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NASA MANNED SPACECRAFT CENTER
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FOREWORD

The Generalized Propulsion System Model is a digital computer program designed to study transient performance of pressure fed rocket engine systems. This is the final report of the work performed for the NASA Manned Spacecraft Center, Houston, Texas under Contract NAS9-10319. This report covers the work accomplished during the period 12 January 1970 to 12 January 1971.

SUMMARY

This program was accomplished in three phases. In the initial phase analytical techniques which could be used to characterize the behavior of pressure-fed rocket engines were evaluated. The selected techniques were programmed for solution on a digital computer in the second phase, and after debugging the necessary manuals and guides were written to allow use of the program. In the third phase the program was demonstrated by modeling the Apollo Ascent and Descent Engines, and the pressurization system of Rocketdyne's SE5-5 engine system. The program was concluded with the successful operation of the program on the NASA, Houston Univac 1108 computer.

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INTRODUCTION

The purpose of the Generalized Propulsion System Model program is to provide a general purpose, modular, digital computer program for simulating transient operation in pressure-fed rocket engine systems. In order to accomplish this, an existing Rocketdyne digital computer program was modified so that it met the requirements of the contract. The effort in this program was divided into three phases. In the first phase an evaluation of the analytical techniques used to characterize the dynamic behavior of pressure-fed rocket propulsion systems was made. In Phase II the techniques selected in Phase I were programmed and the program instruction documents written. In Phase III the use of the program was demonstrated by modeling the Apollo Ascent and Descent engines and the Rocketdyne SE5-5 Propulsion System.

The digital model, resulting from completion of this program, is flexible and has options for calculating the performance of a number of different components. It describes the propellant line dynamics using the wave equations and calculates the pressure and flow conditions when a portion of a line is being filled. The model allows a system to be broken down into a number of segments, and by proper combination, many different plumbing configurations may be simulated.

In between segments, components used in rocket engine feed systems can be installed by use of the input data and since the performance of these components is calculated entirely in subroutines, it is an easy task to add new components or change the existing ones.

The model which was developed in this program was based on an existing Rocketdyne pressure-fed rocket engine model which has been used to calculate the performance of various rocket engine systems. In order to make this program meet the requirements of this contract several modifications were necessary. The most commonly used features had to be built into the program so that they could be called out by input data. In addition, several new features were added as follows:

1. A simplified pressurization system which includes a propellant-gas heat exchanger and allows calculation of gas flow, pressure and temperature.
2. Changes in feed line representation to include effects of two-phase flow.
3. Improvement of thrust chamber and injector response, including the addition of injection stream ballistic dynamics and injector orifice inertance.
4. Injector-thrust chamber blowdown after propellant valve closure.
5. Built-in components which include valves, cavitating venturis, capped lines, accumulators, etc.

The use of subroutines, to calculate the performance of different types of components, was continued and improved by proper grouping of calculations so that maintenance and modifications of the functions will be simplified. The mathematical basis of the various program functions, a description of the digital computer model, and the results of the demonstration phase are given in the following sections. A list of symbols used is presented in Table I.

RESULTS AND CONCLUSIONS

This program has demonstrated that the Generalized Propulsion System Model, described by this report, can be successfully used to model the transient operation of pressure-fed rocket engine systems. In addition, the program has been satisfactorily run on the NASA, Houston, Univac 1108 computer. The operation of the program was demonstrated using four different transient simulations:

1. Apollo Ascent Engine On-Off Pulse

The model simulated this transient quite accurately. The predicted thrust chamber ignition spike agreed with the test data within 6% and the shape of all transients agreed quite well with the data. The small differences seen have been attributed to instrumentation line phenomena which were not simulated in the model.

2. Apollo Descent Engine Start Transient

The purpose of simulating this transient was to demonstrate model operation with two phase propellant flow. The results of this simulation showed good agreement with the test data; by adjusting the rate at which pressurant gas comes out of solution - from saturated propellants - it should be possible to obtain almost exact agreement between the test data and model results. Difficulty in obtaining operation of the model with two phase flow was experienced during the initial simulation of this system. The problem was traced to a computational instability due to a rapid increase in acoustic velocity which occurs after the feed system primes and the pressure increases, causing pressurant gas to go back into solution. The problem was solved by using a fixed value for the density of the pressurant gas in the model.

3. Apollo Descent Engine LM-3 Flight Anomaly

Analysis of flight data from the Apollo 9 flight showed that a period of rough burning, which occurred during the second burn of the Descent Engine, was caused by pressurant gas bubbles in the fuel and oxidizer feed system.

The modeling of this transient required modifications to the program deck and demonstrated the flexibility of the program. Agreement between model results and test data were only qualitative. The model simulated this problem by assuming that there was only one discrete bubble in each of the systems. After running the problem it became apparent that several bubbles separated by propellant must have been in each feedline, and since the model was not set up to simulate this condition, it was not possible to obtain good correlation.

SE5-5 Pressurization System

This model of a Rocketdyne propulsion system was made to demonstrate the operation of the model's pressurization system simulation. The system simulated the pressurization of a fuel and oxidizer propellant tank from a high pressure storage bottle through a regulator. As the propellant pressure increased, burst diaphragms in the tank outlet broke and propellant filled the engine feed lines. After the feed lines were full of propellant, the propellant tank pressure increased to the regulator lockup pressure. The model provided a realistic simulation of all events occurring during pressurization.

RECOMMENDATIONS

The two phase flow description in the model is designed to handle small bubbles of pressurant gas uniformly mixed with liquid propellant. The description used has been demonstrated to be adequate to describe the Apollo Descent Engine start transient. However, to develop confidence in the method used to model this phenomena, additional correlating test data should be obtained.

The present model has not been designed to handle pump fed, regeneratively cooled, cryogenic propellant engines, although it forms a good base to build such a model. Since it is planned to use these engines as maneuvering engines in future space flights, a program should be started to prepare the subroutines needed for this use. This would require the addition of routines to provide performance of turbopumps, heat transfer to propellants, and additional propellant property data to handle the problem of phase changes.

Since one of the areas of proposed use of the model was the study of feed system coupled instabilities, the model should be used to study a known instability of this type. In so doing, its use as a tool to help solve these instabilities could be proven.

MATHEMATICAL CHARACTERIZATION

FEED SYSTEM DYNAMICS

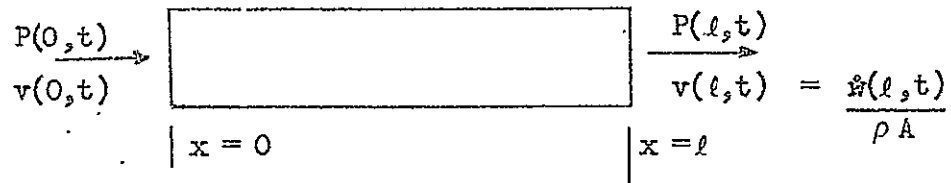
Wave Equation

In order to simulate the dynamics of a pressure fed rocket engine system, it is necessary to consider the dynamics of all of its components. The rocket engine feedline dynamics are involved in the start and cutoff transients and in feed system coupled instabilities, therefore, their correct representation in a dynamic model is both necessary and important. In general, two different methods of simulating feedlines are used; (1) lumped parameters, and (2) distributed parameters. In the first method, it is assumed that the liquid in a line moves as a solid lump; the fact that the fluid is compressible is handled by a storage term in the analytical expression. The distributed parameter representation assumes a continuous media and shows that disturbances are propagated by waves at the speed of sound in the fluid. Both methods can be used to give an adequate dynamic representation of the feedlines, however, it is felt that the wave equations (distributed parameter) are more practical for a general purpose model. The wave equations have theoretically unlimited frequency response, whereas the response of a lumped parameter system will depend on the number of elements into which it is broken. The wave equations are utilized in this model because they yield accurate frequency response independent of the line length assigned to the segment.

The equations used are the normal water hammer equations:

$$\frac{\partial P}{\partial x} = -K_1 \frac{\partial v}{\partial t} \quad \text{and} \quad \frac{\partial v}{\partial x} = -K_2 \frac{\partial P}{\partial t}$$

The solution of these equations involves terms which include past, present, and future values of velocity and pressure. By using Laplace transformation techniques and the equation of continuity, the above expressions may be solved for the pipe segment shown below



The resultant equations are:

$$\dot{w}(l,t) = \rho A v(t) = \dot{w}(t) \quad (1)$$

$$P(l,t) = -\frac{a}{Ag} \dot{w}(l,t) + 2P(0,t-\tau) + \frac{a}{Ag} \dot{w}(l,t-2\tau) - P(l,t-2\tau) \quad (2)$$

$$P(0,t) = P(t) \quad (3)$$

$$\dot{w}(0,t) = \frac{Ag}{a} P(0,t) + 2\dot{w}(l,t-\tau) - \frac{Ag}{a} P(0,t-2\tau) + \dot{w}(0,t-2\tau) \quad (4)$$

and since this solution involves only past history, we may solve for the flow and pressure at each end of a pipe segment directly.

To include the effect of fluid resistance, the segment pressure drop is lumped at the downstream end of the pipe. Thus:

$$P(l,t) = P(l,t) + R \dot{w}(l,t) \cdot |\dot{w}(l,t)| \quad (5)$$

Acoustic Velocity

The acoustic velocity of the fluid enters into the above calculation in two places; (1) directly in the constant relating flow to pressure, and (2) indirectly in the time delay value τ which equals $\frac{L}{c}$ seconds. The acoustic velocity of a fluid is a property of that fluid, however, its effective value is reduced by the elastic walls of a pipe or entrainment of gas and vapor in the liquid-two phase flow. Vapor in the liquid can come from two places. One is direct entrainment from mixing of gas and liquid in the propellant tank, and the second results from evolution of dissolved gas if the liquid is supersaturated.

Dissolved pressurant gas in liquids obeys Henry's law which says that the amount of dissolved gas at equilibrium is a linear function of pressure. Thus the equilibrium value of dissolved gas will decrease as pressure is reduced. Because of the pressure drop in the feedlines, the pressure will decrease as the propellant flows toward the engine, and there is a tendency for gas to be evolved. The rate at which the gas is evolved appears to be at a rate proportional to its excess. Thus

$$\frac{d}{dt} G(t) = - \gamma (G(t) - G_s) \quad (6)$$

Knowing the amount of gas in the liquid, the effective acoustic velocity of the mixture may be calculated. A number of different approaches exist for this calculation, as presented in Ref. (a). The one used in this model assumes isentropic compression of the gas. The change in volume of the liquid can be written:

$$dV_l = - \frac{V_l}{B} dP \quad (7)$$

and for the gas

$$dV_g = -\frac{V_g}{kP} dP \quad (8)$$

Defining a constant α as

$$\alpha = \frac{V_g}{V_l} \quad (9)$$

the following relation is obtained

$$\frac{dV_t}{V_t} = \frac{-dP}{\left[\frac{1+\alpha}{\frac{1}{\beta} + \frac{\alpha}{kP}} \right]} \quad (10)$$

The bracketed term is the compressibility of the mixture. The density of the mixture can be shown to be:

$$\rho_m = \frac{\alpha \rho_g + \rho_l}{(1 + \alpha)} \quad (11)$$

The acoustic velocity of a liquid in an elastic pipe is

$$a = \sqrt{\frac{1}{\frac{\rho}{g} \left(\frac{1}{\beta} + \frac{Dc}{eE} \right)}} \quad (12)$$

Using the above expressions for density, compressibility, and acoustic velocity, we obtain:

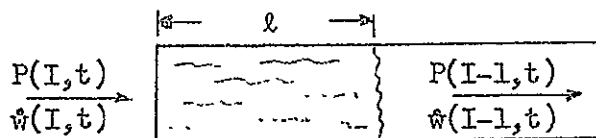
$$a = \left[\frac{1}{\frac{\rho_m}{1+\alpha} + \frac{\alpha}{\rho_l a_l^2} + \frac{1}{\rho_g a_g^2} + \frac{1+\alpha}{g} \cdot \frac{Dc}{eE}} \right]^{\frac{1}{2}} \quad (13)$$

This expression is used along with the wave equations to define the characteristics of a feed system with two phase flow. For an all liquid system, $\alpha = 0$ and the same equation can be used.

Priming

The priming transient is that one during which the empty feed system lines are filled with propellant. When a propellant valve is opened or a burst diaphragm ruptures, the liquid is forced into the empty line segments. The model assumes that no flow leaves a segment until it is filled. This is not completely true in reality, but the assumption greatly simplifies the modeling and correlates well with test data. In a vacuum start, the propellant will vaporize in the unfilled portions of the manifold and a certain amount of this vapor will flow out of the engine. Again this effect is neglected in the present model as the gas outflow is only a small percentage of the liquid inflow.

The priming equations consider the forces acting on an incompressible "slug" of liquid. The slug has the same cross sectional area as the pipe segment being filled and the length of the slug is determined from the amount of fluid in the partially filled element.



Writing a force balance on the fluid slug as,

$$P(I,t) - P = \frac{l}{Ag} \frac{d}{dt} \dot{w} \tag{14}$$

where P is a dummy pressure which represents a net value acting on the slug. P is related to the actual downstream pressure by the effective resistance R of the segment. R is obtained from the expression

$$R = \frac{l}{L_{act}} R_{act} \tag{15}$$

where L_{act} is the true length of the segment and R_{act} is the lumped resistance of the segment. Thus

$$P(I-1,t) = P-R \left[\dot{w}(I-1,t) \right]^2 \quad (16)$$

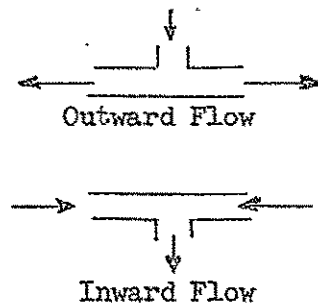
and using the water hammer equation at the junction of the two segments gives;

$$P(I,t) = \frac{a}{Ag} \left[\dot{w}(I,t-2\tau) - \dot{w}(I,t) \right] + 2P(I+1,t-\tau) - R \left[\dot{w}(I,t-2\tau)^2 + \dot{w}(I,t)^2 \right] \quad (17)$$

The downstream pressure is assumed to be given and thus the above equations can be solved for the flows and pressures in the segment being filled. The flow into the segment is integrated to determine if the segment is full, and flags the start of flow into the next downstream segment when filling has been completed.

Branch Lines

The equations derived thus far consider only the flow from one pipe into another and has not covered the problem of branched lines. Branched lines can be classified in three categories, (1) outward flow, (2) inward flow, and (3) a combination of both. To handle branched lines it is assumed that the branch has zero internal volume and that its flow is incompressible. Thus the pressures of all segments which meet at a branch are set equal, and the continuity of flow is used to provide the necessary equations to allow the calculations of flow and pressure in each



branch. For the outward flow branch, priming of the system will work as the single feed line will fill normally and when it is full, the downstream branches can be filled as long as some initial split of the flow is provided. The inward flow branch will have a problem in priming if one of the feed lines primes before the other. The model is set up to provide a normal direction of flow in a segment and this information is used in the priming of lines. To handle the inward flow branch, the program prevents flow out of a branch until enough propellant has been accumulated to fill all segments which normally feed the branch. Thus all segments upstream of the branch are primed before fluid flows out of the branch.

PRESSURIZATION SYSTEM

In a pressure fed rocket system the propellant tank pressurization system has a direct effect on the performance of the system. For this reason, two different pressurization schemes are provided with this model. In one, the tank pressure may be programmed as a function of time; in the second a simplified pressurization system is simulated. The first system needs no further explanation. In the second, the basic elements of the system consist of the storage tank, pressure regulator, heat exchangers, propellant tank ullage volume, and general items such as valves, fittings, and a filter. Equations used for the various components are derived below.

Tank Equations

Figure 1 shows a typical tank with gas flow in and out, liquid outflow, and heat addition. The scheme of subscripts shown there is generally applicable to any series of tanks or other significant volumes in which compressibility is important, although the final model will have only one propellant tank.

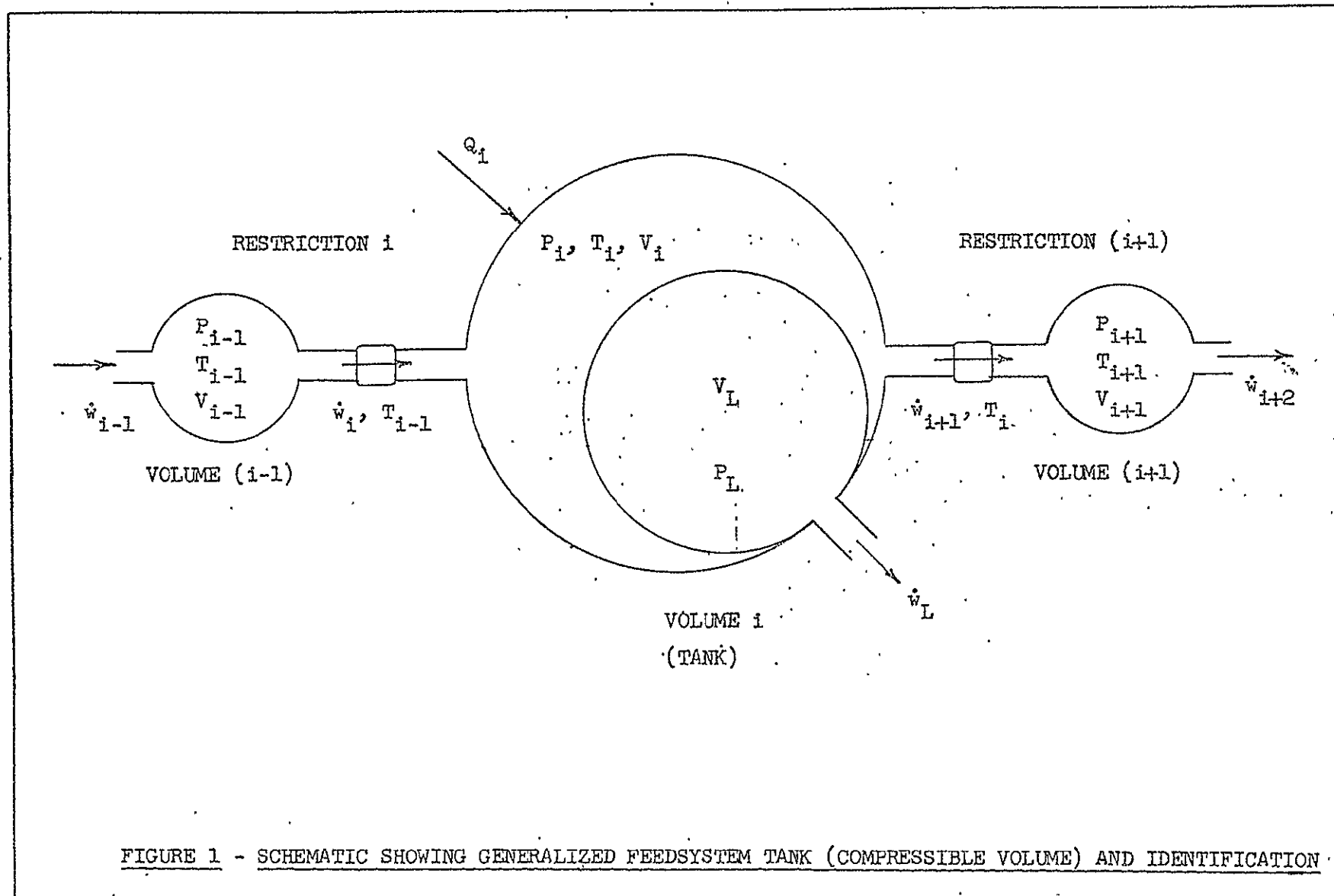


FIGURE 1 - SCHEMATIC SHOWING GENERALIZED FEEDSYSTEM TANK (COMPRESSIBLE VOLUME) AND IDENTIFICATION

Application of mass conservation, energy conservation, and the equation of stage relationships will yield the desired thermodynamic conditions within such a tank at any instant.

By conservation of mass for the gas system,

$$\frac{d}{dt} \dot{W}_i = \dot{w}_i - \dot{w}_{i+1} \quad (18)$$

where \dot{W}_i is the stored weight, and \dot{w}_i and \dot{w}_{i+1} are gas inflow and outflow respectively. Integration of this equation yields the instantaneous stored weight of gas in the i^{th} tank or compressible volume.

By conservation of energy with respect to the gas system in this tank, (ref. b), neglecting potential and kinetic energy,

$$\frac{d}{dt} U_{\text{TOT}} = - \Delta H\dot{w} + Q_i - \dot{W}_i \quad (19)$$

where U_{TOT} is the total internal energy of the gas mass. H represents the enthalpy per unit weight, and the Δ represents the change from inlet to outlet. Q_i is heat added, including convection from the walls or liquid interface, mass transfer from the liquid interface, or from an immersed heat exchanger. \dot{W}_i is the external work, i.e. the work done by the gas on the liquid surface.

The external work is

$$\dot{W}_i = P_i \frac{d}{dt} V_i = P_i \frac{\dot{w}_{li}}{\rho} \quad (20)$$

where it is noted that the rate of change of gas volume, V_i , is simply the negative of the rate of change of liquid volume.

Substituting equation (20) into (19) and applying the relationships

$$\begin{aligned} U_{TOT} &= C_V W T \\ H &= C_P T \\ k &= C_P / C_V \end{aligned}$$

it is found that,

$$\frac{d}{dt} T_i = \frac{1}{W_i} \left[\dot{w}_i (k T_{i-1} - T_i) - (k-1) \dot{w}_{i+1} T_i - \frac{P_i \dot{w}_l}{\rho_l C_V} + \frac{Q_i}{C_V} \right] \quad (21)$$

This equation can be integrated to yield the instantaneous temperature of the gas within the i^{th} tank. Note that the absence of liquid outflow or inflow, or heat addition can be represented simply by striking out the associated term in equation (21):

The instantaneous volume occupied by the gas is found from

$$\frac{d}{dt} V_i = \frac{\dot{w}_l}{\rho_l} \quad (22)$$

Equations (18 and (22) are sufficient to determine the density of the gas in the tank, which is a thermodynamic property. A second thermodynamic property, temperature, is obtained from equation (21). Assuming a single phase, these two properties are sufficient to determine all other properties, specifically pressure. That is

$$P_i = P_i \left(\frac{W_i}{V_i}, T_i \right) \quad (23)$$

which is an equation of state.

If it is assumed at this point that the gas is at a temperature sufficiently above its critical temperature, the equation of state can be approximated by an ideal gas form. That is:

$$P_i = Z \frac{W_i}{V_i} \frac{R_0}{M} T_i \quad (24)$$

where Z is a compressibility factor. The compressibility factor can be taken as constant for a sufficiently small change in temperature and pressure, such as would be expected during an engine start period. The validity of this approximation must be examined in each case, making reference to reduced properties charts, or other representations of actual gas behavior. The alternative would be to include an equation of state in tabular form. The remainder of this development will employ equation (24).

Flow Device Equations

Many flow devices can be represented by the compressible flow orifice equation. A convenient form of this equation is, for the flowrate through the i^{th} device

$$\dot{W}_i = \frac{C_i P_{i-1} A_i}{\sqrt{T_{i-1}}} \Phi \left(\frac{P_i}{P_{i-1}} \right) \quad (25)$$

where Φ is the compressible flow function. Letting the pressure ratio be a , Φ can be expressed as,

$$\Phi = \left[\frac{2kg}{R(k-1)} \left(a^{\frac{2}{k}} - a^{\frac{k+1}{k}} \right) \right]^{\frac{1}{2}}, \quad a \geq a_c \quad (26)$$

$$\Phi = \Phi_M = \Phi(a_c), \quad a < a_c$$

$$a_c = \left(\frac{2}{k+1} \right)^{\frac{k}{k-1}} \quad (27)$$

In this equation k and R are the specific heat ratio and gas constant for the gas being used in this system.

Filters in the gas flow system are generally laminar flow devices, and therefore obey a linear flow-pressure loss relationship. This can be expressed as

$$\dot{w}_i = K \rho \Delta P_i$$

Assuming an ideal gas density

$$\rho = \frac{P}{RT}$$

results in

$$\dot{w}_i = \frac{K_1 P_i}{R T_{i-1}} (P_{i-1} - P_i) \quad (28)$$

The proportionality constant K_1 can be evaluated if the flow temperature and pressure conditions are known at any nominal point, i.e.

$$K_1 = \left(\frac{\dot{w} RT}{P \Delta P} \right)_n \quad (29)$$

Pressure loss through a heat exchanger core is generally expressed in a square-law relationship (Ref. b), i.e.

$$\dot{w}_i = \left(\dot{w} \sqrt{\frac{T}{P \Delta P}} \right)_n \left(\frac{P_{i-1} (P_{i-1} - P_i)}{T_{i-1}} \right)^{\frac{1}{2}} \quad (30)$$

Again, the proportionality constant has been evaluated by reference to some nominal point at which the pressure, temperature, and flowrate are all known.

A pressure regulator in the system can be simulated with equation (25), if it is noted that the flow area is a variable dependent on diaphragm or reference pressure. This relationship can be developed by equating diaphragm force, F_d , to the force exerted by the reference spring, F_r . If it is assumed that the spring has a force deflection curve which is linear over the range of poppet travel, the reference spring force is

$$F_R = F_{R0} + K_1 X, \quad 0 \leq X \leq X_{MAX} \quad (31)$$

where F_{ro} is the spring force when the regulator is closed, and X is the poppet position, measured from the closed position. The local spring slope is K_1 , and diaphragm force is represented as;

$$F_d = (P_R - P_a) A_e \quad (32)$$

where P_R and P_a are the reference and ambient pressures respectively, and A_e is the effective diaphragm area. For small poppet travel, the seat area is a linear function of X , i.e.

$$A_s = K_2 X, \quad 0 \leq X \leq X_{MAX} \quad (33)$$

By equating diaphragm and spring forces, and substituting equation (33), there results,

$$A_s = \left(P_R - P_a - \frac{F_{RO}}{A_e} \right) \frac{K_2 A_e}{K_1}, \quad 0 \leq A_s \leq A_{MAX} \quad (34)$$

In a simple system, the reference pressure is the pressure immediately downstream of the seat, but it could as well be supplied from some other downstream point by means of a sensing line.

Heat Exchangers

Heat exchangers in the pressurization system can be simulated most easily by the effectiveness vs net-transfer-unit method described in Ref. (c).

Figure 2 shows a typical heat exchanger. In a pressurization system, the gas is the colder fluid and is being heated by a secondary flow. Therefore the gas inlet and outlet temperatures are referred to as T_c in and T_c out, and the cooling fluid inlet and outlet temperatures are T_h in and T_h out, following the terminology of Ref. (b). The secondary or heating fluid flowrate is designated \dot{w}_h , whereas the gas flowrate is designated \dot{w}_g . The method is independent of the type of the two flows. That is, the heating flow can be either liquid or gaseous.

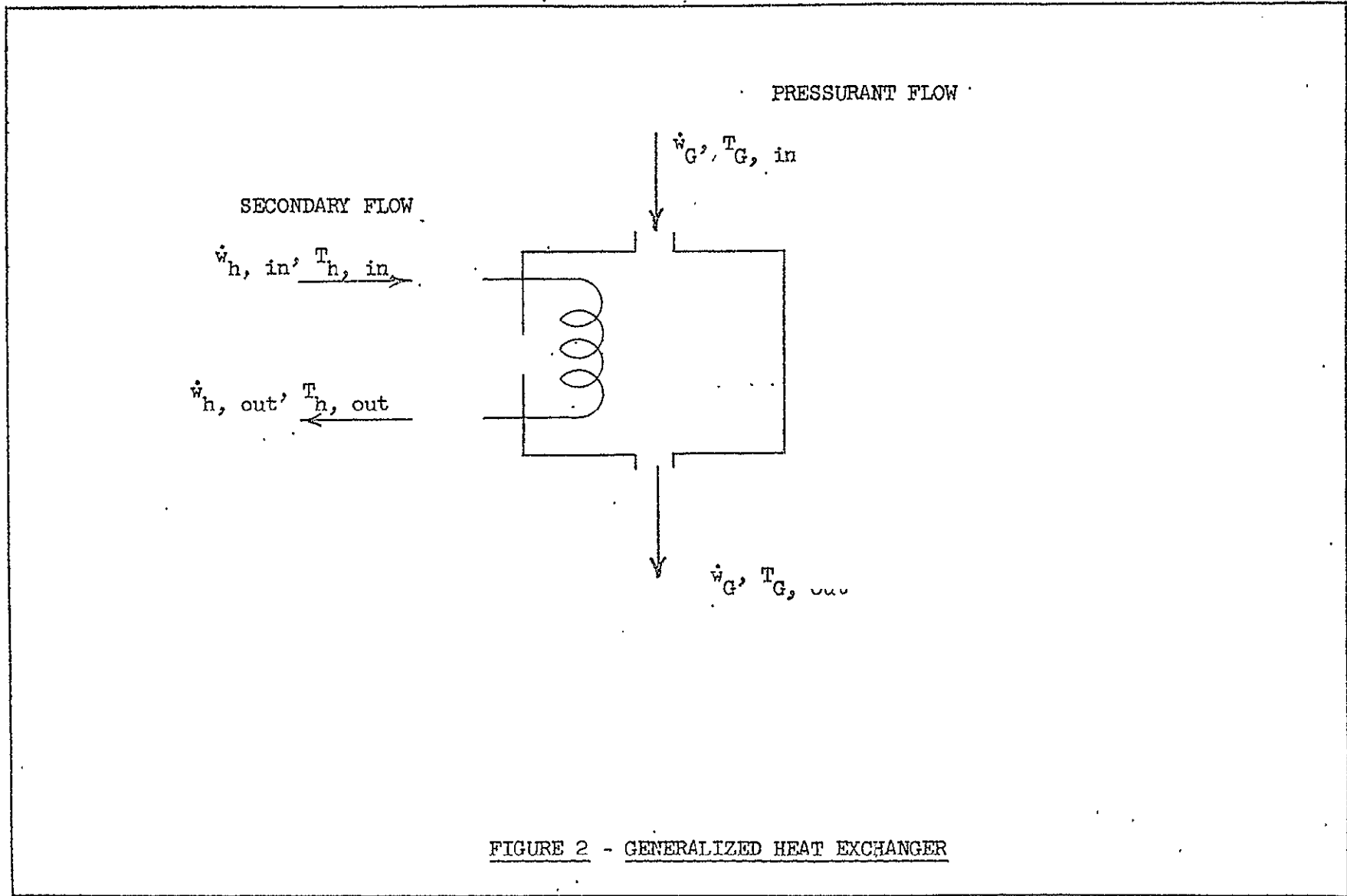


FIGURE 2 - GENERALIZED HEAT EXCHANGER

Capacity rates are defined for both flows as

$$C_h = \dot{w}_h C_{Ph} \quad (\text{hot fluid}) \quad (35)$$

$$C_c = \dot{w}_c C_{Pc} \quad (\text{cold fluid})$$

It is necessary to distinguish between the C which is maximum and that which is minimum in assessing the heat exchanger performance. Therefore, let,

$$\begin{aligned} C_m &= \text{MIN}(C_h, C_c) \\ C_M &= \text{MAX}(C_h, C_c) \end{aligned} \quad (36)$$

where the functions $\text{MIN}(a,b)$ and $\text{MAX}(a,b)$ are defined as the minimum and maximum of the arguments (a,b) respectively. These functions are standard library functions for most digital programming languages.

The number of transfer units, or NTU, is defined as

$$NTU = \frac{A_h U_h}{C_m} = \frac{A_c U_c}{C_m} \quad (37)$$

where AU is the transfer area times the average over-all conductance between the two flows. It can be evaluated either for the hot or the cold fluid side, since conservation of energy requires them to be equal.

Finally, the heat exchanger effectiveness, ξ , can be determined from charts (Ref. c), or can be approximated by closed-form expressions. In general,

$$\xi = \xi(NTU, C_m/C_M, \text{Flow arrangement}) \quad (38)$$

For many systems, the hot fluid will be liquid and the cold fluid gas, in which case, due to the low mass flowrate and C_p of the gas relative to the liquid,

$$\frac{C_m}{C_M} \ll 1$$

and ξ becomes

$$\xi = 1 - e^{-NTU} \quad (39)$$

for all flow arrangements. This is also the case for a heat exchanger submerged in a constant temperature fluid, since C_M is then essentially infinite.

Once the effectiveness of the heat exchanger is known, the heat transferred is found from

$$Q = C_m (T_{h \text{ in}} - T_{c \text{ in}}) \xi \quad (40)$$

The outlet temperature of the two flows is then

$$T_{c \text{ out}} = T_{c \text{ in}} + \frac{Q}{C_c} \quad (41)$$

$$T_{h \text{ out}} = T_{h \text{ in}} + \frac{Q}{C_h} \quad (42)$$

If the heat exchanger is submerged in a propellant or pressurant tank, the Q determined from equation (40) is employed in the tank temperature equation, rather than in equation (42).

From the above it is apparent that the heat supplied from a particular heat exchanger to the pressurant flow is easily determined from upstream temperatures, fluid flowrates, and fluid properties. That is, functionally,

$$Q = f(\dot{w}_h, C_{Ph}, \dot{w}_c, C_{Pc}, AU, T_{h \text{ in}}, T_{c \text{ in}}) \quad (43)$$

which can most efficiently be developed as a digital subroutine program.

Solution for Particular System

The equations developed above can be applied to any combination of elements, thereby describing a large number of different pressurization systems. A typical system is shown in Fig. 3. This system has three heat exchangers, the second of which is submerged in the storage tank. The propellant tank has a liquid outflow, \dot{w}_L , which is assumed to be given. Other known data include the initial conditions in the two tanks, the flowrate for heat exchangers, system geometry and pressurant properties.

Since gas storage volumes in the flow system are small relative to the two tanks, storage will be neglected in the flow system. This implies that all flow devices have the same instantaneous flowrate, \dot{w}_G . Thus equation (25) is applied at the start valve, regulator, and fittings, equation (28) is applied at the filter, and equation (21) at the heat exchangers, all with the same flowrate. The occurrence of this single variable in all of these equations makes it necessary to solve the equations iteratively.

COMBUSTION CHAMBER

The combustion chamber model describes the reaction of the propellant, their storage in the combustion chamber, and the continuity between flow in and out. This can be expressed mathematically as

$$M = \int (\dot{w}_{in} - \dot{w}_{out}) dt \quad (44)$$

The mass M , of reacted propellant is related to the chamber pressure by the perfect gas law

$$P_c V_c = M R_c T_c \quad (45)$$

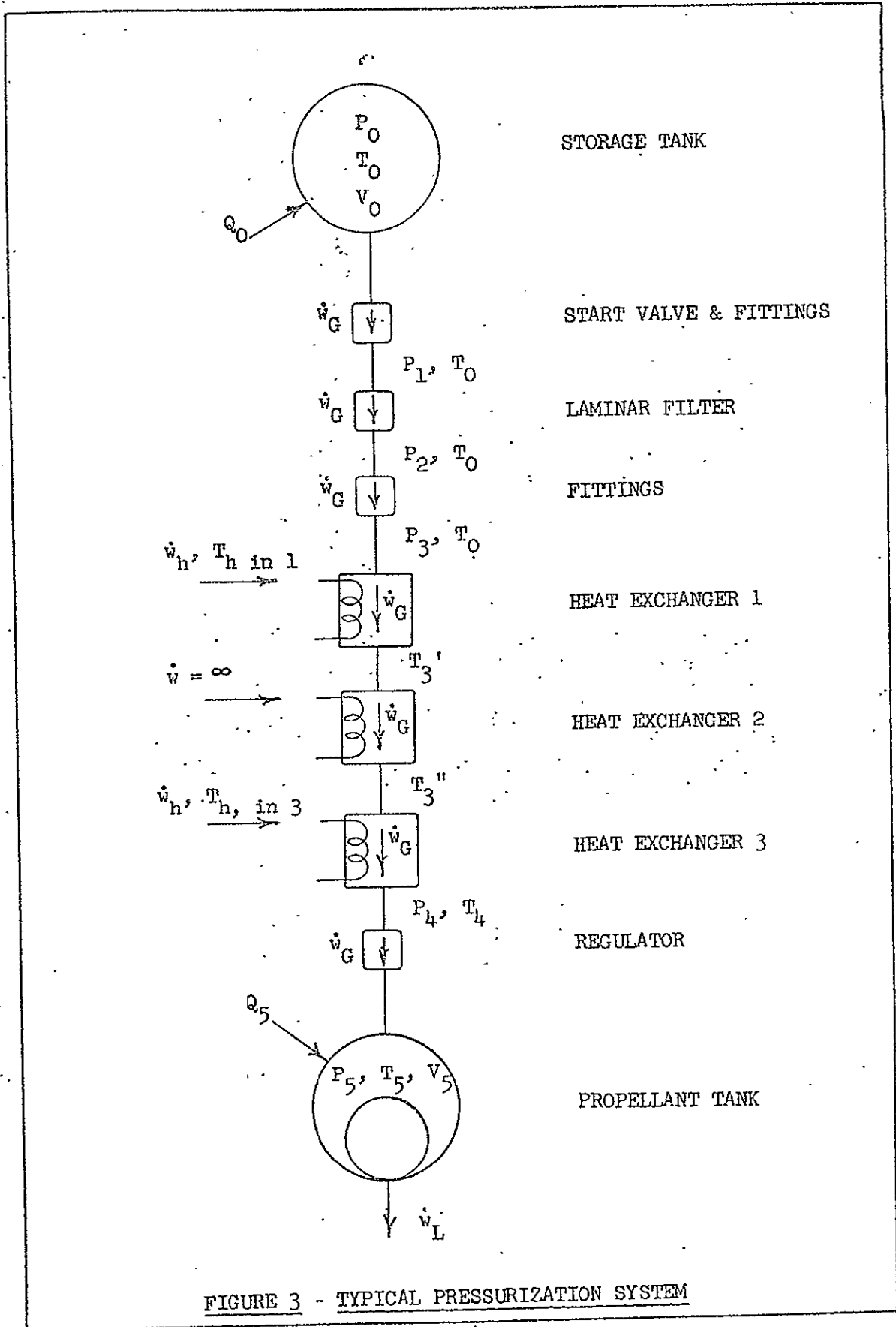


FIGURE 3 - TYPICAL PRESSURIZATION SYSTEM

The flowrate out of the chamber is also related to the chamber pressure and can be written

$$\dot{w}_{out} = \frac{P_c A_T}{\eta_c^* \frac{C^*}{g}} \quad (46)$$

If equations (44) and (45) are differentiated they can be combined with equation (46) to give

$$\frac{d}{dt} P_c = \frac{R_c r_c}{V_c} \dot{w}_{in} - \frac{R_c r_c}{V_c} \cdot \frac{A_T}{\eta_c^* \frac{C^*}{g}} P_c \quad (47)$$

which is the desired form.

The constants in equation (47) vary with mixture ratio and chamber pressure. This variation is supplied from a table which contains $R_c T_c$, C^*/g , and η_c^* as functions of oxidizer fraction $MR/(1 + MR)$ and a correction factor $C_f = (P_c/P_{BASE})^\delta$. These constants are determined from thermochemical calculations for the propellant combination being used. The value of \dot{w}_{in} is the sum of the fuel and oxidizer flowrate which is presently being converted into combustion products, and the quotient of these values determines the mixture ratio used to find chamber properties.

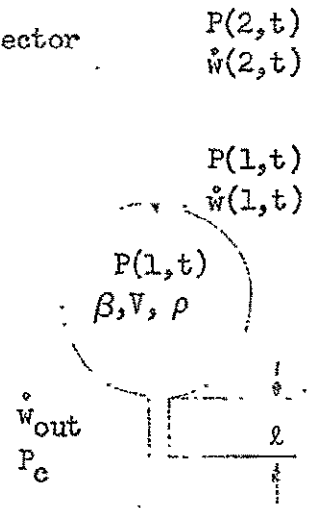
The propellant presently burning is not the propellant leaving the injection orifices. Instead, it is propellant that has finally reached the combustion zone after traveling some finite distance from the injector. The time required for the propellant to travel to the combustion is known as flight time or transport time, and is often assumed to be a constant. Reference (d) discussed the transport process and shows that the flight time should be a variable dependent on the injection velocity. If it is assumed that the combustion

zone is stationary one time delay can be computed from the velocity which is a function of the injector differential pressure. Thus

$$\tau_D = \frac{l}{v} = \frac{l}{\sqrt{2g \Delta P/\rho}} \quad (48)$$

INJECTOR

The injector dynamics are included by treating the injector as a lumped compressible volume as shown in the figure at the right. The flow and pressure at the bottom of the pipe segment are related by the equation:



$$P(1,t) = \frac{a}{Ag} \dot{w}(1,t-2\tau) - \dot{w}(1,t) + 2P(2,t-\tau) - P(1,t-2\tau) - R \dot{w}(1,t)^2 + \dot{w}(1,t-2\tau)^2 \quad (49)$$

The flow out is controlled by the differential pressure across the injector and the resistance and inertia of the injector orifices; thus

$$P(1,t) - P_c = R \dot{w}_{out}^2 + \frac{l}{Ag} \frac{d}{dt} P(1,t) \quad (50)$$

Storage of propellant in the injector manifold can be represented by the following equation.

$$\dot{w}_{out} = \dot{w}_{in} - \frac{V\rho}{\beta} \frac{d}{dt} P(1,t) \quad (51)$$

Since P_c is determined by flow into the combustion chamber some time prior to the present (transport time delay), it can be calculated directly. Then the above equations, which involve only 3 unknowns, may be calculated directly.

CUTOFF

Rocket engine cutoff is initiated by closing one or both of the main propellant valves. As the valves start to close the resistance of the valve segment will increase and flow will start to decrease. When the valve effective area reaches zero, the resistance is set to a value of 10^{31} to act as a flag in the program to signify valve closure. While the valve or valves are closing, the model will operate normally. When the injector manifold is finally separated from the propellant tank, the state of the propellants will be determined by the energy in the system downstream of the closed propellant valves. At valve closure, the quantities of propellant liquid, vapor, and pressurant gas may be determined from known properties of the propellant.

Flow out of the injector is represented by equation (50), and the equations of state for the gas and liquid phase can be represented as follows:

$$M = \frac{V_l \rho_l}{\beta} P_m \quad (52)$$

and

$$M_v = M_g + M_{l v} = \frac{r_g V_g}{R_o T} + \frac{P_{l v} V_g}{R_o T} \quad (53)$$

The liquid vapor pressure is a function of temperature and can be approximated by

$$\text{Log}_{10} P_{l v} = K_1 T + K_2 \quad (54)$$

The total pressure in the injector is the sum of the partial gas pressures, thus:

$$P_m = P_g + P_{l v} = P_g + \text{Log}_{10}^{-1} (K_1 T + K_2) \quad (55)$$

After engine cutoff, heat soakback will raise the temperature of the injector and there will be heat transfer to the propellant. However, as the pressure in the injector falls more of the liquid will vaporize which will tend to lower the propellant temperature in the manifold. The propellant temperature is therefore found from the following heat balance:

$$\begin{aligned}
 T(t) (C_P M_l + C_{PG} M_g + C_{Plv} M_{lv}) \Big|_{t=t} & \quad (56) \\
 = T_{(t-1)} (C_P M_l + C_{PG} M_g + C_{Plv} M_{lv}) \Big|_{t=t-1} \\
 + Q(T_{INJ} - T_{(t-1)}) \Delta t - (M_{lv}(t) - M_{lv}(t-1)) H_v
 \end{aligned}$$

The concentration of dissolved pressurant gas in the propellant is determined using the same equation as used for the derivation of effective acoustic velocity

$$\frac{d}{dt} G = - \gamma(G - G_S) \quad (57)$$

To solve these equations it is assumed that the propellant mixture is homogeneous and therefore if \dot{w} is known, the mass of propellant left in the injector can be calculated. An iteration technique of the predictor-corrector variety is used to solve these equations. First P_m is estimated, and if P_c is known, \dot{w} can be calculated followed by the state of the propellants in the injector. Using these data, the pressure estimate can be checked using equation (55).

At the start of the cutoff transient, the combustion chamber pressure is calculated in a normal fashion as previously described. As the propellant valves close combustion will continue down to some limiting value, which will have to be established. After combustion ceases, the thrust chamber will blow down to a pressure level which will be maintained by the vaporization rate of the propellants. Flow out of the chamber during this period

will be assumed to be propellant vapor plus any pressurization gas which is present. In terms of mass storage,

$$\dot{w}_{in} - \dot{w}_{out} = \frac{V_c}{R_c T_c} \frac{d}{dt} P_c \quad (58)$$

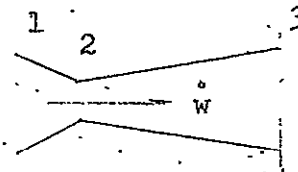
The flow in is that calculated by equation (50) above, and flow out is assumed to be either all oxidizer or all fuel. This assumption allows the calculation to be done in the combustion subprogram.

MISCELLANEOUS COMPONENTS

Cavitating Venturi

These components are used in rocket engine systems to control flowrate and their operation is based on Bernoulli's Equation given below

$$\frac{P_1}{\rho_1} + \frac{V_1^2}{2g} = \frac{P_2}{\rho_2} + \frac{V_2^2}{2g} \quad (59)$$



Using the equation of continuity equation (59) becomes,

$$\frac{P_1}{\rho_1} - \frac{P_2}{\rho_2} = \frac{w_2^2}{2 \rho_2^2 A_2^2 g} - \frac{w_1^2}{2 \rho_1^2 A_1^2 g} \quad (60)$$

For an incompressible liquid, the above equation can be simplified to

$$P_1 - P_2 = \frac{w^2}{2g\rho} \left(\frac{1}{A_2^2} - \frac{1}{A_1^2} \right) \quad (61)$$

From this equation it may be seen that for constant geometry and inlet pressure P_1 , as the flowrate increases the pressure P_2 decreases until it equals the vapor pressure of the fluid. At this point, cavitation occurs in the throat of the Venturi and further increases in flow are not possible without an increase in inlet pressure P_1 . The pressure and flow on either

side of the venturi may be determined by the equations (2) and (21) developed previously. Thus:

$$P_1 = f(\dot{w}_1) \quad (62)$$

The pressure on the downstream side of the venturi for no cavitation will be

$$P_3 = f(\dot{w}_1) \quad (63)$$

This latter function may be either the priming equation or the wave equation depending on whether the segment is filled. P_1 and P_3 are related to the pressure recovery of the venturi

$$P_3 = P_1 - K\dot{w} \quad (64)$$

Using the above equations, the flow through the venturi and the inlet and outlet pressures may be calculated assuming no cavitation. By solving equation (61) for P_2 it can be determined if cavitation is occurring. If the calculated value of P_2 is less than the vapor pressure, cavitation is occurring and the flow and pressure must be calculated using equations (61) and (62). Using this flow, P_3 can be calculated from equation (63).

If there is gas entrained with the liquid, the gas will expand and the density can no longer be assumed to be constant. Thus, equation (60) must be used and the values of P_1 and P_2 determined as functions of pressure. If a perfect gas is assumed,

$$\rho_g = \frac{P}{RT} + \frac{W_g}{V_g} \quad (65)$$

and since the ratio of the masses of gas and liquid are known,

$$B = \frac{W_g}{W_l} \quad \text{and} \quad \rho_l = \frac{W_l}{V_l} \quad (66)$$

The equivalent density of the mixture will be

$$\rho_m = \frac{\frac{W_l}{V_l} + \frac{W_g}{V_g}}{\frac{1}{\rho_l} + \frac{BRT}{P}} \quad (67)$$

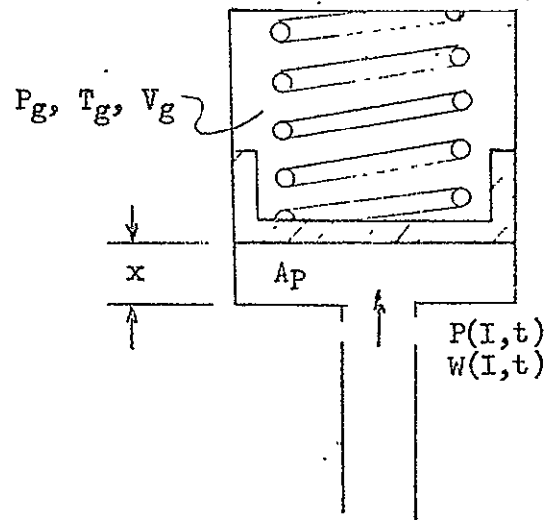
It is assumed that two phase flow in the pipe segments is isothermal but sudden transients are adiabatic. Thus,

$$\rho_1 = \frac{1+B}{\frac{1}{\rho_l} + \frac{BRT_1}{P_1}} \quad \text{and} \quad \rho_2 = \frac{1+B}{\frac{1}{\rho_l} + \frac{BRT_1}{P_1} \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}}} \quad (68)$$

Using these values of density, the performance of the cavitating Venturi can be calculated. The technique is similar to that used with no gas. First the pressures and flows assuming no cavitation are calculated; second, using the calculated value of P_1 and the vapor pressure for P_2 , the maximum allowable flow is determined. If this flow is less than that calculated in the first step, cavitation occurs and equations (60) and (62) must be solved for the value of P_1 and \dot{w} . After these values are obtained, P_3 may be calculated.

ACCUMULATOR

Since accumulators are often used to lower surge pressures or smooth out pressure fluctuations, a model of a simple accumulator will be provided in the program. This element will be mounted on the end of a pipe segment as shown in the sketch. The liquid pressure in the accumulator will be the same as that at the end of the pipe.



Thus, the wave equation (2) can be used to obtain

$$P(I,t) = f(W(I,t)) \quad (69)$$

The accumulator functions when liquid flows into it and moves the piston so as to compress the gas behind the piston and the spring; stops are provided to limit its motion. Depending on the initial pressure behind the piston and preload on the spring, some initial pressure level must generally be reached before the piston will move; also in some cases, the piston or the spring may be missing. The equations are derived for the most general case.

The gas pressure behind the accumulator will depend on the initial value to which it is charged and its instantaneous volume assuming isentropic compression.

$$P_g(t) = P_o \left(\frac{V_o}{V_g(t)} \right)^k \quad (70)$$

A force balance on the piston yields

$$W_p \ddot{X} = (P(I,t) - P_g(t)) A_p - K_s(X_o + X) \quad (71)$$

The gas pressure and liquid flow are related to piston position so that:

$$P_g(t) = P_o \left(\frac{V_o}{V_o - X A_p} \right)^k \quad (72)$$

$$\dot{X} = \frac{\dot{w}(I,t)}{A_p}$$

These equations can be combined to produce a non-linear second order differential equation of the form;

$$M_p \ddot{X} = K_1 - K_2 \dot{X} - K_3 \dot{X} |\dot{X}| - K_4 \left(\frac{1}{1 - K_5 X} \right)^k \quad (73)$$

where the capital K's represent constants. There are several techniques available for solving the above equation, however, an iterative technique will be used so that no special cases develop if one or more of the constants are zero. Secondly, the results will be checked to ensure that X does not exceed its limits, and if this occurs, the flow will be set to zero.

VALVES, FITTINGS, ORIFICES, ETC.

These components are all characterized by the fluid resistance they add to the system. This resistance is handled in two different manners in the model which depends on whether an element is primed or not. For liquid filled lines, the resistance of the pipe and any other component is lumped at the downstream end of the element. Valve resistance can be varied as a function of time for ten different values in either the fuel or oxidizer feed system. When lines are being filled, the resistance of a segment is distributed along the length of an element so that the friction loss will affect the priming. If the resistance is concentrated at an orifice, the priming rate of a line will be reduced too much. This will be prevented during priming by removing the orifice resistance from that line segment until after it is primed.

COMPUTER PROGRAM

The equations described in the preceding section were programmed into a digital computer program. Figure 4 shows a block diagram of this program which contains a main program controlling the data input and output, parameter initialization, and the flow of calculations through 19 subprograms.

To use the program, the system to be modeled is broken up into segments and the required valves, cavitating venturis, orifices, etc., are noted. The model has the capability to handle 60 segments, 10 valves, 4 cavitating venturis, 4 accumulators, and 5 dead end terminations in both the fuel and oxidizer systems. Provisions are also available to handle 4 individual combustion chambers. Additional components may be added by use of subroutines.

