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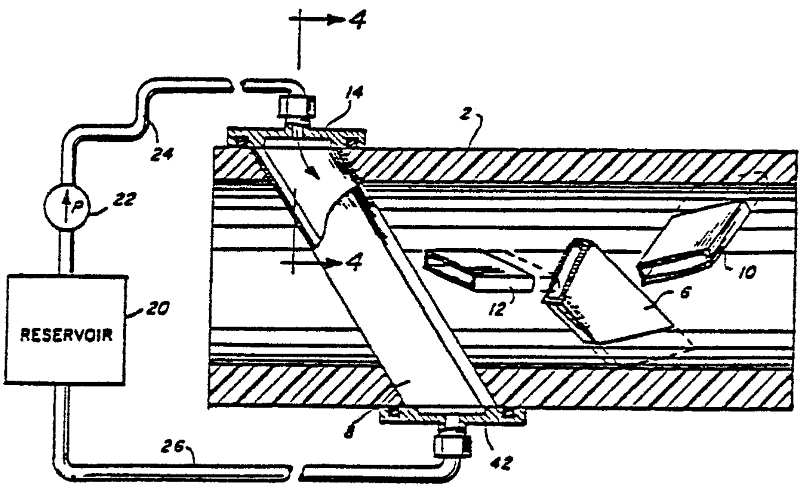
(54) Title: THERMALLY CONTROLLED MIXER AND APPARATUS AND METHODS OF OPERATING SAME

(57) Abstract



A thermally controlled mixer apparatus includes a fluid conduit (2) of the extruder barrel class, a plurality of thermal control vanes (6), (8), (10) supported in the barrel and means (22) for circulating a thermal control fluid through the thermal control blades to induce temperature changes in fluid materials conducted through the mixer apparatus. The fluid conduit is formed with slots (4) (5) occurring in staggered relationship and the thermal control vanes consist of tubular bodies located in angularly disposed relation to one another so as to present flow diverting surfaces for diverting fluid material passing through the fluid conduit in successively differing directions. The means for circulating a thermal control fluid comprises a reservoir (20) of fluid whose temperature may be selectively regulated and pump means (22) for moving the fluid from the reservoir into the thermal control blades. The control vanes may be made of a heat conductive material and when utilized without a thermal control fluid may function to conduct heat away from heated plastic material in the extruder barrel. A non-mixing heat exchanger (120) and modular arrangements of mixers and heat exchangers are also disclosed. Finally, novel control systems are presented.

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THERMALLY CONTROLLED MIXER AND APPARATUS AND METHODS OF OPERATING SAME

Description

Technical Field

This invention relates to plastic extrusion systems and has particular application to static mixers in such systems

Background

Conduit means for receiving and mixing together plastic materials prior to introduction into a forming die is well known in the art and one type of mixer apparatus is commonly referred to as static mixture apparatus in which vanes are interposed in the path of flow of pressurized plastic materials. In these prior art structures it is customary to employ fixed diverter vanes of varying shapes by means of which desirable mixing is carried out. As a example of such devices there may be cited Patent Nos. 3,460,580, 4,093,188, 3,045,984 and 3,243,318. However, in these prior art structures the diverter vanes tend to present wear problems and require replacement from time to time, a procedure which may be expensive and time consuming. In addition, when plastic materials to be mixed are of relatively high viscosities, undesirably large amounts of energy are required to force the plastic materials thru the conduit means. Furthermore, where the plastic materials tend to adhere rather tenaciously to the diverter vanes, as may occur, it becomes necessary to clean the vanes in some way as for example by heating or by forcing a cleaning fluid thru the extruder barrel or by removing the shaft from the barrel in order to expose the vanes to cleaning operations.

In plastic extrusion systems, the plastic is often melted in a screw-type extruder which places the plastic in shear and thus heats, melts and mixes the plastic. The extruder operates most efficiently with the plastic at high temperatures. The melted plastic is then forced through a die which forms the plastic. At the die, sufficient heat must be removed from the plastic to bring the temperature of the plastic below the set point. The rate that material can be processed is limited by the time required to remove sufficient heat at the die; thus the material introduced into the die should be close to the set point for fast processing. This is made difficult by the high operating temperature required by the extruder.

Disclosure of the Invention

The present invention is concerned with an improved mixer apparatus for use in mixing together plastic materials which are to be introduced into a forming die.

A chief object of the invention is to provide an improved static mixer apparatus in which vanes are located through a cylindrical barrel in an angularly disposed relationship to one another and in which the control vanes are of hollow construction to constitute a plurality of tubular members through which a thermal control fluid may be circulated thereby to induce temperature changes in plastic materials which are passed through the mixer apparatus.

Another specific object of the invention is to devise methods of controlling viscosities of plastic materials to be mixed.

Another object is to provide a method of mixing plastic materials contained in mixing barrel which have been brought to a desired temperature prior to being moved along the barrel.

Still another object is to provide a method of heating or cooling a plastic mass in a barrel in which heating or cooling may be carried out uniformly throughout the diametrical cross section of the mass to minimize thermal gradients.

It is also an object of the invention to devise a mixer apparatus having thermal control vanes which are of a composite construction wherein grooved or tubular portions are combined with wear resistant portions.

It is still further an object of the invention to provide for the adjustment of final output temperature of the plastic without varying the speed of output itself and to further provide means for adjusting the temperature of the plastic mass independently of rotative extruder screw speed.

The foregoing objectives are in accordance with the invention achieved by combining a slotted barrel member with thermal control vanes of hollow construction which are of a wear resistant nature. The vanes may take several different forms and may be connected to a reservoir for holding a thermal control fluid which can be introduced into the vanes to induce either heating or cooling. The control vanes may be made of a heat conductive material and may also be activated by electrical means to induce desirable heating.

Brief Description of the Drawings

Fig. 1 is a perspective view illustrating the static mixer apparatus of the invention partly broken away to show in more detail a thermal control vane mounted therein.

Fig. 2 is an end elevational view of the mixer apparatus with thermal control vanes mounted therein and having thermal control fluid conduits connected thereto.

Fig. 3 is a diagrammatic view illustrating means for supplying a thermal control fluid to vanes in the mixer apparatus, a portion of which is indicated in cross section.

Fig. 4 is a cross section taken on the line 4-4 of Fig. 3.

Fig. 5 is a cross section taken on the line 5-5 of Fig. 4.

Fig. 6 is a detail perspective view of the closure component shown in Fig. 1.

Fig. 7 is a detail perspective of a modified form of closure component.

Fig. 8 is a fragmentary cross sectional view of the mixer barrel and vane structure of Fig. 7.

Fig. 9 is a fragmentary perspective view of another modification of vane structure.

