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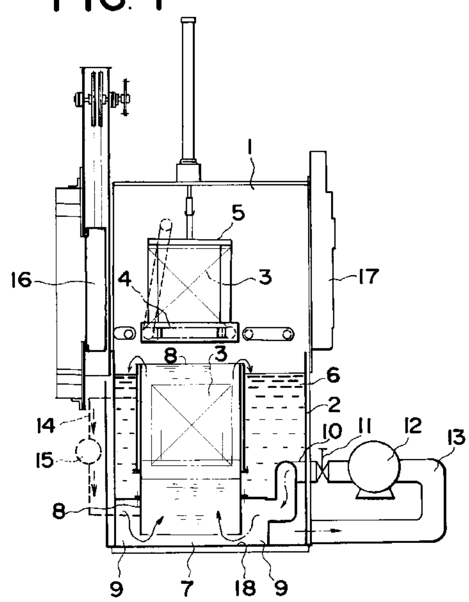
(54) Apparatus and method for steel hardening.

(57) Apparatus for steel hardening comprises a quenching region (8) wherein the quenching region surrounds a companion way of an elevator (5) in a quenching bath (2) and is separated from said quenching bath. The upper part of the quenching region is above the level of quenching fluid in the quenching bath, and an inlet for quenching fluid is provided at the lower part of the quenching region. Quenching fluid is supplied from below the steel part(s) to be hardened, which are dipped into said quenching region, and allowed to flow upwardly and overflow from the top of the quenching region into said quenching bath and thereby cool down the steel parts.

FIG. 1



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This invention relates to a steel hardening method and apparatus therefor, for example for hardening steel parts which have previously had surface treatment such as carburizing, carbonitriding, nitriding and the like.

A steel-hardening step is performed in various heat treatments in order to improve the hardness of the steel. However there are problems associated with these methods, for example changes in shape and distortions in size can easily occur in steel parts during this hardening. Therefore, in order to prevent these changes and distortions in the steel parts, it is important with these methods to cool quickly through the critical temperature zone and then slowly through the dangerous temperature zone. Ordinarily, the martempering or the time quenching is utilized as the hardening method and salt or high temperature quenching oil is utilized as the cooling agent, particularly for steel parts and the like in which any change in the shape and/or distortions are unacceptable.

In the martempering process, steel parts maintained at the hardening temperature are dipped into a salt bath or a high temperature quenching oil bath maintained at a temperature higher than the Ms point of the steel parts to be treated. The parts remain dipped in the bath whose temperature is preferably slightly higher than the Ms point for a while and, when the steel parts reach a predetermined temperature, the steel parts are picked up from the bath and cooled down so as to make the martensitic transformation. Or, in the case where time quenching is simultaneously utilized, a method of making the transformation is carried out by dipping the steel parts in a secondary bath maintained at a temperature lower than the Ms point.

In the aforementioned ordinary hardening a steel part subjected to the martempering was carburized at approximately 0.8% C and was limited to only the outer surface of total carburization.

The inventors of present invention have found that by mixing the quenching oil by the action of mixing blades, which is the technique usually carried out to maintain the quenching bath at a predetermined uniform temperature in order to uniformly cool down the steel parts dipped therein, there is a tendency for the steel parts to undergo a change of shape and/or distortions.

The reason for this is that, when the mixing blades are rotated in the quenching oil, air is sucked into the oil through turbulence, in particular from a rotary shaft of the mixing blades. This air is mixed during the circulation process of the quenching oil by the mixing blades and forms bubbles in the oil. The bubbles are dispersed in the oil by the mixing blades and adhere on the surface of the steel parts which can cause uneven cooling of the steel parts. This causes differences in the heat treatment, in particular at the surface regions which can result in a change of shape and/or distortions in measurement. This phenomenon was particularly significant when the mixing blades were rotated at high speed for quick cooling because a large amount of bubbles were formed in the quenching oil.

Further, it was found that the usual quenching baths were unnecessarily large in order that the mixing blades could be installed to evenly mix the quenching oil and to provide a path of circulating quenching oil. This frequently resulted in local variations in the flow of the quenching oil and hence, variations in its temperature. These variations, or even stagnation of the quenching oil can result in uneven cooling of the steel parts which results in a variation of heat treatment, especially to the treated surface regions, giving rise to internal stresses changing the shape and/or distorting the size of the steel parts.

Furthermore, in a subsequent air cooling process, the characteristics of the environment surrounding the steel parts such as air temperature, humidity, wind and the like were factors which could cause variation in treatment of the steel part, again in particular at the surface, which could result in a change in shape, distortions in measurement and the like.

Further, in the time quenching method, the time difference in dipping the steel parts into the secondary bath, that is, the time difference taken during dipping for the top and bottom of the steel parts to be dipped, causes a further variation in cooling time and therefore cooling rate between and throughout the steel parts since it takes a relatively long time to dip items by a cylinder or a crane during batch dipping.