Program operation proceeds as follows: After reading the input data, subroutine SETUP is entered. Initial conditions are stored in the proper arrays, miscellaneous constants are calculated, and the program made ready for the case to be run. Upon return to the main program, subroutine PLPRNT is called and system data and initial conditions are printed. Then the auxiliary tape headings are written and subroutine P2PRNT is called to write values of variables on the tape at time zero.

The main program then begins the sequential calculation of the transient being simulated. Subroutine DELAY is the first routine entered at each time interval. In this routine, the gas concentration, the value of effective acoustic velocity, and fluid density in each segment are

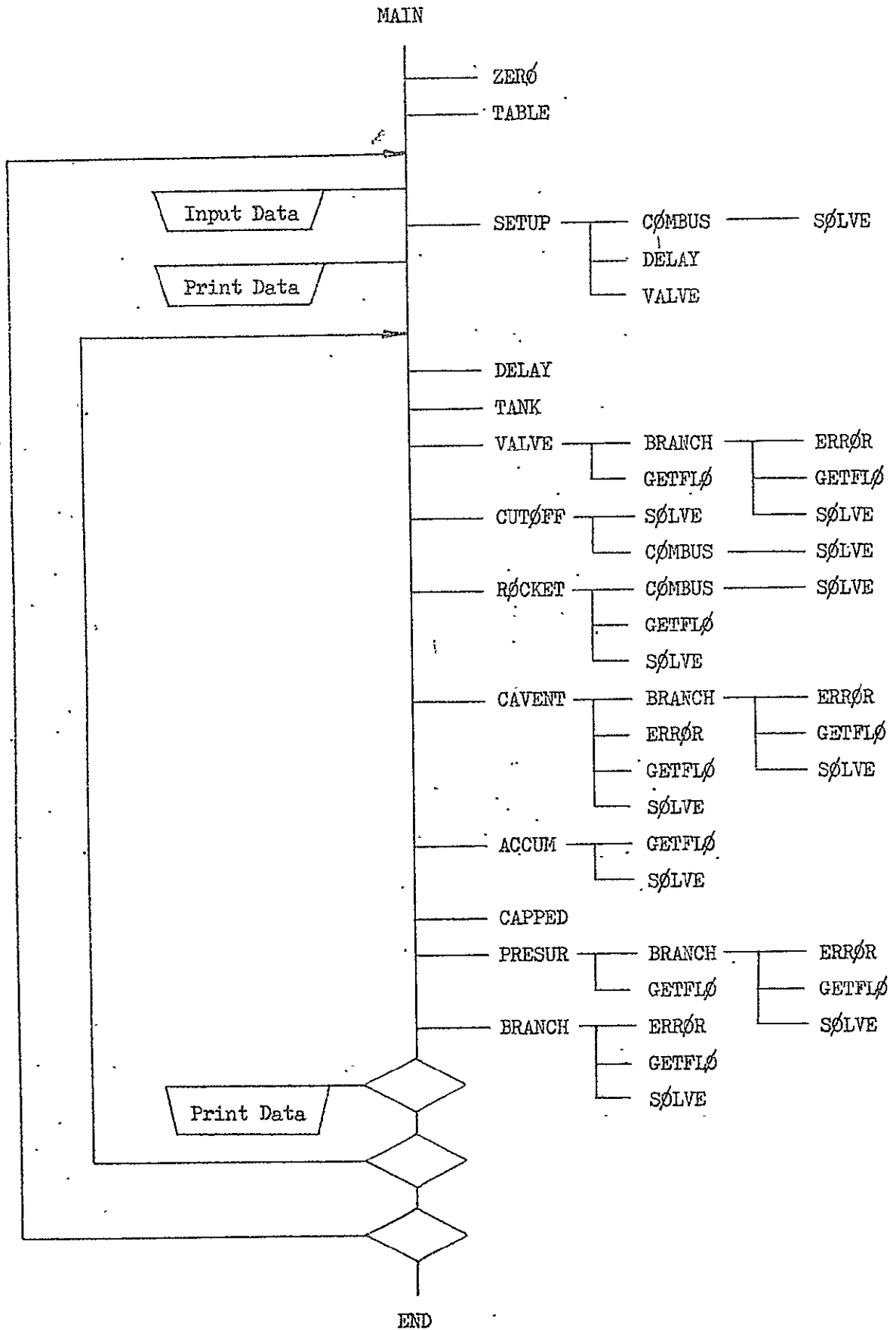


Figure 4 - Block Diagram of Main Program Showing Subprogram Structure

calculated. The time delay flow and pressure terms are then obtained from stored data so that the wave equations can be solved for pressure in each segment. Subroutine TANK calculates the pressures and flows in the pressurization system. This is done using an iterative technique. Also included in the program are provisions to program tank pressure as a function of time. Subroutine VALVE computes the propellant valve opening and closing characteristics. These data are supplied in tables of valve effective area versus time. The subroutine then computes the flow and pressure through the valves, and areas in the variable area cavitating venturis.

The dynamics of other components are next calculated in Subroutines ROCKET, CAVENT, ACCUM, and CAPPED. To simulate blowdown operation of the engine at cutoff subroutine CUTOFF is used.

The main calculation of flow and pressure in the feed system segments is done in subroutines PRESUR and BRANCH. Subroutine PRESUR calculates flow and pressure between single segments which are completely filled with propellant, and calls subroutine BRANCH to fill partially full segments. Subroutine BRANCH calculates flow and pressure in branch elements. The downstream elements can be either full or in the process of being filled. For the latter case it was necessary to include the solution of the priming equations in this subroutine, and thus all priming is done in this subroutine. At specific times during the operation subroutine P2PRNT is entered to write out selected data.

A more detailed description of the program is given in the Engineer and Programmer's Guide. To use the program, the system to be modeled must be divided into segments. The segments and components in the system must then be sequenced so that their location in the system will be known. Data on the length, area, pressure drop, and wall stiffness must be supplied by the user to describe the line segments. Data to describe the physical characteristics of the miscellaneous components, thrust chamber, and pressurization system must also be supplied. After the data describing the physical system to be modeled is supplied, information to describe the function to be simulated must be furnished. This is generally a description of a valve or valves opening or closing, change in area of a cavitating venturi, or change in tank pressure. These functions will allow simulation of engine start, shutdown, or throttling or a combination of all three.

The feed lines of a simple system and engine are shown in segmented form in Fig. 5. Several features should be noted. Segments are numbered from the downstream end to the upstream end of any branch or line. Orifices are lumped with a specific segment. Valves which are in effect variable orifices are identified as separate segments. Branch points or tees are also considered as separate segments but have no characteristics other than as connections.

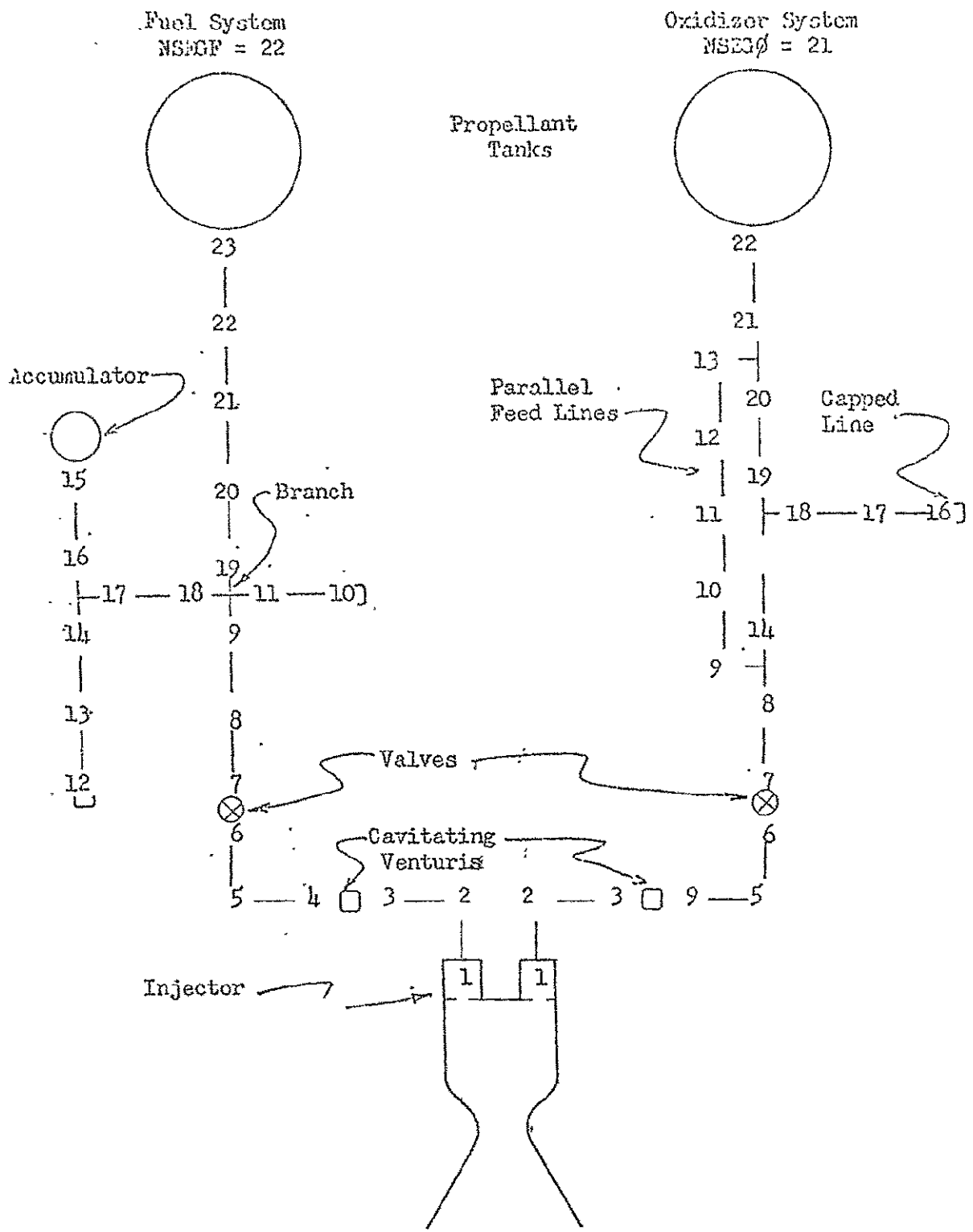


Figure 5 - Typical Rocket Engine System Showing Segment Numbers.

MODEL DEVELOPMENT

Demonstration of the model's use was accomplished by simulating four transients. These were an Apollo Ascent Engine on-off pulse, a Descent Engine start transient with helium saturated propellants, a Descent Engine throttling transient in which a pressurant gas bubble passed through the engine, and an SE5-5 Engine system pressurization transient.

ASCENT ENGINE SIMULATION

The Apollo Ascent Engine transient simulated by the model was an 0.9 second engine on-off pulse. The test simulated was run at the White Sands Test Facility and is designated as Test 006 Run 1. In order to simulate the transient, it was first necessary to prepare a data package for this engine. This required that details of the engine geometry, propellant combustion characteristics, and vehicle feed system configuration be determined and these data put into proper form for use in the model. A description of the work involved in the preparation of the data for input into the model is given in Appendix A.

The results obtained from the computer simulation are shown plotted with the test data in Fig. 6, 7, and 8. Three separate features of the model are demonstrated in this run. First, a start transient is simulated. In this mode, segments downstream of the propellant valve are initially empty. When the valves are opened propellants start to flow, the empty propellant lines fill and when both fuel and oxidizer reach the engine, ignition occurs. Second, when the flow and pressure transients die out a period of steady state performance exists. Third, the propellant valves close and an engine cutoff transient occurs.

The agreement between the test data and model results is good except for the oxidizer injector pressure rise at start and the decay in thrust chamber pressure after the propellant valves close. The variation seen in the oxidizer injector pressure rise is most likely caused by the instrumentation line being empty at the start of the test. This hypothesis is supported by two facts:

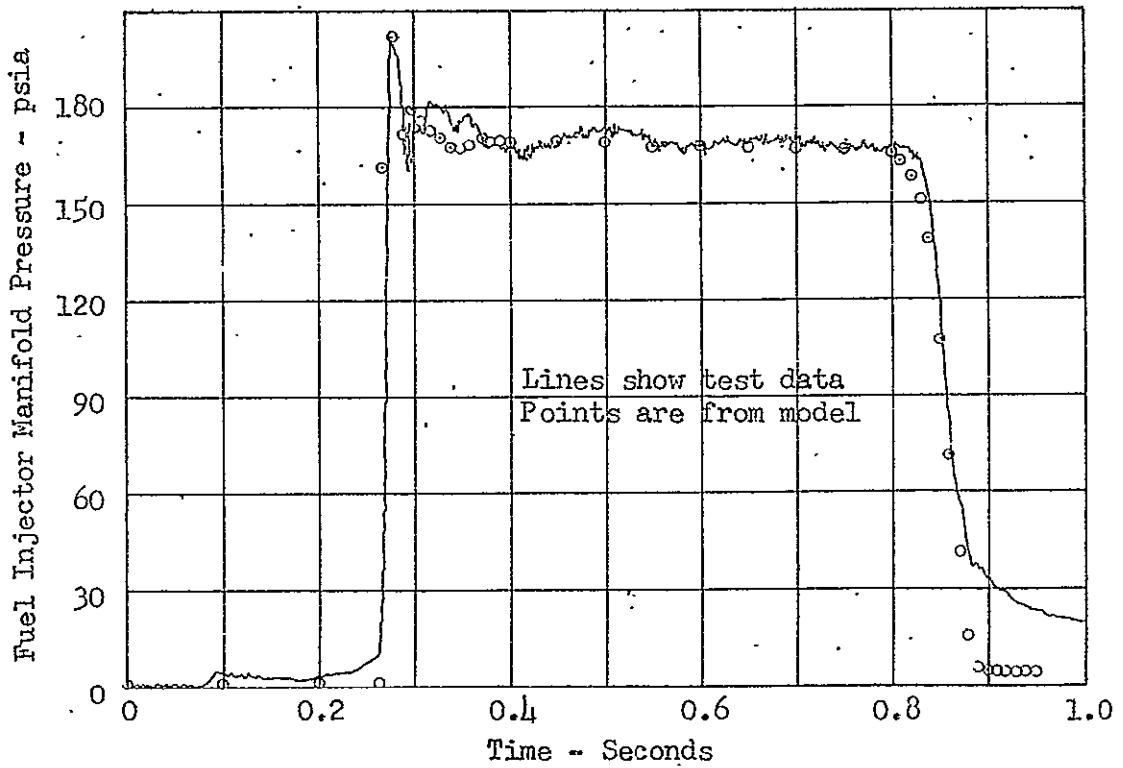
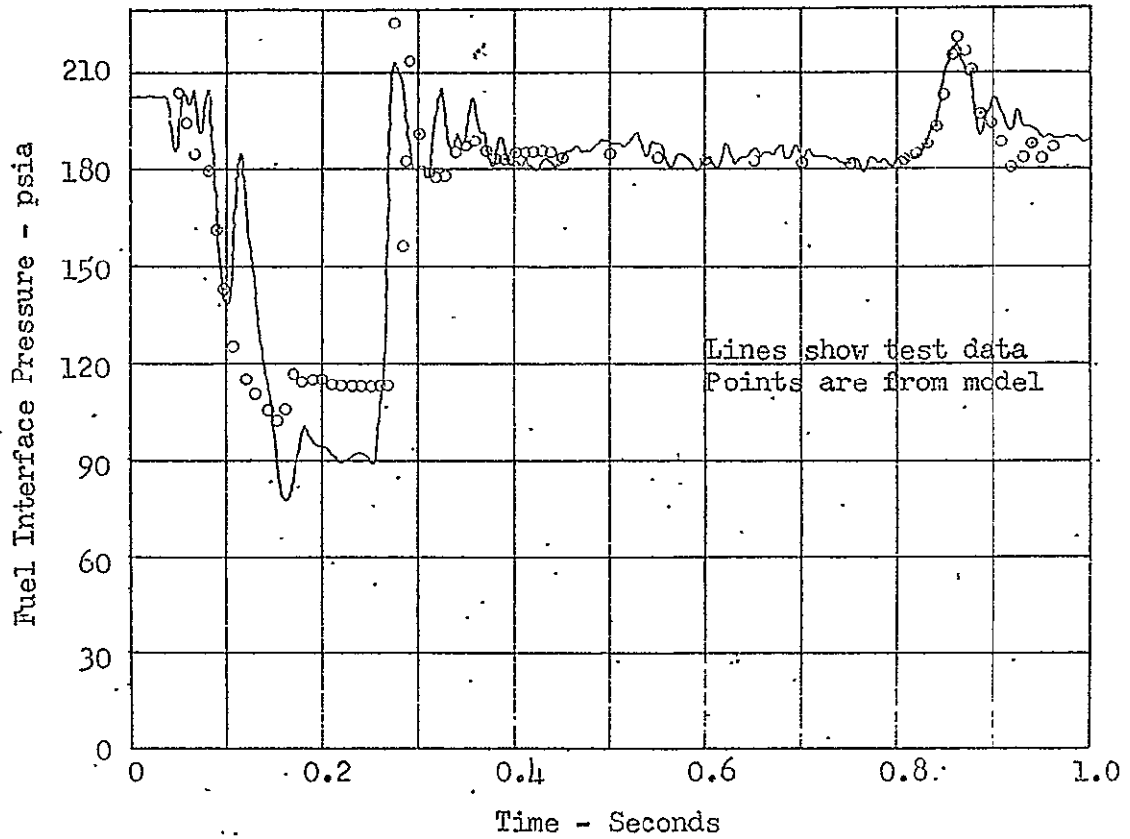


Figure 6 - Apollo Ascent Engine Data Correlation - Fuel System Pressures Subsystem PA-1, Series 7B, Test 006, Run 1

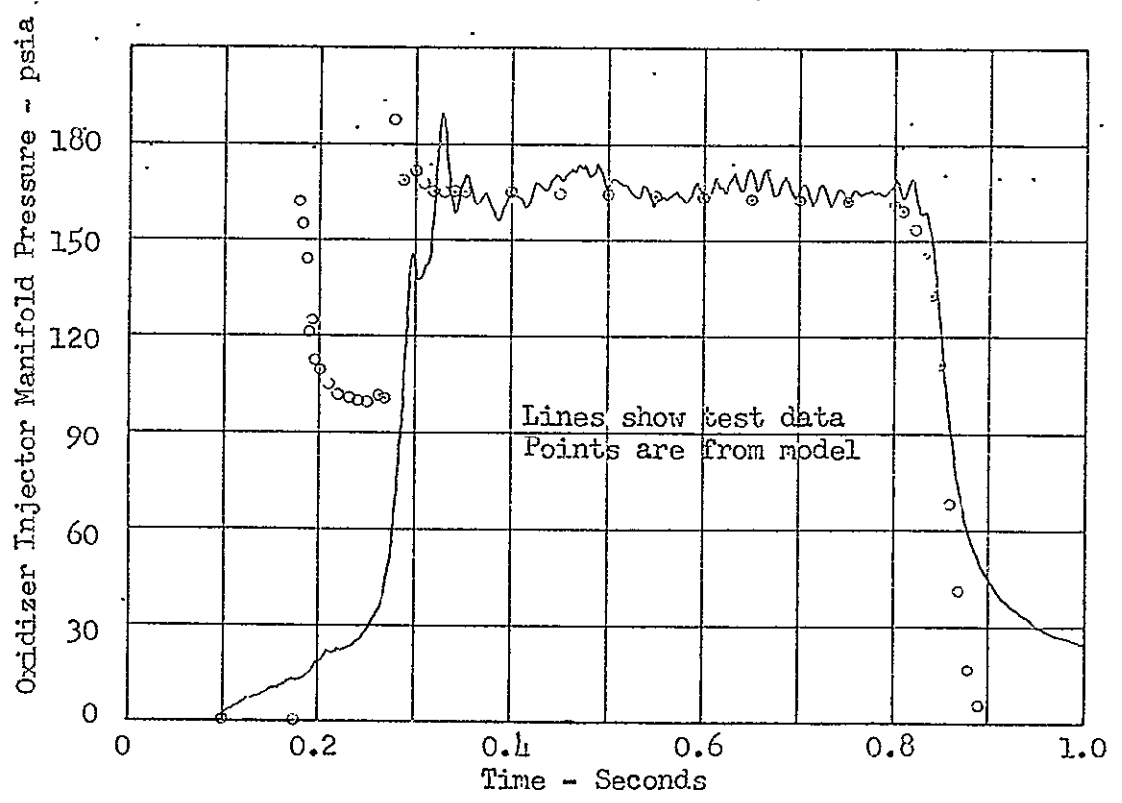
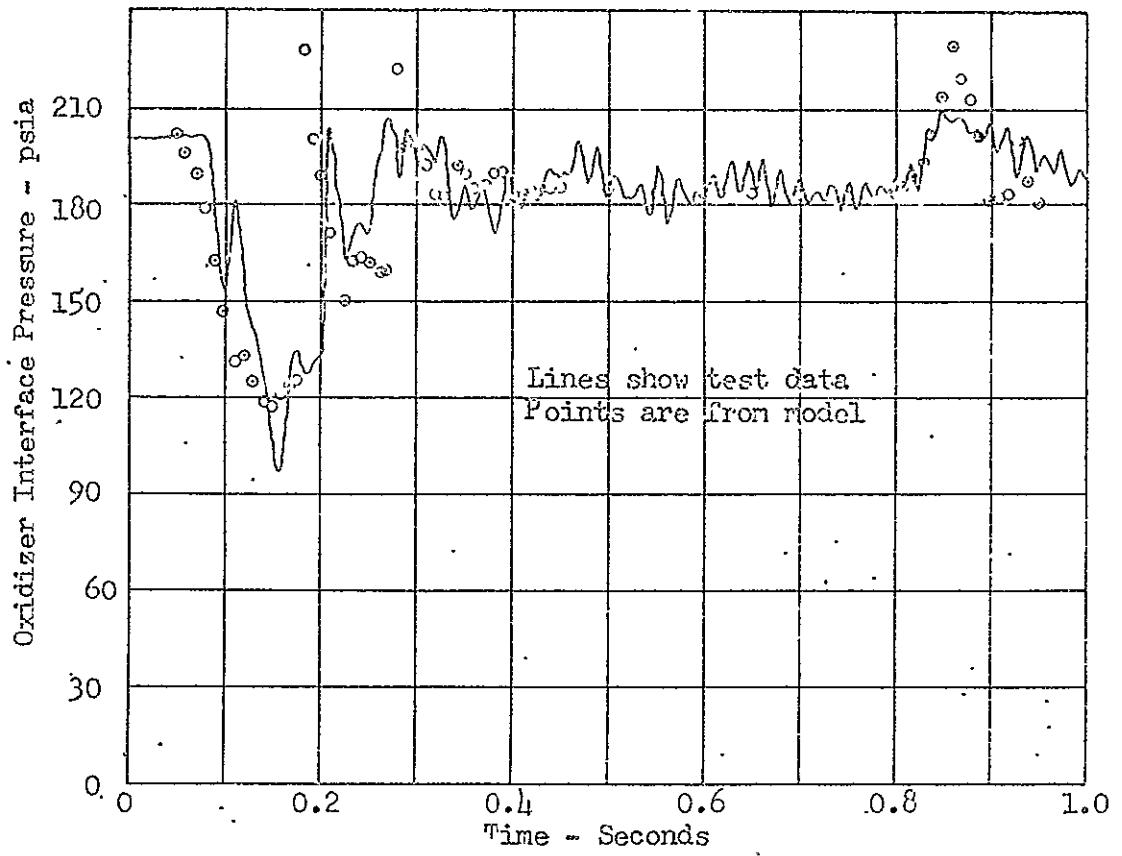


Figure 7 - Apollo Ascent Engine Data Correlation - Oxidizer System Pressures Subsystem PA-1, Series 7B, Test 006, Run 1

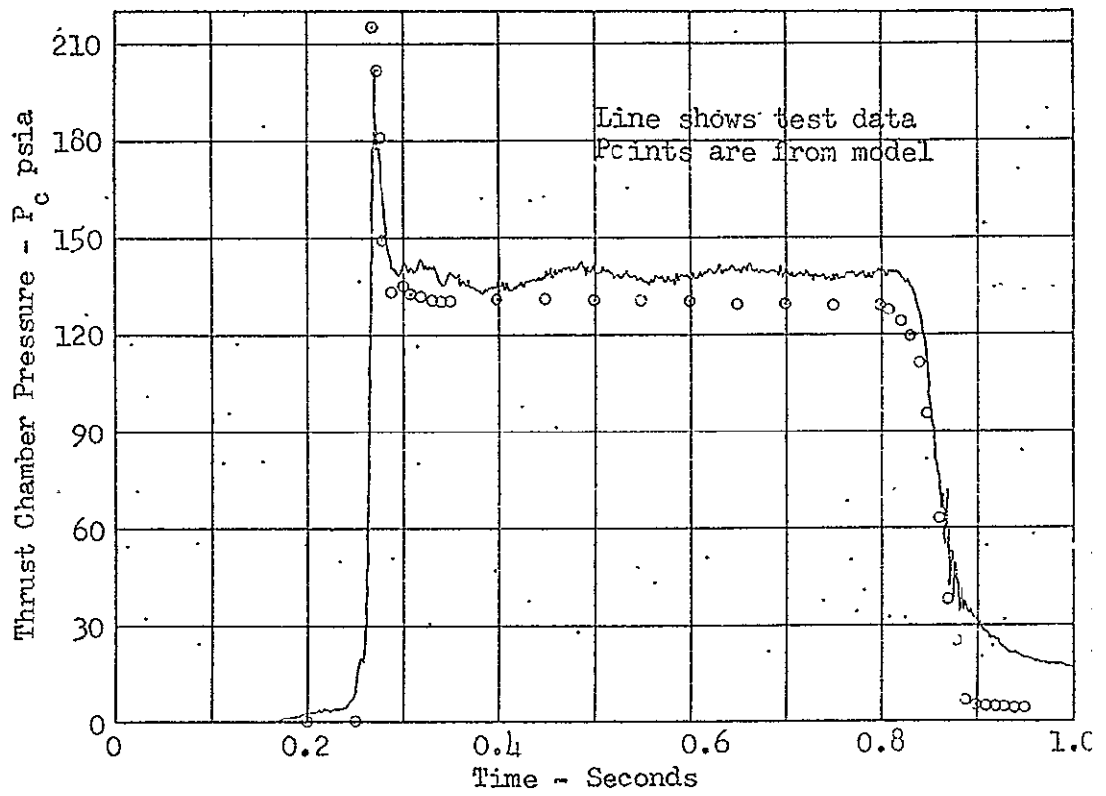


Figure 8 - Apollo Ascent Engine Data Correlation - Thrust Chamber Pressure Subsystem PA-1, Series 7B, Test 006, Run 1

(1) the oxidizer injector primes at 0.2 seconds as evidenced by the rise in the interface pressure measurement and (2) the pressure rise in the model. The injector pressure is increasing slowly at this time and does not reach its correct valve until after engine ignition. This behavior is characteristic of a line priming, and since the model did not simulate the instrumentation lines the model would not show this phenomenon. The differences at cutoff can be considered to be caused by two things; first, the propellant temperature in the injector was assumed to be ambient and second, there was no pressurant gas dissolved in the propellant. Thermal analysis of the Ascent Engine shows that the temperature of the liquid rises an appreciable amount only in the baffles and the run was short enough that steady state temperatures were not reached. However, local heating of the propellant will raise the vapor pressure in the injector and hence raise the chamber pressure after valve closure by forcing out more propellant. The propellants were not saturated with pressurant gas for this run; however, if there was a small amount of dissolved gas present it would start to come out of solution when the injector pressure falls below the saturation level. This phenomenon could also account for the disagreement between test data and model results.

APOLLO DESCENT ENGINE SIMULATION

The second demonstration of the model's use was a simulation of an Apollo Descent Engine start transient using helium saturated propellants. The data needed to model this system is given in Appendix B, and the results are shown in Fig. 9, 10, and 11. The correlation is not as good as that seen in the Ascent Engine simulation, although the two cases shown tend to bracket the data. The difference between the two model runs is the value of the time constant which controls the rate at which the pressurant gas in solution changes its concentration. The two values used were 0.1 and 1.0 second, and from the data it would appear that an intermediate value would give better simulation. Also, the time required for the model to prime appears to be too long. This discrepancy would appear to be caused by the resistance in the system --probably propellant valve--being too high. This would also account for the fact that the low values of steady state injector and thrust chamber pressure.

Lines show test data - LTA-5, Series 11, Test 2, Run 2
Points are from model

o TAUPRG = 0.1 seconds

△ TAUPRG = 1.0 seconds

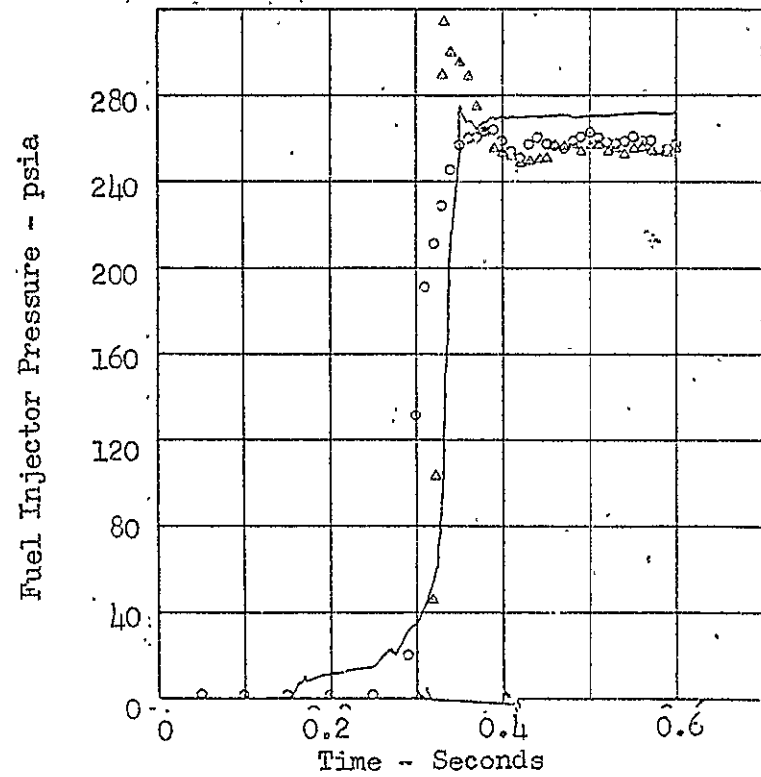
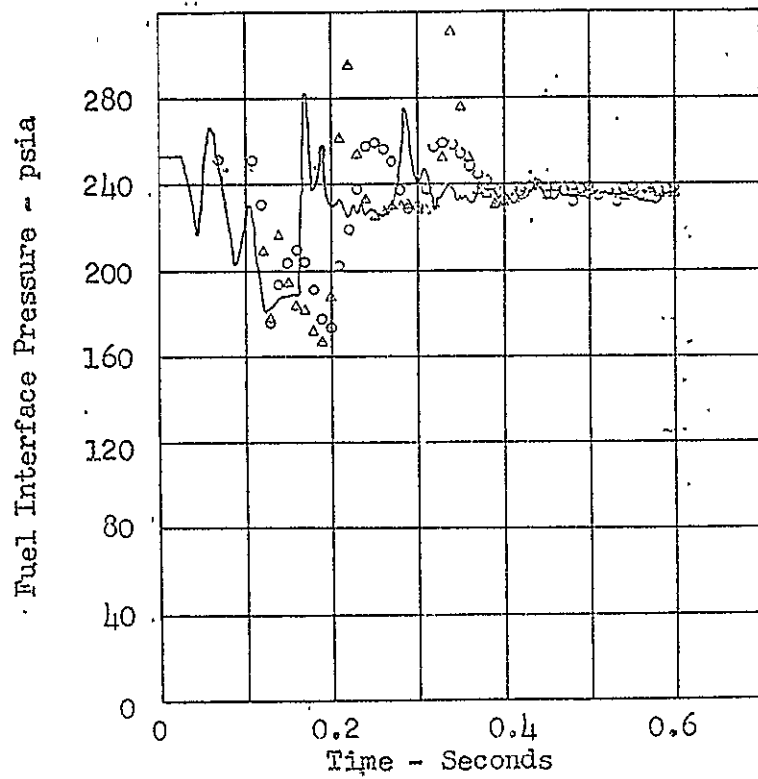
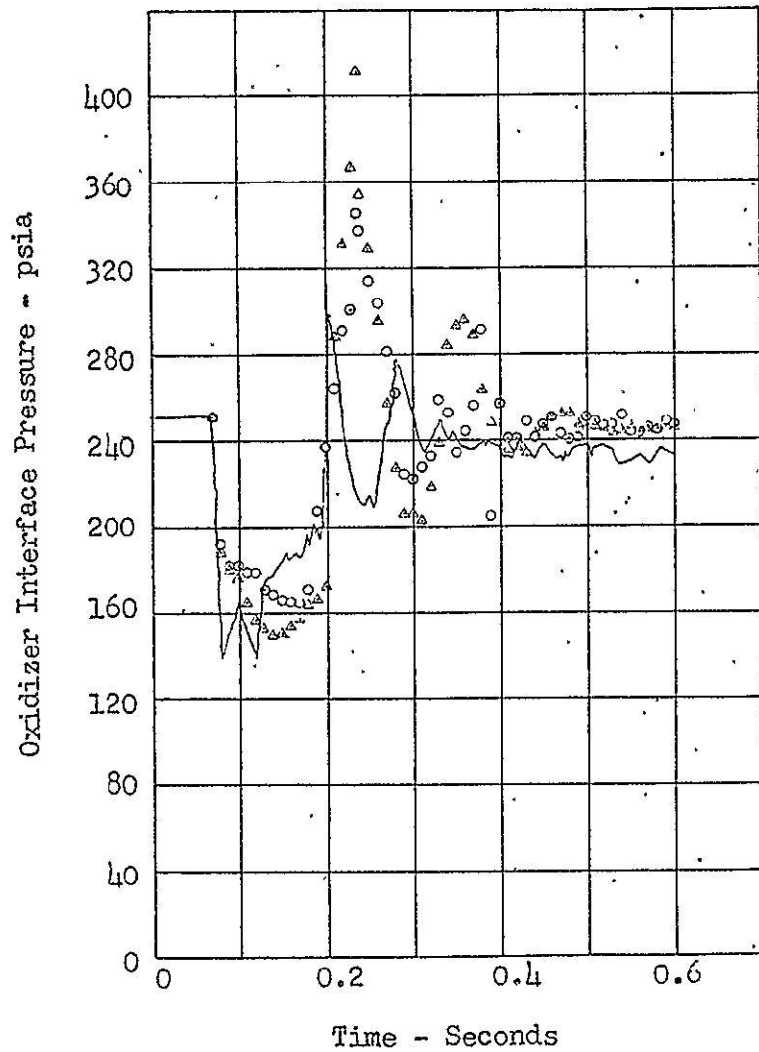


Figure 9 - Apollo Descent Engine Data Correlation Showing Effect of Gas Evolution Rate - Fuel System Pressures



Lines show test data - LTA-5, Series 11,
 Test 2, Run 2
 Points are from model

○ TAUPRG = 0.1 seconds

△ TAUPRG = 1.0 seconds

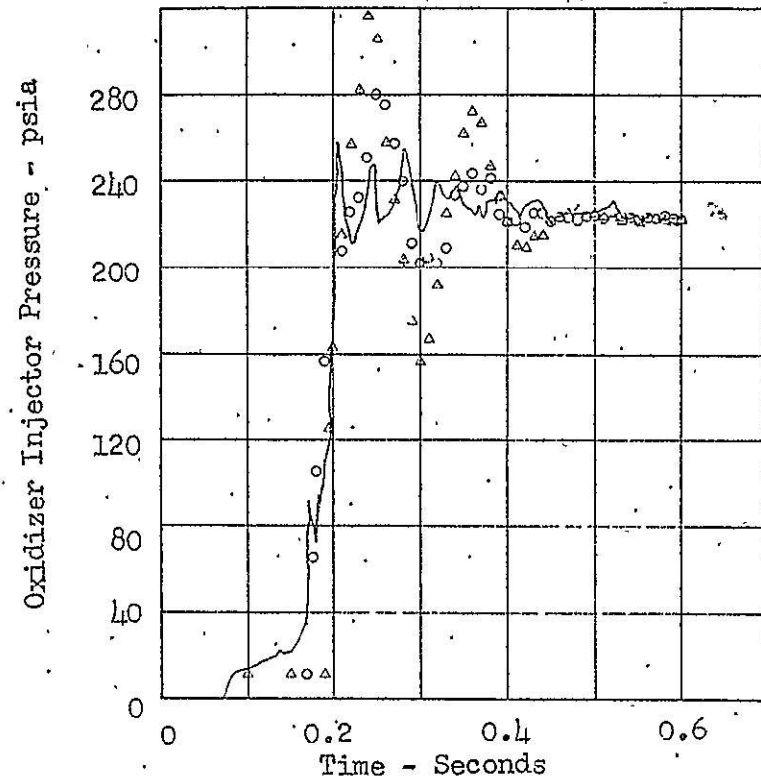
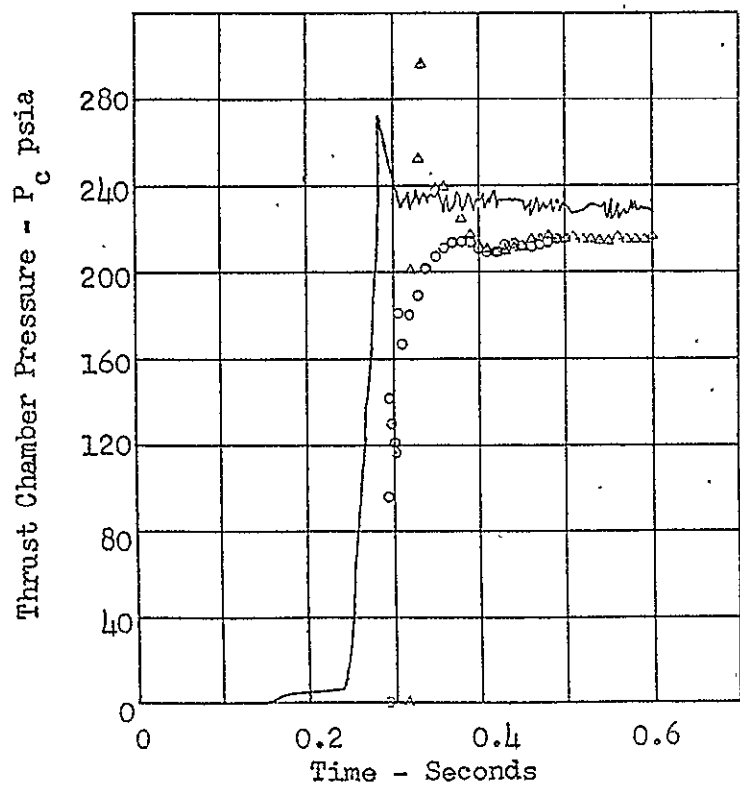


Figure 10 - Apollo Descent Engine data correlation showing Effect of Gas Evolution Rate - Oxidizer System Pressures

Line shows test data - LTA-5, Series 11,
 Test 2, Run 2
 Points are from model

o TAUPRG = 0.1 second

^ TAUPRG = 1.0 second



Oxidizer Acoustic Velocity

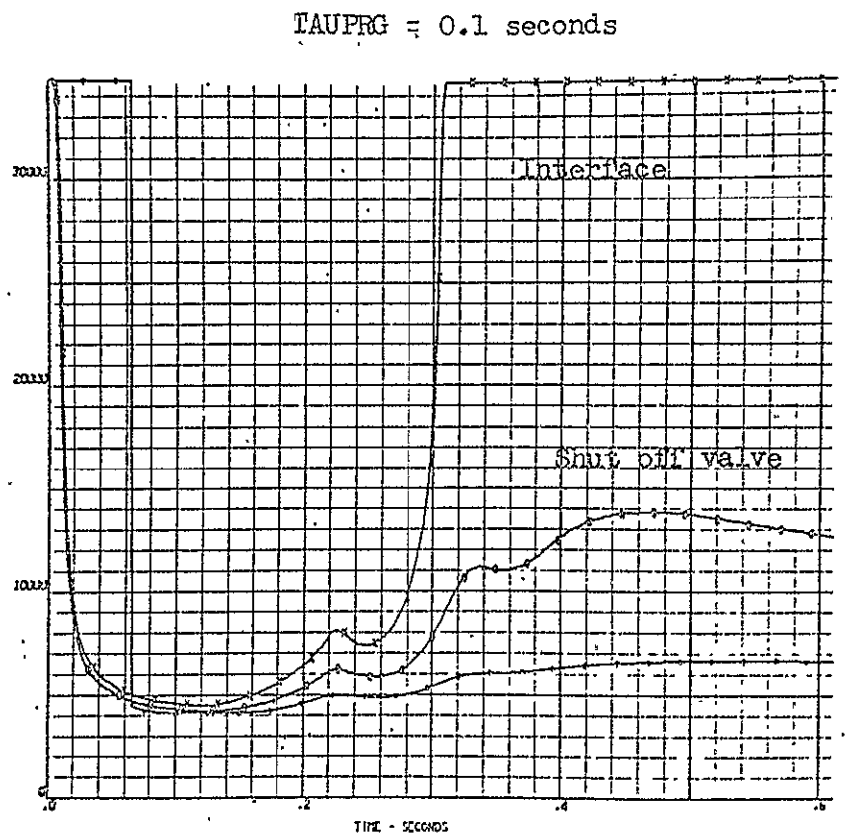


Figure 11 - Apollo Descent Engine Data Correlation Showing Effect of Gas Evolution Rate

While trying to run the Descent Engine simulation an instability occurred in which pressures would fluctuate with increasing amplitude. After much documentation it was determined that this was caused by the variable acoustic velocity. In the model the acoustic velocity is computed using the equation

$$a = \left[\frac{1}{\left(\frac{\rho_m}{1 + \phi \frac{\rho_l}{\rho}} \right) \left(\frac{1}{\rho_l a_l^2} + \frac{\phi \rho_l}{\rho_g a_g^2} + \frac{1 + \phi \frac{\rho_l}{\rho_g}}{g} \frac{Dc}{Ec} \right)} \right]^{1/2}$$

where $\rho_g = \frac{P_{pg}}{R_{pg} T} + \frac{P_{lvp}}{R_{lvp} T}$

During a start transient the pressures downstream of the main propellant valve approach vapor pressure. This low pressure causes dissolved pressurant gas in the propellant to come out of solution, and because the pressure is low, the gas density ρ_g is small. This gives rise to acoustic velocities in the order of 2500 inches per second.

When the engine manifold primes, there is a rise in pressure which increases ρ_g and hence the acoustic velocity increases. As the pressure increases the pressurant gas starts to go back into solution, and the acoustic velocity increases further. In the original analysis for the model it was recognized that the wave equations used to calculate the transient flow and pressures in the system assume that the acoustic velocity is constant; however, initial evaluation showed that a slowly varying acoustic velocity would not cause trouble. The changes in acoustic velocity were expected to be slow in the program as the fluid properties were calculated using an average pressure, and the pressurant gas dissolved or evolved from the liquid at a slow rate. The data showed that when the injector primed, the acoustic velocity increase was much greater than had been expected - Fig. 11.

A method to decrease the rate of increase in acoustic velocity was looked for and as an aid to understanding the problem a five segment version of the model was programmed on a time sharing computer. This program calculated flow and pressure

as in the large model and used a change in resistance at the injector end of a five segment feed line to produce a transient. Variation of acoustic velocity was controlled by use of an equation

$$a = f(\bar{P}) \quad a_1 \quad a_2$$

where the acoustic velocity, a , was allowed to vary between the limits a_1 and a_2 , and \bar{P} is a running average of the last 50 values of pressure in a segment. The results for a few of the cases run are shown in Fig. 12. Generally, changing acoustic velocity tends to sustain the pressure oscillations, and large changes can cause instability. The data generated using this model led to the scheme which allowed the model to run stably. This scheme was to use a constant value for gas density, ρ in the model, and let the acoustic velocity change as a function of free gas concentration, ϕ , only.

DESCENT ENGINE LM-3 ANOMALY SIMULATION

The purpose of modeling this transient was to demonstrate the model's ability to simulate a throttling transient and also schemes of modifying it so that the simulation of the passage of a discrete bubble through the feed system could be simulated. On the Apollo 9 flight the astronauts reported engine roughness during the second burn of the Descent Propulsion Engine, approximately 6 seconds after engine start. Analysis of this event--Ref. (e), showed that a gas bubble had been trapped in the propellant feed lines and the roughness resulted when the bubble passed through the engine.

In order to run this case it was necessary to reprogram subroutines ROCKET and CAVENT, and add two new routines, VENTR 2 and GASFLO. The analytical basis of this version of the model is given in Appendix C. Basically, the model assumes that the system is operating normally at time = 0, which corresponds to 93:47:39.250 flight ground elapsed time. At 1 ms (model time) the bubble in the oxidizer feed system starts to pass through the cavitating venturi; the bubble in the fuel line starts through the fuel cavitating venturi at 0.41 seconds. Fig. 13 and 14 compare the model results with the flight data. The general trend of the model results agree with the data. When the bubble starts through the cavitating venturi the downstream pressure rises; after passage of the bubble completely through the venturi we see a surge in the interface pressure, the downstream pressure falls off while there is an increase in P_c . These events occur because

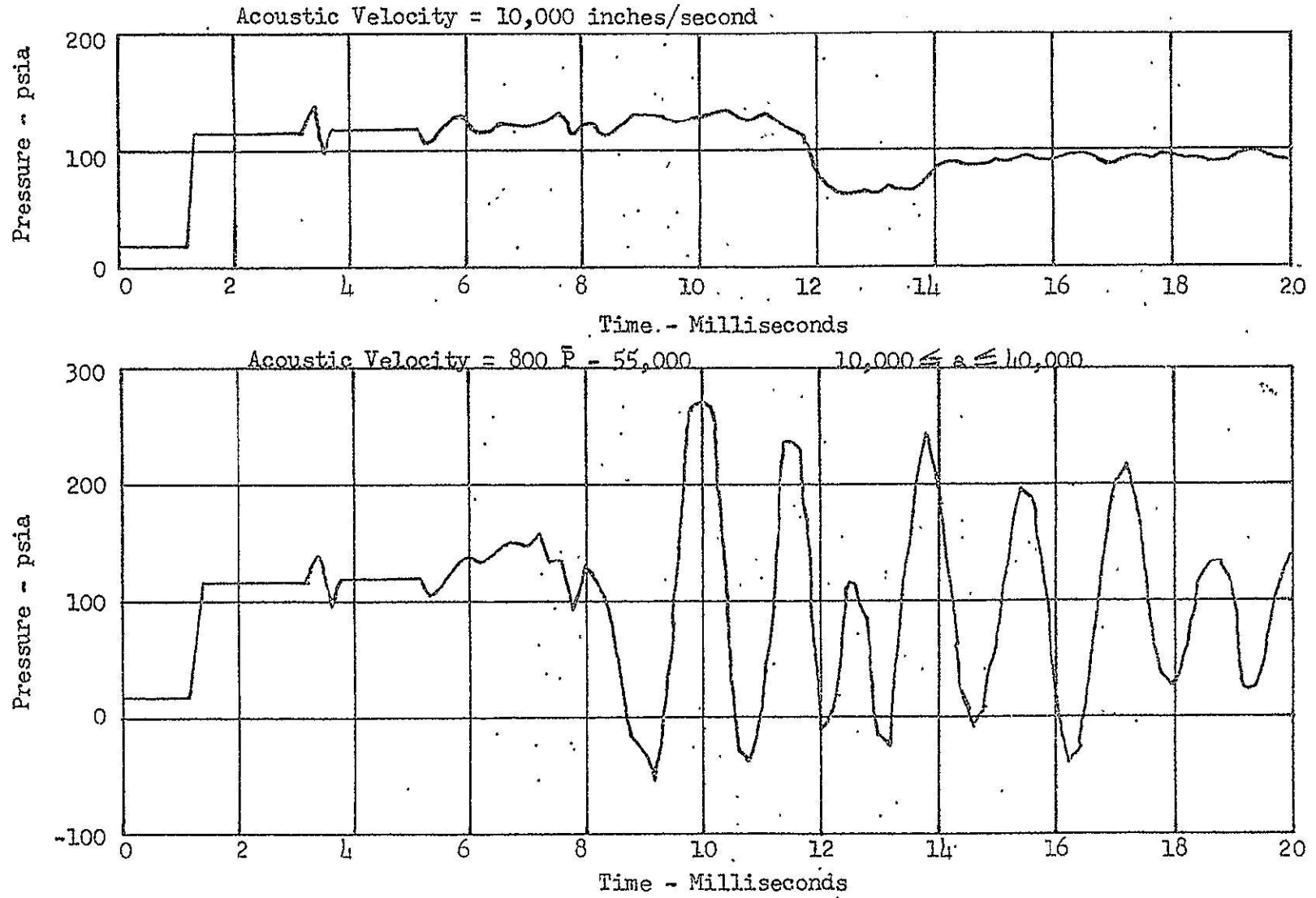
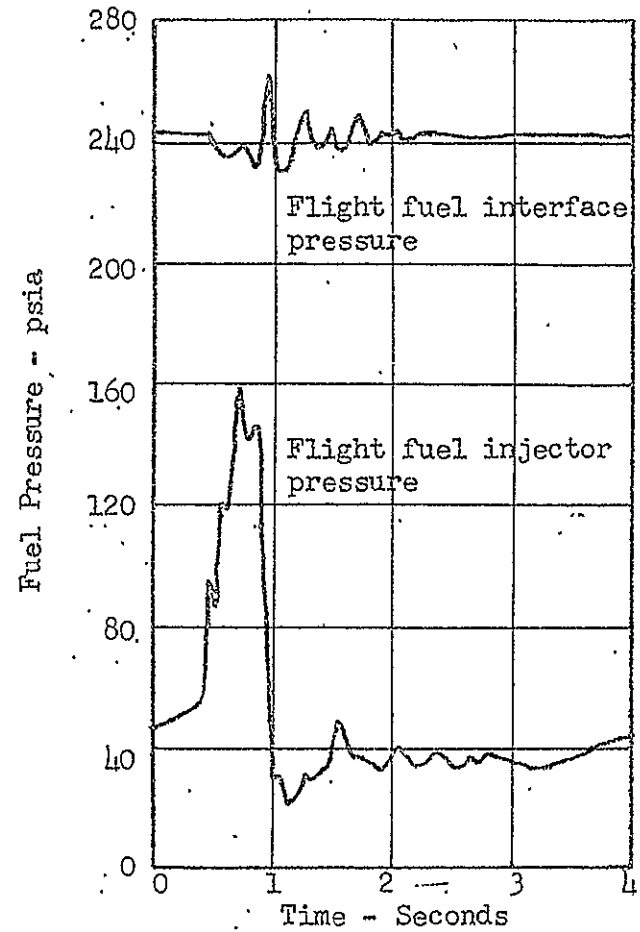
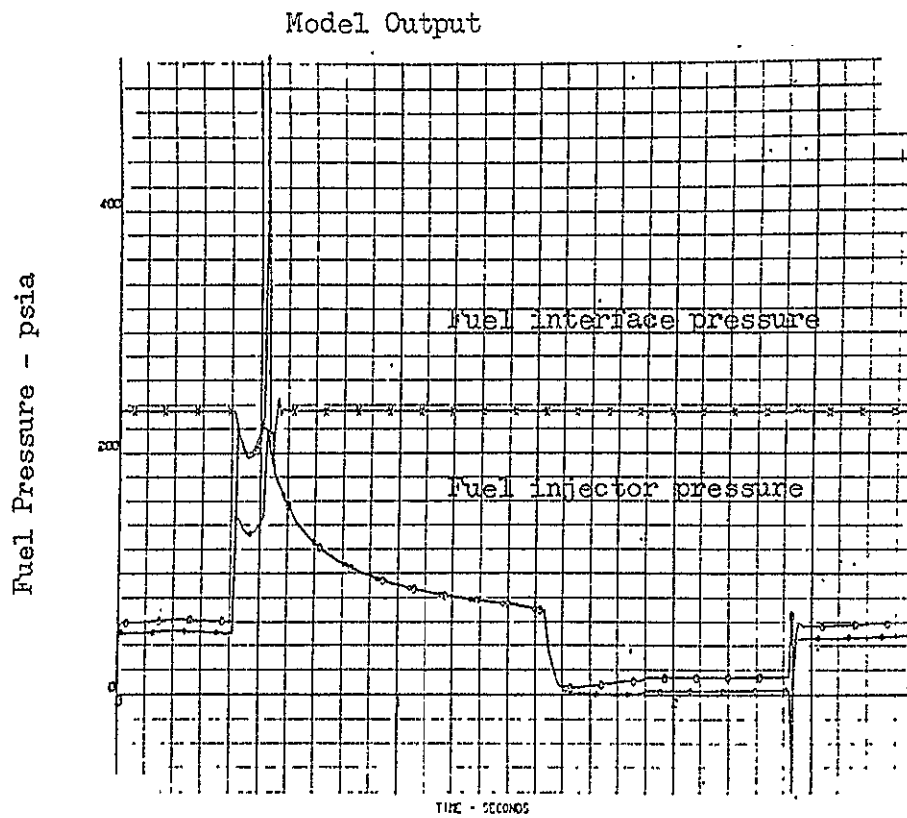
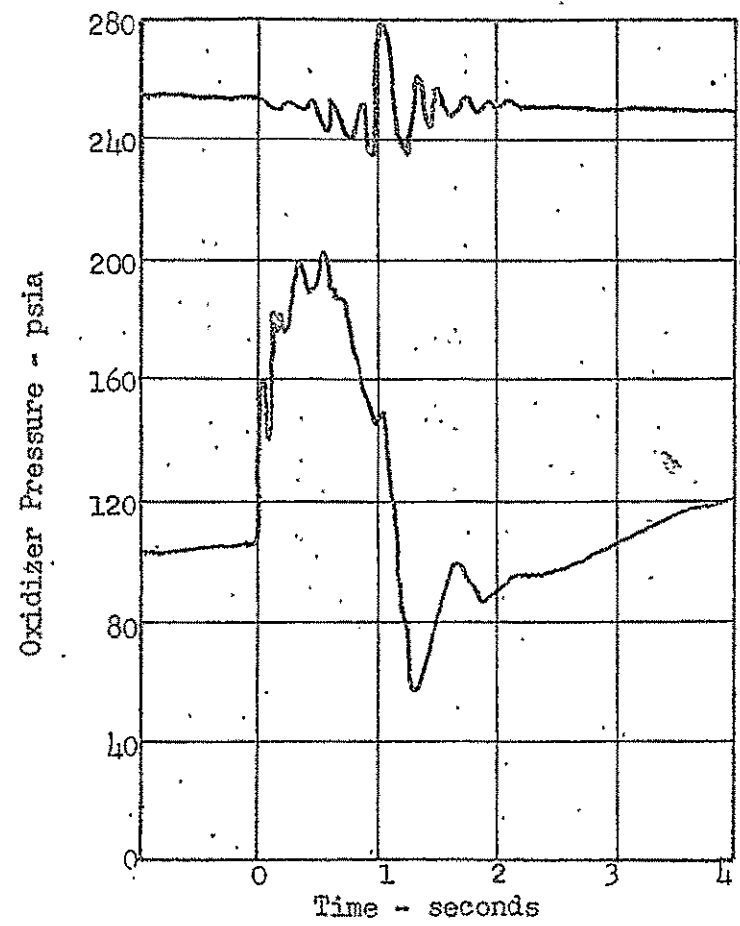
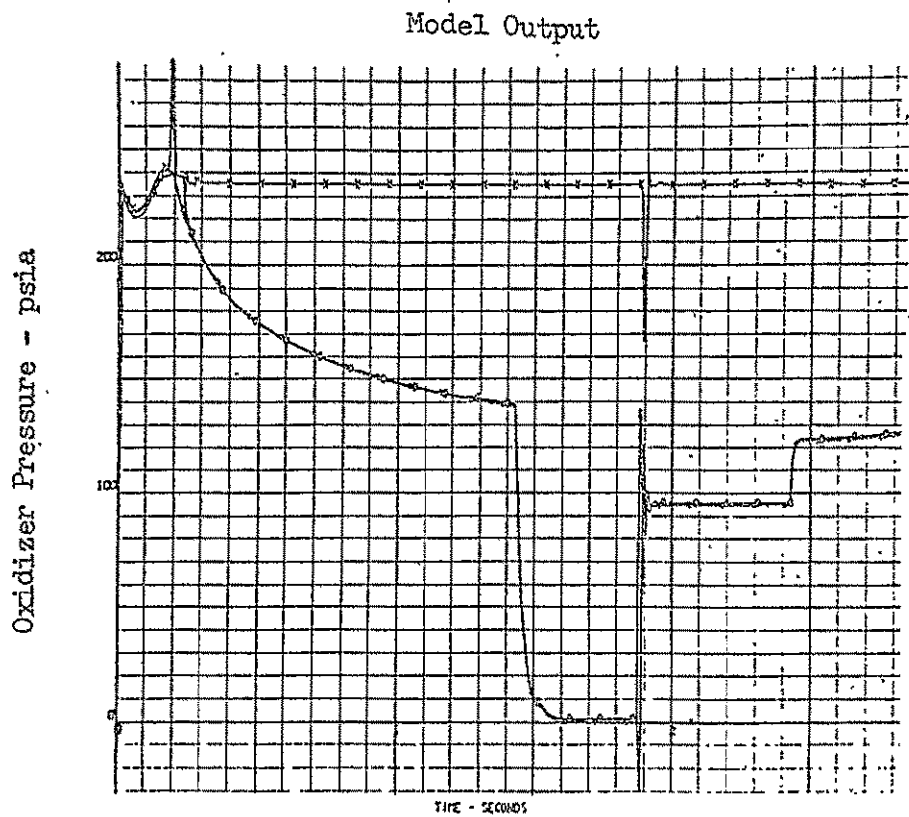


Figure 12 - Effect of Variable Acoustic Velocity on the Response of a Simple feed system



Time 0.0 is Equivalent to 93:47:39.25 Hours
Elapsed Time

Figure 13 - Apollo Descent Engine Data Correlation - LM-3 Flight Anomaly



Time 0.0 is equivalent to 93:47:39.25 hours
Ground Elapsed Time

Figure 14 - Apollo Descent Engine Data Correlation - IM-3 Flight Anomaly

the volumetric flow of the gas through the venturi is much greater than for liquid flow after the bubble passes the venturi. When the bubble has passed through the venturi we see it expand (decrease in pressure) and force propellant out of the injector. When the bubble starts to pass through the injector the manifold pressure drops to a level which is close to the combustion chamber pressure. Chamber pressure of course drops off because of the lack of propellant. After all gas has passed through the system it returns to normal.

