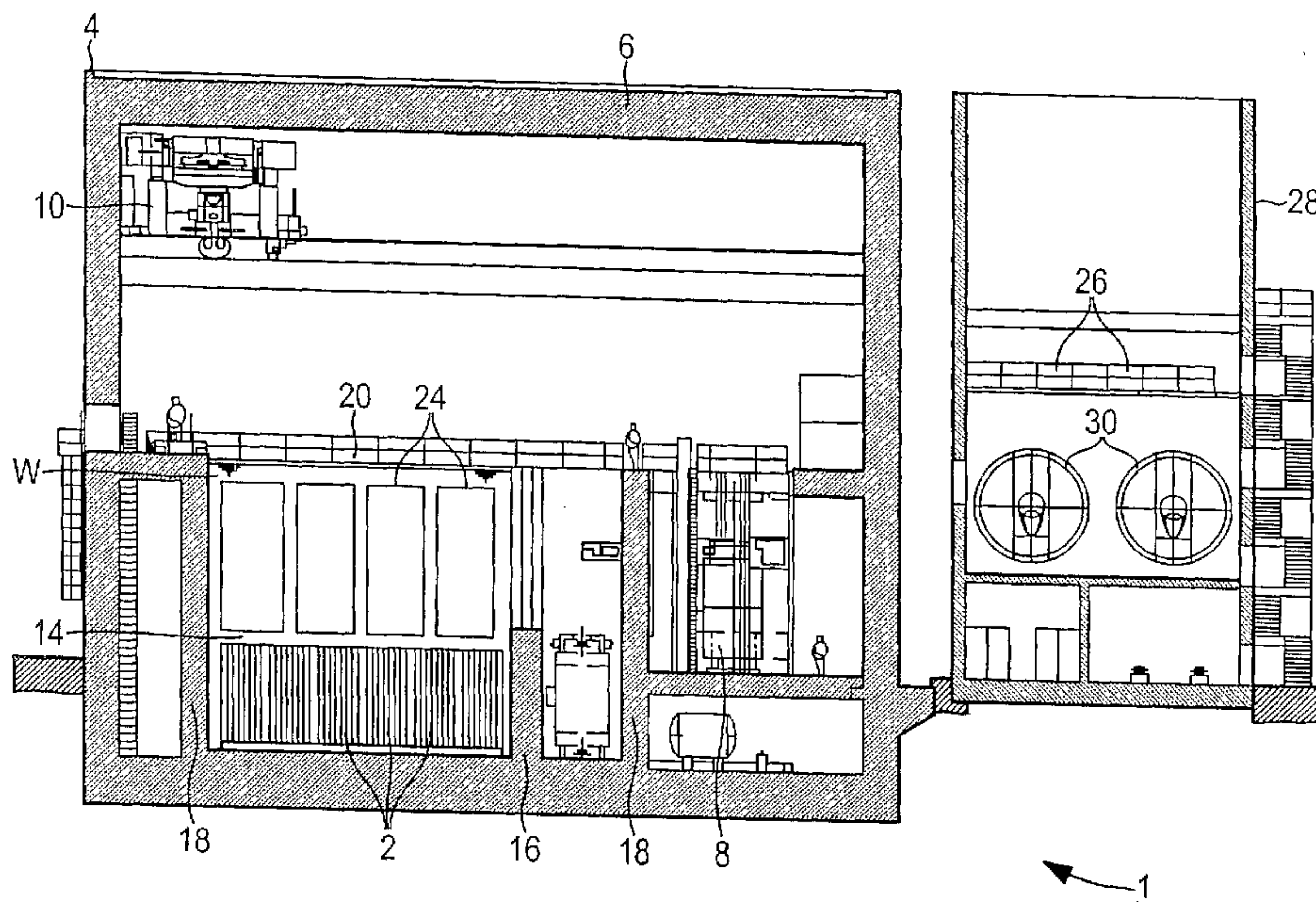




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(54) Titre : SYSTEME DE STOCKAGE INTERMEDIAIRE DESTINE A DES ELEMENTS DE COMBUSTIBLE
PROVENANT D'UNE CENTRALE NUCLEAIRE ET PROCEDE D'UTILISATION D'UN TEL SYSTEME DE
STOCKAGE INTERMEDIAIRE
 (54) Title: INTERMEDIATE STORAGE SYSTEM FOR FUEL ELEMENTS FROM A NUCLEAR FACILITY, AND METHOD
FOR OPERATING ONE SUCH INTERMEDIATE STORAGE SYSTEM



(57) Abrégé/Abstract:

The aim of the invention is to provide an intermediate storage system (1) for fuel elements (2) from a nuclear facility, which enables even fuel elements (2) with a comparatively high burn-up to be reliably intermediately stored, while maintaining high safety standards with especially low means. To this end, the intermediate storage system (1) is designed for wet storage of the fuel elements, and a wet storage reservoir (14) can be cooled down by means of an associated secondary cooling circuit (22) which can be operated in the natural circulation mode. During the operation of the intermediate storage system (1), a coolant supplied to the wet storage reservoir (14) for cooling the fuel elements (2) is cooled down by the secondary cooling circuit (22) which is operated in the natural circulation mode.

