

COOLING TUBE AND METHOD OF USE THEREOF**TECHNICAL FIELD**

5 The present invention relates, in general, to cooling tubes and
is particularly, but not exclusively, applicable to cooling
tubes used in a plastic injection-molding machine to cool
plastic parts, such as plastic parisons or preforms. More
particularly, the present invention relates to a structural
10 configuration of these cooling tubes, and also to method of
manufacturing and using such tubes, for example in the context
of a manufacturing process for preforms made from
polyethyleneterephthalate (PET) or the like.

BACKGROUND OF THE INVENTION

15 In order to accelerate cycle time, molding machines have
evolved to include post mold cooling systems that operate
simultaneously with the injection molding cycle. More
specifically, while one injection cycle is taking place, the
20 post mold cooling system, typically acting in a complementary
fashion with a robotic part removal device, is operative on an
earlier formed set of molded articles that have been removed
from the mold at a point where they are still relatively hot,
25 but sufficiently solid to allow limited handling.

Post mold temperature conditioning (or cooling) molds, nests or
tubes are well known in the art. Typically, such devices are
made from aluminum or other materials having good thermal
30 conductivity properties. Further, it is known to use fluid-
cooled, cooling tubes for post-mold temperature conditioning of
molded plastic parts, such as plastic parisons or preforms.
Typically, such tubes are formed by conventional machining
methods from solid stock.

35 To improve cooling efficiency and cycle time performance, EP
patent 0 283 644 describes a multi-position take-out plate that
has a capacity to store multiple sets of preforms for more than

one injection cycle. In other words, each set of preforms is subjected to an increased period of accentuated conduction cooling by retaining the preforms in the cooling tubes for more than one injection cycle. With increased cooling, the quality of the preforms is enhanced. At an appropriate point in time, a set of preforms is ejected (usually by a mechanical ejection mechanism) from the take-out plate onto a conveyor to allow a new set of preforms to be inserted into the now vacant set of cooling tubes.

European patent EP 0 266 804 describes an intimate fit cooling tube for use with an end-of-arm-tool (EOAT). The intimate fit cooling tube is water cooled and is arranged to receive a partially cooled preform. More particularly, after the preform has undergone some cooling within the closed mold, the mold is opened, the EOAT extended between the cavity and core sides of the mold and the preform off-loaded from a core into the cooling tube that then acts to cool the exterior of the preform through thermal conduction. As the preform cools it will shrink and slide further inside the tube to fit snugly therein.

A problem with the known cooling tube arrangements, is that the preform (at some point, if not from the point of introduction) loses contact with the internal side walls of the cooling tube, which loss of thermal contact lessens cooling efficiency and causes uneven cooling. As will be understood, uneven cooling can induce part defects, including deformation of overall shape and crystallization of the plastic (resulting in areas that are visibly hazed). Furthermore, lack of contact can cause ovality across the circumference of the preform, while the loss of the cooling effect can mean that a preform is removed from the cooling tube at an excessively high temperature. In addition to causing surface scratching and overall dimensional deformation, premature removal of a preform at an overly high temperature can also result in the semi-molten exterior of preform sticking either to the tube or another preform; all of these effects are clearly undesirable and result in part rejection and increased costs to the

manufacturer. It is therefore desirable to configure the cooling tube to include a means to achieve and/or maintain contact between the outer surface of the preform and the internal side walls of the cooling tube.

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U.S. Patent No. 4,047,873 discloses an injection blow mold in which the cavity has a sintered porous sidewall that permits a vacuum to draw the parison into contact with the cooling tube sidewall.

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U.S. Patent No. 4,047,873 discloses a method and apparatus for producing bi-axially oriented blow molded articles wherein the steps of longitudinal and radial expansion are performed sequentially in a longitudinal stretching mold and a radial stretching blow mold, respectively. In particular, a method is described for the longitudinal stretching of the parison in the longitudinal stretching mold which comprises a cavity formed in a porous structure, and a plurality of pressure control zones configured therealong.

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Japanese patent publication 56113433 discloses a process for producing hollow parts that includes the steps of extrusion molding of a foam parison into a vacuum forming mold comprising a cavity formed in a porous structure, and subsequently vacuum forming the parison into the hollow part whereby the foam cells in the hollow part do not collapse.

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German patent publication DE 197 07 292 describes a method and apparatus for producing aseptic bottles that includes the steps of extrusion molding of a parison into a vacuum forming mold, and subsequently expanding the parison in the mold by vacuum suction whereby germs do not enter into the bottle as is the case with conventional blow molding.

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U.S. Patent No. 4,208,177 discloses an injection mold cavity containing a porous element that communicates with a cooling fluid passageway subjecting the cooling fluid to different pressures to vary the flow of fluid through the porous plug.

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U.S. Patent Nos. 4,295,811 and US 4,304,542 disclose an injection blow core having a porous metal wall portion.

5 A "Plastics Technology Online" article entitled "Porous Molds' Big Draw", by Mikell Knights, printed from the Internet on July 27, 2002, discloses a porous tooling composite called METAPOR™. The article discloses the technique of polishing this material to close slightly the pores to improve the surface finish and reduce the porosity.

10 An article from International Mold Steel, Inc., entitled "Porous Aluminum Mold Materials", by Scott W. Hopkins, printed from the Internet on July 27, 2002, also discloses porous aluminum mold materials. The materials and applications
15 disclosed in the above two articles refer to vacuum thermoforming of plastics in the mold itself, in which preheated sheets of plastic are drawn into a single mold half via a vacuum drawn through the porous structure of the mold half.

20 Another problem with known cooling tubes is that they are expensive and time-consuming to make and assemble. Further, the operational mass (i.e. including cooling water) of the cooling tube is of particular concern considering that a
25 typical robot take-out system may include one or more sets of cooling tubes in an array, and therefore the cumulative mass supported by the robot quickly becomes a significant operating and/or design consideration (i.e. inertia or momentum considerations for the robot). Moreover, the robot typically
30 operates to remove many tens of preforms in a single cycle (with present PET systems producing up to one hundred and forty-four preforms per injection cycle) so the energy expended by the robot and the technical specification of the robot are unfortunately relatively high. The provision and operation of a
35 high specification robot therefore impose considerable financial cost penalties on an end user. It is therefore desirable to configure and manufacture the cooling tube according to a simplified structure and method, respectively.

Furthermore, it is desirable to configure the cooling channels as relatively open channels in an effort to reduce the operational mass of the cooling tube.

5 U.S. Patent Nos. 4,102,626 and 4,729,732 are typical of prior art systems in that they show a cooling tube formed with an external cooling channel machined in the outer surface of the tube body, a sleeve is then assembled to the body to enclose the channel and provide an enclosed sealed path for the liquid
10 coolant to circulate around the body.

WO 97/39874 discloses a tempering mold that has circular cooling channels included within its body.

15 EP 0 700 770 discloses another configuration that includes an inner and outer cooling tube assembly to form cooling channels therebetween.

U.S. Patent No. 5,870,921 discloses an extrusion die for use in
20 producing aluminum alloy articles of extruded shapes or tube having a void with defined internal dimension.

