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WAVE GUIDE SYSTEM FOR DROP TIME MEASUREMENT OF DIVERSE SAFETY ROD

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ABSTRACT

In Prototype Fast Breeder Reactor (PFBR) there are 3 Diverse Safety Rods (DSR) in addition to normal control rods to shut down the reactor. During a reactor SCRAM, electromagnet holding the DSR gets de-energized and DSR falls under gravity into the reactor core and at the end of the free fall, it is decelerated by a sodium dashpot and it is brought to rest. Development of a system for measuring free fall time and total travel time of DSR using acoustic technique is in progress. The free fall time is the time elapsed between the instant at which the electromagnet de-energizes and the instant at which dashpot action initiated. At the end of free fall DSR hit top end of the dashpot and will generate a shock signal. Similarly at the end of braking (deceleration) time another shock pulse is generated. By measuring the time delays between the step transition of electromagnet signal and the above shock signals, free fall and braking times can be estimated. The summation of free fall time and braking time will give the total drop time of DSR. Feasibility of using 7.5 m long SS wave guide with high frequency accelerometer mounted on top of it, to measure the shock pulse produced was studied during the performance testing of DSR drive mechanism in a sodium test facility. The wave-guide with accelerometer, installed in the test vessel has shown very good response to shock pulse generated. Experiments were carried out for different temperature of static sodium and the free fall and braking times of DSR were measured.

This paper discusses the description of wave-guide system, selection of wave-guide system, instrumentation used, test procedure and results from the experiment.

Key words: DSRDM, Accelerometer, Acoustics, Sodium dash pot, Wave guide

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Introduction

Prototype Fast Breeder Reactor (PFBR) is liquid metal cooled reactor and sodium is used as the coolant. Control and Safety Rods (CSRs) are provided in the reactor control plug for controlling the reactor power and to shut down the reactor. As a diverse safety mechanism to shut down the reactor, Diverse safety rods (DSRs) are also provided. During normal operation of the reactor they are held outside the active core region using electromagnets. Whenever there is SCRAM signal, the Electromagnet (EM) holding the DSR, gets de-energized and it falls under gravity into the core, thereby shutting down the reactor. The allowable drop time of DSR is 1s including the response time of electromagnet. Development of a system for measuring the drop time of DSR using acoustic technique is in progress. Experiments were carried out with accelerometer mounted on a wave-guide to measure the drop time of DSRs. This paper discusses the details of DSRDM, description of wave-guide system, instrumentation system, test procedure and results and conclusion.

Details of DSRDM

There are 3 DSRs in the reactor for its safe shut down. The DSRs are held by respective drive mechanisms called DSRDMs. Schematic of the DSRDM is shown in Fig-1. DSRDMs are housed and supported at the top of control plug, which is right above the reactor core. During a SCRAM signal the DSRs will be released from its corresponding electromagnets and will fall into the respective subassemblies inside the core. The weight of the DSR rod is ~ 46 kg. A sodium dash pot is provided inside the DSR subassembly to decelerate DSR motion inside and to bring it into rest. Initially DSR is held ~500 mm above the dashpot and length of the dash pot is ~582 mm. The total drop height for the DSR is 1075 mm. When the SCRAM is initiated, the EM holding the DSR will be de-energized and it falls into the dashpot under gravity and it is brought to rest by the dashpot action.