Abstract

The aim of the invention is to provide an intermediate storage system (1) for fuel elements (2) from a nuclear facility, which enables even fuel elements (2) with a comparatively high burn-up to be reliably intermediately stored, while maintaining high safety standards with especially low means. To this end, the intermediate storage system (1) is designed for wet storage of the fuel elements, and a wet storage reservoir (14) can be cooled down by means of an associated secondary cooling circuit (22) which can be operated in the natural circulation mode. During the operation of the intermediate storage system (1), a coolant supplied to the wet storage reservoir (14) for cooling the fuel elements (2) is cooled down by the secondary cooling circuit (22) which is operated in the natural circulation mode.

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**Intermediate storage system for fuel elements from a nuclear
facility and a method for operating such an intermediate
5 storage system**

The invention relates to an intermediate storage system for
fuel elements from a nuclear facility. It also relates to a
method for operating such an intermediate storage system.

10

In nuclear facilities, in particular in nuclear power plants,
nuclear fuel that is enclosed in gastight cladding tubes is
usually used. A number of such cladding tubes or fuel rods
containing the fuel respectively form a fuel element, which is
15 usually used inside a reactor pressure vessel. The
radioactive radiation inside the reactor pressure vessel
initiates nuclear reactions in the nuclear fuel, one effect of
which is that the fuel produces and consumes energy, and
another effect of which is that new radioactive radiation,
20 necessary for maintaining the nuclear reactions, is released.
Enriched uranium oxide or else reprocessed fuel, in particular
a mixed oxide of uranium and plutonium, is usually used here
as the nuclear fuel.

25 As soon as a fuel element consumes more neutrons during its
operation than are produced by the nuclear reaction in its
fuel, this fuel element is spent and is replaced by a fresh
fuel element. Such a spent fuel element may be sent for
reprocessing to recover still usable, fissile materials for
30 use in a new fuel element or alternatively may also be sent
for ultimate storage. Sending for ultimate storage usually
takes place in a three-stage process. In a first stage,
allowance is usually made for the fact that a fuel element
freshly removed from the reactor pressure vessel is still so

highly active that neither direct handling nor transport over land are readily feasible. In this stage, the fuel element is still kept under water until its residual activity and the afterheat thereby produced have largely subsided. This storage, which, depending on the state of the fuel element, may require a time of up to several years, is usually performed in what is known as a spent fuel pit directly in the nuclear power plant.

10 In a second stage, what is known as intermediate storage of the spent fuel elements then usually takes place. The intermediate storage is provided here to allow the residual activity and the afterheat of the respective fuel element to subside to the extent that subsequent transfer into an ultimate storage facility is made possible without an excessive amount of heat being introduced. In intermediate storage, the fuel elements are usually transferred into specially designed transporting and storing containers such as those known for example in Germany by the name "Castor". In such containers, the fuel elements are suitably encapsulated and shielded from the environment, it being possible for a comparatively large number of such transporting and storing containers to be brought together in a central intermediate storage facility. Such an intermediate storage concept is also referred to as "dry container storage".

Once intermediate storage has taken place, i.e. usually after approximately 50 to 100 years have elapsed, and after the residual activity and afterheat of the respective fuel element have subsided to a value below a limit value permissible for transfer into an ultimate storage facility, the fuel elements are transferred into an assigned ultimate storage facility in a third stage. This ultimate storage facility may for example take the form of mineshafts.

The concept that is usually used at present for transferring fuel elements to ultimate storage is essentially designed in its basic principles for standard use of fuel elements in a reprocessing cycle. In such operation of fuel elements in a reprocessing cycle, use is made of the effect that the conversion of the nuclear fuel also includes production of new fissile material. This can be recovered from the fuel by suitable separation and used for its part as fuel for a new fuel element. However, it must be taken into account in this respect that, at the beginning of what is known as the fuel element cycle, that is at the beginning of the typical service life of the respective fuel element, the rate of generation of the fuel additionally obtained as a result of the nuclear reactions is greater than its depletion as a result of the nuclear reactions that are in progress. However, as the operating time of the fuel element proceeds, this effect is shifted increasingly to the detriment of the rate of generation of the additional fissile material, until finally the fuel generated during use of the fuel element is also depleted to a greater extent by the nuclear reactions than it is generated by them. In the case of a concept for the use of the fuel elements based on reprocessing, only a comparatively short operating time of the fuel elements is therefore envisaged, so that a comparatively large amount of newly generated fuel can still be recovered in the course of reprocessing. For this reason, fuel elements intended for reprocessing which have an original content of for example approximately 3.5 to 4% of fissile material in their fuel are usually used for an average burnup of approximately 40,000 MW/dtU. As soon as a fuel element has reached such a level of burnup, it is removed from the reactor pressure vessel and subsequently reprocessed to recover the newly generated fissile material.

