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(54) Internally enhanced tube with smaller groove top

(57) The invention relates to an internally enhanced heat pipe with a groove opening size that is smaller than the size of the groove bottom.

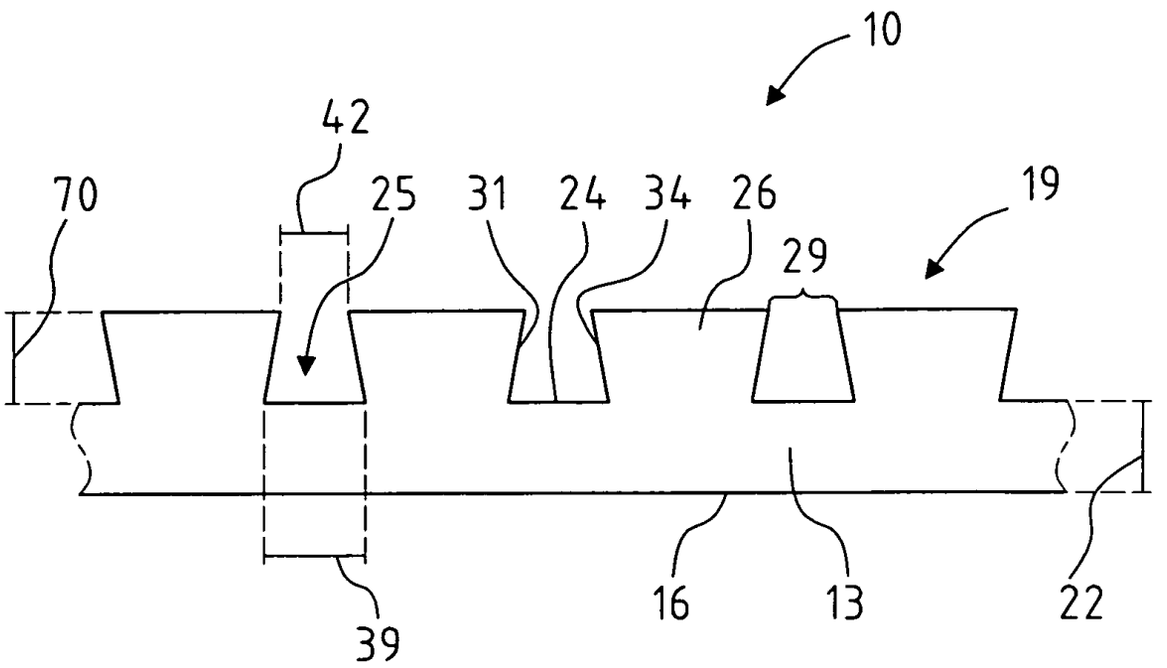

Fig. 1

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Description

FIELD OF INVENTION

[0001] The present invention relates to internally enhanced tubes for improved heat transfer and specifically to a heat transfer tube with inner grooves having a groove top opening that is smaller than the largest opening in the groove.

BACKGROUND OF THE INVENTION

[0002] Heat pipes are typically used in heat exchangers for air conditioning and refrigeration and for thermal management of electronics devices such as computer CPU's. A heat pipe is a tube, which is sealed at both ends and provided with a limited quantity of refrigerant. One end of the tube is exposed to a heat source, where the liquid inside the tube is heated so that the liquid is evaporated. The vapor flows to the opposite end of the tube, which is exposed to a heat sink. The vapor releases its heat to the heat sink and condenses back to liquid form. The liquid will then flow back to the end where the heat source is located to be evaporated. These evaporation and condensation processes continue such that heat is transferred from the heat source to the heat sink in a continuous manner. The heat pipe described above has a much higher heat transfer rate than solid heat conductors made of highly conductive materials such as copper.

[0003] In order to draw liquid from the heat sink end back to the heat source end, a wick structure is required, which has a capillary effect. The capillary effect functions as a pump to move liquid from the heat sink end to the heat source end. In current heat pipes, the inner groove structure has been used as the wick of a heat pipe. However, the current inner groove structures expose the liquid flow to the vapor flow in the center of the heat pipe and in the opposite flow direction to the liquid flow. The vapor flow entrains liquid droplets and carries these droplets away from the liquid stream. This entrainment of the liquid droplets into the vapor flow has a detrimental effect on the performance of the heat pipe.

