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⑤④ **Container heating arrangements.**

⑤⑦ A continuous furnace is arranged to heat a stack of metal containers (10) which are displaced vertically through the furnace (15); the containers (10) can be heated to very high temperatures. The furnace has a gas manifold (18) extending vertically upwardly within the furnace (15) and adapted to engage with gas discharge pipes (11) from the containers in the stack. Each container is supported on a support base which can be engaged and supported by a forked manipulator (24) and also by a jack (23) located below the furnace (15) for lifting the stack of metal containers. The apparatus can be used for sintering thin-walled metal containers containing cold compacted ceramic powder and radioactive waste and can also be used for preheating containers such as bellows containers for use in hot pressing operations, wherein radioactive waste is immobilised in a matrix of ceramic powder or metal powder located within the container.

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CONTAINER HEATING ARRANGEMENTS

The present invention relates to the heating of containers and is more particularly concerned with the heating of heat resistant metal containers carrying supply material incorporating radioactive waste and adapted to be immobilised in the container for subsequent long term storage. For example, the containers may contain synthetic rock precursor impregnated with high level radioactive waste. However, the invention may be applied to other arrangements involving other forms of supply material such as metal powder and ceramic powders generally. This specification will describe the present invention with particular reference to the immobilisation of high level radioactive waste in which the utmost safety of storage is required; however, it will be appreciated that the invention may be applied to other forms of waste if desired.

One important application of the invention is to the preheating of containers before the containers are compressed at high temperature for an extended period of time so that the volume of the container substantially reduces and the contents densify. When the supply material comprises a ceramic powder for forming synthetic rock, the radioactive waste material is immobilised in the synthetic rock which has a density close to its maximum theoretical density.

The present applicants have made patent applications

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in respect of selected synthetic rock materials for immobilising high level waste and for processes and apparatus for effective formation of impregnated synthetic rock in containers. Examples of these processes are described in Australian published patent specifications AU B 65176/80 (531,250) and AU B 72825/82 (524,883) and in the prior art referred to therein. These processes are concerned especially with containers of generally cylindrical form with flat end walls and a bellows like formation in the side wall. The container undergoes hot uniaxial pressing without circumferential support, the bellows like construction of the wall resisting gross outward deformation.

Other known processes concern hot isostatic pressing of synthetic rock. In such processes the high pressure gas surrounding the container applies uniform pressure around the container.

Typical process conditions for the formation of suitable synthetic rocks are temperatures in the range 1050 to 1260°C, pressures in the range 5 to 30 MPa and pressing times in the range 1 to 3 hours. However, the present applicants have discovered that it is necessary to achieve a generally uniform temperature through the container and its contents before the hot pressing step can commence and typically the pre-heating time will be several times longer than the time needed for the hot pressing step.

Any process for the immobilisation of high level radioactive waste must be conducted in an active cell which is a very expensive capital structure. Hydraulic presses suitable for hot uniaxial pressing of bellows like containers are large and expensive capital items and an apparatus for a hot isostatic process is even more complex and bulky. Therefore, to maximise plant throughput it is desirable to minimise the residence time of a container in the press apparatus of whichever type is chosen, and in one aspect the present invention is concerned with an

effective pre heating arrangement suitable for any hot pressing process (including hot isostatic pressing) involving radioactive waste containing supply material in a heat resistant metal container. In another aspect the invention can be used in a sintering process.

The heat resistant metal containers previously proposed have relatively thin walls and even the most suitable metals available have relatively low strength at the temperatures approaching and in the range applicable to processes with which the present invention is concerned. This is specially the case where the invention is applied to synthetic rock pressing operations. There is therefore an intrinsic mechanical handling problem for heated containers, and bearing in mind the extremely high reliability required for an active cell operation, there has been difficulty in conceiving an apparatus and process for effective heating and handling of containers.

