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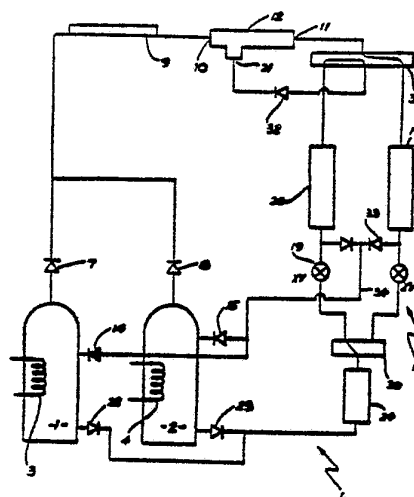
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(54) Title: TWIN TANK HEAT TRANSFER CIRCUIT

## (57) Abstract

A heat transfer circuit has an ejector (12) through which a fluid refrigerant is discharged. The ejector receives the refrigerant from a heated reservoir (1) and discharges it towards a cooled collection reservoir (2). The ejector has a suction inlet (21) which draws part of the refrigerant through a branch circuit containing an expansion valve (19) and an evaporative heat exchanger (20) which produces the desired cooling effect. Valves (30 and 31) are provided to enable the branch circuit to act as a heater or a cooler. The functions of the two reservoirs are reversed when the supply reservoir is empty and the collection reservoir is full of refrigerant. The heat transfer circuit is usable in a cooler, a refrigerator or an air conditioner. The problem solved by the invention is how to operate a closed circuit refrigeration or cooling system without using mechanical compressors for the fluid refrigerant. The use of the differential pressure between two reversible reservoirs, one acting as a supply and the other as a collector, avoids the use of a mechanical compressor.



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## TWIN TANK HEAT TRANSFER CIRCUIT

FIELD OF THE INVENTION

THIS INVENTION relates to heat-transfer circuitry and is more specifically concerned with one in which a refrigerant working fluid flows around a closed circuit to transfer heat between two stations in the circuit.

STATE OF THE ART

Conventional heat-transfer circuitry usually relies on a compressor to pump the working fluid around the circuit. The working fluid changes between its vapour phase and its liquid phase, in accordance with the prevailing temperature and pressure in different parts of the circuit , and whether latent heat is liberated or absorbed.

The motor-driven compressor represents a significant part of the capital cost. For example if the circuitry is being used to provide an air-conditioning unit for a car, the compressor may be one-third of the total cost of the unit.

The motor-driven compressor also has a significant effect on the operating efficiency of the circuitry as it represents a continuous drain of power. In the case of a motor car, the consumption of power to operate an air-conditioning unit can produce a marked increase in the rate of fuel consumption of the car.

W. Martynowski has proposed a form of heat-transfer circuitry in which the running costs are reduced by utilizing waste heat as a source of energy to help operate the circuitry (see KHOLODIL-NAYA TECNIKA (Russian) Vol. 30, No. 1, January-March 1953 edition, page 60). The working fluid is FREON (a commercially available refrigerant) which is boiled by waste heat obtained elsewhere, and the vapour produced is driven under pressure around a primary circuit comprising an ejector and a condenser

cooled by cooling water. The FREON vapour is condensed to its liquid phase in the condenser and part of it is returned by a pump to the boiler while the remainder is fed into a branch circuit extending to a suction inlet of the ejector. The branch  
5 circuit contains an expansion valve and an evaporator so that the liquid working fluid expanded adiabatically through the valve extracts heat from the vicinity of the evaporator before rejoining the primary circuit at the ejector.

The Martynowsky proposal is theoretically interesting but has  
10 commercial disadvantages. For example, a mechanical feed pump is necessary to return liquified working fluid to the boiler and it has to be powerful enough to overcome the back pressure produced in the boiler by the vapourisation of the working medium  
15 in it. The energy required to operate the pump is significant as also are its running costs. Finally FREON has a tendency to produce cavitation effects in a conventionally-designed compressor with a consequent loss in pumping efficiency.

#### OBJECT OF THE INVENTION

An object of this invention is to provide heat-transfer circuitry  
20 which does not require a compressor to operate it.

#### THE INVENTION

In accordance with the present invention there is provided heat-transfer circuitry having a primary flow circuit containing ejector means through which vapourised working fluid, heated in first  
25 reservoir means, is discharged to create low pressure at a suction inlet of the ejector means, means for collecting and cooling working fluid after it has passed through the ejector means, and a branch circuit connected at one end to the suction inlet and containing a heat-exchanger and an expansion valve arranged  
30 to expand liquified working fluid from the primary circuit adiabatically into the heat-exchanger to cool it; the improvement in such

5 circuitry comprising the provision of a second reservoir means in which the bulk of the working fluid from the ejector means is collected in its liquid phase, valve means operable to substitute the second reservoir, when full, for the first reservoir means, when empty, and heating means associated with respective reservoirs and individually operable to boil the working fluid in whichever of the reservoir means is supplying working fluid to the ejector means.

10 The working fluid may be provided to the ejector means in liquified form or in vapour form, depending on the design of the ejector means and the temperatures and pressures of the working fluid in different parts of the circuitry.

15 The circuitry of the invention is entirely heat-operated, and as the heat used to boil the working fluid in the reservoir means may be solely waste heat, a consequential reduction in running costs is readily obtainable. The absence of a compressor also reduces the capital costs and the wear inevitably present with mechanically moving parts.

20 The invention may be used in a static installation, such as commercial or a domestic air-conditioning, refrigeration or chilling installation. It may also be used in a mobile installation such as a motor vehicle when it can operate off the engine waste heat.

