US 20110232856A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2011/0232856 A1

(43) Pub. Date: Sep. 29, 2011

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(54) TEMPERATURE CONTROL METHOD AND APPARATUS

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(21) Appl. No.: 13/157,197

(22) Filed: Jun. 9, 2011

Related U.S. Application Data

(63) Continuation of application No. 09/719,136, filed on Dec. 7, 2000, now Pat. No. 7,964,129, filed as application No. PCT/AU99/00448 on Jun. 9, 1999.

(30) **Foreign Application Priority Data**

Jun. 11, 1998 (AU) .... PP 4403

Publication Classification

(51) Int. Cl.

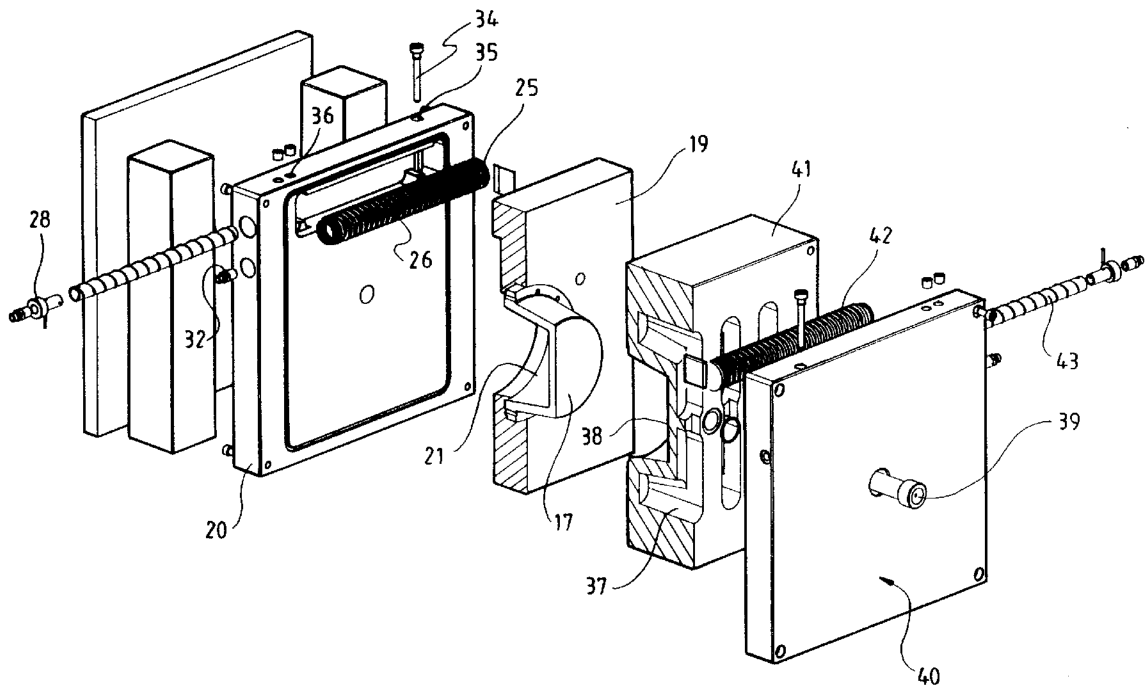
B22D 27/04 (2006.01)

B29C 71/02 (2006.01)

(52) U.S. Cl. 164/348; 425/404

(57) **ABSTRACT**

The invention relates to a method of cooling machines. Typically, the method of cooling is useful in the cooling of dies used in the moulding of plastics or metals. The method relies upon taking advantage of the latent heat of vaporisation of a cooling liquid. A liquid is maintained in a closed chamber in a die such that the liquid is in contact with the surfaces to be cooled and a space above the liquid surface is available. The pressure in the space is adjusted, typically by vacuum equipment, such that the boiling point of the liquid is adjusted to a level which enables the principle cooling process to involve latent heat.



