tained from the signal characteristics in the frequency range as well as in the time domain. In a contribution to this conference we would like to present some conclusions drawn in the meantime from these boiling experiments using different methods of signal analysis.

References

/ 1 / Brinckmann, H.-F. et al.: Process Surveillance in Nuclear Plants by Methods using Dynamic Signals
International Conference on Current Nuclear Power Plant Safety Issues, Stockholm, 20. - 24. October 1980, IAEA-CN-39/49

/ 2 / Buttler, E. et al.: Ein Rauschanalysesystem zur Schadensfrüherkennung an Kernkraftwerken mit Druckwasserreaktoren, Kernenergie 20 (1977), p. 389

/ 3 / Fuge, R. et al.: Electrochemical and Physical Methods for Reactor Diagnosis,
International Conference on Design, Construction and Operating Experiences of Demonstration LMFBRs, Bologna 1978, IAEA-SM-225/40

/ 4 / Pridöhl, E.: Akustische Detektion von Wasserlecks in natriumbeheizten Dampferzeugern unter Verwendung von Methoden der statistischen Entscheidungstheorie, ZfK-428, 1980

/ 5 / Afanas'ev, V. A. et al.: The BOR-60 Sodium Boiling Experiment, Kernenergie 22 (1979) p. 357-363.

STATUS OF SODIUM BOILING NOISE DETECTION PROGRAMME AT REACTOR RESEARCH CENTRE, INDIA

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Acoustic detection of sodium boiling is a promising technique to monitor subassembly fault in a fast reactor. This paper summarises our programme for developing this detection system and describes the design of a high temperature transducer for boiling detection. It is appreciated that the background noise from primary pumps can interfere with this detection. Noise measurements were therefore carried out during water testing of the primary pump of the Fast Breeder Test Reactor. Some preliminary results of these measurements are presented.

1. INTRODUCTION

India's nuclear energy programme for power generation envisages design, construction and operation of fast breeder reactors as part of its long term objective to utilise the vast Thorium reserves available in India. With the presently available knowledge in LMFBR technology in countries pursuing this programme, the necessity for detecting blockage and incipient local boiling in a single subassembly is well understood. Among the various potential techniques, acoustic detection system is a promising one and has the advantage that it is a global measurement system.

This paper outlines our programme for the development of boiling noise detection system and describes the experiments carried out so far. At our Centre, we have also initiated studies on other methods for subassembly fault detection by temperature noise analysis and by neutron noise analysis. All these different techniques would supplement each other and hence enhance the confidence level in detecting a subassembly fault.

2. PROGRAMME FOR DEVELOPMENT OF BOILING NOISE DETECTION SYSTEM

The state of art of this detection system can be considered to be still in its infancy even in countries where development efforts have been started long back; it is seen from literature that none of the operating LMFBRs today (both test and power) have used acoustic detection system for reactor control. There are still many areas of uncertainty requiring further development.

Our programme is basically directed towards understanding of boiling mechanism and signal characteristics, understanding of background noise characteristics, construction of suitable transducers and optimising signal processing and analysis techniques to develop a viable detection system. The facilities available at our Sodium Technology Laboratory and those available later in FBTR will be used. An outline of the activities is given in this section. Details of experiments carried out are given in the subsequent sections.

2.1) Transducer development

Among the two types of transducers, viz. sodium immersible transducers and non-immersible transducers with wave guides, the former has been preferred by us for initial development. This type has the advantage of better signal response and is not affected by signal transfer characteristics of the wave guide. Development of piezoelectric transducer with Lithium Niobate as the sensitive element is already initiated.

2.2) Background noise measurements

For successful detection of boiling, it is necessary to distinguish this signal from the everpresent background noise and hence a knowledge of the latter is essential. Pump noise and subassembly flow noise are two sources of background noise in LMFBRs. Noise measurements are being carried out during testing of FBTR pumps and similar measurements will be carried out during testing of subassemblies in water.

