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1983 FIRST QUARTER INTERIM REPORT ON TWO PHASE INSTRUMENTATION EVALUATION

E. B. Englert

Idaho National Engineering Laboratory
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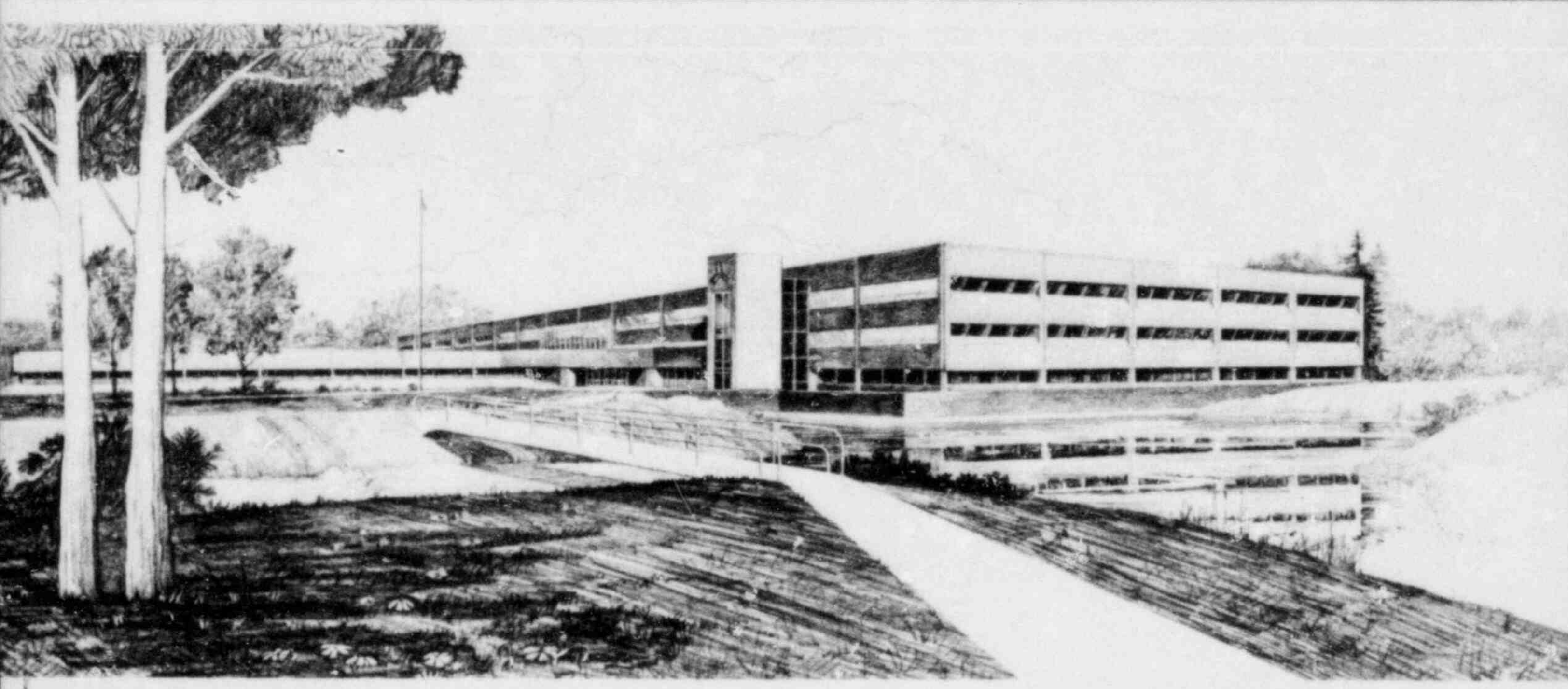

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S. B. Englert

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EG&G Idaho, Inc.
Idaho Falls, Idaho **83415**

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INTERIM REPORT

1983 FIRST QUARTER INTERIM REPORT ON TWO PHASE INSTRUMENTATION EVALUATION

By

S. B. Englert

Instrumentation Development Branch

EG&G Idaho, Inc.

ABSTRACT

This EG&G Idaho report continues the FY1982 preliminary instrumentation evaluation and proposes continued tests or investigation for different instruments or methods. The four areas of interest are low velocity flow, system voiding, u-tube voiding and break identification.

