

**Dec. 15, 1970**

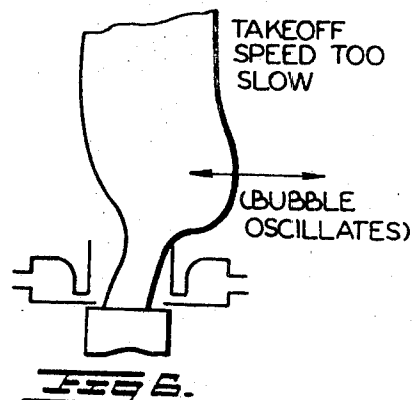
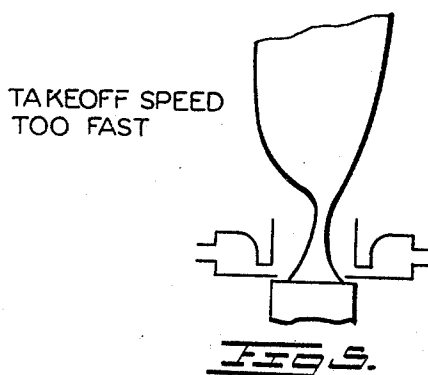
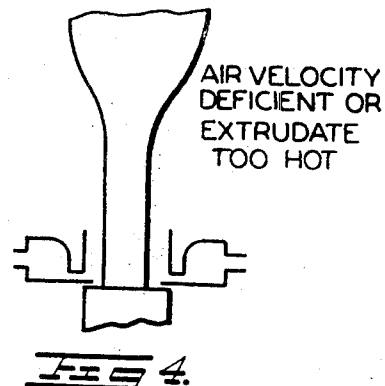
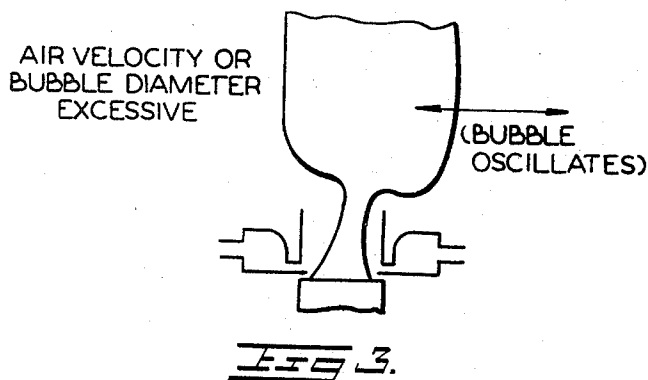
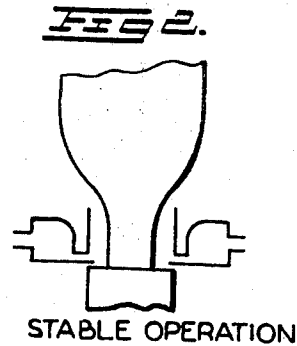
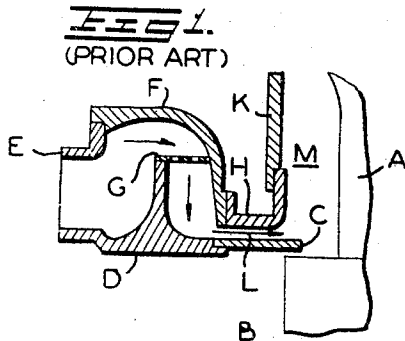
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**3,548,042**

