Modifications on TR-2 Reactor Against an Expected Earthquake

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ABSTRACT

TR-2 Research Reactor is one of the two research reactors in Turkey which was shut down by the regulatory body at 1995 due to seismic safety and has been in the process of being in a long-term shutdown since then. Within the scope safety enhancement, some modifications have been made to take some extra safety precautions. The reinforcement work of the TR-2 Research Reactor, is perhaps the example for some of the reactors in similar positions in the world. The project, which was prepared according to the value of 0.69g PGA, was put into practice after the Fukushima accident and the building was strengthened to the expected seismic events. In this process, some safety measures, from the measures taken after Fukushima, have been evaluated and implemented with the recommendations made in the framework of the different missions made by the IAEA. These include essentially, emergency water spray system above the core and portable emergency energy supply generators and their external connection boxes. Additional safety precautions have been taken, such as fixing the overhead crane against seismic derailing, analyzing all the critical components for nuclear safety and upgrading or retrofitting where necessary.

1. Introduction

After the accident of Fukushima Daiichi, one of the most important and most devastating accidents in nuclear industry, distrust of nuclear energy has started to rise again [1,2]. However, sector representatives are making serious efforts to improve safety in existing nuclear facilities and trying to rebuild public trust. In post-accident emergency action plans taken on a global basis, efforts are being made to avoid post-accident effects by applications such as radioactivity measurements, sample analyzes and environmental decontamination [3,4,5]. International organizations involved in nuclear safety are engaged in informative activities by member states to strengthen the nuclear infrastructure of countries and thus to improve their emergency preparedness and to respond effectively in similar incidents [6,7,8]. TR-2 Research Reactor is open pool type and has 5 MW thermal power, built between the years 1977-1982. Neutron flux of the reactor is $5x10^{13}$ n/cm^{2}s. Reactor was used until 1995, mainly for training, experimental studies and for purposes such as isotope production and neutron activation analysis. The recommissioning of the reactor, which has been in extended shutdown status for a long time since 1995, is ongoing and is expected to be operational again in near future. Significant structural modifications have been made over this period. Firstly, in 2009, the high enriched spent fuels were sent back to the USA and replaced with low enriched ones within the frame of the USA initiated project about HEU fuels. In this way, HEU fuels were replaced to LEU fuels. By the year 2011, the reinforcement project of reactor building was prepared, put into practice in 2012 and completed in 2013, to withstand the highest expected earthquake acceleration value, 0.69 g PGA.

Expert Mission and INSARR Missions were also carried out by the IAEA during this period, and many safety enhancements were carried out to meet the recommendations. Most of these modifications are also considered as extra safety measures taken after Fukushima. The Safety Analysis Report is being updated according to the requirements of the regulatory body; all the topics; from earthquake hazard analysis to accident analysis, quality system update to safety margins settings etc. are revised.

2. Safety Measures Taken After the Fukushima Daiichi Accident

At the TR-2 Research Reactor, the core configuration for the license is called 15.00 Cycle and there are a total of 16 fuel elements in the core. The total amount of ^{235}U is 5,7 kg. and the reactor characteristics are shown in Table I.

TABLE I: Basic Characteristics of TR-2 Research Reactor Core

General	
Type of Reactor	Open pool
Thermal Power	5 MW
Nuclear	
Number of Fuels in the Core	16
Fuel Line	4x4
Number of Control Rod	4 (2 safety, 2 control)
Neutron Absorber Material	% 80 silver, % 15 indium, % 5 cadmium alloy nickel-plated
Core Fuel Load (Beginning of the Cycle)	5,7 kg Uranium-235
Cycle Time	60 days-full power
Fuel	
Type	Plate
Plate per Fuel Element	Standart:23, Control:17, Irradiation:12
Active height	600 mm
Active width	62,3 mm
Thickness of the Plates	Inner plate: 1,27 mm Outer plate: 2,14 mm
Width of cooling channel	2,1 mm
Reactor Pool	
Pool Depth	8,95 m
Water Column Above the Core	6,90 m
Amount of Water in the Pool	450 m^3

TR-2 has an automatic safety system and the scram logic of the reactor is shown in *FIG.1*. There are many safety logic, on different components. With the last modifications additional safety systems has been added. One more seismic detector, ultrasonic pool level detector, flooding detectors and the new radiation detection system can be given as an example.