Therefore, at present the prevention of variations such as a change of the shape and a distortion of measurement due to the transformation at the inner part of steel parts maintained at lower carbon content than 0.8% C depends on experimental overlaying method or improvement of an overlaying jig.

Viewed from one aspect the present invention provides a method of hardening steel, comprising dipping steel to be hardened in a quenching region, characterised by causing quenching fluid to flow upwardly from below the steel dipped into the quenching region, and removing the quenching fluid from above the steel, whereby the steel is cooled by said flow of quenching fluid.

Viewed from another aspect the present invention provides steel hardening apparatus comprising a quenching region arranged to receive steel to be hardened, characterised in that the quenching region is provided with inlet means for supplying quenching fluid to a lower part thereof, and outlet means for removing quenching fluid from an upper part thereof.

There is thus provided a hardening method and apparatus which avoids the formation of bubbles in the quenching fluid, e.g. quenching oil, during hardening. For that purpose, in the present invention, quenching fluid is supplied, preferably continuously, from the bottom of the steel parts and circulated upwards without using mixing blades, unlike the conventional method.

In order to help prevent any cooling variation due to uneven flow, stagnation or the like of quenching fluid which may occur when a large quenching bath is used, the quenching region may be defined in a quenching chamber which surrounds the up and down path for an elevator for carrying the steel to be hardened. In other words, the quenching region may be relatively small, preferably as small as possible whilst still enabling the elevator to move up and down.

Preferably, the outlet means is in the form of an overflow. In a preferred embodiment the quenching region is defined in a quenching chamber disposed in a quenching bath, and the overflow from the quenching chamber is arranged to be above the level of quenching fluid in the quenching bath.

Thus, a preferred hardening method comprises providing a separated quenching region surrounding the up and down path of the elevator in said quenching bath, flowing quenching fluid upward by supplying thereof from the bottom of the steel parts carried down by the elevator into said quenching region and cooling down the steel parts during overflow of said quenching fluid from the top of the quenching region into said quenching bath.

Preferred apparatus is constructed so as to provide a quenching region surrounding the up and down path of an elevator in a quenching bath so that the upper end of the quenching region is lower than the upper end of said quenching bath and the quenching region itself is separated from said quenching bath and a supplying part of quenching fluid at the bottom of said quenching region.

Certain preferred embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawings, in which:

Fig. 1 shows the apparatus of a first preferred embodiment of the present invention;

Fig. 2 shows an enlargement of the quenching tank of a second preferred embodiment of the present invention;

Fig. 3 shows a plan view of the apparatus shown in Fig. 2;

Fig. 4 shows the apparatus according to a third preferred embodiment of the present invention;

Fig. 5 shows a plan view of the apparatus shown in Fig. 4;

Fig. 6 shows a perspective view of a test piece; and

Fig. 7 shows a plan view of the test piece of Fig. 6 indicating each measurement position.

In the drawings, a quenching tank 1 is provided with a quenching bath 2. An elevator 5, having transfer apparatus 4 to load and carry the steel parts 3 after their carburizing treatment or the like, is provided within the quenching tank 1 to lower the steel parts 3 into the quenching bath 2. Numeral 6 in the drawings designates a quenching fluid, preferably oil.

In the preferred embodiments of the present invention, there is be provided a quenching region 8 which surrounds the elevator when immersed in the quenching bath 2. This region can be defined as the volume moved through by the up and down path of the steel parts 3 in said quenching bath 2 and preferably the surface of the quenching oil 6 in the quenching region 8 is higher than the surface of the quenching oil 6 in the quenching bath 2, with preferably a supply for the quenching oil 6 provided in a lower region or bottom of the quenching region 8.

In the embodiment shown in Fig. 1, the quenching region 8 is arranged so as to have a space 7 between the bottom part 18 of said quenching bath 2 and the quenching region 8. Further, said quenching region 8 is constructed so as to be as small as possible but large enough to allow up and down movement of said elevator 5. Consequently, quenching oil 6 can flow quickly upward to enhance the cooling effect experienced by the stel parts 3, as explained in detail later.

Further, in this preferred embodiment, there is provided an auxiliary chamber 9 around the bottom of said quenching region 8 so as to enclose the space 7 together with the bottom part 18 of said quenching bath 2, and to separate the space 7 from the upper part of the quenching bath 2. This auxiliary chamber 9 provided on the bottom part 18 of said quenching bath 2 can be used to support the quenching region 8.

Further, a supply pipe 10 of quenching oil 6 is connected to said auxiliary chamber 9. A circulating pipe line 13 is connected to a circulating pump 12 arranged to feed said supply pipe 10 through a flow control valve 11, and hence the circulating pipe line 13 is coupled to said quenching bath 2.

