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EARTHQUAKE RESPONSE OF SEA-BASED STORAGE TANKS BY A HYBRID ELEMENT METHOD-
THEORY AND COMPUTER ANALYSIS

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FOREWORD

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This study addresses the problem of dynamic response of submerged storage tanks subject to earthquake excitations, in an attempt to formulate a general evaluation procedure using the hybrid-finite element method and to synthesize a comprehensive and predictive computer code for engineering applications. This technical report presents the formulation and encoding of the research findings.

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ABSTRACT

An effective method for the linear analysis of dynamic response of submerged underwater oil storage tanks to loadings of earthquake excitations is presented. The tank is axisymmetric in shape, has a flexible wall/roof. A general hybrid-finite element solution procedure has been formulated, wherein the tank structure, the interior fluids, as well as the near field of the exterior water region are discretized into a toroidal mesh network. The tank displacement is expressed as a superposition of the first few modes of the structure's free vibration. Contribution from the hydrodynbamic interaction to the coupled motion is obtained by solving the Laplace equation with the appropriate boundary conditions, which includes a matching to the exterior far-field pressure (analytic) representation to simplify the computational process. The effects of fluids surrounding and inside the tank are studied. It is demonstrated that these effects are, in general, significant on the tank earthquake response analysis.

A comprehensive and predictive computer program for use in such tank response analysis is developed for design engineering applications.

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INTRODUCTION

In recent years, exploration and production of oil offshore have increased tremendously. Many of the new fields are far into the ocean and the adjacent land area is often desolate and uninhabited, rendering the conventional method of using pipelines and onshore terminals more and more costly. For countries in scarcity of land space (such as Japan), utilization of the sea may become necessary for the purpose of long-term petroleum storage. The alternative of storing crude at the producing sites to be shipped via tankers to harbors is thus becoming more and more economical, both in terms of capital investment and in operating cost.

The first submerged underwater oil storage tank was placed in service in December of 1969. Referred to as the Khazzan Dubai #1, the tank is located in 150 feet of water, 60 miles off the shore of the Trucial Coast in the Arabian Gulf (Chamberin, 1970). It weighs 15,000 ton and holds 500,000 barrels of oil. It has the appearance (Figures 1 and 2) of an inverted funnel with a 270-foot-diameter base and a roof which is a portion of a 180-foot-radius hemisphere. A conical transition connects the roof to a 30-foot-diameter shaft that extends above the ocean surface. The "bottomless" tank rests on the ocean floor and operates on the water displacement principle; it is always filled with either water or oil or a combination of the two. Filling is accomplished by placing oil through the shaft, the additional weight of the oil on the water creates a pressure imbalance which forces the water out of the tank through openings in the wall. Deep-well pumps are used for discharging oil. As oil is withdrawn, inflow of water takes place, replacing the removed oil.

New concepts and designs of oil storage tanks have since been developed for all areas of the world. Some of the tanks rest on ocean floors and are either completely submerged or partially submerged with part of the tank protruding above water; other designs take the form of floating, bottomless tanks, moored to the ocean floors.

The primary forcing function these storage tanks must be designed to resist is that due to waves in the heaviest storm; and for bottom-supported tanks located in earthquake-prone areas, seismic-induced hydrodynamic forces must, of course, also be considered. Because of the exorbitant cost incurred in the construction of these huge structures, and the environmental hazards associated with the failure of such structures, an accurate evaluation of the hydrodynamic forces is vital. In order to predict the response of an underwater tank to waves and earthquakes, the development of a reliable computation method is a pressing need for the construction of storage tanks in seismic areas. This present study is specifically aimed at the earthquake-induced response for a completely submerged tank filled with oil and water.

Earthquake analysis of such cantilever structures requires special considerations which do not arise in land-based structures; any procedure for analysis must recognize the additional dynamic forces and modifications in the dynamic properties caused by the surrounding water and the fluids inside. If the tank is perfectly rigid, the motions of the fluids inside and outside the structure may be treated independently. However, to accommodate for the more stable structures made of flexible resilient materials, extra care needs to be exercised in studying their dynamic behavior, by virtue of the fact that the structure and fluid motions are coupled. The effect of the tank structural deformation on the dynamic response is the emphasis of this investigation.

2. RELATED PAST WORK

There have been few works that directly address the problem intended in the present study. The ones bearing the closest relationship appear to be that of Takayama (1976) and Helou (1981). Takayama treated transient waves inside a vibrated oil storage; the tank is a rigid rectangular or cylindrical structure, submerged undersea. However, no attention was given to the effect of surrounding water, and no numerical results are furnished. Helou extended the problem wherein the tank wall is flexible. However, he was only concerned with cylindrical tanks where analytic solution can be found; no numerical scheme was developed for general applications.

A wealth of research papers do exist which provide valuable sources of pertinent information, most having to do with the hydrodynamic pressure distribution of structures under earthquake excitations. For land-based tanks of simple geometries under the assumption of inviscid, compressible or incompressible fluid, and irrotational motion of small amplitudes, many solution procedures have been formulated. First, Jacobsen (1949) evaluated the dynamic mass effect of fluid inside a cylindrical tank and outside a cylindrical pier, when the base experiences an impulsive seismic load. Then, Housner (1956) set the foundation of general earthquake-proof design analysis by introducing a simple approximation method which avoids partial differential equations and infinite series. Thereafter, many works appear which deal with the deformation of tank structure. Notable among them are Baron and Skalak (1962), Arya, Thakkar and Goyal (1972), and Yang (1976), who use the Rayleigh-Ritz method; and Edwards (1969) and Shaaban and Nash (1975), who employ the finite-element method. In all cases, fluid is treated as a continuum and appropriate shell theories are selected for the development (Sanders, 1959; Flügge, 1960; Basu and Gould, 1975; Ghosh and Wilson, 1975). In Yang's work, the nature of the impulsive and convective effects is carefully identified, and he based his dynamic analysis on assumed mode shapes of the tanks free vibration. Wu *et al.* (1975) developed a computer program to calculate the natural frequencies of the fluid-tank system. Earthquake analysis of the resonant oscillation (sloshing) phenomena in elastic shells can be found in Chester (1968), Faltinsen (1974), Aslam, Godden and Scalise (1979) and Mei, Foda and Tong (1979).

So far we have been quoting only works concerning ground tanks. The problem associated with motion of water surrounding submerged tanks is more difficult to solve. For objects of simple geometries, attempts were made using the Schwinger variational technique (Black and Mei, 1970), the Galerkin method (Garrett, 1971), and the integral equation method (Garrison and Seetharama Rao, 1971). Tung (1979) also pursued the problem of submerged bodies subject to harmonic ground excitation, using a semi-analytical method to obtain the hydrodynamic forces and confirmed the insignificance of the gravity effect, as long as the excitation frequencies are moderately high. For objects of more complicated shapes, numerical methods must be employed. The finite-element method, known for its versatility, was used by Chakrabarti and Chopra (1972) and Liaw and Chopra (1973) in studies of seismic response of gravity dams and intake towers. This approach is further enhanced by the adoption of an analytic super-element, thereby reducing the mesh requirement in the far field (ordinarily it is required that the outer truncation boundary must be far enough away from the longest waves). The so-called "hybrid" finite-element method, which combines judiciously finite-element solution for fluid motion near the object and an analytic representation for the far field, has been proven to be highly efficient. Among the pioneers are Berkhoff (1972), Bai and Yeung (1974), Chen and Mei (1974) and Yue, Chen and Mei (1976).

3. FORMULATION

Although the subject of seismic response of submerged storage tanks is relatively new and unexplored, as we have pointed out in the previous chapter, much of the pertinent analysis tools have been developed. It is the purpose of this research to utilize these tools in formulating a general hybrid-finite element solution procedure, for the hydrodynamic response of flexible underwater storage tanks subject to earthquake motions; and to synthesize this procedure into a comprehensive predictive computer code which can be used for engineering applications.

The tank structure in question is of general axisymmetric shape, has a flexible wall and/or roof, and is rigidly attached to the ocean floor. This assumption that the support foundation does not move relative to the ground reduces the scope somewhat, since the effect of marine soil-structure interaction can have significant consequence on the hydrodynamic analysis. However, it is expected that this variation can be accommodated by our hybrid-finite element procedure, and will be dealt with in a future study. The tank will be completely filled with oil and/or water and sealed (this last restriction can be lifted by simply changing the input format). Finally, in the following presentation, we simplify matters by ignoring irregular bottom topography and depletion of interior compartments. Their presence can be handled straightforwardly by carefully discretizing these components into finite elements.

The equation of motion of the tank structure can be written in terms of the structure discretization as

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = - \{F\} \quad , \tag{3.0}$$

where [M], [C] and [K] are the mass, damping and stiffness matrices of the system, respectively. $\{\ddot{x}\}$, $\{\dot{x}\}$ and $\{x\}$ are the acceleration, velocity and displacement vector of the structure relative to its base,

$\{F\}^*$ is the load vector of the external forces, which includes the hydrodynamic pressure $\{P_S\}$ due to the presence of fluids inside and outside of the system. For nodal circles on the inner shell interfacing with the interior oil and water, $\{P_S\}$ is sought from the equation of motion governing the dynamic interaction between the shell and the interior fluids; the same goes for $\{P_S\}$ at nodal circles on the outer tank surface. Thus, before attacking (3.0), we need to solve two boundary value problem suitably formulated based on the two appropriate Laplace equations. The flexibility of the tank shell is entered into both radial boundary conditions influenced by the ground acceleration, consequently $\{P_S\}$ intertwines with $\{\ddot{x}\}$.

Both boundary value problem are solved using the variational principle of finite element theory. In the "far away" exterior region, a matching of analytic representation of $\{P_S\}$ is invoked (this region is to have been rid of all geometrical irregularities). Once $\{P_S\}$ is obtained (in terms of $\{\ddot{x}\}$ and the earthquake ground acceleration $\{\ddot{f}_h\}$, (3.0) can be solved by transformation into modal coordinates wherein the displacement is expressed in terms of the first few modes of the tank force vibration. The resultant linear second-order differential equation in the generalized displacement amplitude can be solved by the ordinary step-by-step integration schemes.

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* Vectors enclosed in braces { } are associated with the appropriate (interior fluids domain, structure, or exterior water region discretizations) nodal coordinates. Thus, if NO is the number of nodal-circles in the oil domain, $\{P_O\}$ is the column vector of nodal pressure distribution of dimension NO, ordered in the global nodal number sequence. However, in the case of structure discretization, the vector is represented by the (r,z,θ) coordinates at each nodal-circle, making {P} a vector of dimension 3N, if N is the number of nodal-circles in the structure assemblage. The symbol "$\rightarrow$" will be reserved for the ordinary three-dimensional continuum vectors.

3.1 Dynamic Behavior of Fluids

3.1.1 Interior Fluids

A. Problem Formulation

Consider a axisymmetric tank submerged underwater which is filled with oil on top of water (more generally, two fluids of densities ρ_0 and ρ_w, where $\rho_w > \rho_0$) with respective heights of h_0 and h_w as shown in Figure 3 (h_0 depends on the radial distance from the axis). Choose the coordinate system as depicted in Figure 3 with the axis of tank symmetry being the z-axis and the direction of earthquake ground motion being the (positive) x-axis, and the origin at the center of oil-water interface. We will also need the usual (r,z,θ) cylindrical coordinate system.

Let $\vec{v}(x,y,z;t)$ denote the velocity vector of the fluid particle at $(x,y,z;t)$. Then, based on the usual assumptions of inviscid and incompressible fluids, irrotational motion and small amplitude waves, the linearized momentum equations of fluid motion read

$$\frac{\partial \vec{v}_o}{\partial t} = -\frac{1}{\rho_o} \nabla P_o \,,$$

$$\frac{\partial \vec{v}_w}{\partial t} = -\frac{1}{\rho_w} \nabla P_w \,. \tag{3.1}$$

We use the suffixes o and w to represent quantities pertaining to oil and water, respectively.

Take the curl of (3.1) and apply the continuity equations

$$\nabla \cdot \vec{v}_o = 0 \quad ,$$
$$\nabla \cdot \vec{v}_w = 0 \quad , \tag{3.2}$$

we obtain

$$\nabla^2 P_o = 0 \qquad \text{in} \quad V_o \quad ,$$
$$\nabla^2 P_w = 0 \qquad \text{in} \quad V_w \quad . \tag{3.3}$$

Let $\ddot{\vec{f}}_h(t)$ denote the horizontal ground acceleration induced by an earthquake, then since the translatory velocity in the x-direction should be equal to $\dot{\vec{f}}_h$, we have

$$\frac{\partial P_o}{\partial n} = - \rho_o \left[(\ddot{\vec{f}}_h + \ddot{\vec{x}}) \cdot \vec{n} \right] \qquad \text{across } \partial V_{ow} \quad ,$$
$$\frac{\partial P_w}{\partial n} = - \rho_w \left[(\ddot{\vec{f}}_h + \ddot{\vec{x}}) \cdot \vec{n} \right] \qquad \text{across } \partial V_{ww} \quad . \tag{3.4}$$

In (3.4), $\frac{\partial}{\partial n} = \vec{n} \cdot \nabla$, and $\vec{n}$ is the unit outward normal to the tank boundary. $\ddot{\vec{x}}$ is the acceleration of the tank structure relative to the ground. The presence of the $\ddot{\vec{x}}$ term is dictated by the flexibility of the tank shell. Now if the tank had a roof which is rigid, we would have

$$\frac{\partial P_o}{\partial z} = 0 \qquad \text{along } \partial V_{ot} \quad .$$

However, to allow for the general case where the "roof" is also flexible (and more likely, inseparable from the wall as in the case of a half-dome tank), we will use the same boundary condition as in (3.4). Consequently, we include ∂V_{ot} as part of ∂V_{ow}. The assumption of a rigid floor support implies that

$$\frac{\partial P_w}{\partial z} = 0 \qquad (3.5)$$

along ∂V_{wb} $(z = -h_w)$.

Now, if we let $\zeta(x,y,z;t)$ stand for the displacement of the oil-water interface from its equilibrium position, the (linearized) dynamic interfacial condition affirms the continuity of the total pressure such that

$$P_{To} - P_{Tw} = (\rho_o - \rho_w)\, g\zeta \qquad \text{along} \quad z = 0 \ . \qquad (3.6)$$

And the (linearized) kinematic condition maintains fluid particles on interface to stay on the interface (continuity of vertical velocity) so that

$$\frac{\partial^2 \zeta}{\partial t^2} = -\frac{1}{\rho_o}\frac{\partial P_o}{\partial z} = -\frac{1}{\rho_w}\frac{\partial P_w}{\partial z} \qquad \text{along} \quad z = \zeta \ . \qquad (3.7)$$

Under the small amplitude assumption, only minor error is incurred by evaluating equation (3.7) along $z = 0$. If we assume that the gravitational effects are small compared to the forced oscillation so that

$$g\,\frac{(\rho_w - \rho_o)}{\rho_o}\,\frac{T^2}{L} \ll 1 \ , \qquad (3.8)$$

Equation (3.6) is then reduced to

$$P_o = P_w \qquad \text{along } z = 0 \ , \qquad (3.9)$$

so that sloshing waves at the oil and water interface are ignored. Here, L and T are the characteristic scales of length and time, respectively. This assumption can be justified because earthquake excitations are generally of high frequencies. In our validation of the computer results (§ 4), we included such surface wave effects and found that the calculated response was practically frequency independent for moderately high frequency values.

B. Solution via Variational Principle

Since the tanks under consideration are of general shape except for axisymmetry, no closed form analytic solution is readily available. We now present as a prelude to the finite element solution scheme, a variational functional in P_o and P_w whose stationarity is equivalent to the system of equations of §A being satisfied. It is well-known that in general, the less restrictive Galerkin method produces results identical to those one would obtain from any variational principle. We choose to use the variational method to illuminate the process, demonstrating the matrix assembly along the way. The Galerkin method will be employed in the exterior problem to simplify our presentation.

Consider the functional

$$\begin{aligned} F(P_o,P_w) = & \int_{V_o} \frac{1}{2\rho_o} (\nabla P_o)^2 \, dV_o + \int_{\partial V_{ow}} P_o \left[(\ddot{\vec{f}}_n + \ddot{\vec{x}}) \cdot \vec{n} \right] dA_{ow} \\ & - \int_{\partial V_i} \frac{1}{2\rho_w} (P_w - P_o) \frac{\partial P_w}{\partial z} \, dA_i \\ & + \int_{V_w} \frac{1}{2\rho_w} (\nabla P_w)^2 \, dV_w + \int_{\partial V_{ww}} P_w \left[(\ddot{\vec{f}}_n + \ddot{\vec{x}}) \cdot \vec{n} \right] dA_{ww} \\ & - \int_{\partial V_i} \frac{1}{2\rho_o} (P_w - P_o) \frac{\partial P_o}{\partial z} \, dA_i \qquad (3.10) \end{aligned}$$

where we have used $(\nabla P)^2$ to denote $\nabla P \cdot \nabla P$. Clearly if P_o and P_w satisfy the system of equations of §A, then $\delta F(P_o,P_w) = 0$. We now show that, conversely, if $\delta F(P_o,P_w) = 0$ then the system of §A is solved. For simplicity, we will drop all the differential symbol in the integrals provided that there is no chance of confusion.

Now,

$$
\begin{aligned}
\delta F(P_o,P_w) = {} & \int_{V_o} \frac{1}{\rho_o} \nabla P_o \cdot \nabla \delta P_o + \int_{\partial V_{ow}} [(\vec{\ddot{f}}_n + \vec{\ddot{x}}) \cdot \vec{n}]\, \delta P_o \\
& - \frac{1}{2\rho_w} \int_{\partial V_i} (P_w - P_o) \frac{\partial \delta P_w}{\partial z} - \frac{1}{2\rho_w} \int_{\partial V_i} \frac{\partial P_w}{\partial z} \delta P_w \\
& + \frac{1}{2\rho_w} \int_{\partial V_i} \frac{\partial P_w}{\partial z} \delta P_o \\
& + \int_{V_w} \frac{1}{\rho_w} \nabla P_w \cdot \nabla \delta P_w + \int_{\partial V_{ww}} [(\vec{\ddot{f}}_n + \vec{\ddot{x}}) \cdot \vec{n}]\, \delta P_w \\
& - \frac{1}{2\rho_o} \int_{\partial V_i} (P_w - P_o) \frac{\partial \delta P_o}{\partial z} - \frac{1}{2\rho_o} \int_{\partial V_i} \frac{\partial P_o}{\partial z} \delta P_w \\
& + \frac{1}{2\rho_o} \int_{\partial V_i} \frac{\partial P_o}{\partial z} \delta P_o \quad . \qquad (3.11)
\end{aligned}
$$

From Green's identity, we have

$$\int_{V_o} \frac{1}{\rho_o} \nabla P_o \cdot \nabla\delta P_o = - \int_{V_o} \frac{1}{\rho_o} \nabla^2 P_o \delta P_o$$

$$- \int_{\partial V_i} \frac{1}{\rho_o} \frac{\partial P_o}{\partial z} \delta P_o + \int_{\partial V_{ow}} \frac{1}{\rho_o} \frac{\partial P_o}{\partial n} \delta P_o \qquad (3.12)$$

Note that along δV_i we have $\frac{\partial P_o}{\partial n} = - \frac{\partial P_o}{\partial z}$ since $\vec{n}$ is pointing downward. And from $\frac{\partial P_w}{\partial n} = \frac{\partial P_w}{\partial z}$ we deduce

$$\int_{V_w} \frac{1}{\rho_w} \nabla P_w \cdot \nabla\delta P_w = - \int_{V_w} \frac{1}{\rho_w} \nabla^2 P_w \delta P_w - \int_{\partial V_{wb}} \frac{1}{\rho_w} \frac{\partial P_w}{\partial z} \delta P_w$$

$$+ \int_{\partial V_i} \frac{1}{\rho_w} \frac{\partial P_w}{\partial z} \delta P_w + \int_{\partial V_{ww}} \frac{1}{\rho_w} \frac{\partial P_w}{\partial n} \delta P_w \; . \qquad (3.13)$$

Substituting (3.12) and (3.13) into (3.14) we obtain

$$
\begin{aligned}
\delta F(P_o,P_w) = &- \int_{V_o} \frac{1}{\rho_o} \nabla^2 P_o \delta P_o \\
&+ \int_{\partial V_{ow}} \frac{1}{\rho_o}\left(\frac{\partial P_o}{\partial n} + \rho_o \; [(\ddot{\vec{f}}_n + \ddot{\vec{x}}) \cdot \vec{n}]\right) \delta P_o \\
&+ \int_{\partial V_i} \frac{1}{2}\left(\frac{1}{\rho_w}\frac{\partial P_w}{\partial z} - \frac{1}{\rho_o}\frac{\partial P_o}{\partial z}\right) \delta P_o \\
&+ \int_{\partial V_i} \frac{1}{2}\left(\frac{1}{\rho_w}\frac{\partial P_w}{\partial z} - \frac{1}{\rho_o}\frac{\partial P_o}{\partial z}\right) \delta P_w \\
&- \int_{\partial V_i} \frac{1}{2\rho_w} (P_w - P_o) \frac{\partial \delta P_w}{\partial z} - \int_{\partial V_i} \frac{1}{2\rho_o} (P_w - P_o) \frac{\partial \delta P_o}{\partial z} \\
&- \int_{V_w} \frac{1}{\rho_w} \nabla^2 P_w \delta P_w + \int_{\partial V_{wb}} \frac{1}{\rho_w} \frac{\partial P_w}{\partial z} \delta P_w \\
&+ \int_{\partial V_{ww}} \frac{1}{\rho_w}\left(\frac{\partial P_w}{\partial n} + \rho_w \; [(\ddot{\vec{f}}_n + \ddot{\vec{x}}) \cdot \vec{n}]\right) \delta P_w \; . \qquad (3.14)
\end{aligned}
$$

If we observe now that each δ-differential quantity can be varied independently, for $\delta F(P_o,P_w)$ to be zero, each of the integrals in (3.14) must be identically zero. We thus have the system of equations of §A, and our statement is verified.

C. Finite-Element Approximation

By utilizing the axisymmetry of the tank, the interior fluid domain composed of V_0 and V_w may be discretized into a finite-element system comprising of toroidal elements with quadrilateral (vertical) cross-section (cylindrical elements at the axis of symmetry). If we use the cylindrical coordinates (r,z,θ) to define the global coordinate system, and the natural coordinates (s,t,θ) within each element as the local coordinate system (see Figure 4, $-1 \leq s \leq 1$, $-1 \leq t \leq 1$) we can write the coordinate transformation on element e as

$$\begin{aligned} r &= \sum_{k=1}^{4} N_k^e(s,t)\, r_k^e = \{N^e\}^T\{r^e\} \ , \\ z &= \sum_{k=1}^{4} N_k^e(s,t)\, z_k^e = \{N^e\}^T\{z^e\} \ , \end{aligned} \tag{3.15}$$

where

$$\begin{aligned} N_1^e &= (1-s)(1-t)/4 \ , \quad & N_2^e &= (1+s)(1-t)/4 \ , \\ N_3^e &= (1+s)(1+t)/4 \ , \quad & N_4^e &= (1-s)(1+t)/4 \ . \end{aligned} \tag{3.16}$$

are the bilinear interpolation functions, and $(r_k^e,\ z_k^e,\ \theta)$, $k = 1,\ldots 4$ are the global coordinates for the four nodes of the quadrilateral cross-section. Within each element e, the hydrodynamic pressure is then expressed as

$$P^e = \sum_{k=1}^{4} N_k^e \cos\theta \cdot P_k^e = \{N^e\}^T\{P^e\} \cos\theta \ . \tag{3.17}$$

From §B, the system of equations of §A can be solved by imposing $\delta F(P_o,P_w) = 0$. We now do this at the element level, assembling the element stiffness matrices and solve the unknowns $\{p^e\}$.

We first rewrite (3.10) as

$$F(P_o,P_w) = \int_{V_o} \frac{1}{2\rho_o} (\nabla P_o)^2 \, dV_o \qquad I_1$$

$$+ \int_{V_w} \frac{1}{2\rho_w} (\nabla P_w)^2 \, dV_w \qquad I_1'$$

$$+ \int_{\partial V_{ow}} P_o \, [(\dot{\vec{f}}_n + \dot{\vec{x}}) \cdot \vec{n}] \, dA_{ow} \qquad I_2$$

$$+ \int_{\partial V_{ww}} P_w \, [(\dot{\vec{f}}_n + \dot{\vec{x}}) \cdot \vec{n}] \, dA_{ww} \qquad I_2'$$

$$+ \int_{\partial V_i} \frac{1}{2\rho_o} P_o \frac{\partial P_o}{\partial z} \, dA_i \; - \qquad I_3$$

$$- \int_{\partial V_i} \frac{1}{2\rho_w} P_w \frac{\partial P_w}{\partial z} \, dA_i \qquad I_3'$$

$$+ \int_{\partial V_i} \frac{1}{2\rho_w} P_o \frac{\partial P_w}{\partial z} \, dA_i \qquad I_4$$

$$- \int_{\partial V_i} \frac{1}{2\rho_o} P_w \frac{\partial P_o}{\partial z} \, dA_i \qquad I_4'$$

and then evaluate each of these integrals numerically based on the finite-element scheme in the following sections. Due to the similarity between each I_k and I_k', only the details of I_k will be presented.

C1. Integral I_1

If we assume that the domain V_o is divided into E_o number of elements, we can approximate I_1 by

$$I_1 = \sum_{e=1}^{E_o} \int_{V_o^e} \frac{1}{2\rho_o} \left(\nabla P_o^e\right)^2 dV_o^e$$

$$= \sum_{e=1}^{E_o} {}_{V_o^e} \frac{1}{2\rho_o} \left[\nabla\left(\{N^e\}^T \{P_o^e\} \cos\theta\right)\right]^2 dV_o^e$$

$$= \sum_{e=1}^{E_o} \{P_o^e\}^T \int_{V_o^e} \frac{1}{2\rho_o} \left(\nabla\{N^e\} \cos\theta\right) \left(\nabla\{N^e\}^T \cos\theta\right) dV_o^e \{P_o^e\} \ .$$

Denote the integral in the above formula by $[K_{V_o^e}]$, then since

$$\int_{V_o^e} dV_o^e = \int_0^{2\pi} \int_{A_o^e} r dr dz \, d\theta \ ,$$

A_o^e being the area of the finite-element (vertical) cross-section, and since

$$\frac{\partial}{\partial x} = -\cos\theta\frac{\partial}{\partial r} - \frac{\sin\theta}{r}\frac{\partial}{\partial\theta},$$
$$\frac{\partial}{\partial y} = -\sin\theta\frac{\partial}{\partial r} + \frac{\cos\theta}{r}\frac{\partial}{\partial\theta}, \tag{3.18}$$

We can rewrite $[K_{V_o}{}^e]$ as

$$\int_0^{2\pi}\int_{A_o{}^e}\frac{1}{2\rho_o}\left(\left\{\frac{\partial N^e}{\partial r}\right\}^T\left\{\frac{\partial N^e}{\partial r}\right\}\cos^2\theta + \left\{\frac{\partial N^e}{\partial z}\right\}^T\left\{\frac{\partial N^e}{\partial z}\right\}\cos^2\theta + \left\{N^e\right\}^T\left\{N^e\right\}\frac{\sin^2\theta}{r^2}\right) r\,dr\,dz\,d\theta.$$

Thus the (i,j)-th entry of $[K_{V_o}{}^e]$ is

$$[K_{V_o}{}^e]_{ij} = \frac{\pi}{2\rho_o}\int_{A_o{}^e}\left(\frac{\partial N_i{}^e}{\partial r}\frac{\partial N_j{}^e}{\partial r} + \frac{\partial N_i{}^e}{\partial z}\frac{\partial N_j{}^e}{\partial z} + \frac{N_i{}^e N_j{}^e}{r^2}\right) r\,dr\,dz,\quad i,j=1,2,3,4.$$

To facilitate the evaluation of $[K_{V_o}{}^e]_{ij}$, it is convenient to transform the integral into the local coordinates of e. Thus,

$$\int_{A_o{}^e} dr\,dz = \int_{-1}^{1}\int_{-1}^{1} |J|\,ds\,dt ,$$

where $|J|$ is the determinant of the Jacobian

$$[J] = \begin{pmatrix} \frac{\partial r}{\partial s} & \frac{\partial z}{\partial s} \\ \frac{\partial r}{\partial t} & \frac{\partial z}{\partial t} \end{pmatrix} = \begin{Bmatrix} \frac{\partial}{\partial s} \\ \frac{\partial}{\partial t} \end{Bmatrix} \{N^e\}^T \begin{pmatrix} r_1{}^e & z_1{}^e \\ r_2{}^e & z_2{}^e \\ r_3{}^e & z_3{}^e \\ r_4{}^e & z_4{}^e \end{pmatrix}$$

The last relation is obtained from (3.16). Now $[K_{V_o}{}^e]_{ij}$ can be evaluated over element e using the natural coordinates.

We can write I_1 in terms of matrices and vectors relating to all nodes if we extend the $\{P_o{}^e\}$'s to $\{P_o\}$ by placing zeros at the appropriate components. Recall that the components of $\{P_o\}$ is ordered according to the global nodal-circle number sequencing. Then

$$I_1 = \{P_o\}^T \, [K_{V_o}] \, \{P_o\}, \tag{3.19}$$

where $[K_{V_o}]$ is the global matrix whose (i,j)-th entry is

$$\sum [K_{V_o}{}^e]_{e(i)e(j)}$$

The sum is taken over all elements e where nodes i and j belong to simultaneously (e(i) denotes the local node number of i). Since each $[K_{V_o}{}^e]$ is symmetric, so is $[K_{V_o}]$.

C2. Integral I_2

Assuming that V_o has E_{ow} elements in contact with ∂V_{ow}, we can approximate I_2 by

$$I_2 = \sum_{e=1}^{E_{ow}} \int_{\partial V_{ow}} P_o{}^e \, [(\ddot{\vec{f}}_n + \ddot{\vec{x}}) \cdot \vec{n}] \, dA_{ow}{}^e \tag{3.20}$$

Under the structural finite-element discretization, we introduce the nodal acceleration vector $\{\ddot{X}\}$ (cf. Figure 5):

$$\{\ddot{X}\}^T = (\ddot{X}_{1r}, \ddot{X}_{1z}, \ddot{X}_{1\theta}, \ddot{X}_{2r}, \ddot{X}_{2z}, \ddot{X}_{2\theta}, \ldots, \ddot{X}_{Nr}, \ddot{X}_{Nz}, \ddot{X}_{N\theta}). \tag{3.21}$$

And if for each β, the local angle between the normal $\vec{n}$ and the XY-plane, we define the Nx3N transformation matrix [G] by

$$[G](\beta) = \begin{bmatrix} \cos\beta, & \sin\beta, & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & \cos\beta, & \sin\beta, & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \cos\beta, & \sin\beta, & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \cos\beta, & \sin\beta, & 0 \end{bmatrix} \tag{3.22}$$

We can then write

$$(\ddot{\vec{f}}_h + \ddot{\vec{x}}) \cdot \vec{n} = \{N^e\}^T [G] \left(\{\ddot{f}_h^e\} + \{\ddot{x}^e\}\right) \cos\theta \ . \tag{3.23}$$

along the A_{ow}^e surface. Where we have used the same bilinear interpolation functions of (3.16), now acting on the inner fluid-structure interfacial nodes.

Now we can write

$$I_2 = \sum_{e=1}^{E_{ow}} \int_{z_\ell^e}^{z_u^e} \int_0^{2\pi} \{P_o^e\}^T \{N^e\} \{N^e\}^T [G] (\{\ddot{f}_h^e\} + \{\ddot{x}^e\}) \cos^2\theta \, r d\theta dz$$

$$= \{P_o\}^T [O] \left(\{\ddot{f}_h\} + \{\ddot{x}\}\right), \tag{3.24}$$

where z_ℓ^e and z_u^e delimit the vertical extent of element e on V_{ow}, and the global matrix [O] is assembled from the element matrices

$$\int_{z_\ell^e}^{z_u^e} \pi r \{N^e\} \{N^e\}^T [G] \, dz \qquad , \quad e=1,\ldots,E_{ow} \tag{3.25}$$

and

$$\{\ddot{f}_h\}^T = \{L\}\,\ddot{f}_h = (1,0,-1,1,0,-1,\ldots,1,0,-1)\,\ddot{f}_h \quad , \tag{3.26}$$

{L} is the vector which translates ground motion to loads on the nodal-circles.

C3. Integral I_3

$$I_3 = \sum_{e=1}^{E_i} \int_{\partial V_i^e} \frac{1}{2\rho_o} \left(\{N^e\}^T \{P_o^e\} \left\{\frac{\partial N^e}{\partial z}\right\}^T \{P_o^e\} \right) \cos^2\theta \, dA_i^e$$

$$= \sum_{e=1}^{E_i} \{P_o^e\}^T \int_{r_\ell^e}^{r_u^e} \frac{\pi}{2\rho_o} \{N^e\} \left\{\frac{\partial N^e}{\partial z}\right\}^T r dr \, \{P_o^e\} \ ,$$

where r_ℓ^e and r_u^e delimit the radial extent of element e. Also note that N^e and its derivatives are to be evaluated at $z = 0$.

Again, we can write I_3 in global form as

$$I_3 = \{P_o\}^T [K_{io}] \{P_o\} \ . \tag{3.27}$$

C4. Integral I_4

$$I_4 = \sum_{e=1}^{E_i} \int_{\partial V_i^e} \frac{1}{2\rho_w} \left(\{N_o^e\}^T \{P_o^e\} \left\{\frac{\partial N_w^e}{\partial z}\right\}^T \{P_w^e\}\right) \cos^2\theta \, dA_i^e$$

$$= \sum_{e=1}^{E_i} \{P_o^e\}^T \int_{r_\ell^e}^{r_u^e} \frac{\pi}{2\rho_w} \{N_o^e\} \left\{\frac{\partial N_w^e}{\partial z}\right\}^T r dr \; \{P_w^e\}$$

Note that we have added subscripts o and w to N^e here because this integral involves both the upper and the lower layers. In terms of the local coordinates, it is remarked that for $\{N_o^e\}$, we have $t = -1$ and for $\left\{\frac{\partial N_w^e}{\partial z}\right\}^T$ we have $t = 1$.

In the global form we have

$$I_4 = \{P_o\}^T [K_{ow}] \{P_w\}. \tag{3.28}$$

D. Total Global Matrix

Summarizing and treating $\{P_o\}$ and $\{P_w\}$ as unknowns, the functional (3.10) becomes

$$\begin{aligned} F(\{P_o\},\{P_w\}) = {} & \{P_o\}^T[K_{V_o}]\{P_o\} + \{P_w\}^T[K_{V_w}]\{P_w\} \\ & + \{P_o\}^T[O] \; (\{\ddot{f}_h\}+\{\ddot{x}\}) + \{P_w\}^T[W] \; (\{\ddot{f}_h\}+\{\ddot{x}\}) \\ & + \{P_o\}^T[K_{io}]\{P_o\} + \{P_w\}^T[K_{iw}]\{P_w\} \\ & + \{P_o\}^T[K_{ow}]\{P_w\} + \{P_w\}^T[K_{wo}]\{P_o\}. \end{aligned} \tag{3.29}$$

For F to be stationary, we require

$$\frac{\partial F}{\partial P_{ok}} = 0 \quad , \quad k = 1,\ldots,NO$$

$$\frac{\partial F}{\partial P_{wk}} = 0 \quad , \quad k = 1,\ldots,NW. \tag{3.30}$$

Since $P_o = P_w$ at the interface, we have a set of NO + NW - (number of interfacial nodes) equations, which gives

$$2[K_{V_o}]\{P_o\} + 2[K_{io}]\{P_o\} + [K_{ow}]\{P_w\} + [K_{wo}]^T\{P_w\}$$
$$= - [O] \left(\{\ddot{f}_h\} + \{\ddot{x}\}\right),$$

and

$$2[K_{V_w}]\{P_w\} + 2[K_{iw}]\{P_w\} + [K_{ow}]^T\{P_o\} + [K_{wo}]\{P_o\}$$
$$= - [W] \left(\{\ddot{f}_h\} + \{\ddot{x}\}\right) . \tag{3.31}$$

If we define $\{P_{ow}\}$ to be the vector of interior nodal pressure distributions, ordered according to the global nodal number sequence (thus no repetition on interface), we can combine the matrix equations of (3.31) to assemble

$$[K_{INT}] \{P_{ow}\} = - [OW] \left(\{\ddot{f}_h\} + \{\ddot{x}\}\right). \tag{3.32}$$

To solve for the inner pressure distribution (at least in the case of a rigid tank, when $\{\ddot{x}\} = 0$), we can solve (3.32) by Gaussian elimination routines serving this purpose are readily available. However, as $\{\ddot{x}\}$ is still unknown in the general flexible case, (3.32) will be used as input to the general structural equation of motion to solve for the earthquake response later.

3.1.2 Exterior Water Region

A. Problem Formulation

Consider the same axisymmetric tank of §3.1.1 now submerged in water of depth H as depicted in Figure 3. We use the same coordinate system as before, extended to the exterior water region, introducing only the additional boundary surfaces.

Again, under the assumptions of water being inviscid and incompressible, undergoing motion which is irrotational, and that wave amplitudes are small, the governing field equation is

$$\nabla^2 P_w = 0 \qquad \text{in } \; V \tag{3.33}$$

where P_w is the water hydrodynamic pressure. Since water is the only fluid of concern here, we will henceforth omit the subscript w.

The rigid floor support implies the homogeneous boundary condition at the sea bottom since we only consider horizontal ground motion:

$$\frac{\partial P}{\partial z} = 0 \qquad z = -h_w \quad . \tag{3.34}$$

Along the laternal surface of the tank, we have as before

$$\frac{\partial P}{\partial n} = - \rho_w [(\ddot{\vec{f}}_h + \ddot{\vec{x}}) \cdot \vec{n}] \qquad \text{across } S_i \;, \tag{3.35}$$

$\ddot{\vec{x}}$ enters because of the flexibility of the tank shell.

For the free surface boundary condition, generally one combines the dynamic condition $P = \rho_w g(\eta - z)$ with the kinematic condition

$$\frac{\partial^2 \eta}{\partial t^2} = - \frac{1}{\rho_w} \frac{\partial P}{\partial z} \text{ to obtain } \frac{\partial^2 P}{\partial t^2} = - g \frac{\partial P}{\partial z} \quad \text{at } z = 0.$$

However, as demonstrated by Liaw and Chopra (1973), the surface waves have negligible effects on the hydrodynamic response of the fluid-tank system except at very low frequencies. Since most of the earthquake excitation energy is contained in higher frequency components, we can safely assume that the gravity effects are of little consequence. Consequently, we use

$$P = 0 \qquad \text{at } z = H-h_w , \tag{3.36}$$

as the free surface boundary condition.

Finally, since we are dealing with an infinite domain, in order to have a bounded solution, we further require that

$$P \to 0 \qquad \text{as } r \to \infty . \tag{3.37}$$

These conditions are duly adjusted, if necessary, to account for any bottom irregularities.

B. Solution via Galerkin's Method/Hybrid Element Approximation

Since the exterior water region is an infinite domain, the size of the fininte-element discretization is an important issue. A straightforward application of the finite-element method, even with a domain truncation adjusted to the convergence rate, may be potentially cumbersome and costly, due to the conflicting requirements that the size of the elements be a fraction of the shortest wavelength, and that the outer truncation boundary be far enough away from the longest waves. Instead, we adopt the hybrid approach of using the available analytic solution for P at a few wavelengths away from the tank, as soon as most of the significant geometrical irregularities are passed. We introduce a fictitious (cylindrical) surface S_f here and use the analytic P to go backward to match the finite-element solution.

Again using a finite-element discretization of the exterior region between S_i and S_f composing of ring-shaped elements having quadrilateral (vertical) cross-sections, we have, as in (3.17) of §3.1.1

$$P^e = \sum_{k=1}^{4} N_k{}^e \cos\theta \cdot P_k{}^e \ ,$$

$\{N_e\}$ is as defined in (3.16), but note that it now acts on the exterior nodal-circles. Let us denote $N_k{}^e\cos\theta$, the finite-element interpolation functions, by $T_k{}^e$. The Galerkin criterion requires that

$$\int_V T_k(\nabla^2 P)dV = 0 \ . \qquad\qquad k = 1,2,3,4. \qquad\qquad (3.38)$$

From Green's theorem we have

$$-\int_V (\nabla T_k \cdot \nabla P)\ dV + \int_S T_k \frac{\partial P}{\partial n}\, dS = 0 \ , \qquad\qquad k = 1,2,3,4, \qquad\qquad (3.39)$$

where S is the union of all the surface of the discretized domain.

Now

$$\int_V (\nabla T_k \cdot \nabla P)dV$$

$$= \sum_{V^e} \sum_{\ell=1}^{4} \int_{V_e} \left(\frac{\partial T_k{}^e}{\partial r} \frac{\partial T_\ell{}^e}{\partial r} + \frac{\partial T_k{}^e}{\partial z} \frac{\partial T_\ell{}^e}{\partial z} + \frac{1}{r^2} \frac{\partial T_k{}^e}{\partial \theta} \frac{\partial T_\ell{}^e}{\partial \theta} \right) P_\ell{}^e dV^e$$

$$= \sum_{V^e} \sum_{\ell=1}^{4} \int_0^{2\pi} \int_{A^e} \left(\frac{\partial N_k^e}{\partial r} \frac{\partial N_\ell^e}{\partial r} \cos^2\theta + \frac{\partial N_k^e}{\partial z} \frac{\partial N_\ell^e}{\partial z} \cos^2\theta + \frac{N_k^e N_\ell^e}{r^2} \sin^2\theta \right) r dr dz d\theta \ P_\ell^e \qquad (3.40)$$

The similarity between the last expression under the intergral signs and that of $[K_{V_o}{}^e]$ in Section C1 of §3.1.1 is quite apparent. By letting k run from 1 through 4, we can assemble the element matrix $[H_V{}^e]$, and it is then a trivial matter to assemble this into the global form of

$$[H_V]\{P\} \ . \tag{3.41}$$

Recall that {P} is a vector of dimension NE, NE being the number of exterior water nodal-circles.

The second term of (3.39) can be expressed as

$$\int_S T_k \frac{\partial P}{\partial n}\, dS = \int_{S_s} T_k \frac{\partial P}{\partial z}\, dS_s + \int_{S_i} T_k \frac{\partial P}{\partial n}\, dS_i - \int_{S_b} T_k \frac{\partial P}{\partial z}\, dS_b + \int_{S_f} T_k \frac{\partial P}{\partial r}\, dS_f . \tag{3.42}$$

By (3.34) and (3.36), the first and third terms on the right-hand-side of (3.42) vanish. Since P = 0 on S_s, the corresponding rows and columns in the matrix $[H_V]$ also vanish. The solution procedure is therefore simplified by removing all equations associated with nodes at the surface. From (3.35) we have

$$\int_{S_i} T_k \frac{\partial P}{\partial n}\, dS_i = \int_{S_i} - \rho_w T_k \ [(\ddot{\vec{f}}_h + \ddot{\vec{x}}) \cdot \vec{n}]\ dS_i \ .$$

If we use the same $\{N_S{}^e\}$ as defined in (3.16) of §3.1.1 C, acting now on the exterior water-tank interfacial nodes, based on (3.23), we can rewrite

$$\int_{S_i} T_k \frac{\partial P}{\partial n}\, dS_i = \sum_{S^e} \int_0^{2\pi} \int_{z_\ell{}^e}^{z_u{}^e} - \rho_w T_k{}^e \{N_S{}^e\}^T [G] (\{\ddot{f}_h\} + \{\ddot{x}\}) \cos\theta \ r dz d\theta$$

$$= \int_{S^e} \int_{z_\ell{}^e}^{z_u{}^e} -\rho_w \pi r \ N_k{}^e \{N_S{}^e\}^T [G] (\{\ddot{f}_h\} + \{\ddot{x}\}) dz \tag{3.43}$$

If we let k run from 1 through 4, we can then assemble the following global form

$$- [B] (\{\ddot{f}_h\} + \{\ddot{x}\}). \tag{3.44}$$

To evaluate the last term of (3.42) we need to know the pressure distribution on S_f, which is obtained from the analytic representation for P outside of S_f,

$$P_E = \sum_{m=1}^{\infty} \alpha_m K_\ell(k_m r) \cos k_m(z+h_w) \cos\theta . \tag{3.45}$$

where $k_m = \frac{(2m-1)\pi}{2H}$, and K_ℓ is the modified Bessel function of the second kind of order ℓ. α_m is to be determined. Consequently, along S_f we have

$$\frac{\partial P}{\partial n} = \frac{\partial P_E}{\partial r} = - \sum_{m=1}^{\infty} \frac{\alpha_m k_m}{2} [K_0(k_m r_f) + K_2(k_m r_f)] \cos k_m(z+h_w) \cos\theta \tag{3.46}$$

where r_f is the radial coordinate of S_f. If we truncate the series to leave with M terms, we can write (3.45) as

$$\frac{\partial P}{\partial n} = - \sum_{m=1}^{M} d_m \alpha_m , \tag{3.47}$$

with

$$d_m = \frac{k_m}{2} [K_0(k_m r_f) + K_2(k_m r_f)] \cos k_m(z+h_w) \cos\theta .$$

Therefore,

$$\int_{S_f} T_k \frac{\partial P}{\partial n} dS_f = -\int_0^{2\pi} \int_{-h_w}^{H-h_w} T_k \sum_{m=1}^{M} d_m \alpha_m r_f dz d\theta$$

$$= -\sum_{m=1}^{M} \sum_{S_f^e} \int_0^{2\pi} \int_{z_\ell^e}^{z_u^e} T_k^e d_m \; r_f dz d\theta \; \alpha_m$$

$$= -\sum_{m=1}^{M} \sum_{S_f^e} q_{mk}^e \; \alpha_m \; . \tag{3.48}$$

Now the α_m's are determined (in terms of P) from the continuity requirement of pressure across the fictitious surface S_f:

$$P = P_E \qquad\qquad \text{at } S_f \; . \tag{3.49}$$

Using d_m as the weighting function, we get

$$\int_{S_f} d_m P dS_f = \int_{S_f} d_m P_E dS_f \tag{3.50}$$

Substituting the expression $P^e = \sum_{k=1}^{4} T_k^e P_k^e$ and the expression (3.45) for P_E at S_f (truncated to M terms) into (3.50), we have

$$\sum_{k=1}^{4} \sum_{S_f^e} q_{mk}^e \; P_k^e = \sum_{j=1}^{M} \alpha_j \; a_{mj} \; . \tag{3.51}$$

where

$$a_{mj} = \int_0^{2\pi} \int_{-h_w}^{H-h_w} d_m K_1(k_j r_f) \cos k_j(z+h_w) \cos\theta \, r_f dz d\theta$$

$$= \int_0^{2\pi} \int_{-h_w}^{H-h_w} \frac{r_f k_m}{2} K_1(k_j r_f) [K_o(k_m r_f) + K_2(k_m r_f)] \cos k_m(z+h_w) \cos k_j(z+h_w) \cos^2\theta dz d\theta$$

$$= \begin{cases} 0 & \text{if } m \neq j \\ \frac{\pi}{4} k_m r_f H \, K_1(k_m r_f) \, [K_o(k_m r_f) + K_2(k_m r_f)] & \text{if } m = j. \end{cases} \qquad (3.52)$$

Substituting (3.51) into (3.48) we get

$$\int_{S_f} T_k \frac{\partial P}{\partial n} dS_f = \sum_{m=1}^{M} \frac{1}{a_{mm}} \left(\sum_{S_f^e} q_{mk}^e\right) \sum_{\ell=1}^{4} \left(\sum_{S_f^e} q_{m\ell}^e \, P_\ell^e\right) . \qquad (3.53)$$

Define the Mx4 element matrix $[Q^e]$ as having q_{mk}^e as the (m,k)-th entry, and the MxM diagonal matrix $[A]^{-1}$ of entries $1/a_{mm}$, we can form the global equivalent

$$[Q]^T [A]^{-1} [Q] \; \{P\} \; . \qquad (3.54)$$

Consequently, we can write (3.39) in the equivalent global form

$$- [H_V]\{P\} - [Q]^T [A]^{-1} [Q] \; \{P\} = [B](\{\ddot{f}_h\} + \{\ddot{x}\}). \qquad (3.55)$$

As in §3.1.1 D, (3.55) will be input to the equation of motion to solve for the earth quake response in the following section.

3.2 Dynamic Behavior of Fluid-Structure System

The equation of motion of the tank structure under consideration can be written in terms of our finite-element discretization as

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = -\{E\} - \{P_S\}, \tag{3.56}$$

with $\{x\}$ the vector of nodal displacements relative to the tank support, expressed in the nodal r, z and θ components. [M] is the mass matrix

$$[M] = \text{diag}\,\frac{1}{2}\,\{M_1, M_1, M_1, M_2, M_2, M_2, \ldots, M_N, M_N, M_N\}\ , \tag{3.57}$$

with M_k the mass of the tank material between neighboring nodal-circles, which is lumped at the k-th node. [C] and [K] are the damping and stiffness matrices.

$$\{E\} = [M]\{\ddot{f}_h\}\ . \tag{3.58}$$

Finally, $\{P_S\}$ is the vector of nodal loads associated with the hydrodynamic pressures. As these pressures act only on the inner and outer surfaces of the tank, the elements in $\{P_S\}$ corresponding to non-interfacial nodes are zero. Indeed, $\{P_S\}$ has many zero entries, since the pressures act in the direction of the surface normal, thus all θ-components (circumferential) vanish, and if a section of the interface (inner or outer) is cylindrical, the corresponding z-components also vanish.

Since the materials used in the construction of the tank is assumed to be flexible, the structural deformation entails the coupling of the free vibration with the hydrodynamic interaction. Generally based on the algorithm selected, the coupling of this sort can be categorized into a weak and a strong one. In weak coupling, the fluid pressure is first used to "drive" the structure into a new shape, and a new pressure field in turn is evaluated using this new configuration. Strong coupling avoids these cycles, forces acting on the structural nodes and on the fluids are determined simultaneously. We use the latter.

If we now strip off all non-interfacial nodal components from $\{P_{ow}\}$ ((3.32) of §3.1.1) and $\{P\}$ ((3.55) of §3.1.2), rewrite them in terms of the r,z,θ components, and extend them to $\{P_S\}$; at the same time picking out the accompanying terms from $[K_{INT}]$ and $[H_V] + [Q]^T[Q]$ to reassemble the coefficient matrix for $\{P_S\}$, we can combine (3.32) and (3.55) into

$$[H]\{P_S\} = - [F] \left(\{\ddot{f}_h\} + \{\ddot{x}\}\right) \tag{3.59}$$

Here [F] also incorporates the contributions from [OW] and [B].

Assuming that inversion of [H] can be done efficiently, we can then substitute (3.59) into (3.56) to get

$$\left([M] - [H]^{-1}[F]\right)\{\ddot{x}\} + [c]\{\dot{x}\} + [K]\{x\} = - \left([M] - [H]^{-1}[F]\right)\{\ddot{f}_h\} \tag{3.60}$$

This equation has the standard form of a second-order linear ordinary differential equation, which can be solved straightforwardly by a number of conventional time-integration schemes. However, it is quite obvious that inverting [H] should not be recommended. The alternative is to utilize the nodal superposition method commonly used in structural analysis. Therein the structural response $\ddot{x}, \dot{x}$ and x are expressed by the eigenvectors (mode shapes $\{\phi\}$) of the undamped structural vibrations (without fluids). The $\{\phi\}$'s are obtained from the following eigenvalue problem

$$[K]\{\phi_j\} = \omega_j^2 \, [M]\{\phi_j\} \, , \tag{3.61}$$

where ω_j denotes the j-th eigenvalue (natural vibration frequency) of the structure. It should be pointed out here that, in general, the mode shapes and natural frequencies of our entire coupled fluid-tank system are different from the $\{\phi_j\}$ and ω_j here. For the entire system, no precise physical meanings can be imparted to $\{\phi_j\}$ and ω_j, except that $\{\phi_j\}$ is a set of linearly independent vectors out of which structural response can be composed of. For that matter, just about any set of linear independent vectors can be used in this approach, were it not for the advantage of our particular set $\{\phi\}$ that it diagonizes the matrices [M], [C] and [K]:

$$\begin{aligned}
&\{\phi_j\}^T[M]\{\phi_j\} = [M_j^*] \\
&\{\phi_j\}^T[C]\{\phi_j\} = [C_j^*] = 2\zeta_j\omega_j[M_j^*] \qquad (3.62) \\
&\{\phi_j\}^T[K]\{\phi_j\} = [K_j^*] = \omega_j^2\,[M_j^*]
\end{aligned}$$

$[M_j^*]$, $[C_j^*]$ and $[K_j^*]$ are diagonal matrices referred to as the generalized mass, generalized damping and generalized stiffness matrices. ζ_j is the j-th mode damping ratio (assumed to be small).

Using $\{\phi_j\}$, any arbitrary displacment $\{x\}$ can be expressed as a linear combination of them:

$$\{x\} = \sum_{j=1}^{J} \{\phi_j\}\, Y_j. \qquad (3.63)$$

The above expansion is exact if J is equal to the total number of degrees of freedom, 3N, of the structure finite-element system because the $\{\phi_j\}$'s form a basis of a space of dimension 3N. Usually, for earthquake type of excitations, the responses can be approximated by the first few modes fairly well.

Now (3.59) can be written as

$$[H]\{P_S\} = -[F]\{\ddot{f}_h\} - \sum_{j=1}^{J} [F]\{\phi_j\}\ddot{Y}_j \, . \tag{3.64}$$

If we rewrite $\{P_s\}$ as

$$\{P_s\} = \sum_{j=1}^{J} \{P_{sj}\}\ddot{Y}_j + \{P_{so}\}\ddot{f}_h \, , \tag{3.65}$$

where $\{P_{sj}\}$ is the solution of

$$[H]\{P_{sj}\} = -[F]\{\phi_j\} \, , \tag{3.66}$$

and $\{P_{so}\}$ the solution of

$$[H]\{P_{so}\} = -[F]\{L\} \, . \tag{3.67}$$

Note that (3.66) and (3.67) can be solved without inverting [H]. And since in the numerical process, the solution is gotten in a piecemeal fashion, one need not worry about the possible singular behavior of [H] during its construction.

$\{P_{so}\}$ can be viewed as the pressure response due to the rigid body motion of the tank, and $\{P_{sj}\}$ is the pressure response due to the j-th mode of tank free vibration. Substituting the expressions for {x} and $\{P_s\}$ into (3.56), multiplying on the left by $\{\phi_j\}^T$ and using the orthogonality property of the mode shapes, we obtain

$$\begin{aligned}([M_j^*] + \{\phi_j\}^T\{P_{sj}\})\ddot{Y}_j + [C_j^*]\dot{Y}_j + [K_j^*]Y_j \\ = -(\{\phi_j\}^T[M]\{L\} + \{\phi_j\}^T\{P_{so}\})\ddot{f}_h . \qquad j = 1,\ldots,J\end{aligned} \tag{3.68}$$

The term $\{\phi_j\}^T\{P_{sj}\}$ can be interpreted as the modal added mass matrix, and $\{\phi_j\}^T\{P_{so}\}$ the generalized hydrodynamic force due to tank rigid-body motion. To solve (3.68), commonly used time-integration can be applied.

It should be pointed out that the added-mass matrix in (3.68) is not diagonal. Consequently, the system is coupled. This system could, of course, be transformed into an uncoupled set by using the mode shapes of the coupled fluid-tank system, which are eigenvectors of

$$[K^*]\ \{\phi_j\} = \lambda_j^2\ ([M^*] + [\phi]^T[P_S])\{\phi_j\}\ .$$

We choose to solve (3.68) more straightforwardly.

The use of normal modes of the structural free vibration to reduce the number of unknown coordinates may be viewed as an application of the Ritz method.

4. NUMERICAL RESULTS/VALIDATION

A computer program named ERST, for Earthquake Response of Sea-Based Storage Tanks, has been developed to implement the formulation of §3 to evaluate the elasto-hydrodynamic response of axisymmetric storage tanks submerged underwater induced by earthquake ground motions. A detailed discussion of ERST is given in Appendix A and the full program listing is furnished in Appendix B. In this section, we document some results obtained from the computer codes which were used to validate the program.

The simplest test is to see whether we can reproduce the well-known series solutions for cases where the tank structure is a rigid circular cylinder submerged underwater. Due to rigidity, the inner fluid motion and the outer water motion are uncoupled from the tank vibration. Consequently, we can test the interior response and the exterior response separately.

Since many of the available results are obtained with gravity effect included, we modified our program accordingly (we used the variational principle in the new coding to aid in our validation; the results were compared to be within 2% of ERST which uses the Galerkin scheme). We first compared the work of Tung (1979) studying (exterior) hydrodynamic forces on submerged cylindrical tanks under ground excitation. Considering a tank of relative dimensions $H:(H-h_w) = 2$ and $R:H = 1$, under the assumed earthquake ground acceleration of $e^{-i\omega t}$ with $\omega = 10$ rad/sec, we found excellent agreement with the (analytic) data presented in Figure 4 of Tung's paper. We reproduced the relevant portion of the curves in our Figure 6. The pressures are evaluated on the tank wall at $\theta = 0°$.