[0004] The current designs have an inner groove wick structure with a trapezoidal groove shape with the groove top being larger than the groove bottom. This structure enhances the entrainment effect discussed above so that the resulting heat pipe is less efficient with regard to heat transfer. Accordingly, there is a need for a heat pipe design that provides increased heat transfer performance by reducing the entrainment effect described above.

SUMMARY OF THE INVENTION

[0005] The present invention meets the above-described need by providing an internally enhanced tube with a groove opening size that is smaller than the size of the largest opening in the groove.

[0006] The present invention reduces the entrainment effect described above by shielding the liquid flow from the vapor flow. Due to the narrower groove opening at the top, the vapor flow in the center of the tube is partially separated from the liquid flow inside the groove. Accordingly, the liquid droplets are more difficult to be carried away by the vapor flow traveling in the opposite direction. Due to this shielding effect, the entrainment effect is reduced so that more liquid can reach the heat source end of the heat pipe and therefore the total heat transfer can be increased.

[0007] In a first embodiment, the groove geometry is defined by a plurality of trapezoidal-shaped fins.

[0008] In a second embodiment, the groove geometry is defined by a plurality of T-shaped fins.

[0009] In a third embodiment, the groove geometry is defined by a plurality of mushroom-shaped fins.

[0010] Common characteristics of the embodiments include, but are not limited to, the following aspects. The groove opening is smaller than the groove bottom. The groove cross-sectional area is equal to or larger than the cross-sectional area of the fins that form the grooves. And the height of the grooves is equal or larger than the width of the grooves.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention is illustrated in the drawings in which like reference characters designate the same or similar parts throughout the figures of which:

Figure 1 is a side elevation view of a first embodiment of the present invention;
Figure 2 is a side elevation view of a second embodiment of the present invention;
Figure 3 is a side elevation view of a third embodiment of the present invention;
Figure 4 is a side elevational view of a fourth embodiment of the present invention;
Figure 5 is a side elevational view of a fifth embodiment of the present invention; and,
Figure 6 is a side elevational view of a sixth embodiment of the present invention.

DETAILED DESCRIPTION

[0012] In Fig. 1, a section 10 of heat pipe 13 is shown. The pipe 13 may be constructed of copper, copper alloy, or other heat conductive materials. The pipe 13 is shown in a partial view that does not show the overall profile of the pipe. As will be evident to those of ordinary skill in the art, the enhancement of the present invention may be provided for pipe having many cross-sectional shapes including, but not limited to, round, oval, square, rectangular, etc. The longitudinal axis of the pipe 13 is oriented normal to the page. The heat pipe 13 has an outer wall 16 and an internally enhanced inner wall 19.

The heat pipe 13 has a wall thickness 22 measured from the bottom surface 24 of the groove 25 to the outer wall 16. The groove 25 has an opening 29 at the top with respect to the orientation of Fig. 1. As shown, grooves 25 are formed by trapezoidal shaped fins 26 that result in grooves 25 having a bottom surface 24 and opposed angled walls 31 and 34. The walls 31 and 34 angle inward toward each other. As a result, the width 39 at the bottom of the groove 25 is larger than the width 42 of opening 29 at the top of groove 25. By reversing the groove opening size to be smaller than the groove bottom, the liquid flow from the heat sink end to the heat source end is better shielded from the vapor flow. The cross-sectional area of the groove 25 is equal to or larger than the cross-sectional area of the fins 26 that form the grooves 25. Also, the height 70 of the grooves 25 is equal to or larger than the width 39 of the grooves 25. As a result of the shielding effect of the groove shape, the entrainment of liquid into the vapor stream is reduced so that more liquid can reach the heat source end of the heat pipe, and the total heat transferred can be increased.

