United States Patent [19]
Rubinstein

[11] **3,912,584**
[45] **Oct. 14, 1975**

[54] **LMFBR WITH BOOSTER PUMP IN PUMPING LOOP**

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[22] Filed: **Jan. 9, 1974**

[21] Appl. No.: **432,007**

[52] **U.S. Cl.** **176/40;** 176/38; 176/65
[51] **Int. Cl.²** **G21C 15/24**
[58] **Field of Search** 176/40, 38, 65, 50, 63, 176/64, 17, 18

[56] **References Cited**

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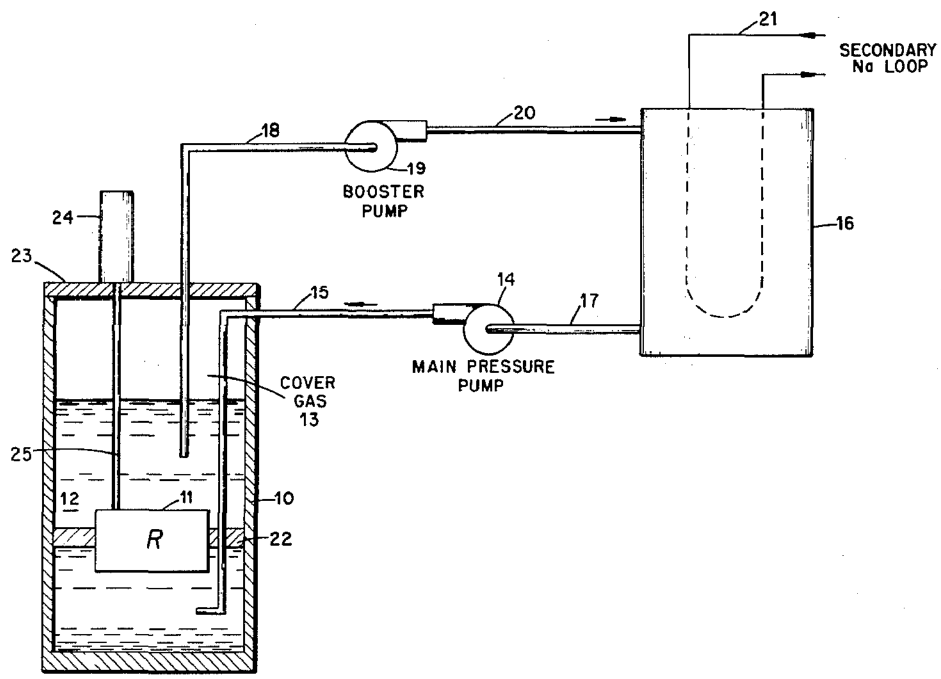
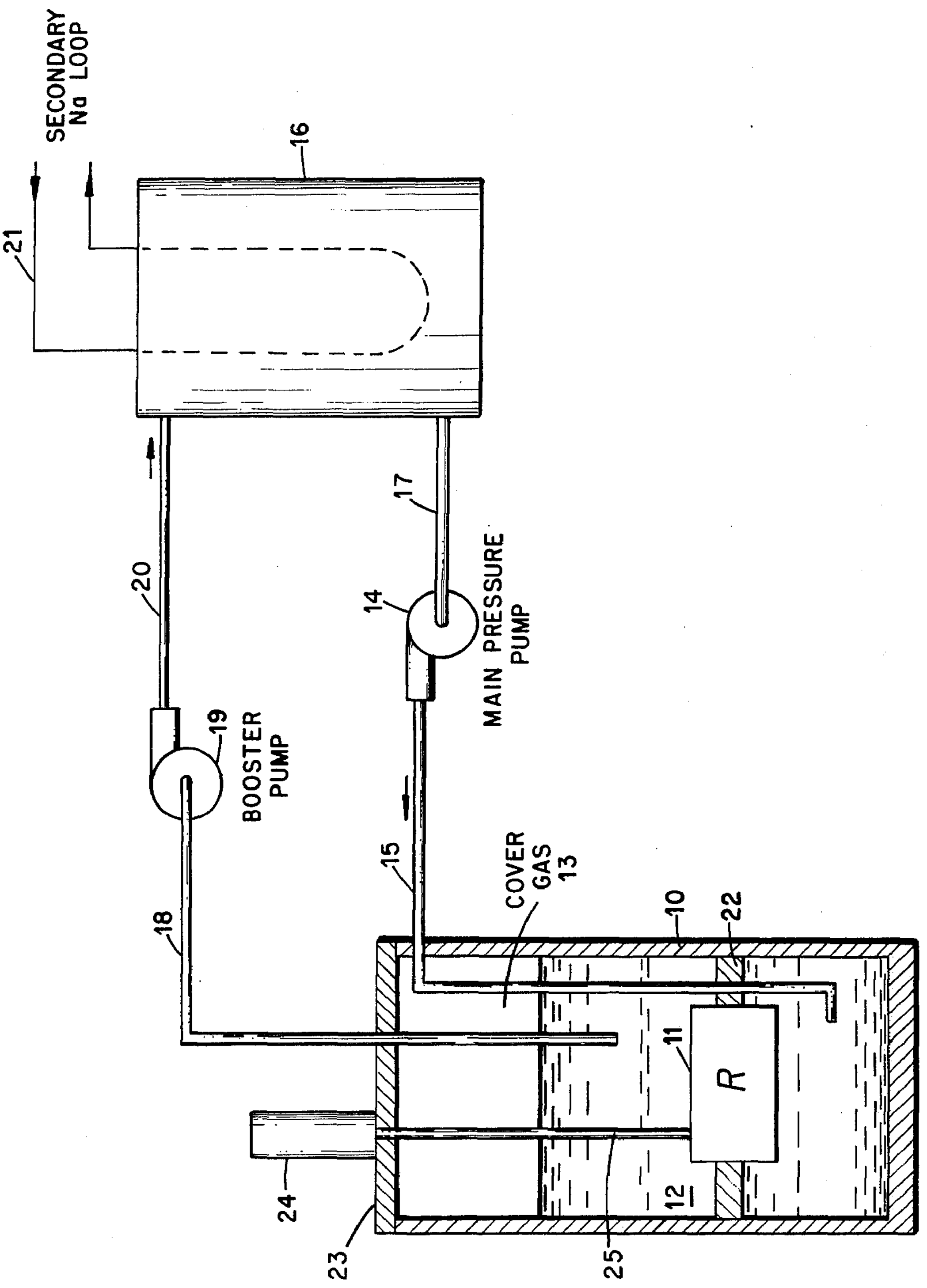
[57] **ABSTRACT**

