TEPLATOR DEMO: Basic Design of the Primary Circuit

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The TEPLATOR is an original way of district and industrial heating using nuclear power using spent nuclear fuel from nuclear power plants. The spent nuclear fuel is the one that did not reach its regulatory and design limits. This fuel can be taken either from spent fuel pool or interim storage. The fuel for TEPLATOR is already manufactured and thus no additional cost for fuel arises.

This one of a kind design will be tested in a demonstration unit "TEPLATOR DEMO". This DEMO unit has 50 MW of thermal power with 55 spent fuel assemblies of VVER-440 in the core. The fluid output temperature from the core is 98 °C, thus the whole unit can work on atmospheric pressure. It is constructed as three loop system with three main pumps and three heat exchangers. This paper describes the basic design of the primary circuit. The main idea concerning the design is explained first. Then the evolution of the design from the first steps to current 3D model is included. Next discussion is focused on individual components of the TEPLATOR (i.e., heat exchangers, pumps etc.) Briefly the construction and operation of compensation means are presented. Finally, the whole concept of the TEPLATOR DEMO and its design is summarized.

1. Introduction

TEPLATOR is an industrial concept of central supply of heat/cold using spent nuclear fuel. It uses only known, verified, and tested components. This concept allows the use of spent nuclear fuel from conventional nuclear power plants (pressurized water or boiling reactor types) without further modifications to this fuel. Spent fuel from a nuclear power plant, one that has already served its purpose in the operation of the power plant, is usually transported from the reactor first to the spent fuel storage pool and after some time is transferred to storage containers, where it remains in interim storage. There, provided it is not reprocessed, it usually ends its life cycle for the operator. TEPLATOR represents another economic use for this fuel. Such fuel will be used in the core of the TEPLATOR and will generate heat, which could be used for industrial or central heating or cooling. After the construction of the TEPLATOR, the fuel costs would be negligible, which would significantly affect the price for the heat supplied and especially its stability. The major parameters can be found in the Table 1 below.

