OPERATIONAL RADIATION PROTECTION AT THE TEHRAN RESEARCH REACTOR TRR

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Abstract

The research reactor TRR is in operation more than 50 years; at the same time the reactor technical condition allows its further safe operation in the case of upgrading of some systems and elements. The basic objective of the reactor modernization implies future utilization complying with the nuclear and radiation safety requirements. The radiation protection system is the subject of such modernization. An overview of the technical and organizational measures aimed on the radiation protection of staff and population at the reactor routine operation is presented. The amount emission rates of Kr and Xe noble gas are measured in TRR. Measuring noble gases is very important in maintaining the health of reactor staff.

Keywords

Research reactor, Radiation protection, Staff exposure, radioactive release, Radiation monitoring, noble gas

1. Introduction

The TRR reactor is a heterogeneous water moderated pool type research reactor operating with the thermal neutrons at a power level of 5 MW, giving a maximum neutron flux of 3.6×10^{13} $n.cm^{-2}.s^{-1}$ at the core center. Main goal of the reactor use is the generation of neutron beams for the research purposes in different areas of physics, Chemistry, Engineering and Industrial. The reactor core is immersed in either section of a two-section, concrete pool filled with water. One of the sections of the pool contains an experimental stall into which beam tubes and other experimental facilities converge. The reactor is located at the site of the atomic energy organization in the Tehran city. For more than 50 years of operation there was not any single incident with the exceeding of norms and conditions of the normal operation as well as there was no contamination detected above the established levels by radionuclides and aerosols for the free access premises. The reactor final shut-down. The reactor final shut-down term is not defined yet and the reactor operation is carried out now in accordance with the separate permissions issued for several years. Lifetime for the reactor vessel and primary circuit is not determined by the design documentation. Surveys performed until now provide evidence that there are no negative changes beyond the design limits in the reactor vessel and primary circuit components. Upgrade of the reactor systems or replacement of the specific equipment was aimed on the safety improvement during the reactor operation. All reactor systems were upgraded completely or partially at the time of reactor many-years' service. The basic objective of the reactor modernization implies its future use complying with the nuclear and radiation safety requirements. The radiation protection system (RPS) is a substantial component of such reactor's modernization. Upgraded RPS along with other safety important systems meets all regulatory requirements for the regular reactor operation and operative decision-making in the case of radiation incidents as well as the forecast of possible emergency situations.

2. RPS structure

Radiation safety provision is the most important element of the whole technological chain at the reactor operation. The staff, population and environment should be protected from the all kinds of radiation hazard [1]. Safety is provided in accordance with the requirements of acting normative documents, norms, rules and standards. The norms establish the following categories of persons being exposed:

Category A (staff) includes those individuals who directly handle permanently or temporarily sources of ionizing radiation; Category B (staff) includes individuals who are not directly dealing with sources of ionizing radiation but due to location of their working places within the premises and on sites of the engineering facilities where radiation and nuclear technologies are available could get additional exposure; Category C includes all the public. Exposure dose limits are 20, 2 and 1 mSv/year for the category A, B and C, respectively. The radiation hazard from the TRR reactor regular operation is determined by following factors:

External gamma- and beta-irradiation of different energies arising from the nuclear fuel and fission products, the induced activity of coolant, reactor constructions and units, corrosion products, the activated materials and samples;

Neutrons of different energies (from fast to thermal) from the reactor core. The neutron impact is possible inside the reactor hall nearby the experimental channels; Radioactive aerosols arising from the fission-fragments and induced activity; Noble gases: 41Ar arising from the irradiation of 40Ar in air by neutrons and the isotopes of xenon and krypton from the reactor core and primary circuit;

Radioactive 131I from the fission-fragments;

Radioactive contamination of the working areas, equipment and overalls;

Possible penetration of the activation products from coolant and moderator into the air of working areas;

Solid and liquid radioactive waste.

The controlled area is established in the reactor building, i.e. the restricted area in which the special protective measures are or can be necessary with the goal of the exposure control or prevention of radioactive contamination spread at the reactor routine operation as well as the limitation of potential exposure [2]. All premises in the controlled are divided on three categories: Non-attended – where the technological equipment and communications are located. The staff stay in these premises is forbidden. The access of staff to these premises is permitted for the survey, repair and equipment replacement only;

Semi-attended – where the radiation conditions allow the staff access during the limited time for the technological maintenance and repair works;

Attended premises – where the staff is staying during the whole shift.

Radiation protection program has established the main directions of activity for the reactor staff protection. The radiation control is executed for the monitoring of followings:

Conditions of protective barriers;

Activity of the primary circuit heat-carrier and other technological media:

Radionuclide content;

Dose rate in the premises;

Individual dose of external exposure.

The basic criterion of the RPS effectiveness is the absence of cases when the annual exposure limits are exceed. There are additional criteria such as the annual maximal and average doses of the staff exposure; the decrease of annual collective dose; the decrease of the aerosol activity in the attended premises; the number of cases with the exceeding of control levels.

Dynamics of individual doses are depending on the character and duration of radiation hazardous works and can be used as an explanation of the collective dose variation during considered period. Thus, the main radiation-hazardous works when the staff has the largest dose load are following:

Repair, assembling and dismantling of technological equipment, especially in the pump-room of primary circuit;

Works on the reactor pool, especially at the core reloading;

Replacement of cleaning resins;

Coolant sampling and analysis;

Collection, conditioning, transportation and storage of radioactive waste;

All kinds of works with the spent nuclear fuel in the cooling pond.