Fig. 10 is a detail cross sectional view of another form of connector means for a thermal control vane.

Fig. 11 is a cross sectional view of a mixer barrel enclosed within a manifold to provide a passageway for circulating a thermal control fluid.

Fig. 12 is a fragmentary perspective view of a portion of the vane of Fig. 11.

Fig. 13 is a perspective view of a portion of a composite vane structure having wear resistant components combined with tubes.

Fig. 14 is a detail perspective view of a vane construction in which one component has formed grooves.

Fig. 15 is a detail perspective of another modification of vane means.

Fig. 16 is a longitudinal sectional view of a heat exchanger module which may be used to control the temperature of the plastic without mixing.

Fig. 17 is a cross sectional view of the heat exchanger of Fig. 16.

Fig. 18 is a cross sectional view of another heat exchanger module utilizing heat pipes.

Fig. 19 is a cross sectional view of one of the heat pipe elements of Fig. 18.

Fig. 20 is one example of a modular heat exchanger and mixer configuration.

Fig. 21 is another modular configuration in which heat exchanger and mixer modules are arranged alternately in series.

Fig. 22 is yet another modular configuration in which two heat exchanger units precede a mixer module.

Fig. 23 is one embodiment of a temperature control system for controlling the amount of heat transfer from the plastic flowing through a mixer.

Fig. 24 is yet another embodiment of a control system.

Fig. 25 is a still further embodiment of a control system in which flow of the temperature control fluid is controlled.

Fig. 26 is another embodiment in which the flow of the temperature control fluid is controlled.

Preferred Modes of Carrying Out the Invention

Referring more in detail to the drawings, numeral 2 denotes a static mixer cylinder or barrel of the class commonly employed in extruding or mixing plastic materials prior to entry into a forming die. Formed in the barrel 2 are a plurality of pairs of slots which in one preferred form are arranged to extend in angularly disposed relation to the central axis of the barrel. Each pair of slots also occurs in an angularly disposed relationship to other pairs and one pair is denoted by the numerals 4 and 5 (Fig. 1).

In accordance with the invention, a plurality of thermal control vanes are mounted in respective pairs of slots so as to extend through the space defined by the barrel wall. These thermal control vanes are designed to induce temperature changes in material contained within the barrel when the vanes are activated by suitable means for heating or cooling portions of the vanes.

Activation of the vanes may be carried out for example by forming the vanes with heater elements therein and passing an electrical circuit through the vanes. In another preferred mode of activating the vanes there may be employed vanes characterized by a hollow construction to constitute tubular members through which a thermal control fluid may be introduced, and if desired circulated, to induce either heating or cooling. When the vanes are thus activated heating and cooling effects are transmitted from the vanes to plastic materials located around the vanes in the barrel member and thus heating and cooling takes place uniformly throughout the mass of contained plastic material so that no problem of temperature gradients is experienced.

In Fig. 1 the thermal control vanes of the invention are illustrated as denoted by the numerals 6, 8 and 10, in fully inserted position in the barrel 2. One other vane 12 is shown removed from the slots 4 and 5 together with a vane connector hereinafter described in more detail.

It will be noted that each of the vanes extends in an angularly disposed relationship to one another in positions such that outer sides of the vanes present diverting surfaces against which plastic materials moving through the barrel are diverted along successively differing paths of travel as well as undergoing, concurrently, either heating or cooling.

In Fig. 2 the vanes 6, 8, 10 and 12 are further illustrated and as will be apparent from an inspection of this figure they are arranged to extend angularly with respect to one another and with respect to the central longitudinal axis of the barrel 2. However, it may be desired to position one or more of the vanes in a manner such that no intersection with the central longitudinal axis of the barrel occurs.

In utilizing the thermal control vanes as diverting means for mixing plastic materials it is desirable to provide diverter surfaces of relatively large size and therefore in the preferred form of tubular structure a shape of rectangular cross section has been provided. However, it is intended that the vanes may have other cross sectional shapes as circular, square, triangular and the like.

In combination with the thermal control vanes shown in Figs. 1 and 2 there is further provided means for supplying a thermal control fluid and introducing such fluid into the several vane members. Fig. 3 illustrates diagrammatically a means for supplying a thermal control fluid to the vane 8 in a manner such that a circulation of the fluid is carried out. As shown in Fig. 3 a reservoir for thermal control fluid is denoted by the numeral 20 from which fluid may be pumped by pump means 22 through conduit means 24 into vane 8 and returned through conduit 26 to provide for either a continuous or intermittent flow suitable for acheiving a desired heating or cooling action.

It will be understood that the pump means 22 indicated diagrammatically in Fig. 3 is shown connected to the inlet conduit 24 for vane 8 and this connection is intended to be illustrative of connecting pump 22 with inlet conduits communicating with other thermal control vanes. Numeral 30 denotes an inlet conduit for vane 10 and numerals 32 and 34 refer to inlet conduits for vanes 6 and 12 respectively. Similarly, numerals 26, 36, 38 and 40 refer to outlet conduits for vanes 8, 10, 6 and 12 respectively.

As one suitable means for sealably connecting the inlet and outlet conduits with the barrel 2 there may be employed connector plates detachably secured to the outer peripheral surface of the barrel 2 and indicated by numerals 14 and 42, 44 and 46, 48 and 50, and 52 and 54.

In Figs. 3-5 there is illustrated in more detail and on a larger scale the mounting of one pair of connector plates 14 and 42 on the barrel 2 to communicate with the thermal control vane 8. The connector plates are formed of a curved shape similar to that of the outer surface of barrel 2 and are of a size suitable for overlying the slots 4 and 5. Each of the plates is formed with openings through which are located threaded fastening as 58 and 60 which are threaded into the barrel as shown.

Each of the connector plates is further formed with fluid passageways centrally disposed therethrough and inner sides of the plates are recessed to provide spaces into which ends of the control vanes may be fitted in an angularly disposed relationship as suggested in Fig. 5. Surrounding the recessed portions are sealing ring grooves in which are received sealing ring means such as O-rings. Numeral 62 denotes one of the fluid passageways shown in Fig. 6. Numeral 64 denotes a sealing ring shown in cross section in Fig. 4 and indicated in dotted lines in Fig. 5. By means of this arrangement the several plates are secured in sealed relationship against the barrel 2 and it will be understood that the sealing means may be varied to deal with thermal control fluids furnished at varying pressures and rates of flow where a circulation of fluid is desired to be carried out.

As shown in Figs. 7 and 8, it may be desired to provide a connector plate as 66 having an opening into which a vane 8 may slideably engage into contact with a sealing ring 70. This connector plate may be secured by screws 72 and 74 as earlier described. In Figs. 9 and 10 a modified structure is shown which includes a connector plate 76 secured to barrel 2' by a threaded fastening 78 and a locking nut arrangement 80.