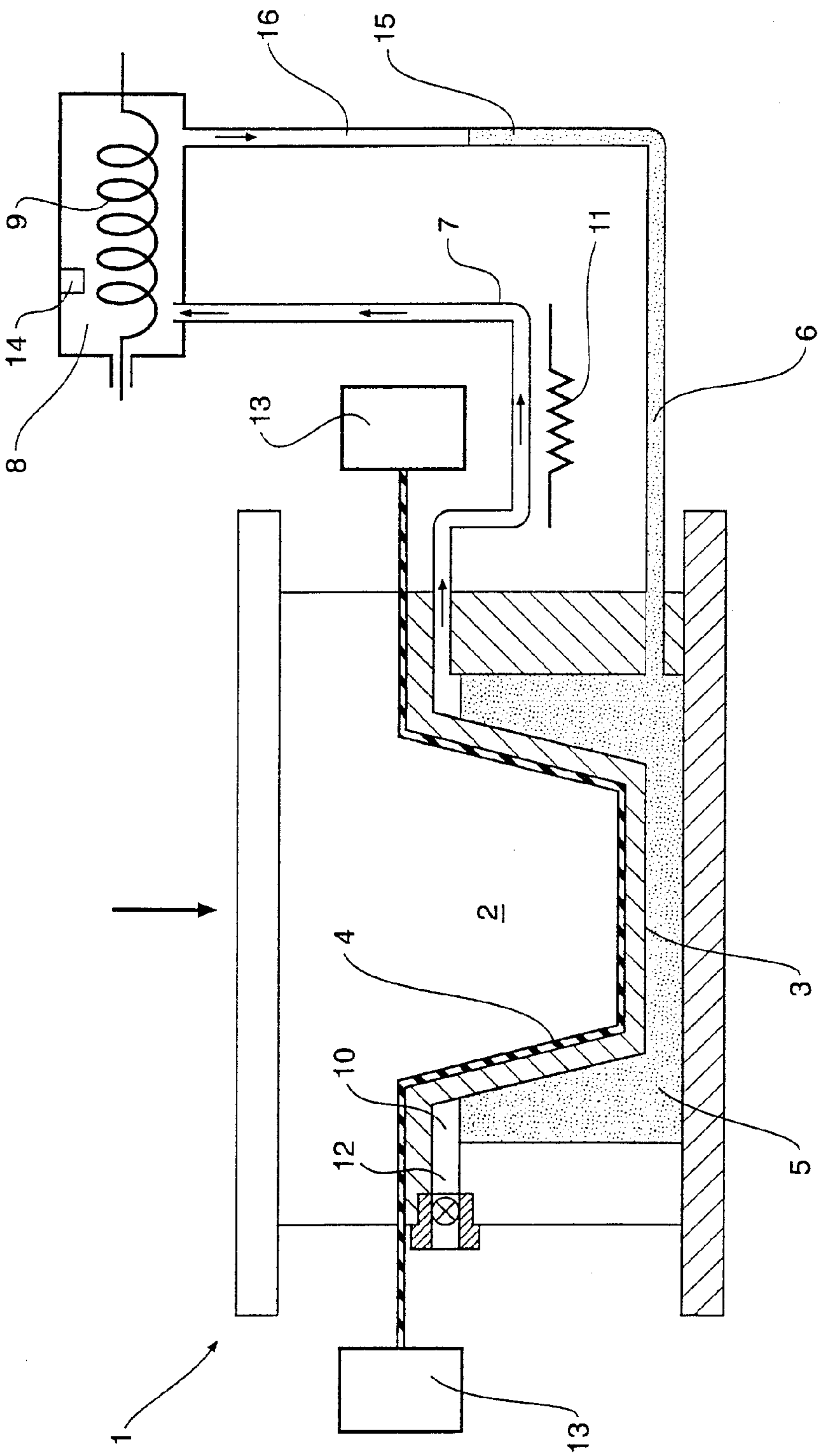


FIG 1

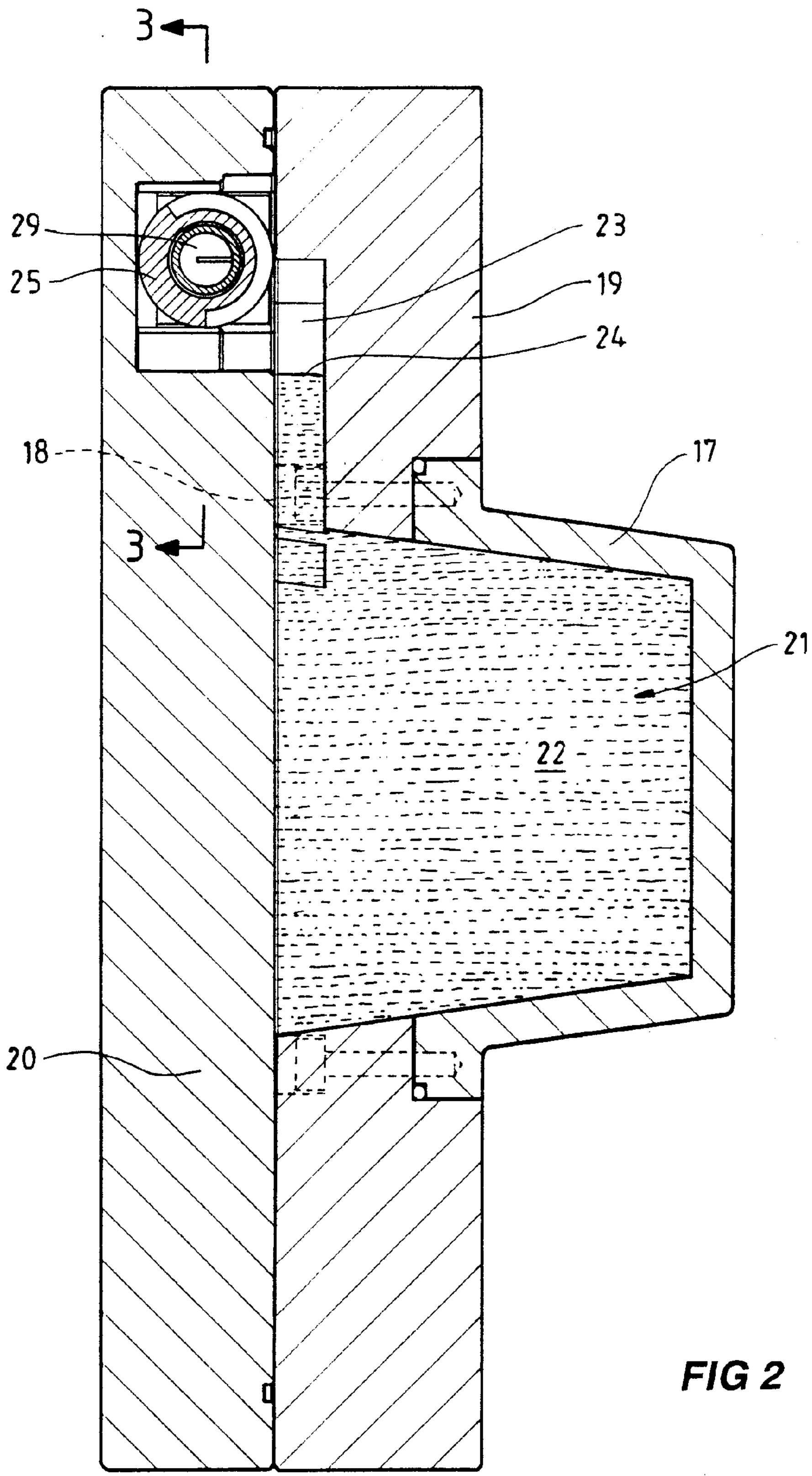


FIG 2

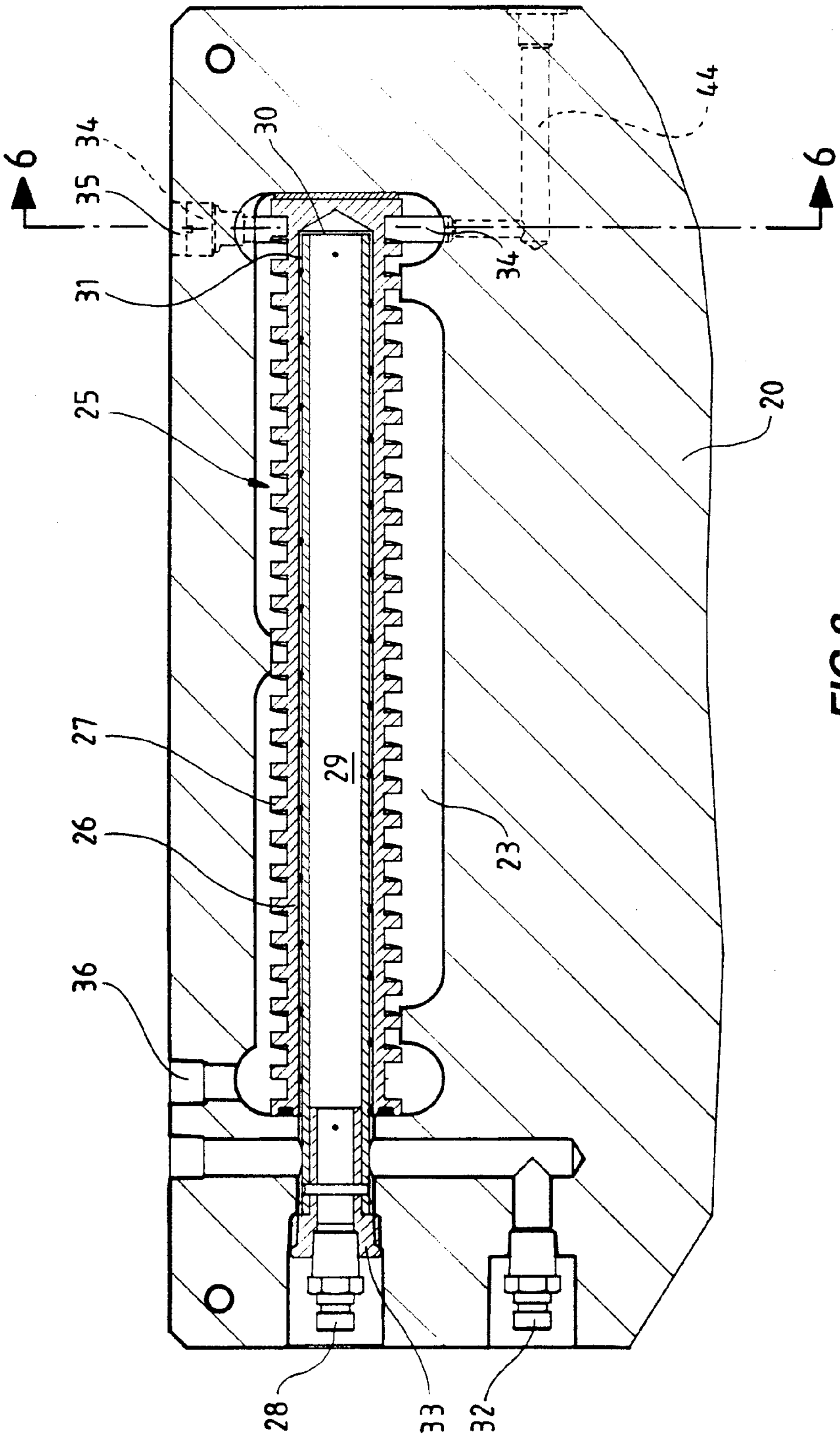


FIG 3

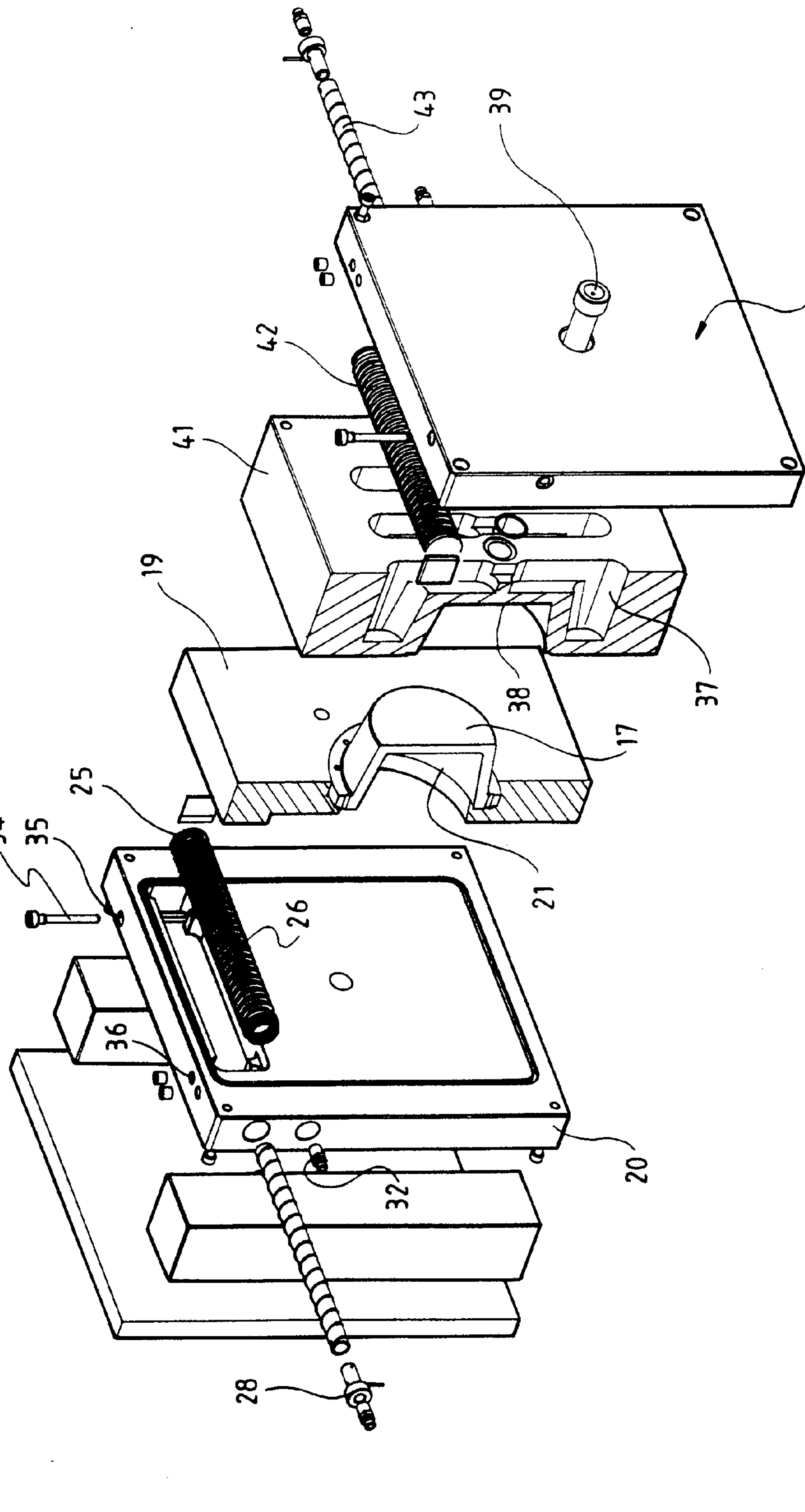


FIG 4

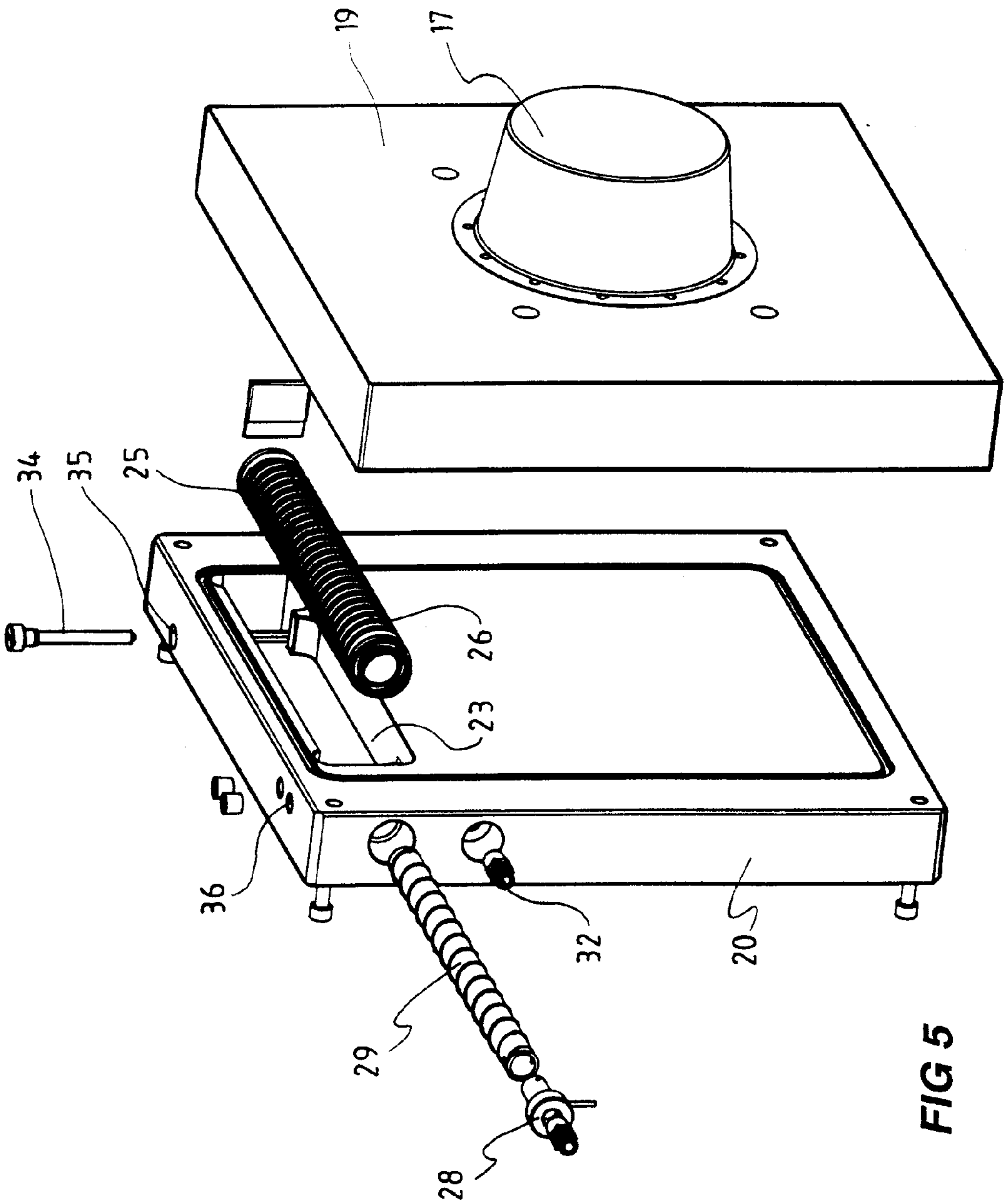


FIG 5

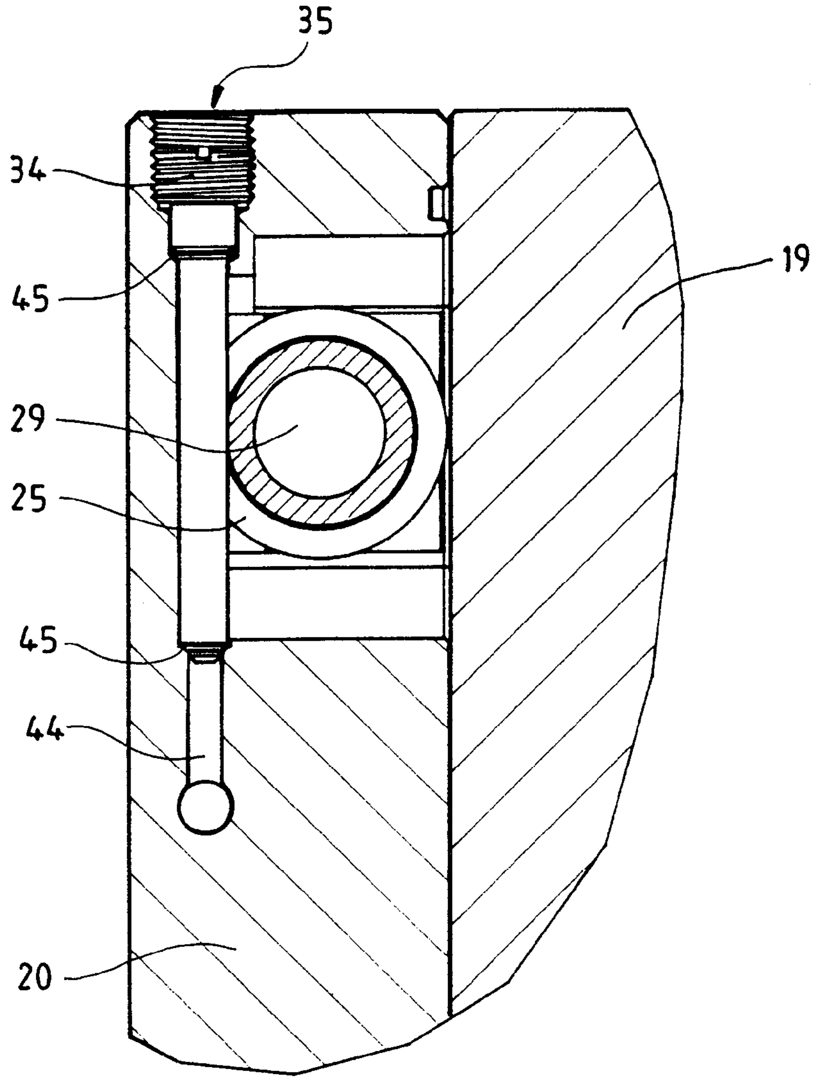


FIG. 6

TEMPERATURE CONTROL METHOD AND APPARATUS

[0001] This application is a continuation of U.S. Pat. No. 7,964,129, filed 7 Dec. 2000, which was the National Stage of International Application PCT/AU99/00448 filed, 9 Jun. 1999, which claims the benefit of Australian Patent Application Serial No. PP 4033, filed 11 Jun. 1998, the specifications of which are all hereby incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to a temperature control method and apparatus applicable to machines and has particular application to dies and to moulding of articles using dies in processes such as injection moulding, thermoforming, vacuum forming metal die casting and the like.

[0004] 2. Description of the Related Art

[0005] The invention will be described with respect to an application but it is not intended that the concept should be constrained simply to that application.

[0006] It is well known that a die can be kept within an acceptable temperature range by use of water passing through passages in the die to a separate heat exchange station.

[0007] One of the challenges in the design of dies is to ensure that the working parts of the die have sufficient access to cooling water. This can at times be very difficult indeed if, for instance, there is very little room for appropriate passages for water to be transported to and from a location in sufficient volume.

[0008] Such a challenge of keeping a die within an acceptable range of temperatures is no small matter and can involve considerable costs in the manufacturing and commissioning of a die. One of the problems experienced is that unless the water is demineralised which is generally uneconomic because of the volume of replacement water needed, then scale build up will occur which again can be costly to treat and can lead to reduced efficiency in cooling over time.