The lack of correlation seen in this case is probably caused by two factors: (1) The bubble size selected was 30 cubic inches in both fuel and oxidizer sides--Ref. (c), and (2) The actual bubble was probably not a single bubble as assumed for the model. A series of bubbles separated by discrete amounts of fuel could cause the stepwise rise seen in the fuel and oxidizer injector pressures. Each rise would correspond to the passage of a bubble and each drop would correspond to expansion of the bubble downstream of the venturi while the propellant separating the bubbles passes through the cavitating venturi.

The rapid falloff in the flight fuel injector pressure would indicate that the size of the fuel bubble in the model is probably much too large; also, the passage of the fuel bubble through the engine, based on the fuel velocity and fuel line lengths would suggest that the fuel bubbles did not start to pass into the combustion chamber until a G.E.T. of 41 seconds. The small perturbations in chamber pressure seen at this time would also suggest that at the low injector pressure the bubbles are quite small.

SE5-5 TANK PRESSURIZATION MODEL

To demonstrate operation of the simplified pressurization feature of the model the feed system of Rocketdyne's SE5-5 engine system was modeled. This system consists of a pressurant storage bottle, a pressure regulator, two propellant tanks, and two engines. Details of the system are shown in Appendix D. Fig. 15 and 16 show the results obtained. At time zero the pressurization transient starts. Initially, the propellant tanks are at a pressure of 16 psia and the regulator is wide open. The pressure in the propellant tank starts to increase; when it reaches 160 psia the propellant burst diaphragms break and the

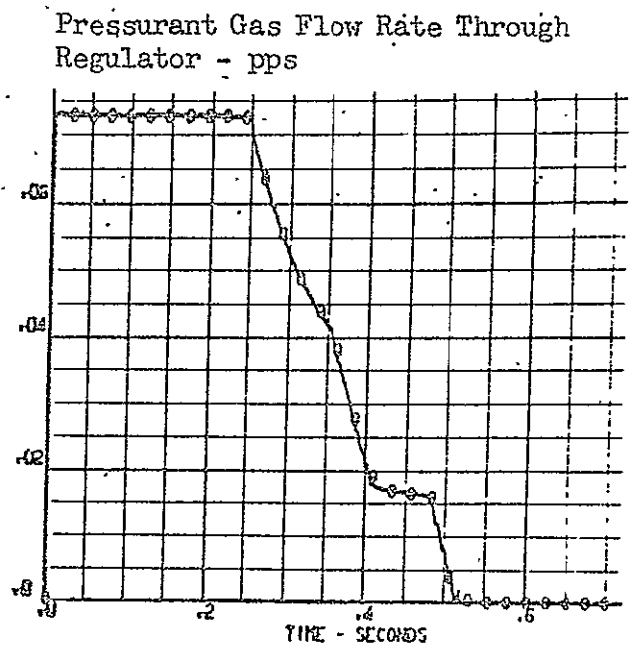
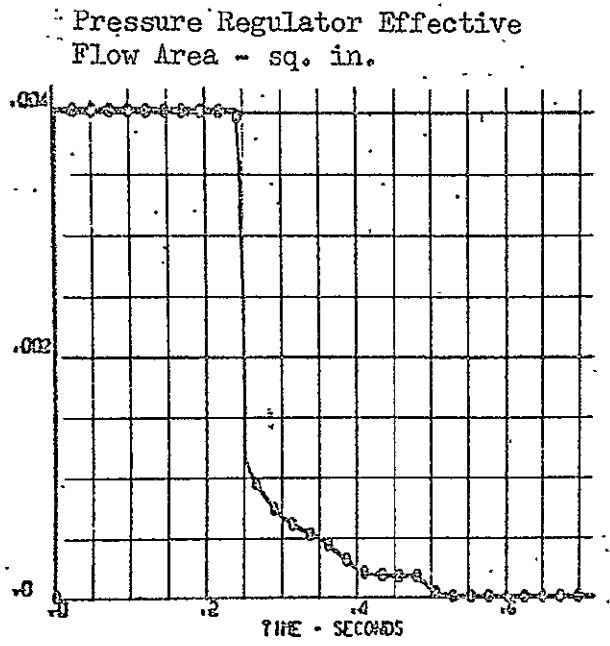
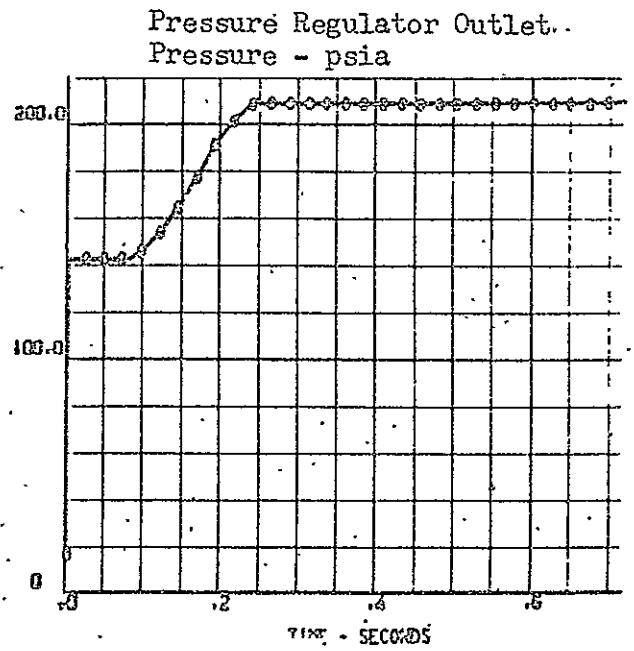
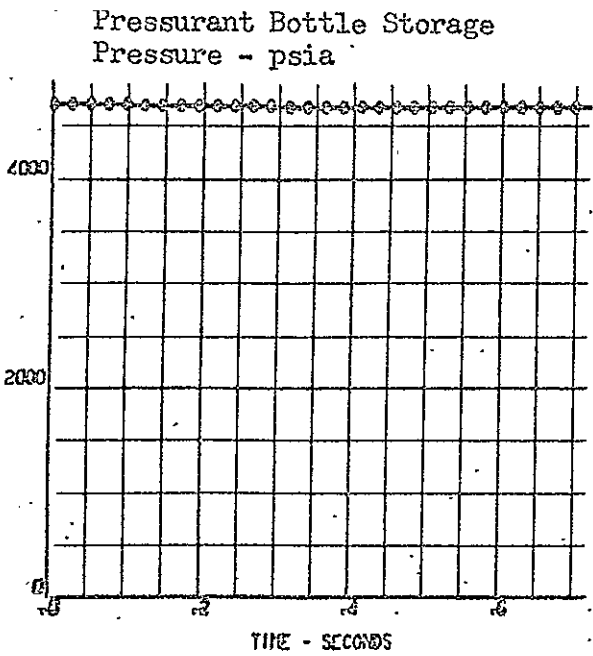
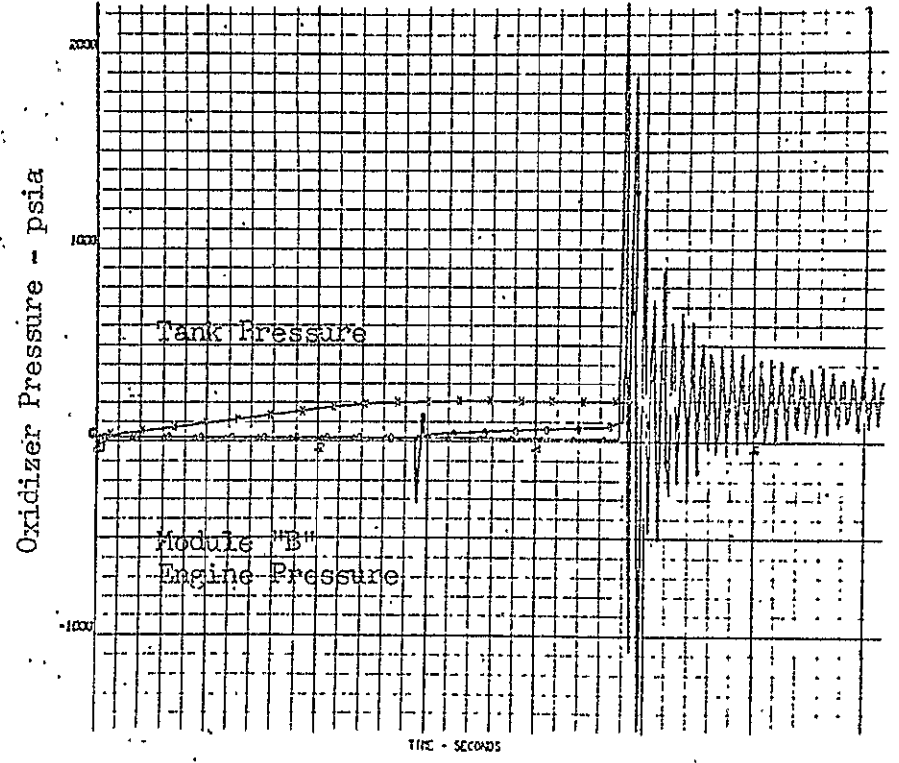
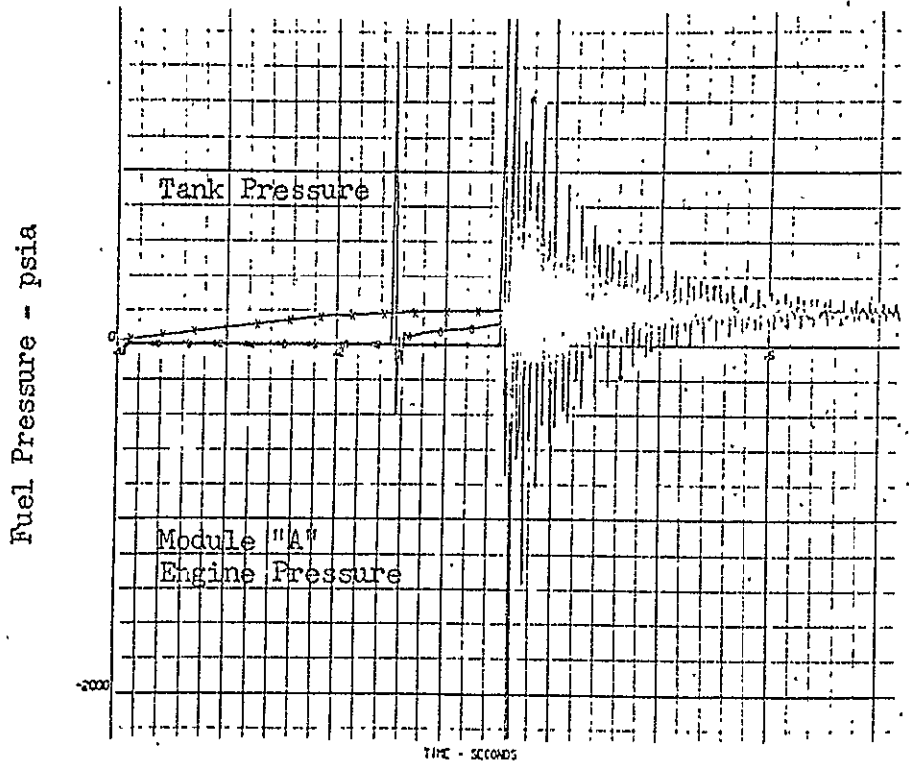


Figure 15 - SE5-5 Engine System Predicted Pressurization Transient Performance

Module "B" Engine Pressure

Module "A" Engine Pressure



NOT REPRODUCIBLE

Figure 16 - SE5-5 Engine System Predicted Pressurization System Performance

and the feed lines between the tank and engine start to prime.

When the feed lines prime a surge of approximately 2000 psi is produced. In the model the pressure then oscillates about the mean pressure level until the water hammer phenomena damps out. Since the surge pressure is several times the normal operating level, the pressures go below zero. This happens because the equations work for negative as well as positive pressures. In a real system, the fluid will vaporize then the pressure decreases below its vapor pressure, and the resultant gas will change the shape of the oscillation wave form.

DEFINITION OF SYMBOLS

A	area	square inches
C*	characteristic velocity	in/sec
CP, C_v	heat capacity	BTU/pound
D	diameter	inches
E	Young's Modulus	psi
G	ratio of dissolved gas weight to fluid weight	---
G_s	equilibrium value of G	---
H	heat of vaporization	BTU/lb
K	constant	---
M	molecular weight	---
P	pressure	psia
R	resistance	psi/(pps) ²
R_o	universal gas constant	psia in ³
T	temperature	degrees R
U	internal energy	BTU/pound
V	volume	cubic inches
W	total mass	pounds
Z	compressibility factor	---
c	pipe end restraint factor	---
e	pipe wall thickness	inches
e	base of natural logarithms	---
g	gravitational constant	386 in/sec/sec
k	ratio of specific heats	---
l	length	inches
t	time	seconds
v	velocity	inches/second
x	distance	inches
\dot{w}	flowrate	pounds/second
β	fluid compressibility	psi

DEFINITION OF SYMBOLS (CONTINUED)

a	ratio of volume of gas to volume of liquid	
γ	time constant	seconds ⁻¹
ξ	heat exchanger effectiveness	---
ρ	density	pounds/cubic inch
τ	time delay constant	seconds
η_c^*	combustion efficiency	

SUBSCRIPTS

c	combustion chamber
g	gas
i	sequence number
l	liquid
lv	liquid vapor
m	mixture
k	piston
s	spring
t	throat
v	vapor

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- (c) Compact Heat Exchangers, Kays, M., and A. L. London, The National Press, Palo Alto, California, 1955.
- (d) Oscillatory Flame Front Flowrate Amplification through Propellant Injection Ballistics (The Klystron Effect), J. R. Fenwick and G. J. Bugler - Presented at Third ICRPG Combustion Symposium, Cape Kennedy, Florida, 17-21 October 1966.
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APPENDIX A

APOLLO ASCENT ENGINE MODELING

Feed Line Modeling

The system geometry and certain system parameters must be defined prior to the computer model operation. A major portion of this information relates to the propellant feed lines. In order to use this data, the feed lines must be broken into segments having some logical order with the length, internal cross-sectional area, fluid resistance, and line compliance factor specified.

Criteria for the sizing of segments is based on changes in line size, branching of lines, location of concentrated fluid resistance elements such as valves and orifices, model frequency response, and the time period to be simulated. The Apollo Ascent Engine transient which is to be modeled is approximately 0.8 seconds long, and the program will produce 300 data points for this transient. Thus, the spacing of the data points will be 2.7 ms, and if 10 data points are assumed necessary to define a sine wave cycle then the model would have a frequency response of 37.5 cps. If one wants a model with 600 cps frequency response then the time interval between points should be 0.167 ms. For this model a calculation interval of 0.170 ms will be selected so that the capability of 600 cps frequency response may be retained.

Having picked an integration interval the minimum and maximum line lengths that can exist in the model will be selected. The minimum line length is related to the maximum fluid acoustic velocity by the relation

$$l_{\min} \geq a_{\max} \Delta t$$

For the fuel, $a_{\max} = 60,000$ in/sec, and thus the line segments must be at least 10.2 inches long. For the oxidizer, $a_{\max} = 40,500$ in/sec, and $l_{\min} = 6.89$ inches. The maximum line length can be found from the relation

$$l_{\max} \geq 25 a_{\min} \Delta t$$

If the propellants are saturated with pressurant gas it is possible for their acoustic velocity to go as low as 2500 inches/second, and thus $l_{\max} = 10.6$ inches. However, it should be pointed out that low values of acoustic velocity will occur only when the average pressure in a segment is very low. This condition will usually only occur downstream of the propellant valves or, in the

case of the Apollo Descent Engine, downstream of the cavitating venturi. Thus, as one approaches the propellant tanks, longer line lengths can be used.

Figure A-1 shows a schematic of the Apollo Ascent Engine feed system which is to be modeled. Starting with the fuel system, the plumbing schematic will be modified to fit the techniques used for modeling. In order to achieve flexibility and the correct frequency response, the length of the line segment at the engine inlet should lie between 10.2 and 10.6 inches. The line between the fuel prime delay volume and the injector is only 3 inches long, and it is reasonable to ignore it in the model. Thus, the fuel prime delay volume, injector volume, and the feed line volume will be combined and the total will be injector volume. Thus, the injector volume will be 38.58 cubic inches.

Next, the propellant valve will be considered. The minimum length of the lines between the balls and the injector is 2.05 inches. Since each of the lines are short, it would seem reasonable to combine them. Thus, the parallel series combination of the main propellant valve will be lumped into a single line with a single valve. The total distance between the upstream ball valve and the engine is 22.8 inches, and this length will be divided into 2 segments. The one nearest the engine will be 10.2 inches long, and the upstream one will be 12.6 inches long. The total volume downstream of the upstream ball is 65.12 cu. in.; the injector contains 38.58 cu. in. so the two line segments need a volume of 26.54 cubic inches. The first segment has an internal diameter of 1.37" so its volume is 15.02 cubic inches. The area of the second segment will have to be $11.52/12.6 = 0.916$ square inches. These numbers assume that the feed system is primed down to the upstream ball valve. If the engine has propellant to the downstream valve there are 2.9 cubic inches less volume to prime and the area would be 0.648 square inches.

Upstream of the ball valve there is the engine interface, trim orifice and line branch to consider. Experience has shown that the location of an orifice in a primed line is not critical, and since the engine-feed system interface is only important because of a pressure measurement located close to it, this line section will be considered as one length and segmented as necessary. The total distance is 52.10 inches. Experience also has shown that a series of identical line lengths tends to cause computational instabilities, and that the segment upstream of a valve should be short. Thus, this line will be broken into 4 segments which are 10.2, 13, 15, and 13.9 inches long. The orifice will be

FOLDOUT FRAME

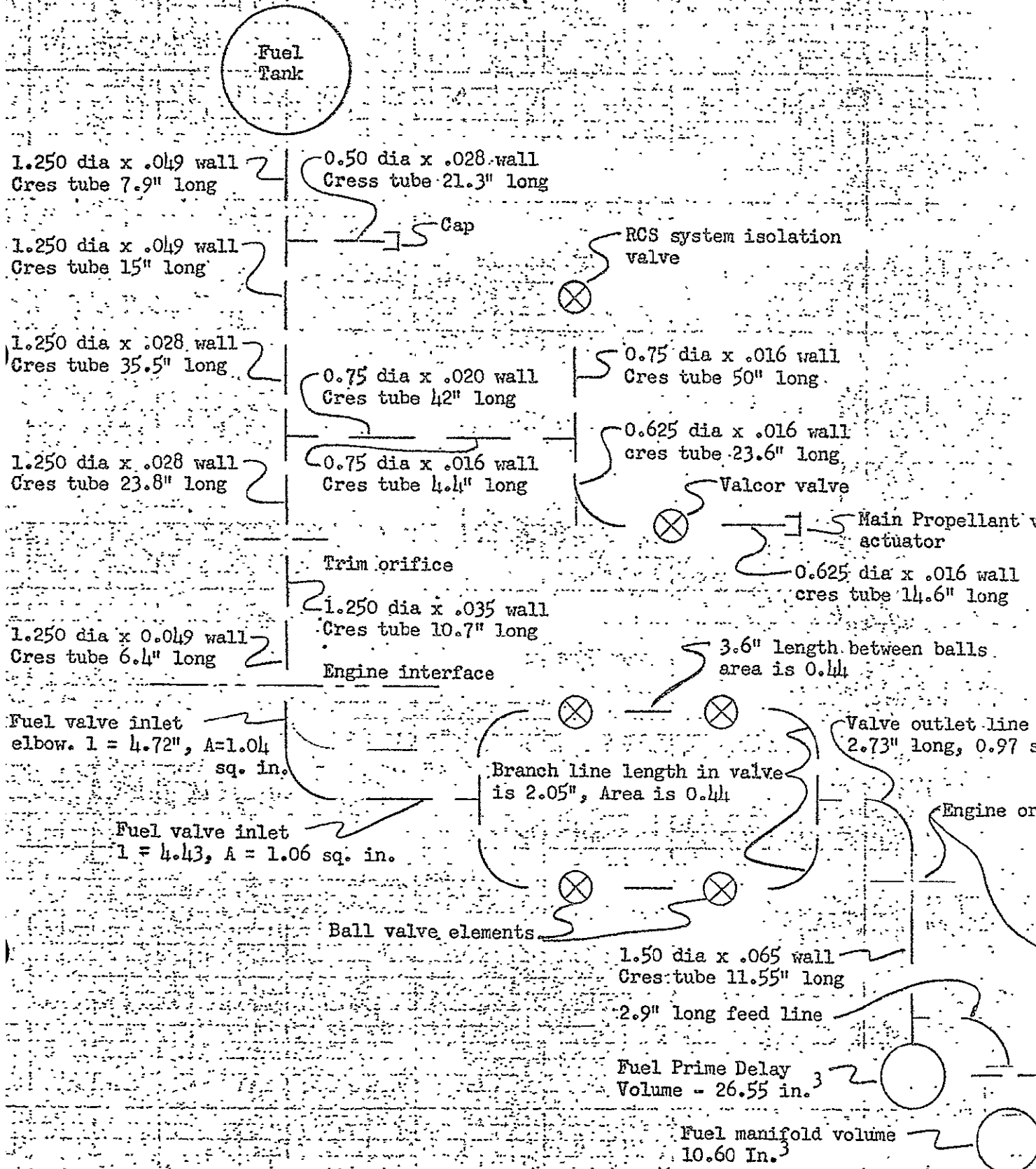
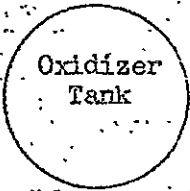


Figure A-1 - Feed System Schematic

FOLDOUT FRAME 2



0.75 dia x .020 wall
cres tube 43" long

1.25 dia x .049 wall
cres tube 4.4" long

Cap

1.25 dia x .049 wall
cres tube 15.9" long

1.25 dia x .028 wall
cres tube 16.4" long

1.25 dia x .035 wall
cres tube 7.6" long

0.75 dia x .020 wall
cres tube 27.1" long

1.25 dia x .028 wall
cres tube 10" long

RCS system
isolation valve

0.75 dia x .016 wall
cres tube 37.9" long

1.25 dia x .035 wall
cres tube 5.8" long

Trim orifice

1.25 dia x .035 wall
cres tube 6.8" long

1.25 dia x .049 wall
cres tube 9.6" long

Engine
Interface

Oxidizer valve outlet line
l = 0.5", A = 1.06 sq. in.

Oxidizer valve
dimensions: same as
fuel valve

Oxidizer valve
inlet elbow
l = 4.72", A = 1.04 sq. in.

1.0 dia x .035 wall
cres tube 12.3" long

Oxidizer valve
inlet l = 4.43",
A = 1.06 sq. in.

Propellant filters

In. area

es

llo Ascent Engine

placed between the 13 and 15 inch segment and is actually only 5 inches from its true location. The engine interface pressure will be between the 10.2 and 13 inch segment and this pressure is only about 1 inch from its true location. The rest of the system is split up in a similar fashion. The resulting model is shown in Figure A-2 with segment numbers assigned to each segment.

To use the model, the line segments which have been generated must be described by their physical properties - length, area, compliance and resistance. These values are shown in Table A-I and A-II. The compliance is calculated using the formula shown in the Engineer and Programmers Manual, pp. 4.1.2. The resistance values are based on actual values shown below, and distributed in accordance with system geometry.

FEED SYSTEM RESISTANCE - SEC ² /IN ⁵		
	<u>Fuel</u>	<u>Oxidizer</u>
Tank Bottom to Interface	.017912	.011458
Interface to Injector Manifold	.023413	.017361
Injector Manifold to Combustion Chamber	.054856	.030382

For example, the oxidizer trim orifice has an area of 0.8784 square inches. Its resistance, assuming an orifice coefficient of 0.65 is,

$$R = \frac{1}{(27.807 \times 0.65 \times 0.8784)^2} = 0.003967 \text{ sec}^2/\text{in}^5$$

The remaining resistance (0.011458 - 0.003967 = 0.007491) will be distributed along the 80.7 inches of line between the oxidizer tank and engine interface.

The resistance of the side branch lines can be calculated from the following formula

$$R = 0.001294 \frac{f \ell}{dA^2}$$

where f = friction factor
 ℓ = length - inches
d = internal diameter - inches
A = internal area - square inches

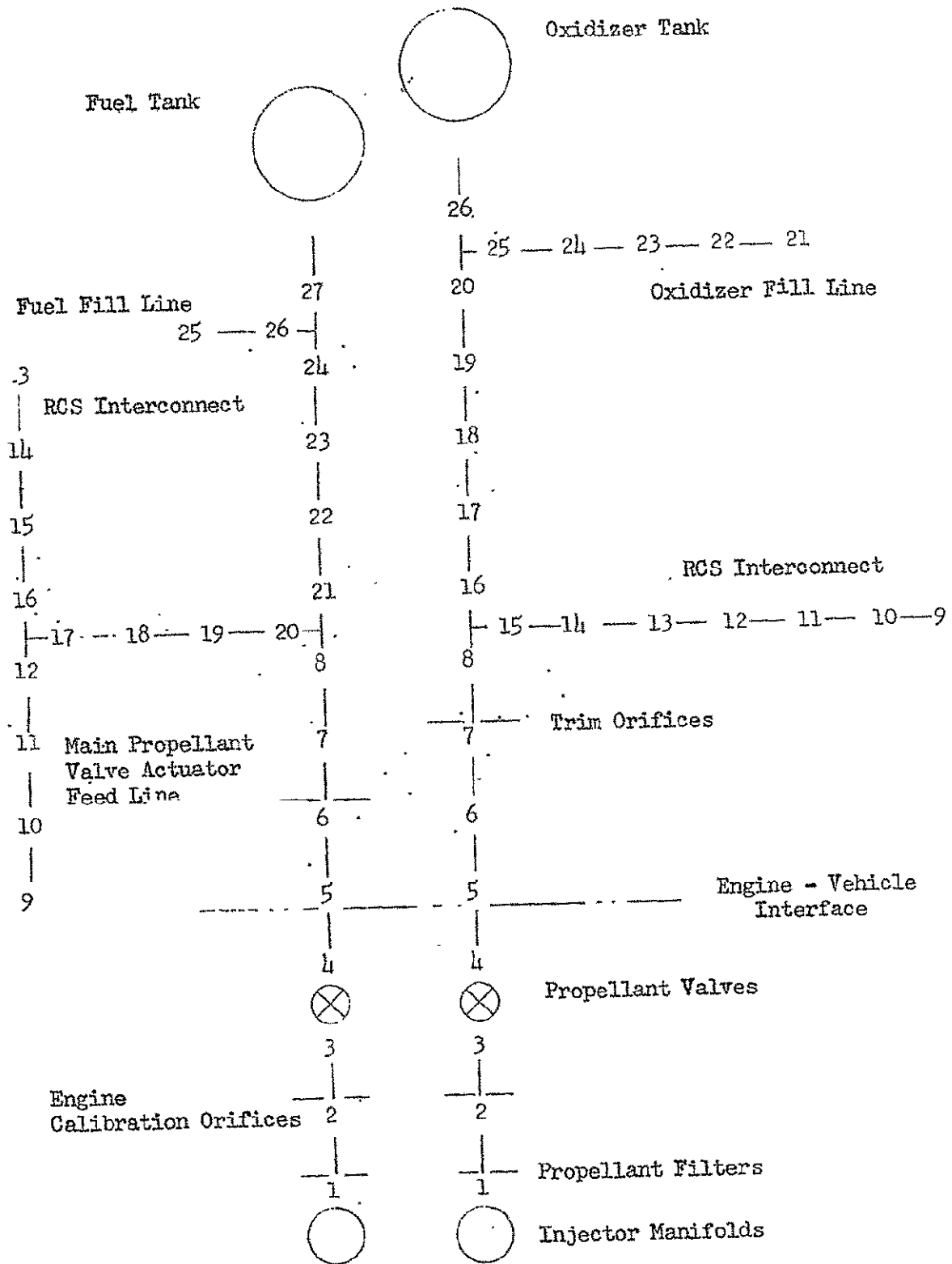


Figure A-2 - Apollo Ascent Engine Feed System
Line Segments Used for Modeling

TABLE A-1

FUEL SYSTEM FEED LINE PARAMETERS

<u>SEGMENT NO.</u>	<u>LENGTH IN.</u>	<u>AREA SQ IN</u>	<u>WALL COMPLIANCE SQ IN/LB X 10⁷</u>	<u>RESISTANCE SEC²/IN⁵</u>	<u>COMMENTS</u>
1	10.2	1.472	7.52	.003335	
2	12.6	.92	2.91	.003989	When ball valve is wet A=.684 in ²
3	-	-	-	-	Valve
4	10.2	1.04	6.67	.003335	
5	13.0	1.09	9.55	.001603	Interface
6	15.0	1.10	12.1	.001850	
7	13.9	1.10	12.1	.007258	Trim Orifice
8	-	-	-	-	Branch
9	14.2	.276	10.5	.010576	
10	13.	.276	10.5	.009682	
11	11.	.276	10.5	.008193	
12	-	-	-	-	Branch
13	11.	.405	12.7	.00345	
14	16.	.405	12.7	.00502	
15	23.	.405	12.7	.00721	
16	-	-	-	-	Branch
17	20.4	.396	10.1	.00640	
18	15.	.396	10.1	.00471	
19	11.	.396	10.1	.00345	
20	-	-	-	-	Branch
21	11.	1.10	12.1	.001356	
22	15.	1.10	12.1	.001850	
23	19.	1.04	6.67	.002343	
24	-	-	-	-	Branch
25	21.3	0.156	4.49	.066322	
26	-	-	-	-	Branch
27	13.4	1.04	6.67	.001652	

TABLE A-II
OXIDIZER FEED LINE PARAMETERS

<u>SEGMENT NO.</u>	<u>LENGTH IN</u>	<u>AREA SQ IN</u>	<u>WALL COMPLIANCE SQ IN/LB X 10⁷</u>	<u>RESISTANCE SEC²/IN⁵</u>	<u>COMMENTS</u>
1	10.0	.679	7.52	.001772	
2	8.9	.912	2.91	.001577	When ball valve is wet A = .542
3	-	-	-	-	Valve
4	6.9	1.04	2.91	.001222	
5	9.0	1.04	2.91	.000835	Interface
6	10.5	1.09	9.55	.000975	
7	6.9	1.09	9.55	.004607	Trim Orifice
8	-	-	-	-	Branch
9	7.	0.405	12.7	.00219	
10	9.	0.405	12.7	.00283	
11	14.	0.405	12.7	.00439	
12	17.	0.396	10.1	.00534	
13	11.	0.396	10.1	.00345	
14	7.	0.396	10.1	.00219	
15	-	-	-	-	Branch
16	7.	1.10	12.1	.000650	
17	13.	1.0	12.1	.001207	
18	15.	1.10	12.1	.001392	
19	12.3	1.04	2.91	.001142	
20	-	-	-	-	Branch
21	7.	0.396	10.1	.00219	
22	13.	0.396	10.1	.00408	
23	15.	0.396	10.1	.00471	
24	8.	0.396	10.1	.00251	
25	-	-	-	-	Branch
26	7.	1.04	2.91	.000650	

which is merely a form of the D'arcy head loss equation. The pressure drop between the engine and injector is made up of that across the propellant valve, engine orifice, and propellant filters in addition to the line resistance.

The effective area of the valve may be calculated and Fig. A-3 shows the results for a single ball and for the parallel series combination. The maximum area is used to calculate the resistance of the valve in the open position. The resistance of the engine filter is based on a pressure drop of 2.7 psi at rated flow, and the resistance of the trim orifice is calculated as before.

Thus the total lumped resistance between the engine interface and the injector is:

	<u>Fuel</u>	<u>Oxidizer</u>
Propellant Valve	.006620	.006620
Engine Trim Orifice	.004279	.005445
Propellant Screen	.001725	.001725
Total Lumped Resistance	.012624	.012790

The difference between the total lumped resistance and the measured resistance will be distributed in the feed lines between the interface and injector. This completes the definition of the feed system.

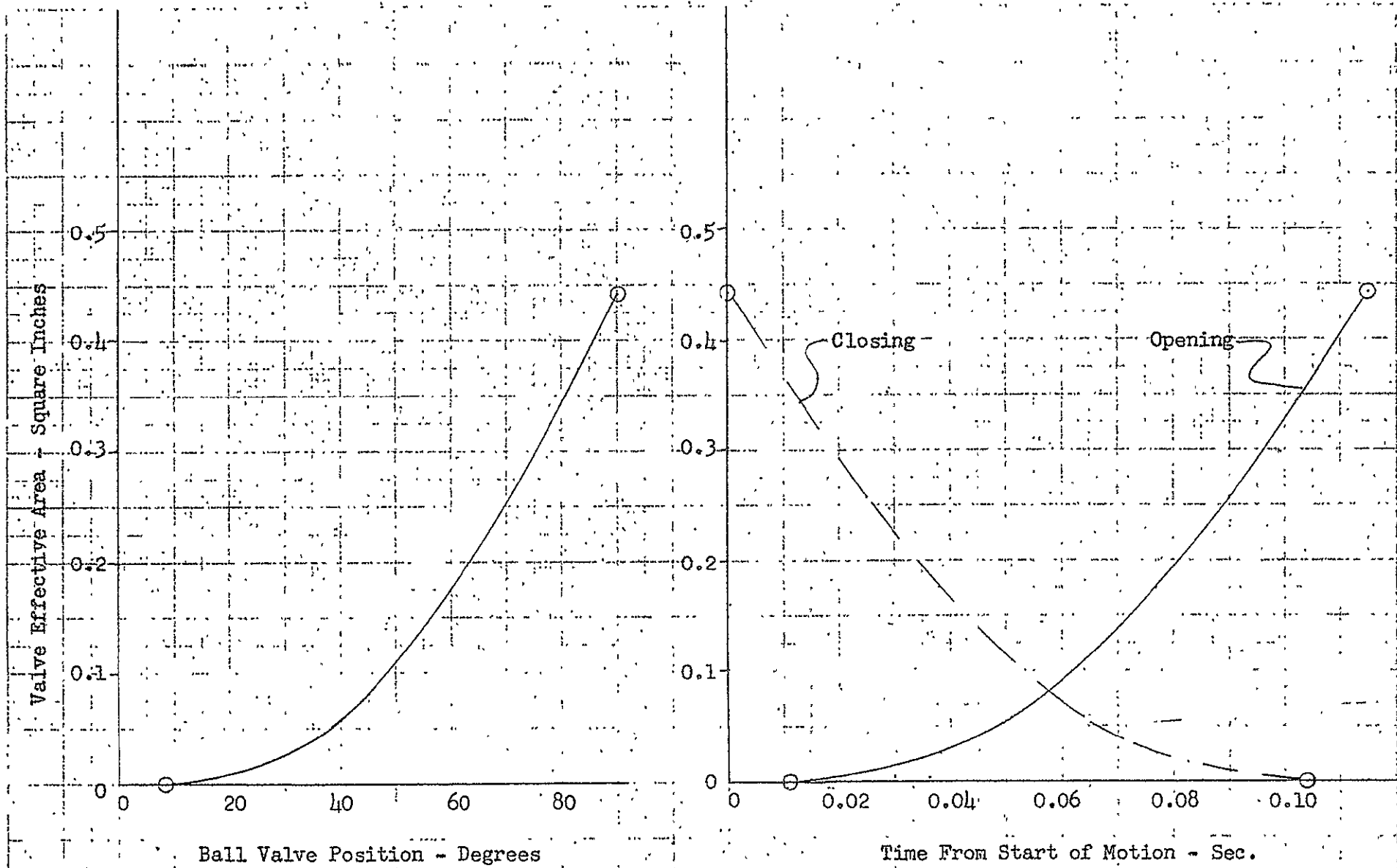


Figure A-3 - Apollo Ascent Engine Bipropellant Valve Data

Combustion Chamber Performance

Combustion performance in the Generalized Propulsion System Model is determined from the lumped parameter equation

$$\frac{d P_c}{dt} = \frac{R_c T_c}{V_c} - \frac{R_c T_c}{V_c} \cdot \frac{A_t P_c}{\eta_{c^*} \frac{C^*}{g}}$$

The constants $R_c T_c$ and C^* are functions of the particular propellants being used and vary with mixture ratio and pressure level. These constants can be determined from thermochemical performance using the properties of the propellants. The results of one such analysis for the Apollo propellants over a range of mixture ratios and pressures are shown in Table A-III. To use them in the program it has been found convenient to use the oxidizer fraction rather than mixture ratio. This allows the combustion property data to be extrapolated to fuel only, $(MR) = 1.0$, or oxidizer only, $(MR) = 0.0$, operation.

During propellant blowdown after engine cutoff the model assumes that no combustion occurs. To calculate thrust chamber pressure during this period, the oxidizer fraction is set to either 0.0 or 1.0 and equation (1) is used. Thus, the values of $R_c T_c$ and C^*/g must be known for each propellant in its vapor phase. This was determined for nitrogen tetroxide and 50-50 UDMH - hydrazine as follows. The value of C_p for the propellants was found at a temperature of $660^\circ R$. Assuming that the vapor phase behaved as a perfect gas, the ratio of specific heats was found from the relation

$$k = \frac{C_p}{C_p - R}$$

and then C^* may be calculated

$$C^* = \frac{\sqrt{gkRT}}{\left[k \frac{2}{k+1} \right] \frac{k+1}{k+1}}$$

Values for the constants which apply to the propellant vapor are shown in Table A-IV. A plot of the combustion parameters as a function of oxidizer

TABLE A-III

COMBUSTION DATA FOR NITROGEN TETROXIDE 50/50 HYDRAZINE-UDMH

<u>MIXTURE RATIO</u>	<u>OXIDIZER FRACTION</u>	<u>CHAMBER PRESSURE (PSIA)</u>	<u>$\frac{C^*}{g}$</u>	<u>$\frac{RT_c}{M.W.} \times 10^{-6}$</u>
0.05	0.048	150.0	132.12	3.054
0.10	0.091	150.0	134.08	3.133
0.20	0.167	150.0	137.16	3.219
0.40	0.286	150.0	141.70	3.351
0.50	0.333	150.0	146.42	3.714
0.60	0.375	150.0	153.29	4.055
0.80	0.444	150.0	164.17	4.566
1.00	0.500	150.0	171.38	4.886
1.20	0.546	150.0	175.48	5.023
1.40	0.583	150.0	177.72	5.059
1.60	0.615	150.0	178.22	5.006
2.00	0.667	150.0	175.14	4.768
2.40	0.706	150.0	170.17	4.495
3.00	0.750	150.0	162.83	4.129
3.60	0.783	150.0	156.24	3.826
5.00	0.833	150.0	143.28	3.276
10.00	0.909	150.0	112.70	2.130
20.0	0.952	150.0	85.63	1.264
50.0	0.980	150.0	58.61	0.613
100.0	0.990	150.0	46.40	0.363
1.6	0.615	5.0	173.03	4.632
1.6	0.615	50.0	176.88	4.899
1.6	0.615	170.0	178.37	5.020
1.6	0.615	190.0	178.50	5.031
1.6	0.615	200.0	178.47	5.048

TABLE A-IV
PROPELLANT VAPOR PROPERTIES

	<u>50-50 UDMH- HYDRAZINE</u>	<u>NITROGEN TETROXIDE</u>
C_p BTU/LB MOLE $^{\circ}R$	17.50	124.0
C_p BTU/LB $^{\circ}R$	0.418	1.35
MOLECULAR WT	41.8	92.02
R PSIA IN ³ /LB $^{\circ}R$	444.	202.
k	1.165	1.016
C^* FT/SEC	1333.94	946.19
T $^{\circ}R$.	.660.	.660.
RT PSIA IN ³ /LB	0.293040×10^6	$.133320 \times 10^6$
C^*/g -	41.478	29.42

fraction is shown in Fig. A-4. Figure A-5 shows a plot of the parameters vs pressure at a mixture ratio of 1.6, and this data is used to find the pressure correction factors.

$$CF_{RT} = \frac{\ln (RT)_{ref} - \ln (RT)_{act}}{\ln \left(\frac{P_{ref}}{P_{act}} \right)}$$

and

$$CF_{c^*/g} = \frac{\ln (C^*/g)_{ref} - \ln (C^*/g)_{act}}{\ln \left(\frac{P_{ref}}{P_{act}} \right)}$$

For the Apollo propellant combination the correction factors are:

$$CF_{RT} = 0.02779$$

$$CF_{c^*/g} = 0.008453$$

The efficiency curve shown in Fig. A-4 is an arbitrary shape except for the fact that it passes through the value of 97.6% at an oxidizer fraction of 0.615. Its correction factor will be set to zero for the present time.

To complete the description of the thrust chamber, data to describe its size and shape are required from Table A-V. The injector manifold volume was defined previously and is noted in the table for reference.

Orifice length used to calculate injector inertance is obtained from a drawing. Injector effective area can be calculated from its resistance, and the flame front distance may be estimated from knowledge of the distance from injector face to impingement, past experience, or actual injector-engine frequency response data. The combustion chamber data may be obtained from engine prints or model specifications.

Program Input/Output

Table A-VI gives a listing of the input data cards, graphical output is presented in Figs. A-6A through A-6F, and Table A-VII contains the program printed output obtained for this case.

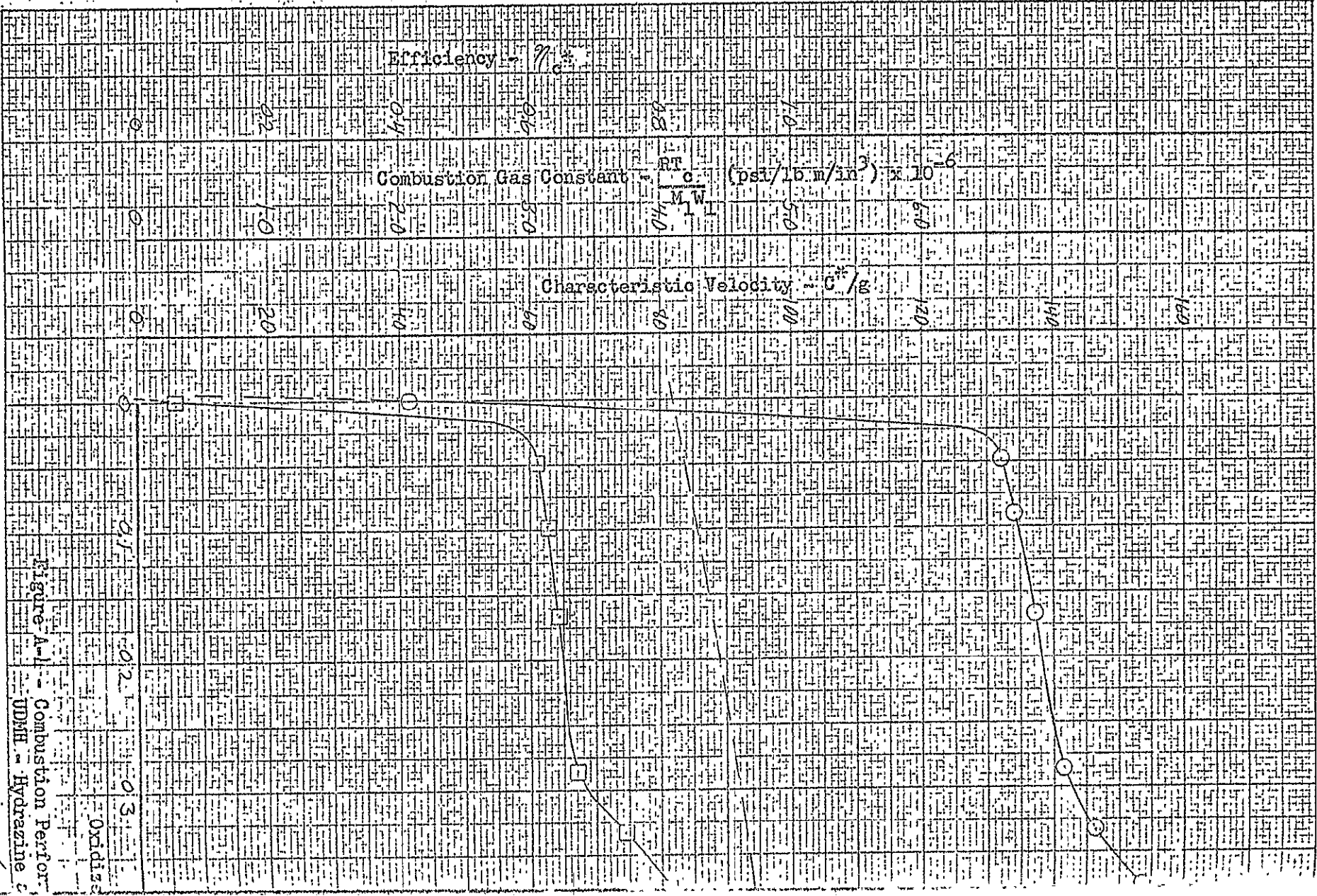
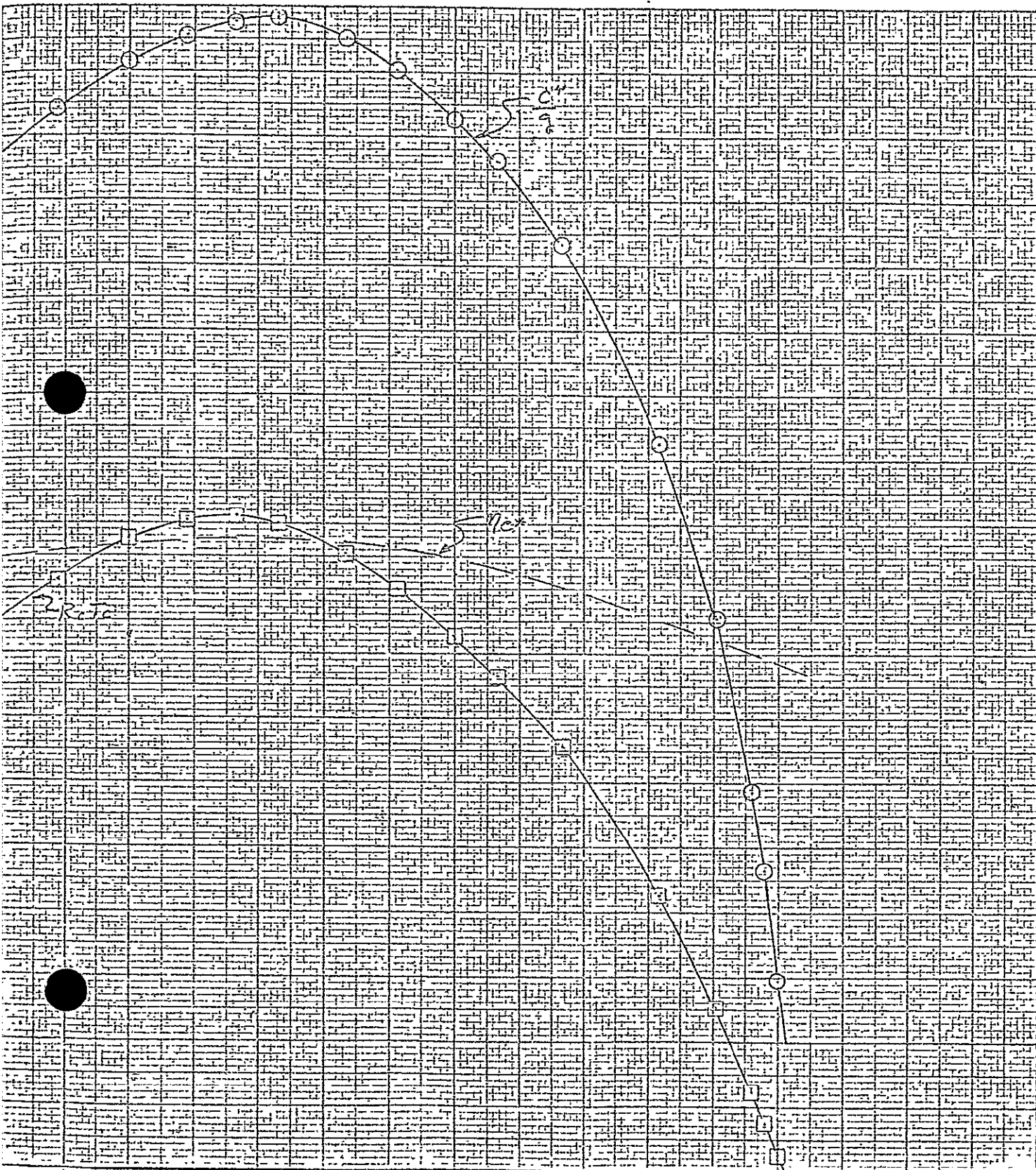


Figure A-1 - Combustion Performance
 UDMH - Hydrazine

FOLDOUT FRAME

FOLDOUT FRAME 2



0.5 0.6 0.7 0.8 0.9 1.0

Parameters for Nitrogen Tetroxide and 50/50
 Chamber Pressure of 150 psia.