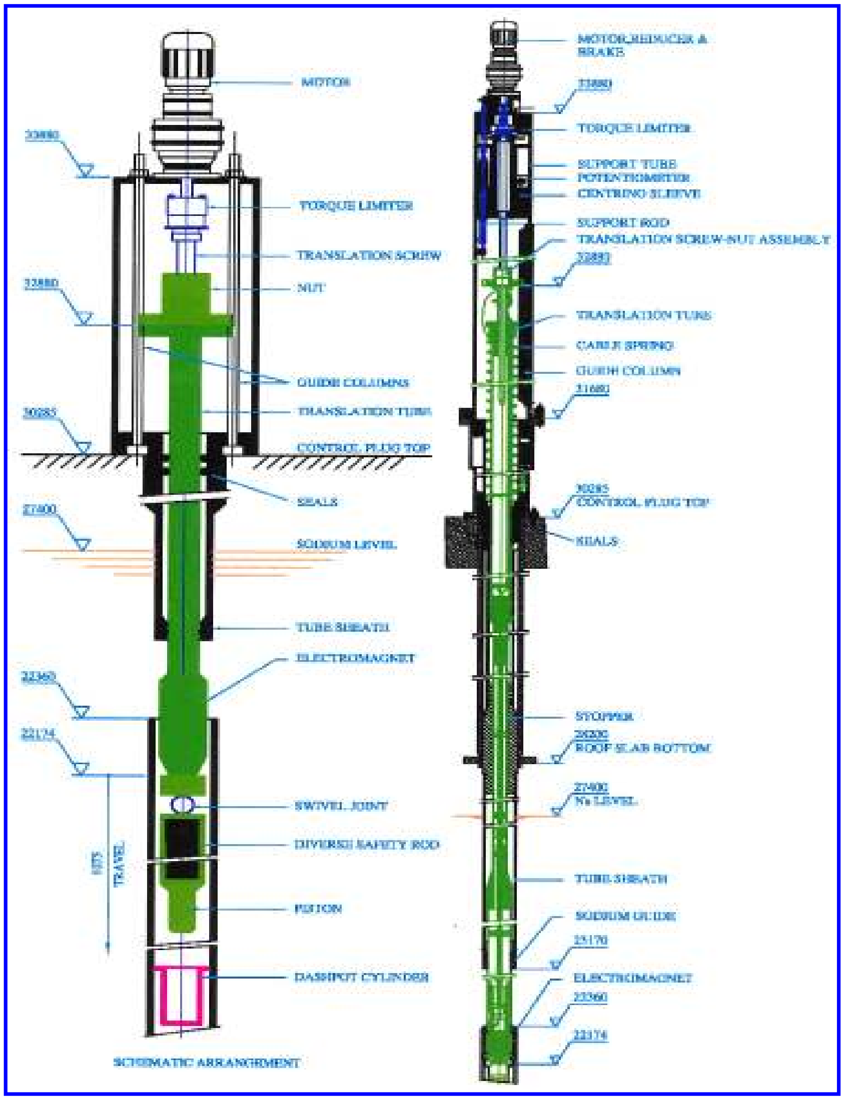

Fig-1 DSRDM Mechanism

Wave-guide development

Sodium inside the reactor vessel is at 550 ^{0}C. As high temperature sensors, with high radiation immunity are not commonly available in the market, it is planned to develop and use a wave-guide system to detect the drop time of DSR in the reactor. Introduction of a wave-guide permits the usage of low temperature accelerometers which are commonly available in the market. Moreover this technique provides ease of replacement of sensors, accessibility of sensor location, easier sensor cabling and routing etc. So developmental activities were started to design and fabricate a wave-guide for this purpose. Different configurations of wave-guides were designed, fabricated and tested in water and a final configuration was selected. The developed wave-guide was fabricated for sodium application and the schematic of the wave-guide system is shown in Fig-2. The wave-guide selected for this study is a tube within a tube type configuration. The wave-guide tube is 2.7 mm thick with an OD of 21.3 mm and is closed at the bottom end with air as the medium inside. The outer skirt is a tube with OD 88.9 mm and Sch 40 and is welded to the inner wave-guide tube such that the inner tube projects outwards around 1 m from the skirt level. Isolation has been provided between the inner wave-guide tube and the skirt so as to prevent external noise from entering the guide tube.

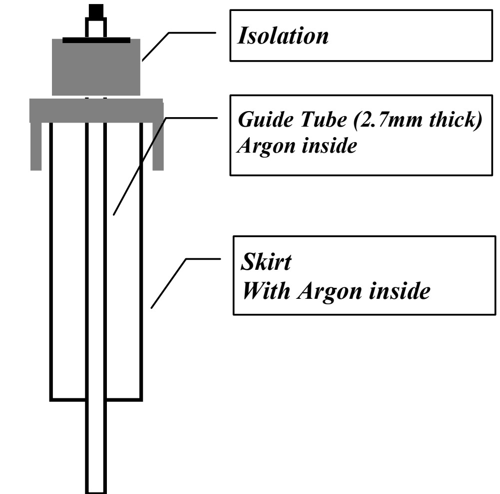

Fig-2Schematic of the Wave-guide system

Instrumentation schematic

High frequency accelerometers were mounted on the wave-guide as well as on the DSR drive mechanism to sense the impact signal produced in the dashpot region. The output of the accelerometers after conditioning, amplification and filtration were fed to digital oscilloscope (Fig-3) for time domain analysis. For drop time measurement and characterization of shock pulse produced, Electro magnet de-energizing signals was also fed to the oscilloscope.

