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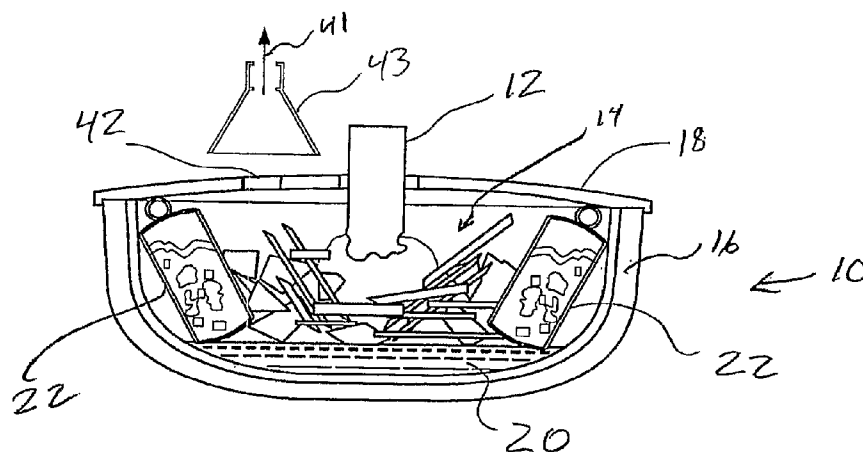
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(54) Title: APPARATUS AND METHOD FOR PROCESSING METALLURGICAL "FINES" IN (EAF) ELECTRIC ARC FURNACES



(57) Abstract: Apparatus and methods for recycling iron fines, such as mill scale. In one form, mill scale is placed in containers that are then placed as part of the charge in an electric arc furnace or other appropriate apparatus used in a metallurgical process. The capsule can be shaped so as to control the movement of the capsule during the melt cycle. In one form, various appendages are coupled to the capsule and used to interact with the vessel wall of the electric arc furnace or other appropriate apparatus used in a metallurgical process to control and/or delay the movement of the capsule during the melt cycle. Appendages can also be attached to the vessel wall to control and/or the movement of the capsule during the melt cycle. In one form, snubber cables can be hooked to the appendages on the vessel wall to aid the control of movement and/or delay movement. In one form, the capsules are sealed so that venting of internal gases is difficult, at least for some time, after heat is applied. Fusible vents can be provided, for example where a portion of the sealed container melts upon application of a sufficient amount of heat for a sufficient time.

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Apparatus and Method for Processing Metallurgical "Fines" in (EAF) Electric Arc Furnaces

[0001] Mill scales (often finely divided Iron Oxides) are generated in huge quantities by the steel industry. Millions of tons of mill scale have accumulated over many decades. These accumulations constitute a troublesome waste product both in terms of the valuable but lost iron they contain but also because of the serious and expensive environmental and disposal issues they present. In addition, current operations in Iron and Steel plants are constantly adding to the global inventory of these wastes.

[0002] This application claim priority to US provisional application no. 60/813,082 filed on 13 June 2006, which is incorporated herein by reference.

[0003] Herein are disclosed apparatus and methods for processing mill scale or other wastes in Electric Arc Furnaces (EAFs) 10 or similar devices. EAFs employ high power electric arcs struck between one or more carbon-graphite electrodes 12 and a mass, "a charge" of steel scrap 14 contained in a large processing vessel 16 that can have a removable top 18. The scrap steel is in solid form, and pieces of the charge can weigh 5 tons each although much smaller pieces are included especially near the center of the EAF 10. An EAF vessel 16 can be 26 feet in diameter and contain some 200 tons of material for melting and processing in a single heat that can take about 2 hours to complete. Loading (typically using large clam-shells and cranes) is done through a removable top cover 18 and can take 20-30 minutes. The EAF 10 is then closed and a low power arc is struck. The low power arc melts the smaller pieces of ferrous scrap positioned near the center of the EAF. The molten steel 20 collects in the bottom of the EAF 10 and the electrode(s) 12 gradually descends into deeper portions of the stack of scrap. As the electrode 12 descends, outlying and generally larger heavier scrap positioned by the EAF operator tend to protect the EAF walls from intense thermal radiation. The arc power can then be increased until all material is molten. At this stage, the furnace walls are also somewhat protected by a frothy metal-gas mixture overlying the hot molten metal 20. The melt is ultimately transferred out of the EAF and loading of another batch of ferrous scrap begins.