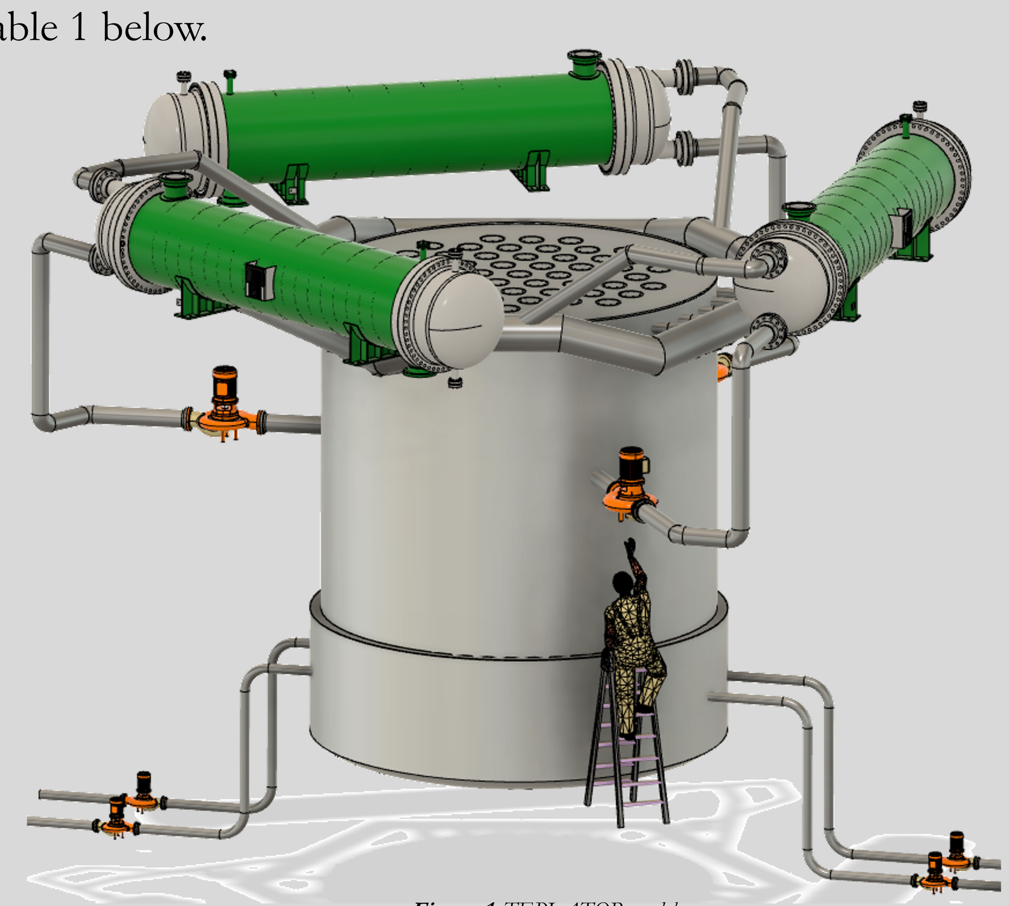

Figure 1. TEPLATOR model

2. General Idea

The design itself includes 3 circuits. The primary circuit includes a so-called calandria, a core with the fuel, three heat exchangers and three pumps. The core is made from Zr channels in which the fuel is based. The space between the channels is filled by the moderator, heavy water. The coolant flows in the channel through a system of pipes at the outlet of which there is a collector. In this collector the coolant from all channels is collected. Three pipes are led out of this collector, each of which is led into one heat exchanger. The coolant passes through the primary side of the heat exchanger and returns to the fuel channels through the pump and the lower distribution chamber.

