions of the die may be adjusted in temperature separately.

[0075] The blow mold is preferably closed with a compressive force of 1,000 to 1,500 N per centimeter of pinch-off weld length.

[0076] The plastics material is preferably dried before processing so the quality of the containers is not impaired by visible streaks or bubbles and is not hydrolytically degraded during processing. The residual moisture content after drying is preferably less than 0.01% by weight. A drying temperature of 120° C. is preferred. Lower temperatures do not ensure sufficient drying, and at higher temperatures there is the risk of plastics material granules sticking together and then no longer being capable of being processed. Dry air driers are preferred.

[0077] The preferred melt temperature for processing plastics materials based on polycarbonate is 230° to 300° C.

[0078] The containers according to the invention may be used for packaging, storing or transporting liquids, solids or gases. The embodiment which, for example, is used for packaging, storing or transporting liquids, is preferred. The embodiment as a water bottle which, for example, may be used for packaging, storing or transporting water, is particularly preferred.

[0079] Polycarbonates in the sense of the present invention are preferably thermoplastically processable aromatic polycarbonates. Both homopolycarbonates and copolycarbonates may be used.

[0080] Particularly preferred polycarbonates are the homopolycarbonate based on bisphenol A, the homopolycarbonate based on 1,1 bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane and the copolycarbonates based on the two monomers bisphenol A and 1,1-bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane.

[0081] The polycarbonates according to the invention also include polycarbonates in which up to 80 mol %, in particular from 20 mol % to 50 mol %, of the carbonate groups are replaced by aromatic dicarboxylic acid ester groups. Polycarbonates of this type which include both acid residues of carbon dioxide and acid residues of aromatic dicarboxylic acids incorporated in the molecule chain, are also called aromatic polyester carbonates.

[0082] The polycarbonates may be produced in a known manner from diphenols, carbon dioxide derivatives, optionally chain terminators and optionally branching agents. A portion of the carbon dioxide derivatives is replaced by aromatic diocarboxylic acids or derivatives of dicarboxylic acids to produce the polyester carbonates. This proceeds

according to the carbonate structural units to be replaced in the aromatic polycarbonates by aromatic dicarboxylic acid ester structural units.

[0083] Details of the production of polycarbonates are known. Reference is made by way of example to:

[0084] 1. Schnell, "Chemistry and Physics of Polycarbonates", Polymer Reviews, Volume 9, Interscience Publishers, New York, London, Sydney 1964;

[0085] 2. D. C. Prevorsek, B. T. Debona und Y. Kesten, Corporate Research Center, Allied Chemical Corporation, Morristown, N.J. 07960: "Synthesis of Poly(ester Carbonate) Copolymers" in Journal of Polymer Science, Polymer Chemistry Edition, Vol. 19, 75-90 (1980);

[0086] 3. D. Freitag, U. Grigo, P. R. Müller, N. Nouvertne', BAYER AG, "Polycarbonates" in Encyclopedia of Polymer Science and Engineering, Vol. 11, Second Edition, 1988, pages 648-718;

[0087] 4. U. Grigo, K. Kircher und P. R- Müller "Polycarbonate" in Becker/Braun, Kunststoff-Handbuch, Vol. 3/1, Polycarbonate, Polyacetale, Polyester, Cellulose ester, Carl Hanser Verlag Munich, Vienna 1992, pages 117-299.

[0088] The polycarbonates, including the polyester carbonates, preferably have mean molecular weights Mw of 12,000 to 120,000 g/mol (determined by measuring the relative viscosity at 25° C. in methylene chloride at a concentration of 0.5 g polycarbonate per 100 ml methylene chloride). 15,000 to 80,000 g/mol are preferred, 15,000 to 60,000 g/mol are particularly preferred.