In another desirable modification of the invention there may be provided a manifold member as 84 (Fig. 11) having an inlet and outlet conduit 82 and 86. The manifold member 84 is mounted around a barrel member 88 in spaced relation thereto as indicated in Fig. 11, and in this arrangement of parts to thermal control vanes as 90 are of a size to project thru the barrel 88 and abut against the manifold 82. Opposite extremities of the vane 90 are formed with apertures as 92, 94 etc. A thermal control fluid is introduced thru inlet conduit 84, passes through the annular spaces between the manifold 82 and barrel 88, and is conducted into apertures 92, then through the vane 90 and out of the aperture 94.

In Fig. 13-15 there are further illustrated vane structures which are suitable for use where a very high wear factor is encountered in a mixing operation. These structures may be of a composite nature and include a hollow vane characterized by a plurality of tubes as 96 (Fig. 13) the opposite sides of which are attached, for example by welding 98 or other suitable means, rod elements as 100 and 102 formed of a very hard wear resistant material.

In another desirable arrangement a vane body 104 may be milled or otherwise formed with grooves as 106 to provide fluid passageways and overlying these grooves 106 is a welded cover plate 108 of a relatively greater wear resistant character. It may also be desired to construct a vane 110 (Fig. 15) through which a thermal control fluid may be passed.

In all of the vanes of the invention now disclosed it may be seen that it is readily possible to carry out a mixing operation without having to deal with a pre-hardened material and with the material heated or cooled to any desired temperature. Also, in such a mixing operation final temperature adjustments may be made without interrupting the normal operation of an extruding screw which is being actuated to enhance the passage through the die. This final temperature is normally less than the optimum temperature for processing in the barrel. The vanes may be utilized in some cases without a thermal control fluid to conduct heat away from a heated plastic mass in a barrel outwardly to the barrel wall.

As an example of a thermal control fluid there may be cited silicone oil which may be heated through a temperature range of from 70° to 400° F.

To increase the surface area provided by any single vane in the mixer, a number of parallel vanes may be connected between each slot in the barrel. For example, each vane shown in Fig. 1-3 may be replaced by three parallel vanes, each vane being 3/8 of an inch thick and being spaced 3/8 inch.

In addition to serving the purpose of a conventional static mixer, the mixer described above serves the additional function of warming plastic which has been allowed to set in a mixer to make that plastic sufficiently fluid for flow of the plastic during a start up period. Further, once the extruder system is in operation, the mixer serves to lower the temperature of the hot plastic received from the extruder to a temperature at which the plastic forced through a die will hold its shape. Thus the heat exchanger and mixer modules described separate the extruder, which for the sake of product quality and uniformity should operate at a higher temperature, and the die. The arrangement of the vanes to form a mixer minimized temperature gradients within the plastic

Figs. 16 and 17 illustrate a heat exchanger module which may be used to control the temperature of the plastic but which does not serve the function of a mixer. Specifically, the module includes a barrel 120 through which the plastic may flow. Top and bottom cavities 121 and 123 are formed in that barrel and closed by caps 122 and 124 to form top and bottom manifolds. A number of parallel vanes are fitted into the barrel 120, and conduits 128 in those veins connect the manifolds 121 and 123. Heat transfer fluid for heating or cooling the plastic is introduced into an inlet port 130, distributed to the various conduits 128 and passed through the vanes to the opposite manifold 123. The liquid is then drawn out through the outlet port 132.

Fig. 18 illustrates another heat exchanger module in which the vanes are flat heat pipes 134 which extend between heat sinks 136 and 138. These heat pipes include wicks 140 and are evacuated but for a low vapor pressure fluid as in conventional heat pipes. The heat pipe fluid is vaporized with heat transfer from the plastic. That vapor provides a high conductivity thermal path to the end heat sinks where the vapor condenses, thereby releasing heat through the heat sinks. The condensed fluid is carried by the wicks back into the barrel region to again be vaporized.

The use of modular heat exchangers and mixers as described increases design flexibility. Any number of heat exchangers and mixers can be connected in series in a configuration most suited to the particular extruder application. For example, as shown in Fig. 20, a single heat exchanger may precede a mixer to cool the plastic before that plastic enters the mixer.

Figs. 21 and 22 show other configurations in which heat exchangers 142 and mixers 144 are arranged. The mixers are preferably of the heat exchanger type as described above but may be conventional mixers.

As noted, a silicone oil is the preferred heat transfer fluid. By controlling either the flow rate of that oil or the temperature of the oil entering the heat exchanger or mixer vanes, one can control the amount of heat transferred to or from the plastic to maintain a desired output to the die. Fig. 23 is one example of a control system for controlling the temperature of the oil at a constant flow rate. This system includes a temperature sensor 146 near the input of the mixer or heat exchanger to provide a signal T_{PI} on line 148. This signal is compared to a set point T_{SP} from a manual input 149. The difference signal T_{IN} is modified by a constant K and a time constant factor in circuit 150. The constant K is determined experimentally and serves to predict the changes in temperature of the heat transfer oil necessary to obtain the desired set point.. The constant K is dependent on the heat transfer characteristics of the plastic and the surface area and other heat transfer characteristics of the vanes. In one successful configuration, this constant is about equal to 6. The time constant factor is $e^{-t/\tau}$ in which τ is the time required for the plastic to flow through the section.

The output of circuit 150 is compared again to the set point and the resultant signal 152 is compared to the oil temperature indicated by a sensor 154. The final signal ΔT then controls the heater or cooler in the oil bath 156. To cool the oil, water is passed into heat exchange relationship with the oil and is quickly vaporized in a quick transfer of heat to the water. An electric heater is used to provide initial heating of the oil during start up and for compensating for overcooling of the oil. An indicator 158 is provided to indicate the temperature of the plastic at the output of the mixer. High and low temperature limits sensors 160 and 162 are also provided.

Fig. 24 illustrates another electrical controller which offers greater precision in the control. In addition to sensing the temperature of the plastic at the input of the mixer and the temperature of the oil which enters the mixer, the temperature of the oil leaving the mixer is sensed. The difference in oil temperatures is proportional to the heat transfer from the oil to the plastic. By comparing the plastic temperature at the input with the set point one provides an indication of the heat transfer which is required. Comparing the required heat transfer with that provided by the oil, as indicated by the change in temperature of the oil, one can more precisely control the temperature of the oil to obtain the necessary heat transfer. The constant K by which the difference in plastic temperature from the set point is modified in circuit 164 is roughly equal to the ratio of the specific heat, flow rate products of the plastic and oil. Again a time constant is provided by a circuit 166 to minimize the effects of transients.

