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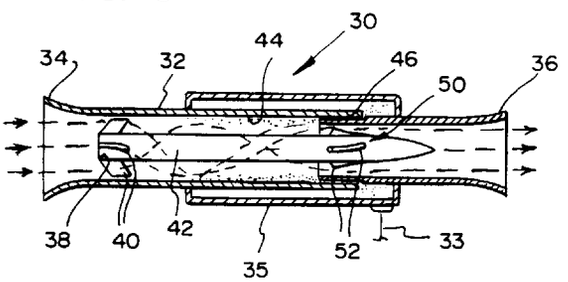
(54) Moisture separation in turbine interstage steam flow.

(57) Any moisture present in a steam flow outletting from a high pressure steam turbine and before that flow is passed to the inlet of a low pressure turbine, is removed by passing the flow through a high velocity separator [30], this separator being a type in which at entry thereto vanes [40] cause vortex-like swirling of the steam flow so that moisture therein is centrifuged against an inner wall surface [44] of a separator housing from thence being carried forward in flow direction to outlet from the housing via a skimmer slot [46] in the housing wall located intermediate the housing ends. The steam flow from which the moisture has been separated, passes to an outlet end of the housing [36] but before making its exit therefrom passes through straightening vanes [52] which reorient the flow from vortex-like swirling to longitudinal straight line course thereof.

FIG. 5



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BACKGROUND OF THE INVENTION

The present invention relates to separation of moisture present in a steam flow exhausted from a high pressure turbine unit to a low pressure turbine unit, and, more particularly, to employement of a high velocity moisture separator for that purpose in place of heretofore used low velocity separation units which are of needless greater bulk and weight than the high velocity separator.

It is known to remove any moisture as may be present therein from the steam hexaust of a high pressure steam turbine before that steam is delivered to a low or intermediate pressure steam turbine, this being done to prevent possibility of damage to the turbine blades from moisture produced incident the extracting (as useful work driving the turbine) of heat from dry high pressure steam. This moisture presence can be dealt by passing the steam following outlet from the high pressure turbine and before it enters a lower pressure turbine unit, through a mechanical moisture separator, e.g., a chevron blade separator wherein moisture levels of as much as about 97% can be achieved. Optionally, the thus-treated steam can be passed through one or more stages of a reheat heat exchanger before inletting to a subsequent turbine stage.

The prior used moisture separators operate with very low steam velocity and consequently, the separator structure must be quite large. Illustrative of the last noted point is the arrangement in a nuclear plant wherein for use with a SBWR reactor system, two moisture separators are used, these being generally cylindrical structure 11 feet in diameter and 60 feet long. Further, these structures are situated in the operating floor requiring significant floor space, and additionally are shielded in concrete so that all-in-all, considerable lost space and need for special and reinforced structural mounting attends their employment in the system.

A moisture separator type which handles separation with high steam velocity is known, such for example, being used by Electricite De France in conjunction with moisture removal from steam to prevent system component erosion and corrosion related steam flow through these components.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide a steam turbine system with improved moisture separator means for removing moisture present in a steam flow exhausting from a high pressure turbine unit and being passed to a lower pressure turbine unit which overcomes the drawbacks of the prior art.

It is a feature of the invention to provide a moisture separator means of considerably smaller size and lesser weight than moisture separations used previously for the same purpose.

It is further feature of the invention to provide a moisture separator means particularly suited to use in a nuclear system wherein because of smaller size and weight than prior used separators, such can be located outside the turbine unit operating space thus allowing for more economical space utilization within the operating space.

Briefly stated, there is provided moisture removal from a steam flow outletting a high pressure turbine and before it inlets a low pressure turbine, effected by passing the flow through a high velocity moisture separator of a type wherein vanes at an entry location of the separator cause vortex-like swirling of the steam flow to produce centrifugal displacement of moisture therefom to impact against a separator inner housing wall along which it can carry to outlet from the housing at a skimmer slot formed in the housing wall. The steam flow from which moisture has been separated before exiting the housing passes through straightening vanes which reorient the steam flow to a longitudinal straight line flow course.

