OCT 24 1967

MASTER

Westinghouse Atomic Power Divisions

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CONTROL OF XENON INSTABILITIES

IN LARGE PWR'S

QUARTERLY PROGRESS REPORT

FOR THE PERIOD ENDING

SEPTEMBER 30, 1967

M. J. O'Boyle
Project Engineer

Prepared for the New York Operations Office
U. S. Atomic Energy Commission
Under AEC Contract AT(30-1)-3680

October 1967

WESTINGHOUSE ELECTRIC CORPORATION
Atomic Power Divisions
Box 355
Pittsburgh, Pennsylvania 15230

NOTICE
This report was released under the provisions
of the Atomic Energy Act
arrangement and is subject to the terms thereof.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

EXTERNAL DISTRIBUTION

USAEC, Brussels Office, APO 667 New York, New York 09667 Attention: Senior AEC Representative	40
USAEC, New York Operations Office, 376 Hudson Street, New York, New York 10014 Attention: Leo Graup	1
USAEC, New York Operations Office, 376 Hudson Street, New York, New York 10014 Attention: Reports Library	1
USAEC, Office of Foreign Activities, GM Washington, D. C. 20545.	1
USAEC, Assistant General Counsel for Patents Washington, D. C. 20545 Attention: Dr. William Holton.	1
USAEC, Division of Technical Information Ext. P. O. Box 62 Oak Ridge, Tennessee 37830	1
USAEC, Division of Reactor Development and Technology, Washington, D. C. 20545.	2
United Nuclear Corporation Grasslands Road, Elmsford, New York 10523 Attention: Irving Klempner, Manager, Information Services.	1
<hr/>	
Total	48

PRELIMINARY REPORT - U. S. EURATOM EXCHANGE

To expedite dissemination of technical information to those persons requiring it, this report has been issued without the administrative review necessary to protect the interests of the U. S. Government, the European Atomic Energy Community (Euratom) and Westinghouse Electric Corporation. The recipient of this report agrees that it is passed on to him in confidence, that he will maintain that confidence and make no disclosures or publication of the contents that would be detrimental to the interests of the U. S. Government, the European Atomic Energy Community (Euratom) and Westinghouse.

TABLE OF CONTENTS

	<u>Page Number</u>
PROGRAM DESCRIPTION.	1
PROGRESS SUMMARY	2
DETAILED PROGRESS REPORTS.	3
EUXE-100 Program Management	4
EUXE-200 Effect of Core Parameters on Spatial Oscillations. .	5
EUXE-300 Remedial Control Procedures.	7
EUXE-400 Three-Dimensional Analysis	10

LEGAL NOTICE

This document was prepared under the sponsorship of the United States Atomic Energy Commission pursuant to the Joint Research and Development Program established by the Agreement for Cooperation signed November 8, 1958 between the Government of the United States of America and the European Atomic Energy Community (Euratom). Neither the United States, the U. S. Atomic Energy Commission, the European Atomic Energy Community, the Euratom Commission, nor any person acting on behalf of either Commission:

- A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this document, or that the use of any information, apparatus, method, or process disclosed in this document may not infringe privately owned rights; or
- B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method or process disclosed in this document.

As used in the above, "person acting on behalf of either Commission" includes any employee or contractor of either Commission or employee of such contractor to the extent that such employee or contractor or employee of such contractor prepares, handles, disseminates, or provides access to, any information pursuant to his employment or contract with either Commission or his employment with such contractor.

PROGRAM DESCRIPTION

This program investigates the characteristics and control of spatial instabilities in large pressurized-water reactors (large PWR's), with particular emphasis on azimuthal xenon instabilities (x-y plane). The program consists of the following technical tasks:

Task EUXE-200 - Effect of Core Parameters on Spatial Oscillations

The aim of this task is to analyze the effect of variations in core design and operating parameters on the propensity for spatial oscillations, with emphasis on those resulting from xenon redistribution. Parameters to be analyzed include, but are not limited to, core dimensions, fuel and moderator temperature feedbacks, and power distributions.

Task EUXE-300 - Remedial Control Procedures

Under this task, two-dimensional x-y calculations will be performed to establish control methods and detector locations which will prevent divergent oscillations. Calculated results will be used to develop criteria for the application of remedial measures to large pressurized-water reactors.

Task EUXE-400 - Three-Dimensional Analysis

Under this task, either direct or synthesized three-dimensional calculations will be performed to further study spatial instabilities in large PWR cores with conditions conducive to oscillations. If a three-dimensional oscillation develops after perturbations have been introduced, selected remedial methods (as developed under Task EUXE-300) will be applied and evaluated. The unique characteristics of three-dimensional oscillations (if observed) will be identified and the criteria for the application of remedial measures will be developed.

PROGRESS SUMMARY

Major progress is summarized below for the three month period ending September 30, 1967:

Analytical effort was completed under Task EUXE-200, Effect of Core Parameters on Spatial Oscillations. A topical report describing in detail this work was prepared and is presently undergoing management and technical review.

One-dimensional analysis of azimuthal xenon oscillations, and controlling procedures, has been started. Data decks have been prepared for two-dimensional analysis of these same oscillations, but the lower-cost one-dimensional analysis is being pursued first to gain insight into control algorithms.