For the pressure response due to the interior fluid motion, we compared with the results of Takayama (1976) and Helou (1981). Again, the tank is a hollow circular cylinder with a flat top. Here, R=10 ft, $h_o=h_w=5$ ft, $\rho_o=0.86$ and $\rho_w=1$ in g/cm^3. We selected a finite-element idealization of 20 elements distributed symmetrically relative to the oil-water interface. In Figure 7, the x-z plane section of the assemblage is presented. From the sources quoted above, we have, for the analytic representation hydrodynamic pressure of oil and water,

$$P_o = -\rho_o R \cos\theta \, e^{-i\omega t} - \rho_o \sum_{m=1}^{\infty} \frac{1}{k_m} G''_m \cosh k_m(z-h_o) \cos\theta \, e^{-i\omega t}, \tag{4.1}$$

$$- \leq z \leq h_o \ ,$$

$$P_w = -\rho_w R \cos\theta \, e^{-i\omega t} + \rho_w \sum_{m=1}^{\infty} \frac{1}{k_m} G''_m \frac{\sinh k_m h_o}{\sinh k_m h_w} \cosh k_m(z+h_w) \cos\theta \, e^{-i\omega t} \tag{4.2}$$

$$-h_w < z < 0 \ ,$$

if the system undergoes a ground velocity (n.B., not acceleration) $e^{-i\omega t}$;

In the above formula,

$$G''_m = \omega^2 \, \overline{G}_m \frac{\sinh k_m h_w}{\sinh k_m h_o} \ , \quad \overline{G}_m = \frac{k_m C_m J_1(k_m R)}{K_m - M_m \omega^2} \ ,$$

and

$$M_m = k_m \left(1 + \frac{\rho_o \tanh k_m h_w}{\rho_w \tanh k_m h_o}\right) \tag{4.3}$$

$$C_m = \left(\frac{\rho_o}{\rho_w} - 1\right) \frac{2k_m R}{J_1(k_m R)(k_m^2 R^2 - 1) \cosh k_m h_w} \tag{4.4}$$

$$K_m = \left(1 - \frac{\rho_o}{\rho_w}\right) g\, k_m^2 \tanh k_m h_w \ , \tag{4.5}$$

k_m for m = 1,2,... are the roots of $J_1'(k_m R) = 0$.

Pressures for a range of frequencies are calculated using the above formulae and our computer program. As can be seen from the results presented in Figures 8 through 11, the comparisons are quite satisfactory. Pressure distribution normalized by the excitation frequency are plotted against the nodes at the inner tank wall (θ=0°). The figures are for ω = 0.5 rad/sec, 1.1 rad/sec, 6 rad/sec and 10 rad/sec. Notice that since gravity effects are considered here, P_o does not equal to P_w exactly. Also, note that the curves are for hydrodynamic pressures only, one would need to add on the hydrostatic pressures to extrapolate the location of equal pressures (where $z = \zeta$).

Close examination of Figures 8 through 11 reveals that, while there is little change of the pressure curves from ω = 0.5 rad/sec to ω = 1.1 rad/sec, there is significant (trend-reversal) difference from there on to ω = 6 rad/sec. Eventually, the curves "stabilized" and become practically frequency independent (this is confirmed from calculation of a number of frequencies ranging from 3.7 rad/sec, 4.8 rad/sec to 60 rad/sec). Now, with the gravitational effects included, one could expect the fluid-structure system to exhibit sloshing phenomena at the natural frequencies ω_m where

$$K_m = \omega_m^2 M_m. \tag{4.6}$$

For the data used in our test, these frequencies are

$$\omega_1 \simeq 1.97, \quad \omega_2 \simeq 3.92, \quad \omega_3 \simeq 4.98, \; \omega_4 \simeq 5.83, \; \omega_5 \simeq 6.57, \ldots$$

Since the density difference between oil and water is small (0.14 g/cm^3) the sloshing amplitudes will be small. Within the frequency spectrum of importance due to earthquake excitations, only high modes of sloshing waves are expected. These are short-length waves of minor importance. Since the pressure distribution is independent of frequencies in this spectrum, this reinforces our belief that as far as our system configuration is concerned, the gravitational effects can be safely ignored, as we did in our analysis.

To ascertain that our 20-element finite-element scheme has converged enough to be believed, we increased the assemblage to 100 elements, whose layout is basically the same as that of the 20-element case, except that 10 columns are used. We present the results in Tables 1 and 2 (for $\omega = 1.1$ rad/sec and 10 rad/sec). As one can see, although the results are certainly more accurate for the finer mesh, the results of the 20-element discretization is very respectable, and from the computational stand-point, by far more cost-efficient.

Although we know of no analytical results for the response problem of an axisymmetric tank with inclined wall, we made several calculations using a 20-element discretization on a slant tank similar to the one we used above, except that an inclination (from vertical axis of 0°, 15° and 30°) is imposed on the side wall. $R = 10$ feet at the tank base. Figures 12 and 13 show that pressure distribution along the side wall ($\theta = 0°$) for $\omega = 1$ rad/sec and $\omega = 6$ rad/sec, respectively. For $\beta = 15°$, it is calculated that resonance occurs at $\omega \simeq 2.5, 4.5, \ldots$(see Figure 14). Again, for earthquake bound frequencies, the sloshing phenomena will be negligible.

ERST has been implemented on the CDC Cyber 176 Computer of the United Computing Systems at Dallas, Texas, under the NOS/BE operating system. For the simple rigid circular cylindrical structure with a 20-element symmetric finite-element discretization as described above, undergoing harmonic ground acceleration, a typical run requires less than 2 seconds CPU time.

Our last series of tests involve a simple flexible (circular) cylindrical tank under a ground acceleration of $\sin\omega t$, for various values of ω. The results are presented in Figures 15 through 17. Here $R = 10$ m, $h_0 = h_w = 5$m and $H = 20$ m. A uniformly positioned 20-element finite-element system is selected for the interior fluid domain, which is then extended naturally to form a 45-element mesh for the exterior water and a 12-element one for the tank structure. In Figure 15, $\omega = 1$ Hz, the hydrodynamic pressure distribution for the first two modes of response is plotted for $t = .25$ sec and .75 sec (1/4 and 3/4 cycles after the initial excitation). In Figures 16 and 17, $\omega = 10$ Hz, and we show response of the first mode as well as the first two modes for $t = .025$ sec and .075 sec. Notice that the interior pressure forces are approximately 1.5 to 2 times in value to that of the exterior pressure. Also notice that in Figure 15, $\frac{\partial P_0}{\partial z}$ is close to zero even though the "roof" is not assumed to be rigid; but in Figures 16 and 17, larger displacements step in and change the pressure distribution now that frequency is bigger. The tank's natural vibration frequencies are $\omega_1 \approx 16.7$ Hz, $\omega_2 \approx 33.7$ Hz.

We were unable to make a comparison of our results to that of Helou's (1981) presented in his Figure 4.3 for, unfortunately, his results are incorrect as evidenced by the fact that $\frac{\partial P_w}{\partial z} \neq 0$ at the ocean floor, violating the rigid boundary condition there.

Table 1. Pressure distribution at wall ($\theta = 0^\circ$) under different finite element discretizations.

	P/ω at Wall		
z	20-element	100-element	Analytical
5.0	-8.438	-8.432	-8.431
2.0	-8.410	-8.404	-8.403
1.0	-8.386	-8.381	-8.381
0.66	-8.376	-8.372	-8.372
0.33	-8.366	-8.361	-8.361
0	-8.354	-8.349	-8.349
0	-10.286	-10.292	-10.292
-0.33	-10.272	-10.278	-10.276
-0.66	-10.260	-10.265	-10.266
-1.0	-10.248	-10.254	-10.255
-2.0	-10.221	-10.228	-10.228
-5.0	-10.188	-10.195	-10.196

$\omega = 1.1$ rad/sec

Table 2. Pressure distribution at wall ($\theta = 0^\circ$) under different finite element discretizations.

	P/ω at Wall		
z	20-element	100-element	Analytical
5.0	-8.999	-8.996	-8.996
2.0	-9.088	-9.078	-9.075
1.0	-9.168	-9.159	-9.153
0.66	-9.203	-9.198	-9.201
0.33	-9.244	-9.247	-9.250
0	-9.293	-9.322	-9.342
0	-9.194	-9.162	-9.137
-0.33	-9.251	-9.247	-9.241
-0.66	-9.298	-9.304	-9.309
-1.0	-9.339	-9.350	-9.357
-2.0	-9.432	-9.444	-9.446
-5.0	-9.536	-9.539	-9.539

$\omega = 10$ rad/sec

5. SUMMARY AND FUTURES WORK

A rational and effective method to assess the effects of fluid-structure interaction, on the dynamic response of submerged underwater oil storage tanks under earthquake excitations, has been developed. Our approach is the hybrid-finite element method, discretizing the tank structure, the interior fluids, as well as the near field of the exterior water region into a ring-shaped mesh network. Solution for the hydrodynamic pressure distribution is substituted into the structural equation of motion in modal coordinates to obtain the system displacement information. A comprehensive and predictive computer code is developed for design engineering applications. The program is described in the Appendices. Our program has ben validated against known analytical solutions and shown to be effective and accurate with the added flexibility for arbitrary axisymmetric tank shapes.

During this investigation, we also reconfirmed the fact that gravity effects can be safely neglected in evaluating the hydrodynamic pressure induced at the wall of a submerged tank, such as the one under study. It is also observed that due to the unappreciable difference of ρ_0 and ρ_W, changes in the ratio h_0/h_W above do not significantly influence the fluid-structure response.

From (3.68), it can be seen that the hydrodynamic interaction caused by the fluids inside and outside the tank contributes to the structural equation of motion in the forms of additional terms which can be viewed as added mass and added excitations. The added inertia of water increases the natural period of the tank free oscillation, and decreases (depends on the deflected shape) the modal damping ratios. However, the presence of water does not influence the stiffness matrix [K].

Finally, the incorporation of analyltic representation of P_w in the hybrid approach proves to be a useful cost-saver especially for tanks of odd shape and with irregular bottom topography. It is anticipated that this super-element should play an even bigger role in the treatment of soil-structure interactions.

The computer program developed in this study can be used, with appropriate modifications, for the following studies:

1. Tanks of open bottoms.
2. Tanks which are floating or moored.
3. Tanks which are non-axisymmetric.
4. Effects of non-rigid tank support and marine soil-structure interaction.

Understanding the nonlinear behavior of the kind of systems we have been investigating should, of course, be the ultimate study goal, but the numerical details it involves are very complicated. An in-depth analysis may also be needed to relax our assumptions that vertical ground motion and fluid incompressibility can be neglected. For the former, other modes of shell vibration, such as the breathing mode may need to be considered. Compressibility may become important for high values of excitation frequencies (for large-scale earthquakes). Indeed, with sound speed in water in the vicinity of 4720 ft/sec such high frequency excitations give rise to sound waves of lengths comparable to the tank dimension and the water depth. For squatty tanks, the compressibility effect may not be ignored.

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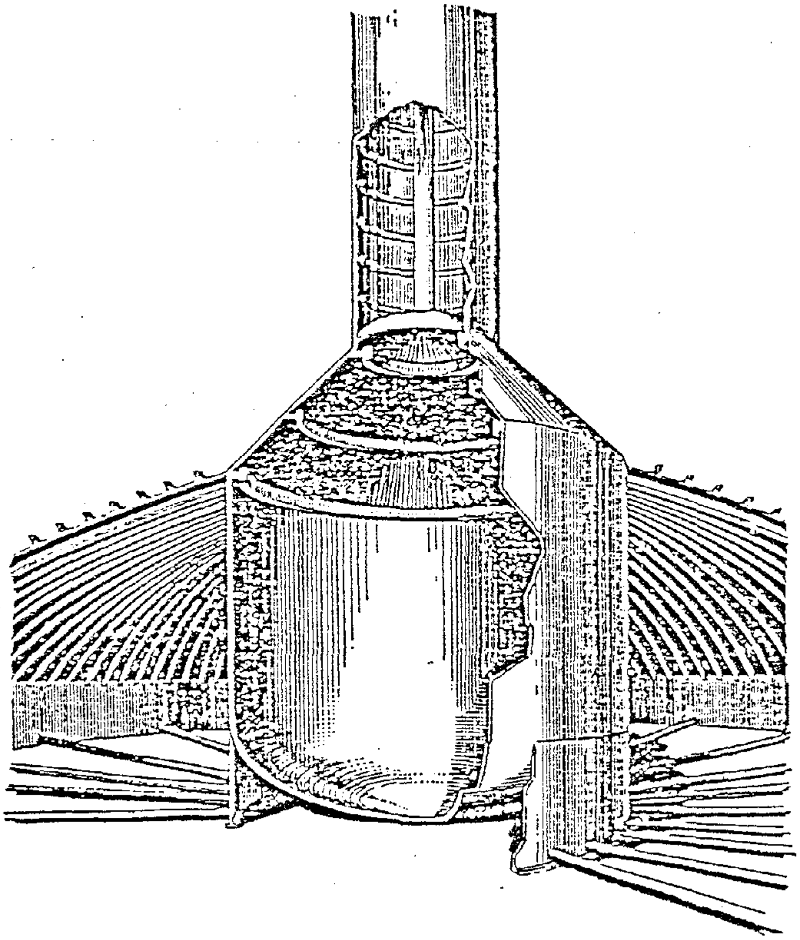


Figure 1. Section Through Khazzan Dubai 1

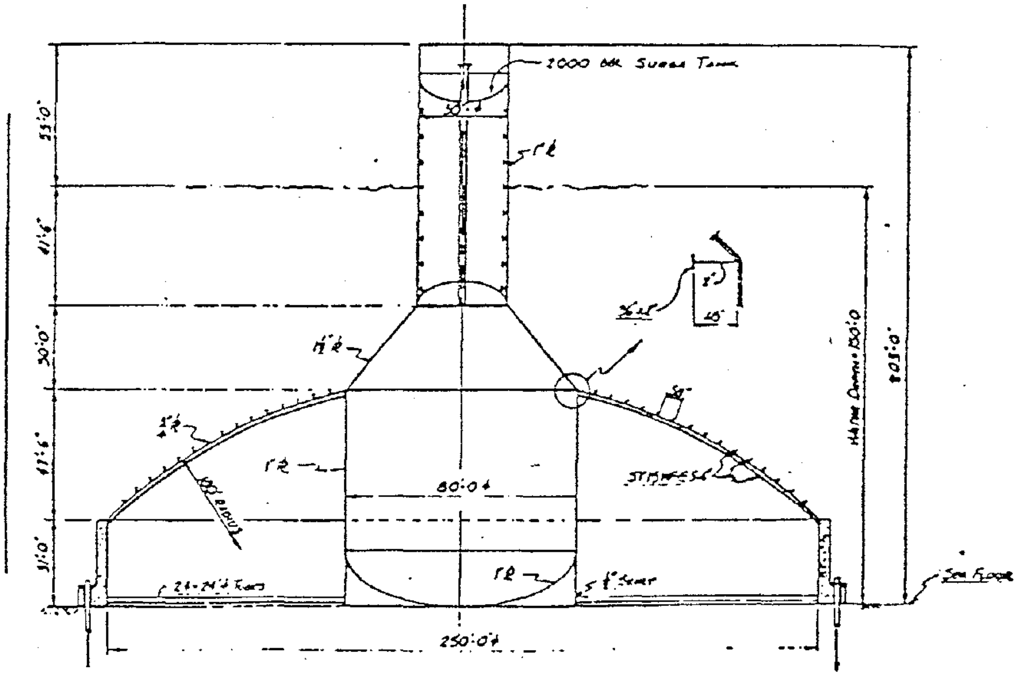


Figure 2. Major Dimensions of Khazzan Dubai 1

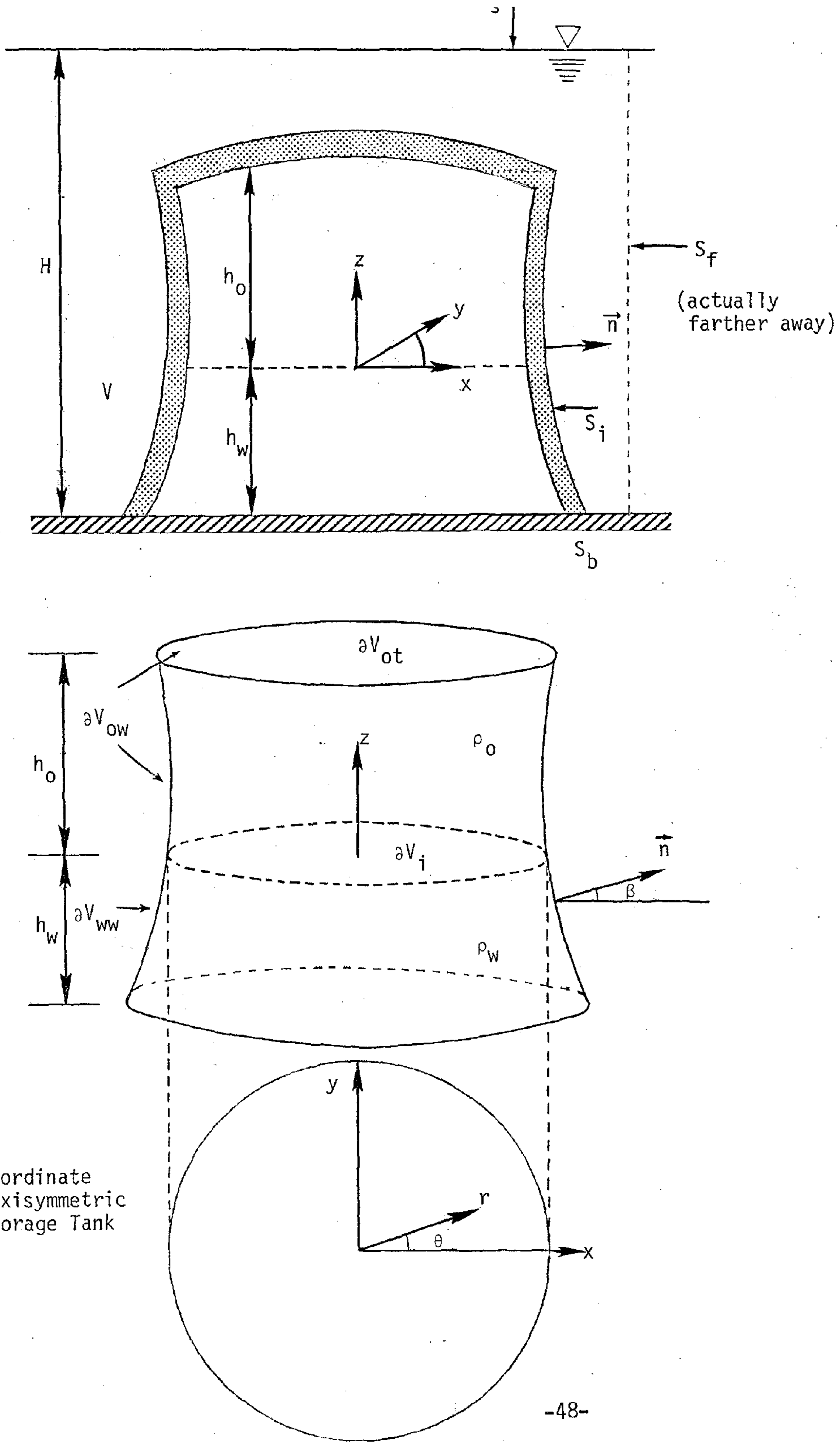
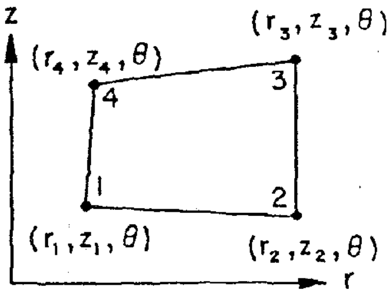
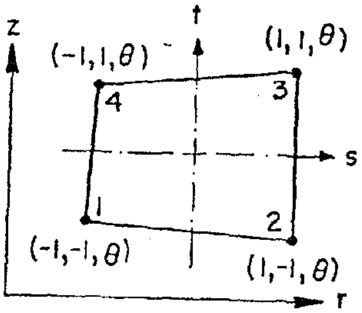


Figure 3. Coordinate System for Axisymmetric Submerged Storage Tank

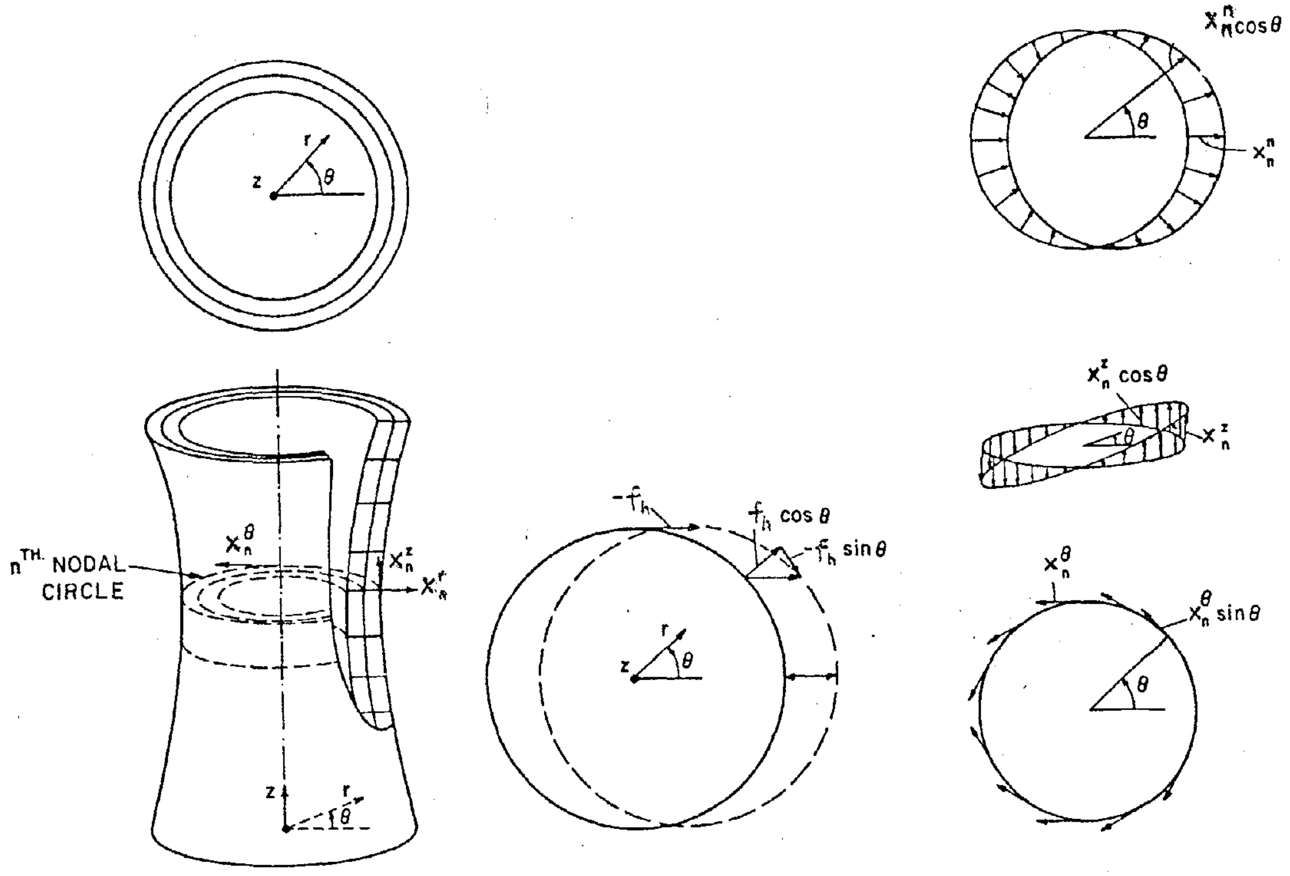


Global Coordinate System



Local Coordinate System

Figure 4. Finite Element Coordinate System



FINITE ELEMENT IDEALIZATION

GROUND DISPLACEMENT

RELATIVE DISPLACEMENTS OF NODAL-CIRCLE n

Figure 5. Axisymmetric Structure Subjected to Horizontal Ground Motion

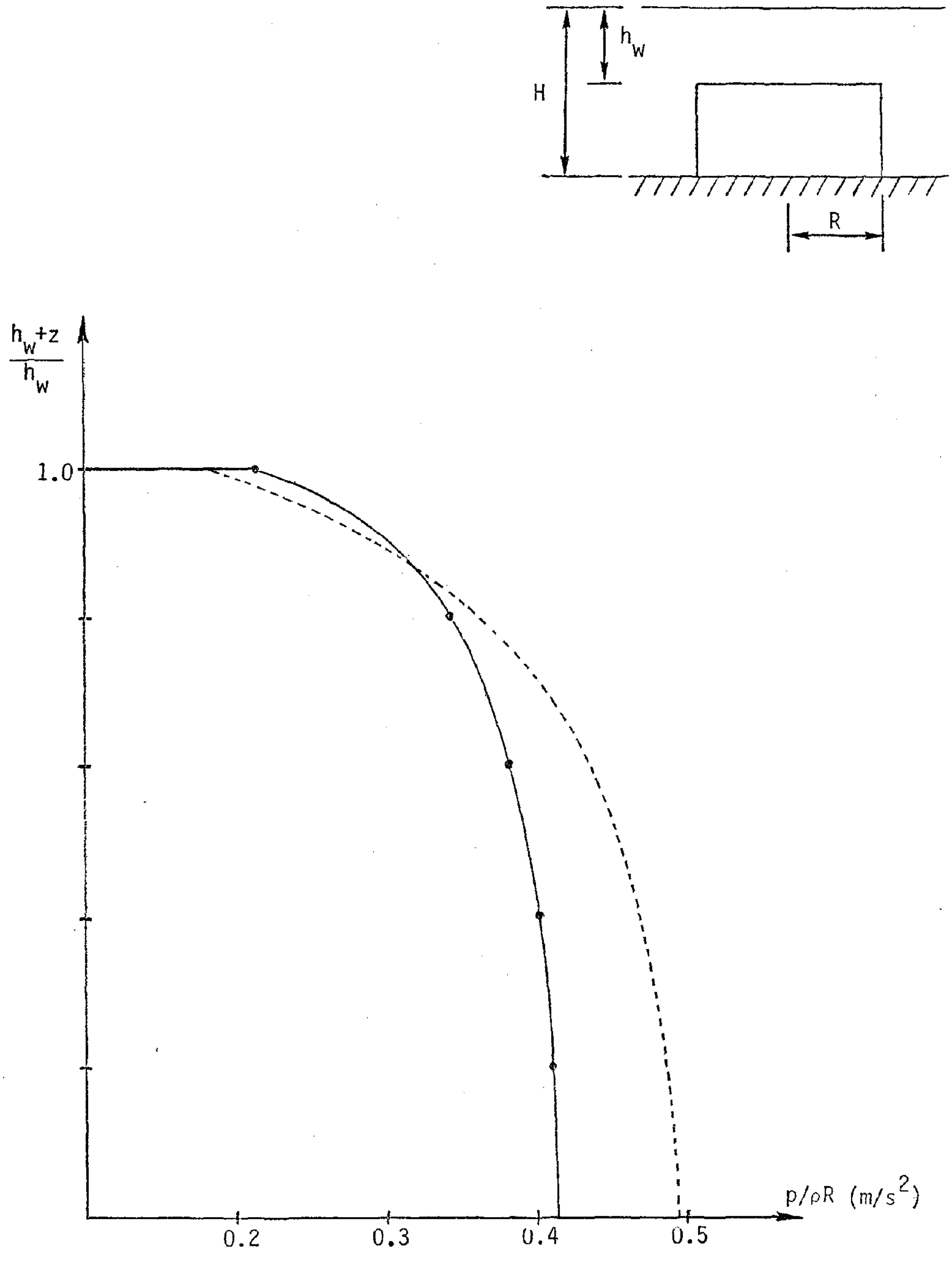


Figure 6. Pressures on wall of cylindrical tank $\theta = 0°$.
——— $H/(H-h_w) = 2$; ----- $H/(H-h_w) = 5$, $R/H = 1$

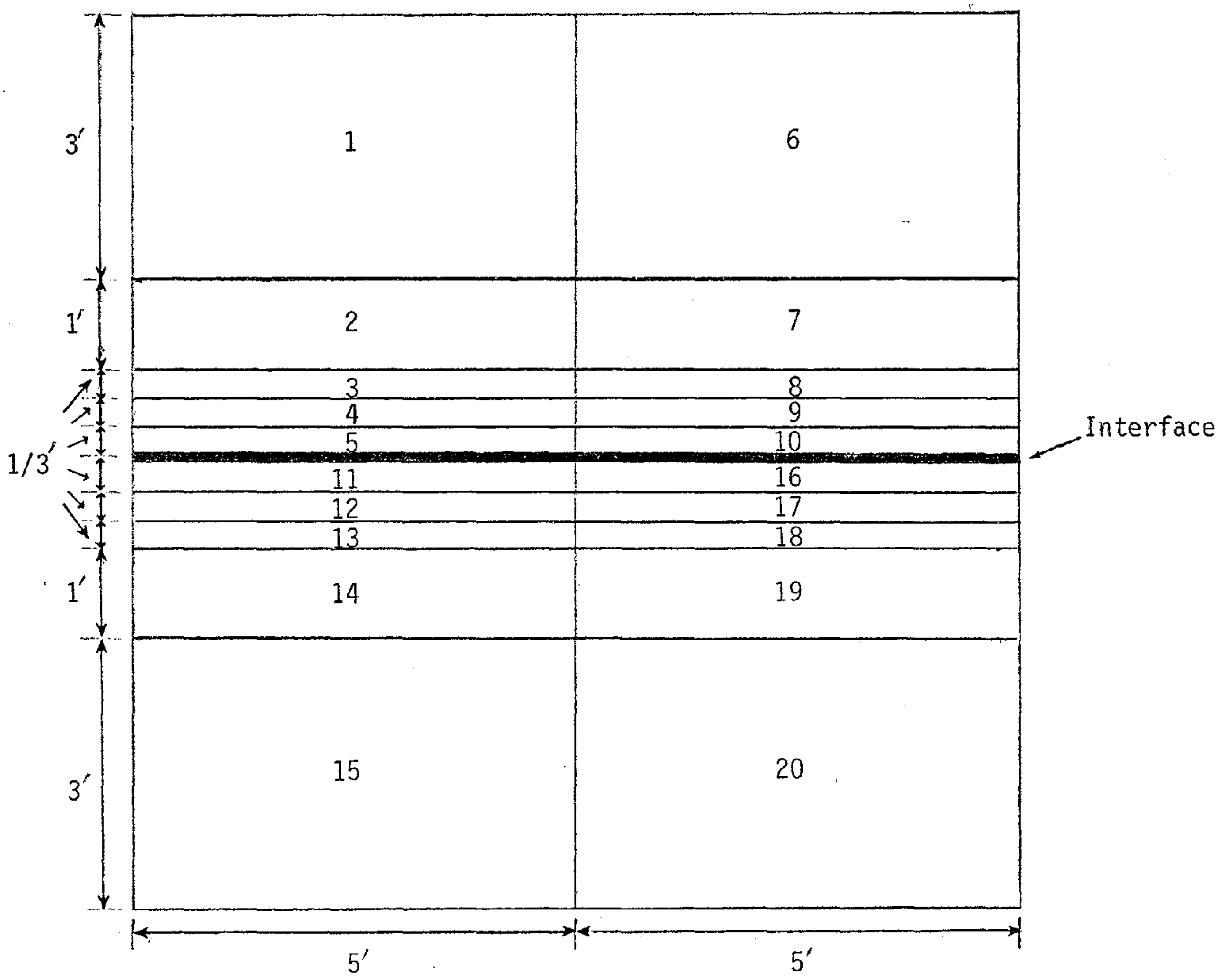
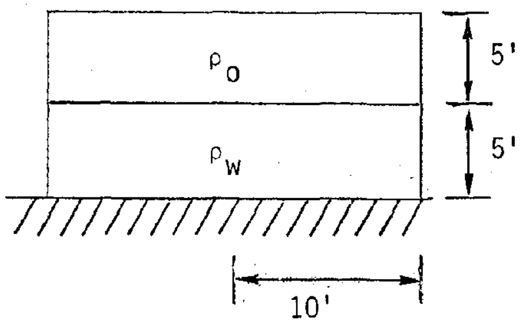


Figure 7. Interior Fluid Domain Finite Element Discretization



Z	FEM	Analytical
5.0	-16.639	-16.637
2.0	-16.631	-16.629
1.0	-16.623	-16.623
0.66	-16.619	-16.619
0.33	-16.616	-16.616
0	-16.612	-16.612

Z	FEM	Analytical
0	-19.491	-19.491
-0.33	-19.485	-19.485
-0.66	-19.481	-19.481
-1.0	-19.478	-19.478
-2.0	-19.470	-19.470
-5.0	-19.460	-19.460

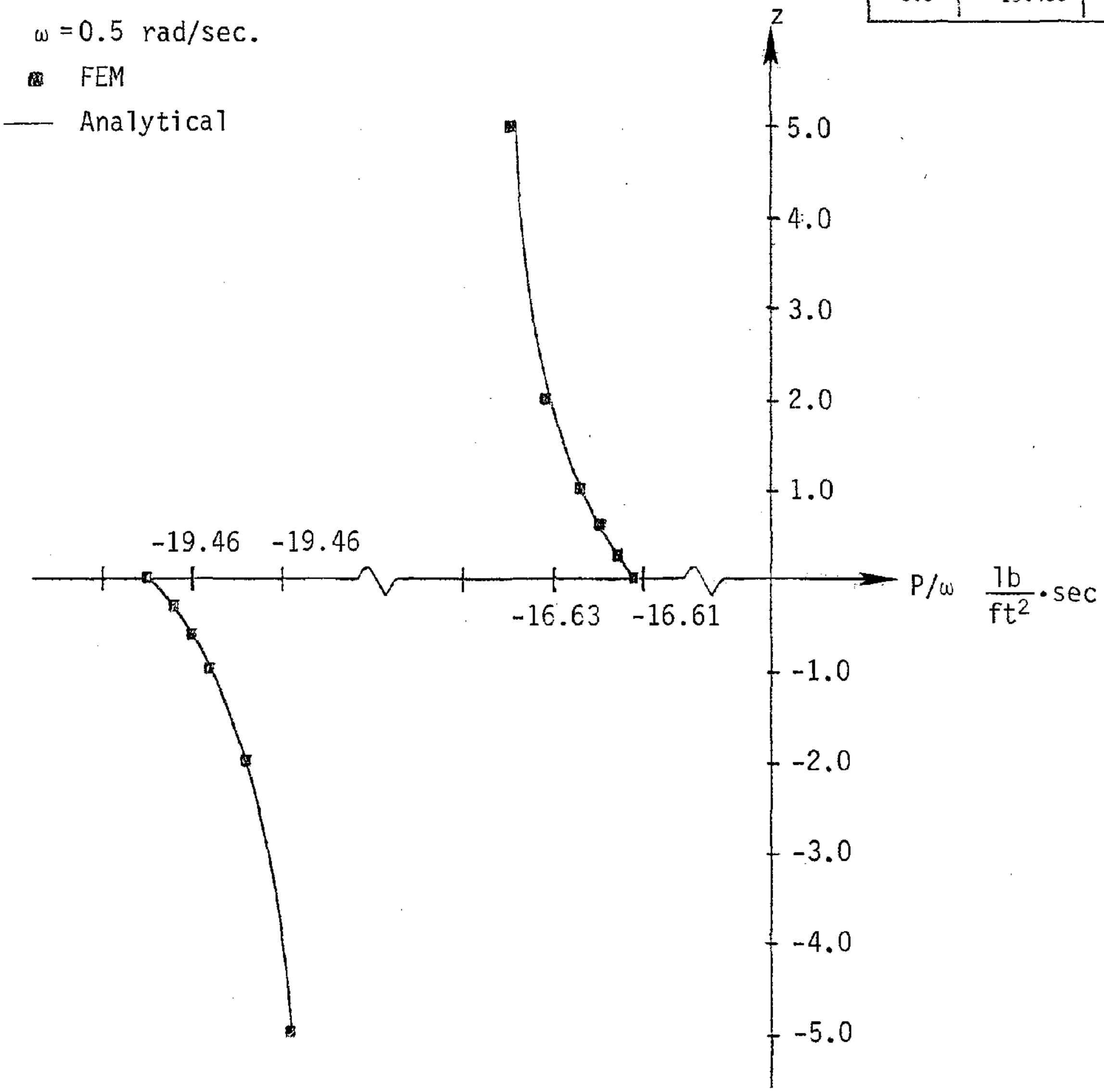
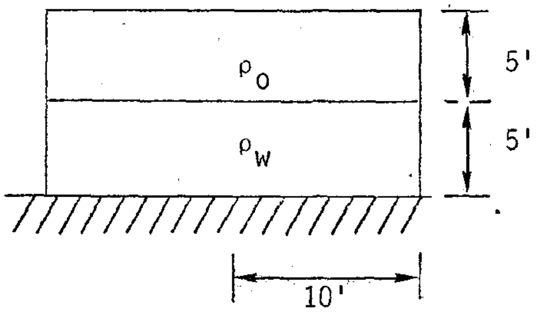


Figure 8. Pressure Distribution at Inner Wall ($\theta = 0°$) of a Submerged Cylindrical Tank



Z	FEM	Analytical
5.0	-16.373	-16.359
2.0	-16.319	-16.305
1.0	-16.272	-16.262
0.66	-16.253	16.245
0.33	-16.233	16.224
0	-16.210	-16.200

Z	FEM	Analytical
0	-19.959	-19.970
-0.33	-19.932	19.939
-0.66	-19.908	19.920
-1.0	-19.885	-19.899
-2.0	-19.833	-19.846
-5.0	-19.769	-19.784

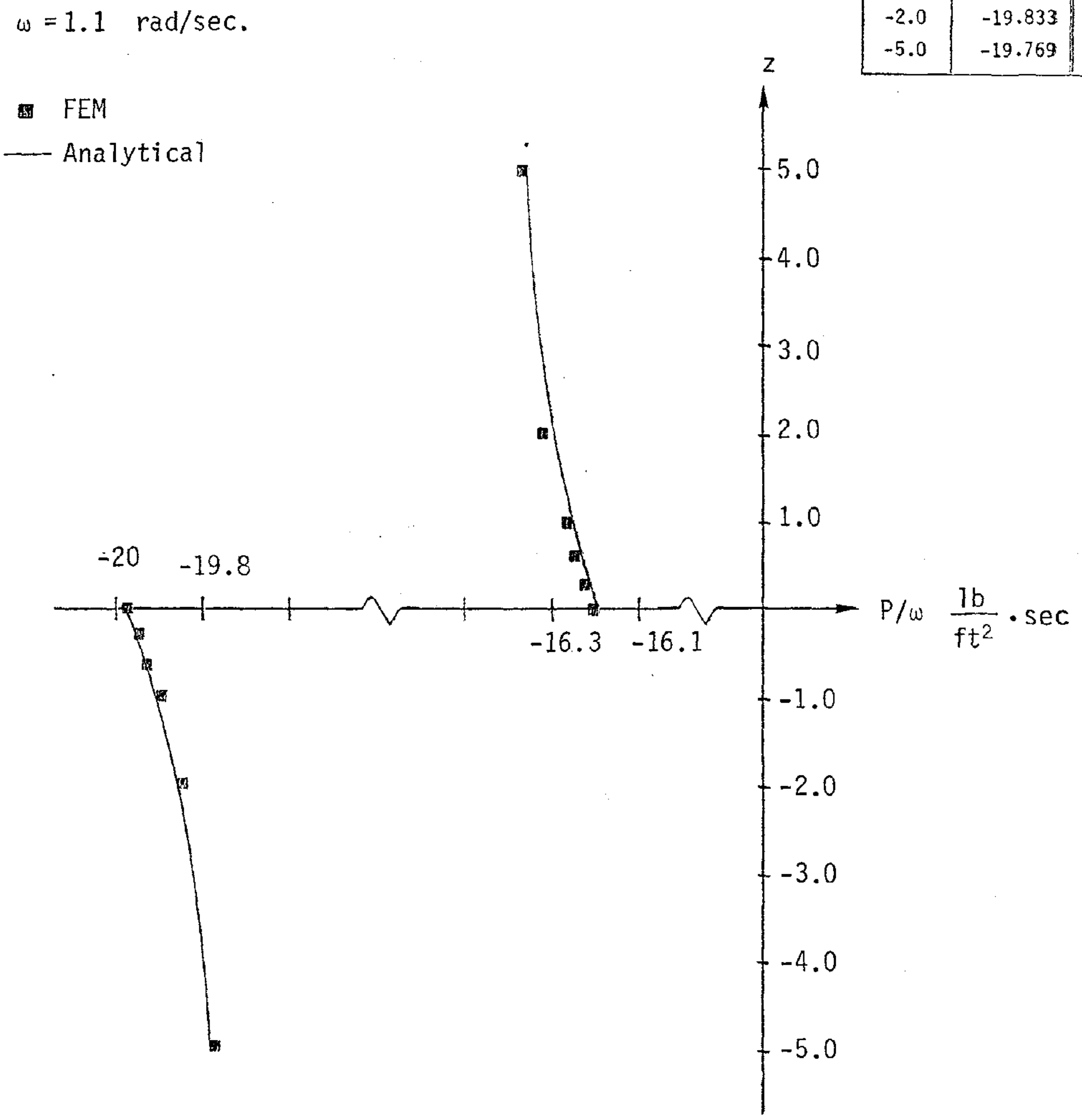
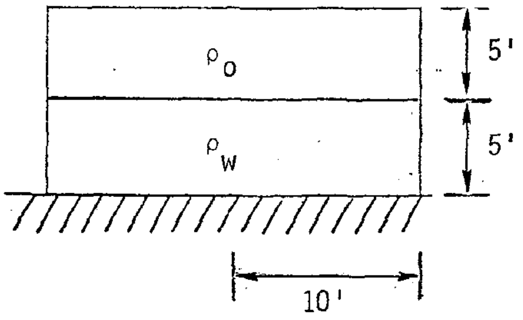


Figure 9. Pressure Distribution at Inner Wall (θ = 0°) of a Submerged Cylindrical Tank



Z	FEM	Analytical
5.0	-17.531	-17.526
2.0	-17.743	-17.731
1.0	-17.943	-17.956
0.66	-18.030	
0.33	-18.133	
0	-18.261	-19.374

Z	FEM	Analytical
0	-17.574	-17.440
-0.33	-17.723	
-0.66	-17.842	
-1.0	-17.945	-17.927
-2.0	-18.176	-18.191
-5.0	-18.422	-18.430

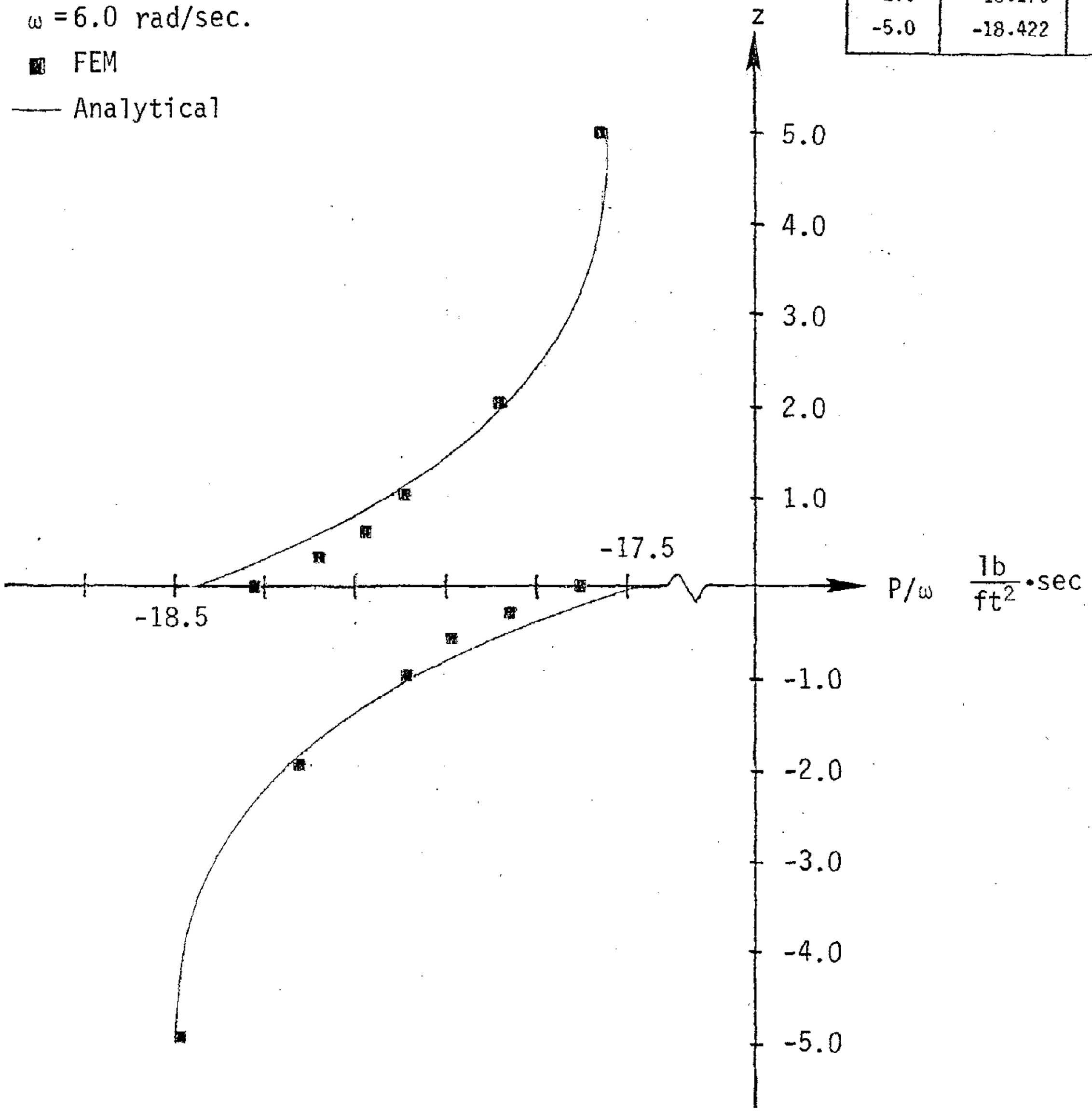
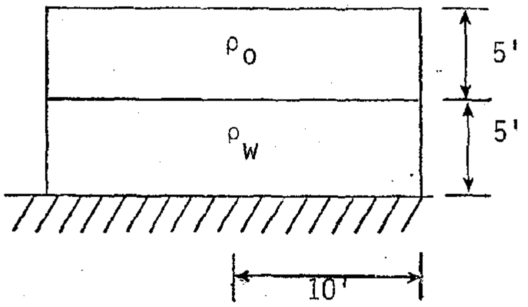


Figure 10. Pressure Distribution at Inner Wall (θ = 0°) of a Submerged Cylindrical Tank



Z	FEM	Analytical
5.0	-17.462	-17.456
2.0	-17.634	-17.609
1.0	-17.789	-17.760
0.66	-17.857	-17.853
0.33	-17.937	-17.949
0	-18.032	-18.127

Z	FEM	Analytical
0	-17.753	-17.729
-0.33	-17.951	-17.931
-0.66	-18.042	-18.063
-1.0	-18.121	-18.156
-2.0	-18.302	-18.333
-5.0	-18.504	-18.509

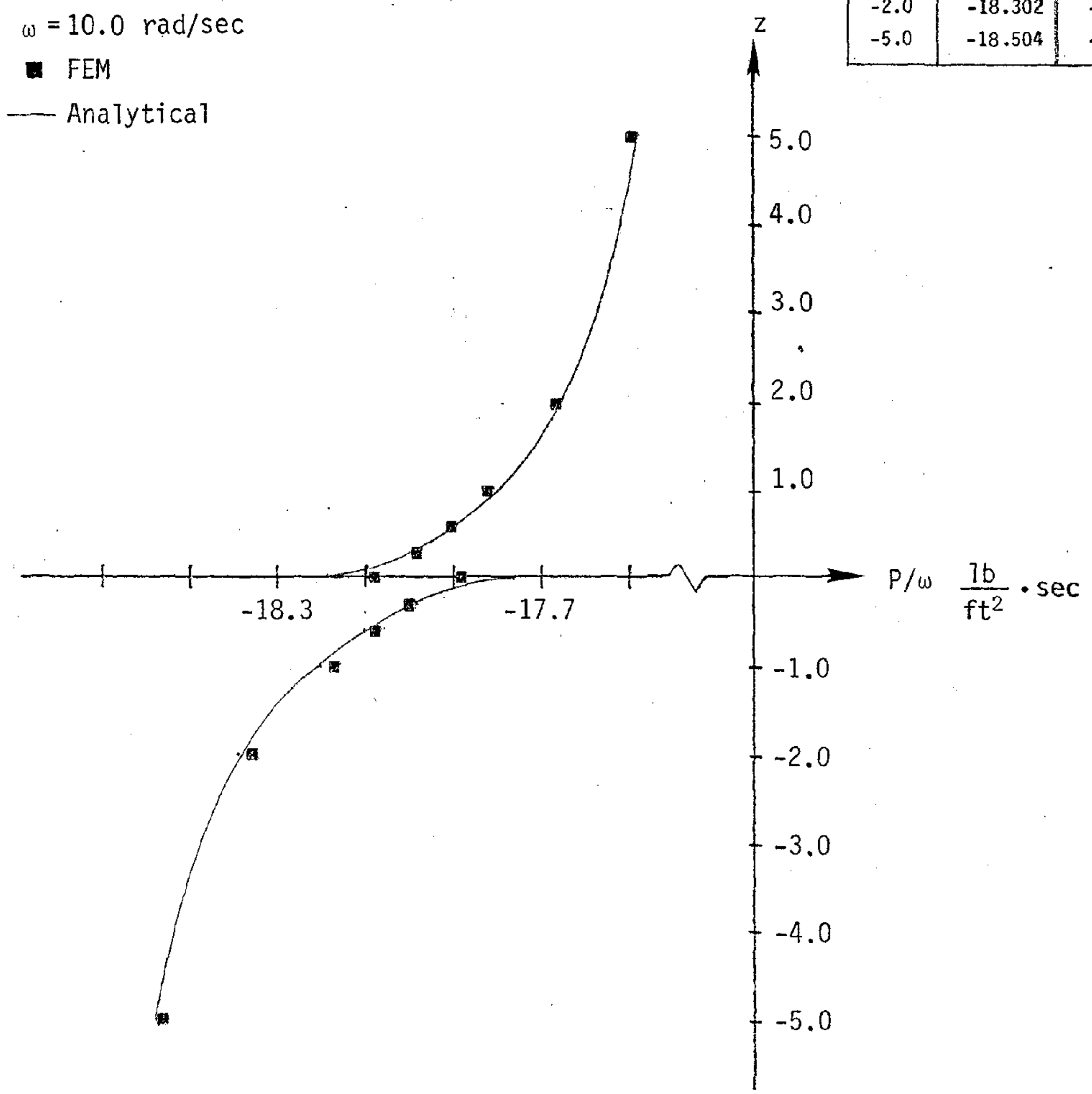


Figure 11. Pressure Distribution at Inner Wall (θ = 0°) of a Submerged Cylindrical Tank

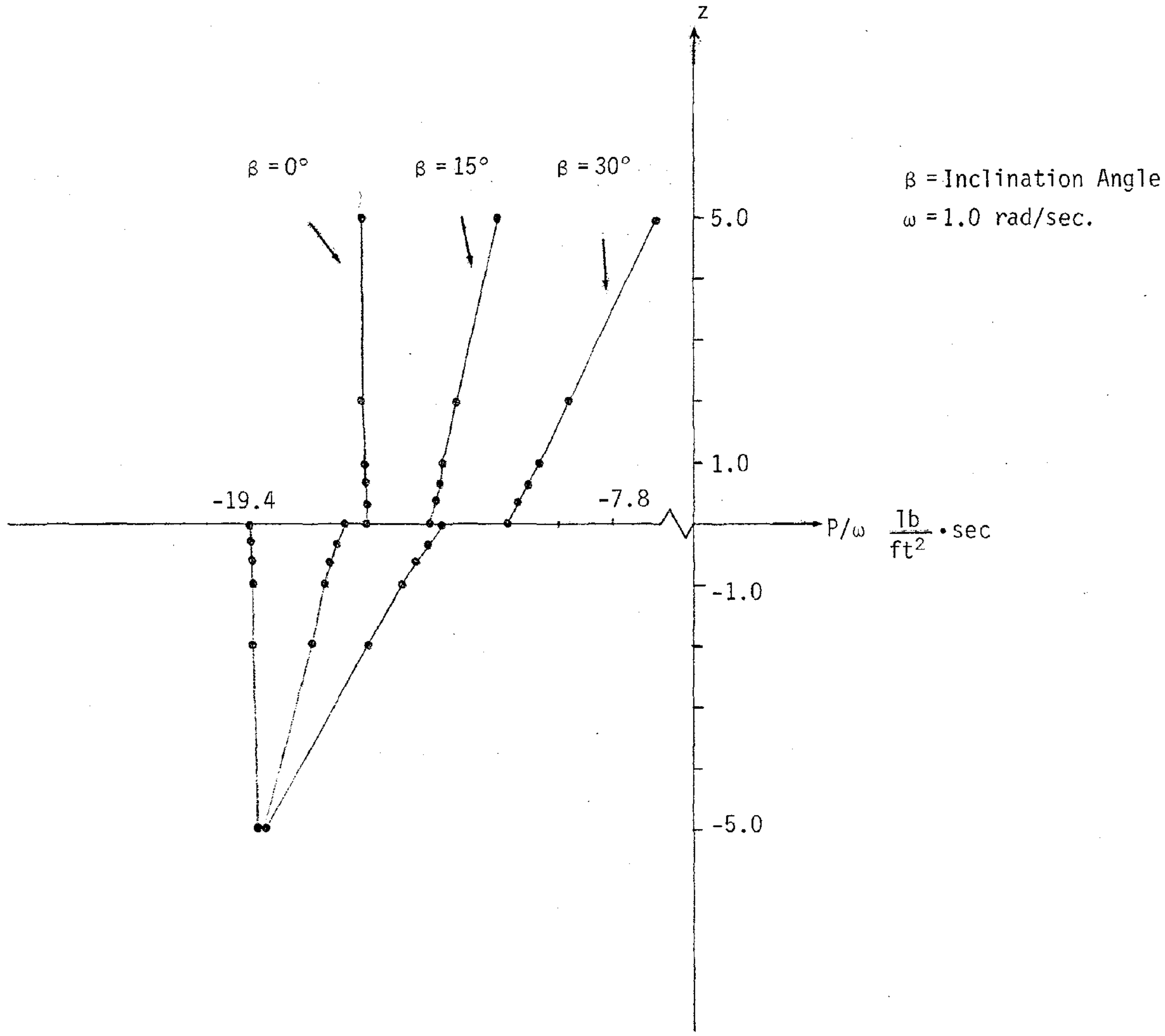


Figure 12. Pressure Distribution at Inner Wall (θ = 0°) of a Submerged Inclined Tank