In accordance with these and other objects of the invention, there is provided in a steam turbine system including a high pressure steam turbine having an inlet flow thereto of dry, high pressure steam drivingly rotating a rotor of the turbine the pressure of which steam reduces during passage through the turbine so that at outlet from the high pressure turbine the steam is at low pressure, there being a low pressure turbine which receives this low pressure steam for passage therethrough for driving the low pressure turbine rotor to extract further useful work from the steam, at least one moisture separator intervening the high pressure turbine steam outlet and an inlet to the low pressure turbine, the moisture separator being operable to remove substantially all of any moisture as may be present in steam flow between the high and low pressure turbines, the separator being a type that includes an elongated housing with an entry end and a discharge end, there being turning vanes proximal the housing entry end for vortexing an incoming straight line flow of moisture-containing steam to a swirling flow thereby to induce centrifugal force within the flow that displaces the moisture radially of the flow course to impingement with an inner wall surface of the housing so that carry forward of the moisture within the housing is along the inner wall surface to exit therefom at a skimmer slot in the housing wall, other vanes being provided near the skimmer slot and oriented to convert the substantially moisture-free steam flow to straight line flow thereof from the separator discharge end.

According to other features of the invention, at least one additional moisture separator can be embodied in line with the first to enhance the extend to which moisture separation is achieved. Additionally, the moisture separators will be such as to have a

length/width ratio of about 2, and exhibit bulk and weight considerably less than in prior used low velocity separators. In a generally cylindrically configured separator, the housing diameter can be about 6 feet, and the length about 12 feet.

The invention also provides methodology for passing an interstage steam flow through a housing to induce a vortex-like swirling flow therein to throw or impinge the moisture against the housing from thence to be carried along such inner wall and exit from the housing, the now "dry" steam being reoriented in its flow to straight line before leaving the housing.

The above, and other objects, features and advantages of the present invention will become apparent from the following description read in conjunction with the accompanying drawings, in which like reference numerals designate the same elements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a fragmentary plan depiction of a prior art nuclear system turbine unit operating space, showing an arrangement of high and low pressure turbine units and the moisture separators used for separating moisture from the steam flowing as exhaust from the high pressure turbine to the low pressure turbine.

FIGURE 2 is a fragmentary end elevational view corresponding to the showing given in FIGURE 1 and illustrating the heavy concrete enclosures which must be provided in the operating space to house the moisture separators.

FIGURE 3 is a fragmentary elevational view of a moisture separator installation in a nuclear system provided in accordance with and for purposes as given by the present invention.

FIGURE 4 is a plan schematic depiction of the FIGURE 3 installation, and

FIGURE 5 is a longitudinal half-section of one of the high velocity moisture separators employed with the present invention, some parts being shown in full, the FIGURE depicting the manner in which the separator functions to remove moisture from steam.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is described herein in connection with a separation of moisture from a steam flow in the turbine system of a steam boiling water reactor nuclear plant for which use it is particularly suited in that it allows considerable weight reduction in respect of system moisture separators and hence, allows for gains in useful space in the operating enclosure as well as reductions in foundation loadings. The invention is however, also applicable to moisture separation in any steam plant installation wherein an interstage "wet steam" flow between higher and lower pressure turbines should be "dried" by having the moisture removed therefrom before it enters the lower pressure turbine.

FIGURES 1 and 2 depict prior moisture separation arrangements and components used in a SBWR. A high pressure turbine 10 and a low pressure turbine 12 aligned therewith are employed to extract heat energy from high pressure (1200 psig, for example) steam generated in a SBWR and convert it to useful energy in the form, e.g., of electrical power produced by an electrical generator 13 which is drivingly coupled to the turbine in known manner.

