INTERIM REPORT

Accession No.
ORNL/FTR-843

Contract Program or Project Title:	Noise Diagnostics for Safety Assessment; Continuous On-Line Reactor Surveillance System
Subject of this Document:	Report of Foreign Travel of F. J. Sweeney, ORNL
Type of Document:	ORNL Foreign Trip Report
Author(s):	F. J. Sweeney
Date of Document:	May 27, 1980
Responsible NRC Individual and NRC Office or Division:	W. S. Farmer, Division of Reactor Safety Research

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Prepared for
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555
Under Interagency Agreement DOE 40-551-75
NRC FIN Nos. B0191 and B0442

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Oak Ridge, Tennessee 37830
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Department of Energy

INTERIM REPORT

OAK RIDGE NATIONAL LABORATORY
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NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

ORNL

FOREIGN TRIP REPORT

ORNL/FTR-843

DATE: May 27, 1980

SUBJECT: Report of Foreign Travel of Frank J. Sweeney, Researcher, Instrumentation and Controls Division

TO: Herman Postma

FROM: Frank J. Sweeney

PURPOSE: To (1) represent ORNL at the NEACRP organizational meeting on SMORN-III, (2) view current projects in light-water surveillance systems at CEA/Saclay, (3) present a scientific paper at the 13th Informal Meeting on Reactor Noise, Cadarache, France.

SITES VISITED: 5/5/80--OCDE, Paris, France
5/6/80--Saclay, Gif-Sur-Yvette, France
5/7-9/80--Conference, Cadarache, France

ABSTRACT: I attended the NEACRP organizational meeting on SMORN-III and presented information previously used in the organization of SMORN-II. I visited the Saclay nuclear installation and reviewed current French projects in surveillance and diagnostics of light-water reactors using noise analysis. I presented an informal paper on theoretical studies of boiling-water reactor neutron noise at the 13th Informal Meeting on Reactor Noise and participated in related discussions.

COMPREHENSIVE REPORT

NEACRP SMORN-III ORGANIZATIONAL MEETING

The main purpose of att nding this meeting was to present information related to ORNL's previous experience in the operation of the SMORN-II (Specialists' Meeting on Reactor Noise) conference in Gatlinburg, Tennessee, and to provide input to the organization of SMORN-III. Discussions at the meeting were confined to changes in a draft call-for-papers announcement to be distributed to nominees in July 1980, and to a noise analysis benchmark test proposed by the Japanese.

The SMORN conferences have been held every 3 to 4 years since 1974, with the first two conferences held in Rome, Italy and Gatlinburg, Tennessee. The SMORN-III conference is tentatively scheduled for October 26-30, 1981 in Tokyo, Japan. As yet the NEACRP has not received a formal invitation from Japan to hold the conference. If budget or scheduling restraints do not allow Japan to host the conference, the meeting will be held in Paris, France.

Discussion on the call-for-papers centered principaily on restricting the scope of the meeting to the reactor noise field. The NEACRP expects to nominate 50 - 60 reactor noise researchers to attend the meeting; only nominees will be allowed active participation. The possibility of having "observers" or conference attendees who do not actually participate in the meeting was discussed; however, no decisions were reached. The Japanese expressed the desire to have ∿50 observers at the meeting.

The delegates were interested in several aspects of reactor noise analysis:

1) Acoustic leak and crack detection (not related to non-destructive assay)

2) Rotating machinery surveillance techniques

3) Vibration surveillance techniques

4) Sodium and PWR boiling detection

5) Existing and proposed safety regulations utilizing noise analysis

6) Physical interpretation of reactor noise

7) Postaccident analysis requirements.

In general, it was my impression that the Europeans have the greatest interest in physical interpretation of reactor noise and the use of noise analysis to detect anomalies before they lead to accident conditions.

The Japanese have proposed a benchmark test for noise analysis techniques. The proposed objectives of this benchmark are to test and compare

the current noise analysis techniques applied to reactor noise. The benchmark consists of both artificial and real reactor noise recorded on 14-channel analog FM tape. The benchmark would be distributed to interested participants (the Japanese expect ~15).