## METHOD AND APPARATUS FOR COOLING EXTRUDED TUBING

Filed July 22, 1966

5 Sheets-Sheet 1



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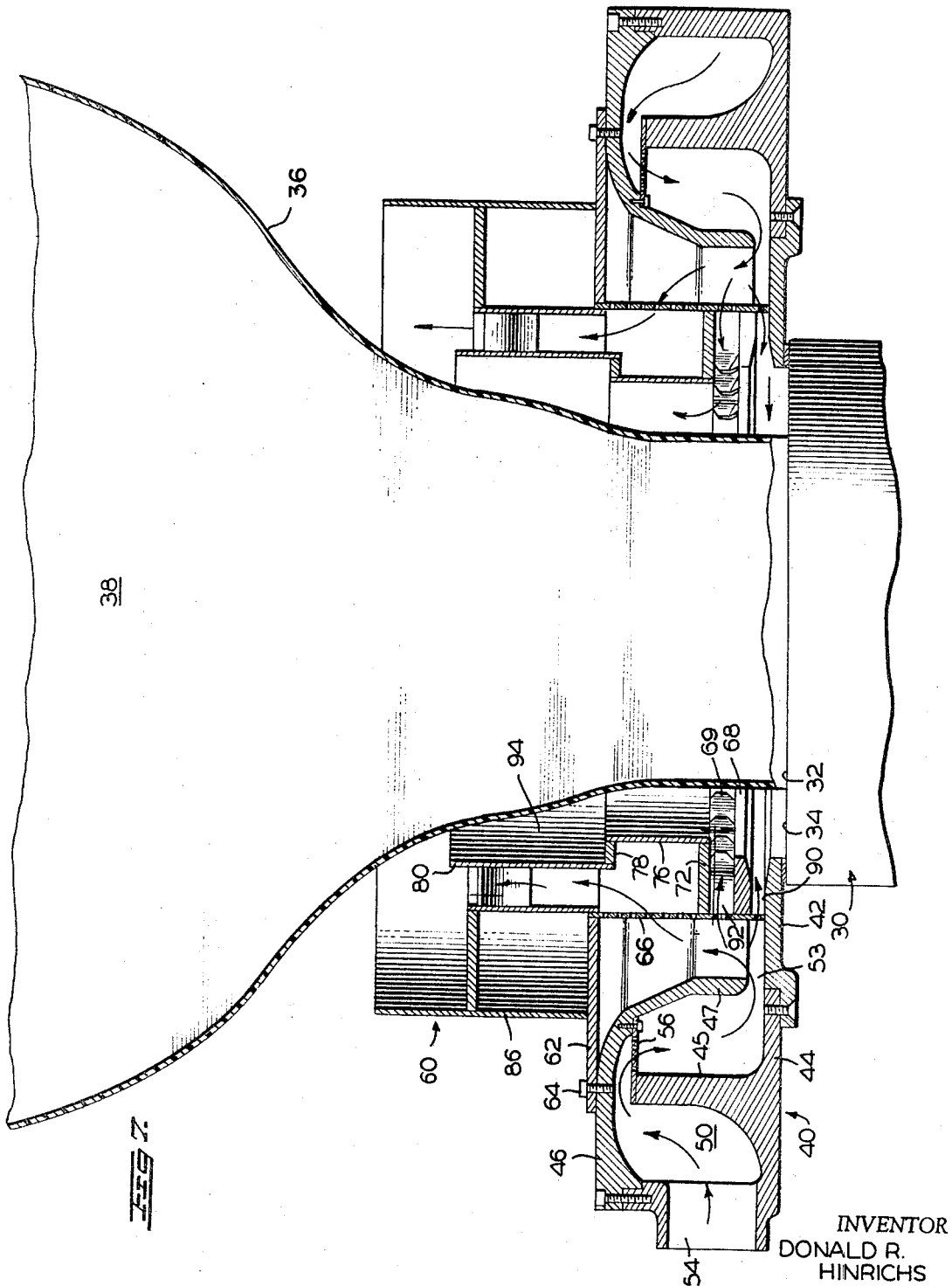
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METHOD AND APPARATUS FOR COOLING EXTRUDED TUBING

