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DYSI - Dynamic Slug Impact
Simulation for the FFTF

Hanford Engineering Development Laboratory

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DYNAMIC SLUG IMPACT
SIMULATION FOR THE FFTF

R. N. Madsen and D. E. Simpson

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DYSI
DYNAMIC SLUG IMPACT
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ABSTRACT

The DYSI simulation models the dynamics of a fluid slug impact against the head of a cylindrical vessel. The simulation is a completely coupled system representing the head, bolting system, compliant underhead material and the region of the vessel affected by the fluid slug; deformations of the system are computed in response to forces and pressures which are themselves calculated as a function of the dynamic response of the system. The model is a one-dimensional point-mass simulation which results in a large set of ordinary differential equations with associated functions that are solved by the MIMIC computer code.

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DYSI-DYNAMIC SLUG IMPACT SIMULATION FOR THE FFTF

INTRODUCTION

A primary safety concern for the FFTF is assuring that the design can accommodate the loads associated with a hypothetical core disruptive accident (HCDA) without gross structural failure. The accommodation of the accompanying energy release and the confinement of damage are objectives included in the design of such components as the reactor vessel, vessel head, head bolting, and vessel support structure.

For FFTF evaluation, two different methods are being used to gain an understanding of the mechanical consequences of the HCDA and the design features necessary to minimize these effects. One method is a primary boundary experimental program, being conducted at Stanford Research Institute (SRI), in which scale models are dynamically tested in simulation of the HCDA. The other method is through mathematical simulation of the dynamic processes. In the analysis portion of this effort, a need was recognized for a more completely coupled simulation of the mechanical consequences resulting from the impact of a sodium coolant slug on the reactor head and associated structure. Such a simulation provides a basis for review of detailed individual component calculations as well as for interpretation and extrapolations of experimental results.

Using the MIMIC⁽¹⁾ computer program as adapted to the HEDL Univac 1108 computer, a relatively straight-forward simulation was originally developed to represent the sodium slug, the upper portion of the vessel, and a simple head and head bolting system. This simulation was gradually expanded to include additional details and features and the model was christened DYSI, for DYnamic Slug Impact. DYSI is thus not a separate computer code, but more correctly a mathematical simulation using the computer code MIMIC. The version of DYSI discussed and described in this document is known more exactly as DYSI8A.

SUMMARY

The DYSI (Dynamic Slug Impact) simulation models the dynamics of a fluid slug impact on the reactor head and upper vessel. Included in the simulation are the reactor head, bolting system, thermal shield, compliant underhead tubes, and the upper portion of the vessel. Head doming effects or the simulation of a head penetration may be analyzed with the model. The simulation calculates the pressure generated by the impact of the slug as a function of the response of the head, the deformation of the crushable material and upper vessel, and the motion of the fluid slug.

The model is essentially a one-dimensional point-mass simulation with the interactions of the masses and the fluid simulated as functions of time. The head is represented by two masses (for analyses of plug dynamics one of these represents a plug, the other the head). The head is connected to a rigid structure via a force-deflection function representing the head bolting system. The thermal shield is also represented by two masses which are connected to the corresponding head masses through a force-deflection function representing the crushable material. The vessel is represented by 10 elements and incorporates the effect of the flange, ring forging and thermal liner. The slug mass and velocity are the major input functions, the model itself calculating the resulting pressure acting on the thermal shield as a function of the response of all components of the simulation. The model results in a large set of ordinary differential equations with associated functions which are solved by using the MINIC computer code.

THE DYSI SIMULATION

The DYSI simulation began as a means of providing a more complete mathematical description of the dynamics of sodium slug impact on the head following a hypothetical core disruptive accident (HCDA). The upper portion of the reactor vessel was segmented into ring elements which could plastically deform and a simple single mass head was added, restrained by a simulation of the head bolting arrangement. To this was coupled the sodium coolant impact and the ensuing deceleration of the slug as the vessel wall and head accelerated and plastically deformed. The major intent of this simulation was to combine the slug kinetics with the dynamic behavior of the vessel and vessel head structure so that a coupled analysis could be obtained, a feature lacking in other prior simulations.

This simple model was revised and enlarged by the addition of other features including an approximation for fluid radial acceleration, additional head masses, and head doming simulation. These features have combined to make the DYSI simulation a useful tool in evaluating the dynamic behavior of the head and upper reactor vessel.

THE MIMIC COMPUTER CODE

The computational tool used in creating the DYSI simulation is the MIMIC computer code⁽¹⁾. MIMIC is a digital computer program for solving systems of ordinary differential equations. The original version was written for the IBM 7090 (7094) computer, but an adaptation and conversion of the code was made by others so that the code is available on the Univac 1108.

"MIMIC is a digital computer program whose input language endows the digital computer, from the viewpoint of the user, with the parallel nature of the analog and at the same time eliminates. . . time scaling and amplitude scaling. MIMIC, then, blends the best of two worlds, the parallel operation of the analog with the large dynamic range of the digital."⁽¹⁾ The integrations performed in MIMIC use a fourth-order variable-step Runge-Kutta algorithm. The integration time step is altered internally within specified limits to keep the relative error less than a preset value.

The MIMIC language consists of the normal arithmetic operators together with a set of functions specified by three-letter mnemonic codes. MIMIC also admits the use of logical variables. The combination of these features provides a powerful means of solving systems of differential equations with diverse boundary conditions. For the sake of clarity, some of the ensuing descriptions of the DYSI simulation will make use of the variable names employed in the MIMIC coding. (A complete listing of the DYSI8A code, together with the results of the MIMIC sort, is given in the Appendix.) Another particularly useful feature of the MIMIC code is its ability to generate up to ten lineprinter plots with up to five dependent variables per plot.

DYSI MODEL DESCRIPTION

The basic configuration of the DYSI model is portrayed in Figure 1. Although various components of the model will be discussed in greater detail in the following sections, a general description of the model will be given here. The model is essentially a one-dimensional (in the z- or axial direction) point-mass simulation with the interactions of the masses and the fluid simulated as functions of time.

The reactor head is represented as two masses, one for the center and one for the outer section. These are connected and the outer section is attached to a rigid anchor via the head bolting system. Below the head masses are the thermal shielding masses; these interact with the corresponding head mass and the fluid, but not with each other. The crushable tube material between the thermal shielding and the head is also represented.

The upper reactor vessel wall, for a distance equal to the length of the fluid slug, is divided into ten segments. In the DYSI8A FFTF geometry, the length is 16.5 ft and the ten segments represent the vessel, the vessel top flange, the support ring forging and, where applicable, also include the thermal liner. The wall is designed to simulate the plastic deformation and rotation of the vessel wall as it interacts with the sodium fluid. The effect of vessel structure below the slug is generally small and is neglected in the model.

FIGURE 1. DYSI Model Configuration.

Each of these portions of the model will now be considered in detail.

A more detailed diagram of the reactor head and the thermal shielding is given in Figure 2 with the identification of some of the variable names used within this section.

FIGURE 2. Head and Thermal Shield Model.

The head is divided into two mass elements, H1 and H2. These masses are associated with an acceleration, AH1 and AH2; a velocity, VH1 and VH2; an initial velocity, which is used as an initial value in the integration, VOH1 and VOH2; a displacement, XH1 and XH2; and an initial location, XOH1 and XOH2, which is used for an initial condition on integration. A weight, WH1 and WH2, and an area, A1 and A2, are also associated with each of the masses. Similar variables are used for the thermal shielding with the addition of the letter "U" to indicate underhead; thus AUH1 is the acceleration of the thermal shielding central mass. An additional parameter is needed for the thermal shield; that is the effective thickness, TUH1 and TUH2. The datum, or zero location, is taken as the initial position of the bottom of the thermal shielding. In the current DYSI8A version, the one mass represents the central portion of the reactor head out to a radius of ~78 in. and the other mass the remaining head. However, this configuration is flexible and in some cases one mass has been used to represent various head plug areas while the other mass represented the head itself.

The dynamics of these masses are represented by Newton's second law expressed as the acceleration being equal to the summation of the forces acting on the mass divided by the mass itself.

Thermal Shield

The accelerations of the thermal shield masses are given by

$$AUH1 = (A1 * (P0 - PSH1) - WUH1)/MUH1 \quad (1)$$

and

$$AUH2 = (A2 * (P0 - PSH2) - WUH2)/MUH2. \quad (2)$$

In these expressions all the quantities have been explained with the exception of P0 and PSH1 and PSH2. P0 is the fluid pressure acting on the thermal shielding. It is a function of time and its calculation is described in the Effective Pressure section on page 13. PSH1 and PSH2 are equivalent pressure components representing the interaction of the head and thermal shielding, including the crushable tubes. The relative motion of the respective head and thermal shield masses is used to compute a crushable tube deflection. This deflection is then used with a tabulated function to determine the resulting force acting on the head and the thermal shielding.

For most of the DYSI simulations an experimental force versus deflection relationship has been available. This force is assumed to be acting only if the relative motion of the head and thermal shield are towards each other. If they are separating, a zero value is assumed for these two pressures. This neglects a small elastic rebound in the crushable tubes. These accelerations are integrated with respect to time to obtain the velocity, the initial velocity being specified as an input value. A limit is applied to this integration so that the velocity becomes zero if the displacement is less than zero. This is a physical constraint of the real system. The velocity is then integrated to determine the displacement, the initial value again being previously specified.

Vessel Head and Head Bolting

The accelerations of the vessel head masses are given by:

$$AH1 = (A1 * PSH1 - WH1 - FH12)/MH1 \quad (3)$$

and

$$AH2 = (A2 * PSH2 - WH2 + FH12 - HDF)/MH2 \quad (4)$$

All the terms have previously been defined with the exception of two, FH12 and HDF. The first of these, FH12, is the force connecting the two head masses and simulating the doming of the vessel head, which is in reality a single continuous mass. The second is the force acting on the head by the head bolting system. These will be discussed in this order.

FH12: The two mass arrangement for simulating the reactor head may be thought of as a disc in the center surrounded by a torus. FH12 then represents the force required to cause the head to deform by doming, or, in the case of the model, for one mass to move relative to the other. The force-deflection characteristic was derived by using head static deflection curves⁽²⁾. The relative displacements of the area centroids of each head mass were plotted against the static force required to produce the deflection and then a bilinear approximation to this curve was derived. This bilinear arrangement approximates an initial elastic region followed by a plastic deformation region. Logic is included so that unloading occurs on the

elastic curve rather than first retracing the plastic region of the force deflection curve. Based upon an assumed doming shape, a total lift at the center of the head is computed. As may be observed from the equations, the sign convention is for the center of the head to lift or dome upward; however, the calculations work the same in either direction.

HDF: This variable represents the total force exerted by the hold-down bolts on the outer head mass, H2. Evaluation of the effect of different head bolting systems has been one of the objectives of this analysis. Consequently, several different functions have been used. In one case the displacement of the outer head mass, H2, is used directly in a force-displacement relationship. (This is the version given in the Appendix.) In another case the displacement is used together with the strain length (HDBL) to compute a bolt strain. A bolt material stress-strain curve and the head bolt area (AHDB) may then be used to compute the total force, HDF.

The acceleration of each head mass is then integrated to determine the velocity; this velocity is then integrated to obtain the displacement. Both of these integrations are performed with the necessary boundary constraints and initial conditions.

Vessel Wall Simulation: Arrangement and Strength

The upper portion of the reactor vessel is simulated by ten cylindrical wall segments. Each segment is of constant thickness. The locations of the ring boundaries are provided in the input as distances above or below the reference datum.

The acceleration of a section of the wall of a cylinder may be given by:

$$AW = \frac{(P-S) * 2\pi R}{MW/L} \quad (5)$$

where: P = the internal pressure at the wall

S = wall stress in terms of equivalent internal pressure

R = radius of the cylinder

MW/L = mass of wall per unit length.

This equation will be more completely developed in the following section. For the present we shall concentrate on the "S" term, a value we shall also refer to as the "strength" of the wall.

The wall strength S is the sum of three components:

$$S_i = FR_i + FLM_i + FLP_i \quad (6)$$

where the subscript i refers to the particular wall segment from 1 to 10. The first of these terms, FR, represents the simple hoop stress contribution. The radial strain is computed as:

$$EPR = DRW/R \text{ [or in standard notation, } \epsilon = \Delta R/R \text{]} \quad (7)$$

A stress-strain function is then used to obtain the corresponding stress, SIGR, which is then used in the simple formula for hoop stress to compute FR:

$$FR = SIGR * W/R \quad [FR = \sigma t/r] \quad (8)$$

where W is the wall thickness of the segment.

The other two components, FLM and FLP, are the contributions due to the adjacent segment at the top and bottom of the segment being calculated. These components take into account the rotation between the segment and the adjacent segments. A diagram of a representative segment is given in Figure 3 in a displaced and rotated configuration.

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FIGURE 3. Wall Segment Strength Calculation Diagram.

In this sketch the segment length is given as L , the vessel wall thickness given as t (indicated as W in the DYSI code), and the differential wall length as dx . Letting M_y be the rotational moment of the given wall segment at collapse, i.e., yielding throughout, we obtain the following expression for M_y :

$$M_y = 2 \int_0^{L/2} P(2\pi R) x dx \quad (9)$$

where P is the equivalent pressure acting on the incremental length dx . However, the equivalent pressure can be related to the yield hoop stress by $\sigma_y = PR/t$, which results in

$$M_y = 2 \int_0^{L/2} \sigma_y t/R 2\pi R x dx \quad (10)$$

and

$$M_y = 4\pi\sigma_y t \int_0^{L/2} x dx \quad (11)$$

which on integration gives

$$M_y = \pi/2 \sigma_y t L^2. \quad (12)$$

The assumption is now made that, if rotation is occurring, the force on adjoining ring elements would be equal to the lower value of F_I calculated for the two adjoining segments. Thus

$$F_I = \frac{M_y}{L/2} = \pi \sigma_y t L \quad (13)$$

and for the segment illustrated in Figure 3

$$\begin{aligned} \text{FLMCP} &= \text{MIN} (F_I, F_I') \\ \text{FLPCP} &= \text{MIN} (F_I, F_I''). \end{aligned} \quad (14)$$

These forces are scalar values and the direction of the force must be determined. They must also be converted from a total force to a force-per-unit area basis to make them consistent with FR . In order to determine the direction of the force, inward or outward, the slope of the displacement of the segment relative to the adjoining segment--above for FLM, below for FLP--

is computed and the sign of the slope is applied to the above computed scalar value. These forces are then divided by the wall area of the associated segment, the results being designated FLMC and FLPC. These values are limited by boundary conditions which prohibit any physical discontinuities from developing. The final values are then designated FLM and FLP. These three values, FLM, FLP and FR are then summed to give the "strength" of the wall segment, S.

