No. S-9-92 FOR IMMEDIATE RELEASE
Tel. 301-504-2240

PUBLIC UNDERSTANDING OF RISK MANAGEMENT OF NUCLEAR PLANT AGING

PRESENTED BY
COMMISSIONER KENNETH C. ROGERS
U. S. NUCLEAR REGULATORY COMMISSION
AT THE
AGING RESEARCH INFORMATION CONFERENCE
ROCKVILLE, MARYLAND
MARCH 25, 1992

Good morning, ladies and gentlemen. I am delighted to join you today to participate in this conference on the timely and important topic of nuclear plant aging research. Aging research provides the technical bases for continued safe plant operation during the initial license period and guides management practices to assure license renewal. I have had the privilege of speaking to other groups on this subject over the past few years. Aging, its recognition and mitigation, remains a key consideration in maintaining safe operation of nuclear reactors. I have previously stated that I regard aging of nuclear power plants as one of the most important world-wide issues facing the nuclear industry and its regulatory agencies. I continue to hold that view, although I have seen considerable progress in raising the industry's awareness of aging issues and work toward their resolutions.

You have had a full day yesterday on the role of aging effects on risk assessment and aging management. Today's and tomorrow's sessions will focus on the nitty-gritty of managing the aging of: reactor coolant pressure boundary components including the reactor vessel, plant systems, and plant electrical and mechanical components. By the end of tomorrow's sessions, I believe that you will agree that aging research is very broad, the problems are challenging, and successful closure will require the coordinated efforts of the regulator and regulated communities alike. We have a common stake in this endeavor.

U S. Electrical Demand

Forecasters are projecting a U.S. need for as much as 150 to 200 Gigawatts electric (GWe) of additional generating capacity later in this decade, and utility interest in preserving the option for continued operation of existing nuclear plants is increasing. As a practical matter, retirement of any nuclear plant will require construction of new sources for generating electric capacity. Industry estimates of costs to replace current installed nuclear capacity range from $200 to $300 billion.

Department of Energy (DOE) and Electric Power Research Institute (EPRI) studies have concluded that license renewal of existing plants offers a significant benefit -- a ratio of approximately 4:1 -- resulting primarily from lower fuel costs and postponement of the capital expense of replacement capacity. Under high economic growth assumptions, DOE believes that 70 percent of the current 112 licensed plants, or approximately 78 plants, will be life-extended for 20 years from the year 2006 through the year 2010, that a new second generation of reactors totaling 6 Gwe will begin operation, and that 4 units totaling 2.4 Gwe will be retired from the year 1992 to the year 2010. License renewal of the 78 existing plants constitutes a strategy to preserve approximately 20% of total current U.S. electrical capacity and contribute approximately 11 Trillion KWhr of electrical energy over the years 2000 to 2030, thus preserving the Nation's electrical capacity.

As many of you are aware, U.S. nuclear plants are on average older than non-U.S. nuclear plants. More than two-thirds of U.S. nuclear plants are over ten years of age; in most other countries, two-thirds of installed nuclear capacity is less than ten years of age. A few countries, however, have operated nuclear plants successfully for over thirty years. In the U.K., for example, the earliest of the Magnox-fueled reactors has been operating for thirty-five years while the oldest of their second generation advanced gas-cooled reactors (AGRs) has been operating for approximately fifteen years. So the U.S. is not alone with aging reactor plants and the concept of life extension. Nuclear plant life extension has been practiced routinely in the U.K. for more than ten years.

<u>Aging Related Degradation Processes</u>

The age-related degradation processes with which this symposium is concerned are believed reasonably well understood in a general sense. Research to date indicates that some of the more significant aging issues include: (1) neutron irradiation embrittlement, (2) fatigue, (3) stress corrosion cracking, (4) thermal aging embrittlement, (5) erosion-corrosion, and (6) intergranular stress corrosion cracking. The most recent studies have not identified any new degradation mechanisms that were not previously known. Current industry and independent NRC research have, however, served to sharpen our knowledge about different manifestations of these mechanisms and where they are operative, and have helped to rank them by their safety significance. More importantly, research has led to improved methods of managing aging.

The message I wish to impart is that U.S. industry, the international nuclear community, and the NRC all agree that applied engineering research on LWR aging issues continues to be necessary. We must improve our common understanding of age-related degradation phenomena and compile a knowledge base that permits development of appropriate ways of dealing with age-related problems, as they arise in operating plants and in new advanced plants as they are designed and developed.