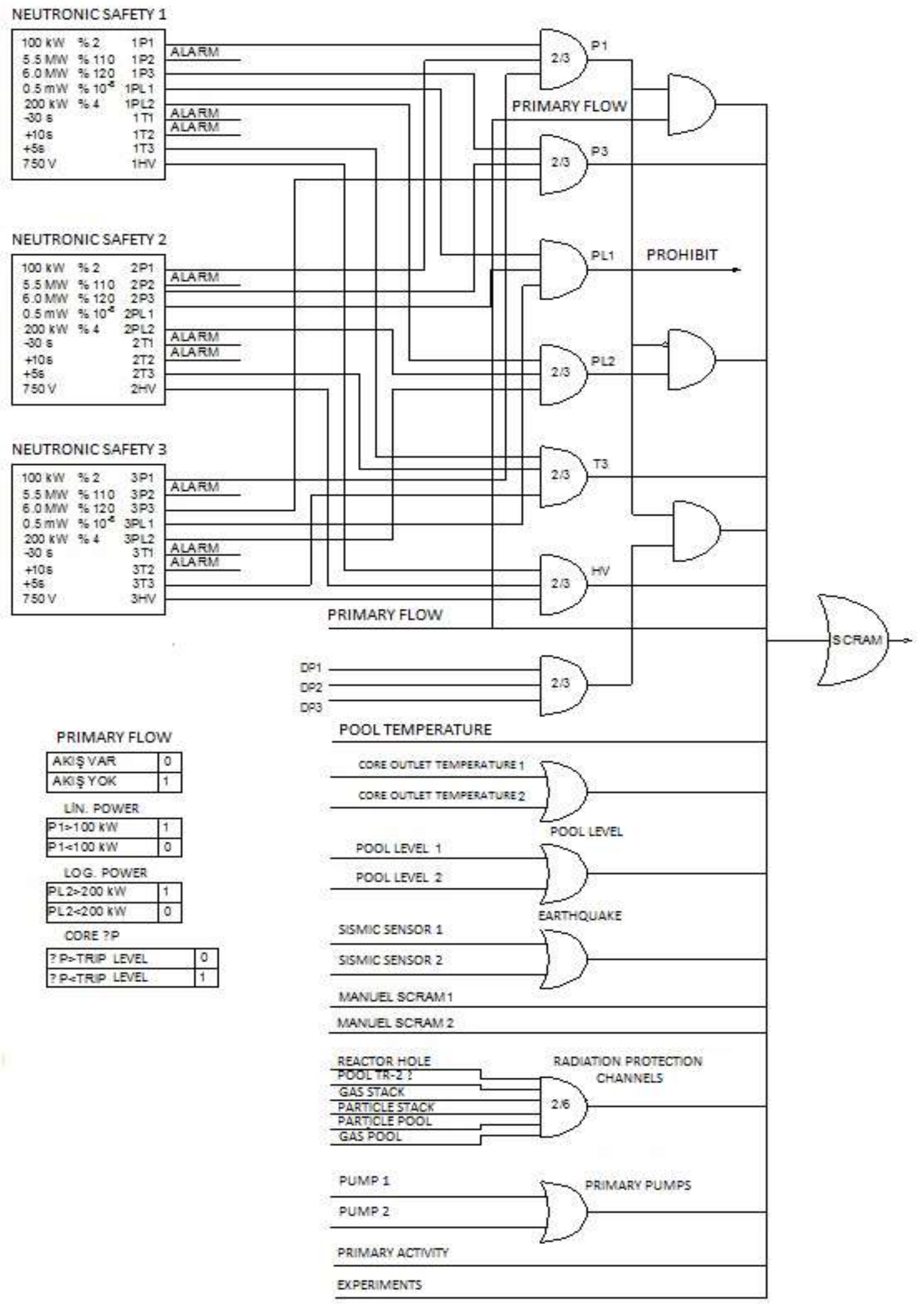

FIG.1 TR-2 Scram logic

The diagram contains the scram logic of TR-2. Neutronic channels data, pool temperature, water level, pressure difference and flow debit data, radiation protection channels and seismic data are some part of this logic system.