Effective Pressure; Fluid Radial Acceleration

The previous section began with a simple representation of the radial acceleration of a wall segment as given in Equation 5, and has defined the strength term, S. In the one-dimensional representation of the fluid, the pressure term, P, must be some kind of an average pressure. (The calculation of this average pressure will be discussed later.) However, it is not the average pressure at any location (Z) which acts upon the vessel wall segment. Some of the energy in the fluid accelerates a portion of the fluid radially as the vessel wall strains, thus affecting the pressure which acts on the wall. To incorporate this effect in the DYSI model, the following approximation was made.

The acceleration of the fluid is defined by the relationship (omitting for the time being the DYSI code nomenclature):

$$\frac{\partial P}{\partial r}(r,t) = - \rho_f a(r,t) \quad (15)$$

where $P(r,t)$ is the internal fluid pressure,

$a(r,t)$ the fluid acceleration, both as a function of time and radial location, and

ρ_f is the fluid mass density.

Neglecting wave transmission in the fluid, we assume that each fluid element maintains a constant relative radial position. Thus, we can represent the fluid acceleration as

$$a(r,t) = \frac{r}{R} * a(R,t). \quad (16)$$

On integration the preceeding equation (15) becomes:

$$P(r,t) = P_0(t) - \frac{\rho_f}{2} R^2 a(R,t). \quad (17)$$

The average pressure, $\bar{P}(t)$, is defined as

$$\begin{aligned} \bar{P}(t) &= \frac{1}{\pi R^2} \int_0^R 2\pi r P(r,t) dr \\ &= P_0(t) - \frac{\rho_f}{4} R^2 a(R,t) \end{aligned} \quad (18)$$

which, when combined with equation (17) gives:

$$P(R,t) = \bar{P}(t) - \frac{\rho_f}{4} R^2 a(R,t). \quad (19)$$

Since

$$a(R,t) = a_w \text{ [or AW in DYSI]}$$

we can then insert $P(R,t)$ for P in Equation 5 and obtain

$$a_w = [\bar{P}(t) - S - \frac{\rho_f}{4} R^2 a_w] \frac{2\pi R}{M_w/L} \quad (20)$$

which can be rearranged to give

$$a_w = \frac{[\bar{P}(t) - S] \frac{2\pi R}{M_w/L}}{1 + \frac{\rho_f}{4} R^2 \cdot \frac{2\pi R}{M_w/L}} \quad (21)$$

This expression can then be reduced to

$$a_w = (2\pi RL) \frac{[\bar{P}(t) - S]}{M_w + M_f/2} \quad (22)$$

where: M_f = mass of the fluid = $\pi R^2 L \rho_f$.

From this expression it can be seen that the inertial effect of the fluid in the radial direction is equal to one-half of the actual fluid mass when the internal pressure is treated as a constant value within the fluid and is equal to the average radial pressure.

Equation 22 can alternately be stated in a more usable form for our purposes as

$$a_w = \frac{\bar{P}(t) - S}{t_w \rho_w + \rho_f R/4} \quad (23)$$

In the DYSI simulation notation, this equation is given by

$$AW = (P-S)/TRHOP \quad (24)$$

where: $TRHOP = TRHO + M4PIR$

and $TRHO = W * RHO_w [t_w \rho_w]$

$$M4PIR = RHO_f * R/4.0 [\rho_f R/4 = M_f/4\pi RL].$$

This now becomes the equation for the radial acceleration of the wall in lieu of Equation 5. The average pressure, P , and the pressure which acts upon the thermal shield, P_0 , are, of course, not independent of each other, and are calculated in the following manner:

The sonic velocity in the sodium slug is given by:

$$c^2 = \frac{1}{\rho \kappa} \quad (25)$$

where: ρ = fluid density,

$$\kappa = \text{isentropic compressibility} = -\frac{1}{v} \frac{\partial v}{\partial P},$$

and v = specific volume.

Making the approximation that for the small time increments which will be used in these calculations,

$$\frac{1}{v} \frac{\partial v}{\partial P} \sim \frac{1}{V} \frac{\Delta V}{\Delta P} \quad (26)$$

We can solve equation 25 for ΔP , obtaining

$$\Delta P = -\rho_f c^2 \frac{\Delta V}{V}. \quad (27)$$

Taking the initial pressure to be zero, we can then determine the pressure rise due to the slug impact. In the notation of the DYSI simulation

$$PC = -RHOFC2 * DVOL/VOL \quad (28)$$

where

$$RHOFC2 = \rho_f c^2. \quad (29)$$

This pressure is then limited to a value greater than zero:

$$\begin{aligned} P_0 &= P_C & P_C > 0 \\ P_0 &= 0 & P_C \leq 0 \end{aligned}$$

This pressure is that which acts upon the thermal shield as described in the section, Vessel Head, Thermal Shield and Head Bolting, on page 7.

The calculation of DVOL/VOL in Equation 28 involves the transmission of the impact shock wave and the dynamics of the entire simulation. The change in fluid volume, DVOL, is composed of three terms: VOLW is the summation of the increased volume available for the slug resulting from the yielding of the wall; VOLH is the increase in volume from the motion of the head thermal shielding; VOLF is the amount of fluid which is accelerated upward and is equal to $A \cdot XF$, where XF is the displacement of the fluid slug. Thus,

$$DVOL = VOLW + VOLH - VOLF. \quad (30)$$

The volume through which the shock wave created by slug impact has traveled, is VOL. Once the shock wave has transversed the entire slug (in time $\tau = L/C$), the volume VOL represents the entire volume of the fluid.

The fluid slug is assumed to be driven by an expanding gas volume in the core region, thus creating the pressure, P_G , on the slug in this simulation. For our purposes, this gas is considered to be a non-condensable gas whose initial volume, V_{G0} , and pressure, P_{G0} , are specified as input values. The pressure acting on the bottom of the slug as a function of time is

$$P_G = P_{G0} * V_{G0} / (V_{G0} + VOLF). \quad (31)$$

Slug and Vessel Wall Dynamics

Newton's second law of motion is now used to determine the acceleration of the fluid slug. The acceleration of the fluid, A_F , is given by

$$A_F = [A * (P_G - P_0) - W_F] / M_F \quad (32)$$

where, to summarize,

- A = slug cross sectional area
- P_G = gas pressure acting on the bottom of the slug
- P_0 = pressure created by slug impact on the thermal shield
- W_F = weight of fluid slug
- M_F = mass of fluid slug.

Integration of this acceleration gives the velocity, V_F , with the initial velocity of the fluid being an essential input parameter. The subsequent integration of the velocity yields the displacement of the slug, X_F . The DYSI code is set up to begin at the moment of slug impact on the thermal shield, so the initial condition for the displacement X_F , is taken as the reference datum (zero), and thus the initial velocity, V_F , is the velocity of the slug at the moment of impact.

Having now defined the dynamics of the fluid slug, the pressure under the slug and the pressure resulting from the slug-thermal shield impact, we can now consider the average pressure acting on the wall segments (see Equation 24). Following slug impact on the thermal shielding, the shock wave created travels downward through the slug at acoustic velocity. Before the arrival of that wave, the pressure acting on a wall segment is a linear fraction of P_G based on the location of the wall segment; that is,

$$P = P_G - P_G(LT-L)/LT \quad (33)$$

where LT is total length and L is the center of the particular segment. Following the arrival of the slug at the wall segment, but before it has completely passed on to the next segment, the pressure is taken to be the sonic wave pressure, P_0 , and the acceleration is then weighted by the fraction of that wall segment that is subjected to this higher pressure. Once the pressure wave has completely passed the given wall segment, and before it has traversed the entire length of the slug, the pressure is taken to be P_0 . Finally, once the pressure wave has reached the bottom of the slug, reflections are neglected and the pressure is now assumed to vary linearly between P_G below the slug to P_0 at the upper surface of the slug.

All the components of Equation 24 have now been completely defined. The acceleration of each segment is then integrated to calculate the velocity. Limits are used to constrain the integration within the limits of the actual physical system. A second integration yields the radial displacement of the wall segment. Both integrations have initial conditions of zero.

VERIFICATION OF THE DYSI SIMULATION

A significant concern with all simulations is the accuracy with which the actual events are represented by the analytical model. This is of particular importance in the area of reactor safety since many such analyses are of hypothetical events for which realistic experimental results are almost impossible to obtain due to the costs, complexity and/or hazards of such an experiment. (It is for these same reasons that computer simulations are a valuable tool in such analyses.) There are, consequently, few yardsticks with which these simulations may be compared; even so, we must be able to demonstrate sufficient evidence that a specific simulation is generating acceptably accurate results. In the case of DYSI, two means have been used to assist in determining the validity of the simulation. These are: 1) the SL-1 accident results;^(3, 4) and, 2) the SRI dynamic scale model tests and feature model tests.

THE SL-1 SLUG IMPACT SIMULATED WITH DYSI

In the SL-1 accident a nuclear excursion in the core region accelerated a mass of water upward in the vessel. This slug impacted the head, generating pressures which were estimated at ~10,000 psi. As the vessel head was securely bolted to the vessel, the resulting force on the head accelerated the entire vessel upward, shearing attached piping and lifting the entire vessel ~11.4 feet.⁽³⁾ Several plugs in the reactor head, which at the time of the incident were not bolted to the head, were also expelled by the fluid slug impact. The upper vessel was also deformed by the fluid impact.

A simulation of the SL-1 vessel was created using DYSI by eliminating the thermal shield masses and making a single mass head with an associated plug. The mass of the head was made equal to the entire SL-1 vessel, in order to simulate the lifting of the entire vessel by the slug impact. Input parameters were adjusted to the SL-1 dimensions and the important parameters of slug impact velocity and weight were taken as 159 ft/sec and 6500 lbf, respectively, based upon values given by Proctor.⁽⁴⁾

From this DYSI analysis the pressure generated by the slug impact was computed to be 10,600 psi. The upward velocity imparted to the vessel is given as 35.7 ft/sec, but this does not include the slug, which at this time has a velocity of -4.44 ft/sec. Taking a mass-average velocity to determine the effective upward velocity of the vessel gives an effective upward velocity of 28.4 ft/sec, compared with the 29 ft/sec reported in the documentation.^(3, 4) An unrestrained vessel at this initial velocity would rise 12.5 ft; this neglects the energy absorbed by the impediments to free vessel rise which existed in the actual case. Finally, the actual vessel deformation (circumferential, or radial strain) versus vessel length is shown in Figure 4.

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FIGURE 4. SL-1 Strain vs. Vessel Length, Actual Compared with DYSI Analysis.

Because of uncertainties in interpreting the reported axial location of the radial strain, these curves may align much better than indicated. The maximum value of radial strain is less in the DYSI calculation by ~10%.

The results from this analysis thus lend good support to the adequacy of the DYSI simulation.

SRI TEST PROGRAM ANALYSIS AS A DYSI VERIFICATION

One of the methods being used to further understand the mechanical consequences to FFTF of a hypothetical core disruptive accident (HCDA) is the primary boundary experimental program conducted at Stanford Research Institute (SRI). This experimental program has dynamically tested scale models of the reactor vessel of varying complexity, using calibrated explosive charges to simulate the postulated excursion in the core region. Most of the early tests were of simple 1/30 scale vessels, serving to calibrate the explosive charge and other features of the model. The three final tests consist of two 1/30 scale complex models and one 1/10 scale complex model. These complex models simulate the vessel internals and underhead shielding in significant detail.

Simulation of SRI Simple Model Test #208 Using DYSI

Early in the development of the DYSI simulation, we felt that the simulation of some of the SRI simple model tests might be a way to further verify the DYSI representation. However, not all the simple tests lend themselves to simulation by DYSI without significant modifications being required in the simulation. Accordingly, one of the tests was selected which would require the least amount of changes to model with the DYSI simulation, SRI test #208.⁽⁵⁾ The modifications which were required included the addition of experimental stress-strain data for the vessel and the head bolts, and a slight revision to the upper vessel wall section arrangements. The actual dimensions of the model were used; this necessitated the inclusion of appropriate scale factors in this version of DYSI.

Since DYSI simulates only the slug impact effects occurring in the upper vessel, a direct comparison with the SRI results would not be meaningful. The SRI vessel deformation results were modified in two ways: 1) the mirror image of the lower vessel deformation was subtracted from the upper vessel strain, this to provide a good estimate of the strain caused by the

slug impact; 2) the deformation of the SRI model was assumed to go to zero at the bottom of the restraining ring located at the top of the vessel. The resulting plot of upper vessel deformation caused by fluid slug impact is given as the dashed curve in Figure 5. The upper DYSI result is for the maximum probable slug velocity of 32.61 m/sec, results which are slightly higher than the experimental. However, it has been estimated that as much as 0.4 kW-sec of energy went into compressing the gas between the fluid and the cover. Subtracting this energy from the 2.55 kW-sec total and then computing the slug velocity results in an estimated velocity at impact of 30.42 m/sec. These results compare very closely with the experimental curve and support the validity of the DYSI representation.

Simulation of SRI Complex Model Tests:

The initial simulations of the SRI complex model tests were performed for pre-shot analysis of the plug bolting arrangement (see page 25). However, following the experiment, comparison with the actual results provided another opportunity to ascertain the accuracy of the DYSI simulation.

The DYSI simulation of the SRI 1/30 scale complex model is essentially identical to the FFTF simulation with the addition of the scaling factors and the correspondingly changed dimensions. The vessel material stress-strain curve and the crushable tube force-deflection relationship were also changed to reflect the actual experimentally determined values for the SRI model.