The U. S. Nuclear Regulatory Commission funded this work under the authorization NRC FIN No. A6376, Two Phase Instrumentation Evaluation.

SUMMARY

The information received from the on going literature search, vendor information and discussion with the utility operators is reflected in the proposed tests. From the information received, tests and evaluations currently being performed do not conflict with any of the proposed tests or evaluations. The test plans are included to allow the scope of work to be examined and discussed.

CONTENTS

TABLES

1. INTRODUCTION

The objective of this research is to evaluate and test instruments and methods used in the detection and measurement of parameters which characterize two-phase (water-steam) presence during normal and accident conditions.

The FY 1983 phase of this program is to assess the current capabilities of U.S. Boiling Water Reactors (BWRs) and Pressurized Water Reactors (PWRs) in detection and measurement of two-phase system parameters. One particular goal is to assess the current practice and capabilities of measuring low flow rates in the primary system corresponding to fluid velocities of 0.1 m/s. The detection and measurement of the onset of boiling or voiding in the reactor vessel, steam generator U-tubes, and primary pumps were examined in particular in FY 1982 and reported in the interim report EGG-ID-6040 titled Preliminary Two-Phase Instrumentation Evaluation. This report examines the data being collected through an ongoing literature and information search begun in FY 1982 and received or reported since the FY 1982 interim report was published.

2. LIST OF PROIMISING INSTRUMENTATION

As reported in the preliminary lst of promising instrumentation, Table 1,[1] a proposal was made to do further testing/investigation into selected instruments and or techniques.

Tentative test plans have been written to continue the investigation into these instruments/techniques and are detailed below.

3. PROPOSED TEST PLAN FOR LOW VELOCITY FLOW MEASUREMENT

3.1 Instrument/Method

Cooled Velocimeter

3.2 Method of Operation

Flow induced heat transfer from the measured medium to the instrument probe.

3.3 Type of Instrument Installation

Penetration into the primary Reactor Coolant System (RCS) is required. Testing will be focused on using an approved penetration method, an approved nuclear grade thermowell.

3.4 Instrument Status

Several prototype developmental probes have been installed and tested at Semi-Scale, FIST, and in a high temperature-pressure test facility. No significant testing has been performed in a thermowell.

3.5 Development Necessary for Continued Testing of Evaluation

Slight design modifications to external probe body to facilitate use in a thermowell.

3.6 Instrument Capability with Nuclear System

This is a passive device, no moving parts. All external parts are stainless steel and used in this application would not be wetted by primary coolant flow.

3.7 Instrument Requirements

Instrument cooling water supply, approximately 1 gal./min at 80 psig., reference junction for Type K thermocouples, and a local RCS temperature measurement are needed.

3.8 Instrument Output

Low level analog output from up to five Type K thermocouples, from -2.0 to + 14.0 mV, depending on reference junction temperature.

3./9 Instrument Range

To be determined in thermowell by proposed test. Probable range should be in the order of 0.05 to 1.0 m/s.

3.10 Instrument Accuracy

Not determined in thermowell, but is expected to be in the order of ± 10% of measurement.

3.11 Proposed Test Sequence

1. Obtain typical nuclear grade thermowell.
2. Modify and fabricate cooled velocimeter for installation in thermowell.
3. Modify test facility flow loops to accept nuclear grade thermowell.
4. Test in moderate temperature (95°C) flow loop at low pressure.

5. Test in high temperature/pressure flow loop (300°C, 14 mPa) to the maximum loop or sensor capabilities, maximum loop flow rate velocity is approximately 2.5 m/s.

6. Report test results.

4. PROPOSED TEST PLAN FOR THE DETECTION OF PRIMARY PUMP AND SYSTEM COMPONENT VOIDING

4.1 Instrument/Method

Recording primary pump power and recording vibration output from an accelerometer on or near the peimary pump and associated piping.

4.2 Method of Operation

1. Measurement of input power to the RCS primary pump.

2. Measurement of primary pump vibration.

4.3 Type of Instrument/Installation

4.3.1 Primary Pump Power

This is an electronic measurement, there are no system or piping penetrations required.

4.3.2 Vibration

The accelerometer is mounted external to the pump and piping--no penetration through the pressure boundary is required.