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5 Sheets-Sheet 2



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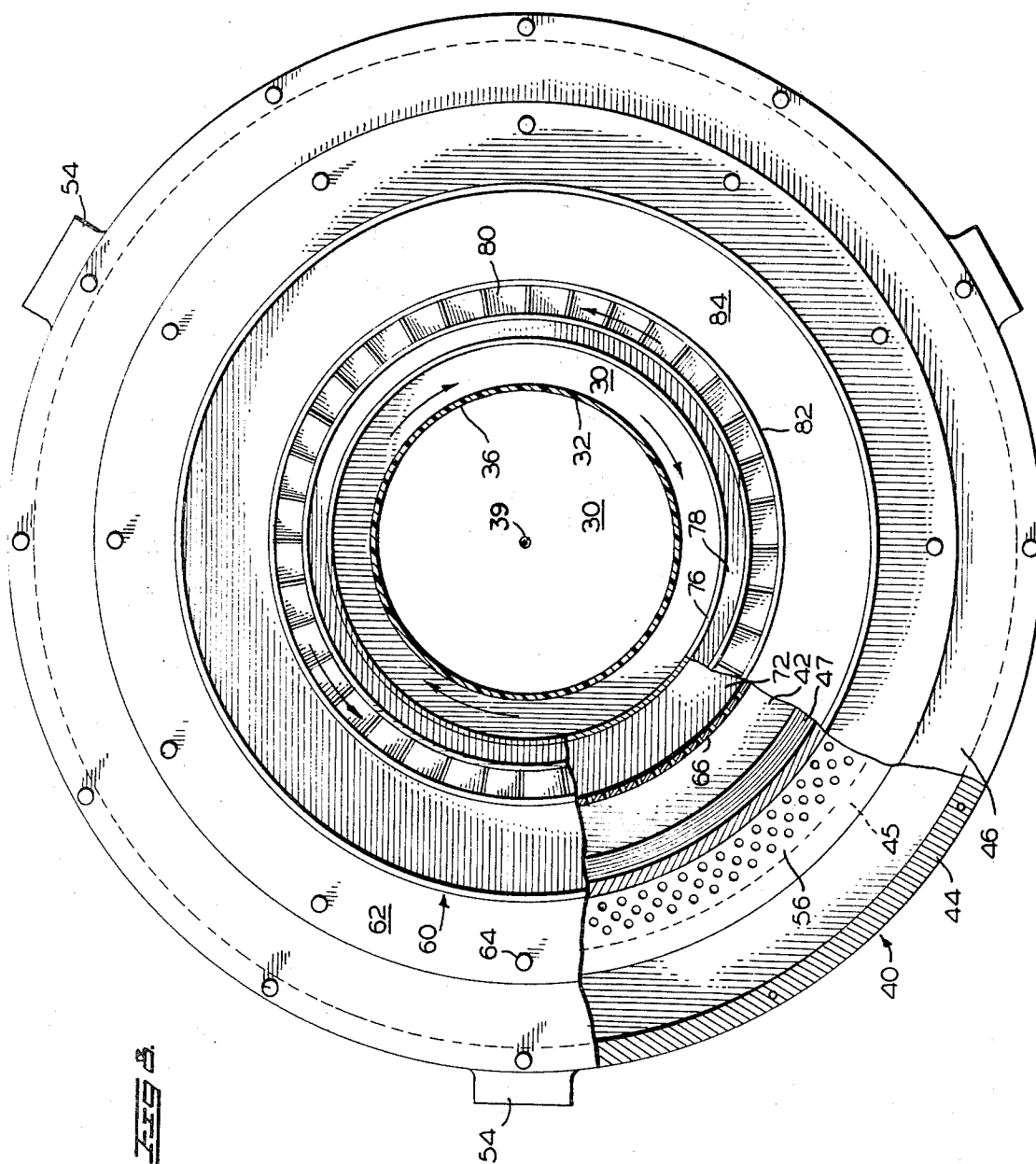
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METHOD AND APPARATUS FOR COOLING EXTRUDED TUBING

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5 Sheets-Sheet 4



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METHOD AND APPARATUS FOR COOLING EXTRUDED TUBING

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FIG 9.

