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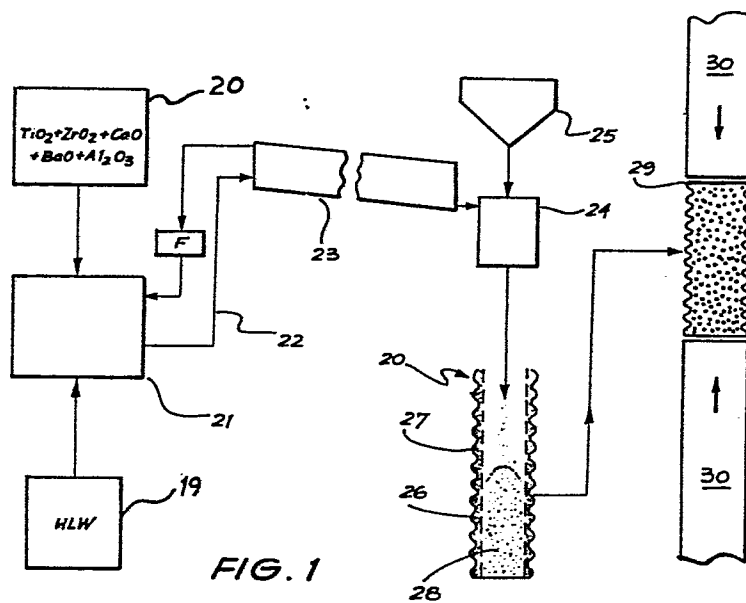
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(54) Containment and densification of particulate material.

(57) Particulate supply material such as a mixture of synthetic rock precursor (20) and radioactive waste (19) is formed in a rotary kiln (23) and poured into a bellows container (20) which, after sealing with a lid, is subjected to cold axial compression by hydraulic rams (30); the bellows containers in sequence are passed through an upright cylindrical induction preheater (31) and are then advanced in turn across a support table (36) to a hydraulic ram (37) which moves upwardly within an inverted metal cannister (38) having a refractory abutment (40) at its upper end and which is surrounded by an induction heating coil (41). Pressure is maintained at a working temperature of about 1200°C to cause axial compression of the bellows container and slight outward radial expansion to jam the bellows container within the outer cannister. For safety, the induction heating coil (41) is embedded within a refractory block (46) having a slightly tapered bore which at its lower narrowest end is at most a sliding fit over the cannister whereby the cannister is restrained by the refractory block from excessive outward deformation during the hot upward pressing of the bellows container. A series of bellows containers are compressed in turn within the metal cannister which then can be sealed and removed.

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CONTAINMENT AND DENSIFICATION OF PARTICULATE MATERIAL

The present invention relates to the containment of waste material, and more particularly is concerned with arrangements for containing waste material which requires very reliable, very long term storage.

Extremely long term safe storage of nuclear wastes is a major problem for the nuclear industry and various proposals have been made for dealing with this problem. One proposal concerns immobilising the waste in a suitable borosilicate glass which can then be deposited in a suitable geological formation. However, doubts concerning possible devitrification of the glass and consequent leaching of radioactive elements have founded criticism of the safety of this technique.

Another recent proposal involves the formation of a synthetic rock in which the nuclear reactor waste is immobilised, details of this method being described by A.E. Ringwood et al in NATURE March 1979. According to the disclosure, a selected synthetic rock is formed with the radioactive elements in solid solution. The constituent minerals of the rock or close structural analogues have survived in a wide range of geochemical

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environments for millions of years and are considered highly resistant to leaching by water.

5 The nuclear reactor waste is incorporated into the crystal lattices of the synthetic rock in the form of a dilute solid solution and therefore should be safely immobilised. A dense, compact, mechanically strong block of the synthetic rock incorporating the nuclear waste is produced by pressure and heat in a densification process and the block may then be safely
10 disposed of in a suitable geological formation.

The following patent applications have been filed by the Australian National University based on the work by A. E. Ringwood et al:-

15 Australian Patent Application 58708/79 (now Patent No. 523,472) entitled "Safe Immobilisation of High Level Nuclear Reactor Wastes"; and

United States Patent Application 124953 (now Patent No. 4,329,248) entitled "A Process for the Treatment of High Level Nuclear Wastes".

20 A further development in the field is disclosed in Australian Patent Specification 65176/80 which is concerned with apparatus and method for immobilising waste material and is directed to selected methods for providing a containment arrangement which will provide a
25 very high degree of safeguarding of the synthetic rock incorporating radioactive waste while nevertheless being produced in a process which is operable within the confines and limitations of a "hot cell". High level radioactive waste must be handled in a hot cell in which
30 all operations are conducted automatically or by an operator using manipulators, and since the apparatus used will inevitably become contaminated itself, the apparatus should be of a form which facilitates servicing within the hot cell and ultimately disposal
35 when its useful working life has come to an end.

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Yet further developments in this field are disclosed in Australian Patent Application 72825/81 in which additional apparatus and methods for immobilising waste material such as high level radioactive waste in
5 synthetic rock is disclosed. Among the configurations described, is a method in which a powder comprising the synthetic rock materials intimately mixed with the radioactive waste is filled into a container having a bellows-like wall structure, and after the container is
10 closed it is located inside an outer canister around which an induction heating coil is placed. A downwardly acting ram then applies pressure for sufficient time to cause densification of the contents of the bellows container. A series of bellows containers are adapted
15 to be stacked in the outer canister which, when full, is then sealed and removed to a safe storage location.

Despite these various proposals, it is still considered that there is a need to conceive of a more effective, practical and, most importantly, reliable
20 arrangement capable of convenient use in a hot cell.