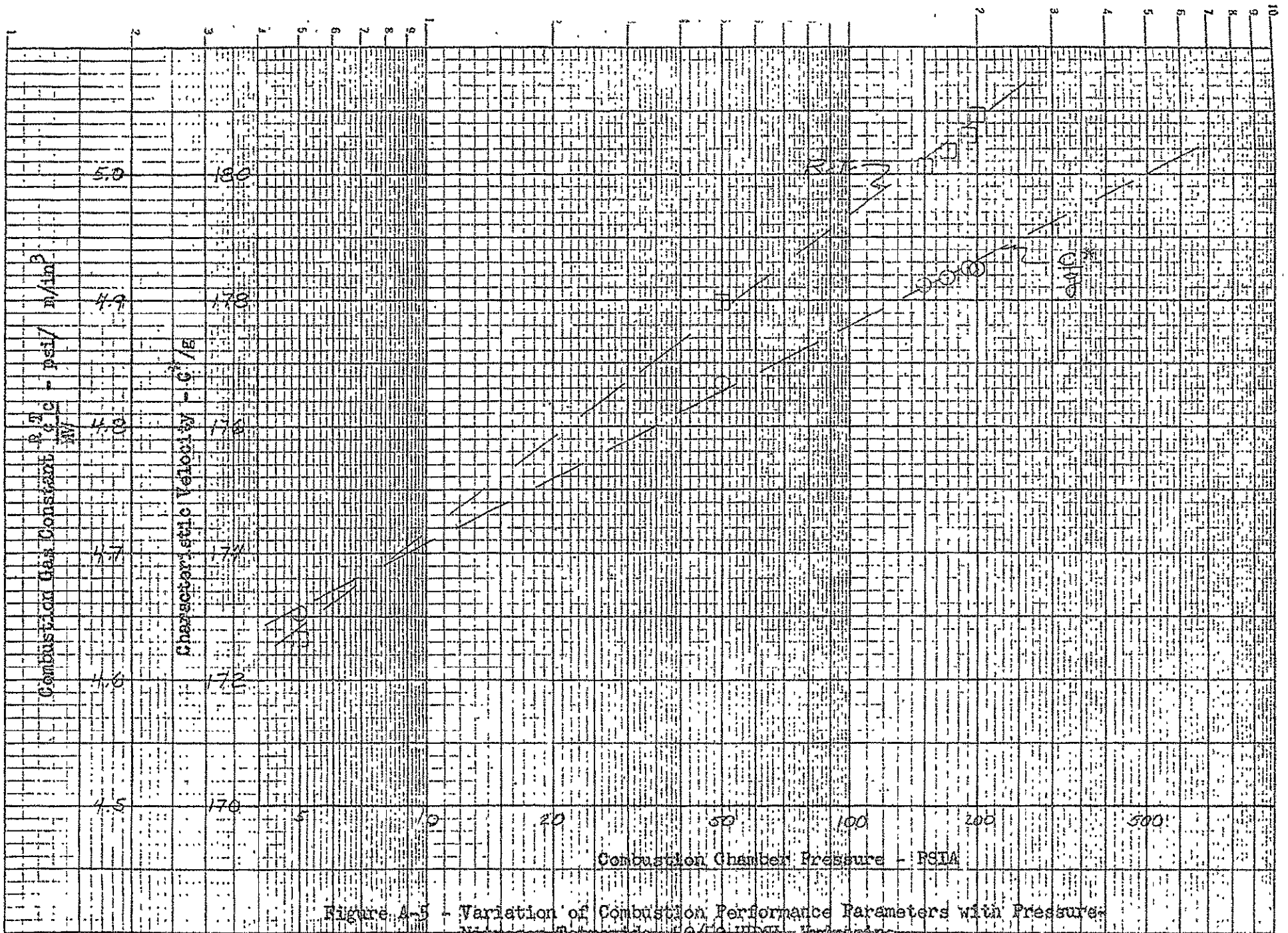


Figure A-5 - Variation of Combustion Performance Parameters with Pressure - Nitrogen Tetroxide, 50/50 UDMT, Hydrazine

TABLE A-V

COMBUSTION CHAMBER AND INJECTOR DATA .

	<u>FUEL</u>	<u>OXIDIZER</u>
MANIFOLD VOLUME - IN ³	38.58	11.38
ORIFICE LENGTH - IN	0.112	0.141
INJECTOR C _p A - IN ²	0.153544	0.206318
FLAME FRONT DISTANCE - IN	0.375	0.375
COMBUSTION CHAMBER THROAT AREA - IN ²		16.4
COMBUSTION CHAMBER VOLUME - IN ³		453.2
THRUST CHAMBER NOZZLE EXIT AREA - IN ²		750.0
THRUST COEFFICIENT		1.784

TABLE A-VI

APOLLO ASCENT ENGINE COMPUTER PROGRAM INPUT DATA

2	1	27	1.472	0.684	0.0	1.04	1.09	0000100,
1.10			1.10	0.0	0.276	0.276	0.276	0000200,
0.0			0.405	0.405	0.405	0.0	0.396	0000300,
0.396			0.396	0.0	1.10	1.10	1.04	0000400,
0.0			0.156	0.0	1.04			0000500,
2	121	27	10.2	12.6	0.0	10.2	13.0	0000600,
15.0			13.9	0.0	14.2	13.0	11.0	0000700,
0.0			11.0	16.0	23.0	0.0	20.4	0000800,
15.0			11.0	0.0	11.0	15.0	19.0	0000900,
0.0			21.3	0.0	13.4			0001000,
2	241	27	7.52 E-08	2.91 E-08	0.0	6.67 E-08	9.55 E-08	00001100,
12.1 E-08			12.1 E-08	0.0	10.5 E-08	10.5 E-08	10.5 E-08	00001200,
0.0			12.7 E-08	12.7 E-08	12.7 E-08	0.0	10.1 E-08	00001300,
10.1 E-08			10.1 E-08	0.0	12.1 E-08	12.1 E-08	6.67 E-08	00001400,
0.0			4.49 E-08	0.0	6.67 E-08			0001500,
2	361	27	0.003335	0.003989	0.0	0.003335	0.001603	0001600,
0.001850			0.007258	0.0	0.010576	0.009682	0.008193	0001700,
0.0			0.00345	0.00502	0.00721	0.0	0.00640	0001800,
0.00471			0.00345	0.0	0.001356	0.001850	0.002343	0001900,
0.0			0.066322	0.0	0.001652			0002000,
2	61	26	0.679	0.542	0.0	1.04	1.04	0002100,
1.09			1.09	0.0	0.405	0.405	0.405	0002200,
0.396			0.396	0.396	0.0	1.10	1.10	0002300,
1.10			1.04	0.0	0.396	0.396	0.396	0002400,
0.396			0.0	1.04				0002500,
2	181	26	10.0	8.9	0.0	6.9	9.0	0002600,
10.5			6.9	0.0	7.0	9.0	14.0	0002700,
17.0			11.0	7.0	0.0	7.0	13.0	0002800,
15.0			12.3	0.0	7.0	13.0	15.0	0002900,
8.0			0.0	7.0				0003000,
2	301	26	7.52 E-08	2.91 E-08	0.0	2.91 E-08	2.91 E-08	00003100,
9.55 E-08			9.55 E-08	0.0	12.7 E-08	12.7 E-08	12.7 E-08	00003200,
10.1 E-08			10.1 E-08	10.1 E-08	0.0	12.1 E-08	12.1 E-08	00003300,
12.1 E-08			2.91 E-08	0.0 E-08	10.1 E-08	10.1 E-08	10.1 E-08	00003400,
10.1 E-08			0.0 E-08	2.91 E-08				0003500,
2	421	26	0.001772	0.001577	0.0	0.001222	0.000835	0003600,
0.000975			0.004607	0.0	0.00219	0.00283	0.00439	0003700,
0.00534			0.00345	0.00219	0.0	0.000650	0.001207	0003800,
0.001392			0.001142	0.0	0.00219	0.00408	0.00471	0003900,
0.00251			0.0	0.00065				0004000,
>	1	26	21	150.0	0.02779	0.008453	0.0	0004100,
-0.005			0.0	0.02	0.04	0.06	0.10	0004200,

0.20			0.25		0.30		0.35		0.45		0.50	0004300,
0.55			0.60		0.65		0.70		0.80		0.90	0004400,
0.98			1.0		1.005							0004500,
5	36	21	-0.2	E+06	0.293	E+06	2.82	E+06	3.04	E+06	3.07	E+060004600,
3.13	E+06		3.24	E+06	3.28	E+06	3.42	E+06	3.87	E+06	4.60	E+060004700,
4.88	E+06		5.03	E+06	5.02	E+06	4.86	E+06	4.55	E+06	3.63	E+060004800,
2.27	E+06		0.37	E+06	0.133	E+06	0.01	E+06				0004900,
5	66	21	15.0		41.5		115.0		131.5		32.9	0005000,
134.7			138.0		139.8		142.6		148.8		.65.0	005100,
171.3			175.8		178.1		176.8		171.1		.52.0	005200,
116.6			58.7		29.4		21.0					005300,
5	96	21	0.816		0.818		0.826		0.833		.841	005400,
0.856			0.889		0.903		0.920		0.933		.959	005500,
0.967			0.974		0.978		0.973		0.964		.922	005600,
0.859			0.801		0.787		0.781					005700,
3	1	47	3.0		0.0		0.0		0.005		0.01	0005800,
0.015			0.02		0.028		0.03		0.053		0.04	0005900,
0.09			0.05		0.137		0.06		0.194		0.07	0006000,
0.257			0.08		0.328		0.09		0.404		0.10	0006100,
0.442			0.105		0.442		0.740		0.370		0.750	0006200,
0.292			0.760		0.225		0.770		0.166		0.780	0006300,
0.114			0.790		0.072		0.800		0.040		0.810	0006400,
0.022			0.820		0.010		0.830		0.0		0.844	0006500,
3	101	47	3.0		0.0		0.0		0.005		0.01	0006600,
0.015			0.02		0.028		0.03		0.053		0.04	0006700,
0.09			0.05		0.137		0.06		0.194		0.07	0006800,
0.257			0.08		0.328		0.09		0.404		0.10	0006900,
0.442			0.105		0.442		0.740		0.370		0.750	0007000,
0.292			0.760		0.225		0.770		0.166		0.780	0007100,
0.114			0.790		0.072		0.800		0.040		0.810	0007200,
0.022			0.820		0.010		0.830		0.0		0.844	0007300,
3	401	5	1.0		38.58		0.112		0.153544		0.375	0007400,
3	433	5	1.0		11.38		0.141		0.206318		0.375	0007500,
3	526	5	16.4		453.2		750.0		1.784		0.0	0007600,
3	497	6	1.0		0.003335		0.001725		2.0		0.003989	0007700,
0.004279												0007800,
3	509	6	1.0		0.001772		0.001725		2.0		0.001577	0007900,
0.005445												0008000,
3	201	9	328.		203.		0.006		200.0		0.10	0008100,
195.0			0.75		193.0		2.0					0008200,
-3	301	9	327.0		202.0		0.006		200.0		0.12	0008300,
194.00			0.82		194.0		2.0					0008400,

SOL ICMT=3, IPR=3, IST=1; NSEGF=27, NSEGO=26, DELT=170E-06,	ID=1000000,
LF=3*1,57*0, LFU=3*1,57*0, ICAPFU=9,13,25,2*0, ICAPOX=9,21,3*0,	ID=1000100,
ILKF=2,5,6,7,10,11,14,15,18,19,22,23,48*0,	ID=1000200,
IURU=2,5,6,7,10,11,12,13,14,17,18,19,22,23,24,45*0,	ID=1000300,
IBRAN(1,1,1)=21, IBRAN(1,2,1)=8, IBRAN(1,3,1)=20,	ID=1000400,
IBRAN(2,1,1)=17, IBRAN(2,2,1)=12, IBRAN(2,3,1)=16,	ID=1000500,
IBRAN(3,1,1)=27, IBRAN(3,2,1)=24, IBRAN(3,3,1)=26,	ID=1000600,
IBRAN(1,1,2)=16, IBRAN(1,2,2)=8, IBRAN(1,3,2)=15,	ID=1000700,
IBRAN(2,1,2)=26, IBRAN(2,2,2)=20, IBRAN(2,3,2)=25,	ID=1000800,
B(3)=0.0325, B(4)=0.052, B(5)=520, B(6)=520,	ID=1000900,
B(7)=60000, B(8)=40500,	ID=1001000,
IWI=5,205,105,305,1,101,403,404,	ID=1001100,
IVARIS=2,100,2,200,2,522,2,525,12*0,	ID=1001200,
ICAP=1, ICUT=1,	ID=1001300,
PF=5*0,25*203,32*0, PU=3*0,24*202,33*0,	ID=1001400,
IRI=1,5,28,3*0,101,105,127,3*0,205,220,4*0,305,314,4*0;	1001500,
ICV,4*0. IPI(25)=9,	ID=1001600,
ENGCUT(1,1,1)=3, ENGCUT(1,1,2)=3,	ID=1005200,
ICUTSG=1,2,3,37*0,1,2,3,37*0,	ID=1005300,
B(9)=0.0083446, B(10)=-4.1095, B(11)=0.0089489, B(12)=-3.62944,	ID=1005400,
B(13)=41.797, B(14)=92.016, B(15)=4, B(16)=4, B(17)=1.67,	ID=1005500,
B(18)=1.67, B(19)=1.05, B(20)=1.10, B(21)=10, B(22)=10,	ID=1005600,
B(23)=8.8889E-06, B(24)=2.0526E-05, B(25)=2760, B(26)=2760,	ID=1005700,
B(31)=0.691, B(32)=0.368, B(33)=0.75, B(34)=0.75,	ID=1005900,
B(81)=0.3, B(82)=0.3, B(83)=0.01, B(84)=0.01,	ID=1007000,
B(85)=600, B(86)=600, B(87)=425.8, B(88)=178.2,	ID=1007100,
INDEX=18,	ID=1008800,
SEND	1008900,
APOLLO ASCENT ENGINE PREDICTED PERFORMANCE	1009000,
NASA HOUSTON DATA CORRELATION	1009100,
SIMULATION OF TEST 006 * RUN NO. 1	1009200,

DATE 12/16/70
TIME 12 11.25

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
NASA HOUSTON DATA CORRELATION
SIMULATION OF TEST 036 * RUN NO. 1

121570 JCH

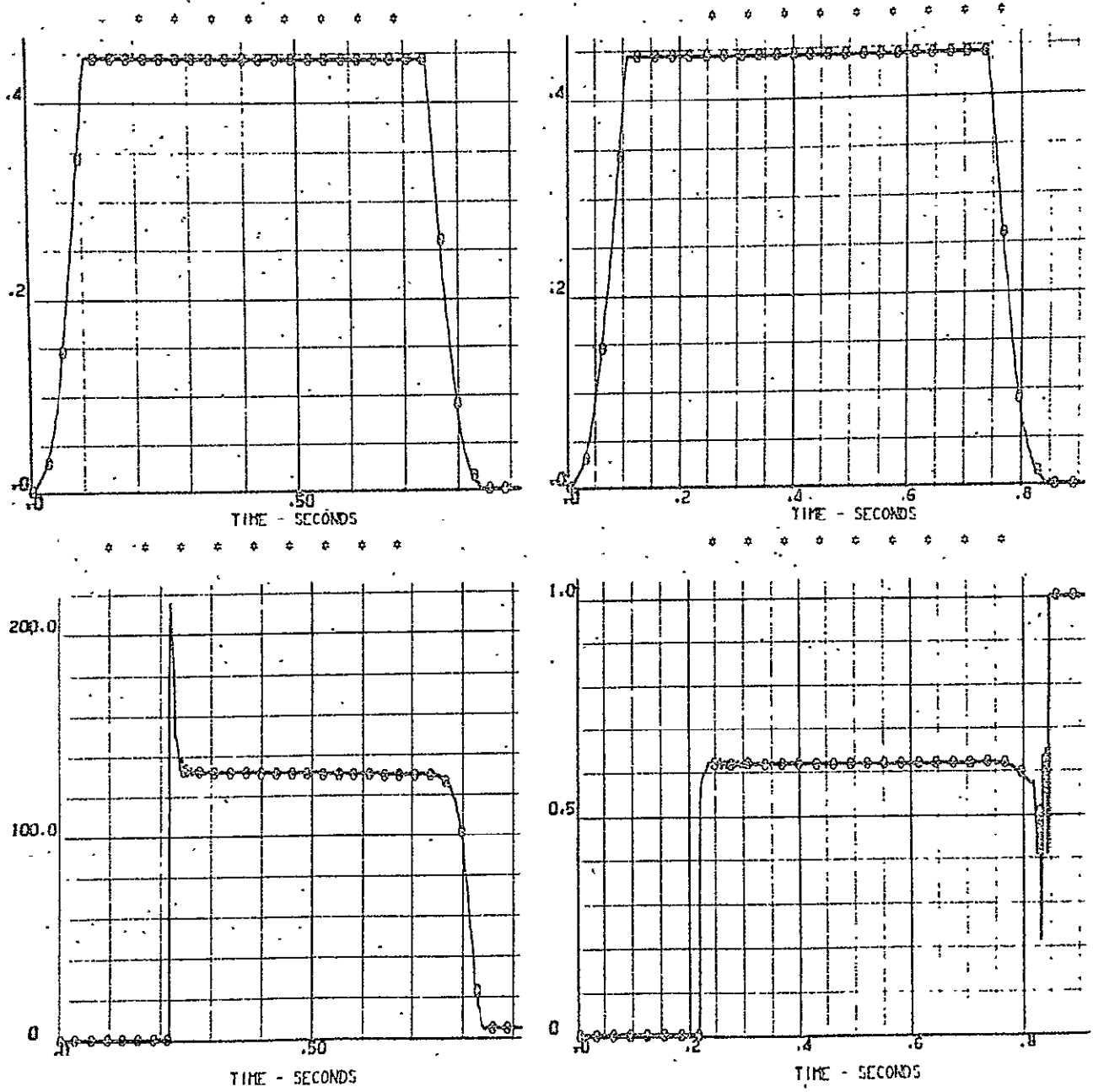


Figure A-6A - Graphical Output of Apollo Ascent Engine Computer Program.

DATE 12/16/70
TIME 12:11.25

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
NASA HOUSTON DATA CORRELATION
SIMULATION OF TEST 006 * RUN NO. 1

121070
121070

* FUEL PRESSURE SEGMENT NO. 1.
X FUEL PRESSURE SEGMENT NO. 20.

o FUEL PRESSURE SEGMENT NO. 5.

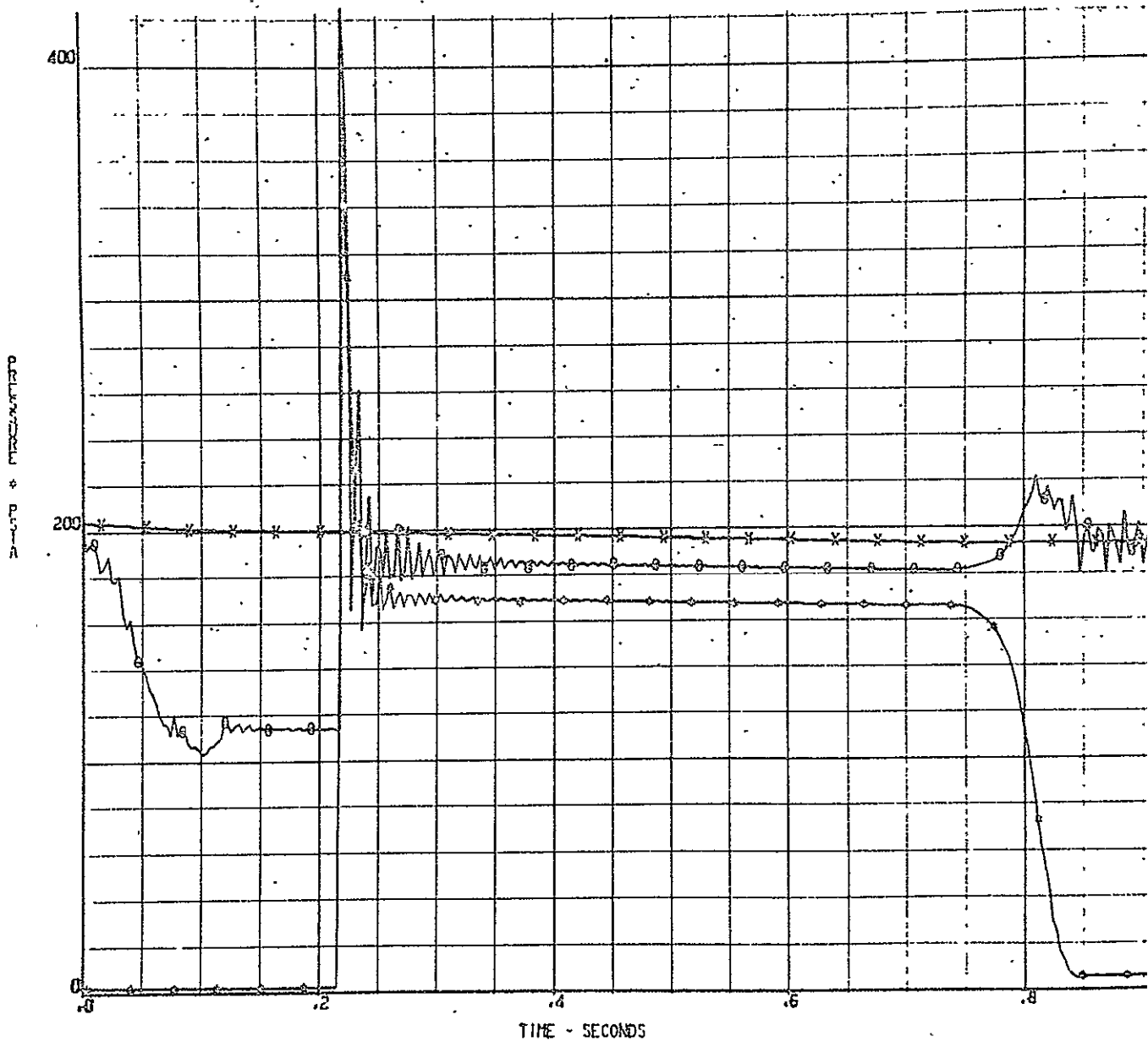


Figure A-6B - Graphical Output of Apollo Ascent Engine Computer Program.

DATE 1/16/70
TIME 11:11.25

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
NASA HOUSTON DATA CORRELATION
SIMULATION OF TEST 0.35 * RUN NO. 1

131331
121670 0223

* OXIDIZER PRESSURE SEGMENT NO. 1.
X OXIDIZER PRESSURE SEGMENT NO. 27.

o OXIDIZER PRESSURE SEGMENT NO. 5.

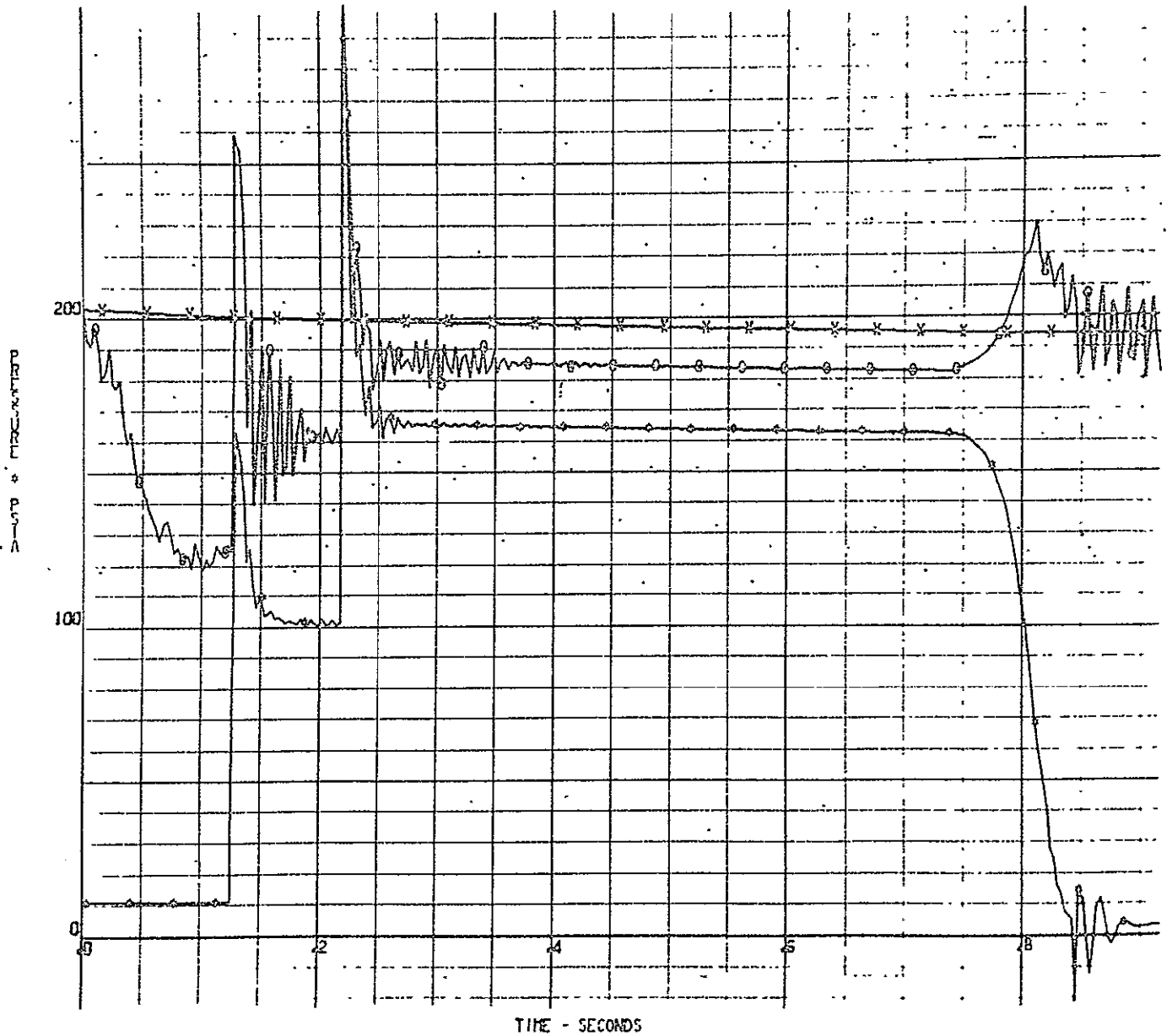


Figure A-6C - Graphical Output of Apollo Ascent Engine Computer Program

DATE 12/16/70
TIME 12:11:25

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
NASA HOUSTON DATA CORRELATION
SIMULATION OF TEST (X) & RUN NO. 1

12/16/70
12:16:30
0024

* FUEL FLOW SEGMENT NO. - 5.

0 FUEL FLOW SEGMENT NO. 20.

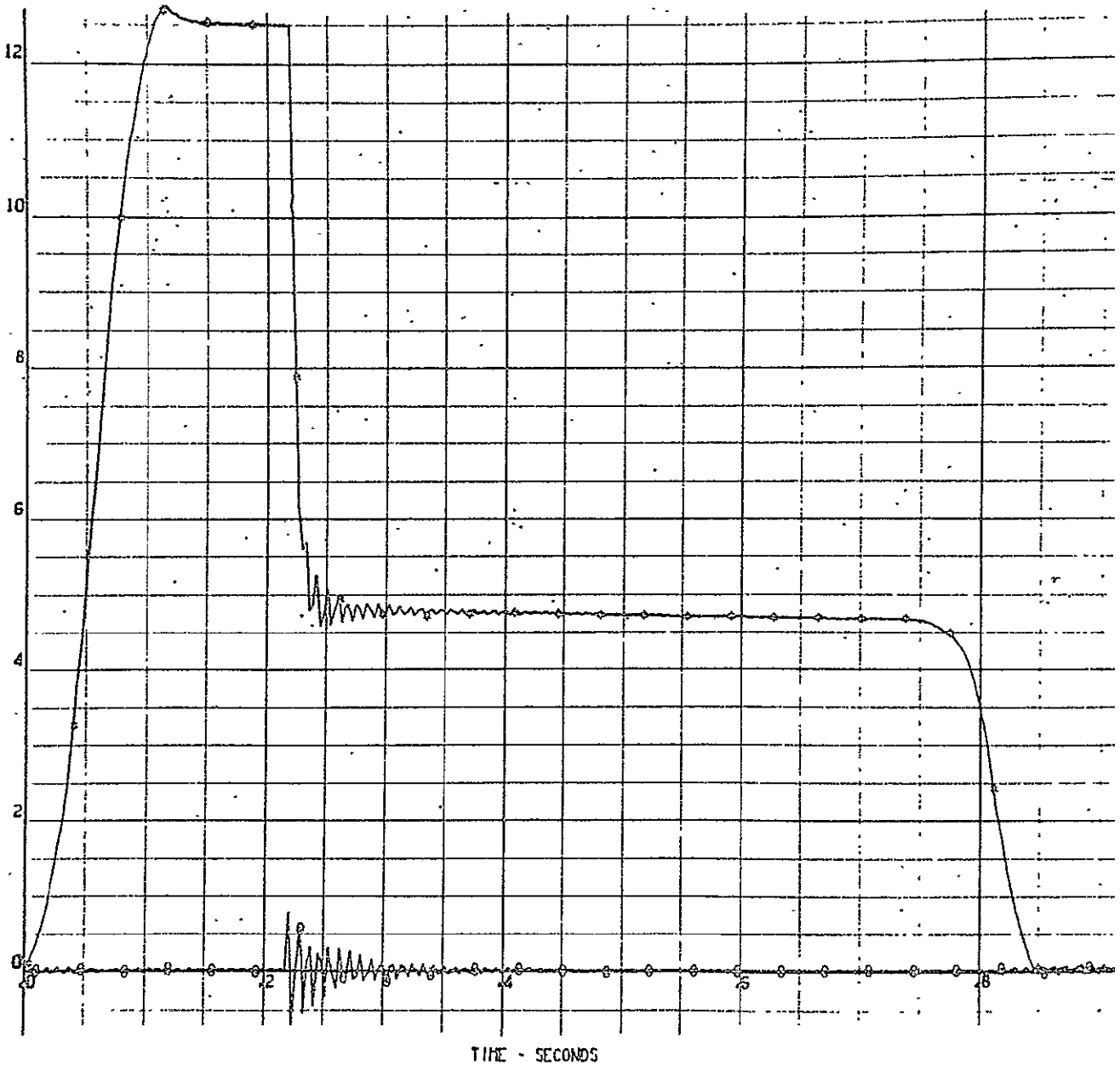


Figure A-6D - Graphical Output of Apollo Ascent Engine Computer Program.

DATE 12/16/70
TIME 12:11:25

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
NASA HOUSTON DATA CORRELATION
SIMULATION OF TEST OGG # RUN NO. 1

11011
121873 JAZ

* OXIDIZER FLOW SEGMENT NO. 5.

- O OXIDIZER FLOW SEGMENT NO. 14.

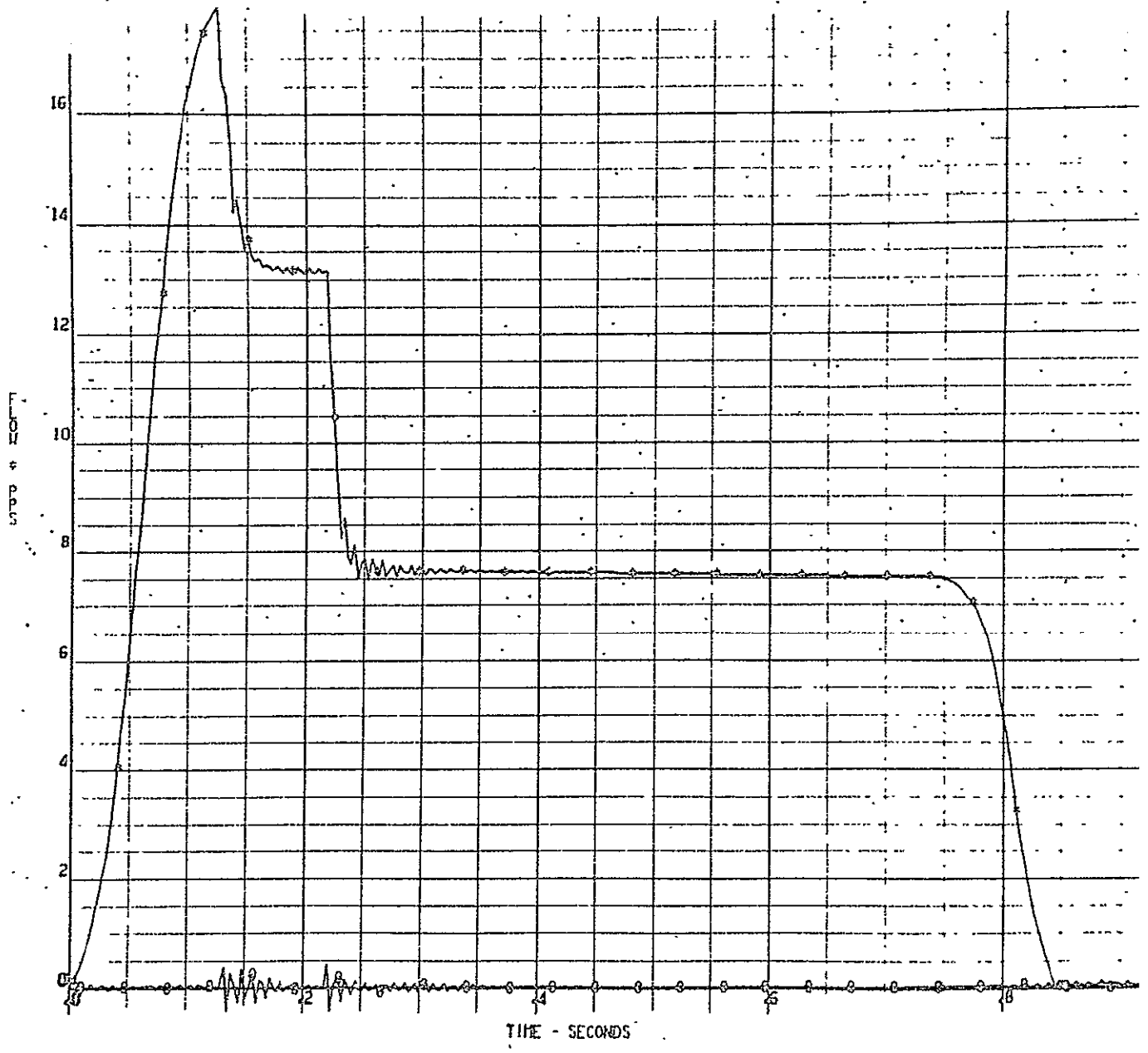


Figure A-6E - Graphical Output of Apollo Ascent Engine Computer Program.

DATE 12/16/70
TIME 12:11:25

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
NASA HOUSTON DATA CORRELATION
SIMULATION OF TEST LOG # RUN NO. 1

12/16/70
12:11:25

* FUEL PRESSURE SEGMENT NO. 9.

@ OXIDIZER PRESSURE SEGMENT NO. 9.

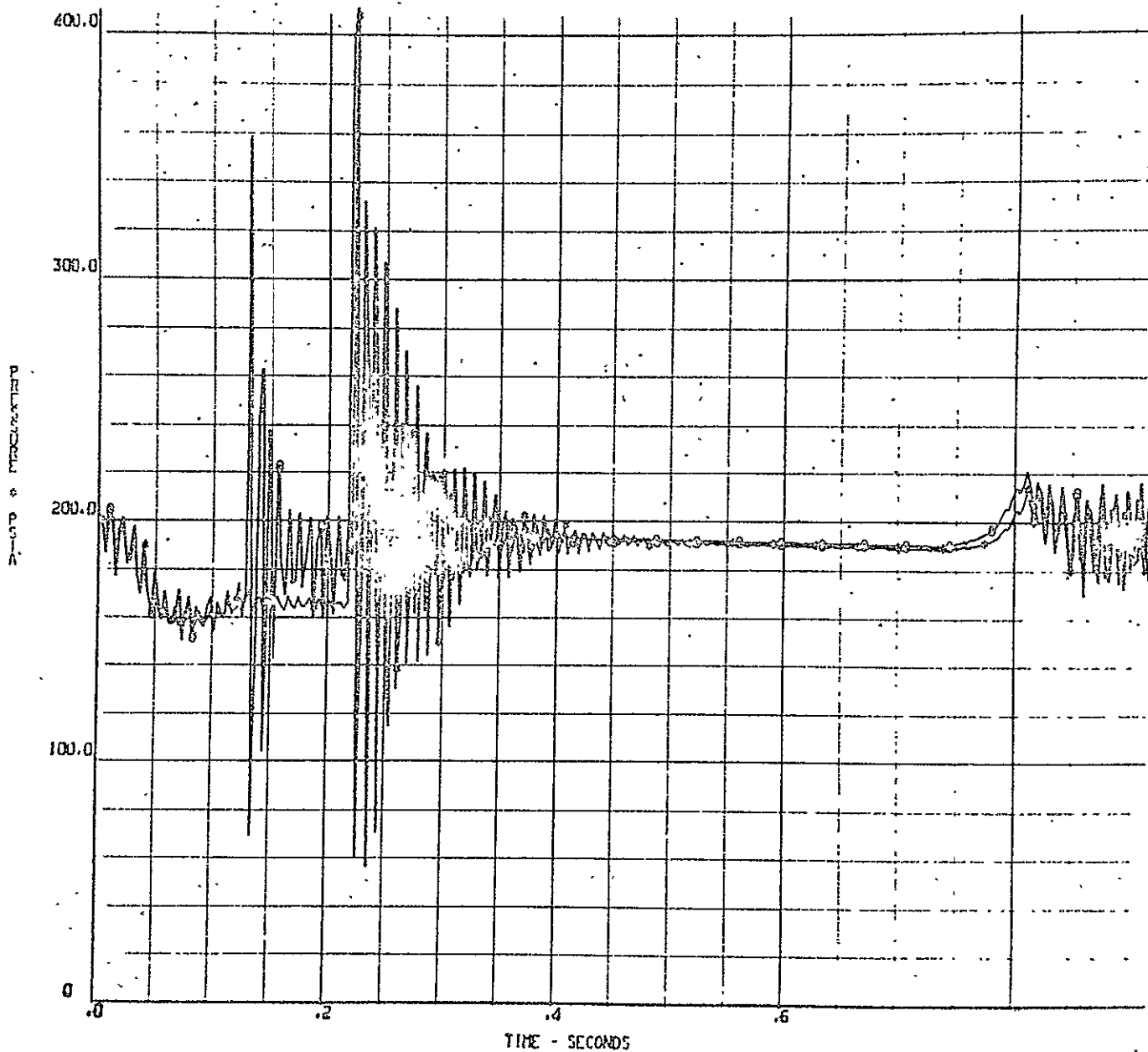


Figure A-6F - Graphical Output of Apollo Ascent Engine Computer Program.

TABLE A-VII

ASCENT ENGINE PROGRAM OUTPUT LISTINGS

DATE 12/16/70 TIME 12: 4.18
 APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
 NASA HOUSTON DATA CORRELATION
 SIMULATION OF TEST 006 * RUN NO. 1

* SEGMENT NO.	* DATA STATE	* PRESSURE PSIA	* FLOW PPS	* FUEL FEEDSYSTEM PARAMETERS *			* RESISTANCE SEC**2/IN**5	* DISOLVED GAS LBS G / LB L
				ACCOUSTIC VELOCITY IN / SEC	AREA SQ. IN.	LENGTH INCHES		
1	EMPTY	1.70	0.0	59327.7	1.4720	10.20	0.3335E-02	0.0
2	EMPTY	1.70	0.0	59737.2	0.6840	12.60	0.3989E-02	0.0
3	EMPTY	1.70	0.0	59402.6	0.0	0.0	0.1000E-32	0.0
4	FULL	203.00	0.0	59402.6	1.0400	10.20	0.3335E-02	0.0
5	FULL	203.00	0.0	59150.0	1.0900	13.00	0.1603E-02	0.0
6	FULL	203.00	0.0	58929.1	1.1000	15.00	0.1850E-02	0.0
7	FULL	203.00	0.0	58929.1	1.1000	13.90	0.7258E-02	0.0
8	FULL	203.00	0.0	58929.1	0.0	0.0	0.0	0.0
9	FULL	203.00	0.0	59067.4	0.2760	14.20	0.1058E-01	0.0
10	FULL	203.00	0.0	59067.4	0.2760	13.00	0.9682E-02	0.0
11	FULL	203.00	0.0	59067.4	0.2760	11.00	0.8193E-02	0.0
12	FULL	203.00	0.0	59102.2	0.0	0.0	0.0	0.0
13	FULL	203.00	0.0	58877.5	0.4050	11.00	0.3450E-02	0.0
14	FULL	203.00	0.0	58877.5	0.4050	16.00	0.5020E-02	0.0
15	FULL	203.00	0.0	58877.5	0.4050	23.00	0.7210E-02	0.0
16	FULL	203.00	0.0	59102.2	0.0	0.0	0.0	0.0
17	FULL	203.00	0.0	59102.2	0.3960	20.40	0.6400E-02	0.0
18	FULL	203.00	0.0	59102.2	0.3960	15.00	0.4710E-02	0.0
19	FULL	203.00	0.0	59102.2	0.3960	11.00	0.3450E-02	0.0
20	FULL	203.00	0.0	58929.1	0.0	0.0	0.0	0.0
21	FULL	203.00	0.0	58929.1	1.1000	11.00	0.1356E-02	0.0
22	FULL	203.00	0.0	58929.1	1.1000	15.00	0.1850E-02	0.0
23	FULL	203.00	0.0	59402.6	1.0400	19.00	0.2343E-02	0.0
24	FULL	203.00	0.0	59402.6	0.0	0.0	0.0	0.0
25	FULL	203.00	0.0	59595.9	0.1560	21.30	0.6632E-01	0.0
26	FULL	203.00	0.0	59402.6	0.0	0.0	0.0	0.0
27	FULL	203.00	0.0	59402.6	1.0400	13.40	0.1652E-02	0.0
28	FULL	203.00	0.0	60000.0	0.0	0.0	0.0	0.0

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
 NASA HOUSTON DATA CORRELATION
 SIMULATION OF TEST 006 * RUN NO. 1

* SEGMENT NO.	* DATA STATE	* PRESSURE PSIA	* FLOW PPS	* OXIDIZER FEED SYSTEM CONSTANTS			* RESISTANCE SEC**2/IN**5	* DISOLVED GAS LBS G / LB L
				ACOUSTIC VELOCITY IN / SEC	ARFA SQ. IN.	LENGTH INCHES		
1	EMPTY	10.57	0.0	40167.6	0.6790	10.00	0.1772E-02	0.0
2	EMPTY	10.57	0.0	40370.4	0.5420	8.90	0.1577E-02	0.0
3	EMPTY	10.57	0.0	40370.4	0.0	0.0	0.1000E-02	0.0
4	FULL	202.00	0.0	40370.4	1.0400	6.90	0.1222E-02	0.0
5	FULL	202.00	0.0	40370.4	1.0400	9.00	0.8350E-03	0.0
6	FULL	202.00	0.0	40079.3	1.0900	10.50	0.9750E-03	0.0
7	FULL	202.00	0.0	40079.3	1.0900	6.90	0.4607E-02	0.0
8	FULL	202.00	0.0	39969.2	0.0	0.0	0.0	0.0
9	FULL	202.00	0.0	39943.4	0.4050	7.00	0.2190E-02	0.0
10	FULL	202.00	0.0	39943.4	0.4050	9.00	0.2830E-02	0.0
11	FULL	202.00	0.0	39943.4	0.4050	14.00	0.4390E-02	0.0
12	FULL	202.00	0.0	40055.5	0.3960	17.00	0.5340E-02	0.0
13	FULL	202.00	0.0	40055.5	0.3960	11.00	0.3450E-02	0.0
14	FULL	202.00	0.0	40055.5	0.3960	7.00	0.2190E-02	0.0
15	FULL	202.00	0.0	39969.2	0.0	0.0	0.0	0.0
16	FULL	202.00	0.0	39969.2	1.1000	7.00	0.6500E-03	0.0
17	FULL	202.00	0.0	39969.2	1.1000	13.00	0.1207E-02	0.0
18	FULL	202.00	0.0	39969.2	1.1000	15.00	0.1392E-02	0.0
19	FULL	202.00	0.0	40370.4	1.0400	12.30	0.1142E-02	0.0
20	FULL	202.00	0.0	40370.4	0.0	0.0	0.0	0.0
21	FULL	202.00	0.0	40055.5	0.3960	7.00	0.2190E-02	0.0
22	FULL	202.00	0.0	40055.5	0.3960	13.00	0.4080E-02	0.0
23	FULL	202.00	0.0	40055.5	0.3960	15.00	0.4710E-02	0.0
24	FULL	202.00	0.0	40055.5	0.3960	8.00	0.2510E-02	0.0
25	FULL	202.00	0.0	40370.4	0.0	0.0	0.0	0.0
26	FULL	202.00	0.0	40370.4	1.0400	7.00	0.6500E-03	0.0
27	FULL	202.00	0.0	40500.0	0.0	0.0	0.0	0.0

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
 NASA HOUSTON DATA CORRELATION

SIMULATION OF TEST 006 * RUN NO. 1

FEEDSYSTEM CONFIGURATION

FUEL

OXIDIZER

SEGMENT BRANCH DATA

INDEX	INLET	BRANCHES	INLET	BRANCHES
1	21	8, 20	16	8, 15
2	17	12, 16	26	20, 25
3	27	24, 26		

CAPPED SEGMENTS

9, 13, 25, 0, 0, 9, 21, 0, 0, 0

FUEL ORDER ARRAY * NSEGF = 27

2 5 6 7 10 11 14 15 18 19 22 23

OXIDIZER ORDER ARRAY * NSEGO = 26

2 5 6 7 10 11 12 13 14 17 18 19 22 23 24

CUTOFF SEGMENTS

FUEL

OXIDIZER

CHAMBER NO. 1 * 1, 2, 3, 0, 0, 0, 0, 0, 0, 0, 0, 1, 2, 3, 0, 0, 0, 0, 0, 0, 0

FUEL VALVE TABLE

INDEX	SEGMENT	*	*	VALUES
1	328	203.000000	0.006000	200.000000 0.100000 193.000000 0.750000 193.000000 2.000000

OXIDIZER VALVE TABLE

INDEX	SEGMENT	*	*	VALUES
1	327	202.000000	0.006000	200.000000 0.120000 194.000000 0.820000 194.000000 2.000000

FUEL FUNGEN TABLE

3.000000	0.0	0.0	0.005000	0.010000	0.015000	0.020000	0.028000	0.030000
0.053000	0.040000	0.090000	0.050000	0.137000	0.060000	0.194000	0.070000	0.257000
0.080000	0.328000	0.090000	0.404000	0.100000	0.442000	0.105000	0.442000	0.740000
0.370000	0.750000	0.292000	0.760000	0.225000	0.770000	0.166000	0.780000	0.114000
0.790000	0.072000	0.800000	0.040000	0.810000	0.022000	0.820000	0.010000	0.830000
0.0	0.844000							

OXIDIZER FUNGEN TABLE

3.000000	0.0	0.0	0.005000	0.010000	0.015000	0.020000	0.028000	0.030000
0.053000	0.040000	0.090000	0.050000	0.137000	0.060000	0.194000	0.070000	0.257000
0.080000	0.328000	0.090000	0.404000	0.100000	0.442000	0.105000	0.442000	0.740000
0.370000	0.750000	0.292000	0.760000	0.225000	0.770000	0.166000	0.780000	0.114000
0.790000	0.072000	0.800000	0.040000	0.810000	0.022000	0.820000	0.010000	0.830000
0.0	0.844000							

CAVITATING VENTURI DATA
FUEL

OXIDIZER

ORIFICE DATA

INDEX NO.	1	2	3	4	1.	2	3	4
SEGMENT NO.	1.	2.	0.	0.	1.	2.	0.	0.
LINE RESIS: SEC**2/IN**5	0.003335	0.003989	0.0	0.0	0.001772	0.001577	0.0	0.0
ORIFICE RESISTANCE	0.001725	0.004279	0.0	0.0	0.001725	0.005445	0.0	0.0

ACCUMULATOR DATA

INJECTOR MANIFOLD DATA

INDEX NO. SEGMENT NO.	FUEL				OXIDIZER			
	1	2	3	4	1	2	3	4
MANIFOLD VOLUME - CU. IN.	38.5800	0.0	0.0	0.0	11.3800	0.0	0.0	0.0
ORIFICE LENGTH - INCHES	0.112000	0.0	0.0	0.0	0.141000	0.0	0.0	0.0
INJECTOR C-SUB-D*A - SQIN	0.153544	0.0	0.0	0.0	0.206319	0.0	0.0	0.0
FLAME FRONT DISTANCE-IN.	0.375000	0.0	0.0	0.0	0.375000	0.0	0.0	0.0