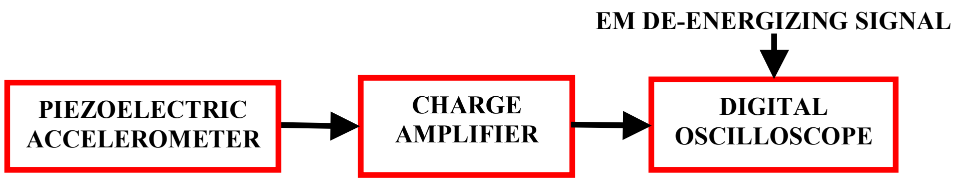

Fig-3Instrumentation schematic

Experimental Methodology

For evaluating the feasibility of using acoustic measurement technique, experiments were carried out in static sodium at DSRDM test facility and the drop time of single DSR was measured. At the end of free fall, DSR hit top end of the dashpot and will generate a shock signal. Similarly at the end of braking (deceleration) time another shock pulse is generated. By measuring the time delays between the step transition of electromagnet signal and the above shock signals, free fall and braking times can be estimated. The free fall time is defined as time elapsed between the instant at which the EM holding the DSR gets de-energizes and the instant at which the dashpot action is initiated. At the end of free fall, deceleration of DSR will takes place in the dashpot region. After deceleration the DSR will rest in the dash pot. The time taken for completion of deceleration of DSR is called braking time. The summation of free fall time and braking time will give the total drop time of DSR.

For the drop time measurement, accelerometers were used as the primary sensing element. The wave-guide was introduced into the test vessel and accelerometers are mounted on the wave-guide to sense the impact signal produced in the DSR subassembly. Fig-4 shows the experimental set up. Sodium level is maintained upto 5m from top of the subassembly. As an alternate method, accelerometers were also installed on the DSR drive mechanism, at a height of ~14 m. Measurements were taken during the dropping of DSR from a fall height of 1075 mm. Experiment was repeated for temperatures 230 ^{0}C, 300 ^{0}C, 400 ^{0}C and 500 ^{0}C.

Results and Conclusion

Accelerometer mounted on the wave-guide has shown a very good response to the shock pulse produced in the dashpot region. Fig-5 and Fig-6 shows time plots at 230^{0}C and 500^{0}C for the drop height of 1075 mm. From the time signal the free fall time, braking time in the dashpot and total drop time of DSR was calculated. The drop time of DSR in static sodium has been found to be well below 1 second. The calculated drop time at various temperatures are tabulated in Table-1. Apart from this, the drop time was also confirmed from the accelerometer output, which was mounted directly on top end of DSR drive mechanism. Signals from accelerometer mounted on wave guide and DSRDM are observed to be similar in nature. The signal obtained from the accelerometer mounted on the wave-guide is found to be 5 times greater than that from DSRDM mechanism. Wave guides are designed for optimal signal output with relatively low attenuation characteristics and also to suit the working environment, thereby an independent and easily maintainable system. Amplitude of signals measured from wave-guide as well as mechanism was found to be increased with temperature (Fig-5 & Fig-6).