A reproduction of the actual upper vessel deformation⁽⁶⁾ is presented as the solid curve in Figure 6. (The upper portion of the curve is dashed, as it was also presented by SRI in this form. This is probably due to the relatively large top flange which rotated slightly in the test.) In this complex model test the energy in the slug was much lower than anticipated. The experimental determination of the two most important parameters for the DYSI simulation, the velocity at impact and the mass of the slug, was difficult, and at best uncertain. Understanding these difficulties, Figure 6 also presents DYSI results for two different calculations of slug conditions. The lower of the two curves (7S2.1) is based on a HEDL

FIGURE 5. SRI Test #208 Compared with Its DYSI Simulation.

HEDL 7211-54.5

FIGURE 6. SRI Complex Model and DYSI Simulation.

calculation in which a slug mass of 2300g (5.0705 lbm) and a velocity of 15.24 m/sec (50 ft/sec) were used. The other curve is based upon SRI's estimate of slug mass, 4720g (10.405 lbm), and the ANL-REXCO prediction of slug velocity at impact, 14.00 m/sec (45.9 ft/sec).

The second of the SRI complete model tests, CM-30-2, included fluid level indicators. Preliminary interpretation of the results from this test substantiate a fluid slug impact velocity of ≈ 50 ft/sec.⁽⁷⁾

The comparison between the DYSI calculations and the complex model experimental results are not so striking as with the simple model results. The reasons for this are not precisely known, but must include the fact that knowledge of the complex model boundary conditions are not well known.

Consideration of the results presented in Figure 6, particularly with respect to the actual dimensions of the vessel, indicate that the method used to simulate the vessel wall does not perform as well at the location of large changes in vessel wall thickness such as occur at the vessel support ring. It is also evident that the effects of the vessel liner are not as great as would result from its inclusion as equivalent vessel wall thickness. Nevertheless, the comparison lends support to the usefulness of the DYSI simulation.

APPLICATIONS OF THE DYSI SIMULATION

The presentation of analyses performed with the DYSI simulation is not within the scope of this report; yet a brief discussion of the several applications of DYSI made so far should help to portray the capabilities of the DYSI simulation.

HEAD PENETRATION DYNAMIC ANALYSIS

One of the major purposes for DYSI, as originally conceived, was the ability to simulate the effect of the HCDA on the head penetrations and the plugs which are attached to the head at those penetrations. For example, analysis of the In-Vessel Handling Machine (IVHM) plug's dynamic bolting characteristics has been performed with DYSI. In this analysis one head mass represents the plug and appropriate force-deflection or stress-strain relationships are used for the bolting.

SRI COMPLEX MODEL PRE-SHOT ANALYSIS

In a manner similar to the above, the IVHM and Instrument Tree (IT) plugs on the SRI 1/30 scale complex model were simulated in order to study the adequacy of the holddown bolting prior to the actual experiment. The bolting on the model's plugs is not prototypic of the actual vessel. To allow for uncertainties in the experiment, the analysis was performed for a range of slug energies extending well above what was anticipated.

FFTF DYNAMIC ANALYSIS AND DESIGN AUDIT

A foremost use of the DYSI simulation has been the dynamic analysis of the response of the entire reactor head system to the postulated HCDA slug impact and the effect of various design alternatives. In this area the DYSI simulation has been used by HEDL to provide an independent audit capability for use in reviewing proposed designs. Among the features studied using the DYSI simulation have been the following: the head bolting system, crushable tube characteristics, thermal shield design and spacing, and plug bolting material. Additional features, such as additional head mounted components and plugs will no doubt be simulated with DYSI in the near future.

CONCLUSION

The DYSI simulation has provided a simple, yet effective means for analyzing the mechanical consequences of the head and upper vessel of a fluid slug impact. The analysis is completely coupled and requires a minimum of dynamic input, in particular only the fluid mass and velocity at the time of impact, in order to calculate the resulting forces and pressures and the corresponding dynamic responses. The simulation is easily modified to represent a large variety of configurations, and has been used with a change in input, to look at water slug cases, in particular the SL-1 accident and the SRI experiments.

Although DYSI was originally intended for the analysis of the plugs which penetrate the reactor vessel head, the simulation reported here can not only model these penetrations, but also can simulate head doming effects, bolting system responses and thermal shield design effects.

REFERENCES

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2. K. Draper and A. Snow. The Ultimate Load Carrying Capacity of the Primary Vessel Head, FRA-535. Westinghouse Advanced Reactors Division, Madison, Pennsylvania, December 1971.
3. Final Report of SL-1 Recovery Operation, IDO-19311, SL-1 Project, General Electric Company, July 27, 1962.
4. J. F. Proctor. "Adequacy of Explosion-Response Data in Estimating Reactor-Vessel Damage," Nuclear Safety, 8:6, November-December 1967.
5. Memo, D. D. Stepnewski (HEDL) to R. E. Peterson (HEDL), "Summary of Primary Boundary Test Program Meeting," February 17, 1972 (Attachment).
6. Memo, A. L. Florence (SRI) to D. D. Stepnewski (HEDL), (preliminary results from test CM-30-1), July 14, 1972.
7. Memo, A. L. Florence (SRI) to D. D. Stepnewski (HEDL), (preliminary results from test CM-30-2), November 1, 1972.

APPENDIX

DYSI CODE LISTING

DYSI8A Version

Including MIMIC Sort.

The following listing shows the actual MIMIC code for the DYSI8A version of the DYSI simulation. The commentary at the beginning of the listing explains the case. All control cards for processing the simulation have been deleted. The left-hand line numbers are for reference only in this listing and do not form part of the input. The asterisk on the first card is the first column of the input.

```

1 *          DYSI CODE ** BY R. N. MADSEN AND D. E. SIMPSON
2 *          HANFORD ENGINEERING DEVELOPMENT LABORATORY
3 *          DYSI8A VERSION * CREATED 9-8-72 * REVISED 9-25-72
4 *
5 *          DYSI CODE ANALYSES THE INERTIAL IMPACT OF THE SODIUM
6 *          SLUG WITH THE REACTOR HEAD AND THE RESULTING PLASTIC
7 *          DEFORMATION OF THE HEAD AND REACTOR COVER. INCLUDES
8 *          HEAD DOMING MODIFICATION; TWO HEAD MASSES AND TWO
9 *          THERMAL SHIELD MASSES ARE USED. HEAD ROTATIONAL
10 *         DYNAMICS ARE SIMULATED FOR COMPARISON WITH ARD'S WORK.
11 *
12 *         REVISED HEDL BOLT DEFLECTION CURVE
13 *         ARD COMPOSITE BOLT DEFLECTION DATA
14 *         ARD CRUSHABLE INTERHEAD MATERIAL ** AS PER FRA-815
15 *
16 *
17 *         INPUT DATA ** ENGINEERING UNITS ON ALL DATA **
18         HDBF      CFN(10.)
19         CTPF      CFN(12.)
20                 CON(C,R)
21 *
22 *         DIMENSIONS:
23         CON(L1,L2,L3,L4,L5,L6)
24         CON(L7,L8,L9,L10,LT,L0)
25         CON(W1,W2,W3,W4,W5,W6)

```

```

26          CON(W7,W8,W9,W10)
27 *
28 *
29          INITIAL CONDITIONS:
30          PAR(WF,VCF,XOF)
31          PAR(PG0,VG0)
32          PAR(WUH1,V0UH1,X0UH1,TUH1,A1)
33          PAR(WUH2,V0UH2,X0UH2,TUH2)
34          PAR(WH1,V0H1,X0H1)
35          PAR(WH2,V0H2,X0H2)
36          PAR(AHDB,HDBL)
37 *
38          FINAL TIME:
39          PAR(TF)
40 *
41 *
42 *          ** SUBPROGRAMS **
43          WALL ACCELERATION CALCULATIONS FOR ALL SEGMENTS
44          WALL =BSP(LJ,LJM,SJ,TRHOJP)
45          TJ =LJ/C
46          TJM =LJM/C
47          TLETJ =FSW(T-TJ,TRUE,TRUE,FALSE)
48          TGTTJ =NOT(TLETJ)
49          TLETJM =FSW(T-TJM,TRUE,TRUE,FALSE)
50          TGTTJM =NOT(TLETJM)
51          JPJ =PG-PG*(LT-(LJ+LJM)/2.0)/LT
52          JAWJ =(JPJ-SJ)/TRHOJP
53          IAWJ =(JPJ-SJ)/TRHOJP*(C*T-LJM)/(LJ-LJM)
54          IPJ =JPJ
55          IPJ =P0
56          IAWJ =(IPJ-SJ)/TRHOJP
57          AWJ =IAWJ
58          PJ =IPJ
59          PJ =PG+(P0-PG)*(LT-(LJ+LJM)/2.0)/LT
60          AWJ =(PJ-SJ)/TRHOJP
61

```

```

62      WALL      =ESP(AWJ,PJ)
63 *
64      STRFLP     =BSP(DENOMJ,FIJ,FIJJ,DDDRPJ)
65      FLPJA      =FIJ/DENOMJ
66      FLPJB      =FIJJ/DENOMJ
67      FLPJCP     =MIN(FLPJA,FLPJB)
68      FLPJC      =FLPJCP*DDDRPJ/ABS(DDDRPJ)
69      STRFLP     =ESP(FLPJ,FLPJCP,FLPJA,FLPJB)
70 *
71      STRFLM     =BSP(DENOMJ,FIJ,FIJM,DDDRMJ)
72      FLMJA      =FIJ/DENOMJ
73      FLMJB      =FIJM/DENOMJ
74      FLMJCP     =MIN(FLMJA,FLMJB)
75      FLMJC      =FLMJCP*DDDRMJ/ABS(DDDRMJ)
76      STRFLM     =ESP(FLMJ,FLMJCP,FLMJA,FLMJB)
77 *
78      STRFRI     =BSP(DRWJ,LJ,LJM,WJ)
79      RJ         =R + DRWJ
80      DENOMJ     =2.0*RJ*(LJ-LJM)
81      EPRJ       =DRWJ/R*100.
82      EPRJ2      =EPRJ*EPRJ
83      EPRJ3      =EPRJ*EPRJ2
84      SIGRJ1     =17.992+5.0711*EPRJ-.3183*EPRJ2+8.2451*EPRJ3/1000.
85      SIGRJ      =SIGRJ1*1000.
86      FIJ        =144.0*SIGRJ*WJ*(LJ-LJM)
87      FRJ        =144.0*SIGRJ*WJ/R
88      TRHOJ      =WJ*RHOW
89      M4PIRJ     =RJ*RHOW/4.0
90      TRHOJP     =TRHOJ + M4PIRJ
91      STRFRI     =ESP(FRJ,FIJ,RJ,DENOMJ,TRHOJP,M4PIRJ)
92 *
93 *      SUBPROGRAM TO CALCULATE CENTRAL AND WALL PRESSURES
94      DELPF      =BSP(RI,AWI,M4PIRI,PI)
95      DPFI       =M4PIRI*2.0*AWI
96      PCI        =PI + DPFI/2.0
97      PWI        =PI - DPFI/2.0

```



```

98      DELPF    =ESP(PCI,PWI,DPFI)
99  *
100  *
101  *      TIME AND OUTPUT CONTROLS:
102      CHANGE  =FSW(T-.00019,FALSE,TRUE,TRUE)
103      INIT    =NOT(CHANGE)
104  INIT      DT      =.00001
105  CHANGE    DT      =.00002
106      DTMIN   =.00001
107      START   =FSW(T,TRUE,TRUE,FALSE)
108      RUN     =NOT(START)
109      STOP    =FSW(VH2,TRUE,FALSE,FALSE)
110      NSTOP   =NOT(STOP)
111  NSTOP     TFIN    =TF
112  NSTOP     TSTOP   =T + .003
113  STOP      TFIN    =TSTOP
114      FIN(T,TFIN)
115  *
116  *      INITIAL CALCULATIONS AND DATA
117  START     XTST    =0.0
118  START     RHOW    =15.463
119  START     RHOF     =1.5842
120  START     TAU     =LT/C
121  START     G       =32.174
122  START     RHOF2    =RHOF*C*C
123  START     MF      =WF/G
124  START     MH1     =WH1/G
125  START     MH2     =WH2/G
126  START     MUH1    =WUH1/G
127  START     MUH2    =WUH2/G
128  START     A       =3.1416*R*R
129  START     A2      =A-A1
130  START     PCONV    =2116.8
131  START     DELOH1   =XOH1-XOUH1-TUH1
132  START     DELOH2   =XOH2-XOUH2-TUH2
133  *

```

```

134 *      FLUID PRESSURE, ACCELERATION, VELOCITY AND DISPLACEMENT
135      PG      =PG0*VG0/(VG0+VOLF)
136      PC      =-RHOFC2*DVOL/VOL
137      P0      =LIM(PC,0.0,ABS(PC))
138      P0ATM    =P0/PCONV
139      TMSEC    =T*1000.
140      DVOL     =VOLW + VOLH - VOLF
141      AF       =(A*(PG-P0)-WF)/MF
142      VF       =INT(AF,VCF)
143      XF       =INT(VF,XCF)
144      VOLF     =A*XF
145      VOLIP    =C*A*T
146      TLETAU   =FSW(T-TAU,TRUE,TRUE,FALSE)
147      TGTtau   =NOT(TLETAU)
148      VOL      =VOLIP
149      TGTtau   =A*LT
150 *
151 *      HEAD ACCELERATION, VELOCITY AND DISPLACEMENT
152      AUH1     =(A1*(P0-PSH1)-WUH1)/MUH1
153      VUH1C    =INT(AUH1,V0UH1)
154      VUH1     =LIN(VUH1C,XUH1,0.0,ABS(XUH1))
155      XUH1C    =INT(VUH1,X0UH1)
156      XUH1     =LIM(XUH1C,0.0,ABS(XUH1C))
157      DELH1    =XH1-XUH1-TUH1
158      DELCT1   =DELOH1-DELH1
159      U1       =FSW(VH1-VUH1,TRUE,TRUE,FALSE)
160      D1       =NOT(U1)
161      PSH1     =FUN(CTPF,DELCT1)
162      PSH1     =0.0
163      AUH2     =(A2*(P0-PSH2)-WUH2)/MUH2
164      VUH2C    =INT(AUH2,V0UH2)
165      VUH2     =LIN(VUH2C,XUH2,0.0,ABS(XUH2))
166      XUH2C    =INT(VUH2,X0UH2)
167      XUH2     =LIM(XUH2C,0.0,ABS(XUH2C))
168      DELH2    =XH2-XUH2-TUH2
169      DELCT2   =DELOH2-DELH2