COMBUSTION CHAMBER DATA

INDEX NO.	1	2	3	4
CHAMBER PRESSURE - PSIA	0.0	0.0	0.0	0.0
OXIDIZER FLOWRATE - PPS	0.0	0.0	0.0	0.0
FUEL FLOWRATE - PPS	0.0	0.0	0.0	0.0
OXIDIZER FRACTION	0.0	0.0	0.0	0.0
THROAT AREA - SQ. IN.	16.400	0.0	0.0	0.0
CHAMBER VOLUME - CU. IN.	453.200	0.0	0.0	0.0
NOZZLE EXIT AREA - SQ. IN.	750.00	0.0	0.0	0.0
THRUST COEFFICIENT	1.78400	0.0	0.0	0.0
ENGINE AMBIENT PRESSURE - PSIA	0.0	0.0	0.0	0.0
ENGINE THRUST - POUNDS	0.0	0.0	0.0	0.0

COMBUSTION DATA

BASE PRESSURE = 150.0 PSIA

CSTAR CORRECTION = 0.008453

GAS CONSTANT CORRECTION = 0.027790

EFFICIENCY CORRECTION = 0.0

OX. FRACTION	GAS CONSTANT	CSTAR / S	EFFICIENCY
-0.0050	-2.0000E 05	15.000	0.8160
0.0	2.9300E 05	41.500	0.8180
0.0200	2.8200E 06	115.000	0.8260
0.0400	3.0400E 06	131.500	0.8330
0.0600	3.0700E 06	132.900	0.8410
0.1000	3.1300E 06	134.700	0.8560
0.2000	3.2400E 06	138.000	0.8890
0.2500	3.2800E 06	139.800	0.9030
0.3000	3.4200E 06	142.600	0.9200
0.3500	3.8700E 06	148.800	0.9330
0.4500	4.6000E 06	165.000	0.9590
0.5000	4.8800E 06	171.300	0.9670
0.5500	5.0300E 06	175.800	0.9740
0.6000	5.0200E 06	178.100	0.9780
0.6500	4.8600E 06	176.800	0.9730
0.7000	4.5500E 06	171.100	0.9640
0.8000	3.6300E 06	152.000	0.9220

0.9000	2.2700E 06	116.600	0.8590
0.9800	3.7000E 05	58.700	0.8010
1.0000	1.3300E 05	29.400	0.7870
1.0050	1.0000E 04	21.000	0.7810

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
 NASA HOUSTON DATA CORELATION
 SIMULATION OF TEST 006 * RUN NO. 1

INPUT DATA CONSTANTS	*	FUEL	OXIDIZER
ENTRAINED GAS - LBS GAS / LB LIQUID		0.0	0.0
PROPELLANT DENSITY - POUNDS / CUBIC INCH		0.03250	0.05200
LIQUID TEMPERATURE - DEGREES RANKINE		520.0	520.0
PROPELLANT ACOUSTIC VELOCITY - INCHES / SECOND		60000.0	40500.0
VAPOR PRESSURE CURVE FIT CONSTANTS - CON1		8.3446E-03	8.9489E-03
(LOG(PVAP) = CON1 * TEMP + CON2)			
	- CON2	-4.1095E 00	-3.6294E 00
PROPELLANT MOLECULAR WEIGHT		41.8	92.0
PRESSURANT GAS MOLECULAR WEIGHT		4.0	4.0
RATIO OF SPECIFIC HEATS - PRESSURANT GAS		1.670	1.670
RATIO OF SPECIFIC HEATS - PROPELLANT VAPOR		1.050	1.100
DISSOLVED GAS EVOLUTION TIME CONSTANT - 1/SEC.		1.0000E 01	1.0000E 01
DISSOLVED GAS CONCENTRATION - LBS GAS / LB LIQ / PSI		8.8889E-06	2.0526E-05
PROPELLANT TANK ULLAGE - CUBIC INCHES		2.7600E 03	2.7600E 03
PROPELLANT TANK INITIAL PRESSURE - PSIA		0.0	0.0
PRESSURANT GAS BOTTLE VOLUME - CUBIC INCHES		0.0	0.0
PROPELLANT LIQUID HEAT CAPACITY - BTU / LB / DEGREE R.		6.9100E-01	3.6800E-01
PRESSURANT - LOW PRESSURE C-SUB-V		7.5000E-01	7.5000E-01
PRESSURANT - HIGH PRESSURE C-SUB-V		0.0	0.0
PRESSURANT - HIGH PRESSURE C-SUB-P		0.0	0.0
PRESSURANT - HIGH PRESSURE GAMMA		0.0	0.0
PROPELLANT VAPOR C-SUB-P		3.0000E-01	3.0000E-01
HEAT SOAKBACK - BTU / LB SEC DEGREE R		1.0000E-02	1.0000E-02
SOAKBACK INJECTOR TEMPERATURE - DEGREES R		600.0	600.0
PROPELLANT HEAT OF VAPORIZATION - BTU / LB		425.8	178.2
		0.0	0.0

APOLLO ASCENT ENGINE PREDICTED PERFORMANCE
 NASA HOUSTON DATA CORRELATION
 SIMULATION OF TEST 006 * RUN NO. 1

0.0	203.00000	0.0	202.00000	0.0	1.69703	10.56785	0.0	0.0
0.003060	191.15545	0.10147	192.08261	0.12635	1.69703	10.56785	0.0	0.0
0.006120	193.31161	0.20297	190.18991	0.25843	1.69703	10.56785	0.0	0.0
0.009180	194.04840	0.32298	196.14391	0.39891	1.69703	10.56785	0.0	0.0
0.012240	189.96640	0.48879	190.82126	0.60303	1.69703	10.56786	0.0	0.0
0.015300	181.69374	0.69042	179.37956	0.84400	1.69703	10.56786	0.0	0.0
0.018360	164.54080	0.90149	182.24158	1.10913	1.69703	10.56785	0.0	0.0
0.021420	188.54604	1.14518	189.45116	1.41850	1.69703	10.56786	0.0	0.0
0.024480	177.86151	1.37418	178.07689	1.69451	1.69703	10.56786	0.0	0.0
0.027540	177.33925	1.63561	176.87059	2.01460	1.69703	10.56785	0.0	0.0
0.030600	179.58345	1.94151	179.03133	2.39194	1.69703	10.56785	0.0	0.0
0.033660	152.76985	2.32594	164.79218	2.88205	1.69703	10.56785	0.0	0.0
0.036720	157.95204	2.75668	158.78745	3.40125	1.69703	10.56785	0.0	0.0
0.039780	151.28201	3.25073	162.40424	4.01677	1.69703	10.56735	0.0	0.0
0.042840	151.07190	3.78499	153.23453	4.68780	1.69703	10.56785	0.0	0.0
0.045900	143.48324	4.31915	146.89807	5.36299	1.69703	10.56785	0.0	0.0
0.048960	143.08915	4.91950	146.22942	6.11604	1.69703	10.56785	0.0	0.0
0.052020	137.52202	5.53300	141.33997	6.89634	1.69703	10.56785	0.0	0.0
0.055080	131.30673	6.11623	136.92305	7.66267	1.69703	10.56786	0.0	0.0
0.058140	129.07494	6.73768	134.42174	8.47462	1.69703	10.56785	0.0	0.0
0.061200	129.01807	7.34993	131.48282	9.28189	1.69703	10.56785	0.0	0.0
0.064260	119.73895	7.92012	127.36034	10.07122	1.69703	10.56785	0.0	0.0
0.067320	115.66161	8.51198	132.50085	10.80408	1.69703	10.56785	0.0	0.0
0.070380	115.26114	9.06132	133.49069	11.50770	1.69703	10.56785	0.0	0.0
0.073439	111.06042	9.55692	128.95630	12.16080	1.69703	10.56785	0.0	0.0
0.076499	119.53014	9.97220	123.64055	12.72213	1.69703	10.56786	0.0	0.0
0.079559	110.76262	10.34180	125.12430	13.37469	1.69703	10.56785	0.0	0.0
0.082619	112.76555	10.70223	121.75716	13.92398	1.69703	10.56785	0.0	0.0
0.085679	112.60459	10.98656	122.53926	14.43808	1.69703	10.56786	0.0	0.0
0.088739	107.43851	11.27830	122.57639	14.96511	1.69703	10.56785	0.0	0.0
0.091799	105.34750	11.56177	118.39241	15.40265	1.69703	10.56785	0.0	0.0
0.094859	105.80255	11.79995	126.32312	15.77643	1.69703	10.56785	0.0	0.0
0.097918	105.20172	12.01590	122.48489	16.13605	1.69703	10.56785	0.0	0.0
0.100978	102.64495	12.20252	117.97188	16.44292	1.69703	10.56785	0.0	0.0
0.104038	102.38077	12.37281	121.22929	16.72545	1.69703	10.56785	0.0	0.0
0.107098	105.59415	12.51435	119.10260	17.02650	1.69703	10.56785	0.0	0.0
0.110158	105.96355	12.59731	120.90974	17.22153	1.69703	10.56785	0.0	0.0
0.113218	107.48259	12.66303	125.80169	17.41722	1.69703	10.56785	0.0	0.0
0.116278	109.36345	12.70697	123.05956	17.57660	1.69703	10.56785	0.0	0.0

0.119337	116.98558	12.65529	123.92807	17.66383	1.69703	10.56786	0.0	0.0
0.122397	115.82516	12.61789	126.11011	17.78780	1.69703	10.56786	0.0	0.0
0.125457	112.49278	12.60432	124.28253	17.86014	1.69703	10.56786	0.0	0.0
0.128517	114.15135	12.56708	258.37427	16.58267	1.69703	152.55981	0.0	0.0
0.131577	115.64755	12.55156	253.34683	16.33722	1.69703	155.10632	0.0	0.0
0.134637	112.24681	12.53622	228.41068	15.55170	1.69703	143.83022	0.0	0.0
0.137697	113.77951	12.52458	164.62885	14.20146	1.69703	120.92560	0.0	0.0
0.140756	115.36130	12.52598	201.76282	14.41042	1.69703	124.84138	0.0	0.0
0.143816	112.91135	12.50608	139.15045	13.96230	1.69703	112.74493	0.0	0.0
0.146876	113.12105	12.50376	159.49695	13.50745	1.69703	105.85847	0.0	0.0
0.149936	114.40480	12.51346	189.52721	13.69931	1.69703	109.33871	0.0	0.0
0.152996	113.26555	12.49424	139.45006	13.40352	1.69703	103.37105	0.0	0.0
0.156056	113.27190	12.49286	189.37213	13.30100	1.69703	103.56548	0.0	0.0
0.159116	113.71346	12.50438	170.71922	13.34439	1.69703	104.69229	0.0	0.0
0.162176	113.43927	12.48824	140.66920	13.19232	1.69703	102.09152	0.0	0.0
0.165235	113.56755	12.48797	186.39926	13.21249	1.69703	102.55080	0.0	0.0
0.168295	113.20981	12.49664	149.13774	13.20780	1.69703	101.82013	0.0	0.0
0.171355	113.32892	12.48452	151.37550	13.13810	1.69703	100.73897	0.0	0.0
0.174415	113.72729	12.43583	180.99710	13.19163	1.69703	101.35437	0.0	0.0
0.177475	113.03285	12.48992	149.20546	13.16830	1.69703	101.01828	0.0	0.0
0.180535	113.19655	12.48092	163.18634	13.10176	1.69703	100.30533	0.0	0.0
0.183595	113.72264	12.48422	170.47678	13.17360	1.69703	101.64529	0.0	0.0
0.186654	113.00829	12.48449	153.91364	13.14085	1.69703	101.01635	0.0	0.0
0.189714	113.11752	12.47753	164.35974	13.08250	1.69703	99.79724	0.0	0.0
0.192774	113.60071	12.48222	161.31302	13.17927	1.69703	101.81238	0.0	0.0
0.195834	113.00095	12.48009	160.19505	13.12231	1.69703	100.49690	0.0	0.0
0.198894	113.13219	12.47448	162.69693	13.08597	1.69703	99.63935	0.0	0.0
0.201954	113.42755	12.47966	159.08246	13.17701	1.69703	101.94029	0.0	0.0
0.205014	112.99911	12.47600	164.37192	13.10054	1.69703	100.12004	0.0	0.0
0.208073	113.15378	12.47191	160.99146	13.10365	1.69703	100.04573	0.0	0.0
0.211133	113.27388	12.47647	159.17740	13.16129	1.69703	101.63736	0.0	0.0
0.214193	112.96074	12.47229	164.03654	13.09127	1.69703	99.92056	0.0	0.0
0.217253	113.18074	12.46946	160.47394	13.12202	161.26497	100.50883	0.0	0.0
0.220313	423.66528	9.90551	299.52197	11.41761	378.20581	290.51245	215.25641	0.53520
0.223373	370.01831	7.85461	254.22887	10.46871	308.70215	255.60889	202.31969	0.57248
0.226433	154.95790	6.12007	198.55469	9.31684	250.60791	233.63129	181.74333	0.59144
0.229493	225.96509	5.56300	222.45074	8.23348	201.54379	187.54999	149.18880	0.59271
0.232552	250.25559	5.63928	212.69870	8.60049	203.41884	191.40900	148.63541	0.60536
0.235612	150.43265	4.76097	191.54123	7.87798	179.99078	178.09819	141.53937	0.61897
0.238672	183.72020	4.81063	198.63438	7.73408	171.40154	168.18175	132.93845	0.61551
0.241732	213.75098	5.22109	195.92717	8.08419	185.37311	177.91347	138.87962	0.61047
0.244792	171.77945	4.56320	176.84978	7.48759	167.04713	164.16771	131.85994	0.61947
0.247852	192.09785	4.69216	183.18048	7.77642	167.64406	166.29318	130.86154	0.62677

.250912	193.77078	5.03461	192.87085	7.81388	179.08159	171.43370	135.63762	0.60527
.253971	179.35442	4.57260	179.86159	7.45175	165.12105	131.10970	129.45996	0.61601
.257931	193.12433	4.73541	189.92177	7.84081	168.38158	147.37914	131.08235	0.62806
.260091	175.85659	4.91259	192.18532	7.61929	174.82292	147.67525	133.64388	0.60591
.263151	180.25433	4.60685	181.89688	7.54012	165.51392	152.66122	129.64622	0.61988
.266211	199.55400	4.79690	188.45642	7.81206	170.09297	137.68784	131.64299	0.62379
.269271	177.49448	4.83019	183.53227	7.52285	172.26514	183.37361	132.49739	0.60504
.272331	181.08820	4.62433	185.56622	7.64849	166.17938	154.31412	130.12967	0.62333
.275391	197.25603	4.83267	186.48413	7.72110	171.11665	166.59001	131.76613	0.61644
.278450	178.08406	4.78158	182.73041	7.52060	170.64676	164.69341	131.82608	0.60911
.281510	182.79912	4.64349	192.41051	7.71189	166.56061	155.37668	130.37236	0.62513
.284570	193.72128	4.84567	182.30957	7.62620	171.43033	155.54248	131.75218	0.61153
.287630	179.12665	4.75139	184.13551	7.57068	169.77126	155.11343	131.57855	0.61377
.290690	185.26799	4.66620	192.59743	7.71608	167.06097	155.54477	130.53323	0.62432
.293750	190.63752	4.84123	177.77344	7.56788	171.43771	154.85670	131.71286	0.60927
.296810	179.82899	4.72940	188.00414	7.62513	169.12770	155.53731	131.38124	0.61707
.299869	187.15277	4.69135	189.86998	7.68495	167.65123	165.20059	130.63409	0.62168
.302929	188.71271	4.83029	178.61185	7.55557	171.12350	164.69136	131.60284	0.60910
.305989	180.33463	4.71339	191.24306	7.65745	168.65039	165.70949	131.20595	0.61917
.309049	188.36978	4.71576	184.92328	7.64743	168.24817	154.91725	130.79555	0.61913
.312109	186.99811	4.81571	182.10960	7.56902	170.73067	154.82751	131.46599	0.61074
.315169	181.00804	4.70298	190.63031	7.66198	168.37915	165.58775	131.10747	0.61967
.318229	188.89093	4.73460	181.20772	7.62152	168.74234	164.77573	130.93173	0.61734
.321288	185.27519	4.80019	186.89510	7.58961	170.25702	164.92621	131.29402	0.61182
.324348	182.09537	4.69759	187.82057	7.65314	168.27820	155.33911	131.06100	0.61963
.327408	188.77733	4.74871	180.64389	7.60956	169.03481	164.74832	130.97844	0.61634
.330468	183.90395	4.78371	190.00348	7.60396	169.85031	164.99176	131.17018	0.61321
.333528	183.22008	4.69706	184.34929	7.64028	168.26460	155.15332	131.05243	0.61940
.336588	188.25053	4.75852	182.21596	7.60399	169.15692	164.72215	130.94470	0.61575
.339648	183.09575	4.76682	190.39948	7.61268	169.50388	165.01422	131.12320	0.61411
.342708	184.23755	4.70012	182.26613	7.63119	168.29422	154.98817	131.00220	0.61918
.345767	187.56682	4.76424	184.39819	7.60054	169.16753	154.63338	130.87541	0.61493
.348827	182.74423	4.75110	188.91600	7.61838	169.28584	165.07336	131.13940	0.61525
.351887	185.00036	4.70585	182.14145	7.62275	168.24501	154.82820	130.90315	0.61850
.354947	186.83007	4.76628	185.78575	7.59684	169.20204	164.55788	130.83719	0.61470
.358007	182.76059	4.73775	186.99742	7.62319	169.03937	165.14267	131.16277	0.61617
.361067	185.45779	4.71284	183.19400	7.61455	168.25995	154.62205	130.76218	0.61834
.364127	186.14532	4.76506	185.94160	7.59606	169.16988	164.54913	130.86485	0.61419
.367186	182.95732	4.72689	185.59634	7.62597	168.87462	155.14240	131.12170	0.61760
.370246	185.64635	4.72050	184.36578	7.60536	168.19769	154.42793	130.64655	0.61693
.373306	185.53555	4.76035	185.50150	7.59817	169.21915	164.61365	130.91019	0.61480
.376366	183.17365	4.71980	185.08728	7.62449	168.60954	155.05443	131.03061	0.61771
.379426	185.77235	4.72621	185.02072	7.59857	168.28333	154.27719	130.56955	0.61653

0.382486	134.88231	4.75469	185.07251	7.60273	169.13315	154.70934	130.96707	0.61591
0.385546	133.54649	4.71427	184.91916	7.61881	168.40993	154.85258	130.38701	0.61802
0.388605	135.54318	4.73269	185.06761	7.59503	168.35889	154.25481	130.58339	0.61617
0.391665	134.58710	4.74541	185.01352	7.60601	169.01553	154.75446	130.95485	0.61570
0.394725	133.59052	4.71418	184.80464	7.61066	168.22813	154.63075	130.75934	0.61767
0.397785	135.67018	4.73370	184.93420	7.59561	168.45137	154.28697	130.60219	0.61597
0.400845	133.87134	4.73996	185.21223	7.60681	168.82269	154.72482	130.91716	0.61605
0.403905	134.20607	4.71167	184.47827	7.60333	168.13371	154.42636	130.64148	0.61733
0.406965	135.14465	4.73707	184.84195	7.59762	168.50934	154.37452	130.66045	0.61626
0.410025	133.86841	4.73066	185.35619	7.60435	168.61357	154.61545	130.81488	0.61624
0.413084	134.20918	4.71448	184.16869	7.59820	168.09464	154.30687	130.58452	0.61732
0.416144	135.07932	4.73485	184.90947	7.59925	168.50114	154.40977	130.66646	0.61611
0.419204	133.56059	4.72568	185.29578	7.60074	168.43571	154.48315	130.72688	0.61650
0.422264	134.48352	4.71532	183.99280	7.59581	168.06194	154.24431	130.54550	0.61699
0.425324	134.68828	4.73328	184.96979	7.59877	168.47804	154.40337	130.65793	0.61641
0.428384	133.58035	4.72031	185.04565	7.59712	168.25375	154.36899	130.64497	0.61659
0.431444	134.48691	4.71708	184.06560	7.59455	168.07475	154.20450	130.51250	0.61710
0.434503	134.45120	4.72996	184.93315	7.59654	168.37820	154.35002	130.62640	0.61608
0.437563	133.53322	4.71678	184.76944	7.59498	168.15927	154.27583	130.57526	0.61708
0.440623	134.50963	4.71778	184.24666	7.59342	168.02383	154.17308	130.49287	0.61666
0.443683	134.14032	4.72662	184.72897	7.59358	168.34036	154.27917	130.58414	0.61672
0.446743	133.61775	4.71377	184.57907	7.59342	167.98087	154.21585	130.52487	0.61664
0.449803	134.38516	4.71818	184.41901	7.59150	168.07962	154.11621	130.44882	0.61732
0.452863	133.96899	4.72286	184.50206	7.59087	168.13028	154.21692	130.55440	0.61580
0.455922	133.63623	4.71157	184.49622	7.59230	168.00839	154.14043	130.45413	0.61772
0.458982	134.27353	4.71814	184.47865	7.58910	167.93530	154.07403	130.43407	0.61615
0.462042	133.79866	4.71852	184.32205	7.58877	168.13733	154.13463	130.48959	0.61693
0.465102	133.65741	4.71073	184.44212	7.59042	167.81337	154.09132	130.42130	0.61680
0.468162	134.16696	4.71638	184.42015	7.58679	167.98973	154.01642	130.38972	0.61697
0.471222	133.59350	4.71603	184.25185	7.58707	167.95132	154.08231	130.45366	0.61642
0.474282	133.75546	4.70844	184.36156	7.58825	167.81410	154.00529	130.35497	0.61734
0.477342	133.92017	4.71599	184.32991	7.58482	167.87347	153.98157	130.37331	0.61638
0.480401	133.58626	4.71165	184.24513	7.58549	167.89627	154.00427	130.38403	0.61698
0.483461	133.64104	4.70860	184.22221	7.58559	167.70688	153.94928	130.32239	0.61680
0.486521	133.88193	4.71290	184.24878	7.58316	167.85518	153.92674	130.32925	0.61680
0.489581	133.37700	4.70982	184.25673	7.58358	167.75420	153.93945	130.33772	0.61676
0.492641	133.73745	4.70655	184.06895	7.58312	167.68500	153.87334	130.27104	0.61704
0.495701	133.61070	4.71171	184.20715	7.58163	167.75476	153.88107	130.30212	0.61665
0.498761	133.42104	4.70620	184.20908	7.58167	167.67336	153.85808	130.27290	0.61694
0.501820	133.55116	4.70654	183.94302	7.58069	167.61629	153.82030	130.24857	0.61708
0.504880	133.55247	4.70829	184.16428	7.57992	167.69095	153.82942	130.25810	0.61689
0.507940	133.26267	4.70509	184.13724	7.57955	167.57719	153.80096	130.23520	0.61698
0.511000	133.71111	4.70209	183.94022	7.57857	167.54672	153.75444	130.19514	0.61601

NOT REPRODUCIBLE

0.514060	183.22473	4.70745	184.10933	7.57805	167.59944	153.77626	130.22519	0.61691
0.517120	183.46704	4.70064	184.02263	7.57768	167.50563	153.72445	130.17245	0.61710
0.520180	183.20038	4.70535	183.84099	7.57636	167.50253	153.70821	130.17894	0.61709
0.523239	183.51928	4.70185	184.00996	7.57609	167.51337	153.69876	130.15695	0.61683
0.526299	183.03902	4.70149	183.93152	7.57568	167.43236	153.67395	130.14021	0.61718
0.529359	183.47582	4.70107	183.81969	7.57433	167.43037	153.63876	130.11769	0.61688
0.532419	183.05356	4.70192	183.91225	7.57414	167.44203	153.64943	130.12958	0.61706
0.535479	183.25211	4.69782	183.84348	7.57379	167.33981	153.60851	130.03846	0.61695
0.538539	183.15799	4.70064	183.79323	7.57219	167.38318	153.58275	130.08337	0.61723
0.541599	183.14331	4.69831	183.79956	7.57216	167.33516	153.58257	130.08124	0.61700
0.544659	183.02858	4.69715	183.77528	7.57171	167.29601	153.54987	130.05132	0.61735
0.547718	183.18367	4.69788	183.75006	7.57016	167.28397	153.51715	130.03888	0.61693
0.550778	182.93643	4.69669	183.71123	7.57024	167.27988	153.51912	130.03616	0.61732
0.553838	183.00020	4.69488	183.70020	7.56961	167.19807	153.48341	130.00644	0.61705
0.556898	182.99133	4.69628	183.69128	7.56824	167.23785	153.45998	129.99832	0.61724
0.559958	182.92204	4.69412	183.63182	7.56826	167.16956	153.45197	129.98837	0.61707
0.563018	182.92683	4.69344	183.61320	7.56746	167.16476	153.42683	129.96191	0.61746
0.566078	182.92839	4.69392	183.62836	7.56639	167.11272	153.40678	129.95834	0.61683
0.569137	182.79532	4.69218	183.56573	7.56627	167.13976	153.38736	129.93758	0.61756
0.572197	182.88675	4.69167	183.53275	7.56530	167.02150	153.36496	129.92639	0.61681
0.575257	182.79250	4.69134	183.56238	7.56460	167.13251	153.34386	129.90616	0.61770
0.578317	182.74577	4.69017	183.49745	7.56410	166.96683	153.33183	129.90627	0.61675
0.581377	182.80420	4.68950	183.45699	7.56325	167.04285	153.29070	129.86923	0.61752
0.584437	182.68298	4.69021	183.49821	7.56264	166.95753	153.29384	129.87671	0.61689
0.587497	182.69836	4.68754	183.42946	7.56206	166.98039	153.25569	129.84288	0.61760
0.590557	182.65010	4.68856	183.37584	7.56123	166.90343	153.24390	129.84409	0.61702
0.593616	182.65871	4.68697	183.41957	7.56076	166.94051	153.22264	129.81909	0.61750
0.596676	182.53029	4.68666	183.35274	7.56000	166.85007	153.20445	129.81244	0.61707
0.599736	182.65551	4.68563	183.31313	7.55925	166.88107	153.17842	129.78889	0.61753
0.602796	182.46016	4.68589	183.34074	7.55873	166.82005	153.17342	129.78879	0.61723
0.605856	182.56416	4.68367	183.28137	7.55801	166.81252	153.13477	129.75897	0.61747
0.608916	182.44717	4.68471	183.25500	7.55722	166.77571	153.12570	129.75571	0.61725
0.611976	182.48415	4.68275	183.25040	7.55679	166.76968	153.10278	129.73764	0.61751
0.615035	182.36673	4.68276	183.21568	7.55599	166.71785	153.07784	129.72272	0.61739
0.618095	182.46170	4.68179	183.18719	7.55523	166.71985	153.05687	129.70711	0.61741
0.621155	182.24071	4.68188	183.17780	7.55470	166.67389	153.04742	129.59914	0.61737
0.624215	182.40653	4.67943	183.14825	7.55398	166.65311	153.01042	129.66812	0.61747
0.627275	182.13277	4.68158	183.12706	7.55316	166.63255	153.00314	129.67366	0.61736
0.630335	182.50567	4.67722	183.08496	7.55278	166.60995	162.97295	129.63838	0.61755
0.633395	181.98402	4.68051	183.08180	7.55194	166.57729	152.96552	129.64696	0.61758
0.636454	182.41598	4.67665	183.04506	7.55126	166.55598	152.92975	129.61458	0.61746
0.639514	182.02438	4.67807	183.01917	7.55072	166.53563	152.92319	129.61214	0.61764
0.642574	182.33287	4.67554	183.00095	7.55001	166.49464	152.89264	129.58420	0.61734

0.645634	181.99997	4.67692	182.98666	7.54923	166.49958	152.87779	129.58212	0.61762
0.648594	182.19443	4.67437	182.94398	7.54872	166.43823	152.85432	129.55994	0.61743
0.651754	181.98028	4.67520	182.93199	7.54793	166.44530	152.83340	129.54596	0.61769
0.654814	182.11018	4.67354	182.91147	7.54727	166.39357	152.81371	129.53261	0.61741
0.657874	181.93434	4.67350	182.87886	7.54663	166.39423	152.79366	129.51909	0.61771
0.660933	182.04442	4.67235	182.85182	7.54595	166.34132	152.77344	129.50601	0.61750
0.663993	181.89441	4.67223	182.84366	7.54528	166.34871	152.75693	129.49120	0.61768
0.667053	181.95537	4.67094	182.80252	7.54461	166.28751	152.72784	129.47441	0.61747
0.670113	181.80359	4.67078	182.77969	7.54393	166.29745	152.71053	129.46016	0.61782
0.673173	181.87364	4.66985	182.76848	7.54332	166.24243	152.68752	129.44482	0.61747
0.676233	181.80479	4.66922	182.73289	7.54258	166.25916	152.66794	129.42531	0.61795
0.679293	181.81679	4.66858	182.71007	7.54191	166.17149	152.65408	129.41808	0.61733
0.682352	181.74976	4.66787	182.69646	7.54133	166.22601	152.62952	129.40074	0.61807
0.685412	181.75287	4.66727	182.66327	7.54057	166.10535	152.61226	129.38885	0.61724
0.688472	181.72394	4.66645	182.63680	7.53995	166.16541	152.58871	129.37059	0.61799
0.691532	181.65126	4.66629	182.62299	7.53927	166.08665	152.57057	129.36391	0.61756
0.694592	181.68259	4.66480	182.59019	7.53860	166.09731	152.54523	129.33987	0.61789
0.697652	181.58375	4.66504	182.57111	7.53788	166.04083	152.53244	129.33437	0.61758
0.700712	181.63165	4.66348	182.54443	7.53732	166.04221	152.50117	129.30797	0.61784
0.703771	181.52792	4.66361	182.52498	7.53653	165.99193	152.48927	129.30208	0.61763
0.706831	181.57575	4.66225	182.49246	7.53590	165.99197	152.46253	129.28270	0.61787
0.709891	181.46059	4.66223	182.47375	7.53529	165.94533	152.44641	129.27368	0.61772
0.712951	181.52298	4.66089	182.44777	7.53458	165.93570	152.42551	129.25182	0.61787
0.716011	181.40402	4.66096	182.42859	7.53387	165.90074	152.40453	129.24315	0.61770
0.719071	181.50211	4.65921	182.39348	7.53332	165.88313	152.38031	129.21849	0.61781
0.722131	181.28915	4.66008	182.38409	7.53252	165.85225	152.36848	129.21706	0.61781
0.725191	181.49278	4.65755	182.35283	7.53191	165.83488	152.33997	129.19307	0.61789
0.728250	181.14676	4.65921	182.33144	7.53121	165.80048	152.32869	129.19128	0.61777
0.731310	181.49321	4.65583	182.30093	7.53062	165.77901	152.29544	129.15994	0.61779
0.734370	181.13403	4.65757	182.28464	7.52987	165.76193	152.28949	129.15926	0.61802
0.737430	181.34151	4.65520	182.25107	7.52927	165.72292	152.26186	129.13832	0.61784
0.740490	181.13788	4.65576	182.26324	7.52828	165.71333	152.24382	129.13094	0.61810
0.743550	181.59592	4.65119	182.71851	7.52179	165.55595	152.10542	129.05000	0.61776
0.746610	181.58621	4.64627	183.17070	7.51069	165.35010	151.86220	128.90289	0.61797
0.749669	181.92925	4.63730	183.51385	7.49326	164.96988	151.46786	128.66971	0.61756
0.752729	182.55589	4.62702	184.03452	7.46780	164.48177	150.89857	128.32608	0.61758
0.755789	182.43532	4.61384	184.61456	7.43732	163.83273	150.20932	127.90102	0.61705
0.758849	182.59720	4.59859	185.24399	7.39710	163.08949	159.32599	127.36462	0.61675
0.761909	183.00647	4.57967	185.97545	7.34782	162.09807	158.22786	126.69582	0.61579
0.764969	183.54955	4.55868	186.70404	7.29107	161.09575	156.96043	125.91661	0.61560
0.768029	183.81055	4.53303	187.61362	7.22118	159.65390	155.43349	124.99194	0.61339
0.771089	184.45572	4.50230	188.89481	7.13935	158.14993	153.61826	123.95960	0.61347
0.774149	185.06229	4.46725	190.02934	7.04366	156.25768	151.52568	122.57095	0.61162

0.777208	185.00717	4.42202	191.59464	6.92744	154.06783	143.97807	120.97830	0.61053
0.730268	187.25734	4.36800	193.85388	6.78917	151.29710	145.95079	119.07033	0.60317
0.783328	188.65429	4.30013	195.88774	6.62597	148.07806	142.37250	116.77386	0.60652
0.735388	190.35553	4.21720	198.66238	6.42728	144.05069	138.04286	113.97701	0.60341
0.789448	193.32997	4.10755	202.56122	6.18688	139.08727	132.78494	110.51100	0.60098
0.792508	195.59689	3.97741	205.94121	5.90650	133.12711	126.62448	106.33269	0.59705
0.795567	198.83247	3.81549	209.29176	5.57814	126.04623	119.43027	101.37184	0.59353
0.793627	203.20799	3.61280	214.34703	5.19136	117.55421	111.00815	95.42091	0.58905
0.801687	207.76782	3.37024	219.45062	4.75540	107.64308	101.45038	88.39095	0.58461
0.804747	210.94144	3.09250	220.52937	4.28320	96.91014	91.20877	80.68877	0.58016
0.807807	215.48166	2.76531	224.20772	3.75972	84.89104	79.98128	71.95837	0.57528
0.810867	221.41287	2.39758	229.75488	3.20899	71.95047	67.98863	62.14359	0.57078
0.813927	212.76822	2.08195	218.99565	2.75172	61.04091	57.98143	53.74811	0.56812
0.816986	211.30604	1.73081	214.14496	2.31750	50.91597	48.60950	45.82312	0.57329
0.820046	216.57744	1.49679	219.62881	1.93452	42.41977	40.74219	37.91672	0.47940
0.823106	211.81398	1.24408	214.17267	1.61586	28.51126	27.27206	25.91008	0.40455
0.826166	206.38612	1.02071	208.69878	1.30094	25.17586	24.34633	23.16362	0.50141
0.829226	210.85553	0.77806	213.89043	0.99114	16.00700	15.67316	15.19649	0.21050
0.832286	210.81161	0.59724	215.89935	0.75846	12.93988	12.96082	12.81731	0.63191
0.835346	197.80710	0.43204	198.88095	0.54352	7.38914	7.26676	7.21308	0.54591
0.838405	203.52456	0.28926	201.86964	0.36578	5.95904	5.76572	6.05581	0.64629
0.841465	212.32610	0.13543	212.29858	0.16948	4.46949	4.61859	4.59879	0.40496

T = 0.843845 J = 1 ENGCUT = 3.00000 62.2128 2.02191

T = 0.843845 J = 2 ENGCUT = 3.00000 22.9938 1.19568

0.844525	201.58527	-0.01439	204.92961	-0.02205	4.38222	-22.51799	4.38222	1.00000
0.847585	179.95360	0.00060	180.98445	-0.00071	4.69054	13.76924	4.69054	1.00000
0.850645	194.38300	0.00011	187.71384	0.00577	4.80390	11.19710	4.80390	1.00000
0.853705	200.13188	0.00858	206.92319	0.00633	4.78163	-2.16744	4.78163	1.00000
0.856765	189.52493	-0.00954	192.56146	-0.01680	4.76391	-13.08785	4.76391	1.00000
0.859825	138.40323	0.00797	182.23650	0.00888	4.74894	-4.33918	4.74894	1.00000
0.862884	198.78574	-0.00583	194.93953	0.01219	4.73496	8.16672	4.73496	1.00000
0.865944	190.35985	-0.00042	208.63519	-0.00332	4.58123	11.20595	4.58123	1.00000
0.869004	150.84518	-0.00170	183.22585	-0.00608	4.64550	5.00542	4.64550	1.00000
0.872064	199.98259	0.01045	187.96808	0.00910	4.67088	-1.80513	4.67088	1.00000
0.875124	195.35892	-0.00693	203.95654	0.01178	4.67229	-3.75095	4.67229	1.00000
0.878184	190.85058	-0.00439	200.53551	-0.01677	4.66455	-1.50316	4.66455	1.00000
0.881244	183.76917	0.00511	181.10538	0.00231	4.65327	1.58329	4.65327	1.00000
0.884303	205.57039	0.00230	194.01807	0.00717	4.64061	3.23497	4.64061	1.00000
0.887363	189.16823	-0.00282	208.27124	0.00022	4.62738	3.23417	4.62738	1.00000
0.890423	188.03271	-0.00205	187.68929	-0.01775	4.61389	2.45533	4.61389	1.00000
0.893483	194.25444	0.00731	185.08095	0.00798	4.60026	1.73434	4.60026	1.00000

0.896543	200.90932	-0.00889	199.75656	0.00703	4.58654	1.41024	4.58654	1.00000
0.899603	183.75421	0.00314	204.14778	-0.01169	4.57273	1.42781	4.57273	1.00000
0.902663	192.02504	0.00144	180.13454	-0.00380	4.55886	1.59993	4.55886	1.00000
0.905722	231.67516	0.00473	191.53931	0.00909	4.54492	1.77983	4.54492	1.00000
0.908782	190.08804	-0.01167	204.97755	0.00591	4.53090	1.90675	4.53090	1.00000
0.911842	186.98824	0.00716	193.93300	-0.01571	4.51683	1.97992	4.51683	1.00000
0.914902	196.49907	0.00055	181.70210	0.00866	4.50269	2.02127	4.50269	1.00000

HC900I EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

HC217I FIOCS - END OF DATA SET ON UNIT 5

RACEBACK ROUTINE CALLED FROM ISN REG: 14 REG: 15 REG: 0 REG: 1

FRDNL#	0003A304	0004B7F8	0000A414	00039A48
MAIN	0000DDIA	010399C8	F0000008	00079FF8

NTRY POINT=010399C8

APPENDIX B

APOLLO DESCENT ENGINE START TRANSIENT MODEL

APOLLO DESCENT ENGINE MODELING

The feed line configuration of the Apollo Descent configuration is shown in Fig. B-1. Since this engine model is to have response requirements similar to the Ascent Engine model, the model will be divided into line segments in the same manner as described in Appendix A. The barrier coolant passage which has a very high resistance will be neglected in the start model and it will be assumed that all fuel goes through the injector. Tables B-I and B-II show the physical data on the line segments for this engine.

The effective area of the engine shutoff valves as a function of time is shown in Fig. B-2. For this particular simulation the flow control valve is in its wide-open position and does not cavitate. Thus, it is treated as a valve with an effective area which gives the correct resistance as noted in Tables B-I and B-II.

Table B-III shows the input data used for the simulation of the start transient and Table B-IV shows the output data, along with the graphical results presented in Figures B-3A through B-3F.

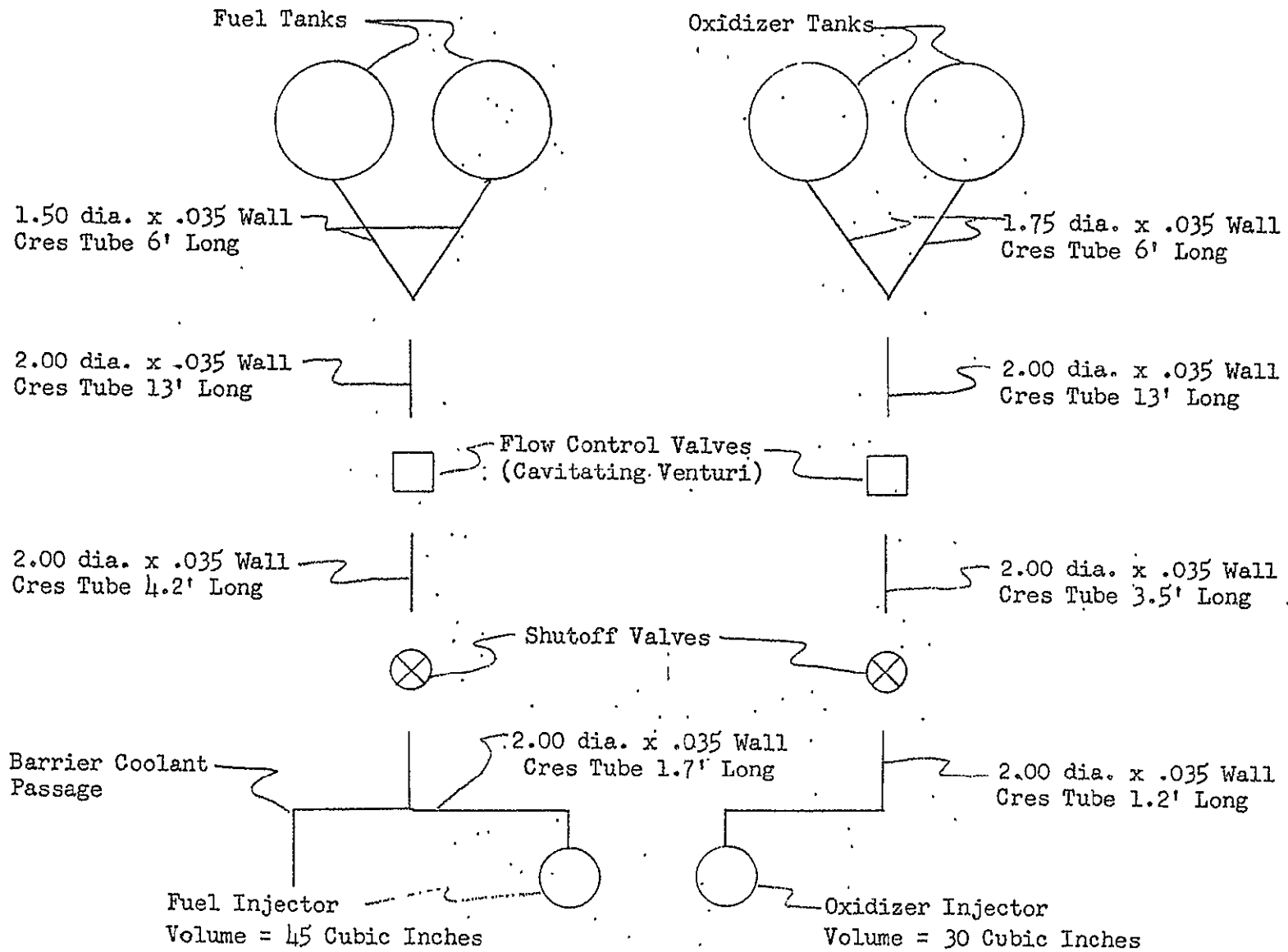


FIGURE B-1 - Apollo Descent Engine Feed System Schematic

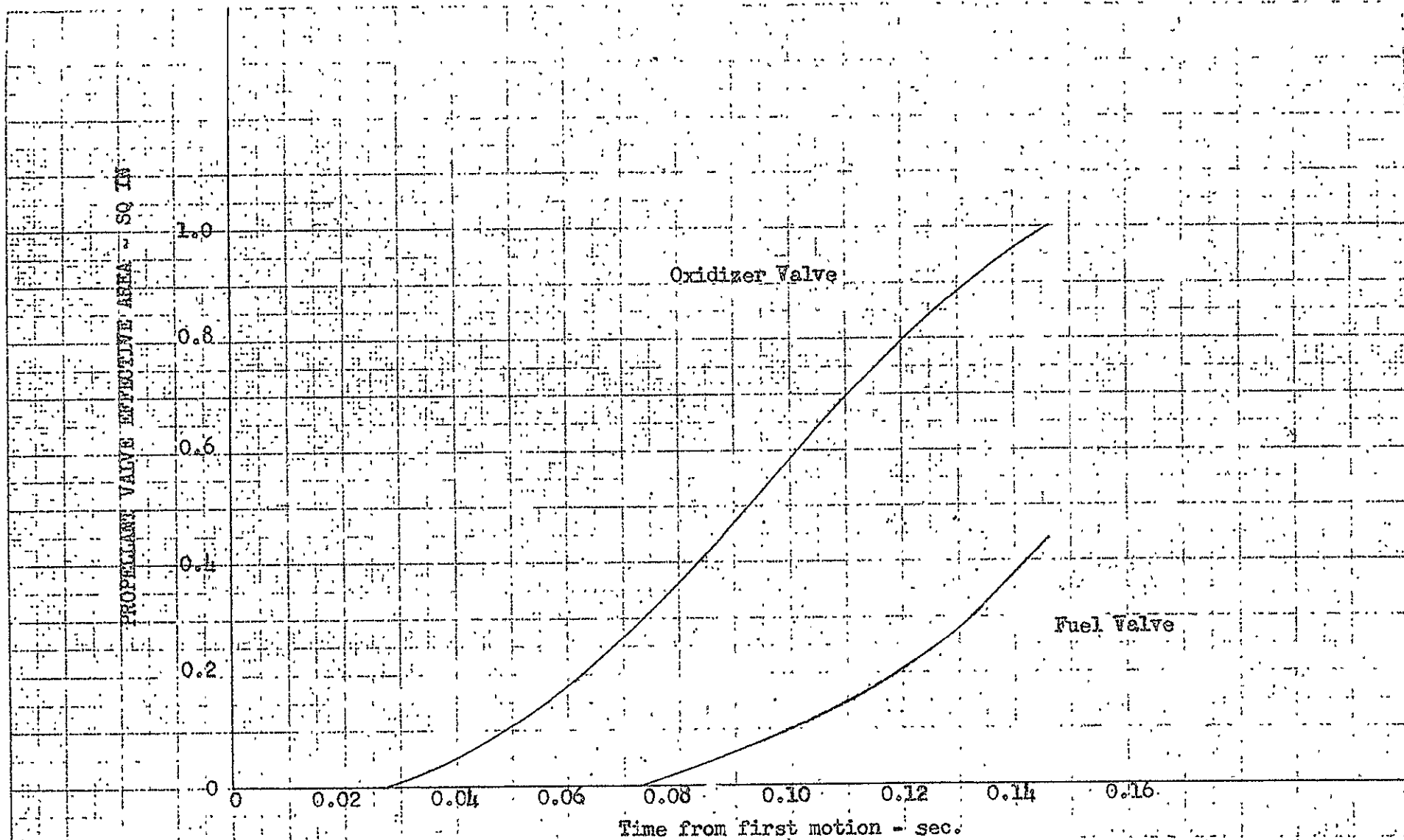


FIGURE B-2 - APOLLO DESCENT ENGINE PROPELLANT VALVE TRANSIENT

TABLE B-I

APOLLO DESCENT ENGINE FUEL FEED LINE PARAMETERS

<u>SEGMENT NO.</u>	<u>LENGTH IN</u>	<u>AREA SQ IN</u>	<u>WALL COMPLIANCE SQ IN/LB X 10⁶</u>	<u>RESISTANCE SEC²/IN⁵</u>	<u>COMMENTS</u>
1	10.2	2.92	1.67	.0000800	
2	10.2	2.92	1.67	.0000800	Orifice Resistance = .0080862 Line Resistance = .0000800
3	-	-	-	-	Shutoff Valve Open $C_d A = .44 \text{ in}^2$ $R = .006680$
4	10.2	2.92	1.67	.0000800	
5	12.	2.92	1.67	.0001019	
6	15.	2.92	1.67	.0001176	
7	12.2	2.92	1.67	.0000956	
8	-	-	-	-	Flow Control Valve Simple Resistance at Max Thrust $R = 0.004340$, $C_d A = 0.5459$
9	11.	2.92	1.67	0.0000862	Interface
10	13.	2.92	1.67	0.0001019	
11	15.	2.92	1.67	0.0001176	
12	17.	2.92	1.67	0.0001333	
13	19.	2.92	1.67	0.0001489	
14	21.	2.92	1.67	0.0001646	
15	23.	2.92	1.67	0.0001803	
16	20.	2.92	1.67	0.0001568	
17	17.	2.92	1.67	0.0001333	
18	11.	3.22	1.24	0.0000862	
19	15.	3.22	1.24	0.0001176	
20	19.	3.22	1.24	0.0001490	
21	17.	3.22	1.24	0.0001333	
22	10.2	3.22	1.24	0.0000800	

TABLE B-II

APOLLO DESCENT ENGINE OXIDIZER FEED LINE PARAMETERS

<u>SEGMENT NO.</u>	<u>LENGTH IN</u>	<u>AREA SQ IN</u>	<u>WALL COMPLIANCE SQ IN/LE X 10⁶</u>	<u>RESISTANCE SEC²/IN⁵</u>	<u>COMMENTS</u>
1	7.0	2.92	1.67	0.0000314	
2	7.4	2.92	1.67	0.0000332	
3	-	-	-	-	Shutoff Valve Open
					$C_d A = 1.0 \text{ in}^2$ $R = .001293$
4	7.	2.92	1.67	0.0000314	
5	9.	2.92	1.67	0.0000403	
6	11.	2.92	1.67	0.0000493	
7	15.	2.92	1.67	0.0000672	
8	-	-	-	-	Flow Control Valve Simple Resistance at Max Thrust $R = 0.001169$, $C_d A = 1.0518$
9	11.	2.92	1.67	0.0000493	Interface
10	13.	2.92	1.67	0.0000583	
11	15.	2.92	1.67	0.0000672	
12	17.	2.92	1.67	0.0000762	
13	19.	2.92	1.67	0.0000852	
14	21.	2.92	1.67	0.0000942	
15	23.	2.92	1.67	0.0001031	
16	20.	2.92	1.67	0.0000897	
17	17.	2.92	1.67	0.0000762	
18	11.	4.42	1.57	0.0000493	
19	15.	4.42	1.57	0.0000672	
20	19.	4.42	1.57	0.0000852	
21	17.	4.42	1.57	0.0000762	
22	10.	4.42	1.57	0.0000448	

TABLE B-III

APOLLO DESCENT ENGINE START TRANSIENT COMPUTER MODEL INPUT DATA

2	121	22	10.2	10.2	0.0	10.2	13.0	0000100,
15.0			12.2	0.0	11.0	13.0	15.0	0000200,
17.0			19.0	21.0	23.0	20.0	17.0	0000300,
11.0			15.0	19.0	17.0	10.2		0000400,
2	181	22	7.0	7.4	0.0	7.0	9.0	0000500,
11.0			15.0	0.0	11.0	13.0	15.0	0000600,
17.0			19.0	21.0	23.0	20.0	17.0	0000700,
11.0			15.0	19.0	17.0	10.0		0000800,
2	361	22	0.000112	0.016038	0.0	0.000112	0.000143	0000900,
0.000165			0.000134	0.0	0.000121	0.000143	0.000165	0001000,
0.000187			0.000209	0.000231	0.000253	0.000220	0.000187	0001100,
0.000115			0.000157	0.000199	0.000178	0.000107		0001200,
2	421	22	0.000039	0.000042	0.0	0.000039	0.000051	0001300,
0.000062			0.000084	0.0	0.000062	0.000073	0.000084	0001400,
0.000096			0.000107	0.000124	0.000129	0.000112	0.000096	0001500,
0.000115			0.000156	0.000197	0.000176	0.000104		0001600,
>	1	26	21	150.0	0.02779	0.008453	0.0	0004100,
-0.005			0.0	0.02	0.04	0.06	0.10	0004200,
0.20			0.25	0.30	0.35	0.45	0.50	0004300,
0.5>			0.60	0.65	0.70	0.80	0.90	0004400,
0.9>			1.0	1.005				0004500,
>	36	21	-0.2 E+06	0.293 E+06	2.82 E+06	3.04 E+06	3.07 E+06	0004600,
3.13	E+06		3.24 E+06	3.28 E+06	3.42 E+06	3.87 E+06	4.60 E+06	0004700,
4.88	E+06		5.03 E+06	5.02 E+06	4.86 E+06	4.55 E+06	3.63 E+06	0004800,
2.27	E+06		0.37 E+06	0.133 E+06	0.01 E+06			0004900,
>	66	21	15.0	41.5	115.0	131.5	132.9	0005000,
134.7			138.0	139.8	142.6	148.8	165.0	0005100,
171.3			175.8	178.1	176.8	171.1	152.0	0005200,
116.6			58.7	29.4	21.0			0005300,
>	96	21	0.816	0.818	0.826	0.833	0.841	0005400,
0.856			0.889	0.903	0.920	0.933	0.959	0005500,
0.967			0.974	0.978	0.973	0.964	0.922	0005600,
0.859			0.801	0.787	0.781			0005700,
>	1	21	3.0	0.0	0.046	0.06	0.063	0005800,
0.10			0.073	0.148	0.083	0.205	0.093	0005900,
0.239			0.098	0.279	0.103	0.326	0.108	0006000,
0.44			0.119	0.44	1.0			0006100,
>	101	31	3.0	0.0	0.0005	0.02	0.005	0006200,
0.036			0.01	0.06	0.015	0.088	0.02	0006300,
0.156			0.03	0.238	0.04	0.331	0.05	0006400,
0.435			0.06	0.662	0.08	0.766	0.09	0006500,
0.859			0.10	0.938	0.11	1.0	0.119	0006600,

1.0	1.0						0006700,
3 201 9 323.0	252.0	0.0	245.5	0.5			0006800,
241.0	1.0	240.0	1.25				0006900,
3 211 3 8.0	0.5459	1.0					0006920,
3 301 9 323.0	260.0	0.0	254.5	0.5			0007000,
251.0	1.0	250.5	1.25				0007100,
3 311 3 8.0	1.0518	1.0					0007120,
3 401 5 1.0	45.0	0.375	0.62065	1.0			0007200,
3 433 5 1.0	30.0	0.25	0.31727	0.5			0007300,
-3 526 4 54.4	2557.0	0.0	1.7				0007400,
SD1 IPR=3, IST=1, ICMT=3, NSEGF=22, NSEGO=22, DELT=170.0E-06,							ID=1000000,
AR=2*2.92,0,4*2.92,0,9*2.92,5*3.22,38*0,							ID=1000100,
CR=2*1.67E-06,0,4*1.67E-06,0,9*1.67E-06,5*1.24E-06,38*0,							ID=1000200,
AU=2*2.92,0,4*2.92,0,9*2.92,5*4.42,38*0,							ID=1000300,
CU=2*1.67E-06,0,4*1.67E-06,0,9*1.67E-06,5*1.57E-06,38*0,							ID=1000400,
ICR=2,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22,43*0,							ID=1000500,
IURU=2,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22,43*0,							ID=1000600,
LFR=3*1,57*0, PF=3*0,20*252,37*0,							ID=1000700,
PRAV=3*130,14*230,5*240,38*0,							ID=1000720,
LFRU=3*1,57*0, PD=3*0,20*252,37*0,							ID=1000800,
PUAV=3*220,14*230,5*240,38*0,							ID=1000820,
IVARIS=2,210,2,310,2,522,6, 64,12*0,							ID=1001200,
IWT=9,209,109,309,1,101,403,404,							ID=1001300,
IPI=1,9,23,3*0,101,109,123,3*0,209,5*0,309,5*0,3,203,4*0,							ID=1001400,
B(1)=0.0021, B(2)=0.0049,							ID=1001700,
GR=3*0,20*0.0021,37*0, GU=3*0,20*0.0049,37*0,							ID=1001720,
B(3)=0.0325, B(4)=0.052, B(5)=530, B(6)=530,							ID=1001800,
B(7)=60000, B(8)=40500,							ID=1001900,
B(9)=0.0083446, B(10)=-4.1095, B(11)=0.0089489, B(12)=-3.62944,							ID=1002000,
B(13)=-1.797, B(14)=92.016, B(15)=4, B(16)=4,							ID=1002100,
B(17)=1.67, B(18)=1.67, B(19)=1.05, B(20)=1.1, B(21)=10, B(22)=10,							ID=1002200,
B(23)=8.8869E-06, B(24)=2.0526E-05,							ID=1002300,
B(31)=0.691, B(32)=0.368, B(33)=0.75, B(34)=0.75,							ID=1002400,
INDEX=12,							ID=1008100,
SEND							1100000,
APULLU DESCENT ENGINE							1200000;
DATA CORRELATION							1200100,
LTA->	SERIES 11	TEST 2	RUN 2	1200200,			

1. 11 12/17/70
TIME 13.53.35

APOLLO DESCENT ENGINE
LTA-5
SERIES II
DATA CORRELATION

TEST 2
RUN 1

1177

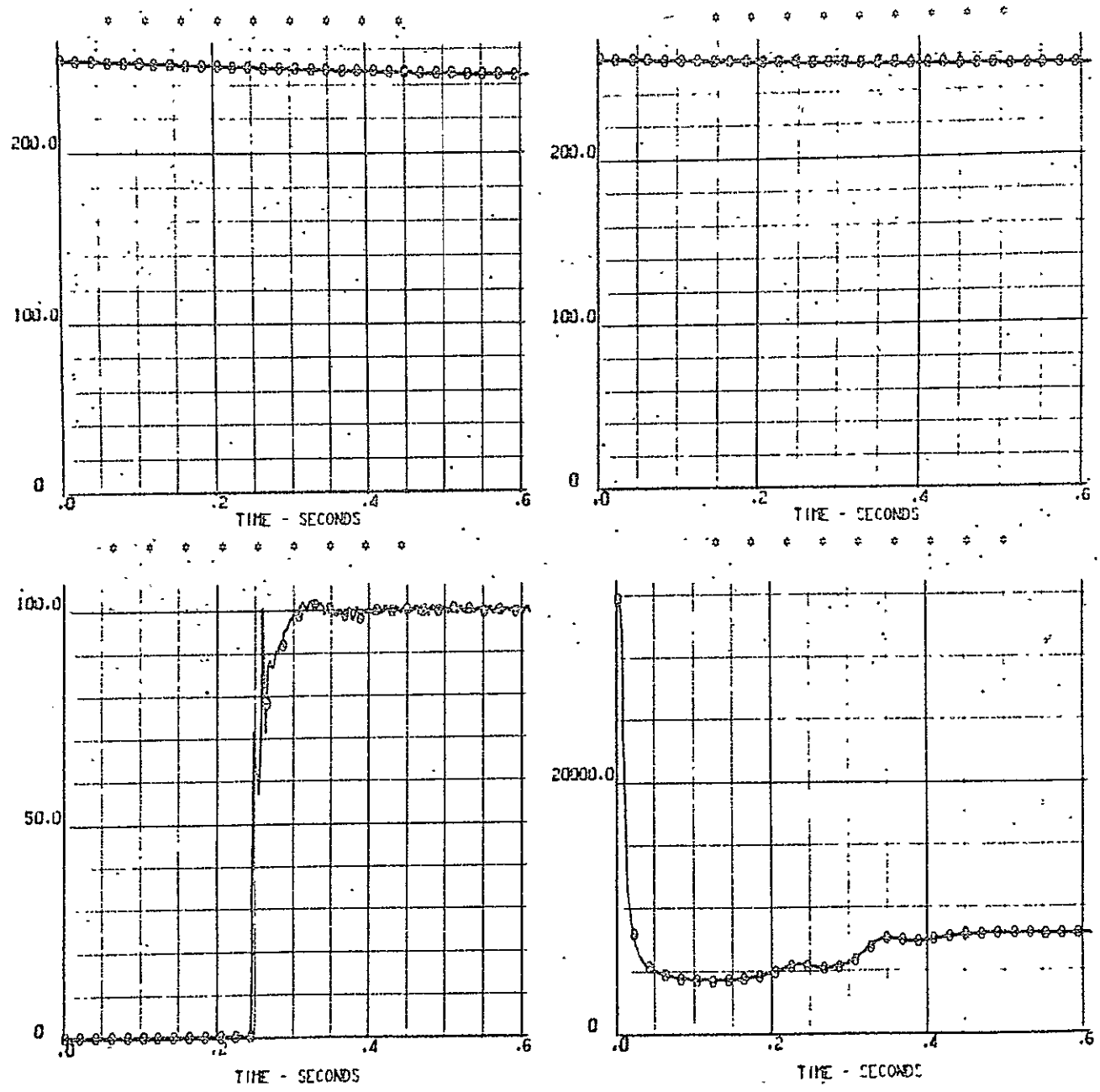


Figure B-3A - Graphical Output of Apollo Descent Engine Start Transient Model.

