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# RELIABILITY AND OPTIMIZATION OF MAINTENANCE OF THE IRT-T REACTOR EQUIPMENTS (TPU)

## 1. Introduction

IRT-T [1] is a pool-type research reactor that uses distilled water as a moderator, coolant, and top shield. The reactor is intended for solid-state physics research, neutron activation study of elemental composition of substances, radionuclide synthesis, silicon doping, and neutron radiography. The reactor core of this reactor is made up of IRT-3M fuel and it uses beryllium as a reflector [2]. At present, close attention has been devoted to the reliability and safety of nuclear power plants, small modular reactors, and research reactors compared to the past. This was because of accidents that happened at Three Mile Island (TMI), the Chernobyl Nuclear Power Plant, and Fukushima. Because the cooling systems of research reactors play a big part in how they work, it would be good for reliability and safety tests to be done on them.

## 2. Major components of IRT-T Reactor Coolant System (RCS)

The Reactor Coolant System (RCS) of an IRT-T reactor consist of primary and secondary loops. The primary circuit which consists of pumps, heat exchangers, fittings, pipelines and holding tank. To cool the primary circuit water in the heat exchangers, process water of the secondary circuit is used. The second circuit includes a cooling tower cooling tower of sprinkler design with the secondary coolant flow rate up to 2100m3/s, four pumps, five heat exchangers, and a system of circulating water supply pipelines as can be shown in figure 1 [1,2].

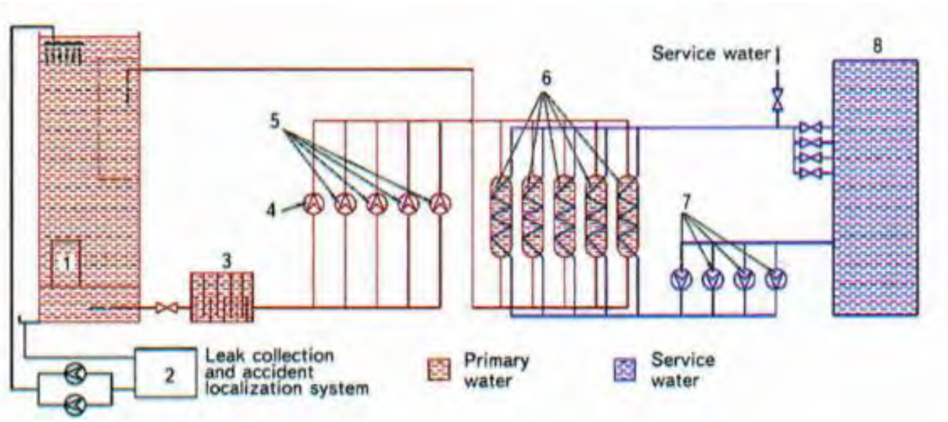


*Fig. 1 Cooling circuit of an IRT-T reactor: 1) Core; 2) 8m3 tank; 3) Retention Reservoir; 4) Emergency Cooling Pumps; 5) Primary Pumps; 6) Heat Exchangers; 7) Secondary Pumps; 8) Cooling Tower; 9) Service Water*

**3. Causes of failures of IRT-T Reactor**

List of initiating events of accidents in IRT-T reactor can be categorized into design basis accidents and beyond design basis accidents. Shutdown of the primary circuit pumps in case of power loss, ruptures of the pipelines of the primary circuit of the heat removal system from the reactor, blocking the coolant flow through the fuel assembly, shutdown of the second cooling circuit, and Jamming of the working bodies of the Control Protection Systems are some of the design basis accidents while loss of external and internal sources of electricity, unplanned input of positive reactivity during refueling operations, with the imposition of an emergency protection failure, spontaneous extraction of the automatic control rod in the event of a complete failure of the emergency protection, and possibility of the formation of critical masses during beyond design basis accidents with melting of the reactor core are some of the beyond design basis accidents [3].

**4. Predicting future probabilities of failures**

There are different methods that can be used in predicting future probabilities of failures. These includes:

- Technique PSA 1 – This technique enables one to investigate project "weak points" and measures to prevent damage to the core.
- Reliability Block Diagram (RBD) – This method is a graphical representation of the success logic of a system utilizing modular or block structures. RBD can be assessed using analytical approaches which are the Truth Table Method, Cut-Set and Tie-Set Method, and Bounds Method
- Markov Models - The underlying premise of the Markov process is that a system's behavior in each state is memoryless, and that the future is dependent on the present but independent of the past.

- Fault Tree Analysis – is a top-down approach to failure analysis, starting with a potential undesirable event (accident) called a TOP event, and then determining all the ways it can happen
- Event Trees – is an inductive procedure that shows all possible outcomes resulting from an accidental

**5. Preparing a mathematical model for calculation reliability and safety**

There are many general formulas used to perform different types of reliability analysis. Some of these formulas are described below.

**5.1. Failure density function**

The formula of failure density function [4] can be written as (1),

$$f(t) = -\frac{dR(t)}{dt} \qquad (1)$$

Where t is time, R(t) is the system /item reliability at time t and f(t) is the failure density function.

To express the reliability of a system used in power plant, the following equation (2) is used.

$$R_{ns}(t) = e^{(-\lambda_{ns} t)} \qquad (2)$$

Where Rns (t) is the system reliability at time t, λ_ns is the nuclear power plant system's constant failure rate.

