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

APR 21 1992

MEMORANDUM FOR: Thomas E. Murley, Director
Office of Nuclear Reactor Regulation

FROM: Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

SUBJECT: TRANSMITTAL OF RESEARCH INFORMATION LETTER 170:
RISK EVALUATIONS OF AGING

The enclosure contains the subject Research Information Letter describing a methodology that has been developed for evaluating the risk impacts of aging. The methodology includes the capability to identify and prioritize those structures, systems, and components (SSCs) in the PRA which are susceptible to age-related degradation and have the most impact on plant risk. The aging-PRA methodology which was developed allows the use of current PRAs and the use of linear and nonlinear aging models for the SSCs. The effectiveness of maintenance and surveillance programs can be evaluated in controlling aging effects on risk. Thus, resources can be focused on maintaining those SSCs most important to risk. We believe that this methodology addresses the NRR needs identified in the memorandum dated April 9, 1987, contained in Attachment A to the enclosure.

The above work was performed as part of the Nuclear Plant Aging Research (NPAR) Program and is documented in NUREG/CR-5510, "Evaluations of Core Melt Frequency Effects Due to Component Aging and Maintenance," June 1990. The methodology has been reviewed by PRA experts inside and outside the NRC. It has also been presented on numerous occasions in meetings, conferences, and symposia in the USA and abroad. It has been published in a peer-reviewed journal. The methodology was also used in the regulatory analysis supporting the license renewal rule. Dr. William Vesely of the Science Applications International Corporation (SAIC) was the principal investigator for this work.

The aging-PRA methodology offers a potentially important tool to aid in managing aging of nuclear power plants. The methodology also provides a potentially important linkage for the component level aging and maintenance effectiveness evaluations with the overall plant level risk evaluations.

Although milestones have been achieved with the development of the aging-PRA methodology, additional work remains to be completed. The areas where additional work is most important are developing data bases for age dependent component failure rates, and evaluating the methodology for specific applications to determine the scope and limitations for given problems. DE (RES) is currently funding a project to evaluate modeling and data sensitivities and uncertainties. However, further work needs to be done to evaluate potential uses of the methodology in a regulatory framework.

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We have been instructed by Mr. Sniezek to arrange a meeting with NRR management to accomplish the work necessary for further applications and utilizations of the results. This additional work will likely require the combined resources of DE and DSIR in RES. We are willing to recommend a list of technical tasks required to accomplish this work upon your request.

Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

Enclosure: As stated

RESEARCH INFORMATION LETTER : RISK EVALUATIONS OF AGING

I. Statement of the Regulatory Issue

The basic regulatory issue is the importance of knowing the risk impacts of aging and the prioritization of aging contributors to focus regulatory actions. Attachment A contains the two user requests identifying the need to develop a methodology to evaluate the risk impacts of aging and to apply the methodology to support the license renewal rule. As quoted from the NRR user need letter of April 9, 1987 in Attachment A:

"For aging-related research to be of maximum benefit to NRR, we must know not only the effects of aging on structures, systems, and components, but also the risk significance to public health... Knowledge of potential risk reductions due to various corrective actions, such as maintenance and replacement, would be extremely useful in assisting us to determine proposed regulatory actions."

II. Statement of Conclusions

As a part of the Nuclear Plant Aging Research (NPAR) Program, a methodology has been developed to quantify and prioritize the risk effects of aging from components, systems, and structures. The methodology allows any present probabilistic risk assessment (PRA) to be used and allows any aging models to be used. Risk results can be evaluated for the effects of aging. As an important part of the evaluations, the effectiveness of maintenance and surveillance programs in controlling risks from aging is quantified. All the aging contributors are furthermore identified and are prioritized. The methodology is efficient in that current PRAs do not have to be redone but instead appropriate information is extracted from the PRA and is combined with aging models.

The methodology has been peer reviewed by various individuals and research review groups. A NUREG/CR and a refereed journal article has been published on the methodology (References (1) and (2) in Attachment B). The methodology was applied to support the regulatory analysis for the rule on nuclear plant license renewal (Reference (3) in Attachment B). The methodology and its applications have also been presented at the last three Water Reactor Safety Meetings and NPAR Research Review Group Meetings. Recently on August 22, 1991, insights gained from applications of the methodology were presented to the inspectors and staff of Region V at the invitation of the Region.