As can be seen, the safety logic chain is set up and working. Nevertheless, accidental analysis of our installation was carried out in SAR Chapter 14, with the possibility of an accident that may occur. In normal operation conditions, the estimated dose limit to the public is calculated as 1,5 µSv/year. Even in the beyond design basis accident scenario, the surrounding radioactive inventory remains at the facility borders and the dose amount is calculated to be 0,34 mSv.

However, engineered safety features have been added to the facility to reduce the impact of an accident that can not be prevented despite all the precautions.

2.1. Reinforcement of the Reactor Building Against Earthquake

TR-2 building of the reactor has been reinforced to withstand the expected earthquake which has a 5000 years return period with 0.69 g PGA value *(see FIG.2)*.

FIG. 2. TR-2 Reactor building after reinforcement

Since the location of the Reactor is so close to the North Anatolian fault, the reinforcement project of the facility has been prepared with cooperation of Gebze High Technology Institute (GYTE) and a private engineering company in 2011, started to be implemented in 2012 and completed in 2013 [9].

2.2. Emergency Pool Water Spray System

There is approximately 460 m^3 of water in the TR-2 pool. The wall thickness of the pool is 1.3 m to 0.5 m depends on the elevation. The pool constructed from barite concrete and analyzed during the above mentioned reinforcement project with the main building and it was stated that it will protect its integrity against the expected earthquake. There is, however, a sealed space adjacent to the pool was planned to prevent pool water leakages that may occur through the primary circuit pipe lines passing through this area. There are also motorized valves on the primary circuit piping in the sealed volume. In addition to this, earthquake hazard analysis of the primary cooling system components has been done and will be mentioned in Section 2.4.

Despite all these precautions, in case of hypothetical accident situations such as the excessive water leakage from the pool while the demineralized water addition system is supposed to be inadequate, emergency pool water spray system has been established to maintain water to the pool *(see FIG.3)*. This system is assumed one of the safety measures taken after Fukushima like emergency core cooling system.

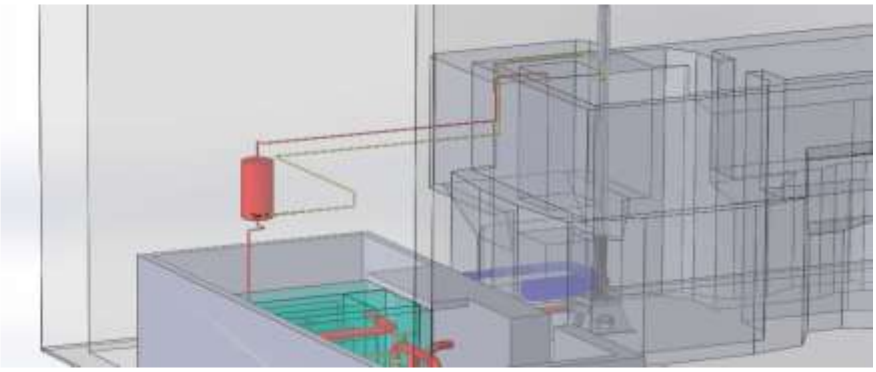

FIG. 3. Emergency pool water spray system

The emergency pool water spray system is constructed of 304L quality stainless steel pipes with TIG welding and ends with a double-sided ball valve collector which can be connected to the standard fire hose outside the building. It has two spray nozzle above the core with the capacity of 1600 lt/min. It is designed to be used manually only the above-mentioned accident situations with raw water addition from the fire system, connected to a 1000 m^3 underground water tank, or by fire brigade connection.

2.3. Portable Emergency Generators

The plant's energy supply system is redundant with two parallel diesel generators, each with enough capacity for the entire facility. Also, important components for safety (compressed air system, emergency lighting system, pool isolation valves, ventilation flaps, etc.) are supplied from a 15kVA uninterruptible power supply (UPS). In addition, the radiation monitoring system, and measurement and monitoring units in the control room are also supplied from an additional UPS. UPS systems have been strengthened and analyzed against the expected earthquake. Besides, as one of the post-Fukushima measures, two portable generators were provided as redundant energy source for the reactor control room and the safety system components. The characteristics of the generators are given in Table II.

