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

April 29, 1982

MEMORANDUM FOR: Chairman Palladino
Commissioner Gilinksy
Commissioner Ahearne
Commissioner Roberts

THRU: Samuel J. Chilk, Secretary

FROM: Demetrios L. Basdekas
Reactor Safety Engineer
Instrumentation & Control Branch
Division of Facility Operations
Office of Nuclear Regulatory Research

SUBJECT: PRESSURIZED THERMAL SHOCK IN COMMERCIAL PRESSURIZED WATER REACTORS AND THE SAFETY IMPLICATIONS OF CONTROL SYSTEMS

PURPOSE: To present to the Commission an updated summary of views and recommendations on the subject matter which may differ from those of the EDO staff.

This memorandum is in response to your request transmitted by memorandum of the Secretary dated April 20, 1982, and it is submitted in advance of my briefing to you on the subject matter scheduled for May 4, 1982, at 1:30 p.m.

Enclosure 1 summarizes my professional qualifications for your convenient reference. Enclosure 2 gives a chronology of significant events and documentation on the issue of the safety implications of control systems, including pressurized thermal shock in Commercial Pressurized Water Reactors (PWR's).

The issue of Pressurized Thermal Shock (PTS) in commercial PWR's has technical and institutional aspects and involves many disciplines of science and engineering. I will attempt to focus on the technical aspects of the issue, give you my perceptions of them, the bases for those preceptions, and my recommendations for steps needed to resolve it.

The major technical elements of PTS may be divided into two groups: First, those related to systems and respective processes which are controlled under normal operating conditions, and which must be controlled under transient or accident conditions, so that public health and safety is adequately protected. Maintaining the operational integrity of a plant is also important, and I believe that it cannot be totally separated from our primary responsibility to

protect public health and safety and promote national security. The second group of the PTS technical elements includes the materials and mechanical properties of the reactor vessel and steam generators, and ultimately of the containment structure. Even though this division is made for purposes of examining PTS in a somewhat organized manner, it is important to point out that we are dealing with the whole plant as a unit, an integral system which is large, complex, and highly interactive.

The early designers of nuclear power plants and their regulators in government have approached the question of safety through a "design basis envelope" by providing safety systems intended to protect against a number of "design basis accidents" typically analyzed in Chapter 15 of the Safety Analysis Report (SAR) for each plant. Under this rationale, control systems and components were thought as "not required for safety" and as such have not been the subject of licensing review by the Commission because it was assumed that any control systems malfunctions, or actions by them, would be mitigated by actions of the safety systems. I have had a great deal of difficulty with this assumption which appears to be so deeply ingrained in the minds of designers and regulators alike, despite substantial and hair-raising operational experiences, let alone common engineering sense.

The TMI-2 accident produced some awareness and appreciation of the problem (See Enclosure 3), but it was quietly allowed to fade into its prior status of inattention.

The most important link of interaction between the Reactor Protection System and Engineered Safety Features Systems, on one hand, and the various Control Systems on the other, is the dynamics of the processes which are monitored or controlled. The dynamic characteristics of the various processes (neutronic, thermal, hydrodynamic, and hydrostructural) must govern the design, analysis, and testing of their associated control systems. The design criteria should include things such as damping ratios, frequency response characteristics, phase and gain margins, and experimental verification of their stability and performance by in situ measurements, in addition to reliability requirements based on their relative importance to safety. Such design criteria do not exist in NRC's regulations. We do not properly review the adequacy of control systems, nebulous statements in Section 7.7 of the Standard Review Plan, and other official documents not withstanding. Presently, the most likely way to find out what, if anything, is wrong with a control system's design is for something wrong to happen. Certainly this is not the correct approach to safety. I believe that this important lesson from TMI, Rancho Seco, Crystal River, and more recently Ginna has not been adequately learned.

About a year and a half ago, and after persistent, pointed questions on the matter by Congressman Udall, the staff and the Commission agreed that this was an important, unresolved safety issue and designated it as USI Task A-47, Safety Implications of Control Systems. As a part of my attempts to convince

the staff and the Commission of the significance of the safety implications of control systems, I attempted to illustrate it by describing to Dr. Murley a group of PTS accident sequences that may be initiated and sustained by malfunctions in the secondary side control systems of a PWR. (See Enclosure 4.) Although Dr. Murley's response to this was prompt and appropriate, the NRR staff's position, a matter of record, had produced a year-long debate internally, culminating in a meeting with the utility owners' groups on March 31, 1981, asking them whether they thought they had a problem with PTS. Again, had it not been for Mr. Udall's oversight function, this matter would have been placed on the ATWS-like path for "resolution."

