Thermo-Mechanical Design of High Temperature Experimental Setup

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Abstract: Nuclear reactor generates heat which is used to generate electricity. Heat is produced by nuclear fission controlled reaction of U-235 at temperature ranges of 550^{0}C - 2000^{0}C. According to first law of thermodynamics "Energy cannot be created Nor be destroyed, it can only be converted one form into another form". Albert .E. Einstein proposed a law $E=MC^2$,where mass 'M' of U-235 is converted into energy 'E' by bombardment of neutron travelling at speed of light 'C'. The energy in form of heat produced is used to convert water into steam then produce electricity. The heat produced can cause thermal stresses in shell and tube. At a phase of shut down the power produced is only due to radioactive decay of nucleoid forms after bombardment of neutron. Neutrons have half-life of the 1000 second, after achieving saturation it emits continuous radiation of radioactive material. The decay power constituted 7% of total power produced by nuclear power plant. The production of radioactive materials violates the philosophy of level 3 & level 4 of defence in depth. So to prevents contamination of radioactive materials and production of decay power, ECCS (Emergency core cooling system) and ESF (Engineered safety feature) is designed to remove the decay heat under pipe break event and bring the increased fuel temperature to coolant temperature in present work it is planned to design an experimental setup to study the adequacy of ECCS injection to remove the decay power and cool the fuel pin simulator. As the test section temperature will be within 500^{o}C hence the design will be done within elastic limit.

Keywords: Nucleioid, Defence in depth, Bellow, Shell & Tube, Thermal Expansion.

1. Introduction

Nuclear Reactor generates heat which is used to generate electricity to remove excess amount of heat and convert it into useful electrical energy a cooling system is used. If the cooling flow is reduced or lost all together the nuclear reactor shut down system is design to stop fission chain reaction however due to radioactive decay the nuclear power will continue to generate significant amount of heat.

Decay heat produced by the reactor after a shutdown initially is equivalent to about 6% of thermal rating of a reactor and then decreases exponentially with the time. The Emergency core cooling system (ECCS) is designed to remove the decay heat under a pipe break event and bring the increased fuel temperature to coolant temperature.

Defence in depth (DiD) is the key design principle in a nuclear safety. The approach is to provide a series of philosophy and physical layer protection against the release of radioactive to public.

The levels of protection are set below along with purpose, method and means of various level of protection:-

Level 1:- Prevention of abnormal operation and failure.

Level 2:- Control of abnormal operation and detection of failure.

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Level 3:- Control of accidents on design basis.

Level 4:- Control of several plant condition including prevention of accident progression and mitigation several accident consequence.

Level 5:- Mitigation of radio-logical consequence of a significant release of radio-active material.

Our project work deals with the third and fourth level of DiD. Engineered safety feature (ESF) are provided to mitigate very long probability accident.

A complete evaluation and analyzed to assess the capability of ESFs in license in design basis evaluation therefore event are occurred i.e. external and internal. Events are like earthquake, flood, tornado, tsunami and internal events are like loss of coolant accident (accident to pipe break) control, event, ejection, spent fuel handling accident (Within plant boundary) these are event of such low probability that may occurs once in an average reactor plants life time but which would have serious consequence if they are not controlled.

These accidents are analysed to evaluate the acceptability of proposed plant life. The engineered safety features the purpose of the engineered safety features is to present or limit the escape of radioactive to the environment in case of a highly and unlikely transient or accident i.e. to severe to be accommodate by the reactor protection system alone.

Engineered safety feature:- Emergency core cooling system. It is plant to design an experimental setup to study the adequacy of (ECCS) injection to remove the decay power and cool the fuel pin simulator and as the test section temperature will be within 500^{o}C, hence design will be done in elastic limit.

Evaluate thermo-mechanical stresses in high temperature test section in ECCS injection system and bellow is to be designed for minimization of thermal expansion and adequacy of bellow.

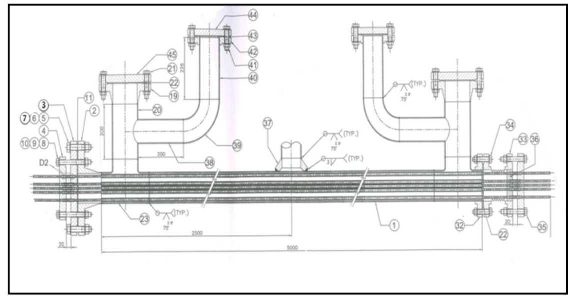

Figure: Experimental setup for Study of ECCS injection for Indian PHWRs (Level 3 DiD system)

2. Literature Review

M. SOBAJIMA, [1], In this paper The combined injection of hot water into the upper plenum and cold water into the lower plenum was experimentally verified to be quite effective for core cooling during blow-down. Hiroshige KUMAMARU, [2], In this paper it is found that There is no significant difference in the mixture level transient among the peak power channel and the three average power channels.