According to a first aspect of the invention, there is provided an apparatus for heating heat resistant metal containers having therein supply material incorporating radioactive waste, each container having a gas discharge pipe and being arranged to be supported on a rigid support base which permits mechanical handling of the base and container, the mechanical handling including the formation of a stack of containers each supported on respective rigid support bases, the apparatus comprising

(i) a furnace having an upwardly extending furnace path and adapted to heat the metal containers in a stack during their residence time in the heating zone of the furnace to temperatures suitable for the formation of a dense matrix of the supply material in the containers, whereby the radioactive waste is immobilised in the containers, the furnace path being of a length sufficient to accommodate the stack comprising several containers,

(ii) a gas collection system comprising a manifold adapted to connect with the gas discharge pipes of each of the containers located in the furnace and to remain

connected during movement of the containers upwardly through the furnace whereby gases discharged from the containers are collected, the gas collection system further including a discharge duct connected to the manifold and adapted to be connected to a gas treatment system,

(iii) means for holding and supporting the stack of containers in the furnace,

(iv) means for lifting a new container from below the furnace to abut and support the stack of containers in the furnace and for raising the stack of containers to discharge the uppermost container from the upper end of the furnace and to install the lowermost container into the heating zone of the furnace,

(v) means for disengaging the holding means during lifting of the stack of containers, and

(vi) a discharge arrangement for the furnace at its upper end to permit the discharge of a heated container and its removal by engagement of moving means with the support base associated with the uppermost container.

Use of the invention can permit an efficient and cost effective process to be constructed and operated in an active cell. By virtue of the rigid support base for each container, mechanical handling is facilitated particularly when the container is heated and very reliable transfer is provided. Furthermore, use of the invention deals with the problem of gases discharged from the contents of the container; these gases may include noxious gases and minor proportions of radioactive gases from volatile components of the high level waste. The gases must be collected and processed.

Furthermore, the invention facilitates implementation in a relatively simple manner with low maintenance requirements and any maintenance is possible with remote manipulators. The apparatus and process can be confined to a compact physical space which is very important in terms of capital costs. Most importantly, however, the

invention permits a process to be implemented in which safe and reliable containment of the material can be provided.

One application of the invention is to provide a method of sintering in containers in which cold pre-compacted blocks are provided, the blocks consisting of a ceramic powder impregnated with radioactive waste. Use of the apparatus permits effective handling and sintering at very high temperatures e.g. of the order 1,200°C. Sintering is a process where under elevated temperature conditions the particles of matter form a dense ceramic material in which the radioactive waste is immobilised. An important application of the invention is to the case where the waste is high level waste in which volatile components at the operating temperatures must be processed. These components such as cesium and ruthenium can be effectively handled with an apparatus according to the invention as described above.

Another application of the invention is to the use of the apparatus for pre-heating containers for subsequent hot isostatic pressing. Preferably the containers are of cylindrical form with a bellows like formation in the side wall to facilitate predictable compaction of the containers in the hot isostatic pressing process.

Yet another use of the apparatus embodying the invention is for the preheating of containers of cylindrical form having a bellows like side wall and which are adapted to be subjected to hot uniaxial pressing.

Processes using the invention may include the use of synthetic rock components for immobilising the waste or may include the use of a metal powder such as copper powder to form a dense matrix surrounding and incorporating the waste material. The waste material could be concentrated high-level radioactive waste or could be spent fuel rods.

The invention may be implemented in various preferred forms and embodiments, examples of which will now be given.

Preferably, the arrangement is such that the support base for each container comprises a solid disc like base plate for supporting the base of the container and a downwardly projecting extension which functions to space the base plate above the next lower container in the stack or from any other support surface. This facilitates efficient handling arrangements whereby a manipulator having a fork like shape (and of a thickness less than the amount to which the extension extends away from the base plate) can be used for insertion under a container support base combination and then slight relative lifting of the manipulator safely picks up the container and moves it even if the container is hot and therefore relatively fragile.

Preferably, the invention is implemented in a manner which does not require the lifting means (such as a mechanical or hydraulic jack) to enter itself into the heating zone of the furnace. This greatly simplifies design arrangements and obviates the need for cooling systems for the jack.

Preferably, the furnace is in the form of an induction furnace having a metal susceptor sleeve and of a length typically equal to about four containers in a stack. The susceptor sleeve provides a safety barrier in the event that a container should rupture during the heating stage. Thus, any spillage is contained in a small part of the apparatus capable of subsequent cleaning after cool down.

Preferably, the invention is arranged to be implemented with the gas discharge pipe of each container being in the form of a laterally extending pipe. For this arrangement, the gas collection system comprises a gas manifold having a collection head of elongated generally U-shaped form extending vertically, so that the discharge pipes of the respective containers can be inserted within the U shaped member and move upwardly therethrough with a clearance fit.