Steam is supplied to the high pressure turbine 10 by main 14, and gives up energy in turbine 10, the steam reducing in pressure and to the an extent that moisture can exist therein which moisture must be removed from the steam after it outlets the high pressure turbine and before it can enter the low pressure turbine where moisture if sufficiently large, could damage the low pressure rotor blades and the like.

In avoidance of that event and as the prior art teaches, steam outletting turbine 10 is conveyed from a turbine outlet trunk 17 through lines 16, 18 to respective ones of two moisture separators 20, 22, these separators being relatively large structures (about 11 feet diameter by 60 feet long) wherein low velocity steam flow attends moisture separation, the separators being chevron blade type separators. The steam following moisture separation therefrom, is conveyed via lines 24 to the inlet trunk 19 of low pressure turbine 12.

The bulk of the separators 20, 22 requires that they be installed on the operating floor 26 where they occupy considerable space that otherwise could be used for different purposes. Further and because these devices are on the operating floor, they must be situated in heavy concrete shielding structure 28. Relocating required moisture separators to an extra-operating floor space is an important advantage of the invention as will be explained below.

Dealing now with details of the invention, it is noted first and with reference to FIGURE 5, that the moisture separator type 30 employed in effecting removal of moisture from steam is a component heretofore used in France by Electricite de France. The separator 30 includes an elongated generally cylindrically configured housing 32 flared or of bell-shape at its respective entry and discharge ends 34, 36. This flaring will be received in transition end pieces (not shown) which join the separator to steam conveying lines.

Within the housing near or proximal the entry thereto, is a turning vane assembly 38 comprised of a circle of vanes 40 fixed to long hub 42, these vanes being set such that an incoming straight line flow of steam is caused to undergo flow course deviation in the form of a vortex-like or cyclonic swirling path around the hub 42.

Incident this changing geometry of the steam flow is the displacing or centrifugal thrusting of any moisture in the steam flow radially away from the steam flow main body and into impingement with the inner surface of the housing wall 44 whereat it is carried forward by flow momentum to a location downstream of vane assembly whereat it can access a skimmer slot 46 formed in housing wall 44 by means of which separated moisture can remove from the housing and be directed to a condensate recovery function via line 33, there being a sleeve 35 encircling the separator to confine the moisture outflow from the skimmer slot and direct it to the line 33.

Located on hub 42 adjacent downstream of the skimmer slot, is a second vane assembly 50 having a number of vanes 52 set in manner to convert or restore the swirling flow of the dry steam to a straight line or longitudinal flow in the housing so it can exit therefrom in that form and pass on to the low pressure turbine.

With reference now to Figures 3 and 4, the further aspects of the invention will be given. As is readily seen from FIGURE 3, two separators 30a, 30b are associated with steam exhaust from one side of the high pressure turbine, and two additional ones 30c, 30d are associated with exhaust from an opposite side of that turbine 10, these pairing and associated steam lines being symmetrically arranged on opposite sides of the aligned axes of the turbine units.

The use of four moisture separators is exemplary of the numbers of such separators as are employed to replace the two used in the FIGURE 1 and 2 depicted system. The high velocity separators 30 have the advantage of weight and size reduction below what is present in the separators 20,22 which is quite significant. Illustrative on this point is the nearly eight-fold reduction of volume of structure for the high velocity separators in the FIGURES 3 and 4 system as compared to those of the FIGURE 1 and 2 system. Thus less space need be used for the separators 30, they can be located below the operating floor as shown in FIGURE 3 eliminating shielding enclosure on the operating floor, and less weight is involved with corresponding lightening of foundation loading and reduction in supporting structure needed.

In a particularly advantageous embodiment, the separators 30 will have a length/width ratio of about 2. The FIGURES 3, 4 separators have a diameter of 6 feet and a length of 12 feet.

The FIGURES 3 and 4 arrangement is successful to effect removal of about 96% of the moisture contained in the interstage steam flow outletting the high pressure turbine.

