

A METHOD AND APPARATUS FOR PRODUCING A TUBULAR OBJECT
FROM A TUBULAR BLANK OF PLASTICS MATERIAL

5 The present invention relates to a method and apparatus for producing a tubular object of plastics material, for example, polyethylene terephthalate or a similar thermoplastic material, from a tubular blank of substantially amorphous material.

10 In an embodiment the tubular object has one or more cylindrical areas of material in which the thickness of the material in the blank has, in the case of polyethylene terephthalate, been reduced by one or more shaping operations until it is approximately 1/3 of the original thickness of the material. In certain applications the thickness of the material is reduced
15 along the entire length of the object. In the areas with reduced wall thickness the material is axially oriented and has, in the case of polyethylene terephthalate, a crystallinity of less than approximately 30%, usually being of the order of 10 to 25%. The initial temperature of the material during shaping is preferably
20 below the glass transition temperature (TG) and the shaping operation takes place with the temperature of the material controlled in the area of shaping, where the material is in surface contact with an external draw ring and/or an internal shaping device.

25 Previously disclosed in UK published Patent application No. 2052367A is a tubular object in which the wall thickness preferably at a central point of said object has been reduced to approximately 1/3 of the original thickness of the material. The
30 reduction in thickness is produced by clamping each end of a tubular blank in which the material is at an initial temperature below the glass transition temperature (TG) in two jaws which are then moved apart. By causing an annular area of the material

to have a higher temperature than the surrounding material, the obtained material properties of the area will cause the reduction in thickness to commence in the area during the stretching operation. In certain applications the internal diameter of the blank is stabilized by the use of an internal mandrel. The process as disclosed will produce an object in which the material is axially oriented and has a crystallinity of less than approximately 30%, usually being of the order of 10 to 25%.

10 Already disclosed in UK published Patent Application No. 2052366A is a method for causing the thickness of the material in a tubular blank to be reduced mechanically by the use of an external device. The device consists of one or more rollers which make contact with the external and/or internal surface of the blank with such force that the desired reduction in thickness will occur as the initial temperature of the material approaches the glass transition temperature. The external device is moved around the periphery of the blank and along the axis of the blank simultaneously. This method will also produce an object in which the crystallinity in the areas of reduced material thickness will be less than approximately 30% and will be of the order of 10 to 25%.

25 However, the material will not have been oriented axially to such a high degree as when the process described in the previous paragraph is used.

30 The methods described above, produce objects in which the transitional zone between stretched and non-stretched material differs. Thus, where a central section of a tubular blank is stretched whilst the material in the blank is at an initial temperature below the glass transition temperature (TG) and the blank is subsequently separated into two parts to form two

5 separate objects, these objects will differ. The difference is due to the fact that one of the objects contains the start zone for the yielding of material produced by the stretching operation, whilst the other object contains the stop zone for the yielding of material.

10 When practising the invention described in UK application No. 2052367A an annular transitional zone between the thinner material which has been stretched and the thicker material which has not been stretched will normally be produced. In the zone the surface of the material will form an angle of approximately 45° with the surfaces of the stretched and non-stretched material respectively. Axially displaced tapering areas will occasionally be produced in the substantially annular transitional zone during
15 the drawing operation, the presence of said areas usually requiring the object to be scrapped.

20 In accordance with the present invention there is provided a method for producing a tubular object of plastics material from a tubular blank having a wall of substantially amorphous material, comprising reducing the thickness of material in the blank or in one or more areas thereof by means of a single or several consecutive re-shaping operations, whereby a mechanical shaping device defines a ring-shaped zone in which a transitional zone
25 between thicker and thinner material of the blank is enclosed, the mechanical shaping device moving said transitional zone along the blank and simultaneously elongating the blank in the axial direction of the blank, wherein after the last re-shaping operation the thinner material has an oriented state, and wherein
30 the thickness of the thinner material corresponds to that which a sheet of amorphous material will obtain by moneaxial stretching to yielding of the material of said sheet, if, immediately before the stretching of said sheet, the thickness of the sheet is the

same as the initial wall thickness of the blank and the temperature of the material of the sheet is the same as the temperature of the material of the blank immediately before the last re-shaping operation.

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The speed at which the thickness of the material is reduced is greater with the present invention than with the previously disclosed methods. The transitional zone between material with the original wall thickness and material with reduced wall thickness will always have a predetermined shape, and the length of each section with a reduced wall thickness will always be precisely defined because the re-shaping of the blank in the transitional zone itself is mechanically controlled. For example, when making an object in the form of two preforms which face each other, the rate of production can be doubled by starting the drawing operation at a central point and then continuing it simultaneously towards the two ends of the tube. The object so produced may then be cut, and the cut sections sealed to form two preforms for future processing. In these preforms, the transitional zone between material with the original wall thickness and material with reduced wall thickness will always have the same predetermined shape and will always contain material with identical characteristics such that each of the preforms will be the same.

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The present invention also makes it possible to produce an object in which the thickness of the material is reduced along the entire length of the object or in one or more cylindrical sections of the object. The object is in the form of a tube which is open at both ends or, in certain applications, in the form of a tube which has been sealed at one end. The object is mainly intended to be moulded into containers whereby each single object is formed into either a single container or a number of

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containers. In the latter case, the object is divided into a number of parts which are then moulded into containers.

5 The production of an object of polyethylene terephthalate or a similar thermoplastic material in accordance with an embodiment of the present invention starts from a tubular blank, the material in this blank being in an amorphous state. In one single operation or in a number of consecutive operations the thickness of the material in the blank is reduced to
10 approximately 1/3 of its original thickness. This reduction in thickness takes place either along the entire length of the blank or in one or more sections of the blank. Preferably, immediately before the reduction in thickness, the material which will undergo a reduction in thickness as the transitional zone is
15 moved has a temperature below or in the range of the glass transition temperature (TG) of the material. The glass transition temperature is abbreviated to TG in the following, the temperature of the material should preferably deviate from TG by no more than 15°C during the reduction in thickness. Although
20 the technical effect of the present invention may be achieved at a much lower temperature, it is advantageous to use an initial temperature close to TG, for instance a temperature which is between 1 to 30°C below TG, since material at this initial temperature will permit the mechanical shaping device to be moved
25 at high speed.