#### PREFERRED FEATURES OF THE INVENTION

25 Preferably the circuitry includes change-over switches enabling the functions of two heat-exchangers remotely situated from one another, to be reversed. Each heat exchanger is thus selectively able to provide a source of heating or a source of cooling. When one of the heat-exchangers is acting as a cooler the  
30 other is acting as a heater. By interchanging the functions of the heat-exchangers to suit the climatic conditions, the circuitry

can provide an air-conditioning unit.

### INTRODUCTION TO THE DRAWINGS

The invention will now be described in more detail, by way of examples, with reference to the accompanying diagrammatic and greatly simplified circuit drawings, in which:-

### IN THE DRAWINGS

FIGURE 1 shows a first form of heat-transfer circuitry using a gas-operated ejector;

FIGURE 2 shows a second form of heat-transfer circuitry having an enhanced pressure drop produced across a branch circuit;

FIGURE 3 shows a third form of heat transfer circuitry using a liquid-operated ejector;

FIGURE 4 shows a modification of the circuitry of figure 3;

FIGURE 5 shows a fourth form of heat-exchange circuitry in a space-cooling mode;

FIGURE 6 shows the circuitry of figure 5 in its space-heating mode;

FIGURE 7 shows a form of branch circuit usable in the heat-transfer circuitry to improve its efficiency;

FIGURE 8 shows a further form of heat transfer circuitry in its space-heating mode.

FIGURE 9 shows parts of the circuitry of figure 8 in the states they assume when the circuitry is operating in its space-cooling mode.

#### DESCRIPTION OF PREFERRED EMBODIMENT

The circuitry shown in figure 1 comprises two tanks 1 and 2 providing reservoirs for a liquified working fluid such as that known commercially as "FREON", or one of the other commercial refrigerants known commercially in Australia as "R-11", "R-12", "R-500", "R-501" or "R-502". By suitably adapting the pressure and temperature parameters of use, the circuitry can be used with most refrigerants which undergo changes in phase while travelling around a closed circuit. The tank 1 is shown in figure 1 three-quarters filled with liquified working fluid and the tank 2 is shown only a quarter filled.

The tanks 1 and 2 respectively contain heating means provided by tube coils 3 and 4, respectively, which have associated valves 6 and 5 controllable to allow a heating medium such as hot water or engine exhaust gas, to flow selectively through the coils.

The tanks 1 and 2 have top outlets controlled by valves 7 and 8 which connect the upper ends of the tanks via an optional superheater 9, to a vapour drive inlet 10 of an ejector 12. The ejector 12 has a vapour outlet 11 connected through a condenser 13 to non-return valves 14,15 for returning liquified working fluid to whichever of the tanks 1,2 is at the lower pressure. The part of the circuitry thus far described will be referred to hereafter as "the primary circuit".

The circuitry is provided with a branch circuit 16 connected at its inlet end 17 to receive part of the vapourised working fluid from the tanks 1,2. If the optional superheater 9 is used, the inlet end 17 is disposed upstream of the superheater 9.

5 The branch circuit 16 contains a condenser 18 to liquify the working fluid, an expansion valve 19 through which the liquified working fluid is adiabatically expanded into an evaporator 20 which is cooled thereby. The outlet end of the branch circuit 16 is connected to a suction inlet 21 of the ejector 12.

#### 10 OPERATION OF THE PREFERRED EMBODIMENT

When the circuitry is in use, the working fluid flows in the direction indicated by the arrows. It is assumed in the figure that heat is being applied to the tank 1. Vapourised working fluid is fed under pressure from the tank 1 through the valve  
15 7 and the superheater 9, to the drive inlet of the ejector 12 to create suction at the inlet 21. The hot vapourised working fluid flows from the ejector outlet 11 to the condenser 13 which liquifies it. It then flows through the non-return valve 15 to the cooled tank 2. Thus, as the working fluid is driven  
20 from the tank 1, it accumulates in the tank 2.

Part of the vapourised working fluid determined by the setting of the expansion valve 19, flows through the branch circuit 16 and extracts heat from the evaporator 10 which may form part of a refrigeration or chilling installation.

25 It will be noticed that the circuitry described does not require a mechanical compressor or pump to make it operate. The disadvantages mentioned above and associated with such equipment are therefore avoided. The circuitry can also be operated entirely from what would otherwise be waste heat produced by an internal  
30 combustion engine. The operation of the circuitry is relatively



insensitive to vibration and tilt, unlike the conventional absorption refrigerator, and the control of the temperature of the evaporator in the branch circuit is relatively unaffected by changes in the flow rate of working fluid through the primary circuit.

- 5 When the tank is almost empty, the tank 2 is almost full. The heater 3 is then turned off and the heater 4 turned on so that the pressure and temperature conditions in the two tanks are reversed. The tank 2 thereupon operates to deliver working fluid to the ejector 12 and the liquified working fluid from the primary  
10 circuit is collected in the tank 1. The above-described periodic reversal of the functions of the two tanks continues to take place as long as the circuitry is operating without any noticeable fluctuation in the cooling effect of the evaporator occurring.

#### SECOND EMBODIMENT

- 15 In the circuitry of figure 2, the primary circuit is the same as that shown in figure 1. The same reference numerals are used to denote corresponding parts which will not therefore be again described.

- The distinction between figures 1 and 2 lies in the branch circuit  
20 16. In figure 2 this is connected to receive liquified working fluid from whichever of the tanks is heated, by way of the non-return valves 22, 23. The tanks are selectively heated by activation of respective heaters 3,4 located in the upper portions of the tanks so that liquified working fluid entering the branch  
25 circuit 16 is not overheated and is at the pressure prevailing in the heated tank.

The liquified working fluid flows from the open non-return valve 22,23 to a cooler 24 which supplies it to an expansion valve 19 discharging into the evaporator 20 as in figure 1.

The advantage of the circuitry of figure 2 over that shown in figure 1, is that the pressure difference between the ends of the branch circuit is greater and thus its cooling effectiveness is increased. The use of the superheater 9 is again optional.