4.4 Instrument Status

Commercial instruments--both measurements already being made in the LOFT facility.

4.5 Instrument Development Necessary for Proposed Tests

No further development is required, both measurements are already being made and recorded.

4.6 Instrument Compatibility with Nuclear System

1. Power measurement made in moderate environment.

2. Vibration measurement utilizes radiation resistant high temperature accelerometers.

4.7 Instrument Requirements

Instrument power for power measurement and charge amplifier necessary for vibration measurement.

4.8 Instrument Output

4.8.1 Pump Power

Analog output relative to pump power or pump voltage and current.

4.8.2 Acceleration

An A-C signal relative to acceleration amplitude and frequency.

4.9 Instrument Range

Pump power; adequate to cover full load motor current.

Acceleration; typically in the range of 250 to 1000g acceleration range. Usable range depends on setting of associated charge amplifier.

4.10 Instrument Accuracy

4.10.1 Pump Power

Pump power measurements have been made to better than ± 5%.

4.10.2 Vibration

Typically, accuracies stated in the ± 10% in the temperature range that it will be exposed to.

4.11 Proposed Test Sequence

1. Confer with LOFT personnel and obtain recorded data from previous tests. Make arrangements to obtain recordings that are to be made during subsequent tests in FY 1983.

2. Analyze data on existing tapes to determine any correlation that may exist, (frequency, amplitude) between RCS density and primary pump power and acceleration as measured by the instruments of interest and existing reference instruments installed in the LOFT RCS.

3. Report results of investigation in the interim or final task report.

5. PROPOSED TEST PLAN FOR U-TUBE VOIDING DETECTION TECHNIQUE

5.1 Instrument/Method

High temperature microphones.

5.2 Method of Operation

Measurement of flow induced acoustic signals generated in the RCS primary inlet plenum and coupled to the outlet plenum by RCS flow.

5.3 Type of Instrument Installation

Microphones to be mounted externally on the LOFT heat exchanger inlet and output plenum.

5.4 Instrument Status

Commercial microphones available rated for high temperature operation.

5.5 Instrument Development Necessary for Continued Testing

Microphones and electronics are on hand, only the exact position and method of mounting needs to be determined.

5.6 Instrument Compatability With Nuclear System

Instruments are to be mounted on heat exchanger inlet and outlet plenum and rated for high temperature operation and are radiation resistant.

5.7 Instrument Requirements

Only instrument power for associated electronics.

5.8 Instrument Range

Microphones are calibrated from 50 Hz to 60 kHz ± 3 db and rated to 10^{10} total integrated dose.

5.9 Instrument Output

A-C signal, range selected by charge amplifier switch.

5.20 Instrument Accuracy

Basic instrument accuracy is ± 3 db 50 Hz to 60 kHz. Just how this accuracy will relate to flow induced acoustic signals, and the signals relation to flow velocity through the steam generator or U-tube voiding has not been determined. It is hoped to establish this relationship by further testing.

5.11 Proposed Test Sequence

1. Select location for mounting microphones and obtain permission for mounting on LOFT steam generator.

2. Have microphones installed on LOFT steam operator inlet and outlet plenums.

3. Make arrangements to have instrument output recorded on analog tape recorder.

4. Analyze data for correlation of signals from inlet to outlet plenums and signs of loss of coupling of flow induced acoustic signals, due to U-tube voiding, should U-tube voiding occur during the planned test sequence for LOFT during the period that we are able to obtain test data. If U-tube voiding does not occur during the period of tests that we are collecting data, we will try to determine if a reliable determination can be made of a velocity measurement of fluid through the U-tubes in the steam generator by correlation of flow induced accoustic emissions from inlet to output plenum transducers.

5. Report test results in project final report or interim report, should data become available.

6. PROPOSED TEST PLANS FOR BREAK IDENTIFICATION, LOCATION, AND SIZE ESTIMATION

6.1 Instrument/Method

It has been proposed to investigate two potential methods to detect, locate, and estimate the size of a break in the RCS primary system.

6.1.1 Method 1

Pressure measurements around the RCS piping, monitoring primary system pressures during normal conditions, and monitoring system for abnormal pressure gradients caused by a break in the system.

