UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

COMMISSION CORRESPONDENCE

OFFICE OF THE COMMISSIONER

May 28, 1980

Mr. Thomas C. Maguire
GEO-CENTERS, INC.
4700 Auth Place
Camp Springs, Maryland 20023

Dear Mr. Maguire,

I appreciated receiving your letter of April 4 in which you provided a brief description of a proposed instrumentation system for measuring water level in the core of a pressurized water reactor. I requested the staff's views on your proposal and am forwarding a copy of their response for your information.

It appears that an additional exchange of information would be necessary to allow the staff to compare the merits of your proposed system to other proposals. If you would like to pursue this matter further, I suggest that you contact Dr. Yin Yun Hsu of our Office of Nuclear Regulatory Research (telephone number 301-427-4260).

Thank you for your interest in this matter of safety significance.

Sincerely,

Richard T. Kennedy

Enclosure:
As stated

bcc: H. Denton, NRR
B. Budnitz, RES
Y. Hsu, RES
H. Richings, NRR

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COMMENTS ON THE GEO-CENTERS, INC.

PROPOSAL FOR PWR CORE WATER LEVEL MEASUREMENT

GEO-CENTERS, INC. in a letter to Commissioner Kennedy has proposed a program leading to the development of an incore nuclear instrumentation system to measure the water level in the core of a PWR during unusual event conditions. This system, consisting most likely of axial arrays of neutron detectors, would determine axial neutron flux distributions and from this information deduce reactor water level. The proposed development program would attempt to adopt existing instrumentation and existing PWR design provisions for incore instrumentation. Its primary initial phase would determine (calculate) relevant axial flux distributions and levels and instrument characteristics in order to examine feasibility.

During events in which water level determination is a potential problem there will (normally) be a control rod trip and reactor shutdown. Neutron flux levels will drop, and over a period of about twenty minutes will reach "source range" levels, about a factor of 10^8 to 10^{10} below full power levels. The flux levels in this range are determined by source strength and (subcritical) neutron multiplication level. The sources are both the fixed sources placed in the reactor for start up and the sources developed from operation. The latter is normally primarily from fission product gamma reactions with deuterium in the water. It varies in strength with time, and for several hours after shutdown can be the primary neutron source. Flux distributions are determined by source and reactivity distributions, which in turn are determined by both existing conditions, particularly water density distribution, and conditions of prior operation.

Information from the measurement of some of the characteristics of the shutdown flux can potentially provide some information about water density distribution. It can also provide confusion. At TMI-2 the source range instrumentation was a midplane excore chamber (two of similar locations). Its readings when carefully analyzed long after the event in conjunction with much other information and analysis, provided valuable insight and confirmation of suspected hydraulic processes. During the event it added to the confusion since it was, logically, interpreted as indicating core multiplication changes (e.g., from deboration). In retrospect it is seen as indicating voiding and low level not in the core, but in the downcomer.

The confusion arises because the flux level at a given single position potentially can be affected by many quite different elements acting on the production and transport of neutrons. If the single measurement position at TMI-2 had been in the core, the significant observed effects may have been different but similar confusion would have existed. A repeat of the TMI-2 event now would undoubtedly result in a correct interpretation of the readings and thus a reasonable estimate of water in the downcomer and thus in the core. But a theoretically possible reactivity event with similar output might well result in similar confusion.

A system which measures the relative aspects of flux distributions in addition to or instead of an absolute level might well reduce or eliminate the confusions of the TMI-2 measurement. For example a system of several axially spaced excore detectors might be a suitable indicator of pressure vessel water level. As with the TMI-2 excore source range monitor it would more likely indicate downcomer levels rather than core levels and would thus be useful only when these two levels were compatible. It would probably not be highly accurate as a level meter and would only indicate downcomer voiding, as did the TMI-2 instrument early in the event, via abnormally high levels and noisy operation. However, it might provide a suitable indication that problems exist.

Bringing the detectors incore could provide more direct indication. Given a simple situation with a reasonably well known "normal" axial flux distribution, a normal uniform water density except for a lowered level, and full, detailed axial flux measurement, the lowered level could probably be determined within about a foot below the top of the core. (Note that the thermal flux does not simply cease at the top of the water level.)