Alternatively, however, it may be desirable when using a fuel element to dispense with reprocessing of the fuel and instead send the fuel element for ultimate storage immediately after it has been used once. In this case, it is not necessary to include the ever-increasing depletion of the newly generated fissile material over time in considerations for the basic design of the fuel element, and in particular for specifying the operating time for the fuel element. Such fuel elements that are not intended for integration in a reprocessing cycle can therefore be designed for example with an initial concentration of approximately 5% of fissile material, removal from the reactor pressure vessel being envisaged only after burnup of for example approximately 60,000 MW/dtU. Consequently, without taking the boundary conditions necessary for a reprocessing cycle into account, comparatively more intensive use of the nuclear fuel is possible with immediate transfer of the fuel elements to an ultimate storage facility.

With regard to the preparation of such an intensely used fuel element for ultimate storage, however, additional problems arise with respect to the handling of such fuel elements. This is so because, as a result of the comparatively high burnup, such a fuel element has a particularly high residual activity and also a particularly high afterheat. These parameters are also significant, inter alia, for the intermediate storage of the fuel elements. This is so because, in the case of dry intermediate storage, that is in the case of intermediate storage of the fuel elements in transporting and storing containers intended for them, characteristic fuel element parameters, such as for example the cladding tube temperature and the globally dissipated radiation values, are limiting factors for the packing density and loading when charging the containers with the fuel

elements. Specifically when handling fuel elements with comparatively high burnup and correspondingly increased afterheat, the use of customary transporting and storing containers is therefore only possible by drastically reducing
5 the density with which fuel elements are loaded. Such intermediate storage consequently involves great effort and is also cost-intensive.

The invention is therefore based on the object of providing an
10 intermediate storage system for fuel elements from a nuclear facility which, while maintaining high standards of safety, allows reliable intermediate storage even of fuel elements with comparatively high burnup with particularly little effort and in a favorable way. Furthermore, a method which is
15 particularly suitable for operating such an intermediate storage system is to be provided.

With respect to the intermediate storage system, this object is achieved according to the invention by a wet storage pit,
20 the interior space of which can be re-cooled by means of an assigned secondary coolant circuit which can be operated with natural circulation.

The invention is based in this respect on the idea that an
25 intermediate storage system designed specifically also for the processing of fuel elements with comparatively high burnup should be especially suitable for being subjected to the comparatively high afterheat to be expected in this case. In order to make this possible along with an appropriately high
30 packing or storage density of the fuel elements and also while maintaining extremely high standards of safety, while departing from the customary concept of dry intermediate storage, particularly intensive cooling should be provided, even of individual fuel elements. This is made possible by

designing the intermediate storage system for a wet storage concept. In order to ensure particularly reliable operation in the case of such a wet storage concept, even when the loading with fuel elements changes, the cooling medium
5 provided for the fuel elements should for its part be re-coolable, so that an approximately constant coolant temperature can be set in the actual storage space for the fuel elements, that is the wet storage pit. Such a system can also be operated with particularly low maintenance intensity
10 and particularly reliably even in the case of long operating times, by the re-cooling being designed in the manner of a passive system, largely dispensing with active components. For this purpose, the secondary coolant circuit provided for the re-cooling can be operated in natural circulation to
15 maintain a re-cooling circulation.

A system which can be operated in natural circulation in this case means a heat exchanger circuit in which the circulation of a cooling medium is maintained by means of a component that
20 emits heat, or for its part is re-cooled, arranged at a higher geodetic level than a component that absorbs heat.

The re-cooling of the cooling medium provided for the fuel elements, which is kept in the wet storage pit, in particular
25 cooling water, takes place in this case by means of introducing heat into the secondary cooling medium carried in the secondary circuit. To make this possible, a number of heat exchangers arranged in the wet storage pit are advantageously connected into the secondary coolant circuit.
30 In this case, a particularly simple and easy-to-maintain arrangement can be achieved in an advantageous development by suspending the heat exchangers in the wet storage pit. This type of construction, that is the use of heat exchangers or coolers suspended in the wet storage pit, makes particularly

favorable fault management possible, one reason being because of the then upper-lying connections for the supply and removal of the secondary cooling medium, since, for example in the event of a leakage in the secondary coolant circuit, it is
5 easily possible to replace the feeding to the suspended cooler by using for example a firefighting water connection. In the case of this type of construction, reliable separation of the possibly slightly contaminated pit water from the secondary cooling medium is still ensured.