According to a second aspect of the invention, there is provided a method for heating heat resistant metal containers having therein supply material incorporating radioactive waste in solid form, the supply material being adapted to form a matrix in which the waste is safely immobilised, and each container having a gas discharge pipe and being arranged to be supported on a rigid support base which permits mechanical handling of the base and container, the mechanical handling including the formation of a stack of containers each supported on respective rigid support bases, the method comprising

(a) supporting a further one of said containers on a rigid support base, which is placed on lifting means located below an upwardly extending furnace, retractable holding means holding and supporting a stack of said containers on their respective rigid support bases in the furnace so as to be heated to temperatures of the order of 500°C to 1250°C,

(b) operating the lifting means to cause the top of the further container to come into abutment with a bottom portion of the support base associated with the lowermost container of the stack and causing the weight of the stack to be taken on the further container,

(c) disengaging the holding means from the stack in the furnace;

(d) further operating the lifting means to raise the stack so that the further container is moved within the furnace and the gas discharge pipe of the further container connects with a gas collection system of the furnace, the other containers in the stack within the furnace remaining connected through their respective discharge pipes to the gas collection system, and the uppermost container of the stack being displaced through the furnace and discharged from its upper end,

(e) removing the heated container discharged from the upper end of the furnace by engagement with its support base,

(f) activating the holding means to engage the support base of said further container to support the stack, and

(g) lowering the lifting means.

5 An important application of the invention will now be described with reference to an embodiment in which the containers are pre heated to a temperature exceeding 1,000°C and contain synthetic rock precursor impregnated with radioactive waste or metal powder surrounding spent
10 fuel rods. In this embodiment, preferably the method extends to the further step of allowing a short cooling period for the pre heated container before it is inserted within the subsequent hot pressing apparatus, this step being carried out so that the skin temperature of the
15 container drops rapidly e.g. from 1000°C to 750°C thereby gaining significant strength for increased safety in the mechanical handling steps, yet a substantially uniform high temperature of 1000°C or more is maintained through the body of the synthetic rock precursor or metal
20 powder in the container. It has been found that an air blast for a short period of time e.g. of the order of 2 minutes is sufficient to lower the skin temperature so that manipulators can grip the periphery of the container, which has a thin metal wall, and transfer it reliably to a
25 pressing apparatus.

The invention is preferably implemented such that closed containers are rotated to the desired orientation of the gas discharge pipe before being placed on their support bases. This ensures correct location in the
30 furnace. Preferably, each support base has a guide member which is correctly orientated before the container is placed on the support base, and the furnace includes upwardly extending guides which co-operate with the guide members to maintain correct alignment of the support bases
35 and the containers thereon. This arrangement ensures that the gas pipes on the containers maintain a clearance fit relative to the manifold of the gas collection system.

In a typical commercial process, several hours will be required for pre heating a bellows container having a diameter of about 40 cm. Therefore, the combination of a pre heating arrangement in accordance with an embodiment
5 of the present invention together with a single press unit can provide a very high plant output in terms of processed material per unit time while keeping capital costs down and facilitating simplicity of apparatus design.

An advantageous embodiment of the invention
10 applicable to the case where the containers are subjected to a hot pressing operation is one in which a secondary furnace is utilised of the same arrangement but operated in a reverse direction as a cooling furnace. This ensures a steady and slow rate of cool down which is particularly
15 important to minimise the risk of cracking where synthetic rock is formed within the container.

For illustrative purposes only, an embodiment of the invention will now be described with reference to the accompanying drawings of which: .

20 Figure 1 is a schematic side elevation partially in section of an embodiment of the invention;

Figure 2 is an inverted plan view of the apparatus of figure 1 and showing the loading manipulators;

Figure 3 is a schematic plan view on an enlarged
25 scale illustrating the co operation of the support base for a bellows container with the susceptor sleeve of a furnace; and

Figure 4 is a view on an enlarged scale of an alternative container for use in the furnace of Figures 1
30 to 3 in a sintering process.

The illustrated apparatus is arranged to handle and heat cylindrical containers 10; in the arrangement illustrated in Figures 1 to 3, each of the cylindrical containers has a bellows-like side wall and flat end walls
35 with a laterally extending gas discharge pipe 11 near the base. Each container has had supply material poured into

the container and then closed at the upper end with a lid which is welded into position. This supply material may comprise particulate synthetic rock precursor impregnated with radioactive high level waste or other radioactive waste such as spent fuel rods; alternatively the supply material may be a metal powder such as copper powder. With advantage, the container is subjected to a pre compaction in a cold state in accordance with another invention of the present applicants and which is the subject of a co-pending application. After such cold pre compaction, where the supply material is synthetic rock precursor impregnated with high level waste, the density of the particulate matter can be up to 35% of the maximum theoretical density of the final synthetic rock. After the final synthetic rock hot pressing operation a density of about 99% of the maximum theoretical density can be achieved.