[0013] The heat pipe 13 of the present invention also has the following properties. The groove height 70 is between 0.05 mm to 5 mm. The groove opening 29 is 0.05 mm to 5 mm in length, and the groove pitch is 0.10 to 5 mm. The ratio of groove cross-sectional area to groove height is 0.02 mm to 1 mm. The ratio of groove cross-sectional area to groove wall length is 0.01 mm to 1 mm. And the ratio of groove opening to the largest width of the groove is 0.01 to 0.99.

[0014] Turning to Fig. 2, an alternate embodiment for a heat pipe 99 of the present invention includes a set of grooves 100 formed between T-shaped fins 103. The heat pipe 99 has an outer surface 106. The longitudinal axis of the pipe is oriented normal to the page with respect to Fig. 2. The pipe 99 has a wall thickness 109 measured between the bottom surface 112 of the groove 100 and the outer surface 106. The groove 100 is formed in part by opposed walls 115, 118. The outer end 113 of the T-shaped fins 103 defines an opening 121. The opening 121 has a width 124. The width 124 is smaller than the width 127 along the bottom surface 112. The cross-sectional area of the groove 100 is equal to or larger than the cross-sectional area of the fins 103. Also, the height 150 of the groove 100 is equal to or larger than the width 127.

[0015] In Fig. 3, another alternate embodiment of the present invention is shown. Heat pipe 200 has a plurality of fins 203 having a mushroom-shaped profile. A plurality of grooves 201 is formed between the fins 203. Heat pipe 200 has an outer surface 206. The longitudinal axis of the pipe is oriented normal to the page with respect to Fig. 2. The pipe 200 has a wall thickness 209 measured between the bottom surface 212 of the groove 201 and the outer surface 206. The groove 201 is formed in part by opposed walls 215, 218. The ends 213 of adjacent fins 203 define an opening 221. The opening 221 has a width 224 that is smaller than the width 227 along bottom surface 212. The cross-sectional area of the groove 201 is equal to or larger than the cross-sectional area of the fins 203. Also, the height 250 of the groove 201 is equal to or larger than the width 127.

[0016] Turning to Fig. 4, another embodiment of the present invention is shown. Heat pipe 300 has a plurality of fins 303 forming grooves 306 between adjacent fins 303. As shown, the bottom of groove 306 is round. Other shapes for the bottom wall may also be suitable including flat and other non-round shapes.

[0017] The longitudinal axis of the pipe is oriented perpendicular to the page. The opening 309 at the top of the groove 306 is smaller than the largest width 312 of the groove 306. The largest width 312 is located in a midportion of groove 306.

[0018] In Fig. 5, angled fins 400 provide triangular shaped grooves 403. The top of the grooves 403 have an opening 406 with a width 409 that is smaller than the largest width of the grooves 403. The largest width for the groove 403 is located at the bottom wall 412.

[0019] In Fig. 6, Y-shaped fins 500 provide grooves 503 located therebetween. The width of the opening 506 at the top of the groove 503 is smaller than the widest opening 512 of the groove 503.

[0020] While the invention has been described in connection with certain embodiments, it is not intended to limit the scope of the invention to the particular forms set forth, but, on the contrary, it is intended to cover such alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

Claims

1. A heat pipe, comprising:

a tubular member (13,99,200,300) having an inner surface (19) defining an inner diameter and having a longitudinal axis, **characterized in that**

a plurality of fins (26,103,203,303,400,500) having side walls and a top wall, the fins (26,103,203,303,400,500) disposed on the inner surface (19) of the tubular member, the fins (26,103,203,303,400,500) disposed so as to define a groove (25,100,201,306,403,503) between adjacent fins, the groove (25,100,201,306,403,503) having an opening (29,121,221,309,406,506) at the top and a groove bottom (24,112,212,412) along the inner surface (19), the groove (25,100,201,306,403,503) having sides (31,34; 115,118;215,218) defined by the side walls of the fins (26,103,203,303,400,500), and the width (39,127,227,312) of the groove (25,100,201,306,403,503) at its widest portion

is greater than the width (42,124,224) of the groove opening (29,121,221,309,406,506).

2. The heat pipe of Claim 1, **characterized in that** the cross-sectional area of the groove (25,100,201,306,403,503) is greater than the cross-sectional area of the fins (26,103,203,303,400,500).