10

In order to be able to re-cool, for its part, the secondary cooling medium circulating in the secondary coolant circuit reliably, and consequently maintain especially a constant temperature level in the wet storage pit, in a further
15 advantageous configuration the heat exchangers are connected by means of the secondary coolant circuit to a number of re-cooling elements. To reliably maintain the natural circulation, the re-cooling elements are in this case advantageously positioned above the heat exchangers in the wet
20 storage pit, in a particularly advantageous configuration approximately five to ten meters above the heat exchangers.

To maintain high standards of safety, the wet storage pit is advantageously safeguarded especially from leakages, even in
25 the case of a pipe rupture. For this purpose, the wet storage pit advantageously has a continuous pit wall, dispensing entirely with perforations or pipe apertures, in particular a concrete pit wall. Such a type of construction in an integral structure is especially helped by the use of the heat
30 exchangers suspended in the wet storage pit, since they can be fed with secondary cooling medium from an area above the wet storage pit, and consequently without apertures through the pit wall. Furthermore, such a type of construction in an integral structure is particularly helped by use of a

circulating cleaning system for the cooling medium kept in the wet storage pit. Such a circulating cleaning system in which the cooling medium is circulated via cleaning filters by means of a number of circulating pumps, makes it possible to
5 maintain a consistently high quality of the cooling medium, without perforation of the pit being required for this.

A particularly failsafe and reliable configuration of the intermediate storage system can be achieved by the cooling
10 medium that is kept in the wet storage pit for the fuel elements being re-coolable by means of a plurality of elements which can be operated in a redundant manner and independently of one another. For this purpose, the secondary coolant circuit advantageously comprises a number of sections which
15 can be operated independently of one another and are connected in parallel on the secondary coolant side.

With respect to the method, the stated object is achieved by a cooling medium that is kept in a wet storage pit for cooling
20 the fuel elements being re-cooled by means of a secondary coolant circuit which is operated in natural circulation. The circulation in the secondary coolant circuit is in this case ensured in a particularly simple and reliable way by the natural circulation advantageously being maintained by means
25 of a re-cooling element which is positioned at a higher level in comparison with a heat exchanger heated by the cooling medium.

Specifically in the case of demand-based handling of fuel
30 elements with a comparatively high burnup of up to approximately 60,000 MW/dtU, an average temperature of approximately 40°C to approximately 45°C is advantageously set for the cooling medium kept in the wet storage pit.

The advantages achieved with the invention are, in particular, that designing the intermediate storage system for a wet storage concept also allows fuel elements with comparatively high afterheat to be intermediately stored reliably with a particularly high loading or packing density. Specifically when water is used as the primary coolant for the fuel elements in the wet storage pit, the storage conditions there correspond especially to those in the spent fuel pit, so that a high degree of compatibility in the operating conditions can be achieved for these two stages of the disposal concept. Since, in the case of such an intermediate storage concept, loading or unloading work only has to be carried out at the wet storage pit for a very small amount of time on the basis of the design, the intermediate storage system can be designed for particularly low maintenance and operating effort. This is particularly helped by the essentially passive design of the re-cooling system, in which the secondary cooling medium is kept in natural circulation and consequently there is largely no need for active components, even though particularly high operational safety is ensured.

The use of suspended coolers, that is heat exchangers suspended in the wet storage pit and connected into the secondary coolant circuit, means that an integral structure of the pit wall of the wet storage pit, that is a structure without perforations or apertures, can additionally be achieved, so that the wet storage pit is safeguarded particularly well against leakages. The fact that the intermediate storage system can be operated easily and with low maintenance also makes it possible, in the manner of a decentralized overall structure, to dispense with an intermediate storage facility of large dimensions and provide a large number of comparatively small intermediate storage facilities, which may be arranged for example in the direct

spatial vicinity of the respective nuclear facility. Consequently, the transporting distances to be covered are particularly short.

5 An exemplary embodiment of the invention is explained in more detail on the basis of a drawing, in which:

Figure 1 shows an intermediate storage system for fuel elements in a plan view of its outline,

10

Figure 2 shows the intermediate storage system according to Figure 1 as a detail in longitudinal section, and

15 Figure 3 shows a connection diagram of a re-cooling system for the intermediate storage system.

The same parts are provided with the same reference numerals in all the figures.

20 The intermediate storage system 1 shown in a plan view in Figure 1 and as a detail in longitudinal section in Figure 2 is intended for demand-based intermediate storage of fuel elements 2, which are merely indicated in Figure 1. For this purpose, the intermediate storage system 1 comprises a main building 4, in which storage positions for the fuel elements 2
25 are provided. The main building 4 is enclosed by a closed, structurally high-strength encasement 6, for example made of concrete, which is designed with regard to its strength, choice of material and wall thickness in such a way that it
30 withstands even considerable external effects, such as for example an aircraft crash, intact or at least virtually undamaged.