[0089] Dihydroxy compounds suitable for producing polycarbonates are, for example, hydroquinone, resorcinol, dihydroxydiphenyl, bis-(hydroxyphenyl)-alkanes, bis-(hydroxyphenyl)-cycloalkanes, bis-(hydroxyphenyl)-sulphides, bis-(hydroxyphenyl)-ether, bis-(hydroxyphenyl)-ketones, bis-(hydroxyphenyl)-sulphones, bis-(hydroxyphenyl)-sulphoxides, ($\alpha,\alpha'$-bis-(hydroxyphenyl)-diisopropylbenzenes, and their compounds alkylated on the nucleus and halogenated on the nucleus.

[0090] Preferred diphenols are 4,4'-dihydroxydiphenyl, 2,2-bis-(4-hydroxyphenyl)-1-phenyl-propane, 1,1-bis-(4-hydroxyphenyl)-phenyl-ethane, 2,2-bis-(4-hydroxy-phenyl)propane, 2,4-bis-(4-hydroxyphenyl)-2-methylbutane, 1,1-bis-(4-hydroxy-phenyl)-m/p diisopropylbenzene, 2,2-bis-(3-methyl-4-hydroxyphenyl)-propane, bis-(3,5-dimethyl-4-hydroxyphenyl)-methane, 2,2-bis-(3,5-dimethyl-4-hydroxyphenyl)-propane, bis-(3,5-dimethyl-4-hydroxyphenyl)-sulphone, 2,4-bis-(3,5-dimethyl-4-hydroxyphenyl)-2-methylbutane, 1,1-bis-(3,5-dimethyl-4-hydroxy-phenyl)-m/p-diisopropyl-benzene, 2,2 and 1,1-bis-(4-hydroxyphenyl)-3,3,5-trimethylcyclohexane.

[0091] Particularly preferred diphenols are 4,4'-dihydroxydiphenyl, 1,1-bis-(4-hydroxy-phenyl)-phenyl-ethane, 2,2-bis-(4-hydroxyphenyl)-propane, 2,2-bis(3,5-dimethyl-4-hydroxyphenyl)-propane, 1,1-bis-(4-hydroxyphenyl)-cyclohexane, 1,1-bis-(4-hydroxyphenyl)-m/p diisopropylbenzene und 1,1-bis-(4-hydroxy-phenyl)-3,3,5-trimethylcyclohexane.

[0092] These and other suitable dihydroxy compounds and their production are disclosed, for example, in U.S. Pat.

Nos. 3,028,635, 2,999,835, 3,148,172, 2,991,273, 3,271, 367, 4,982,014 and 2,999,846, in DE-A 1,570,703, 2,063, 050, 2,036,052, 2,211,956 and 3,832,396, in FR-A 1 561 518, in the monograph "H. Schnell, Chemistry and Physics of Polycarbonates, Interscience Publishers, New York 1964" and in JP-A 62039/1986, 62040/1986 and 105550/1986.

[0093] In the case of the homopolycarbonates, only one dihydroxy compound is used, in the case of the copolycarbonates a plurality of such compounds are used, wherein of course the diphenols used (also called bisphenols) may be contaminated with the impurities originating from their own synthesis, like all other chemicals and auxiliary agents added to the synthesis, although it is desirable to work with raw materials which are as clean as possible.

[0094] Suitable chain terminators which may be used in the production of polycarbonates are monophenols and monocarboxylic acids.

[0095] Suitable monophenols are, for example, phenol, alkyl phenols such as cresols, p-tert.butylphenol, p-n-octylphenol, p-iso-octylphenol, p-n-nonylphenol and p-iso-nonylphenol, halogen phenols such as p-chlorophenol, 2,4-dichlorophenol, p-bromophenol and 2,4,6-tribromophenol and mixtures thereof.

[0096] Suitable monocarboxylic acids are, for example, benzoic acid, alkyl benzoic acids and halogen benzoic acids.

[0097] Preferred chain terminators are the phenols of formula (I)

$$R^6\text{-}Ph\text{=}OH \qquad \qquad (I)$$

[0098] wherein $R^6$ represents H or a branched or unbranched $C_1$-$C_{18}$ alkyl radical.