[0004] Herein are described one or more apparatus and methods of charging EAFs in part using large steel capsules that can contain portions of steel scrap, mill scale, carbon-containing substances, and other materials. They can also contain one or more small sub-capsules of the types disclosed in my US earlier Provisional Patent Applications 60/578,956 (filed 12 June 2004), 60/604,364 (filed 24 August 2004), 60/628,599 (filed 17 November 2004), 60/633,614 (filed 06 December 2004), 60,725,716 (filed on October 11, 2005), 60/811,003 (filed on 5 June

2006), US non-provisional application (serial no. 11/151,014) and a PCT application (serial no. PCT/US2005/020832) both filed on 12 June 2005, PCT application (serial no. PCT/US2006/39969) filed on 11 October 2006, and a PCT application (serial number not yet known) filed on 5 June 2006. All of the aforementioned applications being incorporated herein by reference.

[0005] In one form of the present invention, the capsules 22 can be large, generally cylindrical in form. For example, they might be steel pipes up to 4 feet in diameter or more and perhaps 10 feet high depending on the dimensions of the EAF. Such capsules 22 can contain 10 tons or more of ferrous material. Alternatively, the capsules 22 can be significantly smaller size.

[0006] Some of the concepts disclosed here involves one, or more, of the following: (1) containerizing quantities of ferrous substances and/or other materials in a capsule 22; (2) placing one or more capsules 22 within an EAF 10 or similar facility; (3) preferably rapidly placing a number of such capsules 22 around the perimeter of the melting vessel 16 so positioned that they protect the vessel lining from impact by scrap and from intense radiation during initial stages of melting; (4) arranging the capsules 22 in such a fashion that they leave the center portion of the vessel available for filling with scrap that is traditionally melted during the low power phase of furnace operation to form a pool of molten material 20; (5) arranging for the capsules 22 to melt from the bottom up in such manner that they tend to slide, in orderly fashion, downward and inward toward the vessel center during subsequent higher power phases of furnace operation (see Figs. 2A and 2B); (6) achieve some agglomeration and/or chemical processes such as combustion and oxide reduction of capsule 22 content prior to actual capsule 22 melting by delaying and/or controlling thermal contact between the highest temperatures (e.g. the melt pool or the unshielded arc) and the capsule 22.

[0007] Some aspects of my invention as related to capsule 22 features per se that are displayed, for example in Figure 1. Features shown in all of the Figures contained in this Provisional Patent are merely schematic. Those skilled in the art will readily understand from the descriptions given here that many variations are possible that can achieve the functional purposes of any particular feature portrayed.

[0008] In one form, the capsule 22 might be made of 1/8" steel plate or whatever thickness is required for adequate strength and contains about \$200 of steel at current prices and most, if not all, of this cost is recovered in the EAF melt because the steel container contributes to the melt. Depending upon which features discussed herein are included, the fabrication and fill cost, in quantity, should be under \$150. Assume, for example, eight capsules 22 are loaded per melt and contain 75% fines 24 and 25% scrap 26 by weight for a total cargo weight of 80 tons. On a per melt basis, the net cost difference of the produced hot steel can then be very roughly

estimated at \$9000 in favor of the capsule 22 sources at current scrap prices. This estimate does not include any (positive or negative) differences in electrical energy consumed or combustion BTUs contributed by cargo materials in the capsules. The direct costs of the fines 24 are assumed already written off for accounting purposes. Melts can be processed 8-10 times per day.

[0009] Several indirect advantages can accrue from the use of pre-loaded inventoried capsules 22 including more rapid loading of the EAF 10 (e.g. 80 tons in a single crane operation) and perhaps higher pre-melt net cargo density in the capsule as compared to the scrap load in the rest of the vessel. Both higher density and fast loading can raise facility productivity.