I have discussed this matter several times and with many people within NRC over a long period of time. This has been consistent with my position to attempt repeatedly to exhaust the avenues available to me within the agency, including the procedures of NRC Manual Chapter 4125 on Differing Professional Opinions, to achieve a satisfactory resolution of the issue. On September 17, 1981, you were kind enough, Mr. Chairman, to meet with me at my request. At that time, shortly after you assumed office, I discussed with you a number of items on this issue, including recommendations for dealing with them. You asked the staff to comment on them. The staff did so, with considerable distress, and its responses are contained in Enclosure 5. During the briefing on May 4, 1982, I will give you a more detailed account of my views and recommendations on this issue. The major points which need to be made concerning PTS are:

- Substantial uncertainties and non-conservative assumptions in estimates of consequences and of probabilities cast serious doubts on the validity of conclusions stated by industry and the NRC staff.

- The lack of badly needed design information on control and electrical power systems, and related neutronic and thermal-hydraulic parameters for representative plants (at least one for each NSSS vendor) makes an independent and thorough assessment of this issue by NRC virtually impossible.

- Substantial operational experience with PTS precursor events involving control system and steam generator tube failures, coupled with an understanding of functional and some design aspects of control systems and components in operating plants, suggest an unacceptable level of risk associated with a number of older pressurized water reactors.

The major recommendations which I have to make, based on the above points and related considerations, are for:

- Development of a regimen for short-term measures involving core reconfigurations in plants that are most threatened by PTS. These measures may be scheduled so that the affected plants are shutdown in groups starting with those most threatened, and those in this category already shutdown for other reasons. These measures, such as the addition of a peripheral array of dummy fuel elements would reduce the rate of fast neutron fluence accumulation at the vessel beltline region. These measures should be expected to result in 5-10% reduction in power generation, based on the European experience, but will help prolong the service lifetime of these plants, while allowing a somewhat reduced risk time to determine and implement long-term corrective measures in the safety and control systems.

- Establishment of an ad hoc group, including experts from outside NRC and its contractors, to study and report on this matter, in parallel and independently of any related NRC staff efforts, with emphasis on long-term recommendations for resolving the PTS issue. One option would be the restructuring and broadening of the representation in the ACRS Working Group on PTS, chaired by Mr. Myer Bender, to include members of the National Academy of Sciences group that Professor George Sih has been working to put together. Another option would be the formation of a group similar to the Lewis Committee that evaluated and reported on WASH-1400. I would highly recommend that prominent members of the international scientific community from countries with which we have agreements for cooperation be invited to participate, even on a part-time basis.

- Institution of a consolidated and augmented activity on plant dynamics and control at NRR and RES. An integrated approach in this area is very important and needed because of the interactive character of the control systems and processes involved. Relevant activities in various parts of NRR; i.e., A-47, Safety Implications of Control Systems, A-17, Systems Interactions, A-49, Pressurized Thermal Shock accident sequences, in the Division of Safety Technology, and selected activities in the Division of Systems Integration should be consolidated and augmented under a new activity of Plant Dynamics and Control. A similar consolidation of activities is needed in RES. In addition to the achievement of a well focused and coherent effort in this important area, a higher resource effectiveness should result from these consolidations.

Congressional and public interest and awareness on this and other matters of public health and safety and national security are increasing, and we all should do our part not only to encourage it, but to enhance it in the best traditions of this society.

I wish to close this written discussion as I closed my testimony before Senator Glenn who chaired a hearing on NRC's safety and licensing procedures on December 13, 1976: For those of us who care to see a healthy regulatory program and see the nuclear industry succeed in fulfilling its potential in providing a viable national energy source, it is important that we should realize that we will be answerable to our conscience and the generations of Americans to come for what we do today and why, and for what we do not do and why not.

Demetrios L. Basdekas

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Enclosures: As stated

cc: W. J. Dircks, EDO
R. B. Minogue, RES
H. R. Denton, NRR
OPE
OGC
OIA
OCA
OPA
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ENCLOSURE 1

DEMETRIOS L. BASDEKAS

PROFESSIONAL QUALIFICATIONS

INSTRUMENTATION AND CONTROL BRANCH
DIVISION OF FACILITY OPERATIONS
OFFICE OF NUCLEAR REGULATORY RESEARCH
U. S. NUCLEAR REGULATORY COMMISSION

I am a reactor safety engineer, GS-14, Instrumentation and Control Branch. My present duties consist of research project management on the safety implications of control systems and related plant dynamics along with activities related to standards development for the classification of systems important to safety. From December 1976 until April 1981 I was assigned to other Branches of the Office of Nuclear Regulatory Research.