M. di Marzo , et al ,[3], In this paper A series of ten tests were run in the APEX facility at Oregon State University to investigate the loss of inventory from the reactor vessel during blow-down depressurization for the case where no water is available. L. Sepold, et al, [4], In this paper it is been studied that Pre-oxidation can help prevent the test bundle (QUENCH-01) from triggering a temperature escalation. Test QUENCH-02 experienced a Claude Grand Jean, [5], In this paper Vast experimental programmes have been devoted to answering the question of cool-ability under postulated LOCA conditions of an assembly containing a partial blockage. L. Sepold, et al [6], In this paper Specifics of fuel and fission product behaviour remain out of scope in the QUENCH program but the physical/chemical boundary conditions are investigated. L. Sepold, et al [6], In this paper Specifics of fuel and fission product behaviour remain out of scope in the QUENCH program but the physical/chemical boundary conditions are investigated. J. Stuckert et al, [8], In this paper Significant releases of aerosols and melt relocation from the control rod were observed at peak bundle temperature of 1650 K. The maximum oxide layer thickness at the peak aerosol release amounted to 400 lm (at elevation 0.95 m; based on the first corner rod withdrawn from the QUENCH-13 bundle). R. D'Arcy et al,[9], In this paper A water-cooled Allison-type phase space and W.Y. Ren et al,[10], In this Paper ECCS test about condensation in T-junction, the research illustrated the relationship between condensation and heat transmission in T-junction. S.P. Niu, et al, [11], In this paper The quench velocity declines when the cladding temperature rises. This result could be explained with the Leidenfrost effect. Leandro dos Santos Coelho et al,[12], In the present study a novel Differential Evolution variant and the original Differential Evolution are applied in the optimization process of designing shell-and-tube heat exchangers for two distinct cases. S.Y. Park et al, [13], In this study, comparative fission product behaviours of a severe accident sequence were M. Steinbrück et al, [14], In this paper The experiments in different scales presented here improved the knowledge on failure temperatures. Myoung Jun Kim,et al, [15], This study experimentally investigated the transient performance of an air-cooled condensing heat exchanger mounted on the top lid of the ECT under a decay heat load modelled by the ANS-73 curve. Rakesh Patil, et al, [16], Component equivalent stresses and thermal equivalent stresses for start & end conditions are evaluated on each node of the heat exchanger. R. VenkataRao, et al ,[17], in this paper The design of heat exchanger is a complex task and advanced optimization algorithms are useful to design a best and cheap heat exchanger for a specific duty. Zahra Hajabdollahi et al,[18], In this paper A thermo-economically improvement was served in the case of adding different particle shapes. Jinfeng Huang, et al, [19], In this paper In order to achieve the acceptable cycle lengths of FCM fuel, some design optimizations are taken, including higher TRISO particle packing fraction, higher enrichment and using higher density fuels. Sujay Negi et al, [20], In this paper A Circumferential temperature gradient was found to set -up in the PT. Chuan Li et al , [21], In summary, the adsorption behaviour of four types of main solid radioactive fission products, namely, Cs, Sr, Ag, and I, on the b-SiC surface in HTGR has been studied using the first-principle DFT. Ivanka Milcheva, et al , [22], in this paper For the improvement of the adapted correlation, an enhancement factor is introduced. CFD heat transfer coefficients show satisfactory agreement with the adapted model. Julia C. Lemos, et al, [23], In this paper Fouling is an unsolved problem in heat transfer technology. The intensity of the fouling problem are observed. Yonggang Lei,et al , [24], In this paper Oblique flow pattern is generated in the shell side of the heat exchangers with louver baffles which is smoother than the flow pattern in the shell side of the heat exchangers with segmental baffles. Mustapha Mellal et al, [25], In this paper it is studied that A change in baffle spacing leads to a change in the heat exchanger performance. Abazar Vahdat Azad, et al, [26], In this paper The optimization objective function is the total cost resulting from the pressure drop and heat transfer surface area. The genetic algorithm was used for optimization of the objective function. Jason M. Harp et al, [27], In this paper Gamma spectrometry scans of the US capsules from AGR-2 have been completed. The gamma-emitting fission product inventory of each compact has been determined and compared to imulations of the irradiation test. N.V. Ivanov et al, [28], in this paper it is studied that the longer is the cooling down period the higher value is attain by the transmission factor.

Conclusion:

The design should evaluate thermo-dynamics stress generated in various component of the test section as the test section temperature will be within 500°C hence the design will be done within elastic limits. Evaluate adequacy of the bellow.

Future Scope:

Introducing this project there could be a prevention of accidents under a design basis in Nuclear power plants.

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