Preferably, the supply pipe 10 may be split into a number of further supply pipes and connected to said auxiliary chamber 9 so that quenching oil is supplied evenly into the auxiliary chamber 9. Consequently, an even supply of quenching oil 6 from the auxiliary chamber 9 into said quenching region 8 results, thereby providing further homogeneous cooling of the steel parts 3 in the quenching region 8 so that changes of shape and/or distortions in size of the steel parts 3 can be substantially prevented.

A second preferred embodiment of the apparatus is shown in Figs. 2 and 3. These figures show split supply pipes 10a, 10b, 10c and 10d branched from the supply pipe 10 extending from the circulating pump 12 and the flow control valve 11, and these are evenly connected to both sides of the auxiliary chamber 9 located in the center of the quenching bath 2.

Further, if the end of each split supply pipe 10a, 10b, 10c and 10d is constructed so as to turn up as shown in Fig. 2, and the supplied quenching oil 6 is directed towards the roof of the auxiliary chamber 9, then the quenching oil 6 supplied to the quenching region 8 is further homogenized before being supplied to the bottom of the quenching region 8, preferably in a laminar flow so that the steel parts are cooled down evenly.

In Fig. 1, numeral 14 designates a circulation path connecting the upper and the lower parts of the quenching region 8 which may be provided optionally. In the circulation path 14, ideally a circulation pump 15 is provided at approximately mid-way. Further, the circulation pump 15 is preferably of a reciprocal type.

This circulation path 14 and the circulation pump 15 are not shown in Figs. 2 and 3, but it is preferable to instal them also in these embodiments.

Furthermore, as shown in Fig. 1, there is provided an entrance door 16 to the quenching tank 1 and an exit door 17 from the quenching tank 1.

Figs. 4 and 5 show apparatus according to a third preferred embodiment of the present invention. The main difference between this embodiment and the embodiment shown in Fig. 1 is that the supply pipe 10 is branched at the bottom of the quenching region 8 to form a series of supply pipes 10a, 10b, 10c and 10d, each with supply nozzles 19 arranged equidistantly therealong. In addition, the auxiliary chamber 9 is not provided.

According to this embodiment, quenching oil 6 ie. supplied from the supply nozzles 19 on the supply pipes 10a, 10b, 10c and 10d, is directed towards the bottom part 18 before passing into the quenching region 8 to cool down the steel parts 3.

In the apparatus of the first embodiment shown in Fig. 1 or the second preferred embodiment shown in Figs. 2 and 3, the steel parts 3 after heat treatment such as carburizing and the like are loaded onto the elevator 5 in the quenching tank 1 through the entrance door 16. Then both the elevator 5 and the steel parts 3 are lowered until the steel parts 3 are dipped in the oil 6 in the quenching region 8 for their hardening treatment. Before, or at the same time as the dipping, the flow control valve 11 is opened and the circulation pump 12 is operated. Consequently, quenching oil 6 is supplied into the auxiliary chamber 9 from the supply pipe 10. Quenching oil 6 flowing into the auxiliary chamber 9, which is wider than the diameter of the supply pipe 10, reduces its flow speed, which is controlled to remain constant, and allowed to uniformly flow into the quenching region 8 from the whole area under the quenching region 8. The steel parts 3 in the quenching region 8 are quickly cooled by the upward flowing quenching oil 6, which can then overflow from the top of the quenching region 8 into the quenching bath 2. Thus, quenching oil 6 is circulated. The cooling process aforementioned is substantially the same for the apparatus of the embodiment shown in Figs. 4 and 5.

In the preferred embodiments of the present invention, substantially no bubbles are generated in the quenching oil 6 because mixing blades are not used for maintaining a uniform temperature of the quenching oil as aforementioned. Further, quenching oil 6 that is kept at a constant temperature, for example approximately 160°C, can be supplied and allowed to flow upward around the steel parts 3 continuously and substantially uniformaly at a predetermined rate.

Then, in a preferred embodiment, the flow control valve 11 is closed when the steel parts 3 have been cooled down to a predetermined temperature, for example between 450 to 470°C. Consequently, quenching oil 6 in the quenching region 8 will be heated up to a certain level by heat released from the cooling steel parts 3.

Further, if the steel parts 3 have still not sufficiently cooled down to the predetermined temperature as a result of closing said flow control valve 11, the flow control valve 11 can be re-opened so that quenching oil 6 can be supplied until the steel parts 3 are cooled down to the predetermined temperature. Afterwards, the steel parts 3 may be kept for a further period of time in the quenching region to slowly cool down further.

Furthermore, when the supply of quenching oil 6 is stopped, the circulation pump 15 may be operated so as to circulate quenching oil 6 in the quenching region 8 in order to avoid temperature differences occurring between the upper and lower parts of the quenching region 8.