6.1.2 Method 2

Acoustic emission tranducers mounted at locations around the RCS and monitoring acoustic emissions generated during normal operations, utilizing amplitude discrimination to detect abnormally high levels of acoustic emission indicated by detectors adjacent to a break.

6.2 Method of Operation

See Instrument/Method above.

6.3 Type of Instrument Installation

6.3.1 Method 1

Abnormal pressure indication. RCS penetration of the primary pressure boundary required. The potential exists that existing pressure taps are available at sufficient locations.

6.3.2 Method 2

Acoustic emission generated by coolant flow through a break. Transducers would be mounted external to RCS. Primary pressure boundary penetration would not be required.

6.4 Instrument Status

Commercial instruments are available that are adequate for both methods.

6.5 Instrument Development Necessary for Continued Testing

The instruments basic to the fundamental measurements are developed, the method in which we propose they be used is or would be plant specific in nature.

6.6 Instrument Compatibilty with Nuclear System

Basic sensors commercially available are compatible with use in hostile environment. Data acquisition and reduction equipment would be contained in nonhostile environment.

6.7 Instrument Requirements

No requirements other than instrument power in nonhostile areas are anticipated for either method.

6.8 Instrument Output

6.8.1 Method

Abnormal pressure indication. Potentially process grade, current, or voltage output.

6.8.2 Method 2

Acoustic Emission. Basic output is A-C signal varying in amplitude and frequency in relation to signals generated by acoustic noise source. This output would most probably be amplitude discriminated for indication of a break in the RCS.

6.9 Instrument Range

6.9.1 Method 1

Transducers are available to span any range encountered in the RCS. Range selection would be plant and RCS location specific.

6.9.2 Method 2

Acoustic emission transducers are available with a wide range and individual ranges would be selected along with discriminator settings depending on location and normal levels of acoustic emissions generated at specific locations.

6.10 Instrument Accuracy

6.10.1 Method 1

Abnormal pressure drop measurement. If absolute or gauge transducers are selected, accuracy will have to be better than if differential transmitters, or differential pressure transducers could be used. The extent of accuracy will be looked at as part of this task.

6.10.2 Method 2

Acoustic Emission. Accuracy does not appear to be as much of a factor in this measurement as stability. Stability to maintain a constant output for a constant acoustic level input.

6.11 Proposed Test Method

It is proposed to investigate the feasibility of both methods.

6.11.1 Method 1

The abnormal pressure drop method will be investigated in two basic areas. The first is the location of existing pressure taps in the RCS piping. The second area of interest is the selection of the proper transducer. The standard pressure transducers found to date installed in a pressurized water reactor system may not have enough accuracy to measure a relatively small pressure drop encountered in a straight section of reactor piping. Differential pressure transducers have an obvious advantage in resolution and range, but also present problems in running instrument pressure taps in both line length and the additional problem of primary pressure boundary integrity.

6.11.2 Method 2

Acoustic Emission. It is proposed that experts in the field of acoustic emission testing be contacted and discuss the potential problems of an on-line acoustic emission monitoring system being used to detect a break in the RCS piping and its ability to detect, locate, and approximate the size of that break.

The results of these discussions will be reported in the final task report.

7. RECENTLY AVAILABLE DATA

The on-going literature search has received two items that concern this project.

The first[2] is the fact that a computer-based Safety Parameter Display System (SPDS), has been installed at the Yankee Nuclear Power Plant at Rowe, Mass. Yankee is a 175 MWe Westinghouse PWR. This plant SPDS should be in operation in December 1982 as the plant finished a 13 week outage for refueling and maintenance. It is hoped that experience with this system by plant operators will aid developers of both this system and the Disturbance Analysis and Surveillance System (DASS), in designing a system that is useful to nuclear plant operators in detecting and correcting plant conditions that are off-normal before these conditions shut down the reactor or cause plant damage. The SPDS installed at Yankee will allow operators to be alerted to monitor the status of five critical safety functions that are considered most important. These functions are core heat removal, main coolant inventory, reactivity control, secondary cooling and inventory, and containment integrity. This system and its visual display will allow the operator to view the most recent data from a safety function and view trends that may indicate a potential problem before it occurs.