[0010] As shown in Figure 1, according to the teachings of this invention, a capsule can include one or more of the various features discussed throughout this specification (even if not specifically discussed with respect to this figure).

[0011] An attachment point mechanism and/or hoist mechanism 28 on the capsule 22 to facilitate handling by cranes, such as cranes that utilize an electromagnet to pick up such capsules. A contoured bottom-end 30 shaped to mate stably against the shape of the EAF vessel interior. The Figures show a relatively simple spherical section but the bottom 30 can have any useful symmetrical or asymmetrical shape that facilitates good behavior during loading and settling as the capsule begins to melt.

[0012] A false bottom 32 to temporarily support the capsule as the lower bottom 30 melts away in contact with the molten payload 20 being produced in the EAF 10.

[0013] A fusible or consumable stand-off bar 34 that helps to maintain a stable position and tilt of the capsule 22 as it gradually subsides or settles into the melt 20 (see Figs. 2A and 2B).

[0014] The basic cylindrical body of the capsule 22 can also (or in the alternative) have a shaped steel plate(s) or other consumable appendage(s) 36 that helps control the posture of the capsule and its submergence into the melt 20.

[0015] Sub-capsules 38 can include special chemical mixes and can be part of the cargo contained within capsule 22, as can capsules of the various types disclosed in my above mentioned previously filed Provisional Applications and the US and PCT Applications following there-from can also be used as such sub-capsules 38.

[0016] Vents 40 can be provided that open during heating (such as fusible vents that melt open after exposure to sufficient heat for a sufficient period of time) to release internal capsule pressure as well as combustion and vaporization products 41. The latter can be collected through appropriate gas handling and vapor recovery systems 43 associated with the so-called "second" or "fourth" holes 42 in typical EAFs 10 as shown in Figure 2A.

[0017] In Figure 2A, the EAF 10 has been in low power mode. Melting is occurring in the central scrap. The capsules 22 arrayed around the perimeter in an angle of repose and possibly guided by refractory blocks 44 on the vessel wall (see Figure 4) that insures in-fall toward the vessel center as the capsules 22 are being heated, but not to the point of appreciable melting. As the capsule is heated, its content undergoes some agglomeration and reduction of oxides and combustion of carbonaceous material, when the capsule 22 contains carbon containing materials and iron oxide as part of its cargo. The weight of the overburden in the Capsule tends to prevent its floating on melt 20.

[0018] In one form, some sets of snubbers 46 (see Figs. 5A and 5B) can be provided and can include snubber cable 48 attached to the containers 22 and snubber hooks 50 attached to vessel 16 where the snubber cables are hooked onto the snubber hooks so that capsules 22 stay in position for an appropriate period of time. In one form, the snubber cables can include fusible connectors or joints that melt when exposed to a sufficient amount of heat for a sufficient period of time so that the capsules 22 become released from the vessel 16 to allowed for appropriate positioning and/or controlled descent control of containers 22.

[0019] In Fig. 2A, the EAF 10 is shown in the early stage of the melt cycle. In Figure 2B, the EAF 10 has been brought to full power and is at a later stage of the melt cycle. Melting of the entire charge is proceeding rapidly. Note the possibility of a liquid metal seal 52 developing at the open end of the surviving portion of the capsules 22 and possible injection of content beneath a floating slag layer (see my earlier provisional applications concerning such liquid seal and content injection) that is part of melt 20. Basically, the liquid metal will theoretically provide a seal between the contents and the air such that the contents of capsule 22 can only escape the capsule by entering the liquid metal. Gases and vapors 41 are now flowing copiously through the 2nd hole and into the appropriate filtering, dust collection and handling systems 43.

[0020] Importantly, it is believed that purpose-built versions of the technology disclosed here can be used in waste recovery and utilization processes such as heat and metal recovery, exploitation of scrap tires and/or plastics, thermal reprocessing of ores and the like. For example various waste products, such as elastomers and plastics can be used as a source of carbon or energy. The oil, tar and bitumens in dirty mill scale can also be used as a heat source. Plasma torch technologies have similar aims.