[0099] The quantity of chain terminator to be used is preferably 0.5 mol % to 10 mol %, based on mol of the respectively used diphenols. The chain terminators may be added before, during or after phosgenation.

[0100] The polycarbonates may be branched. Suitable branching agents which may be used to branch the polycarbonates are the tri- or more than trifunctional compounds known in polycarbonate chemistry, in particular those with three or more than three phenolic OH groups.

[0101] Suitable branching agents are, for example phloroglucin, 4,6-dimethyl-2,4,6-tri-(4-hydroxyphenyl)-heptene-2, 4,6-dimethyl-2,4,6-tri-(4-hydroxyphenyl)-heptane, 1,3,5-tri-(4-hydroxyphenyl)-benzene, 1,1,1-tri-(4-hydroxyphenyl)-ethane, tri-(4-hydroxyphenyl)-phenylmethane, 2,2-bis-[4,4-bis-(4-hydroxyphenyl)-cyclohexyl]-propane, 2,4-bis-(4-hydroxyphenyl-isopropyl)-phenol, 2,6-bis-(2-hydroxy-5'-methyl-benzyl)-4-methylphenol, 2-(4-hydroxyphenyl)-2-(2,4-dihydroxyphenyl)-propane, hexa-(4-(4-hydroxyphenyl-isopropyl)phenyl)-orthoterephthalic acid ester, tetra-(4-hydroxyphenyl)-methane, tetra-(4-(4-hydroxy-phenyl-isopropyl)-phenoxy)-methane und 1,4-bis(4',4"-dihydroxy-triphenyl)-methyl)-benzene and 2,4-dihydroxybenzoic acid, trimesic acid, cyanurchloride and 3,3-bis-(3-methyl-4-hydroxyphenyl)-2-oxo-2,3-dihydroindol.

[0102] The quantity of branching agent to optionally be used is preferably 0.05 mol % to 2.5 mol %, based on mol of respectively used diphenols.

[0103] The branching agents may either be introduced with the diphenols and the chain terminators in the aqueous alkaline phase or be added prior to phosgenation dissolved in an organic solvent.

[0104] All of these measures for producing the polycarbonates are familiar to the person skilled in the art.

[0105] Aromatic dicarboxylic acids suitable for producing the polyester carbonates are, for example, phthalic acid, terephthalic acid, isophthalic acid, ter.-buty-lisophthalic acid, 3,3'-diphenyldicarboxylic acid, 4,4'-diphenyldicarboxylic acid, 4,4-benzophenonedicarboxylic acid, 3,4'-benzophenonedicarboxylic acid, 4,4'-diphenyletherdicarboxylic acid, 4,4'-diphenylsulphonicdicarboxylic acid, 2,2-bis-(4-carboxyphenyl)-propane, trimethyl-3-phenylindane-4,5'-dicarboxylic acid.

[0106] Of the aromatic dicarboxylic acids, terephthalic acid and/or isophthalic acid are particularly preferably used.

[0107] Derivatives of the dicarboxylic acids are, for example, the dicarboxylic acid dihalides and the dicarboxylic dialkylesthers, in particular the dicarboxylic acid dichlorides and the dicarboxylic acid dimethylesters.

[0108] The carbonate groups may be replaced substantially stoichiometrically and also quantitatively by the aromatic dicarboxylic acid ester groups, so the molar ratio of the reaction partners is again found in the resulting polyester carbonates. The aromatic dicarboxylic acid ester groups may be incorporated randomly and also block by block.

[0109] The polycarbonates are preferably produced by the interfacial process or the known melt transesterification process. In the first case phosgene preferably serves as carbon dioxide derivative, in the latter case preferably diphenylcarbonate.

[0110] Catalysts, solvents, working up, reaction conditions, etc. for the production of polycarbonate are known in both cases.

