Nuclear Engineering and Design 241 (2011) 1548–1558

Contents lists available at ScienceDirect

Nuclear Engineering and Design

journal homepage: www.elsevier.com/locate/nucengdes

# Pressure and temperature analyses using GOTHIC for Mark I containment of the Chinshan Nuclear Power Plant

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ARTICLE INFO

*Article history:*
Received 23 September 2010
Received in revised form 8 February 2011
Accepted 10 February 2011

ABSTRACT

Chinshan Nuclear Power Plant in Taiwan is a GE-designed twin-unit BWR/4 plant with original licensed thermal power (OLTP) of 1775 MWt for each unit. Recently, the Stretch Power Uprate (SPU) program for the Chinshan plant is being conducted to uprate the core thermal power to 1858 MWt (104.66% OLTP). In this study, the Chinshan Mark I containment pressure/temperature responses during LOCA at 105% OLTP (104.66% OLTP + 0.34% OLTP power uncertainty = 105% OLTP) are analyzed using the containment thermal-hydraulic program GOTHIC. Three kinds of LOCA (Loss of Coolant Accident) scenarios are investigated: Recirculation Line Break (RCLB), Main Steam Line Break (MSLB), and Feedwater Line Break (FWLB). In the short-term analyses, blowdown data generated by RELAP5 transient analyses are provided as boundary conditions to the GOTHIC containment model. The calculated peak drywell pressure and temperature in the RCLB event are 217.2 kPaG and 137.1 °C, respectively, which are close to the original FSAR results (219.2 kPaG and 138.4 °C). Additionally, the peak drywell temperature of 155.3 °C calculated by MSLB is presented in this study. To obtain the peak suppression pool temperature, a long-term RCLB analysis is performed using a simplified RPV (Reactor Pressure Vessel) volume to calculate blowdown flow rate. One RHR (Residual Heat Removal) heat exchanger is assumed to be inoperable for suppression pool cooling mode. The calculated peak suppression pool temperature is 93.2 °C, which is below the pool temperature used for evaluating the net positive suction head of pumps of the RHR system and the Emergency Core Cooling Systems (96.7 °C). The peak containment pressure and temperature are well below the design value (386.1 kPaG and 171.1 °C). Containment integrity of Chinshan Plant can be maintained under the SPU condition.



## 1. Introduction

The Chinshan Nuclear Power Plant owned by Taiwan Power Company is the first nuclear power plant constructed in Taiwan. It has two identical units of GE-designed BWR/4 reactors with Mark I containment. Unit 1 and Unit 2 each had original licensed thermal power (OLTP) of 1775 MWt, and began commercial operation in December 1978 and July 1979, respectively. Through the implementation of the Measurement Uncertainty Recapture Power Uprate (MUR PU) program (Chinshan Nuclear Power Station, 2007), the core thermal power of each unit has been uprated to 1804 MWt (101.63% OLTP) in February 2009 and July 2008, respectively. Currently, the Chinshan Stretch Power Uprate (SPU) program is being conducted to further increase the core thermal power of both units to 1858 MWt (104.66% OLTP).

If a Loss of Coolant Accident (LOCA) occurs, blowdown fluid from the broken pipes will be accommodated by the containment and the pressure and temperature of the containment will increase. To suppress the radioactive releases to outside atmosphere below the regulatory limitation, the containment structure integrity should be maintained. As required by the Standard Review Plan for BWR containments (U.S. NRC, 2007), peak containment pressure and temperature caused by accidents must be below the respective design values. The containment pressure/temperature (P/T) responses in the Chinshan FSAR section 6.2 (Taiwan Power Company, 2008) were analyzed using CONTEMPT-PS more than thirty years ago. However, only the Recirculation Line Break (RCLB) event was considered. Short-term and long-term analyses were not specifically considered in Chinshan FSAR.

The schematics of the Chinshan Mark I containment is shown in Fig. 1. The Reactor Pressure Vessel (RPV) is surrounded by a bulb-shape drywell, which has a free volume of 130,000 ft$^3$ (Taiwan

*Abbreviations:* ADS, Automatic Depressurization System; BOP, Balance of Plant; CS, Core Spray; DW, drywell; ECCS, Emergency Core Cooling System; FSAR, Final Safety Analysis Report; FWLB, Feedwater Line Break; HPCI, High-Pressure Coolant Injection; HX, heat exchanger; LOCA, Loss of Coolant Accident; LPCI, Low-Pressure Coolant Injection; MSLB, Main Steam Line Break; MUR PU, Measurement Uncertainty Recapture Power Uprate; NPSH, Net Positive Suction Head; OLTP, original licensed thermal power; P/T, pressure/temperature; RCLB, Recirculation Line Break; RHR, Residual Heat Removal; RPV, Reactor Pressure Vessel; SPU, Stretch Power Uprate; SRV, Safety Relief Valve; WW, wetwell (suppression chamber).