Having described preferred embodiments of the invention with reference to the accompanying drawings, it is to be understood that the invention is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one of ordinary skill in the art without departing from the scope of the invention as defined in the appended claims.

Claims

1. In a steam turbine system including

   a high pressure steam turbine unit receiving an inlet flow thereto of dry, high pressure steam drivingly rotating a rotor of the high pressure steam turbine unit in its passage through said high pressure steam turbine unit, the pressure of the steam reducing during said passage so that at an outlet from the high pressure steam turbine unit, the steam is at a low pressure,

   a low pressure steam turbine unit receiving steam outletting the high pressure turbine unit and passing therethrough for drivingly rotating a low pressure unit rotor thereby extracting further useful work from the steam,

   at least one moisture separator intervening the high pressure unit outlet and an inlet to the low pressure unit, said moisture separator being operable to remove substantially all of any moisture as may be present in a high velocity interstage steam flow between the high pressure and low pressure units, said moisture separator being of the type that includes

   an elongated housing with an entry end and a discharge end,

   there being turning vanes proximal the housing entrance end for vortexing an incoming straight line flow of moisture-containing steam to a swirling flow thereby to induce centrifugal force within the flow that displaces the moisture therein radially of a flow course axis to impingement with an inner wall surface of the housing so that carry forward of the moisture within the housing is along the inner wall surface to exit therefrom at a skimmer slot in the housing wall, and

   other vanes proximal the skimmer slot and oriented such to convert the substantially moisture-free steam flow to a straight line flow thereof from the separator discharge end.

2. The steam turbine system of claim 1 in which the moisture separator is in a steam leg connecting an outlet trunk of the high pressure unit with an inlet trunk of the low pressure unit.

3. The steam turbine system of claim 2 comprising an additional like moisture separator in said steam leg.

4. The steam turbine system of claim 3 in which the first-mentioned and additional separators are disposed in a space below an operating floor on

which the high and low pressure units are located.

5. The steam turbine system of claim 4 comprising a second steam leg connecting the high pressure unit outlet trunk with the inlet trunk of the low pressure unit, there being first and additional moisture separators in said second steam leg.

6. The steam turbine system of claim 5 in which the moisture separators in said second leg are disposed in said space below said operating floor.

7. The steam turbine system of claim 6 in which said first and second steam legs traverse courses symmetrically disposed on opposite sides of a longitudinal axis of said high pressure unit and have initial course ends at opposite sides of the high pressure unit outlet trunk, with the courses terminating at correspondingly opposites sides of the low pressure unit inlet trunk.

8. The steam turbine system of claim 1 in which the housing has a length/width ratio of about 2.

9. The steam turbine system of claim 87 in which the housing is cylindrical configured and has a diameter of substantially 6 feet.

10. The steam turbine system of claim 1 in which the moisture separator is operable to remove up to at least about 96% of any moisture present in the steam flowed therethrough.

11. In the conveyance of a moisture-containing flow of steam outletting a higher pressure turbine and destined for inlet to a lower pressure turbine, the step of drying the steam to remove substantially all of any moisture present in said flow by

inducing a vortex-like swirling in the flow while it is confined in an elongated housing to cause centrifugal displacement of moisture in the steam radially outwardly relative of a flow direction thereof so that it impinges an inner wall surface of the housing and is carried forwardly therealong to exit from the housing via a skimmer slot therein, and

reorienting the swirling flow of the steam to a straight line one before the steam exits the housing.