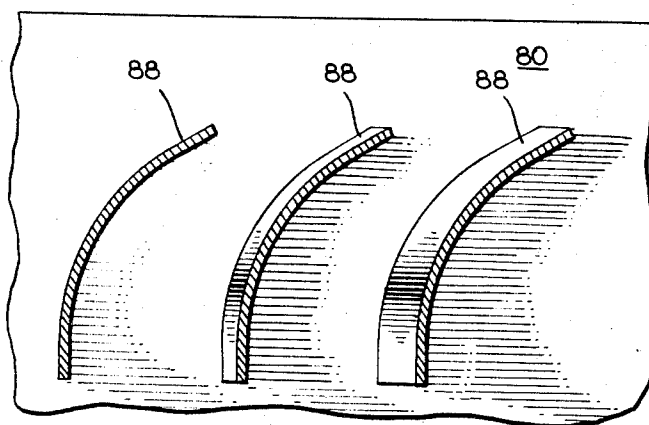


FIG 10.

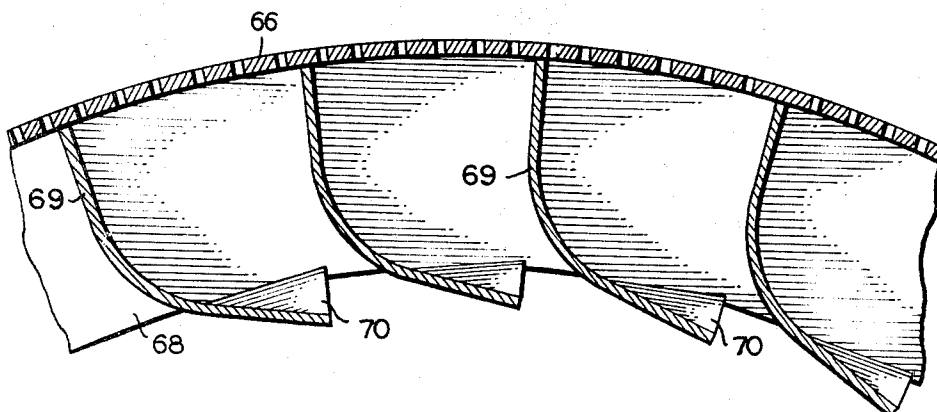
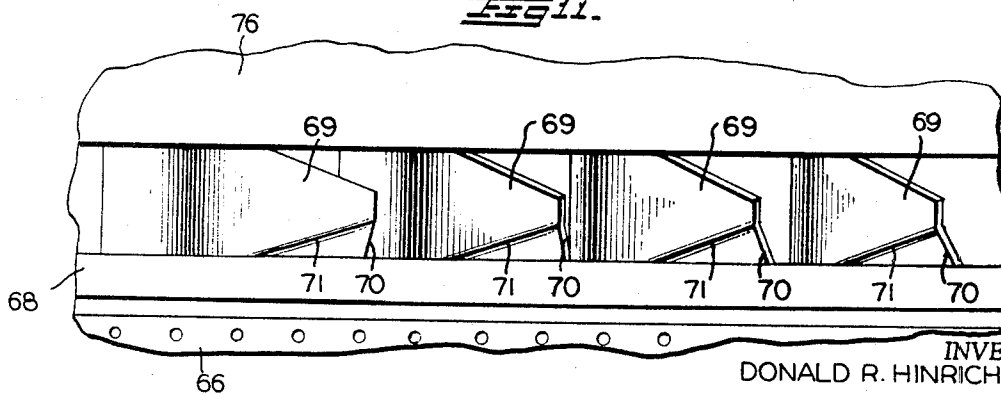


FIG 11.



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## METHOD AND APPARATUS FOR COOLING EXTRUDED TUBING

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13 Claims

### ABSTRACT OF THE DISCLOSURE

Extruded plastic tubing, before it has been stretched around a gaseous mandrel to form a bubble, is cooled by bringing into contact with its circumference two nonradial, axially spaced streams of gaseous coolant. The bubble is stabilized by balancing the rotational forces imparted to it by the two streams and by surrounding the tubing with a cylindrical wall which creates a sharp pressure differential adjacent the tubing.

This invention relates to improvements in systems for cooling inflated extrusions of plastic tubing.