A loop coolant circulation system for a liquid metal fast breeder reactor (LMFBR) utilizing a low head, high specific speed booster pump in the hot leg of the coolant loop with the main pump located in the cold leg of the loop, thereby providing the advantages of operating the main pump in the hot leg with the reliability of cold leg pump operation.

5 Claims, 1 Drawing Figure

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BOOSTER
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LMFBR WITH BOOSTER PUMP IN PUMPING LOOP

BACKGROUND OF THE INVENTION

The invention described herein was made in the course of, or under, Contract No. AT(04-3)-830 with the United States Atomic Energy Commission.

This invention relates to a loop type liquid metal fast breeder reactor (LMFBR), and more particularly to a unique system which provides for high reliability by placing the main circulator in the cold leg of the loop, yet provide the same safety advantages of placing the main circulator in the hot leg of the loop, this being accomplished by utilizing a booster circulator in the hot leg.

There are two generic types of LMFBR now in development throughout the world. These are the tank (or pool) design and the loop (or piped) design, the present invention being directed to the loop design.

A major choice in design of the primary loop of a loop type LMFBR is the location of the main circulating pumps. The choice is between a location either in the hot leg (reactor outlet) or cold leg (reactor inlet). From a safety standpoint, discussed hereinafter, it is clearly desirable to place the pumps in the hot leg piping. From considerations of pump reliability, however, it is clearly desirable to place the pump in the cold leg.

One current design of an LMFBR places the primary pump in the hot leg. The advantage of this is that a low cover gas pressure in the reactor is possible since the pump draws its suction from the reactor outlet. The pump net positive suction head (NPSH) is derived from elevation differences between the operating pump level and reactor levels. This arrangement reduces the gas leakage through the many penetrations of the reactor closure (reactor head) because of the low cover gas pressure. The cover gas pressure in this case can actually be slightly negative to prevent any gas leakage into the building containment.

The placement of the primary pump in the cold leg has the advantage of lower pump operating temperature which results in higher reliability and fewer maintenance problems. The disadvantage of the cold leg pump is the fact that it takes from the output of the intermediate heat exchanger (IHX) and its suction pressure is down because of friction through the IHX and piping. The pump suction pressure (NPSH) may be restored by one of two ways:

1. Increase the reactor cover gas pressure to increase the pump NPSH. This carries with it the problem of leakage of contaminated gas through the reactor closure head.

2. Extend the length of the pump so that the pump suction (NPSH) is increased by static head. This carries with it serious pump problems since the pump shaft length has practical limits and the building and pump maintenance gear becomes unwieldy because of the pump length.