```

```

170      U2      =FSW(VH2-VUH2,TRUE,TRUE,FALSE)
171      D2      =NOT(U2)
172      U2      PSH2      =FUN(CTPF,DELCT2)
173      U2      PSH2      =0.0
174      AH1     =(A1*PSH1-WH1-FH12)/MH1
175      CHK1A   =FSW(AH1,FALSE,TRUE,TRUE)
176      CHK1B   =FSW(PXH1,FALSE,FALSE,TRUE)
177      CHK1C   =IOR(CHK1A,CHK1B)
178      VH1     =INT(AH1,V0H1,CHK1C)
179      XH1     =INT(VH1,X0H1)
180      AH2     =(A2*PSH2-WH2+FH12-HDF)/MH2
181      CHK2A   =FSW(AH2,FALSE,TRUE,TRUE)
182      CHK2B   =FSW(PXH2,FALSE,FALSE,TRUE)
183      CHK2C   =IOR(CHK2A,CHK2B)
184      VH2     =INT(AH2,V0H2,CHK2C)
185      XH2     =INT(VH2,X0H2)
186      DH12    =PXH1-PXH2
187      DHCNTR  =2.093*DH12
188      DHCIN   =DHCNTR*12.
189      DHTOT   =DHCNTR+DXH
190      DHTIN   =DHTOT*12.
191      XCONP   =.68139*DH12 - .03882
192      XCON    =LIM(XCONP,0.0,ABS(XCONP))
193      X0      =MAX(XTST,XCON)
194      XTST    =TDL(X0,0.0,3.0)
195      FH12    =1.566*(DH12-X0)*10000.*10000.
196      DDHDR   =-DH12/4.6079
197      DDHDT   =DER(DDHDR,T,0.0)
198      DDHDT2  =DER(DDHDT,T,0.0)
199      VOLH    =A1*XUH1+A2*XUH2
200      PSH1AT  =PSH1/PCONV
201      PSH2AT  =PSH2/PCONV
202      PXUH1   =XUH1-X0UH1
203      PXUH2   =XUH2-X0UH2
204      PXH1    =XH1-X0H1
205      PXH2    =XH2-X0H2

```

```

206      DXH      =PXH2
207      HBSTR     =DXH*100./HDBL
208      HDBF      =FUN(HDBF,DXH)
209      HDF       =HDBF*1000.*3000.
210 *           FUN(HDBF) IS FOR A SINGLE 'COMPOSITE' HEAD BOLT
211 *           OF WHICH THERE ARE 30 ON THE REACTOR HEAD.
212 *
213 * WALL PSEUDO-STRENGTH CALCULATIONS
214 *
215      STRFRI     =CSP(DRW1,L1,L0,W1)
216                RSP(FR1,FI1,R1,DENOM1,TRH01P,M4PIR1)
217      STRFRI     =CSP(DRW2,L2,L1,W2)
218                RSP(FR2,FI2,R2,DENOM2,TRH02P,M4PIR2)
219      STRFRI     =CSP(DRW3,L3,L2,W3)
220                RSP(FR3,FI3,R3,DENOM3,TRH03P,M4PIR3)
221      STRFRI     =CSP(DRW4,L4,L3,W4)
222                RSP(FR4,FI4,R4,DENOM4,TRH04P,M4PIR4)
223      STRFRI     =CSP(DRW5,L5,L4,W5)
224                RSP(FR5,FI5,R5,DENOM5,TRH05P,M4PIR5)
225      STRFRI     =CSP(DRW6,L6,L5,W6)
226                RSP(FR6,FI6,R6,DENOM6,TRH06P,M4PIR6)
227      STRFRI     =CSP(DRW7,L7,L6,W7)
228                RSP(FR7,FI7,R7,DENOM7,TRH07P,M4PIR7)
229      STRFRI     =CSP(DRW8,L8,L7,W8)
230                RSP(FR8,FI8,R8,DENOM8,TRH08P,M4PIR8)
231      STRFRI     =CSP(DRW9,L9,L8,W9)
232                RSP(FR9,FI9,R9,DENOM9,TRH09P,M4PIR9)
233      STRFRI     =CSP(DRW10,L10,L9,W10)
234                RSP(FR10,FI10,R10,DENOM0,TRH00P,M4PIR0)
235 *
236      DRP1       =DRW1-DRW2
237      DDDRP1     =DER(DRP1,T,0.0)
238      DDDRP1     =DER(ABS(DRP1),T,0.0)
239      STRFLP     =CSP(DENOM1,FI1,FI2,DDDRP1)
240                RSP(FLP1C,FLP1CP,FLP1A,FLP1B)
241      FLP1       =LIN(FLP1C,DDDRP1,0.0,ABS(DDDRP1))

```

```

242      FLM1      =2.0*FI1/(2.0*R1*(L1-L0))
243      S1        =FR1+FLM1+FLP1
244  *
245      DRP2      =DRW2-DRW3
246      DRM2      =DRW2-DRW1
247      STRFLP    =CSP(DENOM2,FI2,FI3,DDDRP2)
248                RSP(FLP2C,FLP2CP,FLP2A,FLP2B)
249      STRFLM    =CSP(DENOM2,FI2,FI1,DDDRM2)
250                RSP(FLM2C,FLM2CP,FLM2A,FLM2B)
251      DDDR2     =DER(DRP2,T,0.0)
252      DDDR2     =DER(DRM2,T,0.0)
253      DDDR2     =DER(ABS(DRM2),T,0.0)
254      DDDR2     =DER(ABS(DRP2),T,0.0)
255      FLM2      =LIN(FLM2C,DDDR2,0.0,ABS(DDDR2))
256      FLP2      =LIN(FLP2C,DDDR2,0.0,ABS(DDDR2))
257      S2        =FR2+FLM2+FLP2
258  *
259      DRP3      =DRW3-DRW4
260      DRM3      =DRW3-DRW2
261      STRFLP    =CSP(DENOM3,FI3,FI4,DDDRP3)
262                RSP(FLP3C,FLP3CP,FLP3A,FLP3B)
263      STRFLM    =CSP(DENOM3,FI3,FI2,DDDRM3)
264                RSP(FLM3C,FLM3CP,FLM3A,FLM3B)
265      DDDR3     =DER(DRP3,T,0.0)
266      DDDR3     =DER(DRM3,T,0.0)
267      DDDR3     =DER(ABS(DRM3),T,0.0)
268      DDDR3     =DER(ABS(DRP3),T,0.0)
269      FLM3      =LIN(FLM3C,DDDR3,0.0,ABS(DDDR3))
270      FLP3      =LIN(FLP3C,DDDR3,0.0,ABS(DDDR3))
271      S3        =FR3+FLM3+FLP3
272  *
273      DRP4      =DRW4-DRW5
274      DRM4      =DRW4-DRW3
275      STRFLP    =CSP(DENOM4,FI4,FI5,DDDRP4)
276                RSP(FLP4C,FLP4CP,FLP4A,FLP4B)
277      STRFLM    =CSP(DENOM4,FI4,FI3,DDDRM4)