Broadly, the present invention provides a method of containing and densifying particulate supply material comprising pouring the waste material into a bellows container of generally cylindrical form with side wall
25 including a bellows-like formation and of heat and decay resistant material, closing the bellows container with a lid, placing the bellows container on an upwardly displaceable ram having a heat resistant surface portion, displacing the ram upwardly to press the
30 bellows container against a fixed abutment, maintaining substantially axially pressure on the bellows container and maintaining a sufficiently elevated temperature in the bellows container for a sufficient length of time to cause densification of said particulate supply material
35 in the bellows container and axial compression of the bellows container, the arrangement being such that

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deformation of the bellows container occurs in its axial direction and removing the bellows container after completion of the densification step.

5 The invention thus can provide a most effective and reliable process for use with supply material in the form of high level radioactive waste and capable of long term operation in a hot cell with ease of operation of the process and maintenance of equipment. Furthermore, the method characterised by the upward pressing
10 technique permits considerable economy of capital equipment and the hot cell space required by virtue of the use of a single ram with a fixed abutment. Since typically operating temperatures in the region of 1100°C will be used, a substantial refractory facing
15 can readily be provided for the fixed abutment and also for the refractory ram. The upward pressing method facilitates, in a preferred embodiment, a most easily serviced apparatus since the refractory facing for the ram can simply be a disc-like pad located by simple
20 locating means such as a spigot and socket with the pad essentially remaining in position under the force of gravity. Thus, using manipulators in a hot cell a worn refractory pad can readily be removed for disposal and a replacement pad fitted.

25 Furthermore, a major improvement in the process can occur when the broad method described above is used in combination with a preheating step substantially without the application of pressure.

30 The high working temperatures for the densification step are best achieved by the use of induction heating and therefore typically it takes many hours for the contents of the bellows container to come to a uniform working temperature. Therefore preheating of the bellows container to bring the contents up to a uniform
35 temperature suitable for the densification step is a major advantage. Not only can the production rate for

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given capital cost be maximized but furthermore a substantial further advantage is that bringing the contents of the bellows container to the uniform densification temperature aids reliable and uniform densification thereby ensuring reliable axial compression of the bellows container which facilitates its later handling and storage. It is to be noted that the bellows container is typically of a heat resistant steel and preferably a stainless steel. Inevitably the mechanical strength of the steel is reduced at the high densification temperatures in the region of 1100 to 1200⁰C.

Furthermore, the broad method may be utilized in a surprisingly effective and synergistic combination of steps in which the bellows container is subjected to the densification step whilst in a cylindrical canister in which the bellows container becomes a tight fit after the pressing operation thereby providing a most effective and convenient extra containment for long term safe storage of the waste material. Such a method may be defined as consisting in a method for the containment of particulate waste material, the method comprising pouring the waste material into bellows containers of generally cylindrical form with a side wall including a bellows-like formation and of heat and decay resistant material, closing each bellows container with a lid, preheating in series the bellows containers to bring the contents thereof to a substantially uniform elevated temperature, placing each bellows container in turn on an upwardly displaceable ram and displacing the ram upwardly to insert the bellows container into a cylindrical canister and applying pressure and maintaining a sufficiently elevated temperature for sufficient time to cause densification of the contents of the bellows container with axial compression of the bellows container and relatively slight outward

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expansion thereof to cause the bellows container to grip the interior wall of the cylindrical canister, and when the canister has been filled with a series of such bellows containers, sealing the canister and removing
5 the canister for storage.

Whilst the invention is particularly useful in relation to the incorporation of high level radioactive waste in synthetic rock of the type described by A. E. Ringwood (and referred to above), the invention can also
10 be applied to other synthetic rock arrangements and furthermore can also be applicable to other materials which require storage and are capable of compaction under heat and pressure. One example of such other material would be shredded waste zirconium alloy nuclear
15 fuel rod tubes and similar waste components.

It will be appreciated that the invention consists in a combination of steps which cooperate together in an advantageous relationship which permits efficient, economic, and convenient operations in a hot cell. The
20 apparatus used can be relatively simple, and this can contribute greatly to the reliability and acceptability of the system due to simplicity of servicing and intrinsic reliability.

In a commercial scale operation, it is envisaged
25 that the cylindrical canister will be of the order of 30 cm diameter and 2 metres long and each bellows container will be compressible from an initial height of about 40 cm to a final height of about 10 cm. The use of induction heating coils is the preferred method of both
30 preheating and maintaining the necessary elevated temperature during the densification step, and due to the fact that heating of the particulate material is due to conduction from the bellows container (which is heated by the induction heating coils) a considerable
35 time is required for the preheating step. In a preferred embodiment of the invention, preheating for

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several hours can be effective whereas the final densification step will be much shorter, e.g. about one hour.

5 Most preferably, the bellows container is given a preliminary axial pressing which can be at ambient temperature or with advantage can be at a bellows container temperature of up to about 800⁰C to anneal the material of the bellows container. Since the bellows container will have a high degree of strength at ambient temperature and also at temperatures up to about 10 800⁰C, good control can be achieved in this preliminary axial pressing and, surprisingly, during the densification step at high temperature (typically 1200⁰C) excellent control of the axial pressing can be 15 achieved thereby essentially minimizing the risk of the bellows container compressing with sideways shear rather than true axial compression.

Preferably, the pressure in the preliminary pressing is of at least 3000 lbs/sq. inch.

20 Particularly when synthetic rock is to be formed, the material is preferably provided in the form of well graded fine particles up to about 2 mm maximum dimension whereby a readily pourable material is provided which can be easily densified in the process.

25 Preferably synthetic rock is used to incorporate radioactive waste, a mixture of synthetic rock precursor and high level waste being sprayed into a rotary kiln to produce the intimately mixed materials. In order to reduce what would otherwise be loss from the solid material of potentially volatile radioactive components, 30 the temperature at the region in which the material is introduced into the rotary kiln is preferably controlled in the range of about 400-600⁰C, and the maximum temperature in the kiln is about 700-800⁰C with the 35 exit from the rotary kiln being at ambient temperature.