TABLE II: Portable Generators Characteristics

AC Nominal Power	8 kW (10kVA)
AC Maksimum Power	8,8 kW
RPM	3000 rev/min
Terminal Number	2
Frequency	50Hz
Voltage	230/400V

If there is a blackout in grid and diesel generators and at the same time a mulfunction in the UPS systems, these emergency generators can be activated manually and energy can be supplied to the critical to safety systems *(see FIG.4).*

FIG. 4. Emergency generators and the connection box

The connection mode of the portable generators is adjustable to the current state of the UPS systems *(see FIG.5)*.

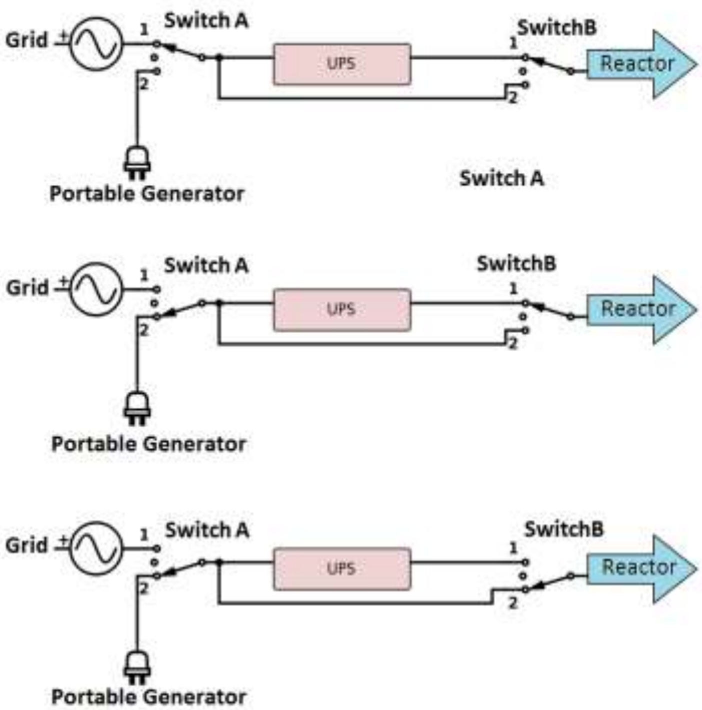

FIG. 5. Connection modes of the portable generators

2.4. Analysis of Important to Safety Components

Earthquake hazard analysis was also carried out between 2016 and 2017 [10], which is important for nuclear safety on the request of the regulatory body after reinforcement of the building.

These include the pool, primary circuit piping, valves and other circuit equipment, core structure, control rods drive mechanism structure, heat exchanger, UPS systems, control room control panels, energy and signaling cable ducts. As a result of analyzes, the necessity of strengthening some of the primary cooling system pipe supports has become clear and strengthened with proper construction.

2.5. Emergency Ventilation System

With the main ventilation system, the building is kept under negative pressure about 200-250 Pa. After receiving a trip signal from one of the gas particle detectors, sampling from the pool surface and stack, the main ventilation system is automatically deactivated, and the fresh air inlet and air discharge flaps are automatically closed by pneumatic pistons. When the internal and external pressures are close to equalizing, the emergency ventilation system is activated by the system. There are particulate and iodine filters in the 3-stage filter system *(see FIG.6)*.

FIG. 6. Emergency ventilation system

2.6. Fixing The Overhead Crane

The TR-2 Pool has a 10-ton capacity movable crane above the pool. In comply with the IAEA mission recommendations, approximately 50 cm huge gaps, between the crane and the columns, were reduced to 3 cm by the way using steel construction buffers. Thus, in the expected earthquake, seismic derailing of the crane was eliminated. 2.4 meters of the 5-meter crane width is covered with buffers and the remaining part is covered with steel rope stretched between the buffers *(see FIG.7)*.

FIG. 7. *Crane buffers*

3. Conclusion

Safety improvements in the TR-2 Research Reactor are aimed at minimizing the potential damage that may arise against the expected earthquake. Also in the process of relicensing the reactor which has been in long-term shutdown, the requirements of the regulatory body have been fulfilled. All the safety measures will continue to be taken in the process. Thus, it is aimed to take the operation license and recommission the reactor. Good practices for improving safety throughout the world also contribute positively to TR-2 safety.

4. References

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