Arranged inside the main building 4 are a number of

conventional operating or manipulating elements 8, which are designed for the demand-based handling of individual fuel elements 2. Furthermore, a movable carrier crane 10, which permits demand-based repositioning of fuel elements 2 within the main building 4, is provided in the main building 4. Outside the encasement 6, the main building 4 is also provided in the manner of an extension with a system wing 12 in which not only technical operating systems but also a stairwell and other service components are arranged.

10

The intermediate storage system 1 is especially designed also to allow it to be used for those fuel elements 2 which are designed from their operational concept not for a reprocessing cycle but rather for transfer to an ultimate storage facility after being used only once. Such fuel elements 2 may be correspondingly designed already with regard to the composition of their nuclear fuel, it being possible in particular to provide a content of for example up to 5% of fissile material in the nuclear fuel. Use of such fuel elements 2 may be envisaged up to a comparatively high burnup of for example approximately 60,000 MW/dtU. The intermediate storage system 1 is now designed in such a way that even fuel elements 2 with such high burnup values and correspondingly high afterheat can be intermediately stored reliably and safely under comparatively favorable conditions with particularly little effort.

For this purpose, the intermediate storage system 1 is designed on the basis of the concept of a wet intermediate storage facility. The storage positions for the fuel elements 2 to be intermediately stored are in this case located in the intermediate storage system 1 in a wet storage pit 14 arranged inside the main building 4. The wet storage pit 14 is formed by a high-strength, structurally very load-resistant pit basin

16, which is bounded in its lateral regions by a continuous concrete pit wall 18. The concrete pit wall 18 is in this case formed such that it is continuous in the sense that a continuously integral wall structure is obtained, dispensing
5 with perforations or pipe apertures.

Inside the wet storage pit 14, the intermediate storage positions for the fuel elements 2 are provided. When it is used as an intermediate storage facility, the wet storage pit
10 14 is filled with cooling water W as cooling medium for the fuel elements 2 up to a design filling level indicated by the line 20 in Figure 2. The cooling of the fuel elements 2 consequently takes place by direct heat exchange with the cooling water W kept in the wet storage pit. A constantly
15 effective cooling action is ensured in this case by standing waves forming in the wet storage pit 14 and the associated local exchange of media.

The interior space of the wet storage pit 14, and consequently
20 the cooling water W kept in it, can for its part be re-cooled by means of a secondary coolant circuit 22. The secondary coolant circuit 22 is in this case designed for particularly little maintenance effort with high operational safety while, as an essentially passive system, largely dispensing with
25 active components such as pumps for example. For this purpose, the secondary coolant circuit 22 can be operated in natural circulation. For the actual re-cooling of the cooling water W, a number of heat exchangers 24 arranged in the wet storage pit 14 are connected into the secondary coolant
30 circuit 22. The heat exchangers 24 are in this case suspended in the wet storage pit 14, so that no pipe apertures through the pit wall 18 are required for their reliable operation. The suspended type of construction of the heat exchangers 24 also ensures particularly high operational safety, especially

since, even in the event of a fault involving losses through leakage, additional secondary cooling water can be fed into the heat exchangers 24 in an especially simple way, for example by means of a firefighting water connection.

5

The heat exchangers 24 are, for their part, connected to a number of re-cooling elements 26 via the secondary coolant circuit. The re-cooling elements 26 are in this case arranged in cooling towers 28 positioned outside the actual main building 4. By means of the secondary coolant circuit 22, consequently, the heat absorbed by the cooling water W from the fuel elements 2 is taken up via the heat exchangers 24 and transported further to the re-cooling elements 26. The re-cooling elements 26, which may be designed in particular as air heat exchangers, then give off the heat to the ambient atmosphere in the cooling towers 28. As a special safeguard even against possible aircraft crashes, the cooling towers 28 are positioned comparatively far apart from one another, so that in any event at least 50% of the cooling capacity is still available.

To reliably maintain a circulation of the secondary coolant in the secondary coolant circuit 22 by natural circulation, the re-cooling elements are positioned approximately five to ten meters higher than the heat exchangers 24. Consequently, the circulation in the secondary coolant circuit 22 is maintained already by the differences in the heating applied to the heat exchangers 24 on the one hand and the re-cooling elements 26 on the other hand, and also by the different geodetic height of the heat exchangers 24 and the re-cooling elements 26, without further active intervention in the circulation behavior of the secondary coolant circuit 22 being necessary. To assist or intensify the re-cooling of the re-cooling

elements 26, the cooling towers 28 are provided with a number of pneumatic conveyors 30 or fans.