FIG. 1

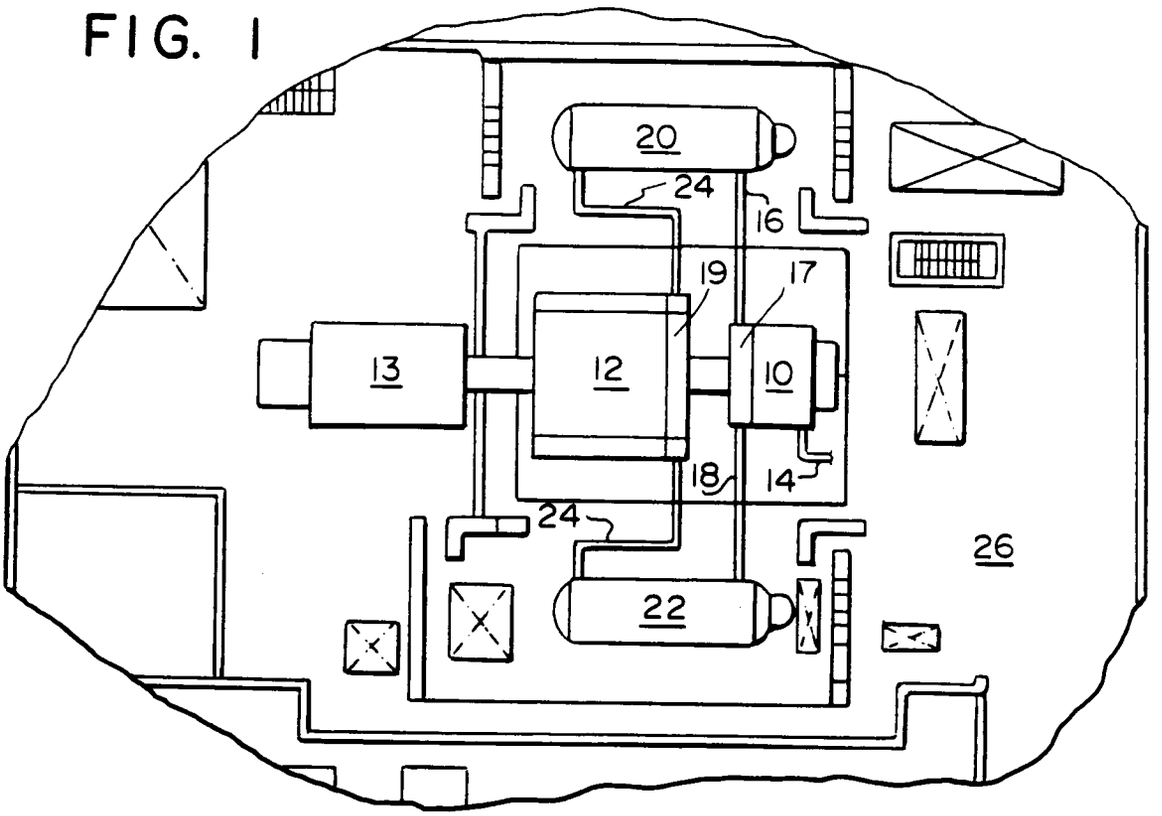