[0021] Figures 3A and 3B display some of the features of one of many possible fast-loading concepts for placing the EAF 10 charge. In Figure 3A, one of a group of eight 10 ton pre-filled capsules 22 is being positioned in a template 54 by a small crane or similar device (not shown) while the EAF 10 is closed and in operation. A re-usable and detachable fast loading rig 56 (see

Fig. 3B) then is coupled to the array of capsules 22 and a heavy lift crane places the capsules 22 gently into the EAF 10 (when it is ready for a new charge) in one operation as shown schematically in Figure 3B.

[0022] This is one of many possible loading schemes and strategies and its use is not essential to the fundamental aspects of the invention. However, it is believed that the use of capsules 22 in this manner, or in some similar way, could bring with it the advantage of pre-encapsulating, say 80 tons of material, and then loading it precisely and quickly into the EAF 10. This could speed melt turn-around times and increase furnace productivity. Other concomitant advantages could include less likelihood of either thermal radiation damage or mechanical damage to the refractory linings of the EAF vessel 16 from the impact of large and heavy scrap.

[0023] Note that the center portion of the EAF 10 remains clear for normal charging practices and initial low power arc operation.

[0024] Figure 4 shows a top view of an open EAF 10 with eight capsules 22 in place. Capsules 22 can be located in non-interfering positions between EAF accessory melt devices eg lances etc. which are not shown. The optional positioning/snubber blocks 50 (or hooks) can be simply protruding short lengths of strong refractory material installed on the furnace wall that can help with maintenance of proper orientation and descent behavior of the capsules before and during the melt cycle. As already noted, the capsules 22 are designed so they tend to settle and sag inward and down toward the horizontal during high power melt phase. Protuberances 36 can be provided on one or more of the capsules 22 to aid with posture and facilitate the radially-inward slide of the melting capsules as noted in the description concerning Figure 1.

[0025] It is important to note that in some circumstances and with some cargoes, processes going on inside the capsule 22 can be important to the overall performance of the system. For example, if coals or other carbon-containing materials are present in the capsule cargo, intermixed or layered coal and scale promotes downward flow of coal tars into and thru scale layers assisting both rapid oxide reduction and agglomeration. Preheating major portions of the capsules with attendant tar percolation, combustion, binding effects and agglomeration can have positive benefits on energy balances, melt chemistry and off-gas production. An important tool in these regards is an ability to tailor the power input profiles to the arc and perhaps electrode height to achieve optimum capsule pre-heating.

[0026] An additional technique is to use external support mechanisms and devices (for example, 34, 36, 44, 48, 50 and/or 46) for controlling the posture and settling behavior of a capsule 22 which, in turn, affects the thermal profile experienced by its cargo. Such devices can be mounted on and used through the sides of the EAF vessel 16 and/or through its top 18, but

typically these introduce complexity that it would be desirable to avoid. For this reason, another and low-complexity alternative is disclosed below which involves thermally-actuated restraints comprised of cables 48 and snubber blocks 50 attached near the cooler top 18 of the EAF 22 and affixed to the capsules. The principles of the method are shown in Figures 5A and 5B.

[0027] While thermal activation is discussed explicitly below, very simple mechanical actuation amounting to cable cutters could also be employed.

[0028] As shown, in the pre-load state, at least one steel cable 48 is attached to each of the capsules 22. When the loader ring 56 lowers the capsule 22 array into its final position, the cable 48 or cables engage, hook onto, or merely drop into a groove (not shown) in the snubber blocks 50 between the capsules. In one form, snubber blocks 50 positioning blocks 44 are one and the same. At this point almost the entire weight of each capsule 22 is supported by the vessel wall since the capsules 22 are designed to rest in a repose posture as shown in Figure 2A (typically with somewhat more head-room than shown in that schematic). The cable(s) are nearly taut. As the heat erodes the lower portions of the capsule 22 or e.g. the fusible stand-off block 34 seen in Figure 1, the downward slide of the capsules will be delayed by the presence of the cable(s) 48 and the majority of the capsule cargo will continue to pre-heat without further rapid descent. After a certain time, fusible links set to release at a given temperature then detach (i.e. effectively cut) the cables 48. The capsules 22 are restrained from sudden lateral motion by the snubber blocks 50 and the posture control plates 36 of Figure 1, if present. The capsules 22 then descend in a manner purely dependent upon melt rate and remaining content weight.

