NRC Central File
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Shapar/Engelhardt/S[illegible]nto
GHCunningham, III/MKarman
Chron
BBevan, 348 Phil.
SBajwa, P-522
SHLewis

BPaton, OELD
DVassallo, 110 Phi[illegible]
HSmith, 314 Phil.
FF OELD (2)

NRC Central

December 21, 1978

Robert M. Lazo, Esq., Chairman
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dr. Richard F. Cole
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dr. Walter H. Jordan
881 West Outer Drive
Oak Ridge, TN 37830

50-263

In the Matter of
Northern States Power Company
(Monticello Nuclear Generating Plant, Unit 1)

Gentlemen:

This is to inform the Board of certain information provided in a preliminary fashion by one of the NRC Staff consultants relating to criteria in buckling of steel containment structures. The report is attached along with a staff evaluation of this matter.

In this connection, the staff believes that the information does not adversely affect the evaluation conducted by the staff in this case. If you have any further information, please let us know.

Sincerely,

Myron Karman
Counsel for NRC Staff

Enclosure:
NRC Staff Evaluation of
Factors of Safety Against Buckling

cc w/enclosure:
Monticello Service List

OFFICE➤	OELD	OELD				
SURNAME➤	MKarman:k	GHCunningham, III				
DATE➤	12/18/78	12/ /78				

ENCLOSURE

NRC STAFF EVALUATION OF FACTORS OF SAFETY AGAINST BUCKLING

In a report entitled "Stability Criteria for Primary Metal Containment Vessel Under Static and Dynamic Loads" written for GE by R. L. Citterley of Anamet Laboratory, Inc., a factor of safety against buckling ranging from 2.0 to 2.75 is recommended. Also recently the 1977 summer addenda of ASME Code requires a factor of safety of between 2.0 and 3.0 against buckling depending upon the applicable service limits.

Due to the lack of experimental data and uncertainties in establishing the theoretical buckling load, we have an ongoing technical assistance program to study this issue. Any final design recommendations or guidelines resulting from this program will be evaluated for possible use in our licensing work. We are not at this time in a position to make any changes to previously accepted criteria. As indicated above, through the help of our outside consultant, the Staff will develop our technical position further.

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

JAN 30 1978

MEMORANDUM FOR: D. B. Vassallo, Assistant Director for Light Water Reactors, Division of Project Management

THRU: J. P. Knight, Assistant Director for Engineering, Division of Systems Safety

FROM: I. Sihweil, Chief, Structural Engineering Branch, Division of Systems Safety

SUBJECT: INFORMATION TO BE PROVIDED TO ACRS AND LICENSING BOARDS (SEB: 001, 002)

We just received the attached progress report from our consultant that questions the current criteria for buckling of steel containment shells. We believe that the appropriate licensing boards and the ACRS should be notified.

It should be realized that this report is preliminary in nature and has not been fully evaluated by our branch. We believe it may have an impact on the design of steel containments such as those used for the BWR Mark III and PWR Ice-Condensers.

/s/ Sihweil

I. Sihweil, Chief
Structural Engineering Branch
Division of Systems Safety

Attachments: As stated

cc w/encl:
R. Mattson
D. Eisenhut
L. Shao
K. Wichman
SEB Members

INTERNATIONAL STRUCTURAL
ENGINEERS, INC.
P. O. BOX 0595
GLENDALE, CALIF. 91206 U.S.A.

January 11, 1978

Dr. A. Hafiz
Division of System Safety
Office of Nuclear Reactor Regulation
Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Buckling Criteria and application of Criteria to design of steel containment shell. Number RS-77-8.

Dear Dr. Hafiz:

Our first progress report is enclosed in accordance with the requirements of our NRC contract.

We have started preparing a buckling design criteria document covering the buckling design of steel containment shells. As parts of this document are completed, they will be forwarded to you.

We are still evaluating the static and dynamic loading conditions which the steel containment shell is subjected. This study should be completed shortly.

Please contact us if you have any questions related to the progress reports.

Sincerly,

A.F. Masri

January 3, 1978 Progress Report for "Buckling Criteria and Application of Criteria to Steel Containment Shell" (#RS-77-8)

As stated in our proposal, after we received the go-ahead from NRC a detailed literature survey would be carried out to determine the state of the art on the use of buckling criteria on the design of metal containment vessels under static and dynamic loads. The following work has been completed on this phase of the contract:

1. Library search. We have conducted a detailed literature search using information retrieval systems such as the Engineering Index, NASA Publications, U.S. Defnese Department Publications, and the International Engineering Index.

2. Solicited Information. We have contacted the leading authorities in the buckling field requesting them to send us any information that would help us to establish buckling criteria for steel containment vessels. Appendix A contains a sample letter and a list of people contacted. Individual meetings were also held with:

Dr. P. Gou (General Electric)

Dr. R. Citerley (Anamet Laboratories)

Dr. C. Babcock (California Institute of Technology)

to obtain their views on establishing buckling criteria, safety factor and ASME Code requirements. Subsequent to the meeting with Dr. Gou we received a summary of the dynamic loads that General Electric uses in the design of their containment structures.

Based on our investigations the following statements can be made about the state of the art to date:

1. Most of the experimental results available in the literature

for determining design criteria are based on model tests and the correspondence between model tests and full size structures still needs to be assessed. Design criteria verified by experiment which considers effects of imperfections, dynamic loads, asymmetric loadings and non-linear effects is practically nonexistent. To obtain this type of information will not be an easy or inexpensive task. It appears that our best method of obtaining experimental data for establishing design criteria is through carrying out a large number of carefully planned model tests.