Fig. 25 shows another approach to controlling the heat transfer to the plastic. In this case, the flow rate of heat transfer oil is controlled by a valve 168. This valve is in turn controlled by a proportional controller 169 such as the Foxboro controller. The controller 169 provides a control signal proportional to the ratio of the set point minus the plastic temperature at the output of the mixer to the change in temperature of the oil. Thus, as in the embodiment of Fig. 24, the heat transfer to the plastic is controlled by monitoring the heat transfer from the oil.

Fig. 26 is another control system in which a proportional controller 170 controls the valve 172 to control the heat transfer fluid flow. In this case, the system also responds to the input temperature of the plastic according to the function

$$\frac{(T_{PI}-T_{SP})}{\Delta T_O} \times (T_{PO}-T_{SP})$$

As in other embodiments, the oil is pumped by a pump 176 from a reservoir 174 the temperature of which is controlled by cooling coils 178 and a heater 180.

The control of the heat transfer from the plastic to the mixer or heat exchanger in any of the above control systems provides for a more constant temperature and thus more constant viscosity and back pressure in the mixer. Surges common to extruders are thus filtered out for a more uniform and efficient extrusion of the plastic material through the die.

CLAIMS

1. In a method of introducing a flow of material into a cylindrical body and exerting pressure to advance the material progressively along the cylindrical body the steps which include interposing in the path of flow of the material thermal control means and activating the thermal control means to induce predetermined temperature changes in the said material.

2. The invention of Claim 1 in which the thermal control means is activated before the material starts to advance along the cylindrical body.

3. The invention of Claim 1 in which the thermal control means is activated while the material is advancing.

4. The invention of Claim 1 in which the thermal control means is activated after portions of the material are no longer advancing.

5. A method according to Claims 2, 3, and 4 in which the material is a mixture of plastic substances and the cylindrical body is an extruder barrel in which the plastic substances are mixed together.

6. The invention of Claim 1 in which the thermal control means consist of tubular members presenting flow diverting surfaces and the thermal means are activated by conducting a heating fluid through the tubular member.

7. The invention of Claim 1 in which the thermal control means consist of tubular members presenting flow diverting surfaces which occur in angularly disposed relation to one another and the thermal means is activated by conducting a cooling fluid through the tubular member.

8. The invention of Claim 1 in which the thermal control means consist of flow diverting vanes which have supported thereon electrical conductor means and the thermal control means is activated by passing an electrical current thru the electrical conductor means.

9. The invention of Claim 1 in which the thermal control means includes a fluid receptacle having a thermal control fluid therein and the thermal control fluid is circulated thru the thermal control means.

10. Fluid conduit apparatus for receiving a flow of material, said fluid control apparatus including a cylindrical body having opposite side wall portions formed with spaced apart slots and thermal control means supported in

the slots for inducing temperature changes in material contained in the cylindrical body.

11. The invention of Claim 10 in which the thermal control means present flow diverting surfaces arranged in angularly disposed relation to one another for diverting material forwardly of the cylindrical body in successively differing directions.

12. The invention of Claim 10 in which the thermal control means includes vanes formed with passageways therein and means for introducing a fluid into the passageway to induce changes in temperature in the same material.

13. Static mixer apparatus including a barrel member formed with slots therein, a plurality of flow diverting vanes mounted in the slots in angularly disposed relationship to one another, said vanes being formed with passageway extruding structure, and means connected to the vanes for introducing a thermal control fluid into the passageways.

14. The invention of Claim 13 in which the means for inducing a thermal control fluid includes a reservoir in which the fluid is contained and pump means for circulating fluid from the reservoir thru the passageways.

15. An interface between an extruder and an output die, that interface comprising a modular configuration of mixer and heat exchanger units, each heat exchanger unit comprising heat transfer flow conduits passing through a plastic transfer barrel in heat exchange relationship with the plastic in the barrel.

16. The invention of Claim 15 in which the mixer modules comprise heat transfer fluid conduits which extend through a plastic transfer barrel in angularly disposed relation to one another.

17. In an extruder system comprising an extruder and a dye, the improvement of a heat exchange unit between the extruder and die, the heat exchange unit comprising heat transfer fluid conduits extending through a plastic transfer barrel and means for controlling the temperature and/or fluid flow of heat transfer fluid through those conduits in reponse to a sensed temperature of the plastic to provide controlled cooling of the plastic from the high temperature at the output of the extruder to a desired lower temperature at the die.

18. The invention as claimed in Claim 17 wherein the means for controlling the temperature and/or fluid flow of the heat transfer fluid responds to the temperature differential between heat transfer fluid entering and heat transfer fluid exiting the conduits through the barrel, that temperature differential providing an indication of the heat transfer from the heat transfer fluid into the plastic.

19. The invention as claimed in Claim 17 further comprising a heat transfer fluid reservoir for providing fluid to the conduits through the barrel, that reservoir including means for both heating and cooling the heat transfer fluid.

20. A method of operating an extruder and die at respective optimum temperatures comprising providing a heat transfer unit between the extruder and dye, that heat transfer unit comprising heat transfer fluid conduits extending through a plastic transfer barrel and controlling the temperature and/or flow of heat transfer fluid through those conduits to cool the plastic flowing therethrough an amount necessary to provide the proper temperature differential between the extruder and die.

21. The invention as claimed in Claim 20 wherein the temperature or flow of the heat transfer fluid is controlled by the difference between the temperatures of the heat transfer fluid entering and exiting the heat exchanger unit.