2.3) Boiling experiments in water and sodium

These experiments are necessary to characterise boiling noise and are likely to be carried out in 1982-83. For water experiments transducers are available from commercial sources while for sodium experiments, the development of Lithium Niobate transducers is being pursued.

2.4) Experiments in FBTR

FBTR being a test reactor, has provisions for carrying out in-core experiments. There are two locations available in breeder zone and one location available in the fissile zone coinciding with reactor core axis in which instrumented subassemblies can be located. The rotating plugs provide the necessary access to these experimental locations for routing signal leads etc. For background acoustic noise measurements, it is possible to position a transducer through this access. It is proposed to obtain background noise recordings for various operating conditions and this will form part of reactor commissioning experiments.

2.5) Development of electronic hardware

In addition to design and assembly of signal conditioning equipments like amplifiers, power supply units etc. development of signal analysis equipments like frequency analysers and correlators also has been taken up at our centre. A Fast

Fourier Transform analyser (FFT) has been already built and is at present being used for analysis of pump noise.

3. PUMP NOISE MEASUREMENT

FBTR primary and secondary sodium pumps are now being tested in water to verify their hydraulic characteristics and mechanical endurance. The test programme also includes measurement of acoustic noise and vibration and necessary transducers are installed for this purpose. A primary pump of 650 M^3/hr capacity at 57 M head was tested in the first quarter of 1981.

Fig.1 shows the layout of the primary pump test loop including the location of the various transducers. Potable water is used as the test fluid and the loop temperature is controlled by feed and bleed system. The loop in its present state does not have provisions for varying the pump suction pressure appreciably or for controlling (or monitoring) the quantity of air entrained in water.

Fig.2 shows the signal conditioning and analysis hardware used. The measurement bandwidth was restricted to 100KHz at 30 ips tape recording speed.

The pump is driven by a d.c. motor which gets supply from a Ward-Leonard set consisting of an induction motor and a d.c. generator and all these electrical machinery contribute to acoustic noise during pump testing. The hydraulic noise sources outside the pump are mainly the flow noise in the pipe line and valve noise from a 200mm globe valve used for flow control in the main loop.

The various measurements carried out included recording of signals from various transducers for the following operating conditions:

a) Only Ward-Leonard set running
b) Ward-Leonard set and D.C. motor running (pump uncoupled)
c) Pump running at speeds of 1450, 1330, 1000 and 750 RPM, at different flows below and above maximum efficiency point at each speed.
d) Pump running with different levels of submergence to vary suction pressure (by 1 metre) at 1300 RPM and 650 M^3/hr flow.

Table-1 gives the overall signal level from various transducers for pump operation at nominal point. The overall signal levels from hydrophone (about 80 dB) and from pressure transducers (94dB) compare reasonably well with the emperically predicted fluid borne noise levels between 80 and 100 dB at pump outlet. The higher acceleration levels measured near the control valve is likely to be due to cavitation in the valve. Initial frequency analysis of the hydrophone signals revealed wide band signal with an amplitude of 25 microbars Pk, in the frequency band above 10KHz and in our opinion this signal magnitude is unlikely to interfere with boiling detection. However analysis of more data traces is necessary before conclusive reference spectra can be obtained, after accounting for electronic noise and other background noise. Work is in progress.

4. TESTING OF A TRIAL TRANSDUCER ASSEMBLY

Fig.3 shows a trial transducer assembled here. In the present design good mechanical bonding is necessary between the crystal and diaphragm and this is ensured by machining the diaphragm to close tolerances in surface finish and flatness. The crystal is loaded onto the diaphragm by tightening the load screw. Since Lithium Niobate discs were not available initially, the assembly was made with 10mm dia, 1mm thick Lead Zirconate Titanate disc and tests were made in water at room temperature. The sensitivity of this transducer was determined by comparing it against a commercial hydrophone and was found to be about 2×10^{-2} Pico coulomb/microbar. The calibration signal was obtained by passing current through a nichrome wire immersed in a water tank and initiating boiling on its surface. Transducer tests have been planned with Lithium Niobate in future.

