Conceptual Design of the Top Mounted In-core Instrumentation for APR1400

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1. Introduction

After Fukushima nuclear accident, severe accident becomes a big issue in the world. In response, Safety issue for nuclear power plant is reviewed. One of the main issue is Top Mounted In-core Instrumentation (TM-ICI) [1].

TM-ICI has the advantage of the structural integrity on the reactor bottom head during severe accident.

This research about adopting the TM-ICI for APR1400 has been performed to have this advantage.

2. Survey of TM-ICI Reactor

Currently, many TM-ICI reactors are developed or developing that some TM-ICI reactors are reviewed in this research.

U.S.EPR is a PWR, designed by AREVA NP, Inc, and it is a four loop plant. All ICIs are top-mounted and details are in Fig.1 [2].

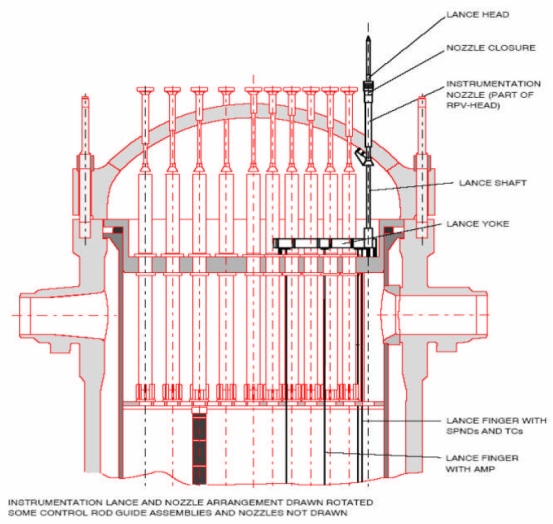

Fig.1. Section view of AREVA U.S EPR

U.S. AP1000 is also PWR, design by Westinghouse, and all ICIs are top-mounted. The ICI nozzles are located between each CEDM nozzles in initial design of AP1000. But all ICI nozzles are moved to the outside of CEDM nozzles. Fig.2 is the current design of U.S. AP1000 [3].

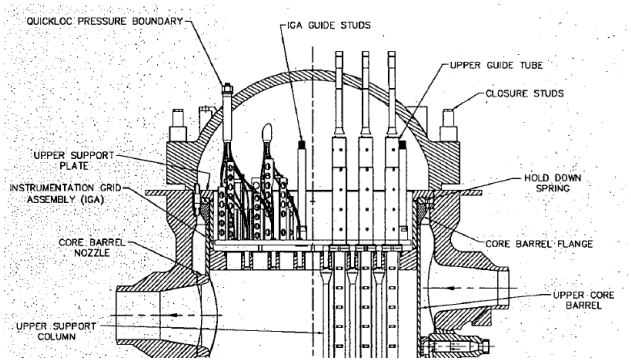

Fig.2. Section view of AP1000

Combustion Engineering (CE) had already developed the TM-ICI and many of reactors are currently operating. Fig.3 is one of the TM-ICI reactors designed by CE [4].

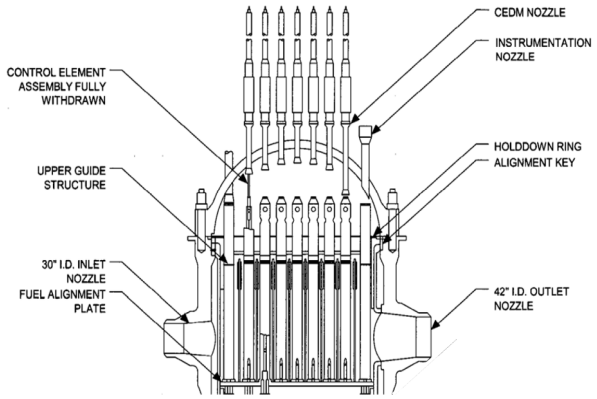

Fig.3. Section view of TM-ICI reactor

As previously stated, detail designs of reactor which adopt the TM-ICI are difference in various reactors, however outline of configuration is similar to all reactor that the research has been performed by reviewing them.

Especially, ICIs are distributed at the upper portion for the RV and RVI that upper portion of the reactor vessel (RV), reactor vessel internals (RVI) and reactor vessel closure head (RVCH) have been reviewed in detail.

First, RVCH has been reviewed. In the APR1400, Control Element Drive Mechanism (CEDM) nozzles are located in the middle of the RVCH due to the fuel assembly location as shown in Fig.4.