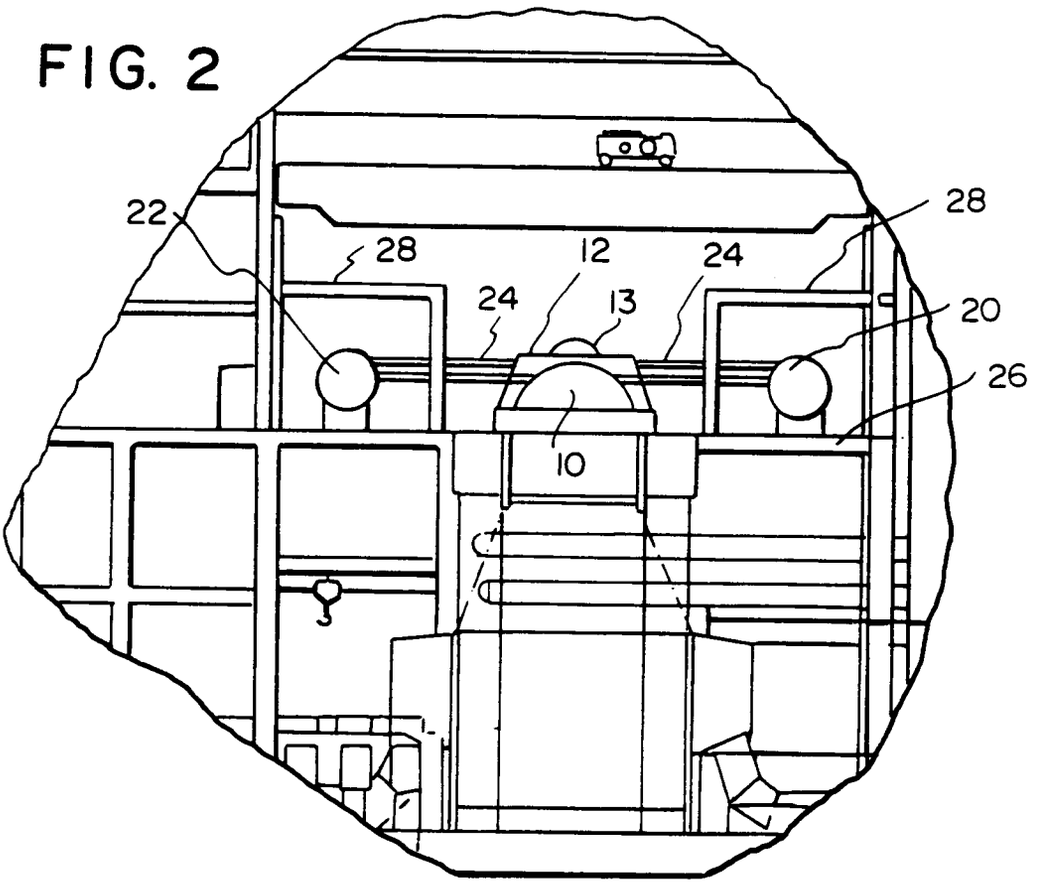