Each container rests on a respective base unit comprising a flat disc like base plate with an integral cylindrical extension 14. The container 10 can be formed from a corrosion resistant high strength alloy such as INCONEL 601 and the base unit 12 can be made from alloys such as INCO alloys MA754 or MA956.

The heating apparatus comprises a vertical induction furnace 15 adapted to contain within its heating zone a stack of four containers. The furnace 15 comprises induction heating coils 16 and a cylindrical metal susceptor sleeve 17, preferably of a high temperature alloy such as INCONEL 601 metal. At one side, a gas collection manifold 18 is provided and comprises an elongated port 19 of U shape in cross section, connection ducts 20 and a discharge pipe 21 connected to a suction system which includes filtering for radioactive components and other particles and a suitable off-gas system for removing any volatile products. The port 19 is arranged to accommodate the discharge pipe 11 of each container with a clearance fit.

Below the furnace is provided a retractable stack holder 22 and a screw jack 23 for receiving cold containers from a swinging manipulator 24 and for raising the container into the stack in the furnace. At its upper
5 end a similar swinging manipulator is provided (but not shown in the drawing) for removing a heated container to an unloading station 25 from which the container can be collected for hot pressing operations.

The retractable holder 22 has a support arm 26 which, as shown in figure 2, has a forked head 27 which is thinner than the axial extent of the extension 14 and engages around the extension. The arm 26 is pivotally mounted on a base 26A and pivotally connected at its mid-portion to a hydraulic ram 28. Normally the arm 26
15 supports the stack of containers but when the stack is supported on a new, lower cold container, as described below, the ram 28 can be actuated to swing the arm back to the position shown in dotted lines in Figure 1 thereby permitting the stack to be raised by operation of the jack
20 23. The jack 23 comprises a motor drive M, a captive nut 29 and a screw column 30 at the top on which a cylindrical pad 31 is mounted and adapted to support a base 12 and its associated container 10A.

As most clearly shown in Figure 3, the susceptor
25 sleeve 17 closely encircles a base 12, the susceptor sleeve having diametrically opposed ribs 33 which, with a clearance, align within corresponding grooves 34 on the opposite sides of the base 12. Orientation of each container 10 is provided by placing the container on a
30 turntable similar to turntable 32 shown in Figure 1, and rotating the turntable until the discharge pipe 11 engages a microswitch, thereby correctly orientating the container. Similarly a support base 12 is placed on the turntable of supply station 32 and rotated until a sensor
35 (not shown) senses the correct orientation of the grooves 34 in the side of the support base. A manipulator grips the sides of the container 10 and transfers it onto the

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orientated support base as generally shown in Figure 1. The forked manipulator 24 shown in Figure 1 is pivotally displaced to engage under the support base of the new container, the turntable of the support station 32 then being lowered slightly so that the container is supported on the manipulator 24 and the manipulator 24 pivotally displaced to move the container into the correct location below the existing stack of containers in the furnace. Motor M is then actuated to raise the screw jack whereby the support base of the new container is engaged to permit pivotal retraction of the manipulator 24, subsequent action of the motor then raising the container 10A so that it abuts the bottom of the support base of the lowermost container in the furnace to take the weight of the stack.

The ram 28 is actuated to swing back the arm 26. Further operation of the motor raises the jack so that the stack of containers is advanced upwardly by one increment. The jack does not penetrate into the heated zone of the furnace. This action causes the uppermost container to be discharged through the top of the furnace for removal by a swinging manipulator similar to manipulator 24. To avoid engineering a vertical control for the manipulator 24, the jack can be raised initially so that there is a clearance for swinging the manipulator into position and the jack is then lowered slightly so that the topmost container is supported on the manipulator, which is then swung away to the unloading station 25. By appropriate engineering this slight lowering action can be synchronised to follow the operation of the ram 28 to reinstate the arm 26 to the position shown in the drawing so that jack is lowered leaving the stack supported on the arm 26.

An airblast apparatus 35 is provided for lowering rapidly the skin temperature of the bellows container 10 at the unloading station 25 so that it can be gripped with a manipulator to be removed from its support base and loaded into a hot pressing station.

