Iowa State University Ames, Iowa 50011

ames laboratory
Energy & Mineral Resources Research Institute

September 10, 1980

Dr. F. P. Schauer
Chief Structural Engineering Branch
Division of Systems Safety
Office of Nuclear Reactor Regulation
Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: AMES LABORATORY TECHNICAL ASSISTANCE TO THE DIVISION OF SYSTEM SAFETY, NUCLEAR REACTOR REGULATION - "REVIEW OF NUCLEAR PLANTS STRUCTURAL DESIGN" (FIN NO. A-4141).

Dear Dr. Schauer:

During our meeting of September 3, 1980, you requested that I perform certain tasks concerning this and next year's work:

(1) Summary and evaluation of the various analyses of the Sequoyah containment presented at the ACRS meeting of September 2: see enclosure.

(2) Interactive computer program in FORTRAN for approximate analysis of steel containments: This will be incorporated into next year's program - see forthcoming Form 189 (current terminology is WPAS), Task 3(a).

(3) Limitation to above approximate analysis: This will be incorporated into next year's program: see forthcoming Form 189, Task 3(c).

(4) Usefulness of instrumentation of full-scale containment during over-pressure test: Instrumentation of an actual containment vessel during the overpressure test would provide useful data for comparison with analytical results. By placing strain gages at a number of locations on the shell and stiffeners, strains could be measured in the linear behavior range of the containment vessel. The data could be used to verify and/or improve the linear analytical results. For example, the effect of stiffeners on shell behavior could be examined. However, these experimental results should not be expected to verify a nonlinear, limit pressure analysis of the containment. Only pressure tests of models to leakage would provide such information. X003

Development and implementation of the instrumentation and data acquisition scheme for such a test would require careful study. If you decide that such an experimental program would be useful, we would be very interested in submitting a proposal to perform the work.

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(5) Extension of previous dynamic analysis to cover other size compartments and vent areas: Work is beginning on this item. Before this work can be completed, we request that you furnish us with realistic information regarding the pressure pulse for the dynamic loading. In particular, the pulse magnitude and duration are requested along with the relationship of these parameters to compartment size and venting area.

(6) Form 189: This will be forthcoming when we receive the Statement of Work and NRC Form 173.

(7) Comments concerning proposal by Morris Reich for interactive structural hardware and software system: I believe Mr. Reich's proposal would be a worthwhile effort, and I would look forward to participating in such an effort. For the immediate future (FY 81, before the interactive capability is available) we would intend to use his program, NFAP, for a significant portion of our finite element analyses.

Sincerely,

Lowell Greimann by D. D. Bluhm

Lowell Greimann
Project Engineer

Enclosure

cc w/encl: Director, Division of Systems Safety
Attention: B. L. Grenier

Harold Polk
Program Manager

Delwyn D. Bluhm, Head
Project Engineering

L. Greimann

SUMMARY & EVALUATION OF SEQUOYAH CONTAINMENT ANALYSES

Presented at

ACRS MEETING, SEPTEMBER 2, 1980

APPROXIMATE METHODS

Common Assumptions
- penetrations do not control
- uniform static internal pressure
- von Mises yield criteria
- local bending effects neglected
- axially symmetric

Ames Lab, L. Greimann (January 1980)
- F_y = 32 ksi
- uniform stress in stiffeners & shells at limit pressure
- limit pressure = 36 psi (+30%, -10%)

R & D Associates, F. Parry
- F_y = 32 ksi
- linear elastic analysis of stringers
- rings neglected
- yield pressure = 27 psi

TVA
- F_y = 45.7 ksi
- neglect all stiffeners
- yield pressure = 38.2 psi

NRC Research, G. Bagchi
- F_y = 32 ksi
- stringers carry pressure load in bending and transmit it to the rings
- limit pressure = 34 psi

Ames Lab, L. Greimann (September 1980)
- F_y = 35.2 ksi
- complete yielding of rings and stringers (mechanism)
- limit pressure = 44 psi

Offshore Power Systems, R. Orr
- F_y = 45 ksi
- smeared rings
- stringers neglected
- limit pressure = 50.5 psi (9'6" ring spacing)
  56.8 psi (6'6" ring spacing)

FINITE ELEMENT ANALYSES

Common Assumptions
- penetrations do not control
- uniform static internal pressure
- von Mises yield criterion (except as noted)

Ames Lab, L. Greimann
- F_y = 35.2 ksi
- geometric and material nonlinearities included
- axisymmetric analysis of complete shell including rings and stringers (neglect circumferential variation of displacement)
- ANSYS program
- limit pressures by ASME ½ linear slope method = 47 psi

Offshore Power Systems, R. Orr
- F_y = 45 ksi
- geometric and material nonlinearities included
- analysis of typical curved ½" panel bounded by a ring and stringer
- ANSYS program
- no limit pressure predicted but load-displacement curve becomes quite flat at 50 psi pressure

Franklin Research Center, Z. Zudans
- F_y = 32 ksi
- linearly elastic analysis
- analysis of typical curved 5/8" panel with ring and stringer which verified smearing of stringers
- axisymmetric analysis of a shell length including rings and smeared stringers (neglects circumferential variation of displacement)
- pressure with average hoop stress at yield = 30.3 psi (max. shear stress criterion)

COMPARISON

For a valid comparison, multiply pressures by 45 ksi/F_y since 45 ksi is the approximate actual yield strength. If the maximum shear stress criterion was used, convert to the von Mises criterion by multiplying by 1.15.

Yield Pressure

R & D Associates (Approximate)	38 psi
TVA (Approximate)	38 psi
Franklin Research (Finite Element)	49 psi

Limit Pressure

Ames Lab - Jan. 1980 (Approximate)	51 psi
NRC Research (Approximate)	48 psi
Ames Lab - Sept. 1980 (Approximate)	56 psi
Offshore Power Systems (Approximate)	50 & 57 psi
Ames Lab (Finite Element)	60 psi
Offshore Power Systems (Finite Element)	Not Specified

OBSERVATIONS

- The yield pressure of 38 psi predicted by R & D Associates and TVA is very conservative because all stiffening is neglected.

- The yield pressure predicted by Franklin Institute (49 psi) is unconservative because it involves complete through thickness yielding. On the other hand, 49 psi is a conservative limit pressure because a full mechanism has not formed in the analytical model.

- The limit pressures predicted by Ames Lab - Jan. 1980, and NRC Research, are conservative because a complete collapse mechanism has not been formed in the analytical model.

- The finite element analyses of a typical panel by Offshore Power Systems and Franklin Institute show that the circumferential variation of displacement is insignificant. Therefore, an axisymmetric finite element model, as used by Ames Lab and Franklin Research, is adequate.

CONCLUSIONS

Within engineering accuracy ($\pm$10%), the limit pressure is probably between 55 and 60 psi. A limit pressure can be achieved if the structure has adequate ductility.