However, an existing situation might be much more complex. There are a wide variety of normal axial flux distributions for the shutdown state of interest. Normal (critical) modes may vary from central peaked, early in life, with a relatively small flux at the core top to strongly top peaked, late in life, with a relatively large flux near the top. In the shutdown state these normal modes are modified by the source distribution and the degree of core multiplication. The source distribution will vary depending on previous operation and shutdown time, with the operational source distributed according to existing water densities and operational power distributions, and the fixed point source usually located at the midplane near the core periphery. Furthermore the distributions will be modified, perhaps strongly, by existing axial water density variations, e.g., those which would exist in natural circulation states. In practice there will not be a simple water "level" in the core, but a complex variation in density. It may be noted that calculations generally are not done for these shutdown, subcritical source multiplication states and thus results probably do not presently exist for easy examination of the variation in range which could be encountered.

All of these complications make it much more difficult to distinguish quickly between normal and abnormal flux (and thus water) distributions in the upper part of the core. At best a continuous or at least axially fine mesh measurement would seem to be required in the upper third of the core. A coarse mesh system, such as the seven axial detector B&W incore system referred to by GEO-CENTERS, INC., would have great difficulty in clearly delineating abnormal distributions. An on-line simplified thermal-hydraulic-neutronic computer system would aid the system but would not be easy to develop or implement.

There is no existing PWR incore instrumentation working in the shutdown range. PWR incore systems are designed for the power range. They are either axially fixed, self powered detectors (seven in a string for B&W) or axially moveable, single fission chambers (Westinghouse), with either system operating in a fuel assembly instrument tube. In the BWR, however, the source range detectors is an incore pulse counting fission chamber, and is of a size compatible with the Westinghouse movable incore detector. It is used in a movable system in a BWR and could be a movable detector in a PWR. However, its count rate in shutdown conditions may be of the order of ten counts a second, thus requiring significant time at any given axial location for good statistics and an extended time for moveable axial mapping. A fixed system might be limited by space problems in the instrument tube. The BWR detectors are about four times larger (radially) than the B&W incore detectors, making a top of the core fine mesh system unlikely. The BWR system is only qualified for a relatively short radiation life and is thus not kept in the core during power operation. A fixed PWR system would probably require similar movement out of the core and return at shutdown. This is possible but adds to the complexity.

In summary, an incore neutron flux detection for water "level" measurement is neither obviously unfeasible nor obviously straightforward. A system for flux distribution detection could provide information relevant to water density determination, but interpretation would be complex. Instrumentation exists for use in such a system, but space could limit detailed measurements. A simpler excore system might provide similar, if less precise, information sufficient to provide warning and guidance for abnormal water conditions. The detailed evaluation of the precision and relative usefulness of such a system compared to other systems appears to be complex. This complexity and the ability to deal with it is not indicated in the GEO-CENTERS, INC. proposal.

During the past year a great amount of activity has centered around questions of improved instrumentation for water level determination in reactors over a possibly wide range of circumstances. This has occurred as a result of TMI-2 and resulting NRC reviews of requirements, other reactor events involving potential water level problems, research programs such as LOFT, and the revisions of Regulatory Guide 1.97 on the instrumentation for reactors to assess conditions during an accident. There have been many ideas, responses and proposals related to such instrumentation, including the use of nuclear detectors, discussed and submitted by utilities, vendors, national laboratories and other organizations. Various aspects of these ideas have been or are being reviewed by groups in the national laboratories and the NRC offices of Nuclear Reactor Regulation and Nuclear Regulatory Research (RES).

The proposal by GEO-CENTERS, INC. provides insufficient information to form a clear basis as to why its proposal is unique or of special interest or why its background is particularly well suited to analyze the complexities of the problem, to compare the merits of the system to other proposals and to develop such instrumentation and associated analytical requirements. As has been previously indicated, there is possible though uncertain merit in the proposed system. If GEO-CENTERS, INC. wishes to continue its presentation further it should discuss the problem and its capabilities with the groups in NRC which have been exploring and evaluating the problem. In particular they should contact Dr. Yih Yun Hsu of RES.

GEO-CENTERS, INC.

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April 4, 1980

Commissioner Richard T. Kennedy
U. S. Nuclear Regulatory Commission
1717 H Street, N.W.
Washington, D.C. 20555

Dear Commissioner Kennedy:

The Kemeny Commission identified the need to develop instrumentation for measuring water level in the core of a pressurized water reactor. An accurate measure of the water level is necessary so that actions may be taken to assure adequate cooling of the reactor fuel. Due to the severe environmental conditions that exist in the core of a nuclear reactor, standard level measuring techniques, such as differential pressure sensors, are not directly applicable. Instrumentation suitable for use in-core must be developed or existing instrumentation must be adapted to meet these measurement needs.

