TOPICAL REPORT EVALUATION

Report Number: WCAP 8252, Rev. 1
Report Title: Documentation of Selected Westinghouse Structural Analysis
               Computer Codes
Report Date: May 1977
Originating Organization: Westinghouse Electric Corporation
Reviewed By: Mechanical Engineering Branch, DSS

SUMMARY OF TOPICAL REPORT:

This topical report provides a description and verification of certain

computer codes used by W for structural analysis and design of primary

structures and components. The objective of this report is to satisfy

the requirements of SRP Section 3.9.1 concerning documentation and

verification of computer programs used for analysis and design of mechanical

systems and components. The codes described in this report are listed

below. Since some are used sequentially, they are grouped together

as follows:

I.   WESTDYN 7, FIXFM3, WESTDYN2

II.   WECAN

III. STRUDL, THESSE

IV.   SAND, SPECTA, MODAL

V.   DARI-WOSTAS

VI.   STHRUST

Following is a summary description of these codes:

I.A. WESTDYN 7

      Performs linear elastic analysis of three-dimensional piping

      systems subjected to thermal, static and dynamic loads. Dynamic

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analysis is performed on lumped mass systems by modal superposition using response spectrum analysis. The resultant internal forces and moments are calculated from the square root of the sum of the squares of the modal forces and moments. It has options which permit calculation of fatigue usage factors in accordance with the ANSI B31.7 and ASME Section III requirements, and the stresses within the piping system in accordance with USAS B31.1, ANSI B31.7 and ASME Section III. This program was verified by comparing the results of a number of problems solved by other means with the program generated solutions. These results compared favorably.

B. FIXFM 3

This program is used to perform transient analysis of a structure where the loading history is known, by integrating numerically (by predictor/corrector integration technique) the modal equations of motion. It is used in conjunction with WESTDYN 7 from which it obtains the natural modes and frequencies. It also permits the solution by modal superposition of a class of problems with non-linear boundary conditions such as supports containing gaps, by considering the impact as external forces.

C. WESTDYN 2

This program accepts the resulting displacement histories from FIXFM 3 and calculates the internal force and stress histories, generating similar results to WESTDYN 7.

The combination WESTI YN 7/FIXFM 3/WESTDYN 2 was checked out by comparing the numeri:al and analytical solutions of a cantilevered beam with three masses, subjected to certain forcing functions. These results also compared favorably.

II. WECAN

This is a large, general-purpose digital computer program for static and dynamic structural analysis by the finite element approach as well as for thermal and flow network analysis. It is intended primarily for elastic and plastic analysis of large structures consisting of rods, beams, plates, and shells with several hundred degrees of freedom. It can be applied to problems invol.ing linear and non-linear structural problems. (Nonlinearity refers to material properties and gaps.) This section was removed from this report and reissued separately as WCAP 8929. This program has therefore, not been reviewed herein, but will be evaluated separately.

III. ICES STRUDL-II, THESSE

A. STRUDL is a structural program originated at M.I.T. which is used to ,erform static linear elastic frame analysis of reactor coolant loop equipment support str:::t:res. Verification for it is claimed thru the fact that it has been in the public domain for many years and therefore no further verification is -quired.

B. THESSE is used to evaluate the stresses in the members of reactor system equipment support structures. It accepts the stiffness calculated from a structural analysis, loads due to deadweight,

thermal, pressure and seismic loads, and loads due to a loss-of-coolant accident from a reactor coolant system analysis. These loads are used individually to obtain the end force and moments components for each member. These components are then combined by a method which differs from any shown in NUREG-0484, Rev. 1 "Methodology for Combining Dynamic Responses". However, Westinghouse has committed to provide the actual load combination method for each plant analysis in the applicants' Final Safety Analysis Report.

The combined force components are used to evaluate buckling and yield interaction ratios, and shear ratios under faulted conditions. These ratios are obtained from equations taken from the AISC Manual of Construction, 1970 version, which are based on elastic-perfectly plastic behavior. Similar ratios are also evaluated for normal, upset and emergency conditions. In addition, the resultant stresses due to these force components are also compared to the allowable values given in the Final Safety Analysis Report, which the applicant is committed to satisfy and which are based on the loading combinations and structural acceptance

criteria as listed in SRP 3.9.3. THESSE was verified by application to a three-legged frame support structure, and comparing with hand solutions which shows that the equations are correctly programmed.