For particularly high operational safety, the secondary coolant circuit 22 is configured in a number of sections, as the connection diagram according to Figure 3 reveals in particular. For this purpose, the secondary coolant circuit 22 comprises a number of sections 32 which can be operated independently of one another and are connected in parallel on the secondary coolant side, each section 32 in the exemplary embodiment respectively connecting two of the heat exchangers 24 that are arranged in the wet storage pit 14 on the secondary coolant side to an assigned re-cooling element 26.

On account of being designed on the basis of the wet storage concept, the intermediate storage system 1 can be operated particularly favorably and with little maintenance even when it is charged with fuel elements 2 with comparatively high burnup. Among the factors helping to achieve high operational safety is that only secondary coolant, which does not come directly into contact with the fuel elements 2, is circulated in the secondary coolant circuit 22. Consequently, contaminated coolant is unlikely to escape even in the event of pipe leakages.

List of designations

- 1 intermediate storage system
- 2 fuel elements
- 5 4 main building
- 6 encasement
- 8 manipulating elements
- 10 carrier crane
- 12 system wing
- 10 14 wet storage pit
- 16 pit basin
- 18 concrete pit wall
- 20 line
- 22 secondary circuit
- 15 24 heat exchangers
- 26 re-cooling elements
- 28 cooling towers
- 30 pneumatic conveyors
- 32 section
- 20
- W cooling water

Claims

1. An intermediate storage system (1) for fuel elements (2) from a nuclear facility, with a wet storage pit (14), the interior space of which can be re-cooled by means of an assigned secondary coolant circuit (22) which can be operated with natural circulation and into which a number of heat exchangers (24) arranged in the wet storage pit (14) are connected, the heat exchangers (24) being suspended in the wet storage pit (14), and the heat exchangers (24) being connected by means of the secondary coolant circuit (22) to a number of re-cooling elements (26) arranged above the design filling level of the wet storage pit (14), characterized in that the re-cooling element or elements (26) is or are positioned approximately 5 to 10 m above the respective heat exchanger (24).

2. The intermediate storage system (1) as claimed in claim 1, in which an average temperature of approximately 40°C to 45°C is set for the cooling medium kept in the wet storage pit (14).

3. The intermediate storage system (1) as claimed in claim 1 or 2, characterized in that additional or replacement feeding of a heat exchanger is made possible.

4. The intermediate storage system (1) as claimed in claim 3, characterized in that the feeding is made possible by means of a firefighting water connection.

5. The intermediate storage system (1) as claimed in one of claims 1 to 4, the wet storage pit (14) of which has a continuous pit wall, in particular a concrete pit wall (18).

6. The intermediate storage system (1) as claimed in claim 5, in which a circulating cleaning system is provided for the cooling medium kept in the wet storage pit (14).

5 7. The intermediate storage system (1) as claimed in one of claims 1 to 6, the secondary coolant circuit (22) of which comprises a number of sections (32) which can be operated independently of one another and are connected in parallel on the secondary coolant side.

10 8. The intermediate storage system (1) as claimed in claim 7, in which each section (32) respectively connects two heat exchangers (24) on the secondary coolant side to an assigned re-cooling element (26).

15 9. The intermediate storage system (1) as claimed in one of the preceding claims, in which a re-cooling element (26) takes the form of an air heat exchanger.

20 10. The intermediate storage system (1) as claimed in claim 9, in which re-cooling elements (26) are arranged in at least two cooling towers (28).