3. The heat pipe of Claim 1, **characterized in that** the fins (26) have a trapezoidal shape.

4. The heat pipe of Claim 1, **characterized in that** the fins (103) are T-shaped.

5. The heat pipe of Claim 1, **characterized in that** the fins (203) are mushroom shaped.

6. The heat pipe of Claim 1, **characterized in that** the fins (500) are Y-shaped.

7. The heat pipe of Claim 1, **characterized in that** the fins (400) are angled toward each other to form a triangular shaped groove (403).

8. The heat pipe of Claim 1, **characterized in that** the groove bottom is curved.

9. The heat pipe of Claim 1, **characterized in that** the groove bottom is round.

10. The heat pipe of Claim 1, **characterized in that** the groove height is .05 mm to 5 mm.

11. The heat pipe of Claim 1, **characterized in that** the width of the groove opening is .05 mm to 5 mm.

12. The heat pipe of Claim 1, **characterized in that** the groove pitch is 0.10 mm to 5 mm.

13. The heat pipe of Claim 1, **characterized in that** the ratio of groove cross-sectional area to groove height is 0.02 mm to 1 mm.

14. The heat pipe of Claim 1, **characterized in that** the ratio of groove cross-sectional/area to groove wall length is 0.01 mm to 1 mm.

15. The heat pipe of Claim 1, **characterized in that** the ratio of the groove opening to the largest width of the groove is 0.01 to 0.99.

16. The heat pipe of Claim 1, **characterized in that** the height of the groove is greater than the width of the groove.

17. The heat pipe of Claim 1, **characterized in that** the width of the groove at the groove bottom is greater than the width of the groove opening.

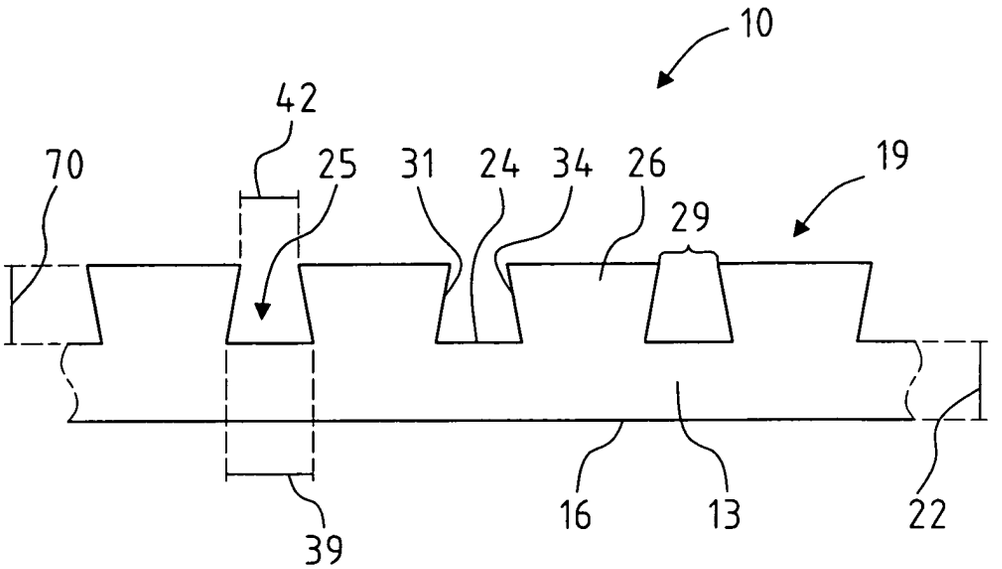
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Fig. 1