5     THIRD EMBODIMENT

The circuitry of figure 3 is based on that of figure 2 and corresponding parts are similarly referenced and will not be again described.

10     The distinction between the circuitry of figures 2 and 3 is that, in figure 3, the ejector 12' receives liquified working fluid from the heated tanks 1,2 rather than vapourised working fluid. Liquid operated ejectors have, in certain circumstances, operating advantages over gas-operated ejectors.

15     In figure 3 the liquified working fluid used to operate the ejector 12' is received under pressure at its drive inlet 10 by way of a line 25 connected to the outlets of the non-return valves 22,23.

FOURTH EMBODIMENT

20     Figure 4 shows a modification of figure 3. Corresponding parts have the same reference numerals and will not be again described. In figure 4 the ejector 12' receives liquified working fluid at its drive inlet 10, from a line 26 which is connected at its other end to the junction of the cooler 24 and the expansion valve 19. The temperature of the liquified working fluid entering the ejector 12' is thus lower than is possible with the circuitry of figure 3.

FOURTH EMBODIMENT

30     The circuitry shown in figure 5 is based on the circuitry shown in figure 2 and once again the same reference numerals have been used to denote corresponding parts so that unnecessary description is avoided. The distinction between the

circuitries of figures 2 and 5 is that, in the latter circuitry, reversing valves are provided to enable the branch circuit to operate either in a space heating or cooling mode. The circuitry is thus well suited for use in an air-conditioner for a static  
5 installation such as a building, or a mobile installation such as a motor car.

Figure 5 shows the circuitry in the space-cooling mode in which cooled liquified working fluid is drawn from the cooler 24 through the reversing valve 30 to the expansion valve 19 which discharges  
10 it into the evaporator 20 to produce the desired cooling effect. The evaporator is disconnected by the second reversing valve 31 to the suction inlet 21 of the ejector 12, by way of a non-return valve 32.

The ejector is driven by vapourised working fluid to create  
15 suction at the inlet 21, and vapourised working fluid is discharged from its outlet 11 and directed, via the reversing valve 31, to the condenser 13. The liquified working fluid flowing from the condenser 13 passes through a non-return valve 33 to a line 34 which discharges it via one of the non-return valves  
20 14,15 to whichever of the tanks 1,2 is acting as a collector.

The circuitry of figure 5 is changed to its space-heating mode by moving the two valves 30,31 to the positions shown in figure 6. Liquified working fluid from the cooler 24 is then directed by the valve 30 to an expansion valve 35 which discharges  
25 it adiabatically into the condenser 13. The condenser 13 is basically a heat-exchanger and drws heat from its surroundings to provide the latent heat of evaporation for the working fluid. The vapourised working fluid from the condenser 13 passes via the valve 31 and the non-return valve 32 to the suction  
30 inlet of the ejector where it mixes with the working fluid in the primary circuit and is discharged with it from the ejector outlet 11. The hot vapourised working fluid from the ejector

12 is directed by the valve 31 into the evaporator heat-exchanger 20. The working fluid condenses in the heat-exchanger 20 to heat its surroundings with its latent heat of condensation. It then flows via a non-return valve 36 to the line 34 and is returned  
5 through it to the tanks 1,2.

#### VARIATION OF FOURTH EMBODIMENT

Figure 7 shows a way of improving the efficiency of the branch circuit shown in figure 5. Liquified working fluid is drawn into the branch circuit by way of the cooler 24 and flows through  
10 a heat-exchanger 40 before discharging through the expansion valve 19 into the evaporator 20. The cooled vapour leaving the evaporator 20 flows back to the heat-exchanger 40 and is drawn off through the ejector 21. The cooled vapour in the heat-exchanger 40 cools the liquified working fluid supplying  
15 the expansion valve 40 to improve the cooling effect produced by the evaporator 20.

#### FIFTH EMBODIMENT

In the circuitry of figure 8 the tanks 1,2 of earlier figures which provide reservoirs of working fluid to be heated, are  
20 replaced by concentrically arranged tube assemblies arranged in coils 50,51, each being of extended length. Each assembly provides two coaxially arranged flow paths in good heat-transfer relationship. The inner paths, provided by the inner tubes 53,54 serve as reservoirs for liquified working fluid, and the outer  
25 paths, provided by the outer tubes 55,56 have circulated through them either a hot fluid if the associated tube is to provide heated working fluid to an ejector 57, or a cold fluid if the associated inner tube is to provide a collector for liquified working fluid from the primary circuit.

30 As with previous embodiments, the reservoirs are substituted

for one another when the heated reservoir is almost empty and the cooled reservoir is almost full.

5 The upper ends of the inner tubes 53,54 are connected through respective non-return valves 58,59 to a drive inlet 60 of the ejector. Vapourised working fluid is fed from the ejector to a reversing valve 61 supplying, in accordance with its operating position, one of two heat-exchangers 62,63. The two operating positions of the valve 61 are respectively shown in figures 8 and 9. In figure 8, the vapourised working fluid passes from 10 the valve 61 to the heat-exchanger 62 which as providing heat used to warm a stream of air supplied tby a fan 64.

The working fluid condenses in the heat-exchanger 62 and is fed through a non-return valve 65 to a cool tank 66. This is kept at a low pressure by part of its contents being drawn 15 off through an expansion valve 67 which discharges it adiabatically into the second heat-exchanger 63. This acts as an evaporator and is connected via the valve 61 and the non-return valve 70 to a suction inlet 72 of the ejector 57.

20 Liquified and cooled working fluid from the cooling tank 66 descends through a line 73 to a pair of non-return valves 74,75 connected respectively to the lower ends of the tubes 53,54.

The circuitry described operates to deliver heat to the fan-blown air continuously, despite the periodic substitution of the full reservoir tube ofr the empty one. The change in operation 25 of the tubes is effected by reversing the hot and cold liquid supply connections to the tubes 55,56.