[0111] The melt transesterification process is described, in particular, in H. Schnell, "Chemistry and Physics of Polycarbonates", Polymer Reviews, Vol. 9, pages 44 to 51, Interscience Publishers, New York, London, Sidney, 1964 and in DE-A 1 031 512, in U.S. Pat. No. 3,022,272, in U.S. Pat. No. 5,340,905 and in U.S. Pat. No. 5,399,659.

[0112] The polycarbonates may also contain the conventional additives, for example pigments, UV stabilizers, heat stabilizers, antioxidants and mold-release agents in the quantities conventional for polycarbonates.

[0113] For the case where the polycarbonates contain additives, the compositions that include polycarbonate and additives are also called polycarbonate molding compounds.

[0114] These conventional additives may be added to the polycarbonates in a known manner.

[0115] When producing polycarbonate, raw materials and auxiliary agents with a low degree of contaminants are preferably used. The bisphenols used and the carbon dioxide derivatives used should be as free from alkali ions and alkaline earth ions as possible, in particular when produced by the melt transesterification process. Pure raw materials of this type may be obtained, for example, by recrystallizing, washing or distilling the carbon dioxide derivatives, for example carbon dioxide esters.

[0116] When producing polycarbonates by the melt transesterification process, the reaction of the bisphenol and of the carbon dioxide diester may be carried out continuously

or discontinuously, for example in agitated tanks, film evaporators, falling-film evaporators, series of stirred-tank reactors, extruders, kneaders, simple disc reactors and high viscosity disc reactors.

[0117] Carbon dioxide diesters which may be used to produce polycarbonates, are, for example, diarylesters of carbon dioxide, the two aryl radicals preferably each having 6 to 14 carbon atoms. The diesters of the carbon dioxide are preferably used on the basis of phenol or alkyl-substituted phenols, in other words, for example diphenylcarbonate or dicresylcarbonate. Based on 1 mol bisphenol the carbon dioxide diesters are preferably used in a quantity of 1.01 to 1.30 mol, particularly preferably in a quantity of 1.02 to 1.15 mol.

[0118] If phenols, alkylphenols and/or arylphenols are used in the production of polycarbonates they have the effect of chain terminators. This means they limit the maximum achievable mean molecular weight. They may be added either together with the monomers required to produce the polycarbonate, or in a later phase of polycarbonate synthesis. They act as monofunctional compounds in the sense of the polycarbonate synthesis and therefore act as chain terminators.

[0119] The phenol, alkylphenols and/or arylphenols optionally used in production of the polycarbonates are preferably used in a quantity of 0.25 to 10 mol %, based on the sum of the respectively used bisphenols.

[0120] Mixtures of phenol and/or one or more alkylphenols and/or arylphenols may also be used.

[0121] The alkylphenols and/or arylphenols optionally used in the production of polycarbonates lead to terminal alkylphenol groups and to terminal arylphenol groups. In addition, other terminal groups may occur in the resulting polycarbonate, depending on the production process, such as phenolic terminal OH groups or terminal chloroformic acid ester groups.

[0122] Phenol, alkylphenols and/or arylphenols without the addition of further substances which may act as chain terminators, are preferably exclusively used as chain terminators.

[0123] Suitable further substances which may act as chain terminators are monophenols and monocarboxylic acids. Suitable monophenols are, for example, phenol, p-chlorophenol or 2,4,6-tribromophenol. Suitable monocarboxylic acids are benzoic acid, alkylbenzoic acids and halogenbenzoic acids.

[0124] The preferred further substances which may act as chain terminators are phenol, p-tert.butylphenol, cumylphenol and isooctylphenol.

[0125] The quantity of further substances which may act as chain terminators is preferably between 0.25 and 10 mol %, based on the sum of respectively used dihydroxy compounds.

[0126] The measuring of the uniaxial stretching viscosity is described hereinafter.

[0127] To measure the uniaxial stretching viscosity a cylindrical plastic sample (effective dimensions: diameter substantially between 4 and 5 mm, length substantially

between 20 and 25 mm) is fixed at the ends by means of clamping jaws and fixed in a stretching rheometer.