III. Statement of Regulatory Application

The most effective application of the methodology is to prioritize aging contributors to risk using a specific PRA. As an illustration of a prioritization application, Table 1 shows the ten top ranked individual aging component contributors to the core damage frequency (CDF) and Table 2 shows the ten top ranked double component aging interactions which are caused by multiple components simultaneously aging. The first column in Table 1 is the component rank and the second column is the PRA component identifier. The third column is the CDF sensitivity (I) of the component determined from the PRA. The CDF sensitivity is basically the derivative of the CDF with regard to the component unavailability. As a reference, the fourth column is the original component unavailability (q) as calculated in the PRA. The fifth column is the increase in component unavailability (Δq) due to aging assuming the same test schedules as in the PRA. The last column is the CDF increase due to aging (ΔC) which is the product of the CDF sensitivity factor (I) and the aging factor (Δq). The CDF increase is the average increase, averaged over the life of the plant (40 years). Table 2 shows similar aging effects, but now applied to double component contributors. The CDF increase is now the product of the joint sensitivity and the unavailability increases for the two components. Attachment C defines the component identifiers used in the tables. Reference (1) in Attachment B gives additional details on the prioritization calculations. As observed from the tables, usually relatively few contributors dominate, allowing effective prioritizations for aging management of components to be carried out.

The methodology can also be used to evaluate the effectiveness of different maintenance programs in controlling risks due to aging. Figure 1 shows an application evaluating different test and maintenance programs for a PWR and BWR with aging of the components modeled. The evaluations are not meant to reflect actual plant practices but are intended to demonstrate the capabilities of the methodology. The Base Program in Figure 1 assumes the same testing schedules as given in the standard PRA with replacements of failures carried out. The Risk-Focused Programs involve carrying out additional scheduled replacements and surveillance tests on the relatively few risk important aging contributors obtained from the risk prioritizations. The plants were near their midlife in age. For the aging evaluations, all the active components in the PRA were assumed to be aging with generic aging failure rates. Attachment D provides further information on the Base Programs and Risk-Focused Programs. Reference (3)

TABLE 1. DOMINANT SINGLE COMPONENT AGING CONTRIBUTORS FOR A SPECIFIC BWR (ACTIVE COMPONENTS ONLY)

Rank	Component ID	CDF Sensitivity I	Component Unavailability q	Aging Factor Δq	ΔC (/yr)
1	ESW-AOV-CC-CCF	9.70E-05	1.0E-03	2.9E-01	2.8E-05
2	EHV-AOV-CC-CCF	6.34E-05	1.0E-03	2.9E-01	1.8E-05
3	ESW-AOV-CC-0241B	3.68E-05	1.0E-03	2.9E-01	1.1E-05
4	ESW-AOV-CC-0241C	3.68E-05	1.0E-03	2.9E-01	1.1E-05
5	EHV-SRV-CC-RV2	2.53E-05	3.0E-04	2.9E-01	7.0E-06
6	EHV-SRV-CC-RV3	2.53E-05	3.0E-04	2.9E-01	7.0E-06
7	DCP-BAT-LF-CCF	2.16E-04	1.08E-03	1.9E-02	4.1E-06
8	HCI-MOV-CC-MV14	5.42E-06	3.0E-03	2.6E-01	1.4E-06
9	HCI-MOV-CC-MV19	5.42E-06	3.0E-03	2.6E-01	1.4E-06
10	ACP-DGN-FR-EDGC	2.09E-05	1.6E-02	3.3E-02	7.0E-07

ΔC = Core damage frequency increase due to aging

TABLE 2. DOMINANT DOUBLE COMPONENT AGING INTERACTIONS FOR A SPECIFIC BWR (ACTIVE COMPONENTS ONLY)