What is claimed is:

1. A metallurgical process carried out in an electric arc furnace, the process comprising:
 - providing at least one container placed within a vessel of an electric arc furnace, the containers having a cargo that includes mill scale;
 - providing a charge of scrap steel within the vessel;
 - heating the charge and the at least one container, the container being initially substantially sealed such that gases formed within the container during the heating process are not easily vented; and
 - melting a portion of the container after the container has been heated to a sufficient temperature for a sufficient period of time, such that the gases formed within the container are vented through such melted portion.
2. A metallurgical process carried out in an electric arc furnace, the process comprising:
 - providing at least one container placed within a vessel of an electric arc furnace, the containers having a cargo that includes mill scale;
 - providing a charge of scrap steel within the vessel;
 - providing control mechanisms coupled to at least one of the containers and the vessel, the control mechanisms adapted to aid the control of movement and/or delay movement of the container within the vessel; and
 - heating the charge and the at least one container.
3. The process of claim 2 wherein the control mechanism is coupled to the container.
4. The process of claim 2 wherein the control mechanism is coupled to the vessel.
5. The process of claim 3 wherein the control mechanism is coupled to each of the container and the vessel.
6. The process of claim 2 further comprising:
 - forming molten steel within the vessel;

melting a portion of the container after the container has been heated to a sufficient temperature for a sufficient period of time; and

controlling the movement of the container within the vessel and thereby providing a liquid metal seal with un-melted portions of the container such that at least a portion of the contents of the container are exposed to the molten steel.

7. The process of claim 6 further comprising controlling the movement of the container within the vessel and thereby providing a liquid metal seal with un-melted portions of the container such that none of the contents of the container are exposed air outside the container.

8. The process of claim 3 wherein the control mechanism comprises a foot attached to the bottom of the container.

9. The process of claim 3 wherein the control mechanism comprises a bottom contoured to interact with the shape of the vessel.

10. The process of claim 4 wherein the control mechanism comprises a protrusion coupled to the vessel, wherein the protrusion extends between adjacent containers.