SUMMARY OF THE INVENTION

25 According to a first aspect of the present invention, structure and/or steps are provided for a tube assembly for operating on a relatively hot, and hence malleable, molded plastic part after it has been molded by a molding structure. The tube assembly includes a porous member having a profiled inside
30 surface for receiving an outside surface portion of the molded plastic part. The inside surface is preferably profiled to substantially correspond with the outside surface portion of the molded plastic part to be cooled. The tube assembly also includes a vacuum structure configured to cooperate with the
35 porous member to provide a reduced pressure adjacent the inside surface. In operation, the reduced pressure causes the outside surface portion of the malleable molded plastic part, locatable within the tube assembly, to contact the inside surface of the

porous member so as to allow a substantial portion of the outside surface portion of the malleable part, upon cooling, to attain a profile substantially corresponding to the profile of the inside surface, and wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

According to a second aspect of the present invention, structure and/or steps are provided for a porous cooling cavity that is configured to cooperate with a vacuum structure for receiving and cooling a relatively hot, and hence malleable, molded plastic article after it has been molded by a molding structure. The porous cooling cavity includes a porous member formed from a porous material. The porous member including (i) an inside surface that is profiled to substantially reflect a shape of a portion of an outside surface of the molded plastic article, and (ii) a vacuum coupling structure. The vacuum coupling structure of the porous member is configured to cooperate with the vacuum structure to provide, in operation, a reduced pressure adjacent the inside surface of the porous member to cause the portion of the outside surface of the malleable molded plastic article to contact the inside surface of the porous member so as to allow the outside surface portion of the malleable part, upon cooling, to maintain a profile substantially corresponding to the profile of the inside surface and thereby a disfiguring of the shape of the outside surface portion of the molded article is substantially prevented.

According to a third aspect of the present invention, structure and/or steps are provided for an end-of-arm tool configured to be carried by a robotic arm in an injection molding machine. The end-of-arm tool includes a carrier configured to be coupled to the robotic arm, the carrier carrying at least one molded article cooling device. The at least one molded article cooling device includes a porous member having a porous inside surface that is profiled to substantially reflect a shape of a portion of an outside surface of a relatively hot, and hence malleable,

molded article. The end-of-arm tool further includes an evacuation structure configured to evacuate the air through the porous member. In operation, the porous member supports the evacuation of air through the porous inside surface to cause the malleable molded article within the porous member to expand to come into contact therewith, wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

According to a fourth aspect of the present invention, structure and/or steps are provided for an injection mold robot. The injection mold robot includes an arm member configured to be disposed adjacent an injection molding machine, a carrier configured to be coupled to the arm member, the carrier carrying at least one molded article cooling device. The at least one molded article cooling device includes a removable porous member having a porous inside surface that is profiled to substantially reflect a shape of a portion of an outside surface of a relatively hot, and hence malleable, molded article. The injection mold robot further includes an evacuation structure configured to evacuate the air through the at least one porous member. In operation, the porous member supports the evacuation of air through the porous inside surface to cause the malleable molded article within the at least one porous member to expand to come into contact therewith, wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

According to a fifth aspect of the present invention, structure and/or steps are provided for an injection molding machine. The injection molding machine includes a molding structure that molds at least one relatively hot, and hence malleable, plastic part. The injection molding machine further including at least one porous cooling cavity having a profiled inside surface that is configured to hold and cool the at least one plastic part after it has been molded by the molding structure. The inside surface is profiled to substantially correspond with the

outside surface portion of the at least one plastic part to be cooled. The injection molding machine also includes at least one vacuum channel that is configured to provide a lower-than-ambient pressure to the inside surface. In operation, the lower-than-ambient pressure adjacent the inside surface causes an outside surface portion of the at least one plastic part to contact the inside surface of the at least one porous cavity, wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

According to a sixth aspect of the present invention, structure and/or steps are provided for a method for cooling a relatively hot, and hence malleable, molded plastic part, wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented. The method includes the steps of: (i) receiving the molded plastic part into a porous cooling cavity that includes an inside surface that is profiled to substantially correspond with an outside surface portion of the molded plastic part to be cooled; (ii) providing a reduced pressure adjacent the profiled inside surface of the porous cooling cavity causing the outside surface portion of the molded plastic part to move into contact therewith and thereby attain a substantially corresponding shape; (iii) extracting heat from the molded plastic part through a heat dissipation path to solidify the molded plastic part to the extent that the shape of the outside surface is preserved; and (iv) ejecting the molded plastic article.

According to a seventh aspect of the present invention, structure and/or steps are provided for forming a molded plastic article. The molded article having a shape of at least a portion of its outside surface defined by an inside surface of a porous cooling cavity that is profiled to substantially reflect a shape of a portion of an outside surface of a relatively hot, and hence malleable, molded article to be cooled. The molded plastic article formed by the process of: (i) receiving the malleable molded plastic article into the porous cooling cavity; (ii) evacuating the air surrounding the

molded plastic article through a plurality of interstitial spaces that are configured along the inside surface of the porous cooling cavity causing the portion of the outside surface of the molded plastic article to move into contact with the profiled inside surface and thereby to attain a shape substantially corresponding to the profiled inside surface; and (iii) extracting heat from the molded plastic article through a heat dissipation path to solidify the molded plastic article sufficiently such that the outer shape of the molded plastic article is preserved; wherein the portion of the outside surface of the cooled molded plastic article takes on a surface finish that corresponds substantially to the interstitial spaces of the porous cooling cavity.

According to an eighth aspect of the present invention, structure and/or steps are provided for a cooling tube for cooling a portion of an injection molded article received therein. In accordance with a preferred embodiment, the cooling tube includes an extruded tube body having an inside surface and an outside surface, and a plurality of cooling channels disposed therebetween that arranged in a longitudinal direction of said tube body. The cooling tube further including a connecting channel configured between said cooling channels for interconnecting said cooling channels into at least one cooling circuit, a seal configured at each end of tube body for closing said cooling channels, and an inlet and an outlet in said tube body for said at least one cooling channel. The cooling tube also includes a plug disposed in a distal end of said tube body. The inside surface of said tube body and an inside surface configured on said plug being machined to provide a profiled cavity that substantially conforms with a profile of an outer surface of said portion of said molded article.

According to a ninth aspect of the present invention, a method for extruding the cooling tube includes the steps of: (i) extruding a tube body having an inside surface, an outside surface, and a plurality of cooling channels disposed therebetween that arranged in a longitudinal direction of said

tube body; (ii) machining the inside surface of the tube body to substantially conform with the outer surface of the molded article; (iii) configuring a connecting channel between the cooling channels; and (iv) forming the plug.

5 The present invention advantageously provides a cooling tube structure that functions to cool rapidly and efficiently a just-molded plastic part located within the cooling tube, thereby improving robustness of the preform and generally enhancing cycle time. Moreover, in the context of cooling PET and the unwanted production of acetaldehyde arising from prolonged exposure of the preform to relatively high temperatures, the rapid cooling afforded by the present invention beneficially reduces the risk of the presence of
10 unacceptably high levels of acetaldehyde in the finished plastic product, such as a drink container. Beneficially, the present invention seeks to maintain a required and defined shape of the molded part, such as a preform.

20 In addition, the present invention advantageously provides an extruded cooling tube that is easily manufactured and which is of a lightweight construction that, beneficially, reduces robot specification requirements and/or improves robot cycle time. Furthermore, the cooling tube has enhanced cooling capabilities as a consequence of improved and integrally formed channeling.

25 In addition, alternative embodiments of the present invention provide cooling tube assemblies that are capable of vacuum forming a molded article.

BRIEF DESCRIPTION OF THE DRAWINGS

30 Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

35 FIG. 1 is a plan view of a typical injection molding machine including a robot, and end-of-arm tool;

FIG. 2 depicts a section through a cooling tube assembly according to a preferred embodiment of the present invention;

FIG. 3 depicts a sectional, but exaggerated view, through the cooling tube assembly of the FIG. 2 embodiment, with a freshly molded part just loaded;

FIG. 4 depicts a section through the cooling tube assembly of the FIG. 2 at a later point in time;

FIG. 5 depicts a section through the cooling tube assembly of an alternate embodiment;

FIG. 6 depicts a view on section A-A of FIG. 5;

FIG. 7 depicts a section through the cooling tube assembly of a second alternate embodiment; and

FIG. 8 depicts a section through the cooling tube assembly of a third alternate embodiment.