OSTI 12-17770
TIME 7.3.75

APOLLO DESCENT ENGINE DATA CORRELATION
LTA-5 SERIES 11

TEST 2

RUN 2

1975

o FUEL PRESSURE SEGMENT NO. 1.
x FUEL PRESSURE SEGMENT NO. 23.

o FUEL PRESSURE SEGMENT NO. 9.

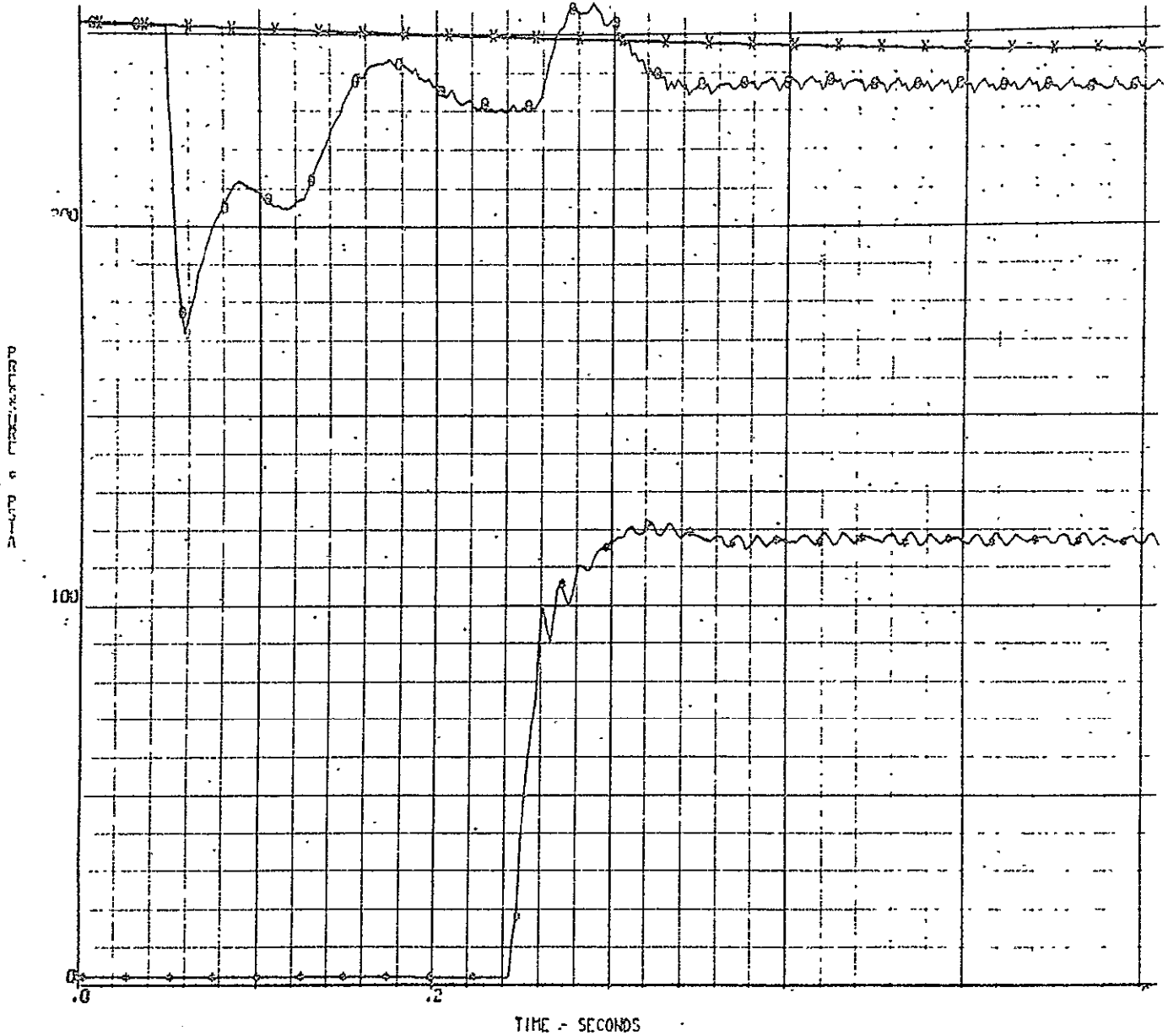


Figure B-3B - Graphical Output of Apollo Descent Engine Start Transient Model.

DATE: 12/70
TIME: 10:30:35

APOLLO DESCENT ENGINE

DATA CORRELATION

TEST 2

RUN 4

11750

LTA-5

SERIES 11

* OXIDIZER PRESSURE SEGMENT NO. 1.
X OXIDIZER PRESSURE SEGMENT NO. 23.

o OXIDIZER PRESSURE SEGMENT NO. 3.

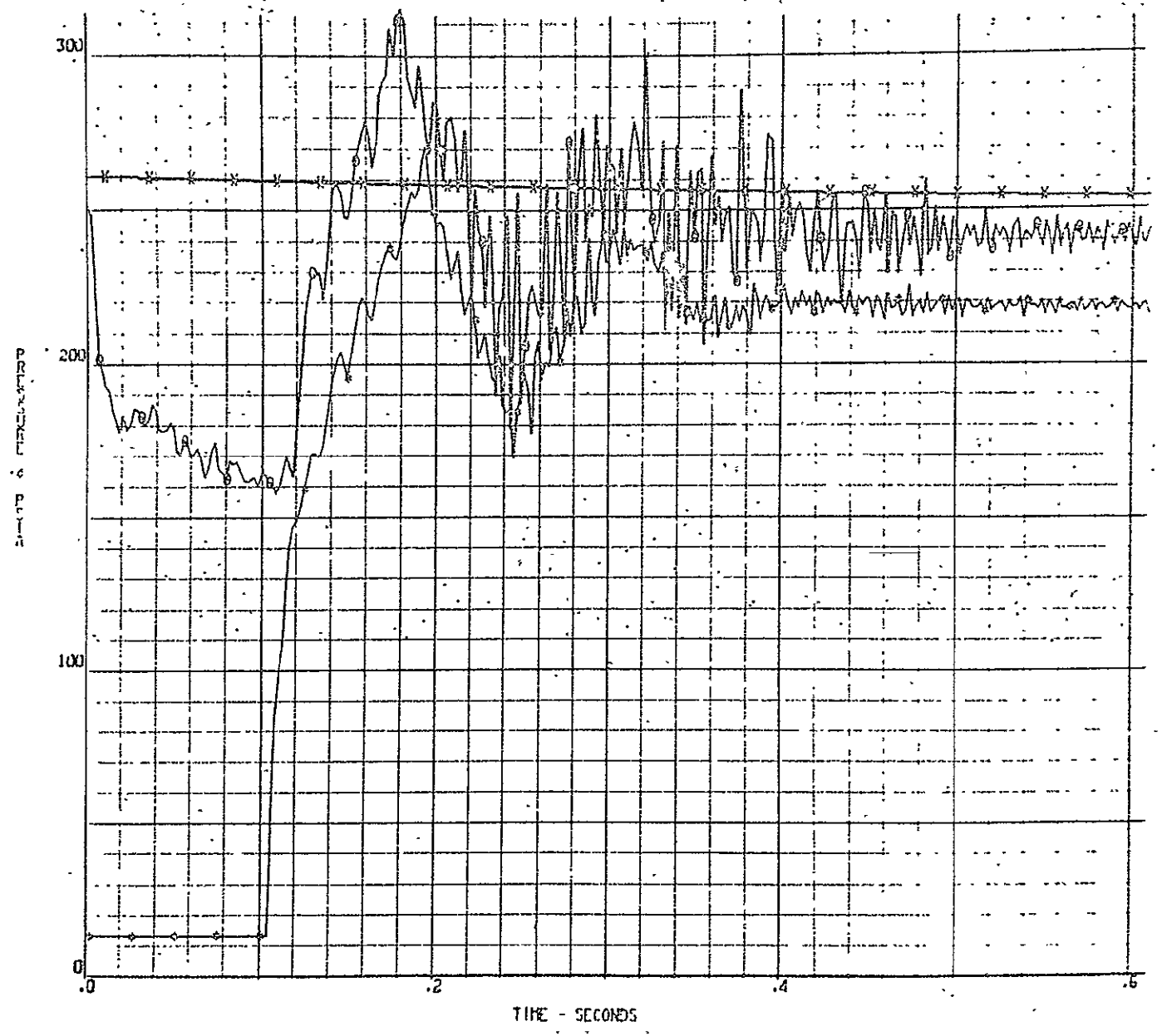


Figure B-3C - Graphical Output of Apollo Descent Engine Start Transient Model.

DATE: 12/17/73
TIME: 11:11:35

APOLLO DESCENT ENGINE

DATA CORRELATION

12/17/73

LTR-5

SERIES 11

TEST 2

RUN 2

* FUEL FLOW SEGMENT NO. 9.

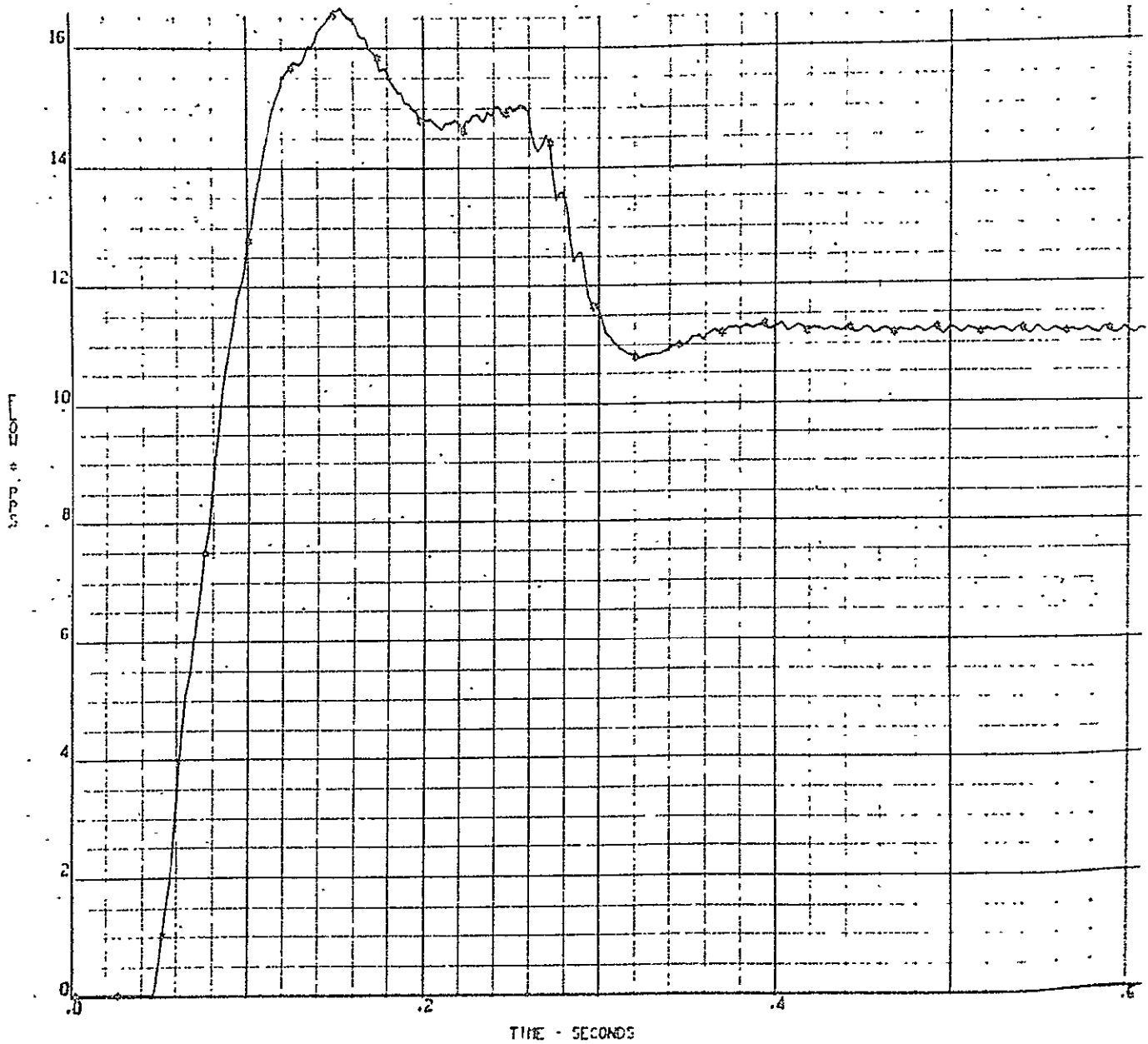


Figure B-3D - Graphical Output of Apollo descent engine Start Transient Model.

DATE 12-17-70
TIME 10:58:25

APOLLO DESCENT ENGINE

DATA CORRELATION

12173

LTA-5

SERIES 11

TEST 1

RUN 2

OXIDIZER FLOW SEGMENT NO. 9.

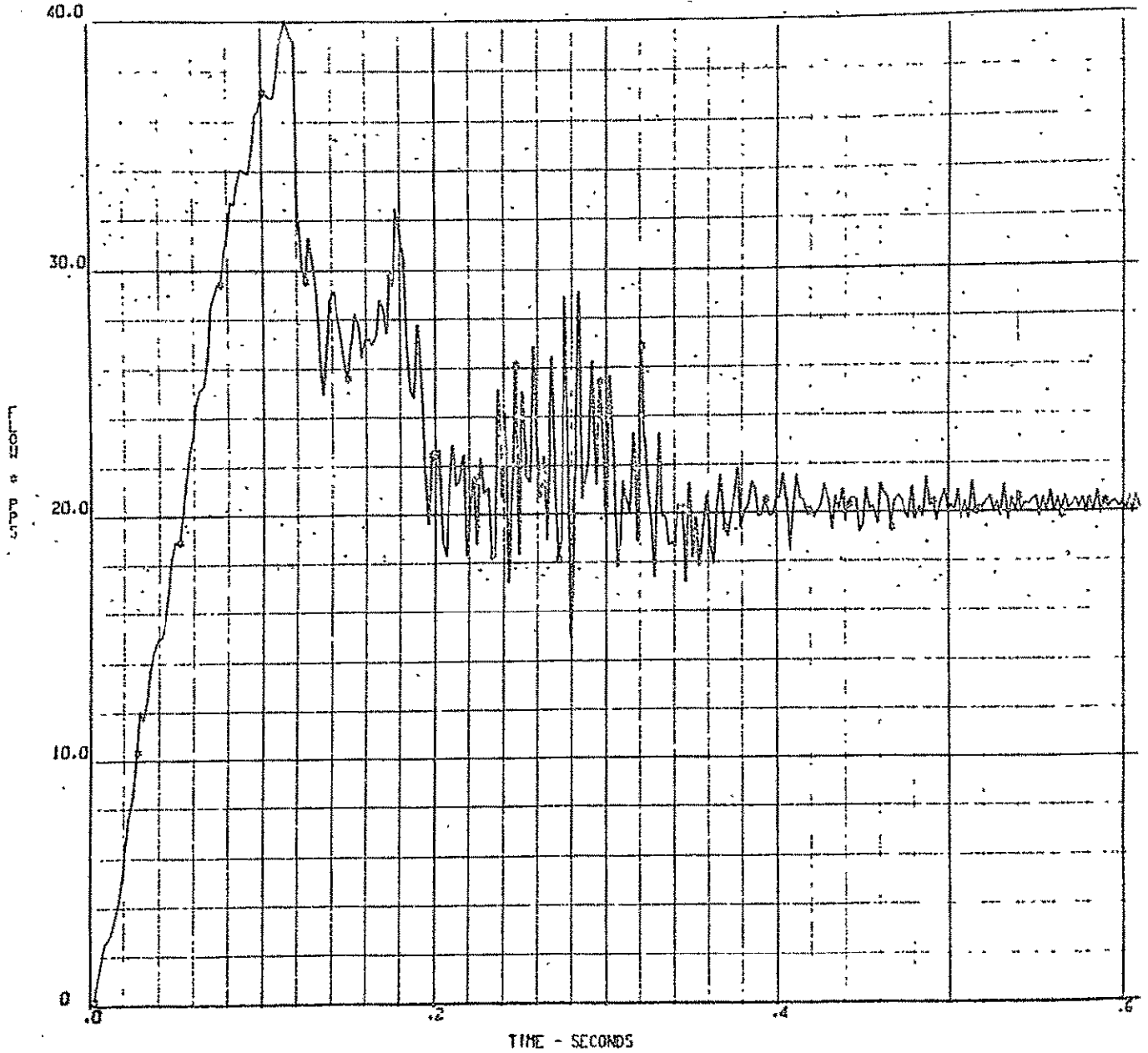


Figure B-3E - Graphical Output of Apollo Descent Engine Start Transient Model.

⊕ 3

APOLLO DESCENT ENGINE

DATA CORRELATION

11/17/68

LTA-5

SERIES 11

TEST 2

RUN 1

* FUEL PRESSURE SEGMENT NO. 3.

0 FUEL FLOW SEGMENT NO. 3.

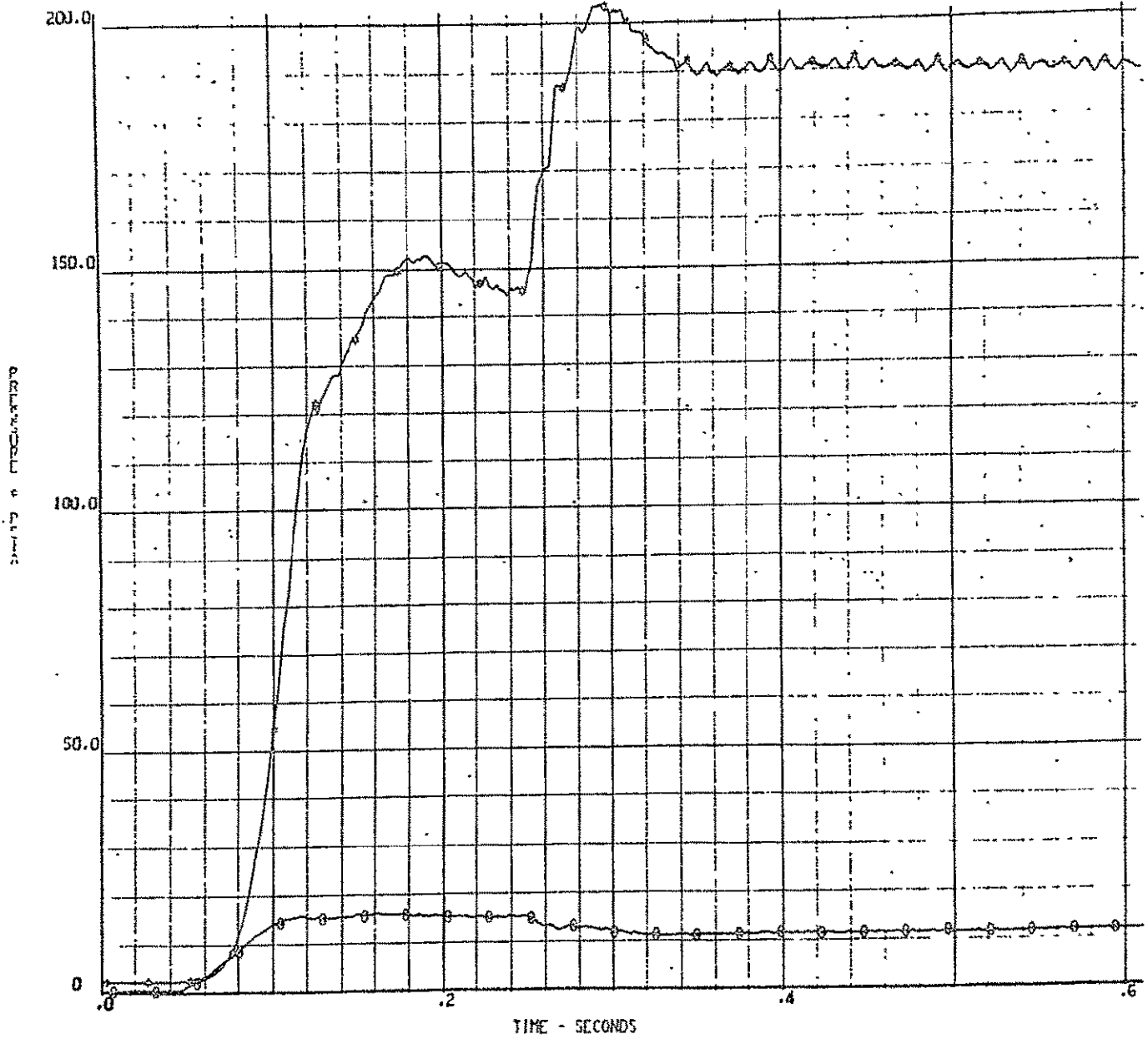


Figure B-3F - Graphical Output of Apollo Descent Engine Start Transient Model.

TABLE B-IV

APOLLO DESCENT ENGINE START TRANSIENT COMPUTER MODEL OUTPUT

APOLLO DESCENT ENGINE DATE 12/17/70 TIME 9:31.16

NOT REPRODUCIBLE

DATA CORRELATION SERIES 11 TEST 2 RUN 2

* SFGMENT DATA		* PRESSURE	* FLOW	* FUEL FEEDSYSTEM PARAMETERS			* RESISTANCE	* DISOLVED GAS
NO.	STATE	PSIA	PPS	ACOUSTIC VELOCITY IN / SEC	AREA SQ. IN.	LENGTH INCHES	SEC##27IV##5	LBS G / LB
1	EMPTY	2.06	0.0	48889.0	2.9200	10.20	0.1120E-03	0.0
2	EMPTY	2.06	0.0	48889.0	2.9200	10.20	0.1604E-01	0.0
3	EMPTY	2.06	0.0	48888.0	0.0	0.0	0.1000E 32	0.2100E-02
4	FULL	252.00	0.0	48888.0	2.9200	10.20	0.1120E-03	0.2100E-02
5	FULL	252.00	0.0	48888.0	2.9200	13.00	0.1430E-03	0.2100E-02
6	FULL	252.00	0.0	48888.0	2.9200	15.00	0.1650E-03	0.2100E-02
7	FULL	252.00	0.0	48888.0	2.9200	12.20	0.1340E-03	0.2100E-02
8	FULL	252.00	0.0000	48888.0	0.0	0.0	0.4340E-02	0.2100E-02
9	FULL	252.00	0.0000	48888.0	2.9200	11.00	0.1210E-03	0.2100E-02
10	FULL	252.00	0.0	48888.0	2.9200	13.00	0.1430E-03	0.2100E-02
11	FULL	252.00	0.0	48888.0	2.9200	15.00	0.1650E-03	0.2100E-02
12	FULL	252.00	0.0	48888.0	2.9200	17.00	0.1870E-03	0.2100E-02
13	FULL	252.00	0.0	48888.0	2.9200	19.00	0.2090E-03	0.2100E-02
14	FULL	252.00	0.0	48888.0	2.9200	21.00	0.2310E-03	0.2100E-02
15	FULL	252.00	0.0	48888.0	2.9200	23.00	0.2530E-03	0.2100E-02
16	FULL	252.00	0.0	48888.0	2.9200	20.00	0.2200E-03	0.2100E-02
17	FULL	252.00	0.0	48888.0	2.9200	17.00	0.1870E-03	0.2100E-02
18	FULL	252.00	0.0	51151.4	3.2200	11.00	0.1150E-03	0.2100E-02
19	FULL	252.00	0.0	51151.4	3.2200	15.00	0.1570E-03	0.2100E-02
20	FULL	252.00	0.0	51151.4	3.2200	19.00	0.1990E-03	0.2100E-02
21	FULL	252.00	0.0	51151.4	3.2200	17.00	0.1780E-03	0.2100E-02
22	FULL	252.00	0.0	51151.4	3.2200	10.20	0.1070E-03	0.2100E-02
23	FULL	252.00	0.0	60000.0	0.0	0.0	0.0	0.2100E-02

APOLLO DESCENT ENGINE

DATA CORRELATION

* * LTA-5		SERIES 11				TEST 2		RUN 2	
SEGMENT DATA	STATE	PRESSURE	FLOW	ACOUSTIC	AREA	LENGTH	RESISTANCE	DISOLVED GAS	
NO.		PSIA	PPS	VELOCITY	SQ. IN.	INCHES	SEC**2/IN**5	LBS G / LB L	
				IN / SEC					
1	EMPTY	12.99	0.0	34613.9	2.9200	7.00	0.3900E-04	0.0	
2	EMPTY	12.99	0.0	34613.9	2.9200	7.40	0.4200E-04	0.0	
3	EMPTY	12.99	0.0	34613.4	0.0	0.0	0.1000E-04	0.4900E-02	
4	FULL	252.00	0.0	34613.4	2.9200	7.00	0.3900E-04	0.4900E-02	
5	FULL	252.00	0.0	34613.4	2.9200	9.00	0.5100E-04	0.4900E-02	
6	FULL	252.00	0.0	34613.4	2.9200	11.00	0.6200E-04	0.4900E-02	
7	FULL	252.00	0.0	34613.4	2.9200	15.00	0.8400E-04	0.4900E-02	
8	FULL	252.00	0.0000	34613.4	0.0	0.0	0.1169E-02	0.4900E-02	
9	FULL	252.00	0.0000	34613.4	2.9200	11.00	0.6200E-04	0.4900E-02	
10	FULL	252.00	0.0	34613.4	2.9200	13.00	0.7300E-04	0.4900E-02	
11	FULL	252.00	0.0	34613.4	2.9200	15.00	0.8400E-04	0.4900E-02	
12	FULL	252.00	0.0	34613.4	2.9200	17.00	0.9600E-04	0.4900E-02	
13	FULL	252.00	0.0	34613.4	2.9200	19.00	0.1070E-03	0.4900E-02	
14	FULL	252.00	0.0	34613.4	2.9200	21.00	0.1240E-03	0.4900E-02	
15	FULL	252.00	0.0	34613.4	2.9200	23.00	0.1290E-03	0.4900E-02	
16	FULL	252.00	0.0	34613.4	2.9200	20.00	0.1120E-03	0.4900E-02	
17	FULL	252.00	0.0	34613.4	2.9200	17.00	0.9600E-04	0.4900E-02	
18	FULL	252.00	0.0	34896.2	4.4200	11.00	0.1150E-03	0.4900E-02	
19	FULL	252.00	0.0	34896.2	4.4200	15.00	0.1560E-03	0.4900E-02	
20	FULL	252.00	0.0	34896.2	4.4200	19.00	0.1970E-03	0.4900E-02	
21	FULL	252.00	0.0	34896.2	4.4200	17.00	0.1760E-03	0.4900E-02	
22	FULL	252.00	0.0	34896.2	4.4200	10.00	0.1040E-03	0.4900E-02	
23	FULL	260.00	0.0	40500.0	0.0	0.0	0.0	0.4900E-02	

APOLLO DESCENT ENGINE

DATA CORRELATION

LTA-5

SERIES 11

TEST 2

RUN 2

FUEL

FEEDSYSTEM CONFIGURATION

OXIDIZER

SEGMENT BRANCH DATA

INDEX INLET * * * BRANCHES * * * INLET * * * BRANCHES *

CAPPED SEGMENTS

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

FUEL IORDER ARRAY

NSEGF = 22

2 5 6 7 10 11 12 13 14 15 16 17 18 19 20 21 22

OXIDIZER IORDER ARRAY

NSEGO = 22

2 5 6 7 10 11 12 13 14 15 16 17 18 19 20 21 22

CUTOFF SEGMENTS

FUEL

OXIDIZER

-- FUEL VALVE TABLE

INDEX	SEGMENT	*	* VALUES						
1	323	252.000000	0.0	245.500000	0.500000	241.000000	1.000000	240.000000	1.250000
2	8	1.545900	1.000000	0.0	0.0	0.0	0.0	0.0	0.0

OXIDIZER VALVE TABLE

INDEX	SEGMENT	*	* VALUES						
1	323	260.000000	0.0	254.500000	0.500000	251.000000	1.000000	250.500000	1.250000
2	8	1.051800	1.000000	0.0	0.0	0.0	0.0	0.0	0.0

FUEL FUNGEN TABLE

3.000000	0.0	0.046000	0.060000	0.063000	0.100000	0.073000	0.148000	0.083000
0.205000	0.093000	0.239000	0.098000	0.279000	0.103000	0.326000	0.108000	0.440000
0.119000	0.440000	1.000000						

OXIDIZER FUNGEN TABLE

3.000000	0.0	0.000500	0.120000	0.005000	0.036000	0.010000	0.060000	0.015000
0.083000	0.020000	0.156000	0.030000	0.238000	0.040000	0.331000	0.050000	0.435000
0.063000	0.662000	0.080000	0.766300	0.090000	0.859000	0.100000	0.938000	0.110000
1.000000	0.119000	1.000000	1.000000					

CAVITATING VENTURI DATA
FUFL

ORIFICE DATA

ACCUMULATOR DATA

OXIDIZER

INJECTOR MANIFOLD DATA

INDEX NO. SEGMENT NO.	FUEL				OXIDIZER			
	1	2	3	4	1	2	3	4
MANIFOLD VOLUME - CU. IN.	45.0000	0.0	0.0	0.0	30.0000	0.0	0.0	0.0
ORIFICE LENGTH - INCHES	0.375000	0.0	0.0	0.0	0.250000	0.0	0.0	0.0
INJECTOR C-SUB-D*A - SQ IN	0.620650	0.0	0.0	0.0	0.317270	0.0	0.0	0.0
FLAME FRONT DISTANCE - IN.	1.000000	0.0	0.0	0.0	0.500000	0.0	0.0	0.0

COMBUSTION CHAMBER DATA

INDEX NO.	1		2		3		4	
	CHAMBER PRESSURE - PSIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OXIDIZER FLOWRATE - PPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
FUEL FLOWRATE - PPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OXIDIZER FRACTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
THRJET AREA - SQ. IN.	54.400	0.0	0.0	0.0	0.0	0.0	0.0	
CHAMBER VOLUME - CU. IN.	2557.000	0.0	0.0	0.0	0.0	0.0	0.0	
NOZZLE EXIT AREA - SQ. IN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
THRUST COEFFICIENT	1.70000	0.0	0.0	0.0	0.0	0.0	0.0	
ENGINE AMBIENT PRESSURE - PSIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
ENGINE THRUST - POUNDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

COMBUSTION DATA

BASE PRESSURE = 150.0 PSIA
 CSTAR CORRECTION = 0.008453

OX. FRACTION	GAS CONSTANT
0.0050	-2.0000 E 05
0.0	2.9300 E 05
0.0200	2.8200 E 06
0.0400	3.0400 E 06
0.0600	3.0700 E 06
0.1000	3.1300 E 06
0.2000	3.2400 E 06
0.2500	3.2800 E 06
0.3000	3.4200 E 06
0.3500	3.8700 E 06
0.4500	4.6000 E 06
0.5000	4.8800 E 06
0.5500	5.0300 E 06
0.6000	5.0200 E 06
0.6500	4.8600 E 06
0.7000	4.5500 E 06
0.8000	3.6300 E 06

GAS CONSTANT CORRECTION = 0.027790
 EFFICIENCY CORRECTION = 0.0

CSTAR / G	EFFICIENCY
15.000	0.8160
41.500	0.8180
115.000	0.8260
131.500	0.8330
132.900	0.8410
134.700	0.8560
138.000	0.8890
139.800	0.9030
142.600	0.9200
148.800	0.9330
165.000	0.9590
171.300	0.9670
175.800	0.9740
178.100	0.9780
176.800	0.9730
171.100	0.9640
152.000	0.9220

0.9000
0.9800
1.0000
1.0050

2.2700 E 06
3.7000 E 05
1.3300 E 05
1.0000 E 04

116.600
58.700
29.400
21.000

0.8590
0.8010
0.7870
0.7810

APOLLO DESCENT ENGINE DATE 12/17/70 TIME 9:31.16

LTA-5 DATA CORRELATION SERIES 11

TEST 2

RUN 2

INPUT DATA CONSTANTS	*	*	FUEL	OXIDIZER
ENTRAINED GAS - LBS GAS / LB LIQUID			2.1000E-03	4.9000E-03
PROPELLANT DENSITY - POUNDS / CUBIC INCH			0.03250	0.05200
LIQUID TEMPERATURE - DEGREES RANKINE			530.0	530.0
PROPELLANT ACOUSTIC VELOCITY - INCHES / SECOND			60000.0	40500.0
VAPOR PRESSURE CURVE FIT CONSTANTS - CON1			8.3446E-03	8.9489E-03
($\log(PVAP) = CON1 * TEMP + CON2$)				
			-4.1095E 00	-3.6294E 00
PROPELLANT MOLECULAR WEIGHT			41.8	92.0
PRESSURANT GAS MOLECULAR WEIGHT			4.0	4.0
RATIO OF SPECIFIC HEATS - PRESSURANT GAS			1.670	1.670
RATIO OF SPECIFIC HEATS - PROPELLANT VAPOR			1.050	1.100
DISSOLVED GAS EVOLUTION TIME CONSTANT - 1/SEC.			1.0000E 01	1.0000E 01
DISSOLVED GAS CONCENTRATION - LBS GAS / LB LIQ / PSI			8.8889E-06	2.0526E-05
PROPELLANT TANK ULLAGE - CUBIC INCHES			0.0	0.0
PROPELLANT TANK INITIAL PRESSURE - PSIA			0.0	0.0
PRESSURANT GAS BOTTLE VOLUME - CUBIC INCHES			0.0	0.0
PROPELLANT LIQUID HEAT CAPACITY - BTU / LB / DEGREE R			6.9100E-01	3.6800E-01
PRESSURANT - LOW PRESSURE C-SUR-V			7.5000E-01	7.5000E-01
PRESSURANT - HIGH PRESSURE C-SUR-V			0.0	0.0
PRESSURANT - HIGH PRESSURE C-SUR-P			0.0	0.0
PRESSURANT - HIGH PRESSURE GAMMA			0.0	0.0

APOLLO DESCENT ENGINE

DATA CORRELATION

NOT REPRODUCIBLE

	ITA-5		SERIES 11		TEST 2		RFIN 2	
0.0	251.99998	0.00000	251.99998	0.00000	2.05654	12.98603	0.0	34613.35938
0.002040	251.99998	0.00000	247.79466	0.13638	2.05654	12.98603	0.0	34613.35938
0.004080	251.99998	0.00000	222.29463	0.96245	2.05654	12.98603	0.0	34613.35938
0.006120	251.97852	-0.00049	200.74428	1.71430	2.05654	12.98603	0.0	32070.95313
0.008160	251.92996	-0.00063	197.26343	2.47837	2.05654	12.98603	0.0	23302.40234
0.010200	251.87631	-0.00061	192.11464	2.64688	2.05654	12.98603	0.0	16960.52734
0.012240	251.82307	-0.00063	190.47972	2.81990	2.05654	12.98603	0.0	13296.42188
0.014280	251.77000	-0.00061	184.19046	3.51208	2.05654	12.98603	0.0	11097.27734
0.016320	251.72569	-0.00044	180.86087	4.09324	2.05654	12.98603	0.0	9677.69922
0.018360	251.70821	0.00005	177.08289	5.02773	2.05654	12.98603	0.0	8677.12891
0.020400	251.71056	0.00001	182.56113	6.31398	2.05654	12.98603	0.0	7924.18750
0.022440	251.71031	-0.00000	177.61127	7.62139	2.05654	12.98603	0.0	7344.20313
0.024480	251.71106	0.00002	179.74863	8.26297	2.05654	12.98603	0.0	6886.50391
0.026520	251.70840	-0.00007	184.46115	10.26412	2.05654	12.98603	0.0	6523.87500
0.028560	251.68495	-0.00047	184.37283	11.96219	2.05654	12.98603	0.0	6234.62109
0.030600	251.63681	-0.00065	181.93489	11.61106	2.05654	12.98603	0.0	5997.86719
0.032640	251.58138	-0.00062	179.06618	12.32423	2.05654	12.98603	0.0	5804.50000
0.034680	251.52896	-0.00060	180.85898	13.63357	2.05654	12.98603	0.0	5646.11719
0.036720	251.47647	-0.00061	185.97922	14.40375	2.05654	12.98603	0.0	5514.00000
0.038760	251.43408	-0.00037	184.23528	14.86636	2.05654	12.98603	0.0	5400.85938
0.040800	251.41914	0.00002	178.08624	14.94370	2.05654	12.98603	0.0	5301.15625
0.042840	251.42101	0.00004	177.36975	15.46395	2.05654	12.98603	0.0	5210.71484
0.044880	251.42154	-0.00002	177.70978	16.59673	2.05654	12.98603	0.0	5127.51953

	ITERATION ERROR IN BRANCH.		TIME = 0.046070, SEGMENT		B PG = 126.738		PANS = -0.135997E 12	
0.046920	251.32021	0.00235	180.29716	18.17114	2.05654	12.98603	0.0	5051.88672
0.048960	229.06276	0.51548	178.52560	18.81091	2.05654	12.98603	0.0	4983.43359
0.051000	207.85471	1.00188	170.76404	18.85364	2.05654	12.98603	0.0	4919.82813
0.053040	189.23865	1.43059	169.80843	19.75922	2.05654	12.98603	0.0	4859.25000
0.055080	176.87076	1.79566	174.59630	21.28186	2.05654	12.98603	0.0	4802.08594
0.057120	171.17711	2.24117	173.84555	22.50418	2.05654	12.98603	0.0	4749.52344
0.059160	175.06183	3.09958	169.54160	23.19884	2.05654	12.98603	0.0	4701.58984
0.061200	178.26009	3.94470	169.88136	24.51541	2.05654	12.98603	0.0	4657.23438
0.063240	181.88177	4.54407	171.49376	24.99030	2.05654	12.98603	0.0	4615.66406
0.065280	187.43063	5.07593	168.75372	25.20300	2.05654	12.98603	0.0	4576.62109
0.067320	190.51494	5.42060	162.17818	26.76967	2.05654	12.98603	0.0	4540.38281
0.069360	193.63976	5.95655	165.05659	28.41769	2.05654	12.98603	0.0	4507.49219
0.071400	196.75717	6.39292	171.15375	28.83673	2.05654	12.98603	0.0	4477.91797
0.073440	199.66837	6.86840	172.73054	29.28029	2.05654	12.98603	0.0	4450.73047

0.075479	200.75729	7.46199	165.19151	29.33351	2.05654	12.98603	0.0	4425.15625
0.077519	203.00180	7.86937	163.48634	30.70485	2.05654	12.98603	0.0	4401.07422
0.079559	204.48126	8.52184	161.78757	31.37794	2.05654	12.98603	0.0	4378.70313
0.081599	206.80084	9.11435	167.54610	32.67938	2.05654	12.98603	0.0	4358.30859
0.083639	208.59979	9.65889	166.38203	32.58719	2.05654	12.98603	0.0	4340.03125
0.085679	210.16672	10.22205	167.22591	33.45799	2.05654	12.98603	0.0	4323.58594
0.087719	211.11708	10.69761	163.65562	34.00713	2.05654	12.98603	0.0	4308.41016
0.089759	210.87666	11.02129	161.06641	33.90813	2.05654	12.98603	0.0	4294.05859
0.091799	210.13162	11.38417	160.87833	33.79723	2.05654	12.98603	0.0	4280.47656
0.093839	209.78459	11.78434	161.43024	34.78352	2.05654	12.98603	0.0	4267.89844
0.095878	209.49984	12.02444	162.14725	36.18880	2.05654	12.98603	0.0	4256.55078
0.097918	208.71263	12.28778	159.32265	36.35318	2.05654	12.98603	0.0	4246.42578
0.099958	208.53171	12.76054	163.63708	37.13531	2.05654	12.98603	0.0	4237.22656
0.101998	206.41710	12.95890	162.83067	37.03690	2.05654	12.98603	0.0	4228.59766
0.104038	206.59761	13.35766	160.63806	36.87155	2.05654	12.98603	0.0	4220.42969
0.106078	205.44394	13.73610	159.74662	36.90016	2.05654	54.23944	0.0	4212.83594
0.108118	204.70956	14.02775	157.45140	37.71587	2.05654	85.55806	0.0	4205.97656
0.110158	204.81546	14.36182	159.71262	38.98872	2.05654	00.09439	0.0	4199.98047
0.112198	204.13953	14.56211	164.33189	39.44740	2.05654	107.18739	0.0	4195.09375
0.114238	204.08954	14.85685	169.52913	39.98555	2.05654	125.94559	0.0	4191.41016
0.116278	203.91818	15.09625	165.50807	39.37622	2.05654	139.82463	0.0	4188.80078
0.118317	204.61102	15.24265	162.53154	39.15363	2.05654	146.39293	0.0	4187.12500
0.120357	205.85536	15.43385	185.48335	31.98744	2.05654	148.41270	0.0	4186.15234
0.122397	206.37602	15.52773	198.90211	30.02068	2.05654	152.75510	0.0	4185.66406
0.124437	206.50125	15.62387	214.54256	29.48955	2.05654	158.45596	0.0	4185.64844
0.126477	208.75073	15.72555	221.79430	31.24358	2.05654	163.83276	0.0	4186.10938
0.128517	211.74173	15.68399	229.15239	30.05247	2.05654	169.75931	0.0	4186.94141
0.130557	213.11687	15.67687	229.03705	28.96053	2.05654	170.34703	0.0	4188.02344
0.132597	216.06499	15.75536	228.23611	26.24142	2.05654	168.98244	0.0	4189.36328
0.134637	218.00203	15.99547	220.44914	24.88695	2.05654	171.96080	0.0	4191.06641
0.136677	219.94896	15.96922	229.55278	26.72188	2.05654	179.93805	0.0	4193.41406
0.138717	222.05353	16.08240	242.81921	28.75142	2.05654	188.00015	0.0	4196.60156
0.140756	224.69949	16.22327	256.66650	29.05974	2.05654	194.60664	0.0	4200.61328
0.142796	227.14101	16.30635	257.57813	28.01913	2.05654	201.33647	0.0	4205.19141
0.144836	228.34204	16.37933	255.22263	27.18654	2.05654	203.31924	0.0	4210.01563
0.146876	231.29564	16.47725	247.69063	26.24855	2.05654	198.59163	0.0	4215.00000
0.148916	233.11818	16.53346	246.83620	25.54750	2.05654	194.84657	0.0	4220.41016
0.150956	234.82506	16.57101	252.26605	26.71220	2.05654	201.94365	0.0	4226.77344
0.152996	237.55627	16.61519	265.63673	28.15176	2.05654	211.17270	0.0	4234.57813
0.155036	239.05893	16.53491	270.27854	27.72462	2.05654	217.84019	0.0	4243.81641
0.157076	238.25515	16.47044	274.60352	26.41409	2.05654	220.76202	0.0	4253.98828
0.159116	238.74030	16.44476	278.21021	27.07486	2.05654	219.79272	0.0	4264.55859
0.161156	240.73622	16.38651	273.57861	27.13011	2.05654	215.21637	0.0	4275.44531