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A preferred embodiment of the invention can also provide further means for safeguarding the cylindrical canister from outward deformation under the pressure of expanding bellows containers within the canister. This is achievable by the use of a block of refractory material having a slightly tapered bore which at its narrowest diameter just fits over the canister, the refractory block being adapted to be moved downwardly in a series of steps corresponding to bellows container locations, the slightly tapered bore permitting release of the block even if some outward deformation of the canister has taken place in a step of densification and compression of the bellows container.

Most preferably, the refractory block is formed so as to embrace the induction heating coil for surrounding the canister.

Most preferably, the refractory block comprises a series of interlocking refractory segments arranged to be mounted inside a cylindrical containment shroud which absorbs any expansion forces applied from the canister.

According to a second aspect of the invention, there is provided apparatus for encapsulating particulate supply material in bellows containers within a cylindrical canister, the apparatus comprising means for pouring the particulate material into a bellows container, means for sealing the bellows container with a lid, means for moving bellows containers in sequence to a pressing station, a pressing station comprising an upwardly displaceable ram for receiving a bellows container, means for mounting a cylindrical container with an open end directed downwardly towards said ram, means for upwardly pressing a bellows container supported on the ram into the canister, upper refractory support means to act as an abutment, heating means for maintaining an elevated temperature in said bellows container whilst said pressure is applied to cause

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densification of said material in the bellows container and expand slightly the bellows container to cause it to jam in the canister, the heating means being adapted to provide heating in a series of zones within the container corresponding to a series of bellows containers inserted one below the other in series therein, and means for removing the canister when a series of bellows containers have been densified and secured therein.

Preferably, the apparatus includes a preheating station adapted to bring the contents of the bellows containers to a substantially uniform elevated temperature, and means for transferring a preheated bellows container to said pressing station.

For illustrative purposes only, the invention will now be exemplified by reference to the accompanying drawings wherein:-

Figure 1 is a representation of the preliminary portion of a process embodying the invention;

Figure 2 is a schematic representation of the final steps of the process initiated in Figure 1;

Figure 3 is an axial sectional elevation illustrating a preferred embodiment of apparatus for effecting the densification step of the waste material;

Figure 4 is an axial sectional elevation on an enlarged scale of a preferred form of refractory block configuration shown generally in slightly exploded view in Figure 3; and

Figure 5 is an isometric view from above of the refractory block and induction heating collar arrangement shown in Figure 4.

Referring first to Figures 1 and 2, the process has a preliminary mixing stage 21 in which synthetic rock precursor from supply 20 is formed into a slurry with high level radioactive waste from waste supply 19 which is in the form of a nitrate solution, and the slurry is

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passed along line 22 to be sprayed into the elevated temperature end of a rotary kiln, at which a maximum temperature in the range 700-800⁰ is maintained. The spraying step immediately vaporises the water content of the slurry sprayed into the rotary kiln and causes chemical decomposition of the radioactive nitrates and will cause the mineral components of the synthetic rock to start to form with the radioactive elements starting to go into mineral phases. A chemical reducing control gas (such as argon-hydrogen, nitrogen-hydrogen, or CO-CO₂) is passed through the rotary kiln. The process could be operated so that synthetic rock particles incorporating the radioactive waste are completely formed in the rotary kiln but this is not essential. The rotary kiln produces cold particulate material of well graded particle size up to about 2 mm maximum dimension, whereas gases produced by the rotary kiln are fed back through a filter F to the preliminary mixing stage 21 since these gases will include some radioactive components.

In order to provide the necessary oxygen potential for the radioactive waste so that it is in the appropriate valency state to be incorporated into the synthetic rock, the particulate material produced by the rotary kiln is fed into a titanium mixing stage 24 which receives metallic titanium powder from a hopper 25 whereby the mixture poured into a bellows container 20 has about 2% titanium metal powder by weight.

An example of a suitable synthetic rock composition is indicated in the table set out below and is produced using tetraisopropyl titanate and tetrabutyl zirconate as ultimate sources of TiO₂ and ZrO₂. The components are mixed with nitrate solutions of the other components, co-precipitated by addition of sodium hydroxide and then washed to produce synthetic rock precursor.

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Typical Compositions of Synthetic rock (Synroc) and
Constituent Phases

"Hollandite" Zirconolite Perovskite Bulk

SYNROC

Composition

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	40%	35%	25%	
	TiO ₂	71.0	50.3	57.8 60.3
	ZrO ₂	0.2	30.5	0.2 10.8
10	Al ₂ O ₃	12.9	2.5	1.2 6.3
	CaO	0.4	16.8	40.6 16.2
	BaO	16.0	-	- 6.4
	Total	100.5	100.1	99.8 100.1

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The precursor material is a product which possesses a very high surface area and functions as an effective ion exchange medium, which is mixed with additives containing Ca, Ba, and Al in solution and mixed in a hot cell with high level nuclear waste (HLW) in the form of nitrate solution to form a thick homogeneous slurry at mixing stage 21. Typically up to about 20% by weight of the solid content of the slurry may comprise the high level wastes.

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The bellows container 20 is of a heat resisting steel such as an austenitic stainless steel, for example Sandvik grade 253MA which retains reasonable mechanical strength even at the elevated temperatures used in the process, although at these temperatures the container is relatively ductile. In the illustrated embodiment, a thin perforated metal liner 26 is located within the bellows container and the space between the liner and bellows wall is filled with zirconium oxide powder 27.

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A stainless steel cap 29 is used to seal the bellows container which is then placed between a pair of pistons 30 for a cold pressing operation which can increase the

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density of particulate material from about 25% of the theoretical maximum density to about 36%.

5 The next stage is illustrated in Figure 2 in which the cold pressed bellows containers 20 are fed in sequence into a vertical induction furnace 31, each bellows container being supported on a refractory disk 32, the lowermost refractory disk being supported by a retractable latch 33. Over a period of several hours the temperature gradually increases up to about 1200°C.