[0009] A further problem is the corrosion in the cooling passages caused by their exposure to aerated cooling water.

[0010] Further the efficiency of cooling can be a very significant factor in the repetition rate of use of a die. If there were a more efficient way of cooling the die may be able to be used at greater repetition rates which is significant as far as costs of production using the die are concerned.

[0011] Further uneven cooling rates between different portions of a moulding die can cause distortion of the moulded parts for which rectification or compensation can be costly.

BRIEF SUMMARY OF THE INVENTION

[0012] It is an object of this invention to propose an alternative way to effect temperature control of a machine which at least reduces some of the above difficulties.

[0013] In one form of this invention this can be said to reside in a machine of a type requiring heat to be taken from the machine from time to time, characterised in that the machine includes at least one closed chamber having liquid therein which extends to cover at least one of the areas from which heat is to be taken, and a space above the liquid and within the closed chamber, wherein pressure is set at a level which will enable the liquid to boil at a selected temperature and condensing means to effect, by cooling, condensation of vapour of the liquid in the space.

[0014] In preference there are more than one chamber and each chamber is shaped and positioned together with the level of liquid therein so that the liquid will cover areas in the machine from which heat is to be taken.

[0015] In preference the liquid is water.

[0016] In preference the machine is a die for moulding of plastics materials.

[0017] In preference the machine is a die for injection moulding of plastics materials.

[0018] In preference the machine is a die for moulding by thermoforming of plastics materials.