[0128] The temperature of the sample is controlled by means of an oil bath which, at the measuring temperature of 200° C., has approximately the same density as the plastics material. After reaching constant temperature, the deformation is predetermined via the take-off rod connected to the clamping jaws at one end of the sample. A constant Hencky elongation rate $\epsilon$ is given. This means that the take-off rate u increases exponentially with time.

[0129] At the other end of the sample the tensile force is measured as a function of time or total elongation. The uniaxial stretching viscosity may be ascertained by referring the tensile stress ascertained to the time-dependent cross-sectional area.

[0130] In the stretching rheometer used for the measurements in the examples of the present document, the maximum take-off length is at approximately 500 mm and this corresponds to a maximum deformation of approximately $L/L_0=25$ or a maximum Hencky elongation of approximately In $(L/L_O)=3.2$. However, the total elongation is not always achieved in the polycarbonates investigated as the samples may tear off or fail beforehand.

[0131] The evaluation of the uniaxial stretching test is as follows. The logarithm of the single stretching viscosity value and of the three-fold shear viscosity value are shown together in a graph as a function of time. It has been found that, in particular the plastics materials suitable for producing containers are those in which the stretching viscosities increase greatly (in terms of the ratio 5 as defined above) in comparison with the three-fold shear viscosity (see **FIG. 1**). The plastics materials in which the stretching viscosities do not increase greatly in comparison with the three-fold shear viscosity (see **FIG. 2**) are less suitable or unsuitable for producing water bottles in accordance with the invention.

[0132] The melts of the polycarbonates which are not advantageous for producing water bottles, may to an extent not deform at high total elongations ($\epsilon > 2.5$) as the samples constrict and/or fail.

[0133] The measured results of the uniaxial stretching viscosity depend heavily on the correct test procedure. With an incorrect test procedure, greatly increased stretching viscosities may be measured which are not real. To ascertain correct measuring values an adequate test procedure and evaluation is to be observed (cf. Th. Schweizer, Rheol. Acta 39 (2000) 5, pages 428 to 443; J. S. Schulze et al., Rheol. Acta 40 (2001) pages 457 to 466; and V. C. Barroso, J. A. Covas, J. M. Maia Rheol. Acta 41 (2002) pages 154 to 161).

[0134] **FIGS. 1 and 2** will be described hereinafter.

[0135] **FIG. 1** shows the uniaxial stretching viscosity $\eta_E(t, \epsilon)$ and the three-fold shear viscosity $3\eta(t)$ for a polycarbonate which is advantageous for producing water bottles by extrusion blow molding (produced in accordance with the example according to the invention). The three-fold shear viscosity $3\eta(t)$ is shown as a solid line. The uniaxial stretching viscosities $\eta_E(t, \epsilon)$ for three different elongation rates $\epsilon$ of 0.1 and 0.03 and 0.01 (unit: 1 divided by seconds) are shown as lines with symbols. It may be seen that for all elongation rates the stretching viscosities increase greatly with increasing time and come to lie above the three-fold shear viscosity.

[0136] FIG. 2 shows the uniaxial stretching viscosity $\eta_E(t, \epsilon)$ and the three-fold shear viscosity $3\eta(t)$ for a polycarbonate which is not advantageous for producing water bottles by extrusion blow molding (produced in accordance with the comparison example). The three-fold shear viscosity $3\eta(t)$ is shown as a solid line. The uniaxial stretching viscosities $\eta_E(t, \epsilon)$ for three different elongation rates $\epsilon$ of 0.2 and 0.1 and 0.05 (unit: 1 divided by seconds) are shown as lines with symbols. It may be seen that for all elongation rates the stretching viscosities do not increase greatly with increasing time and come to lie in the region of the three-fold shear viscosity.