Rank	Component ID	Component ID	Joint CDF Sensitivity I	Aging Factor Δq1	Aging Factor Δq2	ΔC (/yr)
1	ESW-AOV-CC-0241B	ESW-AOV-CC-0241C	1.34E-03	2.9E-01	2.9E-01	1.1E-04
2	ACP-DGN-LP-EDGB	ESW-AOV-CC-0241C	8.50E-04	3.3E-02	2.9E-01	8.1E-06
3	ACP-DGN-LP-EDGC	ESW-AOV-CC-0241B	8.50E-04	3.3E-02	2.9E-01	8.1E-06
4	ACP-DGN-LP-EDGC	EHV-SRV-CC-RV2	7.69E-04	3.3E-02	2.9E-01	7.1E-06
5	ACP-DGN-LP-EDGB	EHV-SRV-CC-RV3	7.69E-04	3.3E-02	2.9E-01	7.1E-06
6	ACP-DGN-FR-EDGC	ESW-AOV-CC-0241B	4.79E-04	3.3E-02	2.9E-01	4.6E-06
7	ACP-DGN-FR-EDGB	ESW-AOV-CC-0241C	4.79E-04	3.3E-02	2.9E-01	4.6E-06
8	ACP-DGN-FR-EDGC	EHV-SRV-CC-RV2	4.40E-04	3.3E-02	2.9E-01	4.1E-06
9	ACP-DGN-FR-EDGB	EHV-SRV-CC-RV3S	4.40E-04	3.3E-02	2.9E-01	4.1E-06
10	ACP-DGN-FR-EDGB	ACP-DGN-FR-EDGC	5.34E-04	3.3E-02	3.3E-02	5.9E-07

ΔC = Core damage frequency increase due to aging

FIGURE 1. AVERAGE CORE DAMAGE FREQUENCY INCREASE ΔC DUE TO AGING VS. TEST AND MAINTENANCE PROGRAMS

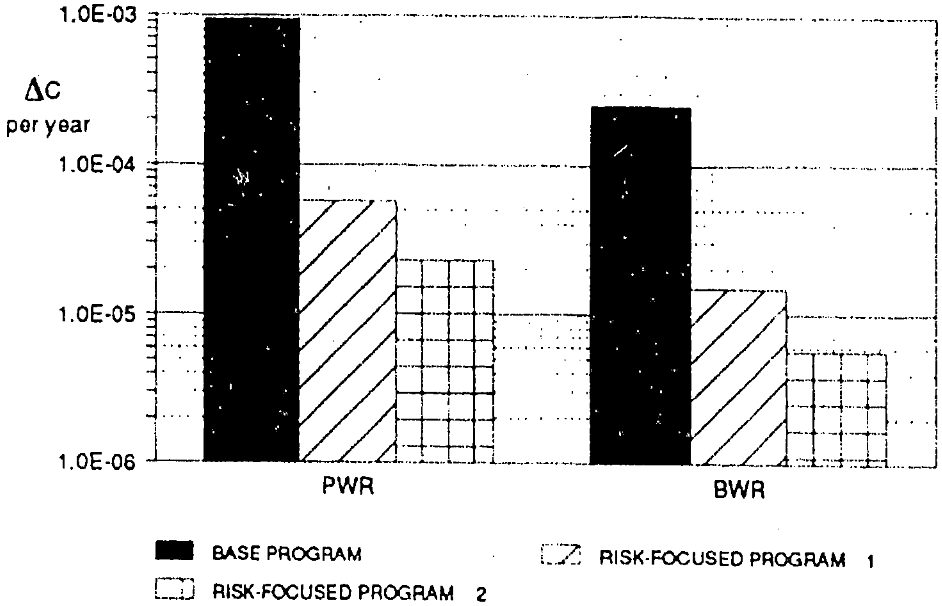
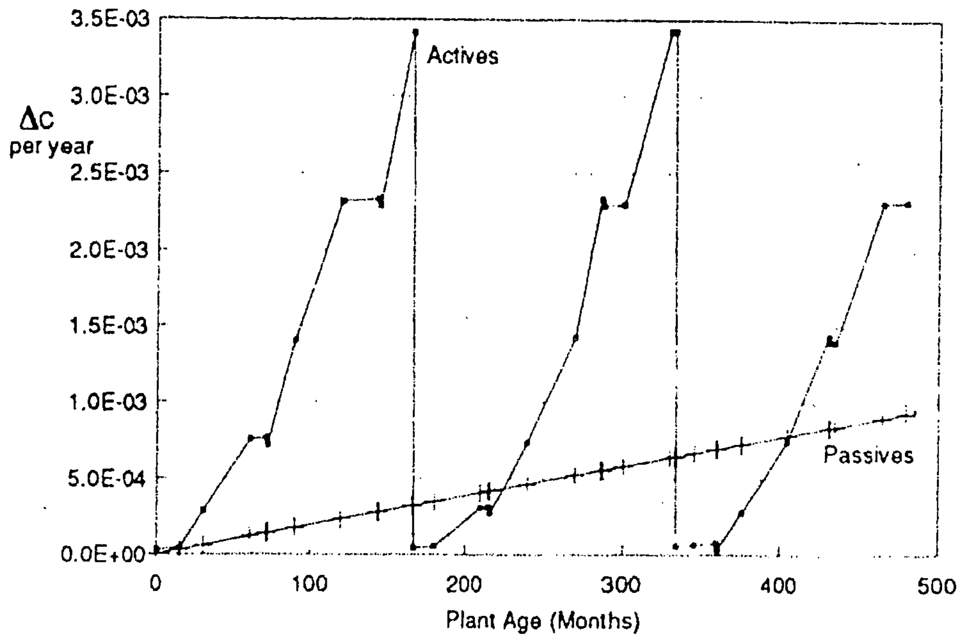