[0019] In preference the machine is a die for the die casting of metals.

[0020] In a further preferred form of this invention this can be said to reside in a die having an internal cooling arrangement which includes a closed chamber having therein a liquid with a volume such that it has an upper level above areas of the die to be cooled and substantially only the vapour of the liquid within the chamber above the upper level of the liquid.

[0021] In a further preferred form of this invention this can be said to reside in a die for injection moulding of plastics materials having an internal cooling arrangement which is a closed chamber partially filled with a liquid with an upper level sufficient that areas of the die within the chamber adjacent to parts of the die to be cooled are covered by the liquid and, in the space in the chamber above the liquid, substantially only the vapour of the liquid. In a further preferred form of this invention this can be said to reside in a die for injection moulding of plastics materials having an internal cooling arrangement which is a closed chamber partially filled with a liquid with an upper level of sufficient height so that areas of the die within the chamber adjacent to parts of the die to be cooled are covered by the liquid and, in the space in the chamber above the liquid, substantially only the vapour of the liquid, and an arrangement to provide cooling of any vapour within the space in the chamber above the liquid level to effect at least some condensation of the vapour thereby.

[0022] In preference there is at least in addition, a heating means located within the chamber within the liquid such that during a standby time, the temperature of the die or mould can be kept within a selected range of temperatures.

[0023] In preference the cooling means include a tube, a core in the tube and means to direct cooling water through the tube.