5. CONCLUDING REMARKS

An attempt has been made in this paper to summarise our efforts in developing boiling noise detection system for use in LMFBRs. Our immediate efforts will be directed towards completion of transducer construction and its testing in sodium loop to ensure availability of transducers for background noise measurements in FBTR.

Table-1

OVERALL SIGNALS FROM DIFFERENT TRANSDUCERS

S.No.	Transducer	Signal level
1.	Hydrophone 8101	16 millibar P-P
2.	Hydrophone 8103	20 millibar P-P
3.	Discharge pressure transducer	2PSI P-P
4.	Suction pressure transducer	2PSI P-P
5.	Accelerometer on pump shell	2.4g P-P
6.	Accelerometer at discharge	2g P-P
7.	Accelerometer at suction	2.2g P-P
8.	Accelerometer on the valve	8g P-P
9.	Microphone	93 dB C

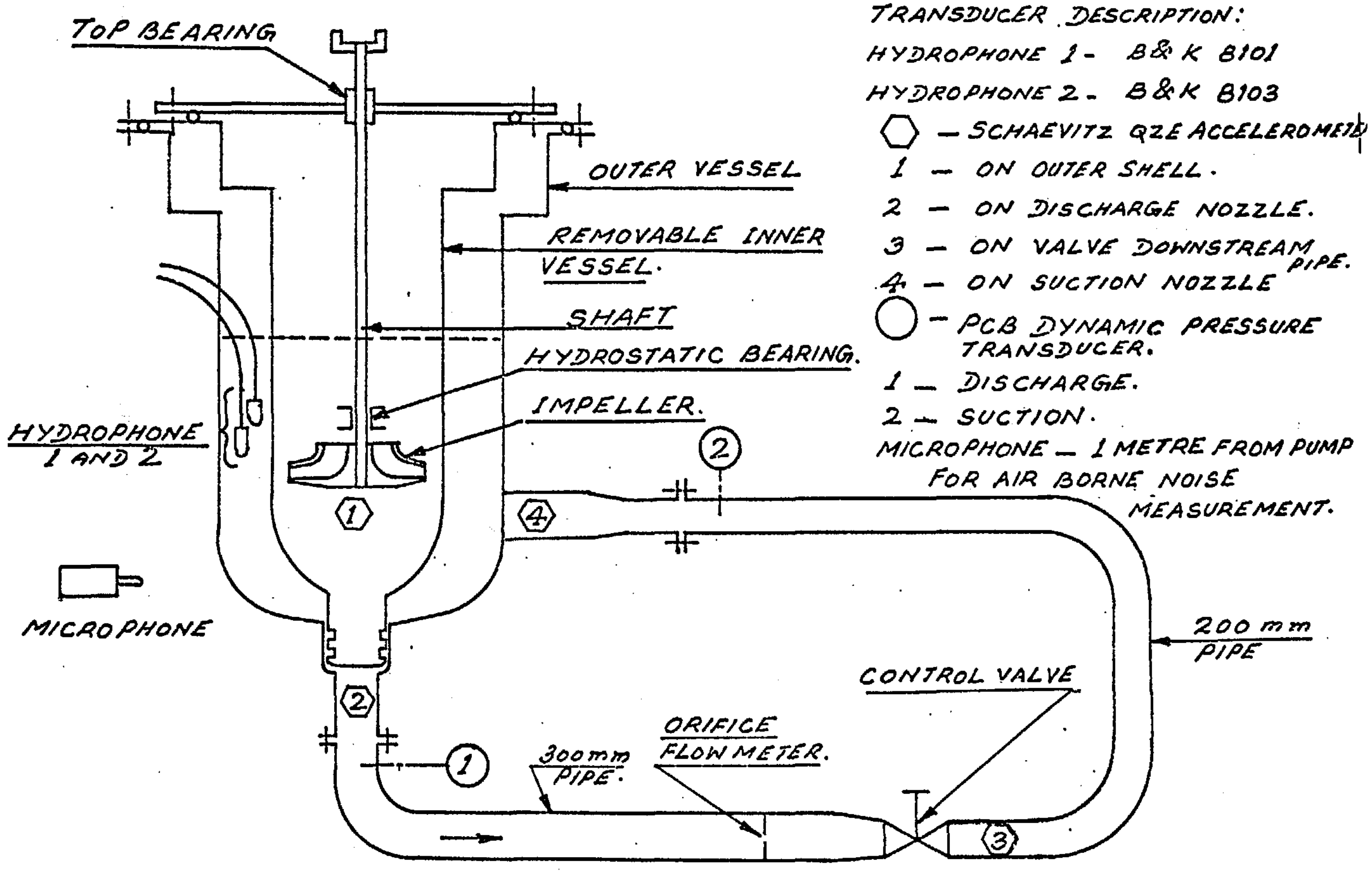

FIG. 1 TRANSDUCER LOCATION.