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Referring now to Figure 4, a container 40 suitable for sintering is illustrated. This container has a plain cylindrical wall 41, a thick metal top cap 43 and a slotted thick base 44 welded to the thin cylindrical side wall. Near the base of the cylindrical thin wall is an off-gas pipe 42. The base has on opposite side recesses or slots 45 to permit the base directly to be picked up with a forked manipulator arm but when the containers are arranged in the stack the weight of the stack is transmitted through the cylindrical side wall.

Cold precompaction, conveniently in a die, is effected and the pressed blocks of ceramic powder and radioactive waste are placed in respective containers and top cap applied to seal the container.

CLAIMS:

1. An apparatus for heating heat resistant metal containers (10) having therein supply material incorporating radioactive waste, characterised by each container (10) having a gas discharge pipe (11) and being arranged to be supported on a rigid support base (12) which permits mechanical handling of the base and container, the mechanical handling including the formation of a stack of containers each supported on respective rigid support bases, the apparatus comprising
- (i) a furnace (15) having an upwardly extending furnace path and adapted to heat the metal containers (10) in a stack during their residence time in the heating zone of the furnace (15) to temperatures suitable for the formation of a dense matrix of the supply material in the containers, whereby the radioactive waste is immobilised in the containers (10), the furnace path being of a length sufficient to accommodate the stack comprising several containers,
- (ii) a gas collection system (20) comprising a manifold (18) adapted to connect with the gas discharge pipes (11) of each of the containers (10) located in the furnace (15) and to remain connected during movement of the containers (18) upwardly through the furnace (15) whereby gases discharged from the containers (10) are collected, the gas collection system (20) further including a discharge duct (21) connected to the manifold (18) and adapted to be connected to a gas treatment system,
- (iii) means (26) for holding and supporting the stack of containers in the furnace,
- (iv) means (23) for introducing a new container (10A) from below the furnace to abut and support the stack of containers in the furnace and for raising the stack of containers to discharge the uppermost container from the upper end of the furnace and to install the lowermost container (10A) into the heating zone of the furnace,

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(v) means (28) for disengaging the holding means (26) during lifting of the stack of containers, and

(vi) a discharge arrangement (25) for the furnace at its upper end to permit the discharge of a heated
5 container and its removal by engagement of moving means with the support base associated with the uppermost container.

2. Apparatus as claimed in claim 1 characterised in that the holding means (26) is adapted to hold the support
10 base (12) of the lowermost container (10A) within the furnace at a location adjacent the bottom of the furnace.

3. Apparatus as claimed in claim 1 or claim 2 characterised in that the holding means (26) comprises a pivotal forked manipulator (24) adapted to engage a
15 reduced diameter extension portion of the support base (12) for the lowermost container (10A) in the stack within the furnace.

4. Apparatus as claimed in any one of the preceding claims and characterised in that the furnace (15) is an
20 induction furnace having a metal susceptor sleeve (17) within which the heating zone is defined, the heating zone having a vertical height equivalent to the height of several of the containers (10).

5. Apparatus as claimed in claim 4 characterised in that the susceptor sleeve (17) has guide means extending
25 up the sleeve and adapted to co operate with corresponding guide means on the respective support bases for the containers thereby maintaining orientation about the vertical axis of the containers (10) and a clearance
30 insertion of the gas discharge pipes (11) of the containers in the manifold (18).

6. Apparatus as claimed in any one of the preceding claims characterised in that the manifold (18) is of elongated generally U shaped form extending vertically
35 whereby the discharge pipes (11) of the respective containers (10) can be inserted within the U shaped form and move upwardly therethrough with a clearance fit.

7. Apparatus as claimed in any one of the preceding claims characterised in that the means for introducing a new container comprises means for orientating a support base (32), means for orientating a container about the vertical axis, means for placing the container on the support base and means for transferring the support base and container for insertion into the stack with an accurately controlled relative orientation.

8. Apparatus as claimed in any one of the preceding claims characterised in that the discharge arrangement includes cooling means (35) for delivering an air blast to effect a surface cooling of a heated container discharged from the top of the furnace (15), thereby permitting the container after a short period of cooling to be gripped around the periphery with a manipulator to be transferred to a subsequent process stage.