FIG. 9 is a sectional view of a cooling tube according to a preferred embodiment of the present invention;

FIG. 10 is a view along section 'A-A' of FIG. 9 cooling tube;

FIG. 11 is an isometric view of a cooling tube porous insert; and

FIG. 12 is a sectional view of a cooling tube according to an alternative embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The present invention will now be described with respect to embodiments in which a porous cooling tube is used in a plastic injection molding machine, although the present invention is equally applicable to any technology in which, following part

formation, cooling of that part is undertaken by a cooling tube or the like. For example, the present invention can find application in a part transfer mechanism from an injection molding machine and a blow-molding machine.

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FIG. 1 shows a typical injection molding machine 10 capable of co-operating with a device supporting the cooling tube of the present invention. During each injection cycle, the molding machine 10 produces a number of plastic preforms (or parisons) corresponding to the number of mold cavities defined by complementary mold halves 12, 14 located within the machine 10.

The injection-molding machine 10 includes, without specific limitation, molding structure such as a fixed platen 16 and a movable platen 18. In operation, the movable platen 18 is moved relative to the fixed platen 16 by means of stroke cylinders (not shown) or the like. Clamp force is developed in the machine, as will readily be appreciated, through the use of tie bars 20, 22 and a machine clamping mechanism 35 that typically generates a mold clamp force (i.e. closure tonnage) using a hydraulic system. The mold halves 12, 14 together constitute a mold generally having one or more mold cavities 22, 24, with the mold halves 12, 14 each located in one of the movable platen 14 and the fixed platen 16. A robot 26 is provided, adjacent the fixed 16 and movable platen 14, to carry an end of arm tool (EOAT) 28, such as a take-out plate. The take-out plate 28 contains a number of preform cooling tubes 30 at least corresponding in number to the number of preforms 32 produced in each injection cycle, and may be a multiple thereof. In use, in a mold open position (as shown in FIG. 1), the robot 26 moves the take-out plate into alignment with, typically, a core side of the mold and then waits until molded articles (e.g. preforms 32) are stripped from respective cores into respectively aligned cooling tubes 30 by operation of a stripper plate 33.

Cooling tubes 30 are generally shaped to reflect the external profile of the molded article (e.g. preform 32), so in the

context of a PET preform the cooling tubes 30 are preferably cylindrically-shaped, open-ended, hollow tubes, each having a channel at the base thereof connected to a vacuum or suction unit 34 operational to draw and/or simply hold the preforms 32 in the tubes 30.

Generally, the take-out plate 28 will be cooled either by connection to a suitable thermal sink and/or by a combination of techniques, including internal water channels, as will be understood.

FIG. 2 shows a cooling tube assembly 50 comprising an inner porous insert 52 made, preferably, of a material such as porous aluminum having a porosity in the range of about 3 to 20 microns. The porous properties of the substrate are generally achieved from either its material configuration or a chemical removal (or adjustment) treatment process in which interstitial spaces are induced into the substrate, thereby producing an internal structure that is somewhat analogous to either honeycomb or a hardened sponge. The present invention can make use of communicating channels through the substrate material having a size outside the range of 3 to 20 microns, albeit that readily commercially available materials, such as METAPOR™ and PORCERAX™ (both manufactured by the International Mold Steel Corporation), are discussed with respect to the preferred embodiments described herein. Porosity is, in any event, a function of surface finish, and machining of working of the surface can affect porosity through the material, as will be understood. In a preferred embodiment, the inner porous insert 52 is made from a structure having definite strength and mechanically resilient properties, although the inner porous insert could also be made from substances like graphite. It is preferably that the inner porous insert 52 is a thermal conductor, with it being particular preferably that the thermal conduction properties are good, e.g. a metal-based or sintered composite material.

As will be understood, METAPOR™ is combination of aluminum and epoxy resin having a mix ratio of between about 65-90% aluminum powder and 35-10% epoxy resin.

5 A typical cooling tube assembly 50 may have an internal length dimension of about 100 millimetres (mm), with an interior diameter of about 25mm and an outer diameter of about 40mm, with these dimensions reflecting the size of the molded article. Of course, tubes may be made of different diameters
10 and lengths to suit the particular preform shape being cooled.

From a practical perspective, the porous insert 52 is preferably located in a tube body 54, which is surrounded by a sleeve 56. Cooling channels (or passageways) 58 are optionally
15 cut or otherwise formed adjacent to the tube body 54, and convey a cooling fluid (e.g. air, gas, or liquid) to cool the body 54 and the insert 52, thus drawing heat from the molded plastic part in the porous insert 52. Each cooling channel preferably configured to have a cross-section comprising a
20 plurality of arcuate, elongated slots which extend around greater than 50% of a circumference of an inside diameter of a respective cooling cavity. Alternatively, the tube body 54 could simply be directly thermally coupled to a heat sink to reduce a combined overall weight of the tubes and end-of-arm-
25 tool 28, provided that the heat sink is capable of drawing sufficient heat from a preform in unit time.

Seals 60-62 between the sleeve 56 and the tube body 54 contain the cooling fluid in the grooves 58. Channels 66 are cut or
30 otherwise formed in the exterior surface of porous insert 52 and provide a means to apply a vacuum through the porous structure of the porous insert 52.

Other than the channels 66, the outer surface of the porous
35 insert 52 is configured such that a good surface contact is maintained between the insert 52 and the tube body 54, thereby to optimize heat transfer from the porous insert to the molded plastic part. The vacuum is applied through the porous insert

such that a freshly loaded molded plastic part 32, shown in FIG. 3, is caused to expand in size to touch an inner surface 82 of the porous insert, as shown in FIG. 4. Thus, heat is conducted from the molded plastic part 32 to and through the porous insert 52 to the cooled tube body 54. It is noted that the position of a dome portion 80 of the preform 32 is exaggerated in FIG. 3 and that FIG. 3 is representative of a time when the preform is being introduced into the cooling tube assembly 50.

Under application of suction or vacuum, a lower-than-ambient pressure is present outside of insert 52, thus causing air to flow through the porous insert 52 from the inside surface 82 thereof and into channels 66. This suction, in turn, causes a lower-than-ambient pressure at the outer surface of the molded plastic part, causing it to move into contact with the inner surface 82 of the porous insert 52.

In a PET environment with a METAPOR™ insert having 3-20 micron interstitial spaces, operational vacuum pressures for the system are achievable within the range of about 254 to 762 millimeters (10 to 30 inches) of mercury (using a U3.6s Becker evacuation pump). However, it will be understood that the applied vacuum pressure is ultimately determined by (and is a function of) the mechanical properties of the plastics material.

A positive pressure may also be applied (by means of a fluid injector and lip seals) to the inside of the preform, to cause the preform to contact at least a portion of the cooling tube inside surface, although this requires a sealed system. Any appropriate pressure differential may therefore be applied between the inside surface of the cooling tube and the outside surface of the plastic part, depending on the shape of the part and the cycle time provided for the cooling. It is preferred that the entire outer surface of the preform (cylindrical outer surface and spherical outer surface at the distal tip, i.e. the dome 80) contact the porous insert cooling tube, although an

outer profile of the preform may, in fact, prevent this along, for example any inwardly tapering portion 84 proximate the neck finish of the preform 32. However, the cooling tube and vacuum structure may be designed to bring any portion(s) of the preform into contact with the cooling tube, depending on the plastic part design and the portion(s) thereof needing cooling. Further, the vacuum (or positive pressure) may be applied in one, two, or three or more stages to effect various cooling profiles of the plastic part. For example, a thick portion of a preform may be brought into immediate contact with the cooling tube, while a thinner portion of the preform may be brought into contact with the cooling tube at a later time. In general, the preform is in contact with the cooling tube 50 for sufficient time only to allow robust handling of the preform without any fear of damage arising, with this dependent upon preform material, size and cross-sectional profile.