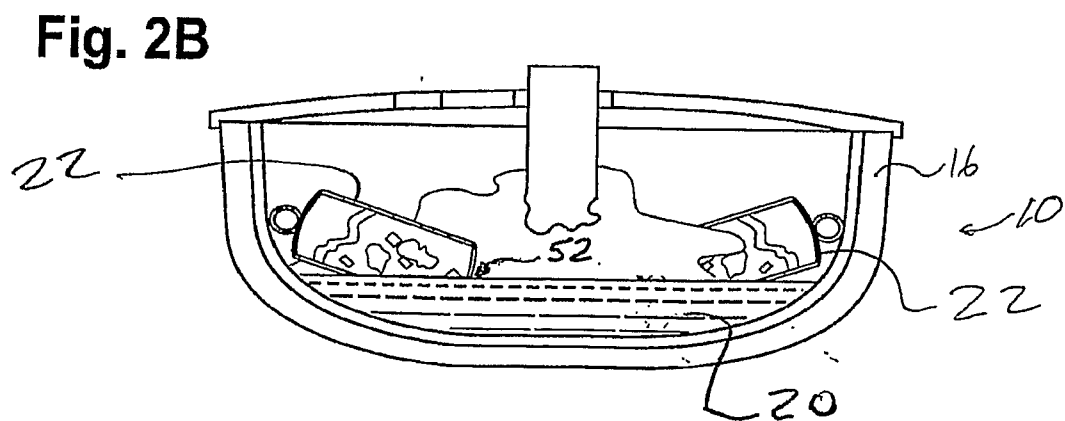
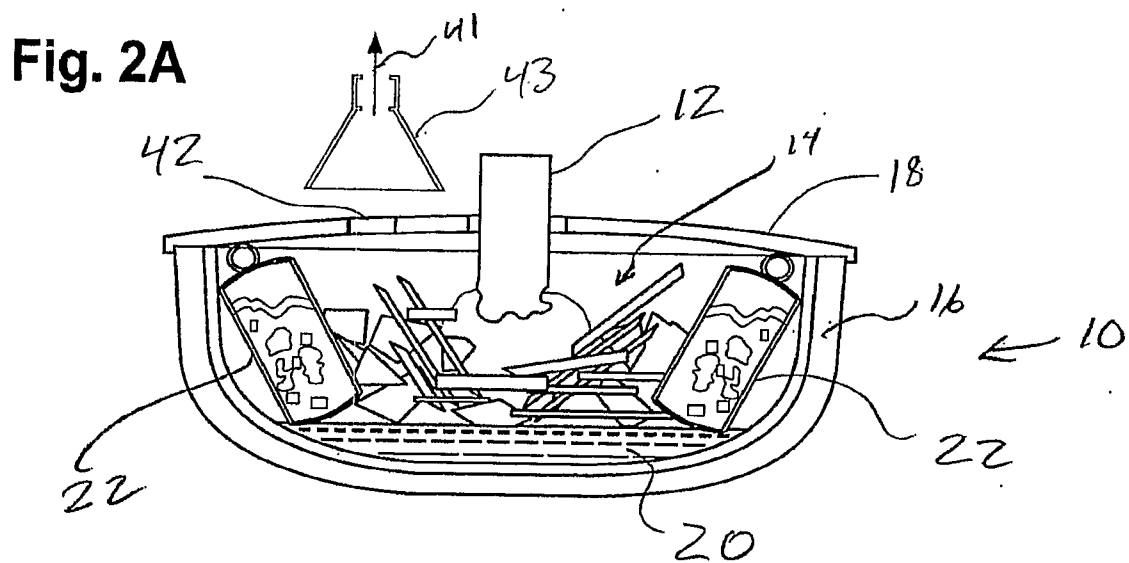
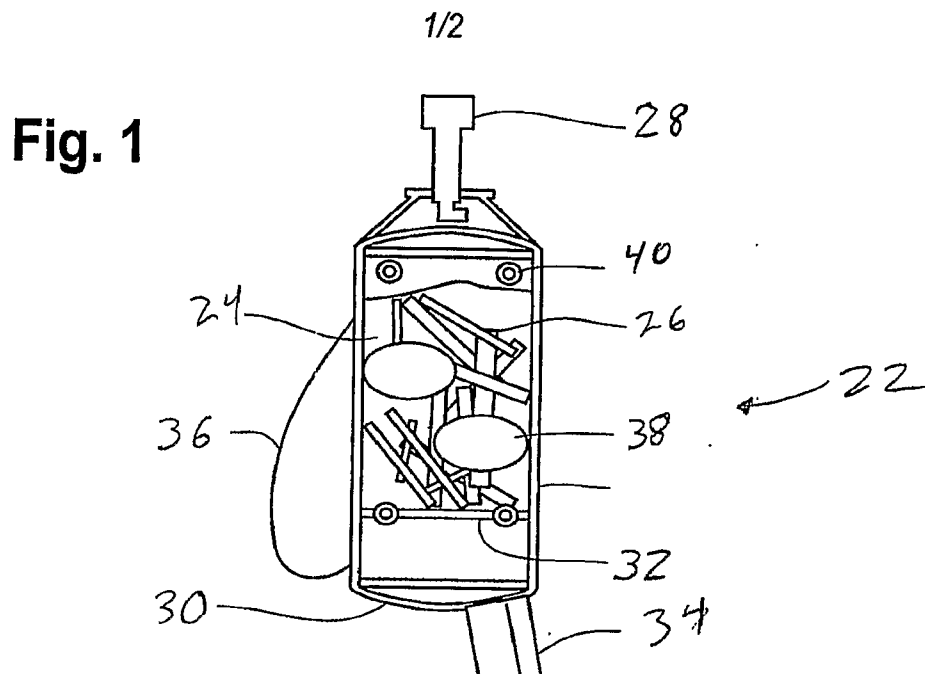
11. The process of claim 4 wherein the control mechanism comprises a protrusion coupled to the vessel and a cable coupled to the container, the cable being hooked on the protrusion.