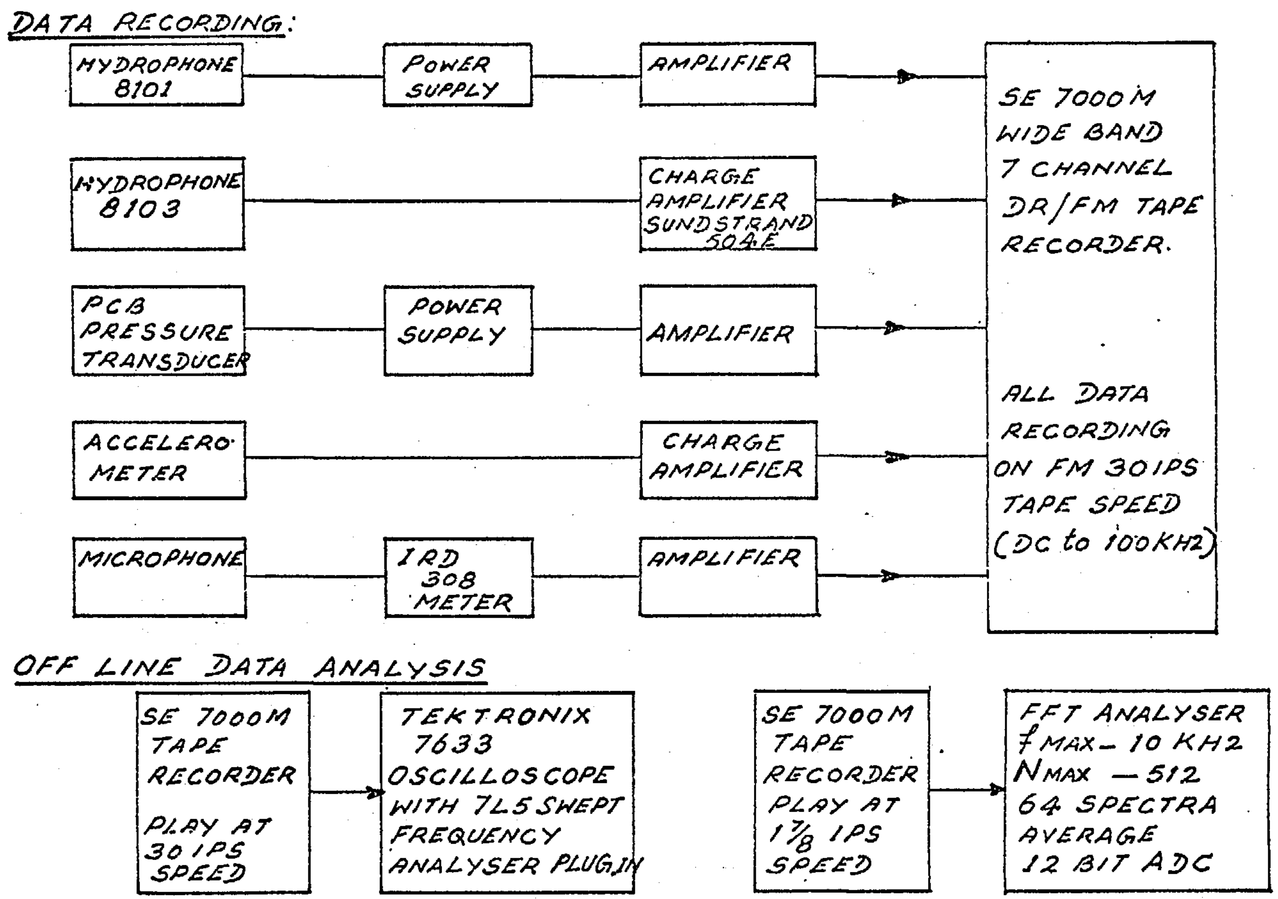

FIG. -2. RECORDING AND ANALYSIS HARDWARE