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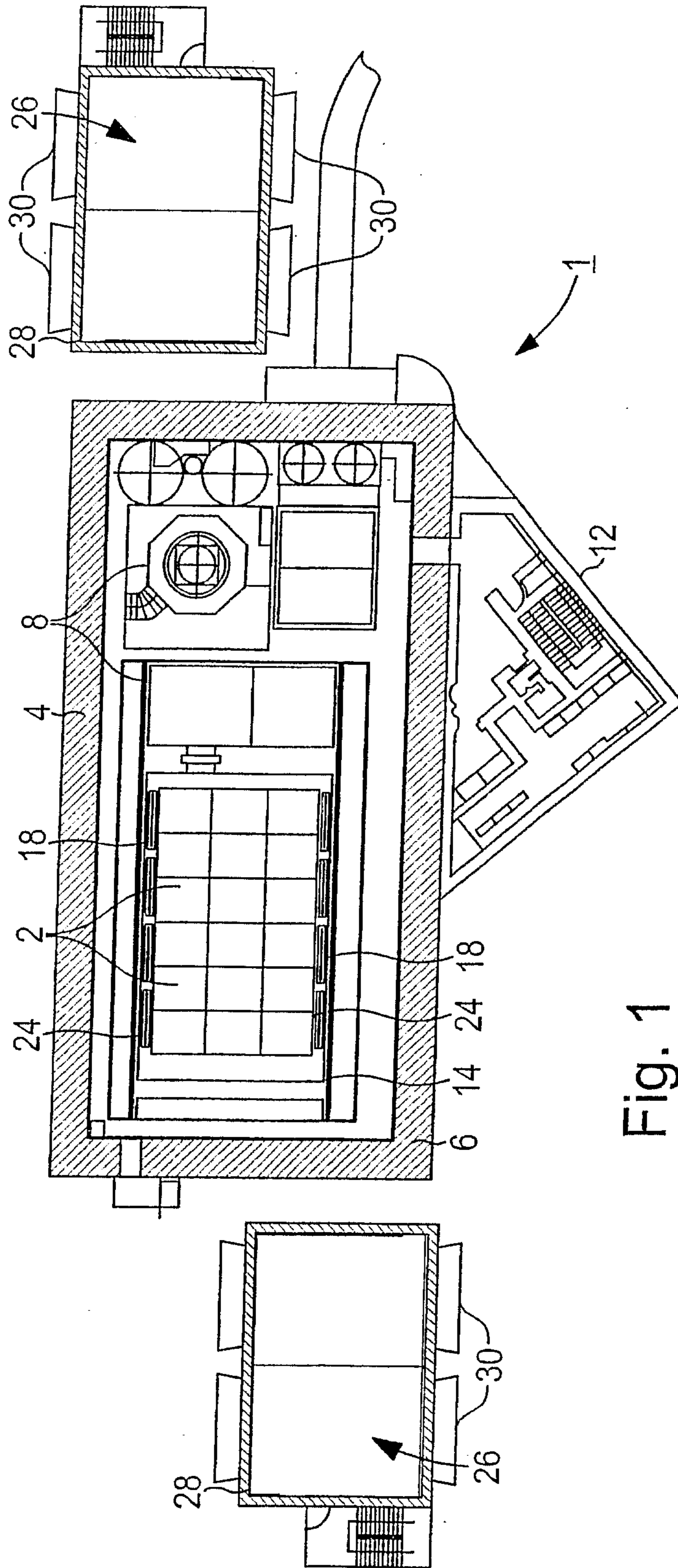