Thus, a need exists for a circulation system for LMFBR which provides the advantages of locating the primary pump in both the hot and cold legs of the coolant loop, while minimizing to disadvantages of each location.

SUMMARY OF THE INVENTION

The present invention provides a coolant circulation system which fulfills the needs of the prior systems and

has the full advantage of the hot leg pump but with a minimum of loss of reliability. This is achieved by using a low head, axial flow or mixed flow hot leg booster pump in addition to the cold leg high pressure main pump. The booster pump provides only enough pressure to provide sufficient NPSH so that the cold leg pump can be located at a high elevation.

Therefore, it is an object of the invention to provide a coolant circulation system for an LMFBR which provides for high reliability by placing the main circulator in the cold leg of the loop, yet provides the same safety advantages of placing the main circulator in the hot leg.

A further object of the invention is to provide a coolant circulation system for an LMFBR which utilizes a booster pump.

Another object of the invention is to provide a coolant circulation system for an LMFBR which utilizes a booster pump in the hot leg of a coolant loop with the main pump located in the cold leg of the loop.

Other objects of the invention will become readily apparent from the following description and accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single FIGURE diagrammatically illustrates the LMFBR circulation system made in accordance with the invention.

DESCRIPTION OF THE INVENTION

Broadly the present invention provides a coolant loop type circulation system in an LMFBR wherein the main pumping head is provided by a high head cold leg pump, while the advantages of the main circulation pump being located in the hot leg is accomplished by use of a low head, high specific speed booster pump in the hot leg, thereby obtaining the advantages of locating the main circulating pump in both legs while minimizing the disadvantages thereof.

Referring now to the drawing, the system illustrating the invention comprises a reactor vessel **10** containing therein a core **11** of nuclear fuel elements, core **11** being surrounded by coolant **12** such as liquid sodium, for cooling the fuel elements as known in the reactor art. A cover gas **13**, such as argon at about **1** atmosphere, fills the space above coolant **12.** Coolant at 720°F, for example, is supplied to the lower portion of vessel **10** by a main circulator or pump **14** as indicated by the arrow via a conduit **15,** pump **14** drawing coolant from an intermediate heat exchanger (IHX) **16** through a conduit **17.** For example, pump **14** may be of a variable speed type running at about 900 rpm having a power requirement of about 4,000 Kw. Coolant heated by reactor core **11** to 1000°F, for example, is drawn from vessel **10** via a conduit **18** by a booster pump **19** and is discharged from booster pump **19** through a conduit **20** into IHX **16.** Booster pump **19,** for example, may be of either an axial flow or mixed flow type, running at a constant speed of about 525 rpm with a power requirement of about 350 Kw. As known in the art, the coolant arrangement thus far described is referred to as a primary loop, a secondary coolant loop, containing liquid sodium, for example, is directed through IHX **16** as indicated at **21,** the heat from reactor core **11** being transferred via IHX **16** through the secondary loop **21** to a point of use. To prevent inlet coolant from bypassing core **11,** a barrier **22** is located in vessel **10.** Also, as known in the art, vessel **10** is provided with a head or closure structure **23** upon which control rod drive mechanism **24** (only one shown) is mounted with control rod **25** penetrating head **23** and extending into core **11.**

Booster pump **19** is a low head, high capacity, high specific speed pump, and may be of the propeller (axial flow) or mixed flow type, which can operate with relatively large clearances without critical losses in efficiencies. This is ideal for a hot leg pump since it is the close clearances that make design of a 1000°F centrifugal pump difficult. Since the specific speed of the booster pump **19** would be about 7000 rpm for a suction of 0 psig, a 1 atmosphere suction pressure as above described would give a pump of about 525 rpm.

The resultant low speed and relative low horsepower makes an ideal situation for a high temperature but reliable booster pump. The horsepower would be:

$$HP = \frac{H \times Q}{4800 \times \text{eff}} = \frac{40 \times 45{,}000}{4800 \times .80}$$
$$= 470\ HP$$
$$= 350\ \text{Kw at 80 percent eff.}$$

This is about one-tenth the size of the main pump **14** for a two loop primary system (only one loop illustrated). The booster pump horsepower requirement will be about 10 percent of the total pumping power for the loop. For a 40 ft. dynamic head and a zero suction lift (14.7 psia suction pressure), the maximum specific speed (Ns) for an axial or mixed flow booster pump is about 7000 rpm. The actual rpm being calculated as follows:

$$\text{Specific Speed } (Ns) = \frac{n\sqrt{Q}}{H^{3/4}}$$
$$\text{or} \qquad n(\text{RPM}) = \frac{Ns\ H^{3/4}}{\sqrt{Q}}$$
$$= \frac{7000\ (40)^{3/4}}{(45{,}000)^{1/2}}$$
$$= \frac{7000\ (15.9)}{212}$$
$$= 525\ \text{RPM or 12 Pole Motor}$$

Where
Pump head = 40 feet
Pump capacity = 45,000 gpm for **2** loops.