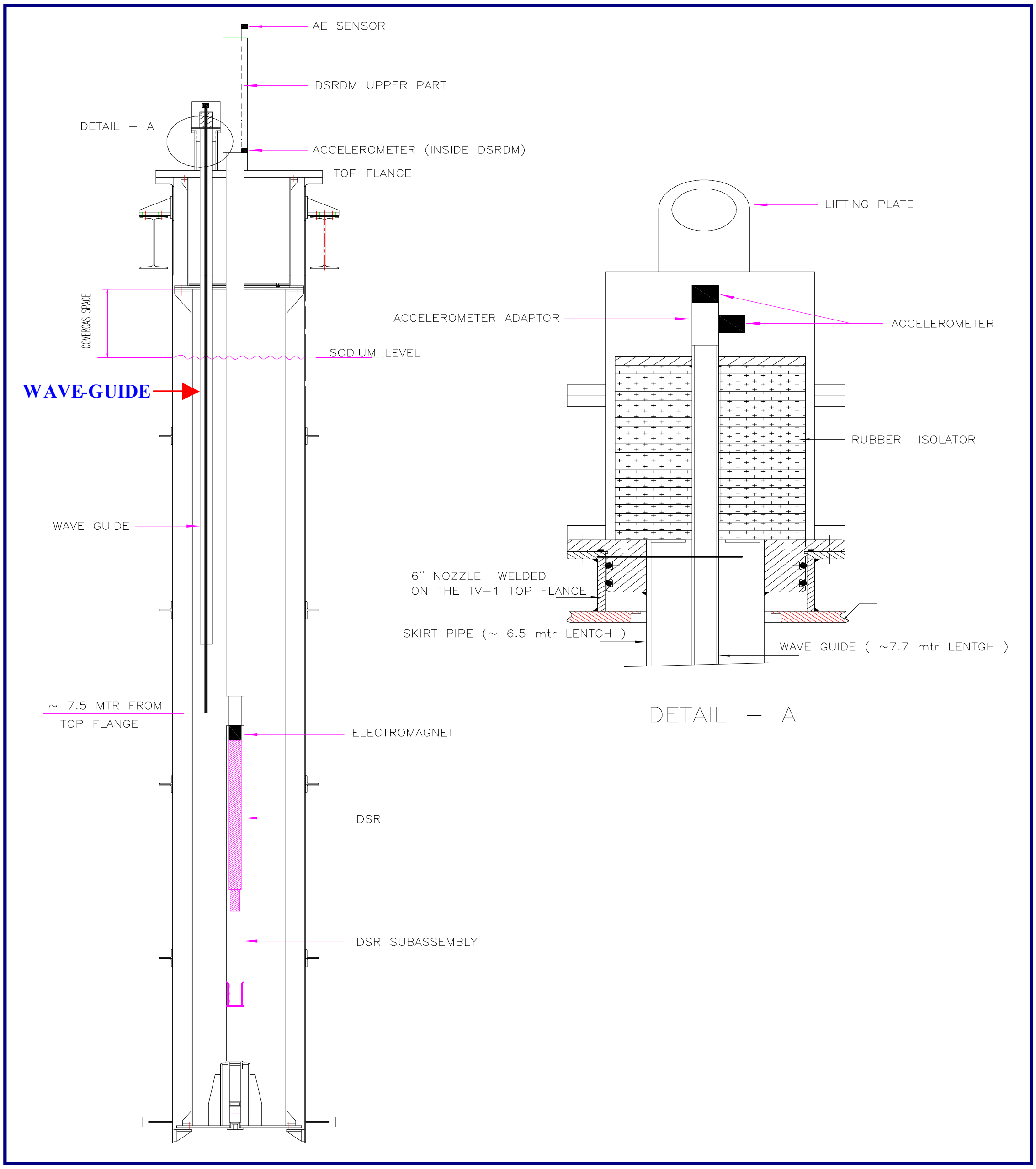

Fig-4 Experimental setup with wave-guide installed

The increase in amplitude of the signal is due to the better acoustic coupling between SS & Na at high temperature, and due to the increase in impact energy produced. It has been observed that the free fall time and total drop time of DSR decreases as sodium temperature increases and is due to the decrease in viscosity of the sodium at higher temperatures. From this experimental result, it is confirmed that the acoustic measurement technique can be used for measuring DSR's free fall time in PFBR. The designed wave-guide responded well to the impact signal produced in the dashpot region. The developmental activities of a wave-guide system for drop time measurement of DSR in PFBR is under progress