10 A first water cooled ram 34 having a top spiggot on which a refractory plate 35 is located is adapted to support and lower one at a time the bellows containers from the furnace for horizontal movement across a support table 36 to a pressing station having a second
15 water cooled ram 37 of similar form. Figure 2 shows the ram 37 both in the lower receiving position and also in the upwardly displaced pressing position inside a metal canister 38 mounted on a support 39 and having its top sealed and in abutment against a fixed refractory block
20 40, vertically displaceable induction heating coils 41 being provided outside the canister 38.

----- In the lower position, the left hand side of the section of a bellows container 20a is shown in its configuration before hot pressing and the right hand
25 side of the section shows a bellows container 20b as it would be after pressing. However, during the hot pressing, the bellows container slightly expands to become an interference fit within the canister 38 as shown by bellows 20c at the top of the canister 38.

30 The refractory plate 32 upon which each of the bellows containers is supported is removed after the pressing stage, the plate 32 being lowered on the water cooled ram 37 and then pushed onto a receiving table from which the plate can be recycled for further use.

35 Refractory plates will wear in use and must be replaced and an important advantage of the design

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illustrated in Figure 2 is a very simple and easily serviced arrangement made possible by the use of an upward pressing technique; this permits the replaceable refractory top plate 35 simply to sit on the head of each water cooled ram. Just a simple spigot and socket engagement is provided so that manipulators can readily remove a worn refractory plate and insert a new one.

Referring now to Figure 3, a practical embodiment of hot pressing apparatus is illustrated, the parts corresponding to the elements in Figure 2 being given the same reference numerals.

The apparatus further includes a base plate 42 with a set of upstanding tubular guides 43 on which sliding mounts for the support 39 and the induction furnace unit 41 are slidably mounted but adapted to be clamped at any selected position. The canister 38 is urged upwardly against the refractory block 40 which is supported by a top cap 44 adapted to be bolted to a top plate 45. Figure 3 shows the parts in slightly exploded view for clarity. The induction heating coil 41 is shown embedded within a refractory block 46 having a tapered bore, the drawing showing a greatly exaggerated taper and clearance between the bore and the container 38. The object of the tapered bore of the refractory block 46 is that any small expansion of the canister 38 causes the canister to be supported against further outward deformation by the refractory block but by virtue of the taper, the refractory block can be released by downward motion to the next location for the succeeding bellows container.

In the enlarged view of Figure 4, like parts are given like reference numerals, and the parts are shown in the assembled condition just prior to pressing.

In this embodiment the refractory block is assembled from refractory segments comprising outer refractory segments 46a of cylindrical profile and inner refractory

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elements 46b having an inner profile adapted to cooperate to form a tapered bore with circumferentially extending grooves for accommodating the turns of the induction coil 41. The refractory elements are
5 contained within a steel outer support cylinder 47 which absorbs the forces of any outward expansion applied by the canister 38.

Figure 5 shows in isometric view the refractory blocks 46a and 46b each having a semi-circular rib 46c
10 on one side thereof and a corresponding cavity 46d on the other side for interengagement purposes.

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WE CLAIM:

1. A method of containing and densifying particulate supply material comprising pouring the supply material (28) into a bellows container (20) of generally
5 cylindrical form with a side wall (27) including a bellows-like formation and of heat and decay resistant material, closing the bellows container with a lid (29), placing the bellows container on an upwardly
displaceable ram (37) having a heat resistant surface
10 portion (35), displacing the ram upwardly to press the bellows container against a fixed abutment (40), maintaining substantially axially pressure on the bellows container and maintaining a sufficiently
elevated temperature in the bellows container for a
15 sufficient length of time to cause densification of said particulate supply material in the bellows container and axial compression of the bellows container, the arrangement being such that deformation of the bellows container occurs in its axial direction, and removing
20 the bellows container after completion of the densification step.
2. A method as claimed in claim 1 wherein the supply material comprises radioactive waste and synthetic rock precursor material.
- 25 3. A method as claimed in claim 1 or claim 2, and wherein after closing the bellows container (20) with the lid (29), a preliminary pre-heating thereof is effected substantially without the application of axial pressure to the bellows container.
- 30 4. A method as claimed in claim 3, wherein the bellows container is of metal and said pre-heating is by induction heating (41) for a period of several hours to bring the bellows container (20) and its contents
substantially to a uniform temperature which is
35 substantially elevated but sufficiently below the temperature to be achieved in the subsequent hot

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pressing step such that the bellows container has significantly greater strength at the pre-heating temperature compared with the hot pressing temperature.

5 5. A method as claimed in any one of the preceding claims wherein said hot pressing step is conducted with the temperature of the bellows container and its contents brought to about 1200°C.

10 6. A method as claimed in any one of the preceding claims and wherein immediately after placing the lid (29) on the bellows container (20) an axial compression is applied to the bellows container, the temperature not exceeding 800°C.

15 7. A method as claimed in claim 6, and wherein the axial compression applied in the pressing step of claim 6 is at least 3000 lbs/sq. inch.

20 8. A method as claimed in any one of the preceding claims, and wherein the supply material has particle size not greater than 2 mm and is readily pourable, the supply material being produced by spraying a slurry into a rotary kiln (23).

25 9. A method as claimed in any one of the preceding claims, wherein said axial compression of the bellows container at elevated temperature is carried out by inserting the bellows container (20) on the displaceable ram (37) into a cylindrical cannister (38) having a downwardly-projecting open end and in which the bellows container is a loose fit before the hot compression step, the bellows container undergoing a small radial expansion during compression so as to be pressed into an interference fit with the interior wall of the cannister.

30 10. A method as claimed in claim 9, wherein the cylindrical cannister (38) is elongated and a series of bellows containers (20) are upwardly pressed one at a time into the cylindrical cannister, and when the
35 cannister has been substantially filled, the cannister is sealed and removed for storage.