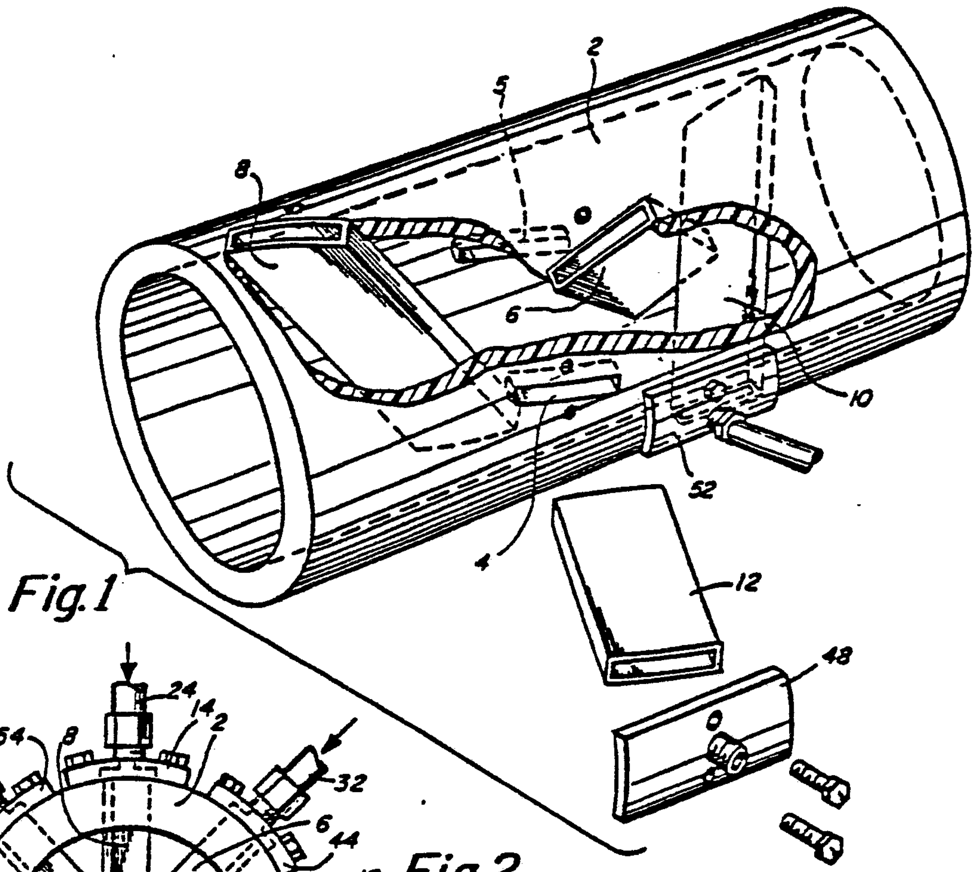

Fig.1

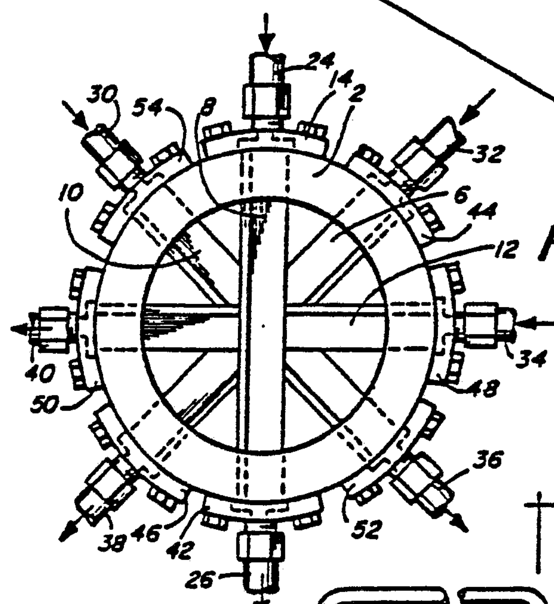

Fig.2

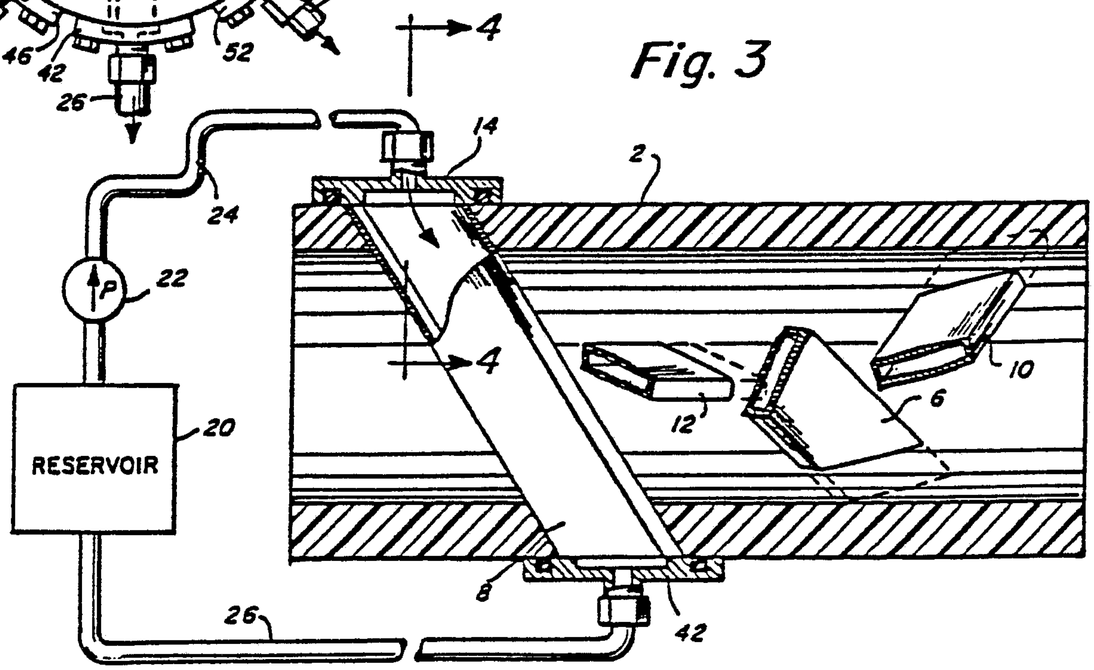

Fig. 3

Fig. 4

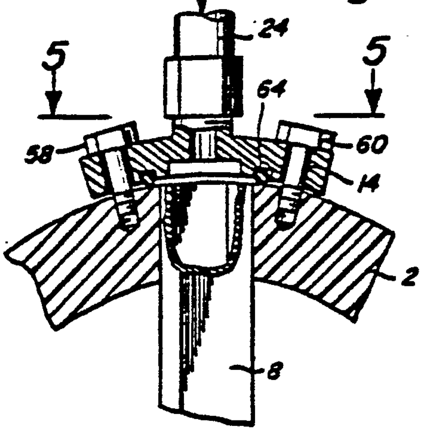

Fig.5

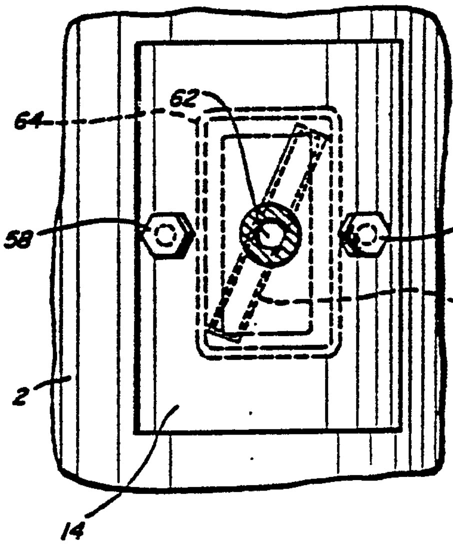

Fig.6

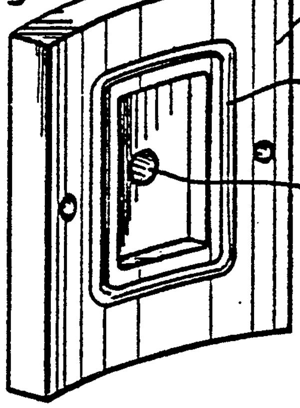

Fig. 7

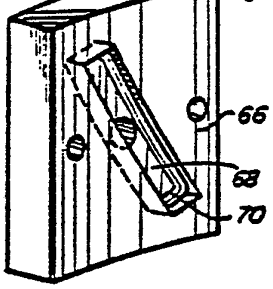

Fig.8

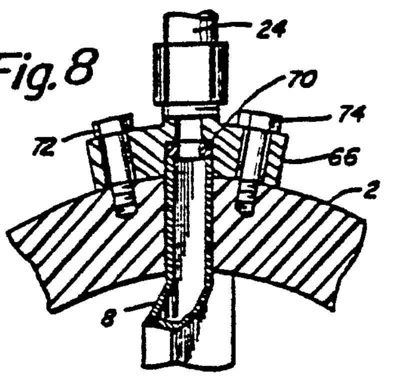