```

```

278      RSP(FLM4C,FLM4CP,FLM4A,FLM4B)
279      DDDR4 =DER(DRP4,T,0.0)
280      DDDR4 =DER(DRM4,T,0.0)
281      DDDR4 =DER(ABS(DRM4),T,0.0)
282      DDDR4 =DER(ABS(DRP4),T,0.0)
283      FLM4 =LIN(FLM4C,DDR4,0.0,ABS(DDR4))
284      FLP4 =LIN(FLP4C,DDR4,0.0,ABS(DDR4))
285      S4 =FR4+FLM4+FLP4
286 *
287      DRP5 =DRW5-DRW6
288      DRM5 =DRW5-DRW4
289      STRFLP =CSP(DENOM5,FI5,FI6,DDR5)
290      RSP(FLP5C,FLP5CP,FLP5A,FLP5B)
291      STRFLM =CSP(DENOM5,FI5,FI4,DDR5)
292      RSP(FLM5C,FLM5CP,FLM5A,FLM5B)
293      DDDR5 =DER(DRP5,T,0.0)
294      DDDR5 =DER(DRM5,T,0.0)
295      DDDR5 =DER(ABS(DRM5),T,0.0)
296      DDDR5 =DER(ABS(DRP5),T,0.0)
297      FLM5 =LIN(FLM5C,DDR5,0.0,ABS(DDR5))
298      FLP5 =LIN(FLP5C,DDR5,0.0,ABS(DDR5))
299      S5 =FR5+FLM5+FLP5
300 *
301      DRP6 =DRW6-DRW7
302      DRM6 =DRW6-DRW5
303      STRFLP =CSP(DENOM6,FI6,FI7,DDR6)
304      RSP(FLP6C,FLP6CP,FLP6A,FLP6B)
305      STRFLM =CSP(DENOM6,FI6,FI5,DDR6)
306      RSP(FLM6C,FLM6CP,FLM6A,FLM6B)
307      DDDR6 =DER(DRP6,T,0.0)
308      DDDR6 =DER(DRM6,T,0.0)
309      DDDR6 =DER(ABS(DRM6),T,0.0)
310      DDDR6 =DER(ABS(DRP6),T,0.0)
311      FLM6 =LIN(FLM6C,DDR6,0.0,ABS(DDR6))
312      FLP6 =LIN(FLP6C,DDR6,0.0,ABS(DDR6))
313      S6 =FR6+FLM6+FLP6

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314 *
315     DRP7      =DRW7-DRW8
316     DRM7      =DRW7-DRW6
317     STRFLP    =CSP(DENOM7,FI7,FI8,DDDRP7)
318             RSP(FLP7C,FLP7CP,FLP7A,FLP7B)
319     STRFLM    =CSP(DENOM7,FI7,FI6,DDDRM7)
320             RSP(FLM7C,FLM7CP,FLM7A,FLM7B)
321     DDDR7     =DER(DRP7,T,0.0)
322     DDDR7     =DER(DRM7,T,0.0)
323     DDDR7     =DER(ABS(DRM7),T,0.0)
324     DDDR7     =DER(ABS(DRP7),T,0.0)
325     FLM7      =LIN(FLM7C,DDDR7,0.0,ABS(DDDR7))
326     FLP7      =LIN(FLP7C,DDDR7,0.0,ABS(DDDR7))
327     S7        =FR7+FLM7+FLP7
328 *
329     DRP8      =DRW8-DRW9
330     DRM8      =DRW8-DRW7
331     STRFLP    =CSP(DENOM8,FI8,FI9,DDDRP8)
332             RSP(FLP8C,FLP8CP,FLP8A,FLP8B)
333     STRFLM    =CSP(DENOM8,FI8,FI7,DDDRM8)
334             RSP(FLM8C,FLM8CP,FLM8A,FLM8B)
335     DDDR8     =DER(DRP8,T,0.0)
336     DDDR8     =DER(DRM8,T,0.0)
337     DDDR8     =DER(ABS(DRM8),T,0.0)
338     DDDR8     =DER(ABS(DRP8),T,0.0)
339     FLM8      =LIN(FLM8C,DDDR8,0.0,ABS(DDDR8))
340     FLP8      =LIN(FLP8C,DDDR8,0.0,ABS(DDDR8))
341     S8        =FR8+FLM8+FLP8
342 *
343     DRP9      =DRW9-DRW10
344     DRM9      =DRW9-DRW8
345     STRFLP    =CSP(DENOM9,FI9,FI10,DDDRP9)
346             RSP(FLP9C,FLP9CP,FLP9A,FLP9B)
347     STRFLM    =CSP(DENOM9,FI9,FI8,DDDRM9)
348             RSP(FLM9C,FLM9CP,FLM9A,FLM9B)
349     DDDR9     =DER(DRP9,T,0.0)

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350      DDDRM9 =DER(DRM9,T,0.0)
351      DDRM9  =DER(ABS(DRM9),T,0.0)
352      DDRP9  =DER(ABS(DRP9),T,0.0)
353      FLM9    =LIN(FLM9C,DDRM9,0.0,ABS(DDRM9))
354      FLP9    =LIN(FLP9C,DDRP9,0.0,ABS(DDRP9))
355      S9      =FR9+FLM9+FLP9
356 *
357      FLP10   =0.0
358      DRM10   =DRW10-DRW9
359      DDDRM10 =DER(ABS(DRM10),T,0.0)
360      DDDRM0  =DER(DRM10,T,0.0)
361      STRFLM  =CSP(DENOM0,FI10,FI9,DDDRM0)
362              RSP(FLM10C,FLM0CP,FLM10A,FLM10B)
363      FLM10   =LIN(FLM10C,DDRM10,0.0,ABS(DDRM10))
364      S10     =FR10+FLM10+FLP10
365 *
366 *      WALL ACCELERATION, VELOCITY AND DISPLACEMENT CALCULATIONS
367      WALL    =CSP(L1,L0,S1,TRH01P)
368              RSP(AW1,P1)
369      P1ATM   =P1/PCONV
370      VLEN1   =FSW(VW1,TRUE,TRUE,FALSE)
371      VGTN1   =NOT(VLEN1)
372      VLEN1   AW1X   =LIM(AW1,0.0,ABS(AW1))
373      VGTN1   AW1X   =AW1
374      VW1     =INT(AW1X,0.0)
375      DRW1    =INT(VW1,0.0)
376      DELPF   =CSP(R1,AW1X,M4PIR1,P1)
377              RSP(PC1,PW1,DPF1)
378      VOLW1   =6.283*R*L1*DRW1
379      WALL    =CSP(L2,L1,S2,TRH02P)
380              RSP(AW2,P2)
381      P2ATM   =P2/PCONV
382      VLEN2   =FSW(VW2,TRUE,TRUE,FALSE)
383      VGTN2   =NOT(VLEN2)
384      VLEN2   AW2X   =LIM(AW2,0.0,ABS(AW2))
385      VGTN2   AW2X   =AW2

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386		VW2	=INT(AW2X,0.0)
387		DRW2	=INT(VW2,0.0)
388		DELPF	=CSP(R2,AW2X,M4PIR2,P2)
389			RSP(PC2,PW2,DPF2)
390		VOLW2	=6.283*R*(L2-L1)*DRW2
391		WALL	=CSP(L3,L2,S3,TRH03P)
392			RSP(AW3,P3)
393		P3ATM	=P3/PCONV
394		VLEN3	=FSW(VW3,TRUE,TRUE,FALSE)
395		VGTN3	=NOT(VLEN3)
396	VLEN3	AW3X	=LIM(AW3,0.0,ABS(AW3))
397	VGTN3	AW3X	=AW3
398		VW3	=INT(AW3X,0.0)
399		DRW3	=INT(VW3,0.0)
400		DELPF	=CSP(R3,AW3X,M4PIR3,P3)
401			RSP(PC3,PW3,DPF3)
402		VOLW3	=6.283*R*(L3-L2)*DRW3
403		WALL	=CSP(L4,L3,S4,TRH04P)
404			RSP(AW4,P4)
405		P4ATM	=P4/PCONV
406		VLEN4	=FSW(VW4,TRUE,TRUE,FALSE)
407		VGTN4	=NOT(VLEN4)
408	VLEN4	AW4X	=LIM(AW4,0.0,ABS(AW4))
409	VGTN4	AW4X	=AW4
410		VW4	=INT(AW4X,0.0)
411		DRW4	=INT(VW4,0.0)
412		DELPF	=CSP(R4,AW4X,M4PIR4,P4)
413			RSP(PC4,PW4,DPF4)
414		VOLW4	=6.283*R*(L4-L3)*DRW4
415		WALL	=CSP(L5,L4,S5,TRH05P)
416			RSP(AW5,P5)
417		P5ATM	=P5/PCONV
418		VLEN5	=FSW(VW5,TRUE,TRUE,FALSE)
419		VGTN5	=NOT(VLEN5)
420	VLEN5	AW5X	=LIM(AW5,0.0,ABS(AW5))
421	VGTN5	AW5X	=AW5

422		VW5	=INT(AW5X,0,0)
423		DRW5	=INT(VW5,C.0)
424		DELPF	=CSP(R5,AW5X,M4PIR5,P5)
425			RSP(PC5,PW5,DPF5)
426		VOLW5	=6.283*R*(L5-L4)*DRW5
427		WALL	=CSP(L6,L5,S6,TRH06P)
428			RSP(AW6,P6)
429		P6ATM	=P6/PCONV
430		VLEN6	=FSW(VW6,TRUE,TRUE,FALSE)
431		VGTN6	=NOT(VLEN6)
432	VLEN6	AW6X	=LIM(AW6,0.0,ABS(AW6))
433	VGTN6	AW6X	=AW6
434		VW6	=INT(AW6X,0.0)
435		DRW6	=INT(VW6,C.0)
436		DELPF	=CSP(R6,AW6X,M4PIR6,P6)
437			RSP(PC6,PW6,DPF6)
438		VOLW6	=6.283*R*(L6-L5)*DRW6
439		WALL	=CSP(L7,L6,S7,TRH07P)
440			RSP(AW7,P7)
441		P7ATM	=P7/PCONV
442		VLEN7	=FSW(VW7,TRUE,TRUE,FALSE)
443		VGTN7	=NOT(VLEN7)
444	VLEN7	AW7X	=LIM(AW7,0.0,ABS(AW7))
445	VGTN7	AW7X	=AW7
446		VW7	=INT(AW7X,0.0)
447		DRW7	=INT(VW7,C.0)
448		DELPF	=CSP(R7,AW7X,M4PIR7,P7)
449			RSP(PC7,PW7,DPF7)
450		VOLW7	=6.283*R*(L7-L6)*DRW7
451		WALL	=CSP(L8,L7,S8,TRH08P)
452			RSP(AW8,P8)
453		P8ATM	=P8/PCONV
454		VLEN8	=FSW(VW8,TRUE,TRUE,FALSE)
455		VGTN8	=NOT(VLEN8)
456	VLEN8	AW8X	=LIM(AW8,0.0,ABS(AW8))
457	VGTN8	AW8X	=AW8

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458      VW8      =INT(AW8X,0,0)
459      DRW8      =INT(VW8,0,0)
460      DELPF     =CSP(R8,AW8X,M4PIR8,P8)
461              RSP(PC8,PW8,DPF8)
462      VOLW8     =6.283*R*(L8-L7)*DRW8
463      WALL      =CSP(L9,L8,S9,TRH09P)
464              RSP(AW9,P9)
465      P9ATM     =P9/PCONV
466      VLEN9     =FSW(VW9,TRUE,TRUE,FALSE)
467      VGTN9     =NOT(VLEN9)
468      VLEN9     AW9X  =LIM(AW9,0.0,ABS(AW9))
469      VGTN9     AW9X  =AW9
470      VW9       =INT(AW9X,0,0)
471      DRW9      =INT(VW9,0,0)
472      DELPF     =CSP(R9,AW9X,M4PIR9,P9)
473              RSP(PC9,PW9,DPF9)
474      VOLW9     =6.283*R*(L9-L8)*DRW9
475      WALL      =CSP(L10,L9,S10,TRH00P)
476              RSP(AW10,P10)
477      P10ATM    =P10/PCONV
478      VLEN10    =FSW(VW10,TRUE,TRUE,FALSE)
479      VGTN10    =NOT(VLEN10)
480      VLEN10    AW10X  =LIM(AW10,0.0,ABS(AW10))
481      VGTN10    AW10X  =AW10
482      VW10      =INT(AW10X,0,0)
483      DRW10     =INT(VW10,0,0)
484      DELPF     =CSP(R10,AW10X,M4PIR0,P10)
485              RSP(PC10,PW10,DPF10)
486      VOLW10    =6.283*R*(L10-L9)*DRW10
487      VOLWA     =VOLW1+VOLW2+VOLW3+VOLW4+VOLW5+VOLW6
488      VOLWB     =VOLW7+VOLW8+VOLW9+VOLW10
489      VOLW      =VOLWA+VOLWB
490      WSTR1     =DRW1*100./R
491      WSTR2     =DRW2*100./R
492      WSTR3     =DRW3*100./R
493      WSTR4     =DRW4*100./R

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494      WSTR5   =DRW5*100./R
495      WSTR6   =DRW6*100./R
496      WSTR7   =DRW7*100./R
497      WSTR8   =DRW8*100./R
498      WSTR9   =DRW9*100./R
499      WSTR10  =DRW10*100./R
500  *
501  *
502  *      OUTPUT CONTROL
503          OUT(T)
504          OUT(P0ATM,P0,PC,P6,PSH1AT,PSH2AT)
505          OUT(AF,VF,XF,DVOL,PSH1,PSH2)
506          OUT(DXH,HBSTR,HDFP,HDF)
507          OUT(DH12,FH12,DHCIN,DHTIN,DHTOT)
508          OUT(DDHDR,DDHDT,DDHDT2)
509          OUT
510          OUT(P1,AW1X,VW1,DRW1,S1,WSTR1)
511          OUT(P2,AW2X,VW2,DRW2,S2,WSTR2)
512          OUT(P3,AW3X,VW3,DRW3,S3,WSTR3)
513          OUT(P4,AW4X,VW4,DRW4,S4,WSTR4)
514          OUT(P5,AW5X,VW5,DRW5,S5,WSTR5)
515          OUT(P6,AW6X,VW6,DRW6,S6,WSTR6)
516          OUT(P7,AW7X,VW7,DRW7,S7,WSTR7)
517          OUT(P8,AW8X,VW8,DRW8,S8,WSTR8)
518          OUT(P9,AW9X,VW9,DRW9,S9,WSTR9)
519          OUT(P10,AW10X,VW10,DRW10,S10,WSTR10,
520          OUT
521          OUT(AH1,VH1,XH1,AH2,VH2,XH2)
522          OUT(,DELCT1,PXH1,,DELCT2,PXH2)