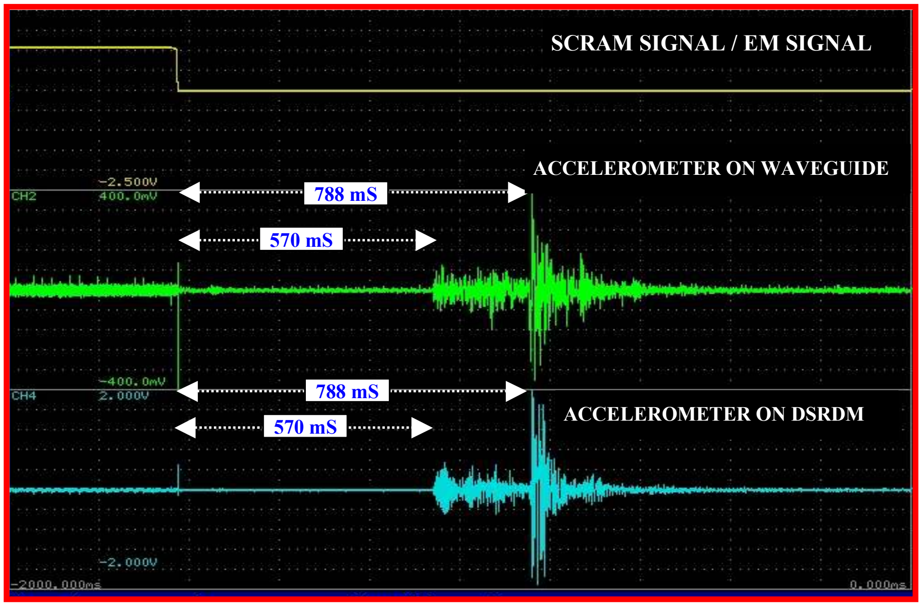

Fig-5 Time signal for the drop height of 1075mm (230 ^{0}C)

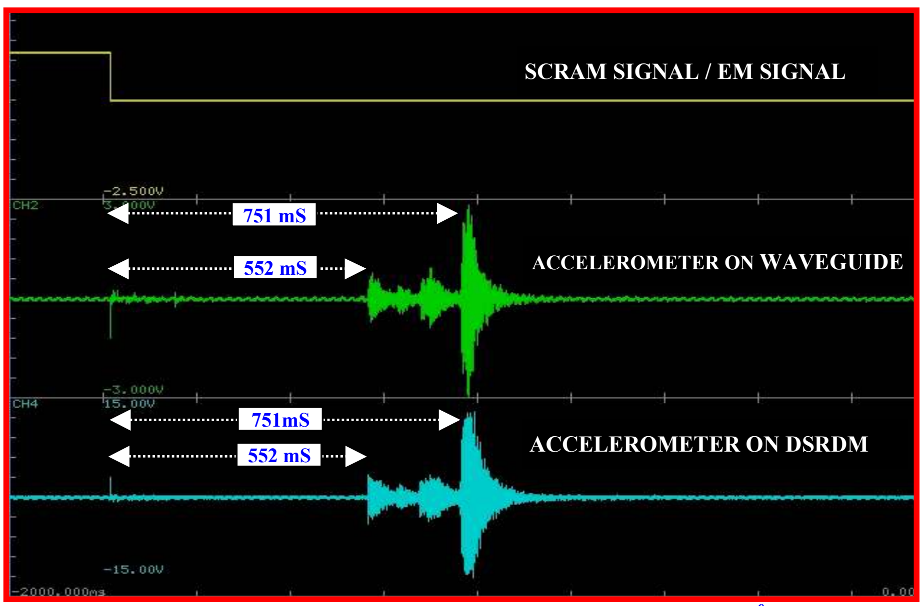

Fig-6 Time signal for the drop height of 1075mm (500 ^{0}C)

Table- 1

Temp. (^{0}C)	Drop Height (mm)	Free Fall time (ms)	Braking time (ms)	Total drop time (ms)
230	1075	570	218	788
300	1075	560	206	766
400	1075	554	200	754
500	1075	552	199	751

Reference

[1]. "Acoustic Surveillance of Fast Reactor Primary Circuits"- Experience with the Dounreay PFR Reactor

[2]. "The Shut down Systems of KNK and SNR 300", IAEA-1978