The second[3] is a progress report on the development of a noninvasive liquid level gauge for nuclear power reactors. This report discusses the results of experimental and computational work that has been conducted to develop the concept for a noninvasive liquid level and density gauge using neutrons that penetrate the vessel wall. This study utilized fission chambers with a variety of shielding materials and techniques in detecting reactor vessel liquid level and simulated downcomer voiding. This report also tests data obtained from the LOFT, L2-5 test in

June 1982. This test was a large break simulation which resulted in repeated uncovering of the core. Conclusions from the report stated that the external detectors produce a unique response depending on the type of voiding taking place in the core.

8. DISCUSSION OF PROPOSED TEST PLANS

8.1 Low Velocity Flow Measurement

The planned testing of the cooled velocimeter in a nuclear grade thermowell will allow us to determine the sensitivity of the device as it is envisioned to be used. The availability of a high temperature and high pressure test facility will allow the test to be performed under simulated operating conditions. A laser Doppler velocimeter will be used for a velocity reference. A test section incorporating sapphire windows has been designed and will be modified to incorporate the nuclear thermowell. The design of the cooled thermal velocimeter includes enough temperature measurements to allow the installation heat loss to be calculated. The proposed test will not simulate the RCS piping directly as the test section is 3 in. Schedule 160 piping, but modifications to the test section allow positioning of the active area of the probe/thermowell installation in the center of the test section flow area.

8.2 Voiding of the Primary Pump and System Component Voiding

This test will involve both the analyses of data that has already been recorded during previous LOFT tests and the analysis of data that might occur during this FY 1983 reporting peoriod. The primary pump power as measured at LOFT(4) during several tests seem to show correlation between pump power and voiding in the primary system. Preliminary analysis on data recorded from an accelerometer mounted on or near the primary pump has shown some correlation may exist between this vibration signal and voiding in the primary system. The goal of this test would be to try to identify this correlation and see if there is a correlation between pump vibration and the primary pump power measurement. Most of the data that would be processed has already been recorded, but has not been examined in this fashion. Results of this examination would be reported in the final task report or as it becomes available.

8.3 U-Tube Voiding Detection

This test will utilize two high temperature microphones. One microphone will be mounted on the outside of inlet primary plenum on the LOFT steam generator and one on the outside of the primary outlet plenum. Using the data from these microphones it will be determined if flow induced acoustic emission can be detected by microphones mounted external to the RCS piping. If flow induced emissions can be detected by the inlet sensor the outlet sensor signal will be examined for any correlation to the inlet signal. The primary coolant flow rate will be monitored and the transit time through the heat exchanger will be calculated and the correlation, if any correlation is found, will be checked to assure that the acoustic signal is transmitted through and received from the primary coolant flow, and not through the metal piping or air. Since there is not an existing voiding detection instrument installed on the steam generator, every effort will be made to obtain verification of a U-tube voiding by utilizing existing reference instruments. These will include gamma densitometers, pressure drop across the steam generator, and other steam generator reference instrumentation. Possible interactions that are caused by secondary side water level or echos from a steam-water interface will be monitored.

8.4 Break Identification, Location and Size Estimation

It is planned to examine the potential of both proposed methods. The first method, abnormal pressure drop will be examined by acquiring the location and availability of the RCS pressure taps around the system. The number, range, and type of pressure transducers that are connected to these taps. Accuracy will be investigated and a normal pressure drop will be calculated if possible to determine the needed accuracy of each pair of transducers.

The second method to be investigated is the use of acoustic emission techniques to detect piping or system breaks if they should occur. It is proposed to contact recognized experts in the field of acoustic emission methods and techniques, and obtain their opinion and advice on the number and type of transducers that would be necessary to obtain this data.

9. CONCLUSIONS

In anticipation of the NRC approval of the proposals contained in the FY 1982 report, EGG-ID-6040 and this report, certain preliminary work has begun. Some of the items that have been initiated are listed below.

9.1 Design

Preliminary design work was initiated on the cooled velocimeter to allow installation in a nuclear grade thermowell.

9.2 Data Sheets and Ordering Information

Data sheets and ordering information have been requested for a typical nuclear grade thermowell.

9.3 Scheduling

Scheduling information has been requested for access to existing test facilities.

9.4 Data Tapes

Information has been requested on the availability of existing data tapes for analysis of previously recorded LOFT test data that includes the pump power and vibration data.

9.5 High Temperature Microphones

High temperature microphones have been located and information on the necessary procedures required to have the instruments installed on the LOFT heat exchanger has been requested.