[0137] In FIGS. 1 and 2, the time axis t for a curve with a specific Hencky elongation rate $\epsilon$ may be converted into the Hencky elongation $\epsilon$ as:

Hencky elongation $\epsilon$=Hencky elongation rate $\epsilon$ multiplied by time t applies.

[0138] FIG. 3 shows the bottles produced in the examples. The dimensions thereof are given in millimetres (mm).

[0139] FIG. 4 shows the position of the measuring points on the bottles at which the wall thickness was measured in the examples. The numerals 1-46 indicate the locals of thickness measurements.

[0140] FIG. 5 is a graphic representation of the locations of the measurements of the wall thickness reported in Table 2. The wall thickness in mm is plotted against the corresponding points 1 to 46. The bottle made of polycarbonate in accordance with the example shows a regular course (square symbols). The bottle made of polycarbonate in accordance with the comparison example shows an irregular course (triangular symbols).

[0141] The invention is further illustrated but is not intended to be limited by the following examples in which all parts and percentages are by weight unless otherwise specified.

## EXAMPLES

[0142] A polycarbonate was produced with the Theological stretching properties in accordance with the example. Water bottles with a volume of 5 gallons were subsequently produced from the plastic granules and the wall thickness distribution measured. The same process was carried out with a comparison product which had the rheological stretching properties in accordance with comparison example.

[0143] Water bottles with a homogeneous wall thickness distribution were obtained from the polycarbonate according to the example but not from the polycarbonate according to the comparison example.

[0144] 1. Producing the Polycarbonates

### Example

[0145] 5515.7 g (24.16 mol) bisphenol A and 31.10 g isatinbiscresol were dissolved in 33.40 kg 6.5% sodium hydroxide solution in a nitrogen atmosphere while stirring. A mixture of 70.6 g phenol and 36.03 kg methylene chloride was added to this solution. 2967.6 g phosgene were then introduced within 30 minutes at 20 to 25° C. and a pH of 13, maintained by adding further sodium hydroxide solution,

while stirring intensively. After this introduction, 28.3 g N-ethylpiperidine were added and the solution stirred for 45 minutes at a pH of 13.

[0146] The alkali phase was separated from the organic phase. The organic phase was adjusted with diluted phosphoric acid or hydrochloric acid to a pH of 1. The phase was then washed free of electrolytes with deionised water. After exchanging the methylene chloride for chlorobenzene the polycarbonate was isolated in a known manner via a stripping extruder.

[0147] The polycarbonate thus obtained had a relative solution viscosity, measured at a concentration of 0.5 g polycarbonate in 100 ml methylene chloride at 25° C., of 1.325.

### Comparison Example

[0148] 6.91 g isatinbiscresol and 78.4 g phenol were used as in the above example. A polycarbonate with a relative solution viscosity of 1.305 was obtained. Isatinbiscresol is commercially obtainable and has the correct name 3,3-bis-(3-methyl-4-hydroxyphenyl)-2-oxo-2,3-dihydroindol.

[0149] 2. Description of the Production of 5 Gallon Water Bottles Made of Polycarbonate by Extrusion Blow Molding

[0150] The bottles were produced using an extrusion blow molding machine KBS 2-20 from SIG Blowtec with the following machine requirements. An extruder with a screw 100 mm in diameter and a length of 25 D was used, which introduced little frictional heat into the material at relatively low screw speeds. The plasticizing capacity was between about 145 and 190 kg/h at a bottle weight of about 750 g net and a piece number of 130 to 144 bottles/hour. The plasticizing cylinder was equipped with regulated heating zones and fans guaranteeing exact and constant temperature control. The drive was provided by a thyristor-controlled d.c. unit which provided for uniform conveying of material and a constant torque. The parison die consisted of a fifo accumulator head (fifo=first in-first out) with 3.5 litre storage volume and overlapping heart-shaped grooves. The double heart-shaped grooves offset by 180° produced an inner and an outer parison and convey the flow of melt into the accumulator chamber. Mandrel and die in the parison die were conical in design. The mandrel was displaced axially with respect to the conical die via a wall thickness control programme. Consequently, it was possible to optimise the weight of the bottle and adapt the wall thicknesses in the corresponding wall regions, for example in the base region.