My assigned duties consisted of program management in advanced reactor safety research involving reactor core disruptive accidents and radioactive aerosol generation and transport.

Since joining the AEC in April 1972 and before I was assigned to the Office of Nuclear Regulatory Research, I served as a reactor engineer, Electrical, Instrumentation and Control Systems Branch, Division of Systems Safety, Office of Nuclear Reactor Regulation. During that time I reviewed instrumentation, control and electrical systems of numerous light water nuclear power reactors as well as research reactors, conceptual designs and R&D aspects of advanced gas-cooled and liquid-metal-cooled fast breeder reactors.

My duties included the audit technical review of the design, fabrication and operation of nuclear power plant electrical power, reactor protection and safety-related instrumentation, control instrumentation and radiation monitoring systems; I reviewed these systems for adherence to appropriate codes and standards, and NRC criteria. The review encompassed evaluation of applicants' safety analysis reports, generic reports and other related information on the safety-related electrical, instrumentation and control systems design. Furthermore, I participated in the development of the bases for Regulatory acceptance criteria for electrical and instrumentation power systems designs; evaluated

experience obtained during the construction and operation of nuclear power plants and related this information to future evaluations and acceptance criteria; and participated in the development of Regulatory Guides and regulations pertaining to electrical, instrumentation and control systems.

In December 1976 I found it necessary to testify before Congress (U. S. Senate Committee on Government Operations) on the deficiencies of the nuclear reactor regulatory program, identifying a number of the precursor safety issues that led to the TMI accident and other near-accident events.

I hold Bachelor's and Master's degrees in Electrical Engineering from Texas A&M University with a minor in Nuclear Engineering. In addition, I have taken courses in physics and Nuclear Engineering and Fluid Mechanics at Texas A&M University, Massachusetts Institute of Technology, the Catholic University of America, Northwestern University, and Dartmouth College.

From June 1961 to January 1964, I was a graduate assistant and nuclear reactor operator at the Nuclear Science Center of Texas A&M University, where I was responsible for installation and maintenance of nuclear reactor instrumentation and control systems, and for the operation and environmental monitoring of a 100 kW research reactor.

From February 1964 to March 1968, I was a Research Engineer at Southwest Research Institute, San Antonio, Texas, worked on the development of methods for the nondestructive assay of nuclear fuels, radiological health and safety, and development of specialized instrumentation. My responsibilities in the field of radiological health and safety included the oversight for the safe condition of Research work throughout the Institute utilizing a variety of isotopes.

From March 1968 to June 1970, I was a Staff Member of the University of California, Los Alamos Scientific Laboratory performing analytical and experimental studies of the test reactors of the Rover nuclear rocket program.

From July 1970 to April 1972, I was a Senior Engineer with Westinghouse Astronuclear Laboratory and Advanced Reactors Division assigned to the NERVA nuclear rocket, and the Liquid Metal Fast Breeder Reactor (LMFBR) programs respectively.

I am a member of the American Association for the Advancement of Science, the Institute of Electrical and Electronics Engineers, and past member and chairman of the Critical Reviews Committee of the American Nuclear Society. I am a registered professional engineer in the State of Texas (1968), and listed in Leaders in American Science of Who Is Who in American Education (1968); I was granted an Atomic Energy Commission Nuclear Operator's License (1962). I hold Patent No. 3,436,538, the first one on neutron interrogation techniques for the nondestructive assay of nuclear fuels (1969), and I have a number of pending patent disclosures for liquid metal fast breeder reactor control systems.

ENCLOSURE 2

CHRONOLOGY OF SIGNIFICANT EVENTS AND DOCUMENTATION ON THE ISSUE OF THE SAFETY IMPLICATIONS OF CONTROL SYSTEMS INCLUDING PRESSURIZED THERMAL SHOCK IN PWRs