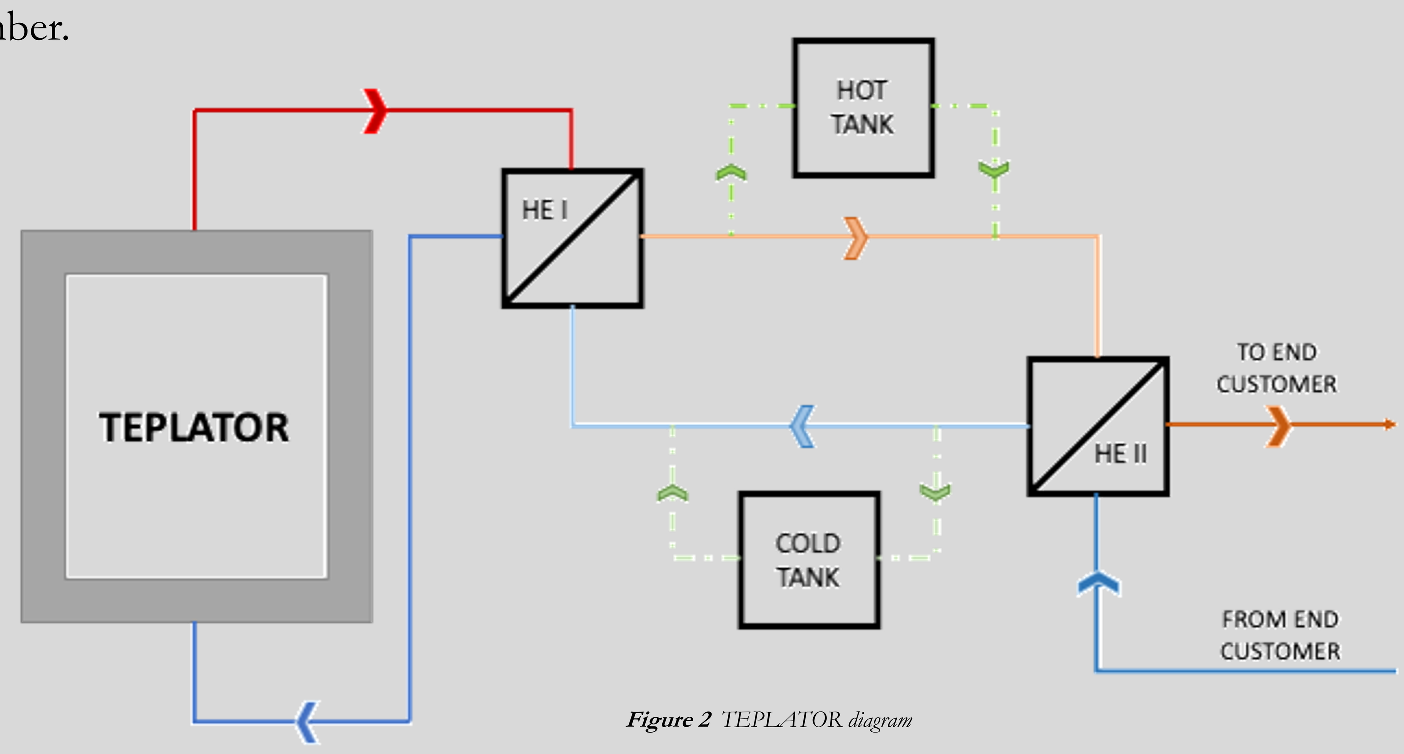

Figure 2. TEPLATOR diagram

In the secondary circuit (the so-called intermediate circuit) the secondary heat transfer fluid (HTF) flows (according to the operating parameters either water or molten salt is considered). The HTF transfers heat from the primary circuit to the heating circuit itself via the secondary exchanger. The intermediate circuit includes two storage tanks serving as an energy storage system for heating demand peaks. These storage tanks are connected to this circuit and are able to simultaneously dissipate and store heat from the residual power of the fuel. The tertiary or heating circuit is then a set of secondary exchanger and pipes, which distributes the heat to the end customer.

Reactor type	Channels in Reactor Vessel
Coolant/moderator	Heavy Water (D_2O) / Heavy Water (D_2O)
Thermal/electrical capacity, MW(t)/MW(e)	50 /Does not produce electricity
Primary circulation	Forced circulation
System pressure (MPa)	Ambient
Core inlet/exit temperatures (°C)	45/98
Fuel type/assembly array	VVER-440 / hexagonal with 126 fuel pins
Number of fuel assemblies	55
Fuel enrichment (%)	Spent fuel (< 1.2 wt% U-235 equivalent)
Fuel burnup (GWd/ton)	2.3
Fuel cycle (months)	10 months with online option
Main reactivity control mechanism	Moderator height, Control blades
Design life (years)	60
Fuel cycle requirements / Approach	LEU - reuse of LWR spent FAs, possibility to run on fresh SEU (≤1.2% U235)
Distinguishing features	District heating zero CO2 source with zero fuel cost, low pressure