In an embodiment, the mechanical shaping devices are in contact with and form bearing surfaces against the material in the area of the transitional zone and in that the material in the
30 transitional zone is maintained at a temperature close to its glass transition temperature by the transfer of heat between the material and the mechanical shaping devices.

Preferably, the material, once it has assumed its reduced wall thickness, is cooled immediately to a temperature below its glass transition temperature.

- 5 In an embodiment, during the forming of the object, the external circumference of the cross-section of those sections of the material in which the thickness of the material is reduced will become smaller, and/or in that the internal circumference of the cross-section of those sections of the material in which the
10 thickness of the material is reduced will become larger.

- Preferably, the reduction in thickness occurs in one or more areas located between and/or adjacent to the ends of the blank and the blank may then be separated where required so as to form
15 a number of objects, each of which will preferably have an area of reduced wall thickness.

- In an embodiment, the reduction in thickness commences in tracks
20 extending all the way round the periphery of the blank and the reduction in the thickness of the wall preferably takes place in both directions from the track or tracks. The tracks may be one or more peripheral grooves formed in the wall of the blank at the same time as external devices are used to subject the blank to
25 tensile stress along its axis. Preferably, in the area of the base of the track, a clamping device moves sections of the material in the wall of the blank into contact with the external surface of a mandrel in order to fix the position of the blank relative to the mandrel, at least during the initial stage of the
30 reduction in the thickness of the wall of the blank by means of the mechanical shaping devices.

This stretching operation reduces the wall thickness in the grooves to about 1/3 of its original thickness at the same time

as the blank is elongated axially. Further reduction of the thickness of the wall of the blank is produced by positioning a draw ring in the aforementioned groove or grooves and moving it axially along the blank. Certain applications use two rings, whereby the reduction in wall thickness takes place simultaneously from a specific groove outwards towards the two ends of the blank.

In the case of a blank which is sealed at one end and in which the wall thickness is to be reduced adjacent to the seal, the draw ring should preferably be moved from the seal towards the other end of the blank. In certain applications the reduction in thickness is allowed to continue along the entire length of the blank.

In an embodiment, one end of the tubular blank is sealed either before or after the aforementioned re-shaping operations by heating the material and press-moulding the end, for example in a cup-shaped mould. German patent specification No. 1 704 119 contains examples of methods suitable for achieving sealing of this kind.

Where the blank is of polyethylene terephthalate and the thickness of the material in said one or more areas is reduced to a final thickness of approximately $1/3$ of the original thickness of the material, the material, at least immediately before the final reduction in thickness takes place, is brought to a temperature below or in the range of its glass transition temperature which deviates from said temperature by no more than 15°C . Preferably, at least immediately before the final reduction in thickness takes place, the material is brought to a temperature which deviates from the glass transition temperature by less than 3°C .

The thickness of the material is reduced in several stages generally where the material is so thick that problems arise in transferring sufficient heat away from the transitional zone. By reducing the thickness of the material a number of times before the final reduction in thickness is made, a thinner material will be produced which will facilitate the transfer of heat away from the transitional zone to the adjacent draw ring and/or internal shaping device.

10 The present invention also extends to apparatus for the production by a method as defined above of a tubular object of plastics material from a tubular blank of substantially amorphous material, the apparatus comprising a mechanical shaping device having a number of draw rings arranged so as to surround said blank and an internal shaping device located inside said blank such that the draw rings and said internal shaping device define a ring-shaped zone, and a number of drive devices arranged to move the draw rings and/or the internal shaping device relative to the blank along its axis, whereby the draw rings and/or the internal shaping device move the one or more transitional zones along the blank and in which the material has bearing surfaces against the draw rings and/or the internal shaping device during the reduction in thickness.

25 Preferably, the draw rings and/or the internal shaping device are provided with channels for the passage of a liquid for stabilizing the temperature of the material in the blank at a value corresponding or close to the range of its glass transition temperature.

30 In an embodiment, the draw rings are composed of a number of draw ring segments which are movable by drive means to and from an operating position in which the draw rings form a substantially

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column-shaped sealed internal surface which fits the surface which defines the limits of the track, and wherein the draw rings are preferably divided axially into ring sections which are generally provided with mutual thermal insulation, and each ring section is provided with liquid channels. Each draw ring may be formed by two draw ring halves movable by said drive means.

The apparatus may further comprise a clamping device arranged to be movable to and from an operating position in which the clamping device holds sections of the wall of the blank in the bottom of the track in firm contact with the external surface of a mandrel in order to fix the position of the blank relative to the mandrel.

The draw rings and the clamping devices are movable axially along the blank, and preferably, whilst the draw rings are moving towards the ends of the tubular blank, the movement of the draw rings is connected to the movement of the clamping devices such that the draw ring and clamping device which are adjacent to each other

are moved in the same direction and such that the correlation between the speed of the respective draw ring and clamping device is determined by the reduction in thickness which it is wished to produce in the material in the tubular blank. For example, when reducing the wall thickness of the blank to $\frac{1}{3}$ of its original thickness, the ratio between the speeds of the clamping device and the draw ring shall be 2:3, with a ratio of 1:2 when reducing the thickness of the material to $\frac{1}{2}$ of its original thickness, etc.

The clamping devices are fitted with axially movable sprung components against which the edges of the tubular blank make contact. Any longitudinal tolerances which are present in the blank both before and during the drawing operation are absorbed

by the sprung components.