The porosity of the porous insert 52 can be lowered to improve the surface finish (i.e. inner surface 82) of the porous insert 52 in contact with the molded plastic part and thereby minimize any marking of the molded part's surface. Reducing the porosity of the insert 52 also, however, reduces the flow of air passing therethrough. A modest flow reduction can be tolerated since this does not greatly impede the effect of the vacuum created or diminish its intensity, especially since, once the molded part's surface contacts the insert, all airflow ceases. The airflow rate only affects the speed at which the vacuum is created when the molded part 32 initially enters the tube 52. Porosity reduction is achieved by milling and grinding procedures, whereas additional process steps of stoning or electric discharge can clear debris from surface interstitial spaces to increase porosity. In any event, flow rate through the material is a function of both applied pressure and porosity, as will be readily understood.

Inside the cooling tube 50, due to the partially cooled, but still malleable, state of the molded part on entry into the molded plastic part, the vacuum will cause the molded plastic

part to expand in diameter and perhaps length. The molded part is subjected to a vacuum applied to most of its external surface, while its internal surface is exposed to ambient pressure.

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In FIG. 5, support ledge 100 of the molded part 32 prevents the part from entering further into the tube 50 as the part cools and shrinks. In this case, the vacuum draws the closed end of the part further into the tube while the support ledge prevents the opposed end from following. In all embodiments the vacuum causes the part to change shape to substantially eliminate the clearance that initially exists between the part's outer surface and the corresponding inner surface of the porous insert 52.

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In the case of molded plastic parts having diametric features, such as the inwardly tapered portion 84, these will not be substantially altered in shape during this expansion phase. The configuration and size of the internal dimensions of the porous insert 52 are made such that the diameter matches or is slightly larger than the corresponding diameter of the part being cooled, thus preventing substantial disfiguring of the plastic part shape.

End seal 104 (of FIG. 3) at the open end of the cooling tube 50 provides a means to initially establish (and as necessary maintain) the vacuum within the assembly. If there are sections of the porous insert 52 that do not engage with portions of the preform, such as region 106 shown in FIG. 4 below support ledge 100, then the end seal 104 is required to ensure that the molded part remains in contact with the inner wall 82 and thereby to resist the effect of shrinkage of the part as it cools, otherwise the end seal 104 may be omitted. If the vacuum were not present, shrinkage of the part would cause a separation between the part's outer wall and the inner cooling wall of the insert 52 (and hence a resulting loss of suction), thereby greatly impeding the transfer of heat from the part to the insert 52 and into the cooling tube. Thus, the continuing

provision of the vacuum ensures intimate contact between the molded part's outer surface and the insert's inner wall 82 is maintained to maximize cooling performance.

5 Returning to FIG. 3, the cooling tube assembly 50 is preferably fastened to a carrier or take-out plate 110 by a screw 112. The insert 52 is retained in the assembly by a collar 114, which is threaded onto the end of the tube body 54 or fastened or otherwise coupled by any other conventional means. A cooling
10 fluid channel inlet 116, and a cooling fluid channel outlet 118 are provided in the carrier plate 110. A vacuum channel (or passageway) 120 is also provided in the carrier plate 110. After sufficient cooling time has elapsed, the vacuum is replaced with pressurized airflow (by inversion of the vacuum
15 pump function), and the part is ejected from the cooling tube assembly 50 by this pressure.

FIGs. 5 and 6 show an alternative embodiment for a cooling tube 150 in which the tube body 54 and the sleeve are 56 replaced
20 with an extruded tube that contains integral cooling channels. An aluminum extrusion 152 forms the tube body and contains integral cooling channels 154 that are alternately connected to each other by grooves 156 at each end of the tube. Sealing rings 158 close the ends of the tube to complete the cooling
25 circuit's integrity. A porous aluminum insert 160, having external grooves 162 that act as a channel for the vacuum, is located (inside the cooling tube 150) by a spacer 164 and a collar 166 attached to the tube by a thread or any other conventional fastening mechanism. The cooling tube assembly is
30 fastened to the carrier plate 110 by any suitable external clamping means, such as a bolt 168 and clamp 800. This alternative embodiment has a lower cost of manufacture and an improved cooling efficiency by virtue of its extruded body component.

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FIG. 7 shows a second alternative embodiment for cooling a molded part having a different shape. In this arrangement, the end seal (reference numeral 104 of FIG. 3) between the top of

the cooling tube and the underside of the support ledge 100 is not necessary. A porous insert 200 is held within the extruded tube 152 by a collar 201 that is threaded 202 onto the top of the cooling tube (in this case the extruded tube 152) or fastened by any suitable means. The collar 201, typically made from aluminum or the like, extends inwardly to conform to the inner profiled shape 204 of an open end of the insert 200 that matches, or is slightly larger, than that of the part being cooled. The collar 201 provides a seal of sufficient efficacy to allow the vacuum applied to the porous insert to cause the part to expand in size to intimately fit against the inner surface of the insert and cool. In some cases it is preferred that the part has a looser fit in the tube when first entering it. In this event, FIG. 8 shows how a lip seal 210 can provide the necessary initial sealing to permit a vacuum to become effective after the loading of a looser fitting part.

Methods of constructing and using the cooling tubes (in an operational environment) of the present invention to accentuate cooling and part formation have been described above. Briefly, a porous cooling tube constructed in accordance with one of the embodiments of the present invention is manufactured by milling or extruding a cooling tube assembly having a porous cooling tube insert and, optional but preferable, cooling fluid channels. The porous insert may be polished, painted, or otherwise treated to reduce porosity and provide a finer finish to the exterior of the molded part. The cooling fluid channels may be wholly enclosed inside the tube, or may be formed by placing a sleeve over open channels formed in the outer surface of the porous insert. Vacuum channels may be milled or extruded on an outer surface of the porous insert, or may be provided with separate structure adjacent the porous insert outer surface. The closed end of the cooling tube may be machined into the tube, or may comprise a plug fitted into one open end of a cooling cylinder. Appropriate seals are then fitted to either end of the cooling tube to provide the required pressure management, as described above.

In operation, the just-molded plastic part is extracted from a mold cavity and inserted into the cooling tube and preferably sealed therein. Then, a vacuum (or partial vacuum) is applied through the porous insert from the outer surface thereof to the inner surface thereof, causing the plastic part to expand in length and diameter to contact the inner surface of the porous insert. The cooling fluid circulates through the cooling channels, extracting heat from the porous insert, which extracts heat from the molded part. When sufficient cooling is complete (when the exterior surfaces of the molded part have solidified and achieved sufficient rigidity), the vacuum is released and the molded part is ejected, for example, into a bin for shipping. If desirable, a positive pressure can be applied through the vacuum channels to force the molded part from the cooling tube.

Thus, what has been described is a novel cooling tube assembly for the improved cooling of partially cooled molded parts that provides a means to maintain intimate surface contact between the part's external surface and the internal cooled surface of the tube during the cooling cycle. The disclosed post mold cooling device preferably uses a vacuum to slightly expand the part to contact the cooled surface and to maintain contact as part cools, thereby counteracting shrinkage that tends to draw the part away from the cooled surface.

The present invention may also be described with respect to embodiments in which the cooling tube includes an extruded tube. The extruded cooling tube has particular use in a plastic injection molding machine, although the present invention is equally applicable to any technology in which, following part formation, cooling of that part is undertaken by a cooling tube or the like. For example, the present invention can find application in a part transfer mechanism from an injection molding machine and a blow-molding machine.