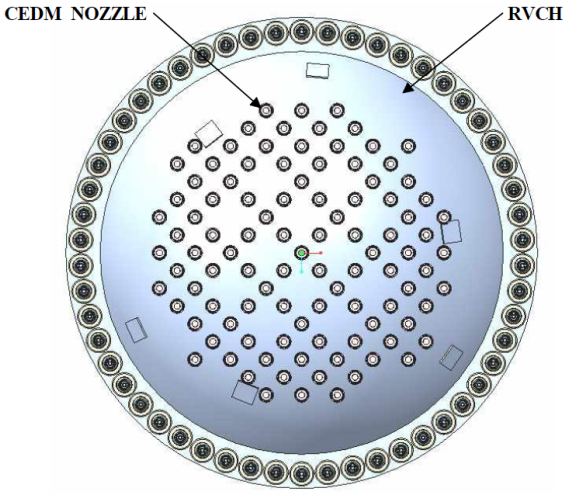

Fig.4. Top view of APR1400

In the same manner of BM-ICI distribution, each ICI needs own nozzle to pass through the RVCH that ICI nozzles will be located between the CEDM nozzles. It can affect the structural integrity of RVCH. Therefore in case of the TM–ICI reactor, ICI nozzle is located outside of the CEDM nozzles as shown in Fig.5. Moreover, more than two of ICIs are assembled together to decrease the penetration of RVCH.

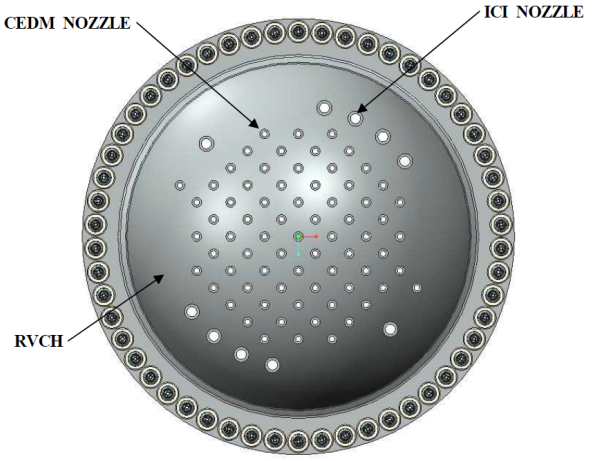

Fig.5. Design concept of top view for TM-ICI

Second, the region between the RVCH and Upper Guide Structure (UGS) support plate has been reviewed.

There is an enough room between the RVCH and UGS support plate in the TM-ICI Reactor, and there are no obstacles between each Control Element Assembly (CEA) shrouds that the ICI guide tube can be distributed easily from bottom of the RVCH to UGS support plate.

3. Review on possibility of TM-ICI for APR1400

Detail reviews about RV, RVI and RVCH are performed in this research to adopt the TM-ICI in APR1400. The configuration of APR1400 RV, RVI and RVCH is shown in Fig.6.

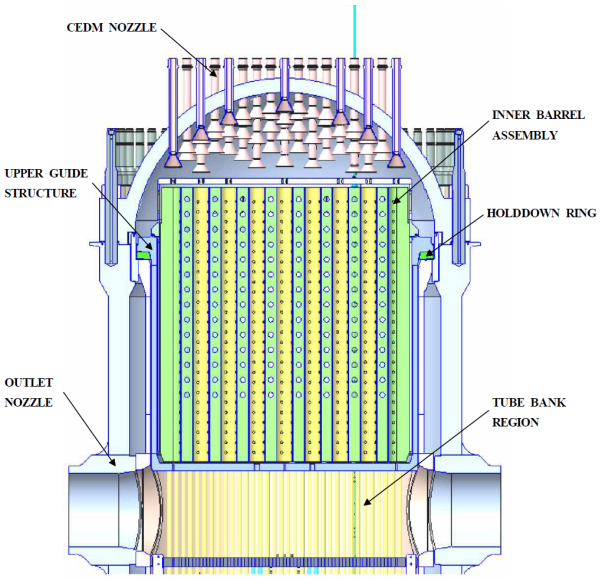

Fig.6. Section view of APR1400

In case of APR1400, CEDM nozzles are located near the middle of the RVCH, and the ICI nozzles shall be located outside of the CEDM nozzles such as TM-ICI reactor arrangement. This will be a minor change on RVCH.