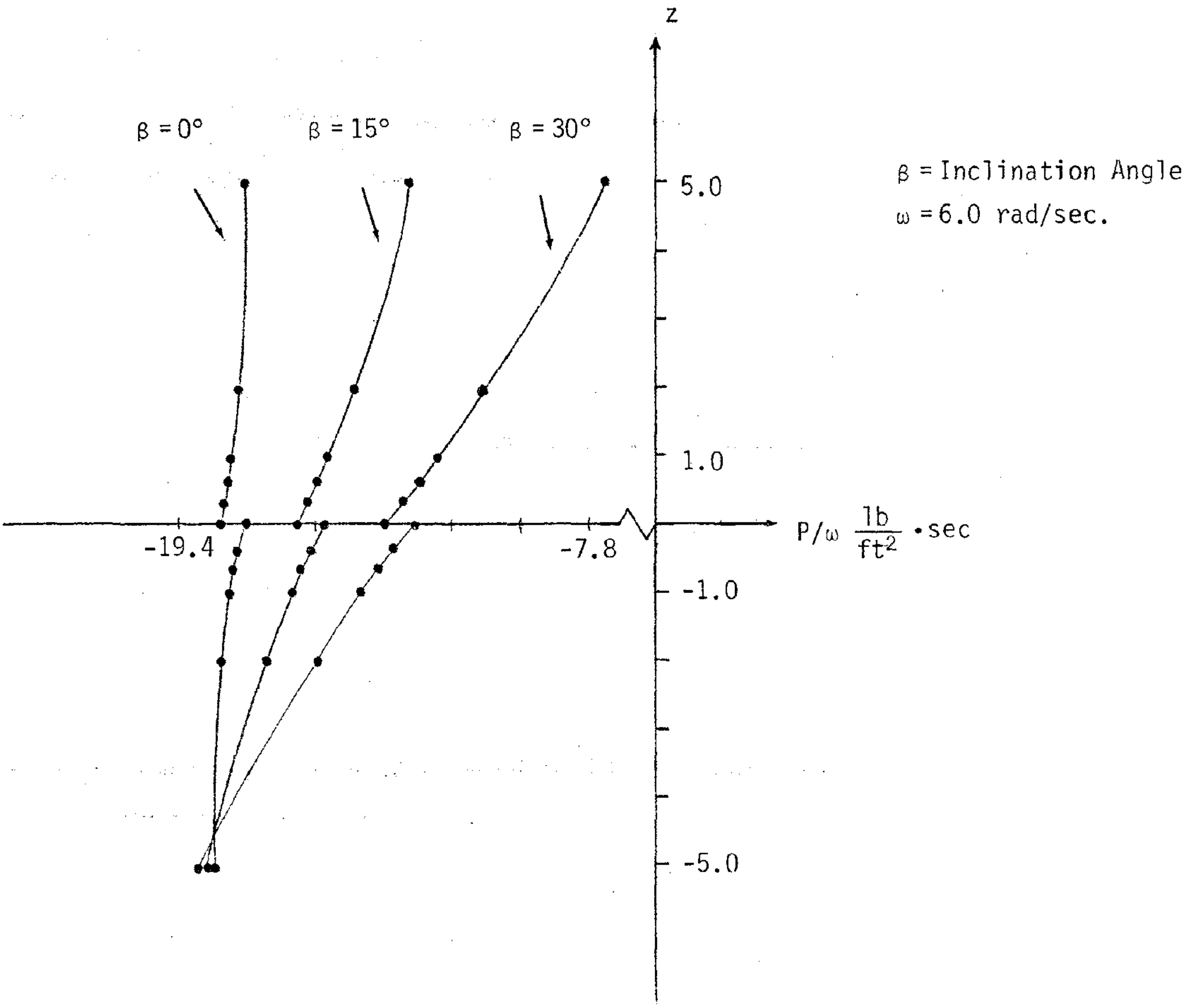


Figure 13. Pressure Distribution at Inner Wall (θ = 0°) of a Submerged Inclined Tank

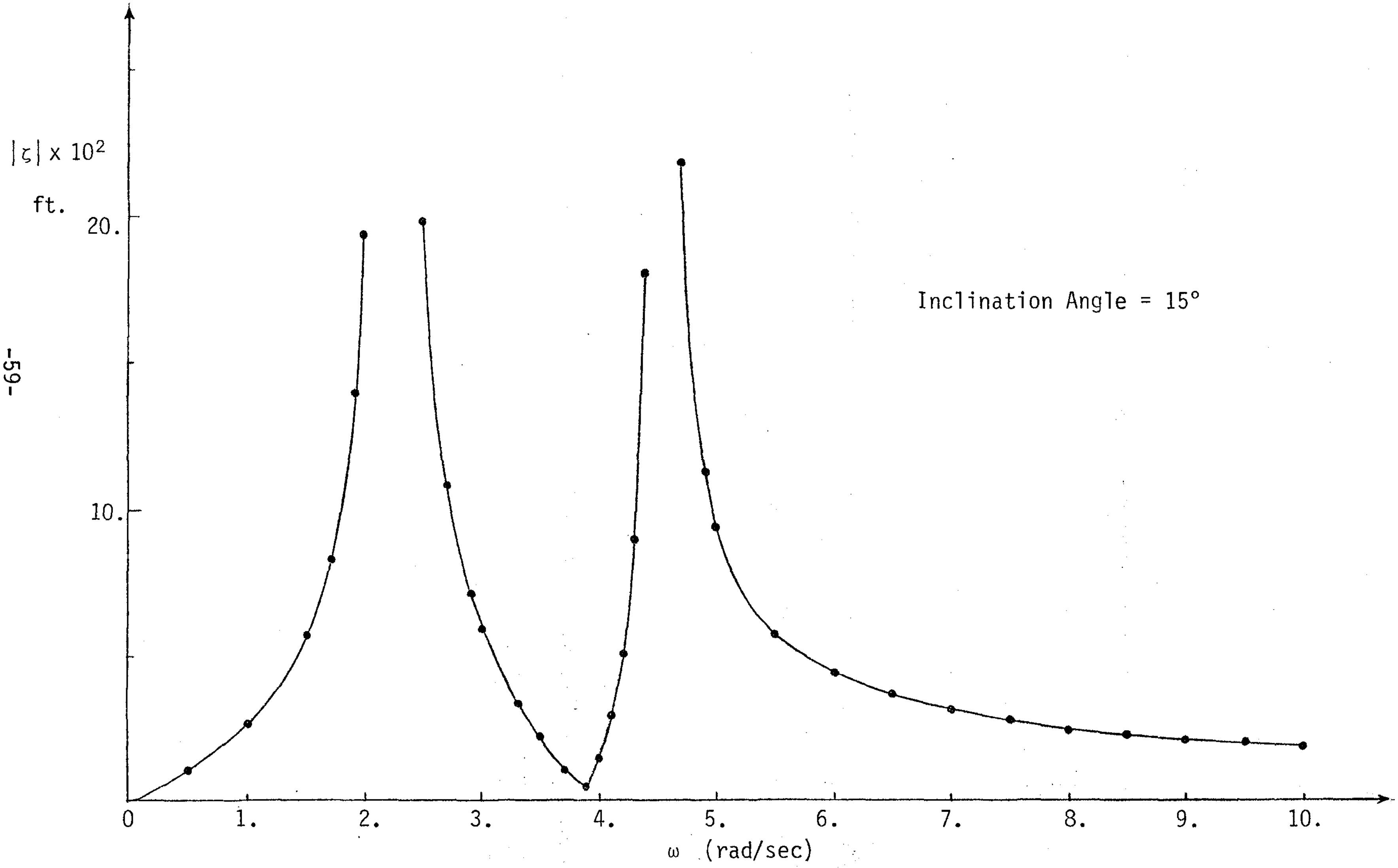


Figure 14. Oil-Water Interface Displacement-Frequency Curve of a Submerged Inclined Tank

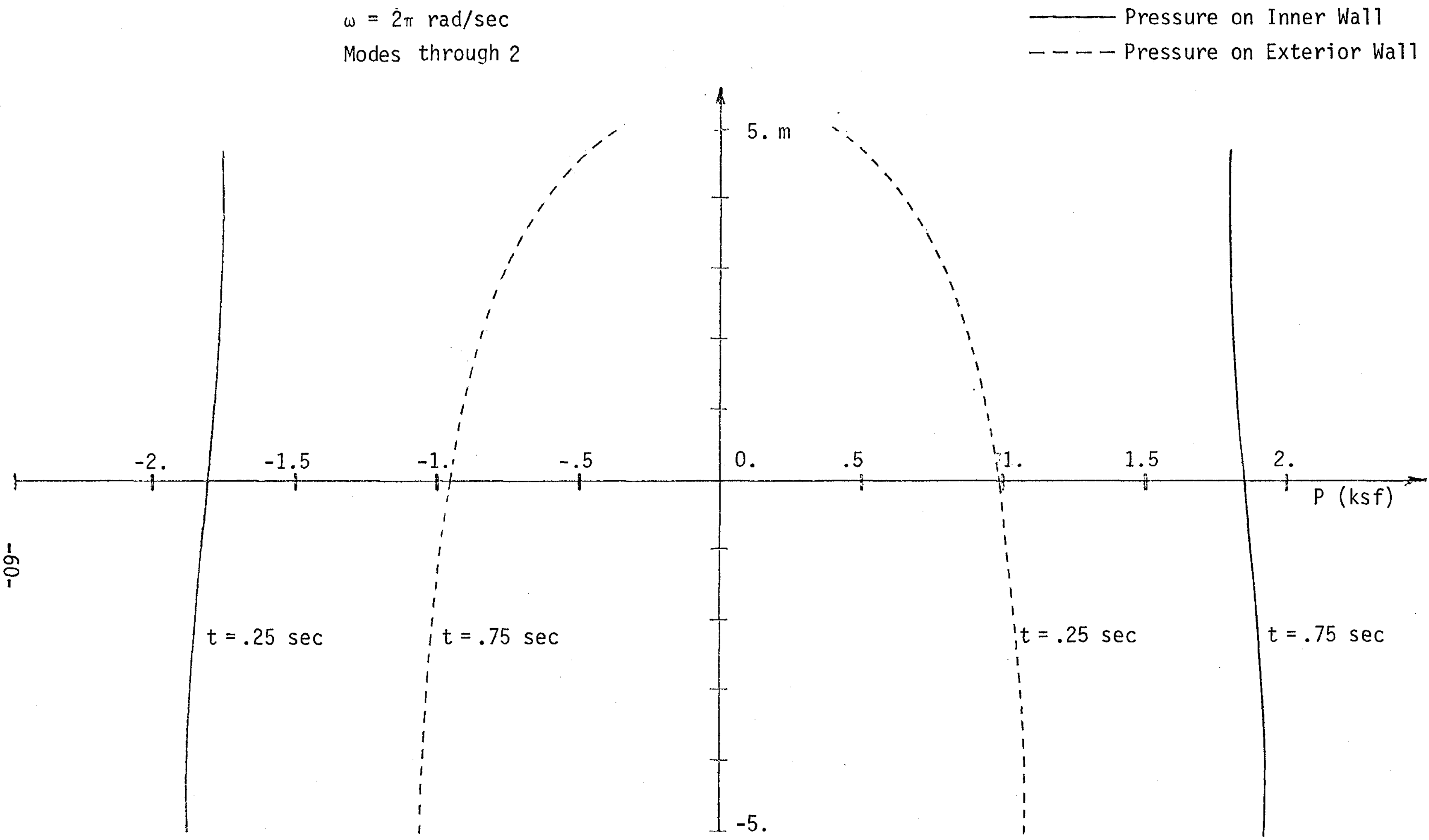


Figure 15. Pressure Distribution at Tank Wall ($\theta = 0°$) of a Submerged Flexible Tank

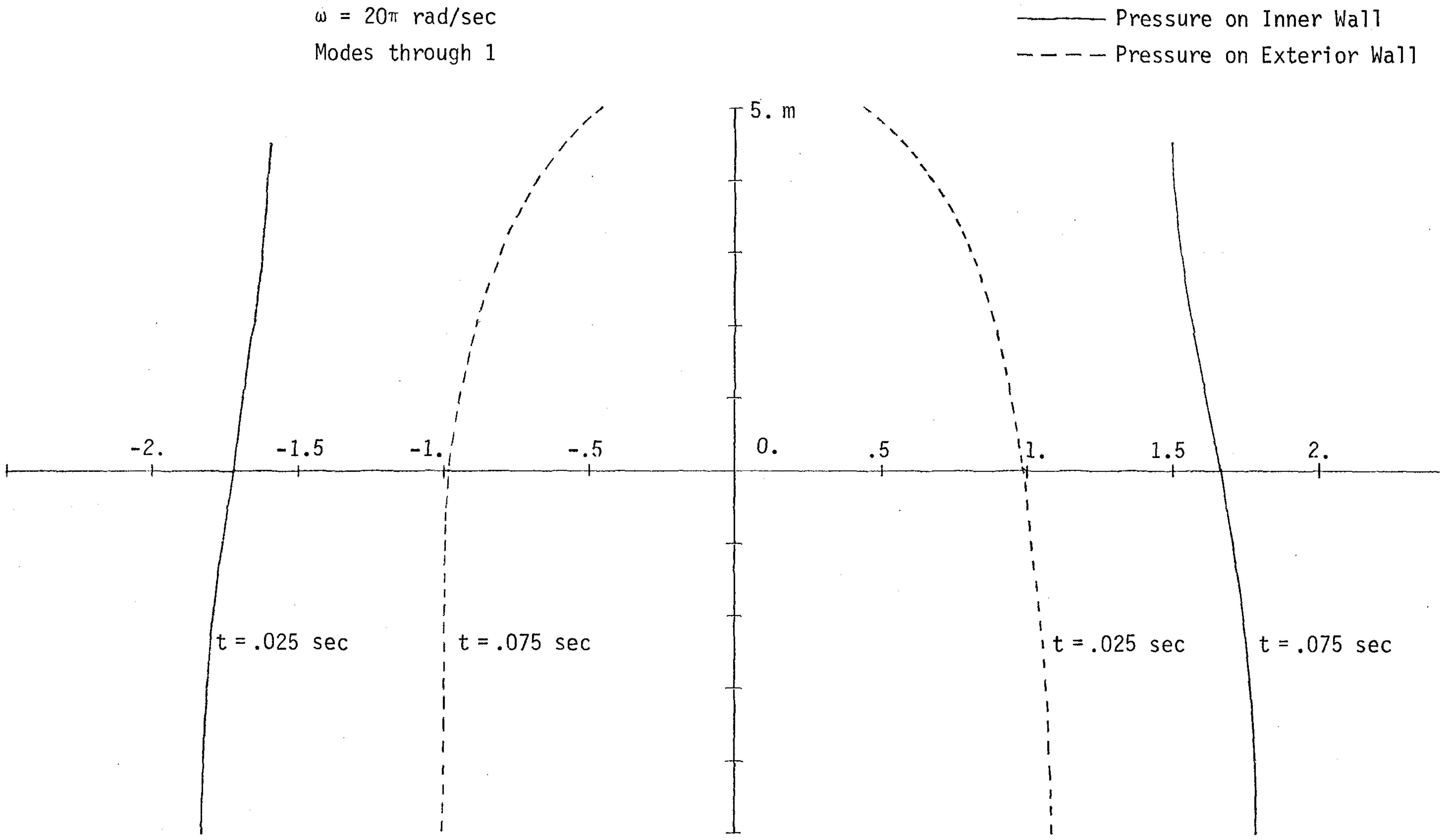


Figure 16. Pressure Distribution at Tank Wall ($\theta = 0°$) of a Submerged Flexible Tank

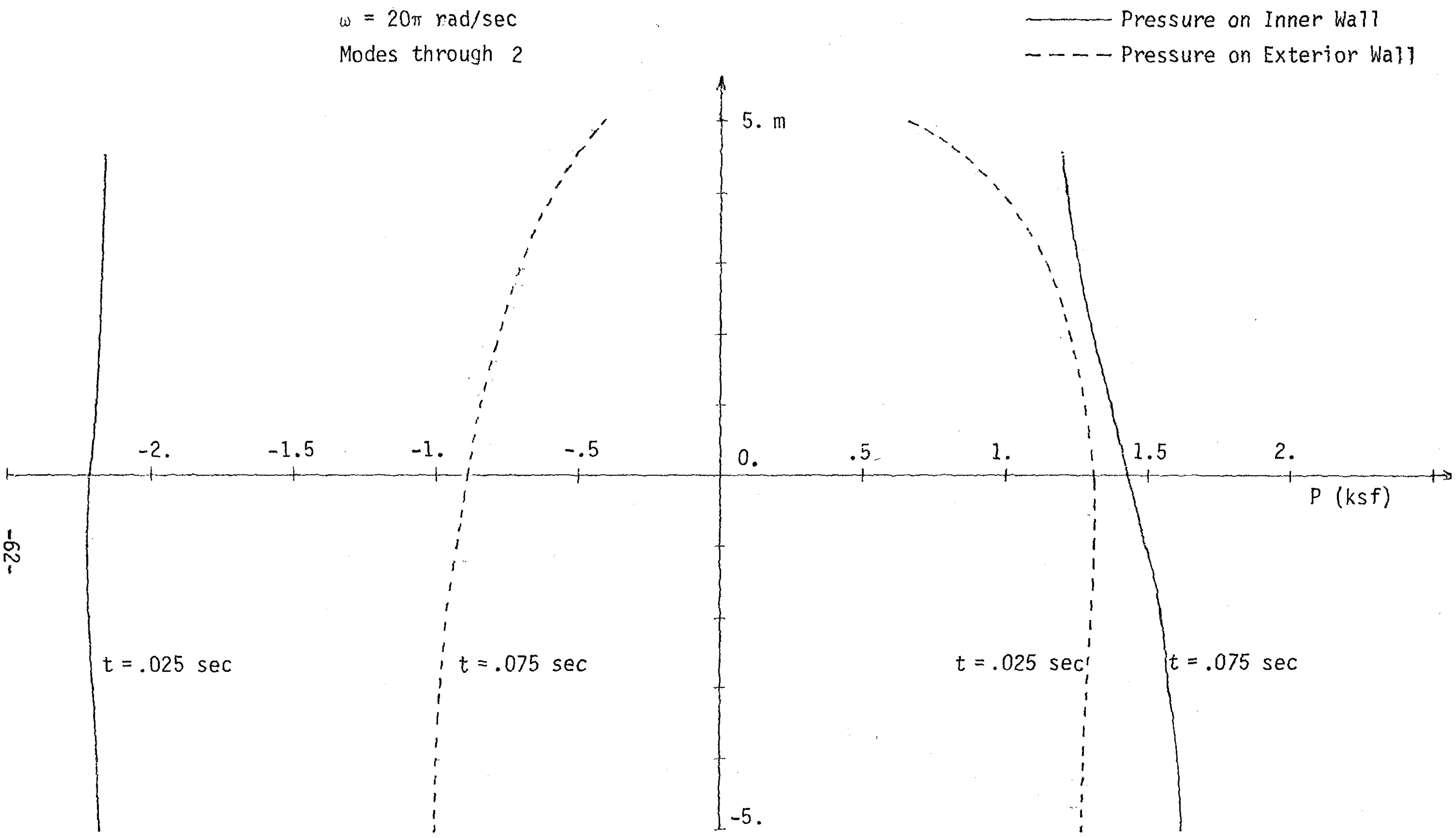


Figure 17. Pressure Distribution at Tank Wall (θ = 0°) of a Submerged Flexible Tank

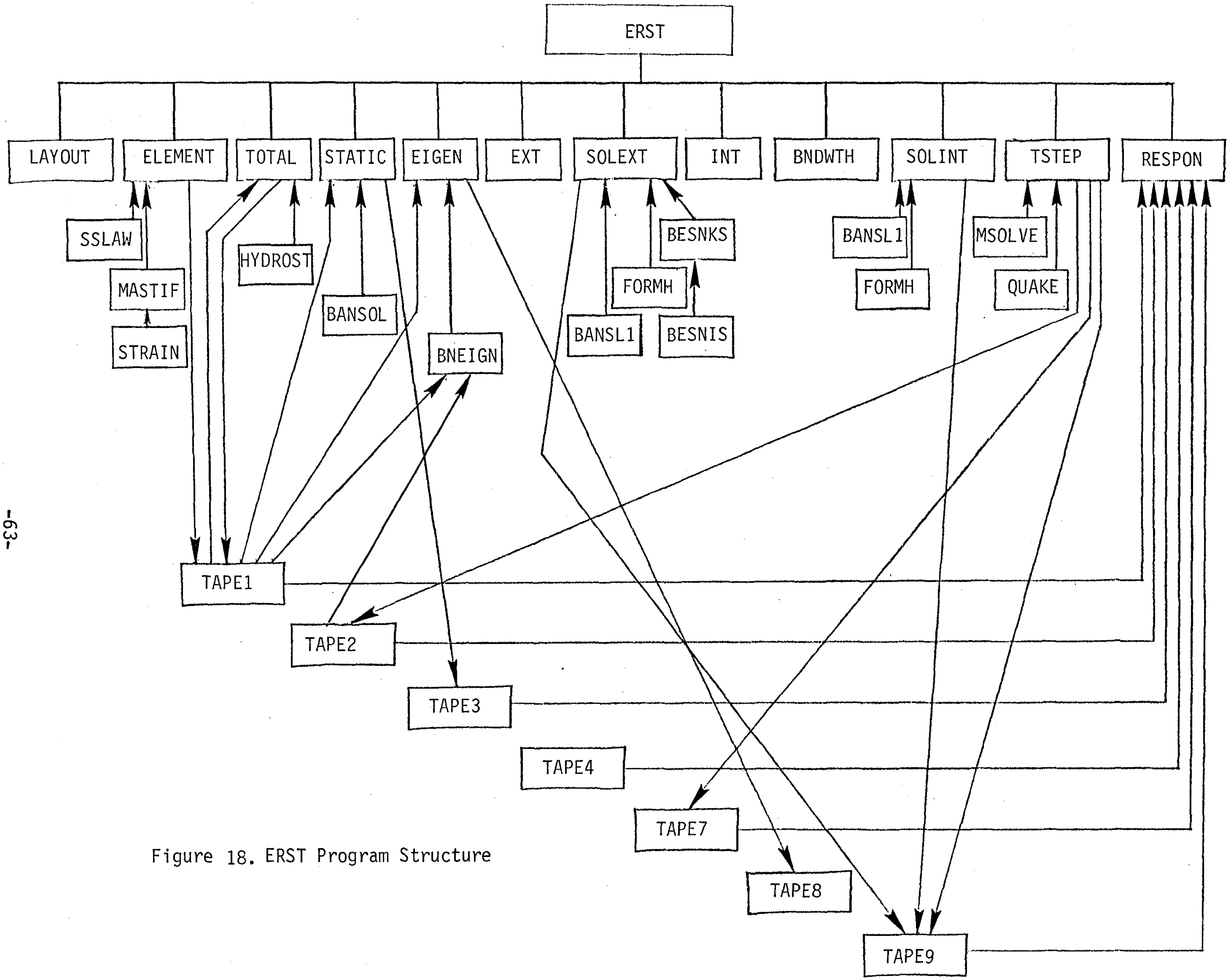


Figure 18. ERST Program Structure

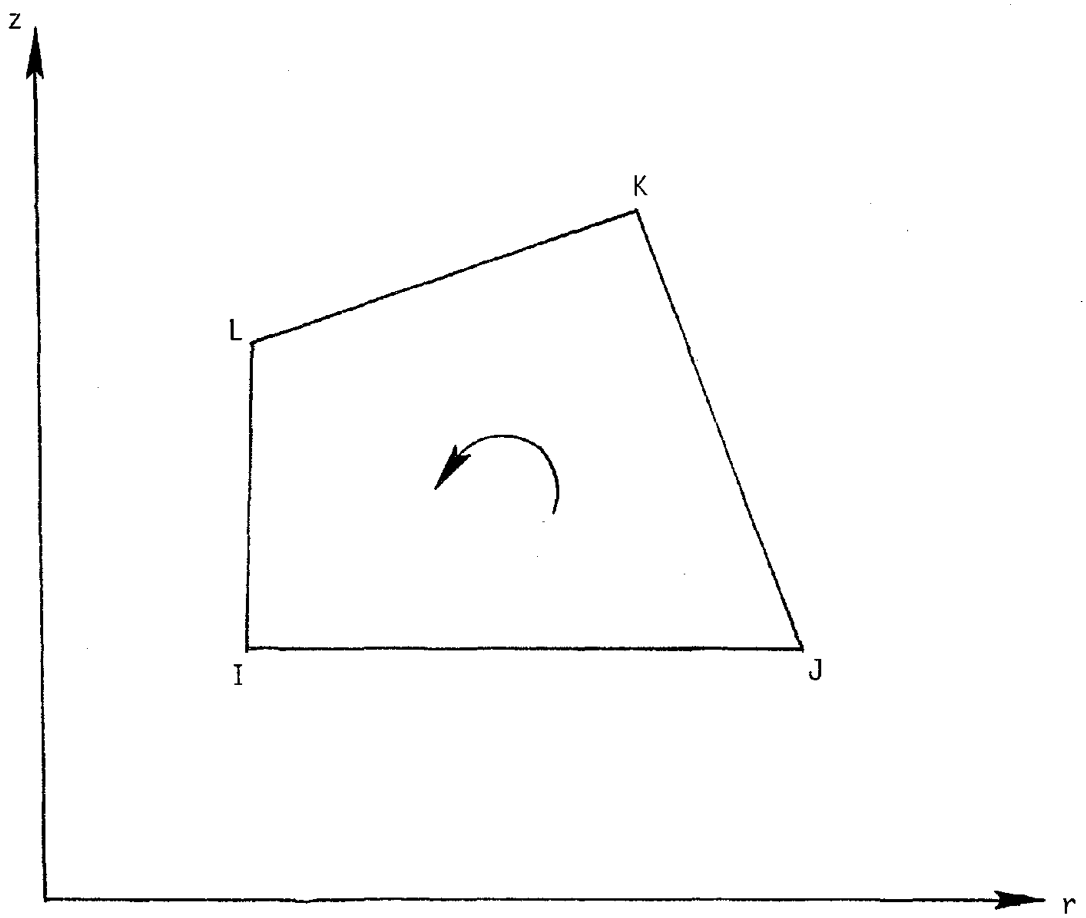


Figure 19. Finite Element Nodal Points Ordering Scheme

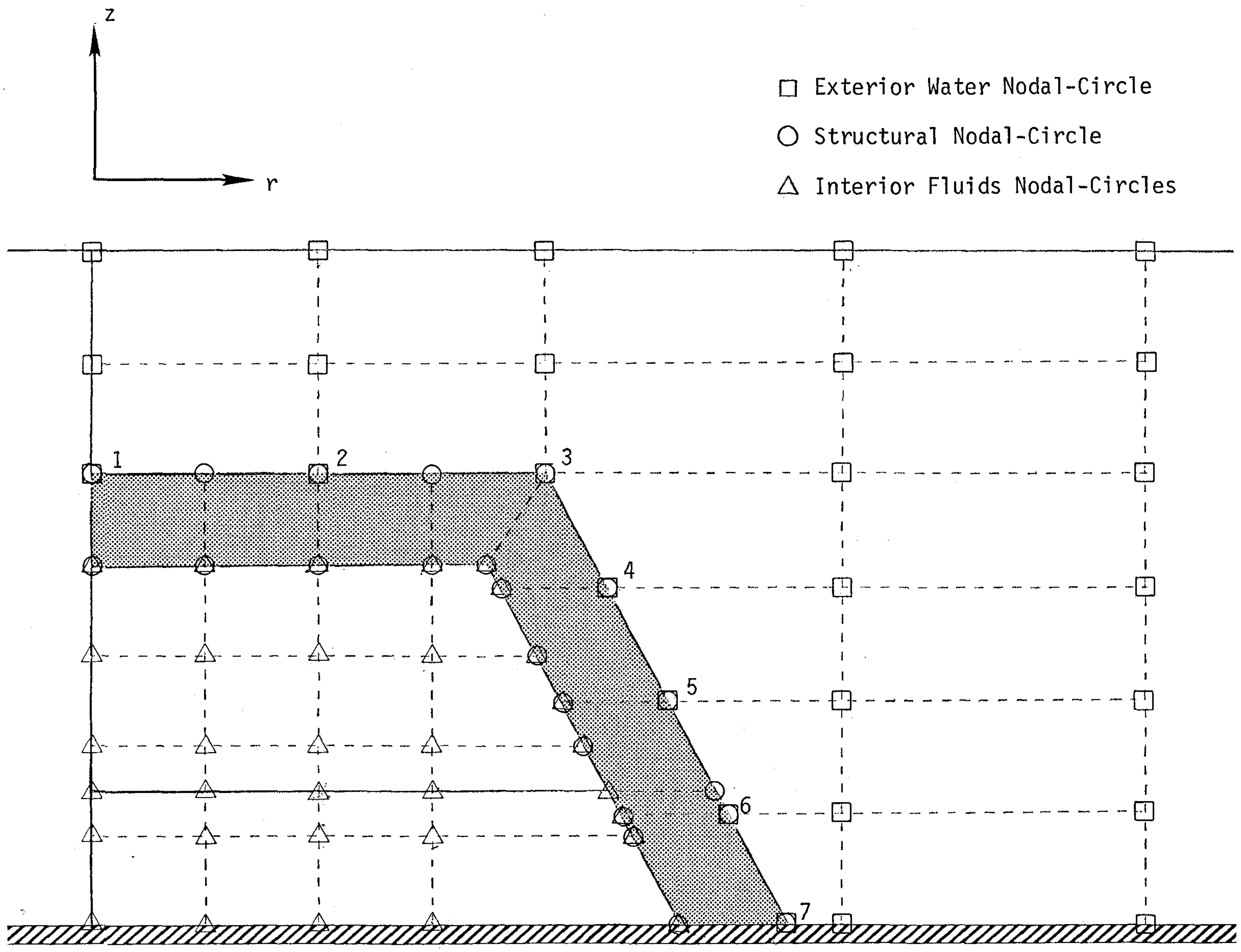


Figure 20. Finite Element Assemblages Shown at Cross-Section $\theta = 0°$.
(Note that exterior water node sequence starts at structure interface.)

Appendix A. USER'S GUIDE TO COMPUTER PROGRAM "ERST"

The computer program named ERST, for Earthquake Response of Sea-Based Storage Tanks, is developed and synthesized to evaluate the elasto-hydrodynamic response of axisymmetric storage tanks submerged underwater induced by earthquake ground motions.

The tank structure is rigidly attached to the ocean floor, has a flexible wall. The tank has a vertical axis of symmetry, is submerged underwater (structures protruding out of ocean surface can also be handled with minimum modifications) and filled with two different layers of fluids. The whole system is discretized into three assemblages of toroidal finite elements for: the interior fluids domain, the tank shell, and the near field exterior water region.

Nodal displacements, stresses, as well as hydrodynamic pressures are output as the response to the input (horizontal) ground acceleration. Both the dynamic and the static responses are evaluated. A significant portion of the code pertaining to the dynamic behavior of exterior water-structure interaction is based on the EATSW program written by Dr. C. Y. Liaw for earthquake analysis of axisymmetric intake tower structures surrounded by water, purchased through the NISEE/Computer Applications Program, and modified to interface with the developed interior fluids-structure interaction program through the kind assistance of Dr. Liaw.

Figure 18 gives the general code structure with accompanying descriptions of the functions of the subroutines and the tape files employed. Note that a plotting scheme is built in based on the available subroutines GRAF11, PLOT, OPLT, MULPLT (in subroutines LAYOUT, EIGEN and TSTEP) interfaced to a Calcomp plotter. Users are advised to modify this portion to suit one's own environment.

ERST - Driver program

LAYOUT - Determines structure characteristics and finite-element configurations

ELEMENT - Determines element stress strain, mass and stiffness matrices

TOTAL - Assembles global mass and stiffness matrices; also evaluates hydrostatic contribution for static analysis

STATIC - Computes static displacements and stress for static analysis

EIGEN - Determines structural free vibration modes and frequencies

EXT - Prepares for exterior water finite-element system set-up

SOLEXT - Computes generalized force vector and mass matrix contributed from exterior water and superelement

INT - Prepares for interior fluids finite-element system set-up

BNDWTH - Determines interior fluid element matrix bandwidth

SOLINT - Computes generalized forces vector and mass matrix contributed from interior fluids

TSTEP - Solves for modal equation of motion by time-step integration

RESPON - Calculates dynamic response by modal superpositions

TAPE1 - Stores element mass and stiffness matrices information

TAPE2 - Stores compacted mass matrix as well as x-displacement response information

TAPE3 - Stores element static response information

TAPE4 - Stores total stress information

TAPE6 - Stores plot information

TAPE7 - Stores Y-displacmeent response information

TAPE8 - Stores eigenmodes and eigenvalues information

TAPE9 - Stores hydrodynamic pressure as well as interpolated earthquake data information

In the following, we describe the data deck structure to be used for executing the program.

I. TITLE CARD (8A10)

II. STRUCTURE INFORMATION (NAMELIST:TANK)

NUMNP: number of structural nodal-circles

NUMEL: number of structural elements

NUMMAT: number of different structural materials

NMODE: number of modes of vibration included. If NMODE=0 and IGRAV=0, only static responses are evaluated.

WLO: level of water surrounding the structure (in feet)

WLI: level of water in the interior of a hollow structure (in feet)

NPO: number of structural nodal-circles on the exterior surface affected by the surrounding water

NPI: number of structural nodal-circles on the interior surface affected by interior fluids

IGRAV=0, perform static analysis only

=1, perform dynamic analysis only

=2, perform static as well as dynamic analysis

READFRQ=.FALSE., compute and write to TAPE8 frequencies and mode shapes of the structure without the surrounding water

READFRQ=.TRUE., skip calculation of frequencies and mode shapes; instead read from TAPE8

PLOTANK=.TRUE., plot structure elements

PLOTMOD=.TRUE., plot mode shapes

III. MATERIAL PROPERTY INFORMATION

One set of cards must be supplied for each different material used in structure.

Card 1 (I5,5X,A11)

Columns 1 - 5: Material sequence number

11 - 21: Either 'ISOTROPIC' or 'ORTHOTROPIC' to indicate material property

Card 2I (3F10.0): Properties of Isotropic Material

Columns 1 - 10: Modulus of elasticity (in ksf - kips per square foot)

11 - 20: Poisson's ratio

21 - 30: Mass density (in kip-sec^2/ft^4)

Card 2O (6F10.0): Properties of Orthotropic Material

Columns 1 - 10: E_n, modulus of elasticity (in ksf)

11 - 20: E_s, modulus of elasticity (in ksf)

21 - 30: E_t, modulus of elasticity (in ksf)

31 - 40: ν_{ns}, Poisson's ratio

41 - 50: ν_{nt}, Poisson's ratio

51 - 60: ν_{st}, Poisson's ratio

Card 3 (5F10.0): Properties of Orthotropic Material (continued from Card 2O)

Columns 1 - 10: G_{ns}, shear modulus (in ksf)

11 - 20: G_{nt}, shear modulus (in ksf)

21 - 30: G_{st}, shear modulus (in ksf)

31 - 40: Mass density (in kip-sec^2/ft^4)

41 - 50: Angle β in degrees measured counter-clockwise from the r-axis to the n-axis

The n-s axes are the principal axes for the orthotropic material, and t is the tangential direction of the axisymmetric coordinates.

IV. STRUCTURAL NODAL-CIRCLE CARDS (I5,F5.0,2F10.0,2I5,2F10.0)

Columns 1 - 5: Nodal-circle number

8 - 10: Boundary condition code
"1" in column 8 if r-displacement is restrained
"1" in column 9 if z-displacement is restrained
"1" in column 10 if θ-displacment is restrained

11 - 20: r-ordinate (in feet)

21 - 30: z-ordinate (in feet)

31 - 40: Used for layer generation, otherwise leave blank.

Nodal-circle cards must be in numerical sequence. If cards are omitted and Columns 31 - 60 are left blank, the omitted nodal-points are generated along a straight line between the defined nodal-points. (See Note 1); or if Columns 31 - 60 are not blank, they are generated in layers (see Note 2).

Note 1: Straight line generation

If the (L-1) cards for nodal-circles N+1, N+2,...,N+L-1 are omitted and Columns 31 - 60 of the card for nodal-circle N are left blank, the omitted nodal-circles are generated at equal intervals on the straight line joining nodes N and (N+L).

Note 2: Layer generation

Layer generation may be used after two rows of nodal-circles are completely defined. If, on the card for node N, the following data is specified:

Columns 31 - 35: MOD: module, m (> 0)

36 - 40: NLIM: limit of generation (> N)

41 - 50: FACX: amplification factor f_r (default $f_r=1$)

51 - 60: FACY: amplification factor f_z (default $f_z=1$)

the r-z coordinates of points N+1,N+2,...,NLIM are generated by the formulas:

$$r_k = r_{k-m} + f_r \cdot (r_{k-m} - r_{k-2m})$$

$$z_k = z_{k-m} + f_z \cdot (z_{k-m} - z_{k-2m})$$

for $k = N+1,\ldots,NLIM$. If NLIM = NUMNP, no more nodal-cards are needed. If NLIM < NUMNP, the card for circle (NLIM+1) must follow.

The boundary condition code for generated nodal-circles is set equal to zero, i.e., these nodal-circles are unrestrained in all r, z and θ coordinates.

V. STRUCTURAL ELEMENT CARDS (6I5)

Columns	Content	
1 - 5:	Element number	
6 - 10:	Nodal-Point I	The maximum difference "b" between these numbers is an indication of the bandwidth of the Stiffness Matrix. "b" may be minimized by a judicious numbering of nodal points.
11 - 15:	Nodal-Point J	
16 - 20:	Nodal-Point K	
21 - 25:	Nodal-Point L	
26 - 30:	Material identification	

Nodal-point numbers I, J, K and L must be in sequence in a counterclockwise direction around the element (cf. Figure 19). Element cards must be in element number sequence. If element cards are omitted, the program automatically generates the omitted information by incrementing by one the preceding I, J, K and L. The material identification for the generated card is set equal to the corresponding value on the last card. The last element card must always be supplied. Triangular elements are also permissible; they are identified by repeating the last nodal number (i.e., I, J, K, K).

VI. WATER PRESSURE CARDS

Card Set 1 (16I5): This set of cards are to be omitted, if NPO = 0.

Columns 1 - 5: Nodal-circles of the structure affected by the
6 - 10: surrounding water; $n_1, n_2, \ldots, n_k$ = NPO, starting
etc. from roof center.

Card Set 2 (16I5): This set of cards are to be omitted, if NPI = 0.

Columns 1 - 5: Nodal-circles of the structure affected by the
6 - 10: interior fluids; $m_1, m_2, \ldots, m_L$, L = NPI, starting
etc. from inner roof center.

VII. EXTERIOR FLUID CARDS

Card 1. FLUID DOMAIN DISCRETIZATION (NAMELIST: EXTFLD)

NUMPEX: number of fluid nodal-circles

NUELEX: number of fluid elements

NUINTEX: number of nodal-circles on the fluid-structure interface in the finite element idealization of the fluid

NUFSF: number of nodal circles on the free surface in the finite element idealization of the fluid and at the z-axis.

NUCOF: number of coefficients of super-element pressure representation.

Card 2. FLUID NODAL-CIRCLES (2I5,2F10.0,2I5,2F10.0)

Nodal-circles in the finite element idealization of the fluid domain must be numbered in such a way, that the first NUINTEX nodal-circles are located on the structure-fluid interface (cf. Figure 20). The numbering must start at the top as shown there. In the finite element idealization for the fluid domain, nodal-circles on the interface must be provided to coincide with the nodal-circle in the structural idealization. Additional nodal-circles can be included in the idealization of the fluid domain, as shown in Figure 20.

One card for each nodal-circle containing the following information must be provided.

Columns 1 - 5: Fluid nodal-circle number

6 - 10: ICODE: Boundary condition code for fluid nodal-circle. If the fluid nodal-circle is on the interface and coincides with a structural nodal-circle, ICODE = the number of the coincident structural nodal circle.

If the fluid nodal-circle is on the interface but does not coincide with a structural nodal-circle, then ICODE = -1.

If the fluid nodal-circle is on the free surface of the fluid domain, ICODE = -2.

For all other nodal-circles, leave Columns 26-30 blank. Special attention must be given to fluid nodal-circle number 1; it must coincide with the roof center of the tank.

11 - 20: r-ordinate (in feet)

21 - 30: z-ordinate (in feet)

31 - 60: Used for layer generation; otherwise leave blank.

Nodal-circle cards must be in numerical sequence starting from one. If cards are omitted and Columns 31-60 are left blank, the omitted nodal-points are generated along a straight ine between the defined nodal-circles (see IV, Note 1); or if columns 31-60 are used, they are generated in layers (see IV, Note 2). The boundary condition code (ICODE) of a generated nodal circle is set equal to the value of ICODE on the last card.

Card 3. FLUID ELEMENTS (9I5)

Columns 1 - 5 Element number

6 - 10: Nodal-Circle I

11 - 15: Nodal-Circle J

16 - 20: Nodal-Circle K

21 - 25: Nodal-Circle L

Fluid Element Surface Code (=2, hybrid surface)

26 - 30: surface IJ

31 - 35: surface JK

36 - 40: surface KL

41 - 45: surface LI

Nodal-circle numbers I, J, K and L must be in sequence in a counter-clockwise direction around the element (cf. Figure 19). Element cards must be in element number sequence. If element cards are omitted, the program automatically generates the omitted information by incrementing by one the preceding I, J, K and L. The last element card must always be supplied. Triangular elements are also permissible; they are identified by repeating the last nodal number (i.e., I, J, K, K)

VIII. INTERIOR FLUID CARDS

Card 1. FLUID DOMAIN DISCRETIZATION (NAMELIST: INTFLD)

NUNPIN: number of fluid nodal-circles

NUELIN: number of fluid elements

ROIL: specific gravity of oil

NUINTIN: number of elements at oil/water interface

NUELOIL: number of oil elements; the oil elements must be numbered from 1 to NUELOIL

2. FLUID NODAL-CIRCLES (2I5,2F10.0,2I5,2F10.0)

One card for each nodal-circle containing the following information must be provided.

Columns 1 - 5: Fluid nodal-circle number

6 - 10: ICODE: Boundary condition code for fluid nodal-circle. If the fluid nodal-circle is on the wall and coincides with a structural nodal-circle, ICODE = the number of the coincident structural nodal-circle.

If the fluid nodal-circle is both on the wall and on the interface and coincides with a structural nodal-circle, then ICODE = - (the number of the coincident structural nodal-circle).

11 - 20: r-ordinate (in feet)

21 - 30: z-ordinate (in feet)

31 - 60: Used for layer generation; otherwise leave blank.

Nodal-circle cards must be in numerical sequence starting from one. If cards are omitted and Columns 31-60 are left blank, the omitted nodal-points are generated along a straight line between the defined nodal-circles (see IV, Note 1), or if Columns 31-60 are used, they are generated in layers (see IV, Note 2). The boundary condition code (ICODE) of a generated nodal-circle is set equal to zero.

Card 3. FLUID ELEMENTS (5I5)

Columns 1 - 5: Element number

6 - 10: Nodal-circle I

11 - 15: Nodal-circle J

16 - 20: Nodal-circle K

21 - 25: Nodal-circle L

Nodal-circle numbers I, J, K and L must be in sequence in a counterclockwise direction around the element (cf. Figure 19). Element cards must be in element number sequence. If element cards are omitted, the program automatically generates the omitted information by incrementing by one the preceding I, J, K and L. The last element card must always be supplied. Triangular elements are also permissible; they are identified by repeating the last number (i.e., I, J, K, K).

Card 4. OIL/WATER INTERFACIAL ELEMENT (16I5)

List of NUINTIN element numbers on the oil-water interface.

IX. RESPONSE CONTROL CARDS (NAMELIST: RESPONS)

NGRD:=1, if only one component of ground motion, along $\theta = 0°$, is to be considered

=2, if two components of ground motion, along $\theta = 0°$ and $\theta = 90°$, are to be included.

NT: number of integration steps in time

DT: time interval in step-by-step integration

NXFH: number of ordinates describing time history of gound motion component 1 along $\theta = 0°$.

NYFH: number of ordinates describing time history of ground motion component 2 along $\theta = 90°$.

PLOTALL=.FALSE., ground motion not plotted.

=.TRUE., plot ground motion.

X. DAMPING RATIO CARDS (7F10.0)

Columns 1 - 10: Damping ratio for first mode of vibration of the tank.

11 - 20: Damping ratio for second mode of vibration of the tank.

21 - 30: Damping ratio for third mode of vibration of the tank.

etc.

XI. GROUND ACCELERATION CARDS

(i) FIRST COMPONENT - Along = 0°

Card 1 TITLE (8A10)

Card 2 ACCELERATION (6(F6.3,F6.4),8X)

NXFH time-acceleration pairs describing the time-history of the component of ground acceleration along $\theta = 0°$ are to be specified on these cards, with six pairs per card. Time must be expressed in seconds and accelerations as multiples of g, the acceleration due to gravity.

(ii) SECOND COMPONENT - Along $\theta = 90°$

Card 1 TITLE (8A10)

Card 2 ACCELERATION (6(F6.3,F6.4),8X)

NYFH time-acceleration pairs describing the time-history of the component of ground acceleration along $\theta = 90°$ are to be specified on these cards, with six pairs per card. Time must be expressed in seconds and accelerations in multiples of g.

XII. OUTPUT INFORMATION CARDS

Card 1. OUTPUT CONTROL (NAMELIST: PRINTIT)

NPRINT: Print interval. Nodal-circle displacement amplitudes and element stress amplitudes are written on TAPE3 every NPRINT time-intervals. If printed output of time history response is required (i.e., NNODE ≠ 0 and/or NNEL ≠ 0), nodal-circle displacements and/or element stresses are also printed every NPRINT time-intervals.

NNODE: Total number of nodal-circles at which time-history of displacements is to be printed.

NNEL: Total number of elements at which time-history of stresses is to be printed.

NANGLE: Total number of different directions around the circumference of a nodal-circle or axisymmetric element at which displacement and stresses are to be printed.

Card 2. ANGLE SELECTION (8F10.0)

List of NANGLE values of angles (in degrees) describing directions along the circumference at which displacements and stresses are to be printed. These cards are to be omitted in NANGLE = 0°.

Card 3. NODAL CIRCLE SELECTION (16I5)

List of NNODE nodal circle numbers at which displacements are to be printed. These cards are to be omitted if NNODE = 0.

Card 4. ELEMENT SELECTION (16I5)

List of NNEL element numbers for which stresses are to be printed. These cards are to be omitted if NNEL = 0.

OUTPUT

The following is printed by the program (note that some of these may be suppressed according to the options provided in Cards II and XII).

1. First set of input data: structural and material properties, options, etc.

2. Hydrostatic loads: i.e., equivalent nodal-circle loads due to hydrostatic pressure of the surrounding water and fluids inside the tank. Nodal-circle displacements and element stresses for static loads. Added-mass due to fluids inside the tank.

3. Frequencies and mode shapes of the structure, including the effect of interior fluids but not the effect of water surrounding the structure.

4. Second set of input data: geometric data for the surrounding and interior fluids, structural nodal-points affected by hydrodynamic interaction.

5. The generalized mass matrix and the generalized force vector, including hydrodynamic effects.

6. Third set of input data: response data including number of time steps, time increment, and modal damping ratios, earthquake acceleration data, control data for output of time history of response.

7. Displacements of selected nodal circles (see card group XII), stresses in selected elements along selected angles at instants of time, determined by the print interval NPRINT. The displacements and stresses printed include the static values at the beginning of the earthquake motion.

8. The peak values of displacement amplitudes of each nodal-circle and amplitudes of stress in each element and with time at which they occur during the earthquake. These peak values exclude the static values.

9. The following quantities are written on TAPE3:

Logical Record 1: NUMNP, NUMEL, NMODE, DT, NT, NPRINT, IGRAV, NGRD

Starting with Record 2, two records are written for every NPRINT time-intervals for each ground motion component using the following two statements:

```
WRITE (3) X

WRITE (3) STRESS
```

X and STRESS are one-dimensional arrays, dimensioned properly so that X(3*1-2), X(3*I-1) and X(3*I) are the r, z and θ-components, respectively, of the displacement amplitude at nodal-circle I, I=1,...,NUMNP. Similarly, STRESS(6*N-5), STRESS(6*N-4), STRESS(6*N-3), STRESS(6*N-2), STRESS(6*N-1) and STRESS(6*N) are the amplitudes of the six components, σ^{rr}, σ^{zz}, $\sigma^{\theta\theta}$, σ^{rz}, $\sigma^{r\theta}$ and $\sigma^{z\theta}$ in the element number N, N=1,2,...,NUMEL.

If IGRAV = 1, the dynamic responses start with the first set of X and STRESS. However, if IGRAV = 2, the first set of X and STRESS is the static response; the dynamic response starts with the second set.

STORAGE REQUIREMENTS

The cord storage requirements of the program are separated into fixed and variable parts with the fixed part consisting of instructions, non-subscripted variables, and those arrays which do not depend on the size of the individual problem. The variable part is stored in Array A, which appears in the blank COMMON statement.

The blank COMMON storage requirements of the program can be changed depending on the size of the problem to be solved. This is done by using the RFL job control statement to increase the program size:

```
RFL(MMAX)
```

MMAX (in octal) is the total memory words requested. N=MMAX-45000 is the available memory size for blank COMMON storage.

The value for N must exceed each of the following:

(1) 3*NUMNP*(4 + MBAND) + 11*NUMEL + 11*NUMMAT + NBC + NPO + NPI

(2) 3*NUMNP*(8 + MBAND) + 5*NUMEL + 11*NUMMAT + NBC + NMODE*(NMODE + 1)

(3) 5*NUMNP + (2 + 3*NUMNP + NMODE + 3*NUINTEX)*NMODE + (3 + NEBAND + NMODE)*NUMPEX + 8*NUELEX + NUINTEX + NUFSF + (1 + NEBAND + NMODE)*NUCOF

(4) 5*NUMNP + (2 + 3*NUMNP + NMODE)*NMODE + 7*NUELIN + (4 + 2*NMODE + NIBAND)*NUNPIN

(5) 5*NUMNP + (408 + 3*NUMNP + 2*NMODE)*NMODE + 2*NXFH + 2*NYFH + NT

(6) 852 + (22 + 4*NMODE)*NUMNP + 805*NMODE + 42*NUMEL + NMODE + NNEL + NANGLE + 2*NT

where:

NUMNP: number of nodal circles in the structural idealization

NUMEL: number of elements in the structural idealization

NUMMAT: number of different structural materials

NBC: number of structural displacement constraints in the structural idealization

NPO: number of nodal circles on the exterior surface of the structure affected by the surrounding water

NPI: number of nodal circles on the interior surface of the structure affected by the fluids in the tank interior

MBAND = 3*(MB + 1)

$\mathrm{MB} = \max\limits_{i} \mathrm{MB}_i,\ i = 1,\ \mathrm{NUMEL}$

MB_i: difference between the largest and smallest structual nodal-circle numbers for structural element i

NMODE: number of modes of vibration included

NUMPEX: number of nodal circles in the exterior water idealization

NUELEX: number of elements in the exterior water idealization

NUINTEX: number of fluid nodal-circles on the exterior structure-fluid interface

NUFSF: number of exterior fluid nodal-circles on the free surface of the fluid

NEBAND = NEB + 1

$NEB = \max_{i} NEB_i$, i = 1, NUELEX

NEB_i: difference between the largest and smallest nodal circle numbers for exterior fluid element i

NUNPIN: number of nodal circles in the interior fluid idealization

NUELIN: number of elements in the interior fluid idealization

NIBAND = NIB + 1

$NIB = \max_{i} NIB_i$, i = 1, NUELIN

NIB_i: difference between the largest and smallest nodal circle numbers for interior fluid element

NXFH: number of ordinates describing time-history of first ground motion component, along $\theta = 0°$

NYFH: number of ordinates describing time-history of second ground motion component, along $\theta = 90°$

NT: number of integration time steps

NNODE total number of structural nodal-circles at which time-history of displacements is to be printed

NNEL: total number of structural elements for which time-history of stresses is to be printed

NANGLE: total number of different locations around the circumference at which displacements and stresses are to be printed

If only frequencies and mode shapes are desired along with static analysis, it suffices to check (1) and (2) above.

The computer time required for solution depends on a number of factors. The more important ones are the number of integration time steps (NT), the number of structural nodal circles (NUMNP), the bandwidth (MBAND) of the structural stiffness matrix (the nodal circles should be numbered in a manner which minimizes the bandwidth), the number of structural elements (NUMEL), the number of modes of vibration to be included (NMODE), interval for printing and writing (NPRINT), and the number of nodal-circles (NUNPEX, NUNPIN) and elements (NUELEX, NUELIN) in the idealization of the fluid domain.