FIG. 9 shows a sectional view through a cooling tube 350 of an embodiment of the present invention. The cooling tube 350

preferably comprises an extruded one-piece tube 352 with an outside surface 384, an inside surface 382 for operating on the preform 32. The cooling tube 350 includes a cooling circuit for cooling inside surface 382 that includes longitudinally oriented cooling channels 354 formed by extrusion between the inside surface 382 and the outside surface 384 of the tube 352. The cooling channels 354 are connected together in a desired flow configuration by any number of connecting channels 356, and the cooling circuit connected to a source and sink of coolant through inlet and outlet channels 390 and 392. The connecting channels 356 are located at the top and base of tube 352, between the outside surface 384 and the inside surface 382, and extend between two or more cooling channels 354. The connecting channels 356 are closed on one side by sealing rings 358. The sealing rings 358, including seals 359, are retained in a groove at the top and base of the cooling tube 350 by snap rings 366 or other known fastening means. The cooling tube 350 further includes a central plug 364 inserted into its base and retained by shoulder 367, the central plug 364 including a contoured inside surface 303 for supporting and otherwise operating on the bottom of a preform 32. The central plug 364 also includes a pressure channel 394, for connection to a vacuum source, for the purpose of assisting in the transfer of a preform 32 into the cooling tube 350. The coolant inlet and outlet channels 390 and 392 of the cooling circuit being provided in the central plug 364.

The tube 352 preferably comprises a one-piece extruded tube with longitudinal cooling channels 354 that may have a cross sectional profile selected from a wide range of shapes. Using conventional machining techniques (e.g. milling) to machine the channels 354 with the shape shown in FIG. 10 is generally not practical beyond a length of about 4 times the diameter of the cutter being used, thereby limiting the length of cooling tube made by this method to an unsuitably small range. Therefore, an extruded tube can be identified as one having an integral cooling channel having a length generally greater than four times the minor diameter of the cooling channel 354, or one as

having a substantially constant non-cylindrical cooling channel 354 shape.

The cooling channels 354 formed in the extrusion process provides channels for cooling fluid to circulate in the tube, extracting heat from the preform 32 through the tube inside surface 382. The cooling tube may include four cooling channels 354 (as shown in FIG. 10). The shapes of channels 354 are preferably arcuate-shaped, elongated slots that present a larger cooling surface area than drilled holes. Preferably, the cumulative angular extent of all elongated slots is greater than 180 degrees, the angular extent of each elongated slot being the measure of the contained angle of an arc concentric with the cooling tube with its terminus points defining a maximum arc length through the elongated slot. Such a shape works to optimize thermal transfer from a preform 32 due to the coolant distribution that extends around a substantial portion of, and in proximity to, the inside surface 382 that contacts the preform 32, and also due from the high volume flow rate of coolant supported by the large cross sectional profile of the coolant channel 53. Further, the preferred coolant channel 354 cross-sectional profile provides for a relatively lightweight cooling tube 350, that results in an overall mass reduction in the carrier plate assembly 11 that may be considerable given that some carrier plate assemblies include upwards of 432 tubes (i.e. a carrier plate assembly with 3 sets of 144 cooling tubes), thereby allowing a lighter duty and hence lower cost robot to be used and/or allowing the plate to move faster thereby saving some cycle time and reducing energy consumption.

In an alternative embodiment of the invention, the four arcuate shape channels shown in FIG. 10 could be changed to only two larger arcuate shapes (not shown) so that one channel represents the input and the other the output, thereby simplifying the connecting channels 356.

The central plug 364 preferably includes a contoured inside surface 303 shaped to substantially match that of the part

being cooled. The central plug 364 is preferably made from aluminum, and functions to cool the gate area of the preform, to define a channel for the vacuum, and to facilitate the coupling of the cooling channels to the carrier plate 11, where necessary. Provision for the pressure channel 394 is preferably at the plug's center. In one embodiment, the central plug 364 is retained between the shoulder 367 of the cooling tube and the take-out plate 28. A tube fastener 368, such as a screw or bolt, is provided to couple the cooling tube 350 to the take-out plate 28. Alternate means of assembling the plug 364 and fastening the cooling tube 350 to the take-out plate 28 may be used.

Exemplary physical dimensions of a cooling tube 350 for an arbitrary preform 32 according to the present invention suggest a representative length of about 100mm long, an interior diameter of about 25mm, and outer diameter of about 41mm. For such an arbitrary cooling tube, the cooling channels 354 are preferably about 1-4mm in thickness, about 80mm in circumference, and about 100mm (preferably the same length as tube) in axial length. Of course, tubes of different diameters and lengths would be made to suit the geometry of any preform 32, and hence wide variations in the coolant channel 354 dimensions are possible. The cooling tube 350 is preferably made from Aluminium.

According to the present invention, an extruding process is used to form a tube 352 including the cooling channels and a hole, the hole preferably sized to be smaller than any of the plastic parts destined for cooling in the tube. The extrusion process is consistent with known techniques. The tube 352 is then cut to length and the molding surface and any other desired features (such as connecting channels 356, sealing ring 358 grooves, and any coolant inlet/outlet or pressure channels, coupling structure, etc.) are then machined. The central plug 364 is then machined, including adding desired features (such as coolant 390, 392 and pressure channel 394). The central plug 364 with all necessary seals is then installed into the

cooling tube 350, and the sealing rings 358 with seals 359 installed into the sealing ring grooves in the top and bottom of the cooling tube 350, so that the entire assembly is ready for installation onto the take-out plate 28.

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In a preferred embodiment, the connecting channels 356 at the top end of the tube 352 may be provided by machining through alternate separation walls (not shown) of the cooling channel 354. At the take-out plate 28 (bottom) end of the tube 352, 10 similar alternate separation walls (not shown) are machined to connect the cooling channels 354 and provide connections to the cooling fluid inlet channel 390 and the cooling fluid outlet channel 392. Alternately, the cooling channels 354 in the tube wall could be connected directly to the corresponding ports in 15 the take-out plate 28.

In an alternative embodiment of the present invention (not shown) the cooling tube is extruded to define a cylindrically-shaped tube with an inside surface, an outside surface, and at 20 least one cooling channel 354 formed on the outer surface of the tube 352. A tubular sleeve fits-around the tube 352 thereby enclosing the cooling channels 354. Seals are provided between the tube 352 and sleeve to provide a water-tight connection. The cooling channels may be connected as 25 previously described in the preferred embodiment of the invention.

In an alternative embodiment of the present invention (not shown) the cooling tube is extruded to define a cylindrically-shaped tube with an inside surface, an outside surface, and at 30 least one cooling channel 354 formed on the outer surface of a tubular sleeve that fits-around the tube 352 thereby enclosing the cooling channels 354. Seals are provided between the tube 352 and sleeve to provide a water-tight connection. The 35 cooling channels may be connected as previously described in the preferred embodiment of the invention.

In operation, the cooling tube is used similarly to that described in US 4,729,732. It is preferred that the internal dimensions of the cooling tube are slightly smaller than the external dimensions of the preform being cooled. Thus, as the preform shrinks, its external size is reduced, and a vacuum acting through the central plug draws the part further into the cooling tube so that an intimate fit or contact of the preform's external surface is maintained with the inside surface of the cooling tube. Alternately, the internal dimensions of the cooling tube can be manufactured to be the same size or slightly larger than the external size of the preform being cooled, so as to permit a flow of air to be drawn past the part's external surfaces by the vacuum.