[0024] In a further preferred form of this invention this can be said to reside in a method of cooling of parts of a machine where the machine has at least one closed chamber having liquid therein which extends to cover at least one of the areas from which heat is to be taken, and a space above the liquid and within the closed chamber in which the pressure is caused to be at a level at which the temperature of the boiling point of the liquid will be to at least a selected extent is below the temperature of the area from which heat is to be taken and there are condensing means to effect, by cooling, condensation of vapour of the liquid in the space.

[0025] In a further preferred form of this invention this can be said to reside in a method of cooling of parts of a machine where the machine has at least one closed chamber having liquid therein which extends to cover at least one of the areas from which heat is to be taken, and a space above the liquid and within the closed chamber in which the pressure is caused to be at a level at which the temperature of the boiling point of the liquid will be at least a selected extent below the temperature of the area from which heat is to be taken this being by reason of, as a first step, filling of the closed chamber with the liquid and then extracting a selected amount of the liquid without allowing air to replace the extracted liquid, and passing at a selected cooling temperature, liquid through condensing means to effect, by such cooling, condensation of vapour of the liquid in the space.

[0026] In use then condensation of the vapour may be effected by providing a heat exchange either by an independent member within the space above the liquid level or by having a portion or all of the wall defining the chamber in an area above the liquid surface which is at a lesser temperature but in any event, so that there will be a reasonably effective exchange of heat from the vapour of the liquid so that this then condenses back into liquid and will flow back into the body of the liquid within the closed chamber.