APPENDIX B. PROGRAM "ERST" LISTINGS

```
      PROGRAM ERST(INPUT,OUTPUT,TAPE1,TAPE2,TAPE3,TAPE4,TAPE6=OUTPUT,
     1             TAPE7,TAPE8,TAPE9)
C
C*********************************************************************
C              EARTHQUAKE RESPONSE OF SEA-BASED STORAGE TANKS
C*********************************************************************
C
C     THIS PROGRAM SHOULD BE COMPILED USING THE FTN "STATIC" OPTION
C     WHEREBY MTOP CAN BE ADJUSTED DYNAMICALLY AT RUN TIME VIA THE CM
C     OR RFL PARAMETER ON THE JOB CARD.
C
      COMMON/FCONST/PI,ROW,WLO
      COMMON/CNTRL/NUMNP,NANGLE,MBAND,NBC,NF,NPO,NPI,TRACE,READFRQ
      DIMENSION HED(8)
      COMMON A(20000)
      LOGICAL READFRQ,PLOTANK,PLOTMOD
      LOGICAL PLOTACC
      NAMELIST /TANK/ NUMNP,NUMEL,NUMMAT,NMODE,WLO,WLI,NPO,NPI,IGRAV,
     1                READFRQ,PLOTANK,PLOTMOD
      NAMELIST /EXTFLD/ NUNPEX,NUELEX,NUINTEX,NUFSF,NUCOF
      NAMELIST /INTFLD/ NUNPIN,NUELIN,NUINTIN,NUELOIL,ROIL
      NAMELIST /RESPONS/ NGRD,NT,DT,NXFH,NYFH,PLOTACC
      NAMELIST /PRINTIT/ NPRINT,NNODE,NNEL,NANGLE
      DATA PLOTANK/.F./,PLOTMOD/.F./,PLOTACC/.F./,READFRQ/.F./
      PI=3.14159265
      ROW=0.0625/32.2
C
C GET THE AVAILABLE BLANK COMMON MEMORY SIZE
C
      CALL PFL(MTOP)
      MSTOR = MTOP - LOCF (A(1)) + 1
C
C     READ AND PRINT OF CONTROL INFORMATION
C
      READ 1000, HED
      READ TANK
      PRINT TANK
      PRINT 2000, HED,NUMNP,NUMEL,NUMMAT,NMODE,WLO,WLI,NPO,NPI
C
C     READ DATA AND DETERMINE ELEMENT PROPERTIES
C
      N2=1+NUMNP
      N3=N2+NUMNP
      N4=N3+5*NUMEL
      N5=N4+NUMMAT*9
      N6=N5+NUMMAT
      N8=N6+NUMMAT
      NEQ=3*NUMNP
      N9=N8+NEQ
      CALL MSCHECK(MSTOR,N9+NUMNP,"LAYOUT")
      CALL LAYOUT(A(1),A(N2),A(N3),A(N4),A(N5),A(N6),A(N8),A(N9),
     1 NUMMAT,NUMEL,PLOTANK)
      NF=0
      IF(IGRAV.EQ.1) NF=1
  120 CALL ELEMENT(A(1),A(N2),A(N3),A(N4),A(N5),A(N6),A(N8),NF,NUMEL)
C
C     FORM TOTAL MASS AND STIFFNESS MATRICES
```

```
C
      N9=N8+NBC
      N10=N9+NEQ
      N11=N10+NEQ
      N12=N11+(NEQ*MBAND)
      N13=N12+NPO
      CALL MSCHECK(MSTOR,N13+NPI,"TOTAL")
      CALL TOTAL(A(1),A(N2),A(N8),A(N9),A(N10),A(N11),A(N12),A(N13),WLO
     1    ,WLI,NPO,NEQ,MBAND,NUMEL,IGRAV)
C
C     SOLVE FOR STATIC LOADS
C
      NUM=6*NUMEL
      IF(NF.NE.0) GO TO 150
      N14=N13+NPI
      CALL MSCHECK(MSTOR,N14+NUM,"STATIC")
      CALL STATIC(A(N8),A(N9),A(N10),A(N11),A(N14),NEQ,MBAND
     1,NUM,NUMEL)
  150 IF(NF.EQ.0) GO TO 200
C
C     MODE SHAPES AND NATURAL FREQUENCIES
C
      N12=N11+NMODE
      N13=N12+(NEQ*MBAND)
      N14=N13+NEQ
      N15=N14+NEQ
      N16=N15+NEQ
      N17=N16+NEQ
      CALL MSCHECK(MSTOR,N17+NMODE**2,"EIGEN")
      CALL EIGEN(A(N8),A(N9),A(N10),A(N11),A(N12),A(N13),A(N1
     1 4),A(N15),A(N16),A(N17),NEQ,NMODE,MBAND,A(1),A(N2),PLOTMOD)
C
C     SOLVE FOR HYDRODYNAMIC RESPONSE (INCOMPRESSIBLE FLUID)
C
      N13=N12+(NEQ*NMODE)
      NTEMP=N10-1
      WRITE (1) (A(I),I=N9,NTEMP)
      NTEMP=N13-1
      WRITE (1) (A(I),I=N11,NTEMP)
      BACKSPACE 1
      BACKSPACE 1
      N4=N3+NEQ
      N5=N4+NMODE
      N6=N5+(NEQ*NMODE)
      N7=N6+NMODE
      N8=N7+(NMODE*NMODE)
      NTEMP=N4-1
      READ(1) (A(I),I=N3,NTEMP)
      NTEMP=N6-1
      READ(1) (A(I),I=N4,NTEMP)
      BACKSPACE 1
      BACKSPACE 1
C
C     WATER TREATED AS A FINITE-ELEMENT SYSTEM
C
      READ EXTFLD
      PRINT EXTFLD
```

```
      PRINT 2040
C
C     READ AND PRINT WATER ELEMENT PROPERTIES
C
      PRINT 2050,  NUNPEX,NUELEX,NUINTEX,NUFSF,NUCOF
      N9=N8+NMODE*NUINTEX*3
      N10=N9+NUINTEX
      N11=N10+NUNPEX
      N12=N11+NUNPEX
      N13=N12+8*NUELEX
      CALL MSCHECK(MSTOR,N13+NUFSF,"EXT")
      CALL EXT(A(N9),A(N10),A(N11),A(N12),A(N13),
     1 NUNPEX,NUELEX,NEBAND,NUINTEX,NUCOF,WLO)
C
C     SOLVE FOR RESPONSES OF WATER FINITE-ELEMENT SYSTEM
C
      NEQF=NUNPEX+NUCOF
      N14=N13+NUFSF
      N15=N14+NEQF
      N16=N15+NEQF*NMODE
      N17=N16+NEQF*NEBAND
      CALL MSCHECK(MSTOR,N17,"SOLEXT")
      CALL SOLEXT(A(N3),A(N4),A(N5),A(N6),A(N7),A(N8),A(N9),
     1 A(N10),A(N11),A(N12),A(N13),A(N14),A(N15),A(N16),
     2 NMODE,NEQ,NUNPEX,NUELEX,NUINTEX,NUFSF,NEBAND,NEQF)
C
C     INTERIOR FLUIDS TREATED AS A FINITE-ELEMENT SYSTEM
C
      READ INTFLD
      PRINT INTFLD
      N9=N8+NUNPIN
      N10=N9+NUNPIN
      N11=N10+NUNPIN
      N12=N11+4*NUELIN
      N13=N12+NUELIN
      N14=N13+NUELIN
      N15=N14+NUELIN
      CALL MSCHECK(MSTOR,N15,"INT")
      CALL INT(A(N8),A(N9),A(N10),A(N11),A(N12),A(N13),A(N14),
     1             ROIL,NUINTIN,NUELIN,NUNPIN,NUELOIL)
      CALL BNDWTH(A(N8),A(N9),A(N11),A(N12),A(N14),NUELIN,NUNPIN,
     1            NIBAND)
      N13=N12+NMODE*NUNPIN
      N14=N13+NUNPIN*NIBAND
      N15=N14+NUNPIN
      N16=N15+NUNPIN*NMODE
      CALL MSCHECK(MSTOR,N16,"SOLINT")
      CALL SOLINT(A(N5),A(N6),A(N7),A(N8),A(N9),A(N10),A(N11),A(N12),
     1      A(N13),A(N14),A(N15),ROIL,NUELIN,NIBAND,NUNPIN,NEQ,NMODE,
     2            NUELOIL)
C
C     TIME RESPONSE OF MODAL DISPLACEMENTS
C
      READ RESPONS
      PRINT RESPONS
      IF (NGRD.EQ.1) PRINT 2020,  NT,DT
      IF (NGRD.EQ.2) PRINT 2021,  NT,DT
```

```
      NG=NGRD
      NBUF=200*NMODE
      N10=N8
      N11=N10+NMODE
      NTAPE=2
  179 N12=N11+NXFH
      N13=N12+NXFH
      N14=N13+NMODE
      N15=N14+NMODE
      N16=N15+NMODE
      N17=N16+NMODE
      N18=N17+NMODE
      N19=N18+NBUF
      N20=N19+NT
      N21=N20+NBUF
      N22=N21+NMODE*NMODE
      CALL MSCHECK(MSTOR,N22,"TSTEP")
      CALL TSTEP(A(N4),A(N6),A(N7),A(N10),A(N11),A(N12),A(N13),A(N14),
     1 A(N15),A(N16),A(N17),A(N18),A(N19),A(N20),A(N21),
     2 NMODE,NT,DT,NXFH,NBUF,MBUF,NBLOCK,NGRD,NTAPE,NG,PLOTACC)
      IF (NG.EQ.1) GO TO 185
      NG=1
      NTAPE=7
      NXFH=NYFH
      GO TO 179
C
C     SUPERPOSITION OF MODES AND EVALUATION OF STRESSES
C
  185 CONTINUE
      READ PRINTIT
      PRINT PRINTIT
      IF(NANGLE.EQ.0) NANGLE=1
      N2=1+NANGLE
      N3=N2+NMODE
      N4=N3+(NEQ*NMODE)
      READ (1)
      NTEMP=N4-1
      READ(1) (A(I),I=N2,NTEMP)
      N5=N4+NUM
      N6=N5+NNODE
      N7=N6+NNEL
      N8=N7+NBUF
      N9=N8+NBUF
      N10=N9+NMODE
      N11=N10+NMODE
      N12=N11+NEQ
      N13=N12+NEQ
      N14=N13+6
      N15=N14+6
      N16=N15+12*10
      N17=N16+6*12*10
      N18=N17+NUM
      N19=N18+NEQ
      N20=N19+NEQ
      N21=N20+NUM
      N22=N21+NEQ
      N23=N22+NUM
```

```
      N24=N23+NEQ
      N25=N24+NUM
      N26=N25+NEQ
      N27=N26+NUM
      N28=N27+NUM
      N29=N28+NUMNP
      N30=N29+NUMNP*NMODE
      N31=N30+NT
      N32=N31+NT
      N33=N32+NBUF
      N34=N33+NBUF
      N35=N34+NMODE
      N36=N35+NMODE
      CALL MSCHECK(MSTOR,N36,"RESPON")
      CALL RESPON(A(1),A(N2),A(N3),A(N4),A(N5),A(N6),A(N7),A(N8),
     1 A(N9),A(N10),A(N11),A(N12),A(N13),A(N14),A(N15),A(N16),A(N17),
     2 A(N18),A(N19),A(N20),A(N21),A(N22),A(N23),A(N24),A(N25),A(N26),
     3 A(N27),A(N28),A(N29),A(N30),A(N31),A(N32),A(N33),A(N34),A(N35),
     3 NMODE,NEQ,NANGLE,NPRINT,NNODE,NNEL,NUMNP,NUMEL,NUM,
     4 NBLOCK,NBUF,MBUF,IGRAV,DT,NT,NGRD)
  200 IF(IGRAV.NE.2) GO TO 250
      IF(NF.GE.1) GO TO 250
      NF=1
      GO TO 120
  250 PRINT 3000
 1000 FORMAT (8A10)
 2000 FORMAT (1H1,8A10//
     1 35H  NUMBER OF NODAL POINTS----------- I4 /
     2 35H  NUMBER OF ELEMENTS--------------- I4 /
     3 35H  NUMBER OF DIFF. MATERIALS-------- I4 /
     4 35H  NUMBER OF EIGENMODES------------- I4 /
     5 35H  WAER LEVEL OUTSIDE TANK---------- F10.3,3HFT. /
     6 35H  WAER LEVEL  INSIDE TANK---------- F10.3,3HFT. /
     7 35H NUMBER OF PRESSURE POINTS OUTSIDE- I4 /
     8 35H NUMBER OF PRESSURE POINTS INSIDE-- I4/ )
 2020 FORMAT (1H1/46H ONLY ONE COMPONENT OF GROUND MOTION INCLUDED /
     1 * NO.  OF TIME STEPS SELECTED =*,I7/* DT IN SECONDS  =*,F10.4/)
 2021 FORMAT (1H1/42H TWO COMPONENTS OF GROUND MOTION INCLUDED /
     1 * NO.  OF TIME STEPS SELECTED =*,I7/* DT IN SECONDS  =*,F10.4/)
 2040 FORMAT (1H1/41H INTERACTION PROBLEM IS SOLVED BY F.E.M.    /)
 2050 FORMAT (//35H NUMBER OF NODAL POINTS OF FLUID = ,I10,
     1        /35H NUMBER OF ELEMENT  OF FLUID     = ,I10,
     2        /35H NUMBER OF N.P.  ON THE INTERFACE = ,I10,
     3        /38H NUMBER OF N.P.  ON THE FREE SURFACE = ,I7,
     4        /49H NUMBER OF POWER SERIES TERMS FOR SUPERELEMENT = ,I2)
 3000 FORMAT (///17H  END OF PROBLEM  )
      STOP
      END
```

SYMBOLIC REFERENCE MAP (R=2)

```
          PROGRAM ERST      76/176  OPT=1 STATIC              FTN 4.8+498         03/16/81  16.39.39        PAGE      6

ENTRY POINTS     DEF LINE     REFERENCES
22633  ERST           1

VARIABLES   SN  TYPE              RELOCATION
    0  A        REAL      ARRAY  / /                 REFS       15       31     8*51     7*55     8*65     5*74    12*87
                                                       94       96    5*126   14*137    7*153    5*155   11*162   15*189
                                                   35*243  DEFINED      105      107      209
24642  DT       REAL                                 REFS       22      170      171      189      243
24731  HED      REAL      ARRAY                      REFS       14       38  DEFINED       35
24674  I        INTEGER                              REFS       94       96      105      107      209
                                                  DEFINED       94       96      105      107      209

24625  IGRAV    INTEGER                              REFS       18       54       65      243      249
    2  MBAND    INTEGER          CNTRL               REFS       13       62       65       74       81       87
24711  MBUF     INTEGER                              REFS      189      243
24651  MSTOR    INTEGER                              REFS       50       64       73       86      125      136      152
                                                      161      188      242  DEFINED       31

24650  MTOP     INTEGER                              REFS       30       31
    1  NANGLE   INTEGER          CNTRL               REFS       13       23      203      204      243
                                                  DEFINED      203

    3  NBC      INTEGER          CNTRL               REFS       13       59
24712  NBLOCK   INTEGER                              REFS      189      243
24702  NBUF     INTEGER                              REFS      184      186      189      213      214      238      239
                                                      243  DEFINED      173

24676  NEBAND   INTEGER                              REFS      126      135      137
24660  NEQ      INTEGER                              REFS       49       60       61       62       65       74       81
                                                       82       83       84       85       87       92       99      101
                                                      137      162      206      217      218      224      225      227
                                                      229      231      243  DEFINED       48

24677  NEQF     INTEGER                              REFS      133      134      135      137  DEFINED      131
    4  NF       INTEGER          CNTRL               REFS       13       55       71       76      250
                                                  DEFINED       53       54      251

24701  NG       INTEGER                              REFS      189      192  DEFINED      172      193
24640  NGRD     INTEGER                              REFS       22      170      171      172      189      243
24700  NIBAND   INTEGER                              REFS      155      158      162
24623  NMODE    INTEGER                              REFS       18       38       80       86       87       92      100
                                                      101      102    2*103      120      134      137      157      160
                                                      162      173      175      179      180      181      182      183
                                                    2*187      189      205      206      215      216      235      240
                                                      241      243

24647  NNEL     INTEGER                              REFS       23      212      243
24646  NNODE    INTEGER                              REFS       23      211      243
    6  NPI      INTEGER          CNTRL               REFS       13       18       38       64       72
    5  NPO      INTEGER          CNTRL               REFS       13       18       38       63       65
24645  NPRINT   INTEGER                              REFS       23      243
24641  NT       INTEGER                              REFS       22      170      171      185      189      236      237
                                                      243

24703  NTAPE    INTEGER                              REFS      189  DEFINED      176      194
24673  NTEMP    INTEGER                              REFS       94       96      105      107      209
                                                  DEFINED       93       95      104      106      208

24632  NUCOF    INTEGER                              REFS       20      119      126      131
24627  NUELEX   INTEGER                              REFS       20      119      124      126      137
24634  NUELIN   INTEGER                              REFS       21      148      149      150      151      153      155
                                                      162

24636  NUELOIL  INTEGER                              REFS       21      153      162
24631  NUFSF    INTEGER                              REFS       20      119      125      132      137
24630  NUINTEX  INTEGER                              REFS       20      119      120      121      126      137
24635  NUINTIN  INTEGER                              REFS       21      153
```

```
      PROGRAM ERST        76/176  OPT=1 STATIC                  FTN 4.8+498         03/16/81  16.39.39       PAGE     7

VARIABLES      SN  TYPE            RELOCATION
24666  NUM       INTEGER                         REFS       73       74      210      223      226      228      230
                                                  232      233      243  DEFINED       70
24621  NUMEL     INTEGER                         REFS       18       38       44       51       55       65       70
                                                   74      243
24622  NUMMAT    INTEGER                         REFS       18       38       45       46       47       51
    0  NUMNP     INTEGER          CNTRL          REFS       13       18       38       42       43       48       50
                                                  234      235      243
24626  NUNPEX    INTEGER                         REFS       20      119      122      123      126      131      137
24633  NUNPIN    INTEGER                         REFS       21      145      146      147      153      155      157
                                                  158      159      160      162
24643  NXFH      INTEGER                         REFS       22      177      178      189  DEFINED      195
24644  NYFH      INTEGER                         REFS       22      195
24662  N10       INTEGER                         REFS       61       65       74       87       93      122      126
                                                  137      147      153      162      175      189      216      243
                                               DEFINED      60      121      146      174      215
24663  N11       INTEGER                         REFS       62       65       74       80       87       96      123
                                                  126      137      148      153      155      162      177      189
                                                  217      243  DEFINED       61      122      147      175      216
24664  N12       INTEGER                         REFS       63       65       81       87       92      124      126
                                                  137      149      153      155      157      162      178      189
                                                  218      243  DEFINED       62       80      123      148      177
                                                  217
24665  N13       INTEGER                         REFS       64       65       72       82       87       95      125
                                                  126      132      137      150      153      158      162      179
                                                  189      219      243  DEFINED       63       81       92      124
                                                  149      157      178      218
24667  N14       INTEGER                         REFS       73       74       83       87      133      137      151
                                                  153      155      159      162      180      189      220      243
                                               DEFINED      72       82      132      150      158      179      219
24670  N15       INTEGER                         REFS       84       87      134      137      152      160      162
                                                  181      189      221      243  DEFINED       83      133      151
                                                  159      180      220
24671  N16       INTEGER                         REFS       85       87      135      137      161      182      189
                                                  222      243  DEFINED       84      134      160      181      221
24672  N17       INTEGER                         REFS       86       87      136      183      189      223      243
                                               DEFINED      85      135      182      222
24704  N18       INTEGER                         REFS      184      189      224      243  DEFINED      183      223
24705  N19       INTEGER                         REFS      185      189      225      243  DEFINED      184      224
24652  N2        INTEGER                         REFS       43       51       55       65       87      205      209
                                                  243  DEFINED       42      204
24706  N20       INTEGER                         REFS      186      189      226      243  DEFINED      185      225
24707  N21       INTEGER                         REFS      187      189      227      243  DEFINED      186      226
24710  N22       INTEGER                         REFS      188      228      243  DEFINED      187      227
24713  N23       INTEGER                         REFS      229      243  DEFINED      228
24714  N24       INTEGER                         REFS      230      243  DEFINED      229
24715  N25       INTEGER                         REFS      231      243  DEFINED      230
24716  N26       INTEGER                         REFS      232      243  DEFINED      231
24717  N27       INTEGER                         REFS      233      243  DEFINED      232
24720  N28       INTEGER                         REFS      234      243  DEFINED      233
24721  N29       INTEGER                         REFS      235      243  DEFINED      234
24653  N3        INTEGER                         REFS       44       51       55       99      105      137      206
                                                  243  DEFINED       43      205
24722  N30       INTEGER                         REFS      236      243  DEFINED      235
24723  N31       INTEGER                         REFS      237      243  DEFINED      236
24724  N32       INTEGER                         REFS      238      243  DEFINED      237
24725  N33       INTEGER                         REFS      239      243  DEFINED      238
24726  N34       INTEGER                         REFS      240      243  DEFINED      239
```

```
VARIABLES      SN  TYPE            RELOCATION
24727  N35        INTEGER                           REFS        241       243    DEFINED       240
24730  N36        INTEGER                           REFS        242    DEFINED       241
24654  N4         INTEGER                           REFS         45        51         55       100       104       107       137
                                                     189        208       210        243    DEFINED        44        99       206
24655  N5         INTEGER                           REFS         46        51         55       101       137       162       211
                                                     243    DEFINED        45        100       210
24656  N6         INTEGER                           REFS         47        51         55       102       106       137       162
                                                     189        212       243    DEFINED        46       101       211
24675  N7         INTEGER                           REFS        103       137        162       189       213       243
                                                 DEFINED        102       212
24657  N8         INTEGER                           REFS         49        51         55        59        65        74        87
                                                     120        137       145        153       155       162       174       214
                                                     243    DEFINED        47        103       213
24661  N9         INTEGER                           REFS         50        51         60        65        74        87        94
                                                     121        126       137        146       153       155       162       215
                                                     243    DEFINED        49         59       120       145       214
    0  PI         REAL             FCONST           REFS         12    DEFINED         25
24301  PLOTACC    LOGICAL                           REFS         17        22        189   DEFINED        24
24277  PLOTANK    LOGICAL                           REFS         16        18         51   DEFINED        24
24300  PLOTMOD    LOGICAL                           REFS         16        18         87   DEFINED        24
   10  READFRQ    LOGICAL          CNTRL            REFS         13        16         18   DEFINED        24
24637  ROIL       REAL                              REFS         21       153        162
    1  ROW        REAL             FCONST           REFS         12    DEFINED         26
    7  TRACE      REAL             CNTRL            REFS         13
24624  WLI        REAL                              REFS         18        38         65
    2  WLO        REAL             FCONST           REFS         12        18         38        65       126

FILE NAMES       MODE
    0  INPUT     MIXED                 READS         35        36       113        143       168       201
 2054  OUTPUT    MIXED                WRITES         37        38       114        115       119       144       169       170
                                         171        202       253
 4130  TAPE1     UNFMT                WRITES         94        96     READS        105       107       207       209
                                      MOTION         97        98       108        109

 6204  TAPE2
10260  TAPE3
12334  TAPE4
 2054  TAPE6
14410  TAPE7
16464  TAPE8
20540  TAPE9

EXTERNALS             TYPE    ARGS         REFERENCES
       BNDWTH                   8             155
       EIGEN                   16              87
       ELEMENT                  9              55
       EXT                     11             126
       INT                     12             153
       LAYOUT                  11              51
       MSCHECK                  3              50        64        73        86       125       136       152       161       188
                                              242
       PFL                      1              30
       RESPON                  51             243
       SOLEXT                  22             137
       SOLINT                  18             162
       STATIC                   9              74
       TOTAL                   15              65
       TSTEP                   26             189
```

```
INLINE FUNCTIONS   TYPE   ARGS         DEF LINE  REFERENCES
       LOCF      INTEGER    1  INTRIN              31

NAMELISTS        DEF LINE     REFERENCES
       EXTFLD          20      113       114
       INTFLD          21      143       144
       PRINTIT         23      201       202
       RESPONS         22      168       169
       TANK            18       36        37

STATEMENT LABELS             DEF LINE   REFERENCES
22706  120                      55       252
22767  150                      76        71
23316  179                     177       196
23370  185                     200       192
23546  200                     249        76
23553  250                     253       249       250
24447  1000    FMT             254        35
24451  2000    FMT             255        38
24516  2020    FMT             264       170
24533  2021    FMT             266       171
24550  2040    FMT             268       115
24557  2050    FMT             269       119
24610  3000    FMT             274       253

COMMON BLOCKS   LENGTH
       FCONST        3
       CNTRL         9
       / /       20000

STATISTICS
  PROGRAM LENGTH               3003B    1539
  BUFFER LENGTH               21762B    9202
  SCM LABELED COMMON LENGTH      14B      12
  SCM BLANK COMMON LENGTH     47040B   20000
          52000B SCM USED
```

```
     SUBROUTINE MSCHECK     76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39        PAGE      1

   1           *DECK MSCHECK
                     SUBROUTINE MSCHECK(MMAX,MNEED,MESSAGE)
                     IF (MMAX.GE.MNEED) RETURN
                     PRINT 5, MESSAGE, MNEED-MMAX
   5               5 FORMAT (//* --- NOT ENOUGH MEMORY FOR SUBROUTINE - *,A10,
                    1          /* --- NEED*,I9,*  MORE WORDS*
                    2          /* --- PROGRAM STOPPED*//)
                     STOP "NOT ENOUGH MEMORY"
                     END


     SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  MSCHECK          2          3

VARIABLES      SN  TYPE           RELOCATION
    0  MESSAGE   INTEGER              F.P.         REFS         4    DEFINED         2
    0  MMAX      INTEGER              F.P.         REFS         3         4    DEFINED         2
    0  MNEED     INTEGER              F.P.         REFS         3         4    DEFINED         2

FILE NAMES          MODE
       OUTPUT    FMT                    WRITES         4

STATEMENT LABELS              DEF LINE   REFERENCES
   21   5        FMT                5          4

STATISTICS
  PROGRAM LENGTH                  41B       33
          52000B SCM USED
```

```
      SUBROUTINE LAYOUT(R,Z,IX,E,RO,WANG,NEBC,CODE,NUMMAT,NUMEL,PLOTT)
C
C*********************************************************************
C     GEOMETRY AND MATERIAL PROPERTIES OF STRUCTURE ARE READ IN.
C     NODAL POINTS CAN BE GENERATED AT EQUAL INTERVAL OR IN LAYERS.
C*********************************************************************
C
      LOGICAL PLOTT
      DIMENSION R(1),Z(1),NEBC(1),CODE(1),IX(NUMEL,1),E(9,1),RO(1),WANG(
     1 1),NPTS(100),IFIG(100),RPLOT(5,100),ZPLOT(5,100)
      COMMON/CNTRL/NUMNP,NANGLE,MBAND,NBC
      DATA XMAT/6HISOTRO/
C
C     READ AND PRINT OF MATERIAL PROPERTIES
C
      DO 110 M=1,NUMMAT
      READ 1001,  MTYPE,XXMA
      IF (XXMA.NE.XMAT) GO TO 109
      READ 1010,  EE,EEU,RO(MTYPE)
      PRINT 2006,  MTYPE,EE,EEU,RO(MTYPE)
      WANG(MTYPE)=0.
      DO 102 I=1,9
      IF (I.LE.3) E(I,MTYPE)=EE
      IF (I.GT.3.AND.I.LE.6) E(I,MTYPE)=EEU
      IF (I.GT.6) E(I,MTYPE)=EE/(2.*(1.+EEU))
  102 CONTINUE
      GO TO 110
  109 READ 1011,  (E(I,MTYPE),I=1,9),RO(MTYPE),WANG(MTYPE)
      PRINT 2007,  MTYPE,(E(I,MTYPE),I=1,9),RO(MTYPE),WANG(MTYPE)
  110 CONTINUE
C
C     READ AND PRINT NODAL POINT DATA
C
      PRINT 2004
      L=0
      NBC=0
  120 READ 1002,  N,CODE(N),R(N),Z(N),MOD,NLIM,FACR,FACZ
      L1=L+1
      IF (N-L1) 190,170,130
  130 IF (L.LE.0) GO TO 180
      DIV=N-L
      DR=(R(N)-R(L))/DIV
      DZ=(Z(N)-Z(L))/DIV
      M=N-1
      DO 140 K=L1,M
      CODE(K)=0.0
      R(K)=R(K-1)+DR
  140 Z(K)=Z(K-1)+DZ
      GO TO 170
  150 L1=N+1
      IF(FACR.LE.0.0) FACR=1.0
      IF (FACZ.LE.0.0) FACZ=1.0
      PRINT 2100,  MOD,NLIM,FACR,FACZ
  160 N=N+1
      N1=N-MOD
      N2=N1-MOD
      IF (N1.LE.0.OR.N2.LE.0) GO TO 200
```

```
      CODE(N)=0.0
      R(N)=R(N1)+FACR*(R(N1)-R(N2))
      Z(N)=Z(N1)+FACZ*(Z(N1)-Z(N2))
      IF (N.LT.NLIM) GO TO 160
      MOD=0
  170 L=N
      PRINT 2002, (K,CODE(K),R(K),Z(K),K=L1,N)
      COD=CODE(N)
      IF(COD.EQ.0.0) GO TO 175
      D=100
      DO 172 J=1,3
      IF(COD.LT.D) GO TO 172
      NBC=NBC+1
      NEBC(NBC)=3*N-3+J
      COD=COD-D
  172 D=D/10.
  175 IF (MOD.GT.0) GO TO 150
      IF (N-NUMNP) 120,220,210
  180 PRINT 2130
      STOP
  190 PRINT 2140, N
      STOP
  200 PRINT 2150
      STOP
  210 PRINT 2160, N,NUMNP
      STOP
  220 CONTINUE
C
C     READ AND PRINT OF ELEMENT PROPERTIES
C
      PRINT 2001
      N=0
      MBAND=0
  230 READ 1003, M,(IX(M,I),I=1,5)
  240 N=N+1
      IF(M.EQ.N) GO TO 260
      DO 250 I=1,4
  250 IX(N,I)=IX(N-1,I)+1
      IX(N,5)=IX(N-1,5)
  260 PRINT 2003, N,(IX(N,I),I=1,5)
      IF (N.EQ.NUMEL) GO TO 270
      IF (N.EQ.M) GO TO 230
      GO TO 240
  270 IF (.NOT.PLOTT) GO TO 280
      DO 278 N=1,NUMEL
      NPTS(N)=5
      IFIG(N)=2
      DO 275 I=1,4
      RPLOT(I,N)=R(IX(N,I))
  275 ZPLOT(I,N)=Z(IX(N,I))
      RPLOT(5,N)=RPLOT(1,N)
  278 ZPLOT(5,N)=ZPLOT(1,N)
      CALL QPLT
      CALL MULPLT(RPLOT,ZPLOT,NPTS,NUMEL,1,5,100,"R-AXIS",6,
     1 "Z-AXIS",6,9,IFIG)
      CALL PLOT(0.,0.,999)
C     DETERMINE BAND WIDTH
```

```
       280 MB=0
           DO 290 N=1,NUMEL
           DO 290 I=1,4
           DO 290 J=1,4
           MM=IABS(IX(N,I)-IX(N,J))
           IF (MM.GT.MB) MB=MM
       290 CONTINUE
           MBAND=3*MB+3
      1001 FORMAT (I5,5X,A6)
      1002 FORMAT (I5,F5.0,2F10.0,2I5,2F10.0)
      1003 FORMAT (6I5)
      1010 FORMAT (3F10.0)
      1011 FORMAT (6F10.0/5F10.0)
      2001 FORMAT (1H1,*ELEMENT NO.       I      J      K      L       MATERIAL*/)
      2002 FORMAT (I7,F10.2,2F10.3)
      2003 FORMAT (1I13,4I6,I12)
      2004 FORMAT (38H1NO. PT. RESTRAINT    R-ORD      Z-ORD //)
      2006 FORMAT (///16H MATERIAL NUMBER ,I3,15H      ISOTROPIC //
          1 6H  E  =,F16.6,6HK/SFT./6H NU  =,F16.6/6H RHO =,F16.6,
          2 16H K-SEC**2/FT.**4/)
      2007 FORMAT (///16HOMATERIAL NUMBER I1, 17H       ORTHOTROPIC//
          1 6H  EN =,F16.6,4X,6H  ES =,F16.6,4X,6H  ET= ,F16.6,6HK/SFT.//
          2 6H NUNS=,F16.6,4X,6H NUNT=,F16.6,4X,6H NUST=,F16.6/
          3 6H  GNS=,F16.6,4X,6H  GNT=,F16.6,4X,6H  GST=,F16.6/
          4 4HORO= F16.6,16H K-SEC**2/FT.**4/
          5 12H ANGLE BELT=,F16.6)
      2100 FORMAT (21H GENERATION WITH MOD=I3,3X,6H MLIM=I4,3X,6H FACR=F10.5,
          1 3X,6H FACZ=F10.5)
      2130 FORMAT (28H FIRST JOINT CARD IS MISSING)
      2140 FORMAT (31H COORDINATE CARD FOR JOINT NO. I5,16H NOT IN SEQUENCE)
      2150 FORMAT (42H INSUFFICIENT INFORMATION TO GENERATE MESH)
      2160 FORMAT (14H JOINT NUMBER I5,21H EXCEEDS GIVEN NUMNP=I5)
           RETURN
           END
```

```
    SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
   3  LAYOUT          1          147

VARIABLES     SN  TYPE          RELOCATION
 1043  COD        REAL                             REFS        66       69       72   DEFINED       65       72
    0  CODE       REAL          ARRAY      F.P.    REFS         9       64       65   DEFINED        1       37       46
                                                     58
 1044  D          REAL                             REFS        69       72       73   DEFINED       67       73
 1035  DIV        REAL                             REFS        42       43  DEFINED       41
 1036  DR         REAL                             REFS        47  DEFINED       42
 1037  DZ         REAL                             REFS        48  DEFINED       43
    0  E          REAL          ARRAY      F.P.    REFS         9       29  DEFINED        1       23       24       25
                                                     28
 1023  EE         REAL                             REFS        20       23       25   DEFINED       19
 1024  EEU        REAL                             REFS        20       24       25   DEFINED       19
 1032  FACR       REAL                             REFS        51       53       59   DEFINED       37       51
```

```
       SUBROUTINE LAYOUT     76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39        PAGE    4

VARIABLES     SN  TYPE           RELOCATION
  1033 FACZ      REAL                              REFS        52        53        60   DEFINED        37        52
  1025 I         INTEGER                           REFS      2*23      3*24      2*25        28        29        91      2*95
                                                     97     2*106     2*107       119   DEFINED        22        28        29
                                                     91        94        97       105       117
  1214 IFIG      INTEGER    ARRAY                  REFS         9       111   DEFINED       104
     0 IX        INTEGER    ARRAY    F.P.          REFS         9        95        96        97       106       107     2*119
                                                DEFINED         1        91        95        96
  1045 J         INTEGER                           REFS        71       119   DEFINED        68       118
  1040 K         INTEGER                           REFS        46      2*47      2*48      4*64   DEFINED        45        64
  1026 L         INTEGER                           REFS        38        40        41        42        43
                                                DEFINED        35        63
  1034 L1        INTEGER                           REFS        39        45        64   DEFINED        38        50
  1020 M         INTEGER                           REFS        45        91        93        99   DEFINED        16        44
                                                     91
  1046 MB        INTEGER                           REFS       120       122   DEFINED       115       120
     2 MBAND     INTEGER             CNTRL         REFS        11   DEFINED        90       122
  1047 MM        INTEGER                           REFS     2*120   DEFINED       119
  1030 MOD       INTEGER                           REFS        53        55        56        74   DEFINED        37        62
  1021 MTYPE     INTEGER                           REFS        19      2*20        21        23        24        25      3*28
                                                   4*29   DEFINED        17
  1027 N         INTEGER                           REFS      3*37        39        41        42        43        44        50
                                                     54        55        58        59        60        61        63        64
                                                     65        71        75        78        82        92        93      2*95
                                                   2*96      2*97        98        99       103       104     2*106     2*107
                                                  2*108     2*109     2*119   DEFINED        37        54        89        92
                                                    102       116
     1 NANGLE    INTEGER             CNTRL         REFS        11
     3 NBC       INTEGER             CNTRL         REFS        11        70        71   DEFINED        36        70
     0 NEBC      INTEGER    ARRAY    F.P.          REFS         9   DEFINED         1        71
  1031 NLIM      INTEGER                           REFS        53        61   DEFINED        37
  1050 NPTS      INTEGER    ARRAY                  REFS         9       111   DEFINED       103
     0 NUMEL     INTEGER             F.P.          REFS         9        98       102       111       116
                                                DEFINED         1
     0 NUMMAT    INTEGER             F.P.          REFS        16   DEFINED         1
     0 NUMNP     INTEGER             CNTRL         REFS        11        75        82
  1041 N1        INTEGER                           REFS        56        57      2*59      2*60   DEFINED        55
  1042 N2        INTEGER                           REFS        57        59        60   DEFINED        56
     0 PLOTT     LOGICAL             F.P.          REFS         8       101   DEFINED         1
     0 R         REAL       ARRAY    F.P.          REFS         9      2*42        47      3*59        64       106
                                                DEFINED         1        37        47        59
     0 RO        REAL       ARRAY    F.P.          REFS         9        20        29   DEFINED         1        19        28
  1360 RPLOT     REAL       ARRAY                  REFS         9       108       111   DEFINED       106       108
     0 WANG      REAL       ARRAY    F.P.          REFS         9        29   DEFINED         1        21        28
   472 XMAT      REAL                              REFS        18   DEFINED        12
  1022 XXMA      REAL                              REFS        18   DEFINED        17
     0 Z         REAL       ARRAY    F.P.          REFS         9      2*43        48      3*60        64       107
                                                DEFINED         1        37        48        60
  2344 ZPLOT     REAL       ARRAY                  REFS         9       109       111   DEFINED       107       109

FILE NAMES        MODE
       INPUT     FMT                    READS        17        19        28        37        91
       OUTPUT    FMT                   WRITES        20        29        34        53        64        76        78        80
                                           82        88        97

EXTERNALS          TYPE   ARGS       REFERENCES
       MULPLT              13           111
       OPLT                 0           110
```

```
EXTERNALS              TYPE    ARGS         REFERENCES
       PLOT                      3             113

INLINE FUNCTIONS      TYPE    ARGS         DEF LINE   REFERENCES
       IABS         INTEGER     1  INTRIN                 119

STATEMENT LABELS                   DEF LINE    REFERENCES
     0  102                           26          22
    56  109                           28          18
   100  110                           30          16         27
   106  120                           37          75
     0  130         INACTIVE          40          39
     0  140                           48          45
   152  150                           50          74
   164  160                           54          61
   207  170                           63          39         49
   250  172                           73          68         69
   254  175                           74          66
   261  180                           76          40
   264  190                           78          39
   267  200                           80          57
   272  210                           82          75
   275  220                           84          75
   301  230                           91          99
   316  240                           92         100
     0  250                           95          94
   336  260                           97          93
   357  270                          101          98
     0  275                          107         105
     0  278                          109         102
   415  280                          115         101
     0  290                          121         116        117        118
   636  1001     FMT                 123          17
   640  1002     FMT                 124          37
   644  1003     FMT                 125          91
   646  1010     FMT                 126          19
   650  1011     FMT                 127          28
   653  2001     FMT                 128          88
   662  2002     FMT                 129          64
   665  2003     FMT                 130          97
   670  2004     FMT                 131          34
   676  2006     FMT                 132          20
   713  2007     FMT                 135          29
   745  2100     FMT                 141          53
   756  2130     FMT                 143          76
   763  2140     FMT                 144          78
   772  2150     FMT                 145          80
  1000  2160     FMT                 146          82

LOOPS   LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
    11  110       M            16 30       72B                EXT REFS  NOT INNER
    37  102       I            22 26       15B        OPT
   144  140       K            45 48        5B      INSTACK
   214            K         -  64 64       12B                EXT REFS
   243  172       J            68 73       10B      INSTACK
   304            I            91 91       11B                EXT REFS
   327  250       I            94 95        2B      INSTACK
   341            I            97 97       11B                EXT REFS
```

```
LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
  362  278      N          102 109      25B               NOT INNER
  374  275      I          105 107       4B     INSTACK
  417  290      N          116 121      25B               NOT INNER
  420  290      I          117 121      21B               NOT INNER
  430  290      J          118 121       6B     INSTACK

COMMON BLOCKS   LENGTH
       CNTRL         4

STATISTICS
  PROGRAM LENGTH                3364B    1780
  SCM LABELED COMMON LENGTH        4B       4
          52000B SCM USED
```

```
      SUBROUTINE ELEMENT    76/176  OPT=1 STATIC                  FTN 4.8+498        03/16/81  16.39.39         PAGE      1

   1                    SUBROUTINE ELEMENT(R,Z,IX,E,RO,WANG,NEBC,NF,NUMEL)
                  C
                  C*****************************************************************
                  C     STRUCTURAL ELEMENT MASS AND STIFFNESS MATRICES ARE FORMED AND
   5              C     WRITTEN ONTO TAPE1 ELEMENTWISE
                  C*****************************************************************
                  C
                        DIMENSION R(1),Z(1),NEBC(1),IX(NUMEL,1),E(9,1),RO(1),
                       1 WANG(1)
  10                    COMMON/LS4ARG/LM(12),SS(6,12),XC,YC,ELMASS(4),S(12,12),MTYPE,Q(12)
                       1,C(6,6)
                        DIMENSION RR(4),ZZ(4),EE(9)
                        MC=0
                        DO 400 N=1,NUMEL
  15                    MTYPE=IX(N,5)
                        IF(MTYPE.EQ.MC) GO TO 307
                        DO 305 MM=1,9
                    305 EE(MM)=E(MM,MTYPE)
                        BETA=WANG(MTYPE)
  20                    RHO=RO(MTYPE)
                        CALL SSLAW(EE,BETA,C,NF)
                    307 DO 310 I=1,4
                        II=IX(N,I)
                        RR(I)=R(II)
  25                310 ZZ(I)=Z(II)
                        CALL MASTIF(RR,ZZ,XC,YC,ELMASS,C,S,SS,Q,RHO,NF)
                        DO 320 I=1,4
                        IK=3*IX(N,I)-3
                        DO 320 J=1,3
  30                    JK=4*J-4+I
                        LM(JK)=IK+J
                    320 CONTINUE
                        MC=MTYPE
                    400 CALL WRITE1(LM,283,N,NUMEL)
  35                    RETURN
                        END


      SYMBOLIC REFERENCE MAP (R=2)

  ENTRY POINTS      DEF LINE      REFERENCES
      3  ELEMENT        1            35

  VARIABLES      SN  TYPE           RELOCATION
    136  BETA        REAL                              REFS       21    DEFINED      19
    367  C           REAL       ARRAY    LS4ARG        REFS       10       21        26
      0  E           REAL       ARRAY     F.P.         REFS        8       18   DEFINED         1
    155  EE          REAL       ARRAY                  REFS       12       21   DEFINED        18
    126  ELMASS      REAL       ARRAY    LS4ARG        REFS       10       26
    140  I           INTEGER                           REFS       23       24        25        28        30
                                                     DEFINED      22       27
    141  II          INTEGER                           REFS       24       25   DEFINED        23
    142  IK          INTEGER                           REFS       31    DEFINED      28
      0  IX          INTEGER    ARRAY     F.P.         REFS        8       15        23        28   DEFINED         1
```

```
      SUBROUTINE ELEMENT    76/176  OPT=1 STATIC                 FTN 4.8+498         03/16/81  16.39.39        PAGE      2

VARIABLES     SN  TYPE           RELOCATION
  143  J          INTEGER                         REFS        30        31   DEFINED      29
  144  JK         INTEGER                         REFS        31   DEFINED        30
    0  LM         INTEGER    ARRAY    LS4ARG      REFS        10        34   DEFINED      31
  133  MC         INTEGER                         REFS        16   DEFINED        13      33
  135  MM         INTEGER                         REFS      2*18   DEFINED        17
  352  MTYPE      INTEGER             LS4ARG      REFS        10        16        18      19        20        33
                                                DEFINED       15
  134  N          INTEGER                         REFS        15        23        28      34   DEFINED        14
    0  NEBC       INTEGER    ARRAY     F.P.       REFS         8   DEFINED         1
    0  NF         INTEGER              F.P.       REFS        21        26   DEFINED       1
    0  NUMEL      INTEGER              F.P.       REFS         8        14        34  DEFINED         1
  353  Q          REAL       ARRAY    LS4ARG      REFS        10        26
    0  R          REAL       ARRAY     F.P.       REFS         8        24   DEFINED       1
  137  RHO        REAL                            REFS        26   DEFINED        20
    0  RO         REAL       ARRAY     F.P.       REFS         8        20   DEFINED       1
  145  RR         REAL       ARRAY                REFS        12        26   DEFINED      24
  132  S          REAL       ARRAY    LS4ARG      REFS        10        26
   14  SS         REAL       ARRAY    LS4ARG      REFS        10        26
    0  WANG       REAL       ARRAY     F.P.       REFS         8        19   DEFINED       1
  124  XC         REAL                LS4ARG      REFS        10        26
  125  YC         REAL                LS4ARG      REFS        10        26
    0  Z          REAL       ARRAY     F.P.       REFS         8        25   DEFINED       1
  151  ZZ         REAL       ARRAY                REFS        12        26   DEFINED      25

EXTERNALS          TYPE   ARGS        REFERENCES
       MASTIF              11             26
       SSLAW                4             21
       WRITE1               4             34

STATEMENT LABELS              DEF LINE   REFERENCES
    0  305                        18         17
   34  307                        22         16
    0  310                        25         22
    0  320                        32         27          29
    0  400                        34         14

LOOPS  LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
   12  400       N            14 34        71B              EXT REFS  NOT INNER
   23  305       MM           17 18         3B      INSTACK
   42  310       I            22 25         5B      INSTACK
   53  320       I            27 32        21B              NOT INNER
   64  320       J            29 32         4B      INSTACK

COMMON BLOCKS    LENGTH
       LS4ARG       283

STATISTICS
  PROGRAM LENGTH                 203B       131
  SCM LABELED COMMON LENGTH      433B       283
        52000B SCM USED
```

```
      SUBROUTINE SSLAW(EE,BETA,C,NF)
C
C***********************************************************
C     STRESS STRAIN LAW IN N-S-T SYSTEM
C***********************************************************
C
      DIMENSION EE(9),C(6,6),D(6,6),CC(6,6)
      DO 65 II=1,6
      DO 65 KK=1,6
      C(II,KK)=0.
   65 D(II,KK)=0.
      C(1,1)=1.0/EE(1)
      C(1,2)=-EE(4)*C(1,1)
      C(1,3)=-EE(5)*C(1,1)
      C(2,1)=C(1,2)
      C(2,2)=1.0/EE(2)
      C(2,3)=-EE(6)*C(2,2)
      C(3,1)=C(1,3)
      C(3,2)=C(2,3)
      C(3,3)=1.0/EE(3)
      C(4,4)=EE(7)
      IF (NF.EQ.0) GO TO 70
      C(5,5)=EE(8)
      C(6,6)=EE(9)
   70 CONTINUE
      DO 200 N=1,3
      DD=C(N,N)
      DO 100 J=1,3
  100 C(N,J)=-C(N,J)/DD
      DO 150 I=1,3
      IF (N-I) 110,150,110
  110 DO 140 J=1,3
      IF (N-J) 120,140,120
  120 C(I,J)=C(I,J)+C(I,N)*C(N,J)
  140 CONTINUE
  150 C(I,N)=C(I,N)/DD
      C(N,N)=1.0/DD
  200 CONTINUE
C
C     ROTATE MATERIAL PROPERTIES TO R-Z-TH SYSTEM
C
      IF (BETA.EQ.0.0) GO TO 500
      ANG=BETA/57.2957795
      SS=SIN(ANG)
      CS=COS(ANG)
      S2=SS*SS
      C2=CS*CS
      SC=SS*CS
      D(1,1)=C2
      D(1,2)=S2
      D(1,4)=SC
      D(2,1)=S2
      D(2,2)=C2
      D(2,4)=-SC
      D(3,3)=1.0
      D(4,1)=-2.*SC
      D(4,2)=-D(4,1)
```

```
                        D(4,4)=C2-S2
                        D(5,5)=1.0
 60                     D(6,6)=1.0
                        DO 287 JJ=1,6
                        D1=C(1,1)*D(1,JJ)+C(1,2)*D(2,JJ)+C(1,3)*D(3,JJ)
                        D2=C(2,1)*D(1,JJ)+C(2,2)*D(2,JJ)+C(2,3)*D(3,JJ)
                        D3=C(3,1)*D(1,JJ)+C(3,2)*D(2,JJ)+C(3,3)*D(3,JJ)
 65                     D4=C(4,4)*D(4,JJ)
                        D5=C(5,5)*D(5,JJ)
                        D6=C(6,6)*D(6,JJ)
                        DO 287 II=JJ,6
                        CC(II,JJ)=D(1,II)*D1+D(2,II)*D2+D(3,II)*D3+D(4,II)*D4+D(5,II)*D5+D
 70                    1(6,II)*D6
                    287 CC(JJ,II)=CC(II,JJ)
                        DO 300 I=1,6
                        DO 300 J=1,6
                    300 C(I,J)=CC(I,J)
 75                 500 RETURN
                        END


      SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  SSLAW           1          75

VARIABLES      SN  TYPE           RELOCATION
  245  ANG         REAL                            REFS        44       45   DEFINED       43
    0  BETA        REAL                 F.P.       REFS        42       43   DEFINED        1
    0  C           REAL       ARRAY     F.P.       REFS         7       13        14       15       17       18       19
                                                             27       29     3*34        36     3*62     3*63     3*64       65
                                                             66       67  DEFINED         1       10       12       13       14
                                                             15       16       17        18       19       20       21       23
                                                             24       29       34        36       37       74
  326  CC          REAL       ARRAY                REFS         7       71        74  DEFINED       69       71
  247  CS          REAL                            REFS      2*47       48   DEFINED       45
  251  C2          REAL                            REFS        49       53        58  DEFINED       47
  262  D           REAL       ARRAY                REFS         7       57      3*62     3*63     3*64       65       66
                                                             67     6*69  DEFINED        11       49       50       51       52
                                                             53       54       55        56       57       58       59       60
  242  DD          REAL                            REFS        29       36        37  DEFINED       27
  254  D1          REAL                            REFS        69  DEFINED        62
  255  D2          REAL                            REFS        69  DEFINED        63
  256  D3          REAL                            REFS        69  DEFINED        64
  257  D4          REAL                            REFS        69  DEFINED        65
  260  D5          REAL                            REFS        69  DEFINED        66
  261  D6          REAL                            REFS        69  DEFINED        67
    0  EE          REAL       ARRAY     F.P.       REFS         7       12        13       14       16       17       20
                                                             21       23       24  DEFINED        1
  244  I           INTEGER                         REFS        31     3*34      2*36     2*74  DEFINED       30       72
  237  II          INTEGER                         REFS        10       11      7*69     2*71  DEFINED        8       68
  243  J           INTEGER                         REFS      2*29       33      3*34     2*74  DEFINED       28       32
                                                             73
  253  JJ          INTEGER                         REFS      3*62     3*63      3*64       65       66       67       68
```

```
VARIABLES     SN  TYPE           RELOCATION
                                                    69      2*71   DEFINED       61
  240  KK        INTEGER                          REFS        10        11   DEFINED        9
  241  N         INTEGER                          REFS      2*27      2*29        31        33      2*34      2*36      2*37
                                                DEFINED       26
    0  NF        INTEGER              F.P.        REFS        22   DEFINED        1
  252  SC        REAL                             REFS        51        54        56   DEFINED       48
  246  SS        REAL                             REFS      2*46        48   DEFINED       44
  250  S2        REAL                             REFS        50        52        58   DEFINED       46

EXTERNALS          TYPE   ARGS       REFERENCES
       COS       REAL       1 LIBRARY     45
       SIN       REAL       1 LIBRARY     44

STATEMENT LABELS             DEF LINE   REFERENCES
    0  65                       11         8         9
   44  70                       25        22
    0  100                      29        28
    0  110         INACTIVE     32      2*31
    0  120         INACTIVE     34      2*33
  101  140                      35        32        33
  104  150                      36        30        31
    0  200                      38        26
    0  287                      71        61        68
    0  300                      74        72        73
  233  500                      75        42

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
    7  65       II           8 11       14B              NOT INNER
   15  65       KK           9 11        3B     INSTACK
   45  200      N           26 38       52B              NOT INNER
   54  100      J           28 29        4B     INSTACK
   62  150      I           30 36       30B              NOT INNER
   75  140      J           32 35        6B     INSTACK
  142  287      JJ          61 71       54B              NOT INNER
  177  287      II          68 71       13B        OPT
  217  300      I           72 74       14B              NOT INNER
  225  300      J           73 74        3B     INSTACK

STATISTICS
  PROGRAM LENGTH                406B     262
          52000B SCM USED
```

```
      SUBROUTINE STRAIN(S,T,RR,ZZ,H,B,FAC,N)
C
C***********************************************************************
C     FORM STRAIN DISPLACEMENT MATRIX
C***********************************************************************
C
      DIMENSION B(6,18),HS(6),HT(6),HR(6),HZ(6)
      DIMENSION RR(4),ZZ(4),H(6)
      DIMENSION II(6),JJ(6),LL(6)
      DATA II/1,2,3,4,13,14/,JJ/5,6,7,8,15,16/,LL/9,10,11,12,17,18/
      DO 50 I=1,108
   50 B(I)=0.0
      SM=1.0-S
      SP=1.0+S
      TM=1.0-T
      TP=1.0+T
      H(1)=SM*TM/4.
      H(2)=SP*TM/4.
      H(3)=SP*TP/4.
      H(4)=SM*TP/4.
      H(5)=(1.0-S*S)
      H(6)=(1.0-T*T)
      HS(1)=-TM/4.
      HS(2)=-HS(1)
      HS(3)=TP/4.
      HS(4)=-HS(3)
      HS(5)=-2.0*S
      HS(6)=0.
      HT(1)=-SM/4.
      HT(2)=-SP/4.
      HT(3)=-HT(2)
      HT(4)=-HT(1)
      HT(5)=0.
      HT(6)=-2.0*T
      PZT=HT(1)*ZZ(1)+HT(2)*ZZ(2)+HT(3)*ZZ(3)+HT(4)*ZZ(4)
      PZS=HS(1)*ZZ(1)+HS(2)*ZZ(2)+HS(3)*ZZ(3)+HS(4)*ZZ(4)
      PRS=HS(1)*RR(1)+HS(2)*RR(2)+HS(3)*RR(3)+HS(4)*RR(4)
      PRT=HT(1)*RR(1)+HT(2)*RR(2)+HT(3)*RR(3)+HT(4)*RR(4)
      XJ=PRS*PZT-PRT*PZS
      PSR=PZT/XJ
      PTR=-PZS/XJ
      PSZ=-PRT/XJ
      PTZ=PRS/XJ
      DO 100 I=1,6
      HR(I)=PSR*HS(I)+PTR*HT(I)
  100 HZ(I)=PSZ*HS(I)+PTZ*HT(I)
      R=H(1)*RR(1)+H(2)*RR(2)+H(3)*RR(3)+H(4)*RR(4)
      DO 200 K=1,6
      I=II(K)
      J=JJ(K)
      L=LL(K)
      B(1,I)=HR(K)
      B(2,J)=HZ(K)
      B(3,I)=H(K)/R
      B(3,L)=N*B(3,I)
      B(4,I)=HZ(K)
      B(4,J)=HR(K)
```

```
              B(5,I)=-B(3,L)
              B(5,L)=B(1,I)-B(3,I)
   60         B(6,J)=B(5,I)
          200 B(6,L)=B(2,J)
              FAC=XJ*R
              RETURN
              END




    SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS     DEF LINE     REFERENCES
  3  STRAIN          1           63

VARIABLES    SN  TYPE          RELOCATION
   0  B     REAL      ARRAY  F.P.       REFS       7      55      58    2*59      60      61
                                     DEFINED       1      12      52      53      54      55      56
                                          57      58      59      60      61
   0  FAC   REAL             F.P.    DEFINED       1      62
   0  H     REAL      ARRAY  F.P.       REFS       8    4*47      54 DEFINED       1      17      18
                                          19      20      21      22
 242  HR    REAL      ARRAY             REFS       7      52      57 DEFINED      45
 226  HS    REAL      ARRAY             REFS       7      24      26    4*36    4*37      45      46
                                     DEFINED      23      24      25      26      27      28
 234  HT    REAL      ARRAY             REFS       7      31      32    4*35    4*38      45      46
                                     DEFINED      29      30      31      32      33      34
 250  HZ    REAL      ARRAY             REFS       7      53      56 DEFINED      46
 204  I     INTEGER                     REFS      12    3*45    3*46      52      54      55      56
                                          58    2*59      60 DEFINED      11      44      49
 256  II    INTEGER   ARRAY             REFS       9      49 DEFINED      10
 224  J     INTEGER                     REFS      53      57      60      61 DEFINED      50
 264  JJ    INTEGER   ARRAY             REFS       9      50 DEFINED      10
 223  K     INTEGER                     REFS      49      50      51      52      53      54      56
                                          57 DEFINED      48
 225  L     INTEGER                     REFS      55      58      59      61 DEFINED      51
 272  LL    INTEGER   ARRAY             REFS       9      51 DEFINED      10
   0  N     INTEGER          F.P.       REFS      55 DEFINED       1
 213  PRS   REAL                        REFS      39      43 DEFINED      37
 214  PRT   REAL                        REFS      39      42 DEFINED      38
 216  PSR   REAL                        REFS      45 DEFINED      40
 220  PSZ   REAL                        REFS      46 DEFINED      42
 217  PTR   REAL                        REFS      45 DEFINED      41
 221  PTZ   REAL                        REFS      46 DEFINED      43
 212  PZS   REAL                        REFS      39      41 DEFINED      36
 211  PZT   REAL                        REFS      39      40 DEFINED      35
 222  R     REAL                        REFS      54      62 DEFINED      47
   0  RR    REAL      ARRAY  F.P.       REFS       8    4*37    4*38    4*47 DEFINED       1
   0  S     REAL             F.P.       REFS      13      14    2*21      27 DEFINED       1
 205  SM    REAL                        REFS      17      20      29 DEFINED      13
 206  SP    REAL                        REFS      18      19      30 DEFINED      14
   0  T     REAL             F.P.       REFS      15      16    2*22      34 DEFINED       1
 207  TM    REAL                        REFS      17      18      23 DEFINED      15
 210  TP    REAL                        REFS      19      20      25 DEFINED      16
 215  XJ    REAL                        REFS      40      41      42      43      62
```

```
       SUBROUTINE STRAIN     76/176  OPT=1 STATIC                   FTN 4.8+498        03/16/81  16.39.39       PAGE     3

VARIABLES     SN  TYPE           RELOCATION
                                                DEFINED      39
    0  ZZ        REAL       ARRAY     F.P.        REFS        8       4*35      4*36   DEFINED        1

STATEMENT LABELS             DEF LINE   REFERENCES
    0  50                       12         11
    0  100                      46         44
    0  200                      61         48

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   12  50       I           11 12        2B     INSTACK
  114  100      I           44 46       10B     INSTACK
  144  200      K           48 61       25B        OPT

STATISTICS
  PROGRAM LENGTH                303B     195
          52000B SCM USED
```

```
      SUBROUTINE MASTIF(RR, ZZ, RM, ZM, ELMASS, D, QK, QC, Q, RHO, N)
C
C****************************************************************
C     FORM ELEMENT MASS MATRIX M AND ELEMENT STIFFNESS MATRIX K
C****************************************************************
C
      DIMENSION SS(2), RR(4), ZZ(4), ELMASS(4), QK(12, 12), QC(6, 12), Q(12)
      DIMENSION B(6, 18), BB(6, 18), S(18, 18), D(6, 6), P(18), H(6)
      DATA SS/-0. 57735026918963, 0. 57735026918963/
      FZ=-RHO*32. 2
      DO 150 I=1, 4
  150 ELMASS(I)=0. 0
      DO 170 J=1, 18
      P(J)=0. 0
      DO 160 I=1, 6
      BB(I, J)=0. 0
  160 B(I, J)=0. 0
      DO 170 I=1, 18
  170 S(I, J)=0. 0
      RM=(RR(1)+RR(2)+RR(3)+RR(4))/4. 0
      ZM=(ZZ(1)+ZZ(2)+ZZ(3)+ZZ(4))/4. 0
      DO 500 II=1, 2
      DO 500 JJ=1, 2
      CALL STRAIN(SS(II), SS(JJ), RR, ZZ, H, B, FAC, N)
      IF(N. EQ. 0) FAC=2. *FAC
      DO 400 J=1, 18
      D1=(D(1, 1)*B(1, J)+D(1, 2)*B(2, J)+D(1, 3)*B(3, J)+D(1, 4)*B(4, J)+D(1, 5)
     1 *B(5, J)+D(1, 6)*B(6, J))*FAC
      D2=(D(2, 1)*B(1, J)+D(2, 2)*B(2, J)+D(2, 3)*B(3, J)+D(2, 4)*B(4, J)+D(2, 5)
     1 *B(5, J)+D(2, 6)*B(6, J))*FAC
      D3=(D(3, 1)*B(1, J)+D(3, 2)*B(2, J)+D(3, 3)*B(3, J)+D(3, 4)*B(4, J)+D(3, 5)
     1 *B(5, J)+D(3, 6)*B(6, J))*FAC
      D4=(D(4, 1)*B(1, J)+D(4, 2)*B(2, J)+D(4, 3)*B(3, J)+D(4, 4)*B(4, J)+D(4, 5)
     1 *B(5, J)+D(4, 6)*B(6, J))*FAC
      D5=(D(5, 1)*B(1, J)+D(5, 2)*B(2, J)+D(5, 3)*B(3, J)+D(5, 4)*B(4, J)+D(5, 5)
     1 *B(5, J)+D(5, 6)*B(6, J))*FAC
      D6=(D(6, 1)*B(1, J)+D(6, 2)*B(2, J)+D(6, 3)*B(3, J)+D(6, 4)*B(4, J)+D(6, 5)
     1 *B(5, J)+D(6, 6)*B(6, J))*FAC
      DO 400 I=J, 18
      S(I, J)=S(I, J)+B(1, I)*D1+B(2, I)*D2+B(3, I)*D3+B(4, I)*D4+B(5, I)*D5+B(
     1 6, I)*D6
  400 S(J, I)=S(I, J)
      IF(N. EQ. 0) GO TO 470
      DO 450 I=1, 4
  450 ELMASS(I)=ELMASS(I)+FAC*H(I)*RHO
  470 IF (N. NE. 0) GO TO 500
      BZ=FZ*FAC
      P(5)=P(5)+BZ*H(1)
      P(6)=P(6)+BZ*H(2)
      P(7)=P(7)+BZ*H(3)
      P(8)=P(8)+BZ*H(4)
  500 CONTINUE
      IF (N. NE. 0) GO TO 510
      DO 505 I=1, 18
  505 IF (S(I, I). EQ. 0. 0)  S(I, I)=1. 0
C
C     FORM STRESS DISPLACEMENT MATRIX
```

```
                C
                  510 CALL STRAIN(0.0,0.0,RR,ZZ,H,BB,FAC,N)
   60                 DO 530 I=1,6
                      DO 530 J=1,18
                      B(I,J)=0.0
                      DO 530 K=1,6
                  530 B(I,J)=B(I,J)+D(I,K)*BB(K,J)
   65           C
                C     ELIMINATE EXTRA DEGREES OF FREEDOM
                C
                      DO 550 NN=1,6
                      L=18-NN
   70                 K=L+1
                      DO 550 I=1,L
                      C=S(I,K)/S(K,K)
                      DO 540 J=1,6
                  540 B(J,I)=B(J,I)-C*B(J,K)
   75                 DO 550 J=1,L
                  550 S(I,J)=S(I,J)-C*S(K,J)
                      IF(N.NE.0) GO TO 570
                      DO 560 I=9,12
                  560 S(I,I)=0.
   80           C
                C     RELOCATE STIFFNESS MATRIX AND LOAD VECTOR
                C
                  570 DO 580 I=1,12
                      Q(I)=P(I)
   85                 DO 580 J=1,12
                  580 QK(I,J)=S(I,J)
                      DO 590 J=1,6
                      DO 590 K=1,12
                  590 QC(J,K)=B(J,K)
   90                 RETURN
                      END


    SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  MASTIF        1            90

VARIABLES      SN  TYPE           RELOCATION
  520  B           REAL       ARRAY                    REFS         8        24      6*27      6*29      6*31      6*33      6*35
                                                          6*37      6*40        64      2*74        89   DEFINED        17        62
                                                            64        74
  674  BB          REAL       ARRAY                    REFS         8        59        64   DEFINED        16
  511  BZ          REAL                                REFS        48        49        50        51   DEFINED        47
  515  C           REAL                                REFS        74        76   DEFINED        72
    0  D           REAL       ARRAY     F.P.           REFS         8      6*27      6*29      6*31      6*33      6*35      6*37
                                                            64   DEFINED         1
  503  D1          REAL                                REFS        40   DEFINED        27
  504  D2          REAL                                REFS        40   DEFINED        29
  505  D3          REAL                                REFS        40   DEFINED        31
  506  D4          REAL                                REFS        40   DEFINED        33
```

```
VARIABLES   SN    TYPE      RELOCATION
   507  D5        REAL                           REFS       40  DEFINED       35
   510  D6        REAL                           REFS       40  DEFINED       37
     0  ELMASS    REAL      ARRAY   F.P.         REFS        7       45  DEFINED        1       12       45
   502  FAC       REAL                           REFS       24       25       27       29       31       33       35
                                                   37       45       47       59  DEFINED       25
   475  FZ        REAL                           REFS       47  DEFINED       10
  1576  H         REAL      ARRAY                REFS        8       24       45       48       49       50       51
                                                   59
   476  I         INTEGER                        REFS       12       16       17       19     8*40     2*42     3*45
                                                 4*55       62     3*64       72     2*74     2*76     2*79     2*84
                                                 2*86  DEFINED       11       15       18       39       44       54
                                                   60       71       78       83
   500  II        INTEGER                        REFS       24  DEFINED       22
   477  J         INTEGER                        REFS       14       16       17       19     6*27     6*29     6*31
                                                 6*33     6*35     6*37       39     2*40     2*42       62     3*64
                                                 3*74     3*76     2*86     2*89  DEFINED       13       26       61
                                                   73       75       85       87
   501  JJ        INTEGER                        REFS       24  DEFINED       23
   512  K         INTEGER                        REFS     2*64     3*72       74       76     2*89
                                              DEFINED       63       70       88
   514  L         INTEGER                        REFS       70       71       75  DEFINED       69
     0  N         INTEGER           F.P.         REFS       24       25       43       46       53       59       77
                                              DEFINED        1
   513  NN        INTEGER                        REFS       69  DEFINED       68
  1554  P         REAL      ARRAY                REFS        8       48       49       50       51       84
                                              DEFINED       14       48       49       50       51
     0  Q         REAL      ARRAY   F.P.         REFS        7  DEFINED        1       84
     0  QC        REAL      ARRAY   F.P.         REFS        7  DEFINED        1       89
     0  QK        REAL      ARRAY   F.P.         REFS        7  DEFINED        1       86
     0  RHO       REAL              F.P.         REFS       10       45  DEFINED        1
     0  RM        REAL              F.P.      DEFINED        1       20
     0  RR        REAL      ARRAY   F.P.         REFS        7     4*20       24       59  DEFINED        1
  1050  S         REAL      ARRAY                REFS        8       40       42       55     2*72     2*76       86
                                              DEFINED       19       40       42       55       76       79
   516  SS        REAL      ARRAY                REFS        7     2*24  DEFINED        9
     0  ZM        REAL              F.P.      DEFINED        1       21
     0  ZZ        REAL      ARRAY   F.P.         REFS        7     4*21       24       59  DEFINED        1

EXTERNALS         TYPE   ARGS       REFERENCES
        STRAIN              8          24       59

STATEMENT LABELS           DEF LINE   REFERENCES
     0  150                      12          11
     0  160                      17          15
     0  170                      19          13       18
     0  400                      42          26       39
     0  450                      45          44
   235  470                      46          43
   251  500                      52          22       23       46
     0  505                      55          54
   270  510                      59          53
     0  530                      64          60       61       63
     0  540                      74          73
     0  550                      76          68       71       75
     0  560                      79          78
   405  570                      83          77
     0  580                      86          83       85
```

```
STATEMENT LABELS             DEF LINE   REFERENCES
    0  590                      89        87        88

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   14  150      I           11 12       2B     INSTACK
   20  170      J           13 19      25B              NOT INNER
   27  160      I           15 17       3B     INSTACK
   40  170      I           18 19       2B     INSTACK
   61  500      II          22 52     175B              EXT REFS  NOT INNER
   62  500      JJ          23 52     172B              EXT REFS  NOT INNER
   75  400      J           26 42     127B              NOT INNER
  204  400      I           39 42      15B        OPT
  230  450      I           44 45       4B     INSTACK
  263  505      I           54 55       4B     INSTACK
  277  530      I           60 64      27B              NOT INNER
  300  530      J           61 64      23B              NOT INNER
  314  530      K           63 64       4B     INSTACK
  327  550      NN          68 76      46B              NOT INNER
  333  550      I           71 76      37B              NOT INNER
  350  540      J           73 74       3B     INSTACK
  363  550      J           75 76       4B     INSTACK
  402  560      I           78 79       2B     INSTACK
  406  580      I           83 86      20B              NOT INNER
  417  580      J           85 86       3B     INSTACK
  427  590      J           87 89      14B              NOT INNER
  435  590      K           88 89       3B     INSTACK

STATISTICS
  PROGRAM LENGTH               1627B     919
          52000B SCM USED
```

```
SUBROUTINE WRITE1      76/176  OPT=1 STATIC                    FTN 4.8+498         03/16/81  16.39.39         PAGE      1

     1                 SUBROUTINE WRITE1(A,LA,N,NUMEL)
                 C
                 C***********************************************************
                 C         WRITE MATRIX A ON TAPE1 AS AN ARRAY
     5           C***********************************************************
                 C
                       DIMENSION A(LA)
                       COMMON/BUF/B(2830)
                       LB=2830
    10                 IF (N.NE.1) GO TO 100
                       REWIND 1
                       M=0
                   100 MM=M+LA
                       DO 200 I=1,LA
    15                 II=I+M
                   200 B(II)=A(I)
                       M=MM
                       IF (N.EQ.NUMEL) GO TO 300
                       IF ((M+LA).LE. LB) GO TO 400
    20             300 WRITE (1) B
                       M=0
                   400 RETURN
                       END


        SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  WRITE1          1          22

VARIABLES      SN  TYPE            RELOCATION
    0  A           REAL        ARRAY     F.P.         REFS          7         16    DEFINED        1
    0  B           REAL        ARRAY    BUF           REFS          8         20    DEFINED       16
   52  I           INTEGER                            REFS         15         16    DEFINED       14
   53  II          INTEGER                            REFS         16    DEFINED        15
    0  LA          INTEGER               F.P.         REFS          7         13        14        19     DEFINED         1
   47  LB          INTEGER                            REFS         19    DEFINED         9
   50  M           INTEGER                            REFS         13         15        19   DEFINED        12         17         21
   51  MM          INTEGER                            REFS         17    DEFINED        13
    0  N           INTEGER               F.P.         REFS         10         18    DEFINED        1
    0  NUMEL       INTEGER               F.P.         REFS         18    DEFINED         1

FILE NAMES         MODE
      TAPE1        UNFMT                    WRITES        20     MOTION        11

STATEMENT LABELS                DEF LINE    REFERENCES
   13  100                         13         10
    0  200                         16         14
   37  300                         20         18
   42  400                         22         19

LOOPS  LABEL      INDEX       FROM-TO     LENGTH     PROPERTIES
   23  200        I            14 16         4B        INSTACK
```

```
COMMON BLOCKS   LENGTH
       BUF        2830

STATISTICS
  PROGRAM LENGTH                  54B       44
  SCM LABELED COMMON LENGTH     5416B     2830
          52000B SCM USED
```

```
      SUBROUTINE TOTAL(R,Z,NEBC,MASS,XS,A,IJBCO,IJBCI,WLO,WLI,
     1     NPPO,NEQ,MBAND,NUMEL,IGRAV)
C
C*********************************************************************
C     TOTAL STIFFNESS AND MASS MATRICES AND LOAD VECTOR ARE FORMED BY
C     READING ELEMENTAL INFORMATIN FROM TAPE1.
C     NODAL LOADS DUE TO WATER PRESSURE ARE CALCULATED.
C*********************************************************************
C
      COMMON/CNTRL/NUMNP,NANGLE,MBAN ,NBC,NF,NPP ,NPPI,TRACE
      COMMON/LS4ARG/LM(12),SS(6,12),XC,YC,ELMASS(4),S(12,12),MTYPE,Q(12)
     1,C(6,6)
      DIMENSION R(1),Z(1),NEBC(1),MASS(1),XS(1),A(NEQ,MBAND),IJBCO(NPPO)
     1,IJBCI(1)
      REAL MASS
C
C     FORM MASS AND STIFFNESS MATRICES
C
      DO 100 I=1,NEQ
      MASS(I)=0.0
      XS(I)=0.0
      DO 100 J=1,MBAND
  100 A(I,J)=0.0
      DO 140 N=1,NUMEL
      CALL READ1(LM,283,N,NUMEL)
      DO 120 I=1,12
      II=LM(I)
      XS(II)=XS(II)+Q(I)
      DO 110 J=1,12
      JJ=LM(J)-II+1
      IF(JJ.LT.1) GO TO 110
      A(II,JJ)=A(II,JJ)+S(I,J)
  110 CONTINUE
  120 CONTINUE
      IF(NF.EQ.0) GO TO 140
      DO 130 I=1,4
      II=LM(I)
      MASS(II)=MASS(II)+ELMASS(I)
      MASS(II+1)=MASS(II)
  130 MASS(II+2)=MASS(II)
  140 CONTINUE
C
C     STATIC PRESSURE
C
      IF (NPPO.EQ.0.AND.NPPI.EQ.0) GO TO 160
      IF (NPPO.EQ.0) GO TO 145
      IF (IGRAV.EQ.2.AND.NF.NE.0) GO TO 145
      READ 1010, (IJBCO (K),K=1,NPPO)
      PRINT 2010
      CALL HYDROST(R,Z,IJBCO,NPPO,XS,WLO,-1.0)
  145 IF (NPPI.EQ.0) GO TO 160
      IF (IGRAV.EQ.2.AND.NF.NE.0) GO TO 165
      READ 1010, (IJBCI(K),K=1,NPPI)
      PRINT 2011
      CALL HYDROST(R,Z,IJBCI,NPPI,XS,WLI,1.0)
  160 CONTINUE
C
```

```
              C      DISPLACEMENT BOUNDARY CONDITION
              C
   60           165 TRACE=0.
                    DO 170 I=1,NEQ
                170 TRACE=TRACE+ABS(A(I,1))
                    IF (NF.NE.0) GO TO 187
                    DO 185 I=3,NEQ,3
   65               IF (A(I,1).EQ.0.0) A(I,1)=1.0
                185 CONTINUE
                187 IF (NBC.LE.0) GO TO 190
                    DO 189 K=1,NBC
                    I=NEBC(K)
   70               A(I,1)=0.0
                    XS(I)=0.
                    DO 189 J=2,MBAND
                    A(I,J)=0.
                    L=I-J+1
   75               IF (L.LE.0) GO TO 189
                    A(L,J)=0.
                189 CONTINUE
                190 WRITE (1) A
                    BACKSPACE 1
   80               REWIND 4
                    WRITE (4) IJBCO
                    BACKSPACE 4
               1010 FORMAT (16I5)
               2010 FORMAT ( 1H1/26H WATER OUTSIDE THE TANK   /)
   85          2011 FORMAT (///26H FLUIDS INSIDE THE TANK   /)
                    RETURN
                    END


      SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  TOTAL          1           86

VARIABLES      SN  TYPE            RELOCATION
    0  A           REAL       ARRAY     F.P.      REFS       13        32        62        65        78
                                                DEFINED       1        23        32        65        70        73        76
  367  C           REAL       ARRAY    LS4ARG     REFS       11
  126  ELMASS      REAL       ARRAY    LS4ARG     REFS       11        38
  346  I           INTEGER                        REFS       20        21        23        27        28        32        37
                                                    38       62      2*65        70        71        73        74
                                                DEFINED      19        26        36        61        64        69
    0  IGRAV       INTEGER              F.P.      REFS       47        52   DEFINED         1
  351  II          INTEGER                        REFS     2*28        30      2*32      2*38      2*39      2*40
                                                DEFINED      27        37
    0  IJBCI       INTEGER    ARRAY     F.P.      REFS       13        55   DEFINED         1        53
    0  IJBCO       INTEGER    ARRAY     F.P.      REFS       13        50        81   DEFINED         1        48
  347  J           INTEGER                        REFS       23        30        32        73        74        76
                                                DEFINED      22        29        72
  352  JJ          INTEGER                        REFS       31      2*32   DEFINED        30
  353  K           INTEGER                        REFS       48        53        69   DEFINED        48        53        68
```

```
VARIABLES     SN  TYPE          RELOCATION
  354  L         INTEGER                         REFS        75        76   DEFINED        74
    0  LM        INTEGER   ARRAY    LS4ARG       REFS        11        25        27        30        37
    0  MASS      REAL      ARRAY     F. P.       REFS        13        15        38        39        40
                                              DEFINED         1        20        38        39        40
    2  MBAN      INTEGER            CNTRL        REFS        10
    0  MBAND     INTEGER             F. P.       REFS        13        22        72   DEFINED         1
  352  MTYPE     INTEGER            LS4ARG       REFS        11
  350  N         INTEGER                         REFS        25   DEFINED        24
    1  NANGLE    INTEGER            CNTRL        REFS        10
    3  NBC       INTEGER            CNTRL        REFS        10        67        68
    0  NEBC      INTEGER   ARRAY     F. P.       REFS        13        69   DEFINED         1
    0  NEQ       INTEGER             F. P.       REFS        13        19        61        64   DEFINED         1
    4  NF        INTEGER            CNTRL        REFS        10        35        47        52        63
    5  NPP       INTEGER            CNTRL        REFS        10
    6  NPPI      INTEGER            CNTRL        REFS        10        45        51        53        55
    0  NPPO      INTEGER             F. P.       REFS        13        45        46        48        50
                                              DEFINED         1
    0  NUMEL     INTEGER             F. P.       REFS        24        25   DEFINED         1
    0  NUMNP     INTEGER            CNTRL        REFS        10
  353  Q         REAL      ARRAY    LS4ARG       REFS        11        28
    0  R         REAL      ARRAY     F. P.       REFS        13        50        55   DEFINED         1
  132  S         REAL      ARRAY    LS4ARG       REFS        11        32
   14  SS        REAL      ARRAY    LS4ARG       REFS        11
    7  TRACE     REAL               CNTRL        REFS        10        62   DEFINED        60        62
    0  WLI       REAL                F. P.       REFS        55   DEFINED         1
    0  WLO       REAL                F. P.       REFS        50   DEFINED         1
  124  XC        REAL               LS4ARG       REFS        11
    0  XS        REAL      ARRAY     F. P.       REFS        13        28        50        55   DEFINED         1        21
                                                   28        71
  125  YC        REAL               LS4ARG       REFS        11
    0  Z         REAL      ARRAY     F. P.       REFS        13        50        55   DEFINED         1

FILE NAMES        MODE
       INPUT     FMT                    READS      48        53
       OUTPUT    FMT                   WRITES      49        54
       TAPE1     UNFMT                 WRITES      78    MOTION        79
       TAPE4     UNFMT                 WRITES      81    MOTION        80        82

EXTERNALS          TYPE   ARGS      REFERENCES
       HYDROST                7             50       55
       READ1                  4             25

INLINE FUNCTIONS   TYPE   ARGS        DEF LINE  REFERENCES
       ABS       REAL         1  INTRIN               62

STATEMENT LABELS             DEF LINE   REFERENCES
    0  100                      23         19        22
   51  110                      33         29        31
    0  120                      34         26
    0  130                      40         36
   71  140                      41         24        35
  124  145                      51         46        47
  150  160                      56         45        51
  150  165                      60         52
    0  170                      62         61
    0  185                      66         64
  174  187                      67         63
```

```
STATEMENT LABELS                DEF LINE   REFERENCES
  216  189                         77          68        72        75
  224  190                         78          67
  327  1010     FMT                83          48        53
  331  2010     FMT                84          49
  336  2011     FMT                85          54

LOOPS  LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
   11  100        I           19 23        14B               NOT INNER
   20  100        J           22 23         2B      INSTACK
   26  140        N           24 41        46B               EXT REFS  NOT INNER
   32  120        I           26 34        24B               NOT INNER
   43  110        J           29 33        10B      INSTACK
   63  130        I           36 40         5B      INSTACK
  156  170        I           61 62         4B      INSTACK
  170  185        I           64 66         3B      INSTACK
  177  189        K           68 77        25B               NOT INNER
  213  189        J           72 77         5B      INSTACK

COMMON BLOCKS   LENGTH
       CNTRL         8
       LS4ARG      283

STATISTICS
  PROGRAM LENGTH                400B      256
  SCM LABELED COMMON LENGTH     443B      291
          52000B SCM USED
```

```
        SUBROUTINE READ1       76/176  OPT=1 STATIC                    FTN 4.8+498         03/16/81  16.39.39        PAGE      1

 1                  SUBROUTINE READ1(A,LA,N,NUMEL)
              C
              C*******************************************************************
              C     READ MATRIX A (IN ARRAY FORM) FROM TAPE1.
 5            C*******************************************************************
              C
                    DIMENSION A(LA)
                    COMMON/BUF/B(2830)
                    LB=2830
10                  IF (N.NE.1) GO TO 100
                    REWIND 1
                    M=0
                    READ (1) B
                100 MM=M+LA
15                  DO 200 I=1,LA
                    II=I+M
                200 A(I)=B(II)
                    M=MM
                    IF (N.EQ.NUMEL) GO TO 400
20                  IF ((M+LA).LE.LB) GO TO 400
                    READ (1) B
                    M=0
                400 RETURN
                    END


        SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  READ1           1          23

VARIABLES      SN  TYPE            RELOCATION
    0  A           REAL        ARRAY     F.P.          REFS         7   DEFINED         1         17
    0  B           REAL        ARRAY    BUF            REFS         8        17   DEFINED        13         21
   57  I           INTEGER                             REFS        16        17   DEFINED        15
   60  II          INTEGER                             REFS        17   DEFINED        16
    0  LA          INTEGER               F.P.          REFS         7        14        15        20   DEFINED         1
   54  LB          INTEGER                             REFS        20   DEFINED         9
   55  M           INTEGER                             REFS        14        16        20   DEFINED        12        18        22
   56  MM          INTEGER                             REFS        18   DEFINED        14
    0  N           INTEGER               F.P.          REFS        10        19   DEFINED         1
    0  NUMEL       INTEGER               F.P.          REFS        19   DEFINED         1

FILE NAMES         MODE
       TAPE1     UNFMT                  READS        13         21     MOTION        11

STATEMENT LABELS              DEF LINE    REFERENCES
   15  100                       14          10
    0  200                       17          15
   42  400                       23          19          20

LOOPS  LABEL     INDEX      FROM-TO     LENGTH    PROPERTIES
   25  200       I            15 17         3B      INSTACK
```

```
COMMON BLOCKS    LENGTH
       BUF          2830

STATISTICS
  PROGRAM LENGTH                 61B       49
  SCM LABELED COMMON LENGTH    5416B     2830
          52000B SCM USED
```

```
      SUBROUTINE HYDROST(R,Z,IJBC,NPP,XS,WL,SGN)
C
C***************************************************************
C     CALCULATE HYDROSTATIC PRESSURE
C***************************************************************
C
      DIMENSION IJBC(1),XS(1),R(1),Z(1)
      PRINT 2020
      I=IJBC(1)
      J=IJBC(2)
      R1=0.
      R2=0.
      L1=1.
      IF (WL.LT.Z(I)) GO TO 50
      PJ=.0625*(WL-Z(I))*SGN*R(I)
      NN=NPP-1
      GO TO 100
   50 II=3*I-2
      JJ=3*J-2
      X=WL-Z(J)
      PJ=0.0625*X*SGN*R(J)
      DZ=Z(I)-Z(J)
      DR=R(I)-R(J)
      F=X/DZ
      RI1=PJ*F**2*DZ/6.
      RI2=-PJ*F**2*DR/6.
      RJ1=PJ*F*(1.-F/3.)*DZ/2.
      RJ2=-PJ*F*(1.-F/3.)*DR/2.
      XS(II)=XS(II)+RI1
      XS(II+1)=XS(II+1)+RI2
      XS(JJ)=XS(JJ)+RJ1
      XS(JJ+1)=XS(JJ+1)+RJ2
      R1=RJ1
      R2=RJ2
      PRINT 2030, I,RI1,RI2
      NN=NPP-1
      L1=2.
  100 DO 150 L=L1,NN
      PI=PJ
      I=IJBC(L)
      J=IJBC(L+1)
      II=3*I-3
      JJ=3*J-3
      DR=R(I)-R(J)
      DZ=Z(I)-Z(J)
      PJ=0.0625*(WL-Z(J))*SGN*R(J)
      RI1=(2.*PI+PJ)*DZ/6.
      RI2=-(2.*PI+PJ)*DR/6.
      RJ1=(2.*PJ+PI)*DZ/6.
      RJ2=-(2.*PJ+PI)*DR/6.
      XS(II+1)=XS(II+1)+RI1
      XS(II+2)=XS(II+2)+RI2
      XS(JJ+1)=XS(JJ+1)+RJ1
      XS(JJ+2)=XS(JJ+2)+RJ2
      RI1=RI1+R1
      RI2=RI2+R2
      R1=RJ1
```

```
                            R2=RJ2
                            PRINT 2030, I, RI1, RI2
          60            150 CONTINUE
                            PRINT 2030, J, R1, R2
                       2020 FORMAT (1X,46HEQUIVALENT NODAL FORCES DUE TO FLUID PRESSURE  //
                           1 32H     NO. PT.     R-LOAD     Z-LOAD/)
                       2030 FORMAT (I12,2F10.3)
          65                RETURN
                            END


    CARD NR.  SEVERITY  DETAILS    DIAGNOSIS OF PROBLEM

          10       I     IJBC       ARRAY REFERENCE OUTSIDE DIMENSION BOUNDS.


            SYMBOLIC REFERENCE MAP (R=2)

     ENTRY POINTS       DEF LINE       REFERENCES
         3  HYDROST         1             65

     VARIABLES     SN   TYPE            RELOCATION
       246  DR        REAL                                REFS        26        28        48        50   DEFINED        23        44
       245  DZ        REAL                                REFS        24        25        27        47        49
                                                       DEFINED        22        45
       247  F         REAL                                REFS        25        26      2*27      2*28   DEFINED        24
       233  I         INTEGER                             REFS        14      2*15        18        22        23        35        42
                                                            44        45        59   DEFINED         9        40
       242  II        INTEGER                             REFS      2*29      2*30      2*51      2*52   DEFINED        18        42
         0  IJBC      INTEGER    ARRAY     F.P.           REFS         7         9        10        40        41
                                                       DEFINED         1
       234  J         INTEGER                             REFS        19        20        21        22        23        43        44
                                                            45      2*46        61   DEFINED        10        41
       243  JJ        INTEGER                             REFS      2*31      2*32      2*53      2*54   DEFINED        19        43
       254  L         INTEGER                             REFS        40        41   DEFINED        38
       237  L1        INTEGER                             REFS        38   DEFINED        13        37
       241  NN        INTEGER                             REFS        38   DEFINED        16        36
         0  NPP       INTEGER              F.P.           REFS        16        36   DEFINED         1
       255  PI        REAL                                REFS        47        48        49        50   DEFINED        39
       240  PJ        REAL                                REFS        25        26        27        28        39        47        48
                                                            49        50   DEFINED        15        21        46
         0  R         REAL       ARRAY     F.P.           REFS         7        15        21      2*23      2*44        46
                                                       DEFINED         1
       250  RI1       REAL                                REFS        29        35        51        55        59
                                                       DEFINED        25        47        55
       251  RI2       REAL                                REFS        30        35        52        56        59
                                                       DEFINED        26        48        56
       252  RJ1       REAL                                REFS        31        33        53        57   DEFINED        27        49
       253  RJ2       REAL                                REFS        32        34        54        58   DEFINED        28        50
       235  R1        REAL                                REFS        55        61   DEFINED        11        33        57
       236  R2        REAL                                REFS        56        61   DEFINED        12        34        58
         0  SGN       REAL                 F.P.           REFS        15        21        46   DEFINED         1
```

```
       SUBROUTINE HYDROST    76/176  OPT=1 STATIC                 FTN 4.8+498        03/16/81  16.39.39       PAGE      3

VARIABLES     SN  TYPE           RELOCATION
    0  WL         REAL               F.P.        REFS        14        15        20        46     DEFINED        1
  244  X          REAL                           REFS        21        24    DEFINED       20
    0  XS         REAL       ARRAY     F.P.      REFS         7        29        30        31         32        51        52
                                                   53        54     DEFINED       1        29         30        31        32
                                                   51        52        53        54
    0  Z          REAL       ARRAY     F.P.      REFS         7        14        15        20        2*22      2*45      46
                                               DEFINED        1

FILE NAMES        MODE
       OUTPUT    FMT                   WRITES        8        35        59        61

STATEMENT LABELS             DEF LINE   REFERENCES
   30  50                       18         14
  106  100                      38         17
    0  150                      60         38
  207  2020    FMT              62          8
  222  2030    FMT              64         35         59        61

LOOPS  LABEL    INDEX     FROM-TO     LENGTH     PROPERTIES
  110  150      L           38 60       47B                EXT REFS

STATISTICS
  PROGRAM LENGTH                271B     185
          52000B SCM USED
```

```
      SUBROUTINE STATIC(NEBC,SMASS,XS,A,STRES,NEQ,MBAND,NUM,NUMEL)
C
C*********************************************************************
C     DISPLACEMENTS DUE TO STATIC LOADS ARE CALCULATED. ELEMENT STRESSES
C     ARE COMPUTED.  STATIC DISPLACEMENTS AND STRESSES ARE WRITTEN
C     ONTO TAPE3.
C*********************************************************************
C
      COMMON/CNTRL/NUMNP,NANGLE,MBAN ,NBC,NF,NPPO,NPPI,TRACE
      COMMON/LS4ARG/LM(12),SS(6,12),XC,YC,ELMASS(4),S(12,12),MTYPE,Q(12)
     1,C(6,6)
      DIMENSION NEBC(1),SMASS(1),XS(1),A(NEQ,MBAND),STRES(NUM),SIG(6)
      REWIND 3
      READ (1) A
      BACKSPACE 1
      DO 50 K=1,NBC
      I=NEBC(K)
   50 A(I,1)=1.0
      CALL BANSOL(NEQ,MBAND,NEQ,A,XS,0)
      CALL BANSOL(NEQ,MBAND,NEQ,A,XS,1)
      MPRINT=0
      REWIND 1
      DO 300 N=1,NUMEL
      CALL READ1(LM,283,N,NUMEL)
      IY=6
      IF (NF.EQ.0) IY=4
      DO 180 I=1,6
      SIG(I)=0.0
      DO 180 J=1,12
      JJ=LM(J)
  180 SIG(I)=SIG(I)+SS(I,J)*XS(JJ)
      DO 190 J=1,IY
  190 SIG(J)=6.94444*SIG(J)
      NN=6*N
      DO 195 I=1,6
      STRES(NN-6+I)=SIG(I)
  195 CONTINUE
      IF (MPRINT) 280,270,280
  270 CONTINUE
      PRINT 2000
      MPRINT=50
  280 MPRINT=MPRINT-1
      PRINT 2001, N,XC,YC,(SIG(I),I=1,IY)
  300 CONTINUE
      PRINT 2009
      DO 360 I=1,NEQ
  360 XS(I)=XS(I)*12.
      PRINT 2010, (N,XS(3*N-2),XS(3*N-1),XS(3*N),N=1,NUMNP)
      WRITE (3) (XS(I),I=1,NEQ)
      WRITE (3) STRES
 2000 FORMAT (1H1,23HELEMENT STRESSES IN PSI//
     1 6H EL.NO  7X  1HR  7X  1HZ  7X  5HSIG R  7X  5HSIG Z  7X  5HSIG T
     2 6X  6HTAU RZ  6X  6HTAU RT 6X  6HTAU ZT  /)
 2001 FORMAT (I5,1X,2F8.2,6E12.4)
 2009 FORMAT (1H1,44HDISPLACEMENTS DUE TO STATIC LOADS--IN INCHES //
     1 41H NODAL PT  R-DISPLACEMENT  Z-DISPLACEMENT
     2 16H  T DISPLACEMENT  )
```

```
      SUBROUTINE STATIC      76/176  OPT=1 STATIC                       FTN 4.8+498         03/16/81  16.39.39         PAGE      2

                  2010 FORMAT (I9,3E16.4)
                       RETURN
   60                  END



      SYMBOLIC REFERENCE MAP (R=2)

 ENTRY POINTS       DEF LINE       REFERENCES
     3  STATIC           1           59

 VARIABLES       SN  TYPE            RELOCATION
      0  A            REAL         ARRAY     F.P.          REFS          12          19          20   DEFINED           1          14          18
    367  C            REAL         ARRAY    LS4ARG         REFS          10
    126  ELMASS       REAL         ARRAY    LS4ARG         REFS          10
    340  I            INTEGER                              REFS          18          28        3*31        2*36          43        2*47          49
                                                        DEFINED          17          27          35          43          46          49
    343  IY           INTEGER                              REFS          32          43     DEFINED          25          26
    344  J            INTEGER                              REFS          30          31        2*33     DEFINED          29          32
    345  JJ           INTEGER                              REFS          31     DEFINED          30
    337  K            INTEGER                              REFS          17     DEFINED          16
      0  LM           INTEGER      ARRAY    LS4ARG         REFS          10          24          30
      2  MBAN         INTEGER               CNTRL          REFS           9
      0  MBAND        INTEGER                F.P.          REFS          12          19          20     DEFINED           1
    341  MPRINT       INTEGER                              REFS          38          42     DEFINED          21          41          42
    352  MTYPE        INTEGER               LS4ARG         REFS          10
    342  N            INTEGER                              REFS          24          34          43        4*48     DEFINED          23          48
      1  NANGLE       INTEGER               CNTRL          REFS           9
      3  NBC          INTEGER               CNTRL          REFS           9          16
      0  NEBC         INTEGER      ARRAY     F.P.          REFS          12          17     DEFINED           1
      0  NEQ          INTEGER                F.P.          REFS          12        2*19        2*20          46          49
                                                        DEFINED           1
      4  NF           INTEGER               CNTRL          REFS           9          26
    346  NN           INTEGER                              REFS          36     DEFINED          34
      6  NPPI         INTEGER               CNTRL          REFS           9
      5  NPPO         INTEGER               CNTRL          REFS           9
      0  NUM          INTEGER                F.P.          REFS          12     DEFINED           1
      0  NUMEL        INTEGER                F.P.          REFS          23          24     DEFINED           1
      0  NUMNP        INTEGER               CNTRL          REFS           9          48
    353  Q            REAL         ARRAY    LS4ARG         REFS          10
    132  S            REAL         ARRAY    LS4ARG         REFS          10
    347  SIG          REAL         ARRAY                   REFS          12          31          33          36          43
                                                        DEFINED          28          31          33
      0  SMASS        REAL         ARRAY     F.P.          REFS          12     DEFINED           1
     14  SS           REAL         ARRAY    LS4ARG         REFS          10          31
      0  STRES        REAL         ARRAY     F.P.          REFS          12          50     DEFINED           1          36
      7  TRACE        REAL                  CNTRL          REFS           9
    124  XC           REAL                  LS4ARG         REFS          10          43
      0  XS           REAL         ARRAY     F.P.          REFS          12          19          20          31          47        3*48          49
                                                        DEFINED           1          47
    125  YC           REAL                  LS4ARG         REFS          10          43

 FILE NAMES          MODE
        OUTPUT      FMT                     WRITES          40          43          45          48
        TAPE1       UNFMT                    READS          14      MOTION          15          22
```

```
       SUBROUTINE STATIC     76/176  OPT=1 STATIC                   FTN 4.8+498       03/16/81  16.39.39       PAGE     3

FILE NAMES        MODE
       TAPE3     UNFMT                WRITES       49        50     MOTION       13

EXTERNALS          TYPE   ARGS        REFERENCES
       BANSOL              6              19         20
       READ1               4              24

STATEMENT LABELS             DEF LINE   REFERENCES
    0  50                       18          16
    0  180                      31          27         29
    0  190                      33          32
    0  195                      37          35
    0  270         INACTIVE     39          38
  127  280                      42         2*38
    0  300                      44          23
    0  360                      47          46
  272  2000    FMT              51          40
  306  2001    FMT              54          43
  311  2009    FMT              55          45
  326  2010    FMT              58          48

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   26  50       K           16 18       4B      INSTACK
   55  300      N           23 44      64B               EXT REFS  NOT INNER
   64  180      I           27 31      17B               NOT INNER
   73  180      J           29 31       5B      INSTACK
  106  190      J           32 33       3B      INSTACK
  120  195      I           35 37       2B      INSTACK
  146  360      I           46 47       3B      INSTACK
  154           N           48 48      12B               EXT REFS

COMMON BLOCKS   LENGTH
       CNTRL         8
       LS4ARG      283

STATISTICS
  PROGRAM LENGTH                365B     245
  SCM LABELED COMMON LENGTH     443B     291
          52000B SCM USED
```

```
      SUBROUTINE BANSOL(NN,MM,NDIM,A,B,KK)
C
C     ****************************************************************
C     LINEAR EQUATION SOLVER FOR SYMMETRIC BANDED MATRICES
C      KK = 0  TRIANGULARIZES BAND MATRIX A
C      KK = 1  REDUCES AND BACKSUBSTITUTES VECTOR B
C      KK = 2  BACKSUBSTITUTES VECTOR B
C     ****************************************************************
C
      DIMENSION A(NDIM,1), B(1)
C
      NR = NN - 1
      IF (KK-1) 100,300,400
  100 DO 200  N = 1,NR
      M = N - 1
      IF (A(N,1).EQ.0.) A(N,1) = 1.0E-16
      PIVOT = A(N,1)
      MR = MINO (MM,NN-M)
      DO 200  L = 2,MR
      C = A(N,L)/PIVOT
      IF (C.EQ.0.) GO TO 200
      I = M + L
      J = 0
      DO 180  K = L,MR
      J = J + 1
  180 A(I,J) = A(I,J) - C*A(N,K)
      A(N,L) = C
  200 CONTINUE
      IF (A(NN,1).EQ.0.) A(NN,1) = 1.0E-16
      GO TO 500
  300 DO 350  N = 1,NR
      M = N - 1
      MR = MINO (MM,NN-M)
      C = B(N)
      B(N) = C/A(N,1)
      DO 350  L = 2,MR
      I = M + L
  350 B(I) = B(I) - A(N,L)*C
  400 B(NN) = B(NN)/A(NN,1)
      DO 450  K = 2,NN
      M = NN - K
      N = M + 1
      MR = MINO (MM,K)
      DO 450  L = 2,MR
      I = M + L
  450 B(N) = B(N) - A(N,L)*B(I)
  500 RETURN
      END
```