*Serial connection of elements*

In cases where the system consists of several parts, the failure of at least one of any of which results in the failure of the entire system is said to be serial connected. The block diagram of a series connection with K elements is shown in the figure 2 below.

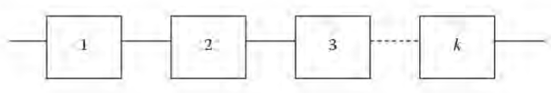


*Fig. 2. A k-unit series system*

The reliability of this system is expressed by (4),

$$R_s = P(E_1 E_2 E_3 ... E_k) \qquad (4)$$

where

$E_j$ is the successful operation (i.e., success event) of unit j, for j = 1, 2, 3, …, k.

P ($E_1 E_2 E_3 … E_k$) is the occurrence probability of events $E_1$, $E_2$, $E_3$, …, $E_k$.

$R_s$ is the series system reliability.

*Parallel connection of elements*

In cases where the system consists of several parts and the failure of only all parts results in the failure of the system, it is said that these parts are connected in parallel. The block diagram of a parallel connection with K elements is shown figure 3 below.

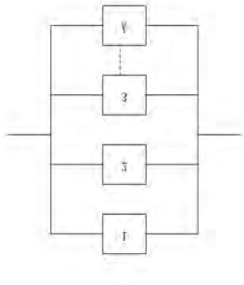

*Fig. 3. Parallel connection of elements*

Then,

$$F_P = F_1 F_2 F_3 ... F_K = \prod_{j=1}^{k} F_j \quad (5)$$

where

Fj is the unit j failure probability, for j = 1, 2, 3, …, k.

**5.2. Analytical performance based**

Based on strength-and-load performance functions, such as the advanced second moment method and computer-based Monte Carlo simulation employing direct and importance sampling.

*Advanced Second-Moment Method*

A performance function can be described in terms of fundamental random variables (Xi) for appropriate loads and structural strength, and this can be used to determine the reliability of an element of a system. The performance function Z is described mathematically as follows (6),

$$Z = Z(X_1, X_2 ..., X_n) = Supply - Demand \quad (6)$$

*Monte Carlo Simulation Method*

Monte Carlo simulation (MCS) approaches are essentially sampling algorithms that are used to evaluate a component's or system's failure probability. There are three ways,

- Direct Monte Carlo Simulation Method - samples of the basic noncorrelated variables are drawn based on their probabilistic properties and fed into the performance function Z as provided by Eq (6). If Nf is the number of simulation cycles in which Z is less than 0 in N simulation cycles, then the mean failure probability can be calculated as follows (7),

$$\overline{P_f} = \frac{N_f}{N} \quad (7)$$

- Conditional Expectation - The CE technique entails producing all of the basic random variables in Eq. (6), with the exception of the random variable with the largest variability (i.e., coefficient of variation). The cumulative distribution function of the control variable is used to calculate the conditional expectation.
- Importance Sampling - The basic random variables in this method are constructed using certain carefully chosen probability distributions (the significance density function) that have mean values that are closer to the design point than their original (real) probability distributions.

**6. Ways in which reliability can be improved**

1. Changing the type of connection between different components
2. Adding parallel connection to a system
3. Use of quorum element. If quorum element is used in the system, then changing the logical forms of quorum element can help to improve the reliability.

**7. Conclusion**

Nuclear technology's benefits have been rediscovered in recent years as a means of meeting future global energy needs in an ecologically aware and resource-sustainable manner. Securing a very high degree of design and operating safety at low costs will be essential not just for the developing nuclear sector, but also from a policy standpoint in order to overcome the public's negative impression of nuclear power. As a result, the safety margin and cost efficiency of reactors in the present fleet will be improved. To improve the reliability of different equipment in NPP, there is need for us to identify the causes of failures of these equipment and ways of predicting them. Calculation of reliability of this equipment will also be essential as it will enable us to know the probability of any equipment to work without failure and also identify ways of improving the reliability if the values are found to be too low.

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# THE DEVELOPMENT OF NUCLEAR WEAPONS: A HISTORICAL AND SCIENTIFIC ASPECTS

## 1. Introduction

Nuclear weapons development may be traced back to 1896, when Henri Becquerel revealed the discovery or finding of radioactivity to the Academy of Sciences in Paris after discovering the radioactive properties of uranium [1]. Rutherford and Soddy defined their hypothesis of radioactivity in 1902 as a spontaneous disintegration of the radioactive element due to particle expulsion, resulting in the formation of new elements. Rutherford later demonstrated, with the help of James Chadwick, that any light atom could be dissolved when struck by alpha particles. In Rutherford's group, John Cockroft and Ernest Walton invented the technique for producing accelerated particle beams for atom disintegration [2]. The main fundamentals of nuclear explosives operation are, nuclear reaction, nuclear fission, nuclear fusion, chain reaction, and critical mass. Nuclear weapons are explosive devices that derives its destructive force from nuclear reactions (fission or fusion). Detonators, chemical explosives, and unique nuclear material make up nuclear weapons, which are controlled by arming, fuzing, firing, and safety systems. Bombs, ballistic missiles, and cruise missiles are all examples of nuclear weapons [3].

## 2. How nuclear weapons work

### *2.1. Gun-assembled fission device*