Several examples might help put these comments in perspective. As you know, the steam generator tubes of pressurized water reactors (PWRs) constitute a significant portion of the primary system pressure boundary surface area. Steam generator tubes at many domestic and foreign PWRs are experiencing wide-spread intergranular stress corrosion cracking (IGSCC). These IGSCC problems have necessitated extensive plugging and sleeving repairs of the tubing and, at many units, can be expected to lead to replacement of the steam generators prior to the 40-year design life. In this morning's session, Dr. Muscara of the Office of Nuclear Regulatory Research and Mr. Kurtz of Pacific Northwest Laboratory will discuss improved inservice inspection for management of steam generator tubing.

One session tomorrow will be devoted to radiation embrittlement of reactor pressure vessels, an age-related degradation of increasing concern to the agency. The LWR reactor vessel regions most affected by exposure to neutron irradiation are at the beltline, especially the axial and circumferential welds required in the fabrication of these multiple shell course vessels. Embrittlement is manifested in loss of fracture toughness, as measured in an upward shift in the nil-ductility transition (NDT) temperature and a reduction in upper shelf energy. This age-related degradation phenomenon poses three principal concerns:

- Potential reactor vessel crack initiation or propagation as a result of high stresses on the inside surface of the vessel upon a rapid cooldown of the reactor coolant system while still at high system pressure -- the Pressurized Thermal Shock (PTS) transient;

- Potential insufficient structural integrity of the reactor vessel at normal temperatures and pressures due to low upper shelf toughness; and

- o Potential operational restrictions on allowable pressure-temperature limits during normal startup and cooldown sequences which would effect operational capabilities.

While each of these concerns had been previously addressed by regulations and operating procedures developed throughout the 1980s, additional data have been acquired since the development of the screening criteria of the PTS rule (10 CFR Part 50.61). It is likely that revisions to existing criteria will result from on-going research in neutron radiation embrittlement, including reevaluation of potential excessive embrittlement in the upper shell (nozzle) course of PWR vessels at nozzle-to-vessel welds. Development of an extensive Power Reactor Embrittlement Database (PR-EDB) by the Oak Ridge National Laboratory under the NRC's Plant Aging Research program, the topic of a paper in this afternoon's session, should enable the necessary technical information to be available by the time it is needed. Other major technical issues which require additional research, such as fatigue, stress corrosion cracking, thermal aging embrittlement, and environmentally assisted corrosion, are recognized by the industry and the agency, and some are topics of discussion at this conference. While there is general agreement on the broad generic age-related degradation issues or questions, the answers will only come from on-going applied research on age-related phenomena.

I recognize that the international community already is actively exchanging information on age-related degradation, but I believe that even more sharing could be accomplished. I am aware, for example, that the Harwell Research Laboratory of U.K.'s AEA Technology has developed new nondestructive examination techniques for reactor vessels. New reactor vessel sample preparation techniques, combined with improvements in modern microscopy, have permitted quantitative analysis of impurities in reactor vessel plate and weld materials by field ion microscopy (FIM) with a transmission electron microscope/scanning transmission electron microscope (TEM/STEM). The Harwell technique permits mass spectroscopy of atoms extracted from FIM needle tips which image the matrix and precipitates of the specimen material. Analysis of the spectra in turn permits quantitative determination of the degree of embrittlement of the vessel specimen. The two privatized utilities in the U.K. have hopes of extending the service life of their Magnox plants to 40 years or possibly longer through use of such advanced NDE techniques and research facilities.

License Renewal Requirements

I now wish to discuss the nexus between aging research and license renewal requirements. The requirements governing operating license extension under the provisions of Part 54 are based upon two principles:

- First, the regulatory process is adequate to ensure that the licensing bases of all currently operating plants provide and maintain an acceptable level of safety during the current period of operation.

- Second, each plant's current licensing basis must be maintained during the renewal term, in part through a program for management of age-related degradation in systems, structures, and components that are important to license renewal as defined in the rule.

Development and implementation of a systematic program for management of age-related degradation of systems, structures, and components important to license renewal requires maintaining the current licensing basis. The NRC's NPAR program is intended to develop an independent body of data on aging mechanisms to complement industry findings from NUMARC's nuclear plant life extension (NUPLEX) program.