Fig. 1

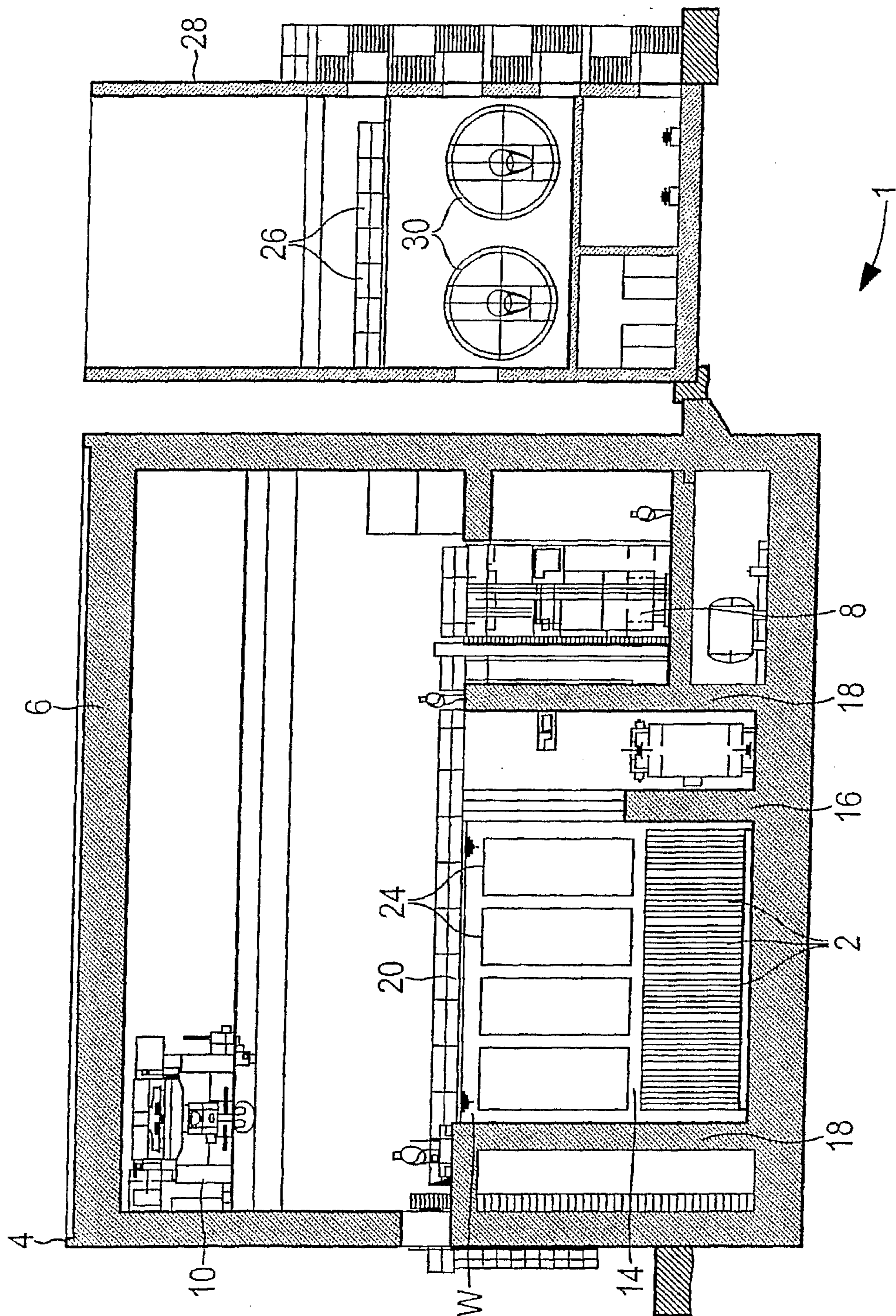


Fig. 2

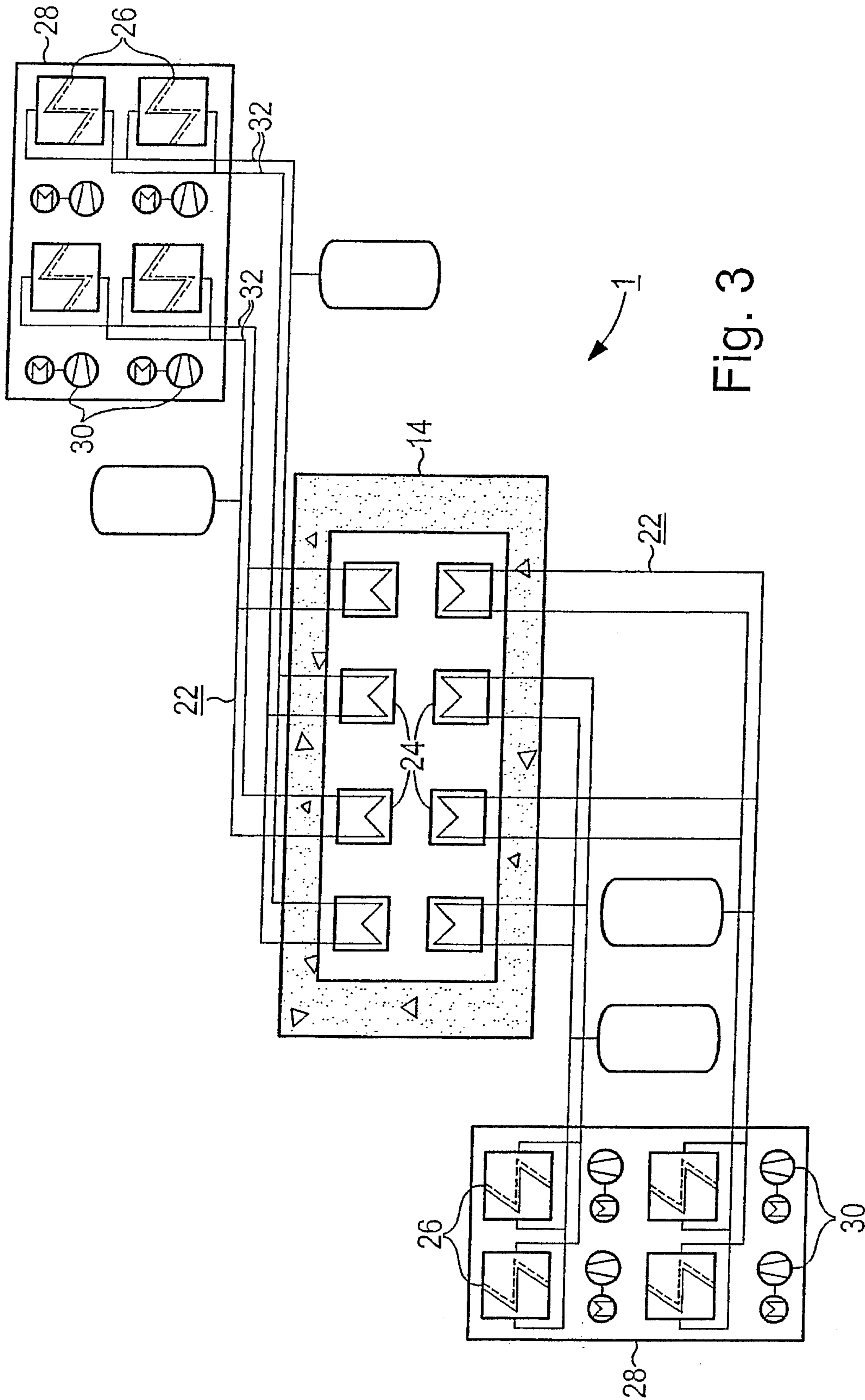


Fig. 3