[0027] The portion of the chamber to receive heat will, by reason of a raised temperature of the immediately adjacent liquid to above that of the liquid in adjacent areas, effect an exchange of state of the liquid in this area to vapour which by reason of the latent heat capacity of the vapour will be a very substantial carrier of heat. By reason of relative densities then, the vapour thus formed will rise to the surface of the liquid, continuing to fill the space above the liquid where continuing condensation is being effected by a reverse exchange of heat.

[0028] What we have then is a closed chamber with its selected liquid operating so that it is at a temperature and pressure governed by its own vapour pressure and by external inputs of heat.

[0029] A number of variations can be incorporated within the general concept.

[0030] In a first method, the internal chamber is filled with the liquid to be used. In preference, such liquid is previously treated so as to remove dissolved gases and other unnecessary materials so that in preference, the liquid is a pure liquid without impurities which may otherwise interfere with the process or the efficiency in general of the process.

[0031] Once full and sealed, the chamber is then accessed through a gate valve so that some of the liquid is then extracted with a pump to a level that is chosen such that the level will be below a condensation member or means within the upper part of the chamber, and that there will be liquid in contact with heat source which is to provide the heat to be dissipated.

[0032] Following these steps, the die is then ready to be used where there is a heat exchanger in an upper part of the internal chamber to provide heat exchange where a further liquid is pumped through the heat exchanger at a preferred mould or die operating temperature but in preference not a low enough temperature to cause freezing of the liquid.

[0033] It is expected at this stage that the liquid would normally be water but it is understood that there are many liquids other than water that would provide a good effect.

[0034] For each individual circumstance, the degree of heat to be shifted, the extent of the hot surfaces to be cooled, and the general temperature that has to be worked on, need to be considered to take into account the overall dimensions of the chamber, the fluid to be used, the degree of vapour space above the liquid level, and the condensing means within the vapour space.

[0035] In experiments so far conducted, such an arrangement provides very effective and relatively uniform heat transfer. While reference has been made to a chamber, this does not of itself exclude the case where there can be separate bodies connected by sealed conduits.

[0036] A chamber then is to be considered as a concept broad enough to encompass any closed environment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] For a further explanation of the invention this will be described with reference to a further embodiment which shall be described with reference to an accompanying drawing wherein:

[0038] FIG. **1** is a schematic cross sectional view of a thermoforming apparatus in accordance with a first embodiment;

[0039] FIG. **2** is a cross sectional view of the male side of a plastic injection die;

[0040] FIG. **3** is a cross sectional view along the lines **3-3** in FIG. **2** of the second embodiment;

[0041] FIG. **4** is an exploded perspective view of the plastic injection die, the male side of which is shown in FIGS. **2** and **3**;

[0042] FIG. **5** is an exploded perspective view of the parts forming the portion of the second embodiment as shown in FIGS. **2** and **3**; and

[0043] FIG. **6** is a section along the lines **6-6** in FIG. **3**.

DETAILED DESCRIPTION OF THE INVENTION

[0044] Referring in detail to FIG. **1** there is shown a thermoforming apparatus **1** with a plug **2** arranged to push plastic sheet into a shaping cavity **3**. The sheet **4** is subject to conventional treatment including having air at pressure drive the formed sheet **4** into close conforming shape of the cavity **3**.

[0045] The cavity **3** is surrounded by a hollow body **5** which defines a closed chamber together with conduits **6** and **7** and condensing container **8**. Within the condensing container **8** is a heat exchange coil **9** which is supplied with appropriate cooling refrigerant.

[0046] Conduit **7** passes beneath plastic sheet holding means **13** and therefore could cause a liquid blockage to passage of vapour through to the condensing container **8**.

[0047] This effect can be removed by introducing additional heat through heating coil **11** which will effect a vaporisation of the liquid at this location.

[0048] Initial startup of this apparatus is achieved by filling the chamber which includes the hollow body **5**, the conduits **6** and **7** and the container **8** with water. Through the valve **12** water is then extracted until its level is lowered to a level as shown at **15**. This then leaves an upper evacuated space **16** which will then be filled implicitly by substantially the vapour of the liquid.

[0049] From here on the arrangement will remain as a closed system so that heat from the wall of the cavity **3** will be converted into latent heat of vaporisation with the vapour reaching the condensing chamber **8** to be returned to liquid. as it gives up the latent heat of vaporisation to the heat exchange coil **9**.

[0050] Now referring to FIGS. **2** through to **5**, there is shown specifically in FIGS. **2**,**3** and **5** the male side of an injection die and for ease of description, reference will be made to these parts and then later to the female side of the die as more generally shown in FIG. **4**.

[0051] Accordingly, the male form **17** is attached through appropriate bolts which are located at position such as at **18** to a block **19** which together with a backplate **20** forms a closed chamber **21** which holds a selected quantity of water shown generally at **22**. Male form **17** and block **18** may be formed as a single piece.

[0052] The water **22** does not totally fill the enclosed and closed space **21** thereby leaving a space **23** above an upper level of the water **24**.

[0053] There is a heat exchanging cooling device at **25** which is arranged by reason of tube **26** which has a plurality of fins **27** to effect a cooling of water vapour as it exists within the space **23**.

[0054] The temperature of the fins **27** is governed by arranging for flow of cooling water through an inlet **28** which then proceeds through the centre of a removable core **29** to an end **30** where the water then is caused to pass through a spirally shaped gap **31** so that it will pass fully the length of the hollow core **29** to then exit through passageway **32**.

[0055] An advantage of this arrangement is that the hollow core **29** is held by plug **33** so that from time to time, the core can be easily removed and any build up of deposits, debris or otherwise can be then effectively cleaned.

[0056] A gate valve **34** is adapted to effect a closure of aperture **35** and evacuation port **44** and there is a further closable plug at **36**.

[0057] In order to charge the die, water is first vigorously boiled for at least one minute so as to reduce possible dissolve gas from the water.

[0058] The water is then poured into the chamber **21** through aperture **36** so that it will fully fill the chamber. The gate valve **34** includes a pair of sealing members **45** thereon which act so that when open, water can be extracted from the chamber through evacuation port **44** while maintaining the closure of aperture **35** and when closed, to prevent air from flowing into the chamber through the evacuation port **44**.

[0059] The amount of water removed is such as to provide a sufficient space above the selected water level to allow for the cooling device to operate within the environment generally only of the water vapour and not the liquid water.