I wish to stress to those of you who may not be familiar in detail with the provisions of 10 CFR 54, the new license renewal rule, that the process of license renewal is to be a <u>public</u> process. The rule provides an opportunity for members of the public to raise questions as to whether age-related degradation mechanisms, at least those unique to license renewal, have been adequately addressed by the licensee and the agency. Moreover, license renewal will not be limited strictly to plant technical safety issues; it will also address environmental issues. Public concerns may be litigated in a formal adjudicatory hearing before an Atomic Safety and Licensing Board (ASLB). Moreover, the public may petition the Commission to consider issues other than age-related degradation, which are unique to license renewal (as was done in the case of the Yankee Rowe pressure vessel integrity in July 1991). Under the rule, the Commission must determine the best means to address the concerns raised by such petitions, with public hearings as one option.

There are several things I believe that might be done to improve or expedite the acquisition of the remaining age-related degradation information needed to assure the workability of the new license renewal rule.

<u>First</u>, I believe that licensees should attempt to improve the quality and timeliness of documenting significant plant events under both the industry's Nuclear Plant Reliability Data System (NPRDS) and the agency's License Event Report (LER) system to improve root cause analyses involving age-related phenomena. Until an age-related event is "captured" by the system, the event

is unavailable to the technical community for interpretative or statistical analysis. It is very important that all failures or indications of degradation of plant systems, structures, and components (SSCs) be thorough, timely, and appropriately documented in order that the event be subject to discovery and analysis by others through LER and NPRDS search techniques for trending and comparison with other possibly similar events. As the inventory of nuclear power plants gets older and certain systems and components approach limits for operation, the need for good records that establish equipment history will increase. Such records are being incorporated into the data bases which a number of U.S. utilities are developing.

Second, further consideration should be given to development of a collaborative government-industry research program of examination and analysis of structures, components, and systems of interest from licensed facilities that have been retired from service and are to be decommissioned and dismantled, such as Shoreham, Fort St. Vrain, Rancho Seco, possibly San Onofre Unit 1, and now Yankee Rowe. Information from these plants, if a comprehensive inspection and research program were established, could increase the available storehouse of knowledge of age-related degradation of operating LWRs and HTGRs for current operating plants and future advanced designs. The program I have in mind would identify "information gaps" of aging phenomena and target specific SSCs for examination in plants to be decommissioned with sufficient lead time that appropriate industry and federal programs and funding could be arranged. The planned detailed examination of the Yankee Rowe pressure vessel is one such example.

Third, I believe that the international nuclear community has much to gain from sharing its collective experience and information from the decommissioning and dismantlement of its early vintage commercial plants, as has been demonstrated from the Department of Energy's Shippingport Decommissioning and Dismantlement Program. The Shippingport program included the development of a structured data base for documenting the decommissioning and dismantlement "lessons learned" on a system by system basis. A number of power plants are being decommissioned in other countries, and this experience should also be captured for future assessment of age-related degradation effects. Dr. Richard Allen, of Battelle's Pacific Northwest Laboratory, will discuss the Shippingport Station aging management lessons learned tomorrow.

Particularly useful could be the experience and data to be acquired by the Commonwealth of Independent States (CIS) in the decommissioning and dismantlement of early VVER 440 LWR plants. Russian experience in assessing the degree of pressure vessel embrittlement, as well as the other areas of degradation previously cited, would be especially of interest to Western countries. I am pleased to note that scientists and technical experts from the Commonwealth of Independent States are present in the audience. Next week, they will be participating in the joint US-CIS Working Group 12 Meeting on Nuclear Power Plant Aging and Life Extension.

Fourth, further improvements in existing diagnostic and nondestructive examination (NDE) techniques are needed in situ to assess the true material state of pressure retaining SSCs of LWR plants. I am impressed by advances being made in signal conditioning and computational processing of data acquired by these techniques, especially with multifrequency eddy current test (ECT) magnetic field detection and multi-beam V path ultrasonic test (UT) wave detection techniques. These data can now be displayed in a computerized three dimensional representation of the component being examined, with companion software which permits the ASME Level 3 NDE inspector to investigate various "portions" of the color-coded flaw indication for further detailed electronic "visual" examination and qualification on the workstation console.

Further technological breakthroughs in NDE techniques might involve the application of other known scientific phenomena, such as the "Barkhausen Effect", to measure changes in the crystalline lattice of materials which are exposed to stressors as has been done at Southwest Research Institute. I urge you to consider the possibility of further applications of basic solid state phenomena as indicators of changes in the material state of components exposed to the stressors I have discussed. In this connection, more attention should be given to the potential for embedding miniature sensors in components which can signal incipient failure. This technology is in an advanced stage of development in the U.S. as a result of defense-related expenditure and development; we should scrutinize this technology for possible applications to reactor SSC age-related degradation and advanced designs.