5 In one embodiment of the invention each draw ring consists of three ring sections with a certain degree of thermal insulation between the sections. Each ring section is provided with channels for a fluid for either heating or cooling the ring section. The aforementioned mandrel is also provided with channels for a fluid. The central ring section includes that part of the draw ring against which the transitional zone between
10 material with its original thickness and material with reduced wall thickness is formed during the drawing of the tubular blank. Of the neighbouring ring sections, the one with the largest internal diameter is in contact with the material with its original thickness during the drawing operation, whilst the
15 other ring section with the smallest internal diameter is in contact with the material with reduced thickness.

When drawing a tubular blank, said blank is positioned on the mandrel in such a way that it is held securely by the clamping
20 devices and a central peripheral groove in the base of which the wall thickness has been reduced to approximately 1/3 of its original thickness is formed in the tubular blank. The draw ring halves are then moved to their operating position. The shape and the axial length of those parts of the draw rings which are
25 introduced into the groove correspond to the shape and the axial length of the groove. The material of the blank in the area which is to be drawn should preferably be heated to a temperature close to but below TG before the blank is positioned on the mandrel. The material will be raised to the correct drawing
30 temperature through the contact surfaces formed between the material of the blank and the draw rings and mandrel.

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During the actual drawing operation the draw rings and the clamping devices are moved away from the track by the drive devices, when the aforementioned relative speed between the draw rings and the clamping devices is maintained. Thus the thickness of the material in the blank will continue to be reduced by the draw rings for as long as movement continues. At the same time the blank is lengthened along its axis.

An important factor is the control of the temperature of the material in the transitional zone between amorphous material with the original wall thickness and material which has been reduced in thickness. The draw ring has an internal profile which matches the change in the thickness of the material which occurs in the transitional zone. The profile has been selected such that it will form contact surfaces with the internal surface of the draw ring not only in the transitional zone, but also ahead of and after it during the drawing operation. The draw ring is able in this way to control the shape of the transitional surface in the transitional zone. The temperature of the material in the blank is regulated during the entire drawing operation by the transfer of heat between the material in the blank and the draw rings and/or the mandrel. It is particularly important that the section of the draw ring which is in contact with the material in the transitional zone should maintain the material in the blank at a temperature close to TG.

A simplified embodiment of the present invention makes use of a single draw ring which is moved from a start track preferably all the way to the edge at one of the ends of the blank. In this way an object is produced in which the wall thickness is reduced at one end only. This embodiment preferably makes use of an internal mandrel as a dolly which will take up the axial forces which arise as the wall thickness is reduced. The movement of

the draw ring is interrupted in certain applications before it passes over the edge of the tubular blank. The edge will thus be bordered by a rim in which the wall thickness has not been reduced after the drawing operation is complete. The object which is produced in this way is suitable for use as a preform, possibly after a certain amount of re-shaping of the rim, i.e. what will become the edge of the mouth, for a container intended to be closed by means of a "crown cork", for instance. Before the object is moulded into a container, the area which will become the mouth is stabilized by heating and by thermal crystallisation, with crystallisation usually being allowed to continue until the material in the aforementioned rim becomes opaque.

15 In a preferred embodiment of the present invention the blank is provided with a start track of such axial length that space is provided in the track for a clamping device together with the draw ring or draw rings. At least during the initial stage of the movement of the draw ring or draw rings, the clamping device holds sections of the wall of the material in the base of the track pressed against the mandrel. In this way the position of the blank relative to the mandrel is fixed. In the embodiment of the present invention in which two draw rings are moved away from each other, the clamping device is designed to hold the wall of the blank in an area situated between the draw rings. By holding the blank securely against the mandrel, this will prevent any axial movement of the blank in relation to the mandrel which might arise depending on the axial forces which occur at the contact surfaces between the respective draw ring and the material in the transitional zone between the wall of the blank with reduced thickness and the wall of the blank with non-reduced thickness. Any movement could, for instance, lead to the disadvantage that in the variant of the invention in which an

area surrounding the track has the thickness of its wall reduced, the area with reduced wall thickness may be positioned unsymmetrically in relation to the start track.

5 The use of a clamping device in accordance with the previous paragraph offers the possibility of producing any desired axial length in the area in which the wall thickness of the material has been reduced. In certain applications this involves
10 producing such a reduction in the thickness of the wall of the material along the entire length of the blank, whereas in other applications the reduction in thickness is interrupted before the draw ring or draw rings reach and pass beyond the end or ends of the blank. By leaving an area of amorphous material at the very end or ends of the blank, a section of material will be produced
15 which is highly suitable, for example, for sealing to produce the base of a preform by the use of a method which is described in Patent Specification DE PS 1 704 119 or, after having been subjected to thermal crystallisation, for forming a rim for use with the "crown cork" type of closure.

20 In an alternative embodiment the draw ring is used to reduce the wall thickness of the material in a tubular blank with a sealed bottom, the mouth of which is already provided with a means of closure, for example screw threads. The blank in which the
25 material is intended to be subjected to a reduction in thickness is produced by some previously disclosed method, for example by injection moulding or by extrusion followed by sealing and moulding the bottom and mouth.

30 When using an external draw ring to reduce the thickness of the material in the wall of the blank, a certain reduction in the internal diameter of the blank will also be produced, as has already been mentioned. The mandrel inside the blank thus acts

as a shaping device which will determine the extent of the reduction in diameter. Surprisingly, it has been found that, for material within the range of temperatures indicated above during the re-shaping operation, the contact between the wall of the material and the mandrel and produced by the contraction, generates relatively little contact pressure between the internal surface of the wall of the blank and the external surface of the mandrel, for which reason no problems are encountered in removing the finished blank from the mandrel after the shaping (drawing) of the blank is complete.

By selecting an internal mandrel with an external circumference which is smaller than the internal circumference of the blank, it is possible to control the reduction in the internal circumference of the blank during the drawing operation to a value which is suitable for the envisaged specific application.