The booster pump **19,** as pointed out above, is a constant speed pump, the variable flow being provided by the main primary pump **14.**

Booster pump leakage (or bypassing of fluid within the pump) is reduced drastically in high specific speed pumps. As shown in "Centrifugal and Axial Flow Pumps" by Stephanoff, 1948, Chapter 10, for a pump of specific speed (Ns) of 7000 as compared with an Ns ≅ 2000 (main primary pump), the percent power loss due to leakage is dropped by a factor of about 7. This infers that the high specific speed pump is not very sensitive to clearance and may be relatively sloppy without loss of efficiency.

The above specific values have been based on a coolant circulation system described as follows:
Two loop design
45,000 gals. per min. (GPM)/loop
Total System Losses = 405′
Booster Pump total dynamic head (TDH) = 40′
Booster Pump Suction Pressure = 1 ATM
Main Pump Suction Pressure = 1 ATM
IHX discharge pressure (DP) = 15 psi

While the above calculations were made for a two loop primary system, the principle of using the booster pump would hold for any number of loops. The flows and pressures set forth are representative of a typical LMFBR design for a 350 MWe output.

It is anticipated to future LMFBR plants will use higher reactor outlet temperatures (as high as 1100°F) which makes the primary pump designs even more difficult, thus illustrating the advantage provided by the present invention by the use of a booster pump in the hot leg of a loop with the main pump located in the cold leg.

The following additional advantages are provided by the inventive coolant circulation system:

1. The axial and mixed flow pump has a very high shut-off head characteristic. This means that at very low flows, the pump will provide a higher head than its normal operating head. The booster pump may then be considered for emergency cooling as well as the shutdown and startup pump. This may relieve the main pump of its high turndown characteristics and pony motor.

2. The axial and mixed flow pump has a low locked rotor resistance. Sudden loss or locking of the booster pump would not cause a loss of primary flow, but would only cause a reduction due to the onset of cavitation in the main pump.

3. The layout and safety advantages, as pointed out above, of this system are paramount. There will be cost savings in containment building volume and, by proper layout, there may also be net piping reductions.

4. The booster pump may be of the electromagnetic (EM) type.

It has thus been shown that the present invention provides a coolant circulation system for the primary loop of an LMFBR which involves the positioning of the main pump in the cold leg, and a low head, high specific speed booster pump in the hot leg, thereby adding to the advantages of the cold leg main pump location by the increased advantages of locating a circulation means in the hot leg, thereby substantially increasing the performance of the overall pumping operation.

While a particular embodiment of the invention has been illustrated and described, modifications will become apparent to those skilled in the art, and it is intended to cover in the appended claims all such modifications as come within the spirit and scope of the invention.

What I claim is

1. In a coolant circulation system for a liquid metal fast breeder reactor having a reactor core containing nuclear fuel and positioned in a containment vessel, liquid metal coolant contained by said vessel and surrounding said core, a cover gas under pressure above the said coolant in said vessel, a heat exchanger means positioned externally of said containment vessel, and means for circulating coolant from said heat exchanger means to said containment vessel and from said containment vessel to said heat exchanger; the improvement comprising: at least one main coolant pump positioned in the coldleg to supply coolant to said containment vessel from said heat exchanger means, said main coolant pump being located at a high elevation with respect to said core and at least one low head, high capacity, high specific speed booster pump positioned to pump coolant heated by said reactor core from said containment vessel to said heat exchanger means.

2. The system defined in claim 1, wherein said booster pump is an axial flow pump.

3. The system defined in claim 1, wherein said main coolant pump is of a variable speed type, and wherein said booster pump is of a constant speed type.

4. The system defined in claim 1, wherein said heat exchanger means and said means for circulating coolant comprises a primary loop, and additionally including conduit means passing through said heat exchanger means forming a secondary coolant loop.

5. The system defined in claim 1, wherein said main coolant pump means is operatively connected to supply coolant from said heat exchanger means to a lower portion of said containment vessel, and wherein said booster pump is operatively connected to pump coolant from an upper portion of said containment vessel to said heat exchanger.

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