EVALUATION OF DOSE PROBABILITY DUE INCIDENTS ACCORDING TO THE TYPE OF NUCLEAR RESEARCH REACTORS

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ABSTRACT

This work is intended to establish a risk probability analyses evaluation of incidents according to the type of nuclear research reactors. With this aim, two different IAEA databases were used: Research Reactor Data Base (RRDB) and Incident Report System for Research Reactor (IRSRR). This evaluation employs a Probabilistic Safety Analysis (PSA) for two distributions, Fischer and Chi-square, and the analyses were done considering a 90% confidence level.

INTRODUCTION

Nuclear research reactors have been considered important tools in the nuclear science knowledge. During more than 50 years they allowed scientists to obtain huge contributions for educational and development programs in more than 70 countries around the world. More than 675 research reactors were built until the year of 2007 and 278 of them are maintained in continuous operation (86 settled at development countries). Along all this period, considering all research reactors still under regulatory control, they account for an amount of 17,400 years of operational experience, (the operational experience is named demand (d) in this work). Safety and security concerns, as well as prevention policy, have stimulated the development of this work which leads to the comparison and analysis of incidents, here considered until level 3 in the International Nuclear Events Scale (INES) of the IAEA. So, with basis on operational experience accumulated (d) and with knowledge obtained from abnormal events, it is possible to obtain a classification by type of research reactor incidents and calculate the occurrence probabilities.

OBJECTIVE

The main purpose of this work is to study the various types of nuclear research reactor incidents described by IRSRR and produce a statistical analysis procedure for the prevention of possible occurrences, inside operational nuclear research reactors and new plants. Besides, it is also aimed to estimate maximum allowable doses for such events, so that annual risk limits established by ICRP may be enforced.

METHODS

Total operational experience (d) was obtained from RRDB data for each nuclear research reactor by means of the operational experience summation, since the first criticality until March 2008. From IRSRR, the incident number for the same time interval was obtained and, later, all data were co-related. Data from IRSRR are restricted to member countries of the IAEA and may be accessed only by authorization of the country nuclear regulatory commission. The data presented in this study was authorized disclosure.

A specific PSA calculation computational program, for the Chi-square and Fischer distributions, was developed inserting the equations recommended by the IAEA TECDOC-636- Appendix D, pages 77-79 at Scilab 5.1.1.

Using Sordi equations, the maximum admissible doses to compare with the risk limits established by the International Commission on Radiological Protection, ICRP-64, were achieved.

RESULTS

TABLE 1 – Maximum Incident Probability as a function of doses calculated by Sordi equation

Dose (Sv)	Maximum Incident Probability/year
0.10	1.0×10^{-2}
0.11	1.5×10^{-3}
0.12	8.0×10^{-4}
0.15	2.6×10^{-4}
0.20	1.0×10^{-4}
0.50	1.0×10^{-5}
1.0	2.5×10^{-6}
2.0	1.0×10^{-6}

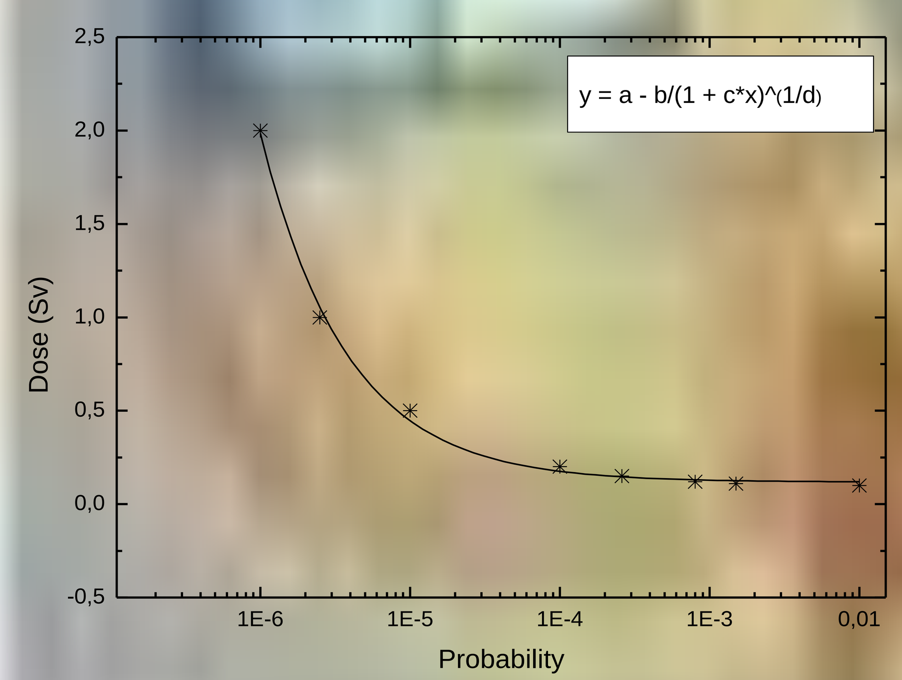

Figure 1 – Relation between maximum allowable dose and incident occurrence probability. Experimental error bar was set within the own graphic representation of experimental points.