SYMBOLIC REFERENCE MAP (R=2)

```
       SUBROUTINE BANSOL     76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39       PAGE     2

ENTRY POINTS     DEF LINE     REFERENCES
    3  BANSOL          1        47

VARIABLES     SN  TYPE           RELOCATION
    0  A         REAL       ARRAY     F.P.         REFS        10        16        17        20      2*26        29        35
                                                     38        39        46   DEFINED         1        16        26        27
                                                     29
    0  B         REAL       ARRAY     F.P.         REFS        10        34        38        39      2*46
                                                DEFINED         1        35        38        39        46
  167  C         REAL                              REFS        21        26        27        35        38
                                                DEFINED        20        34
  170  I         INTEGER                           REFS      2*26      2*38        46   DEFINED        22        37        45
  171  J         INTEGER                           REFS        25      2*26   DEFINED        23        25
  172  K         INTEGER                           REFS        26        41        43   DEFINED        24        40
    0  KK        INTEGER              F.P.         REFS        13   DEFINED         1
  166  L         INTEGER                           REFS        20        22        24        27        37        38        45
                                                     46   DEFINED        19        36        44
  163  M         INTEGER                           REFS        18        22        33        37        42        45
                                                DEFINED        15        32        41
    0  MM        INTEGER              F.P.         REFS        18        33        43   DEFINED         1
  165  MR        INTEGER                           REFS        19        24        36        44   DEFINED        18        33
                                                     43
  162  N         INTEGER                           REFS        15      2*16        17        20        26        27        32
                                                     34      2*35        38      3*46   DEFINED        14        31        42
    0  NDIM      INTEGER              F.P.         REFS        10   DEFINED         1
    0  NN        INTEGER              F.P.         REFS        12        18      2*29        33      3*39        40        41
                                                DEFINED         1
  161  NR        INTEGER                           REFS        14        31   DEFINED        12
  164  PIVOT     REAL                              REFS        20   DEFINED        17

INLINE FUNCTIONS   TYPE   ARGS        DEF LINE  REFERENCES
       MINO      INTEGER    0  INTRIN                18        33        43

STATEMENT LABELS             DEF LINE   REFERENCES
    0  100          INACTIVE     14          13
    0  180                       26          24
   61  200                       28          14        19        21
   73  300                       31          13
    0  350                       38          31        36
  123  400                       39          13
    0  450                       46          40        44
  156  500                       47          30

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   15  200      N           14 28       51B              NOT INNER
   31  200      L           19 28       33B              NOT INNER
   50  180      K           24 26        5B     INSTACK
   74  350      N           31 38       27B              NOT INNER
  113  350      L           36 38        5B     INSTACK
  131  450      K           40 46       25B              NOT INNER
  146  450      L           44 46        5B     INSTACK

STATISTICS
  PROGRAM LENGTH                221B     145
          52000B SCM USED
```

```
      SUBROUTINE BNEIGN(NN,MM,NMO,NBC,EV,NEBC,SMASS,A,B,V,R,CN,SN,TRACE)
C
      DIMENSION EV(1),NEBC(1),SMASS(1),A(NN,1),B(1),R(1),SN(1),CN(1),
     1  V(1)
C
C     INITIALIZE
C
      TOL=1.0E-12
      IFLAG = 0
      NLOOP = 5
      NSMAX = 50
      PSHIFT = 0.
      MM1 = MM + 1
      NW = NN*MM
      NEIG = 0
      NR = NN
      NNR = NN - 1
      REWIND 2
C
C     REDUCE TO CLASSICAL EIGENVALUE PROBLEM  A*X = E*X
C
      DO 120  I = 1,NN
      X = SMASS(I)
      IF (X.GT.0.)  GO TO 110
      PRINT 12, I
   12 FORMAT (30HONEG.  OR ZERO MASS, EQUATION = I5)
      IFLAG = 1
      GO TO 120
  110 SMASS(I) = 1./SQRT(X)
  120 CONTINUE
      IF (IFLAG.NE.0)  STOP
      DO 130  I = 1,NN
      L = I - 1
      MR = MINO (MM,NN-I+1)
      DO 130  J = 1,MR
      K = L + J
  130 A(I,J) = A(I,J)*SMASS(I)*SMASS(K)
C
C     IMPOSE BOUNDARY CONDITIONS ON A
C
      IF (NBC.LE.0) GO TO 150
      DO 140  N = 1,NBC
      I = NEBC(N)
      A(I,1) = 100.*TRACE
  140 CONTINUE
C
C     COMPACT MATRIX A INTO A 1-D ARRAY V
C
  150 DO 160  J = 2,MM
      L = NN*(J-1)
      M = NN - J + 1
      DO 160  I = 1,M
      K = L + I
  160 V(K) = A(I,J)
      WRITE (2) (V(I),I=1,NW)
C
C     COMPUTE SMALLEST EIGENVALUE AND ASSOCIATE EIGENVECTOR OF A
```

```
C     BY INVERSE ITERATION
C
  165 NEIG = NEIG + 1
      E1 = 0.
      SHIFT = 0.
      NS = 0
      KKT = 2
      CALL BANSOL(NR,MM,NN,V,B,0)
      DO 170  I = NR,NN
  170 B(I) = 0.
      DO 180  I = 1,NR
  180 B(I) = 1.
      IF (NBC.LE.0)  GO TO 200
      DO 190  N = 1,NBC
      I = NEBC(N)
  190 B(I) = 0.
  200 NS = NS + 1
      CALL BANSOL(NR,MM,NN,V,B,KKT)
      KKT = 1
      E = 0.
      DO 220  I = 1,NR
      IF (ABS(B(I)).GT.ABS(E))  E = B(I)
  220 CONTINUE
      E = 1./E
      EPS = (E-E1)/E*100.
      DO 230  I = 1,NR
  230 B(I) = B(I)*E
      E1 = E
      IF (ABS(EPS).GT.1..AND.NS.LT.15)  GO TO 200
      NL = NLOOP - 3
  250 DO 260  I = 1,NR
  260 R(I) = B(I)
      NS = NS + 1
      CALL BANSOL(NR,MM,NN,V,B,1)
      E = 0.
      DO 300  I = 1,NR
      IF (ABS(B(I)).GT.ABS(E)) E = B(I)
  300 CONTINUE
      DMAX = 0.
      SUMD = 0.
      DO 320  I = 1,NR
      B(I) = B(I)/E
      D = ABS(B(I)-R(I))
      SUMD = SUMD + D**2
      IF (D.GT.DMAX) DMAX = D
  320 CONTINUE
      IF (DMAX.LE.TOL.OR.NS.GE.NSMAX) GO TO 400
      NL = NL + 1
      IF (NL.LT.NLOOP) GO TO 250
      REWIND 2
      READ (2) (V(I),I=1,NW)
      NL = 0
      X = 0.
      Y = 0.
      DO 340  I = 1,NR
      X = X + B(I)*R(I)
  340 Y = Y + B(I)*B(I)
```

```
      SHIFT = SHIFT + AMAX1(1.-4.*SUMD,0.9)*X/(Y*E)
      DO 350  I = 1,NR
  350 V(I) = V(I) - SHIFT
      CALL BANSOL(NR,MM,NN,V,B,0)
      GO TO 250
  400 X = 0.
      Y = 0.
      DO 420  I = 1,NR
      X = X + B(I)*R(I)
  420 Y = Y + B(I)*B(I)
      SHIFT = SHIFT + X/(Y*E)
      EV(NEIG) = SHIFT + PSHIFT
      SHIFT = SHIFT - TOL
      PSHIFT = EV(NEIG) - TOL
      Y = SQRT(Y)
      DO 430  I = 1,NN
  430 R(I) = B(I)/Y
      IF (NEIG.GE.NMO) GO TO 650
C
C     DEFLATE BAND MATRIX
C
      REWIND 2
      READ (2) (V(I),I=1,NW)
      DO 450  NX = 1,NR
      FB = R(NX)
      IF (FB.NE.0.) GO TO 480
  450 CONTINUE
  480 DO 500  I = 1,NR
      L = NW + I
      V(I) = V(I) - SHIFT
  500 V(L) = 0.
      NRS = NR - 1
      NR1 = NR + 1
      Q1 = R(1)**2
      S2 = 0.
      C  = 1.
      DO 600  I = 1,NRS
      K = I + 1
      Q = Q1 + R(K)**2
      IF (I.LT.NX) GO TO 550
      S2 = Q1/Q
      C = R(K)/SQRT(Q)
      IF (FB.LT.0.) C = -C
  550 S = SQRT(S2)
      C2 = C*C
      SN(I) = S
      CN(I) = C
      Q1 = Q
      L = NN + I
      A11 = V(I)
      A22 = V(K)
      A12 = V(L)
      X = 2.*A12*S*C
      V(I) = A11*C2 + A22*S2 - X
      V(K) = A22*C2 + A11*S2 + X
      V(L) = A12*(C2-S2) + (A11-A22)*S*C
      MR = MIN0 (I,MM)
```

```
      IF (MR.LE.1) GO TO 570
      L1 = I
      DO 560  J = 2,MR
      L1 = L1 + NNR
      L2 = L1 + NN
      A1 = V(L1)
      A2 = V(L2)
      V(L1) = A1*C - A2*S
  560 V(L2) = A2*C + A1*S
  570 MR = MINO (MM1,NR1-I)
      IF (MR.LT.3) GO TO 600
      L2 = K
      DO 580  J = 3,MR
      L2 = L2 + NN
      L1 = L2 + NNR
      A1 = V(L1)
      A2 = V(L2)
      V(L1) = A1*C - A2*S
  580 V(L2) = A2*C + A1*S
  600 CONTINUE
C
C     STORE DEFLATED MATRIX, EIGENVECTOR, SINES AND COSINES OF
C     JACOBI ROTATION MATRICES
C
      REWIND 2
      WRITE (2) (V(I),I=1,NW)
      WRITE (1) (R(I),SN(I),CN(I),I=1,NN)
      NR = NR - 1
      IF (NBC.LE.0) GO TO 165
      DO 620  N = 1,NBC
      I = NEBC(N)
      IF (I.GE.NX) NEBC(N) = I - 1
  620 CONTINUE
      GO TO 165
C
C     RECOVER EIGENVECTORS OF ORIGINAL MATRIX
C     AND CHECK EIGENVALUE ARRANGEMENT
C
  650 DO 700 I = 1,NN
  700 A(I,NMO) = R(I)
      IF (NMO.LE.1) GO TO 900
      LL = NMO - 1
      DO 800  N = 1,LL
      M = NMO - N
      NRS = NN - M
      NR = NRS + 1
      BACKSPACE 1
      READ (1) (A(I,M),SN(I),CN(I),I=1,NN)
      BACKSPACE 1
      KK = M + 1
      DO 800  L = 1,NRS
      I = NR - L
      K = I + 1
      DO 800  J = KK,NMO
      A1 = A(I,J)
      A2 = A(K,J)
      A(I,J) = A1*CN(I) + A2*SN(I)
```

```
                  800 A(K,J) = A2*CN(I) - A1*SN(I)
    230               DO 830  K = 1,LL
                      M = LL - K + 1
                      DO 830  J = 1,M
                      E1 = EV(J)
                      E2 = EV(J+1)
    235               IF (E1.LT.E2) GO TO 830
                      EV(J+1) = E1
                      EV(J)   = E2
                      DO 820  I = 1,NN
                      TEMP = A(I,J)
    240               A(I,J) = A(I,J+1)
                  820 A(I,J+1) = TEMP
                  830 CONTINUE
                  900 DO 920  I = 1,NN
                      X = SMASS(I)
    245               SMASS(I) = 1./X**2
                      DO 920  J = 1,NMO
                  920 A(I,J) = A(I,J)*X
                      RETURN
                      END


       SYMBOLIC REFERENCE MAP (R=2)

 ENTRY POINTS      DEF LINE       REFERENCES
     3  BNEIGN          1          248

 VARIABLES      SN  TYPE          RELOCATION
     0  A           REAL      ARRAY      F.P.       REFS        3        37        54       226       227       239       240
                                                     247   DEFINED         1        37        44       211       219       228
                                                     229       240       241       247
  1237  A1          REAL                            REFS      179       180       189       190       228       229
                                                 DEFINED      177       187       226
  1232  A11         REAL                            REFS      168       169       170   DEFINED       164
  1234  A12         REAL                            REFS      167       170   DEFINED       166
  1240  A2          REAL                            REFS      179       180       189       190       228       229
                                                 DEFINED      178       188       227
  1233  A22         REAL                            REFS      168       169       170   DEFINED       165
     0  B           REAL      ARRAY      F.P.       REFS        3        65        75      2*79        84        89        91
                                                    2*94        99       100       113     2*114       118       123     2*124
                                                     131   DEFINED         1        67        69        73        84        99
  1226  C           REAL                            REFS      157     2*159       161       167       170       179       180
                                                     189       190   DEFINED       150       156       157
     0  CN          REAL      ARRAY      F.P.       REFS        3       198       228       229   DEFINED         1       161
                                                     219
  1231  C2          REAL                            REFS      168       169       170   DEFINED       159
  1216  D           REAL                            REFS      101     2*102   DEFINED       100
  1214  DMAX        REAL                            REFS      102       104   DEFINED        96       102
  1211  E           REAL                            REFS       79        81      2*82        84        85        94        99
                                                     115       125   DEFINED        77        79        81        92        94
  1212  EPS         REAL                            REFS       86   DEFINED        82
     0  EV          REAL      ARRAY      F.P.       REFS        3       128       233       234   DEFINED         1       126
                                                     236       237
```

```
     SUBROUTINE BNEIGN      76/176  OPT=1 STATIC                FTN 4.8+498        03/16/81  16.39.39        PAGE      6

  VARIABLES      SN  TYPE          RELOCATION
   1205  E1          REAL                                 REFS        82      235      236  DEFINED       61       85      233
   1243  E2          REAL                                 REFS       235      237  DEFINED      234
   1221  FB          REAL                                 REFS       140      157  DEFINED      139
   1175  I           INTEGER                              REFS        23       25       29       33       34     3*37       44
                                                            53        54       55       67       69       73     2*79     2*84
                                                          2*89      2*94     2*99    2*100      108    2*113    2*114    2*117
                                                         2*123     2*124    2*131      137      143    2*144      152      154
                                                           160       161      163      164      168      171      173      181
                                                           197     3*198    2*203    2*211    3*219      224      226    3*228
                                                         2*229       239    2*240      241      244      245    2*247
                                                       DEFINED        22       32       43       52       55       66       68
                                                            72        78       83       88       93       98      108      112
                                                           116       122      130      137      142      151      197      198
                                                           202       210      219      223      238      243
   1164  IFLAG       INTEGER                              REFS        31  DEFINED        9       27
   1201  J           INTEGER                              REFS        36     2*37       50       51       54      226      227
                                                           228       229      233      234      236      237      239    2*240
                                                           241     2*247  DEFINED       35       49      174      184      225
                                                           232       246
   1202  K           INTEGER                              REFS        37       54      153      156      165      169      183
                                                           227       229      231  DEFINED       36       53      152      224
                                                           230
   1242  KK          INTEGER                              REFS       225  DEFINED      221
   1210  KKT         INTEGER                              REFS        75  DEFINED       64       76
   1177  L           INTEGER                              REFS        36       53      145      166      170      223
                                                       DEFINED        33       50      143      163      222
   1241  LL          INTEGER                              REFS       214      230      231  DEFINED      213
   1235  L1          INTEGER                              REFS       175      176      177      179      187      189
                                                       DEFINED       173      175      186
   1236  L2          INTEGER                              REFS       178      180      185      186      188      190
                                                       DEFINED       176      183      185
   1204  M           INTEGER                              REFS        52      216      219      221      232
                                                       DEFINED        51      215      231
      0  MM          INTEGER                F.P.          REFS        13       14       34       49       65       75       91
                                                           118       171  DEFINED        1
   1170  MM1         INTEGER                              REFS       181  DEFINED       13
   1200  MR          INTEGER                              REFS        35      172      174      182      184
                                                       DEFINED        34      171      181
   1203  N           INTEGER                              REFS        43       72      202      203      215
                                                       DEFINED        42       71      201      214
      0  NBC         INTEGER                F.P.          REFS        41       42       70       71      200      201
                                                       DEFINED         1
      0  NEBC        INTEGER       ARRAY    F.P.          REFS         3       43       72      202  DEFINED        1      203
   1172  NEIG        INTEGER                              REFS        60      126      128      132  DEFINED       15       60
   1213  NL          INTEGER                              REFS       105      106  DEFINED       87      105      109
   1165  NLOOP       INTEGER                              REFS        87      106  DEFINED       10
      0  NMO         INTEGER                F.P.          REFS       132      211      212      213      215      225      246
                                                       DEFINED         1
      0  NN          INTEGER                F.P.          REFS         3       14       16       17       22       32       34
                                                            50        51       65       66       75       91      118      130
                                                           163       176      185      198      210      216      219      238
                                                           243   DEFINED        1
   1174  NNR         INTEGER                              REFS       175      186  DEFINED       17
   1173  NR          INTEGER                              REFS        65       66       68       75       78       83       88
                                                            91        93       98      112      116      118      122      138
                                                           142       146      147      199      223  DEFINED       16      199
                                                           217
```

```
VARIABLES     SN  TYPE           RELOCATION
 1222  NRS       INTEGER                          REFS       151       217       222    DEFINED      146       216
 1223  NR1       INTEGER                          REFS       181    DEFINED      147
 1207  NS        INTEGER                          REFS        74        86        90       104    DEFINED       63        74
                                                    90
 1166  NSMAX     INTEGER                          REFS       104    DEFINED       11
 1171  NW        INTEGER                          REFS        55       108       137       143       197
                                                DEFINED       14
 1220  NX        INTEGER                          REFS       139       154       203    DEFINED      138
 1167  PSHIFT    REAL                             REFS       126    DEFINED       12       128
 1227  Q         REAL                             REFS       155       156       162    DEFINED      153
 1224  Q1        REAL                             REFS       153       155    DEFINED      148       162
    0  R         REAL       ARRAY     F.P.        REFS         3       100       113       123       139       148       153
                                                   156       198       211    DEFINED        1        89       131
 1230  S         REAL                             REFS       160       167       170       179       180       189       190
                                                DEFINED      158
 1206  SHIFT     REAL                             REFS       115       117       125       126       127       144
                                                DEFINED       62       115       125       127
    0  SMASS     REAL       ARRAY     F.P.        REFS         3        23      2*37       244    DEFINED        1        29
                                                   245
    0  SN        REAL       ARRAY     F.P.        REFS         3       198       228       229    DEFINED        1       160
                                                   219
 1215  SUMD      REAL                             REFS       101       115    DEFINED       97       101
 1225  S2        REAL                             REFS       158       168       169       170    DEFINED      149       155
 1244  TEMP      REAL                             REFS       241    DEFINED      239
 1163  TOL       REAL                             REFS       104       127       128    DEFINED        8
    0  TRACE     REAL                 F.P.        REFS        44    DEFINED        1
    0  V         REAL       ARRAY     F.P.        REFS         3        55        65        75        91       117       118
                                                   144       164       165       166       177       178       187       188
                                                   197    DEFINED        1        54       108       117       137       144
                                                   145       168       169       170       179       180       189       190
 1176  X         REAL                             REFS        24        29       113       115       123       125       168
                                                   169       245       247    DEFINED       23       110       113       120
                                                   123       167       244
 1217  Y         REAL                             REFS       114       115       124       125       129       131
                                                DEFINED      111       114       121       124       129

FILE NAMES        MODE
       OUTPUT    FMT                   WRITES       25
       TAPE1     UNFMT                 WRITES      198     READS       219    MOTION       218       220
       TAPE2     UNFMT                 WRITES       55       197     READS       108       137    MOTION       18       107
                                         136       196

EXTERNALS          TYPE   ARGS       REFERENCES
       BANSOL               6             65        75        91       118
       SQRT      REAL       1 LIBRARY     29       129       156       158

INLINE FUNCTIONS   TYPE   ARGS    DEF LINE  REFERENCES
       ABS       REAL       1  INTRIN             2*79        86      2*94       100
       AMAX1     REAL       0  INTRIN              115
       MINO      INTEGER    0  INTRIN               34       171       181

STATEMENT LABELS             DEF LINE   REFERENCES
 1104  12     FMT               26        25
   35  110                      29        24
   40  120                      30        22        28
    0  130                      37        32        35
    0  140                      45        42
```

```
STATEMENT LABELS                DEF LINE   REFERENCES
  110  150                         49         41
    0  160                         54         49          52
  137  165                         60        200         205
    0  170                         67         66
    0  180                         69         68
    0  190                         73         71
  203  200                         74         70          86
    0  220                         80         78
    0  230                         84         83
  252  250                         88        106         119
    0  260                         89         88
    0  300                         95         93
    0  320                        103         98
    0  340                        114        112
    0  350                        117        116
  406  400                        120        104
    0  420                        124        122
    0  430                        131        130
    0  450                        141        138
  465  480                        142        140
    0  500                        145        142
  522  550                        158        154
    0  560                        180        174
  601  570                        181        172
    0  580                        190        184
  627  600                        191        151         182
    0  620                        204        201
  674  650                        210        132
    0  700                        211        210
    0  800                        229        214         222         225
    0  820                        241        238
 1022  830                        242        230         232         235
 1027  900                        243        212
    0  920                        247        243         246

LOOPS  LABEL     INDEX      FROM-TO     LENGTH    PROPERTIES
   26  120       I           22 30        15B                EXT REFS
   46  130       I           32 37        24B                NOT INNER
   63  130       J           35 37         4B      INSTACK
  103  140       N           42 45         4B      INSTACK
  111  160       J           49 54        20B                NOT INNER
  123  160       I           52 54         3B      INSTACK
  157  170       I           66 67         2B      INSTACK
  165  180       I           68 69         2B      INSTACK
  177  190       N           71 73         3B      INSTACK
  221  220       I           78 80         5B      INSTACK
  237  230       I           83 84         3B      INSTACK
  257  260       I           88 89         2B      INSTACK
  277  300       I           93 95         5B      INSTACK
  313  320       I           98 103       10B      INSTACK
  352  340       I          112 114        5B      INSTACK
  373  350       I          116 117        3B      INSTACK
  414  420       I          122 124        5B      INSTACK
  441  430       I          130 131        3B      INSTACK
  460  450       NX         138 141        5B      INSTACK    EXITS
  472  500       I          142 145        4B      INSTACK
  506  600       I          151 191      124B                EXT REFS  NOT INNER
```

```
LOOPS  LABEL    INDEX     FROM-TO     LENGTH    PROPERTIES
  567  560      J          174 180       10B     INSTACK
  615  580      J          184 190       10B     INSTACK
  644           I          198 198       11B               EXT REFS
  666  620      N          201 204        5B     INSTACK
  704  700      I          210 211        2B     INSTACK
  713  800      N          214 229       64B               EXT REFS  NOT INNER
  724           I          219 219       13B               EXT REFS
  745  800      L          222 229       27B               NOT INNER
  762  800      J          225 229        7B     INSTACK
 1000  830      K          230 242       27B               NOT INNER
 1003  830      J          232 242       22B               NOT INNER
 1016  820      I          238 241        3B     INSTACK
 1030  920      I          243 247       16B               NOT INNER
 1040  920      J          246 247        3B     INSTACK

STATISTICS
  PROGRAM LENGTH              1327B      727
          52000B SCM USED
```

```
      SUBROUTINE EIGEN(NEBC,SMASS,XS,EV,A,W1,W2,W3,W4,CC,
     1 NEQ,NMODE,MBAND,R,Z,PLOTT)
C
C*********************************************************************
C     STRUCTURAL FREE VIBRATION MODE SHAPES AND NATURAL FREQUENCIES ARE
C     CALCULATED OR READ IN.  MBAND+1 SETS LIMIT ON MAX MODE FURNISHED.
C*********************************************************************
C
      COMMON/CNTRL/NUMNP,NANGLE,MBAN ,NBC,NF,NPPO,NPPI,TRACE,READFRQ
      DIMENSION NEBC(1),SMASS(1),XS(1),A(NEQ,MBAND),EV(1),W1(1),W2(1),
     1 W3(1),W4(1),CC(NMODE,1),R(1),Z(1),KEEP(100),
     2 ZPLOT(100,20),NPTS(20),IFIG(20),APLOT(100,20)
      LOGICAL READFRQ
      LOGICAL PLOTT
      IF (READFRQ) GO TO 180
      READ (1) A
      BACKSPACE 1
      CALL BNEIGN(NEQ,MBAND,NMODE,NBC,EV,NEBC,SMASS,A,W1,A,W2,W3,W4
     1                 ,TRACE)
C
C     COMPUTE EIGENVALUES AND EIGENVECTORS
C
      PRINT 2006
      DO 90 I=1,NMODE
      EV(I)=SQRT(EV(I))
   90 PRINT 2005,  I,EV(I)
      PRINT 2007
      CALL PRINTA(A,NEQ,NMODE)
      IF (.NOT.PLOTT) GO TO 108
      ZPREV=100000.
      IND=0
   92 ZMAX=0.
      IND=IND+1
      DO 94 I=1,NUMNP
   94 IF (Z(I).GT.ZMAX.AND.Z(I).LT.ZPREV) ZMAX=Z(I)
      RMAX=0.
      DO 96 I=1,NUMNP
      IF (Z(I).NE.ZMAX) GO TO 96
      IF (R(I).GT.RMAX) KEEP(IND)=I
      IF (R(I).GT.RMAX) RMAX=R(I)
   96  CONTINUE
      ZPREV=ZMAX
      IF (ZMAX.NE.0.) GO TO 92
C
      DO 102 I=1,IND
      DO 100 N=1,NMODE
  100 ZPLOT(I,N)=Z(KEEP(I))
  102 KEEP(I)=1+3*(KEEP(I)-1)
      CALL OPLT
      DO 106 J=1,3
      IF (J.EQ.1) YTITLE="R DISPL."
      IF (J.EQ.2) YTITLE="Z DISPL."
      IF (J.EQ.3) YTITLE="T DISPL."
      DO 104 K=1,NMODE
      NPTS(K)=IND
      IFIG(K)=3
      DO 104 I=1,IND
```

```
      INEW=KEEP(I)+(J-1)
  104 APLOT(I,K)=A(INEW,K)
      CALL MULPLT(ZPLOT,APLOT,NPTS,NMODE,1,100,20,
     1 "Z-AXIS",6,YTITLE,8,9,IFIG)
  106 CONTINUE
      CALL PLOT (0.,0.,999)
  108 PRINT 2008
      DO 150 I=1,NMODE
      DO 120 J=I,NMODE
      SUM=0.0
      DO 110 K=1,NEQ
  110 SUM=SUM+A(K,I)*SMASS(K)*A(K,J)
  120 CC(I,J)=SUM
      II=I-1
      IF (II) 150,150,130
  130 DO 140 L=1,II
  140 CC(I,L)=CC(L,I)
  150 CONTINUE
      CALL PRINTA(CC,NMODE,NMODE)
C
C     WRITE FREQUENCIES AND MODE SHAPES
C
      WRITE (8) (EV(N),N=1,NMODE)
      DO 170 N=1,NMODE
      DO 170 M=1,NUMNP
      L=3*M-2
  170 WRITE (8) M,A(L,N),A(L+1,N),A(L+2,N)
      RETURN
C
C     READ FREQUENCIES AND MODE SHAPES
C
  180 READ (8) (EV(N),N=1,NMODE)
      DO 190 N=1,NMODE
      DO 190 M=1,NUMNP
      L=3*M-2
  190 READ (8) MM,A(L,N),A(L+1,N),A(L+2,N)
      PRINT 2006
      DO 200 I=1,NMODE
  200 PRINT 2005, I,EV(I)
      PRINT 2007
      CALL PRINTA(A,NEQ,NMODE)
 2005 FORMAT (2H W,I1,2H =,F10.3)
 2006 FORMAT (1H1/* STRUCTURE NATURAL FREQUENCIES IN RAD/SEC.*)
 2007 FORMAT (///* EIGENVECTORS PHI NORMALIZED W.R.T. MASS MATRIX*)
 2008 FORMAT (//" VERIFICATION OF IMPOSED ORTHOGONALITY RELATION:"/
     1        "       (PHI)T * (M) * (PHI) = I")
      RETURN
      END
```