However, major design change is required on the UGS to distribute the ICIs from bottom of the RVCH to top of UGS support plate. As shown in Fig.6, the space between the bottom of the CEDM nozzle and the top of the UGS assembly is narrow in the APR1400, and ICI cannot distribute inside the upper portion of the reactor.

Two alternative methods are reviewed in this research to resolve this problem. One is to distribute the ICI inside the Inner Barrel Assembly (IBA) and the other is to distribute the ICI inside the tube bank.

IBA in Fig.6 is the web structure which is the vertical configuration and is mounted between the CEA shrouds, and it may disturb the ICI guide tube path for distribution. Therefore, the first method is very difficult to use.

In addition, there are two types of CEAs for APR1400 and CEAs are alternately located in Fig.7. It may disturb the distribution of the ICI. CEAs are fully withdrawn near top of the IBA and fully inserted near bottom of the IBA that ICI cannot pass through the CEAs. It may disturb the CEAs movement while CEAs are inserting to the fuel assembly or withdrawing from the fuel assembly. Therefore, the ICI shall be bent to avoid CEAs and it makes many point of bending. Many bending point will cause functional problem of ICI.

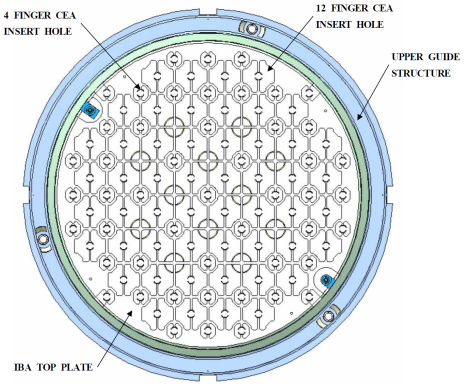

Fig.7. Top view of the UGS for APR1400

ICIs can be distributed in the tube bank region. However, main coolant flows in the tube bank region that the ICI guide tube support is needed to maintain the ICI functions. But distance between CEA guide tubes is very narrow so that there is no room for ICI guide tube Support.

For this reason, the design change of UGS is needed to adopt TM-ICI in APR1400, and CEA types shall be unified for suitable distribution of ICI.

4. Design change of UGS for TM-ICI

To adopt the TM-ICI, UGS design shall be changed into Fig.8. Especially, two types of CEAs shall be unified and only one CEA shall be inserted in one fuel assembly.

Webs which are located inside of the IBA shall be removed for suitable distribution of ICI. It can help the ICI guide tube to pass through between the CEA shrouds.

UGS height shall be determined by active core length, and CEA length and UGS barrel height shall be determined by ICI bending radius that ICI shall maintain the function.

Configuration of UGS design concept is shown in Fig.8.

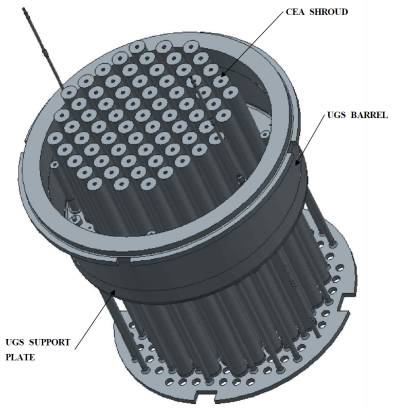

Fig.8. Configuration of UGS design concept for TM-ICI

Fig.9 is distribution concept of ICIs for TM-ICI.

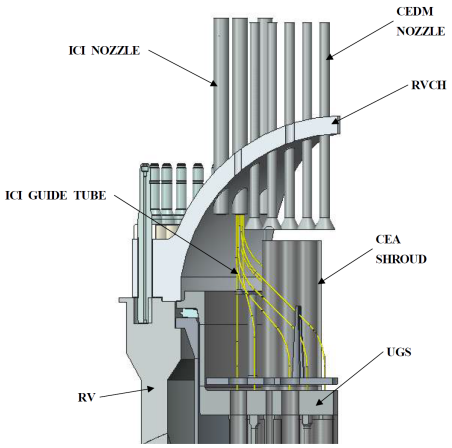

Fig.9. Distribution concept of ICIs for TM-ICI

5. Conclusions

Designing the nuclear power plant, safety issue is very important, and TM-ICI is one of the main issue. For the research of the TM-ICI, APR1400 has been reviewed for possibility of the TM-ICI and the results are as follows:

- The ICI nozzle head penetration shall be located outside of the CEDM nozzles.
- Two types of CEAs shall be unified into one type.
- Web structures are removed from inside of UGS.

6. Acknowledgments

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