BY DEMETRIOS L. BASDEKAS

Nov. 10, 19 and Dec. 20, 1976	Memoranda from D. L. Basdekas to B. C. Rusche (See also NUREG-0138 and NUREG-0153, Issues No. 6 and 22, 23, respectively).
Dec. 13, 1976	Testimony of D. L. Basdekas to U.S. Senate, Committee on Government Operations chaired by Senator Glenn.
Feb. 14, 1979	Memorandum from D. L. Basdekas to the Commissioners on the treatment of unresolved safety issues.
May 25, 1979	Note from D. L. Basdekas to NRC Commissioners with comparative chronological listing dated back to December 20, 1976.
June 25, 1979	Memorandum from D. L. Basdekas to Mitchell Rogovin, Director, NRC/TMI Special Investigation Group, transmitting the same as above comparative chronological listing on this issue.
Sept. 4, 1979	Memorandum from D. L. Basdekas to Commissioner Ahearne discussing the issue and formulating recommendations for its resolution.
Sept. 10, 1979	Fortune magazine publishes an article entitled, "The Way to Save Nuclear Power" by R. A. Brightsen. Mr. Brightsen, commenting on my early expressions of concern on this issue writes: "Had the safety engineers' pleas been heeded in 1976, the accident might never have happened." (See next item.)
Oct. 31, 1979	Appendix 19 of the report of the President's Commission on the Accident at Three Mile Island concludes on page 3 -- "The TMI-2 accident would probably not have progressed beyond a severe feedwater transient, had the PORV been recognized and treated as a safety-related component."
Dec. 13, 1979	ACRS Subcommittee on Electrical Systems meets to discuss issue. Basdekas is invited and states his views including an emphasis on the Failure Mode and Effects Analyses.
Dec. 17, 1979	Briefing for Chairman Ahearne by Denton, Ross, Hanauer, and Basdekas. (Transcript available).

Dec. 20, 1979	Memorandum to Chairman Ahearne commenting further on the issue.
Feb. 7, 1980	Mr. Udall asks NRC for information on issue.
Feb. 27, 1980	Memorandum from D. L. Basdekas to T. E. Murley posing the Pressurized Thermal Shock issue.
Feb. 28, 1980	Memoranda from Murley to Basdekas and Tong/Shao initiating effort of special task force to address reactor vessel overcooling transients.
May 14, 1980	NRC responds to Mr. Udall's letter of Feb. 7, 1980.
May 23, 1980	Memorandum from D. L. Basdekas to Commissioner Bradford.
May 28, 1980	Letter from Basdekas to Mr. Udall commenting on the NRC response of May 14, 1980.
May 28, 1980	Memorandum from D. L. Basdekas to T. E. Murley commenting on work in progress at Brookhaven National Laboratory.
June 17, 1980	Mr. Udall raises questions on NRC's response to him of May 14, 1980.
July 24, 1980	Memorandum from T. E. Murley to L. S. Tong expressing concern on lack of progress, and poor shape of the agency to analyze transients in nuclear power plants.
Aug. 18, 1980	Letter from D. L. Basdekas to Mr. Udall commenting on the lack of effectiveness by the ACRS and recommending steps to enhance its effectiveness.
Sept. 12, 1980	Memorandum from D. L. Basdekas to David Okrent, ACRS, discussing a number of safety concerns including the safety implications of control systems and plant dynamics with specific reference to the Diablo Canyon and its seismicity related considerations.
Nov. 17, 1980	NRC responds to Mr. Udall's letter of June 17, 1980.
Nov. 26, 1980	Board Notification 80-15 transmitting Differing professional Opinion of Basdekas on this issue.
Dec. 4, 1980	Mr. Udall asks NRC for additional information and the consideration of the issue by the ACRS.
Jan. 29, 1981	Mr. Udall asks the NRC to give a progress report on the issue during the budget authorization hearing on February 24, 1981
Apr. 10, 1981	Letter from D. L. Basdekas to Mr. Udall elaborating on the current status of overcooling transients and recommending the interim shutdown of PWRs that have operated for 4 Full Power Years Equivalent (FPYE) or more, with high copper content in welds and vessel materials.

Apr. 23, 1981	Personnel Performance Appraisal for Basdekas states that "Because of his aggressive action in the past in filing differing opinions challenging NRR, he has not been able to establish good rapport with the I&C Branch in NRR."
Apr. 22, 1981	Memorandum to James R. Tourtellotte on the TMI-1 Restart ASLB Hearing.
June-July 1981	Research programs on the safety implications of control systems and associated electrical power systems are initiated at the Oak Ridge National Laboratory and Sandia National Laboratories.
Sept. 17, 1981	Meeting of D. L. Basdekas with Chairman Palladino to discuss twelve items concerning the safety implications of control systems and related aspects of the pressurized thermal shock of PWR pressure vessels.
Oct. 8, 1981	EDO Staff responds to Chairman Palladino on Basdekas' twelve items on pressurized thermal shock.
Oct. 14, 1981	Memorandum from D. L. Basdekas to Denwood Ross responding to his memo of October 9, 1981 on the filing of a Differing Professional Opinion on the issue of Pressurized Thermal Shock.
Beginning June 1981 to April 23, 1982	Numerous attempts to secure design information on control systems and related plant characteristics for Oconee-1, the first operating PWR chosen for review as well as other operating plants. The Licensing Staff had not asked for such information and the final disposition of such requests is not known.
February 9, 1982	Mr. Udall asks for additional information on Pressurized Thermal Shock and the significance of control systems in related accident sequences
March 29, 1982	Senator Glenn inquires on safety issues No. 22, 23 and 27, NUREG-0153 and NRC's response to Basdekas' Op-Ed article in the New York Times.
March 29, 1982 and later	Public Statements by D. L. Basdekas on PTS and Safety Implications of Control Systems.
April 6, 1982	The NRC responds to Mr. Udall's letter of February 9, 1982.