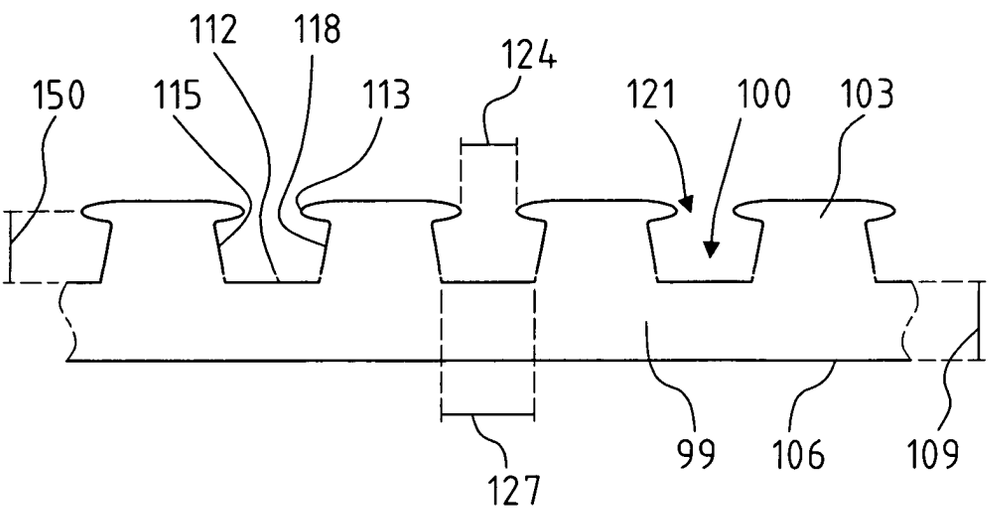
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Fig. 2

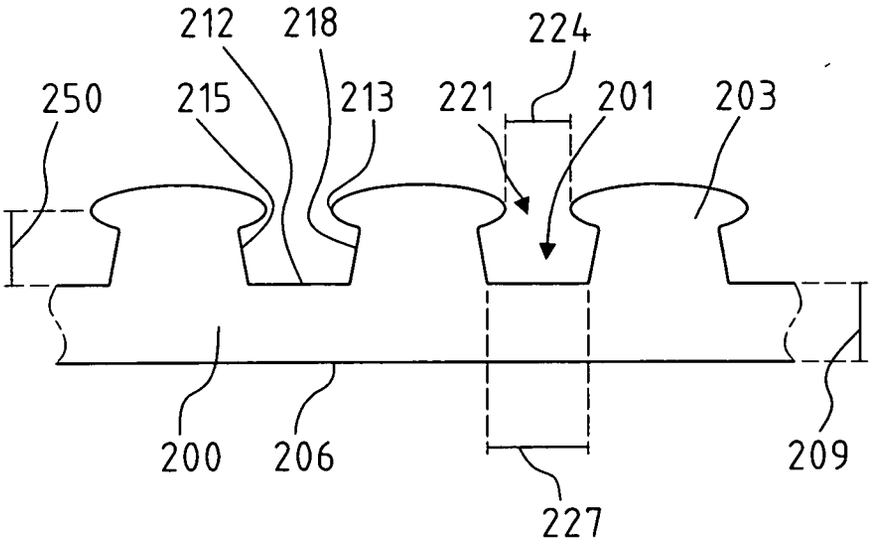
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Fig. 3

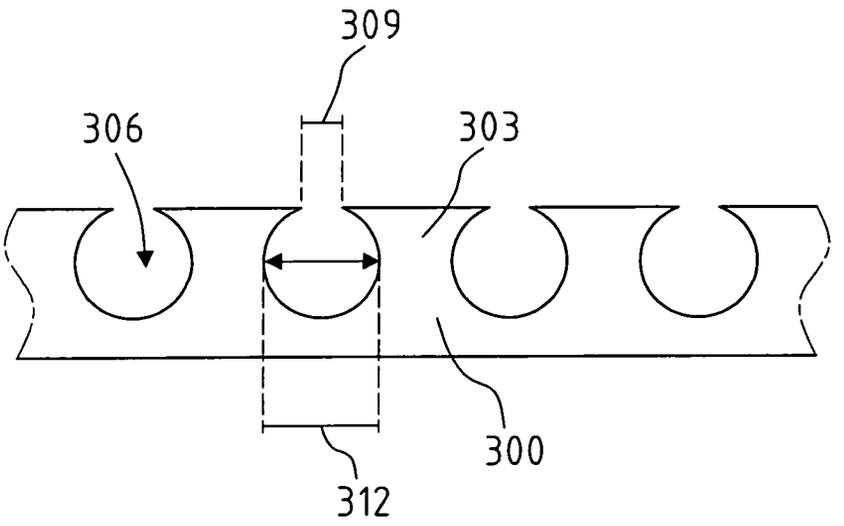
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Fig. 4