12. The process of claim 2 wherein providing at lease one container placed within a vessel of an electric arc furnace comprises:

preloading a plurality of containers onto a template;

lifting, simultaneously, the plurality of containers using a lifting mechanism; and

loading the containers within the vessel.



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Fig. 3A

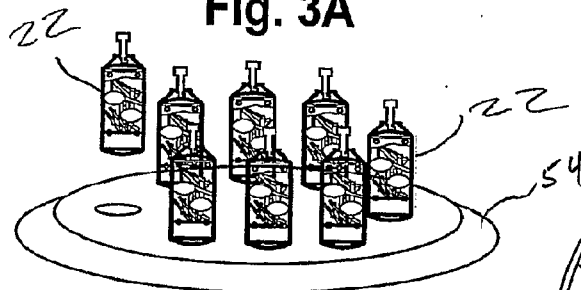


Fig. 4

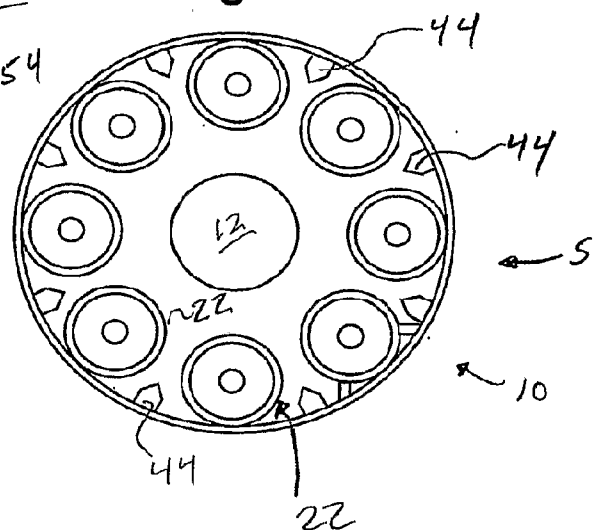


Fig. 3B

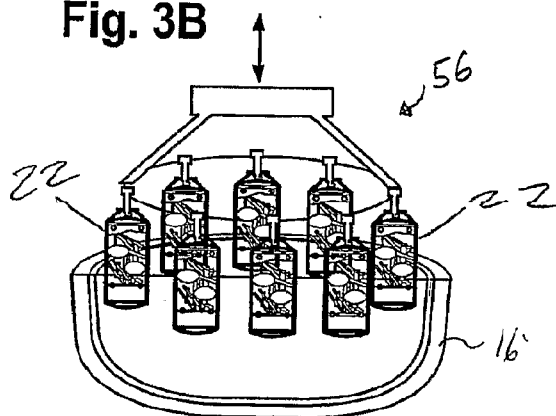


Fig. 5A

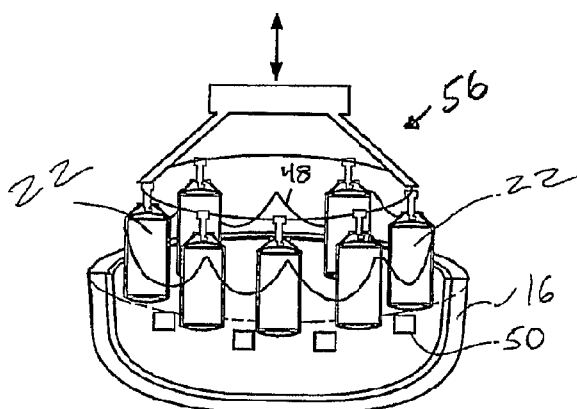


Fig. 5B