It is known that thermoplastic materials may be extruded in a molten or semimolten condition through a die orifice to form seamless plastic tubing in film or other thicknesses. For various reasons it may be desirable to stretch the extruded tubing soon after it has emerged from the extrusion die; for example, stretching will decrease the thickness of the tubing while increasing another dimension, and if performed at certain temperatures, which will vary with the composition of the tubing, will permanently orient the molecules of the material in the direction of stretching, thereby increasing its strength or endowing it with the capability of shrinking in a predetermined manner when subsequently heated. Such stretching may be performed conveniently by inflating the tubing with a gaseous medium in a sufficient quantity to act as a mandrel, so that the tubing is continuously stretched laterally around the gaseous medium.

It is important that the stretching, in order to produce its desired effect, must be performed within a predetermined temperature range. If the temperature at which stretching occurs exceeds the maximum of this temperature range, the molecules will not retain the orientation achieved by the stretching, and the extrudate may even be so fluid that the stretching causes it to rupture. Normally this upper limit will be substantially below the temperature of the extrudate emerging from the die, so that if stretching is to be performed a short time thereafter, the extrudate must be subjected to artificial cooling during stretching, or, more preferably, before stretching begins. Various systems for performing such cooling have been devised, e.g., immersing the extrudate in a liquid cooling bath, spraying a liquid or liquid-gas mixture directly upon the surface of the extrudate, bringing the extrudate into contact with a metal member which in turn is in a heat-exchange relationship with a secondary coolant, or impinging a gaseous coolant against the surface of the extrudate. The last-mentioned system has been found advantageous because it avoids bringing the extrudate into contact with a substance which could mar its finish, and it provides for a flexible, economical, compact, and simple operation.

One disadvantage of gaseous cooling, however, is that the low volumetric specific heat of gases may limit the rate at which the plastic material can be extruded. Attempts to overcome this disadvantage by increasing the flow rate of the coolant increases the force which the coolant exerts on the extrudate. This often adversely

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affects the stability of the extruded tubing, with a commensurate reduction of the flexibility of the entire operation, as will be described in more detail hereinafter.

For a better understanding of the prior art, of certain problems associated with systems for producing inflated extrusions of plastic tubing, and of the present invention, reference is now made to the accompanying drawings, which are to be regarded as illustrative only. In the drawings:

FIG. 1 is a sectional elevation of the left side of cooling apparatus according to the prior art;

FIGS. 2-6 are schematic representations of various operating conditions which occur in producing inflated extrusions of seamless plastic tubing;

FIG. 7 is an elevation view, partially in section, of apparatus according to the present invention;

FIG. 7A is a detail of FIG. 7;

FIG. 8 is a plan view of the apparatus shown in FIG. 7 with a broken away portion in section along VIII—VIII in FIG. 7A, and with the extruded tubing broken away at the extrusion die;

FIG. 9 is a sectional view taken at IX—IX in FIG. 7A;

FIG. 10 is a sectional view taken at X—X in FIG. 7A; and

FIG. 11 is a sectional view taken at XI—XI in FIG. 7A.

FIG. 1 shows a prior art apparatus for cooling tubing A extruded from die B. This apparatus includes lower lip ring C attached to die B, air ring body D with inlet E, air ring cover F, perforated plate G, upper lip ring H, and cylindrical member K, all of which are secured together. The gaseous coolant, e.g., air, is introduced under pressure into inlet E, and passes inwardly through the space defined by body D and cover F, and thence through annular coolant passage L defined by upper and lower lip rings C and H. The coolant then cools the tubing A by impinging upon its exterior and exiting through annulus M between tubing A and cylindrical member K.

FIG. 2 shows the prior art cooling apparatus during stable operation, wherein extruded tubing emerges from the die orifice, retains its initial diameter for a short distance, and then stretches uniformly just above the top of the cooling apparatus to form the "bubble."