Embodiments of the present invention will hereinafter be described by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a perspective view of apparatus of the invention;

Fig. 2 shows a longitudinal section through the apparatus of Fig. 1 in which draw rings are shown in their initial position before drawing;

5 Fig. 3 shows part of a longitudinal section corresponding to that of Fig. 2, in which the draw rings have been separated from each other;

Fig. 4 shows a support plate fitted with a draw ring in its operating position;

10 Fig. 5 shows a longitudinal section through a tubular blank with a draw ring in its initial position;

15 Fig. 6 shows a longitudinal section through a tubular blank during drawing in the direction away from its sealed part;

Fig. 7 shows a section through a tubular blank with a draw ring in the initial position prior to drawing the blank in a short section at one end;

20 Fig. 8 shows a section of the tubular blank in accordance with Fig. 7 with the draw ring in its final position;

25 Fig. 9 shows a longitudinal section through an alternative embodiment of apparatus of the invention having a central clamping device and with the draw rings or the clamping device in the initial position before drawing;

Fig. 10 shows part of a longitudinal section corresponding to Fig. 9 with the draw rings moved apart;

Fig. 11 shows the central area in accordance with Fig. 9 in detail;

Fig. 12 shows the central area in accordance with Fig. 10 in detail;

Figs. 13 - 14 show objects of alternative embodiments.

Fig. 1 shows an overall perspective view of a drawing apparatus of the present invention having a base 30 from which a number of guide pins 31 project vertically upwardly. The description which follows refers to the apparatus in the position illustrated although the invention is in no way restricted to the orientation of the apparatus. Thus, the designations "upper" or "lower" and other similar designations are occasionally used below in connection with a variety of components, but these designations are used only for clarity.

The base is fitted with drive devices with gearing (not shown in the Figure) for a number of drive screws 32 which extend parallel to the guide pins. Four support plates 50, 60, 70 and 80 are positioned at right angles to the guide pins and to the drive screws. Each support plate is provided with bearings through which the guide pins 31 extend and threaded holes 52, 62, 72 and 82 through

which selected drive screws 32 extend in engagement therewith. The support plates are also provided with openings 58, 68, 78, 88 for those drive screws which are not in threaded contact with the actual support plate.

- 5 The top and bottom support plates 50 and 60 are in engagement with the two drive screws 32a and 32c, whereas the two interjacent support plates 70 and 80 are in engagement with the two remaining drive screws 32b and 32d. Furthermore, the upper part of the drive screws which
- 10 operate in conjunction with the support plates 50 and 70 are threaded in the opposite direction to the lower parts of the drive screws which operate in conjunction with the support plates 60 and 80. This means that as the drive screws are rotated the two upper support plates 50 and 70
- 15 will move in the same direction, although this will be opposite to the direction in which the two lower support plates 60 and 80 will move.

Since the top and bottom support plates 50 and 60 are driven by the screws 32a and 32c and the two middle support

20 plates 70 and 80 are driven by the screws 32b and 32d, the speed at which the respective support plates move will be determined by the rotational speed and the pitch of the screws which drive the respective support plate. The pitch of the thread on the drive screws is selected such

25 that the top and bottom support plates will always move at

5 a lower speed than the two middle support plates. In the initial position, the two middle plates are in close contact with each other and the top and bottom plates are positioned such that movement towards the ends of the guide pins can take place. After movement has taken place, the middle support plates will have moved away from each other and closer to the upper and lower support plate respectively.

The top support plate 50 and the bottom support plate 60 are provided with clamping devices 51 and 61, each of which holds one end of a tubular blank 10. The blank is provided with a peripheral starting track 12 (Fig. 2), preferably positioned substantially centrally of its length, in which the thickness of the material is approximately $1/3$ of its original thickness. The starting track is preferably formed before the blank is positioned in the device by the application of external pressure to the wall of the material, for example by means of a number of interacting rollers, at the same time as the tubular blank is subjected to tensile stresses along its axis. When forming the start track, the use of rollers in conjunction with a stretching operation produces a track having a predetermined axial length which has a profile which is substantially identical to the profile of parts of draw rings which are to be introduced into the track, as described below, to re-shape the blank into a tubular object. The axial length of the tubular

blank is increased when the start track is formed.

The two middle support plates 70 and 80 are each fitted with a respective draw ring 71 and 81, the draw ring 81 being obscured in Figure 1. The clamping device 51 of the top support plate and the draw rings 71, 81 of the two middle support plates each consist of two halves 51a, 51b; 71a, 71b, and 81a, 81b which are movable by a respective drive 53, 73 and 83 to and from the closed position which is shown in Figure 1.

Figure 2 shows a longitudinal section of the apparatus of Figure 1, the left-hand part of this Figure showing the upper clamping device 51 and the two draw rings 71, 81 in their open position, while the right-hand part of the Figure portrays the device with the upper clamping device 51 and the two draw rings 71, 81 in their closed (operating) position.

The Figure also shows the blank 10. At its centre is a peripheral start track 12 which is formed in accordance with the above description.

In addition to the details shown in Figure 1, Figure 2 shows that the upper and lower clamping devices 51 and 61 are each provided with a respective sprung support plate 54 and 64 against which the end edges of the tubular blank 10 make contact. The required spring function is provided by springs 55 and 65 around guide rods 56 and 66 for the

support plates 54 and 64, the guide rods being screwed firmly to the support plates.

The Figure also shows that the two draw rings 71 and 81 each consist of two draw ring halves 71a, 71b and 81a, 81b. In addition, each draw ring is divided into three sections 74, 75, 76 and 84, 85, 86, each of which is split into two ring sections. The ring sections are separated from each other by a certain degree of thermal insulation. The ring sections are held together by means of ring casings 77a, 77b and 87a, 87b such that they combine to form the two halves of the draw rings. Each ring section is provided with channels 174, 175, 176 and 184, 185, 186 to permit the flow of liquid.