Table 1. Main Parameters of TEPLATOR

3. Design

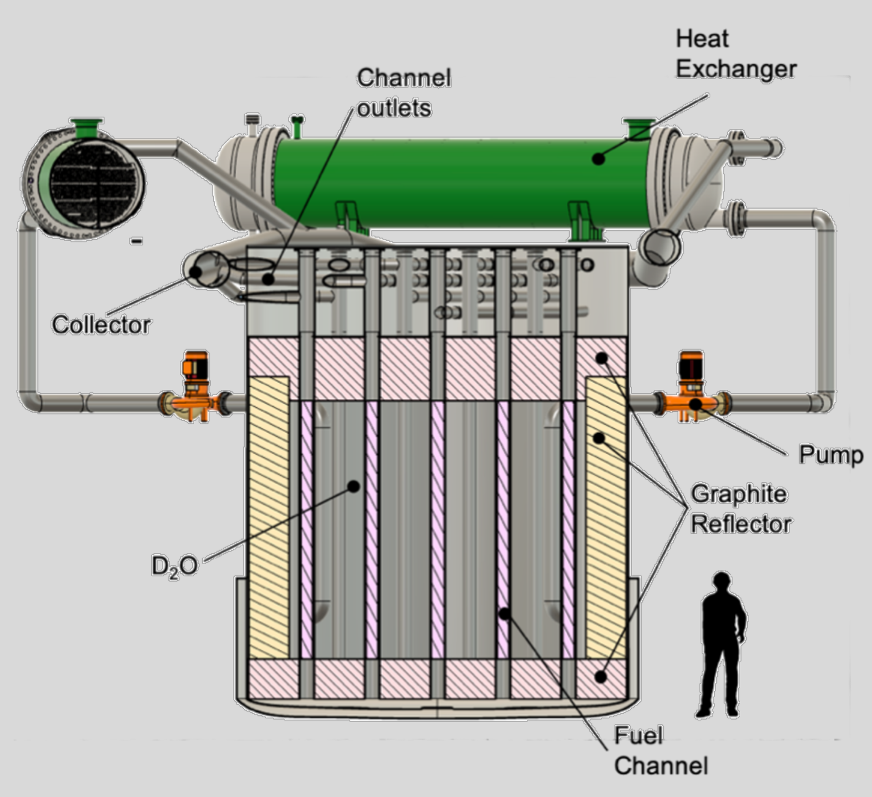

Figure 3 TEPLATOR cut

The fuel channels are made from zirconium as mentioned earlier. They are hexagonal shaped because of neutronics properties. These fuel channels are placed in calandria. The calandria is filled with heavy water, the total volume of heavy water in calandria is around 30 m^3. The calandria is surrounded by a graphite reflector from all sides. Heavy water flows inside the fuel channels and the total volume of D_2O in the primary circuit is approx. 26 m^3. The channel outlets are in four rows above each other. All of the channel outlets are aggregated in the upper collector. This collector is an anulus around the TEPLATOR calandria. The horizontal heat exchanger was chosen for TEPLATOR, in total number of three. The heat transfer surface of one heat exchanger is 520 m^2. Each heat exchanger is able to cool 100% of the core power, in case of failure of the others. The pump system consists of three standardized pumps, each has a nominal power of 130 kW and the volume flow rate is 450 m^3/h, more than sufficient for cooling the core at full power.

The control system of the TEPLATOR is achieved by controlling the moderator (i.e., D_2O) level in the calandria. The pump system ensures the filling or draining of heavy water. As a second reactivity control, system of three blades from absorber material (B_4C) are used. These blades are in a louver arrangement. They are placed below the upper lid and graphite reflector in a third symmetry. In case of SCRAM they will fall into the moderator and stops the chain reaction.

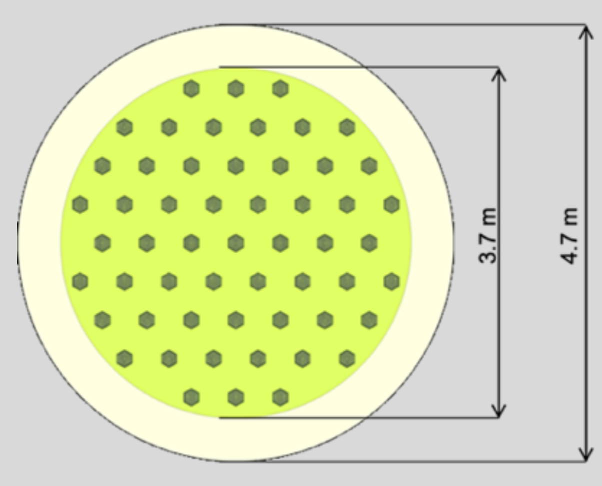

Figure 4. Hexagonal channels

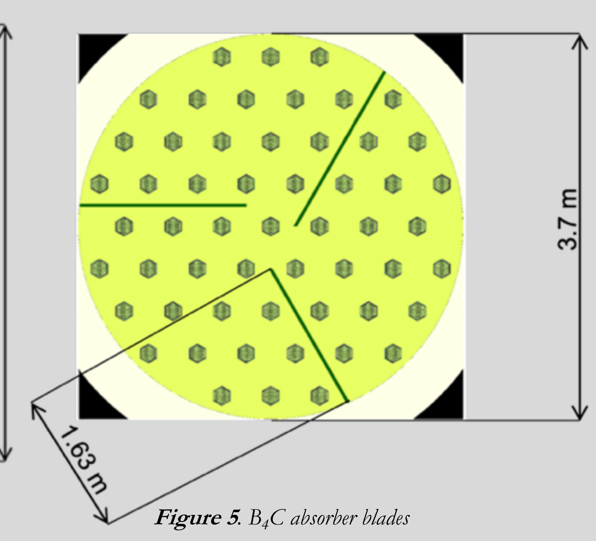

Figure 5. B_4C absorber blades

4. Conclusions

The TEPLATOR is an innovative way of district heating or cooling using spent nuclear fuel assemblies. Before the full scale TEPLATOR can be build, the demonstration unit needs to be tested. The demonstration unit has a 50 MW$_{(th)}$ and this paper deals with its preliminary basic design. The first steps in the constructional design were taken and first 3D model of TEPLATOR was obtained. In this step all of the main components, circuits and the overall construction were designed. The control and safety systems of the TEPLATOR were also taken into account. For operation reactivity control of the TEPLATOR we use the control of D_2O level. Heavy water is filled into the calandria from the storage tank or it is drained from the calandria, ensuring the desired level of power is obtained. As a second safety system, the absorber plates from B_4C are used. They are utilized in a louver arrangement in order to safe space in the upper part of the calandria. This preliminary basic design is a start to a more comprehensive process which is taking place. The TEPLATOR team is already working on a more detailed design of the TEPLATOR, which will take into account all the valves, auxiliary pumps, the secondary and tertiary (heating) circuit and the plant layout itself as well.

5. Acknowledgments

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6. References

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