Ocean-based Passive Decay Heat Removal in the Offshore Floating Nuclear Plant (OFNP)

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ABSTRACT

The Offshore Floating Nuclear Plant (OFNP) concept offers the potential for superior economics and safety. The 300 MWe version of the OFNP features an integral primary system PWR, and adopts an ocean-based direct reactor auxiliary cooling system (DRACS) which provides passive and indefinite decay-heat removal from the reactor pressure vessel during abnormal occurrences without primary system depressurization, e.g. a loss of flow accident. In this paper we present analyses aimed at sizing and evaluating the performance of the DRACS loops and heat exchangers, to ensure adequate core cooling and a compact layout. We assume that all the residual heat is removed by the DRACS for the condition that the reactor coolant pumps have stopped and thus the system operates in natural circulation mode. The DRACS effectively consists of three coupled flow loops: first, natural circulation in the primary system from the core to the core makeup tank (CMT); second, natural circulation from the CMT to the ultimate heat exchanger; third, natural convection of seawater in the shell of the ultimate heat exchanger. The asymptotic (quasi-steady) behavior of these loops was first modeled using hand calculations, which allowed estimation of the size of the heat exchangers. Then a transient analysis of this preliminary design was performed with the code RELAP5, to confirm that the principal safety margins (margin to boiling, MDNBR, and maximum allowable reactor coolant pressure) are not challenged.

KEYWORDS
Offshore Floating Nuclear Plant (OFNP), direct reactor auxiliary cooling system (DRACS), core makeup tank (CMT), ultimate heat exchanger, natural circulation

1. INTRODUCTION

The Offshore Floating Nuclear Plant (OFNP) concept combines two mature and successful technologies, i.e., LWRs and floating platforms of the type used in offshore oil/gas operations, each with an established and cost-effective global supply chain [1]. OFNP is a plant that can be entirely built within a floating platform in a shipyard, transported to the site, where it can be moored within a dozen miles off the coast, within territorial waters, and connected to the grid via submarine transmission cables. The OFNP can achieve excellent economics through plant simplification, modularity and shipyard construction and efficient decommissioning. Two OFNP designs are being developed in parallel, to be used in different markets: the OFNP-300 and OFNP-1100, designated according to their electric power rating. In this paper we focus on the OFNP-300, shown in Figure 1. The OFNP-300 could be based on a class 300 MWe reactor, such as Westinghouse's Small Modular Reactor (WSMR) [2-5]. The floating structure chosen to house the nuclear plant is a cylindrical-hull platform that shares many of its characteristics with platforms used in the offshore oil and gas drilling industry. Cylindrical platforms offer superior hydrostatic and hydrodynamic stability at the scale the OFNP is designed for [6], as well excellent protection to the reactor itself when compared to other offshore platform designs, such as semi-submersibles or floating barges. Locating the reactor in a center annulus offers it substantial physical protection via multiple hulls. Additionally, the