FIGS. 3 through 6 show various types of unstable operation. In each type the instability results in a progressive displacement of the tubing from the position it occupied under stable conditions. This progressive displacement, if uncorrected, would lead ultimately to rupture of the tubing and loss of the mandrel of air, or at the very least, to tubing with irregular or inadequate stretching, or with a defective surface. Frequently the mandrel of air is lost within a few seconds after the instability first occurs. FIG. 3 shows how the extrusion distorts and oscillates if the coolant velocity or bubble diameter becomes excessive. FIG. 4 shows the effect of excessive temperature of the tubing, which could be caused by either inadequate coolant velocity or excessive temperature of the extrudate leaving the die orifice. FIG. 5 shows what happens when the takeoff speed is too fast. (The takeoff speed is determined by the speed of the power-driven takeoff or pinch rolls collapsing and longitudinally stretching the tubing.) FIG. 6 shows what happens when the takeoff speed is too slow.

Although the system of the present invention cannot entirely eliminate the possibility of unstable operation, it does broaden substantially the ranges of conditions under which stable operation can be maintained. Since in general these ranges are closely interrelated, such broadening can be translated into a number of distinct advantages, for example: greater flexibility of operation, leading to fewer shutdowns and less critical control; increased cooling capacity and hence higher output; and greater

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stretching capability, making possible the production of tubing having a higher degree of molecular orientation and hence more desirable tensile properties and/or heat-shrinkability.

The presently preferred embodiment of apparatus according to the invention, as shown in FIGS. 7-11, consists of three main parts: die 30, air ring 40, and air ring insert 60.

Die 30 has its circular extrusion orifice 32 extending upwardly through top face 34. The molten plastic material is expelled from orifice 32 in the form of a tube of extrudate 36, which subsequently is stretched to about one to three times its original diameter over a stationary "mandrel" of air 38. Suitable power-driven pinch rolls (not shown) located well above the die confine the mandrel of air 38 to the interior of tubing 36. The rotational speed of the pinch rolls may be adjusted to provide the desired amount of stretching of extruded tubing 36 in a longitudinal direction. The mandrel of air 38 is introduced into tubing 36, and its volume adjusted, through port 39 extending through die 30.

In air ring 40, lower lip ring 42 is bolted to body 44, which in turn is bolted to cover 46. Body 44 has a vertical baffle 45, and a cover 46 has a downwardly turned inner lip 47, so as to form an annular outer chamber 50, an annular inner chamber 52, and an annular outlet 53. Three air inlets 54 in body 44 communicate with chamber 50. Annular perforated plate 56 is bolted at its inner edge to the underside of cover 46 and rests at its outer edge upon baffle 45. Lower lip ring 42 is mounted upon face 34 of die 30, with Teflon gasket 58 forming a gas-tight seal therebetween.

Air ring insert 60 fits as an integral unit within air ring 40. Annular disk 62 rests upon, and is secured by bolts 64 to, air ring cover 46, while cylindrical perforated baffle 66 rests at its lower end upon lower lip ring 42. Upper lip ring 68 is fastened to the inner surface of baffle 66. Forty-six lower deflector fins 69 are secured to the top surface of upper lip ring 68, so as to be abutting and equally spaced about the inner circumference of perforated baffle 66. As shown in greater detail in FIGS. 10 and 11, fins 69 are curved in the clockwise direction and have inclined tab portions 70 bent at angles of about 45 degrees along lines 71 with their lower edges secured to the top surface of upper lip ring 68. Annular disk 72 is secured to the inner surface of baffle 66 with its bottom surface in contact with the top surfaces of fins 69. Extending upwardly from the inner edge of disk 72 is an inner wall 74 of increasing diameter formed by cylinder 76, annular disk 78, and cylinder 80. Cylinder 82 is spaced outwardly of wall 74 with its lower edge secured to baffle 66 and its upper end secured to the inner

edge of annular disk 84. The outer edge of annular disk

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a blower (not shown) through ducts (not shown) and into inlets 54. The air then flows radially inwardly while at the same time becoming distributed uniformly in the circumferential direction, passing into annular chamber 50, over baffle 45, and into annular chamber 52, and being discharged radially inwardly through outlet 53.