Enclosed is a brief description of a proposed system which would utilize an axial array of in-core neutron detectors to provide water level information. A program leading to the development of the instrumentation is outlined. Advantages of the proposed system include:

- utilization of existing technology
- compatibility with current reactor designs
- stationary detectors
- redundancy provided by duplicate arrays

Since existing technology is utilized, time required for implementing the system would be minimal.

Your consideration of the proposed system is appreciated. We would welcome the opportunity to discuss the system and proposed development program with you or your staff.

Sincerely,

Thomas C. Maguire

Thomas C. Maguire
Senior Engineer

Development of a Water Level Detector

for Pressurized Water Reactor Measurements

I. Introduction

As a result of the accident at the Three Mile Island Nuclear Station, several inadequacies in equipment design were noted by the Kemeny Commission. One such inadequacy was the measurement of water levels in key areas of the primary reactor coolant system. Water level measurement in the core of a pressurized water reactor presents considerable problems due to the severe environmental conditions (high temperature and pressure, large mass flow rates of water and high radiation fields). It is proposed that certain existing incore instrumentation could be adapted for use in this application. The following summary describes the proposed system and outlines a number of tasks which would lead to its development.

II. Measurement of Water Level in a Pressurized Water Reactor.

Incore instrumentation is subjected to high temperatures and pressures and high radiation environments. Techniques which utilize changes in nuclear parameters to monitor non-nuclear variables, are particularly attractive for use in incore instrumentation. Also, adapting existing instrumentation to new measurement requirements minimizes the time required for implementation. Due to the dependence of thermal neutron flux on the presence of moderator, modification of existing incore flux monitors could provide a measure of the water level in a pressurized water reactor.

Part of the nuclear instrumentation system of pressurized water reactors designed and built by the Babcock and Wilcox Co.

includes a fixed incore monitoring system. This system continuously measures the axial neutron flux distribution during reactor power operation. During a loss of coolant accident (LOCA) resulting in a partial uncovering of the fuel incore, a signficant change in the axial distribution of the thermal neutron flux is expected. The loss of moderation in the uncovered portion of the core leads to a thermal flux depression since neutrons in this region are not being thermalized. Thermal neutron detectors located there would have decreased signals indicating the loss of moderation due to the uncovering of the fuel.

Present incore neutron flux mapping systems utilize either fission chambers in the current mode or self-powered rhodium detectors which are useable in the power range of operation. Since water level measurements are particularly important following a reactor trip, these detectors are not suitable for this application due to their relatively poor sensitivity. Possible detector candidates for use in this application include fission chambers operated in the pulsed mode and boron filled or lined proportional counters. Since loss of sensitivity due to burnup is a problem with the latter type of detectors, a scheme for the protection of the sensitive volume of the detector needs to be devised. One such scheme might require the detector to reside out of core during normal operation, ready to be inserted along with the control rods upon initiation of a reactor trip.

The proposed system has several advantages:

1) Provisions currently exist for incore neutron detectors.

2) Once activated, movement of the detector is not required for a complete axial flux distribution measurement.

3) Existing detector technology should be adaptable for use in this application

4) Two or more detectors should provide independent, redundant measurements, since the water level should be constant across the core.

III. Outline of Tasks

Geo-Centers, Inc., proposes a multiphase program to develop a system to monitor the water levels in key areas of the primary reactor cooling system. The first phase, which is projected as a three to four month technical effort, includes a technical study to evaluate the feasibility of the detector system and, if appropriate, provide design parameters and performance characteristics. The study would include compiling existing data on axial thermal neutron flux distributions and calculating such distributions as necessary to define all conditions of interest. The calculational work involves the use of reactor kinetics codes available in the nuclear industry. Specific tasks are:

1) Determine the axial distribution of the thermal neutron flux for a typical pressurized water reactor following a reactor trip.

2a) Evaluate the sensitivity of existing thermal neutron detectors with respect to the flux levels determined in 1). Detectors to be considered include boron proportional counters and pulsed fission chambers.

b) Tasks 1 and 2a will determine if a measurement of the thermal neutron flux will be sensitive enough to determine water level. If not, the possibility of measuring neutron energy differences between covered and uncovered portions of the core will be evaluated.

3) Select an appropriate detector type from those evaluated and design a configuration compatible with current parameters for incore instrumentation. Such parameters would include physical dimensions and performance criteria (expected lifetime, output signal requirements, etc.). Design considerations would include effects of the detector system on the reactor configuration (operation, hot standby, cold shutdown, etc.) in addition to performance specifications of the detector system.

Future phases of the program, which depend on the results obtained from the tasks outlined above, include building a prototype instrument, testing it at a suitable facility, and comparing the test results with performance calculations.