The draw ring sections consist of a first section 74 and 84 having an internal circumference which corresponds to the circumference of the material in the blank in the areas in which the thickness of the material has not been reduced, a second section 76 and 86 having an internal circumference which corresponds to the circumference of the material in the blank in the areas in which the thickness of the material has been reduced, and a further section 75 and 85 having an internal profile which forms contact surfaces for contacting the material in the transitional zone between material in the blank which has and which has not been reduced in thickness.

Figure 2 also shows a mandrel 20 which fits the internal surface of the blank 10 and which is provided with channels 21 for liquid.

Figure 3 shows part of a longitudinal section of the apparatus of Figure 2 showing the central area with the draw rings 71, 81 spaced apart or in the course of moving apart along the axis of the blank such that the thickness of the material in a central section 11 of the blank 10' has been reduced. At the transitional zone 13, 14 between material 10 with its original wall thickness and material with reduced wall thickness, contact surfaces are formed between the middle draw rings 75, 85 and the material in the transitional zone. In this way the draw rings are able to control the shape of the transitional surface between material with its original wall thickness and material with reduced wall thickness.

Figure 4 shows a plan view of the support plate 70 viewed from above with the draw ring 71 in its closed position. The Figure also illustrates the locations of the bearings for the guide pins 31 and the openings 78 and the threaded holes 72 for the drive screws 32. The other support plates which are fitted with the draw ring 81 or with the clamping devices 51 or 61 are similarly equipped. As has already been mentioned, the clamping device 61 is not divided, and does not therefore have a drive corresponding to the drive 73.

Figures 5 and 6 show a typical application of the present invention in which the wall thickness of a tubular blank 15, 15' which is sealed at one end is reduced, starting at the sealed end of the blank by a draw ring 23. As shown, the draw ring is made up of three ring sections 24, 25, 26 having respective channels 124, 125, 126 for liquid. The ring sections are dimensioned similarly to the ring sections which have already been described and are held together by a ring casing 27. A mandrel 28 operates in conjunction with the draw ring 23 in the re-shaping of the blank. The mandrel is normally provided with liquid channels, which however, cannot be seen in the Figure. The draw ring 23 is preferably dimensioned such that both before and at the start of the drawing operation contact will be made between both the middle ring section 25 and the upper ring section 24 and the outer surface of the tubular blank.

Figure 6 shows the manner in which re-shaping is begun and shows a section 16 of the blank with reduced wall thickness which has been formed in the lower section of the blank. Re-shaping normally continues until all the material in the cylindrical part of the blank has had its wall thickness reduced. If the mouth of the blank has already been formed, which may be the case with an injection-moulded blank, the re-shaping of the blank is, of course, interrupted as the draw ring reaches the mouth. The transitional zone between material with

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its original wall thickness and material with reduced wall thickness is indicated in the Figure by the designation 113.

Figures 7 and 8 show an alternative embodiment of the present invention in which a draw ring 29 is composed of only two ring sections 96 and 97 each having separate liquid channels 94 and 95. In this embodiment there is also preferably a certain degree of thermal insulation between the ring sections. If necessary, the draw ring may be extended by the addition of a third ring section having a separate liquid channel and which is dimensioned as already described above. The draw ring 29 operates in conjunction with an internal mandrel 28, which is normally provided with liquid channels which are not shown in the Figures. The draw ring 29 re-shapes the mouth of a tubular blank 17 which is sealed at one end. In an area which is usually quite close to the opening in the blank, a peripheral start track 19 is provided in which the thickness of the material has been reduced to approximately 1/3 of its original thickness.

In Figure 8 the draw ring 29 has been moved relative to the blank with the help of the mandrel 28 in such a way that a section 18 of the blank with reduced wall thickness is produced adjacent to the opening in the blank 17'.

Figures 9 and 10 show a further alternative embodiment of the present invention in which a central clamping device

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41a, 41b is located between the draw rings 71 and 81. The clamping device 41a, 41b is positioned on a central support plate 40 which has a fixed position in the device. This fixed position is obtained, for example, by attaching the support plate 40 to the guide pins 31. The central
5 support plate is also fitted with drives 43a, 43b for moving the two parts 41a, 41b of the clamping device to and from the operating position of the respective parts. In certain embodiments, the central clamping device is provided with liquid channels 141a, 141b. In other respects
10 the device shown in Figures 9 and 10 corresponds to the device shown in Figures 1 to 4, and similar features have been accorded the same reference numerals as used in Figures 1 to 4. An equivalent device to the clamping device 51 is not present in this embodiment.

15 Figures 11 and 12 show details of the central areas in Figures 9 and 10, i.e. those areas in which the wall of the material in the blank is provided with a start track or in which the wall of the material has undergone a
reduction in thickness in conjunction with the movement
20 of the draw rings. The reference numeral 112 indicates an area of contact between the internal surface of the blank 10, 10' and the external surface of the mandrel 20 caused by a certain amount of deformation in the wall of the blank produced by the clamping device 41a when this
25 is in the operation position. The reference numerals 115, 116 indicate areas of contact with the mandrel by the inter-

nal surface of sections of the material in the blank 10' of which the thickness has been reduced by the drawing operation.

In accordance with the present invention the central
5 clamping device 41 may be designed in accordance with several alternative embodiments. The clamping device 41a, 41b in its operating position surrounds the wall of the blank, thus forming contact surfaces with the external surface of the wall of the blank which are distributed
10 at various points around the periphery of the blank. Such a distribution of contact surfaces may be provided by a clamping device having internal surfaces which face the blank which are not cylindrical surfaces of circular cross-section, but instead are cylindrical surfaces of, for example,
15 elliptical or polygonal cross-section.