The air continues through perforated baffle 66, whereupon its flow is divided into three components:

(1) The lowermost component is directed through passage 90 between lower lip ring 42 and upper lip ring 68 to impinge perpendicularly against the wall of the extrudate 36 immediately after it leaves die orifice 32. The cooling provided by this component is vital under certain conditions, e.g., high melt temperatures, because otherwise the extrudate will not form a self-supporting film after leaving the die orifice. After impinging upon tubing 36, the air flows upwardly within passage 94 defined by the inner surface of wall 74 and the outer surface of extruded tubing 36.

(2) The intermediate component flows through passage 92 between upper lip ring 68 and annular disk 72, and against deflectors 69. The curves of deflectors 69 direct the air flow in a clockwise direction, while the incline of their tab portions 70 direct the air flow upwardly. This results in a clockwise helical flow of air (including the air discharged through passage 90) within passage 94, creating a centrifugal effect and hence an abrupt pressure differential therein. This static pressure is positive and a maximum adjacent the inner surface of wall 74 and decreases rapidly toward tubing 36, becoming negative a few inches from wall 74. Since the air pressure within the tubing is maintained slightly positive, the tubing seeks an equilibrium position close to wall 74. The abrupt pressure differential thus restricts the movement of tubing 36 and increases its stability. In addition, the helical movement of the coolant within passage 94 prolongs its contact with the tubing and causes it to spew out tangentially when it reaches the top of wall 74, without impacting vertically against and distorting the underside of the bubble.

(3) The uppermost component flows through annular passage 96 between cylinders 80 and 82 and against deflectors 88, which impart to it a counter-clockwise rotation against the exterior of the extruded tubing 36, at that stage sufficiently stretched to be disposed above passage 96. This counter-clockwise rotation balances the clockwise forces exerted upon tubing 36 by the air rotating within passage 94, thereby preventing the tubing from gyrating. This uppermost component of air flowing through annular passage 96, being disposed outside the clockwise-rotating air flowing through passage 94 and rotating in the opposite direction, tends to confine it and straighten it out, so that the air flowing through passage

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ly 138 pounds per hour, resulting in a takeoff speed of 75 feet per minute. Two different bubble diameters were used for each apparatus. The air flow rate was the maximum which would not cause bubble instability. The results of the comparative tests are shown in Table 1. The shrinkages were determined for both the longitudinal or machine direction (MD) and the lateral or cross direction (CD) by measuring the dimensional change of 20 cm. samples exposed to 150° F. water for 2 minutes or 250° F. air for 10 minutes.

TABLE I

| Air ring type  | 150° F. shrinkage |             | 250° F. shrinkage |             | Lay-flat film width in inches | Bubble pressures in inches of water |
|----------------|-------------------|-------------|-------------------|-------------|-------------------------------|-------------------------------------|
|                | MD, percent       | CD, percent | MD, percent       | CD, percent |                               |                                     |
| Prior art..... | 1.25              | 3.0         | 6.12              | 12.25       | 25                            | 0.15                                |
| Do.....        | 1.37              | 2.37        | 6.12              | 13.12       | 30                            | 0.135                               |
| Inventive..... | 1.5               | 3.5         | 7.25              | 13.0        | 25                            | 0.23                                |
| Do.....        | 1.5               | 5.0         | 7.0               | 17.0        | 30                            | 0.26                                |

It can be seen that the film produced by the system according to the invention exhibited superior heat-shrinkability. Also, the internal bubble pressure obtained with the system according to the invention, being 5% to 100% higher, indicates that this system effected greater cooling since internal bubble pressure is directly related to the force required to stretch the film.

Another test indicated that the system according to the present invention permitted the extruded tubing's maximum bubble diameter to be at least 10% greater than the maximum bubble diameter possible with the prior art apparatus shown in FIG. 1.

Still another test showed that the apparatus according to the invention achieved stable operation at certain high melt temperatures while at these same temperatures the prior art apparatus shown in FIG. 1 could not even enable a bubble to be formed.