523          OUT(AUH1,VUH1,XUH1,AUH2,VUH2,XUH2)
524          OUT(CHK1A,CHK1B,CHK1C,CHK2A,CHK2B,CHK2C)
525          OUT
526          OUT(PC1,PW1,DPF1,PC2,PW2,DPF2)
527          OUT(PC3,PW3,DPF3,PC4,PW4,DPF4)
528          OUT(PC5,PW5,DPF5,PC6,PW6,DPF6)
529          OUT(PC7,PW7,DPF7,PC8,PW8,DPF8)

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530      OUT(PC9,PW9,DPF9,PC10,PW10,DPF10)
531      OUT
532      OUT
533      OUT
-----
534 *   PLOT #1
535      PLO(TMSEC,P0ATM,PSH1AT,PSH2AT)
536      SCA(.50,5.,5.,5.)
537      ZER(0.,0.,0.,0.)
538      TTP(COMP. WAVE AND INTERHEAD PRESSURES)
539      TTX(TIME,  MILLISECONDS)
-----
540      TTY(PRESSURE,  ATMOSPHERES)
541 *   PLOT #2
542      PLO(TMSEC,AUH1,VUH1,PXUH1)
543      SCA(.50,1000.,1.,.01)
544      ZER(0.,30.,20.,0.)
545      TTP(DYNAMICS OF UNDERHEAD CENTER SECTION)
546      TTX(TIME,  MILLISECONDS)
547      TTY(ACC., VEL., DISPL.)
-----
548 *   PLOT #3
549      PLO(TMSEC,AUH2,VUH2,PXUH2)
550      SCA(.50,1000.,1.,.01)
551      ZER(0.,30.,20.,0.)
552      TTP(DYNAMICS OF UNDERHEAD OUTER SECTION)
553      TTX(TIME,  MILLISECONDS)
554      TTY(ACC., VEL., DISPL.)
-----
555 *   PLOT #4
556      PLO(TMSEC,AH1,VH1,PXH1)
557      SCA(.50,100.,.2,.01)
558      ZER(0.,20.,0.,0.0)
559      TTP(DYNAMICS OF HEAD CENTER SECTION)
560      TTX(TIME,  MILLISECONDS)
561      TTY(ACC., VEL., DISPL.)
-----
562 *   PLOT #5
563      PLO(TMSEC,AH2,VH2,PXH2)
564      SCA(.50,100.,.2,.01)
565      ZER(0.,20.,0.,0.0)

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566      TTP(DYNAMICS OF HEAD OUTER SECTION)
567      TTX(TIME, MILLISECONDS)
568      TTY(ACC., VEL., DISPL.)
569 *   PLOT #6
570      PLO(TMSEC,AF,VF,XF)
571      SCA(.50,500.,1.,.02)
572      ZER(0.,90.,0.,0.)
573      TTP(DYNAMICS OF FLUID SURFACE)
574      TTX(TIME, MILLISECONDS)
575      TTY(ACC., VEL., DISPL.)
576 *   PLOT #7
577      PLO(TMSEC,DRW1,DRW2,DRW3,DRW4,DRW5)
578      SCA(.50,.005,.005,.005,.005)
579      ZER(0.,0.,0.,0.,0.,0.)
580      TTP(WALL DISPLACEMENT)
581      TTX(TIME, MILLISECONDS)
582      TTY(RADIAL DISPLACEMENT, FT.)
583 *   PLOT #8
584      PLO(TMSEC,DDHDR,DDHDT,DDHDT2)
585      SCA(.50,.001,4.,.0025)
586      ZER(0.,40.,40.,40.)
587      TTP(SIM. ROTATIONAL DYNAMICS OF HEAD)
588      TTX(TIME, MILLISECONDS)
589      TTY(ROTATION * VEL,R/SEC * ACC,R/SEC**2)
590 *   PLOT #9
591      PLO(TMSEC,DH12,FH12,DHTOT)
592      SCA(.50,.0025,20.*10000.,.01)
593      ZER(0.,0.,0.,0.)
594      TTP(HEAD DOMING SIMULATION)
595      TTX(TIME, MILLISECONDS)
596      TTY(DISP.,FT * FORCE,LBF * CNT. LIFT, FT)
597 *   PLOT #10
598      PLO(TMSEC,AHDB,DXH,HDF)
599      SCA(.50,5.,.01,30.*10000.)
600      ZER(0.,0.,0.,0.)
601      TTP(HEAD BOLT CHARACTERISTICS)

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602	TTX(TIME, MILLISECONDS)					
603	TTY(DISPLACEMENT, FT, * FORCE, LBS.)					
604 *						
605	END					
606	0.0		0.0			
607	4.1667	-3	0.5			
608	6.6667	-2	0.65			
609	7.0833	-2	2.75			
610	8.3333	-2	3.0			
611	1.00	-1	3.15			
612	1.04167	-1	6.3			
613	1.6667	-1	7.3			
614	4.16667	-1	10.1			
615	5.83333	-1	11.7			
616	0.0		0.0			
617	4.1667	-2	0.0			
618	5.3333	-2	1.1965	+5		
619	8.3333	-2	1.282	+5		
620	1.250	-1	1.5213	+5		
621	1.6667	-1	1.9657	+5		
622	1.875	-1	2.3930	+5		
623	2.16667	-1	3.3674	+5		
624	2.3125	-1	4.4442	+5		
625	2.4583	-1	7.7774	+5		
626	2.5625	-1	8.9739	+5		
627	2.6042	-1	1.3675	+6		
628	7.5	+3	10.0			
629	-0.75		0.0	0.91667	2.00	3.00
630	4.75		6.00	10.00	16.50	16.5
631	0.7083		0.3073	0.198	0.281	0.281
632	0.3333		0.600	0.281	0.281	0.281
633	2.58	+5	75.	0.0		
634	2.52	+4	700.			
635	6.75	+4	0.0	0.0	1.46667	132.73
636	6.75	+4	0.0	0.0	1.46667	
637	4.90	+5	0.0	1.800		

638	7.35 +5	0.0	1.800
639	550.	5.8	
640	0.025		

The following pages give the listing of the DYSI simulation as processed by the MIMIC SORT. The first column, IFN, is a line identification and an index. The next column lists the logical control variable, LCV, if any. The entries in the RESULT column consist of: variable names for the results of specified operations, function names for tabular functions, subprogram names, and temporary interim variables which are the integers in parenthesis. The column headed FIN gives the three letter mnemonic code for the operation and the following six columns give the necessary arguments.

FUNCTION-LANGUAGE PROGRAM GENERATED

IF..	LCV	RESULT	FILE	A	B	C	D	E	F
1		HDBF	CHN	10.					
2		CTPF	CHN	12.					
3			CON	C	R				
4			CON	L1	L2	L3	L4	L5	L6
5			CON	L7	L8	L9	L10	LT	L0
6			CON	W1	W2	W3	W4	W5	W6
7			CON	W7	W8	W9	W10		
8			PAR	WF	V0F	X0F			
9			PAR	PG0	VG0				
10			PAR	WUH1	VGUH1	XGUH1	TUH1	A1	
11			PAR	WUH2	VGUH2	XGUH2	TUH2		
12			PAR	WH1	VGH1	XGH1			
13			PAR	WH2	VGH2	XGH2			
14			PAR	AHDB	HDBL				
15			PAR	TF					
16		WALL	BSP	LJ	LJM	SJ	TRHOJP		
17		TJ	DIV	LJ	C				
18		TJM	DIV	LJM	C				
19		(019)	SUB	T	TJ				
20		TLETJ	FSW	(019)	TRUE	TRUE	FALSE		
21		TGTTJ	NOT	TLETJ					
22		(022)	SUB	T	TJM				
23		TLETJM	FSW	(022)	TRUE	TRUE	FALSE		
24		TGTTJM	NOT	TLETJM					
25	TLETJM	(025)	ADD	LJ	LJM				
26	TLETJM	(026)	DIV	(025)	2.0				
27	TLETJM	(027)	SUB	LT	(026)				
28	TLETJM	(028)	MPY	PG	(027)				
29	TLETJM	(029)	DIV	(028)	LT				
30	TLETJM	JPJ	SUB	PG	(029)				
31	TGTTJM	JPJ	EQL	PG					

32	TLETJM	(032)	SUB	JPJ	SJ		
33	TLETJM	JAWJ	DIV	(032)	TRHOJP		
34	TGTTJM	(034)	SUB	JPJ	SJ		
35	TGTTJM	(035)	MPY	C	T		
36	TGTTJM	(036)	SUB	(035)	LJM		
37	TGTTJM	(037)	SUB	LJ	LJM		
38	TGTTJM	(038)	DIV	(034)	TRHOJP		
39	TGTTJM	(039)	MPY	(038)	(036)		
40	TGTTJM	JAWJ	DIV	(039)	(037)		
41	TLETJ	IAWJ	EQL	JAWJ			
42	TLETJ	IPJ	EQL	JPJ			
43	TGTTJ	IPJ	EQL	PG			
44	TGTTJ	(044)	SUB	IPJ	SJ		
45	TGTTJ	IAWJ	DIV	(044)	TRHOJP		
46	TLETAU	AWJ	EQL	IAWJ			
47	TLETAU	PJ	EQL	IPJ			
48	TGTTAU	(048)	SUB	PG	PG		
49	TGTTAU	(049)	ADD	LJ	LJM		
50	TGTTAU	(050)	DIV	(049)	2.0		
51	TGTTAU	(051)	SUB	LT	(050)		
52	TGTTAU	(052)	MPY	(048)	(051)		
53	TGTTAU	(053)	DIV	(052)	LT		
54	TGTTAU	PJ	ADD	PG	(053)		
55	TGTTAU	(055)	SUB	PJ	SJ		
56	TGTTAU	AWJ	DIV	(055)	TPHOJP		
57		WALL	ESP	AWJ	PJ		
58		STRFLP	BSP	DENOMJ	FIJ	FIJJ	DDDRPJ
59		FLPJA	DIV	FIJ	DENOMJ		
60		FLPJB	DIV	FIJJ	DENOMJ		
61		FLPJCP	MIN	FLPJA	FLPJB		
62		(062)	ABS	DDDRPJ			
63		(063)	MPY	FLPJCP	DDDRPJ		
64		FLPJC	DIV	(063)	(062)		
65		STRFLP	ESP	FLPJC	FLPJCP	FLPJA	FLPJB
66		STRFLM	BSP	DENOMJ	FIJ	FIJM	DDDRMJ
67		FLMJA	EQL	FLPJA			

68	FLMJB	DIV	FIJM	DENOMJ		
69	FLMJCP	MIN	FLMJA	FLMJB		
70	(070)	ALS	DDDRMJ			
71	(071)	MPY	FLMJCP	DDDRMJ		
72	FLMJC	DIV	(071)	(070)		
73	STRFLM	ESP	FLMJC	FLMJCP	FLMJA	FLMJB
74	STRFRI	ESP	DRWJ	LJ	LJ:1	WJ
75	RJ	ADD	R	DRWJ		
76	(076)	SUB	LJ	LJM		
77	DENOMJ	MPY	(076)	2.0	RJ	
78	(078)	DIV	DRWJ	R		
79	EPRJ	MPY	(078)	100.		
80	EPRJ2	MPY	EPRJ	EPRJ		
81	EPRJ3	MPY	EPRJ	EPRJ2		
82	(082)	NAL	5.0711	EPRJ	17.992	
83	(083)	MPY	.3183	EPRJ2		
84	(084)	SUB	(082)	(083)		
85	(085)	MPY	8.2451	EPRJ3		
86	(086)	DIV	(085)	1000.		
87	SIGRJ1	ADD	(084)	(086)		
88	SIGRJ	MPY	SIGRJ1	1000.		
89	FIJ	MPY	(076)	WJ	144.0	SIGRJ
90	(090)	MPY	WJ	144.0	SIGRJ	
91	FRJ	DIV	(090)	R		
92	TRHOJ	MPY	WJ	RHOW		
93	(093)	MPY	RJ	RHOF		
94	M4PIRJ	DIV	(093)	4.0		
95	TRHOJP	ADD	TRHOJ	M4PIRJ		
96	STRFRI	ESP	FRJ	FIJ	RJ	DENOMJ TRHOJP M4PIRJ
97	DELPI	ESP	RI	AWI	M4PIPI	PI
98	DPFI	MPY	AWI	M4PIPI	2.0	
99	(099)	DIV	DPFI	2.0		
100	PCI	ADD	PI	(099)		
101	PWI	SUB	PI	(099)		
102	DELPI	ESP	PCI	PWI	DPFI	
103	DTMIN	EQL	.00001			

104	(136)	MPY	P00	VG0
105	(273)	SUB	L1	L0
106	FLP10	EOL	0.0	L1
107	(449)	SUB	L2	L1
108	(463)	SUB	L3	L2
109	(477)	SUB	L4	L3
110	(491)	SUB	L5	L4
111	(505)	SUB	L6	L5
112	(519)	SUB	L7	L6
113	(533)	SUB	L8	L7
114	(547)	SUB	L9	L8
115	(561)	SUB	L10	L9
116	(666)	MPY	20.	L9
117	(673)	MPY	30.	L8
118	URP7	SUB	DKW7	DRW8
119	URM7	SUB	DKW7	DRW6
120	UDURP7	DEF	DRP7	T
121	UDORM7	DEF	DKM7	T
122	(371)	ABS	DKM7	0.0
123	UDRM7	DEF	(371)	T
124	(373)	ABS	DKP7	0.0
125	UDRP7	DEF	(373)	T
126	(375)	ABS	DUKM7	0.0
127	(377)	ABS	DUKRP7	
128	URP8	SUB	DKW8	DRW9
129	URM8	SUB	DKW8	
130	UDURP8	DEF	DRP8	T
131	UDORM8	DEF	DKM8	0.0
132	(388)	ABS	DRM8	T
133	UDRM8	DEF	(388)	0.0
134	(390)	ABS	DKP8	T
135	UDRP8	DEF	(390)	0.0
136	(392)	ABS	DUKM8	
137	(394)	ABS	DUKRP8	
138	URP9	SUB	DKW9	DRW10
139	URM9	SUB	DKW9	DRW8

140	DDDRP9	DER	DRP9	T	0.0		
141	DDDRM9	DEF	DRM9	T	0.0		
142	(405)	ABS	DRM9				
143	DDRM9	DER	(405)	T	0.0		
144	(407)	ABS	DRP9				
145	DDRP9	DEF	(407)	T	0.0		
146	(409)	ABS	DDRM9				
147	(411)	ABS	DDRP9				
148	DRM10	SUB	DRW10	DRW9			
149	(416)	ABS	DRM10				
150	DDRM10	DER	(416)	T	0.0		
151	DDDRM10	DEF	DRM10	T	0.0		
152	(421)	ABS	DDRM10				
153	VLEN1	FSW	VW1	TRUE	TRUE	FALSE	
154	VGTN1	NOT	VLEN1				
155	DRW1	INT	VW1	0.0			
156	VOLW1	MPY	DRW1	L1	6.283	R	
157	VLEN2	FSW	VW2	TRUE	TRUE	FALSE	