IV. SAND, SPECTA, MODAL

A. SAND performs static, dynamic and thermal stress analysis of linear elastic frame structures. It is applied to the following five types of structures:

1. Three-dimensional structure-pinned joints.

2. Three-dimensional structure-rigid joints with equal member cross-section moment of inertia.

3. Planar structural-rigid joints loaded in a plane.

4. Planar structure-rigid joints loaded in a plane.

5. Three-dimensional structure-rigid joints doubly symmetric cross-sections.

The dynamic analysis yields frequencies and mode shapes, which are then used with SPECTA and MODAL for obtaining the responses of the analyzed structures.

B. SPECTA admits the modes and frequencies from SAND and perfroms a response spectrum analysis of SAND-type structures subjected to seismic excitation.

C. MODAL also admits the modes and frequencies from SAND, but performs a time history analysis for obtaining the seismic response of the SAND-type structures. It can also be used for obtaining response

spectra within the structures.

These three programs were verified by comparison with hand solutions and solutions which have appeared in the open literature.

V.   DARI-WOSTAS

This is a special purpose finite element program for the dynamic analysis of reactor internal structures subjected to time-varying hydraulic loads which occur during blowdown, from reactor coolant flow, and resulting impact froces.

For analysis the reactor structural system is divided into a number of masses connected together by elastic and rigid members which are postulated to experience small vertical, or transverse and rotational, motion.

The program is a combination of two separate structural programs designed to solve specific problems:

1. WOSTAS for vertical vibration of the reactor internals. Each mass possesses one vertical displacement degree of freedom.

2. DARI for transverse* vibration of the reactor internals. Each mass possesses one horizontal displacement and one-inplane rotational degree of freedom.

To utilize DARI-WOSTAS the reactor internal structural system is idealized by two models: (1) a transverse model comprised of masses connected by elastic vertical beam and pinjoint

*Transverse means a vertical structure with horizontal displacements.

elements, and horizontal rigid members and spring and dampers and, (2) a vertical model consisting of masses connected by vertical spring, damper and friction elements. Both models are also capable of treating impact due to gaps between nodes.

The equations of motion are solved by step-by-step integration using Hamming's modified predicto-corrector method, developed by IBM.

This program was verified by comparing the results of a number of problems with those obtained from the program WESTDYN. The comparisons show very close agreement of the calculations.

VI. STHRUST

This program is used for calculating time-history blowdown forcing functions, which are used as input to programs for structural analysis of pressurized water reactor coolant loops. It is used in conjunction with the hydrodynamic program SATAN. This program provides the transient pressure, mass flow rates, and other thermodynamic properties as a function of time. STHRUST then calculates the transient hydraulic forces at various locations in the coolant loop, such as elbows, pumps and steam generator plenums and tubes.

The equation for calculating the resultant forces is based on the one-dimensional equation for conservation of linear momentum from fluid dynamics. The loop and its components is represented by

one-dimensional control volumes on which act the fluid pressure
and forces due to gravity and friction. The actual equations used
for calculating the forces do not include inertia nor friction
terms. Neglecting the frictional terms is conservative; exclusion
of the inertia terms is conservative only if the fluid parameters
(mass flow) change relatively slowly with time, and the length
of the control volumes is short.

Verification for this program was claimed by comparing hand and
computer calculations for the same sample data obtained from SATAN

SUMMARY OF REGULATORY EVALUATION

The topical report was evaluated in accordance with the requirements
stipulated in the Standard Review Plan, Rev. 1, Section 3.9.1, by a
detailed review of the theoretical bases and the verification problems
for the computer codes considered as proprietary. The problems
consisted of a comparison of computer generated solutions with
hand calculated solutions, or solutions obtained from other sources.
Confirmatory calculations were also performed to verify the methodology
used in the code FIXFM 3 for solving non-linear problems involving
gaps in structural systems. This work was performed by the Brookhaven
National Laboratory and is summarized in a note submitted to the NRC
titled "Non-linear Dynamic Analysis of Piping Systems Using the
Pseudo force Method." These calculations confirmed the adequacy of
this methodology.

Westinghouse has also committed to provide the actual method of internal load combination due to static and dynamic loads, in the applicant's Final Safety Analysis Report. The method described in the FSAR should correspond to one of those described in NUREG-0484, Rev. 1, "Methodology for Combining Dynamic Responses".

REGULATORY POSITION

We find this report acceptable as a reference to support the applicants conclusions when referenced in utility applications, and an acceptable basis for fulfilling the requirements of 10 CFR 50, Appendix B.