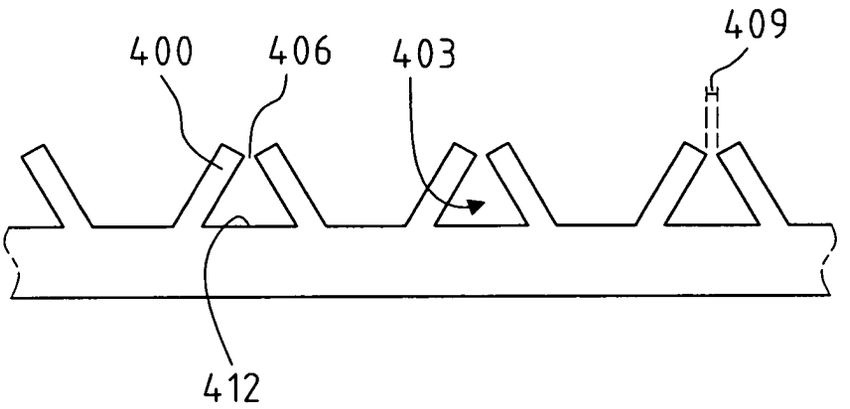

Fig. 5

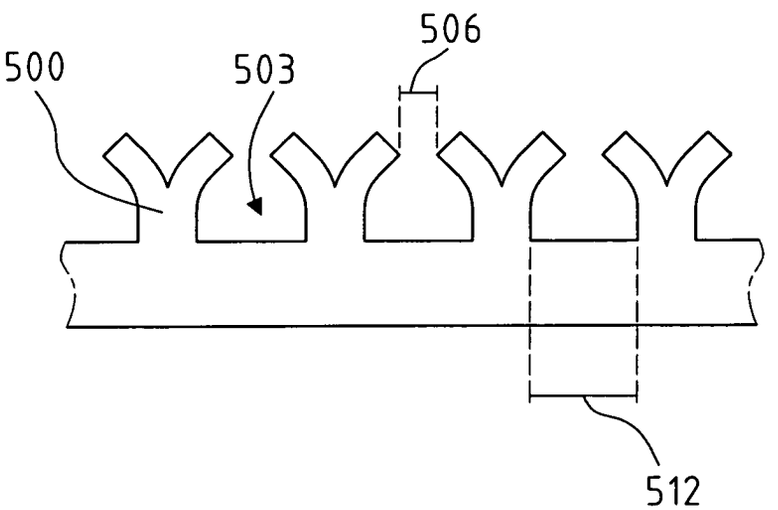

Fig. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 04 02 7134

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X A	US 4 216 575 A (CARNAVOS, THEODORE C ET AL) 12 August 1980 (1980-08-12) * column 3, line 53 - line 59; figure 1 *	1,8,9, 15,17 2-7, 10-14,16	F28F1/40 F28D15/04
P,X	FR 2 850 453 A (ALCATEL) 30 July 2004 (2004-07-30) * abstract; figure 1b *	1,3,5, 7-9,16, 17	
A	US 6 298 909 B1 (FUKATAMI TAKAO ET AL) 9 October 2001 (2001-10-09) * column 4, line 52 - line 58 *	10-14	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

F28F
F28D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	12 April 2005	Bain, D

CATEGORY OF CITED DOCUMENTS

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12-04-2005

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4216575 A	12-08-1980	CA 1123587 A1	18-05-1982
		DE 3000506 A1	14-08-1980
		GB 2041795 A ,B	17-09-1980
		JP 1214703 C	27-06-1984
		JP 55106622 A	15-08-1980
		JP 58049337 B	04-11-1983
FR 2850453 A	30-07-2004	FR 2850453 A1	30-07-2004
US 6298909 B1	09-10-2001	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82