In more detail, after the preforms are formed in the injection molding machine, the mold opens by stroking the movable platen 18 away from the fixed platen 16, and the robot arm (carrying the carrier plate assembly 11) moves between the mold halves 12 and 14 so that the cooling tubes 30 can receive a set of preforms 32 that are ejected from cores 23. Applied suction may be used to encourage transfer of the preforms 32 from the cores 23 to the cooling tubes 30, and/or to retain the preforms therein. The carrier plate assembly 11 is then moved out from between the mold halves 12, 14, and then orientated so that the carrier plate assembly 11 is sequentially or selectively placed adjacent to a cooling station, a receiving station, or a conveyor. The preforms may then be transferred thereto.

In addition to the improved cooling performance of the cooling tube, there is a substantial benefit in reduced cost of manufacture. An extruded cooling tube according to the present invention can benefit from a cost reduction relative to conventionally manufactured tube due to substantially reduced machining requirements.

In an alternative embodiment of the invention (not shown) the cooling tube assembly 350 of FIG. 9 may be modified to include a tubular porous insert 452, as shown in FIG. 11, along the

inside surface 482 for vacuum forming a preform 32 and to improve preform 32 cooling efficiency due to a better heat conduction interface (i.e. larger surface area contact and more intimate fit). The porous insert 452 includes an inner surface 482 and outer surface 483, the inner surface 482 contoured to correspond substantially with the final desired molding surface of the preform 32, the outer surface 483 may be segmented by a set of longitudinally directed pressure channels 466. The pressure channels 466 provide a conduit for establishing a region of very low vacuum pressure in proximity to the portion of the porous insert 452 between the inside surface 482 and the outside surface 483 and thereby to evacuate air through the porous structure of the porous insert 450 for the purpose of drawing a deformable preform 32 into contact with the contoured inside surface 482 of the porous insert 452, thereby vacuum forming the preform 32. The porous insert 452 is preferably made from a highly thermally conductive material, such as aluminum. The material selection for the porous insert further characterized by the requirement for a porous structure with a porosity preferably in the range of about 3-20 microns. Further, the porous insert 452 may be advantageously manufactured in a process that includes the step of extrusion.

Yet another alternative embodiment of the invention is shown in FIG. 12, wherein a cooling tube assembly 450 for vacuum forming a preform 32 is provided. The cooling tube assembly 450 includes a tube 454 that may be machined from available tube stock, however an extruded tube such as tube 352 (as exemplified in FIG. 9) may also be used. The tube 454 includes an insert bore 455 for receiving a porous insert 452, as exemplified in FIG. 11. The porous insert 452 is retained in the tube 454 by a central plug 464, the central plug 464 received in a first and second plug bore 457, 458 of the tube 454. The central plug 464 is further retained in the tube 454 by its shoulder 467 bearing against the step between the first and second plug bore 457, 458. The shoulder 467 on the central plug 464 corresponds to a step in the diameter of the central plug 464 with a narrowed portion at its upper end that provides

an annular channel 465 between the central plug 464 and the second plug bore 458 of the tube 454. The annular channel 465 connects the pressure channels 466 of porous insert 452 with a channel 420 that is formed in the central plug 464 that is in turn connected in use to a first vacuum channel in take-out plate 28. The central plug 464 includes a contoured inside surface 403 that substantially corresponds to the dome portion of preform 32 that may be used for forming and cooling the region. The central plug 464 further includes inlet and an outlet coolant channel 490, 492, and a pressure channel 494, for connection to coolant inlet and outlet channels 116, 118 and a second pressure channel in the take-out plate 28 respectively. The inlet and outlet channels 490, 492 of the central plug 464 are further connected to a cooling groove 493 formed on the outer surface of the tube 454 thereby forming a cooling circuit. The cooling tube assembly 454 further includes a sleeve 456 that is retained on the outer surface of the tube 454. Seals 459 are also provided between the sleeve 456 and tube 454, and between the central plug 464 and the tube 454 to provide air and water tight connections between components forming the cooling tube assembly 450. The tube 454 further includes a groove at its open end for receiving an end seal 404 that provides in use an airtight seal between the preform support ledge 100 and the cooling tube assembly 450 for enclosing the volume formed between the preform 32 and cooling tube assembly 450, thereby enabling the development of the required low vacuum forming pressure. The primary components of the cooling tube assembly 450 are preferably made from a highly thermally conductive material, such as aluminum. The operation of the cooling tube assembly 454 installed on the take-out plate 28 of the carrier plate assembly 11 will now be described. The take-out plate 28 provides cooling fluid inlet and outlet channels and first and second vacuum channels to correspond with the ports on the central plug 464. In use, a preform 32 is drawn into the cooling tube assembly 450 by a relatively high flow rate suction acting through the pressure channel 494 that further retains the preform 32 once the preform support ledge 100 is sealed against the end seal 404

thereby stopping air flow. A high vacuum is then applied through the vacuum channel 420 in the central plug 464, then through the annular channel 465 and pressure channels 466, whereupon the vacuum acts through the porous wall of the porous insert 452. The volume of air between the preform 32 and the inner surface 482 of the porous insert 452 is at least partially evacuated to cause the drawing of the preform outer surface into contact with the porous insert 452. Once in contact with the porous insert 452, the preform 32 is cooled by conduction, its heat moving through a path from the preform outer surface to the porous insert 452, to the tube 454, and to the circulating coolant. Once enough heat has been removed from the preform 32 to ensure that it will retain its shape, the high vacuum acting through the vacuum channels 466 is released and a positive pressure is applied through the pressure channel 494 to assist in the ejection of the preform 32.

Thus, what has been described is an extruded cooling tube for a plastic part, a porous insert for use with a cooling tube assembly for vacuum forming preforms, various advantageous embodiments of cooling tube assemblies, methods of making the afore mentioned, and a method of using a cooling tube assembly, which will greatly reduce the cost of such tubes in injection molding and/or improve the quality of the molded preform 32.

All U.S. and foreign patent documents, and articles, discussed above are hereby incorporated by reference into the Detailed Description of the Preferred Embodiment.

The individual components shown in outline or designated by blocks in the attached Drawings are all well-known in the injection molding arts, and their specific construction and operation are not critical to the operation or best mode for carrying out the invention.

While the present invention has been described with respect to what is presently considered to be the preferred embodiments,

it is to be understood that the invention is not limited to the disclosed embodiments. For example, whilst the preferred embodiment of the present invention discusses the present invention in terms of a porous insert, it will be appreciated that the insert could, in fact, be realized by a thermally conductive but porous coating applied to a profiled housing, although use of an insert benefits ease of manufacture and assembly. The application of the cooling technology is not, as will be understood, limited to size or weight (of, e.g. preforms), with the defining criteria being the ability to establish a vacuum to encourage contact of an outer surface of the molded article with the inner surface of the porous profiled substrate. Furthermore, while the cooling tube assembly of the present invention has been described in the context of a plastic injection molding machine, it will be appreciated that it is equally applicable to any technology in which, following part formation, cooling of that part is undertaken by a cooling tube or the like, e.g. in a part transfer mechanism between an injection molding machine and a blow-molding machine. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

Claims

1. A tube assembly for operating on a relatively hot, and hence malleable, molded plastic part after it has been molded by a molding structure, the tube assembly comprising:

a porous member having a profiled inside surface for receiving an outside surface portion of the molded plastic part; and

a vacuum structure configured to cooperate with the porous member to provide a reduced pressure adjacent the inside surface to cause the outside surface portion of the malleable molded plastic part, locatable within the tube assembly, to contact the inside surface of the porous member so as to allow a substantial portion of the outside surface portion of the malleable part, upon cooling, to attain a profile substantially corresponding to the profile of the inside surface; and

the inside surface is profiled to substantially correspond with the outside surface portion of the molded plastic part to be cooled;

wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

2. The tube assembly according to claim 1, further comprising a cooling structure configured for connecting the porous member into a heat dissipation path.
3. The tube assembly according to claim 2, wherein the vacuum structure comprises a tube body for receiving the porous

member, and at least one vacuum channel configured to connect the porous member to a vacuum source.