If the circuitry is to function in its cooling mode, the valve 61 is moved to the position shown in figure 9. Vapourised working fluid from the ejector 57 then passes to the heat exchanger 30 63 where it is cooled and liquified and passes through a non-

return valve 80 to the cooling tank 66. Most of the working fluid returns via the line 73 to whichever of the reservoir tubes 53,54 is acting as a collector. The remainder of the liquified working fluid is drawn off the lower end of the cooling tank 66 through the line 81 and discharges adiabatically through an expansion valve 82 into the heat exchanger 62. The air driven by the fan 64 is then cooled by passage past the heat-exchanger 62. The vapourised working fluid flows through the reversing valve 61, now in the position shown in figure 9, to the suction inlet 72 of the ejector 57.

It will be noted that in all of the circuitry described the use of a compressor or mechanical pump in the working fluid flow path is avoided by the use of two reservoirs which interchange functions periodically. This is important as some working fluids, such as "FREON" are so sensitive to pressure changes that the variations in pressure which occur around the impeller of a compressor or pump, can cause localised vapourisation of the working fluid with consequent cavitation and a loss of pumping pressure and efficiency. The circuitry of the invention is also well adapted to use in locations where electrical power is not available and there is a plentiful source of unusable heat which may be solar or waste heat. Naturally the circuitry is also usable in conventional domestic refrigerators when the heat can be provided electrically, as there is minimal noise when the circuitry is operating.

Although the reservoirs are described as being heated by coiled tubular heaters, heat may instead be applied to the outside walls of the tanks 1,2 directly by placing them alternately against a source of heat.

1. Heat-transfer circuitry having a primary flow circuit containing ejector means through which vapourised working fluid, heated in first reservoir means, is discharged to create low pressure at a suction inlet of the ejector means, means for cooling and collecting working fluid after it has passed through the ejector means, and a branch circuit connected at one end to the suction inlet and containing an evaporative heat-exchanger and an expansion valve arranged to expand liquified working fluid from the primary circuit adiabatically into the heat-exchanger to cool it; characterised in that a second reservoir means (2,61) is provided in which most of the working fluid from the ejector means (11, 12, 75) is collected in its liquid phase, valve means (7,8,9,10,29,30,) are operable to substitute the full second reservoir means for the empty first reservoir means (1,74), and heating means (3,4,63 and 64) are individually operable to heat whichever reservoir means is supplying working fluid to the ejector means.

2. Circuitry as claimed in claim 1, characterised in that the ejector means (12) are connected to receive vapourised working fluid from the upper ends of the reservoir means (1,2 and 50,51).

3. Circuitry as claimed in claim 2, characterised by the provision of a superheater (9) in the primary flow circuit upstream of the ejector means (12).

4. Circuitry as claimed in claim 2, characterised by the reservoir means comprising a double-walled tube (50,51) of extended length providing concentric separate flow paths, the inner tube (53,54) being connected for the flow of the working fluid through it, and the outer tube (55,56) being connected for the selective flow of hot and cold media through it to provide the heating

means.

5. Circuitry as claimed in claim 1, characterised in that the ejector means (12) is connected to receive liquified working fluid from the lower ends of the reservoir means.

6. Circuitry as claimed in claim 5, characterised in that liquified working fluid flows to the ejector means along a flow path (25, 26) which is in parallel with the branch circuit.

7. Circuitry as claimed in claim 5 or claim 6, characterised in that liquified working fluid from the reservoir means (1,2) flows to the branch circuit through a cooler (24).

8. Circuitry as claimed in claim 7, characterised in that the branch circuit includes a heat exchanger (40) which provides two oppositely directed flow paths in heat-exchange relationship, the first flow path being connected in series between the cooler (24) and the expansion valve (19), and the second flow path being connected in series between the evaporative heat exchanger (20) and the suction inlet (21) of the ejector means.

9. Circuitry as claimed in any one of claims 1 to 4 and forming part of an air-conditioning unit, characterised by the provision of reversing valve means (30,31 and 61) which controls the flow of working fluid through the branch circuit to provide, selectively, heating and cooling of the air in accordance with the operating position of the reversing valve means.

10. Circuitry as claimed in claim 9, characterised by the provision of a cooling tank (66) from which liquified and cooled working fluid is supplied to the reservoir means (53,54).

11. A method of operating heat transfer circuitry using



two reservoirs (1,2 and 53,54) for collecting working fluid from, and delivering working fluid to a primary flow circuit containing ejector means (12 and 57), one of the reservoirs supplying the ejector means with working fluid while the other reservoir is receiving working fluid from the primary circuit, and valves operating to exchange the functions of the two reservoirs when the one supplying the working fluid to the ejector means is substantially empty.