Figures 13 to 15 show examples of objects 210', 210" and 210''' in accordance with the invention. The object 210' in Figure 13 has at its lower part a cylindrical wall section 213 of amorphous material adjacent to a sealed
20 bottom 211' which is also of amorphous material. Figure 14 shows an object 210" in which the external cylindrical surface has the same diameter along the entire length of the object. The sealed bottom 211" of the object is also of amorphous material in this embodiment. Finally, Figure 15
25 shows an embodiment in which the edge of the mouth 212 of the object consists of material with its original thickness,

whereas the remaining parts of the object are similar in design to those in Figure 14.

The blank 10 is positioned over the mandrel 20 in the embodiment of the present invention in accordance with the typical example shown in Figures 1 to 4. The clamping device 51 and the draw rings 71 and 81 are in their open position as shown in the left-hand part of Figure 2. The blank which is placed around the mandrel 20 forms contact surfaces with the mandrel. Once the blank is in place and is in contact with the sprung support plate 64 of the lower clamping device 61 the upper clamping device 51 and the draw ring halves are moved to their closed position. The two draw rings 71 and 81 enter the start track 12 and in so doing form contact surfaces with the outer wall of the blank where the wall thickness has not been reduced, where the wall thickness has been reduced to its minimum value, and at the transitional zone between the two aforementioned areas.

The material of the blank will preferably be at a high temperature, although preferably below TG, when it is placed on the mandrel. The final temperature of the material is set by the transfer of heat between the mandrel and the blank and/or between the draw rings and the blank. The temperature is controlled by means of the liquid which flows through the liquid channels 21 in the mandrel and/or through the liquid channels 174, 165, 176 and 184, 185, 186 in the draw rings. The thermal

insulation which is provided between the ring sections of the draw rings generally maintains a predetermined difference in temperature between different areas of material in the blank. The ring sections 74, 84 which have the largest internal diameter will, when in the position shown in the right-hand part of Figure 2, set the material to a temperature in the range of or just below TG, and preferably to a temperature which is not more than 15° C below TG. The ring sections 75, 85 have a similar function, whereas the ring sections 76, 86 will preferably maintain a temperature well below TG, and preferably at a temperature which is at least 15° C below TG, in order to cool the material once it has undergone the reduction in thickness.

Once the material has reached the specified temperatures the drive devices in the base 30 will begin to rotate the drive screws 32, causing the support plates 50 and 70 and the associated clamping device 51 and draw ring 71 to move upwardly as shown in the Figures. The support plates 60 and 80 and the associated clamping device 61 and draw ring 81 will be moved downwardly as shown in the Figures. The thickness of the material in the blank is thus reduced by the draw rings as long as movement continues. At the same time, the blank will be lengthened axially and this elongation will be proportional to the reduction in the thickness of the material and to the axial movement

of the draw rings. The speeds at which the support plates 50 and 60 move are therefore selected such that the positions of the clamping devices 51, 61 will match the elongation of the blank. Any irregularities which may occur will be absorbed by the sprung support plates 54 and 64.

The middle draw ring sections 75 and 85 are in contact with the transitional zone between material with reduced thickness and material with its original thickness. The profile of the middle ring section is selected such that the material during the re-shaping operation will form contact surfaces with the internal surfaces of the ring section. In this way the ring section will control the shape of the transitional surface between material with reduced thickness and material with its original thickness. The ring section also has a temperature regulating function in that the transfer of heat takes place at the aforementioned contact surfaces such that the material in the transitional zone is maintained at a temperature close to TG throughout the entire drawing operation. It is important, particularly when drawing takes place at high speed or when the material used is very thick, that the middle draw ring sections have excellent heat conducting properties so that the material in the transitional zone will not reach too high a temperature.

Once the draw rings have been moved apart so that the central section 11 of the blank has reached a predetermined length, the movement of the support plates is stopped. The drives 53, 73, 83 then move the clamping
5 device 51 and the draw rings 71 and 81 to their open position, and the object which has been formed in the manner described is then removed from the mandrel, whereupon a new tubular blank is placed on the mandrel and the operation is repeated.

10 The section 11 which has the reduced wall thickness forms the central section of the finished object and this central section is cut in order to produce two symmetrical parts. Each part is then sealed at the end having the original wall thickness, thus producing a pre-
15 form which may be used, for example, to produce a blow-moulded container. Those sections of the preform which have reduced wall thickness are subsequently re-shaped to form the basis for the mouth of the future container.

In the embodiment of the invention shown in Figures
20 5 and 6, the operation is in principle identical to that described above. The internal mandrel 28 acts as a dolly which takes up those forces which arise as the draw ring 23 is moved axially along the blank. Regulation of the temperature in the different areas of the material is
25 also important in this application. The mandrel 28 is normally provided with liquid channels corresponding to

the liquid channels 21 in the mandrel 20 shown in Figures 2 and 3. In certain applications the thickness of all the material in the cylindrical section of the blank is reduced, whilst the re-shaping stops sooner in other applications.

The embodiment shown in Figures 7 and 8 is applicable in those cases in which it is required to produce a number of areas of material in which the thickness of the material has been reduced. Each such area of material requires a start track in which the reduction in the thickness of the material may begin. When producing the object the draw ring 29 is moved to an initial start track and the halves of the draw ring take up their operating position. The draw ring is moved from the start track over a short distance along the axis of the blank, reducing the thickness of the material until the first section of material with reduced wall thickness has been produced. The draw ring halves are then moved apart and the draw ring is moved to the next start track, when the draw ring halves take up their new operating position. The draw ring is now moved once more along the axis of the blank in order to produce a new area of material with reduced wall thickness, and so on. The operation is repeated until the desired number of areas with reduced material thickness have been produced.

