Design Characteristics of APR+ CCWS operating modes

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1. Introduction

The CCWS (Component Cooling Water System) removes the heat from all safety and some non-safety-related components required for normal power plant operation, and normal shut-down of the plant, and rejects the heat to the essential service water through the component cooling water heat exchangers. In APR+ (Advanced Power Reactor Plus), which is upgraded by enhancing the safety, the four train design philosophy is applied to the operating mode of CCWS. Also, the system is reinforced by adding some components.

This paper describes the operating mode of APR+ CCWS which consists of start-up/shut-down, normal plant operation and abnormal/accident conditions.

2. The system operation

The APR+ CCWS consists of four independent trains. Each train of the CCWS is capable of supporting 100% of the cooling functions required for ~~a~~ safe shut-down. In other words, the N+2 design concept ensures a safe shut-down even if a single failure occurs as one train is in maintenance. Therefore, the number of equipments is increased for redundancy over domestic NPPs which implemented 2 train of OPR1000 and semi-4 train of APR1400, as below in table 1.

Table 1. Comparison with APR+ CCWS and the other domestic NPPs

	unit	OPR1000	APR1400	APR+
Pump	EA	4	4	4
Heat exchanger	EA	4	6	8
Makeup water pump	EA	2	2	4
Surge tank	EA	2	2	4
Chemical addition tank	EA	2	2	4

In Table 2, CCWS of APR+ is compared with overseas competitive NPPs. Although all NPPs employed N+2 design concept, APR+ guarantees more redundancy. While two 50% trains in overseas competitive NPPs are involved for safe shut-down in maintenance and single failure, APR+ CCWS enables one 100% train to safe shut-down. Thus, the remaining one 100% train in APR+ is stand-by for redundancy.

Table 2. Comparison with APR+ CCWS and overseas competitive NPPs

	APR+	US-APWR	US-EPR
Mechanical	100%×4	50%×4	50%×4
Electrical	100%×4	50%×4	50%×4

PAFS (Passive Auxiliary Feedwater System) is introduced first in APR+ in place of previous auxiliary feedwater system. Consequently, the auxiliary feedwater storage tank is removed and a storage tank is added to supply seismic category I makeup water.

As shown in figure 1, each train has one CCW pump, two 50% CCW exchangers, a surge tank and a chemical addition tank. And the CCWS is connected to its corresponding ESWS (Essential Service Water System) train through the component cooling water heat exchanger.

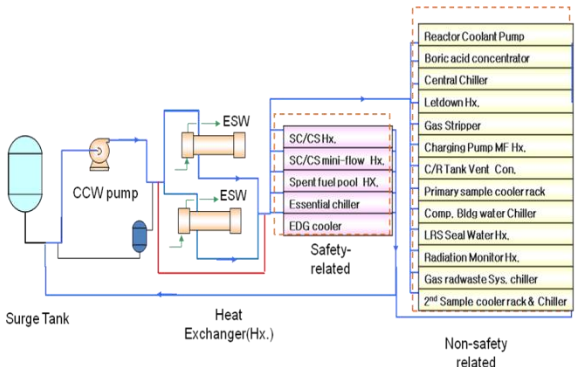

Fig. 1. One Train Schematic of APR+ CCWS

The operating modes of CCWS in APR+ are comprised of five operational conditions. The fundamental functions of these modes are similar to the other domestic NPPs except the number of components and system formation caused by N+2 design concept.

2.1 Start-up

To start-up the plant, temperature and pressure of the reactor coolant are increased to hot stand-by condition through the frictional heat of the operation of the reactor coolant pumps and decay heat. The cooling water is supplied to all equipments except for the EDG (Emergency Diesel Generator) coolers. This requires the use of four trains of the component cooling water system, i.e. eight CCW heat exchangers, and four CCW pumps.

2.2 Normal power operation

During normal operation, two CCW pumps, which are the one from either train A or C and the other one from B or D, supply cooling water through four CCW heat exchangers to safety and non-safety related components except the EDG coolers and the SC (Shut-down Cooling)/CS (Containment Spray) heat exchangers in the train shown in figure 1. Non-safety related components are arranged separately into two divisions so that the heat load and flow rate are distributed equally as possible in both divisions. The cooling water temperature is maintained between 65°F and 95°F at the component cooling water heat exchanger outlet during normal power operation. In previous domestic NPPs, cross-tie was applied between trains to prepare for maintenance or failure of one train. By Lim et al. [4], cross-tie operating can cause some impact pressure. In APR+, however, these concerns are removed thanks to the N+2 design.

2.3 Normal shut-down

Four trains of the CCWS, 8 heat exchangers and 4 pumps, are operated to accomplish a normal reactor shut-down that is to cool the reactor coolant from normal operating temperature to 140°F within 24 hours of reactor shut-down. A normal reactor shut-down is achieved by cooling the reactor coolant 350°F through the steam generators and then cooling to 140°F with use of four trains of the SCS, CCWS and ESWS. In winter season, the temperature of the CCWS is affected because temperature of the ESWS is lower than other seasons. Thus, the bypass valves are appropriately controlled by jogging function to maintain the cooling water temperature above the minimum temperature of 65°F.

2.4 Refueling Operation

With four trains of the CCWS supplying cooling water, the RCS (Reactor Coolant System) will be at a refueling temperature of 120°F at 96 hours after reactor shut-down. The component cooling water is supplied to all components other than the emergency diesel generator coolers and RCP (Reactor Coolant Pump) cooler. The heat load on SC/CS heat exchanger is from the reactor decay heat.

2.5 Plant abnormal/accident condition

During plant abnormal/accident operation, one pump in one train is involved operating to supply cooling water to the essential components required for safe shut-down and mitigation of the plant abnormal conditions. Compared with the other NPPs with 100% × 2 train or 50% × 4 trian, 100% × 4 train of APR+ retains more enough cooling capacity for safe shut-down. In response to a SIAS (Safety Injection Actuation Signal), cooling water is supplied to all safety-related components and cooling water to all non-safety-related components except the reactor coolant pump is automatically isolated. The cooling water to the RCP is supplied until the CSAS (Containment Spray Actuation Signal) occurs. Cooling water is automatically supplied to the emergency diesel generators by the isolation valves opening on a SIAS or D/G starting signal. Upon receipt of SIAS or CSAS, the isolation valves for the SCS/CSS heat exchangers are opened automatically to provide the cooling water required for the SCS/CSS heat exchangers.

In the event of the loss of offsite power, each train of the CCWS is automatically powered from the emergency diesel generator in accordance with the emergency load sequence.

3. Conclusions

CCWS provides the safety-related and non-safety-related components with the cooling water during a variety of operating modes through CCW heat exchanges. In APR+ which enhances the safety and economy from existing NPPS, four train design philosophy is employed to CCWS and thus each train has 100% cooling capacity required for safe shut-down.

During normal operation, each one train in two divisions is operated to supply cooling water to all components except the EDG coolers and the SC/CS heat exchangers. In the other operating modes, all trains are involved by considering the heat load and actuation signals.

CCWS of APR+ is designed more reliable and credible through N+2 design philosophy in comparison with overseas and domestic NPPs. In case of accident, affordable cooling capacity is achieved. And, each train is designed independently so that one train enables reactor to cool down even if the other train is in maintenance that gives no need for additional component such as cross-tie.

REFERENCES

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