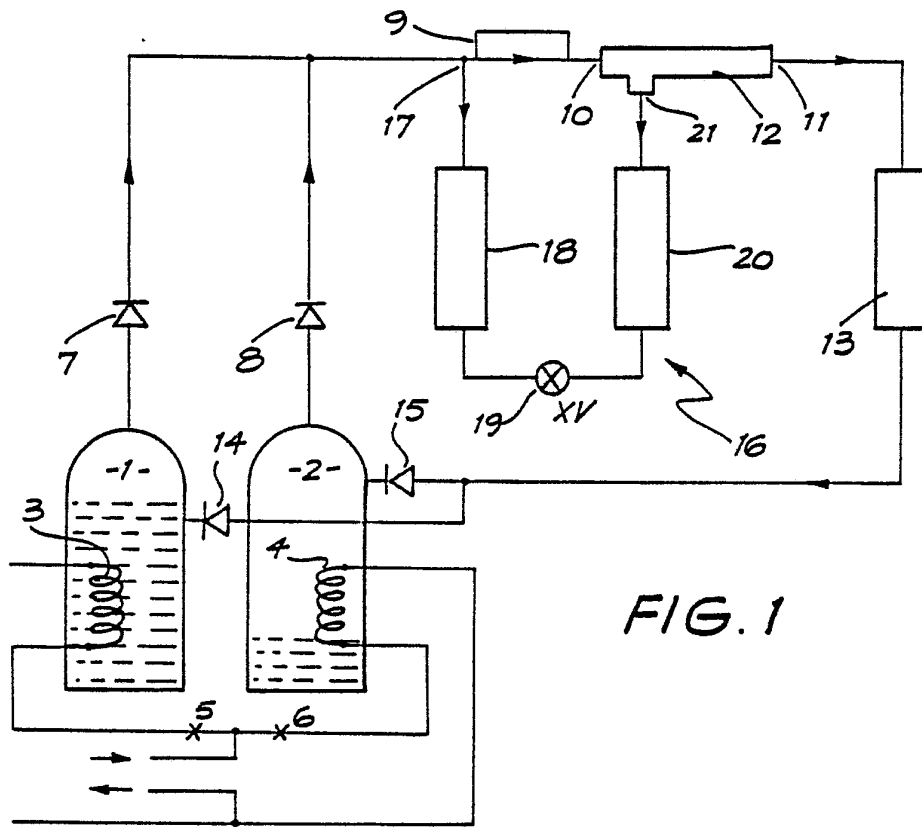


FIG. 1

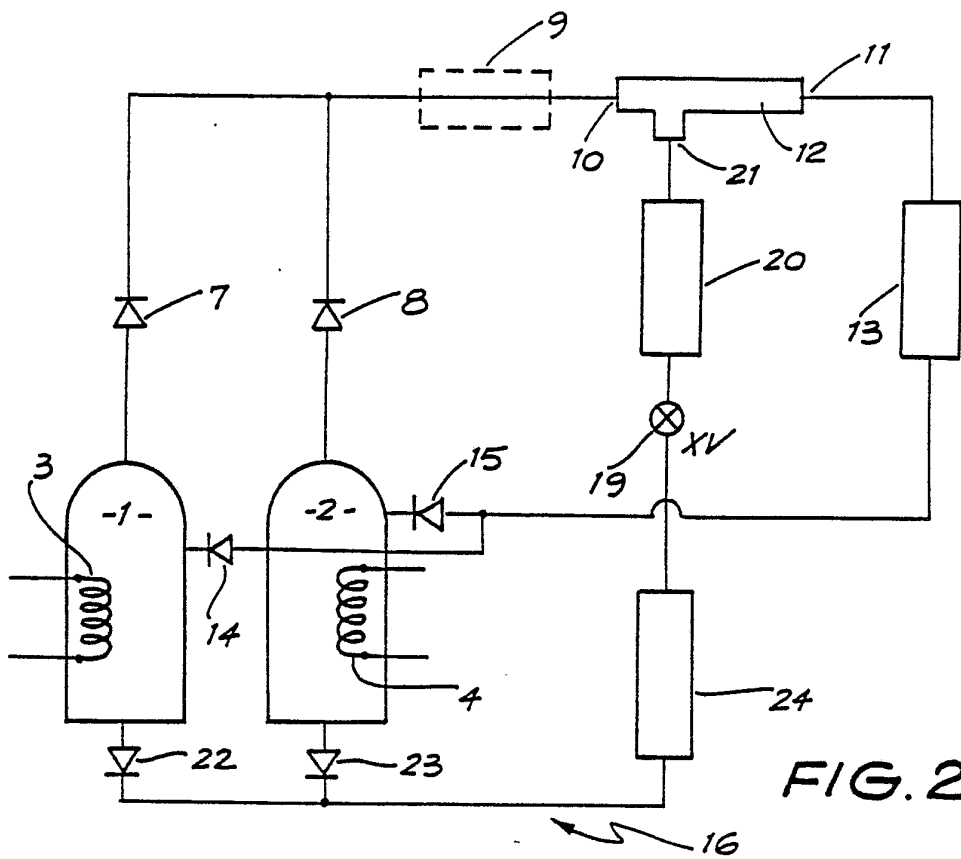
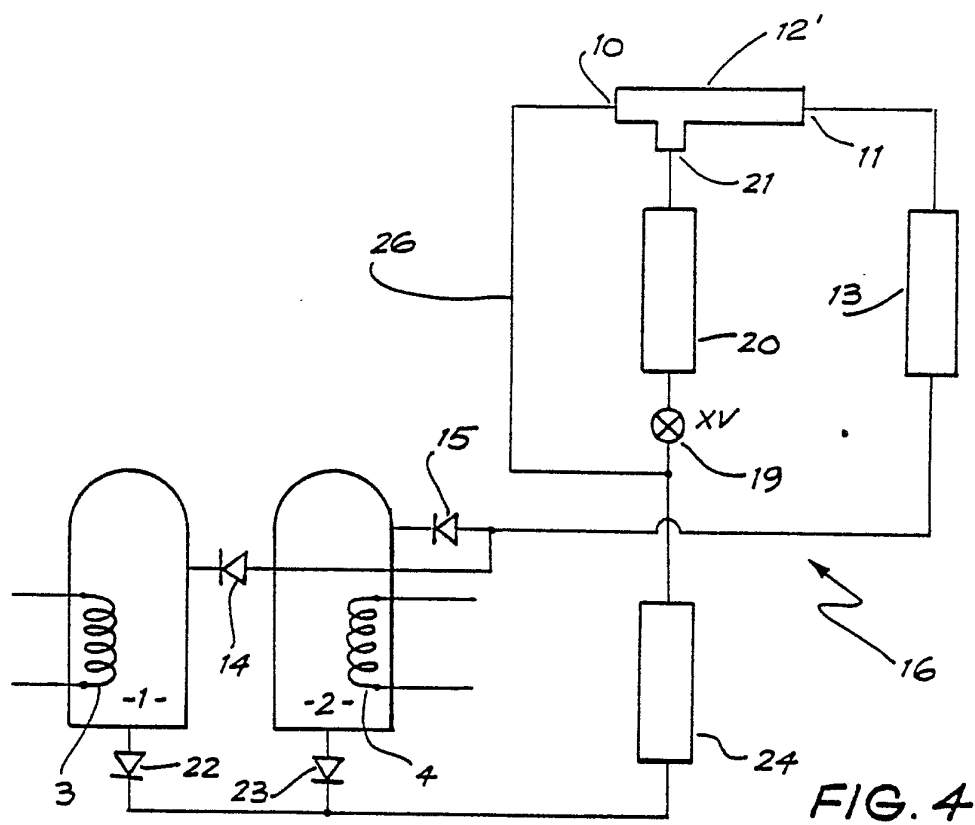
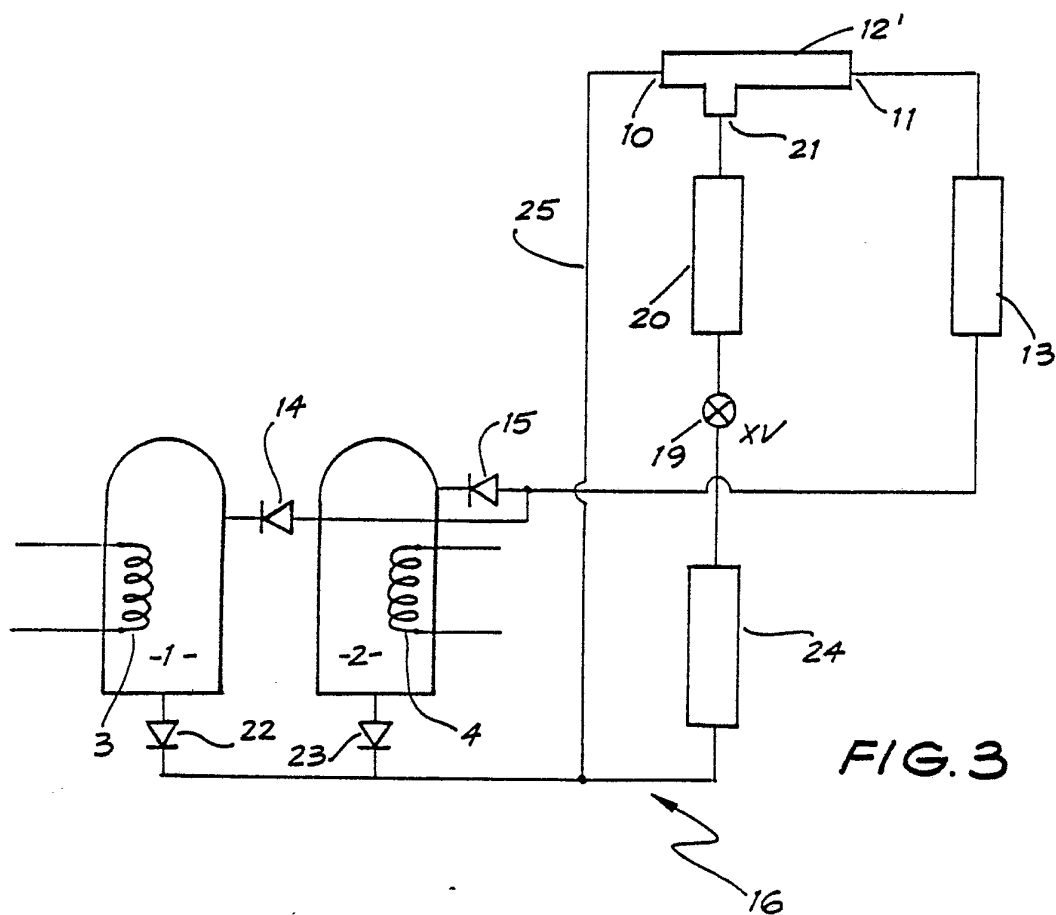
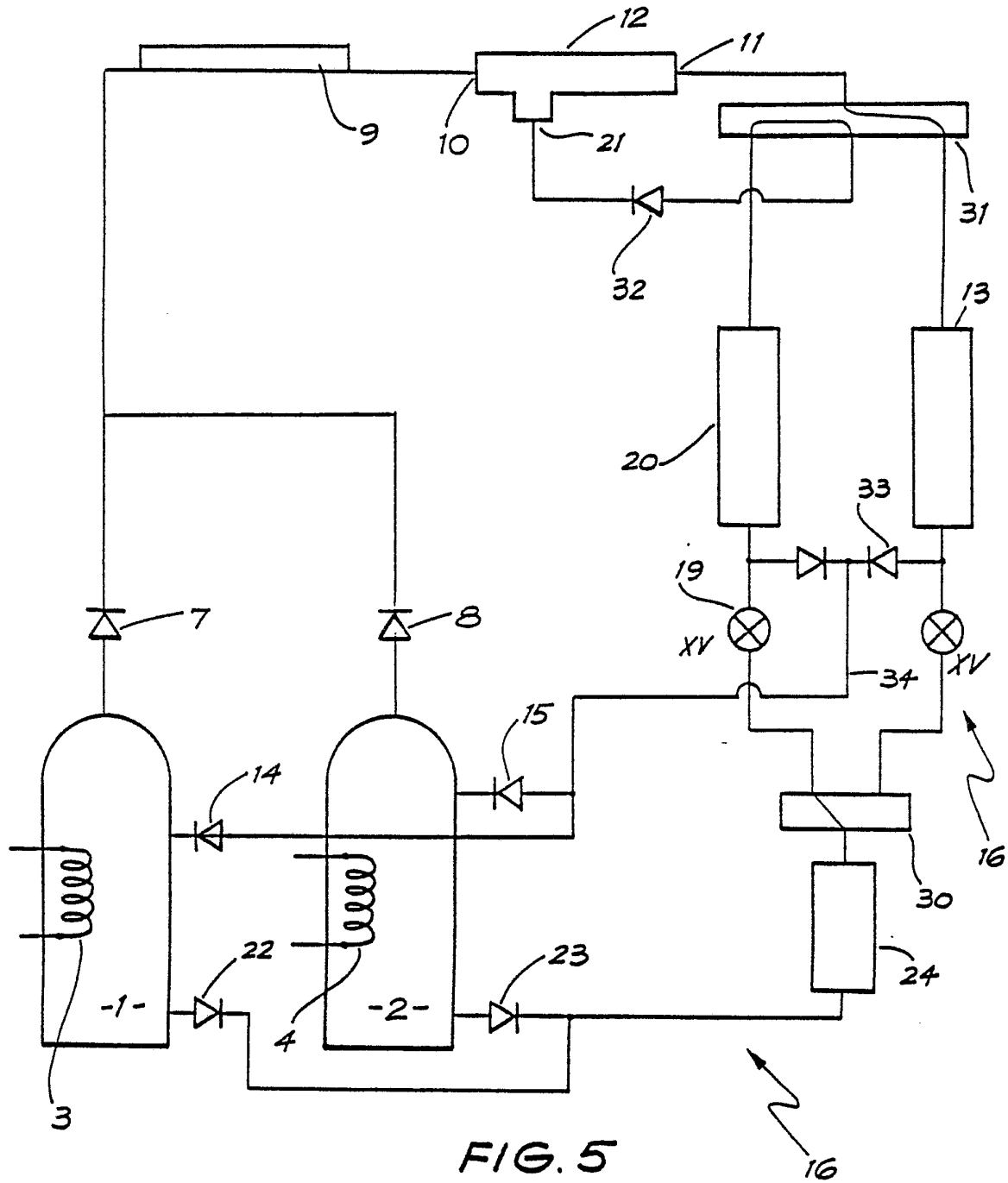
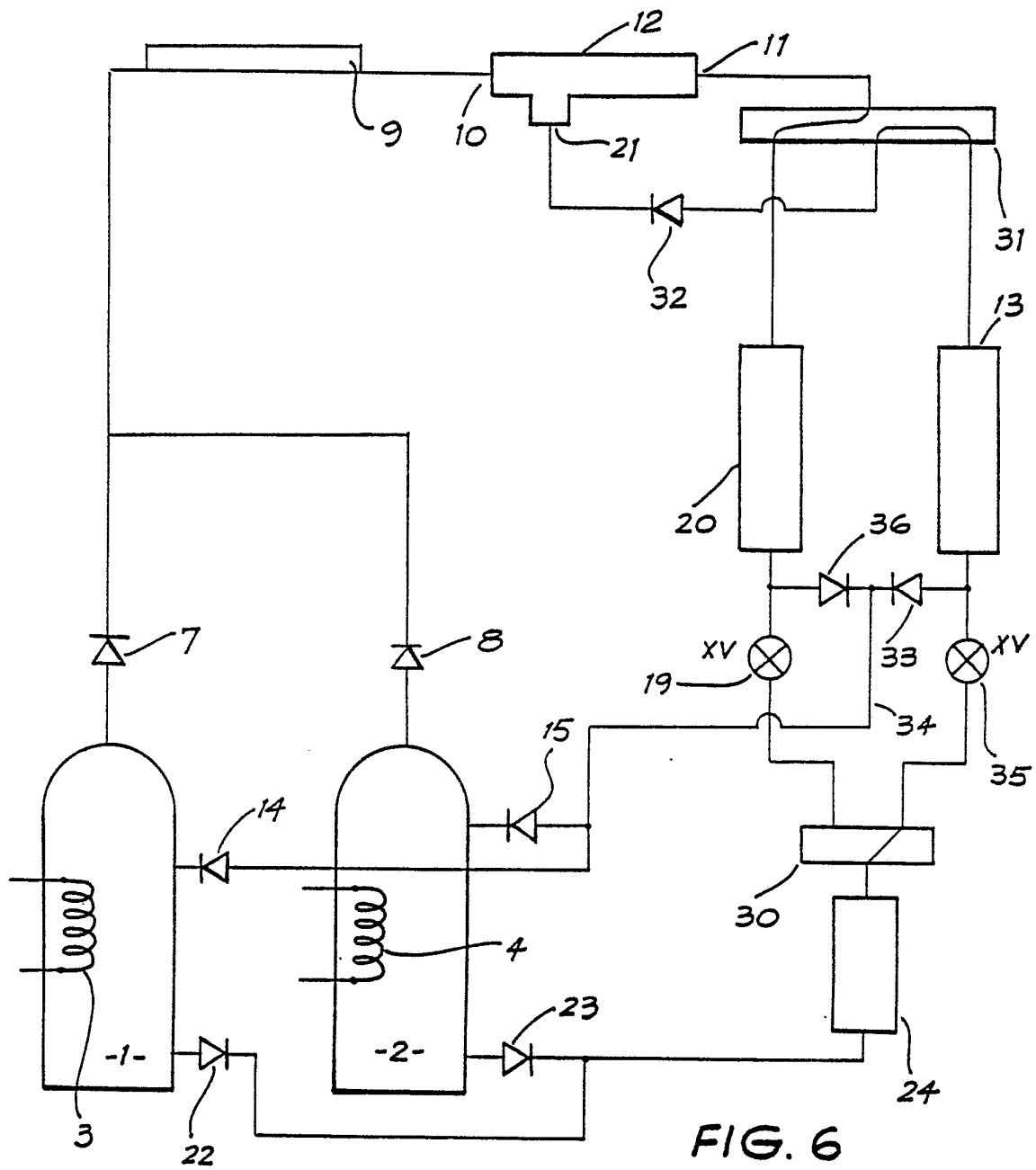
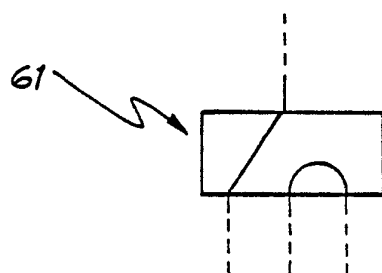
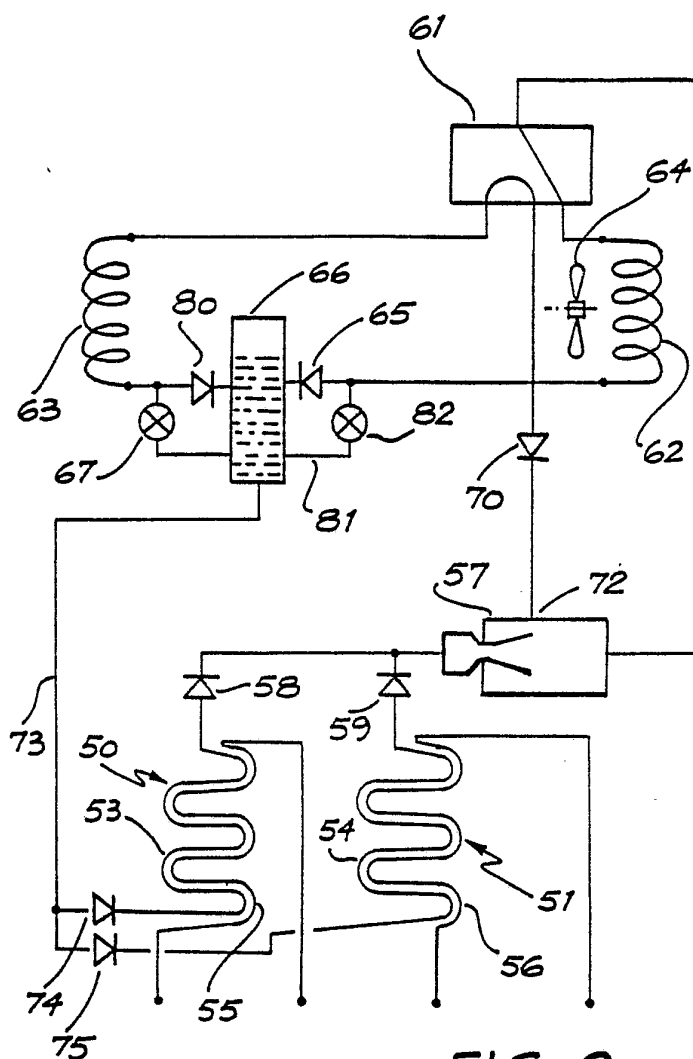
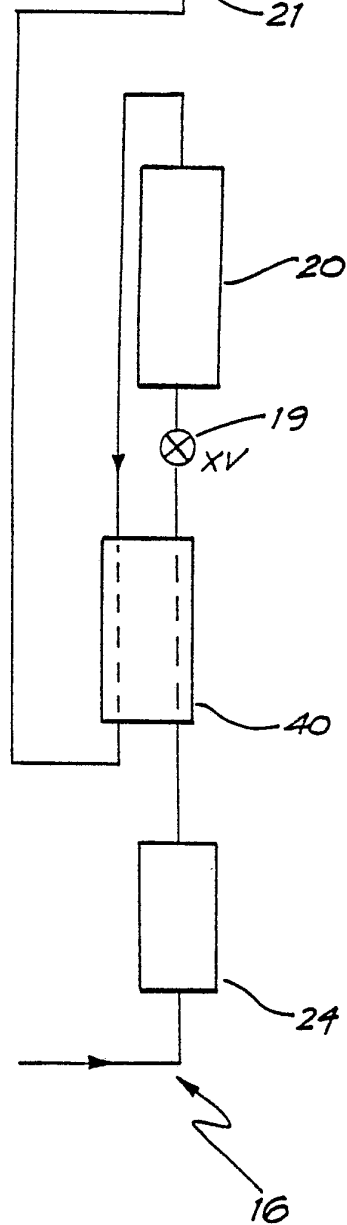
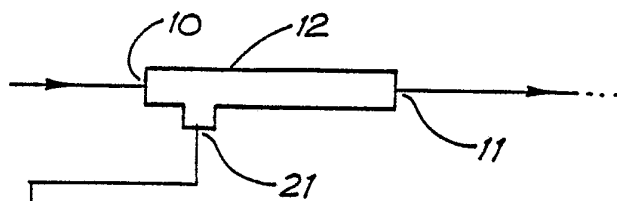


FIG. 2









# INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 85/00126

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl. <sup>4</sup> F25B 41/00		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
IPC	F25B 41/00	
US Cl.	62/116, 62/500	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
AU: IPC as above; Australian Classification 29.4151, 29.4152		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>9</sup>		
Category <sup>10</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No <sup>13</sup>
A	US, A, 2 763 998 (TULLENERS) 25 September 1956 (25.09.56)	(1-2,11)
A	US, A, 3 199 310 (SCHLICHTIG) 10 August 1965 (10.08.65)	(1-2,11)
<p>* Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published 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</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"Z" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
3 September 1985 (03.09.85)	(09.09.85) 19 SEPTEMBER 1985	
International Searching Authority	Signature of Authorized Officer	
Australian Patent Office	B.R. DASHWOOD	