STATION BLACKOUT CORE DAMAGE FREQUENCY REDUCTION- THE CONTRIBUTION OF AN AC INDEPENDENT CORE RESIDUAL HEAT REMOVAL SYSTEM

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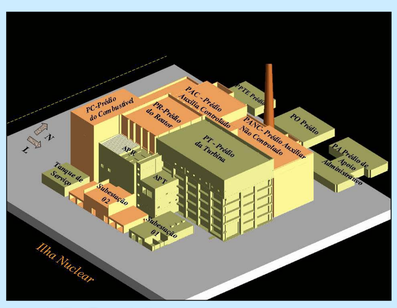
ABSTRACT

An event of station blackout (SBO) can result in severe core damage and undesirable consequences to the public and the environment. To cope with an SBO, nuclear reactors are provided with protection systems that automatically shut down the reactor, and with safety systems to remove the core residual heat. In order to reduce core damage frequency, the design of new reactors incorporates passive systems that rely only on natural forces to operate. This paper presents an evaluation of the SBO core damage frequency of a PWR reactor being designed in Brazil. The reactor has two core residual heat removal systems - an AC dependent system, and a passive system. Probabilistic safety assessment is applied to identify failure scenarios leading to SBO core damage. The SBO is treated as an initiating event, and fault trees are developed to model those systems required to operate in SBO conditions. Event trees are developed to assist in the evaluation of the possible combinations of success or failure of the systems required to cope with an SBO. The evaluation is performed using SAPHIRE, as the software for reliability and risk assessment. It is shown that a substantial reduction in the core damage frequency can be achieved by implementing the passive system proposed for the LABGENE reactor design.

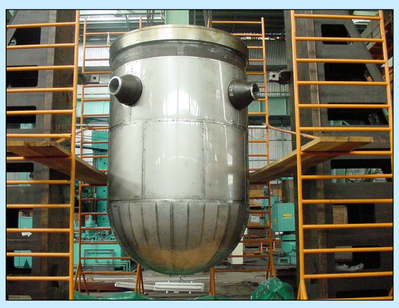
THE LABGENE NUCLEAR REACTOR

The LABGENE is a 48 MW thermal PWR prototype reactor being designed in Brazil. The reactor is intended to serve as a test bed for developing the capability to design small and medium power reactors for electricity production, and for nuclear propulsion. The total cost of LABGENE is estimated to be around US$ 488 million. So far US$ 318 million have been spent in this project. Some of the main components of the reactor have been delivered to the site, namely the pressure vessel and its internals, the pressurizer, the two steam generators, the primary coolant pumps, and components of the secondary circuit. The reactor site is located in a rural area about 120 km from the city of São Paulo, Brazil. The reactor has two primary coolant loops. The pressure vessel, steam generators, the primary pumps, and the pressurizer are enclosed in a steel containment, which is surrounded by a water tank used as a shielding pool and also as a heat sink. A confinement building houses the steel containment and a secondary system having two turbo-generators. Facilities for spent fuel storage, waste treatment, and auxiliary systems are located in adjacent buildings. The LABGENE reactor has two independent systems to remove decay heat from the core: A forced circulation AC dependent system (FCR), and a natural circulation system (NCR) that exchange decay heat with the shielding pool.