Fig. 9

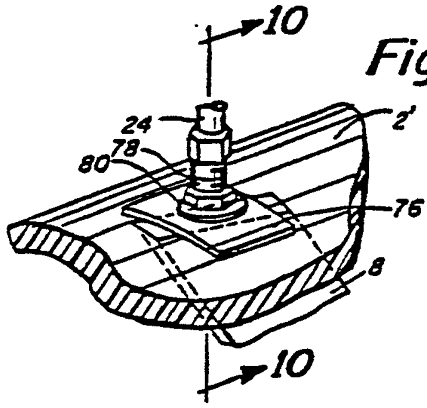

Fig.11

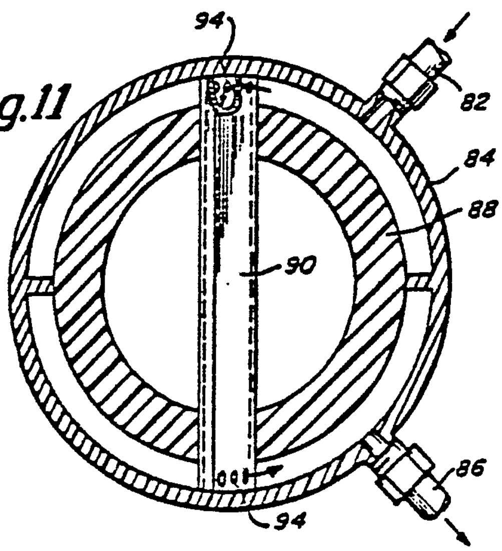

Fig. 10

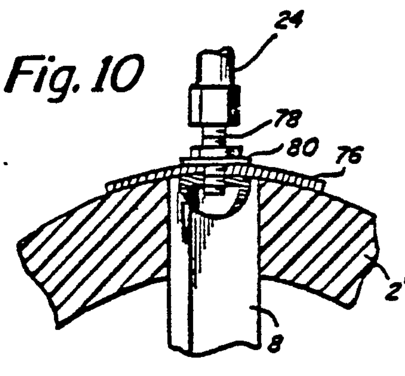

Fig.12

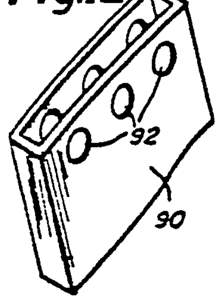

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Fig. 13

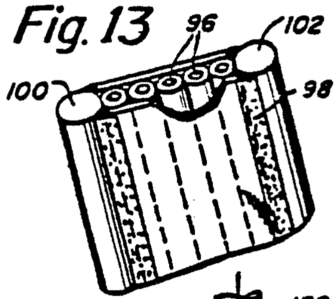


Fig. 14

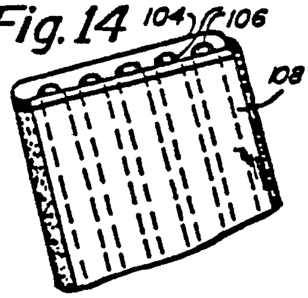


Fig. 15