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doi:10.1016/j.nucengdes.2011.02.004

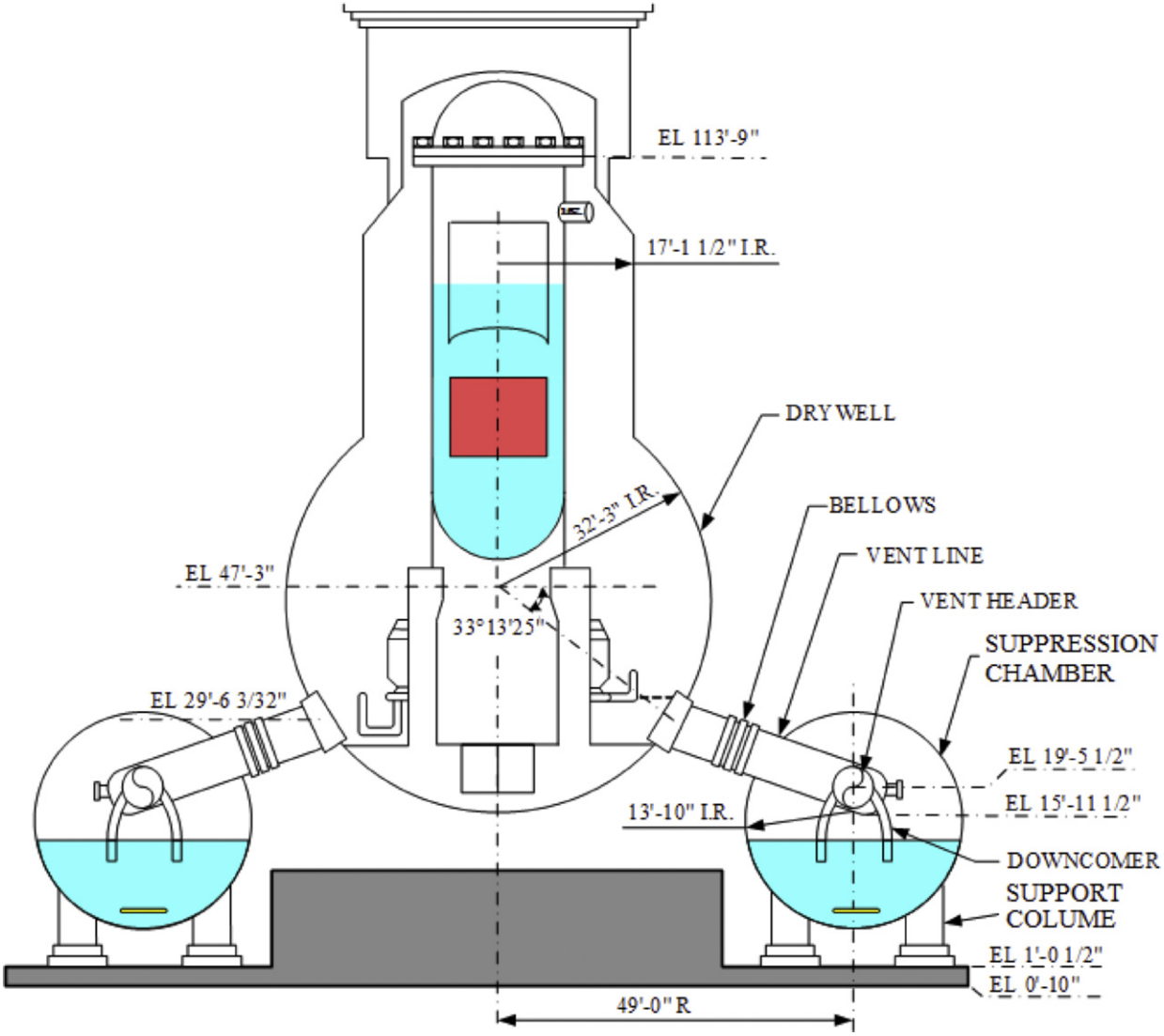


**Fig. 1.** Schematics of the Chinshan Mark I containment.

Power Company, 2008). If a pipe breaks within the containment, blowdown fluid will be discharged to the drywell first. Eight vent lines with an inner diameter of 6.75 ft are connected to the drywell bottom, and then merged into a common vent header which has an inner diameter of 4.75 ft. Ninety-six (96) downcomers with an outer diameter of 2 ft are connected to the header, and extended downward to vent the blowdown fluid to the suppression pool. The downcomers terminate at 8 ft height above the bottom of the suppression chamber (wetwell). The suppression chamber is a torus structure composed of an air space filled with nitrogen and a suppression pool filled with water normally. It has a total free volume of 173,000 $ft^3$ (Taiwan Power Company, 2008) and has an inner diameter of 27 ft and 8 in. To assure that the blowdown steam can be well condensed, the suppression pool water level is required to be above the ends of the downcomers. Based on the Chinshan Technical Specification (Taiwan Power Company, 2006), the high water level of the suppression pool is 2 ft and 6 in. below the torus center, and the low water level is 2 ft and 11.125 in. below the torus center.

In this study, the Chinshan Mark I containment P/T responses are analyzed using the containment program GOTHIC version 7.2a (EPRI, 2006a, 2006b). The whole primary containment is divided into control volumes and flow paths (junctions). Mass, momentum, and energy conservations of the vapor, liquid and drop phases are solved to obtain the transient P/T responses. The vapor phase fluid consists of steam and non-condensable gases. The non-condensable gases considered in this study include nitrogen and oxygen. The perfect gas law is applied to the non-condensable gases, and the Dalton model is used to calculate the partial pressures of steam and non-condensable gases. Heat transfer between fluid and solid walls is considered by modeling the walls of the drywell and wetwell as one-dimensional heat conductors.

In addition to the RCLB event, Main Steam Line Break (MSLB) and Feedwater Line Break (FWLB) events under 105% OLTP condition are also analyzed in this study. Double-ended-guillotine pipe break are assumed in these LOCA events. Short-term analyses of these three events are investigated to find the peak drywell pressure and temperature. The peak temperature of the suppression pool is calculated in the long-term analysis, in which only the RCLB event is considered. For Chinshan Mark I containment, the design pressure and temperature are 56 psig and 340 °F (Taiwan Power Company, 2008), respectively. Under SPU condition, the containment peak pressure and temperature during LOCA should be below the design values to maintain the containment integrity. The present study is