[0151] The extruder temperatures were 110° C. in the feed zone and between 245° C. and 265° C. in the individual heating zones. The die head temperatures were 245° C. to 250° C. and the die temperature 275° C. The melt temperature was 267° C. The mean cycle time was ±0.2 s at 25.8 s, with an ejection time of the parison of 5.3 s, corresponding to a piece number of 138 to 140 bottles per hour. A conventional vertical wall thickness profile for 5 gallon polycarbonate bottles was used to control the wall thickness. The bottles produced had a net weight of 750 g to 850 g and were immediately adjusted in temperature by means of infrared radiation. The temperature control served to rapidly relax the material and to relax the process-induced internal stress associated therewith. A Protherm 850-3 model, Serial No.: KRK 7110, infrared radiation oven from Process

Dynamics Inc., USA was used. The adjustable temperatures of the seven heating zones present were selected such that a surface temperature of the bottles of 130° C.±2° C. was ensured.

TABLE 1

Bottle geometry and weight of the water bottle example/comparison example:

| Example | Average wall thickness [mm] | Area [cm²] | Volume [cm³] | Calculated weight [g] |
|---|---|---|---|---|
| Neck | 2.35 | 129.53 | 30.440 | 36.53 |
| Shoulder | 2.01 | 642.44 | 129.130 | 154.96 |
| Bod | 1.30 | 2747.82 | 357.217 | 428.66 |
| Base | 2.14 | 547.11 | 117.082 | 140.50 |
| Total | 4066.90 | 633.87 | 760.65 | |

| Comparison Example | Average wall thickness [mm] | Area [cm²] | Volume [cm³] | Calculated weight [g] |
|---|---|---|---|---|
| Neck | 2.75 | 129.53 | 35.588 | 42.71 |
| Shoulder | 2.30 | 642.44 | 147.681 | 177.22 |
| Bod | 1.35 | 2747.82 | 369.696 | 443.64 |
| Base | 2.23 | 547.11 | 122.224 | 146.67 |
| Total | 4066.90 | 675.19 | 810.23 | |

[0152]  3. Description of the Wall Thickness Measurement of the Water Bottles:

[0153]  The wall thicknesses were ascertained using an ultrasonic wall thickness measuring apparatus from Krautkramer GmbH & Co, Hürth, Germany of the CL3 DL type. This apparatus operates by the impulse-echo principle. Measurement of the time covered by the pulse in the material starts with the entry echo produced when a portion of the ultrasonic pulse is reflected from the boundary face between advance section and the surface of the material to be measured. Depending on the thickness of the material the CL3 DL automatically decides on a measurement from the entry echo to the first slap-back (interface-to-first modes) or on a measurement between successive slap-back echoes (multi-echo-modes). An ultrasonic advance probe specifically for plastics materials called ALPHA DFR-P and with a nominal frequency of 22 MHz and a connecting face of 6.4 mm was used for a measuring range of 0.125 mm to 3.8 mm. The wall thickness measurements were made at 46 measuring points (see **FIG. 4**) directly on the bottle using an ultrasonic coupling means.

TABLE 2

Wall thickness of the measuring point

| Measuring point | Measuring region | Wall thickness [mm] Example | Wall thickness [mm] Comparison example |
|---|---|---|---|
| 1 | Neck | 2.47 | 2.57 |
| 2 | Neck | 2.42 | 2.92 |
| 3 | Shoulder | 2.28 | 2.78 |
| 4 | Shoulder | 2.14 | 2.66 |
| 5 | Shoulder | 1.88 | 2.39 |
| 6 | Shoulder | 1.72 | 1.92 |
| 7 | Body | 1.53 | 1.63 |