9. A method of heating heat resistant metal containers having therein supply material incorporating radioactive waste in solid form, characterised by the supply material being adapted to form a matrix in which the waste is safely immobilised, and each container (10) having a gas discharge pipe (11) and being arranged to be supported on a rigid support base (12) which permits mechanical handling of the base and container, the mechanical handling including the formation of a stack of containers each supported on respective rigid support bases, the method comprising

(a) supporting a further one (10A) of said containers on a rigid support base (12), which is placed on lifting means (23) located below an upwardly extending furnace (15), retractable holding means (26) holding and supporting a stack of said containers on their respective rigid support bases in the furnace so as to be heated to temperatures of the order of 500°C to 1250°C,

(b) operating the lifting means (23) to cause the top of the further container (10A) to come into abutment with a bottom portion of the support base (12) associated

with the lowermost container of the stack and causing the weight of the stack to be taken on the further container,

(c) disengaging the holding means (26) from the stack in the furnace;

5 (d) further operating the lifting means (23) to raise the stack so that the further container (10A) is moved within the furnace and the gas discharge pipe (11) of the further container (10A) connects with a gas collection system (20) of the furnace, the other
10 containers in the stack within the furnace (15) remaining connected through their respective discharge pipes (11) to the gas collection system, and the uppermost container of the stack being displaced through the furnace and discharged from its upper end,

15 (e) removing the heated container discharged from the upper end of the furnace by engagement with its support base (12),

(f) activating the holding means (26) to engage the support base (12) of said further container (10A) to
20 support the stack, and

(g) lowering the lifting means (23).

10. A method as claimed in claim 9 characterised in that the containers contain synthetic rock precursor and radioactive waste, and including operating the furnace to
25 achieve temperatures through the container and its contents of greater than 1000°C.

11. A method as claimed in claim 10 characterised by airblast cooling a container (10) while supported on its support base (12) downstream of the discharge arrangement
30 to achieve a surface cooling, and transferring the container for subsequent processing by gripping the container around its periphery with a manipulator.

12. A method as claimed in any one of claims 9 to 11 characterised in that the furnace (15) has vertically
35 extending first guide means and each support base (12) has corresponding second guide means for co operating with the first guide means and for maintaining the desired

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alignment of the support base (10) and furnace (15) during
passage through the furnace (15), the method including
rotating the support base on a turntable (32) and by
detecting the guide means orientating the support base
5 (12) to a desired position, rotating the cold container on
the turntable (32) and by detecting the position of the
gas discharge pipe (11) orientating the container (10) to
desired position, placing the container on the support
base (10) and subsequently transferring the container and
10 support base to the furnace (15), whereby the gas
discharge pipe (11) is aligned with said manifold.

13. A method of sintering comprising forming cold
pre compacted blocks of ceramic powder impregnated with
radioactive waste, loading the pre compacted blocks into a
15 cylindrical container having a rigid base and a rigid top
cap and a gas discharge pipe projecting from the side wall
thereof and effecting a sintering operation using an
apparatus as claimed in claim 1.