Discussion of the benchmark revealed that the objectives of such a test were unclear. Many of the meeting participants expressed the opinion that the benchmark would not be useful merely as a test of analysis techniques. The participants expressed the need for such a benchmark to be applied to specific surveillance requirements (core barrel motion, vibration, boiling, etc.). The Japanese also hope to place this information into the NEA databank.

A list of the meeting participants is included in Appendix I.

SACLAY NUCLEAR INSTALLATION, GIF-SUR-YVETTE, FRANCE

The primary purpose of this visit was to review current French projects in surveillance and diagnostics of light-water reactors. Mr. Gilles Zwingelstein was the primary contact at Saclay, but brief discussions were also held with Mr. Yiannis Anastasiou.

The surveillance and diagnostics group at Saclay operates in a manner similar to the Development Group of the Instrumentation and Controls Division at ORNL. The group consists of 15 people headed by Mr. Zwingelstein, and works in two principal areas: automatic reactor control and noise analysis.

The automatic control work is further subdivided into:

1) Modeling

2) Digital simulation

3) Model validation

4) New control schemes

5) Operator guidance systems

6) Disturbance analysis systems.

The noise analysis work is subdivided into surveillance and diagnostics. The interface between the noise analysis and control work occurs through modeling. The models are used to provide physical interpretation of the noise analysis results. Most modeling in the U.S.A. is being performed by Combustion Engineering and Westinghouse, and by Cadarache in France.

The surveillance work emphasizes three areas of interest: monovariate analysis, multivariate analysis, and pattern recognition studies.

The monovariate analysis studies include the traditional frequency analysis (PSDs, APDs) and time-domain techniques (ACF and AR modeling). The frequency alanysis is currently being used to determine the sensitivity of detecting common anomalies (vibration, flow blockages, boiling, etc.). The AR models are presently being developed to monitor sensor response times and ex-core neutron detector noise. A prototype microprocessor-based sensor response time monitor has been developed which utilizes AR models. The monitor is based on the Z-80 microprocessor, and provides a sensor response time on-line in 3-5 minutes. The microprocessor computes the AR optimal model up to order 20 (typical order for temperature sensors is 10-12).

The multivariate analysis is being applied principally to ex-core neutron detectors of the Fessenheim type PWR reactors. Additional applications include thermocouple, neutron, pressure, and flow signals of the Phenix LMFBR. The emphasis of this analysis is on AR(2) models, although some work has been done using frequency analysis. A comparison of the AR(2) model results and Fourier Analysis has shown that the same results can be obtained using AR(2) models in ∿1/10-th the time requirement of Fourier Analysis. An AR(2) analyzer similar to the monovariate AR analyzer is being built, utilizing an 80-80 microprocessor.

Numerous pattern recognition studies are being performed for core surveillance. Statistical techniques involve characterization of signals in a complex 2-dimensional vector space. The difficulties that have been encountered with this technique are due to the necessity of identifying all the abnormal states of the reactor. Furthermore, neutron noise signals tend to evolve continuously during normal operation. Studies are being undertaken to apply adaptive pattern recognition techniques for identifying the "normal trajectory" of a set of characterization vectors. A study is planned to obtain normal trajectories for the 40 PWR units currently being built. Very heavy emphasis is being placed on this inter-plant comparison to reduce false-alarm rates encountered in the pattern recognition systems. Deterministic pattern recognition techniques are being applied to the detection of stuck solenoids and valves, control rod vibration and operation, and worn bearings in electrical motors.

THIRTEENTH INFORMAL MEETING ON REACTOR NOISE

My presentation, entitled "Stochastic Models of BWR Neutron Noise," was well received and the participants asked a number of questions.

The major conclusion of the conference was that noise analysis techniques have proved valuable in the surveillance and diagnosis of

reactor systems. There was also a consensus that reactor vendors are reluctant to provide access to signals or install additional instrumentation that could aid in the surveillance and diagnosis of reactor plants.