11. A method as claimed as in claim 9 or claim 10, and including positioning a block of refractory material (46) having a slightly tapered bore over the cannister (38) during hot pressing of a bellows container (20) therein, the tapered bore, at its narrowest diameter, being at most a sliding fit over the cannister, whereby any tendency for outward deformation of the cannister is resisted by the refractory block, the refractory block (46) being moved downwardly relative to the cannister (38) after hot pressing of a bellows container.
12. A method as claimed in claim 11, and wherein the refractory block (46) has an induction heating coil (41) extending therethrough.
13. A method as claimed in any of the preceding claims, and including using a cylindrical partition (26) within the bellows container (20) and confining said particulate material to the zone within said cylindrical partition, an alternative supply material being located between said partition and the interior wall of the bellows container whereby said supply material is excluded from the convolutions of the wall of the bellows container (20).
14. Apparatus for encapsulating particulate supply material in bellows containers (20) within a cylindrical canister (38), the apparatus comprising means (24) for pouring the particulate material into a bellows container (20), means for sealing the bellows container with a lid (29), means (36) for moving bellows containers in sequence to a pressing station, a pressing station comprising an upwardly displaceable ram (37) for receiving a bellows container (20), means for mounting a cylindrical cannister (38) with an open end directed downwardly towards said ram, means (37) for upwardly pressing a bellows container supported on the ram into the cannister, upper refractory support means (40) to act as an abutment, heating means (41) for maintaining

an elevated temperature in said bellows container (20) whilst said pressure is applied to cause densification of said supply material in the bellows container and to expand slightly the bellows container to cause it to jam in the cannister, and the heating means (41) being adapted to provide heating in a series of zones within the container corresponding to a series of bellows containers inserted one below the other in series therein, the cannister being adapted by being removed and sealed when a series of bellows containers have been densified and secured therein.

15. Apparatus as claimed in claim 14, and wherein the apparatus includes a preheating station (31) adapted to bring the contents of the bellows containers (20) to a substantially uniform elevated temperature, and means (36) for transferring a preheated bellows container to said pressing station (37).

16. Apparatus as claimed in claim 15, and wherein said preheating station (31) comprises an upwardly extending cylindrical induction heated zone having refractory support means (32,33) for holding a stack of bellows containers in said zone, and means for handling the bellows containers whereby the bellows containers (20) are inserted cold into the top of the cylindrical zone and are removed after preheating at the bottom of the zone, said transferring means operating in a horizontal direction to transfer the preheated bellows container to said displaceable ram.

17. Apparatus claimed in any one of claims 14 to 16, wherein said displaceable ram (37) has a refractory facing (35) located on the head of the ram by a spiggot.

18. Apparatus as claimed in any one of claims 14 to 17 and further comprising compression means (30) for axially compressing substantially at ambient temperature each bellows container (20) after the bellows container has been sealed with the lid (29).

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19. Apparatus as claimed in any one of claims 14 to 18
and further comprising a vertically displaceable block
(46) of refractory material arranged to surround said
cannister (38), and the refractory block having a
5 slightly tapered bore which at its narrowest is no more
than a sliding fit over the cannister, the refractory
block being adapted to support the cannister against
radially outward expansion at the location at which a
bellows container is being compressed, the refractory
10 block subsequently being downwardly displaceable.

20. Apparatus as claimed in claim 19, and wherein said
refractory block incorporates turns of an induction
heating coil (41).

21. Apparatus as claimed in claim 20, wherein said
15 refractory block is formed from a series of interlocking
refractory segments (46a, 46b) located within an outer
cylindrical shell (47).

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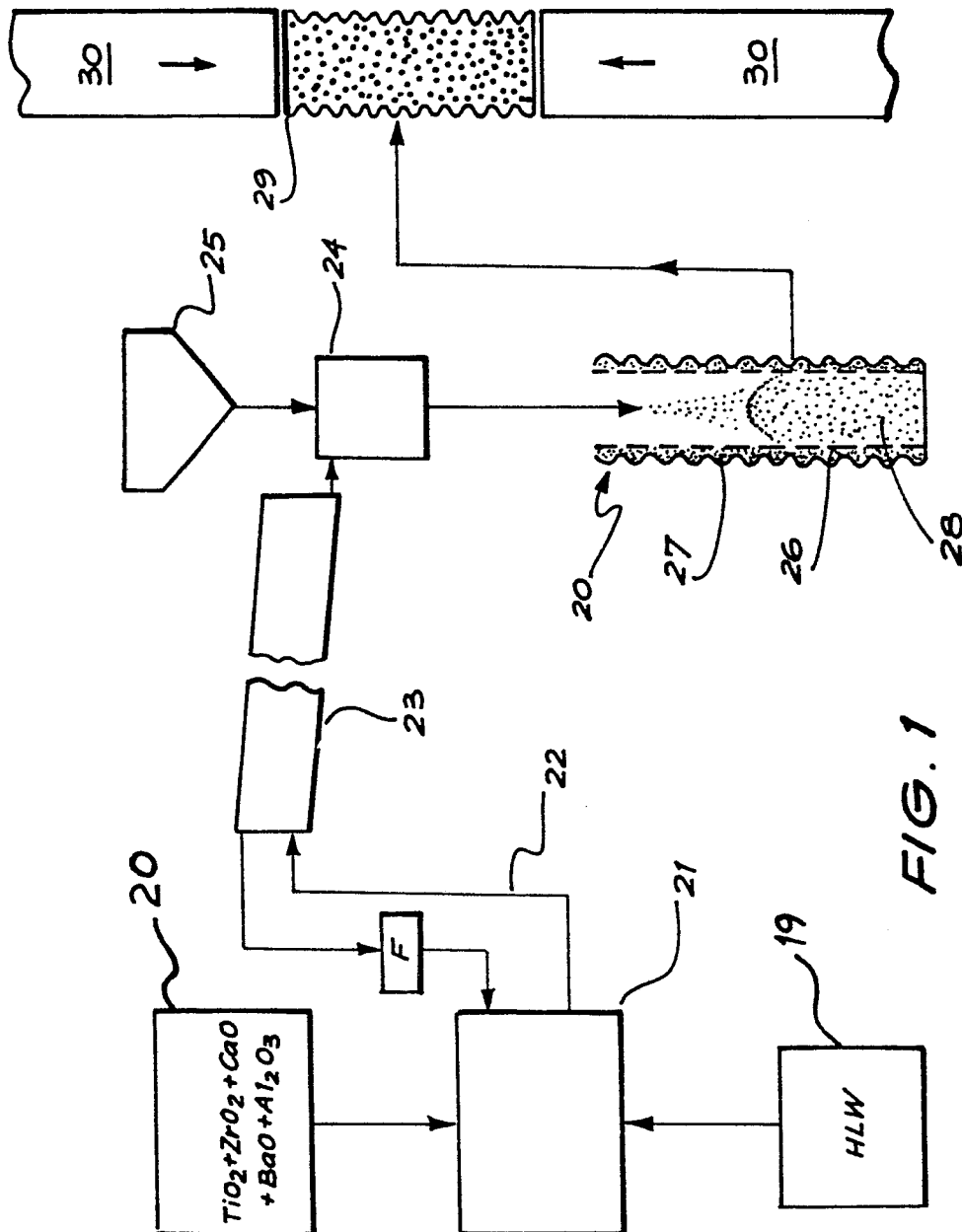