The blank used in conjunction with the unidirectional

drawing described in connection with Figures 5 to 8 is shown as being sealed at one end. In this way the seal will have operated in conjunction with the internal mandrel to absorb the axial forces produced during the drawing operation. It is, of course, possible to use external clamping devices which replace the function of the mandrel in this respect. This alternative is used when drawing tubular blanks which are open at both ends.

10 In the application of the present invention which utilizes the embodiment shown in Figures 9 to 12, the blank 10 is slid over the mandrel 20 until it makes contact with the lower clamping device 61. In this case the clamping device 61 serves as a device for determining the axial position of the blank, thereby ensuring that the track 12 on the blank adopts a position which is suitable for the positioning of the draw rings 71, 81 and for the clamping device 41. This situation corresponds to the left-hand half of Figure 9. The drives 43, 73, 83 then move the clamping device 41 and the draw rings 71, 81 into contact with the external surface of the blank in and adjacent to the track 12. The temperature conditioning of the material in the blank then takes place in the manner which has already been described, in addition to which in certain typical applications liquid is also caused to flow through the channels

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141 in the clamping device 41. This situation corresponds to what is shown in the right-hand part of Figure 9 and in detail in Figure 11.

In its operating position the central clamping device 41 surrounds the blank 10 in the bottom of the track 12. This forms contact surfaces with the bottom of the track which are divided into a number of areas around the circumference of the blank. The contact pressure present at these surfaces in turn causes the internal surface of the blank and the surface of the mandrel to bear against each other. The bearing surfaces adopt positions which correspond to the distribution of the contact surfaces. The bearing surfaces are produced because the clamping device deforms the shape of the surface defining the internal limits of the blank. The contact pressure of the clamping device is selected such that in the event of the shape being deformed, the thickness of the material in the bottom of the track will remain largely unchanged. A bearing surface is shown in detail in Figure 12 and is given the reference designation 112.

The drive devices in the base 30 (Figure 1) then rotate the drive screws 32 causing the draw rings 71, 81 to move apart along the axis of the blank, simultaneously re-shaping the wall of the material and elongating the blank. The friction between the blank and the mandrel at the aforementioned bearing surfaces 112 fixes the position of

the blank on the mandrel and ensures that the re-shaping of the blank will take place symmetrically around the track 12. The driving of the support plate 60 is selected such that the clamping device 61 will be

5 reliably moved away from the end of the tube so as not to have any effect on the elongation of the tube which occurs in conjunction with the reduction in the thickness of the wall of the blank. This operating situation corresponds to Figures 10 and 12. Figure 12 also show that, in

10 addition to the stretching of the material which occurs during the re-shaping of the wall of the blank, contraction of the blank also takes place, causing its internal surface to be moved into contact with the mandrel 20. These contact surfaces are indicated in the Figure

15 by the reference numerals 115 and 116. The formation of these contact surfaces contributes to the fixing of the position of the blank relative to the mandrel which is achieved with the help of the central clamping device 41. It has been found in the majority of typical applications

20 that additional fixing by means of the contact surfaces 115 and 116 is not essential to achieving the desired symmetrical re-shaping of the blank.

The description in the previous paragraph indicates that the alternative embodiment of the invention shown in

25 Figures 9 to 12 permits any desired length of the blank

to have the thickness of its material reduced. Thus, it is possible to reduce the thickness of the material along the entire length of the blank, to interrupt the reduction in thickness immediately before the ends of the blank, or to reduce the thickness in a number of areas distributed axially along the blank and separated by sections of material in which there has been no reduction in thickness. In each area with reduced material thickness, the reduction of the thickness is begun in a new start track.

Surprisingly, it has been found that when the blank is re-shaped at the temperatures indicated above, relatively low contact pressure is produced between the material of the blank and the mandrel, for which reason no problems are encountered in removing the moulded object from the mandrel after the moulding operation is complete.

The objects shown in Figures 13 to 15 are examples of objects produced in the manner described above. When producing the object shown in Figure 13 the thickness of a tubular blank which is open at both ends may be reduced with an area of amorphous material left at the end of the blank. This area of amorphous material is then heated and sealed in accordance with the method described above. Figures 14 and 15 relate to embodiments in which an already sealed tubular blank of amorphous material

is given cylindrical areas of the walls consisting of substantially monoaxially oriented material. In Figure 14 the monoaxially oriented material is present around the object over its entire length, whereas in Figure 15 the edge of the mouth 212 consists of material which has not undergone such orientation.

It is also possible to further increase the crystallinity of the material over and above the crystallinity which is produced in the material in conjunction with the monoaxial orientation by heating the material. This crystallinity should not be allowed to continue to such a point that the ability of the material to undergo further re-shaping is impaired where the object formed is a preform which will be re-shaped in a subsequent operation to produce a finished article. The crystallinity of an object is normally allowed to reach a maximum level of approximately 30 % when the object is to undergo further re-shaping. Preferably, the crystallinity allowed to lie between 10 and 25 %, the crystallinity produced by monoaxial orientation achieving a maximum value of approximately 17 %.

It has been assumed in the above description that the reduction in the thickness of the material to the final value required takes place in a single reduction operation. However, the thickness of the material may be reduced in

a number of consecutive reduction stages, before the thickness of the material is reduced finally to approximately 1/3 of its original thickness. In this case the draw ring or draw rings will consist of a number
5 of ring sections for the consecutive gradual reduction of the thickness of the material. The embodiment described in this paragraph is used mainly when the material in the blank has a large wall thickness and/or when the draw rings are moved at high speed.

10 Tubular blanks of circular cross-section have been shown in the above description. The invention may, of course, be applied to tubular blanks of other cross-sections.