DETAILED PROGRESS REPORTS

EUXE-100

PROGRAM MANAGEMENT

M. J. O'Boyle, Project Engineer

Development Projects
PWR Plant Division

L. W. Weidman

This is the fifth in a series of technical progress reports on the U.S.-Euratom program titled "Control of Xenon Instabilities in Large PWR's". The preceding reports in this series are:

EURAEC-1721 "Control of Xenon Instabilities in Large PWR's,
WCAP-3680-1 Technical Progress Report for the Period Ending
September 30, 1966"

EURAEC-1781 "Control of Xenon Instabilities in Large PWR's,
WCAP-3680-2 Quarterly Progress Report for the Period Ending
December 31, 1966"

EURAEC-1830 "Control of Xenon Instabilities in Large PWR's,
WCAP-3680-3 Quarterly Progress Report for the Period Ending
March 31, 1967"

EURAEC-1880 "Control of Xenon Instabilities in Large PWR's,
WCAP-3680-4 Quarterly Progress Report for the Period Ending
June 30, 1967"

Program management is not discussed in this technical progress report, since separate reports emphasizing the administrative aspects of the program are published monthly for limited distribution.

EUXE-200

EFFECT OF CORE PARAMETERS ON SPATIAL OSCILLATIONS

R. J. French, Manager	Nuclear Engineering PWR Plant Division
G. H. Minton, Manager	Reactor Physics and Mathematics Section
J. E. Olhoeft, Manager	Reactor Physics
C. G. Poncelet	
A. M. Christie	

This task was completed during the reporting period. The following is a summary of work performed under this task:

The characteristics of free-running xenon-induced spatial oscillations in large pressurized water reactors (PWR's) were investigated both from a phenomenological point of view and from the standpoint of the theoretical and calculational methods employed in their analysis. The digital simulation of spatial xenon instabilities with multidimensional, multi-group diffusion theory programs was investigated in detail. An extensive study of the effect of a finite, nonzero time-step length on calculated stability characteristics was performed, including a set of correlations which permits the extrapolation of digital calculations to effectively zero time-step length. The sensitivity of the digital results to the spatial mesh length, the energy mesh, and the treatment of temperature feedback effects was investigated. The effect of a non-zero flux convergence criterion on spatial xenon oscillations was investigated. A comparison was made of modal theory results and digital simulation calculations. The space-dependent transfer function formalism was employed in a number of analyses, including the effect of delayed neutrons and the effect of finite temperature feedback time-lags.

The space-time characteristics of xenon-induced instabilities in the two-dimensional plane perpendicular to the direction of coolant flow

were studied for a large variety of core sizes, power distributions and temperature feedback effects. The effect of perturbation size and location was evaluated. Extensive parametric and sensitivity analyses were performed, based on a modal expansion method. Parameters investigated were core size, power distribution, power level, power coefficient, fuel enrichment, Xe-135 absorption cross section, I-135 fission yield and direct Xe-135 fission yield. Parametric calculations with one- and two-dimensional diffusion theory programs were performed to corroborate the modal theory results.

A topical report which discusses in detail the work performed under this task was prepared and is presently undergoing management and technical review.

EUXE-300

REMEDIAL CONTROL PROCEDURES

R. J. French, Manager

Nuclear Engineering
PWR Plant Division

D. L. Miller, Manager

Nuclear Core Design

R. F. Barry

T. D. Knight

A. Summary

This report will cover work in progress rather than work accomplished. The work in progress includes diametral (one-dimensional) transient analysis and X-Y (two-dimensional) transient analysis of xenon instabilities.

B. Diametral Analysis

A one-dimensional analysis of azimuthal xenon transients is possible if one approximates the reactor's transverse geometry as square. This approximation ignores the fact that the extreme fuel assembly positions suffer more leakage than the square model allows. Furthermore, the one-dimensional traverse along a diameter cannot have the correct effective fuel characteristics at each point unless the core is uniformly loaded.

With these reservations in mind, the diametral analysis is still of great utility in xenon transient analysis simply because the cost of analysis is reduced by an order of magnitude. Keeping the cost down is especially significant in seeking remedial control procedures, because the search necessarily involves some groping.

A good remedial control procedure has two components: First, simple policies for using control rods to dampen transients; second, an information handling scheme to know when xenon transients are present. Each control policy can be studied by assuming perfect information. Then, policies which work and are not excessively sensitive to system parameter variations (which is to say that the total control system must be structurally stable) can be coupled with possible detection schemes. The detection schemes may rely on excore detectors, incore detectors, thermocouples, or combinations thereof.

An ideal procedure would recognize the presence of an azimuthal xenon transient, select one or two control rods to be inserted to counter the transient, dampen the oscillation, and return to normal operation, all without exceeding hot channel factor design limits or placing an undue burden on the plant operators.

C. X-Y Analysis

X-Y two-dimensional analysis will definitely be required to corroborate any judgments made on the basis of the diametral analysis.

Furthermore, there are problems which are not amenable to diametral analysis. For instance, an oscillation might be forced to precess around the core if remedial action should insert a control rod on the wrong azimuth.

The X-Y analysis is most fruitfully done after the diametral analysis has been substantially completed because the exploratory work can be done more cheaply with diametral analysis.

EUXE-400

THREE-DIMENSIONAL ANALYSIS

This task was inactive during this report period.