FIG. 1

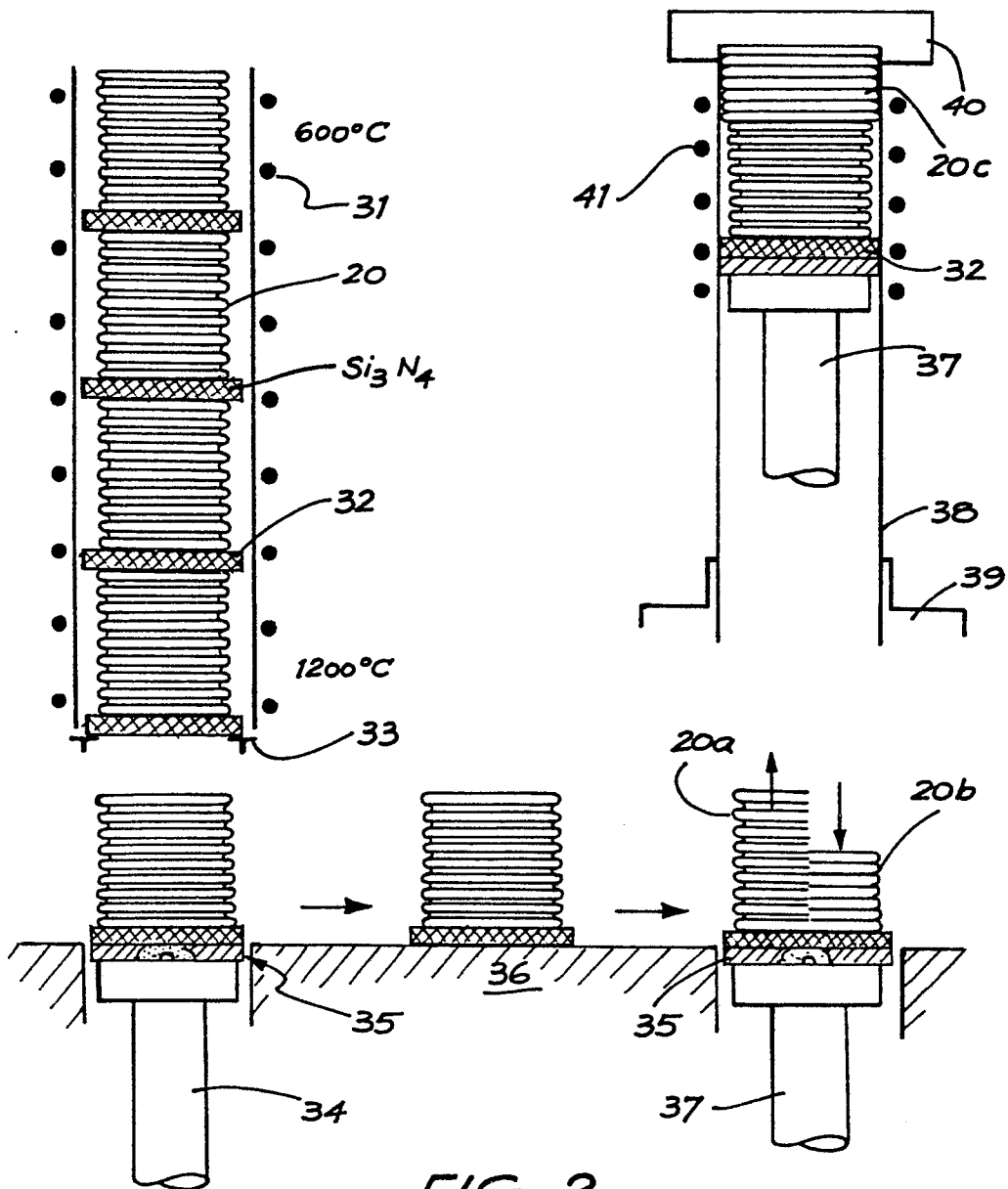


FIG. 2