SYMBOLIC REFERENCE MAP (R=2)

```
       SUBROUTINE EIGEN      76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39        PAGE     3

ENTRY POINTS    DEF LINE     REFERENCES
    3  EIGEN           1        85        104

VARIABLES      SN  TYPE            RELOCATION
     0 A         REAL       ARRAY     F. P.        REFS        10      2*18        28        59      2*69      3*84        98
                                                DEFINED         1        16      3*93
  4763 APLOT     REAL       ARRAY                  REFS        10        60   DEFINED        59
     0 CC        REAL       ARRAY     F. P.        REFS        10        74        76   DEFINED         1        70        74
     0 EV        REAL       ARRAY     F. P.        REFS        10        18        25        26        80        96
                                                DEFINED         1        25        89
   610 I         INTEGER                           REFS      2*25      2*26      3*35        38      2*39      2*40      2*47
                                                   2*48        58        59        66        69        70        71      2*74
                                                   2*96   DEFINED        24        34        37        45        57        65
                                                     95
  4737 IFIG      INTEGER    ARRAY                  REFS        10        60   DEFINED        56
   623 II        INTEGER                           REFS        72        73   DEFINED        71
   612 IND       INTEGER                           REFS        33        39        45        55        57
                                                DEFINED        31        33
   621 INEW      INTEGER                           REFS        59   DEFINED        58
   616 J         INTEGER                           REFS        51        52        53        58        69        70
                                                DEFINED        50        66
   620 K         INTEGER                           REFS        55        56      2*59      3*69   DEFINED        54        68
   627 KEEP      INTEGER    ARRAY                  REFS        10        47        48        58   DEFINED        39        48
   624 L         INTEGER                           REFS      2*74      3*84      3*93   DEFINED        73        83        92
   625 M         INTEGER                           REFS        83        84        92   DEFINED        82        91
     2 MBAN      INTEGER             CNTRL         REFS         9
     0 MBAND     INTEGER              F. P.        REFS        10        18   DEFINED         1
   626 MM      * INTEGER                        DEFINED        93
   615 N         INTEGER                           REFS        47        80      3*84        89      3*93
                                                DEFINED        46        80        81        89        90
     1 NANGLE    INTEGER             CNTRL         REFS         9
     3 NBC       INTEGER             CNTRL         REFS         9        18
     0 NEBC      INTEGER    ARRAY     F. P.        REFS        10        18   DEFINED         1
     0 NEQ       INTEGER              F. P.        REFS        10        18        28        68        98
                                                DEFINED         1
     4 NF        INTEGER             CNTRL         REFS         9
     0 NMODE     INTEGER              F. P.        REFS        10        18        24        28        46        54        60
                                                     65        66      2*76        80        81        89        90        95
                                                     98   DEFINED         1
     6 NPPI      INTEGER             CNTRL         REFS         9
     5 NPPO      INTEGER             CNTRL         REFS         9
  4713 NPTS      INTEGER    ARRAY                  REFS        10        60   DEFINED        55
     0 NUMNP     INTEGER             CNTRL         REFS         9        34        37        82        91
     0 PLOTT     LOGICAL              F. P.        REFS        14        29   DEFINED         1
     0 R         REAL       ARRAY     F. P.        REFS        10        39      2*40   DEFINED         1
    10 READFRQ   LOGICAL             CNTRL         REFS         9        13        15
   614 RMAX      REAL                              REFS        39        40   DEFINED        36        40
     0 SMASS     REAL       ARRAY     F. P.        REFS        10        18        69   DEFINED         1
   622 SUM       REAL                              REFS        69        70   DEFINED        67        69
     7 TRACE     REAL                CNTRL         REFS         9        18
     0 W1        REAL       ARRAY     F. P.        REFS        10        18   DEFINED         1
     0 W2        REAL       ARRAY     F. P.        REFS        10        18   DEFINED         1
     0 W3        REAL       ARRAY     F. P.        REFS        10        18   DEFINED         1
     0 W4        REAL       ARRAY     F. P.        REFS        10        18   DEFINED         1
     0 XS        REAL       ARRAY     F. P.        REFS        10   DEFINED         1
   617 YTITLE    REAL                              REFS        60   DEFINED        51        52        53
     0 Z         REAL       ARRAY     F. P.        REFS        10      3*35        38        47   DEFINED         1
```

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       SUBROUTINE EIGEN      76/176  OPT=1 STATIC                  FTN 4.8+498        03/16/81  16.39.39        PAGE      4

VARIABLES     SN  TYPE             RELOCATION
  613  ZMAX      REAL                             REFS        35         38        42        43   DEFINED        32        35
  773  ZPLOT     REAL       ARRAY                 REFS        10         60   DEFINED        47
  611  ZPREV     REAL                             REFS        35    DEFINED        30        42

FILE NAMES         MODE
       OUTPUT    FMT                   WRITES        23        26        27        64        94        96        97
       TAPE1     UNFMT                  READS        16    MOTION        17
       TAPE8     UNFMT                 WRITES        80        84     READS        89        93

EXTERNALS            TYPE    ARGS        REFERENCES
       BNEIGN                  14            18
       MULPLT                  13            60
       OPLT                     0            49
       PLOT                     3            63
       PRINTA                   3            28        76        98
       SQRT          REAL       1 LIBRARY    25

STATEMENT LABELS                  DEF LINE   REFERENCES
    0  90                          26        24
   73  92                          32        43
    0  94                          35        34
  124  96                          41        37        38
    0  100                         47        46
    0  102                         48        45
    0  104                         59        54        57
    0  106                         62        50
  223  108                         64        29
    0  110                         69        68
    0  120                         70        66
    0  130          INACTIVE       73        72
    0  140                         74        73
  267  150                         75        65      2*72
    0  170                         84        81        82
  327  180                         89        15
    0  190                         93        90        91
    0  200                         96        95
  540  2005     FMT                99        26        96
  543  2006     FMT               100        23        94
  552  2007     FMT               101        27        97
  561  2008     FMT               102        64

LOOPS  LABEL    INDEX      FROM-TO     LENGTH    PROPERTIES
   47  90        I          24 26        12B              EXT REFS
  101  94        I          34 35         5B     INSTACK
  115  96        I          37 41        10B     INSTACK
  131  102       I          45 48        20B              NOT INNER
  140  100       N          46 47         3B     INSTACK
  153  106       J          50 62        47B              EXT REFS  NOT INNER
  170  104       K          54 59        24B              NOT INNER
  204  104       I          57 59         5B     INSTACK
  226  150       I          65 75        44B              NOT INNER
  230  120       J          66 70        23B              NOT INNER
  241  110       K          68 69         4B     INSTACK
  264  140       L          73 74         2B     INSTACK
  305  170       N          81 84        21B              EXT REFS  NOT INNER
  306  170       M          82 84        16B              EXT REFS
  336  190       N          90 93        21B              EXT REFS  NOT INNER
```

```
LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
  337  190      M           91 93       16B              EXT REFS
  362  200      I           95 96       10B              EXT REFS

COMMON BLOCKS   LENGTH
       CNTRL         9

STATISTICS
  PROGRAM LENGTH                10741B    4577
  SCM LABELED COMMON LENGTH        11B       9
          52000B SCM USED
```

```
      SUBROUTINE EXT(IJBC,R,Z,IX,IJFS,NUFNP,NUFEL,NFBAND,NUINTF,
     1 NUCOF,WLO)
C
C***********************************************************************
C     READ AND PRINT EXTERIOR WATER ELEMENT PROPERTIES
C***********************************************************************
C
      DIMENSION R(1),Z(1),IX(NUFEL,1),IJBC(1),IJFS(1)
      L=0
      MB=0
      IB=0
      IS=1
      IJFS(1)=1
      PRINT 2004
   20 READ 1002,  N,ICODE,R(N),Z(N),MOD,NLIM,FACR,FACZ
      IF (N.GT.1) GO TO 25
      IF (Z(1).LT.WLO.AND.R(1).LT.0.0001) IS=0
   25 L1=L+1
      IF (N-L1) 90,70,30
   30 IF (L.LE.0) GO TO 80
      DIV=N-L
      DR=(R(N)-R(L))/DIV
      DZ=(Z(N)-Z(L))/DIV
      M=N-1
      DO 40 K=L1,M
      R(K)=R(K-1)+DR
   40 Z(K)=Z(K-1)+DZ
      GO TO 70
   50 L1=N+1
      IF (FACR.LE.0.0) FACR=1.0
      IF (FACZ.LE.0.0) FACZ=1.0
      PRINT 2100,  MOD,NLIM,FACR,FACZ
   60 N=N+1
      N1=N-MOD
      N2=N1-MOD
      IF (N1.LE.0.OR.N2.LE.0) GO TO 100
      R(N)=R(N1)+FACR*(R(N1)-R(N2))
      Z(N)=Z(N1)+FACZ*(Z(N1)-Z(N2))
      IF (N.LT.NLIM) GO TO 60
      MOD=0
   70 L=N
      DO 74 K=L1,N
      IF (R(K).LT.0.0001) GO TO 73
      IF (ICODE.EQ.0) GO TO 74
      IF (ICODE.LT.-1) GO TO 73
   72 CONTINUE
      IB=IB+1
      IF (IB.GT.NUINTF) GO TO 78
      IF (ICODE.GT.0) IJBC(IB)=ICODE
      IF (ICODE.EQ.-1) IJBC(IB)=0
      GO TO 74
   73 IS=IS+1
      IJFS(IS)=K
      IF (ICODE.GT.0) GO TO 72
   74 CONTINUE
      PRINT 2002,  (K,R(K),Z(K),ICODE,K=L1,N)
      IF (MOD.GT.0) GO TO 50
```

```
      IF (N-NUFNP) 20,120,110
   78 PRINT 2120
      STOP
   80 PRINT 2130
      STOP
   90 PRINT 2140, N
      STOP
  100 PRINT 2150
      STOP
  110 PRINT 2160, N, NUFNP
      STOP
  120 CONTINUE
      PRINT 2001
      N=0
  130 READ 1003, M, (IX(M,I),I=1,8)
  140 N=N+1
      IF (M.EQ.N) GO TO 160
      DO 150 I=1,4
  150 IX(N,I)=IX(N-1,I)+1
      DO 155 I=5,8
  155 IX(N,I)=IX(N-1,I)
  160 PRINT 2003, N, (IX(N,I),I=1,8)
C
C     DETERMINE BAND WIDTH
C
      DO 170 I=1,4
      DO 170 J=I,4
      MM=IABS(IX(N,I)-IX(N,J))
      IF (MM.GT.MB) MB=MM
  170 CONTINUE
      IF (NUCOF.LE.0) GO TO 196
      MC=NUCOF+NUFNP
      DO 190 I=5,8
      II=I-4
      IF (IX(N,I).EQ.2) GO TO 192
  190 CONTINUE
      GO TO 196
  192 DO 194 I=1,2
      MM=IABS(MC-IX(N,II))
      IF (MM.GT.MB) MB=MM
      II=II+1
      IF (II.GT.4) II=1
  194 CONTINUE
  196 CONTINUE
      IF (N.EQ.NUFEL) GO TO 199
      IF (N.EQ.M) GO TO 130
      GO TO 140
  199 NFBAND=MB+1
 1002 FORMAT (2I5,2F10.0,2I5,2F10.0)
 1003 FORMAT (16I5)
 2001 FORMAT (1H1//33H EXT.FLD.EL.NO.   I     J     K     L,
     1 8X,2HIJ,3X,2HJK,3X,2HKL,3X,2HLI)
 2002 FORMAT (I7,8X,F10.3,4X,F10.3,5X,I5)
 2003 FORMAT (1I12,1X,4I5,5X,4I5)
 2004 FORMAT (//38H EXT.FLD.N.P.       R-ORD          Z-ORD ,7X,5HICODE//)
 2100 FORMAT (21H GENERATION WITH MOD=I3,3X,6H MLIM=I4,3X,6H FACR=F10.5,
     13X,6H FACZ=F10.5)
```

```
115           2120 FORMAT (/31H  INTERFACE NODAL NUMBER ERROR  /)
              2130 FORMAT (28H FIRST JOINT CARD IS MISSING)
              2140 FORMAT (31H COORDINATE CARD FOR JOINT NO.  I5,16H NOT IN SEQUENCE)
              2150 FORMAT (42H INSUFFICIENT INFORMATION TO GENERATE MESH)
              2160 FORMAT (14H JOINT NUMBER I5,21H EXCEEDS GIVEN NUFNP= I5)
120                RETURN
                   END


       SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS     DEF LINE     REFERENCES
    3  EXT              1       120

VARIABLES     SN  TYPE           RELOCATION
  615  DIV       REAL                             REFS        22        23   DEFINED        21
  616  DR        REAL                             REFS        26   DEFINED        22
  617  DZ        REAL                             REFS        27   DEFINED        23
  612  FACR      REAL                             REFS        30        32        37   DEFINED        15        30
  613  FACZ      REAL                             REFS        31        32        38   DEFINED        15        31
  624  I         INTEGER                          REFS        72      2*76      2*78        79        84        85        91
                                                    92   DEFINED        72        75        77        79        83        90
                                                    95
  604  IB        INTEGER                          REFS        47        48        49        50   DEFINED        11        47
  607  ICODE     INTEGER                          REFS        44        45      2*49        50        54        56
                                               DEFINED        15
  630  II        INTEGER                          REFS        96        98        99   DEFINED        91        98        99
    0  IJBC      INTEGER    ARRAY     F. P.       REFS         8   DEFINED         1        49        50
    0  IJFS      INTEGER    ARRAY     F. P.       REFS         8   DEFINED         1        13        53
  605  IS        INTEGER                          REFS        52        53   DEFINED        12        17        52
    0  IX        INTEGER    ARRAY     F. P.       REFS         8        76        78        79      2*85        92        96
                                               DEFINED         1        72        76        78
  625  J         INTEGER                          REFS        85   DEFINED        84
  621  K         INTEGER                          REFS      2*26      2*27        43        53      3*56
                                               DEFINED        25        42        56
  602  L         INTEGER                          REFS        18        20        21        22        23
                                               DEFINED         9        41
  614  L1        INTEGER                          REFS        19        25        42        56   DEFINED        18        29
  620  M         INTEGER                          REFS        25        72        74       103   DEFINED        24        72
  603  MB        INTEGER                          REFS        86        97       105   DEFINED        10        86        97
  627  MC        INTEGER                          REFS        96   DEFINED        89
  626  MM        INTEGER                          REFS      2*86      2*97   DEFINED        85        96
  610  MOD       INTEGER                          REFS        32        34        35        57   DEFINED        15        40
  606  N         INTEGER                          REFS      2*15        16        19        21        22        23        24
                                                    29        33        34        37        38        39        41        42
                                                    56        58        63        67        73        74      2*76      2*78
                                                  2*79      2*85        92        96       102       103
                                               DEFINED        15        33        71        73
    0  NFBAND    INTEGER              F. P.    DEFINED         1       105
  611  NLIM      INTEGER                          REFS        32        39   DEFINED        15
    0  NUCOF     INTEGER              F. P.       REFS        88        89   DEFINED         1
    0  NUFEL     INTEGER              F. P.       REFS         8       102   DEFINED         1
    0  NUFNP     INTEGER              F. P.       REFS        58        67        89   DEFINED         1
    0  NUINTF    INTEGER              F. P.       REFS        48   DEFINED         1
```

```
       SUBROUTINE EXT        76/176  OPT=1 STATIC                   FTN 4.8+498        03/16/81  16.39.39       PAGE     4

VARIABLES     SN  TYPE           RELOCATION
  622  N1        INTEGER                         REFS        35        36       2*37      2*38   DEFINED       34
  623  N2        INTEGER                         REFS        36        37        38    DEFINED        35
    0  R         REAL       ARRAY     F.P.       REFS         8        17       2*22       26       3*37       43        56
                                              DEFINED         1        15        26        37
    0  WLO       REAL                 F.P.       REFS        17    DEFINED        1
    0  Z         REAL       ARRAY     F.P.       REFS         8        17       2*23       27       3*38       56
                                              DEFINED         1        15        27        38

FILE NAMES        MODE
       INPUT     FMT                    READS      15        72
       OUTPUT    FMT                   WRITES      14        32        56        59        61        63        65        67
                                          70       79

INLINE FUNCTIONS   TYPE   ARGS        DEF LINE  REFERENCES
       IABS      INTEGER    1  INTRIN              85        96

STATEMENT LABELS             DEF LINE   REFERENCES
   16  20                   15        58
   36  25                   18        16
    0  30          INACTIVE     20        19
    0  40                   27        25
   67  50                   29        57
  101  60                   33        39
  123  70                   41        19       28
  133  72                   46        54
  145  73                   52        43       45
  152  74                   55        42       44        51
  176  78                   59        48
  201  80                   61        20
  204  90                   63        19
  207  100                 65        36
  212  110                 67        58
  215  120                 69        58
  220  130                 72       103
  235  140                 73       104
    0  150                 76        75
    0  155                 78        77
  262  160                 79        74
    0  170                 87        83       84
    0  190                 93        90
  337  192                 95        92
    0  194                100        95
  360  196                101        88       94
  364  199                105       102
  475  1002  FMT             106        15
  501  1003  FMT             107        72
  503  2001  FMT             108        70
  513  2002  FMT             110        56
  517  2003  FMT             111        79
  522  2004  FMT             112        14
  531  2100  FMT             113        32
  542  2120  FMT             115        59
  547  2130  FMT             116        61
  554  2140  FMT             117        63
  563  2150  FMT             118        65
  571  2160  FMT             119        67
```

```
       SUBROUTINE EXT       76/176  OPT=1 STATIC                FTN 4.8+498         03/16/81  16.39.39        PAGE      5

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   61  40       K          25 27         4B     INSTACK
  126  74       K          42 55        27B               EXITS
  160           K          56 56        10B             EXT REFS
  223           I          72 72        11B             EXT REFS
  246  150      I          75 76         2B     INSTACK
  257  155      I          77 78         2B     INSTACK
  265           I          79 79        11B             EXT REFS
  300  170      I          83 87        22B             NOT INNER
  311  170      J          84 87         6B     INSTACK
  327  190      I          90 93        10B     INSTACK   EXITS
  344  194      I          95 100       13B       OPT

STATISTICS
  PROGRAM LENGTH                646B     422
          52000B SCM USED
```

```
      SUBROUTINE SOLEXT(SMASS,W,A,BI,BII,D,IJBC,R,Z,IX,IJFS,
     1 HB,HL,HM,NMO,NEQ,NUFNP,NUFEL,NUINTF,NUFSF,NFBAND,NEQF)
C
C*********************************************************************
C     COMPUTE GENERALIZED FORCE VECTOR AND MASS MATRIX
C     FROM EXTERIOR WATER
C*********************************************************************
C
      DIMENSION SS(2),RR(4),ZZ(4),H(4,4),HH(4,4),FK(50)
      DIMENSION SMASS(1),W(1),A(NEQ,1),HM(NEQF,1),HB(1),HL(NEQF,1),
     1 D(NMO,1),BI(1),BII(NMO,1),IJFS(1),IJBC(1),R(1),Z(1),IX(NUFEL,1)
      COMMON/CNTRL/NUMNP,NANGLE,MBAND,NBC,NF,NPPO,NPPI,TRACE
      COMMON/FCONST/PI,ROW,HS
      DATA SS/ -0.57735026918963,0.57735026918963/
C
      PRINT 2006, (IJBC(I),I=1,NUINTF)
      PRINT 2008, (IJFS(I),I=1,NUFSF)
C
C     GENERATE BOUNDARY DISPLACEMENTS
C
      DO 97 K=1,NUINTF
      II=IJBC(K)
      IF(K.EQ.NUINTF) GO TO 92
      KK=K+1
   91 JJ=IJBC(KK)
      IF(JJ.NE.0) GO TO 92
      KK=KK+1
      GO TO 91
   92 DO 96 M=1,NMO
      IF(II.EQ.0) GO TO 94
      DO 93 I=1,3
      KI=3*K-I+1
   93 D(M,KI)=A(3*II-I+1,M)
      GO TO 96
   94 S=(R(K-1)-R(K))**2+(Z(K-1)-Z(K))**2
      S=SQRT(S)
      S1=(R(K-1)-R(KK))**2+(Z(K-1)-Z(KK))**2
      S1=SQRT(S1)
      RS=S/S1
      DO 95 I=1,3
      KI=3*K-I+1
      D(M,KI)=D(M,KI-3)+(A(3*JJ-I+1,M)-D(M,KI-3))*RS
   95 CONTINUE
   96 CONTINUE
   97 CONTINUE
C
C     FORM MATRIX H
C
      DO 100 I=1,NEQF
      DO 100 J=1,NFBAND
  100 HM(I,J)=0.
      NUCOF=NEQF-NUFNP
      NUF1=NUFNP+1
      B=0.5*PI/HS
      DO 600 N=1,NUFEL
      DO 150 I=1,4
      II=IX(N,I)
```

```
          RR(I)=R(II)
      150 ZZ(I)=Z(II)
C
          DO 200 I=1,4
          DO 200 J=1,4
      200 HH(I,J)=0.
          DO 300 II=1,2
          DO 300 JJ=1,2
          CALL FORMH(SS(II),SS(JJ),RR,ZZ,H)
          DO 250 I=1,4
          DO 250 J=I,4
          HH(I,J)=HH(I,J)+H(I,J)
      250 HH(J,I)=HH(I,J)
      300 CONTINUE
          DO 320 I=1,4
          II=IX(N,I)
          DO 320 J=1,4
          JJ=IX(N,J)-II+1
          IF(JJ.LT.1) GO TO 320
          HM(II,JJ)=HM(II,JJ)+HH(I,J)
      320 CONTINUE
          IF (NUCOF.LE.0) GO TO 600
          DO 350 I=5,8
          II=I-4
          IF (IX(N,I).EQ.2) GO TO 370
      350 CONTINUE
          GO TO 600
      370 GO TO (371,371,372,373),II
      371 I1=IX(N,II)
          I2=IX(N,II+1)
          GO TO 375
      372 I1=IX(N,4)
          I2=IX(N,3)
          GO TO 375
      373 I1=IX(N,1)
          I2=IX(N,4)
      375 SIJ=ABS(Z(I1)-Z(I2))
          BR=B*R(I1)
          DO 380 K=1,2
          A2=(1.0-SS(K))/2.0
          A3=(1.0+SS(K))/2.0
          ZIJ=Z(I1)*A2+Z(I2)*A3
          DO 380 M=1,NUCOF
          J1=NUF1+M-I1
          J2=NUF1+M-I2
          EIG=(2.0*M-1.)*BR
          CALL BESNKS(EIG,3,FK)
          HK=0.5*SIJ*EIG*(FK(1)+FK(3))*COS(B*ZIJ)
          HM(I1,J1)=HM(I1,J1)+HK*A2
          HM(I2,J2)=HM(I2,J2)+HK*A3
      380 CONTINUE
          M=0
          DO 400 I=NUF1,NEQF
          M=M+1
          EIG=(2.0*M-1.0)*BR
          CALL BESNKS(EIG,3,FK)
          HM(I,1)=EIG*HS/4.0*FK(2)*(FK(1)+FK(3))
```

```
  400 CONTINUE
  600 CONTINUE
C
C     FREE-SURFACE BOUNDARY CONDITION
C
      DO 650 I=1,NUFSF
      II=IJFS(I)
      HM(II,1)=1.0
      IF(II.EQ.1) GO TO 640
      KM=MINO(II,NFBAND)
      DO 630 K=2,KM
      IK=II-K+1
  630 HM(IK,K)=0.0
  640 DO 650 J=2,NFBAND
  650 HM(II,J)=0.0
C
C     FORM MATRICES DO AND DJ
C
      DO 700 I=1,NEQF
      HB(I)=0.
      DO 700 J=1,NMO
  700 HL(I,J)=0.
      NN=NUINTF-1
      DO 750 I=1,NN
      J=I+1
      RIJ=-R(I)+R(J)
      ZIJ=Z(I)-Z(J)
      SIJ=SQRT(RIJ**2+ZIJ**2)
      CSN=ZIJ/SIJ
      SSN=RIJ/SIJ
      DO 750 K=1,2
      A1=(1.0-SS(K))/2.0
      A4=(1.0+SS(K))/2.0
      RF=(R(I)*A1+R(J)*A4)*ROW
      HB(I)=HB(I)+RF*A1*ZIJ/2
      HB(J)=HB(J)+RF*A4*ZIJ/2
      DO 750 M=1,NMO
      TI=D(M,3*I-2)*CSN+D(M,3*I-1)*SSN
      TJ=D(M,3*J-2)*CSN+D(M,3*J-1)*SSN
      AF=TI*A1+TJ*A4
      HL(I,M)=HL(I,M)+RF*A1*SIJ*AF/2.0
      HL(J,M)=HL(J,M)+RF*A4*SIJ*AF/2.0
  750 CONTINUE
C
C     INITIALIZE  BI AND BII
C
      DO 770 M=1,NMO
      BI(M)=0.
      DO 770 N=1,NMO
  770 BII(M,N)=0.
      CALL BANSL1(R,NEQF,NFBAND,HM,HB,1)
      CALL BANSL1(R,NEQF,NFBAND,HM,HB,2)
      DO 780 I=1,NUINTF
      DO 780 M=1,NMO
  780 D(M,I)=HL(I,M)/ROW
      DO 790 M=1,NMO
  790 CALL BANSL1(R,NEQF,NFBAND,HM,HL(1,M),2)
```

```
C
C      RESET FREE-SURFACE BOUNDARY CONDITION
C
       DO 800 I=1,NUFSF
       II=IJFS(I)
       IF(II.GT.NUINTF) GO TO 800
       HB(II)=0.
       DO 799 M=1,NMO
   799 HL(II,M)=0.
   800 CONTINUE
       PRINT 2001
       CALL PRINTA(HB,NEQF,1)
       PRINT 2002
       CALL PRINTA(HL,NEQF,NMO)
       NWALL=0
       DO 805 J=1,NUINTF
       IF (IJBC(J).GT.0) NWALL=NWALL+1
   805 CONTINUE
       WRITE (9) NWALL
       DO 810 J=1,NUINTF
       IF (IJBC(J).GT.0) WRITE (9) IJBC(J),HB(J),(HL(J,M),M=1,NMO)
       DO 810 M=1,NMO
       BI(M)=BI(M)+D(M,J)*HB(J)
       DO 810 N=M,NMO
       BII(M,N)=BII(M,N)+D(M,J)*HL(J,N)
   810 BII(N,M)=BII(M,N)
       PRINT 2010
       PRINT 2050,  (BI(I),I=1,NMO)
       PRINT 2012
       PRINT 2050,  ((BII(I,J),I=1,NMO),J=1,NMO)
       DO 850 I=1,NMO
   850 BII(I,I)=1.+BII(I,I)
       DO 870 I=1,NMO
       DO 870 M=1,NUMNP
       K=3*M
       TERM=-A(K,I)*SMASS(K)+A(K-2,I)*SMASS(K-2)
   870 BI(I)=BI(I)+TERM
       PRINT 2003
       CALL PRINTA(BI,NMO,1)
       PRINT 2004
       CALL PRINTA(BII,NMO,NMO)
  2001 FORMAT (///* PRES. COEFF. OF RIGID MODE*)
  2002 FORMAT (///* PRES. COEFF. OF FLEX MODES*)
  2003 FORMAT (///* GENERALIZED FORCE VECTOR (EXT) --- A+BI*)
  2004 FORMAT (///* GENERALIZED MASS MATRIX (EXT) --- M+BII*)
  2006 FORMAT (1H1//* STRUCTURAL NODAL POINTS ON THE WATER-TANK*,
      1 * INTERFACE*/(10I5))
  2008 FORMAT (//40H WATER NODAL POINTS ON THE FREE SURFACE /(10I5))
  2010 FORMAT (///5H  BI    )
  2012 FORMAT (///6H  BII    )
  2050 FORMAT (5X,2E15.6)
       RETURN
       END
```

```
       SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  SOLEXT         1           223

VARIABLES      SN  TYPE              RELOCATION
    0  A           REAL      ARRAY      F.P.      REFS        10       33       42     2*207   DEFINED        1
 1430  AF          REAL                           REFS       155      156  DEFINED      154
 1423  A1          REAL                           REFS       148      149      154      155   DEFINED      146
 1406  A2          REAL                           REFS        99      106  DEFINED       97
 1407  A3          REAL                           REFS        99      107  DEFINED       98
 1424  A4          REAL                           REFS       148      150      154      156   DEFINED      147
 1400  B           REAL                           REFS        95      105  DEFINED       54
    0  BI          REAL      ARRAY      F.P.      REFS        10      194      199      208      210
                                               DEFINED         1      162      194      208
    0  BII         REAL      ARRAY      F.P.      REFS        10      196      197      201      203      212
                                               DEFINED         1      164      196      197      203
 1405  BR          REAL                           REFS       103      112  DEFINED       95
 1421  CSN         REAL                           REFS       152      153  DEFINED      143
    0  D           REAL      ARRAY      F.P.      REFS        10     2*42    2*152    2*153      194      196
                                               DEFINED         1       33       42      169
 1413  EIG         REAL                           REFS       104      105      113      114   DEFINED      103      112
 1505  FK          REAL      ARRAY                REFS         9      104    2*105      113    3*114
 1445  H           REAL      ARRAY                REFS         9       66       69
    0  HB          REAL      ARRAY      F.P.      REFS        10      149      150      165      166      183      192
                                                   194  DEFINED        1      134      149      150      178
 1465  HH          REAL      ARRAY                REFS         9       69       70       77   DEFINED       63       69
                                                    70
 1414  HK          REAL                           REFS       106      107  DEFINED      105
    0  HL          REAL      ARRAY      F.P.      REFS        10      155      156      169      171      185      192
                                                   196  DEFINED        1      136      155      156      180
    0  HM          REAL      ARRAY      F.P.      REFS        10       77      106      107      165      166      171
                                               DEFINED         1       51       77      106      107      114      122
                                                   127      129
    2  HS          REAL                 FCONST    REFS        13       54      114
 1363  I           INTEGER                        REFS        16       17       32       33       41       42       51
                                                    57       58       59       63       68     3*69     2*70       73
                                                    77       81       82      114      121      134      136      139
                                                   140      141      148    2*149    2*152    2*155    2*169      176
                                                   199      201    4*203    2*207    2*208   DEFINED       16       17
                                                    31       40       49       56       61       67       72       80
                                                   110      120      133      138      167      175      199      201
                                                   202      204
 1365  II          INTEGER                        REFS        30       33       58       59       66       75     2*77
                                                    85       86       87      122      123      124      126      129
                                                   177      178      180  DEFINED       22       57       64       73
                                                    81      121      176
    0  IJBC        INTEGER   ARRAY      F.P.      REFS        10       16       22       25      188    2*192
                                               DEFINED         1
    0  IJFS        INTEGER   ARRAY      F.P.      REFS        10       17      121      176   DEFINED        1
 1416  IK          INTEGER                        REFS       127  DEFINED      126
    0  IX          INTEGER   ARRAY      F.P.      REFS        10       57       73       75       82       86       87
                                                    89       90       92       93  DEFINED        1
 1402  I1          INTEGER                        REFS        94       95       99      101    2*106
                                               DEFINED        86       89       92
 1403  I2          INTEGER                        REFS        94       99      102    2*107   DEFINED       87       90
```

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      SUBROUTINE SOLEXT      76/176  OPT=1 STATIC                FTN 4.8+498        03/16/81  16.39.39        PAGE     6

  VARIABLES      SN  TYPE           RELOCATION
                                                   93
   1375  J           INTEGER                     REFS        51        63      3*69      2*70        75        77       129
                                                  136       140       141       148     2*150     2*153     2*156       188
                                                4*192     2*194     2*196       201   DEFINED        50        62        68
                                                   74       128       135       139       187       191       201
   1367  JJ          INTEGER                     REFS        26        42        66        76      2*77
                                              DEFINED        25        65        75
   1411  J1          INTEGER                     REFS     2*106   DEFINED       101
   1412  J2          INTEGER                     REFS     2*107   DEFINED       102
   1364  K           INTEGER                     REFS        22        23        24        32      4*35      2*37        41
                                                   97        98       126       127       146       147     4*207
                                              DEFINED        21        96       125       145       206
   1371  KI          INTEGER                     REFS        33      3*42   DEFINED        32        41
   1366  KK          INTEGER                     REFS        25        27      2*37   DEFINED        24        27
   1415  KM          INTEGER                     REFS       125   DEFINED       124
   1370  M           INTEGER                     REFS      2*33      4*42       101       102       103       111       112
                                                2*152     2*153     2*155     2*156       162       164     2*169       171
                                                  180       192     3*194       195     3*196     2*197       206
                                              DEFINED        29       100       109       111       151       161       168
                                                  170       179       192       193       205
      2  MBAND       INTEGER          CNTRL      REFS        12
   1401  N           INTEGER                     REFS        57        73        75        82        86        87        89
                                                   90        92        93       164     3*196     2*197
                                              DEFINED        55       163       195
      1  NANGLE      INTEGER          CNTRL      REFS        12
      3  NBC         INTEGER          CNTRL      REFS        12
      0  NEQ         INTEGER           F.P.      REFS        10   DEFINED         1
      0  NEGF        INTEGER           F.P.      REFS      2*10        49        52       110       133       165       166
                                                  171       183       185   DEFINED         1
      4  NF          INTEGER          CNTRL      REFS        12
      0  NFBAND      INTEGER           F.P.      REFS        50       124       128       165       166       171
                                              DEFINED         1
      0  NMO         INTEGER           F.P.      REFS      2*10        29       135       151       161       163       168
                                                  170       179       185       192       193       195       199     2*201
                                                  202       204       210     2*212   DEFINED         1
   1417  NN          INTEGER                     REFS       138   DEFINED       137
      6  NPPI        INTEGER          CNTRL      REFS        12
      5  NPPO        INTEGER          CNTRL      REFS        12
   1376  NUCOF       INTEGER                     REFS        79       100   DEFINED        52
      0  NUFEL       INTEGER           F.P.      REFS        10        55   DEFINED         1
      0  NUFNP       INTEGER           F.P.      REFS        52        53   DEFINED         1
      0  NUFSF       INTEGER           F.P.      REFS        17       120       175   DEFINED         1
   1377  NUF1        INTEGER                     REFS       101       102       110   DEFINED        53
      0  NUINTF      INTEGER           F.P.      REFS        16        21        23       137       167       177       187
                                                  191   DEFINED         1
      0  NUMNP       INTEGER          CNTRL      REFS        12       205
   1431  NWALL       INTEGER                     REFS       188       190   DEFINED       186       188
      0  PI          REAL             FCONST     REFS        13        54
      0  R           REAL       ARRAY  F.P.      REFS        10      2*35      2*37        58        95     2*140     2*148
                                                  165       166       171   DEFINED         1
   1425  RF          REAL                        REFS       149       150       155       156   DEFINED       148
   1420  RIJ         REAL                        REFS       142       144   DEFINED       140
      1  ROW         REAL             FCONST     REFS        13       148       169
   1435  RR          REAL       ARRAY            REFS         9        66   DEFINED        58
   1374  RS          REAL                        REFS        42   DEFINED        39
   1372  S           REAL                        REFS        36        39   DEFINED        35        36
   1404  SIJ         REAL                        REFS       105       143       144       155       156
```

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       SUBROUTINE SOLEXT     76/176  OPT=1 STATIC                   FTN 4.8+498        03/16/81  16.39.39       PAGE      7

VARIABLES     SN  TYPE           RELOCATION
                                               DEFINED        94      142
     0 SMASS     REAL       ARRAY     F.P.        REFS        10    2*207   DEFINED         1
  1433 SS        REAL       ARRAY                 REFS         9     2*66        97        98       146       147
                                               DEFINED        14
  1422 SSN       REAL                             REFS       152      153   DEFINED       144
  1373 S1        REAL                             REFS        38       39   DEFINED        37        38
  1432 TERM      REAL                             REFS       208  DEFINED       207
  1426 TI        REAL                             REFS       154  DEFINED       152
  1427 TJ        REAL                             REFS       154  DEFINED       153
     7 TRACE     REAL                CNTRL        REFS        12
     0 W         REAL       ARRAY     F.P.        REFS        10  DEFINED         1
     0 Z         REAL       ARRAY     F.P.        REFS        10     2*35      2*37        59      2*94      2*99     2*141
                                               DEFINED         1
  1410 ZIJ       REAL                             REFS       105      142       143       149       150
                                               DEFINED        99      141
  1441 ZZ        REAL       ARRAY                 REFS         9       66   DEFINED        59

FILE NAMES        MODE
       OUTPUT    FMT                    WRITES        16        17      182       184       198       199       200       201
                                           209       211
       TAPE9     UNFMT                  WRITES       190       192

EXTERNALS          TYPE   ARGS       REFERENCES
       BANSL1               6              165       166       171
       BESNKS               3              104       113
       COS       REAL       1 LIBRARY      105
       FORMH                5               66
       PRINTA               3              183       185       210       212
       SQRT      REAL       1 LIBRARY       36        38       142

INLINE FUNCTIONS   TYPE   ARGS      DEF LINE  REFERENCES
       ABS       REAL       1  INTRIN               94
       MINO      INTEGER    0  INTRIN              124

STATEMENT LABELS             DEF LINE   REFERENCES
    36 91                        25        28
    42 92                        29        23        26
     0 93                        33        31
    65 94                        35        30
     0 95                        43        40
   130 96                        44        29        34
     0 97                        45        21
     0 100                       51        49        50
     0 150                       59        56
     0 200                       63        61        62
     0 250                       70        67        68
     0 300                       71        64        65
   263 320                       78        72        74        76
     0 350                       83        80
   303 370                       85        82
   314 371                       86      2*85
   322 372                       89        85
   330 373                       92        85
   335 375                       94        88        91
     0 380                      108        96       100
     0 400                      115       110
   434 600                      116        55        79        84
```

```
STATEMENT LABELS               DEF LINE   REFERENCES
    0  630                       127        125
  463  640                       128        123
    0  650                       129        120        128
    0  700                       136        133        135
    0  750                       157        138        145        151
    0  770                       164        161        163
    0  780                       169        167        168
    0  790                       171        170
    0  799                       180        179
  725  800                       181        175        177
    0  805                       189        187
    0  810                       197        191        193        195
    0  850                       203        202
    0  870                       208        204        205
 1275  2001     FMT              213        182
 1302  2002     FMT              214        184
 1307  2003     FMT              215        209
 1315  2004     FMT              216        211
 1323  2006     FMT              217         16
 1334  2008     FMT              219         17
 1343  2010     FMT              220        198
 1346  2012     FMT              221        200
 1351  2050     FMT              222        199        201