0.163105	241.33089	16.17416	263.54541	26.89011	2.05654	214.10417	0.0	4287.25391
0.165235	241.71372	16.14270	271.20972	27.23322	2.05654	221.23441	0.0	4300.85938
0.167275	242.06847	16.13321	287.00342	28.71548	2.05654	227.83055	0.0	4316.79297
0.169315	242.13838	15.98092	291.12500	28.43620	2.05654	231.98604	0.0	4334.26563
0.171355	242.37579	15.91501	292.90112	27.37531	2.05654	235.71384	0.0	4352.91797
0.173395	243.25290	15.80783	308.11328	29.68025	2.05654	237.43477	0.0	4372.69922
0.175435	241.80194	15.56429	299.70947	29.29558	2.05654	234.48987	0.0	4393.60547
0.177475	242.06890	15.60215	310.79614	32.45024	2.05654	233.86172	0.0	4415.65234
0.179515	241.94611	15.59896	314.29346	31.33229	2.05654	238.76204	0.0	4438.90625
0.181555	241.42657	15.39102	310.75610	30.38557	2.05654	245.75018	0.0	4463.51172
0.183595	240.91905	15.30583	292.43018	26.53726	2.05654	250.61066	0.0	4489.56250
0.185634	239.83162	15.21688	287.30469	24.99893	2.05654	255.60329	0.0	4517.07813
0.187674	240.71959	15.20808	283.10962	24.74403	2.05654	253.79828	0.0	4546.09375
0.189714	238.54404	15.05641	296.48730	27.71657	2.05654	255.74805	0.0	4576.66016
0.191754	238.23112	15.01937	286.58960	25.15993	2.05654	265.67529	0.0	4608.78125
0.193794	237.56567	14.93726	274.61133	21.58141	2.05654	270.18726	0.0	4642.40234
0.195834	238.22446	14.92203	268.35913	19.60283	2.05654	259.75610	0.0	4677.47266
0.197874	236.11623	14.76244	284.35645	22.37302	2.05654	248.85889	0.0	4713.87891
0.199914	236.46162	14.78140	282.50586	22.27667	2.05654	244.54652	0.0	4751.64063
0.201954	234.84949	14.76578	269.33228	22.58505	2.05654	245.92027	0.0	4790.94922
0.203994	233.60498	14.77898	259.92261	18.79436	2.05654	244.72968	0.0	4831.91406
0.206034	233.42720	14.73606	277.81641	18.23396	2.05654	237.21414	0.0	4874.66797
0.208073	235.18250	14.67309	279.78564	21.17767	2.05654	227.40088	0.0	4919.48828
0.210113	233.14171	14.62234	273.68311	22.74504	2.05654	231.91496	0.0	4966.32422
0.212153	232.00703	14.70532	255.79492	21.17242	2.05654	236.20592	0.0	5015.19531
0.214193	231.21050	14.71452	260.01782	21.31367	2.05654	223.49841	0.0	5066.27734
0.216233	231.77098	14.72583	275.32910	22.32280	2.05654	215.70793	0.0	5117.74609
0.218273	232.43449	14.77410	240.52916	18.27138	2.05654	220.54314	0.0	5167.56641
0.220313	230.98637	14.69913	222.45592	20.28682	2.05654	222.35394	0.0	5214.33594
0.222353	230.02458	14.60345	256.13477	21.30484	2.05654	213.96283	0.0	5255.31250
0.224393	230.51929	14.75643	243.74460	18.75804	2.05654	201.73671	0.0	5291.99219
0.226433	231.67355	14.74468	239.49571	22.25148	2.05654	205.17491	0.0	5321.83203
0.228473	229.95023	14.83585	218.44841	20.84805	2.05654	209.35236	0.0	5344.24219
0.230512	230.08858	14.85256	248.00453	21.04052	2.05654	199.70499	0.0	5362.83594
0.232552	229.60300	14.78697	221.74376	18.14240	2.05654	194.79391	0.0	5376.71484
0.234592	229.79391	14.74846	189.23442	18.23160	2.05654	193.73590	0.0	5384.25000
0.236632	230.22592	14.90341	217.90245	25.07097	2.05654	202.43213	0.0	5384.08203
0.238672	229.52090	14.83275	221.32895	20.68040	2.05654	185.91562	0.0	5378.41016
0.240712	230.12883	14.96610	247.95801	24.10693	2.05654	183.95773	0.0	5365.30469
0.242752	231.21703	14.98748	178.69882	17.20702	2.05654	184.70396	0.0	5341.65234
0.244792	229.67621	14.87532	216.00151	21.17705	11.60011	160.19429	0.0	5315.07422
0.246832	229.90611	14.88746	255.28052	26.03624	18.03334	183.93675	57.61061	5285.58984
0.248872	230.41244	14.90322	186.62316	18.30528	38.07981	188.21385	71.20061	5259.66016

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0.250912	231.00262	14.92520	205.55037	24.95918	50.66214	196.20341	64.76981	5231.82422
0.252952	230.66458	14.96106	221.15913	21.57518	60.04472	191.22067	60.18648	5200.45313
0.254991	230.000023	15.01758	225.21835	21.30885	68.15117	176.91858	56.78569	5179.49609
0.257031	231.44149	14.90453	220.12450	26.80899	73.85385	202.16940	70.39720	5160.40234
0.259071	233.07657	14.90766	215.66171	22.60568	89.38498	206.97401	100.03549	5146.00781
0.261111	236.90314	14.54199	215.59595	20.65085	99.60506	194.44467	86.04308	5139.24609
0.263151	242.53551	14.33242	257.90067	22.30730	93.10954	199.99625	71.18285	5129.00781
0.265191	245.32808	14.24853	204.39227	18.90009	90.22661	198.67033	77.89638	5124.55469
0.267231	240.01505	14.36838	219.84648	26.40868	96.76389	208.93604	86.49959	5125.61328
0.269271	251.00328	14.53006	255.52518	20.93556	104.15161	211.79132	87.80904	5127.22266
0.271311	251.44901	14.38951	233.69965	18.04257	105.35242	200.27884	86.29333	5134.02344
0.273351	255.43864	13.78038	205.64226	18.88153	101.83366	206.73740	86.31918	5139.37500
0.275391	256.30396	13.40940	271.90601	28.85582	99.85023	217.37782	87.77295	5145.00000
0.277430	256.71533	13.55268	245.21124	22.47585	102.68370	208.90636	90.10722	5158.92969
0.279470	255.12198	13.54044	219.13876	14.95407	107.21181	219.04732	89.60724	5175.86719
0.281510	255.02892	13.32045	258.36841	21.77034	110.47644	222.01706	91.16553	5190.87109
0.283550	255.05765	12.73078	276.29321	29.02548	109.87163	210.00851	91.56120	5209.44922
0.285590	255.97597	12.37352	240.09439	20.57707	108.87584	212.38623	91.46216	5234.26953
0.287630	257.53198	12.51913	252.00464	21.34363	109.13651	240.72734	94.06645	5259.71875
0.289670	256.16895	12.54078	247.95667	22.23749	111.75467	220.47418	94.91533	5290.49609
0.291710	255.27773	12.10911	280.43921	26.21255	113.58188	215.64771	94.90170	5328.16797
0.293750	252.30722	11.79123	262.05737	21.20107	114.53793	233.21794	95.97346	5368.66406
0.295790	252.09357	11.62376	242.41232	25.36292	114.96219	242.26764	97.35693	5418.84375
0.297830	253.35980	11.66044	271.03589	23.02994	115.60869	232.78473	97.20850	5476.43750
0.299869	252.73021	11.55968	262.86230	19.48453	116.37357	236.01334	98.57727	5540.97656
0.301909	248.86467	11.36192	263.93628	25.64294	116.90079	243.70697	99.08604	5607.86328
0.303949	247.29114	11.18876	242.39386	22.98457	117.38763	239.92007	99.43834	5676.25000
0.305989	247.26811	11.12318	269.76855	17.78247	117.60236	232.17230	98.45766	5753.30469
0.308029	247.84657	11.03113	244.93102	18.71822	118.90140	244.01472	100.12315	5833.82422
0.310069	244.26283	10.98180	256.78784	21.30942	119.96776	235.42223	100.48090	5918.17578
0.312109	245.01154	10.90658	270.34839	20.57790	120.57449	240.39273	101.47725	6006.63281
0.314149	242.87894	10.87715	278.47998	20.02235	118.99213	236.93443	100.33893	6099.39063
0.316189	243.02936	10.82047	270.62280	23.28877	118.38400	238.00781	99.99121	6196.95313
0.318229	239.97238	10.80432	256.70996	18.85759	118.60356	238.70325	100.07159	6297.91406
0.320269	241.05234	10.75907	299.36719	26.80351	120.98103	236.19984	101.37869	6403.68750
0.322308	239.16276	10.75156	267.52981	23.09731	121.71605	233.14429	101.72896	6512.54297
0.324348	239.72011	10.75305	247.00046	21.21356	121.03346	239.63875	101.79660	6623.34766
0.326388	238.68911	10.79325	239.16476	19.77435	118.81905	232.46779	101.05806	6728.79297
0.328428	238.85289	10.77978	245.61198	17.43741	118.17346	229.63158	99.85312	6842.10547
0.330468	235.05777	10.70677	272.26123	23.29050	119.19862	236.01129	100.86516	6943.95703
0.332508	237.60207	10.79503	211.07724	19.87706	121.07236	222.53171	100.60123	7035.52734
0.334548	235.75102	10.80725	248.69980	19.88358	120.93044	222.52235	101.15576	7118.89453
0.336588	239.09600	10.83922	217.22832	18.06815	119.47211	224.15508	101.08455	7194.87891

0.338628	236.2.977	10.85140	270.70166	18.75061	117.80998	224.06332	100.52278	7257.40625
0.340668	236.79055	10.92071	219.19690	18.68001	117.85481	215.18575	98.35179	7312.68750
0.342708	234.03928	10.93926	232.08852	20.28912	118.67142	221.71503	99.68816	7353.75391
0.344747	235.17534	10.98223	212.82782	20.12891	119.09334	216.16484	99.18219	7385.75391
0.346787	235.83090	10.94718	262.23584	17.20671	118.78336	218.37546	100.16707	7405.81641
0.348827	236.95619	10.96425	240.92413	21.20471	118.03125	213.85144	99.56184	7414.60931
0.350867	235.85071	11.01007	261.98291	18.13994	117.76631	219.68137	99.69978	7418.16400
0.352907	237.01376	11.10275	263.28784	19.76099	117.15132	213.34393	98.40590	7413.25781
0.354947	234.40726	11.10151	206.45702	17.83279	116.93042	218.28377	98.78630	7398.96480
0.356987	234.94814	11.11610	241.85358	19.49681	116.72815	213.78128	98.11505	7379.53121
0.359027	236.34169	11.05468	267.53613	20.73322	117.57256	214.29355	98.92462	7364.37891
0.361067	236.67220	11.12802	245.32733	18.68646	117.91106	221.92444	99.51370	7337.50391
0.363107	236.88129	11.18354	254.10785	17.90041	117.68959	208.58501	98.53754	7316.26561
0.365147	236.95462	11.22506	240.03032	20.13541	115.76225	215.41162	98.20383	7297.26171
0.367186	235.71579	11.20208	248.06441	21.53278	115.23077	221.30244	98.50116	7275.14841
0.369226	235.40044	11.17584	250.86382	19.35022	115.89211	212.12619	97.37976	7250.56251
0.371266	236.53719	11.19007	229.39862	19.04976	117.93362	212.76714	98.54057	7237.44531
0.373306	237.21820	11.25431	226.52826	19.86763	118.08269	218.65288	100.02403	7218.08201
0.375346	237.07234	11.25807	288.45605	20.64085	116.78561	213.63652	99.37682	7201.45701
0.377386	237.33504	11.26945	257.41479	21.79521	114.64021	218.47147	97.57996	7195.32031
0.379426	237.28079	11.23740	230.82037	19.41339	115.13402	216.33211	97.12074	7183.97261
0.381466	235.20076	11.26517	249.45366	20.09918	116.71935	209.65179	98.33675	7176.39061
0.383506	236.97711	11.28638	248.69026	20.27701	118.20483	225.55278	100.27557	7178.39451
0.385546	237.20029	11.27119	245.91609	21.26714	117.31158	221.94263	99.53940	7177.19921
0.387586	237.46024	11.25764	232.98453	20.98846	116.14993	214.32884	97.78368	7179.26561
0.389625	238.29253	11.27691	241.25752	19.84708	115.19566	218.75404	98.14101	7186.17181
0.391665	237.62172	11.29078	274.33862	19.91747	116.19348	221.73909	99.35785	7195.50781
0.393705	234.93181	11.32353	272.52905	20.48944	116.99326	217.61238	99.26825	7204.24601
0.395745	237.06583	11.26276	239.51088	19.87222	117.55463	218.39351	98.86775	7218.33591
0.397785	237.27087	11.23309	223.84735	19.88368	116.98114	218.47154	99.03688	7232.85931
0.399825	238.60469	11.25573	258.86035	20.54356	116.99863	220.60332	99.38394	7247.10931
0.401865	238.14626	11.29718	236.59880	20.56721	116.40721	225.39488	99.45584	7269.41011
0.403905	237.29668	11.32136	253.98570	21.57510	116.50336	218.68793	98.78770	7285.60931
0.405945	235.07047	11.27066	241.41747	20.51799	116.28354	216.13916	98.52164	7307.10541
0.407985	237.15198	11.20500	249.21806	18.47147	117.36011	221.23875	99.72672	7329.60931
0.410025	237.91460	11.23977	252.32454	20.08446	118.15127	217.93245	100.02675	7352.99211
0.412064	238.75690	11.26771	248.51541	21.51610	118.15350	223.25450	100.29158	7375.34761
0.414104	237.34604	11.29475	235.19179	20.56427	116.48805	218.79242	99.02632	7400.86711
0.416144	237.51523	11.26506	229.78236	20.50310	115.77557	221.64680	98.81075	7423.51561
0.418184	235.3.132	11.20172	246.69976	19.97774	116.24326	216.36861	99.06274	7444.33981
0.420224	237.23545	11.21732	255.29939	20.15569	118.42058	222.82309	100.11002	7474.24211
0.422264	237.87439	11.24815	240.59219	19.78497	119.00043	221.59970	100.53662	7493.25001
0.424304	238.58005	11.24449	230.15291	20.05913	117.92577	216.09050	99.60960	7514.21641

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0.426344	237.20713	11.22909	236.38400	20.33090	115.73422	220.99136	99.29800	7539.39844
0.428384	237.91295	11.20391	252.25124	21.17340	115.88246	218.60548	99.29199	7557.60156
0.430424	235.13075	11.22588	254.90996	20.56400	117.31702	220.33727	99.55972	7574.66016
0.432464	237.00844	11.24851	233.86032	19.31694	119.07858	219.50432	99.55775	7599.35156
0.434503	237.12180	11.21003	218.83920	20.65944	118.40500	219.80560	100.19290	7612.13672
0.436543	237.94455	11.19099	245.29730	20.09215	117.13446	216.06874	99.75970	7628.08594
0.438583	237.48090	11.20265	245.28386	20.92937	116.03288	223.24940	99.71989	7647.27734
0.440623	237.55360	11.23334	245.33728	19.62410	116.89705	218.60144	99.17897	7656.50391
0.442663	234.62332	11.26115	238.87843	20.25110	117.59775	216.57599	98.88297	7669.89453
0.444703	236.45474	11.20127	227.48878	20.59648	118.16443	221.78221	99.76631	7683.62109
0.446743	236.76924	11.15176	255.36319	20.54057	117.67798	218.73685	100.10640	7691.71094
0.448783	238.36865	11.18600	251.42715	19.18484	117.60806	221.12502	99.91350	7702.04297
0.450823	237.04492	11.23363	235.96288	19.43401	116.97974	220.88754	99.63991	7711.68359
0.452863	236.77681	11.26174	250.22577	20.98790	116.82172	214.69354	99.07094	7713.75391
0.454903	234.41225	11.21081	239.06021	20.09219	116.46368	221.66338	99.24361	7724.94531
0.456942	236.24971	11.14066	236.74643	20.23672	117.67404	219.95488	99.64229	7728.69141
0.458982	236.91284	11.17494	254.18944	19.48306	118.44453	214.22958	99.63927	7731.69531
0.461022	238.26262	11.22444	228.97375	21.11174	118.34212	222.50536	100.42371	7742.48438
0.463062	236.10391	11.24240	249.15170	20.77126	116.55885	218.03838	99.94604	7739.04688
0.465102	236.67757	11.21388	247.56134	20.58716	115.68338	217.91428	98.65007	7744.08203
0.467142	234.66284	11.16199	229.01482	19.29701	116.31081	220.38576	98.65846	7749.54297
0.469182	236.13020	11.18181	240.53128	20.41203	118.62616	215.54642	99.50562	7747.44141
0.471222	236.73087	11.22639	247.76637	20.66148	118.94504	216.88602	100.52036	7753.16406
0.473262	237.63416	11.20786	238.17450	20.44923	117.61160	225.10352	100.63315	7756.20703
0.475302	235.82806	11.19839	247.11407	19.89612	115.61508	214.86821	98.83981	7753.33594
0.477342	237.21710	11.18781	240.48576	19.69092	115.86429	218.24066	98.21719	7756.79688
0.479381	234.53764	11.20951	228.38693	21.00812	117.30386	219.78310	99.61266	7758.57422
0.481421	235.60497	11.23642	258.95776	19.66895	118.81021	215.96602	100.07141	7757.13672
0.483461	236.37320	11.18937	234.88689	20.17975	117.93456	222.75404	100.40775	7762.80859
0.485501	237.51689	11.15931	236.74092	19.78088	116.90665	216.46431	99.28923	7761.44531
0.487541	236.23489	11.20063	250.62204	21.41077	116.06540	217.84341	98.97818	7759.83984
0.489581	237.10422	11.23517	236.18883	20.23343	116.76299	219.67369	99.47244	7764.75000
0.491621	233.84073	11.24644	247.31223	20.38802	117.17491	220.31920	99.74463	7760.85547
0.493661	235.34032	11.19808	241.19455	19.57368	117.76213	215.38013	99.11281	7764.07422
0.495701	236.50999	11.13246	234.44528	20.46194	117.49263	221.37129	99.77521	7767.04297
0.497741	237.75691	11.18686	247.04535	20.87987	117.68147	216.76508	99.92418	7762.54688
0.499781	236.12149	11.24685	245.71046	19.94638	116.76816	219.20485	99.67029	7767.04297
0.501820	236.31517	11.20253	235.38107	20.27829	116.31482	220.64453	99.34766	7765.85156
0.503860	233.77821	11.19384	240.89270	19.95665	116.16614	214.63684	98.54352	7763.82031
0.505900	235.67000	11.13608	244.75032	20.88902	117.62674	220.42618	99.36295	7767.89063
0.507940	236.57288	11.17430	240.95507	19.69449	118.46423	219.95104	100.32280	7769.16406
0.509980	237.52176	11.23644	244.40646	20.38531	118.16849	218.00931	100.19151	7765.34766
0.512020	236.52097	11.22500	237.90498	19.69725	116.02103	218.03490	99.34107	7768.31141

0.514060	236.12883	11.18942	238.34357	21.22925	115.46422	219.30673	98.88838	7766.36719
0.516100	234.36375	11.16909	249.40715	20.00281	116.43297	216.66747	98.75032	7763.91016
0.518140	235.57529	11.18174	238.24719	20.18983	118.64185	220.82988	99.76855	7768.48438
0.520180	236.08720	11.22472	236.95345	20.14398	118.67393	217.34866	100.29691	7765.59766
0.522220	237.24101	11.19314	244.53265	20.43068	117.19737	218.17155	99.86235	7764.50000
0.524259	235.47115	11.17164	240.61700	20.62047	115.36377	219.25655	99.21602	7765.09375
0.526299	236.49611	11.19460	244.08311	19.94144	116.04242	219.35722	98.83073	7762.21094
0.528339	234.41965	11.21481	241.33180	20.33560	117.34116	216.28532	98.98463	7761.02734
0.530379	234.89876	11.21228	235.65552	19.76358	118.48125	219.90385	99.83180	7763.65625
0.532419	235.84865	11.17423	244.08090	21.05824	117.63429	218.15617	100.17303	7759.58594
0.534459	237.45370	11.13727	246.53699	19.62346	116.78375	218.14423	99.44469	7759.58594
0.536499	235.72900	11.20039	236.98842	20.52031	116.17650	221.20706	99.39066	7758.99609
0.538539	236.25647	11.24271	242.28146	19.95097	116.77910	214.72148	98.93161	7753.50391
0.540579	233.89851	11.21470	241.90666	20.56761	116.79947	220.08463	99.38641	7755.36326
0.542619	234.73631	11.15911	240.26897	20.01221	117.50871	218.55882	99.55763	7754.26953
0.544659	236.12808	11.12810	244.61649	20.27562	117.56738	218.64919	99.62898	7750.80859
0.546698	237.55977	11.17853	240.88583	20.22084	117.73772	217.50201	99.71329	7751.31250
0.548738	235.53377	11.24965	237.89000	20.42290	116.60550	220.36368	99.76691	7748.70313
0.550778	235.53128	11.21509	245.88657	20.57849	115.96875	215.89273	99.05481	7743.49609
0.552818	233.95892	11.15972	241.89931	19.74403	115.95064	219.70511	98.75269	7745.17188
0.554858	235.18710	11.13577	234.90979	20.52789	117.84711	218.82123	99.30719	7742.15236
0.556898	235.97238	11.17344	247.07678	19.88240	118.53050	215.88153	99.85037	7738.63672
0.558938	237.18549	11.22084	237.47481	20.80316	117.81004	220.91721	100.32210	7739.55469
0.560978	235.22168	11.20691	242.08406	19.92915	115.64153	217.55525	99.31081	7733.78125
0.563018	235.30942	11.15621	244.62546	20.55328	115.35707	217.90308	98.50838	7729.69922
0.565058	234.57353	11.16859	235.00029	19.80104	116.63643	217.97754	98.73555	7730.69141
0.567098	235.08125	11.17925	243.94763	20.61392	118.70226	219.28160	99.89819	7725.61328
0.569137	235.21193	11.20038	243.43037	20.02380	118.27388	216.58755	100.14595	7724.11719
0.571177	237.11049	11.16858	239.27966	20.17119	116.75201	220.91821	99.77133	7722.95313
0.573217	235.37817	11.15465	239.70663	20.48747	115.31372	216.67865	98.77577	7716.06641
0.575257	235.43919	11.18397	244.58678	20.04579	116.17780	217.36919	98.74583	7713.99609
0.577297	234.54640	11.21836	238.30798	20.53951	117.27396	219.97766	99.50717	7712.34766
0.579337	234.44661	11.17496	243.36449	19.86069	118.10634	216.95061	99.68846	7707.88672
0.581377	234.94717	11.15005	241.79779	20.51947	117.24773	218.49661	99.60161	7706.15625
0.583417	237.52939	11.12604	236.14720	19.89120	116.77393	219.10442	99.41035	7704.51172
0.585457	235.45427	11.19623	245.48166	20.82251	116.23479	217.23024	99.26343	7697.27344
0.587497	235.07138	11.23121	242.13844	19.80937	116.51958	217.82799	99.15784	7696.86328
0.589537	234.01418	11.19016	237.78717	20.41502	116.45450	219.68097	99.19572	7692.93359
0.591576	234.45932	11.12068	241.47215	20.08083	117.29271	215.95610	99.03854	7687.78516
0.593616	235.37566	11.13056	242.42947	20.28020	117.58440	219.51108	99.60840	7688.02734
0.595656	237.46194	11.16997	238.56322	20.37044	117.67996	218.49062	99.90984	7682.56250
0.597696	235.68188	11.23666	244.61258	20.09752	116.26019	217.62341	99.43280	7677.67969
0.599736	234.65131	11.18502	239.68599	20.35094	115.57996	217.44540	98.74675	7674.92158

0.601776	233.94162	11.13532	237.53636	20.00294	115.90953	219.12698	98.65652	7671.59766
0.603816	235.05957	11.12628	246.44232	20.56027	117.94695	216.78947	99.34311	7666.42180
0.605856	235.09004	11.17568	239.15924	19.79517	118.39977	218.80217	99.96498	7666.66016
0.607896	236.77808	11.19233	238.94653	20.62619	117.41655	218.56429	100.08771	7661.33594
0.609936	235.03061	11.18837	243.68048	20.00739	115.26129	215.52226	98.76115	7655.05469

HC900I EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

HC217I FIDCS - END OF DATA SET ON UNIT 5

TRACEBACK	RJUTINE	CALLLED FROM ISN	REG. 14	REG. 15	REG. 0	REG. 1
FRDNL#			000364A4	00049358	0000A414	00035BE8
MAIN			0000DD1A	01035868	FD000008	00074FF8

ENTRY PGINT= 01035R68

APPENDIX C

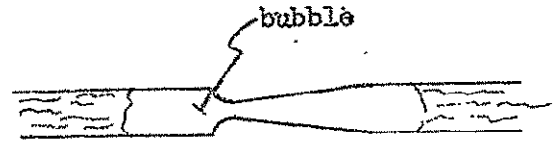
APOLLO DESCENT ENGINE IM-3 FLIGHT ANOMALY

The LM-3 anomaly simulation considers the passage of a gas bubble through both the fuel and oxidizer feed systems of the Apollo Descent Engine. It is assumed that the bubble has no effect on the system until it starts to pass through the cavitating venturi. This model will use the same segmentation and physical characteristics as the start transient demonstration - Appendix B. The equations and procedures used to calculate the performance of the system are presented as well as the calculations of parameters needed for the input data shown in Table C-I. Table C-II contains a listing of the modified program subroutines. The program pictorial output is shown in Figs. C-1A through C-1F and a listing of the output data is presented in Table C-III.

LM-3 DESCENT ENGINE ANOMALY

I. Gas Flow Through the Cavitating Venturi

The upstream fluid flow and pressure are:



$$P(I,t) = C4(I) - C3(I) \cdot \dot{w}(I,t) - R(I) \cdot \dot{w}(I,t) \cdot |w(I,t)| \quad (C-1)$$

Downstream

$$P(I-1,t) = C3(I-2) \cdot \dot{w}(I-1,t) - C2(I-1) \quad (C-2)$$

The gas flow through the cavitating venturi will be calculated using the compressible flow equation.

$$\dot{w}_g = f(P(I,t), P(I-1,t), A_t, \dots) \quad (C-3)$$

The upstream gas pressure can be found from the perfect gas law.

$$P(I,t) = \frac{M_{gu}(t) RT}{V_{gu}(t)} \quad \text{when:} \quad \begin{aligned} M_{gu}(t) &= M_{gu}(t-1) - \dot{w}_g \Delta t \\ V_{gu}(t) &= V_{gu}(t-1) - \dot{w}(I,t) \frac{\Delta t}{\rho_l} \end{aligned} \quad (C-4)$$

The downstream gas pressure is found in a similar fashion

$$P(I-1,t) = \frac{M_{gd}(t) RT}{V_{gd}(t)} \quad \text{when:} \quad \begin{aligned} M_{gd}(t) &= M_{gd}(t-1) + \dot{w}_g \Delta t \\ V_{gd}(t) &= V_{gd}(t-1) - w(I,t) \frac{\Delta t}{\rho_l} \end{aligned} \quad (C-5)$$

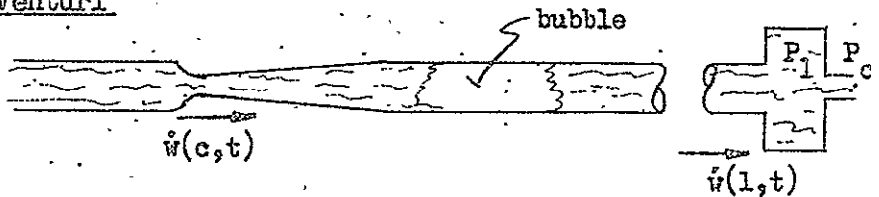
These equations will be programmed as follows:

1. Estimate P_{Gu} and P_{Gd}
2. Calculate \dot{w}_g - Eq. (C-3)
3. Calculate $\dot{w}(I-1,t)$ - Eq. (C-2)

4. Calculate $M_{gd}(t), V_{gd}(t)$ - Eq. (C-5)
5. Calculate $P(I-L, t)$ - Eq. (C-5)
6. Reiterate if necessary
7. Calculate $\dot{w}(I, t)$ - Eq. (C-1)
8. Calculate $M_{gu}(t), V_{gu}(t)$ - Eq. (C-4)
9. Calculate $P(I, t)$ - Eq. (C-4)
10. Reiterate if necessary

II. Gas Bubble Downstream of Venturi

We have the following relations:



Upstream flow determined by cavitating venturi flow, downstream pressure will be bubble pressure.

The injector flow will be calculated by

$$P(l, t) - P_c(t) = R_i \dot{w}(l, t) \cdot |\dot{w}(l, t)| + \frac{l i}{A_i g} \cdot \frac{\dot{w}(l, t) - \dot{w}(l, t-1)}{\Delta t} \quad (C-6)$$

and the flow in the line is:

$$P(B, t) - P(l, t) = R_l \dot{w}(l, t) \cdot |\dot{w}(l, t)| + \frac{l}{A_g} \cdot \frac{\dot{w}(l, t) - \dot{w}(l, t-1)}{\Delta t} \quad (C-7)$$

Solving these equations to eliminate $P(l, t)$ we have:

$$P(B, t) - P_c(t) = R_l \dot{w}(l, t) \cdot \dot{w}(l, t) - \frac{l}{A_g \Delta t} \dot{w}(l, t) + \frac{l}{A_g \Delta t} \dot{w}(l, t-1) - R_i \dot{w}(l, t) \cdot |\dot{w}(l, t)| - \frac{l i}{A_g \Delta t} \dot{w}(l, t) + \frac{l i}{A_g \Delta t} \dot{w}(l, t-1) = 0 \quad (C-8)$$

or

$$\begin{aligned}
 & (R_1 + R_2) \dot{w}(1, t) |w(1, t)| + \left(\frac{\ell i}{A_g \Delta I} + \frac{L}{A_g \Delta I} \right) \dot{w}(1, t) \\
 & - \left[P(B, t) - P_c(t) + \left(\frac{\ell i}{A_g \Delta t} + \frac{L}{A_g \Delta t} \right) \dot{w}(1, t-1) \right] = 0 \\
 & + \frac{\ell i}{\Delta t A_{1g}} (P(1, t-1) - P(B, t)) - 1 - \left[\frac{\ell i}{\Delta t A_{1g}} \right] \left(\frac{L}{A_g \Delta t} \right) (P(B, t) - P(B, t-1)) \quad (C-9)
 \end{aligned}$$

The pressure in the bubble is:

$$P(B, t) = \frac{M_{RT}}{V_B}, \quad V_B = V_T - \frac{(M_c + \Delta t \dot{w}(c, t))}{\rho} - \frac{(M_1 \Delta t \dot{w}(1, t))}{\rho} \quad (C-10)$$

The flows and pressures will be calculated as follows:

1. Estimate P_B
2. Calculate $\dot{w}(c, t)$ - Subroutine Cavent
3. Calculate $\dot{w}(1, t)$ - Eq. (C-9)
4. Calculate $V_B, P(B, t)$ - Eq. (C-10)
5. Reiterate if necessary
6. Calculate $P(I, t)$ - Eq. (C-7)

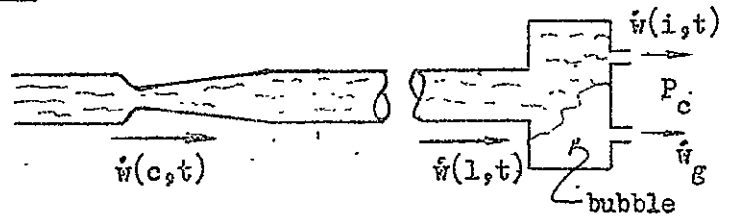
The length of the fluid column L will be calculated from $M_1(t-1)$ as follows:

$$L = \left(\frac{M_1(t-1)}{\rho} - V_i \right) \cdot \frac{1}{A} \quad (C-11)$$

The minimum value of L will be set to 1 inch to prevent computational difficulties.

III. Gas Bubble Passing Through Injector

It will be assumed that the bubble starts to flow into the combustion chamber when $M_1(t)/\rho$ falls below some level (set by data). The gas will flow through a fixed proportion of the injector area. Thus:



$$A_i = A_g + A_l \quad (C-12)$$

$$\dot{w}_g = f(P_B, P_c, A_g) \quad (C-13)$$

$$\dot{w}(i,t) = 27,807 A_l \sqrt{(P_B - P_c)} \quad (C-14)$$

$$\dot{w}(c,t) = f(\text{cavitating venturi}) \quad (C-15)$$

$$P_B = \frac{M_g(t) RT}{V_g(t)}, \quad M_g(t) = M_g(t-1) - \dot{w}_g \Delta t \quad (C-16)$$

$$V_g(t) = V_T - \frac{M_c + \Delta \dot{w}(c,t)}{\rho} + \frac{\Delta \dot{w}(i,t)}{\rho}$$

The calculation will proceed as follows:

1. Estimate P_B
2. Calculate $\dot{w}_g, \dot{w}(i,t)$ - Eq. (C-13), (C-10)
3. Calculate $\dot{w}(c,t)$ - Eq. (C-15)
4. Calculate P_B - Eq. (C-16)
5. Reiterate if necessary

IV. Distribution of Resistance

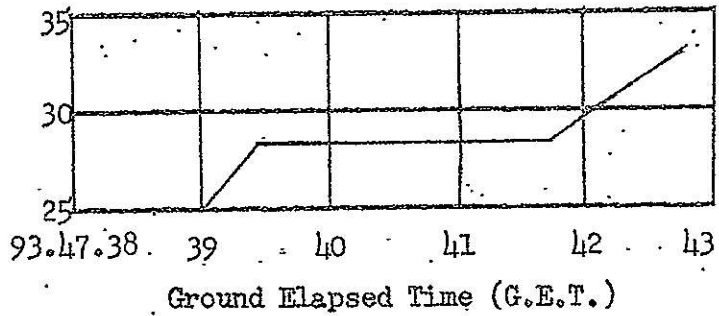
The resistance of the line between the cavitating venturi and the injector will be initially lumped at the injector end. All pressures and flows will be set equal. As the line downstream of the venturi starts

to fill with liquid the lumped resistance will be reduced and re-
sistance added to the upstream element.

Data Package

The anomaly started at a G.E.T. of 40:47:39.25, and is noted by a rise in oxidizer injector pressure. The period to be simulated in the model will be from 39.25 sec through 42.80 sec, the throttling transient during this period. The throttle position is related to command voltage by the relation

Percent Throttle
(100% = 10,500 lb thrust)



$$VDC = 0.116X + 1.12 \quad \text{where: } X = \text{Percent Throttle}$$

$$VDC = \text{Volts}$$

Using TRW data, the area time relations can be obtained for the injector:

<u>G.E.T.</u>	<u>Model Time (sec)</u>	<u>Throttle (%)</u>	<u>V.D.C.</u>	<u>Fuel Res.</u>	<u>Area</u>	<u>Oxidizer Res.</u>	<u>Area</u>
39.25	0	26.6	4.205	0.03384	0.195489	0.14904	0.092893
39.50	.250	28.3	4.403	0.03131	0.203234	0.13341	0.098459
41.80	2.550	28.3	4.403	0.03131	0.203234	0.13341	0.098459
42.80	3.550	33.0	4.948	0.02579	0.223938	0.10213	0.112530

Units -

$$\text{Res} = \text{lb}_F \text{ sec}^2 / \text{lb}_m \text{ in}^5$$

$$\text{Area} = \text{sq. in.}$$

The throat area of the cavitating venturi will be determined from the equation:

$$P_1 - P_2 = \frac{\dot{w}^2}{2g\rho} \left(\frac{1}{A_2^2} - \frac{1}{A_1^2} \right)$$

$$A_1 = 2.92 \text{ in}^2$$

$$g = 386 \frac{\text{LB}_m \text{ in}}{\text{LB}_F \text{ sec}^2}$$

$$\dot{w} = \text{Flowrate PPS}$$

$$\rho = \text{Density lb}_m/\text{in}^3$$

$$P_1 = \text{Upstream pres. 235 psia}$$

$$P_2 = \text{Vapor Pressure - psia}$$

$$A_2 = \text{Throat Area - in}^2$$

Solving for A_2 we obtain:

$$A_2 = \left[\frac{\dot{w}^2 A_1^2}{2g\rho A_1^2 (P_1 - P_2) + \dot{w}^2} \right]^{1/2}$$

The flowrates at various throttle settings will be determined as follows:

$$\dot{w}_I = \frac{10,500}{300} \cdot \frac{X}{100} = .35X$$

$$\dot{w}_O + \dot{w}_F = \dot{w}_t, \text{ and } \frac{\dot{w}_O}{\dot{w}_F} = 1.6$$

<u>Model Time</u>	<u>X</u>	<u>\dot{w}_t</u>	<u>\dot{w}_O</u>	<u>\dot{w}_F</u>	<u>A_f</u>	<u>A_o</u>
0	26.6	9.30	5.73	3.57	0.046646	0.059659
0.250	28.3	9.90	6.09	3.81	0.049781	0.063405
2.550	28.3	9.90	6.09	3.81	0.049781	0.063405
3.550	33.0	11.55	7.11	4.44	0.058009	0.074018

	<u>Fuel</u>	<u>Oxidizer</u>
ρ	0.0325	0.052
P_r	1.60	5.30

The size of the bubble is given in cubic inches and the model uses weight.
 The perfect gas law will be used to relate the two.

$$W_t = \frac{PV}{RT} = \frac{235 V}{\frac{18544}{4} \times 525}$$

$$= 9.6552 \times 10^{-5} V$$

Input Data

Time bubble starts through venturi

E (161)	0.410	Fuel
E (162)	0.001	Oxidizer

Initial bubble weight = $9.6552 \times 10^{-5} \times 30$

E (163)	0.00290	Fuel
E (164)	0.00290	Oxidizer

Ratio of liquid flow area to total injector flow area when bubble goes through injector

E (165)	0.1	Fuel
E (166)	0.1	Oxidizer

TABLE C-1

APOLLO DESCENT ENGINE COMPUTER MODEL
INPUT DATA - LM-3 FLIGHT ANOMALY

2	121	22	10.2		10.2	0.0	10.2	13.0	0000100,				
15.0			12.2		0.0	11.0	13.0	15.0	0000200,				
17.0			19.0		21.0	23.0	20.0	17.0	0000300,				
11.0			15.0		19.0	17.0	10.2		0000400,				
2	181	22	7.0		7.4	0.0	7.0	9.0	0000500,				
11.0			15.0		0.0	11.0	13.0	15.0	0000600,				
17.0			19.0		21.0	23.0	20.0	17.0	0000700,				
11.0			15.0		19.0	17.0	10.0		0000800,				
2	361	22	0.000112		0.016038	0.0	0.000112	0.000143	0000900,				
0.000165			0.000134		0.0	0.000121	0.000143	0.000165	0001000,				
0.000187			0.000209		0.000231	0.000253	0.000220	0.000187	0001100,				
0.000115			0.000157		0.000199	0.000178	0.000107		0001200,				
2	421	22	0.000039		0.000042	0.0	0.000039	0.000051	0001300,				
0.000062			0.000084		0.0	0.000062	0.000073	0.000084	0001400,				
0.000096			0.000107		0.000124	0.000129	0.000112	0.000096	0001500,				
0.000115			0.000156		0.000197	0.000176	0.000104		0001600,				
5	1	26		21	150.0	0.02779	0.008453	0.0	0004100,				
0.005			0.0		0.02	0.04	0.06	0.10	0004200,				
0.20			0.25		0.30	0.35	0.45	0.50	0004300,				
0.55			0.60		0.65	0.70	0.80	0.90	0004400,				
0.98			1.0		1.005				0004500,				
5	36	21	-0.2	E+06	0.293	E+06	2.82	E+06	3.04	E+06	3.07	E+06	0004600,
3.13	E+06		3.24	E+06	3.28	E+06	3.42	E+06	3.87	E+06	4.60	E+06	0004700,
4.88	E+06		5.03	E+06	5.02	E+06	4.86	E+06	4.55	E+06	3.63	E+06	0004800,
2.27	E+06		0.37	E+06	0.133	E+06	0.01	E+06					0004900,
5	66	21	15.0		41.5		115.0		131.5		132.9		0005000,
134.7			138.0		139.8		142.6		148.8		165.0		0005100,
171.3			175.8		178.1		176.8		171.1		152.0		0005200,
116.6			58.7		29.4		21.0						0005300,
5	96	21	0.816		0.818		0.826		0.833		0.841		0005400,
0.856			0.889		0.903		0.920		0.933		0.959		0005500,
0.967			0.974		0.978		0.973		0.964		0.922		0005600,
0.859			0.801		0.787		0.781						0005700,
3	201	5	323.0		235.0		0.0		235.0		10.0		0006800,
3	211	3	3.0		0.44		10.0						0006820,
3	221	9	108.0		0.046646		0.0		0.049781		0.250		0006840,
0.049781			2.550		0.058009		3.550						0006860,
3	231	9	201.0		0.195489		0.0		0.203234		0.250		0006880,
0.203234			2.550		0.223938		3.550						0006900,
3	301	5	323.0		236.0		0.0		236.0		10.0		0007000,
3	311	3	3.0		1.0		10.0						0007020,
3	321	9	108.0		0.059659		0.0		0.063405		0.250		0007040,

0.063405	2.550	0.074018	3.550			0007060,
3 331 9 201.0		0.092893	0.0	0.098459	0.250	0007080,
0.098459	2.550	0.112530	3.550			0007100,
3 401 5 1.0		45.0	0.375	0.62065	1.0	0007200,
3 433 5 1.0		30.0	0.25	0.31727	0.5	0007300,
-3 526 4 54.4		2557.0	0.0	1.7		0007400,
\$D1 IPR=3, IST=1, ICMT=3, NSEGF=22, NSEGO=22, DELT=170.0E-06,						ID=1000000,
AT=2*2.92,0,4*2.92,0,9*2.92,5*3.22,38*0,						ID=1000100,
CF=2*1.67E-06,0,4*1.67E-06,0,9*1.67E-06,5*1.24E-06,38*0,						ID=1000200,
AU=2*2.92,0,4*2.92,0,9*2.92,5*4.42,38*0,						ID=1000300,
CU=2*1.67E-06,0,4*1.67E-06,0,9*1.67E-06,5*1.57E-06,38*0,						ID=1000400,
IURF=2,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22,43*0,						ID=1000500,
IURU=2,5,6,7,10,11,12,13,14,15,16,17,18,19,20,21,22,43*0,						ID=1000600,
PF=8*45,15*235,37*0, WF=23*3.57,37*0,						ID=1000700,
PU=8*105,15*236,37*0, WD=23*5.73,37*0,						ID=1000800,
IVARIS=5,171,5,172,2,522,2,525,12*0,						ID=1001200,
IWT=1,201,101,301,401,402,403,404,						ID=1001300,
IP1=1,8,9,3*0,101,108,109,3*0,201,209,4*0,301,309,4*0,207,307,4*0,						ID=1001400,
B(3)=0.0325, B(4)=0.052, B(5)=530, B(6)=530,						ID=1001800,
B(7)=60000, B(8)=40500,						ID=1001900,
B(9)=0.0083446, B(10)=-4.1095, B(11)=0.0089489, B(12)=-3.62944,						ID=1002000,
B(13)=41.797, B(14)=92.016, B(15)=4, B(16)=4,						ID=1002100,
B(17)=1.67, B(18)=1.67, B(19)=1.05, B(20)=1.1, B(21)=10, B(22)=10,						ID=1002200,
B(23)=8.8889E-06, B(24)=2.0526E-05,						ID=1002300,
B(31)=0.691, B(32)=0.368, B(33)=0.75, B(34)=0.75,						ID=1002400,
E(161)=0.41, E(162)=0.001, E(163)=0.00290, E(164)=0.00290,						ID=1003000,
E(165)=0.1, E(166)=0.1,						ID=1003100,
CAVTAT(1,1,1)=8, CAVTAT(2,1,1)=2.92, CAVTAT(4,1,1)=0.1,						ID=1003200,
CAVTAT(1,1,2)=8, CAVTAT(2,1,2)=2.92, CAVTAT(4,1,2)=0.1,						ID=1003300,
AF(1)=2.5, AF(2)=2.5, AF(4)=2.5, AF(5)=2.5, AF(6)=2.5, AF(7)=2.5,						ID=1006000,
CKT1=0.0,						ID=1008000,
INDEX=56,						ID=1009000,
SEND						1100000,
APULLU DESCENT ENGINE						1200000,
EM-3 FLIGHT ANOMALY						1200100,
DATA CORRELATION						1200200,
						2000000,

TABLE C-II

APOLLO DESCENT ENGINE MODIFIED COMPUTER
SUBPROGRAM LISTINGS, LM-3 FLIGHT ANOMALY

FOR HOCKET,ROCKART
 UNIVAC 110A FORTRAN V LEVEL 2206 001# F301EH
 THIS COMPILATION WAS DONE ON 11 FEB 71 AT 15:15:47

SUBROUTINE ROCKET ENTRY POINT 002601

STORAGE USED (BLOCK, NAME, LENGTH)

```
0001 #CODE, 002740
0000 #DATA 000254
0002 #BLANK 000000
0003 DATUM1 043120
0004 DATUM2 000740
0005 DATUM3 001344
0006 DATUM4 000144
0007 CAL2 000740
0010 CAL3 000062
0011 CAL4 001441
0012 CAL5 000310
0013 CAL6 000360
0014 DIRECT 001214
```

EXTERNAL REFERENCES (BLOCK, NAME)

```
0015 COMBUS
0016 GETFLO
0017 SOLVE
0020 CAVENT
0021 GASFLO
0022 VENTRZ
0023 HERR25
0024 KRDUS
0025 HIO13
0026 HIO25
0027 SORT
0030 HERR33
```

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000131	100L	0001	002536	1000L	0001	000180	120L	0001	000106	137G	0001	000272	146L				
0000	000137	150F	0001	000323	160L	0001	000341	100L	0001	000044	20L	0001	000370	200L				
0001	000410	220L	0001	000437	240L	0001	000455	260L	0001	000574	260L	0001	000600	300L				
0001	001041	311G	0001	000700	320L	0001	000765	340L	0001	001010	360L	0001	000066	40L				
0001	001070	440L	0001	001767	444G	0001	001173	480L	0001	001314	500L	0001	002154	506G				
0001	001350	520L	0001	001367	540L	0001	001417	560L	0001	001610	620L	0001	001642	640L				
0001	001657	660L	0001	002002	700L	0001	002064	720L	0001	002113	740L	0001	002143	760L				
0001	002157	800L	0001	002174	900L	0001	002305	920L	0001	002318	940L	0001	002410	960L				
0001	002413	980L	0004	R	000000	A	0000	R	000113	AGAS	0012	R	000244	AGRAT				
0013	R	000000	AVFL	0000	D	000004	A1	0000	D	000000	B1	0005	R	000720	CAVTAT			
0012	R	000006	CDUM1	0012	R	000272	CDUM2	0000	D	000010	C1	0007	R	000000	C2CON			
0007	R	000360	C4CON	0007	R	000350	D	0012	R	000250	DENSITY	0000	R	000102	DLTPTB			
0004	R	000360	DUM1	0005	R	000000	DUM2	0005	R	000760	DUM3	0005	R	001004	DUM4			
0000	R	000006	DUM6	0006	R	000022	DUM7	0005	R	000620	ENGMAN	0000	R	000110	FLINER			
0012	R	000004	CCONPG	0014	R	000000	GETPLG	0000	I	000104	I	0014	I	000000	IDUM1			
0000	I	000055	IGO	0000	I	000063	II	0000	I	000074	IJD	0000	I	000087	IJK			
0000	I	000000	ISAVE	0000	I	000002	ISTEP	0000	I	000002	IS	0000	I	000064	J			
0011	I	000000	KCC	0000	I	000131	KL	0014	I	000502	LPILL	0000	I	000070	N			
0003	R	000000	P	0000	R	000073	PD	0000	R	000111	PDM4	0000	R	000060	PG			
															0001	000272	146L	
															0001	000370	200L	
															0001	000600	300L	
															0001	000066	40L	
															0001	002154	506G	
															0001	001642	640L	
															0001	002143	760L	
															0001	002410	960L	
															0000	R	000112	ALIQ
															0005	R	001010	CCDATA
															0007	R	000170	C3CON
															0000	R	000127	DT
															0000	R	000000	DUM5
															0001	H	000000	GASPLD
															0014	I	000612	IDUM2
															0000	I	000072	IJU
															0000	I	000117	K
															0001	I	000700	NSPD
															0012	R	000002	PHICOM

0000000000
0000000000
0000000000

0012 R 000000 PLVAP	0000 D 000012 PS	0000 D 000016 PF	0006 H 000020 PTGAM	0000 R 000071 PI
0004 R 000550 R	0012 R 000204 RDN	0000 R 000115 RDM	0000 H 000108 RMAX	0000 R 000105 RYOT
0012 R 000202 RLP	0010 R 000000 T	0012 R 000240 THRLK	0000 H 000112 TDM	0000 R 000125 TH
0006 R 000004 TLIG	0000 R 000123 TLD	0000 R 000111 TMAX	0000 H 000114 TMIN	0000 R 000121 TI
0000 R 000122 T2	0003 R 027140 V	0013 R 000170 VBAR	0000 R 000114 VDM	0000 R 000116 VLIQ
0000 R 000103 VOLBLB	0000 R 000100 VOIDM	0012 R 000260 VOLTOT	0000 R 000101 VOLLP	0012 R 000246 VDIRI
0012 R 000250 VOL2BL	0000 R 000120 V+FG	0003 R 013560 W	0000 R 000075 WXYT	0012 R 000254 WXTTAV
0000 R 000120 WHI	0000 R 000124 WLO	0000 R 000176 WMAX	0000 R 000175 WMIN	0011 R 000001 W-TORR
0012 R 000242 WTBBL	0000 R 000077 WTDGM	0000 R 000076 WTLIP	0012 R 000270 WTPCAV	0012 R 000260 WTPINJ
0012 R 000252 WTBUB	0004 R 000170 X	0000 R 000107 XDM	0000 R 000110 YN	

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00000 *DIAGNOSTIC* THE NAME IMAN APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED
00100 1* C J. ROEHLERIN * D586-112 * EX 2721 03600000
00101 2* SURROUTINE ROCKET (KA, KAM1, KAM2, DELT) 03600100
00101 3* C 03600200
00103 4* COMMON /DATM1/ P(60,50,2) , W(60,50,2) , V(60,50,2) 07600100
00103 5* 1 /DATM2/ A(60,2) , X(60,2) , DUM1(120) , 03600400
00103 6* 2 R(60,2) 03000500
00103 7* 3 /DATM3/ DUM2(400) , BKNMAN(8,4,2) , CAVTAT(4,4,2) , 03600600
00103 8* 4 DUM3(24) , CCDATA(11,4) , DUM4(176) 03600700
00103 9* 5 /DATM4/ DUM5(4) , TLIG(2) , DUM6(10) , 03600800
00103 10* 6 PTGAM(2) , DELT(2) 03600900
00103 11* C 03601000
00104 12* COMMON /CAL2/ C2CON(60,2) , C3CON(60,2) , C4CON(60,2) , 03601100
00104 13* 1 D(60,2) 03601200
00104 14* 2 /CAL3/ T(50) 03601300
00104 15* 3 /CAL4/ KCC , WSTORE(100,4,2) 03601400
00104 16* 4 /CAL5/ PLVAP(2) , PHICOM(2) , GCOMPG(2) , 03601500
00104 17* 5 CDUM1(154) , WTBUB(2) , WTBUBL(2) , AGRAT(2) , 03601600
00104 18* 6 VOL1BL(2) , VOL2BL(2) , WTBUB(2) , WDOTGV(2) , 03601700
00104 19* 7 DENSTY(2) , VOLTOT(2) , RUP(2) , RDN(2) , 03601800
00104 20* 8 WTPINJ(2) , WTPCAV(2) , CDUM2(14) , 03601900
00104 21* 9 /CAL6/ AVEL(60,2) , VBAR(60,2) 03602000
00104 22* C 03602100
00105 23* COMMON /DIRECT/ IDUM1(120) , NSRG(2) , LPILL(60,2) , 03602200
00105 24* 1 IDUM2(210) 03602300
00105 25* C 03602400
00106 26* DIMENSION IMAN(2) , ISAVE(2) , ISTEP(2) 03602500
00106 27* C 03602600
00107 28* DOUBLE PRECISION A1 , B1 , C1 03602700
00107 29* 1 PS(10) , PT(10) , 03602800
00107 30* C 03602900
00110 31* DATA ISTEP, ISAVE / 1, 1, 7, 7 / 03603000
00113 32* DATA II / 1 / 03603100
00113 33* C 03603200
00115 34* KCC = KCC + 1 03603300
00116 35* IF (KCC .GT. 100) KCC = 1 03603400
00116 36* C 03603500
00116 37* C CALCULATE COMBUSTION CHAMBER PRESSURE. 03603600
00116 38* C 03603700
00120 39* CCDATA(4,1) = WSTORE(KCC,1,1) / DELT 03603800
00121 40* WSTORE(KCC,1,1) = 0.0 03603900
00122 41* CCDATA(3,1) = WSTORE(KCC,1,2) / DELT 03604000
00123 42* WSTORE(KCC,1,2) = 0.0 03604100
00124 43* IF (CCDATA(4,1) .GT. 1.0E-10) GO TO 20 03604200
00126 44* CCDATA(5,1) = 1.0 03604300
00127 45* GO TO 40 03604400
00130 46* 20 CCDATA(5,1) = CCDATA(3,1) / CCDATA(4,1) 03604500
00130 47* 1 / (1.0 + CCDATA(3,1) / CCDATA(4,1)) 03604600
00131 48* IF (CCDATA(5,1) .LT. 0.0) CCDATA(5,1) = 0.0 03604700