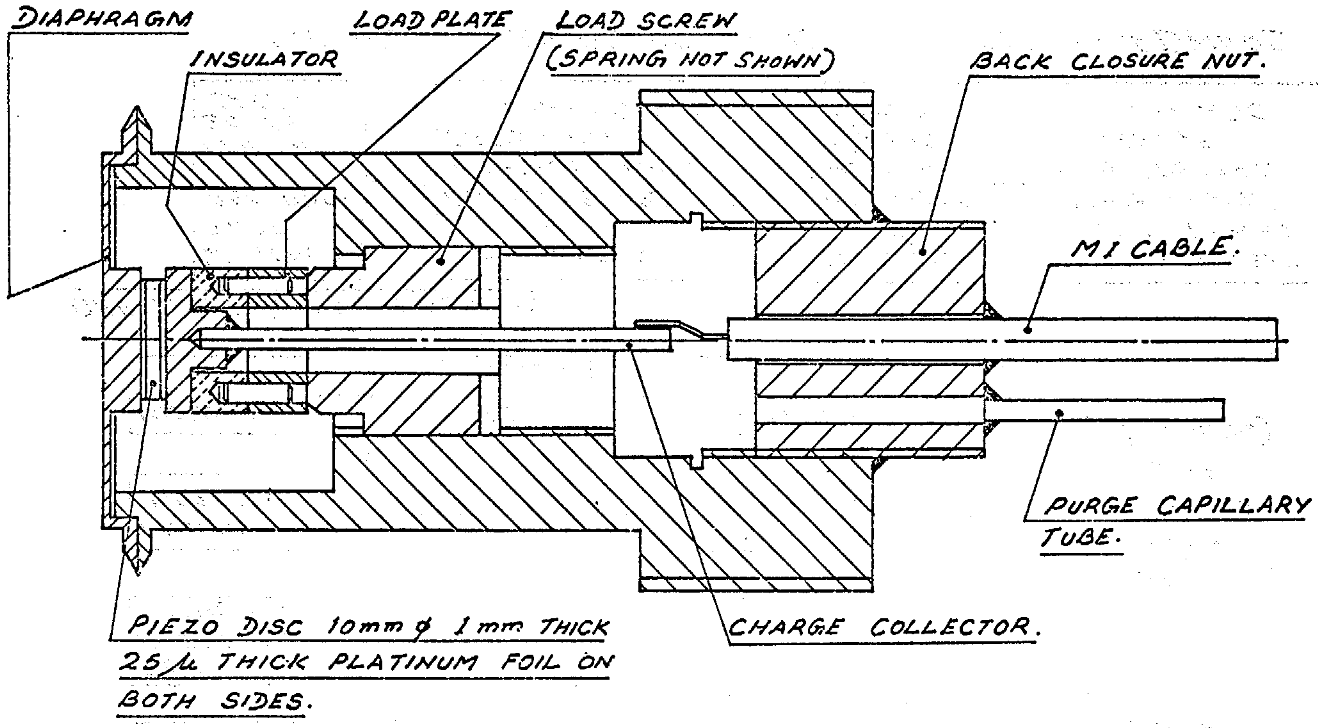

FIG – 3 ACOUSTIC TRANSDUCER