LOOPS  LABEL    INDEX      FROM-TO     LENGTH    PROPERTIES
   31  97       K           21 45       104B                EXT REFS  NOT INNER
   43  96       M           29 44        70B                EXT REFS  NOT INNER
   60  93       I           31 33         3B      INSTACK
  121  95       I           40 43         6B      INSTACK
  136  100      I           49 51        12B                NOT INNER
  143  100      J           50 51         2B      INSTACK
  157  600      N           55 116      260B                EXT REFS  NOT INNER
  165  150      I           56 59         5B      INSTACK
  174  200      I           61 63        12B                NOT INNER
  200  200      J           62 63         2B      INSTACK
  207  300      II          64 71        32B                EXT REFS  NOT INNER
  210  300      JJ          65 71        27B                EXT REFS  NOT INNER
  216  250      I           67 70        16B                NOT INNER
  225  250      J           68 70         4B      INSTACK
  242  320      I           72 78        26B                NOT INNER
  255  320      J           74 78        10B      INSTACK
  273  350      I           80 83        10B      INSTACK     EXITS
  344  380      K           96 108       47B                EXT REFS  NOT INNER
  355  380      M          100 108       33B                EXT REFS
  415  400      I          110 115       17B                EXT REFS
  440  650      I          120 129       35B                NOT INNER
  457  630      K          125 127        3B      INSTACK
  470  650      J          128 129        2B      INSTACK
  476  700      I          133 136       14B                NOT INNER
  505  700      J          135 136        2B      INSTACK
  515  750      I          138 157      102B                EXT REFS  NOT INNER
  531  750      K          145 157       63B                NOT INNER
  567  750      M          151 157       22B         OPT
  620  770      M          161 164       14B                NOT INNER
  627  770      N          163 164        2B      INSTACK
  655  780      I          167 169       16B                NOT INNER
  665  780      M          168 169        3B      INSTACK
```

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LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
  674  790      M          170 171      14B              EXT REFS
  711  800      I          175 181      17B              NOT INNER
  722  799      M          179 180       2B     INSTACK
  752  805      J          187 189       4B     INSTACK
  761  810      J          191 197      57B              EXT REFS  NOT INNER
  772           M          192 192      11B              EXT REFS
 1005  810      M          193 197      30B              NOT INNER
 1025  810      N          195 197       5B     INSTACK
 1066  850      I          202 203       3B     INSTACK
 1073  870      I          204 208      22B              NOT INNER
 1103  870      M          205 208       7B     INSTACK

COMMON BLOCKS   LENGTH
       CNTRL         8
       FCONST        3

STATISTICS
  PROGRAM LENGTH                1736B      990
  SCM LABELED COMMON LENGTH      13B       11
          52000B SCM USED
```

```
SUBROUTINE BESNKS      76/176  OPT=1 STATIC                  FTN 4.8+498        03/16/81  16.39.39         PAGE      1

  1                SUBROUTINE BESNKS(X,KMAX,FK)
             C
             C*****************************************************************
             C     MODIFIED BESSEL FUNCTIONS OF THE SECOND KIND (K)
  5          C*****************************************************************
             C
                   DIMENSION FI(50), FK(50)
                   IF(X-2.) 2,3,3
                 2 T=.5*X
 10                T=T*T
                   FK(1)= (((((.00000740*T+.00010750)*T+.00262698)*T+.03488590)*T+
                  1  .23069756)*T+.42278420)*T-.57721566
                   FK(2)= (((((-.00004686*T-.00110404)*T-.01919402)*T-.18156897)*T-
                  1  .67278579)*T+.15443144)*T+1.
 15                CALL BESNIS (X,20,FI)
                   T2=.5*ALOG(T)
                   FK(1)=FK(1)-T2*FI(1)
                   FK(2)=FK(2)/X+T2*FI(2)
                   T=2./X
 20                GO TO 5
                 3 T=2./X
                   FK(1)= (((((.00053208*T-.00251540)*T+.00587872)*T-.01062446)*T+
                  1  .02189568)*T-.07832358)*T+1.25331414
                   FK(2)= (((((-.00068245*T+.00325614)*T-.00780353)*T+.01504268)*T-
 25               1  .03655620)*T+.23498619)*T+1.25331414
                   T1=EXP(-X)/SQRT(X)
                   FK(1)=FK(1)*T1
                   FK(2)=FK(2)*T1
                 5 DO 6 N=3,KMAX
 30                DK=N-2
                 6 FK(N)=T*DK*FK(N-1)+FK(N-2)
                   RETURN
                   END


         SYMBOLIC REFERENCE MAP (R=2)

 ENTRY POINTS      DEF LINE      REFERENCES
    3  BESNKS          1            32

 VARIABLES       SN  TYPE            RELOCATION
   164  DK           REAL                           REFS        31    DEFINED      30
   165  FI           REAL        ARRAY              REFS         7      15         17      18
     0  FK           REAL        ARRAY      F.P.    REFS         7      17         18      27      28      2*31
                                                 DEFINED        1      11         13      17      18      22      24
                                                      27       28      31
     0  KMAX         INTEGER                F.P.    REFS        29    DEFINED       1
   163  N            INTEGER                        REFS        30     3*31   DEFINED      29
   160  T            REAL                           REFS      2*10     6*11      6*13     16    6*22    6*24      31
                                                 DEFINED        9      10         19      21
   162  T1           REAL                           REFS        27      28   DEFINED      26
   161  T2           REAL                           REFS        17      18   DEFINED      16
     0  X            REAL                   F.P.    REFS         8       9         15      18      19      21    2*26
                                                 DEFINED        1
```

```
EXTERNALS          TYPE   ARGS        REFERENCES
       ALOG       REAL       1 LIBRARY      16
       BESNIS                3              15
       EXP        REAL       1 LIBRARY      26
       SQRT       REAL       1 LIBRARY      26

STATEMENT LABELS               DEF LINE   REFERENCES
    0  2            INACTIVE       9           8
   47  3                          21          2*8
  101  5                          29          20
    0  6                          31          29

LOOPS  LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
  106  6         N            29 31        6B       INSTACK

STATISTICS
  PROGRAM LENGTH                247B      167
          52000B SCM USED
```

```
     SUBROUTINE BESNIS      76/176  OPT=1 STATIC                      FTN 4.8+498         03/16/81  16.39.39        PAGE      1

      1                    SUBROUTINE BESNIS(X,NMAX,FI)
                     C
                     C***************************************************************
                     C     MODIFIED BESSEL FUNCTIONS OF THE FIRST KIND (I)
      5              C***************************************************************
                     C
                           DIMENSION FI(50), PI(200)
                           SUM=0.
                           I=X
     10                    JMAX=I+21
                           TZ=2./X
                           JM2=JMAX+2
                           DO 4 J=JM2,NMAX
                           PI(J)=0.
     15                  4 CONTINUE
                           PI(JMAX+1)=1.E-20
                           DO 6 J=1,JMAX
                           K=JMAX+2-J
                           DK=K-1
     20                    PI(K-1)=DK*TZ*PI(K)+PI(K+1)
                         6 SUM=SUM+PI(K)
                           SUM=SUM+SUM
                           A=EXP(X)/(PI(1)+SUM)
                           DO 8 N=1,NMAX
     25                  8 FI(N)=A*PI(N)
                           RETURN
                           END



     SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  BESNIS          1          26

VARIABLES       SN  TYPE              RELOCATION
   70  A            REAL                                REFS        25    DEFINED      23
   67  DK           REAL                                REFS        20    DEFINED      19
    0  FI           REAL        ARRAY      F.P.         REFS         7    DEFINED       1        25
   61  I            INTEGER                             REFS        10    DEFINED       9
   65  J            INTEGER                             REFS        14        18    DEFINED      13        17
   62  JMAX         INTEGER                             REFS        12        16        17        18    DEFINED       10
   64  JM2          INTEGER                             REFS        13    DEFINED      12
   66  K            INTEGER                             REFS        19      3*20        21    DEFINED      18
   71  N            INTEGER                             REFS      2*25    DEFINED      24
    0  NMAX         INTEGER                F.P.         REFS        13        24    DEFINED       1
   72  PI           REAL        ARRAY                   REFS         7      2*20        21        23        25
                                                     DEFINED        14        16        20
   60  SUM          REAL                                REFS        21      2*22        23    DEFINED       8        21        22
   63  TZ           REAL                                REFS        20    DEFINED      11
    0  X            REAL                   F.P.         REFS         9        11        23    DEFINED       1

EXTERNALS           TYPE    ARGS          REFERENCES
      EXP           REAL       1 LIBRARY       23
```

```
       SUBROUTINE BESNIS      76/176  OPT=1 STATIC                    FTN 4.8+498         03/16/81  16.39.39        PAGE      2

STATEMENT LABELS                DEF LINE    REFERENCES
    0  4                           15          13
    0  6                           21          17
    0  8                           25          24

LOOPS  LABEL     INDEX       FROM-TO      LENGTH     PROPERTIES
   16  4         J            13 15          2B       INSTACK
   30  6         J            17 21         10B       INSTACK
   52  8         N            24 25          3B       INSTACK

STATISTICS
  PROGRAM LENGTH                  402B      258
          52000B SCM USED
```

```
      SUBROUTINE INT(R,Z,ICODE,IX,OIL,DUMMY1,INTE,ROIL,
     1       NUINTIN,NUELIN,NUNPIN,NUELOIL)
C
C*****************************************************************
C     READ AND PRINT INTERIOR FLUIDS ELEMENT PROPERTIES
C*****************************************************************
C
      DIMENSION R(NUNPIN),Z(NUNPIN),IX(NUELIN,4),OIL(NUELIN)
      DIMENSION DUMMY1(NUELIN),INTE(NUELIN)
      DIMENSION ICODE(NUNPIN)
      INTEGER DUMMY1
      LOGICAL OIL,INTE
C
C     INPUT NODAL POINT DATA--
C     IF NODAL POINT IS ON STRUCTURAL WALL, THEN ICODE IS NO. OF
C     CORRESPONDING STRUCTURAL NODE;
C     IF NODAL POINT IS ON BOTH WALL AND INTERFACE,
C     THEN ICODE IS -(NO. OF CORRESPONDING STRUCTURAL NODE)
C
      L=0
   20 READ 1002, N,ICODE(N),R(N),Z(N),MOD,NLIM,FACR,FACZ
      L1=L+1
      IF (N-L1) 90,70,30
   30 IF (L.LE.0) GO TO 80
      DIV=N-L
      DR=(R(N)-R(L))/DIV
      DZ=(Z(N)-Z(L))/DIV
      M=N-1
      DO 40 K=L1,M
      R(K)=R(K-1)+DR
   40 Z(K)=Z(K-1)+DZ
      GO TO 70
   50 L1=N+1
      IF (FACR.LE.0.0) FACR=1.0
      IF (FACZ.LE.0.0) FACZ=1.0
      PRINT 2100, MOD,NLIM,FACR,FACZ
   60 N=N+1
      N1=N-MOD
      N2=N1-MOD
      IF (N1.LE.0.OR.N2.LE.0) GO TO 100
      R(N)=R(N1)+FACR*(R(N1)-R(N2))
      Z(N)=Z(N1)+FACZ*(Z(N1)-Z(N2))
      ICODE(N)=0
      IF (N.LT.NLIM) GO TO 60
      MOD=0
   70 L=N
      IF(MOD.GT.0) GO TO 50
      IF(N-NUNPIN) 20,120,110
   80 PRINT 2130
      STOP
   90 PRINT 2140, N
      STOP
  100 PRINT 2150
      STOP
  110 PRINT 2160, N,NUNPIN
      STOP
  120 CONTINUE
```

```
      N=0
  130 READ 1003, M, (IX(M,I),I=1,4)
  140 N=N+1
      IF (M.EQ.N) GO TO 160
      DO 150 I=1,4
  150 IX(N,I)=IX(N-1,I)+1
  160 CONTINUE
      IF (N.EQ.NUELIN) GO TO 180
      IF (N.EQ.M) GO TO 130
      GO TO 140
C
C     INITIALIZE LOGICAL ARRAYS
C
  180 DO  274N=1,NUELIN
      OIL(N)=.FALSE.
  274 INTE(N)=.FALSE.
      DO  280N=1,NUELOIL
  280 OIL(N)=.TRUE.
      READ 1020, (DUMMY1(I),I=1,NUINTIN)
      DO  300I=1,NUINTIN
      N=DUMMY1(I)
      INTE(N)=.TRUE.
  300 CONTINUE
C
C     PRINT INPUT PARAMETERS
C
      PRINT 1000
      PRINT 400, ROIL
      PRINT 600
      DO 310 NOD=1,NUNPIN
  310 PRINT 700, NOD,R(NOD),Z(NOD),ICODE(NOD)
      PRINT 800
      DO 320 N=1,NUELIN
  320 PRINT 900, N,(IX(N,I),I=1,4),OIL(N),INTE(N)
  400 FORMAT (7X,*ROIL=*,F12.5,* --- DENSITY OF OIL*)
  600 FORMAT (//6X,*NODE*,15X,*R-ORD*,15X,*Z-ORD*,15X,*ICODE*/)
  700 FORMAT (I10,2F20.5,I20)
  800 FORMAT (//3X,*ELEMENT*,5X,*NODE1*,5X,*NODE2*,5X,*NODE3*,5X,
     1 *NODE4*,12X,*OIL*,*    INTERFACE*/)
  900 FORMAT (5I10,5X,2L10)
 1000 FORMAT (1H1,* FINITE ELEMENT ANALYSIS OF TANK INTERIOR:*//)
 1002 FORMAT (2I5,2F10.0,2I5,2F10.0)
 1003 FORMAT (16I5)
 1020 FORMAT (16I5)
 2100 FORMAT (21H GENERATION WITH MOD=I3,3X,6H MLIM=I4,3X,6H FACR=F10.5,
     13X,6H FACZ=F10.5)
 2130 FORMAT (28H FIRST JOINT CARD IS MISSING)
 2140 FORMAT (31H COORDINATE CARD FOR JOINT NO. I5,16H NOT IN SEQUENCE)
 2150 FORMAT (42H INSUFFICIENT INFORMATION TO GENERATE MESH)
 2160 FORMAT (14H JOINT NUMBER I5,21H EXCEEDS GIVEN NUNPIN= I5)
      RETURN
      END
```

```
       SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS     DEF LINE     REFERENCES
    3  INT             1       108

VARIABLES     SN  TYPE           RELOCATION
  542 DIV       REAL                              REFS        26        27   DEFINED        25
  543 DR        REAL                              REFS        30   DEFINED        26
    0 DUMMY1    INTEGER    ARRAY     F.P.         REFS         9        11        78   DEFINED         1        76
  544 DZ        REAL                              REFS        31   DEFINED        27
  537 FACR      REAL                              REFS        34        36        41   DEFINED        21        34
  540 FACZ      REAL                              REFS        35        36        42   DEFINED        21        35
  551 I         INTEGER                           REFS        59      2*63        76        78        91
                                               DEFINED        59        62        76        77        91
    0 ICODE     INTEGER    ARRAY     F.P.         REFS        10        88   DEFINED         1        21        43
    0 INTE      LOGICAL    ARRAY     F.P.         REFS         9        12        91   DEFINED         1        73        79
    0 IX        INTEGER    ARRAY     F.P.         REFS         8        63        91   DEFINED         1        59        63
  546 K         INTEGER                           REFS      2*30      2*31   DEFINED        29
  533 L         INTEGER                           REFS        22        24        25        26        27
                                               DEFINED        20        46
  541 L1        INTEGER                           REFS        23        29   DEFINED        22        33
  545 M         INTEGER                           REFS        29        59        61        66   DEFINED        28        59
  535 MOD       INTEGER                           REFS        36        38        39        47   DEFINED        21        45
  534 N         INTEGER                           REFS      3*21        23        25        26        27        28        33
                                                    37        38        41        42        43        44        46        48
                                                    51        55        60        61      2*63        65        66        72
                                                    73        75        79      4*91   DEFINED        21        37        58
                                                    60        71        74        78        90
  536 NLIM      INTEGER                           REFS        36        44   DEFINED        21
  552 NOD       INTEGER                           REFS      4*88   DEFINED        87
    0 NUELIN    INTEGER              F.P.         REFS       2*8       2*9        65        71        90
                                               DEFINED         1
    0 NUELOIL   INTEGER              F.P.         REFS        74   DEFINED         1
    0 NUINTIN   INTEGER              F.P.         REFS        76        77   DEFINED         1
    0 NUNPIN    INTEGER              F.P.         REFS       2*8        10        48        55        87
                                               DEFINED         1
  547 N1        INTEGER                           REFS        39        40      2*41      2*42   DEFINED        38
  550 N2        INTEGER                           REFS        40        41        42   DEFINED        39
    0 OIL       LOGICAL    ARRAY     F.P.         REFS         8        12        91   DEFINED         1        72        75
    0 R         REAL       ARRAY     F.P.         REFS         8      2*26        30      3*41        88
                                               DEFINED         1        21        30        41
    0 ROIL      REAL                 F.P.         REFS        85   DEFINED         1
    0 Z         REAL       ARRAY     F.P.         REFS         8      2*27        31      3*42        88
                                               DEFINED         1        21        31        42

FILE NAMES       MODE
       INPUT     FMT                     READS      21        59        76
       OUTPUT    FMT                    WRITES      36        49        51        53        55        84        85        86
                                            88      89        91

STATEMENT LABELS             DEF LINE   REFERENCES
   11  20                       21         48
    0  30          INACTIVE     24         23
    0  40                       31         29
   55  50                       33         47
   67  60                       37         44
```

```
STATEMENT LABELS                    DEF LINE    REFERENCES
   112  70                              46          23         32
   120  80                              49          24
   123  90                              51          23
   126  100                             53          40
   131  110                             55          48
   134  120                             57          48
   135  130                             59          66
   152  140                             60          67
     0  150                             63          62
   166  160                             64          61
   172  180                             71          65
     0  274                             73          71
     0  280                             75          74
     0  300                             80          77
     0  310                             88          87
     0  320                             91          90
   414  400      FMT                    92          85
   422  600      FMT                    93          86
   431  700      FMT                    94          88
   434  800      FMT                    95          89
   446  900      FMT                    97          91
   451  1000     FMT                    98          84
   460  1002     FMT                    99          21
   464  1003     FMT                   100          59
   466  1020     FMT                   101          76
   470  2100     FMT                   102          36
   501  2130     FMT                   104          49
   506  2140     FMT                   105          51
   515  2150     FMT                   106          53
   523  2160     FMT                   107          55

LOOPS   LABEL     INDEX       FROM-TO     LENGTH     PROPERTIES
   47   40        K            29 31         4B       INSTACK
  140             I            59 59        11B                EXT REFS
  163   150       I            62 63         2B       INSTACK
  177   274       N            71 73         2B       INSTACK
  206   280       N            74 75         2B       INSTACK
  223   300       I            77 80         3B       INSTACK
  235   310       NOD          87 88        13B                EXT REFS
  252   320       N            90 91        24B                EXT REFS  NOT INNER
  255             I            91 91        11B                EXT REFS

STATISTICS
   PROGRAM LENGTH                  565B      373
            52000B SCM USED
```

```
      SUBROUTINE BNDWTH(R,Z,IX,OIL,INTE,NUMEL,NUMNOD,NBAND)
      DIMENSION R(NUMNOD),Z(NUMNOD),IX(NUMEL,4),OIL(NUMEL),INTE(NUMEL)
      LOGICAL OIL,INTE
      MAXDIF=0
      DO 10 N=1,NUMEL
      DO 10 I=1,3
      JMIN=I+1
      DO 10 J=JMIN,4
      IDIF=IABS(IX(N,I)-IX(N,J))
      IF (IDIF.GT.MAXDIF) MAXDIF=IDIF
   10 CONTINUE
C
C     CHECK FOR INCREASE IN BANDWIDTH DUE TO INTERELEMENT
C     COMBINATIONS OF NODE POINTS NEAR INTERFACE
C
      N1=0
      N2=0
   20 N1=N1+1
      IF (N1.GT.NUMEL) GO TO 40
      IF (.NOT.INTE(N1)) GO TO 20
      IF (OIL(N1)) I1=1
      IF (OIL(N1)) J1=2
      IF (OIL(N1)) I2=4
      IF (.NOT.OIL(N1)) I1=4
      IF (.NOT.OIL(N1)) J1=3
      IF (.NOT.OIL(N1)) I2=1
      R1=R(IX(N1,I1))
      Z1=Z(IX(N1,I1))
   30 N2=N2+1
      IF (N2.GT.NUMEL) PRINT 100
      IF (N2.GT.NUMEL) STOP
      R2=R(IX(N2,I2))
      Z2=Z(IX(N2,I2))
      IF (R1.NE.R2.OR.Z1.NE.Z2) GO TO 30
C
C     "MATCHING" ELEMENT ALONG INTERFACE FOUND
C
      IDIF1=IABS(IX(N1,I1)-IX(N2,1))
      IDIF2=IABS(IX(N1,I1)-IX(N2,2))
      IDIF3=IABS(IX(N1,I1)-IX(N2,3))
      IDIF4=IABS(IX(N1,I1)-IX(N2,4))
      IDIF5=IABS(IX(N1,J1)-IX(N2,1))
      IDIF6=IABS(IX(N1,J1)-IX(N2,2))
      IDIF7=IABS(IX(N1,J1)-IX(N2,3))
      IDIF8=IABS(IX(N1,J1)-IX(N2,4))
      IDIF=MAX0(IDIF1,IDIF2,IDIF3,IDIF4,IDIF5,IDIF6,IDIF7,IDIF8)
      IF (IDIF.GT.MAXDIF) MAXDIF=IDIF
      N2=0
      GO TO 20
   40 CONTINUE
      NBAND=2*MAXDIF+1
  100 FORMAT (* ELEMENT NOT FOUND*)
      RETURN
      END
```

```
       SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS     DEF LINE     REFERENCES
    3  BNDWTH          1        53

VARIABLES     SN TYPE            RELOCATION
  227  I         INTEGER                           REFS         7         9   DEFINED         6
  232  IDIF      INTEGER                           REFS      2*10      2*47   DEFINED         9        46
  244  IDIF1     INTEGER                           REFS        46   DEFINED        38
  245  IDIF2     INTEGER                           REFS        46   DEFINED        39
  246  IDIF3     INTEGER                           REFS        46   DEFINED        40
  247  IDIF4     INTEGER                           REFS        46   DEFINED        41
  250  IDIF5     INTEGER                           REFS        46   DEFINED        42
  251  IDIF6     INTEGER                           REFS        46   DEFINED        43
  252  IDIF7     INTEGER                           REFS        46   DEFINED        44
  253  IDIF8     INTEGER                           REFS        46   DEFINED        45
    0  INTE      LOGICAL    ARRAY     F.P.         REFS         2         3        20   DEFINED         1
    0  IX        INTEGER    ARRAY     F.P.         REFS         2       2*9        27        28        32        33      2*38
                                                   2*39      2*40      2*41      2*42      2*43      2*44      2*45
                                               DEFINED         1
  235  I1        INTEGER                           REFS        27        28        38        39        40        41
                                               DEFINED        21        24
  237  I2        INTEGER                           REFS        32        33   DEFINED        23        26
  231  J         INTEGER                           REFS         9   DEFINED         8
  230  JMIN      INTEGER                           REFS         8   DEFINED         7
  236  J1        INTEGER                           REFS        42        43        44        45   DEFINED        22        25
  225  MAXDIF    INTEGER                           REFS        10        47        51   DEFINED         4        10        47
  226  N         INTEGER                           REFS       2*9   DEFINED         5
    0  NBAND     INTEGER              F.P.     DEFINED         1        51
    0  NUMEL     INTEGER              F.P.         REFS       3*2         5        19        30        31
                                               DEFINED         1
    0  NUMNOD    INTEGER              F.P.         REFS       2*2   DEFINED         1
  233  N1        INTEGER                           REFS        18        19        20        21        22        23        24
                                                     25        26        27        28        38        39        40        41
                                                     42        43        44        45   DEFINED        16        18
  234  N2        INTEGER                           REFS        29        30        31        32        33        38        39
                                                     40        41        42        43        44        45
                                               DEFINED        17        29        48
    0  OIL       LOGICAL    ARRAY     F.P.         REFS         2         3        21        22        23        24        25
                                                     26   DEFINED         1
    0  R         REAL       ARRAY     F.P.         REFS         2        27        32   DEFINED         1
  240  R1        REAL                              REFS        34   DEFINED        27
  242  R2        REAL                              REFS        34   DEFINED        32
    0  Z         REAL       ARRAY     F.P.         REFS         2        28        33   DEFINED         1
  241  Z1        REAL                              REFS        34   DEFINED        28
  243  Z2        REAL                              REFS        34   DEFINED        33

FILE NAMES        MODE
       OUTPUT    FMT                    WRITES       30

INLINE FUNCTIONS   TYPE   ARGS        DEF LINE  REFERENCES
       IABS      INTEGER    1  INTRIN                 9        38        39        40        41        42        43        44
                                                     45
       MAXO      INTEGER    0  INTRIN                46
```

```
STATEMENT LABELS             DEF LINE   REFERENCES
    0  10                       11         5         6         8
   42  20                       18        20        49
  106  30                       29        34
  207  40                       50        19
  220  100     FMT              52        30

LOOPS  LABEL    INDEX     FROM-TO    LENGTH   PROPERTIES
   12  10       N            5 11       27B             NOT INNER
   13  10       I            6 11       23B             NOT INNER
   25  10       J            8 11        6B     INSTACK

STATISTICS
  PROGRAM LENGTH                260B     176
          52000B SCM USED
```

```
      SUBROUTINE SOLINT(A,BI,BII,R,Z,ICODE,IX,D,HM,HB,HL,
     1                  RO1,NUMEL,NBAND,NP,NEQ,NMO,NUELOIL)
C
      DIMENSION A(NEQ,1),BI(NMO),BII(NMO,NMO),IX(NUMEL,4),R(NP),Z(NP),
     1          ICODE(NP),HM(NP,NBAND),HB(NP),HL(NP,NMO),D(NMO,1)
      DIMENSION RR(4),ZZ(4),HH(4,4),H(4,4),SS(2),IJ(3)
      COMMON /FCONST/ PI,ROW,HS
      DATA SS /-.57735026918963, .57735026918963/
      DO 30 I=1,NP
      HB(I)=0.
      DO 22 M=1,NMO
      D(M,I)=0.
   22 HL (I,M)=0.
      DO 30 J=1,NBAND
   30 HM(I,J)=0.
      DO 100 N=1,NUMEL
      IJ(1)=0
      IJ(2)=0
      IJ(3)=0
      IK=0
      RO=ROW
      IF (N.LE.NUELOIL) RO=RO1*ROW
      DO 60 I=1,4
      II=IX(N,I)
      IF (ICODE(II).EQ.0) GO TO 52
      IK=IK+1
      IJ(IK)=II
   52 RR(I)=R(II)
   60 ZZ(I)=Z(II)
      DO 65 I=1,4
      DO 65 J=1,4
   65 HH(I,J)=0.
      DO 70 II=1,2
      DO 70 JJ=1,2
      CALL FORMH(SS(II),SS(JJ),RR,ZZ,H)
      DO 68 I=1,4
      DO 68 J=I,4
      HH(I,J)=HH(I,J)+H(I,J)
   68 HH(J,I)=HH(I,J)
   70 CONTINUE
      DO 80 I=1,4
      II=IX(N,I)
      DO 80 J=1,4
      JJ=IX(N,J)-II+1
      IF (JJ.LT.1) GO TO 80
      HM(II,JJ)=HM(II,JJ)+HH(I,J)/RO
   80 CONTINUE
      IF (IK.LT.2) GO TO 100
      NN=IK-1
      DO 85 I=1,NN
      II=IJ(I)
      JJ=IJ(I+1)
      I1=IABS(ICODE(II))
      J1=IABS(ICODE(JJ))
      RIJ=-R(II)+R(JJ)
      ZIJ=Z(II)-Z(JJ)
      SIJ=SQRT(RIJ**2+ZIJ**2)*SIGN(1.,ZIJ)
```

```
      CSN=-ZIJ/SIJ
      SSN=-RIJ/SIJ
      CSN=ABS(CSN)
      IF (ZIJ.GT.0.) SSN=-SSN
      ZIJ=ABS(ZIJ)
      DO 85 K=1,2
      A1=(1.-SS(K))/2.
      A4=(1.+SS(K))/2.
      RF=R(II)*A1+R(JJ)*A4
      RRR=RF*SIJ*CSN/2.
      HB(II)=HB(II)+RRR*A1
      HB(JJ)=HB(JJ)+RRR*A4
      DO 85 M=1,NMO
      TI=A(3*I1-2,M)*CSN + A(3*I1-1,M)*SSN
      TJ=A(3*J1-2,M)*CSN + A(3*J1-1,M)*SSN
      AF=(TI*A1+TJ*A4)*SIJ/2.*RF
      HL(II,M)=HL(II,M)+AF*A1
      HL(JJ,M)=HL(JJ,M)+AF*A4
      D(M,II)=D(M,II)+AF*A1
      D(M,JJ)=D(M,JJ)+AF*A4
   85 CONTINUE
  100 CONTINUE
      CALL BANSL1(R,NP,NBAND,HM,HB,1)
      CALL BANSL1(R,NP,NBAND,HM,HB,2)
      DO 110 M=1,NMO
  110 CALL BANSL1(R,NP,NBAND,HM,HL(1,M),2)
      NWALL=0
      DO 130 I=1,NP
  130 IF (ICODE(I).NE.0) NWALL=NWALL+1
      WRITE (9) NWALL
      PRINT 1020
      DO 200 I=1,NP
      IF (ICODE(I).EQ.0) GO TO 200
      WRITE (9) IABS(ICODE(I)),HB(I),(HL(I,M),M=1,NMO)
      PRINT 1025, I,HB(I),(HL(I,M),M=1,NMO)
      DO 150 M=1,NMO
      BI(M)=BI(M)+D(M,I)*HB(I)
      DO 150 N=M,NMO
      BII(M,N)=BII(M,N)+D(M,I)*HL(I,N)
  150 BII(N,M)=BII(M,N)
  200 CONTINUE
      PRINT 1030
      CALL PRINTA(BI,NMO,1)
      PRINT 1031
      CALL PRINTA(BII,NMO,NMO)
 1020 FORMAT (1H1/6X,4HNODE,5X,*PRES.  COEFF.  UNDER RIGID MODE*,6X,
     1         *PRES.  COEFF.  UNDER FLEX MODES*/)
 1025 FORMAT (5X,I4,15X,E10.3,15X,5E15.3,/(49X,5E15.3))
 1030 FORMAT (///5X,*GENERALIZED FORCE VECTOR (EXT + INT) --- A+BI*)
 1031 FORMAT (///5X,*GENERALIZED MASS MATRIX (EXT + INT) --- M+BII*)
      RETURN
      END
```

```
     SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
 '  3  SOLINT           1          108

VARIABLES    SN  TYPE            RELOCATION
     0 A          REAL      ARRAY   F.P.        REFS       4    2*71    2*72 DEFINED       1
   704 AF         REAL                          REFS      74      75      76      77 DEFINED      73
   676 A1         REAL                          REFS      66      68      73      74      76
                                             DEFINED      64
   677 A4         REAL                          REFS      66      69      73      75      77
                                             DEFINED      65
     0 BI         REAL      ARRAY   F.P.        REFS       4      94     100 DEFINED       1      94
     0 BII        REAL      ARRAY   F.P.        REFS       4      96      97     102 DEFINED       1      96
                                                  97
   673 CSN        REAL                          REFS      60      67      71      72 DEFINED      58      60
     0 D          REAL      ARRAY   F.P.        REFS       4      76      77      94      96
                                             DEFINED       1      12      76      77
   736 H          REAL      ARRAY               REFS       6      35      38
     0 HB         REAL      ARRAY   F.P.        REFS       4      68      69      80      81      91      92
                                                  94 DEFINED       1      10      68      69
   716 HH         REAL      ARRAY               REFS       6      38      39      46 DEFINED      32      38
                                                  39
     0 HL         REAL      ARRAY   F.P.        REFS       4      74      75      83      91      92      96
                                             DEFINED       1      13      74      75
     0 HM         REAL      ARRAY   F.P.        REFS       4      46      80      81      83
                                             DEFINED       1      15      46
     2 HS         REAL              FCONST      REFS       7
   655 I          INTEGER                       REFS      10      12      13      15      24      28      29
                                                  32      37    3*38    2*39      42      46      51      52
                                                  86      90    3*91    3*92    2*94    2*96
                                             DEFINED       9      23      30      36      41      50      85
                                                  89
     0 ICODE      INTEGER   ARRAY   F.P.        REFS       4      25      53      54      86      90      91
                                             DEFINED       1
   663 II         INTEGER                       REFS      25      27      28      29      35      44    2*46
                                                  53      55      56      66    2*68    2*74    2*76
                                             DEFINED      24      33      42      51
   760 IJ         INTEGER   ARRAY               REFS       6      51      52 DEFINED      17      18      19
                                                  27
   661 IK         INTEGER                       REFS      26      27      48      49 DEFINED      20      26
     0 IX         INTEGER   ARRAY   F.P.        REFS       4      24      42      44 DEFINED       1
   666 I1         INTEGER                       REFS    2*71 DEFINED      53
   657 J          INTEGER                       REFS      15      32    3*38    2*39      44      46
                                             DEFINED      14      31      37      43
   664 JJ         INTEGER                       REFS      35      45    2*46      54      55      56      66
                                                2*69    2*75    2*77 DEFINED      34      44      52
   667 J1         INTEGER                       REFS    2*72 DEFINED      54
   675 K          INTEGER                       REFS      64      65 DEFINED      63
   656 M          INTEGER                       REFS      12      13    2*71    2*72    2*74    2*75    2*76
                                                2*77      83      91      92    3*94      95    3*96    2*97
                                             DEFINED      11      70      82      91      92      93
   660 N          INTEGER                       REFS      22      24      42      44    3*96    2*97
                                             DEFINED      16      95
     0 NBAND      INTEGER           F.P.        REFS       4      14      80      81      83
                                             DEFINED       1
```

```
      SUBROUTINE SOLINT     76/176  OPT=1 STATIC              FTN 4.8+498        03/16/81  16.39.39        PAGE     4

VARIABLES      SN  TYPE            RELOCATION
     0  NEQ        INTEGER             F.P.        REFS          4  DEFINED        1
     0  NMO        INTEGER             F.P.        REFS        5*4       11       70       82       91       92       93
                                                     95        100    2*102  DEFINED        1
   665  NN         INTEGER                         REFS         50  DEFINED       49
     0  NP         INTEGER             F.P.        REFS        6*4        9       80       81       83       85       89
                                                DEFINED          1
     0  NUELOIL    INTEGER             F.P.        REFS         22  DEFINED        1
     0  NUMEL      INTEGER             F.P.        REFS          4       16  DEFINED        1
   705  NWALL      INTEGER                         REFS         86       87  DEFINED       84       86
     0  PI         REAL              FCONST        REFS          7
     0  R          REAL       ARRAY    F.P.        REFS          4       28     2*55     2*66       80       81       83
                                                DEFINED          1
   700  RF         REAL                            REFS         67       73  DEFINED       66
   670  RIJ        REAL                            REFS         57       59  DEFINED       55
   662  RO         REAL                            REFS         46  DEFINED       21       22
     1  ROW        REAL              FCONST        REFS          7       21       22
     0  RO1        REAL                F.P.        REFS         22  DEFINED        1
   706  RR         REAL       ARRAY                REFS          6       35  DEFINED       28
   701  RRR        REAL                            REFS         68       69  DEFINED       67
   672  SIJ        REAL                            REFS         58       59       67       73  DEFINED       57
   756  SS         REAL       ARRAY                REFS          6     2*35       64       65  DEFINED        8
   674  SSN        REAL                            REFS         61       71       72  DEFINED       59       61
   702  TI         REAL                            REFS         73  DEFINED       71
   703  TJ         REAL                            REFS         73  DEFINED       72
     0  Z          REAL       ARRAY    F.P.        REFS          4       29     2*56  DEFINED        1
   671  ZIJ        REAL                            REFS       2*57       58       61       62  DEFINED       56       62
   712  ZZ         REAL       ARRAY                REFS          6       35  DEFINED       29

FILE NAMES         MODE
       OUTPUT      FMT                  WRITES       88         92       99      101
       TAPE9       UNFMT                WRITES       87         91

EXTERNALS           TYPE    ARGS         REFERENCES
       BANSL1                 6             80       81         83
       FORMH                  5             35
       PRINTA                 3            100      102
       SQRT        REAL       1 LIBRARY     57

INLINE FUNCTIONS    TYPE    ARGS        DEF LINE  REFERENCES
       ABS         REAL       1  INTRIN              60         62
       IABS        INTEGER    1  INTRIN              53         54       91
       SIGN        REAL       2  INTRIN              57

STATEMENT LABELS                DEF LINE    REFERENCES
     0  22                          13          11
     0  30                          15           9       14
    66  52                          28          25
     0  60                          29          23
     0  65                          32          30       31
     0  68                          39          36       37
     0  70                          40          33       34
   165  80                          47          41       43         45
     0  85                          78          50       63         70
   316  100                         79          16       48
     0  110                         83          82
     0  130                         86          85
     0  150                         97          93       95
```

```
STATEMENT LABELS                 DEF LINE   REFERENCES
   466  200                         98         89        90
   613  1020     FMT               103         88
   625  1025     FMT               105         92
   632  1030     FMT               106         99
   641  1031     FMT               107        101

LOOPS  LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
   15  30        I             9 15        26B                 NOT INNER
   26  22        M            11 13         2B      INSTACK
   36  30        J            14 15         2B      INSTACK
   44  100       N            16 79       255B                 EXT REFS  NOT INNER
   62  60        I            23 29        10B      INSTACK
   75  65        I            30 32        12B                 NOT INNER
  101  65        J            31 32         2B      INSTACK
  110  70        II           33 40        32B                 EXT REFS  NOT INNER
  111  70        JJ           34 40        27B                 EXT REFS  NOT INNER
  117  68        I            36 39        16B                 NOT INNER
  126  68        J            37 39         4B      INSTACK
  143  80        I            41 47        27B                 NOT INNER
  156  80        J            43 47        11B      INSTACK
  176  85        I            50 78       120B                 EXT REFS  NOT INNER
  226  85        K            63 78        65B                 NOT INNER
  265  85        M            70 78        23B         OPT
  342  110       M            82 83        14B                 EXT REFS
  363  130       I            85 86         3B      INSTACK
  373  200       I            89 98        76B                 EXT REFS  NOT INNER
  403            M            91 91        11B                 EXT REFS
  423            M            92 92        11B                 EXT REFS
  436  150       M            93 97        30B                 NOT INNER
  456  150       N            95 97         5B      INSTACK

COMMON BLOCKS   LENGTH
       FCONST        3

STATISTICS
  PROGRAM LENGTH                 1053B      555
  SCM LABELED COMMON LENGTH        3B         3
         52000B SCM USED
```

```
       SUBROUTINE PRINTA      76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39       PAGE      1

      1                SUBROUTINE PRINTA(A,NR,NC)
                 C
                 C******************************************************************
                 C     PRINT MATRIX A.
      5          C******************************************************************
                 C
                       DIMENSION A(NR,1)
                       DO 100 J=1,NC,8
                       JH=J+7
     10                IF (JH-NC) 75,75,50
                     50 JH=NC
                     75 PRINT 1000,(N,N=J,JH)
                       DO 100 I=1,NR
                    100 PRINT 1001, I, (A(I,K),K=J,JH)
     15            1000 FORMAT (///8I14)
                   1001 FORMAT (I4,4X,8E14.5)
                       RETURN
                       END



       SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS     DEF LINE     REFERENCES
    3  PRINTA           1        17

VARIABLES     SN  TYPE           RELOCATION
    0  A         REAL       ARRAY ,   F.P.         REFS         7        14    DEFINED         1
  101  I         INTEGER                           REFS      2*14    DEFINED       13
   76  J         INTEGER                           REFS         9        12        14    DEFINED         8
   77  JH        INTEGER                           REFS        10        12        14    DEFINED         9       11
  102  K         INTEGER                           REFS        14    DEFINED       14
  100  N         INTEGER                           REFS        12    DEFINED       12
    0  NC        INTEGER              F.P.         REFS         8        10        11    DEFINED         1
    0  NR        INTEGER              F.P.         REFS         7        13    DEFINED         1

FILE NAMES        MODE
       OUTPUT    FMT                    WRITES       12        14

STATEMENT LABELS             DEF LINE   REFERENCES
    0  50          INACTIVE      11         10
   15  75                        12       2*10
    0  100                       14          8        13
   71  1000    FMT               15         12
   73  1001    FMT               16         14

LOOPS  LABEL    INDEX     FROM-TO    LENGTH     PROPERTIES
   11  100      J              8 14       41B               EXT REFS  NOT INNER
   21           N             12 12        4B               EXT REFS
   27  100      I             13 14       21B               EXT REFS  NOT INNER
   33           K             14 14       11B               EXT REFS

STATISTICS
  PROGRAM LENGTH                 110B      72
          52000B SCM USED
```

```
  1                 SUBROUTINE FORMH(S,T,RR,ZZ,H)
              C
              C************************************************************
              C     FORM FLUID ELEMENT MATRIX H
  5           C************************************************************
              C
                    DIMENSION RR(4),ZZ(4),H(4,4),A(4),AS(4),AT(4),AR(4),AZ(4)
                    SM=1.-S
                    SP=1.+S
 10                 TM=1.-T
                    TP=1.+T
                    A(1)=SM*TM/4.
                    A(2)=SP*TM/4.
                    A(3)=SP*TP/4.
 15                 A(4)=SM*TP/4.
                    AS(1)=-TM/4.
                    AS(2)=-AS(1)
                    AS(3)=TP/4.
                    AS(4)=-AS(3)
 20                 AT(1)=-SM/4.
                    AT(2)=-SP/4.
                    AT(3)=-AT(2)
                    AT(4)=-AT(1)
                    PZT=AT(1)*ZZ(1)+AT(2)*ZZ(2)+AT(3)*ZZ(3)+AT(4)*ZZ(4)
 25                 PZS=AS(1)*ZZ(1)+AS(2)*ZZ(2)+AS(3)*ZZ(3)+AS(4)*ZZ(4)
                    PRS=AS(1)*RR(1)+AS(2)*RR(2)+AS(3)*RR(3)+AS(4)*RR(4)
                    PRT=AT(1)*RR(1)+AT(2)*RR(2)+AT(3)*RR(3)+AT(4)*RR(4)
                    XJ=PRS*PZT-PRT*PZS
                    R=A(1)*RR(1)+A(2)*RR(2)+A(3)*RR(3)+A(4)*RR(4)
 30                 FAC=XJ*R
                    PSR=PZT/XJ
                    PTR=-PZS/XJ
                    PSZ=-PRT/XJ
                    PTZ=PRS/XJ
 35                 DO 50 I=1,4
                    AR(I)=AS(I)*PSR+AT(I)*PTR
                 50 AZ(I)=AS(I)*PSZ+AT(I)*PTZ
                    DO 100 I=1,4
                    DO 100 J=I,4
 40                 H(I,J)=FAC*(AR(I)*AR(J)+AZ(I)*AZ(J))+XJ/R*A(I)*A(J)
                100 H(J,I)=H(I,J)
                    RETURN
                    END
```

```
       SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
   3  FORMH           1           42

VARIABLES       SN  TYPE            RELOCATION
  204  A            REAL        ARRAY                    REFS          7        4*29        2*40   DEFINED         12          13          14
                                                             15
       AS           REAL        ARRAY                    REFS          7        2*40   DEFINED         36
```

```
       SUBROUTINE FORMH      76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39       PAGE     2

VARIABLES     SN  TYPE           RELOCATION
  210  AS        REAL       ARRAY                 REFS         7        17        19      4*25      4*26        36        37
                                               DEFINED        16        17        18        19
  214  AT        REAL       ARRAY                 REFS         7        22        23      4*24      4*27        36        37
                                               DEFINED        20        21        22        23
  224  AZ        REAL       ARRAY                 REFS         7      2*40   DEFINED        37
  175  FAC       REAL                             REFS        40   DEFINED        30
    0  H         REAL       ARRAY     F.P.        REFS         7        41   DEFINED         1        40        41
  202  I         INTEGER                          REFS      3*36      3*37        39      4*40      2*41
                                               DEFINED        35        38
  203  J         INTEGER                          REFS      4*40      2*41   DEFINED        39
  171  PRS       REAL                             REFS        28        34   DEFINED        26
  172  PRT       REAL                             REFS        28        33   DEFINED        27
  176  PSR       REAL                             REFS        36   DEFINED        31
  200  PSZ       REAL                             REFS        37   DEFINED        33
  177  PTR       REAL                             REFS        36   DEFINED        32
  201  PTZ       REAL                             REFS        37   DEFINED        34
  170  PZS       REAL                             REFS        28        32   DEFINED        25
  167  PZT       REAL                             REFS        28        31   DEFINED        24
  174  R         REAL                             REFS        30        40   DEFINED        29
    0  RR        REAL       ARRAY     F.P.        REFS         7      4*26      4*27      4*29   DEFINED         1
    0  S         REAL                 F.P.        REFS         8         9   DEFINED         1
  163  SM        REAL                             REFS        12        15        20   DEFINED         8
  164  SP        REAL                             REFS        13        14        21   DEFINED         9
    0  T         REAL                 F.P.        REFS        10        11   DEFINED         1
  165  TM        REAL                             REFS        12        13        16   DEFINED        10
  166  TP        REAL                             REFS        14        15        18   DEFINED        11
  173  XJ        REAL                             REFS        30        31        32        33        34        40
                                               DEFINED        28
    0  ZZ        REAL       ARRAY     F.P.        REFS         7      4*24      4*25   DEFINED         1

STATEMENT LABELS             DEF LINE   REFERENCES
    0  50                       37        35
    0  100                      41        38        39

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
  107  50       I          35 37       10B      INSTACK
  121  100      I          38 41       30B              NOT INNER
  135  100      J          39 41       11B      INSTACK

STATISTICS
  PROGRAM LENGTH                233B     155
          52000B SCM USED
```

```
SUBROUTINE MSOLVE     76/176  OPT=1 STATIC                    FTN 4.8+498         03/16/81  16.39.39        PAGE      1

  1                SUBROUTINE MSOLVE(A,B,NN,KK)
             C
             C*********************************************************************
             C     KK=0  TRIANGLARIZES MATRIXA AND REDUCES, BACKSUBSTITUTES VECTOR B
  5          C     KK=1  REDCES AND BACKSUBSTITUTES VECTOR B ONLY
             C*********************************************************************
             C
                   DIMENSION A(NN,1),B(1)
                   DO 450 N=1,NN
 10                N1=N+1
                   B(N)=B(N)/A(N,N)
                   IF(N.EQ.NN) GO TO 500
                   IF(KK.GE.1) GO TO 350
                   DO 250 J=N1,NN
 15            250 A(N,J)=A(N,J)/A(N,N)
                   DO 300 I=N1,NN
                   DO 300 J=I,NN
                   A(I,J)=A(I,J)-A(I,N)*A(N,J)
               300 A(J,I)=A(I,J)
 20            350 CONTINUE
                   DO 400 I=N1,NN
               400 B(I)=B(I)-A(I,N)*B(N)
               450 CONTINUE
               500 N1=N
 25                N=N-1
                   IF(N.EQ.0) RETURN
                   DO 600 J=N1,NN
               600 B(N)=B(N)-A(N,J)*B(J)
                   GO TO 500
 30                END


      SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
    3  MSOLVE          1            26

VARIABLES      SN  TYPE          RELOCATION
    0  A           REAL       ARRAY     F.P.        REFS         8        11      2*15      3*18        19        22        28
                                                 DEFINED         1        15        18        19
    0  B           REAL       ARRAY     F.P.        REFS         8        11      2*22      2*28   DEFINED         1        11
                                                      22        28
  116  I           INTEGER                          REFS        17      3*18      2*19      3*22   DEFINED        16        21
  115  J           INTEGER                          REFS      2*15      3*18      2*19      2*28   DEFINED        14        17
                                                      27
    0  KK          INTEGER              F.P.        REFS        13   DEFINED         1
  113  N           INTEGER                          REFS        10      4*11        12      4*15      2*18      2*22        24
                                                      25        26      3*28   DEFINED         9        25
    0  NN          INTEGER              F.P.        REFS         8         9        12        14        16        17        21
                                                      27   DEFINED         1
  114  N1          INTEGER                          REFS        14        16        21        27   DEFINED        10        24
```

```
      SUBROUTINE MSOLVE     76/176  OPT=1 STATIC                  FTN 4.8+498         03/16/81  16.39.39        PAGE     2

STATEMENT LABELS              DEF LINE   REFERENCES
     0  250                      15         14
     0  300                      19         16         17
    56  350                      20         13
     0  400                      22         21
     0  450                      23          9
    73  500                      24         12         29
     0  600                      28         27

LOOPS  LABEL    INDEX     FROM-TO     LENGTH     PROPERTIES
   11  450      N            9 23        62B                  EXITS   NOT INNER
   27  250      J           14 15         3B      INSTACK
   34  300      I           16 19        22B                NOT INNER
   46  300      J           17 19         4B      INSTACK
   65  400      I           21 22         3B      INSTACK
  105  600      J           27 28         3B      INSTACK

STATISTICS
  PROGRAM LENGTH               141B       97
          52000B SCM USED
```

```
      SUBROUTINE BANSL1(NA,NEQ,MBAND,A,B,KK)
      DIMENSION NA(1)
      DIMENSION A(NEQ,1),B(1)
      NEQQ = NEQ - 1
      MBAA = MBAND - 1
      IF (KK.EQ.2) GO TO 250

      REDUCE MATRIX A

      NADR = 1
      DO 140 N=2,MBAA
      NADR = NADR + NEQ
      JADR = NADR
      N1   = N - 1
      DO 130 I=1,N1
      IF(A(JADR).NE.0.) GO TO 140
  130 JADR = JADR - NEQQ
      I=N1
  140 NA(N)= I
      M    = 0
      NADR = NEQ*MBAA
      DO 160 N=MBAND,NEQ
      M    = M + 1
      NADR = NADR + 1
      JADR = NADR
      N1   = N - 1
      DO 150 I=M,N1
      IF(A(JADR).NE.0.) GO TO 160
  150 JADR = JADR - NEQQ
      I=N1
  160 NA(N)= I
      NA(1)= 1
      JI   = 0
      DO 200 J=2,NEQ
      IF   = NA(J)
      IF1  = IF + 1
      IL   = J - 1
      JI   = JI + NEQ
      JK   = JI + NEQ
      IFN  = IF*NEQQ
      IF (IF1.GT.IL) GO TO 185
      JIA  = JI - IFN + 1
      DO 180 I=IF1,IL
      KF   = MAX0(NA(I),IF)
      KL   = I - 1
      KFN  = KF*NEQQ
      JKA  = JK - KFN
      IKA  = I*NEQ - KFN
      AA   = A(JIA)
      DO 170 K=KF,KL
      AA   = AA - A(JKA)*A(IKA)
      JKA  = JKA - NEQQ
  170 IKA  = IKA - NEQQ
      A(JIA) = AA
  180 JIA  = JIA - NEQQ
  185 JKA  = JK - IFN
      AA   = A(J)
```

```
                   DO 190 K=IF,IL
                   CC    = A(JKA)/A(K)
  60               AA    = AA - A(JKA)*CC
                   A(JKA) = CC
               190 JKA   = JKA - NEQQ
                   A(J) = AA
               200 CONTINUE
  65               GO TO 500
             C
             C     REDUCE VECTOR B  AND  BACK SUBSTITUTE
             C
               250 DO 270 N=1,NEQQ
  70               IF(B(N).NE.0.) GOTO 280
               270 CONTINUE
                   N=NEQQ
               280 N1    = N + 1
                   NADR = N1*NEQ
  75               DO 290 I=N1,NEQ
                   KF    = MAX0(NA(I),N)
                   KL    = I - 1
                   JADR = NADR - KF*NEQQ
                   BB    = B(I)
  80               DO 285 K=KF,KL
                   BB    = BB - A(JADR)*B(K)
               285 JADR = JADR - NEQQ
                   B(I) = BB
               290 NADR = NADR + NEQ
  85               DO 300 I=N,NEQ
               300 B(I) = B(I)/A(I)
                   NN    = NEQ
                   NADR = NN*NEQ
                   DO 400 N=1,NEQQ
  90               KF    = NA(NN)
                   KL    = NN - 1
                   JADR = NADR - KF*NEQQ
                   BB    = B(NN)
                   DO 390 K=KF,KL
  95               B(K) = B(K) - A(JADR)*BB
               390 JADR = JADR - NEQQ
                   NADR = NADR - NEQ
               400 NN    = NN - 1
               500 RETURN
 100               END


     SYMBOLIC REFERENCE MAP (R=2)

 ENTRY POINTS      DEF LINE      REFERENCES
    3  BANSL1          1           99

 VARIABLES      SN  TYPE           RELOCATION
    0  A            REAL        ARRAY      F.P.       REFS        3         16         28          49        2*51         57        2*59
                                                       60        81         86         95     DEFINED         1         54          61
                                                       63
```

```
      SUBROUTINE BANSL1     76/176  OPT=1 STATIC                   FTN 4.8+498        03/16/81  16.39.39       PAGE     3

VARIABLES     SN  TYPE           RELOCATION
  313 AA        REAL                              REFS        51        54        60        63   DEFINED        49        51
                                                    57        60
    0 B         REAL       ARRAY     F.P.         REFS         3        70        79        81        86        93        95
                                               DEFINED         1        83        86        95
  316 BB        REAL                              REFS        81        83        95   DEFINED        79        81        93
  315 CC        REAL                              REFS        60        61   DEFINED        59
  274 I         INTEGER                           REFS        19        31        44        45        48        76        77
                                                    79        83      3*86   DEFINED        15        18        27        30
                                                    43        75        85
  300 IF        INTEGER                           REFS        36        40        44        58   DEFINED        35
  304 IFN       INTEGER                           REFS        42        56   DEFINED        40
  301 IF1       INTEGER                           REFS        41        43   DEFINED        36
  312 IKA       INTEGER                           REFS        51        53   DEFINED        48        53
  302 IL        INTEGER                           REFS        41        43        58   DEFINED        37
  277 J         INTEGER                           REFS        35        37        57        63   DEFINED        34
  272 JADR      INTEGER                           REFS        16        17        28        29        81        82        95
                                                    96   DEFINED        13        17        25        29        78        82
                                                    92        96
  276 JI        INTEGER                           REFS        38        39        42   DEFINED        33        38
  305 JIA       INTEGER                           REFS        49        54        55   DEFINED        42        55
  303 JK        INTEGER                           REFS        47        56   DEFINED        39
  311 JKA       INTEGER                           REFS        51        52        59        60        61        62
                                               DEFINED        47        52        56        62
  314 K         INTEGER                           REFS        59        81      2*95   DEFINED        50        58        80
                                                    94
  306 KF        INTEGER                           REFS        46        50        78        80        92        94
                                               DEFINED        44        76        90
  310 KFN       INTEGER                           REFS        47        48   DEFINED        46
    0 KK        INTEGER              F.P.         REFS         6   DEFINED         1
  307 KL        INTEGER                           REFS        50        80        94   DEFINED        45        77        91
  275 M         INTEGER                           REFS        23        27   DEFINED        20        23
  267 MBAA      INTEGER                           REFS        11        21   DEFINED         5
    0 MBAND     INTEGER              F.P.         REFS         5        22   DEFINED         1
  271 N         INTEGER                           REFS        14        19        26        31        70        73        76
                                                    85   DEFINED        11        22        69        72        89
    0 NA        INTEGER    ARRAY     F.P.         REFS         2        35        44        76        90
                                               DEFINED         1        19        31        32
  270 NADR      INTEGER                           REFS        12        13        24        25        78        84        92
                                                    97   DEFINED        10        12        21        24        74        84
                                                    88        97
    0 NEQ       INTEGER              F.P.         REFS         3         4        12        21        22        34        38
                                                    39        48        74        75        84        85        87        88
                                                    97   DEFINED         1
  266 NEGQ      INTEGER                           REFS        17        29        40        46        52        53        55
                                                    62        69        72        78        82        89        92        96
                                               DEFINED         4
  317 NN        INTEGER                           REFS        88        90        91        93        98
                                               DEFINED        87        98
  273 N1        INTEGER                           REFS        15        18        27        30        74        75
                                               DEFINED        14        26        73

INLINE FUNCTIONS    TYPE   ARGS        DEF LINE  REFERENCES
      MAXO      INTEGER      0  INTRIN                  44        76

STATEMENT LABELS             DEF LINE   REFERENCES
    0 130                          17         15
   32 140                          19         11        16
```

```
      SUBROUTINE BANSL1      76/176  OPT=1 STATIC                    FTN 4.8+498         03/16/81  16.39.39         PAGE      4

STATEMENT LABELS               DEF LINE    REFERENCES
     0  150                       29          27
    57  160                       31          22         28
     0  170                       53          50
     0  180                       55          43
   135  185                       56          41
     0  190                       62          58
     0  200                       64          34
   161  250                       69           6
     0  270                       71          69
   167  280                       73          70
     0  285                       82          80
     0  290                       84          75
     0  300                       86          85
     0  390                       96          94
     0  400                       98          89
   265  500                       99          65

LOOPS  LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
    16  140        N          11 19       20B                  NOT INNER
    23  130        I          15 17        5B       INSTACK      EXITS
    43  160        N          22 31       20B                  NOT INNER
    50  150        I          27 29        5B       INSTACK      EXITS
    66  200        J          34 64       72B                  NOT INNER
   101  180        I          43 55       34B                  NOT INNER
   121  170        K          50 53        4B       INSTACK
   146  190        K          58 62        5B       INSTACK
   162  270        N          69 71        4B       INSTACK      EXITS
   173  290        I          75 84       27B                  NOT INNER
   210  285        K          80 82        4B       INSTACK
   230  300        I          85 86        2B       INSTACK
   237  400        N          89 98       26B                  NOT INNER
   252  390        K          94 96        4B       INSTACK

STATISTICS
  PROGRAM LENGTH                   356B       238
          52000B SCM USED
```

```
     SUBROUTINE QUAKE       76/176  OPT=1 STATIC                    FTN 4.8+498         03/16/81  16.39.39        PAGE

     1                SUBROUTINE QUAKE(T,XFH,K,DT,FH,NX)
                C
                      DIMENSION FH(1)
                      DIMENSION T(1),XFH(1)
     5                DO 3 J=1,K
                    3 FH(J)=0.
                      PRINT 47,  DT*(K-1)
                      I=0
                      J=1
    10                TE=0.
                    5 I=I+1
                      IF(I.GT.NX) RETURN
                   10 IF(T(I)-TE) 11,14,12
                   11 IF(2.*(TE-T(I))-DT) 14,5,5
    15             12 IF(J.GT.1) FH(J)=((T(I)-TE)*FH(J-1)+DT*XFH(I))/(T(I)-TE+DT)
                      J=J+1
                      IF (J.GT.K) RETURN
                      TE=TE+DT
                      GO TO 10
    20             14 FH(J)=XFH(I)
                      J=J+1
                      IF (J.GT.K) RETURN
                      TE=TE+DT
                      GO TO 5
    25             47 FORMAT (//* TRUNCATED EARTHQUAKE DATA LENGTH T =*,F10.4,* SEC*/)
                      END


     SYMBOLIC REFERENCE MAP (R=2)

 ENTRY POINTS      DEF LINE      REFERENCES
     3  QUAKE          1          12          17          22

 VARIABLES      SN  TYPE              RELOCATION
     0  DT          REAL                   F.P.        REFS        7          14       2*15        18        23
                                                     DEFINED       1
     0  FH          REAL       ARRAY       F.P.        REFS        3          15    DEFINED         1         6        15        20
   106  I           INTEGER                            REFS       11          12         13        14      3*15        20
                                                     DEFINED       8          11
   105  J           INTEGER                            REFS        6        3*15         16        17        20        21        22
                                                     DEFINED       5           9         16        21
     0  K           INTEGER                F.P.        REFS        5           7         17        22   DEFINED         1
     0  NX          INTEGER                F.P.        REFS       12     DEFINED          1
     0  T           REAL       ARRAY       F.P.        REFS        4          13         14      2*15   DEFINED         1
   107  TE          REAL                               REFS       13          14       2*15        18        23
                                                     DEFINED      10          18         23
     0  XFH         REAL       ARRAY       F.P.        REFS        4          15         20   DEFINED         1

 FILE NAMES        MODE
     OUTPUT      FMT                      WRITES        7

 STATEMENT LABELS               DEF LINE    REFERENCES
     0  3                          6          5
    24  5                         11        2*14        24
```

```
STATEMENT LABELS             DEF LINE   REFERENCES
   27  10                       13         19
    0  11           INACTIVE    14         13
   36  12                       15         13
   57  14                       20         13         14
   75  47      FMT              25          7

LOOPS  LABEL    INDEX     FROM-TO    LENGTH    PROPERTIES
   11  3        J            5 6         2B     INSTACK

STATISTICS
  PROGRAM LENGTH                110B       72
          52000B SCM USED
```

```
PFL                                                                COMPASS 3.6-498.     03/16/81  16.40.14.       PAGE     1
STORAGE ALLOCATION.

          ADDRESS   LENGTH           BINARY CONTROL CARDS.

                0       15           IDENT  PFL
               15                    END

                                ENTRY POINTS.

                                PFL          2+
```

```
                                      IDENT  PFL
                                      ENTRY  PFL
                            *
                            * FIND THE MAXIMUM FIELD LENGTH
                            *
 0  20061400000000000002 +   NAME     VFD    24/3LPFL,36/PFL
 1  000000000000000000 1     SAVE
 2                     1     PFL      BSSZ   1
 3  63110                             SB1    X1
 4  5110000001               WAIT1    SA1    1           .WAIT FOR RA+1 TO CLEAR
              0311000004 +            NZ     X1,WAIT1
 5  5110000013 +                      SA1    FORM        .FORM THE MEM REQUEST TO ASSERTAIN
              43600                   MX6    0           .PRESENT FIELD LENGTH
 6  5160000014 +                      SA6    IFL
              74260                   SX2    A6
                   12612              BX6    X1+X2
 7  5160000001                        SA6    1           .PLACE THE CALL AND WAIT FOR RA+1
10  54160                    WAIT2    SA1    A6          .TO CLEAR
         0311000010 +                 NZ     X1,WAIT2
11  5110000014 +                      SA1    IFL
              21136                   AX1    30          .FIELD LENGTH
                   10611              BX6    X1
12  56610                             SA6    B1
         0400000002 +                 EQ     B0,PFL      .RETURN
13  15051560000000000000     FORM     VFD    18/3LMEM,2/3,40/0
14                     1     IFL      BSSZ   1
15                                    END

                 51000B SCM STORAGE USED             27 STATEMENTS         7 SYMBOLS
                            MODEL 176 ASSEMBLY    0.024 SECONDS           15 REFERENCES
```

```
PFL                                                           COMPASS 3.6-498.     03/16/81  16.40.14.       PAGE      3
SYMBOLIC REFERENCE TABLE.

FORM           13     PROGRAM*        2/12      2/25 L
 IFL           14     PROGRAM*        2/14 S    2/20      2/26 L
NAME            0     PROGRAM*        2/06 L
PFL             2     PROGRAM*        2/02 E    2/06      2/08 L     2/24
SAVE            1     PROGRAM*        2/07 L
WAIT1           4     PROGRAM*        2/10 L    2/11
WAIT2          10     PROGRAM*        2/18 L    2/19
```

```
      SUBROUTINE TSTEP(W,BI,BII,DAMP,XFH,XT,C4,C5,Y,VEL,ACEL,YBUF,FH,
     1 ABUF,TEM,NMO,NT,DT,NXFH,NBUF,MBUF,NBLOCK,NGRD,NTAPE,NG,PLOTT)
C
C*****************************************************************
C     SOLVE MODAL EQUATION OF MOTION USING STEP-BY-STEP TIME
C     INTEGRATION TECHNIQUES.
C*****************************************************************
C
      DIMENSION W(1),BI(1),BII(NMO,1),DAMP(1),XFH(1),FH(1),C4(1),C5(1),
     1Y(1),ABUF(1),VEL(1),ACEL(1),YBUF(1),XT(1),TEM(NMO,1)
      DIMENSION ALINE(8)
      LOGICAL PLOTT
      REWIND NTAPE
      DO 10 I=1,NMO
      DO 10 J=1,NMO
   10 TEM(I,J)=BII(I,J)
      IF (NGRD.EQ.2.AND.NG.EQ.1) GO TO 15
C
C     READ AND PRINT MODAL DAMPING RATIOS
C
      READ 1000, (DAMP(I),I=1,NMO)
      PRINT 2000, (I,DAMP(I),I=1,NMO)
   15 FAC=32.2
C
C     READ AND PRINT TIME HISTORY OF GROUND ACCELERATION
C
      READ 2040, ALINE
      PRINT 2045, ALINE
      IF (ALINE(1).NE.10HCONSTANT  ) GO TO 30
C CONSTANT FREQUENCY
      READ 2020, TLATE,OMEGA,HIGH
      DO 25 K=1,NXFH
      XT(K)=(K-1)*TLATE/(NXFH-1)
      XFH(K)=SIN(XT(K)*OMEGA) * HIGH
   25 CONTINUE
      GO TO 35
   30 READ 1001, (XT(K),XFH(K),K=1,NXFH)
   35 CONTINUE
      PRINT 2001, (XT(K),XFH(K),K=1,NXFH)
      IF (.NOT.PLOTT) GO TO 90
      CALL OPLT
      CALL GRAF11(XT,XFH,NXFH,1,"TIME(SEC.)","GRND. ACC.")
      CALL PLOT (0.,0.,999)
   90 DO 100 K=1,NXFH
  100 XFH(K)=XFH(K)*FAC
C
C     GROUND ACCELERATION RECORD IS INTERPOLATED BY EQUAL TIME-INCREMENT
C
      CALL QUAKE(XT,XFH,NT,DT,FH,NXFH)
      WRITE (9) (FH(K),K=1,NT)
C
      C1=DT/2.
      C2=C1*DT/3.
      C3=C2*2
      DO 260 I=1,NMO
      C4(I)=W(I)**2
      C5(I)=2.*DAMP(I)*W(I)
```

```
        TEM(I,I)=TEM(I,I)+C5(I)*C1+C4(I)*C2
        ACEL(I)=-FH(1)*BI(I)
    260 CONTINUE
        CALL MSOLVE(TEM,ACEL,NMO,0)
        M=0
        MC=1
        NBLOCK=0
        DO 265 I=1,NMO
        Y(I)=0.0
        VEL(I)=0.0
        M=M+1
        YBUF(M)=Y(I)
        ABUF(M)=ACEL(I)
    265 CONTINUE
C
    270 MC=MC+1
        DO 280 I=1,NMO
        Y(I)=Y(I)+DT*VEL(I)+C3*ACEL(I)
        VEL(I)=VEL(I)+C1*ACEL(I)
        ACEL(I)=-FH(MC)*BI(I)-C5(I)*VEL(I)-C4(I)*Y(I)
    280 CONTINUE
        CALL MSOLVE(TEM,ACEL,NMO,1)
        DO 350 I=1,NMO
        VEL(I)=VEL(I)+C1*ACEL(I)
        Y(I)=Y(I)+C2*ACEL(I)
C
C       WRITE ON TAPE2 OR TAPE7 (IN BLOCKS) OF DISPLACEMENT DATA
C
        M=M+1
        YBUF(M)=Y(I)
        ABUF(M)=ACEL(I)
        IF (MC.EQ.NT.AND.I.EQ.NMO) GO TO 340
        IF (M.LT.NBUF) GO TO 350
        WRITE (NTAPE) (YBUF(J),J=1,NBUF)
        WRITE (NTAPE) (ABUF(J),J=1,NBUF)
        NBLOCK=NBLOCK+1
        M=0
        GO TO 350
    340 NBLOCK=NBLOCK+1
        MBUF=M
        WRITE (NTAPE) (YBUF(J),J=1,MBUF)
        WRITE (NTAPE) (ABUF(J),J=1,MBUF)
        M=0
    350 CONTINUE
        IF (MC-NT) 360,400,400
    360 GO TO 270
    400 CONTINUE
   1000 FORMAT (7F10.0)
   1001 FORMAT (6(F6.3,F6.4))
   2000 FORMAT (//* MODE   MODAL DAMPING RATIO*/(I4,10X,F10.3))
   2001 FORMAT (//*  EARTHQUAKE DATA  *//(2X,6(F8.4,E12.4)))
   2020 FORMAT (3F10.0)
   2040 FORMAT (8A10)
   2045 FORMAT (1H1,1X,8A10)
        RETURN
        END
```

```
      SUBROUTINE TSTEP      76/176  OPT=1 STATIC                FTN 4.8+498        03/16/81  16.39.39        PAGE      3

      SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS     DEF LINE     REFERENCES
    3  TSTEP          1         112

VARIABLES      SN  TYPE           RELOCATION
     0  ABUF       REAL       ARRAY     F.P.         REFS         9        92        99   DEFINED         1        70        88
     0  ACEL       REAL       ARRAY     F.P.         REFS         9        61        70        75        76        79        81
                                                       82        88   DEFINED         1        59        77
   576  ALINE      REAL       ARRAY                  REFS        11        28        29   DEFINED        27
     0  BI         REAL       ARRAY     F.P.         REFS         9        59        77   DEFINED         1
     0  BII        REAL       ARRAY     F.P.         REFS         9        16   DEFINED         1
   571  C1         REAL                              REFS        53        58        76        81   DEFINED        52
   572  C2         REAL                              REFS        54        58        82   DEFINED        53
   573  C3         REAL                              REFS        75   DEFINED        54
     0  C4         REAL       ARRAY     F.P.         REFS         9        58        77   DEFINED         1        56
     0  C5         REAL       ARRAY     F.P.         REFS         9        58        77   DEFINED         1        57
     0  DAMP       REAL       ARRAY     F.P.         REFS         9        22        57   DEFINED         1        21
     0  DT         REAL                 F.P.         REFS        49        52        53        75   DEFINED         1
   564  FAC        REAL                              REFS        45   DEFINED        23
     0  FH         REAL       ARRAY     F.P.         REFS         9        49        50        59        77
                                                  DEFINED         1
   567  HIGH       REAL                              REFS        34   DEFINED        31
   562  I          INTEGER                           REFS      2*16        21      2*22      2*56      3*57      6*58      2*59
                                                       66        67        69        70      4*75      3*76      6*77      3*81
                                                     3*82        87        88        89   DEFINED        14        21        22
                                                       55        65        74        80
   563  J          INTEGER                           REFS      2*16        91        92        98        99
                                                  DEFINED        15        91        92        98        99
   570  K          INTEGER                           REFS      2*33      2*34      2*37      2*39      2*45        50
                                                  DEFINED        32        37        39        44        50
   574  M          INTEGER                           REFS        68        69        70        86        87        88        90
                                                       97   DEFINED        62        68        86        94       100
     0  MBUF       INTEGER              F.P.         REFS        98        99   DEFINED         1        97
   575  MC         INTEGER                           REFS        73        77        89       102   DEFINED        63        73
     0  NBLOCK     INTEGER              F.P.         REFS        93        96   DEFINED         1        64        93        96
     0  NBUF       INTEGER              F.P.         REFS        90        91        92   DEFINED         1
     0  NG         INTEGER              F.P.         REFS        17   DEFINED         1
     0  NGRD       INTEGER              F.P.         REFS        17   DEFINED         1
     0  NMO        INTEGER              F.P.         REFS       2*9        14        15        21        22        55        61
                                                       65        74        79        80        89   DEFINED         1
     0  NT         INTEGER              F.P.         REFS        49        50        89       102   DEFINED         1
     0  NTAPE      INTEGER              F.P.      DEFINED         1  I/O REFS        13        91        92        98        99
     0  NXFH       INTEGER              F.P.         REFS        32        33        37        39        42        44        49
                                                  DEFINED         1
   566  OMEGA      REAL                              REFS        34   DEFINED        31
     0  PLOTT      LOGICAL              F.P.         REFS        12        40   DEFINED         1
     0  TEM        REAL       ARRAY     F.P.         REFS         9        58        61        79   DEFINED         1        16
                                                       58
   565  TLATE      REAL                              REFS        33   DEFINED        31
     0  VEL        REAL       ARRAY     F.P.         REFS         9        75        76        77        81
                                                  DEFINED         1        67        76        81
     0  W          REAL       ARRAY     F.P.         REFS         9        56        57   DEFINED         1
     0  XFH        REAL       ARRAY     F.P.         REFS         9        39        42        45        49
                                                  DEFINED         1        34        37        45
     0  XT         REAL       ARRAY     F.P.         REFS         9        34        39        42        49
```

```
       SUBROUTINE TSTEP      76/176  OPT=1 STATIC                    FTN 4.8+498        03/16/81  16.39.39        PAGE     4

VARIABLES     SN  TYPE           RELOCATION
                                              DEFINED         1         33         37
    0  Y          REAL        ARRAY     F.P.    REFS          9         69         75         77         82         87
                                              DEFINED         1         66         75         82
    0  YBUF       REAL        ARRAY     F.P.    REFS          9         91         98   DEFINED          1         69         87

FILE NAMES        MODE
       INPUT     FMT                      READS      21        27        31        37
       OUTPUT    FMT                     WRITES      22        28        39
       TAPE9     UNFMT                   WRITES      50
       VARIABLES USED AS FILE NAMES, SEE ABOVE

EXTERNALS           TYPE    ARGS         REFERENCES
       GRAF11                6               42
       MSOLVE                4               61        79
       OPLT                  0               41
       PLOT                  3               43
       QUAKE                 6               49
       SIN          REAL     1 LIBRARY       34

STATEMENT LABELS                 DEF LINE   REFERENCES
     0  10                           16          14        15
    55  15                           23          17
     0  25                           35          32
   102  30                           37          29
   116  35                           38          36
   144  90                           44          40
     0  100                          45          44
     0  260                          60          55
     0  265                          71          65
   251  270                          73         103
     0  280                          78          74
   343  340                          96          89
   362  350                         101          80        90        95
     0  360          INACTIVE       103         102
   370  400                         104       2*102
   522  1000    FMT                 105          21
   524  1001    FMT                 106          37
   527  2000    FMT                 107          22
   535  2001    FMT                 108          39
   543  2020    FMT                 109          31
   545  2040    FMT                 110          27
   547  2045    FMT                 111          28

LOOPS   LABEL     INDEX      FROM-TO     LENGTH     PROPERTIES
    13  10         I          14  16        15B                NOT INNER
    22  10         J          15  16         2B      INSTACK
    45             I          22  22         7B                EXT REFS
    67  25         K          32  35        13B                EXT REFS
   105             K          37  37        10B                EXT REFS
   121             K          39  39        10B                EXT REFS
   150  100        K          44  45         3B      INSTACK
   211  260        I          55  60        11B      INSTACK
   243  265        I          65  71         4B      INSTACK
   265  280        I          74  78        12B      INSTACK
   306  350        I          80 101        57B                EXT REFS
```

```
STATISTICS
  PROGRAM LENGTH              666B      438
          52000B SCM USED
```

```
      SUBROUTINE RESPON(XANG,W,A,STRESX,IJND,IJEL,XBUF,YBUF,XM,YM,X,Y,
     1 SIGX,SIGY,LMM,SSM,STREST,XST,XMAX,STRMAX,TX,TST,YMAX,STTMAX,TY,
     2 TTT,STRESY,HB,HL,FHX,FHY,AXBUF,AYBUF,AXM,AYM,
     3 NMO,NEQ,NANGLE,NPRINT,NNODE,NNEL,NUMNP,NUMEL,NUM,
     4 NBLOCK,NBUF,MBUF,IGRAV,DT,NT,NGRD)
C
C*********************************************************R*************
C     SUPERPOSITION OF MODES AND TIME RESPONSES OF DISPLACEMENTS
C     AND STRESSES
C*********************************************************R*************
C
      COMMON/LS4ARG/LM(12),SS(6,12),XC,YC,ELMASS(4),S(12,12),MTYPE,Q(12)
     1,C(6,6)
      DIMENSION W(1),A(NEQ,1),IJND(1),IJEL(1),XBUF(1),YBUF(1),XM(1),
     1 YM(1),X(NEQ),Y(NEQ),SIGX(6),SIGY(6),STRESX(NUM),STRESY(NUM),
     2 LMM(12,10),SSM(6,12,10),XANG(1),XMAX(1),YMAX(1),STRMAX(1),
     3 STTMAX(1),TX(1),TST(1),TY(1),TTT(1)
      DIMENSION STREST(NUM),XST(NEQ)
      DIMENSION HB(NUMNP),HL(NUMNP,NMO),FHX(NT),FHY(NT)
      DIMENSION AXBUF(NBUF),AYBUF(NBUF),AXM(NMO),AYM(NMO)
      DATA PI/0.01745293/
      IMAX=3*NUMNP
      DO 5 I=1,IMAX
      TX(I)=0.
    5 TY(I)=0.
      PRINT 2005, (W(I),I=1,NMO)
C
C     OUTPUT ANGLES
C
      READ 1002, (XANG(N),N=1,NANGLE)
      PRINT 2002, (XANG(N),N=1,NANGLE)
C
C     READ AND PRINT SELECTED NODE CIRCLES AND ELEMENTS FOR OUTPUT
C     PRINTING
C
      IF (NNODE.EQ.0) GO TO 12
      IF (NNODE.GE.NUMNP) GO TO 11
      READ 1010, (IJND(I),I=1,NNODE)
      PRINT 2010, (IJND(I),I=1,NNODE)
      GO TO 12
   11 PRINT 2012
      NNODE=NUMNP
   12 IF (NNEL.EQ.0) GO TO 18
      IF (NNEL.GE.NUMEL) GO TO 15
      READ 1010, (IJEL(I),I=1,NNEL)
      PRINT 2020, (IJEL(I),I=1,NNEL)
      GO TO 18
   15 PRINT 2022
      NNEL=NUMEL
   18 CONTINUE
C
      REWIND 3
      DO 20 I=1,NUM
   20 STREST(I)=0.
      DO 21 I=1,NEQ
   21 XST(I)=0.
      IF (IGRAV.NE.2) GO TO 24
```

```
C
C     READ FROM TAPE 3 THE STATIC RESPONSES
C
      READ (3) XST
      READ (3) STREST
      WRITE (3) NUMNP,NUMEL,NMO,DT,NT,NPRINT,IGRAV,NGRD
      WRITE (3) XST
      WRITE (3) STREST
      GO TO 25
   24 PRINT 2008
      WRITE (3) NUMNP,NUMEL,NMO,DT,NT,NPRINT,IGRAV,NGRD
   25 DO 28 MN=1,10
      DO 28 J=1,12
      LMM(J,MN)=0
      DO 28 I=1,6
      SSM(I,J,MN)=0.
   28 CONTINUE
      MN=0
      REWIND 1
      REWIND 4
      DO 40 N=1,NUMEL
      CALL READ1(LM,283,N,NUMEL)
      MN=MN+1
      DO 31 J=1,12
      LMM(J,MN)=LM(J)
      DO 31 I=1,6
      SSM(I,J,MN)=SS(I,J)
   31 CONTINUE
      IF (N.EQ.NUMEL) GO TO 32
      IF (MN.LT. 10) GO TO 40
   32 WRITE(4) LMM
      WRITE(4) SSM
      MN=0
   40 CONTINUE
      DO 50 I=1,NEQ
      YMAX(I)=0.
      Y(I)=0.
   50 XMAX(I)=0.0
      DO 60 I=1,NUM
      STTMAX(I)=0.
   60 STRMAX(I)=0.
C
      REWIND 9
      DO 90 I=1,NUMNP
      HB(I)=0.
      DO 90 MN=1,NMO
   90 HL(I,MN)=0.
      DO 100 I=1,2
      READ (9) NWALL
      IF (NWALL.LE.0) GO TO 100
      DO 95 J=1,NWALL
   95 READ (9) N,HB(N),(HL(N,MN),MN=1,NMO)
  100 CONTINUE
      READ (9) FHX
      IF (NGRD.EQ.2) READ (9) FHY
C
C     READ FROM TAPE2 AND TAPE7 THE MODAL RESPONSES
```

```
C
      REWIND 2
      REWIND 7
      IBLOCK=0
      TS=0.
      IT=1
      NB=NBUF
      M=0
  200 IBLOCK=IBLOCK+1
      IF (IBLOCK.EQ.NBLOCK) NB=MBUF
      READ (2) (XBUF(J),J=1,NB)
      READ (2) (AXBUF(J),J=1,NB)
      IF (NGRD.EQ.2) READ (7) (YBUF(J),J=1,NB)
      IF (NGRD.EQ.2) READ (7) (AYBUF(J),J=1,NB)
  205 DO 210 I=1,NMO
      M=M+1
      IF (NGRD.EQ.2) YM(I)=YBUF(M)
      IF (NGRD.EQ.2) AYM(I)=AYBUF(M)
      AXM(I)=AXBUF(M)
  210 XM(I)=XBUF (M)
      IF (NNODE.NE.0.OR.NNEL.NE.0) PRINT 2050, TS
C
C COMPUTE DISPLACEMENT
C
      IF (NNODE.NE.0) PRINT 2051
      DO 250 I=1,NUMNP
      SUM1=0.
      SUM2=0.
      SUM3=0.
      DO 220 MN=1,NMO
      SUM1=SUM1+XM(MN)*A(3*I-2,MN)
      SUM2=SUM2+XM(MN)*A(3*I-1,MN)
  220 SUM3=SUM3+XM(MN)*A(3*I,MN)
      X(3*I-2)=SUM1*12.
      X(3*I-1)=SUM2*12.
      X(3*I)=SUM3*12.
      DO 230 J=1,3
      II=3*I-3+J
      XABS=ABS(X(II))
      XX=ABS(XMAX(II))
      IF (XX.GE.XABS) GO TO 230
      XMAX(II)=X(II)
      TX(II)=TS
  230 CONTINUE
      IF (NGRD.EQ.1) GO TO 234
      SUM1=0.
      SUM2=0.
      SUM3=0.
      DO 232 MN=1,NMO
      SUM1=SUM1+YM(MN)*A(3*I-2,MN)
      SUM2=SUM2+YM(MN)*A(3*I-1,MN)
  232 SUM3=SUM3+YM(MN)*A(3*I,MN)
      Y(3*I-2)=SUM1*12.
      Y(3*I-1)=SUM2*12.
      Y(3*I)=SUM3*12.
      DO 233 J=1,3
      II=3*I-3+J
```

```
          XABS=ABS(Y(II))
          XX=ABS(YMAX(II))
          IF (XX.GE.XABS) GO TO 233
          YMAX(II)=Y(II)
          TY(II)=TS
      233 CONTINUE
      234 CONTINUE
          IF (NNODE.EQ.0) GO TO 250
          IF (NUMNP.EQ.NNODE) GO TO 237
          DO 235 II=1,NNODE
      235 IF (I.EQ.IJND(II)) GO TO 237
          GO TO 250
    C
    C COMPUTE PRESSURE
    C
      237 CONTINUE
          SUMXP=FHX(IT)*HB(I)
          SUMYP=0.
          IF (NGRD.EQ.2) SUMYP=FHY(IT)*HB(I)
          DO 238 MN=1,NMO
          SUMXP=SUMXP+AXM(MN)*HL(I,MN)
          IF (NGRD.EQ.2) SUMYP=SUMYP+AYM(MN)*HL(I,MN)
      238 CONTINUE
    C
    C COMPUTE AND PRINT FOR DIFFERENT ANGLES
    C
          DO 240 J=1,NANGLE
          THETA=XANG(J)*PI
          SUM1= X(3*I-2)*COS(THETA)+Y(3*I-2)*SIN(THETA)+XST(3*I-2)
          SUM2= X(3*I-1)*COS(THETA)+Y(3*I-1)*SIN(THETA)+XST(3*I-1)
          SUM3= X(3*I)*SIN(THETA)+Y(3*I)*COS(THETA)+XST(3*I)
          SUM4= SUMXP*COS(THETA)+SUMYP*SIN(THETA)
      240 PRINT 2060,  I,SUM1,SUM2,SUM3,SUM4,XANG(J)
      250 CONTINUE
    C
    C     WRITE ON TAPE3 DISPLACEMENTS OF ALL NODAL CIRCLES
    C
          WRITE(3) X
          IF(NGRD.EQ.2) WRITE (3) Y
    C
    C     COMPUTE ELEMENT STRESSES
    C
          REWIND 4
          IF (NNEL.NE.0) PRINT 2100
          N=0
      305 READ (4) LMM
          READ (4) SSM
          DO 390 MN=1,10
          N=N+1
          IF (N.GT.NUMEL) GO TO 400
          DO 350 I=1,6
          SIGX(I)=0.
          SIGY(I)=0.
          DO 350 J=1,12
          JJ=LMM(J,MN)
          IF (NGRD.EQ.1) GO TO 350
          SIGY(I)=SIGY(I)+SSM(I,J,MN)*Y(JJ)
```

```
  350 SIGX(I)=SIGX(I)+SSM(I,J,MN)*X(JJ)
      DO 360 J=1,6
      IF (NGRD.EQ.1) GO TO 360
      SIGY(J)=0.57870*SIGY(J)
  360 SIGX(J)=0.57870*SIGX(J)
      NN=6*N
      DO 365 I=1,6
      II=NN-6+I
      STRESX(II)=SIGX(I)
      SABS=ABS(SIGX(I))
      SMAB=ABS(STRMAX(II))
      IF (SMAB.GE.SABS) GO TO 365
      STRMAX(II)=STRESX(II)
      TST(II)=TS
  365 CONTINUE
      IF (NGRD.EQ.1) GO TO 367
      DO 366 I=1,6
      II=NN-6+I
      STRESY(II)=SIGY(I)
      SABS=ABS(SIGY(I))
      SMAB=ABS(STTMAX(II))
      IF (SMAB.GE.SABS) GO TO 366
      STTMAX(II)=STRESY(II)
      TTT(II)=TS
  366 CONTINUE
  367 CONTINUE
      IF (NNEL.EQ.0) GO TO 390
      IF (NUMEL.EQ.NNEL) GO TO 369
      DO 368 II=1,NNEL
  368 IF (N.EQ.IJEL(II)) GO TO 369
      GO TO 390
  369 DO 370 J=1,NANGLE
      THETA=XANG(J)*PI
      SUM1=SIGX(1)*COS(THETA)+STREST(NN-5)+SIGY(1)*SIN(THETA)
      SUM2=SIGX(2)*COS(THETA)+STREST(NN-4)+SIGY(2)*SIN(THETA)
      SUM3=SIGX(3)*COS(THETA)+STREST(NN-3)+SIGY(3)*SIN(THETA)
      SUM4=SIGX(4)*COS(THETA)+STREST(NN-2)+SIGY(4)*SIN(THETA)
      SUM5=SIGX(5)*SIN(THETA)+STREST(NN-1)+SIGY(5)*COS(THETA)
      SUM6=SIGX(6)*SIN(THETA)+STREST(NN)+SIGY(6)*COS(THETA)
  370 PRINT 2110, N,SUM1,SUM2,SUM3,SUM4,SUM5,SUM6,XANG(J)
  390 CONTINUE
      IF (N.LT.NUMEL) GO TO 305
C
C     WRITE ON TAPE3 STRESSES OF ALL ELEMENTS
C
  400 WRITE (3) STRESX
      IF (NGRD.EQ.2) WRITE (3) STRESY
      TS=TS+DT*NPRINT
      IT=IT+NPRINT
      M=M+(NPRINT-1)*NMO
      IF ((M+NMO).GT.NB) GO TO 500
      GO TO 205
  500 IF (IBLOCK.GE.NBLOCK) GO TO 550
      M=M-NB
      GO TO 200
  550 ANGLE=0.
      PRINT 2200, ANGLE
```

```
                     DO 570 I=1,NUMNP
                 570 PRINT 2205,  I,(TX(3*I-3+J),XMAX(3*I-3+J),J=1,3)
                     PRINT 2210,  ANGLE
                     DO 580 N=1,NUMEL
290              580 PRINT 2215,  N,(TST(6*N-6+I),STRMAX(6*N-6+I),I=1,6)
                     IF (NGRD.NE.2) RETURN
                     ANGLE=90.
                     PRINT 2200,  ANGLE
                     DO 585 I=1,NUMNP
295              585 PRINT 2205,  I,(TY(3*I-3+J),YMAX(3*I-3+J),J=1,3)
                     PRINT 2210,  ANGLE
                     DO 590 N=1,NUMEL
                 590 PRINT 2215,  N,(TTT(6*N-6+I),STTMAX(6*N-6+I),I=1,6)
                1002 FORMAT (8F10.0)
300             1010 FORMAT (16I5)
                2002 FORMAT (//14H ANGLE OUTPUT ,/(10X,F10.0))
                2005 FORMAT (//* FREQ OF SYSTEM IN RAD/SEC*/(5X,10F10.4))
                2008 FORMAT(1H1/50H STATIC RESPONSES ARE NOT INCLUDED IN TIME HISTORY)
                2010 FORMAT (//22H NODAL PTS FOR OUTPUT /(5X,10I10))
305             2012 FORMAT (//41H OUTPUTS ARE PRINTED FOR ALL NODAL POINTS /)
                2020 FORMAT (//23H ELEMENT NO FOR OUTPUT /(5X,10I10))
                2022 FORMAT (//37H OUTPUTS ARE PRINTED FOR ALL ELEMENTS /)
                2050 FORMAT (////4H  T=,F10.4,5H SEC.   )
                2051 FORMAT (//10X,24H DISPLACEMENT IN INCHES
310                 1/18X,2HNP,10X,1HR,18X,1HZ,18X,1HT,15X,8HPRESSURE,
                    2 16X,15H ANGLE(DEGREES) /)
                2060 FORMAT (15X,I5,4(4X,E15.8),10X,F10.4)
                2100 FORMAT (//10X,  15H STRESS IN PSI
                    1/15X,6H EL.NO   6X   5HSIG R   7X   5HSIG Z   7X   5HSIG T   6X   6HTAU RZ
315                 26X   6HTAU RT   6X   6HTAU ZT   7X   15H ANGLE(DEGREES)   /)
                2110 FORMAT (15X,I5,6E12.4,5X,F10.4)
                2200 FORMAT (1H1/41H DYNAMIC DISPLACEMENT ENVELOPE IN INCHES  ///
                    1 64H -DUE TO HORIZONTAL GROUND MOTION ALONG THE DIRECTION OF ANGLE
                    2= ,F5.1,////
320                 1 3X,2HNP,6X,4HTIME,11X,1HR,6X,4HTIME,11X,1HZ,6X,4HTIME,11X,1HT)
                2205 FORMAT (I5,3(2X,F8.2,E12.4))
                2210 FORMAT (1H1/32H DYNAMIC STRESS ENVELOPE IN PSI    ///
                    1 64H -DUE TO HORIZONTAL GROUND MOTION ALONG THE DIRECTION OF ANGLE
                    2= ,F5.1,////
325                 1 1X,5HEL.NO,4X,4HTIME,5X,5HSIG R,4X,4HTIME,5X,5HSIG Z,4X,4HTIME,
                    2 5X,5HSIG T,4X,4HTIME,4X,6HTAU RZ,4X,4HTIME,4X,6HTAU RT,4X,4HTIME,
                    3 4X,6HTAU ZT)
                2215 FORMAT (I6,6(F8.2,E10.4))
                     RETURN
330                  END


     SYMBOLIC REFERENCE MAP (R=2)

ENTRY POINTS      DEF LINE      REFERENCES
   3  RESPON          1          291         329
```

```
VARIABLES      SN   TYPE              RELOCATION
    0  A           REAL       ARRAY    F. P.       REFS       14      145      146      147      164      165      166
                                                DEFINED        1
 2216  ANGLE       REAL                            REFS      285      288      293      296  DEFINED      284      292
    0  AXBUF       REAL       ARRAY    F. P.       REFS       20      133  DEFINED        1      126
    0  AXM         REAL       ARRAY    F. P.       REFS       20      192  DEFINED        1      133
    0  AYBUF       REAL       ARRAY    F. P.       REFS       20      132  DEFINED        1      128
    0  AYM         REAL       ARRAY    F. P.       REFS       20      193  DEFINED        1      132
  367  C           REAL       ARRAY    LS4ARG      REFS       12
    0  DT          REAL                F. P.       REFS       63       68      276  DEFINED        1
  126  ELMASS      REAL       ARRAY    LS4ARG      REFS       12
    0  FHX         REAL       ARRAY    F. P.       REFS       19      188  DEFINED        1      111
    0  FHY         REAL       ARRAY    F. P.       REFS       19      190  DEFINED        1      112
    0  HB          REAL       ARRAY    F. P.       REFS       19      188      190  DEFINED        1      102      109
    0  HL          REAL       ARRAY    F. P.       REFS       19      192      193  DEFINED        1      104      109
 2164  I           INTEGER                         REFS       24       25       26       38       39       45       46
                                                     54       56       73     2*84       93       94       95       97
                                                     98      102      104      131      132      133      134      145
                                                    146      147      148      149      150      152      164      165
                                                    166      167      168      169      171      182      188      190
                                                    192      193    3*200    3*201    3*202      204      223      224
                                                  3*228    3*229      236      237      238      246      247      248
                                                  3*287    2*290    3*295    2*298  DEFINED       23       26       38
                                                     39       45       46       53       55       72       83       92
                                                     96      101      105      129      140      222      235      245
                                                    286      290      294      298
 2171  IBLOCK      INTEGER                         REFS      123      124      281  DEFINED      118      123
    0  IGRAV       INTEGER             F. P.       REFS       57       63       68  DEFINED        1
 2201  II          INTEGER                         REFS      153      154    2*156      157      172      173    2*175
                                                    176      182      237      239    2*241      242      247      249
                                                  2*251      252      258  DEFINED      152      171      181      236
                                                    246      257
    0  IJEL        INTEGER    ARRAY    F. P.       REFS       14       46      258  DEFINED        1       45
    0  IJND        INTEGER    ARRAY    F. P.       REFS       14       39      182  DEFINED        1       38
 2163  IMAX        INTEGER                         REFS       23  DEFINED       22
 2173  IT          INTEGER                         REFS      188      190      277  DEFINED      120      277
 2167  J           INTEGER                         REFS       71       73     2*82     2*84      125      126      127
                                                    128      152      171      199      204      226      228      229
                                                  2*232    2*233      261      268    2*287    2*295
                                                DEFINED       70       81      108      125      126      127      128
                                                    151      170      198      225      230      260      287      295
 2210  JJ          INTEGER                         REFS      228      229  DEFINED      226
    0  LM          INTEGER    ARRAY    LS4ARG      REFS       12       79       82
    0  LMM         INTEGER    ARRAY    F. P.       REFS       14       88      226  DEFINED        1       71       82
                                                    217
 2175  M           INTEGER                         REFS      130      131      132      133      134      278      279
                                                    282  DEFINED      122      130      278      282
    0  MBUF        INTEGER             F. P.       REFS      124  DEFINED        1
 2166  MN          INTEGER                         REFS       71       73       80       82       84       87      104
                                                    109    2*145    2*146    2*147    2*164    2*165    2*166    2*192
                                                  2*193      226      228      229  DEFINED       69       75       80
                                                     90      103      109      144      163      191      219
  352  MTYPE       INTEGER             LS4ARG      REFS       12
 2165  N           INTEGER                         REFS       30       31       79       86    2*109      220      221
                                                    234      258      268      270    3*290    3*298
                                                DEFINED       30       31       78      109      216      220      289
                                                    297
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        SUBROUTINE RESPON     76/176  OPT=1 STATIC                  FTN 4.8+498         03/16/81  16.39.39        PAGE     8

 VARIABLES      SN   TYPE            RELOCATION
     0  NANGLE     INTEGER                F.P.         REFS        30        31       198       260   DEFINED         1
  2174  NB         INTEGER                             REFS       125       126       127       128       279       282
                                                    DEFINED       121       124
     0  NBLOCK     INTEGER                F.P.         REFS       124       281   DEFINED         1
     0  NBUF       INTEGER                F.P.         REFS      2*20       121   DEFINED         1
     0  NEG        INTEGER                F.P.         REFS      3*14        18        55        92   DEFINED         1
     0  NGRD       INTEGER                F.P.         REFS        63        68       112       127       128       131       132
                                                        159       190       193       210       227       231       244       275
                                                        291   DEFINED         1
     0  NMO        INTEGER                F.P.         REFS        19      2*20        26        63        68       103       109
                                                        129       144       163       191       278       279
                                                    DEFINED         1
  2211  NN         INTEGER                             REFS       236       246       262       263       264       265       266
                                                        267   DEFINED       234
     0  NNEL       INTEGER                F.P.         REFS        43        44        45        46       135       215       255
                                                        256       257   DEFINED         1        49
     0  NNODE      INTEGER                F.P.         REFS        36        37        38        39       135       139       179
                                                        180       181   DEFINED         1        42
     0  NPRINT     INTEGER                F.P.         REFS        63        68       276       277       278
                                                    DEFINED         1
     0  NT         INTEGER                F.P.         REFS      2*19        63        68   DEFINED         1
     0  NUM        INTEGER                F.P.         REFS      2*14        18        53        96   DEFINED         1
     0  NUMEL      INTEGER                F.P.         REFS        44        49        63        68        78        79        86
                                                        221       256       270       289       297   DEFINED         1
     0  NUMNP      INTEGER                F.P.         REFS      2*19        22        37        42        63        68       101
                                                        140       180       286       294   DEFINED         1
  2170  NWALL      INTEGER                             REFS       107       108   DEFINED       106
  1416  PI         REAL                                REFS       199       261   DEFINED        21
   353  Q          REAL       ARRAY     LS4ARG         REFS        12
   132  S          REAL       ARRAY     LS4ARG         REFS        12
  2212  SABS       REAL                                REFS       240       250   DEFINED       238       248
     0  SIGX       REAL       ARRAY       F.P.         REFS        14       229       233       237       238       262       263
                                                        264       265       266       267   DEFINED         1       223       229
                                                        233
     0  SIGY       REAL       ARRAY       F.P.         REFS        14       228       232       247       248       262       263
                                                        264       265       266       267   DEFINED         1       224       228
                                                        232
  2213  SMAB       REAL                                REFS       240       250   DEFINED       239       249
    14  SS         REAL       ARRAY     LS4ARG         REFS        12        84
     0  SSM        REAL       ARRAY       F.P.         REFS        14        89       228       229   DEFINED         1        73
                                                         84       218
     0  STREST     REAL       ARRAY       F.P.         REFS        18        65       262       263       264       265       266
                                                        267   DEFINED         1        54        62
     0  STRESX     REAL       ARRAY       F.P.         REFS        14       241       274   DEFINED         1       237
     0  STRESY     REAL       ARRAY       F.P.         REFS        14       251       275   DEFINED         1       247
     0  STRMAX     REAL       ARRAY       F.P.         REFS        14       239       290   DEFINED         1        98       241
     0  STTMAX     REAL       ARRAY       F.P.         REFS        14       249       298   DEFINED         1        97       251
  2204  SUMXP      REAL                                REFS       192       203   DEFINED       188       192
  2205  SUMYP      REAL                                REFS       193       203   DEFINED       189       190       193
  2176  SUM1       REAL                                REFS       145       148       164       167       204       268
                                                    DEFINED       141       145       160       164       200       262
  2177  SUM2       REAL                                REFS       146       149       165       168       204       268
                                                    DEFINED       142       146       161       165       201       263
  2200  SUM3       REAL                                REFS       147       150       166       169       204       268
                                                    DEFINED       143       147       162       166       202       264
  2207  SUM4       REAL                                REFS       204       268   DEFINED       203       265
  2214  SUM5       REAL                                REFS       268   DEFINED       266
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VARIABLES     SN  TYPE           RELOCATION
  2215 SUM6      REAL                             REFS       268   DEFINED       267
  2206 THETA     REAL                             REFS     2*200     2*201     2*202     2*203     2*262     2*263     2*264
                                                 2*265     2*266     2*267   DEFINED       199       261
  2172 TS        REAL                             REFS       135       157       176       242       252       276
                                               DEFINED       119       276
     0 TST       REAL       ARRAY     F. P.       REFS        14       290   DEFINED         1       242
     0 TTT       REAL       ARRAY     F. P.       REFS        14       298   DEFINED         1       252
     0 TX        REAL       ARRAY     F. P.       REFS        14       287   DEFINED         1        24       157
     0 TY        REAL       ARRAY     F. P.       REFS        14       295   DEFINED         1        25       176
     0 W         REAL       ARRAY     F. P.       REFS        14        26   DEFINED         1
     0 X         REAL       ARRAY     F. P.       REFS        14       153       156       200       201       202       209
                                                   229   DEFINED         1       148       149       150
  2202 XABS      REAL                             REFS       155       174   DEFINED       153       172
     0 XANG      REAL       ARRAY     F. P.       REFS        14        31       199       204       261       268
                                               DEFINED         1        30
     0 XBUF      REAL       ARRAY     F. P.       REFS        14       134   DEFINED         1       125
   124 XC        REAL                LS4ARG       REFS        12
     0 XM        REAL       ARRAY     F. P.       REFS        14       145       146       147   DEFINED         1       134
     0 XMAX      REAL       ARRAY     F. P.       REFS        14       154       287   DEFINED         1        95       156
     0 XST       REAL       ARRAY     F. P.       REFS        18        64       200       201       202
                                               DEFINED         1        56        61
  2203 XX        REAL                             REFS       155       174   DEFINED       154       173
     0 Y         REAL       ARRAY     F. P.       REFS        14       172       175       200       201       202       210
                                                   228   DEFINED         1        94       167       168       169
     0 YBUF      REAL       ARRAY     F. P.       REFS        14       131   DEFINED         1       127
   125 YC        REAL                LS4ARG       REFS        12
     0 YM        REAL       ARRAY     F. P.       REFS        14       164       165       166   DEFINED         1       131
     0 YMAX      REAL       ARRAY     F. P.       REFS        14       173       295   DEFINED         1        93       175

FILE NAMES        MODE
       INPUT     FMT                   READS        30        38        45
       OUTPUT    FMT                  WRITES        26        31        39        41        46        48        67       135
                                         139       204       215       268       285       287       288       290       293
                                         295       296       298
       TAPE1                          MOTION        76
       TAPE2     UNFMT                 READS       125       126    MOTION       116
       TAPE3     UNFMT                WRITES        63        64        65        68       209       210       274       275
                                       READS        61        62    MOTION        52
       TAPE4     UNFMT                WRITES        88        89     READS       217       218    MOTION        77       214
       TAPE7     UNFMT                 READS       127       128    MOTION       117
       TAPE9     UNFMT                 READS       106       109       111       112    MOTION       100

EXTERNALS          TYPE   ARGS       REFERENCES
       COS       REAL       1 LIBRARY    200       201       202       203       262       263       264       265       266
                                         267
       READ1                4             79
       SIN       REAL       1 LIBRARY    200       201       202       203       262       263       264       265       266
                                         267

INLINE FUNCTIONS   TYPE   ARGS        DEF LINE  REFERENCES
       ABS       REAL       1  INTRIN              153       154       172       173       238       239       248       249

STATEMENT LABELS            DEF LINE   REFERENCES
     0  5                       25        23
    62 11                       41        37
    66 12                       43        36        40
   106 15                       48        44
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STATEMENT LABELS             DEF LINE   REFERENCES
  112  18                        50         43         47
    0  20                        54         53
    0  21                        56         55
  166  24                        67         57
  172  25                        69         66
    0  28                        74         69         70         72
    0  31                        85         81         83
  257  32                        88         86
  264  40                        91         78         87
    0  50                        95         92
    0  60                        98         96
    0  90                       104        101        103
    0  95                       109        108
  361  100                      110        105        107
  412  200                      123        283
  453  205                      129        280
    0  210                      134        129
    0  220                      147        144
  554  230                      158        151        155
    0  232                      166        163
  623  233                      177        170        174
  626  234                      178        159
    0  235                      182        181
  637  237                      187        180        182
    0  238                      194        191
    0  240                      204        198
  743  250                      205        140        179        183
  771  305                      217        270
 1025  350                      229        222        225        227
 1045  360                      233        230        231
 1070  365                      243        235        240
 1111  366                      253        245        250
 1114  367                      254        244
    0  368                      258        257
 1125  369                      260        256        258
    0  370                      268        260
 1220  390                      269        219        255        259
 1225  400                      274        221
 1256  500                      281        279
 1263  550                      284        281
    0  570                      287        286
    0  580                      290        289
    0  585                      295        294
    0  590                      298        297
 1755  1002     FMT             299         30
 1757  1010     FMT             300         38         45
 1761  2002     FMT             301         31
 1766  2005     FMT             302         26
 1774  2008     FMT             303         67
 2003  2010     FMT             304         39
 2010  2012     FMT             305         41
 2016  2020     FMT             306         46
 2023  2022     FMT             307         48
 2031  2050     FMT             308        135
 2035  2051     FMT             309        139
 2050  2060     FMT             312        204
 2054  2100     FMT             313        215
```