FIGURE 2. TIME DEPENDENT INCREASE ΔC IN CORE DAMAGE FREQUENCY FOR THE BASE PROGRAM FOR THE PWR



gives further details on the aging calculations. The methodology can furthermore be used to track the time dependent effects of aging as illustrated in Figure 2. Figure 2 shows a time trend plot of the increase in CDF due to aging for the Base Program for the PWR. The periodic nature of the aging effects from active components occurs because of periodic replacements being carried out. The large spikes indicate the replacements are not being carried out frequently enough. The dominant passive contributors include steam generator tubes, cables and connectors, and small safety piping. Linear aging failure rates were used to model the aging behavior of the active and passive components. Reference (3) provides further details on the evaluations.

IV. Statement of Restrictions on Application

Application of the methodology requires age dependent component failure rates for the active or passive components to be evaluated for their aging effects. An expert-generated aging rate data base exists which was produced in 1988 for relative research prioritizations (Reference (4) in Attachment B). However, this data base has large uncertainties. Some plant specific data has been analyzed and particular component aging rates have been estimated, however these are very limited (Reference (5) in Attachment B). Because of the limited data, sensitivity and uncertainty analyses are required as a part of any application. The most meaningful applications are those which focus on the relative prioritizations and which focus on results which are not sensitive to variations in the aging data.

V. Unresolved Questions/Further Work

The question of the specific roles of risk analysis of aging in regulatory applications still needs to be resolved. Validation of specific procedures for applications of the methodology also still needs to be carried out. A draft NUREG/CR reporting on validation of selected procedures is planned for FY 1993, to help address this issue. A second NUREG/CR is also being prepared which describes procedures for applying the methodology for prioritization and sensitivity studies. A revised draft of this NUREG/CR was completed at the end of December, 1991. An additional NUREG/CR is also planned describing different implementations of the methodology including analysis of plant data to obtain component aging failure rates. An expanded treatment of evaluations of passive component contributions to aging risks is also planned for this NUREG/CR.

ATTACHMENT A: USER REQUEST LETTERS

NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 4 5 1987

MEMORANDUM FOR: Eric S. Beckjord, Director
Office of Nuclear Regulatory Research

FROM: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

SUBJECT: USER NEED LETTER - NUCLEAR PLANT AGING RESEARCH PROGRAM

RES is currently formulating a major research effort to study the effects of aging on nuclear power plant structures, systems, and components. We are in full agreement that aging effects are a major concern of this agency and we endorse the general objectives of your program.

My staff has been working closely with yours over the past year and we are currently reviewing the details of your aging program plan. The purpose of this memo is to provide you with some additional guidance regarding the scope of your aging research programs to ensure that their usefulness to the regulatory staff will be maximized.

The usefulness of any research result is in a large part measured by its quantitative safety significance. For aging-related research to be of maximum benefit to NRR, we must know not only the effects of aging on structures, systems, and components, but also the risk significance to public health and safety of the aging process in structures, systems, and components if aging is allowed to proceed uncorrected. Knowledge of potential risk reductions due to various corrective actions, such as maintenance and replacement, would be extremely useful in assisting us to determine proposed regulatory actions. The aging data should also include information which permits extrapolation of the aging process and associated risk significance into a time frame appropriate to the periods expected to be requested for license renewal. We would like your aging program to include these additional elements in it so that research results could be more easily and justifiably implemented into the regulatory process. Our staffs should work closely together regarding the detailed implementation of these suggestions.

I also ask you to consider implementing a program of establishing the risk significance of results in other appropriate research areas.