4. The tube assembly according to claim 3, wherein the cooling structure comprises at least one cooling channel provided on the tube body.

5. The tube assembly according to claim 1, further including a sealing structure configured to cooperate with the molded plastic part to assist in establishing the reduced pressure adjacent the inside surface of the porous member.

6. The tube assembly according to claim 1, further comprising:

a tube body; and wherein

the porous member is a tubular porous insert located in the tube body, the porous insert including an inside surface and an outside surface; and

the vacuum structure is at least one vacuum channel in fluid communication with the porous insert, the vacuum channel configured for connection with a vacuum source to provide the reduced pressure adjacent the inside surface.

7. The tube assembly according to claim 6, further comprising:

a cooling structure configured for connecting the porous insert into a heat dissipation path.

8. The tube assembly according to claim 7, wherein the inside surface of the porous insert includes a closed end that is shaped to correspond to a domed portion of the molded plastic part.

9. The tube assembly according to claim 8, further including a channel at the base thereof the channel is connected to a

vacuum or suction unit to draw the molded plastic part into the tube assembly.

- 5 10. The tube assembly according to claim 9, further including a plug fitted into the tube body for providing a closed end of the tube body.
- 10 11. The tube assembly according to claim 7, wherein the porous insert is a thermally conductive porous coating applied to an inside surface of the tube body.
12. The tube assembly according to claim 7, wherein the porous insert has porosity in the range of about 3-20 microns.
- 15 13. The tube assembly according to claim 7, wherein the inner porous insert is made of a porous aluminum.
- 20 14. The tube assembly according to claim 7, wherein the cooling structure is provided by at least one cooling channel provided in the tube body that is configured to carry a cooling fluid.
- 25 15. The tube assembly according to claim 7, wherein the cooling structure is provided by thermally coupling the tube body to a heat sink.
16. The tube assembly according to claim 7, further including a spacer for locating the porous insert in the tube body.
- 30 17. The tube assembly according to claim 7, wherein the at least one vacuum channel is provided in the tube body adjacent the porous insert outer surface.
- 35 18. The tube assembly according to claim 7, wherein the porous insert includes the at least one vacuum channel.

19. The tube assembly according to claim 18, wherein the at least one vacuum channel are provided as a plurality of channels in the exterior surface of porous insert.
- 5 20. The tube assembly according to claim 7, further including an end seal at the open end of the tube assembly the end seal assists in establishing the reduced pressure adjacent the inside surface of the porous insert.
- 10 21. The tube assembly according to claim 7, further including a collar on top of the tube body to retain the porous insert within the tube body.
- 15 22. The tube assembly according to claim 21, wherein the collar extends inwardly to conform to the inside surface of the porous insert.
- 20 23. The tube assembly according to claim 21, wherein the collar further includes a lip seal.
24. The tube assembly according to claim 1, further comprising:
a tube; and wherein
the porous member is a porous substrate configured within the tube.
- 25 25. The tube assembly according to claim 24, wherein:
the porous substrate is a porous coating applied to a profiled inside surface of the tube.
- 30 26. A porous cooling cavity that is configured to cooperate with a vacuum structure for receiving and cooling a relatively hot, and hence malleable, molded plastic article after it has been molded by a molding structure, the porous
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cooling cavity comprising:

5 a porous member formed from a porous material, the porous member including (i) an inside surface that is profiled to substantially reflect a shape of a portion of an outside surface of the molded plastic article, and (ii) a vacuum coupling structure;

10 wherein the vacuum coupling structure of the porous member is configured to cooperate with the vacuum structure to provide a reduced pressure adjacent the inside surface of the porous member to cause the portion of the outside surface of the malleable molded plastic article to contact the inside surface of the porous member so as to allow the
15 outside surface portion of the malleable part, upon cooling, to maintain a profile substantially corresponding to the profile of the inside surface and thereby a disfiguring of the shape of the outside surface portion of the molded article is substantially prevented.

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27. The porous cooling cavity according to claim 26, wherein the vacuum coupling structure comprises an outside surface of the porous member.

25 28. The porous cooling cavity according to claim 26, wherein the vacuum coupling structure comprises at least one channel formed in an outside surface of the porous member.

29. The porous cooling cavity according to claim 26, wherein

the porous member is configured as a porous insert with at least a portion of an outer surface thereof comprising a mounting surface configured to connect with an inside surface of a cooling tube.

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30. The porous cooling cavity according to claim 26, wherein the porous member is configured to cooperate with a plug for providing a closed end to the profile of the inside surface of the porous insert.

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31. The porous cooling cavity according to claim 28, further comprising at least one vacuum channel configured to be coupled to the at least one channel formed in an outside surface of the porous member.

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32. The porous cooling cavity according to claim 26, wherein the inside surface of the porous member includes a closed end that is shaped to correspond to a domed end portion of the molded plastic article.

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33. The porous cooling cavity according to claim 32, wherein the porous member further includes a channel extending therethrough at a base of the closed end thereof, the channel being configured to be connected to a low pressure, source to draw the molded plastic article into the tube assembly.

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34. The porous cooling cavity according to claim 26, wherein the porous member has porosity in the range of about 3-20

microns.

35. The porous cooling cavity according to claim 26, wherein the porous member comprises a porous aluminum.

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36. The porous cooling cavity according to claim 26, further including a cooling structure configured for connection with a heat dissipation path, for cooling the molded plastic article in contact with the inside surface of the porous member.

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37. The porous cooling cavity according to claim 26, wherein the porous member is configured as a tubular porous member that is removably installable within a post mold device.

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38. An end-of-arm tool configured to be carried by a robotic arm in an injection molding machine, the end-of-arm tool comprising:

20 a carrier configured to be coupled to the robotic arm, the carrier carrying at least one molded article cooling device;

25 at least one porous member installed in the at least one molded article cooling device, the at least one porous member having a porous inside surface that is profiled to substantially reflect a shape of a portion of an outside surface of a relatively hot, and hence malleable, molded article and that supports the evacuation of air

therethrough to cause the malleable molded article within the at least one porous member to expand to contact the porous inside surface; and

5 an evacuation structure configured to evacuate the air through the at least one porous member;

10 wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

39. The end-of-arm tool according to claim 38, wherein:

15 each of the at least one molded article cooling devices is a tube assembly arranged on the carrier plate;

 each of the tube assembly comprising:

20 the at least one porous member as a porous tube having the inside surface and an outside surface; and

25 a vacuum structure configured to cooperate with the porous tube to provide for the evacuation of air through the inside surface.

40. The end of arm tool according to claim 39, wherein the tube assembly further comprises a cooling structure configured for connection into a heat dissipation path.

30 41. The end of arm tool according to claim 40, wherein the vacuum structure comprises a tube body for receiving the porous tube, and at least one vacuum channel configured for connection to a vacuum source.

42. The end of arm tool according to claim 39, wherein the number of tube assemblies corresponds with the number of molded plastic parts produced in each corresponding injection cycle of the molding system.

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43. The end of arm tool according to claim 39, wherein the number of tube assemblies corresponds with a multiple of the number of molded plastic parts produced in each corresponding injection cycle of the molding system.

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44. The end of arm tool according to claim 39, wherein the porous insert has porosity in the range of about 3-20 microns.

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45. The end of arm tool according to claim 44, wherein the inner porous insert is made of a porous aluminum.