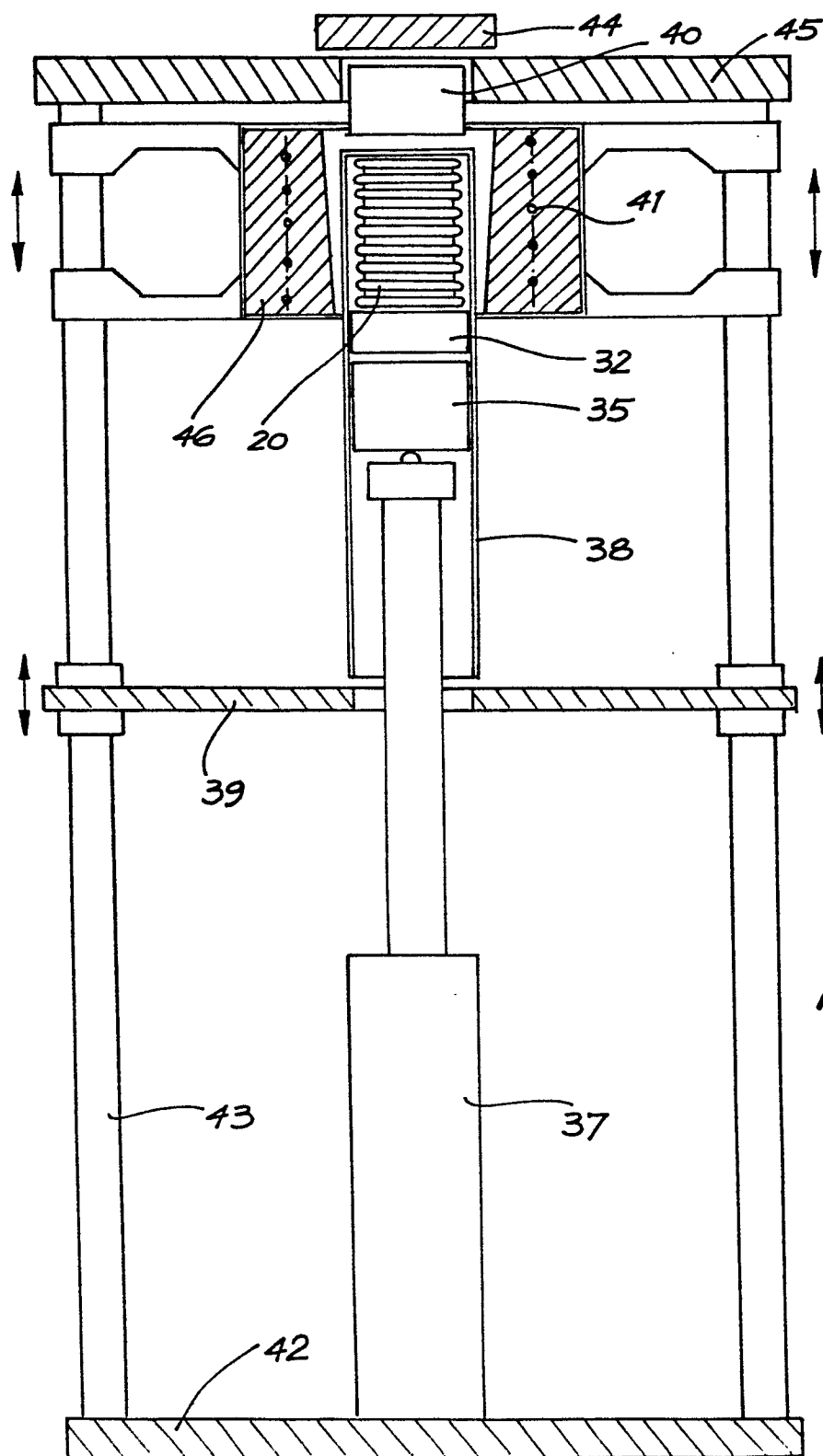
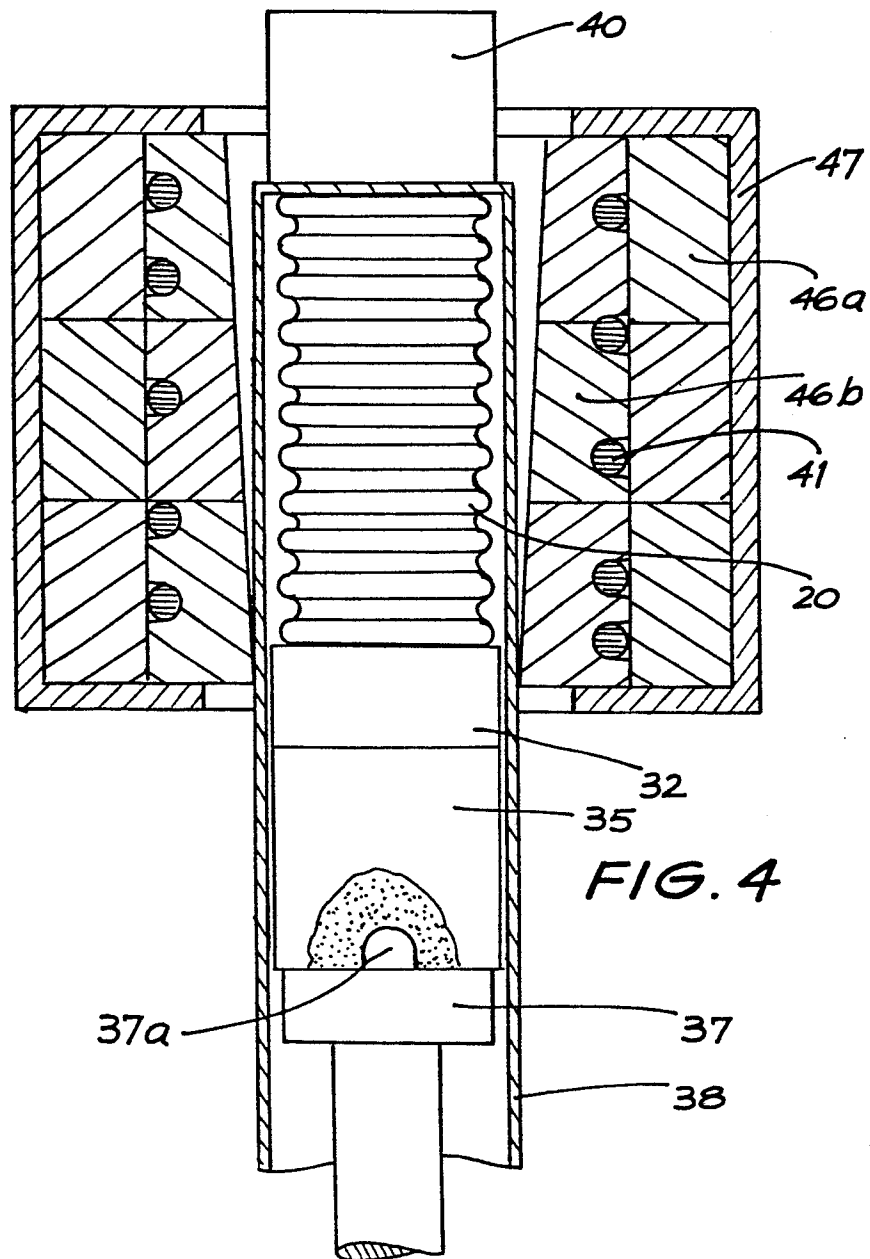