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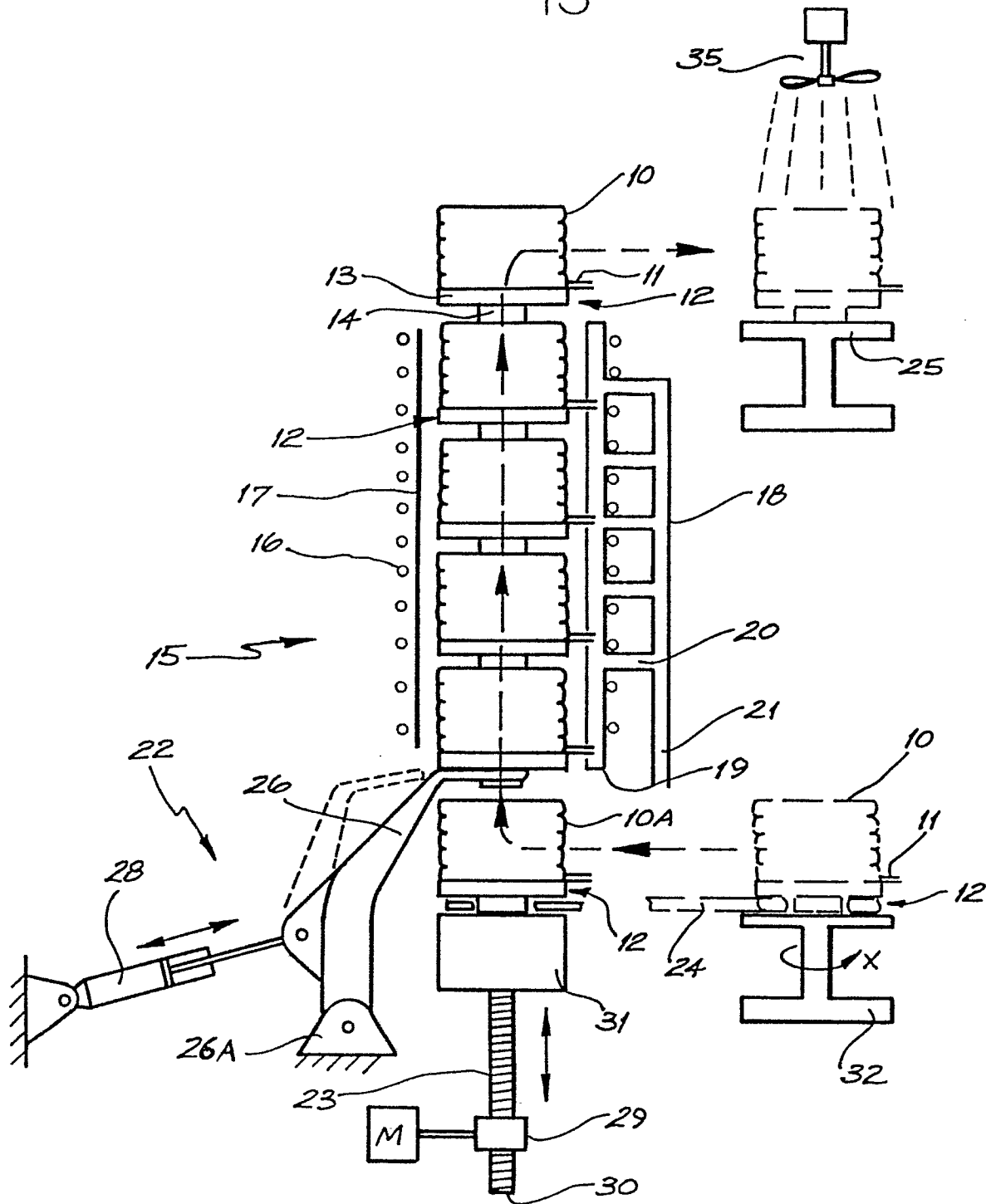
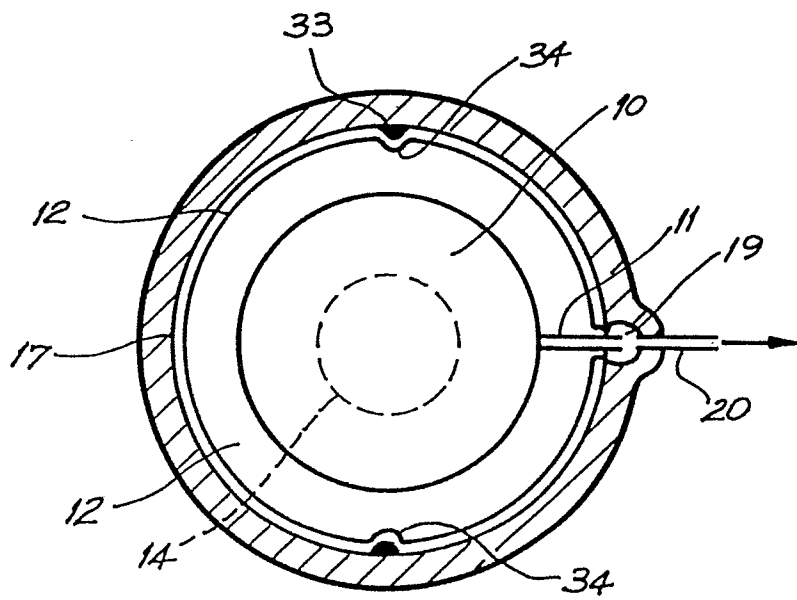
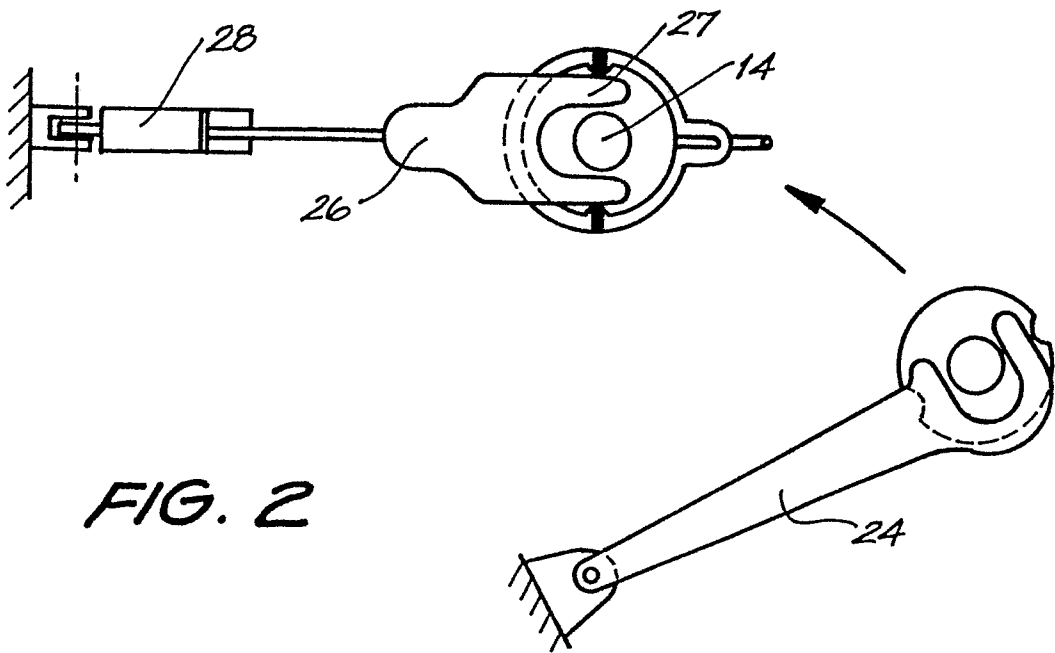