158	VGTN2	NOT	VLEN2				
159	DRW2	INT	VW2	0.0			
160	VOLW2	MPY	DRW2	(449)	6.283	R	
161	VLEN3	FSW	VW3	TRUE	TRUE	FALSE	
162	VGTN3	NOT	VLEN3				
163	DRW3	INT	VW3	0.0			
164	VOLW3	MPY	DRW3	(463)	6.283	R	
165	VLEN4	FSW	VW4	TRUE	TRUE	FALSE	
166	VGTN4	NOT	VLEN4				
167	DRW4	INT	VW4	0.0			
168	VOLW4	MPY	DRW4	(477)	6.283	R	
169	VLEN5	FSW	VW5	TRUE	TRUE	FALSE	
170	VGTN5	NOT	VLEN5				
171	DRW5	INT	VW5	0.0			
172	VOLW5	MPY	DRW5	(491)	6.283	R	
173	VLEN6	FSW	VW6	TRUE	TRUE	FALSE	
174	VGTN6	NOT	VLEN6				
175	DRW6	INT	VW6	0.0			

NAME	TYPE	VALUE	UNIT	STATUS	DESCRIPTION
VOLW6	MPY	6.283	R	TRUE	FALSE
VLEN7	FSW	6.283	TRUE	TRUE	FALSE
VGTN7	NOT	6.283	TRUE	TRUE	FALSE
VRW7	INT	0.0			
VLEN7	FSW	6.283	TRUE	TRUE	FALSE
VLEN8	FSW	6.283	TRUE	TRUE	FALSE
VGTN8	NOT	6.283	TRUE	TRUE	FALSE
VRW8	INT	0.0			
VLEN8	MPY	6.283	R	TRUE	FALSE
VLEN9	FSW	6.283	TRUE	TRUE	FALSE
VGTN9	NOT	6.283	TRUE	TRUE	FALSE
VRW9	INT	0.0			
VLEN9	MPY	6.283	R	TRUE	FALSE
VLEN10	FSW	6.283	TRUE	TRUE	FALSE
VGTN10	NOT	6.283	TRUE	TRUE	FALSE
VRW10	INT	0.0			
VLEN10	MPY	6.283	R	TRUE	FALSE
VOLW6	ADL	6.283	R	TRUE	FALSE
VOLW5	ADL	6.283	R	TRUE	FALSE
VOLW4	ADL	6.283	R	TRUE	FALSE
VOLW3	ADL	6.283	R	TRUE	FALSE
VOLW2	ADL	6.283	R	TRUE	FALSE
VOLW1	ADL	6.283	R	TRUE	FALSE
VOLW0	ADL	6.283	R	TRUE	FALSE
VLEN1	MPY	6.283	R	TRUE	FALSE
VLEN2	MPY	6.283	R	TRUE	FALSE
VLEN3	MPY	6.283	R	TRUE	FALSE
VLEN4	MPY	6.283	R	TRUE	FALSE
VLEN5	MPY	6.283	R	TRUE	FALSE
VLEN6	MPY	6.283	R	TRUE	FALSE
VLEN7	MPY	6.283	R	TRUE	FALSE
VLEN8	MPY	6.283	R	TRUE	FALSE
VLEN9	MPY	6.283	R	TRUE	FALSE
VLEN10	MPY	6.283	R	TRUE	FALSE
VLEN11	MPY	6.283	R	TRUE	FALSE
VLEN12	MPY	6.283	R	TRUE	FALSE
VLEN13	MPY	6.283	R	TRUE	FALSE
VLEN14	MPY	6.283	R	TRUE	FALSE
VLEN15	MPY	6.283	R	TRUE	FALSE
VLEN16	MPY	6.283	R	TRUE	FALSE
VLEN17	MPY	6.283	R	TRUE	FALSE
VLEN18	MPY	6.283	R	TRUE	FALSE
VLEN19	MPY	6.283	R	TRUE	FALSE
VLEN20	MPY	6.283	R	TRUE	FALSE
VLEN21	MPY	6.283	R	TRUE	FALSE
VLEN22	MPY	6.283	R	TRUE	FALSE
VLEN23	MPY	6.283	R	TRUE	FALSE
VLEN24	MPY	6.283	R	TRUE	FALSE
VLEN25	MPY	6.283	R	TRUE	FALSE
VLEN26	MPY	6.283	R	TRUE	FALSE
VLEN27	MPY	6.283	R	TRUE	FALSE
VLEN28	MPY	6.283	R	TRUE	FALSE
VLEN29	MPY	6.283	R	TRUE	FALSE
VLEN30	MPY	6.283	R	TRUE	FALSE
VLEN31	MPY	6.283	R	TRUE	FALSE
VLEN32	MPY	6.283	R	TRUE	FALSE
VLEN33	MPY	6.283	R	TRUE	FALSE
VLEN34	MPY	6.283	R	TRUE	FALSE
VLEN35	MPY	6.283	R	TRUE	FALSE
VLEN36	MPY	6.283	R	TRUE	FALSE
VLEN37	MPY	6.283	R	TRUE	FALSE
VLEN38	MPY	6.283	R	TRUE	FALSE
VLEN39	MPY	6.283	R	TRUE	FALSE
VLEN40	MPY	6.283	R	TRUE	FALSE
VLEN41	MPY	6.283	R	TRUE	FALSE
VLEN42	MPY	6.283	R	TRUE	FALSE
VLEN43	MPY	6.283	R	TRUE	FALSE
VLEN44	MPY	6.283	R	TRUE	FALSE
VLEN45	MPY	6.283	R	TRUE	FALSE
VLEN46	MPY	6.283	R	TRUE	FALSE
VLEN47	MPY	6.283	R	TRUE	FALSE
VLEN48	MPY	6.283	R	TRUE	FALSE
VLEN49	MPY	6.283	R	TRUE	FALSE
VLEN50	MPY	6.283	R	TRUE	FALSE

212		(582)	MPY	DRW9	100.			
213		WSTR9	DIV	(582)	R			
214		(584)	MPY	DRW10	100.			
215		WSTR10	DIV	(584)	R			
216		(103)	SUB	T	.00019			
217		CHANGE	FSW	(103)	FALSE	TRUE	TRUE	
218		INIT	NOT	CHANGE				
219	INIT	DT	EQL	.00001				
220	CHANGE	DT	EQL	.0002				
221		START	FSW	T	TRUE	TRUE	FALSE	
222		RUN	NOT	START				
223		STOP	FSW	VH2	TRUE	FALSE	FALSE	
224		NSTOP	NOT	STOP				
225	NSTOP	TFIN	EQL	TF				
226	NSTOP	TSTOP	ADD	T	.003			
227	STOP	TFIN	EQL	TSTOP				
228			FI	T	TFIN			
229	START	XTST	EQL	0.0				
230	START	RHOW	EQL	15.463				
231	START	RHOF	EQL	1.5842				
232	START	TAU	DIV	LT	C			
233	START	G	EQL	32.174				
234	START	RHOF2	MPY	C	RHOF	C		
235	START	MF	DIV	WF	G			
236	START	MH1	DIV	WH1	G			
237	START	MH2	DIV	WH2	G			
238	START	MUH1	DIV	WUH1	G			
239	START	MUH2	DIV	WUH2	G			
240	START	A	MPY	R	3.1416	R		
241	START	A2	SUB	A	A1			
242	START	PCONV	EQL	2116.8				
243	START	(131)	SUB	XCH1	XOUH1			
244	START	DEL0H1	SUB	(131)	TUH1			
245	START	(133)	SUB	XCH2	XOUH2			
246	START	DEL0H2	SUB	(133)	TUH2			
247		(138)	NEG	RHOF2				

248		TMSEC	MPY	T	1000.		
249		XF	INT	VF	XGF		
250		VOLF	MPY	A	XF		
251		VOLIP	MPY	T	C	A	
252		(155)	SUB	T	TAU		
253		TLETAU	FSK	(155)	TRUE	TRUE	FALSE
254		TGTTAU	NOT	TLETAU			
255	TLETAU	VOL	EQL	VOLIP			
256	TGTTAU	VOL	MPY	A	LT		
257		(168)	ABS	XUH1C			
258		XUH1	LIM	XUH1C	0.0	(168)	
259		(170)	SUB	XH1	XUH1		
260		DELH1	SUB	(170)	TUH1		
261		DELCT1	SUB	DELOH1	DELH1		
262		(186)	ABS	XUH2C			
263		XUH2	LIM	XUH2C	0.0	(186)	
264		(188)	SUB	XH2	XUH2		
265		DELH2	SUB	(188)	TUH2		
266		DELCT2	SUB	DELOH2	DELH2		
267		XH1	INT	VH1	XOH1		
268		XH2	INT	VH2	XOH2		
269		(232)	MPY	A1	XUH1		
270		VOLH	MAD	A2	XUH2	(232)	
271		PXUH1	SUB	XUH1	XOUH1		
272		PXUH2	SUB	XUH2	XOUH2		
273		PXH1	SUB	XH1	XOH1		
274		PXH2	SUB	XH2	XOH2		
275		DXH	EQL	PXH2			
276		(241)	MPY	DXH	100.		
277		HBSTR	DIV	(241)	HDBL		
278		HDFP	FUN	HDBF	DXH		
279		HDF	MPY	3000.	HDFP	1000.	
280		STRFRI	CSP	DRW1	L1	L0	W1
281			RSP	FR1	FI1	R1	DENOM1 TRH01P M4PIR1
282		STRFRI	CSP	DRW2	L2	L1	W2
283			RSP	FR2	FI2	R2	DENOM2 TRH02P M4PIR2

284	STRFR1	CSP	DRW3	L3	L2	W3
285		RSP	FR3	FI3	R3	DENOM3 TRH03P M4PIR3
286	STRFR1	CSP	DRW4	L4	L3	W4
287		RSP	FR4	FI4	R4	DENOM4 TRH04P M4PIR4
288	STRFR1	CSP	DRW5	L5	L4	W5
289		RSP	FR5	FI5	R5	DENOM5 TRH05P M4PIR5
290	STRFR1	CSP	DRW6	L6	L5	W6
291		RSP	FR6	FI6	R6	DENOM6 TRH06P M4PIR6
292	STRFR1	CSP	DRW7	L7	L6	W7
293		RSP	FR7	FI7	R7	DENOM7 TRH07P M4PIR7
294	STRFR1	CSP	DRW8	L8	L7	W8
295		RSP	FR8	FI8	R8	DENOM8 TRH08P M4PIR8
296	STRFR1	CSP	DRW9	L9	L8	W9
297		RSP	FR9	FI9	R9	DENOM9 TRH09P M4PIR9
298	STRFR1	CSP	DRW10	L10	L9	W10
299		RSP	FR10	FI10	R10	DENOM10 TRH00P M4PIR0
300	DRP1	SUB	DRW1	DRW2		
301	DDDRP1	DEF	DRP1	T	0.0	
302	(267)	ABS	DRP1			
303	DDRP1	DLR	(267)	T	0.0	
304	STRFLP	CSP	DENOM1	FI1	FI2	DDDRP1
305		RSP	FLP1C	FLP1Cp	FLP1A	FLP1B
306	(271)	ABS	DDRP1			
307	FLP1	LIN	FLP1C	DDRP1	0.0	(271)
308	(274)	MPY	(273)	2.0	R1	
309	(275)	MPY	2.0	FI1		
310	FLM1	DIV	(275)	(274)		
311	S1	ADD	FLP1	FR1	FL41	
312	DRP2	SUB	DRW2	DRW3		
313	DRM2	SUB	DRW2	DRW1		
314	DDDRP2	DEF	DRP2	T	0.0	
315	DDDRM2	DLR	DRM2	T	0.0	
316	(286)	ABS	DRM2			
317	DDRM2	DEF	(286)	T	0.0	
318	(288)	ABS	DRP2			
319	DDRP2	DLR	(288)	T	0.0	

356	(354)	ABS	DRM6			
357	DDRM6	DEL	(354)	T	0.0	
358	(356)	ABS	DRP6			
359	DDRP6	DEL	(356)	T	0.0	
360	(358)	ABS	DDRM6			
361	(360)	ABS	DDRP6			
362	STRFLP	CSP	DENOM7	FI7	FI8	DDDRP7
363		RSP	FLP7C	FLP7CP	FLP7A	FLP7B
364	STRFLM	CSP	DENOM7	FI7	FI6	DDDRM7
365		RSP	FLM7C	FLM7CP	FLM7A	FLM7B
366	FLM7	LIN	FLM7C	DDRM7	0.0	(375)
367	FLP7	LIN	FLP7C	DDRP7	0.0	(377)
368	S7	ADD	FLP7	FR7	FLM7	
369	STRFLP	CSP	DENOM8	FI8	FI9	DDDRP8
370		RSP	FLP8C	FLP8CP	FLP8A	FLP8B
371	STRFLM	CSP	DENOM8	FI8	FI7	DDDRM8
372		RSP	FLM8C	FLM8CP	FLM8A	FLM8B
373	FLM8	LIN	FLM8C	DDRM8	0.0	(392)
374	FLP8	LIN	FLP8C	DDRP8	0.0	(394)
375	S8	ADD	FLP8	FR8	FLM8	
376	STRFLP	CSP	DENOM9	FI9	FI10	DDDRP9
377		RSP	FLP9C	FLP9CP	FLP9A	FLP9B
378	STRFLM	CSP	DENOM9	FI9	FI8	DDDRM9
379		RSP	FLM9C	FLM9CP	FLM9A	FLM9B
380	FLM9	LIN	FLM9C	DDRM9	0.0	(409)
381	FLP9	LIN	FLP9C	DDRP9	0.0	(411)
382	S9	ADD	FLP9	FR9	FLM9	
383	STRFLM	CSP	DENOM0	FI10	FI9	DDDRM0
384		RSP	FLM10C	FLM10CP	FLM10A	FLM10B
385	FLM10	LIN	FLM10C	DDRM10	0.0	(421)
386	S10	ADD	FLP10	FR10	FLM10	
387	WALL	CSP	L1	L0	S1	TRH01P
388		RSP	Aw1	P1		
389	P1ATM	D.V	P1	PCONV		
390	VLEN1	(429)	Aw1			
391	VLEN1	AW1X	LIM	Aw1	0.0	(429)

392	WG1N1	AW1X	EQL	AW1	0.0	AW1X	INT	AW1X	0.0	AW1X	P1	M4PIR1	DPF1	S7	TRH07P
393		W1	INT	AW1	0.0	AW1X	CSP	R1	AW1X	0.0	AW1X	P1	M4PIR1	DPF1	
394		DELPR	CSP	R1		AW1X	RSP	PC1	PW1		AW1X	P1	M4PIR1	DPF1	
395						AW1X	CSP	L7	L6		AW1X	P1	M4PIR1	DPF1	
396		WALL	CSP	L7		AW1X	RSP	AW7	P7		AW1X	P1	M4PIR1	DPF1	
397		P7ATM	RSP	AW7		AW1X	DIV	P7	PCONV		AW1X	P1	M4PIR1	DPF1	
398	VLN7	(512)	ABS	AW7		AW1X	AW7	AW7			AW1X	P1	M4PIR1	DPF1	
399	VLN7	(512)	LIM	AW7		AW1X	AW7	AW7			AW1X	P1	M4PIR1	DPF1	
400	VLN7	AW7X	EQL	AW7		AW1X	AW7	AW7			AW1X	P1	M4PIR1	DPF1	
401	WG1N7	AW7X	INT	AW7X		AW1X	AW7	AW7X	0.0		AW1X	P1	M4PIR1	DPF1	
402		W7	INT	AW7X		AW1X	CSP	R7	AW7X		AW1X	P1	M4PIR1	DPF1	
403		DELPR	CSP	R7		AW7X	RSP	PC7	PW7		AW7X	P7	M4PIR1	DPF1	
404						AW7X	CSP	L8	L7		AW7X	P7	M4PIR1	DPF1	
405		WALL	CSP	L8		AW7X	RSP	AW8	P8		AW7X	P7	M4PIR1	DPF1	
406		P8ATM	RSP	AW8		AW7X	DIV	P8	PCONV		AW7X	P7	M4PIR1	DPF1	
407	VLN8	(526)	ABS	AW8		AW7X	AW8	AW8			AW7X	P7	M4PIR1	DPF1	
408	VLN8	AW8X	LIM	AW8		AW7X	EQL	AW8	0.0		AW7X	P7	M4PIR1	DPF1	
410	WG1N8	AW8X	INT	AW8X		AW7X	AW8	AW8X	0.0		AW7X	P7	M4PIR1	DPF1	
411		W8	INT	AW8X		AW7X	CSP	R8	AW8X		AW7X	P7	M4PIR1	DPF1	
412		DELPR	CSP	R8		AW8X	RSP	PC8	PW8		AW8X	P8	M4PIR1	DPF1	
413						AW8X	CSP	L9	L8		AW8X	P8	M4PIR1	DPF1	
414		WALL	CSP	L9		AW8X	RSP	AW9	P9		AW8X	P8	M4PIR1	DPF1	
415		P9ATM	RSP	AW9		AW8X	DIV	P9	PCONV		AW8X	P8	M4PIR1	DPF1	
416	VLN9	(540)	ABS	AW9		AW8X	AW9	AW9			AW8X	P8	M4PIR1	DPF1	
417	VLN9	AW9X	LIM	AW9		AW8X	EQL	AW9	0.0		AW8X	P8	M4PIR1	DPF1	
418	VLN9	AW9X	INT	AW9X		AW8X	AW9	AW9X	0.0		AW8X	P8	M4PIR1	DPF1	