TABLE 2-continued

Wall thickness of the measuring point

| Measuring point | Measuring region | Wall thickness [mm] Example | Wall thickness [mm] Comparison example |
|---|---|---|---|
| 8 | Body | 1.36 | 1.36 |
| 9 | Body | 1.22 | 1.14 |
| 10 | Body | 1.16 | 1.45 |
| 11 | Body | 1.14 | 1.08 |
| 12 | Body | 1.16 | 1.32 |
| 13 | Body | 1.19 | 1.17 |
| 14 | Body | 1.24 | 1.78 |
| 15 | Body | 1.3 | 1.86 |
| 16 | Body | 1.38 | 1.96 |
| 17 | Body | 1.45 | 1.76 |
| 18 | Body | 1.57 | 1.89 |
| 19 | Base | 1.72 | 1.78 |
| 20 | Base | 1.94 | 2.28 |
| 21 | Base | 2.16 | 2.56 |
| 22 | Base | 2.33 | 2.73 |
| 23 | Base | 2.46 | 2.53 |
| 24 | Base | 2.45 | 2.39 |
| 25 | Base | 2.35 | 2.48 |
| 26 | Base | 2.19 | 2.29 |
| 27 | Base | 2.02 | 1.94 |
| 28 | Base | 1.76 | 1.36 |
| 29 | Body | 1.58 | 1.21 |
| 30 | Body | 1.45 | 1.09 |
| 31 | Body | 1.35 | 1.37 |
| 32 | Body | 1.29 | 1.43 |
| 33 | Body | 1.25 | 1.34 |
| 34 | Body | 1.19 | 0.94 |
| 35 | Body | 1.16 | 1.18 |
| 36 | Body | 1.15 | 0.96 |
| 37 | Body | 1.14 | 1.27 |
| 38 | Body | 1.22 | 0.94 |
| 39 | Body | 1.33 | 1.03 |
| 40 | Body | 1.48 | 1.13 |
| 41 | Shoulder | 1.68 | 1.35 |
| 42 | Shoulder | 1.92 | 2.09 |
| 43 | Shoulder | 2.12 | 2.51 |
| 44 | Shoulder | 2.3 | 2.69 |
| 45 | Neck | 2.45 | 2.86 |
| 46 | Neck | 2.25 | 2.64 |

[0154]  Although the invention has been described in detail in the foregoing for the purpose of illusion, it is to be understood that such detail is solely for that purpose and that variations may be made therein by those skilled in the art without departing from the spirit and scope of the invention except as it may be limited by the claims.

What is claimed is:

1. A container having uniform wall thickness, molded of a thermoplastic composition the wall at its thickest being at most three times as thick as at its thinnest.

2. The container according to claim 1, wherein at its thickest the wall is at most 2.6 times as thick as at its thinnest.

3. The container according to claim 1, wherein at its thickest the wall is at most 2.2 times as thick as at its thinnest.

4. The container according to claim 1, wherein the container is a bottle.

5. The container according to claim 1, wherein the container is a water bottle.

6. The container according to claim 1 wherein the thermoplastic composition comprise polycarbonate.

**7**. A process for producing the container according to claim 1 comprising molding by a process selected from the group consisting of extrusion blow molding and injection stretch blow molding thermoplastic material characterized in that at a temperature of 200° C., S is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.0 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, and S is greater than 1.1 at a Hencky elongation $\epsilon$ of 2.5 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, wherein S is $\eta_E$ divided by $3\eta$.

**8**. A process for producing the container according to claim 1 comprising molding by a process selected from the group consisting of extrusion blow molding and injection stretch blow molding a thermoplastic material characterized in that at a temperature of 200° C., S is greater than 1.3 at a Hencky elongation $\epsilon$ of 2.0 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, and S is greater than 1.5 at a Hencky elongation $\epsilon$ of 2.5 and an elongation rate range $\epsilon$ of between 0.1 and 0.01, wherein S is $\eta_E$ divided by $3\eta$.

\* \* \* \* \*