[0060] With the then degassed water partially filling the closed chamber **21**, it will be seen that the water then covers those parts of the die as shown, for instance, in FIG. **2** which are immediately adjacent those areas that will be in contact with heated plastics materials and from which heat is to be extracted.

[0061] By reducing the pressure within the closed chamber **21**, the water adjacent to the hotter parts of the die will be caused to boil at temperatures somewhat lower than 100 degrees Centigrade (212 degrees Fahrenheit) and because of the high value of the latent heat of evaporation of water such effect results in very efficient extraction of heat from the hotter parts of the die.

[0062] By reason of the orientation of the die, and by reason of shaping of the internal parts of the die so that vapour when formed can rise into the uppermost space within the closed chamber **21**, this then will further concentrate water vapour in the space which in turn will be cooled and therefore be condensed by heat exchange from the heat exchanger system.

[0063] While different methods of preparing the status of liquid within the closed chamber **21** can be used, and there has been described in a general way, such an arrangement, in a further method, there is firstly provided a funnel with a spout threaded to fit the inlet or filling port to a capacity greater than the volume of water to be removed from the filled enclosed chamber **21**.

[0064] A reciprocating vacuum pump with a single stroke capacity equal to the volume of water to be removed is attached to an evacuation port.

[0065] Once the water has filled the chamber, the vacuum pump can be used so as to withdraw and then return a number of times so as to cause water within the system to surge back and forth so as to assist in removal of any significant air bubbles which may have been trapped while filling.

[0066] The chamber is then again topped up with water on the basis that some air has been dislodged and driven to the surface of the water and the inlet or filling port is then closed.

[0067] The vacuum pump can again be caused to withdraw and return a number of times so as to cause water in the system to surge back and forth. With each withdrawal, the pressure inside the chamber will be considerably reduced and any remaining trapped bubbles of gas will expand and most will rise to the surface of the water. The vacuum pump stroke is then returned and the chamber is again topped up with water and the inlet port is closed.

[0068] With a full stroke of the vacuum pump the required amount of water will be extracted and the gate valve **34** is then screwed in to close the evacuation port **44**.

[0069] In this process, it is provided that the gate valve **34** allows the water to gravitate easily into the pump. Since air is excluded substantially, gravity is needed to move the liquid into the vacuum pump.

[0070] This describes, as has been previously stated, one side of an injection die where the further portion of the injection die is shown in exploded detail in FIG. **4**. In this case then, there is a closed chamber **37** which surrounds a female shape **38** into which the male part **17** is located to form there between a moulding space served by inlet port **39**.

[0071] A back plate **40** has sealed engagement with the die **41** and there are shown heat exchange means at **42** with a hollow removable core **43**.

[0072] The filling procedure of this side of the die is the same as with the first male portion of the die.

[0073] One of the advantages of the arrangement described is that the temperature of the die is automatically evened out because boiling will occur preferentially at the higher temperature locations thereby reducing its temperature to that of its surrounding areas.

[0074] Consequently, with this system, there is a preferential evening effect of the temperature which means that more sophisticated techniques for attempting to keep temperatures even are no longer necessary.

[0075] The mould temperature, for instance, can be controlled very evenly and effectively by controlling the flow of coolant such as water, through the heat exchanger. This leads to the further arrangement including the location of a thermostat so as to respond to the temperature of the liquid in the closed chamber.

[0076] Accordingly, this can be connected through a servo controller so as to interrupt flow of coolant liquid through the heat exchanger whenever the temperature falls below a selected value and can restore or increase the flow rate of cooling liquid whenever the temperature of the fluid in the enclosed chamber rises above another slightly higher selected level.

Experimental Results

[0077] A prototype unit has been made and tested. This unit was manufactured as the male portion of the injection die which is the arrangement as shown in FIGS. **2**, **3** and **5** with a face area of 250 mm and of course the disclosed protruding core, 70 mm in diameter and 55 mm long. The enclosed chamber then had a wall thickness at the die portion of 12 mm.

[0078] The described method of effecting a charging of water which had been degassed and then having a portion removed to leave only water vapour in a space was applied.

[0079] The effectiveness of the cooling action described was tested as follows: 1. Coolant water was supplied to the heat exchanger at a temperature of 27 degrees Centigrade which was the ambient temperature at the time of the test.

[0080] 2. Two gas blow torches were directed at the surface of the core and kept continuously heating on the outer surface of the protruding die surface.

[0081] The temperature of the coolant, of the core and of water in the enclosed chamber were monitored using digital pyrometers.

[0082] 3. The flow rate of coolant through the heat exchanger was adjusted to achieve a flow rate of four litres per minute.

[0083] 4. The output of the blow torches was adjusted until a temperature rise of 2.7 degrees Centigrade in the coolant was achieved. This corresponded to a heat extraction rate of 750 watts.

[0084] 5. The temperature of the die was found under these conditions to reach and be sustained at **48** degrees Centigrade which is to say 21 degrees

[0085] Centigrade above the coolant temperature.

[0086] 6. The temperature of water in the enclosed chamber was stabilised and was 35 degrees Centigrade.

[0087] Direct calculation of an expected temperature of the core, based on its geometry and the test conditions, were also made. The calculated temperature differential through the walls of the core is 12 degrees Centigrade and this was found to correspond very well with the experimental result. The remainder of the temperature differential (8 degrees Centigrade) is a function of the efficiency of the heat exchanger.

[0088] It is considered from the above experimental results that these illustrate a very outstanding effective result which will be of very significant value in many applications where machines are to be cooled and where achieving a uniformity of the cooling effect is of value.

[0089] Further, because the closed chamber keeps the same water through the full cooling process, it is not expected that there will be mineral deposit or other significant corrosion (as a result of the absence of air).

[0090] While in preference only water is used, other liquids or mixtures of liquids can be used and, in such a case, it is substantially only the vapours of the liquids that will exist only in the space above the level of the liquid in the closed chamber.