420		W9	INT	AW9X		AW8X	CSP	R9	AW9X		AW8X	P8	M4PIR1	DPF1	
421		DELPR	CSP	R9		AW9X	RSP	PC9	PW9		AW9X	P9	M4PIR1	DPF1	
422						AW9X	CSP	L10	L9		AW9X	P9	M4PIR1	DPF1	
423		WALL	CSP	L10		AW9X	RSP	AW10	P10		AW9X	P9	M4PIR1	DPF1	
424		P10ATM	RSP	AW10		AW9X	DIV	P10	PCONV		AW9X	P9	M4PIR1	DPF1	
425	VLN10	(554)	ABS	AW10		AW9X	AW10	AW10			AW9X	P9	M4PIR1	DPF1	
426	VLN10	AW10X	LIM	AW10		AW9X	AW10	AW10	0.0		AW9X	P9	M4PIR1	DPF1	
427						AW10X	AW10	AW10	0.0		AW10X	P9	M4PIR1	DPF1	

428	VG TN10	AW10X	EQL	Aw10			
429		VW10	INT	Aw10x	0.0		
430		DELPF	CSP	R10	AW10X	M4PIR0	P10
431			RSP	PC10	PW10	DPF10	
432		(135)	ADD	VG0	VOLF		
433		PG	DIV	(136)	(135)		
434		(145)	ADD	VJLW	VOLH		
435		JVOL	SUB	(145)	VOLF		
436		(165)	ABS	XUH1			
437		VUH1	LIN	VUH1C	XUH1	0.0	(165)
438		XUH1C	INT	VUH1	XGUH1		
439		(173)	SUB	VH1	VUH1		
440		U1	FSW	(173)	TRUE	TRUE	FALSE
441		U1	NOT	U1			
442	U1	PSH1	FUN	CTPF	DELCT1		
443	L1	PSH1	EQL	0.0			
444		(183)	ABS	XUH2			
445		VUH2	LIN	VUH2C	XUH2	0.0	(183)
446		XUH2C	INT	VUH2	XGUH2		
447		(191)	SUB	VH2	VUH2		
448		U2	FSW	(191)	TRUE	TRUE	FALSE
449		U2	NOT	U2			
450	U2	PSH2	FUN	CTPF	DELCT2		
451	L2	PSH2	EQL	0.0			
452		(196)	MPY	A1	PSH1		
453		(197)	SUB	(196)	WH1		
454		CHK1B	FSW	PxH1	FALSE	FALSE	TRUE
455		(205)	MPY	A2	PSH2		
456		(206)	SUB	(205)	WH2		
457		CHK2B	FSW	PxH2	FALSE	FALSE	TRUE
458		DH12	SUB	PxH1	PxH2		
459		DHCNTR	MPY	2.093	DH12		
460		DHCIN	MPY	DHCNTR	12.		
461		DHTOT	ADD	DHCNTR	DXH		
462		DHTIN	MPY	DHTOT	12.		
463		(220)	MPY	.68139	DH12		

464	XCONP	SUB	(220)	.03882		
465	(222)	ABS	XCONP			
466	XCON	LIM	XCONP	0.0	(222)	
467	X0	MAX	XTST	XCON		
468	XTST	TUL	X0	0.0	3.0	
469	(226)	SUB	DH12	X0		
470	FH12	MPY	10000.	10000.	1.566	(226)
471	(228)	NEG	DH12			
472	DDHDR	DIV	(228)	4.6079		
473	DDHDT	DER	DDHDR	T	0.0	
474	DDHDT2	DER	DDHDT	T	0.0	
475	PSH1AT	DIV	PSH1	PCONV		
476	PSH2AT	DIV	PSH2	PCONV		
477	STRFLP	CSP	DENOM2	FI2	FI3	DDDRP2
478		RSP	FLP2C	FLP2CP	FLP2A	FLP2B
479	STRFLM	CSP	DENOM2	FI2	FI1	DDDRM2
480		RSP	FLM2C	FLM2CP	FLM2A	FLM2B
481	FLM2	LIN	FLM2C	DDRM2	0.0	(290)
482	FLP2	LIN	FLP2C	DDRP2	0.0	(292)
483	S2	ADD	FLP2	FR2	FLM2	
484	STRFLP	CSP	DENOM3	FI3	FI4	DDDRP3
485		RSP	FLP3C	FLP3CP	FLP3A	FLP3B
486	STRFLM	CSP	DENOM3	FI3	FI2	DDDRM3
487		RSP	FLM3C	FLM3CP	FLM3A	FLM3B
488	FLM3	LIN	FLM3C	DDRM3	0.0	(307)
489	FLP3	LIN	FLP3C	DDRP3	0.0	(309)
490	S3	ADD	FLP3	FR3	FLM3	
491	STRFLP	CSP	DENOM4	FI4	FI5	DDDRP4
492		RSP	FLP4C	FLP4CP	FLP4A	FLP4B
493	STRFLM	CSP	DENOM4	FI4	FI3	DDDRM4
494		RSP	FLM4C	FLM4CP	FLM4A	FLM4B
495	FLM4	LIN	FLM4C	DDRM4	0.0	(324)
496	FLP4	LIN	FLP4C	DDRP4	0.0	(326)
497	S4	ADD	FLP4	FR4	FLM4	
498	STRFLP	CSP	DENOM5	FI5	FI6	DDDRP5
499		RSP	FLP5C	FLP5CP	FLP5A	FLP5B

500		STRFLM	CSP	DENOM5	FI5	FI4	DDDRM5
501			RSP	FLM5C	FLM5CP	FLM5A	FLM5B
502		FLM5	LIM	FLM5C	DDRM5	0.0	(341)
503		FLP5	LIM	FLP5C	DDRP5	0.0	(343)
504		S5	ADD	FLP5	FR5	FLM5	
505		STRFLP	CSP	DENOM6	FI6	FI7	DDDRP6
506			RSP	FLP6C	FLP6CP	FLP6A	FLP6B
507		STRFLM	CSP	DENOM6	FI6	FI5	DDDRM6
508			RSP	FLM6C	FLM6CP	FLM6A	FLM6B
509		FLM6	LIM	FLM6C	DDRM6	0.0	(358)
510		FLP6	LIM	FLP6C	DDRP6	0.0	(360)
511		S6	ADD	FLP6	FR6	FLM6	
512		WALL	CSP	L2	L1	S2	TRH02P
513			RSP	AW2	P2		
514		P2ATM	DIV	P2	PCONV		
515	VLEN1	(442)	ABS	AW2			
516	VLEN2	AW2X	LIM	AW2	0.0	(442)	
517	VGTN2	AW2X	EQL	AW2			
518		VW2	INT	AW2X	0.0		
519		DELPH	CSP	R2	AW2X	M4PIR2	P2
520			RSP	PC2	PW2	DPF2	
521		WALL	CSP	L3	L2	S3	TRH03P
522			RSP	AW3	P3		
523		P3ATM	DIV	P3	PCONV		
524	VLEN1	(456)	ABS	AW3			
525	VLEN3	AW3X	LIM	AW3	0.0	(456)	
526	VGTN3	AW3X	EQL	AW3			
527		VW3	INT	AW3X	0.0		
528		DELPH	CSP	R3	AW3X	M4PIR3	P3
529			RSP	PC3	PW3	DPF3	
530		WALL	CSP	L4	L3	S4	TRH04P
531			RSP	AW4	P4		
532		P4ATM	DIV	P4	PCONV		
533	VLEN4	(470)	ABS	AW4			
534	VLEN4	AW4X	LIM	AW4	0.0	(470)	
535	VGTN4	AW4X	EQL	AW4			

Category	Material	Quantity	Unit	Value
WALL	INT	44X	0.0	
	CSP	R4	44X	
	RSP	P44	44X	
	CSP	L4	44X	
	CSP	LS	44X	
	RSP	P44	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
DELPH	CSP	R4	44X	
	RSP	P44	44X	
	CSP	L4	44X	
	CSP	LS	44X	
	RSP	P44	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
PSATM	DIV	P5	44X	
	RSP	P5	44X	
	CSP	L4	44X	
	CSP	LS	44X	
	RSP	P44	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
DELPH	CSP	R5	44X	
	RSP	P5	44X	
	CSP	L5	44X	
	CSP	LS	44X	
	RSP	P5	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
PSATM	DIV	P5	44X	
	RSP	P5	44X	
	CSP	L5	44X	
	CSP	LS	44X	
	RSP	P5	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
DELPH	CSP	R6	44X	
	RSP	P6	44X	
	CSP	L6	44X	
	CSP	LS	44X	
	RSP	P6	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
PSATM	DIV	P6	44X	
	RSP	P6	44X	
	CSP	L6	44X	
	CSP	LS	44X	
	RSP	P6	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
DELPH	CSP	R6	44X	
	RSP	P6	44X	
	CSP	L6	44X	
	CSP	LS	44X	
	RSP	P6	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
PSATM	DIV	P6	44X	
	RSP	P6	44X	
	CSP	L6	44X	
	CSP	LS	44X	
	RSP	P6	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
DELPH	CSP	R6	44X	
	RSP	P6	44X	
	CSP	L6	44X	
	CSP	LS	44X	
	RSP	P6	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
PSATM	DIV	P6	44X	
	RSP	P6	44X	
	CSP	L6	44X	
	CSP	LS	44X	
	RSP	P6	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
	CSP	LS	44X	
DELPH	CSP	R6	44X	

572	(178)	SUB	PC	PSH2				
573	(179)	MPY	A2	(178)				
574	(180)	SUB	(179)	WUH2				
575	AUH2	DIV	(180)	MUH2				
576	VUH2C	INT	AUH2	VUH2				
577	(198)	SUB	(197)	FH12				
578	AH1	DIV	(198)	MH1				
579	CHK1A	FSH	AH1	FALSE	TRUE	TRUE		
580	CHK1C	IOR	CHK1A	CHK1F				
581	VH1	INT	AH1	VCH1	CHK1C			
582	(207)	ADD	(206)	FH12				
583	(208)	SUB	(207)	HDF				
584	AH2	DIV	(208)	MH2				
585	CHK2A	FSH	AH2	FALSE	TRUE	TRUE		
586	CHK2C	IOR	CHK2A	CHK2B				
587	VH2	INT	AH2	VCH2	CHK2C			
588		OUT	T					
589		OUT	PCATM	PC	PC	PG	SH1AT	PSH2AT
590		OUT	AF	VF	XF	DVOL	PSH1	PSH2
591		OUT	DXH	H8STR	HDEF	HDF		
592		OUT	DH12	FH12	DHCIN	DHTIN	DHTOT	
593		OUT	DDHDP	DDHDT	DDHDT2			
594		OUT						
595		OUT	P1	AW1X	VW1	DRW1	S1	WSTR1
596		OUT	P2	AW2X	VW2	DRW2	S2	WSTR2
597		OUT	P3	AW3X	VW3	DRW3	S3	WSTR3
598		OUT	P4	AW4X	VW4	DRW4	S4	WSTR4
599		OUT	P5	AW5X	VW5	DRW5	S5	WSTR5
600		OUT	P6	AW6X	VW6	DRW6	S6	WSTR6
601		OUT	P7	AW7X	VW7	DRW7	S7	WSTR7
602		OUT	P8	AW8X	VW8	DRW8	S8	WSTR8
603		OUT	P9	AW9X	VW9	DRW9	S9	WSTR9
604		OUT	P10	AW10X	VW10	DRW10	S10	WSTR10
605		OUT						
606		OUT	AH1	VH1	XH1	AH2	VH2	XH2
607		OUT		DELCT1	PXH1		DELCT2	PXH2

608	OUT	AUH1	VUH1	XUH1	AUH2	VUH2	XUH2
609	OUT	CHK1A	CHK1B	CHK1C	CHK2A	CHK2B	CHK2C
610	OUT						
611	OUT	PC1	PW1	DPF1	PC2	PW2	DPF2
612	OUT	PC3	PW3	DPF3	PC4	PW4	DPF4
613	OUT	PC5	PW5	DPF5	PC6	PW6	DPF6
614	OUT	PC7	PW7	DPF7	PC8	PW8	DPF8
615	OUT	PC9	PW9	DPF9	PC10	PW10	DPF10
616	OUT						
617	OUT						
618	OUT						
619	PLO	TMSEC	POATM	PSH1AT	PSH2AT		
620	SCA	.50	5.	5.	5.		
621	ZER	0.	0.	0.	0.		
622	TIP	COMP.	WAVE A	ND INT	ERHEAD	PRESS	URES
623	TIX	TIME,	MILLI	SECOND	S		
624	TIY	PRESSU	RE, A	TMOSPH	ERES		
625	PLO	TMSEC	AUH1	VUH1	PXUH1		
626	SCA	.50	1000.	1.	.01		
627	ZER	0.	30.	20.	0.		
628	TIP	DYNAMI	CS OF	UNDERH	EAD CE	NTER S	ECTION
629	TIX	TIME,	MILLI	SECOND	S		
630	TIY	ACC.,	VEL.,	DISPL.			
631	PLO	TMSEC	AUH2	VUH2	PXUH2		
632	SCA	.50	1000.	1.	.01		
633	ZER	0.	30.	20.	0.		
634	TIP	DYNAMI	CS OF	UNDERH	EAD OU	TER SE	CTION
635	TIX	TIME,	MILLI	SECOND	S		
636	TIY	ACC.,	VEL.,	DISPL.			
637	PLO	TMSEC	AH1	VH1	PXH1		
638	SCA	.50	100.	.2	.01		
639	ZER	0.	20.	0.	0.0		
640	TIP	DYNAMI	CS OF	HEAD C	ENTER	SECTION	
641	TIX	TIME,	MILLI	SECOND	S		
642	TIY	ACC.,	VEL.,	DISPL.			
643	PLO	TMSEC	AH2	VH2	PXH2		

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644 SCA .50 100. .2 .01
645 ZLR 0. 20. 0. 0.0
646 TIP DYNAMI CS OF HEAD O UTER S FCTION
647 TIX TIME, MILLI SECON'D S
648 TIY ACC., VEL., DISPL.
649 PLO TMSEC AF VF XF
650 SCA .50 500. 1. .02
651 ZLR 0. 90. 0. 0.
652 TIP DYNAMI CS OF FLUID SURFAC ,
653 TIX TIME, MILLI SECON'D S
654 TIY ACC., VEL., DISPL.
655 PLO TMSEC DRW1 DRW2 DRW3 DRW4 DRW5
656 SCA .50 .005 .005 .005 .005 .005
657 ZLR 0. 0. 0. 0. 0. 0.
658 ITF WALL D ISPLAC EMENT
659 TIX TIME, MILLI SECON'D S
660 TIY RADIAL DISPL ACEMEN T, FT.
661 PLO TMSEC DDHDP DDHDT DDHDT2
662 SCA .50 .001 4. .0025
663 ZLR 0. 40. 40. 40.
664 TIP SIM. R OTATIO NAL DY NAMICS OF HE AD
665 TIX TIME, MILLI SECON'D S
666 TIY ROTATI ON * V EL,R/S EC * CC,R/ SEC**2
667 PLO TMSEC DH12 FH12 DHTOT
668 SCA .50 .0025 (666) .01
669 ZLR 0. 0. 0. 0.
670 TIP HEAD D OMING SIMULA TION
671 TIX TIME, MILLI SECON'D S
672 TIY DISP., FT * F ORCE,L BF * C HT. LI FT, FT
673 PLO TMSEC AHDB DXH HDF
674 SCA .50 5. .01 (673)
675 ZLR 0. 0. 0. 0.
676 TIP HEAD B OLT CH ARACTE RISTIC S
677 TIX TIME, MILLI SECON'D S
678 TIY DISPLA CEMENT , FT. * FORC E, LBS .
679 END

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