TABLE 2 - Type of nuclear research reactor, a operational experience in partial demand of nuclear research reactor without incidents and with incidents, sum of partial demand (demand total) and total number of the incidents

Type of nuclear research reactor	Demand partial without Incidents-year	Demand partial with Incidents-year	Demand total by type of research reactor(d) - year	Number of Incidents (nd)
Argonaut	684.2	85.4	769.6	2
Critical assembly	2793.6	40.5	2834.1	4
Fast Breeder	166.4	12.1	178.5	1
Fast, Na cooled	12.1	31.0	43.1	1
Graphite	284.2	51.9	336.1	1
Heavy Water	762.7	296.8	1059.6	17
Homogenous (L)	379.7	56.6	436.3	3
Loop Type	0.0	49.9	49.9	2
Pool	3072.2	982.4	4054.6	54
Pressurized Vessel	0.0	47.2	47.2	1
Power PWR	0.0	24.9	24.9	1
Tank in pool	1298.3	371.9	1670.2	34
Tank WWR	285.9	271.2	557.1	13
Triga Conventional	355.4	70.7	426.1	2
Triga Dual core	0.0	28.4	28.4	3
Triga Mark II	613.7	180.0	793.7	8
Triga Mark III	70.2	63.2	133.3	7
Total	10778.6	2664.1	13442.7	154
95 Others reactors without incidents	503 reactors without incidents	77 reactors with incidents	Total of the 675 research reactors	
Operational experience research reactors, without incidents.	3959.5			
	14738.1	2664.1	17402.2	

Where:
nd = incident number
d= Demand (total operational experience for each type of research reactor incident in years)

TABELA 3 – Average Probabilities calculated by PSA, Fischer and Chi-Square distribution for all type of nuclear research reactor with incidents. Decreasing order and maximum allowable dose (mSv) increasing order

Type of nuclear research reactor	$P_{AvFischer}$/year	P_{AvChi}/year	Maximum allowable dose (mSv)
Triga Dual Core	1.41×10^{-1}	1.53×10^{-1}	50.0
Power PWR	8.90×10^{-2}	9.59×10^{-2}	50.0
Loop Type	6.39×10^{-2}	6.65×10^{-2}	50.0
Triga Mark III	6.07×10^{-2}	6.17×10^{-2}	50.0
Fast, Na cooled	5.84×10^{-2}	5.57×10^{-2}	50.0
Pressurized Vessel	4.90×10^{-2}	5.10×10^{-2}	50.0
Tank WWR	2.53×10^{-2}	2.54×10^{-2}	50.0
Triga Mark II	2.31×10^{-2}	2.31×10^{-2}	50.0
Tank in pool	2.10×10^{-2}	2.10×10^{-2}	50.0
Heavy water	1.71×10^{-2}	1.71×10^{-2}	50.0
Pool	1.33×10^{-2}	1.34×10^{-2}	50.0
Fast breeder	1.32×10^{-2}	1.33×10^{-2}	50.0
Homogenous (l)	9.78×10^{-3}	9.83×10^{-3}	100.1
Triga conventional	7.76×10^{-3}	8.89×10^{-3}	100.3
Graphite	7.09×10^{-3}	7.80×10^{-3}	100.6
Argonaut	4.30×10^{-3}	4.32×10^{-3}	102.8
Critical Assembly	1.17×10^{-3}	1.17×10^{-3}	114.0

Where:
PAvFischer = PAvChi= average probability for two distribution are similar

CONCLUSION

Data from Table 3 show uniformity for average probabilities by type of research reactor incidents for two distributions calculated by PSA. The maximum allowable doses (114.0 mSv /year) for type of research reactor 'Critical Assembly' are 2.28 times the annual limit of the effective doses (50.0 mSv /year) for workers in radioactive and nuclear installations [8]. In TECDOC-636[7], the use of Chi–square distribution for the failure probability calculations is limited to 50 events. For a greater number of events, it is recommended Fischer distribution. From all results obtained, it can be observed that there is no difference in the application of both distributions for a number of events lower or greater than 50 of the Table 2. If consider questions about the confidence level by type of nuclear research reactor, it is necessary a better analysis for conclusion.

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