Fifth, I am concerned that the important role of human factors and licensee organizational factors in managing plant aging may not have been sufficiently considered in age-related research to date. There is a greater tendency to consider human factors in advanced plant design certification reviews than in existing plants. In new, advanced plant designs, based on human capabilities and limitations, greater opportunity exists to incorporate human factors in hardware and software. Notwithstanding this fact, license renewals will inevitably entail enhanced requirements for inspection, surveillance, testing, and maintenance of critical SSCs; the demands on station personnel and the licensee's organization will increase, at least for those plants whose licenses are extended first. Training, procedural compliance, maintenance control, and increased standards for documentation will assume even greater importance for life-extended plants. I believe we need to give greater attention to the limitations of the human operator under these situations.

Sixth, I think we need to step back and reexamine afresh as a part of age-related research the underlying philosophical issues which govern a decision to replace a structure, system, or component important to safety, versus the decision to repair or refurbish such SSCs. I believe we need a more rational "decision logic" for this purpose -- a matrix -- one which captures the essential decision criteria in some form of philosophical "construct", including safety, economics, public acceptance or approbation, and possibly others such as effectiveness of ongoing programs.

What might be the key vectors of such a matrix? Obviously, one might be the increased marginal safety offered by replacement of the degraded SSC versus that of repair or refurbishment of the degraded SSC. An analysis of the relative safety of a component replacement -- or "buy" -- option, versus a refurbishment -- or "repair" -- option, would require knowledge of the prospective failure rate distribution of the component; i.e., whether the failure could be attributed to early "infant mortality" or to late in design life "wearout". One quantitative measure useful to the analysis would be the safety significance of the component in terms of an objective measure such as core melt probability. We have the only useful tool for such determinations -- probabilistic risk analysis (PRA).

Out of the tens of thousands of SSCs in a modern LWR plant, perhaps 100 to 1,000 are truly significant to safety in terms of the effect of their failure on the core melt frequency. Provided one has a current Level 1 PRA, existing software can perform comparative evaluations of individual SSC failures on overall core melt probability easily and quickly. Inclusive off-site safety consequences could be evaluated if the utility had a Level 3 PRA, but for my illustrative "philosophical construct", I will stick to a Level 1 PRA which licensees either have or are presently developing under the IPE program. In short, a methodology exists for establishing the SSC safety significance vector.

There still remains the task of establishing the incremental or marginal additional safety offered by the "replace" versus the "repair" option. Here, the generic failure rate distributions would be required for both the new and the repaired SSC; alternatively, a judgment must be made. We make intuitive judgments every time we decide not to replace the fan belts or hoses on our cars after 30,000 miles. That is not to say that the correct decision is always made; fan belts usually begin to break after 30,000 miles! In our case, these considerations could be complicated by such additional issues as the potential for common mode failures -- the so-called Beta factor -- which could introduce a "multiplier effect" on the consequences of the failure with which we are concerned. A fan belt failure, for example, can easily result in other equipment failing. Experience has shown that aging has the potential to cause multiple component failures.

Another consideration in our decision logic is obviously the economic vector. Here one might wish to use life-cycle costs of a new versus a refurbished SSC including the costs of component repair or replacement, related construction and erection costs for each, and other outage costs such as replacement power. The life cycle cost analysis would also appropriately distinguish between all embedded costs of the "buy" versus "repair" options, including that for training, facilities, and on-site maintenance organizational structures. Such analyses are a normal utility management function and present no unique impediments to the development of our decision logic model.

Finally, I would suggest as a third vector in our decision logic some appropriate measure of "public acceptance" or public approbation of the "buy" versus "repair" options. How, you ask, could something as intangible as public acceptance or "public comfortableness" be measured? An established industry has arisen over the past two decades in this country which determines consumer satisfaction with commercial products in terms of quantitative measures -- levels of public acceptance or comfortableness -- by another name. The process is simple, one simply asks the consumer! Commercial polling organizations offer such services to public advocacy groups now, including anti-nuclear public advocacy groups. In principle, I see no reason why existing techniques for measuring public reaction or approbation could not be adapted to the proposed repair of a major plant component significant to safety versus replacement of that component.