Tests were carried out using test pieces 20 as shown in Fig. 6, that is, sleeves (100mm in length and 60mm in diameter) with a notch or key gutter which had all been subjected to the same carburizing treatment. With these test pieces, distortions after various hardening treatments were determined. Results obtained are shown in the following Tables 1 and 2. Fig. 7 shows the measurement points on the test piece 20. "Upper" and "Lower" in Tables 1 and 2 indicate the upper and the lower parts of the test piece 20 shown in Fig. 6, respectively.

Table. 1

	Position determined	Conventional method Hot oil		Conventional method Cold oil		Present invention Semi-hot oil	
		Upper	Lower	Upper	Lower	Upper	Lower
Distortion after treatment (μ) (mean)	1	−57	−116	24	187	−136	−114
	2	−63	−154	24	167	−140	−104
	3	−83	−159	1	116	−150	−117
	4	−69	−110	9	29	−151	−123
	5	−70	−98	7	7	−145	−130
	6	−68	−95	7	31	−130	−149
	7	−58	−78	18	62	−114	−141
	8	−33	−70	47	107	−108	−131
	Mean distortion ($\bar{x}$)	−62.6	−110	17.1	88.3	−134.3	−126.1
	Maximum distortion (R)	50	89	46	180	43	45
	Standard deviation (S)	14.5	32.4	14.7	66.7	16.0	14.7
Standard deviation Within batch		34.5		59.4		15.4	

Table. 2

Distortion after treatment (μ) (mean)		Conventional method Hot oil		Conventional method Cold oil		Present invention Semi-hot oil	
	Position determined	Upper	Lower	Upper	Lower	Upper	Lower
	1	−57	−116	24	187	4	6
	2	−63	−154	24	167	6	8
	3	−83	−159	1	116	29	22
	4	−69	−110	9	29	46	40
	5	−70	−98	7	7	49	42
	6	−68	−95	7	31	46	36
	7	−58	−78	18	62	31	13
	8	−33	−70	47	107	4	−3
	Mean distortion ($\bar{x}$)	−62.6	−110	17.1	88.3	26.9	20.5
	Maximum distortion (R)	50	89	46	180	45	45
	Standard deviation (S)	14.5	32.4	14.7	66.7	19.7	17.2
Standard deviation Within batch		34.5		59.4		18.2	

The data shown in Table 1 was taken from a test piece 20 before and after a hardening treatment by the apparatus shown in Fig. 1, and the data shown in Table 2 was taken from a test piece 20 before and after hardening treatment by the apparatus shown in Figs. 4 and 5.

According to Tables 1 and 2, the range of actual measured distortion at both the upper and lower parts of the test pieces 20 treated by the apparatus and the method in accordance with the present invention was very small compared to each of the conventional methods. These results confirm that the present invention can provide a superior effect in preventing changes in shape and distortions of the steel parts. This also demonstrates that there is no variation in the treated layer of the steel parts. The tests also demonstrate that an advantageous treatment method can be effectively implemented by the apparatus described above.

Claims

1. A method of hardening steel, comprising dipping steel to be hardened in a quenching region, characterised by causing quenching fluid to flow upwardly from below the steel dipped into the quenching region, and removing the quenching fluid from above the steel, whereby the steel is cooled by said flow of quenching fluid.

2. Steel hardening apparatus comprising a quenching region arranged to receive steel to be hardened, characterised in that the quenching region is provided with inlet means for supplying quenching fluid to a lower part thereof, and outlet means for removing quenching fluid from an upper part thereof.

3. Steel hardening apparatus as claimed in claim 2, wherein the outlet means is in the form of an overflow.

4. Steel hardening apparatus as claimed in claim 3, wherein the quenching region is defined in a quenching chamber disposed in a quenching bath, and wherein the overflow from the quenching chamber is arranged to be above the level of quenching fluid in the quenching bath.

5. Steel hardening apparatus as claimed in claim 4, wherein an auxiliary chamber separated from the upper part of the quenching bath is provided adjacent to said lower part of the quenching chamber.

6. Steel hardening apparatus as claimed in claim 5, comprising a supply pipe for supplying quenching fluid to the auxiliary chamber via a plurality of inlets.

7. Steel hardening apparatus as claimed in claim 2, 3 or 4, wherein the inlet means comprises a plurality of supply nozzles provided on the under surfaces of supply pipes.