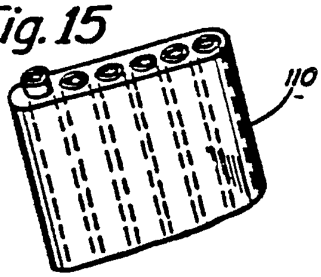


Fig. 16

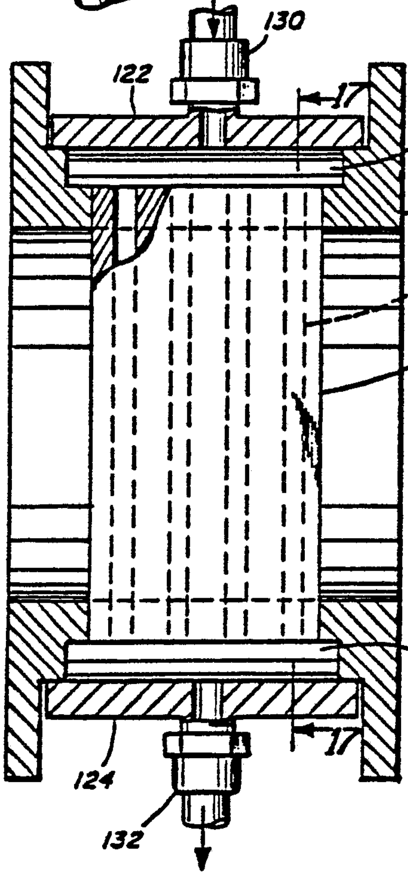


Fig. 17

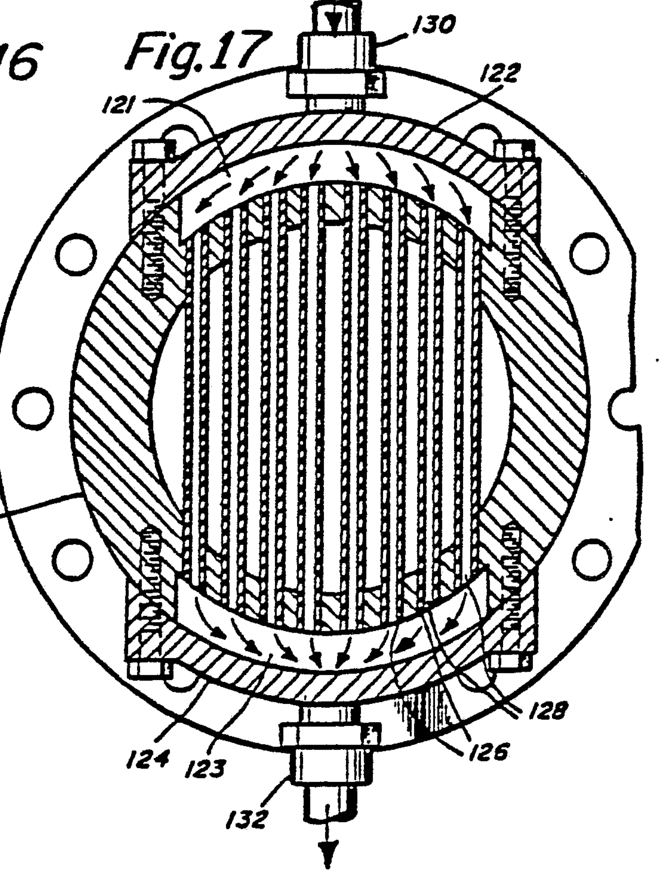


Fig. 18

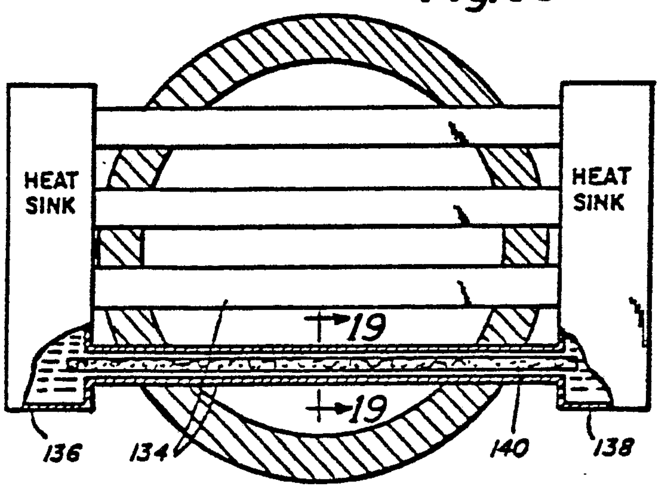


Fig. 19

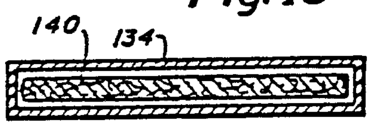


Fig.20

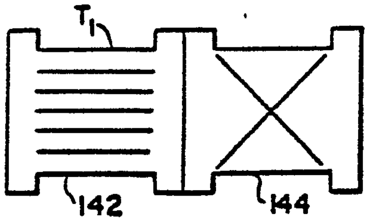


Fig.21

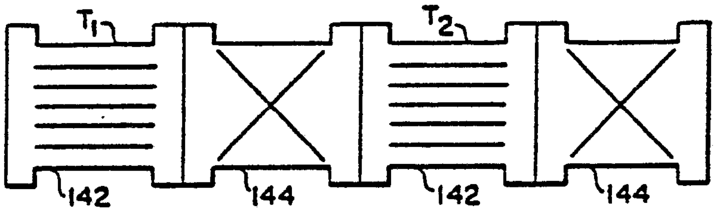
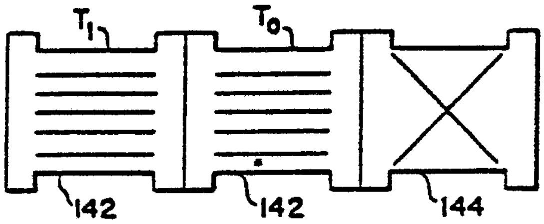