Yet another test showed that, during startup of the extruding operation, the prior art apparatus shown in FIG. 1 required constant adjustment of air flow as the size of the bubble increased, while under similar conditions the apparatus according to the invention had to be adjusted only once.

It will be clear that the present invention is not limited in its application to the production of polyvinyl chloride tubing, but may also be used in the production of other extruded tubing of other plastics, such as cellulose acetate, cellulose acetate butyrate, ethyl cellulose, methyl methacrylate polymer, nylon, polystyrene, polyvinyl formal-acetate butyral, copolymers of vinyl chloride and vinyl acetate, copolymers of vinyl chloride and vinylidene chloride, and Surllyn, a class of ionomer polymers. It will also be clear that the terms "coolant" and "gaseous coolant" as used herein are not limited to air at atmospheric conditions, but include any suitable coolant gas or mixtures of gases, at operable temperatures and pressures. Moreover, additives, such as fine droplets of liquid, may be combined with such gaseous coolant without departing from the present invention.

While present preferred embodiments of the invention have been illustrated and described, it will be understood that the invention may be otherwise variously embodied and practiced within the scope of the following claims set forth below.

I claim:

1. A method of producing inflated plastic tubing comprising the steps of: extruding said tubing, surrounding said tubing by a cylindrical wall defining therewith an annular passage, inflating said tubing, and directing fluid nonradially into contact with said tubing and thence helically around said tubing in said annular passage, thereby stabilizing said tubing.

2. A method of producing inflated plastic tubing comprising the steps of: extruding said tubing, surrounding

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said tubing by a wall defining therewith an annular passage, inflating said tubing, and directing fluid nonradially into contact with said tubing and thence around said tubing in said annular passage, the rotation of said fluid creating in said annular passage a sharp pressure differential having maximum pressure at the interior of said wall, thereby stabilizing said tubing.

3. The method of claim 2 wherein said maximum pressure is positive.

4. The method of claim 2 wherein said fluid flows helically in said annular passage.

5. A method of cooling extruded plastic tubing by simultaneously bringing into uniform contact with the circumference thereof two axially spaced streams of gaseous coolant, said method comprising the steps of extruding the tubing, directing one said stream to the left of the longitudinal axis of the tubing so that it passes clockwise over said circumference, and directing the other said stream to the right of said axis so that it passes counterclockwise over said circumference and thereby tends to balance rotational forces imparted to said tubing by said one stream.

6. The method of claim 5 wherein a third stream of gaseous coolant separate and axially spaced from said two streams is impinged uniformly and radially inwardly against said circumference.

7. The method of claim 5 wherein the coolant in a said stream follows a rotary path about said circumference after initial contact therewith.

8. The method of claim 7 wherein said rotary path is helical.

9. The method of claim 7 wherein said rotary path is within an annular passage defined by said tubing and a surrounding wall, and the rotation of said coolant creates in said annular passage a sharp pressure differential having maximum pressure at the interior of said wall.

10. Apparatus for cooling upwardly moving extruded plastic tubing prior to the completion of lateral stretching thereof, said apparatus comprising: means defining a plurality of separate, annular, gaseous coolant passages adapted to surround said tubing; first deflectors uniformly spaced around one said passage to direct coolant flowing in that passage to the left of the longitudinal axis of the tubing and into uniform contact with the circumference thereof, so that said coolant thereafter passes clockwise over said circumference; and second deflectors uniformly spaced around another said passage to direct coolant flowing in that passage to the right of the longitudinal axis of the tubing and into uniform contact with the circumference thereof, so that said coolant thereafter passes clockwise over said circumference.

11. The apparatus according to claim 10 wherein the passage-defining means includes a cylindrical wall adapted to surround the tubing.

12. The apparatus of claim 10 wherein the first and second deflectors are curved, and the first deflectors have inclined tabs for directing coolant upwardly.

13. The apparatus of claim 10 comprising further an air ring having an annular compartment adapted to surround the tubing, and an outlet communicating with said compartment and adapted to discharge coolant from said compartment inwardly toward said passages.

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U.S. Cl. X.R.

18—14; 165—47, 122; 264—95, 209, 237