9.6 Specifications and Technical Data Sheets

Specifications and technical data sheets for acoustic emission methods and techniques have been requested.

9.7 RCS Pressure Transducers

Initial inquiries about the number and types of RCS pressure transducers have begun.

Hopefully this initial effort will aid the further testing and investigations of the proposed instruments/methods.

TWO-PHASE INSTRUMENTATION SURVEY

Instruments for Further Evaluation

TABLE 1

Instrument (Method)	1.Low Flow Cooled Velocimeter	2.Primary Pump Power & Vibration
Instrument Status	Moderately developed. More testing required to develop application and installation techniques.	Power measurement already required. High temperature sensors commercially available for installation on primary pump system for vibration measurement.
Power Plant Suitability	Passive device,no moving parts. Requires only cooling water.	Instruments should be very suitable for nuclear plant use.
Reliability	Good: Type K thermocouples have an excellent history in nuclear applications.	Should be good. Power measurement already being made. Other sensors have proven usable in radiation environment.
Retrofit Capability	Plan to try to use nuclear grade thermowells.Existing thermowells or penetrations might be usable.	No vessel or piping modifications should be necessary.
Performance	Performance is good, basic instrument accuracy is good. Accuracy and performance in thermowells would be established in further testing.	Measurement uses techniques and sensors utilized with good results and are currently in use.
Signal Processing	Simple processing is required to obtain direct velocity information	Power data should require simple processing.Vibration data processing could become more complex and require some interpretation.
Signal Usability	Range would have to be established in thermowell. Signal would be usable in RCS decreased flow conditions probably in the velocity range of 0.05 to 2.0 meters/sec.	Information could be directly used by operator as a status indicator and could potentially indicate the onset of other pump or system problems.

TWO-PHASE INSTRUMENTATION SURVEY

Instruments for Further Evaluation

TABLE 1

Instrument (Method)	3. Steam Generator U-Tube Voiding	4. RCS Piping Break (Pressure) [Acoustic Emission]
Instrument Status	Application is developmental Acoustic measurements now in use for reactor applications.	(Application is developmental. Would be plant specific in utilizing existing instruments) [Commercially available systems could be directly applicable to measurement technique. Would be plant specific in transducer location.]
Power Plant Suitability	No penetration into RCS.	(Would attempt to use existing sensors) [Acoustic systems already in use in nuclear plants. (loose parts monitors and valve leak detection)]
Reliability	High temperature and radiation resistant transducers are available.	(Good, utilizing qualified and approved instruments.) [Good, Transducers have a history of operation in nuclear environment.]
Retrofit Capability	Outside pressure boundary installation. Minimal perturbance	(No additional penetrations should be required.) [Outside pressure boundary installation]
Performance	Should be good. Sensitivity may be a problem and discrimination of signal and system generated noise.	(Possibilities are good. Presure resolution and accuracy of existing sensors may be a problem) [Has potential. Techniques are in use in the industry.]
Signal Processing	Processing is required, using proven principals.	(Processing is required. Comparison of normal versus measured pressure readings and establishing limits.) [Processing required. Techniques have been developed.]
Signal Usability	Signal potentially useful in several ways. (loose parts monitor, steam generator status indicator.)	(If method proves feasible, output could be RCS status indicator.) [Potentially to detect loose parts or leaking valves as well as RCS break.]

10. REFERENCES

1. S. B. Englert, Preliminary Two-Phase Instrumentation Evaluation, EGG-ID-6040, September 1982.

2. "Computer-Based Display to Aid Operators" Nuclear News, Volume 25, No. 13, October 1982, pp 45-46.

3. A. J. Baratta, et al., Final (Preliminary) Progress Report on the Developmnet of a Non-Invasive Liquid Level Gauge for Nucler Power Reactors, Pennsylvania State University Nuclear Engineering Department Publication No. 72, September 1982, U.S. NRC Grant Number NRC-G-04-81-024.

4. Glen McCreery, J. H. Linebarger, J. E. Koske, "Primary Pump Power as a Measure of Fluid Density During Bubbly Two-Phase Flow," to be presented at The Second International Meeting on Nuclear Reactor Thermal-Hydraulics, January 11-14, 1983, Santa Barbara, California.