FIG. 1



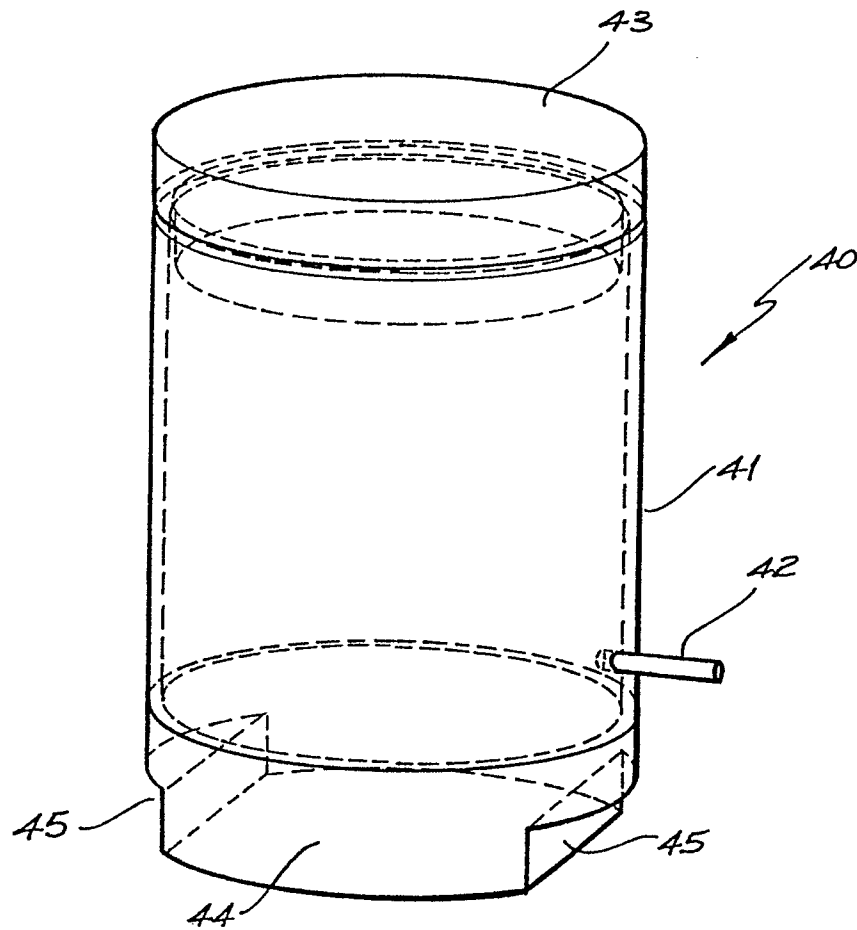


FIG. 4