The application of noise analysis techniques to reactor systems was summarized in this way:

I. Surveillance
   a) Vibrations
      1) Internal Structures
      2) Instrument Tube (BWR)
      3) Control Rods
   b) Loose Parts
   c) Leak Detection
   d) Boiling Detection (a safety application for LMFBRs)
   e) Temperature and Coolant Flow (LMFBRs)
   f) Sensor Health
   g) Subassembly Fault Detection (preaccident)

II. Measurement of Physical Parameters
   a) Neutron Kinetics
   b) Thermal Properties of Core and Secondary Loop
   c) Reactivity Coefficients
   d) Coolant Flow Rates
   e) Sensor Response Times

III. Basic Investigations
   a) Two-Phase Flow Noise Characteristics (BWR)
   b) Temperature Fluctuations (eddy currents and temperature gradients)

IV. Postaccident Diagnosis
   a) State of Sensors and Validity of Measurement
   b) Two-Phase Conditions (existence of boiling)
   c) Fuel Damage Estimation
   d) Pressure Boundary Integrity
   e) Structural Integrity
   f) Failure of Electrical Control Devices

A list of papers presented at the conference is presented in Appendix II.

In the course of discussions at the meeting, several important points about European noise analysis research became evident:

1) Physical interpretation of noise signals (i.e., cause/effect relationships) is a high-priority goal.

2) Application of noise analysis to improve plant availability and to detect anomalies prior to catastrophic failure or accidents is a high-priority goal.

3) Long-term experience with operating reactors has been identified as important to understanding noise signatures.

4) Access to operating power reactors by noise analysts in Europe is generally good.

5) Manpower and funds are dedicated to high-priority goals.

Several discussions were pursued concerning the response of European nations to the TMI-2 accident. It was the opinion of several researchers that while official government reactions indicated no overt change in safety policy, the scientific community was concerned with the complex interaction of the reactor systems. Therefore, more emphasis was being placed on dynamic modeling of the reactor systems.

The research projects presented at the meeting tend to indicate that ORNL's Development Group has been and is continuing to pursue state-of-the-art research in noise analysis. Nearly all the presentations at the meeting concerned topics which ORNL has studied in the past or is currently studying.

TRIP EVALUATION

The information obtained during this trip, both at Saclay and at the conference, will be useful in the following NRC/RSR programs at ORNL: "Noise Diagnostics for Safety Assessment" - FIN No. B0191 and "Continuous On-Line Reactor Surveillance System" - FIN No. B0442. In terms of cost effectiveness, the trip has reinforced our belief that discussions with noise analysts and sharing experimental experience can prevent repetitive mistakes and can help to establish important research directions.

APPENDIX I

Participants at the SMORN-III Organization Meeting

OECD Paris, 5th May, 1980

Dr. J. Bouchard	Commisariat à l'Energie Atomique Cadarache (France)
Dr. R. J. Cox	UKAEA, Atomic Energy Establishment Winfrith, Dorset (England)
Dr. M. Edlemann	Gesellschaft für Kernforschungszentrum Karlsruhe (F. R. of Germany)
Dr. F. Sweeney	Oak Ridge National Laboratory Oak Ridge, Tennessee (USA)
Prof. N. Pacilio	Comitato Nazionale per l'Energia Nucleare CSN-Casaccia, S. Maria di Galeria (Italy)
Dr. J. B. Dragt	Netherlands Energy Research Foundation Petten (The Netherlands)
Dr. Y. Shinohara	Japanese Atomic Energy Research Institute Tokai-Mura (Japan)
Dr. W. Bastl	Gesellschaft für Reaktorsicherheit, mbH Forschungsgelände, D-8046 Gärching (F. R. of Germany)
Mr. J. Rosen	NEA, OECD
Dr. D. Johnson	NEA, OECD
Dr. P. Johnston	NEA, OECD
Dr. J. Royen	NEA, OECD
Dr. V. Tosi	C.N.E.N. (Italy)