LABGENE


Turbine Building


Pressure Vessel

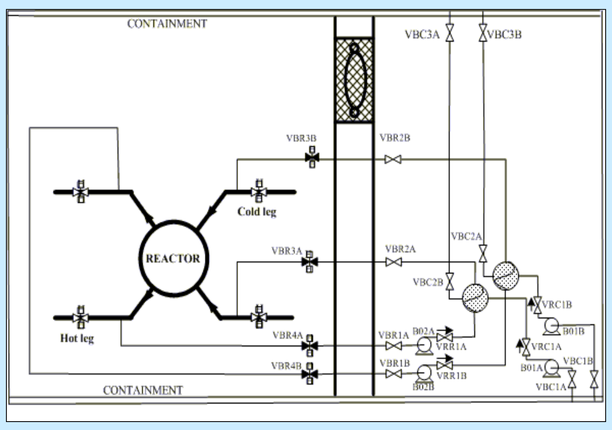

Internals


Steam Generator

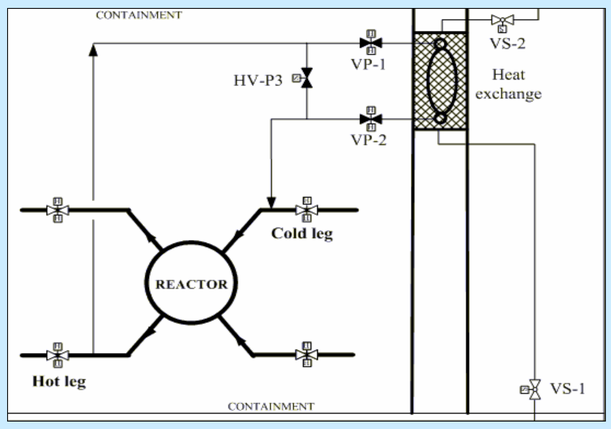

Pressurizer

STATION BLACKOUT AT LABGENE

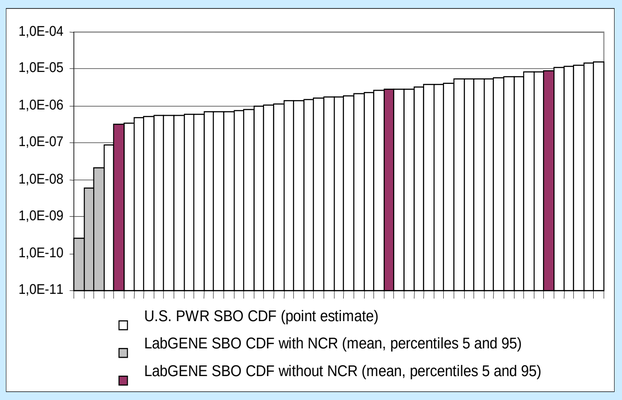
Station blackout at LABGENE reactor is defined by the following sequence of events: loss of electric power provided by the turbo-generators, concurrent with the unavailability of on-site power (four class 1E diesel generators), and the loss of the off-site power sources.



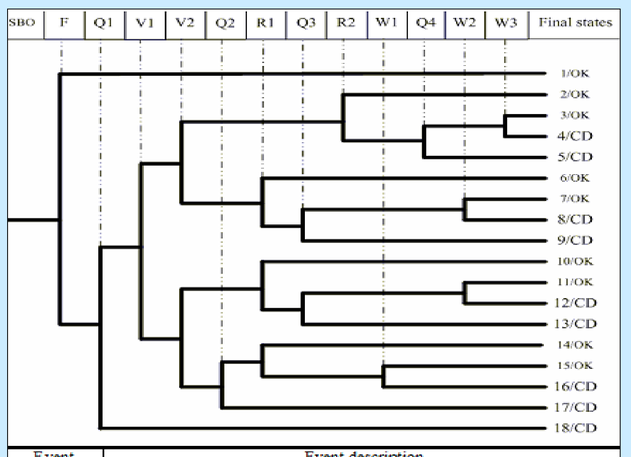
Forced Circulation Core Residual Heat Removal System (FCR)



Natural Circulation Core Residual Heat Removal System (NCR)

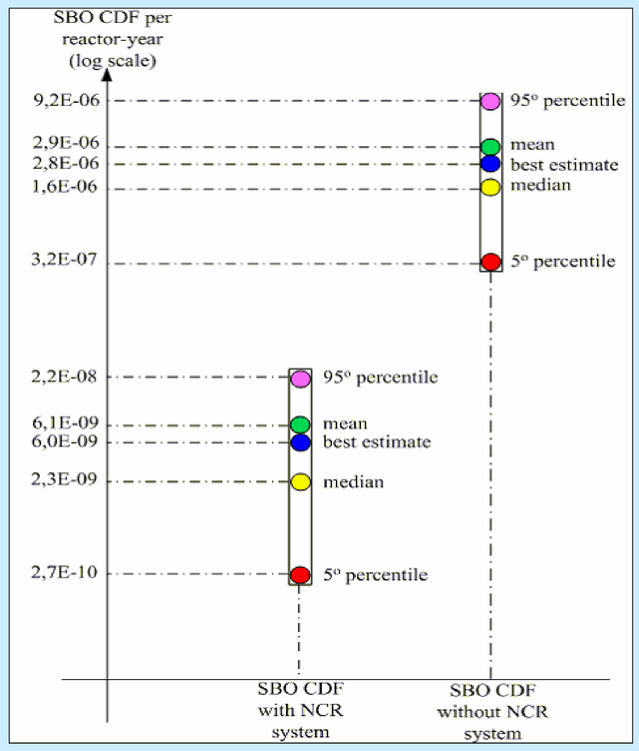


Comparison SBO-CDF



Event Acronym	Event description
SBO	Station blackout
F	Core residual heat removal by the FCR system
Q1	Initial pressure relief by pressurizer
V1	Steam Generator number one pressure relief
V2	Steam Generator two pressure relief
Q2	Pressurizer provides additional pressure relief
R1	Lining up FCR system 40 minutes after the SBO
Q3	Pressure relief by the pressurizer after 40 minutes following the SBO
R2	Lining up FCR system 80 minutes after the SBO
W1	AC recovering after 80 minutes of SBO
Q4	Pressure relief by the pressurizer after 80 minutes following the SBO
W2	AC recovering after 120 minutes of SBO
W3	AC recovering after 120 minutes of SBO

Event tree with NCR and FCR core residual heat removal system



SBO-CDF LABGENE

RESULTS AND CONCLUSIONS

- The initiating event SBO, has an estimated frequency of 7.1E-05 per reactor year.

- It is estimated that the proposed natural convection system will reduce the core damage frequency of the LABGENE reactor by a factor of about 500 times. From 2.8E-06 to 6.0E-09 per reator year.

- The LABGENE reactor plant under construction in Brazil has been designed to ensure adequate protection against station blackout. This is achieved by having sufficient AC and DC power sources capacity and by also having a passive natural convection system to remove the residual heat from the reaction core.