SAFETY CONCERNS EXPRESSED BY D. L. BASDEKAS, REACTOR SAFETY ENGINEER, U. S. NUCLEAR REGULATORY COMMISSION, ON NOVEMBER 10 & 19, 1976 AND DECEMBER 20, 1976, SAFETY ISSUE NO. 22, NUREG-0153

SAFETY IMPLICATIONS OF CONTROL SYSTEM FAILURES AND PLANT DYNAMICS *

"The effects of control system failures or, sometimes, non-faulted operation on safety are not being systematically reviewed. I believe that their effects on safety and plant availability should receive the proper attention. The first step would be to have the applicants perform a Failure Mode and Effects Analysis (FMEA) for normal operation, and in conjunction with postulated accidents and other off-normal events."

"In evaluating plant safety, the effects of control system malfunctions should be reviewed as initiating events for anticipated transients and also as failures that could occur concurrently or subsequent to postulated anticipated events (initiated by a different malfunction) or postulated accidents."

"... one has to consider that design features to mitigate the consequences of such events are not established, and therefore, those provided for postulated and analysed accidents may not be sufficient, thus, in essense, having an unprotected series of events."

On a related issue on reliability and risk assessment:

"... common mode failures and events that may result in such failures, along with human factors, are expected to contribute most significantly to the unavailability of the shutdown system. ..." (From Discussion of Issue No. 88, NUREG-0138)

* In countering Basdekas' arguments in December 1976 the NRC Regulatory Staff maintained:

"Although analyses have not been performed for these postulated sequences of events, the staff believes that the consequences would be acceptable, and much less severe than those calculated for postulated accidents."

In a Report to the Congress, NUREG-0438, April 12, 1978, The Office of Nuclear Regulatory Research of NRC, in justifying its position that no further research effort was needed on "Improved Plant Controls", reported:

"It is believed that only a small reduction in risk could result from improvements in plant controls ", and that "....the industry may explore this area voluntarily."

RECOMMENDATIONS BY THE NRC REGULATORY STAFF INCLUDING A COMMITMENT MADE BY BABCOCK AND WILCOX COMPANY, DESIGNER OF THREE MILE ISLAND (TMI) UNIT 2 NUCLEAR POWER PLANT SUBSEQUENT TO THE ACCIDENT AT TMI

On April 26, 1979, almost a month after the TMI accident The Babcock and Wilcox Company, designer of the TMI Nuclear Power Plant, made the following commitment to NRC by letter from J. H. MacMillan, Vice-President Nuclear Division to H. R. Denton, Director, Office of Nuclear Reactor Regulation, U.S.N.R.C.:

"Subject: Integrated Control System

This letter documents the commitment of Babcock and Wilcox to undertake a reliability analysis of the Integrated Control System (ICS) which will include a failure mode and effects analysis.* This analysis will identify sources of transients, if any, initiated by the ICS and develop recommended design improvements which may be necessary to reduce the frequency of these transients.

In addition, means will be developed for decoupling of the auxiliary feedwater control of steam generator water level from the ICS. This modification will provide control of feedwater under emergency conditions independent of the ICS.

The scope of the reliability analysis and schedule for both the analysis and development of independent feedwater control will be provided within 48 hours."

On May 16, 1979 the NRC Regulatory Staff issued report NUREG-0560 entitled Staff Report on the Generic Assessment of Feedwater Transients in Pressurized Water Reactors Designed by The Babcock and Wilcox Company."

The report recommends that:

"All classes of operating plants should be reanalyzed using failure mode and effects analysis to identify realistic plant interactions resulting from failures in non-safety systems, safety systems and operator actions during transients and accidents."

"The role of control systems in all plants, and their significance to safety, should be reevaluated by NRC and the vendors. The evaluations should be performed by the industry with guidelines developed by the NRC. Consideration should be given to establishing criteria regarding the rate at which transients challenge the plant safety systems. Such transients should include (a) those initiated by control failure plus (b) those initiated outside the control system that are not successfully mitigated by the control system."

* Report BAW-1564 was submitted to NRC on August 17, 1979.

ENCLOSURE 3