APPENDIX II

13th Informal Meeting on Reactor Noise

CADARACHE – MAY 7 - 9 1980

PROGRAM

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MAY 7, 1980

TIME	AUTHORS	TITLE OF PAPER
9:00 a.m.		Welcome of participants and formalities
9:30 a.m.		Introductory speech
10:00 a.m.	J.C. ROBINSON	Diagnostics at TMI Using Noise Analysis
10:20 a.m.	C. MAYO G. ZIGLER	Emergency response diagnostic
10:40 a.m.		Coffee break
11:00 a.m.	R. BAEYENS	Neutron noise r.m.s. to DC converter
11:20 a.m.	F. TÜRKCAN	Results of the noise measurements in the Borssele reactor (PWR) at power, during normal shutdouwn and during the startup
11:40 a.m.	V. BAUERNFEIND	The application of correlation analysis in acoustic leakage detection
12:00 a.m.		Group picture Lunch
2:00 p.m.	R.ASSEDO - P.BERNARD JC.CARRE - A.EPSTEIN G.CASTELLO - C.PUYAL Ch. MESSAINGUIRAL S. SIGHICELLI	Surveillance of french PWRs by noise technique
2:20 p.m.		
2:40 p.m.	R. SUNDER	Experiences with vibration monitoring of reactor internals and primary system components
3:00 p.m.	F. ÅKERHIELM	Detection of vibrations in PWR by analysis of neutron detector noise
3:20 p.m.		
3:40 p.m.		Coffee break
4:00 p.m.	K. DACH	Simulation of absorber vibrations in the core of SR-0 reactor
4:20 p.m.	J.B. DRAGT	Partial and multiple correlations
4:40 p.m.	P. FASKO H. ROGGENBAUER	Basic investigations on the applicability of noise analysis techniques to process instrumentation
6:50 p.m.		Departure of buses from AIX-EN-PROVENCE to place of dinner reception

MAY 8, 1980

TIME	AUTHORS	TITLE OF PAPER
7:45 a.m.		Departure of buses from AIX EN PROVENCE to CADARACHE
9:00 a.m.	P. GEBURECK	Experimental and theoretical determination of thermal-hydraulic quantities in a BWR
9:20 a.m.	E.B.J. KLEISS	Incore power feedback and reactor modelling in a BWR
9:40 a.m.	G. GRONDEY	Multichannel on line noise analysis system, (MONAS)
10:00 a.m.	S. BERGMAN	The impact on BWR-process noise from the normal instrumentation system
10:20 a.m.		Coffee break
10:40 a.m.	F. SWEENEY	Stochastic modeling of BWR neutron noise
11:00 a.m.	T. KATONA	Thermohydraulic aspects of boiling and flow-pattern recognition by temperature and pressure noise analysis
11:20 a.m.	D. LÜBBESMEYER	A new method for time-dependent fluid-velocity measurements in two-phases flow
11:40 a.m.	S.HORANYI - D. PALLAGI S. TOZSER	Technological noise measurements in the primary loop of the Hungarian WWR-SM reactor
12:00 a.m.		Lunch
2:00 p.m.	W. VÄTH	Flow induced reactivity noise at the KNK-II
2:20 p.m.	F. MITZEL	Measurement of the fuel surface to cladding gap conductance with inherent noise
2:40 p.m.	M. EDELMANN	Precision heat balance measurements at the KNK-II reactor core
3:00 p.m.	G. LE GUILLOU B. BERNARDIN I. CRIGNON	Surveillance of a nuclear reactor by pattern recognition analysis of the neutronic noise. Experience on PHENIX LMFBR.
3:20 p.m.	M.VAL - B.DUBUISSON M. BRUNET	Acoustic detection of boiling in LMBR using the pattern recognition methods
3:40 p.m.		Coffee break
4:00 p.m.	G. ZWINGELSTEIN J.P. JACQUOT	Noise analysis by time series and applications to PWR surveillance
4.40 p.m.	B. MAVKO	Triga reactor noise analysis
5:00 p.m.	R.CROWE - K. BEHRINGER H. WINKLER	Detection of the onset of coolant boiling in the swimming pool reactor SAPHIR by neutron noise analysis
5:20 p.m.	YORIO GOTOH	Study of the stochastic point reactor kinetic equation