What is claimed is:

1. A temperature control apparatus configured to uniformly cool a molding surface of a mold or die comprising:

a molding surface;

at least one completely closed chamber having air substantially removed therefrom;

a single quantity of liquid in said at least one completely closed chamber wherein said single quantity of liquid extends to cover at least one area adjacent to and on an opposite side of the molding surface of said mold;

wherein said molding surface comprises a separating wall or walls having a uniform thickness through all of the wall or walls through which cooling is effected;

wherein a level of the liquid is sufficient to cover all of said at least one area including said separating wall or walls of the at least one completely closed chamber from which heat is to be taken and wherein each of said at least one completely closed chamber is integrated within the mold;

a space above the single quantity of liquid and within the at least one completely closed chamber in which pressure within the space is caused to be set at a level which enables the single quantity of liquid to boil into a vapor at a selected temperature, said selected temperature being at a level such that the selected temperature is below a temperature of the at least one area adjacent to the molding surface; and,

a condenser configured to cool the vapor to a selected cooling temperature, wherein condensation of the vapor returns condensed vapor to the single quantity of liquid.

2. The apparatus as claimed in claim **1** wherein the single quantity of liquid is water.

3. The apparatus as claimed in claim **1** further comprising:

at least one heating element located within the at least one completely closed chamber and within the single quantity of liquid such that during standby time, temperature of the mold or die is kept within a selected temperature range.

4. A temperature control apparatus configured to uniformly cool a molding surface of a mold or die comprising:

a molding surface;

at least one completely closed chamber having air substantially removed therefrom;

a single quantity of liquid in said at least one completely closed chamber wherein said single quantity of liquid extends to cover at least one area adjacent to and on an opposite side of the molding surface of said mold;

wherein said molding surface comprises a separating wall or walls having a uniform thickness through all of the wall or walls through which cooling is effected;

wherein a level of the liquid is sufficient to cover all of said at least one area including said separating wall or walls of the at least one completely closed chamber from which heat is to be taken and wherein each of said at least one completely closed chamber is integrated within the mold;

wherein said at least one completely closed chamber is configured such that if there is a temperature differential between any two locations within the at least one completely closed chamber, the single quantity of fluid boils at a location with a higher temperature and a resultant vapor condenses at a location with a lower temperature, in order to maintain a uniform temperature throughout the at least one completely closed chamber; and,

a space above the single quantity of liquid and within the at least one completely closed chamber in which pressure within the space is caused to be set at a level which enables the single quantity of liquid to boil into the vapor at a selected temperature, said selected temperature being at a level such that the selected temperature is below a temperature of the at least one area adjacent to the molding surface.

5. The apparatus as claimed in claim **4** further comprising:

a condenser configured to cool the vapor to a selected cooling temperature, wherein condensation of the vapor returns condensed vapor to the single quantity of liquid.

6. A temperature control apparatus configured to uniformly cool a molding surface of a mold or die comprising:

at least one adjacent closed chamber adjacent to the molding cavity;

a separating wall or walls between the molding cavity and the at least one adjacent closed chamber having a uniform thickness through all of the wall or walls through which cooling is effected;

wherein said at least one adjacent closed chamber comprises a liquid to an extent to effect substantial exclusion of any other fluid, so that there is both a liquid portion and a saturated vapor portion of the said liquid within the at least one adjacent closed chamber and only this liquid;

wherein a level of the liquid is sufficient to cover all of at least one area including said wall or walls of the chamber from which heat is to be taken; and,

a condenser coupled with the at least one adjacent closed chamber.

7. The apparatus as claimed in claim **6**, wherein the fluid is a single selected fluid.

8. The apparatus as claimed in claim **6** wherein said mold or die comprises two molds or dies configured to fit together and hold an item to be formed.

9. The apparatus as claimed in claim **6**, wherein said at least one adjacent closed chamber adjacent to the molding cavity is within the mold.

10. The apparatus as claimed in claim **8**, wherein said at least one adjacent closed chamber adjacent to the molding cavity is within the mold.

11. The apparatus as claimed in claim **8**, wherein the level of the liquid portion is sufficient to cover an area or areas of the said wall or walls of the chamber from which heat is to be taken, and within the space above the liquid portion of the fluid, such space containing substantially only the vapor of the fluid, the pressure in the space thereby being substantially equal to the vapor pressure of the fluid which results in, upon there being a temperature differential between any portion of the surface of the wall or walls and a cooler portion of the surface of the wall or walls within the space, some liquid of the fluid boiling at the said higher temperature location and effecting thereby removal of heat as latent heat of vaporization from the higher temperature location through a phase conversion of the fluid to a vapor and thereafter effecting, by condensation of the vapor which effects release of its latent heat of vaporization at said lower temperature location in the space above the said liquid to reduce said temperature differential and, by condensation of vapor at the condenser which is cooled from time to time so as to control the temperature of the fluid to be within a selected range.

12. The apparatus as claimed in claim **10**, wherein the level of the liquid portion is sufficient to cover an area or areas of the said wall or walls of the chamber from which heat is to be taken, and within the space above the liquid portion of the fluid, such space containing substantially only the vapor of the fluid, the pressure in the space thereby being substantially equal to the vapor pressure of the fluid which results in, upon there being a temperature differential between any portion of the surface of the wall or walls and a cooler portion of the surface of the wall or walls within the space, some liquid of the fluid boiling at the said higher temperature location and effecting thereby removal of heat as latent heat of vaporization from the higher temperature location through a phase conversion of the fluid to a vapor and thereafter effecting, by condensation of the vapor which effects release of its latent heat of vaporization at said lower temperature location in the space above the said liquid to reduce said temperature differential and, by condensation of vapor at a condenser which is cooled from time to time so as to control the temperature of the fluid to be within a selected range.

13. The apparatus as claimed in claim **6**, wherein the level of the liquid portion is sufficient to cover an area or areas of the said wall or walls of the chamber from which heat is to be taken, and within the space above the liquid portion of the fluid, such space containing substantially only the vapor of the fluid, the pressure in the space thereby being substantially equal to the vapor pressure of the fluid which results in, upon there being a temperature differential between any portion of the surface of the wall or walls and a cooler portion of the surface of the wall or walls within the space, some liquid of the fluid boiling at the said higher temperature location and effecting thereby removal of heat as latent heat of vaporization from the higher temperature location through a phase conversion of the fluid to a vapor and thereafter effecting, by condensation of the vapor which effects release of its latent heat of vaporization at said lower temperature location in the space above the said liquid to reduce said temperature differential and, by condensation of vapor at a condenser which is cooled from time to time so as to control the temperature of the fluid to be within a selected range.

14. The apparatus as claimed in claim **13**, further comprising an element configured to control a passage of coolant through the condenser so as to maintain the temperature of the fluid within a selected range.

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