The above description relates to the plastics material
15 polyethylene terephthalate. The values indicated in the description for the reductions in thickness and the temperatures to be used are also related to this material. A large number of materials of the polyester or polyamide type are known to exist and known to have similar character-
20 istics, and thus, the invention is also applicable either in whole or in part to these materials, provided that the reductions in thickness and the temperatures used are adjusted to suit the specific requirements of the respective material. The following are typical materials for which
25 the present invention is suitable, after the indicated adjustments have been made: polyethylene terephthalate,

polyhexamethylene adipamide, polycaprolactam, polyhexamethylene sebacamide, polyethylene-2, 6- and 1, 5-naphthalate, polytetramethylene-1,2-dioxybenzoate, and copolymers of ethylene teraphthalate, ethylene isophthalate, and other similar plastics polymers.

The crystallinity values stated in the present application relate to the theories disclosed in the published "Die Makromolekulare Chemie" 176, 2459-2465 (1975).

10 A tubular object formed from a tubular blank as described above is described and claimed in copending British Patent Application No. 8327044 which was divided from the present application.



CLAIMS:

1. A method for producing a tubular object of plastics material from a tubular blank having a wall of substantially amorphous material, comprising reducing the thickness of material in the blank or in one or more areas thereof by means of a single or several consecutive re-shaping operations, whereby a mechanical shaping device defines a ring-shaped zone in which a transitional zone between thicker and thinner material of the blank is enclosed, the mechanical shaping device moving said transitional zone along the blank and simultaneously elongating the blank in the axial direction of the blank, wherein after the last re-shaping operation the thinner material has an oriented state, and wherein the thickness of the thinner material corresponds to that which a sheet of amorphous material will obtain by moneaxial stretching to yielding of the material of said sheet, if, immediately before the stretching of said sheet, the thickness of the sheet is the same as the initial wall thickness of the blank and the temperature of the material of the sheet is the same as the temperature of the material of the blank immediately before the last re-shaping operation.

2. A method as claimed in Claim 1, wherein immediately before the reduction in thickness, the material which will undergo a reduction in thickness as the transitional zone is moved has a temperature below or in the range of the glass transition temperature of the material.

3. A method as claimed in Claim 1 or 2, ^{wherein} the mechanical shaping devices are in contact with and form bearing surfaces against the material in the area of the transitional zone and in that the material in the transitional zone is maintained at a temperature close to its glass transition temperature by the transfer of heat between the material and the mechanical shaping devices.



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4. A method as claimed in any preceding claim, wherein the material, once it has assumed its reduced wall thickness, is cooled immediately to a temperature below its glass transition temperature.

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5. A method as claimed in any preceding claim, wherein during the forming of the object, the external circumference of the cross-section of those sections of the material in which the thickness of the material is reduced will become smaller, and/or in that the internal circumference of the cross-section of those sections of the material in which the thickness of the material is reduced will become larger.

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6. A method as claimed in any preceding claim, wherein the reduction in thickness occurs in one or more areas located between and/or adjacent to the ends of the blank and the blank may then be separated where required so as to form a number of objects, each of which will preferably have an area of reduced wall thickness.

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7. A method as claimed in any preceding claim, wherein the reduction in thickness commences in tracks extending all the way round the periphery of the blank and the reduction in the thickness of the wall preferably takes place in both directions from the track or tracks.

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8. A method as claimed in Claim 7, wherein in the area of the base of the track, a clamping device moves sections of the material in the wall of the blank into contact with the external surface of a mandrel in order to fix the position of the blank relative to the mandrel, at least during the initial stage of the reduction in the thickness of the wall of the blank by means of the mechanical shaping devices.

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9. A method as claimed in any preceding claim, wherein one end of the tubular blank is sealed either before or after the aforementioned re-shaping operations by heating the material and press-moulding the end, for example in a cup-shaped mould.

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10. A method as claimed in any preceding claim, wherein the blank is of polyethylene terephthalate and the thickness of the material in said one or more areas is reduced to a final thickness of approximately 1/3 of the original thickness of the material, and wherein the material, at least immediately before the final reduction in thickness takes place, is brought to a temperature below or in the range of its glass transition temperature which deviates from said temperature by no more than 15°C.

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11. A method as claimed in Claim 10, wherein at least immediately before the final reduction in thickness takes place, the material is brought to a temperature which deviates from the glass transition temperature by less than 3°C.

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12. Apparatus for the production by a method as claimed in Claim 1 of a tubular object of plastics material from a tubular blank of substantially amorphous material, the apparatus comprising a mechanical shaping device having a number of draw rings arranged so as to surround said blank and an internal shaping device located inside said blank such that the draw rings and said internal shaping device define a ring-shaped zone, and a number of drive devices arranged to move the draw rings and/or the internal shaping device relative to the blank along its axis, whereby the draw rings and/or the internal shaping device move the one or more transitional zones along the blank and in which the material has bearing surfaces against the draw rings and/or the internal shaping device during the reduction in thickness.

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13. Apparatus as claimed in Claim 12, wherein the draw rings and/or the internal shaping device are provided with channels for the passage of a liquid for stabilizing the temperature of the material in the blank at a value corresponding or close to the range of its glass transition temperature.

14. Apparatus as claimed in Claim 12 or 13, wherein the draw rings are composed of a number of draw ring segments which are movable by drive means to and from an operating position in which the draw rings form a substantially column-shaped sealed internal surface which fits the surface which defines the limits of the track, and wherein the draw rings are preferably divided axially into ring sections which are generally provided with mutual thermal insulation, and each ring section is provided with liquid channels.

15. Apparatus as claimed in Claim 14, wherein each draw ring is formed by two draw ring halves movable by said drive means.

16. Apparatus as claimed in any of Claims 12 to 15, further comprising a clamping device arranged to be movable to and from an operating position in which the clamping device holds sections of the wall of the blank in the bottom of the track in firm contact with the external surface of a mandrel in order to fix the position of the blank relative to the mandrel.

17. A method for producing a plastics material object from a tubular blank substantially as hereinbefore described with reference to the accompanying drawings.

18. Apparatus for the production of a plastics material object from a tubular blank substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.