So what might my decision logic structure look like? It might look something like this (Slide 1). We have a three, orthogonal vector geometrical representation of salient factors in our "buy" versus "repair" decision logic. Here I have labeled the x-axis as my "Safety Significance" vector, shown here in terms of the relative Increase in Core Melt Probability. The y-axis is labeled as my "Economics" vector, shown here as Increase in Investment Cost in dollars per kilowatt of electrical energy ($/KWe). Finally, my "Public Acceptance" vector is displayed on the z-axis in units of "Increase in Public Discomfort" or "PD" units over the life of the plant. There is a presumed nexus between "Public Acceptance" and "Safety Significance". If industry is to achieve the ambitious goals set for it by the Administration's National Energy Strategy, it needs the support of the public.

How, you ask, could such a "philosophical construct" possibly be of help or use? Well, first, the datum points for both "buy" and "repair" options would have to be determined to establish a datum point in three dimensional solution space. Various "buy" and "repair" alternatives exist, each of which would "map" a different solution surface -- one for "buy" options and one for "repair" options. Both options would strictly meet regulatory criteria, but in one case greater plant investment might be entailed, greater safety significance might result, and greater public acceptance might be achieved.

You might want to give further thought to the philosophical issues involved and develop a "construct" of your own on "buy" versus "repair" strategic issues as they apply to age-related degradation, especially those involved in license renewal issues.

<u>Augmentation of Aging Awareness</u>

Essential to the solution of aging problems is a broadly-based awareness of aging phenomena and their potential impacts on plant safety. This awareness needs to exist on the licensee side, including managers and engineering and maintenance staff. Awareness also is essential on the regulatory side at all levels.

Awareness includes management commitment to provide needed funding for efforts to detect and mitigate age-related degradation. It includes effective training of engineering and maintenance staff to assure that the day-to-day work is conducted to address aging. It includes vigilance in looking for any new phenomena that may be the precursors of age-related failures.

On the regulatory side, awareness again means sustained commitment of staff and resources to efforts needed to identify and resolve aging issues and to maintain independent expertise among NRC staff, (one of our five Principles of Good Regulation, the very first one - Independent) as alluded to by Chairman Selin yesterday. Awareness means having the technical insights to: conduct case studies, review license renewal requests, and to update the regulations to reflect the improved understanding of age-related degradation. Awareness also means knowledgeable alertness of the NRC Inspector staff for shortcomings in compliance relating to aging management and to new phenomena.

Chairman Selin cited the international efforts that are underway to raise awareness of aging and its impacts on safety. I want to reinforce his recognition of the importance of those efforts and to endorse his recommendation that those efforts be sustained and augmented.

Summary

Let me review the main points I have made. First, a significant base of operational experience exists which provides confidence that age-related degradation can be successfully managed through monitoring, testing, inspection, repairing/refurbishing or replacing degraded SSCs.

Second, the problem with which we are confronted I believe is one involving quantification. What are to be the quantitative measures for the "three R's" (repair, refurbishment, replacement), and what form of analysis should establish the "trigger values" for reporting and/or plant shutdown for one of the three R's? Each licensee must get on with the task of reconstruction of its plant operational history with specific reference to safety significant SSCs, in order to meet the requirements of the license renewal rule, if renewal is to be a viable option for them.

Third, while the experience base is favorable, the need exists for continued strong engineering efforts by both industry and the NRC on age-related degradation. To be successful in making the transition from the license renewal concept embodied in Part 54 into a workable procedure, answers to their questions must be available to a skeptical public since license renewal is to be a public process.

Fourth, discovery and development of new, innovative diagnostic principles and monitoring techniques will help and may be needed as we encounter possibly unknown new age-related degradation mechanisms. Perhaps this is the time to sound a clarion call to educational institutions and research institutes for assistance in the development of diagnostic and inspection techniques. We should investigate known physical phenomena for their potential for new NDE applications. We should also redouble our efforts to search for and adapt NDE techniques established in related industries which may have relevance to aging phenomena in the nuclear industry.

Fifth, we should not forget the role of the human in detecting and correcting age-related degradation of SSCs. It is the plant systems engineers and maintenance technicians on whom the long-term reliability of SSCs will depend, and possibly the health of nuclear energy in this country as well. We must think carefully about their training, their environment, and their human limitations in assuring detection and correction of age-related degradation.

<u>Sixth</u>, I urge you to examine the underlying arguments governing the "repair" versus "buy" options of age-related SSCs in the context of plant life extension. The non-congruent consequences of public safety, economics, and public approbation have to be reconciled.

Finally, I am pleased that the NRC has taken a sustained and systematic approach to develop an understanding of age-related degradation and its impacts. I also commend those throughout the agency who have participated in efforts to utilize the results of the research programs and make them widely available within the NRC, the U.S. industry, and internationally.

I wish you a successful and rewarding experience in the remaining days of this conference.