8. A method of hardening steel by using the apparatus as claimed in any of claims 2 to 7.

FIG. 1

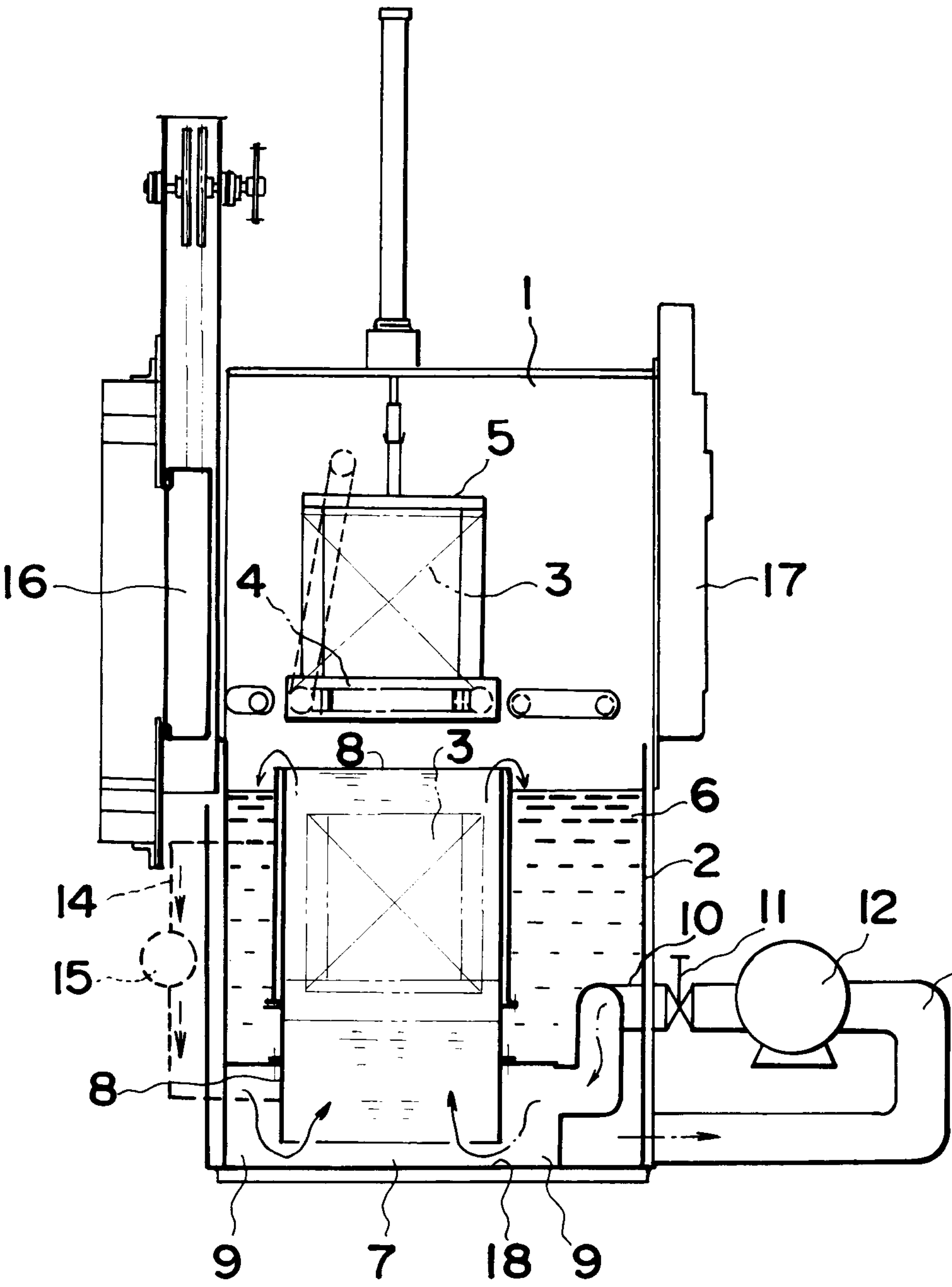


FIG. 2

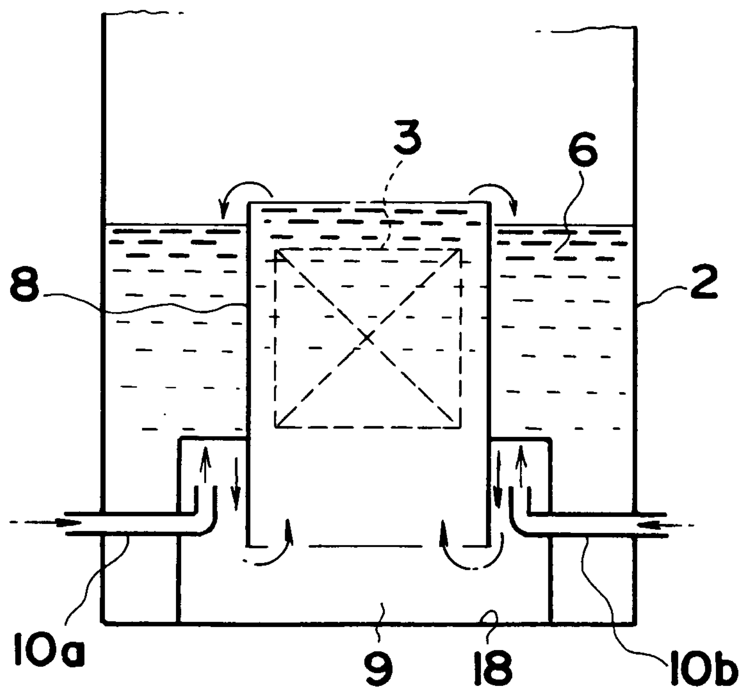


FIG. 3

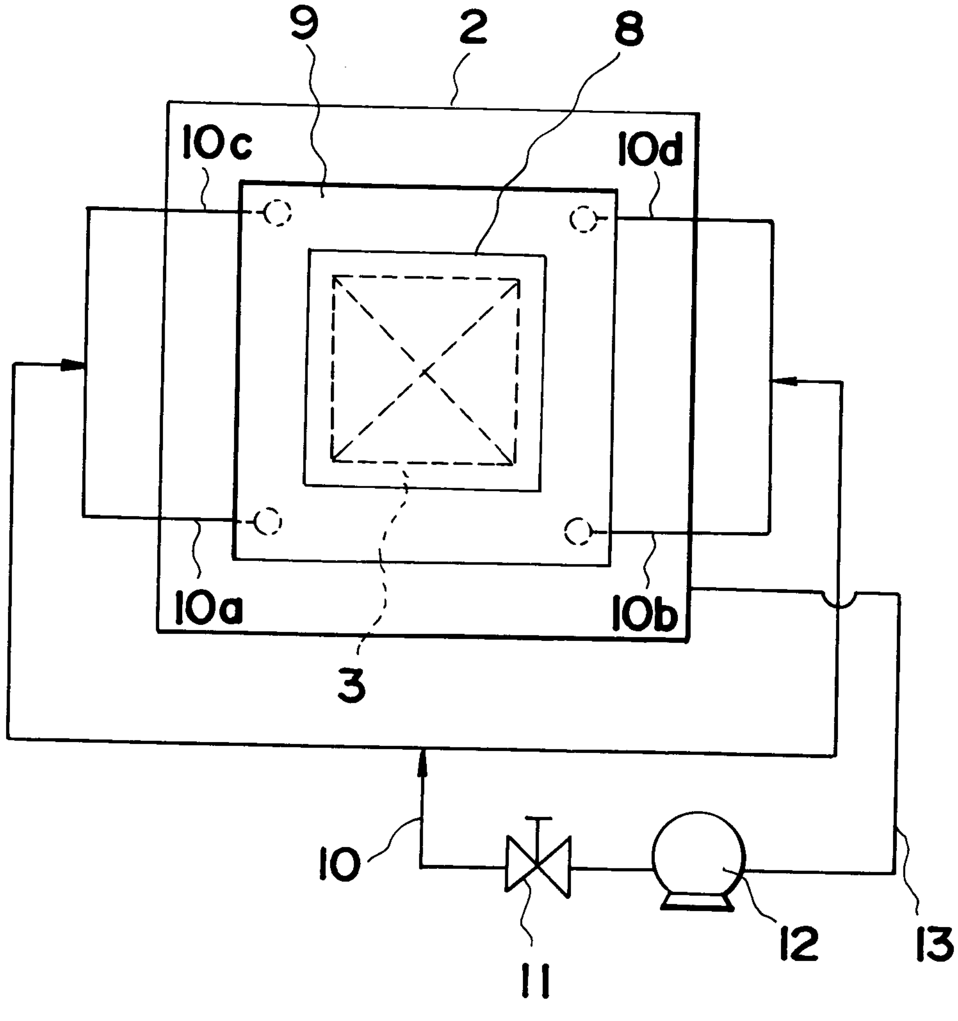


FIG. 4

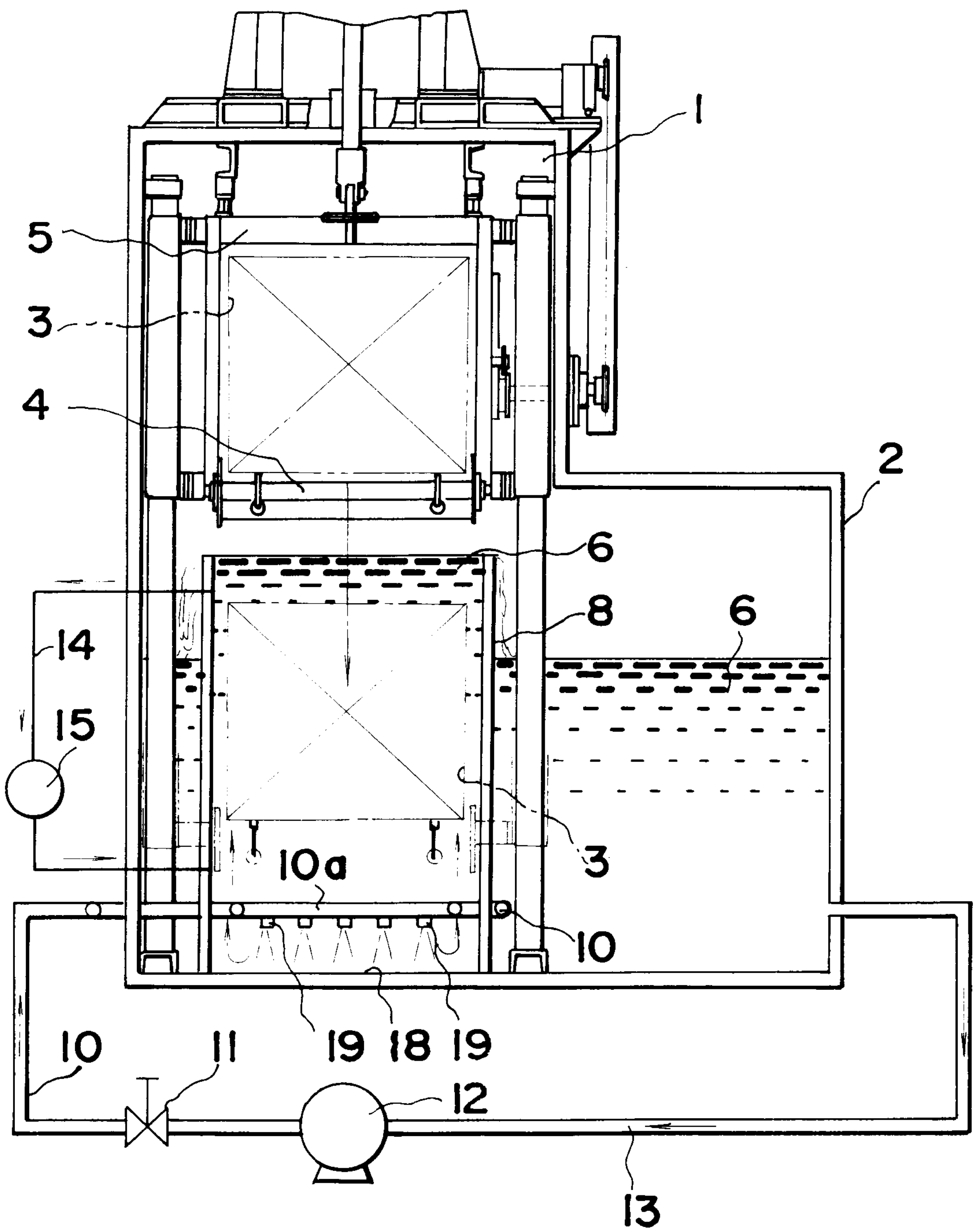