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46. The end of arm tool according to claim 40, wherein the cooling structure is provided by at least one cooling channel provided in the tube body that is configured to connect with cooling fluid channels provided in the carrier plate.

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47. The end of arm tool according to claim 40, wherein the cooling structure is provided by thermally coupling the at least one tube assembly to a heat sink provided by the cooled carrier plate.

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48. The end of arm tool according to claim 41, wherein the at least one vacuum channel is configured to connect with vacuum channels provided in the carrier plate.

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49. The end of arm tool according to claim 39, wherein the tube assembly further includes a sealing structure configured to cooperate with the molded plastic part to assist in establishing the reduced pressure adjacent the inside surface of the porous tube.

50. An injection mold robot, comprising:

an arm member configured to be disposed adjacent an injection molding machine;

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a carrier configured to be coupled to the arm member, the carrier carrying at least one molded article cooling device;

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at least one porous member configured to be removably installed in the at least one molded article cooling device, the at least one porous member having a porous inside surface that is profiled to substantially reflect a shape of a portion of an outside surface of a malleable molded article and that supports the evacuation of air therethrough to cause the malleable molded article within the at least one porous member to expand to contact the porous inside surface; and

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an evacuation structure configured to evacuate the air through the at least one porous member.

51. An injection molding machine, comprising:

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a molding structure that molds at least one relatively hot, and hence malleable, plastic part; and

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at least one porous cooling cavity having a profiled inside surface that is configured to hold and cool the at least one plastic part after it has been molded by the molding structure; and

at least one vacuum channel respectively configured to provide a lower-than-ambient pressure to the inside surface to cause an outside surface portion of the at least one plastic part to contact the inside surface of the at least one porous cavity; and

the inside surface is profiled to substantially correspond with the outside surface portion of the at least one plastic part to be cooled;

wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

52. The injection-molding machine according to claim 51, wherein each the cooling cavity comprises a porous insert disposed in a tube body.

53. The injection molding machine according to claim 52, wherein the cooling cavity further includes cooling structure configured for connection into a heat dissipation path.

54. The injection molding machine according to claim 51, wherein the cooling cavity further includes a sealing structure configured to cooperate with the plastic part to assist in establishing the lower-than-ambient pressure adjacent the inside surface of the porous cooling cavity.

55. The injection molding machine according to claim 51, wherein the porous cooling cavity further includes a sealing structure configured to cooperate with the molded plastic part to assist in establishing the lower-than-ambient pressure adjacent the inside surface of the porous cooling cavity.

56. A method for cooling a relatively hot, and hence malleable, molded plastic part including the steps of:

(i) receiving the molded plastic part into a porous cooling cavity that includes an inside surface that is profiled to substantially correspond with an outside surface portion of the molded plastic part to be cooled;

(ii) providing a reduced pressure adjacent the profiled inside surface of the porous cooling cavity causing the outside surface portion of the molded plastic part to move into contact therewith and thereby attain a substantially corresponding shape; and

(iii) extracting heat from the molded plastic part through a heat dissipation path to solidify the molded plastic part to the extent that the shape of the outside surface is preserved; and

(iv) ejecting the molded plastic article;

wherein a substantial disfiguring of the shape of the outside surface portion of the at least one plastic part is prevented.

57. The method according to claim 56, further including the step of maintaining the reduced pressure through the inside surface of the porous cooling cavity as the molded plastic part cools.

58. The method according to claim 56, wherein the step of ejecting the molded plastic article includes applying a positive pressure through the inside surface of the porous cooling cavity.

59. A molded plastic article with a shape of at least a portion of its outside surface defined by an inside surface of a porous cooling cavity that is profiled to substantially reflect a shape of a portion of an outside surface of a

relatively hot, and hence malleable, molded article to be cooled, the molded plastic article formed by the process of:

5 (i) receiving the malleable molded plastic article into the porous cooling cavity;

10 (ii) evacuating the air surrounding the molded plastic article through a plurality of interstitial spaces that are configured along the inside surface of the porous cooling cavity causing the portion of the outside surface of the molded plastic article to move into contact with the profiled inside surface and thereby to attain a shape substantially corresponding to the profiled inside surface;
15 and

20 (iii) extracting heat from the molded plastic article through a heat dissipation path to solidify the molded plastic article sufficiently such that the outer shape of the molded plastic article is preserved;

25 wherein the portion of the outside surface of the cooled molded plastic article takes on a surface finish that corresponds substantially to the interstitial spaces of the porous cooling cavity.

60. The molded plastic article according to claim 59, wherein the porous cooling cavity is formed of a porous substrate with the profiled inside surface having interstitial spaces

preferably within a range of about 3 to 20 microns.

61. The molded plastic article according to claim 59, wherein molded plastic article is a preform.

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62. The molded plastic article according to claim 59, wherein the molded article comprises a preform.

63. A cooling tube for cooling a portion of an injection molded article received therein, cooling tube comprising:

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an extruded tube body having an inside surface and an outside surface, and a plurality of cooling channels disposed therebetween that arranged in a longitudinal direction of the tube body;

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a connecting channel configured between the cooling channels for interconnecting the cooling channels into at least one cooling circuit;

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a seal configured at each end of tube body for closing the cooling channels;

an inlet and an outlet configured in the tube body for the at least one cooling channel;

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a plug disposed in a distal end of the tube body;

the inside surface of the tube body and an inside surface configured on the plug being machined to provide a profiled cavity that substantially conforms with a profile of an outer surface of the portion of the molded article.

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64. The cooling tube in accordance with Claim 63, wherein the plurality of cooling channels have a length which is at least four times a minor diameter thereof.
- 5 65. The cooling tube in accordance with Claim 64, wherein the tube has a cross-section comprising a plurality of the cooling channels that are furthermore configured as arcuate, elongated slots.
- 10 66. The cooling tube in accordance with Claim 65, wherein the cumulative angular extent of all elongated slots is greater than 180 degrees.
- 15 67. The cooling tube in accordance with Claim 64, wherein the plug includes a cooling channel inlet, a cooling channel outlet, for connecting a source and drain of coolant with the cooling circuit inlet and outlet on the tube body.
- 20 68. The cooling tube in accordance with Claim 64, wherein the plug includes a pressure channel extending therethrough from a base of the inside surface for connecting the cavity with a controllable vacuum structure for assisting in the entry and ejection of the molded article in the cavity.
- 25 69. The cooling tube in accordance with Claim 64, wherein the cavity is configured to provide an intimate fit with the outside surface of the molded article.
- 30 70. The cooling tube in accordance with claim 64, wherein the cooling tube is configured for use on an end-of-arm tool.
71. The cooling tube in accordance with claim 70, wherein the end-of-arm tool includes:
35 a carrier plate for mounting to a robot in a molding system; and

at least one of the cooling tube arranged on a surface of the carrier plate.

72. The cooling tube in accordance with claim 71, wherein the number of the cooling tube assemblies corresponds with the number of molded articles produced in a cycle of the molding system.

73. The cooling tube in accordance with claim 71, wherein the number of the cooling tube assemblies corresponds with a multiple of the number of molded articles produced in a cycle of the molding system.

74. A method for forming the cooling tube in accordance with any according to claims 63 through 73, comprising the steps of:

(i) extruding the tube body having an inside surface, an outside surface, and a plurality of cooling channels disposed therebetween that arranged in a longitudinal direction of the tube body;

(ii) machining the inside surface of the tube body to substantially conform with the outer surface of the molded article;

(iii) configuring a connecting channel between the cooling channels;

(iv) forming the plug.

75. The method according to Claim 74, wherein the step of extruding the tube includes extruding the cooling channels as arcuate, elongated slots.