James H Sniezek / for
Harold R. Denton, Director
Office of Nuclear Reactor Regulation

CONTACT: D. Cleary, EIB, DSRO
49-28547

MEMORANDUM FOR: Guy A. Arlotto, Director
Division of Engineering
Office of Nuclear Regulatory Research

FROM: R. Wayne Houston, Director
Division of Safety Issue Resolution
Office of Nuclear Regulatory Research

SUBJECT: ESTIMATES OF CORE DAMAGE FREQUENCY DUE TO AGING

By this memorandum I am requesting assistance from EMEB/DE in obtaining estimates of core damage frequency due to the effects of multiple component aging at a representative BWR and a representative PWR. Uncertainties in failure rates and aging degradation rates should be incorporated in the estimates. Also, an analysis should be provided of adjustments to core damage frequency estimates which may be required to account for aging of passive components and structures. The estimates are needed by June 30, 1989 with a report explaining the computation of the estimates by July 14, 1989. DSIR will cover the direct contract costs for this effort.

This request has emerged from discussions among my staff and their contractors, the staff of EMEB/DE and their contractors, and the staff of PRA/DSR concerning the use of risk numbers in the draft regulatory analysis for license renewal rulemaking which was prepared by DSIR and several contractors. The risk numbers were taken from NUREG/CR 5248, Prioritization of TIRGALEX-Recommended Components for Further Aging Research. It was agreed that a short term effort by EMEB contractors, with some involvement by PRAB, would produce better, more defensible core damage frequency estimates than those now used in the regulatory analysis.

R. Wayne Houston, Director
Division of Safety Issue Resolution
Office of Nuclear Regulatory Research

*PREVIOUS CONCURRENCE ON FILE w/RPSIB
[ESTIMATE OF CORE DAMAGE]

OFFC:	DSIR/RPSIB*	DSIR/RPSIB*	DSIR/RPSIB*	DSIR/DD	DSIR/D
NAME:	DCleary/jf	PNorian	KKniel	WMinners	RWHouston
DATE:	06/ /89	06/ /89	06/ /89	06/ /89	06 /23/89

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ATTACHMENT B: REFERENCES

1. NUREG/CR-5510, "Evaluations of Core Melt Frequency Effects Due to Component Aging and Maintenance", June 1990.

2. W.E. Vesely, "Incorporating Aging Effects into Probabilistic Risk Analysis", Reliability Engineering and System Safety, Vol. 32, No. 3, June 1991.

3. NUREG-1362, "Regulatory Analysis for Proposed Rule on Nuclear Power Plant License Renewal", July 1990.

4. NUREG/CR-5248, "Prioritization of TIRGALEX-Recommended Components for Further Aging Research", November 1988.

5. W.E. Vesely, D.E. Korns, P.L. Appignani, and S.M. Scalzo, "Evaluation of Aging Effects in Component Failure and Maintenance Data", SAIC Technical Report 90/1119, September 29, 1989.

ATTACHMENT C: COMPONENT IDENTIFIERS USED IN TABLES 1 AND 2

COMPONENT IDENTIFIER SCHEME

XXX	-	XXX	-	XX	-	XXXX
System		Component Type		Failure Mode		Component ID

SYSTEM IDENTIFIER

ESW - Essential Service Water

EHV - Emergency Heating, Ventilation, and Air Conditioning

DCP - DC Power

HCI - High Pressure Coolant Injection

ACP - AC Power

COMPONENT TYPE IDENTIFIER

AOV - Air Operated Valve

SRV - Safety Relief Valve

BAT - Battery

MOV - Motor Operated Valve

DGN - Diesel Generator

FAILURE MODE

CC - Common Cause Failure (of Loss of Function)

LF - Loss of Function

FR - Failure to Run

LP - Loss of Power

ATTACHMENT D: DESCRIPTION OF NO MAINTENANCE AND RISK-FOCUSED ALTERNATIVES FOR FIGURE 1

BASE PROGRAM

Follow technical specifications and replace components at failure.

RISK-FOCUSED PROGRAM 1

Carry out the technical specification tests and replacements plus test the 14 ECCS motor operated valves every 6 months instead of every 18 months and install new valves every 5 years.

RISK-FOCUSED PROGRAM 2

Carry out Risk-Focused Program 1 plus improve efficiency on the monthly diesel testing, replace the three check valves in the High Pressure Injection System and the actuation trains at 20 years.