MAY 9, 1980

TIME	AUTHORS	TITLE OF PAPER
7:45 a.m.		Departure of buses from AIX EN PROVENCE to CADARACHE
9:00 a.m.	S. COLLATZ	Neutron flux perturbation in PWR cores introduced by vibration of a subassembly
9:20 a.m.	L. KEMENY	A mobile - versatile nuclear plant monitor
9:40 a.m.	G.C. VAN UITERT	Identification of noise sources and transfer functions of a multiple input - multiple output system
10:00 a.m.	G. WEINKÖTZ	Title not yet known
10:20 a.m.		Coffee break
10:40 a.m.		Discussion
12:00 a.m.		Lunch
2:00 p.m.		Visite of nuclear center (Cadarache)
4:15 p.m.		Departure of buses to MARIGNANE airport and AIX EN PROVENCE

APPENDIX III

Itinerary

Dates	Location or Activity	Individuals Contacted	Discussion Subject
May 2-4, 1980	Travel from Knoxville, TN to Paris, France via plane and weekend		
May 5, 1980	OECD headquarters Paris, France	Peter Johnston	SMORN-III organizational meeting
May 6, 1980	Saclay Nuclear Installation	Gilles Zwingelstein	French LWR Noise Analysis
May 7-9, 1980	Cadarache, France		13th Informal Meeting on Reactor Noise
May 10, 1980	Return to Knoxville, TN via plane		

APPENDIX IV

Literature Acquired

1. Abstracts for each paper shown in Appendix II.

2. P. Bernard, Fluctuations Neutroniques Dans Les Reacteurs De Puissance A Eau Sons Pression (title: Neutron Fluctuations in Pressurized Water Reactors), Ph.D. dissertation, Universite De Paris-Sud Centre D'Orsay (1978).

3. Leslie G. Kemeny, "A Mobile, Versatile Nuclear Power Plant Noise Monitor," The University of New South Wales (1980).

4. B. Mavko, "TRIGA Reactor Noise Analysis," J. Stefan Institute, Ljubljana, Yugoslavia (1980).

5. P. Fasko and H. Roggenbauer, "Basic Investigations on the Applicability of Noise Analysis Techniques to Process Instrumentation," Osterreichische Studiengesellschaft für Atomenergie, Institut für Reaktorsicherheit (1980).

6. B. Arcipiani, F. Carloni, and M. Marsequerra, "Neutron Counting Statistics in a Subcritical Cyclo-Stationary Multiplying System, I: Die-away Experiment," *Nuclear Instruments and Methods* 167, 465-73 (1979).

7. R. Assedo et al., "PWR Neutron Noise Surveillance: Noise Sources and Their Effects," paper presented at IAEA-NPPCI Specialist Meeting, Munich (1979).

8. Y. Gotoh, "Study of the Stochastic Point Reactor Kinetic Equation," Division of Reactor Engineering, JAERI, Tokai-mura, Naka-gun, Ibaraki-ken, Japan (1980).

9. G. Th. Analytis, "An Application of Stochastic Differential Equations to the Investigation of the Effects of Space- and Time-Dependent Random Parametric Excitations in Heterogeneous Reactors," CEGB Research Division, Berkeley Nuclear Laboratories, Gloucestershire, UK (1980).

10. G. Th. Analytis, "Remarks on the Functional Equivalence of Two Approaches to Space-Dependent Reactor Noise," Ibid.

11. G. Th. Analytis, "A Three-Dimensional Theoretical Investigation of the Local and Global Component of Neutron Noise In a Bare Homogeneous Water-Moderated Reactor and Applications," Ibid.

12. P. Bernard et al., "Surveillance of French PWRs by Noise Techniques," CEA, Cadarache, France (1980).

13. G. Zwingelstein, "Application of Pattern Recognition Techniques to the Detection of the Phenix Reactor Control Rods Vibrations," French Atomic Energy Commission, Saclay, France (1980).

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