FIG. 5

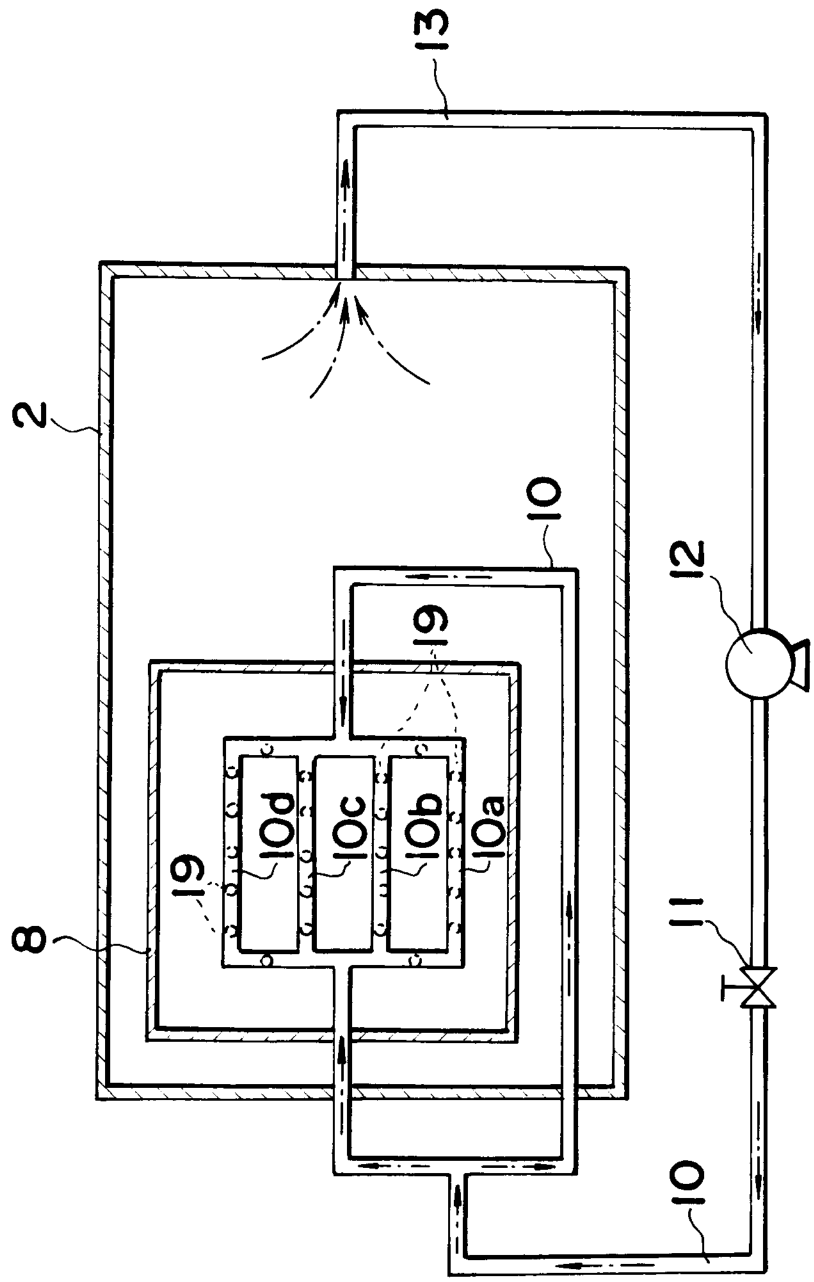


FIG. 6

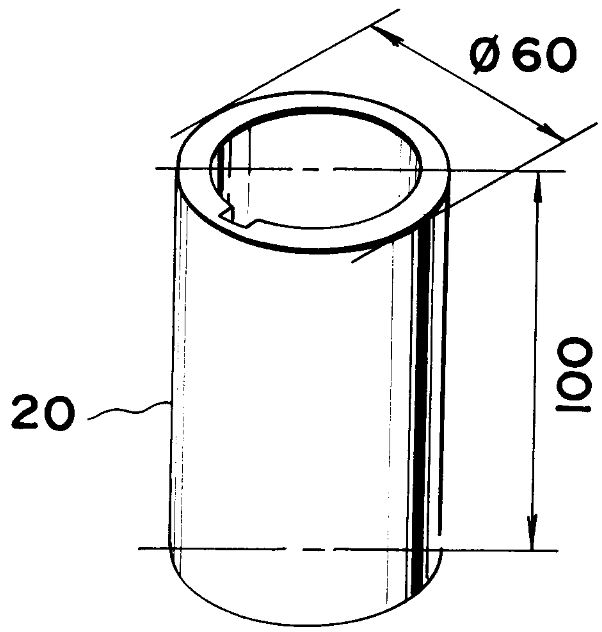
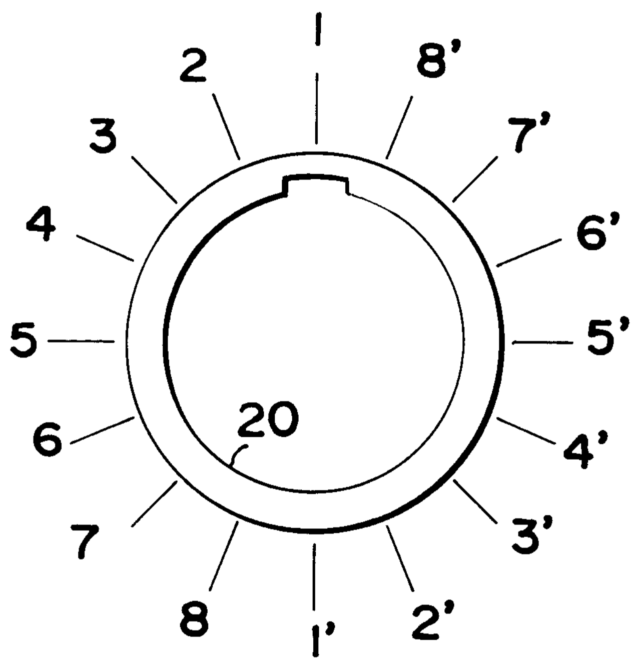


FIG. 7



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EUROPEAN SEARCH REPORT

Application Number
EP 94 30 0592

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.5)
X	DE-A-30 28 901 (BROWN, BOVERI & CIE) * page 9, line 25 - page 10, line 17; claim 1; figure 8 *	1-8	C21D1/64
X	FR-A-2 282 470 (LUDWIG-OFAG-INDUGAS INDUSTRIEOFENANLAGEN G.M.B.H.) * the whole document *	1,2	
A	GB-A-987 338 (GIBBONS BROTHERS LTD)		
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A	US-A-3 203 470 (P. AYERS)		

TECHNICAL FIELDS SEARCHED (Int.Cl.5)
C21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20 May 1994	Mollet, G

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