FIG. 3



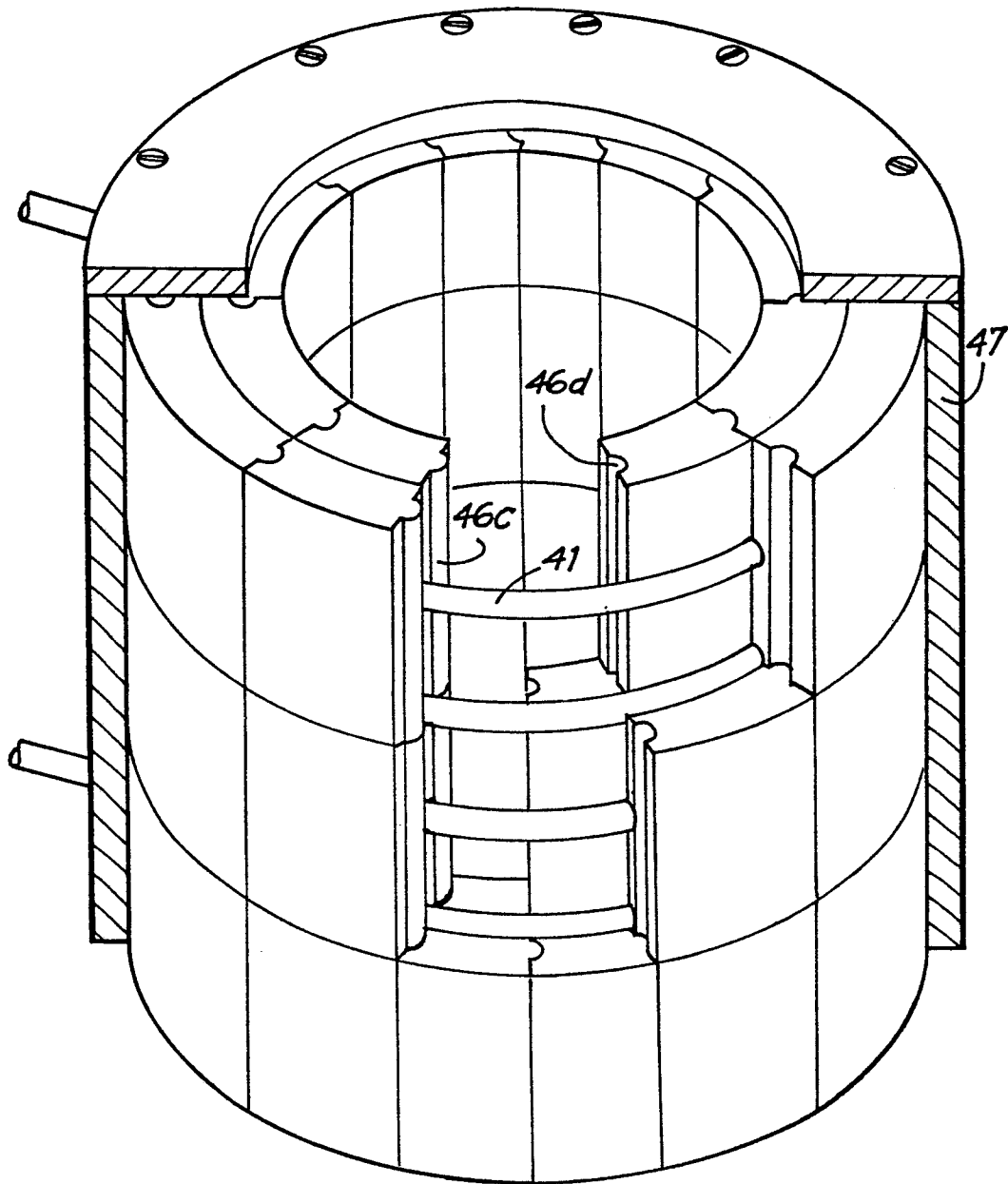


FIG. 5



European Patent
Office

EUROPEAN SEARCH REPORT

0102246

Application number

EP 83 30 4974

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. ³)
X	EP-A-0 044 692 (AUSTRALIAN ATOMIC ENERGY COMMISSION) * Claims *	1,2,5 7,8,9 10,11 12,14 19,20	G 21 F 9/34
X	EP-A-0 044 381 (ASEA) * Claims 1,2,4,9 *	1,6	
P,X	DE-A-3 129 852 (GNS) * Claims 1,4 *	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
			G 21 F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 17-11-1983	Examiner NICOLAS H.J.F.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	