FIG. 2



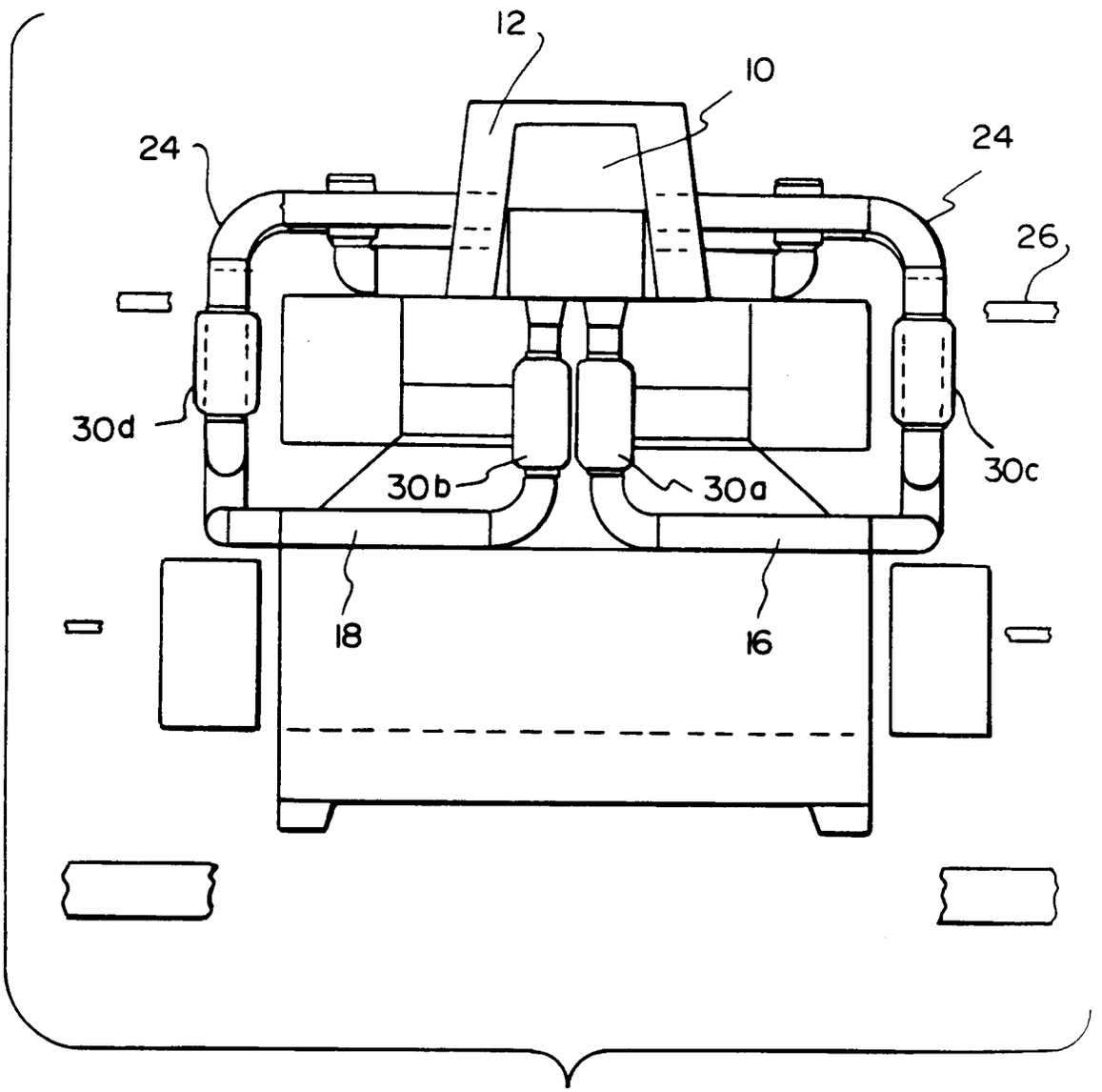


FIG. 3

FIG. 4

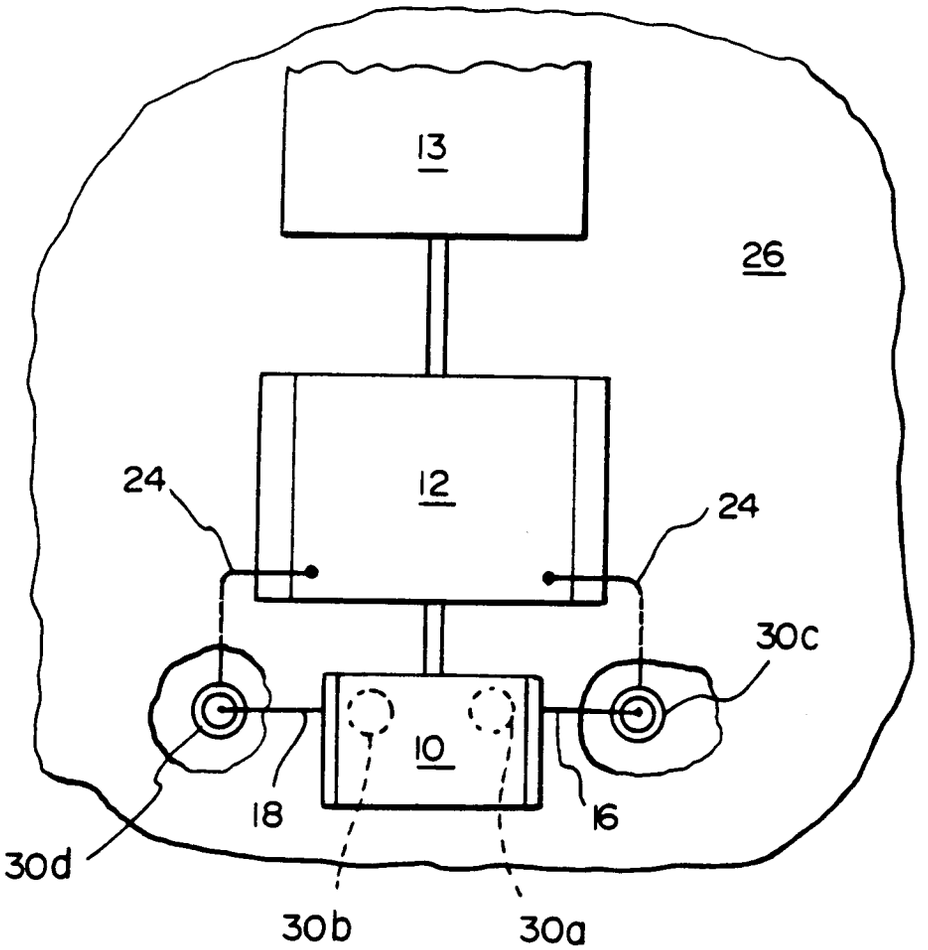

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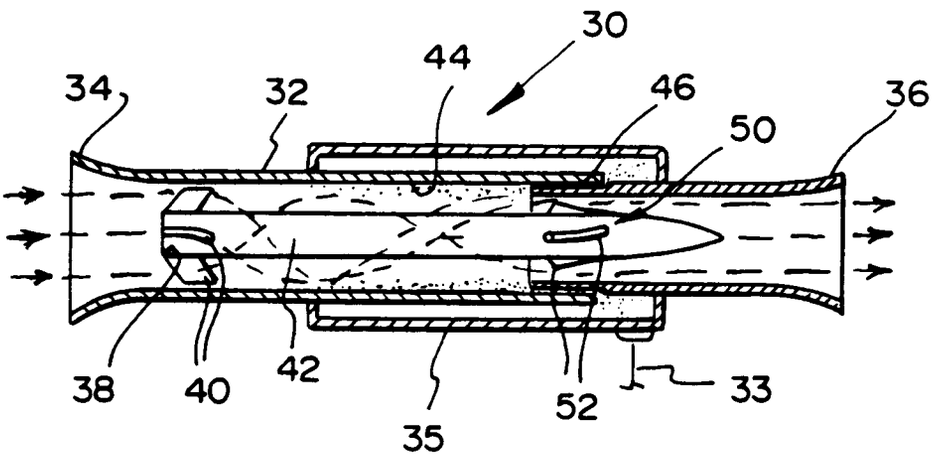
FIG. 5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EUROPEAN SEARCH REPORT

Application Number
EP 92 30 5684

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	REVUE ALSTHOM no. 4, 1985, PARIS pages 19 - 26 H.COENCA 'Progress achieved in steam drying: the high velocity separator'	1-2,8-11	F01K7/22 F22B37/32
Y	*Page 20,"High velocity separator", Description, Figs. 3,5* *Page 25,"In France",Nuclear applications ,Fig.12*	3-7	
Y	EP-A-0 377 435 (STEIN INDUSTRIE) * column 2, line 8 - line 24; figure 1 *	3-7	
X	DE-A-1 912 805 (LITENTIA PATENTS-VERWALTUNGS-GMBH) * figure 1 *	1-2,8-11	
A	DE-A-2 312 725 (KRAFTWERK UNION) * page 2, line 18 - line 20; figure *	4	
A	DE-A-3 832 420 (PODOL'SKIJ MASINOSTROITELNYJ ZAVOD)		TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	FR-A-2 630 027 (STEIN INDUSTRIE ET ELECTRICITE DE FRANCE)		F01D F01K F22B
A	FR-A-2 553 296 (STEIN INDUSTRIE ET ELECTRICITE DE FRANCE)	1	
A	FR-A-2 558 741 (STEIN INDUSTRIE ET ELECTRICITE DE FRANCE)	1	
A	FR-A-2 644 084 (STEIN INDUSTRIE ET ELECTRICITE DE FRANCE.)	1	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	18 SEPTEMBER 1992	CRIADO Y JIMENEZ, F.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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