3. Control of the radioactive effluents

The noble radioactive gases (NRG) and radioactive iodine isotopes are the main components of the reactor release into atmosphere. All radioactive gases and particulates of containment after filtering through washable metal & chemically activated glass wool filters are discharged to reactor stack. In general, the radioactive noble gases cannot be detected in the environmental samples. All gases concentrated in Hold-Up-Tank (H.U.T) are released through the stack (Table 1) [4]. Individual dose limits exist in order to protect individuals so that they do not receive an unacceptably high dose contribution while the collective dose is being optimized. These dose limits are naturally far below the values at which acute effects are manifested.

Control level values for the reactor staff shows that in table 2. 85Kr is the only radionuclide with a half-life longer that a few days (10.7 years). It is detectable, in very low concentrations, in the atmosphere. 41Ar is produced by the neutron activation of cooling air. Direct radiation from 41Ar plume results in a significant fraction of the dose which the most exposed members of the public receive.

Table 1. Emission Rates of Noble Gases in TRR

Isotopes	Half-Life	µCi/sec
85 Kr	10.7 yr	5×10^{0}
135 Xe	9.2 hr	9×10^{3}
133 Xe	5.27 days	2.5×10^{3}
89 Kr	3.2 min	1.5×10^{2}

Table 2. Control level values for the reactor staff

Place		Gamma-ray dose rate, *µSv/hour*	Neutron dose rate, *µSv/hour*	Concentration**		Contamination β-*part /cm2 ·min*		Annual dose equivalent, µsv
				β-aerosols In air (cps)	NRG in air	Body overalls	functional surface	
Non-attended premises (pump-house):	Hold up tank	⊗	⊗	⊗	⊗	⊗	⊗	6
	Storage tank	⊗	⊗	⊗	⊗	⊗	⊗	6
Semi-attended premises (reactor cover plate)	Spent fuel storage pool	150	⊗	⊗	⊗	<4	<4	6
	Truck door area	2	⊗	⊗	⊗	<0.4	<0.4	6
Other semi-attended premises	Make up	⊗	⊗	⊗	⊗	⊗	<0.4	6
	WTP	0.2	⊗	⊗	⊗	⊗	0.4	6
Attended premises	PAF	1	0.1	⊗	⊗	⊗	⊗	6
Other attended premises	Ventilation room	0.5	⊗	300	⊗	⊗	<0.4	6
Free access zone	Entrance	0. 1	⊗	100	⊗	⊗	<0.4	1

⊗ Not established

** At the operation reactor

WTP Waste Treatment Plan

PAF POOL Access Floor

As a thumb rule, the concentrations of the released radionuclides into environment are often too low to be measurable. Therefore, the dose estimates for the population have to be based on modeling the atmospheric transport and environmental transfer of the released radioactivity [3].

In accordance with results of systematical measurements during 2011-2019, the activity of fission products at the reactor operation was caused by following radionuclides: Ag-110m, Ce-141, Co-60, Cr-51, Cs-137, Cs-138, I-131, I-133, Na-24, Tc-99m,Sb-122,Sb-124,Sr-92, Te-132, W-187, Xe-135, Mn-56,Zn-65

4- External radiation monitoring

Radiation Monitoring

To provide measurements and warning in order to minimize the radiation exposure of operating and research personnel, the following radiation monitoring facilities are used in reactor buildings:
• Gamma area monitoring system. The gamma area monitoring system is a gross gamma election system capable of monitoring six fixed areas of the reactor facility for gamma radiation.
• Air particulate monitoring and sampling system. This system intended to monitor selected area for air borne particulate activity and gaseous activity.

Regarding all safety principles adopted in the design, construction and operation of the TRR, one may conclude that the overall safety objectives are fulfilled. Operation and utilization of the TRR are justified under radiation protection considerations, so that during operational states, radiation exposure of site personnel and the public remains below limits prescribed by national authorities and is kept as ALARA. High standards of engineering design, conservative design margins, engineered safety features and application of passive systems mitigate the probability of radiation hazards. All postulated accidental conditions have been considered in the design stage of the facility and the accidents with significant consequences are extremely unlikely. On the other hand, the design criteria adopted for the resistance of structures, systems and component against natural and man- induced external events meet the overall safety objectives. [4]

Individual external doses should be determined by using approved individual monitoring devices: Thermo luminescent dosimeters (TLD), Film badges, Optically stimulated luminescent dosimeters (OSL), Direct Ion Store dosimeters (DIS), Electronic dosimeters, Evaluation of dose is an important aspect of occupational radiation protection: It confirms compliance with dose limits, It confirms the effectiveness of optimization, It is important that workers always wear their dosimeters, It is important that workers return dosimeters on time for processing, Delays in the evaluation of a dosimeter can result in the loss of the stored information, It is important that the monitoring results are reviewed and used to improve RP. [5]

5- Conclusions

The TRR reactor is an operational nuclear installation during more than 50 years and there are plans to continue its operation. Reactor is equipped by all necessary tools for the provision of radiation protection for the staff, population and environment. Long-term experience of the RPS operation has demonstrated its adequacy and efficiency. The reactor operation has negligible influence on environment and cannot be a reason of any negative ecological changes.

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