Fig. 22



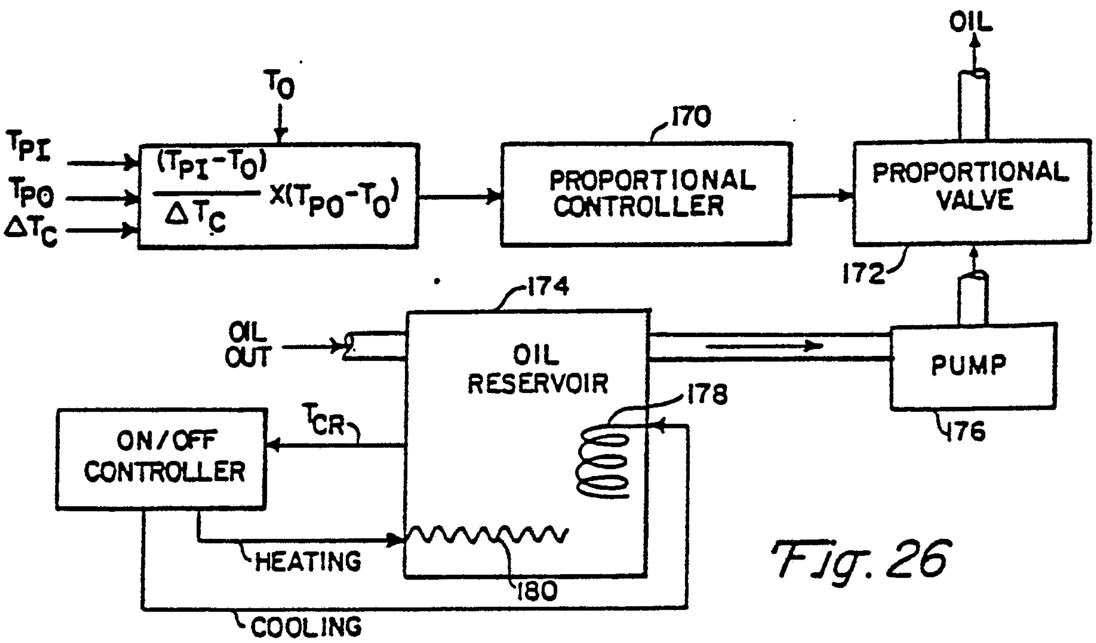


Fig. 26

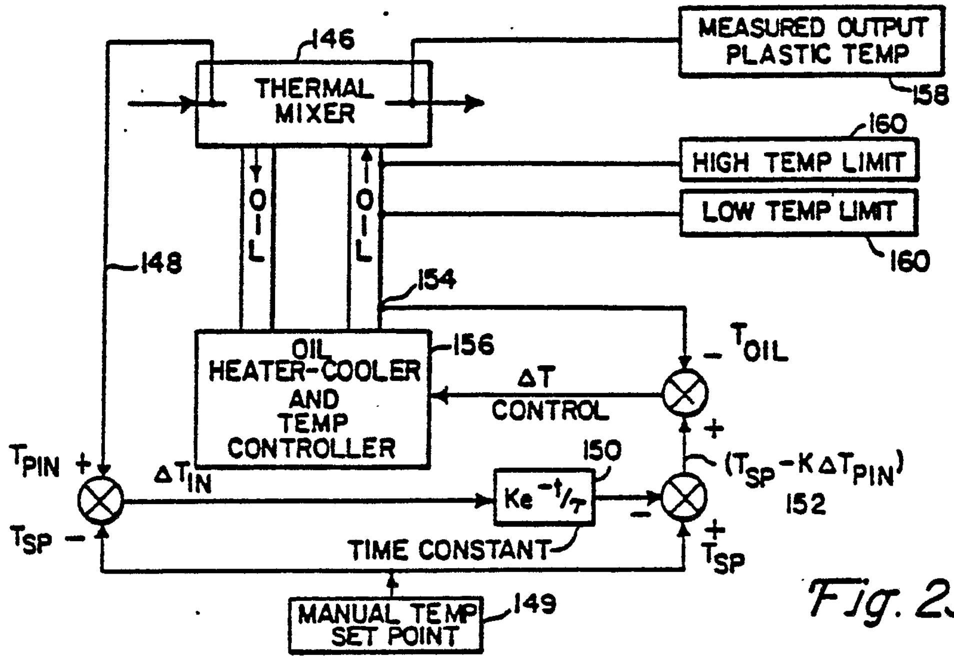


Fig. 23

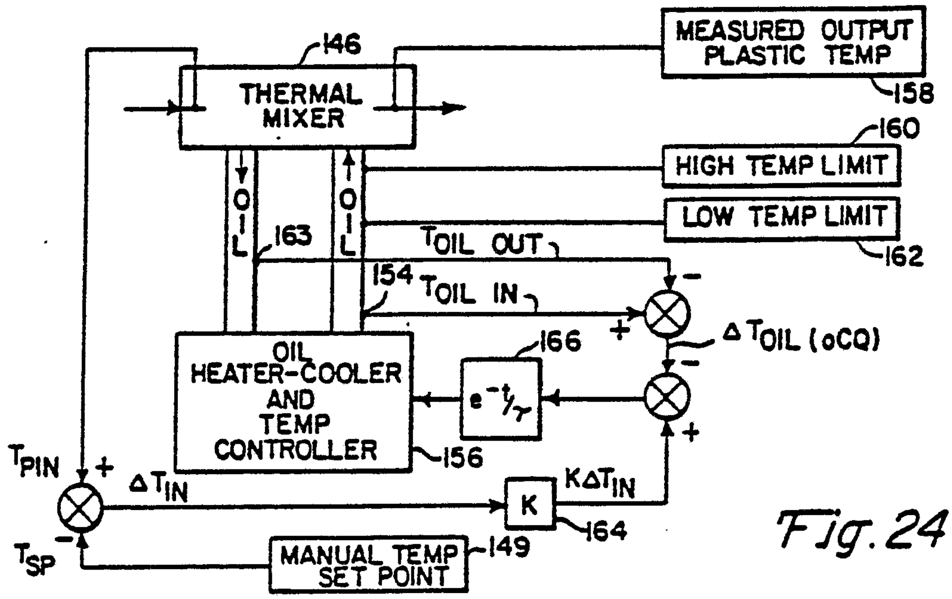


Fig. 24

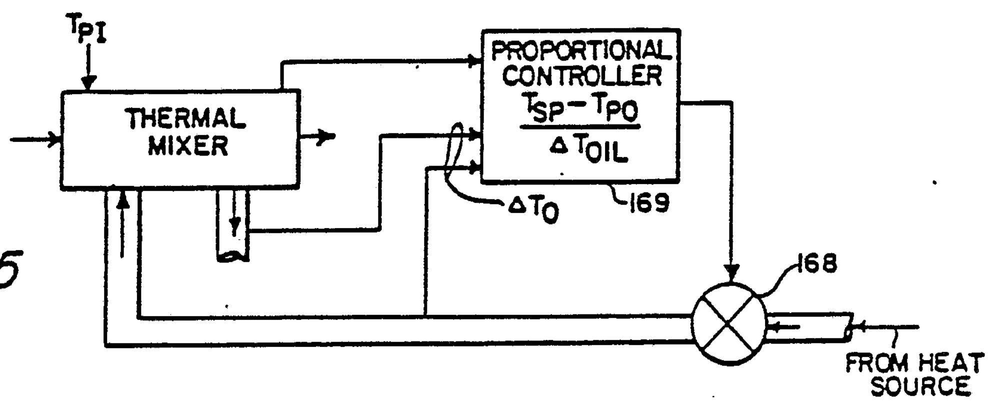


Fig. 25

INTERNATIONAL SEARCH REPORT

International Application No PCT/US80/01623

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL3 B01F 5/06; B29B 1/06

U.S. CL. 366/96,337,147; 138/38 ; 165/164 ;425/207,199 ;264/349

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	366/96,144-147,336-340,77,87 425/207,208,199,378R 138/38,42 165/164,47,109T 264/349,176R,328.19

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	US, A, 624,748, Published 9 May 1899, Bretherton	1-22
X	US, A, 1,528,859, Published 10 March 1925, Taylor	1-21
L	US, A, 4,004,785, Published 25 January 1977 Kajimoto et al	9,14
A	US, A, 4,062,524, Published 13 December 1977 Brauner et al	1-14
A	US, A, 4,198,168, Published 15 April 1980 Penn	1-14
A	US, A, 3,460,580, Published 12 August 1969, Carter	1-14
X	US, A, 4,170,446, Published 9 October 1979, Schutz et al	5,15-21
X,E	US, A 4,249,877, Published 10 February 1981, Machen	15-21

* Special categories of cited documents: [15]

"A" document defining the general state of the art

"E" earlier document but published on or after the international filing date

"L" document cited for special reason other than those referred to in the other categories

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but on or after the priority date claimed

"T" later document published on or after the international filing date or priority date and not in conflict with the application, but cited to understand the principle or theory underlying the invention

"X" document of particular relevance

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
29 July 1980	18 AUG 1981

International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	Simone

International Application No. PCT/US81/01623

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [10]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers ______, because they relate to subject matter [12] not required to be searched by this Authority, namely:

2.☐ Claim numbers ______, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out [13], specifically:

VI.☒ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [11]

This International Searching Authority found multiple inventions in this international application as follows:

Invention I: 1-9
Invention II: 10-14
Invention III: 15-21

1.☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.