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STATEMENT LABELS              DEF LINE   REFERENCES
 2071  2110    FMT              316        268
 2075  2200    FMT              317        285        293
 2120  2205    FMT              321        287        295
 2123  2210    FMT              322        288        296
 2154  2215    FMT              328        290        298

LOOPS  LABEL    INDEX      FROM-TO    LENGTH    PROPERTIES
   20  5        I            23 25       2B      INSTACK
  120  20       I            53 54       2B      INSTACK
  127  21       I            55 56       2B      INSTACK
  173  28       MN           69 74      24B              NOT INNER
  174  28       J            70 74      20B              NOT INNER
  207  28       I            72 74       2B      INSTACK
  224  40       N            78 91      43B              EXT REFS  NOT INNER
  231  31       J            81 85      22B              NOT INNER
  246  31       I            83 85       2B      INSTACK
  275  50       I            92 95       2B      INSTACK
  305  60       I            96 98       2B      INSTACK
  313  90       I           101 104     14B              NOT INNER
  322  90       MN          103 104      2B      INSTACK
  330  100      I           105 110     34B              EXT REFS  NOT INNER
  335  95       J           108 109     24B              EXT REFS  NOT INNER
  344           MN          109 109     11B              EXT REFS
  466  210      I           129 134     10B      INSTACK
  511  250      I           140 205    235B              EXT REFS  NOT INNER
  522  220      MN          144 147      7B      INSTACK
  546  230      J           151 158     10B      INSTACK
  571  232      MN          163 166      7B      INSTACK
  615  233      J           170 177     10B      INSTACK
  632  235      II          181 182      5B      INSTACK   EXITS
  656  238      MN          191 194      7B      INSTACK
  667  240      J           198 204     54B              EXT REFS
  776  390      MN          219 269    225B              EXT REFS    EXITS    NOT INNER
 1002  350      I           222 229     33B              NOT INNER
 1021  350      J           225 229     11B      INSTACK
 1042  360      J           230 233      6B      INSTACK
 1061  365      I           235 243     11B      INSTACK
 1102  366      I           245 253     11B      INSTACK
 1120  368      II          257 258      5B      INSTACK   EXITS
 1126  370      J           260 268     72B              EXT REFS
 1267  570      I           286 287     21B              EXT REFS  NOT INNER
 1272           J           287 287     12B              EXT REFS
 1312  580      N           289 290     21B              EXT REFS  NOT INNER
 1315           I           290 290     12B              EXT REFS
 1341  585      I           294 295     21B              EXT REFS  NOT INNER
 1344           J           295 295     12B              EXT REFS
 1364  590      N           297 298     21B              EXT REFS  NOT INNER
 1367           I           298 298     12B              EXT REFS

COMMON BLOCKS   LENGTH
       LS4ARG      283

STATISTICS
  PROGRAM LENGTH                2407B    1287
  SCM LABELED COMMON LENGTH      433B     283
         52000B SCM USED
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LOAD MAP - ERST                                          CYBER LOADER 1.5-498       03/16/81  16.40.25.       PAGE    1


FWA OF THE LOAD           111
LWA+1 OF THE LOAD      173113

TRANSFER ADDRESS -- ERST            22760

PROGRAM ENTRY POINTS --       ERST          . 22760


PROGRAM AND BLOCK ASSIGNMENTS.

BLOCK        ADDRESS   LENGTH    FILE      DATE     PROCSSR VER LEVEL  HARDWARE   COMMENTS

/FCONST/         111        3
/CNTRL/          114       11
ERST             125    24765    LGO      03/16/81 FTN     4.8 498    767X I     PROGRAM    OPT=1 STATIC
MSCHECK        25112       41    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
LAYOUT         25153     3364    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
/LS4ARG/       30537      433.
ELEMENT        31172      203    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
SSLAW          31375      406    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
STRAIN         32003      303    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
MASTIF         32306     1627    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
/BUF/          34135     5416
WRITE1         41553       54    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
TOTAL          41627      400    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
READ1          42227       61    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
HYDROST        42310      271    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
STATIC         42601      365    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
BANSOL         43166      221    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
BNEIGN         43407     1327    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
EIGEN          44736    10741    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
EXT            55677      646    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
SOLEXT         56545     1736    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
BESNKS         60503      247    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
BESNIS         60752      402    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
INT            61354      565    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
BNDWTH         62141      260    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
SOLINT         62421     1053    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
PRINTA         63474      110    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
FORMH          63604      233    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
MSOLVE         64037      141    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
BANSL1         64200      356    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
QUAKE          64556      110    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
PFL            64666       15    LGO      03/16/81 COMPASS 3.6 498
TSTEP          64703      666    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
RESPON         65571     2407    LGO      03/16/81 FTN     4.8 498    767X I     SUBROUTINEOPT=1 STATIC
/DO11Z2B/      70200        3
AXIS           70203      505 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
DASH           70710      453 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
/JBL/          71363        6
STATJ          71371        7 UL-DTCPLOT  08/13/80 COMPASS 3.6 498
NEWPEN         71400       35 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
/OOI1Z2A/      71435        4
OFFSET         71441       16 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
QUADAX         71457      420 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
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BLOCK        ADDRESS   LENGTH     FILE      DATE     PROCSSR VER LEVEL  HARDWARE   COMMENTS

SCALE          72077      170 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
SETAXIS        72267      225 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
SYMBOL         72514      747 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
PDMP           73463      471 UL-DTCPLOT  10/22/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1
BUFF           74154      720 UL-DTCPLOT  10/22/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1
/DEVICE/       75074        3
PLOTS          75077       36 UL-DTCPLOT  10/28/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1
RSTR           75135       42 UL-DTCPLOT  10/28/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1
GRAF11         75177      261 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
JSTAT          75460       44 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
NUMBER         75524      243 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
WHERE          75767       32 UL-DTCPLOT  08/13/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
SLINE          76021      121 UL-DTCPLOT  08/21/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
/MULPLOT/      76142        2
MULPLT         76144      506 UL-DTCPLOT  08/21/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1 TRACE
PACK1          76652       14 UL-DTCPLOT  10/22/80 COMPASS 3.6 498
OPLT           76666      135 UL-DTCPLOT  10/28/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1
PLOT           77023      414 UL-DTCPLOT  10/28/80 FTN     4.8 498    767X I     SUBROUTINEOPT=1
ALOG10         77437        6 SL-FORTRAN  09/20/79 COMPASS 3.6 498               CALL-BY-REFERENCE LINK TO ALOG10.  .
ITOJ.          77445       32 SL-FORTRAN  09/20/79 COMPASS 3.6 498               INTEGER TO INTEGER EXPONENTIATION.  OPT=ALL
SIN            77477        6 SL-FORTRAN  09/20/79 COMPASS 3.6 498               FCL4 - EVALUATE SINE FUNCTION.CALL-BY-REFER
SINCOS.        77505       60 SL-FORTRAN  09/20/79 COMPASS 3.6 498               TRIGONOMETRIC SINE OR COSINE OF X.  OPT=ALL.
SQRT           77565        6 SL-FORTRAN  09/20/79 COMPASS 3.6 498               CALL-BY-REFERENCE LINK TO SQRT.  .
SYSAID=        77573        1 SL-FORTRAN  09/20/79 COMPASS 3.6 498               LINK BETWEEN SYS=AID AND INITIALIZATION COD
SYS=AID        77574        7 SL-FORTRAN  09/20/79 COMPASS 3.6 498               AUXILIARY MATH LIBRARY LINK FOR ERRORS.
TAN.           77603       36 SL-FORTRAN  09/20/79 COMPASS 3.6 498               TRIGONOMETRIC TANGENT.  OPT=ALL.
XTOI*          77641       11 SL-FORTRAN  09/20/79 COMPASS 3.6 498               CALL-BY-REFERENCE LINK TO XTOI.
BACKSP=        77652       55 SL-FORTRAN  04/15/80 COMPASS 3.6 498               BACKSPACE LOGICAL RECORD.
/Q8.IO./       77727      135
/FCL=ENT/     100064       42
/FCL.C./      100126       26
COMIO=        100154       10 SL-FORTRAN  04/15/80 COMPASS 3.6 498               COMMON CODED I/O ROUTINES AND CONSTANTS.
ENCODE=       100164      126 SL-FORTRAN  04/15/80 COMPASS 3.6 498               FORMATTED WRITE INTO CORE.
FCL=FDL       100312       40 SL-FORTRAN  04/15/80 COMPASS 3.6 498               FCL CAPSULE LOADING
FEIFST=       100352        3 SL-FORTRAN  04/15/80 COMPASS 3.6 498                CONVERTED DATA STORAGE
FLTOUT=       100355      315 SL-FORTRAN  04/15/80 COMPASS 3.6 498               COMMON FLOATING OUTPUT CODE
FORSYS=       100672      464 SL-FORTRAN  04/15/80 COMPASS 3.6 498               FORTRAN OBJECT LIBRARY UTILITIES.
INCOM=        101356      145 SL-FORTRAN  04/15/80 COMPASS 3.6 498               COMMON INPUT FORMATTING CODE
INPC=         101523      207 SL-FORTRAN  04/15/80 COMPASS 3.6 498               FORMATTED READ FORTRAN RECORD.
KODER=        101732      476 SL-FORTRAN  04/15/80 COMPASS 3.6 498               OUTPUT FORMAT INTERPRETER.
NAMOUT=       102430      267 SL-FORTRAN  04/15/80 COMPASS 3.6 498               NAMELIST OUTPUT ROUTINE.
/IO.BUF./     102717      227
OUTB=         103146      205 SL-FORTRAN  04/15/80 COMPASS 3.6 498               BINARY WRITE FORTRAN RECORD.
OUTCOM=       103353      204 SL-FORTRAN  04/15/80 COMPASS 3.6 498               COMMON OUTPUT CODE
REWIND=       103557       33 SL-FORTRAN  04/15/80 COMPASS 3.6 498               POSITION FILE AT BEGINNING-OF-INFORMATION.
STLCRM=       103612       31 SL-FORTRAN  04/15/80 COMPASS 3.6 498               STATIC LOADING OF FCL CAPSULES
STLIBI.       103643       24 SL-FORTRAN  04/15/80 COMPASS 3.6 498               STATIC LOAD FOR BINARY INPUT.
STLICO.       103667       16 SL-FORTRAN  04/15/80 COMPASS 3.6 498               STATIC LOAD FOR CODED INPUT.
STLREW.       103705       14 SL-FORTRAN  04/15/80 COMPASS 3.6 498               STATIC LOAD FOR REWIND.
CLOCK=        103721       53 SL-FORTRAN  04/15/80 COMPASS 3.6 498               ACCESS SYSTEM CLOCKS FOR FORTRAN.
GOTOER=       103774       14 SL-FORTRAN  04/15/80 COMPASS 3.6 498               COMPUTED GO TO ERROR PROCESSOR.
ALOG.         104010       63 SL-FORTRAN  09/20/79 COMPASS 3.6 498               COMPUTE COMMON AND NATURAL LOGARITHMS.  OPT=
EXP.          104073       73 SL-FORTRAN  09/20/79 COMPASS 3.6 498               EXPONENTIAL FUNCTION.  E TO POWER X.  OPT=ALL
EXP.MSG       104166       16 SL-FORTRAN  09/20/79 COMPASS 3.6 498               COMMON ERROR MESSAGES FOR EXPONENTIATION.
ITOJ*         104204       11 SL-FORTRAN  09/20/79 COMPASS 3.6 498               CALL-BY-REFERENCE LINK TO ITOJ.  .
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LOAD MAP - ERST                                        CYBER LOADER 1.5-498       03/16/81  16.40.25.       PAGE      3

BLOCK        ADDRESS   LENGTH    FILE       DATE      PROCSSR VER LEVEL  HARDWARE    COMMENTS

COS           104215        6 SL-FORTRAN  09/20/79 COMPASS 3.6 498                   FCL4 - EVALUATE COSINE FUNCTION.         CAL
SQRT.         104223       32 SL-FORTRAN  09/20/79 COMPASS 3.6 498                   COMPUTE THE SQUARE ROOT OF X. OPT=ALL.
SYS=1ST       104255       65 SL-FORTRAN  09/20/79 COMPASS 3.6 498                   MATH LIBRARY LINK TO ERROR MESSAGE PROCESSO
TAN           104342        6 SL-FORTRAN  09/20/79 COMPASS 3.6 498                   CALL-BY-REFERENCE LINK TO TAN.  .
XTOI.         104350       63 SL-FORTRAN  09/20/79 COMPASS 3.6 498                   REAL TO INTEGER EXPONENTIATION.
/STP.END/     104433        1
Q2NTRY=       104434        1 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   FCL INITIALIZATION ROUTINE.
FECMSK=       104435       41 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   INITIALIZE CONSTANTS.
FLTIN=        104476      156 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   COMMON FLOATING INPUT CONVERTER.
FMTAP=        104654      377 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   CRACK APLIST AND FORMAT FOR KODER/KRAKER.
FORUTL=       105253       47 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   FCL MISC. UTILITIES.
GETFIT=       105322       61 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   LOCATE AN FIT GIVEN A FILE NAME.
INPB=         105403      406 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   BINARY READ FORTRAN RECORD.
KRAKER=       106011      454 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   PROCESS FORMATTED FORTRAN INPUT.
NAMIN=        106465      527 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   NAMELIST INPUT ROUTINE.
OUTC=         107214      150 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   FORMATTED WRITE FORTRAN RECORD.
SPA=          107364       11 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   SPA= - SUBSTITUTE PARAMETER ADDRESSES.
STLBAK.       107375       12 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   STATIC LOAD FOR BACKSPACE.
STLOBI.       107407       15 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   STATIC LOAD FOR BINARY OUTPUT.
STLOCO.       107424       12 SL-FORTRAN  04/15/80 COMPASS 3.6 498                   STATIC LOAD FOR CODED OUTPUT.
CPU.SYS       107436       40 SL-SYSLIB   09/20/79 COMPASS 3.5 470                   PROCESS SYSTEM REQUEST.
CMM.KIL       107476       12 SL-SYSLIB   09/20/79 COMPASS 3.6 498                   CMM V1.1 - DEACTIVATE CMM.
CTL$PTL       107510       34 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM CONTROLLER - PARTIAL GET/PUT.
CTL$SKP       107544       57 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM CONTROLLER - SKIP PHYSICAL/FILE.
LIST$RM       107623       67 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM - ALLOCATE SPACE FOR LIST OF FILES
RM$SYS=       107712        5 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM - POST RA+1 REQUEST
CTL$RM        107717      576 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM CONTROLLING ROUTINE.
CTL$WR        110515       40 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM CONTROLLER - WEOX, REWIND
ERR$RM        110555       25 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM ERROR PROCESSOR ENTRY.
ERRCAP=       110602      324 SL-FORTRAN  04/15/80 LOADER  1.5 498
RBL$RM        110602        0 SL-SYSLIB   12/11/79 COMPASS 3.6 498                   CRM - MANIFEST BAMLIB/AAMLIB FOR STATIC LOA
FERCAP=       111126      227 SL-FORTRAN  04/15/80 LOADER  1.5 498
CHEK$SQ       111355       77 SL-BAMLIB   12/11/79 LOADER  1.5 498
CLSV$SQ       111454      222 SL-BAMLIB   12/11/79 LOADER  1.5 498
DF$CRM        111676      226 SL-BAMLIB   12/11/79 LOADER  1.5 498
EF$CRM        112124      445 SL-BAMLIB   12/11/79 LOADER  1.5 498
GET$W         112571       51 SL-BAMLIB   12/11/79 LOADER  1.5 498
GET$WA        112642      175 SL-BAMLIB   12/11/79 LOADER  1.5 498
PUT$SQ        113037      571 SL-BAMLIB   12/11/79 LOADER  1.5 498
PUT$W         113630      213 SL-BAMLIB   12/11/79 LOADER  1.5 498
PUT$WA        114043      172 SL-BAMLIB   12/11/79 LOADER  1.5 498
REW$SQ        114235      125 SL-BAMLIB   12/11/79 LOADER  1.5 498
SKBL$SQ       114362      752 SL-BAMLIB   12/11/79 LOADER  1.5 498
SKIP$SQ       115334      234 SL-BAMLIB   12/11/79 LOADER  1.5 498
WAR$SQ        115570      162 SL-BAMLIB   12/11/79 LOADER  1.5 498
CLSF$RM       115752      425 SL-BAMLIB   12/11/79 LOADER  1.5 498
COMM$WA       116377      306 SL-BAMLIB   12/11/79 LOADER  1.5 498
GET$SQ        116705      616 SL-BAMLIB   12/11/79 LOADER  1.5 498
GET$FU        117523      117 SL-BAMLIB   12/11/79 LOADER  1.5 498
GET$S         117642      505 SL-BAMLIB   12/11/79 LOADER  1.5 498
GET$Z         120347      166 SL-BAMLIB   12/11/79 LOADER  1.5 498
GPTM$SQ       120535      442 SL-BAMLIB   12/11/79 LOADER  1.5 498
LBUF$RM       121177      134 SL-BAMLIB   12/11/79 LOADER  1.5 498
OPEN$RM       121333     1332 SL-BAMLIB   12/11/79 LOADER  1.5 498
PUT$CI        122665       65 SL-BAMLIB   12/11/79 LOADER  1.5 498
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LOAD MAP - ERST                                       CYBER LOADER 1.5-498      03/16/81  16.40.25.      PAGE      4

BLOCK       ADDRESS   LENGTH    FILE      DATE      PROCSSR VER LEVEL  HARDWARE   COMMENTS

PUT$S        122752      357 SL-BAMLIB   12/11/79 LOADER  1.5 498
PUT$Z        123331       75 SL-BAMLIB   12/11/79 LOADER  1.5 498
RPE$SQ       123426      166 SL-BAMLIB   12/11/79 LOADER  1.5 498
SKFL$SQ      123614       36 SL-BAMLIB   12/11/79 LOADER  1.5 498
WEOX$SQ      123652      137 SL-BAMLIB   12/11/79 LOADER  1.5 498
FCL$RM       124011       42 SL-BAMLIB   12/11/79 COMPASS 3.6 498             LINK/DELINK STATIC CAPSULES.
PLG$RM       124011        0 SL-BAMLIB   12/11/79 COMPASS 3.6 498
 //          124053    47040


     .410 CP SECONDS            144500B CM STORAGE USED                  176 TABLE MOVES
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  UDS     UCS-176 NOS/BE 1.3 REL499-14 03/16/81
16.39.36.KCCANRE  FROM    /AN AT P 3
16.39.36.IP  00009024 WORDS - FILE INPUT  , DC 04
16.39.36.KCC,P3,T10.*********,*****,**,**,ERSTLGO
16.39.36. BUILD
16.39.38.PURGE,A,ERSTLGO,ID=DYNATECH.
16.39.39.PR ID= DYNATECH PFN=ERSTLGO
16.39.39.PR CY= 001  00013440 WORDS.
16.39.39.RETURN,A.
16.39.39.EXIT,U.
16.39.39.REQUEST,LGO,*PF.
16.39.39.FTN,R,A,STATIC.
16.40.18.     4.135 CP SECONDS COMPILATION TIME
16.40.18.CATALOG,LGO,ERSTLGO,ID=DYNATECH.
16.40.19.INITIAL CATALOG
16.40.19.RP = 999 DAYS
16.40.19.CT ID= DYNATECH PFN=ERSTLGO
16.40.19.CT CY= 001  00013440 WORDS.
16.40.19.MAP,PART.
16.40.19.ATTACH,DTCPLOT,ID=DYNATECH,MR=1.
16.40.19.PFN IS
16.40.19.DTCPLOT
16.40.20.PF CYCLE NO.  = 004
16.40.20.LIBRARY,DTCPLOT.
16.40.20.LOAD,LGO.
16.40.20.NOGO.
16.40.26.EXIT,U.
16.40.26.DAYCOPY.
16.40.29.OP  00043008 WORDS - FILE OUTPUT , DC 40
16.40.29.MS   53760  WORDS  (   96768 MAX USED)
16.40.30.CPA      4.605 SEC.
16.40.30.IO      20.561 SEC.
16.40.30.CM     514.698 KWS.
16.40.30.SRU                      16.000
16.40.30.EJ  END OF JOB, AN
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