2. A large number of computer programs exist for determining buckling loads of shells of revolution and general shells. Programs which seem to have gained the confidence of engineers developing design criteria are BOSOR 4, STAGS, NASTRAN and MARC. Even though many of these programs consider nonlinear effects, very little correlation has been obtained between the results of these computer programs to predict experimental buckling results even when the imperfections of the test models are well known beforehand. For the actual design condition when imperfections and loadings are not well defined, computer programs can only be used as guidelines or as a first step before knockdown factors are imposed. It also seems important that the limitations of these computer programs should be well documented and the codes should be easily available to those interested in the buckling characteristics of containment structures.

3. The ASME Section III Buckling Criteria Regulation Guide 1.57 NE-3224 which states that

(A) One half the value of critical buckling stress determined by one of the methods given below

1. Rigorous analysis which considers gross and local buckling, geometric imperfections, nonlinearities, large deformations, and inertia forces (dynamic loads only).
2. Classical (linear) analysis reduced by margins which reflect the difference between theoretical and actual load capacities.
3. Tests of physical models under conditions of constraint which reflect the difference between theoretical and actual load capacities.

must be changed. The use of these criteria permits designers to select the method which yields a buckling stress which is least conservative. In fact, even with the use of the one half factor it is possible for a shell to buckle at a stress below that predicted by Method 3. For example, it is well known that some axial compression cylinder model tests yield results for carefully made specimens close to 90 percent of the classical buckling value and others with imperfections yield results less than 20 percent of the classical value. The use of Method 3 is valuable in establishing guidelines for buckling criteria but could be dangerous and yield unconservative buckling stresses if the physical models did not exactly approximate the loading and imperfections of the full scale operating model. Since it is impossible to know the exact geometric imperfections and static and dynamic loadings of the full scale operating model, Method 1 which uses rigorous analysis has some of the same problems of Method 3. In cases where these factors were known for test models, rigorous analyses were not, in most cases, able to accurately predict the experimental buckling values. Most authorities in the field agree that Method 2 is the most reliable method and this should be reflected in the ASME Section III Regulatory Guide 1.57.

The other methods should be used in conjunction with Method 2 and only in special cases, determined by NRC, used to establish design criteria.

4. Until more test data is obtained to study the effects of imperfections, asymmetric loading, load interaction, dynamic and nonlinear effects, a conservative factor of safety such as 3 should be used.

5. A general procedure for determining the buckling stress of a metal containment structure has been developed and is summarized below.

1. The containment structure will be accurately modeled by using a general finite element program such as SAP 6 or NASTRAN.

2. The dynamic and static load combinations of

a) dead loads

b) construction loads

c) accident design loads (LOCA)

d) external pressure

e) seismic loads

f) penetration loads

g) thermal loads

H) symmetric and asymmetric loads

will be imposed on the finite element model of the containment structure and a linear static and dynamic analysis using SAP 6 or NASTRAN programs will be performed for all critical laod combinations. Maximum stresses will be determined and tabulated.

3. After determining a set of critical maximum stress combinations the maximum stress along any meridian will be assumed to be axisymmetric. This has been shown in the past to be an accurate and conservative approximation. These critical maximum stress combinations will then be input to the BOSOR 4 program and the

overall buckling load will be determined. The BOSOR 4 program considers nonlinear prebuckling deformations and performs a bifurcation analysis to determine the buckling load. Using this proposed procedure asymmetric loads, interaction effects, dynamic loadings, seismic effects and nonlinear prebuckling deformation can be consideredd.

4. Once the overall buckling stresses are determined, these buckling stresses will be reduced by margins which will reflect the difference between theoretical and actual load capacities. The NASA design criteria lower bound curves based on experimental data will be used to determine these reduced margins of safety.

5. After overall buckling is investigated, localized buckling will then be considered based on the stresses obtained from the linear static and dynamic analysis. Any part of the structure that does not satisfy both the local and overall buckling requirements will be redesigned until these criteria are satisfied.

At the present time we are

1) evaluating the various containment vessel loading conditions which must be considered to determine the applied static and dynamic stresses.

2) synthesizing the information that we have obtained and evaluating and recasting this information in the form of a buckling criteria design document.

UNIVERSITY OF SOUTHERN CALIFORNIA

UNIVERSITY PARK • LOS ANGELES, CALIFORNIA 90007

SCHOOL OF ENGINEERING
DEPARTMENT OF CIVIL ENGINEERING

October 12, 1977

Dear Colleague:

The undersigned are involved in a project which requires the compilation of information on the buckling of shells, including shells of revolution, under localized and nonsymmetric loading. We intend doing a thorough survey of the open literature as well as relying on such compendiums as the Column Research Committee of Japan's Handbook of Structural Stability and Applied Mechanics Reviews. We are concerned, however, that much useful information will be overlooked because of the relative obscurity of the journal in which it is published or its unavailability in journal form.

Thus, we would be grateful for any help which you might give us in this task by taking a few moments to search your memory and your files for titles and authors of papers and reports on the subject of buckling under nonsymmetric loading. Copies of hard-to-get items would be appreciated. Your aid will be acknowledged in the final report on the subject.

Sincerely,

S.F. Masri
Professor

P. Seide
Professor

V.I. Weingarten
Professor and Chairman
Dept. Civil Engineering

PS/lrm

B. Budiansky, Harvard University
J.W. Hutchinson, Harvard University
W.T. Koiter, Technological University of Delft, the Netherlands
N.J. Hoff, Stanford University
C.R. Steele, Stanford University
W. Flugge, Stanford University
J. Singer, Technion-Israel Institute of Technology
W. Nachbar, University of California at La Jolla
Dr. L.H. Donnell
Dr. D. Bushnell, Lockheed-Palo Alto Research Laboratories
Dr. B.O. Almroth, Lockheed-Palo Alto Research Laboratories
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M. Baruch, University of Wisconsin
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