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00133 49*      IF (CCDATA(5,1) .GT. 1.0)      CCDATA(5,1) = 1.0
00135 50*      40 CALL COMBUS (KA, KAM1, 1, DELT)
00135 51*      C
00135 52*      C      CALCULATE FLOW AND PRESSURES.
00135 53*      C
00136 54*      DO 1000          J = 1, 2
00141 55*      ENGMAN(7,1,J) = ENGMAN(8,1,J)
00142 56*      IGO = ISTEP(J)
00143 57*      GO TO (100, 200, 220, 300, 440, 540, 760, 800), IGO
00143 58*      C
00143 59*      C      CALCULATE FLOW FOR NORMAL OPERATION.
00143 60*      C
00144 61*      100 PG          = 2.0 * P(1,KAM1,J) - P(1,KAM2,J)
00145 62*      IJK          = 0
00146 63*      A1          = R(1,J) / D(1,J)
00147 64*      B1          = C3CON(1,J)
00150 65*      120 C1          = C4CON(1,J) - PG
00151 66*      W(1,KA,J) = GETFLO (A1, B1, C1)
00152 67*      ENGMAN(8,1,J) = W(1,KA,J) - 388.0 * ENGMAN(2,1,J) * (PG
00152 68*      1          - P(1,KAM1,J)) / (DELT * AVEL(1,J) ** 2)
00153 69*      P(1,KA,J) = CCDATA(2,1) + ENGMAN(8,1,J) * ABS(ENGMAN(R,1,J))
00153 70*      1          / (D(1,J) * (27.807 * ENGMAN(4,1,J)) ** 2)
00153 71*      2          + ENGMAN(3,1,J) * (ENGMAN(R,1,J) - ENGMAN(7,1,J))
00153 72*      3          / (388.0 * ENGMAN(4,1,J) * DELT)
00154 73*      135 IF (IJK .GT. 30)
00156 74*      CALL SOLVE (PG, P(1,KA,J), PS, IJK, 0.0001, 0.0005)      GO TO 140
00157 75*      IP (IJK - 100)          120, 120, 160
00162 76*      140 N          = 140.
00163 77*      WRITE (6,150) N, T(KA), J, PG, P(1,KA,J)
00172 78*      150 FORMAT (1H0 10X ITERATION ERROR IN ROCKET * * STATEMENT NO. 15,
00172 79*      1          2X'TIME =', PG, 0, 2X'J =', I2 / 11X'PG =', G13.6,
00172 80*      2          5X'PANS =', G13.6 )
00173 81*      160 GO TO (180, 180, 900, 900, 900, 900, 180), IGO
00174 82*      180 CALL CAVENT (KA, KAM1, KAM2, DELT, J)
00175 83*      IP (IGO .GT. 1)
00177 84*      IP (T(KA) .GT. TBUBBLE(J))          ISTEP(J) = 2      GO TO 900
00201 85*      GO TO 900
00201 86*      C
00201 87*      C      * INITIALIZE PARAMETERS FOR GAS IN CAVITATING VENTURI.
00201 88*      C
00202 89*      200 VOL1BL(J) = WTUBBL(J) * GCONPG(J) * TLIQ(J) / P(9,KAM1,J)
00203 90*      VOL2BL(J) = 0.0
00204 91*      WTUBBL(J) = WTUBBL(J)
00205 92*      WDOTGV(J) = 0.0
00206 93*      ISTEP(J) = 3
00206 94*      C
00206 95*      C      * CALCULATE GAS FLOW THROUGH CAVITATING VENTURI.
00206 96*      C
00207 97*      220 PU          = 2.0 * P(9,KAM1,J) - P(9,KAM2,J)
00210 98*      IJU          = 0
00211 99*      A1          = R(9,J) / D(9,J)
00212 100*      B1          = C3CON(9,J)
00213 101*      PD          = 2.0 * P(9,KAM1,J) - P(9,KAM2,J)
00214 102*      IJD          = 0
00215 103*      260 WDOT          = GASFLO (CAVTAT(3,1,J), PU, PD, GCONPG(J), TLIQ(J),
00216 104*      1          FTOAM(J))
00216 105*      WTOP          = WTUBBL(J) - 0.5 * (WDOT + WDOTGV(J)) * DELT
00217 106*      IP (WTOP .LT. 1.0E-10)          WTOP = 1.0E-10
00221 107*      WTOPK          = WTUBBL(J) - WTOP
00222 108*      W(8,KA,J) = C2CON(7,J) * PD / C3CON(7,J)
00223 109*      VOLDN          = VOL2BL(J) + 0.5 * (W(8,KA,J) + W(8,KAM1,J))
00223 110*      1          * DELT / D(7,J)
00224 111*      P(8,KA,J) = WTOPK * GCONPG(J) * TLIQ(J) / VOLDN

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00225 112*      IF (IJD .GT. 30)                                GO TO 240 03611100
00227 113*      CALL SOLVE (PD, P(8,KA,J), PT, IJD, 0.0001, 0.0005) 03611200
00230 114*      IP (IJD = 100)                                260, 260, 300 03611300
00233 115*      200 IJD = - 1                                03611400
00234 116*      N = 260                                     03611500
00235 117*      300 C1 = CACON(9,J) - PU                    03611600
00236 118*      W(9,KA,J) = GETPLO (A1, B1, C1)              03611700
00237 119*      VOLUP = VOLIBL(J) - 0.5 * (W(8,KA,J) + W(9,KAMI,J)) 03611800
00237 120*      * DELT / D(8,J)                             03611900
00240 121*      IF (VOLUP .LT. 1.0E-10) VOLUP = 1.0E-10 03612000
00242 122*      P(9,KA,J) = WTGUP * GCONPG(J) * TLIQ(J) / VOLUP 03612100
00243 123*      IP (IJU .GT. 10)                               GO TO 320 03612200
00245 124*      CALL SOLVE (PU, P(9,KA,J), PS, IJU, 0.0001, 0.0005) 03612300
00246 125*      IP (IJU .LT. 100)                             GO TO 240 03612400
00250 126*      320 IP (IJD .LT. 0)                           WRITE (8,150) N, T(KA), J, PG, 03612500
00250 127*      P(8,KA,J)                                    GO TO 340 03612600
00260 128*      IP (IJU .GT. 100)                               GO TO 340 03612700
00262 129*      N = 320                                       03612800
00263 130*      WRITE (8,150) N, T(KA), J, PG, P(9,KA,J) 03612900
00272 131*      340 DLTWTB = WTIBUB(J) - WTGU                03613000
00273 132*      WTIBUB(J) = WTGLP                            03613100
00274 133*      WDOTGV(J) = WDOT                             03613200
00275 134*      VOLIBL(J) = VOLUP                            03613300
00276 135*      VOLZBL(J) = VOLDN                            03613400
00277 136*      IP (WTIBUB(J) .LT. 2.0 * DLTWTB) ISTEP(J) = 4 03613500
00301 137*      GO TO 100                                     03613600
00301 138*      C * INITIALIZE CONDITIONS WHEN THE GAS BUBBLE IS THROUGH VENTURI 03613700
00301 139*      C                                           03613800
00301 140*      C                                           03613900
00302 141*      380 ISTEP(J) = 5                               03614000
00303 142*      DENSTY(J) = D(1,J)                            03614100
00304 143*      VOLBUB = WTIBUB(J) + GCONPG(J) * TLIQ(J) / P(8,KAMI,J) 03614200
00307 144*      VOLTOT(J) = ENGMAN(2,1,J)                    03614300
00306 145*      RUP(J) = 0.0                                  03614400
00307 146*      RDN(J) = 0.0                                  03614500
00310 147*      DO 400 I = 1, 7                               03614600
00313 148*      LPILL(I,J) = - 1                              03614700
00314 149*      VOLTOT(J) = VOLTOT(J) + A(1,J) * X(1,J) 03614800
00315 150*      400 RDN(J) = RDN(J) + R(1,J) / DENSTY(J) 03614900
00317 151*      RTOT = RDN(J)                                 03615000
00320 152*      WTPINJ(J) = (VOLTOT(J) - VOLBUB) * DENSTY(J) 03615100
00321 153*      WTPCAV(J) = 0.0                              03615200
00322 154*      WTIBUB(J) = WTIBUB(J)                       03615300
00323 155*      ISAVE(J) = 7                                  03615400
00323 156*      C                                           03615500
00323 157*      C * PERFORMANCE APTER BUBBLE HAS GONE THROUGH VENTURI. 03615600
00323 158*      C                                           03615700
00324 159*      440 I = ISAVE(J)                               03615800
00325 160*      RINJ = 1.0 / (27.007 * ENGMAN(4,1,J)) ** 2 / DENSTY(J) 03615900
00320 161*      XDUM = (WTPINJ(J) / DENSTY(J) - ENGMAN(2,1,J)) / A(1,J) 03616000
00327 162*      IP (XDUM .LT. 1.0) XDUM = 1.0                03616100
00331 163*      FLINER = (XDUM / A(1,J) + ENGMAN(3,1,J) / ENGMAN(4,1,J)) 03616200
00331 164*      / (386.0 * DELT)                             03616300
00332 165*      A1 = RINJ + RDN(J)                            03616400
00333 166*      B1 = FLINER                                    03616500
00334 167*      PDUM = FLINER * W(1,KAMI,J) - CCDA(2,1) 03616600
00335 168*      PG = 2.0 * P(1,KAMI,J) - P(1,KANZ,J) 03616700
00336 169*      IJK = 0                                       03616800
00337 170*      480 CALL VENTR2 (KA, KAMI, KANZ, RUP(J), PG, DELT, J) 03616900
00340 171*      C1 = PG + PDUM                                  03617000
00341 172*      W(1,KA,J) = GETPLO (A1, B1, C1)              03617100
00342 173*      480 VOLBUB = VOLTOT(J) - (WTPCAV(J) + 0.5 * DELT * (W(8,KA,J) 03617200
00342 174*      + W(8,KAMI,J))) / DENSTY(J) - (WTPINJ(J) - 0.5 * DELT 03617300

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00342 175*      2      * (W(I,KA,J) * W(I,KAM1,J)) / DENSTY(J)      03617400
00343 176*      P(I,KA,J) = WTBUB(J) * GCONPG(J) * TLIQ(J) / VOLBUB      04617500
00344 177*      IP (IJK .GT. 30)      GO TO 500      07617600
00346 178*      CALL SOLVE (PG, P(I,KA,J), PS, IJK, 0.0001, 0.0005)      07617700
00347 179*      IP (IJK = 100)      460, 480, 660      03617800
00352 180*      500 N      = 500      03617900
00353 181*      IP (PG .LT. 0.1)      GO TO 520      03618000
00355 182*      WRITE (6,150) N, T(KA), J, PG, P(I,KA,J)      03618100
00364 183*      520 P(I,KA,J) = 0.1      GO TO 660      07618200
00365 184*      520 P(I,KA,J) = 0.1      GO TO 660      03618300
00366 185*      C      03618400
00366 186*      C      * CALCULATION WHEN BUBBLE PASSES THROUGH INJECTOR.      03618500
00366 187*      C      03618600
00366 188*      C      03618700
00367 189*      540 IJK      = 0      03618800
00370 190*      I      = ISAVE(J)      03618900
00371 191*      PG      = 2.0 * P(I,KAM1,J) - P(I,KAM2,J)      03619000
00372 192*      ALIQ      = AGRAT(J) * ENGMAN(4,1,J)      03619100
00373 193*      AGAS      = ENGMAN(4,1,J) - ALIQ      03619200
00374 194*      560 WDOT      = GASFLO (AGAS, PG, CCDATA(2,1), GCONPG(J), TLIQ(J),      03619300
00374 195*      PTGAM(J)).      03619400
00375 196*      W(I,KA,J) = 27.807 * ALIQ * SORT(DENSTY(J))      03619500
00375 197*      I      * ABS(PG - CCDATA(2,1)))      03619600
00376 198*      IP (PG .LT. CCDATA(2,1))      W(I,KA,J) = 0.0      03619700
00400 199*      560 CALL VENTR2 (KA, KAM1, KAM2, RUP(J), PG, DELT, J)      03619800
00401 200*      VOLBUB      = VOLTOT(J) - (WTPCAV(J) + 0.5 * DELT * (W(0,KA,J)      03619900
00401 201*      I      + W(0,KA,J) - W(1,KA,J) - ENGMAN(7,1,J))) / DENSTY(J)      03620000
00402 202*      WTCUP      = WTIBUB(J) - 0.5 * (WDOT + WDOTGV(J)) * DELT      03620100
00403 203*      IP (VOLBUB .LT. 1.0E-04)      VOLBUB = 1.0E-04      03620200
00405 204*      IP (WTCUP .LT. 1.0E-12)      WTCUP = 1.0E-12      03620300
00407 205*      600 P(I,KA,J) = WTCUP * GCONPG(J) * TLIQ(J) / VOLBUB      03620400
00410 206*      IP (IJK .GT. 30)      GO TO 620      03620500
00412 207*      CALL SOLVE (PG, P(I,KA,J), PS, IJK, 0.0001, 0.0005)      03620600
00413 208*      IP (IJK = 100)      580, 580, 640      03620700
00416 209*      620 N      = 620      03620800
00417 210*      WRITE (6,150) N, T(KA), J, PG, P(I,KA,J)      03620900
00417 211*      C      03621000
00417 212*      C      * FINALIZE CONDITIONS DOWNSTREAM OF VENTURI.      03621100
00417 213*      C      03621200
00420 214*      640 WTIBUB(J) = WTCUP      03621300
00427 215*      WDOTGV(J) = WDOT      03621400
00430 216*      IP (VOLBUB .LT. 0.1)      ISTEP(J) = 7      03621500
00432 217*      660 WTPCAV(J) = WTPCAV(J) + 0.5 * DELT * (W(0,KA,J) + W(0,KAM1,J))      03621600
00433 218*      WTPINJ(J) = WTPINJ(J) + 0.5 * DELT * (W(1,KA,J) + W(1,KAM1,J))      03621700
00434 219*      IP (ISTEP(J) .LT. 6 .AND. WTPINJ(J) .LT. 1.0E-06)      03621800
00434 220*      I      ISTEP(J) = 0      03621900
00436 221*      ENGMAN(6,1,J) = W(1,KA,J)      03622000
00437 222*      VDUM      = 0.0      03622100
00440 223*      RDUM      = 0.0      03622200
00441 224*      RTOT      = 0.0      03622300
00442 225*      VLIC      = WTPCAV(J) / DENSTY(J)      03622400
00443 226*      DO 060      K = 1, 7      03622500
00440 227*      RTOT      = RTOT + R(K,J) / DENSTY(J)      03622600
00447 228*      P(K,KA,J) = P(I,KA,J)      03622700
00450 229*      680 W(K,KA,J) = W(1,KA,J)      03622800
00452 230*      K      = 7      03622900
00453 231*      700 VSEG      = A(K,J) * X(K,J)      03623000
00454 232*      W(K,KA,J) = W(0,KA,J)      03623100
00455 233*      IP (VDUM + VSEG .GT. VLIC)      GO TO 720      03623200
00457 234*      P(K,KA,J) = P(K-1,KA,J) - R(K,J) * W(0,KA,J) + ABS(W(0,KA,J))      03623300
00400 235*      VDUM      = VDUM + VSEG      03623400
00461 236*      RDUM      = RDUM + R(K,J) / DENSTY(J)      03623500
00462 237*      IP (K .EQ. 2)      GO TO 740      03623600
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00464 238*      K      = K - 1                                03623700
00465 239*                                           GO TO 700 03623800
00466 240*      T20 RUP(J) = RDM * (VLIQ - VDM) * R(K,J) / (VSEG * DENSITY(J)) 03623900
00467 241*      RDN(J) = RTOT - RUP(J)                                03624000
00470 242*      IF (RDN(J) .LT. 0.0)      RDN(J) = 0.0                03624100
00472 243*      ISAVE(J) = K                                           03624200
00473 244*                                           GO TO 900 03624300
00474 245*      T40 K      = I .                                     03624400
00475 246*      VSEG = A(I,J) * X(I,J)                                03624500
00476 247*      IF (VDM + VSEG .LT. VLIQ)      GO TO 720 03624600
00500 248*      RDN(J) = 0.0                                           03624700
00501 249*      RUP(J) = RTOT                                         03624800
00502 250*      W(I,KA,J) = W(B,KA,J)                                03624900
00503- 251*                                           GO TO 900 03625000
00501 252*      C
00503 253*      C * CALCULATE CONDITIONS WITH NO BUBBLE IN SYSTEM. 03625100
00503 254*      C
00504 255*      T60 ISTEP(J) = 0                                         03625200
00505 256*      DO T40      I = 1, 7                                03625300
00510 257*      T70 LPILL(I,J) = 0                                     03625400
00512 258*                                           GO TO 100 03625500
00513 259*      T80 IF (T(KA) .LT. 2.0 * DELT)      ISTEP(J) = 1    03625600
00515 260*                                           GO TO 100 03625700
00515 261*      C
00515 262*      C PUT INJECTOR FLOW INTO WSTORE ARRAY. 03625800
00515 263*      C
00516 264*      T90 PDUM = P(I,KAM1,J) - CCDATA(1,I)                03625900
00517 265*      IF (PDUM .LT. 1.0E-20)      PDUM = 1.0E-20          03626000
00521 266*      T1 = ENGMAN(5,II,J) / (27.807 * SQRT(PDUM / D(1,J))) 03626100
00521 267*      I + T(KAM1)                                           03626200
00522 268*      PDUM = P(I,KA,J) - CCDATA(2,II)                    03626300
00523 269*      IF (PDUM .LT. 1.0E-20)      PDUM = 1.0E-20          03626400
00525 270*      T2 = ENGMAN(5,II,J) / (27.807 * SQRT(PDUM / D(1,J))) 03626500
00525 271*      I + T(KA)                                           03626600
00526 272*      IF (T2 .LT. T1)                                           GO TO 920 03626700
00530 273*      TLO = T1                                           03626800
00531 274*      WLO = ENGMAN(7,II,J)                                03626900
00532 275*      THI = T2                                           03627000
00533 276*      WHI = ENGMAN(8,II,J)                                03627100
00534 277*                                           GO TO 940 03627200
00535 278*      TLO = T2                                           03627300
00530 279*      WLO = ENGMAN(8,II,J)                                03627400
00537 280*      THI = T1                                           03627500
00540 281*      WHI = ENGMAN(7,II,J)                                03627600
00541 282*      T90 DT = THI - TLO                                  03627700
00542 283*      XN = (TLO - T(KA)) / DELT + 1.0                    03627800
00543 284*      IF (XN .GE. 100.0 .OR. XN .LT. 1.0)      GO TO 1000 03627900
00545 285*      N = XN                                           03628000
00546 286*      KL = KCC * N                                           03628100
00547 287*      IF (KL .GT. 100)      KL = KL - 100                03628200
00551 288*      IF (DT .GT. 0.1 * DELT)      GO TO 960 03628300
00553 289*      WSTORE(KL,II,J) = WSTORE(KL,II,J) + 0.5 * (WHI + WLO) * DELT 03628400
00554 290*                                           GO TO 1000 03628500
00555 291*      T0UM = DELT / DT                                       03628600
00556 292*      T90 TMAX = T(KA) + N * DELT                          03628700
00557 293*      IF (TMAX .GT. THI)      TMAX = THI                    03628800
00561 294*      TMIN = T(KAM1) * N * DELT                            03628900
00562 295*      IF (TMIN .LT. TLO)      TMIN = TLO                    03629000
00564 296*      WMIN = ((TMIN - TLO) * (WHI - WLO) / DT + WLO) * T0UM 03629100
00565 297*      WMAX = ((TMAX - TLO) * (WHI - WLO) / DT + WLO) * T0UM 03629200
00566 298*      WSTORE(KL,II,J) = 0.5 * (WMIN + WMAX) * (TMAX - TMIN) 03629300
00566 299*      I + WSTORE(KL,II,J)                                03629400
00567 300*      IF (TMAX .GE. THI)      GO TO 1000 03629500

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00571 301*      IF (N .GT. 99)      GO TO 1000 03630000
00573 302*      N          = N + 1      03630100
00574 303*      KL          = KL + 1    03630200
00575 304*      IF (KL .GT. 100)      KL = 1 :      03630300
00577 305*      GO TO 990 01630400
00600 306*      1000 CONTINUE      . 03630500
00602 307*      RETURN .          03630600
00603 308*      END                03630700

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END OF UNIVAC 1104 FORTRAN V COMPILATION.
ROCKET      SYMBOLIC
ROCKET CODE  RELOCATABLE

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I. *DIAGNOSTIC* MESSAGE(S)
08 JAN 71 14:31:28  0 01537640 14 146 (DEFINED)
08 JAN 71 14:31:28  1 01543634 60  1 (DEFINED)
0 01541730 14  74

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UNIVERSITY MICROFILMS
SERIALS ACQUISITION
300 N ZEEB RD
ANN ARBOR MI 48106

Q FOR CAVENT,CAVENT
UNIVAC 1102 PORTMAN V LEVEL 2206 0016-F5012H
THIS COMPILATION WAS DONE ON 11 FEB 71 AT 19:15:54

SUBROUTINE CAVENT, ENTRY POINT 001151

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	001223
0000	*DATA	000252
0002	*BLANK	000000
0003	DATUM1	043120
0004	DATUM2	000740
0005	DATUM3	001344
0006	DATUM4	000144
0007	CAL1	000740
0010	CAL2	000740
0011	CAL3	000062
0012	CAL5	000310
0013	DIRECT	001214

EXTERNAL REFERENCES (BLOCK, NAME)

0014	GETFLO
0015	ERROR
0016	SOLVE
0017	BRANCH
0020	HEXP65
0021	NWD15
0022	NID15
0023	NID25
0024	SORT
0025	HERR25
0026	HERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000145	100L	0001	001132	1000L	0001	000248	120L	0001	000251	200L	0001	000363	220L					
0001	000365	300L	0001	000427	320L	0001	000501	340L	0001	000522	360L	0000	000003	370F					
0001	000604	380L	0001	000641	400L	0001	000708	420L	0001	000710	500L	0001	000722	520L					
0001	000746	540L	0001	000875	60L	0001	001011	660L	0001	001026	900L	0001	001047	920L					
0000	000103	930F	0001	001100	940L	0000	000113	950F	0004	R	000000	A	0000	D	000024	A1			
0000	D	000020	A2	0000	D	000030	B1	0000	D	000011	B2	0004	R	000360	C	0005	R	000720	CAVTAT
0012	R	000006	CDUM1	0000	D	000034	C1	0000	D	000016	C2	0010	R	000000	C2CON	0010	R	000170	C1CON
0010	R	000360	CACOM	0010	R	000450	D	0000	R	000000	DEQUAL	0000	D	000040	DUM	0000	R	000061	DUMCON
0005	R	000000	DUM1	0005	R	000760	DUM2	0006	R	000008	DUM3	0006	R	000022	DUM4	0000	R	000053	ER
0000	R	000054	ERN	0015	R	000000	ERROR	0007	R	000000	G	0012	R	000004	GCONPG	0014	R	000000	GETFLO
0000	I	000045	I	0013	I	000170	IBRAN	0013	I	000672	IDUM1	0000	I	000046	IERROR	0000	I	000042	IPLAO
0000	I	000047	IOO	0000	I	000050	IJK	0013	I	000000	IORDER	0000	I	000044	K	0013	I	000502	LFILL
0013	I	000500	HSEG	0003	R	000000	P	0007	R	000170	PRAR	0000	R	000057	PDUM	0000	R	000051	PO
0000	R	000060	PHI	0012	R	000002	PHICOM	0012	R	000000	PLVAP	0000	D	000000	PS	0006	R	000020	PTGAM
0004	R	000550	R	0008	R	000002	RHO	0000	R	000055	RHO1	0000	R	000056	RHO2	0011	R	000000	T
0008	R	000004	TLIQ	0003	R	027340	V	0007	R	000550	VOL	0003	R	013560	W	0007	R	000360	WAR
0000	R	000002	WDUM	0004	R	000170	X	0000	R	000052	XDUM								



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00100 1* C J. BOEHN (FIN # D596-112 * EX 2721 03800000
00101 2* SUBROUTINE CAVENT (KA, KAM1, KAM2, DFLT, J) 03800100
00101 3* C 03800200
00103 4* COMMON /DATUM1/ P(60,50,2) , W(60,50,2) , V(60,50,2) 03800300
00103 5* 1 /DATUM2/ A(60,2) , X(60,2) , C(60,2) 03800400
00103 6* 2 R(60,2) 03800500
00103 7* 3 /DATUM3/ DUM1(464) , CAVTAT(4,4,2) , DUM2(244) 03800600
00103 8* 4 /DATUM4/ DQUAL(2) , RHO(2) , TLIO(2) 03800700
00103 9* 5 DUM3(10) , PTCAN(2) , DUM4(82) 03800800
00103 10* C 03800900
00104 11* COMMON /CAL1/ G(60,2) , PBAR(60,2) , WBAR(60,2) , 03801000
00104 12* 1 VOL(60,2) 03801100
00104 13* 2 /CAL2/ C2CON(60,2) , C3CON(60,2) , C4CON(60,2) 03801200
00104 14* 3 D(60,2) 03801300
00104 15* 4 /CAL3/ T(50) 03801400
00104 16* 5 /CAL5/ PLVAP(2) , PHICON(2) , GCONPG(2) 03801500
00104 17* 6 CDUM1(194) 03801600
00104 18* C 03801700
00105 19* COMMON /DIRECT/ IORDER(60,2) , IBRAN(10,10,2) , N5PG(2) 03801800
00105 20* 1 LPILL(60,2) , IDUM1(210) 03801900
00105 21* C 03802000
00106 22* DOUBLE PRECISION PS(10) , A1 , A2 03802100
00106 23* 1 B1 , B2 , C1 , C2 03802200
00106 24* 2 DUM 03802300
00107 25* DIMENSION IFLAG(2) 03802400
00107 26* C 03802500
00107 27* C 03802600
00110 28* K = 1 03802700
00111 29* I = 8 03802800
00112 30* IP (I .LT. 1) GO TO 1000 03802900
00114 31* IERROR = 1 03803000
00115 32* IP (LPILL(I+1,J) .NE. 0) GO TO 1000 03803100
00117 33* IP (LPILL(I-1,J) .EQ. 0) GO TO 200 03803200
00117 34* C 03803300
00117 35* C * CALCULATE PRIMING WITHOUT CAVITATION. 03803400
00117 36* C 03803500
00121 37* IGO = 1 03803600
00122 38* IJK = 0 03803700
00123 39* PG = 2.0 * P(I,KAM1,J) - P(I,KAM2,J) 03803800
00124 40* XDUM = VOL(I-1,J) / A(I-1,J) 03803900
00125 41* IP (XDUM .GT. 0.01) GO TO 80 03804000
00127 42* XDUM = 0.01 03804100
00130 #DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL.
00130 43* IP (W(I,KAM1,J) .EQ. 0.0) W(I,KAM1,J) = W(I+1,KAM1,J) 03804200
00132 44* 80 A1 = R(I-1,J) * XDUM / (X(I-1,J) * D(I+1,J)) 03804300
00133 45* B1 = XDUM / (386.0 * DELT * A(I-1,J)) 03804400
00134 46* C1 = P(I-1,KA,J) - W(I,KAM1,J) * B1 03804500
00135 47* 100 DUM = CAVTAT(4,K,J) * PG - C1 03804600
00136 48* W(I-1,KA,J) = GETFLO(A1, B1, DUM) 03804700
00137 49* W(I,KA,J) = W(I-1,KA,J) 03804800
00140 50* P(I+1,KA,J) = C4CON(I+1,J) - C3CON(I+1,J) * W(I,KA,J) 03804900
00140 51* 1 - R(I+1,J) * W(I,KA,J) * ABS(W(I,KA,J)) / D(I+1,J) 03805000
00141 52* P(I,KA,J) = CAVTAT(4,K,J) * P(I+1,KA,J) 03805100
00142 53* IP (IJK .GT. 30) GO TO 120 03805200
00144 54* ER = ERROR(PG) 03805300
00145 55* ERM = 5.0 * ER 03805400
00146 56* CALL SOLVE (PG, P(I,KA,J), PS, IJK, ER, ERM) 03805500
00147 57* IP (IJK - 100) 100, 300, 300 03805600
00152 58* 120 IERROR = 2 03805700
00153 59* GO TO 300 03805800
00153 60* C 03805900
00153 61* C * CALCULATE NORMAL FLOW WITHOUT CAVITATION. 03806000
00153 62* C 03806100

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NOT REPRODUCIBLE

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00154 63* 200 A2 = R(I+1,J) / D(I+1,J) 03806200
00155 64* BZ = C1CON(I-1,J) + C1CON(I+1,J) + CAVTAT(4,K,J) 03806100
00156 65* CZ = C2CON(I+1,J) + C2CON(I,J) + C1CON(I-1,J) 03806400
00157 66* W(I,KA,J) = GETFLD(AZ, BZ, CZ) 03806500
00160 67* P(I,KA,J) = C1CON(I-1,J) * (W(I,KA,J) - C2CON(I,J)) 03806600
00161 68* P(I+1,KA,J) = P(I,KA,J) + W(I,KA,J) + CAVTAT(4,K,J) 03806700
00162 *DIAGNOSTIC* THE TEST FOR EQUALITY BETWEEN NON-INTEGERS MAY NOT BE MEANINGFUL
00162 69* IF (W(I,KAM1,J) .NE. 0.0) GO TO 220 03806900
00164 70* IP (DABS(C1) .GT. 1.0E-06 = ABS(C4CON(I,J))) GO TO 220 03806900
00166 71* W(I,KA,J) = 0.0
00167 72* P(I,KA,J) = P(I,KAM1,J) 03807100
00170 73* 220 IGO = 2 03807200
00170 74* C 03807300
00170 75* C * CHECK TO SEE IF CAVITATION IS OCCURRING 03807400
00170 76* C 03807500
00171 77* 300 RHO1 = D(I+1,J) 03807600
00172 78* PG = 2.0 * P(I+1,KAM1,J) - P(I+1,KAM2,J) 03807700
00173 79* IF (PG .LT. PLVAP(J)) PG = 1.0 + PLVAP(J) 03807800
00175 80* IF (DEQUAL(J) .GT. 1.0E-20) GO TO 320 03807900
00177 81* RHO2 = D(I+1,J) 03808000
00200 82* GO TO 340 03808100
00201 83* 320 PDM = 180.0 - PLVAP(J) 03808200
00202 84* PHI = (DEQUAL(J) - G(I,J)) * (1.0 + PHICON(J)) / PDM 03808300
00202 85* I = / (1.0 + G(I,J)) 03808400
00203 86* IF (PHI .LT. 0.0) PHI = 0.0 03808500
00205 87* RHO2 = (1.0 + PHI) / (1.0 / RHO(J) + PHI * GCONPG(J)) 03808600
00205 88* 1 * TLIQ(J) * (PLVAP(J) / PDM) ** ((PTGAM(J) - 1.0) 03808700
00205 89* 2 / PTGAM(J)) / PDM 03808800
00206 90* 340 DUMCON = 772.0 / (1.0 / (RHO2 * CAVTAT(1,K,J)) ** 2 03808900
00206 91* 1 = 1.0 / (RHO1 * CAVTAT(2,K,J)) ** 2) 03809000
00207 92* 360 WDM = DUMCON * (PG / RHO1 - PLVAP(J) / RHO2) 03809100
00210 93* IF (WDM .LT. 0.0) WRITE (6,370) T(KA), J, I, IJK, 03809200
00210 94* 1 PG, WDM 03809300
00221 95* 370 FORMAT (1H'10X' TIME =', F9.6, 3X', J =', I2, 3X', I =', I3, 3X', IJK =', 03809400
00221 96* 1 I3, 3X', PG =', G15.6, 3X', WDM =', G15.6) 03809500
00222 97* IF (WDM .LT. 0.0) WDM = 0.0 03809600
00224 98* WDM = SORT(WDM) 03809700
00225 99* GO TO (380, 380, 400, 400), IGO 03809800
00226 100* 380 IF (WDM .GE. W(I,KA,J)) GO TO 540 03809900
00230 101* IGO = IGO + 2 03810000
00231 102* IERROR = 1 03810100
00232 103* IJK = 0 03810200
00233 104* PG = 2.0 * P(I+1,KAM1,J) - P(I+1,KAM2,J) 03810300
00234 105* GO TO 360 03810400
00234 106* C 03810500
00234 107* C * CALCULATE UPSTREAM FLOW AND PRESSURE WITH CAVITATION. 03810600
00234 108* C 03810700
00235 109* 400 W(I,KA,J) = WDM 03810800
00236 110* P(I+1,KA,J) = C4CON(I+1,J) - C3CON(I+1,J) * WDM - R(I+1,J) 03810900
00236 111* I * WDM * ABS(WDM) 03811000
00237 112* IF (IJK .GT. 30) GO TO 420 03811100
00241 113* CALL SOLVE (PG, P(I+1,KA,J), PS, IJK, 0.0001, 0.0005) 03811200
00242 114* IF (IJK - 100) 360, 300, 500 03811300
00245 115* 420 IERROR = 3 03811400
00246 116* 500 GO TO (380, 380, 520, 880), IGO 03811500
00246 117* C 03811600
00246 118* C * CALCULATE DOWNSTREAM PRESSURE DURING PRIMING. 03811700
00246 119* C 03811800
00247 120* 520 W(I-1,KA,J) = WDM 03811900
00250 121* W(I,KA,J) = WDM 03812000
00251 122* P(I,KA,J) = A1 * WDM * ABS(WDM) + B1 * WDM + C1 03812100
00252 123* 540 IF (IGO .EQ. 2) GO TO 900 03812200
00254 124* 03812300

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00255 125*      IF (J .EQ. 2)      IFLAG(1) = - IFLAG(1)      03#12400
00257 126*      IFLAG(2) = 100 + I      03#12500
00260 127*      CALL BRANCH (KA, RAN1, RAN2, DFLT, IFLAG)      03#12600
00261 128*      IF (LFILE(I-1,J) .EQ. 1)      GO TO 900      03#12700
00263 129*      LFILE(I-1,J) = 2      03#12800
00264 130*      GO TO 900      03#12900
00264 131*      C      03#13000
00264 132*      C      *      CALCULATE DOWNSTREAM PRESSURE, AND FINISH THIS CASE      03#13100
00264 133*      C      03#13200
00265 134*      READ P(I,KA,J) = C1CON(I-1,J) + (RDXM - C2CON(I,J))      03#13300
00265 135*      C      03#13400
00266 136*      900 W(I+1,KA,J) = W(I,KA,J)      03#13500
00267 137*      GO TO (1000, 920, 940), IFFLOW      03#13600
00270 138*      920 WRITE (6, 970) T(KA), I, J, P(I,KA,J), W(I,KA,J)      03#13700
00277 139*      930 FORMAT (1H0 10X AN ERROR OCCURRED IN SUBROUTINE CAVENT AT TIME'      03#13800
00277 140*      1      F9.0, ', SEGMENT NO. ', I3, ', J = ', I2 / 11X 'THE CALCULATED'      03#13900
00277 141*      2      1X 'PRESSURE WAS' G13.6, 5X 'THE FLOW WAS' G13.6,      03#14000
00277 142*      3      5X 'NO CAVITATION OCCURRED' )      03#14100
00300 143*      GO TO 1000      03#14200
00301 144*      940 WRITE (6, 950) T(KA), I, J, PG, P(I+1,KA,J), W(I,KA,J)      03#14300
00311 145*      950 FORMAT (1H0 10X AN ERROR OCCURRED IN THE CAVITATION CALCULATION'      03#14400
00311 146*      1      1X 'AT TIME' F9.0, ', SEGMENT NO. ', I3, ' AND J = ', I2 /      03#14500
00311 147*      2      11X 'PG = ' G13.6, 5X 'PANS = ' G13.6, 5X 'FLOW = ' G13.6 )      03#14600
00312 148*      1000 CONTINUE      03#14700
00313 149*      RETURN      03#14800
00314 150*      END      03#14900

```

```

END OF UNIVAC 1108 FORTRAN V COMPILATION.      2 *DIAGNOSTIC MESSAGE(S)
CAVENT      .SYMBOLIC      06 JAN 71 14:31:04      0      01462426      14      150      (DFLTFD)
CAVENT CODE      .RELOCATABLE      06 JAN 71 14:31:04      1      01466512      60      1      (DFLTFD)
                                0      01466606      14      74

```



FOR GASFLO,GASFLO
 UNIVAC 1108 FORTRAN V LEVEL 2206.001R F5014H
 THIS COMPILATION WAS DONE ON 11 FEB 71 AT 19:15:57

11 FEB 71

19 15:57

FUNCTION GASFLO ENTRY POINT 000205

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000215
 0000 *DATA 000023
 0002 *BLANK 000000

EXTERNAL REFERENCES (BLOCK, NAME)

0003 NEXPBS
 0004 SORT
 0005 HERR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000034 100L 0001 000112 500L 0001 000122 600L 0000 R 000001 CRPR 0000 R 000000 GASFLO
 0000 R 000002 PR

```

00100 1* C THIS FUNCTION SUBPROGRAM WILL CALCULATE THE GAS FLOWRATE 03900000
00100 2* C THROUGH AN ORIFICE. THE VALUE OF THE FUNCTION IS THE FLOWRATE IN 03900100
00100 3* C POUNDS PER SECOND. 03900200
00100 4* C 03900300
00100 5* C R SPECIFIC GAS CONSTANT * * LBS-P INCH / LBS-M DEGREES R 03900400
00100 6* C T GAS INLET TEMPERATURE * * DEGREES RANKINE 03900500
00100 7* C GAMMA RATIO OF SPECIFIC HEATS 03900600
00100 8* C PUP UPSTREAM PRESSURE * * PSIA 03900700
00100 9* C PDOWN DOWNSTREAM PRESSURE * * PSIA 03900800
00100 10* C CDA EFFECTIVE AREA OF ORIFICE HES 03900900
00100 11* C 03901000
00101 12* C FUNCTION GASFLO(CDA, PUP, PDOWN, R, T 03901100
00101 13* C 03901200
00103 14* C CRPR = (2.0 / (GAMMA + 1.0)) ** (A - 1.0) 03901300
00104 15* C IP (PDOWN .GT. PUP) GO TO 500 03901400
00106 16* C IP (PUP .GT. 0.0) GO TO 100 03901500
00110 17* C GASFLO = 0.0 03901600
00111 18* C RETURN 03901700
00112 19* 100 PR = PDOWN / PUP 03901800
00113 20* C IP (PR .LT. CRPR) PR = 03901900
00115 21* C GASFLO = CDA * SORT(772.17 * GAMMA 03902000
00115 22* 1 * (PR ** (2.0 / GAMMA) - PR 1.0) / GAMMA)) 03902100
00115 23* 2 / ((GAMMA - 1.0) * R * T)) 03902200
00116 24* C RETURN 03902300
00117 25* 500 IP (PDOWN .GT. 0.0) GO TO 800 03902400
00121 26* C GASFLO = 0.0 03902500
00122 27* C RETURN 03902600
00123 28* 600 PR = PUP / PDOWN 03902700
00124 29* C IP (PR .LT. CRPR) PR = 03902800
00126 30* C GASFLO = - CDA * SORT(772.17 * GAM 2 03902900
00126 31* 1 * (PR ** (2.0 / GAMMA) - PR 1.0) / GAMMA)) 03903000

```

```

00126 32*      2      / ((GAMA - 1.0) * R * T)
00127 33*      RETURN
00130 34*      END

```

```

01901100
01901200
03901100

```

END OF UNIVAC 1108 PORTMAN V COMPILATION. 0 *DIAGNOSTIC* MESSAGE(S)

UNIVERSITY OF MICHIGAN
LIBRARY

FOR VENTR2, VENTR2
UNIVAC 110A FORTRAN V LEVEL 2206 001A F501MH
THIS COMPILATION WAS DONE ON 11 FEB 71 AT 19:15:5

11 FEB 71

19:15:54

SUBROUTINE VENTR2 ENTRY POINT 000702 .

STORAGE USED (BLOCK, NAME, LENGTH)

0001	*CODE	000753
0000	*DATA	000245
0002	*BLANK	000000
0003	DATUM1	043120
0004	DATUM2	000740
0005	DATUM3	001744
0006	DATUM4	000144
0007	CAL1	000740
0010	CAL2	000740
0011	CAL3	000062
0012	CAL5	000310
0013	DIRECT	001214

EXTERNAL REFERENCES (BLOCK, NAME)

0014	GETFLO
0015	SOLVE
0016	BRANCH
0017	NEXP6S
0020	NWDUS
0021	NIO1S
0022	NIO2S
0023	SORT
0024	HERR2S
0025	HERR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000661	1000L	0001	000157	320L	0001	000231	340L	0001	000252	360L	0000	000056	370F					
0001	000334	380L	0001	000371	400L	0001	000438	420L	0001	000440	500L	0001	000452	520L					
0001	000476	540L	0001	000541	880L	0001	000555	900L	0001	000576	920L	0000	000076	930F					
0001	000627	940L	0000	000136	950F	0004	R	000000	A	0000	D	000024	A1	0000	D	000026	A2		
0000	D	000030	B1	0000	D	000032	B2	0004	R	000360	C	0005	R	000720	CAVTAT	0012	R	000006	CDUM1
0000	D	000034	C1	0000	D	000036	C2	0010	R	000000	C2CON	0010	R	000170	C3CON	0010	R	000360	C4CON
0010	R	000550	D	0006	R	000000	DEQUAL	0000	R	000054	DUMCON	0005	R	000000	DUM1	0005	R	000760	DX42
0006	R	000006	DUM3	0006	R	000022	DUM4	0007	R	000000	Q	0012	R	000004	QCONPG	0014	R	000000	GETFLO
0000	I	000046	F	0013	I	000176	IBRAX	0013	I	000672	IDUM1	0000	I	000043	IERROR	0000	I	000040	IFLAG
0000	I	000044	IGO	0000	I	000045	IJK	0013	I	000000	IORDER	0000	I	000042	K	0013	I	000502	LFILL
0013	I	000500	NSEQ	0003	R	000000	P	0007	R	000170	PBAR	0000	R	000052	PCUM	0000	R	000050	PG
0000	R	000053	PHI	0012	R	000002	PHICON	0012	R	000000	PLVAP	0000	D	000000	PS	0006	R	000020	PTGAM
0004	R	000550	R	0006	R	000002	RHO	0000	R	000047	RHO1	0000	R	000051	RHO2	0011	R	000000	T
0006	R	000004	TLIQ	0003	R	027340	V	0007	R	000550	VOL	0003	R	013560	W	0007	R	000360	WBAR
0000	R	000055	WDM	0004	R	000170	X												

00000 *DIAGNOSTIC* THE VARIABLE, A1, IS REFERENCED IN THIS PROGRAM, BUT IS NOWHERE ASSIGNED A VALUE.
00000 *DIAGNOSTIC* THE VARIABLE, B1, IS REFERENCED IN THIS PROGRAM, BUT IS NOWHERE ASSIGNED A VALUE.


```

00000 *DIAGNOSTIC* THE VARIABLE, C1, IS REFERENCED IN THIS PROGRAM, BUT IS NOWHERE ASSIGNED A VALUE
00000 *DIAGNOSTIC* THE NAME DUM APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED
00100 1* C J. BOHRNIEK * D596-112 * FK ZT21 01700000
00101 2* SUBROUTINE VENTREZ (KA, KAM1, KAM2, RFS, PDOWN, DFLT, J) 01700100
00101 3* C 01700200
00101 4* COMMON /DATE1/ P(60,50,2) , D(60,50,2) , V(60,50,2) 01700100
00103 5* 1 /DATE2/ A(60,2) , X(60,2) , C(60,2) 01700400
00103 6* 2 N(60,2) 01700500
00103 7* 3 /DATE3/ DM4(404) , CAVTAT(4,4,2) , DUM2(244) 01700600
00103 8* 4 /DATE4/ DSDA(4,2) , RHO(2) , TL10(2) 01700700
00101 9* 5 DUM1(10) , PTOAM(2) , DUM4(42) 01700800
00103 10* C 01700900
00104 11* COMMON /CAL1/ G(60,2) , PBAH(60,2) , WBAH(60,2) 01701000
00104 12* 1 VOL(60,2) 01701100
00104 13* 2 /CAL2/ C2CON(60,2) , C1CON(60,2) , C4CON(60,2) 01701200
00104 14* 3 D(60,2) 01701300
00104 15* 4 /CAL3/ Y(50) 01701400
00104 16* 5 /CAL5/ PLVAP(2) , PHICON(2) , GCONPG(2) 01701500
00104 17* 6 DUM4(104) 01701600
00104 18* C 01701700
00105 19* COMMON /DIRFCT/ TOROFR(60,2) , IFRAN(10,10,2) , HSEQ(2) 01701800
00105 20* 1 LPILL(60,2) , IDUM1(210) 01701900
00105 21* C 01702000
00106 22* DOUBLE PRECISION PS(10) , A1 , A2 01702100
00106 23* 1 B1 , B2 , C1 , C2 01702200
00106 24* 2 DUM 01702300
00107 25* DIMENSION IFLAG(2) 01702400
00107 26* C 01702500
00107 27* C 01702600
00110 28* K = 1 01702700
00111 29* IERROR = 1 01702800
00112 30* IGO = 1 01702900
00113 31* IJK = 0 01703000
00114 32* I = 0 01703100
00114 33* C 01703200
00114 34* * CALCULATE NORMAL FLOW WITHOUT CAVITATION. 01703300
00114 35* C 01703400
00115 36* 200 A2 = R(0,J) / D(9,J) + RES 01703500
00116 37* B2 = C3CON(9,J) + CAVTAT(4,1,J) 01703600
00117 38* C2 = C4CON(9,J) - PDOWN 01703700
00120 39* W(I,KA,J) = GETFLO(A2, B2, C2) 01703800
00121 40* IP (W(I,KA,J) .LT. 0.0) W(I,KA,J) = 0.0 01703900
00123 41* P(9,KA,J) = C4CON(9,J) - C3CON(9,J) * W(I,KA,J) 01704000
00123 42* 1 - R(0,J) * W(I,KA,J) * ABS(W(I,KA,J)) / D(9,J) 01704100
00124 43* 220 IGO = 2 01704200
00124 44* C 01704300
00124 45* * CHECK TO SEE IF CAVITATION IS OCCURRING. 01704400
00124 46* C 01704500
00125 47* 300 RHO1 = D(I+1,J) 01704600
00126 48* PG = 2.0 * P(I+1,KAM1,J) - P(I+1,KAM2,J) 01704700
00127 49* IP (PG .LT. PLVAP(J)) PG = 1.0 + PLVAP(J) 01704800
00131 50* IP (DEQUAL(J) .GT. 1.0E-20) GO TO 320 01704900
00133 51* RHO2 = D(I+1,J) 01705000
00134 52* GO TO 340 01705100
00135 53* 320 PDUM = 160.0 - PLVAP(J) 01705200
00136 54* PHI = (DEQUAL(J) - G(I,J)) * (1.0 + PHICON(J) / PDUM) 01705300
00136 55* 1 / (1.0 + G(I,J)) 01705400
00137 56* IP (PHI .LT. 0.0) PHI = 0.0 01705500
00141 57* RHO2 = (1.0 + PHI) / (1.0 / RHO(J) + PHI * DCONPG(J) 01705600
00141 58* 1 * TL10(J) * (PLVAP(J) / PDUM) ** ((PTOAM(J) - 1.0) 01705700
00141 59* 2 / PTOAM(J)) / PDUM 01705800
00142 60* 340 DUMCON = 772.0 / (1.0 / (RHO2 * CAVTAT(3,K,J)) ** 2 01705900
00142 61* 1 - 1.0 / (RHO1 * CAVTAT(2,K,J)) ** 2) 01706000

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NOT REPRODUCIBLE

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00141 62* 380 WDXM = DOWN * (PG / RHO1 - P(VAP(J) / RHO2) 03706100
00144 63* IP (WDXM .LT. 0.0) WRITE (6,370) T(KA), J, I, IJK, 03706200
00144 64* I PG, WDXM 03706400
00155 65* 370 FORMAT (1H0 10X'TIME =', P9.6, 3X'J =', I2, 3X'I =', I3, 3X'IJK =', 03706400
00155 66* I 13, 3X'PG =', G15.6, 3X'WDXM =', G15.6 ) 03706500
00156 67* IP (WDXM .LT. 0.0) WDXM = 0.0 03706600
00160 68* WDXM = SORT(WDXM) 03706700
00161 69* GO TO (3*0, 3*0, 400, 400), IGO 03706800
00162 70* 380 IF (WDXM .GE. W(I,KA,J)) GO TO 540 03706900
00164 71* IGO = IGO + 2 03707000
00165 72* IERROR = I 03707100
00166 73* IJK = 0 03707200
00167 74* PG = 2.0 * P(I+1,KAM1,J) - P(I+1,KAM2,J) 03707300
00170 75* GO TO 360 03707400
00170 76* C 03707500
00170 77* C * CALCULATE UPSTREAM FLOW AND PRESSURE WITH CAVITATION. 03707600
00170 78* C 03707700
00171 79* 400 W(I,KA,J) = WDXM 03707800
00172 80* P(I+1,KA,J) = CACON(I+1,J) - C3CON(I+1,J) * WDXM - R(I+1,J) 03707900
00172 81* I * WDXM * ABS(WDXM) 03708000
00173 82* IP (IJK .GT. 30) GO TO 420 03708100
00175 83* CALL SOLVE (PG, P(I+1,KA,J), PS, IJK, 0.0001, 0.0005) 03708200
00176 84* IP (IJK - 100) 380, 380, 500 03708300
00201 85* 420 IERROR = 3 03708400
00202 86* 500 GO TO (380, 380, 520, 880), IGO 03708500
00202 87* C 03708600
00202 88* C * CALCULATE DOWNSTREAM PRESSURE DURING PRIMING. 03708700
00202 89* C 03708800
00203 90* 520 W(I-1,KA,J) = WDXM 03708900
00204 91* W(I,KA,J) = WDXM 03709000
00205 92* P(I,KA,J) = A1 * WDXM * ABS(WDXM) + B1 * WDXM + C1 03709100
00206 93* 540 IP (IGO .EQ. 2) GO TO 900 03709200
00210 94* IFLAG(1) = I + 1 03709300
00211 95* IP (J .EQ. 2) IFLAG(1) = - IFLAG(1) 03709400
00213 96* IFLAG(2) = 100 * I 03709500
00214 97* CALL BRANCH (KA, KAM1, KAM2, DELT, IFLAG) 03709600
00215 98* IP (LFILL(I-1,J) .EQ. 1) GO TO 500 03709700
00217 99* LPILL(I-1,J) = 2 03709800
00220 100* GO TO 900 03709900
00220 101* C 03710000
00220 102* C * CALCULATE DOWNSTREAM PRESSURE, AND FINISH THIS CASE. 03710100
00220 103* C 03710200
00221 104* 880 P(I,KA,J) = PDOWN + RES * W(I,KA,J) * ABS(W(I,KA,J)) 03710300
00221 105* C 03710400
00222 106* 900 W(I+1,KA,J) = W(I,KA,J) 03710500
00223 107* GO TO (1000, 920, 940), IERROR 03710600
00224 108* 920 WRITE (6, 930) T(KA), I, J, P(I,KA,J), W(I,KA,J) 03710700
00233 109* 930 FORMAT (1H0 10X'AN ERROR OCCURRED IN SUBROUTINE CAVENT AT TIME' 03710800
00233 110* I P9.6, ', SEGMENT NO.' I3, ', J =', I2 / 11X'THE CALCULATED' 03710900
00233 111* 2 1X'PRESSURE WAS' G13.6, 5X'THE FLOW WAS' G13.6, 03711000
00233 112* 3 5X'NO CAVITATION OCCURRED' ) 03711100
00234 113* GO TO 1000 03711200
00235 114* 940 WRITE (6,950) T(KA), I, J, PG, P(I+1,KA,J), W(I,KA,J) 03711300
00245 115* 950 FORMAT (1H0 10X'AN ERROR OCCURRED IN THE CAVITATION CALCULATION' 03711400
00245 116* I 1X'AT TIME' P9.6, ', SEGMENT NO.' I3, ' AND J =', I2 / 03711500
00245 117* 2 11X'PG =', G13.6, 5X'PANS =', G13.6, 5X'FLOW =', G13.6 ) 03711600
00246 118* 1000 CONTINUE 03711700
00247 119* RETURN 03711800
00250 120* END 03711900

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 4 *DIAGNOSTIC* MESSAGE(S)

DATE: 11/12/71
TIME: 14:27:17

APOLLO DESCENT ENGINE
LM-3 FLIGHT ANOMALY

DATA CORRELATION

0191

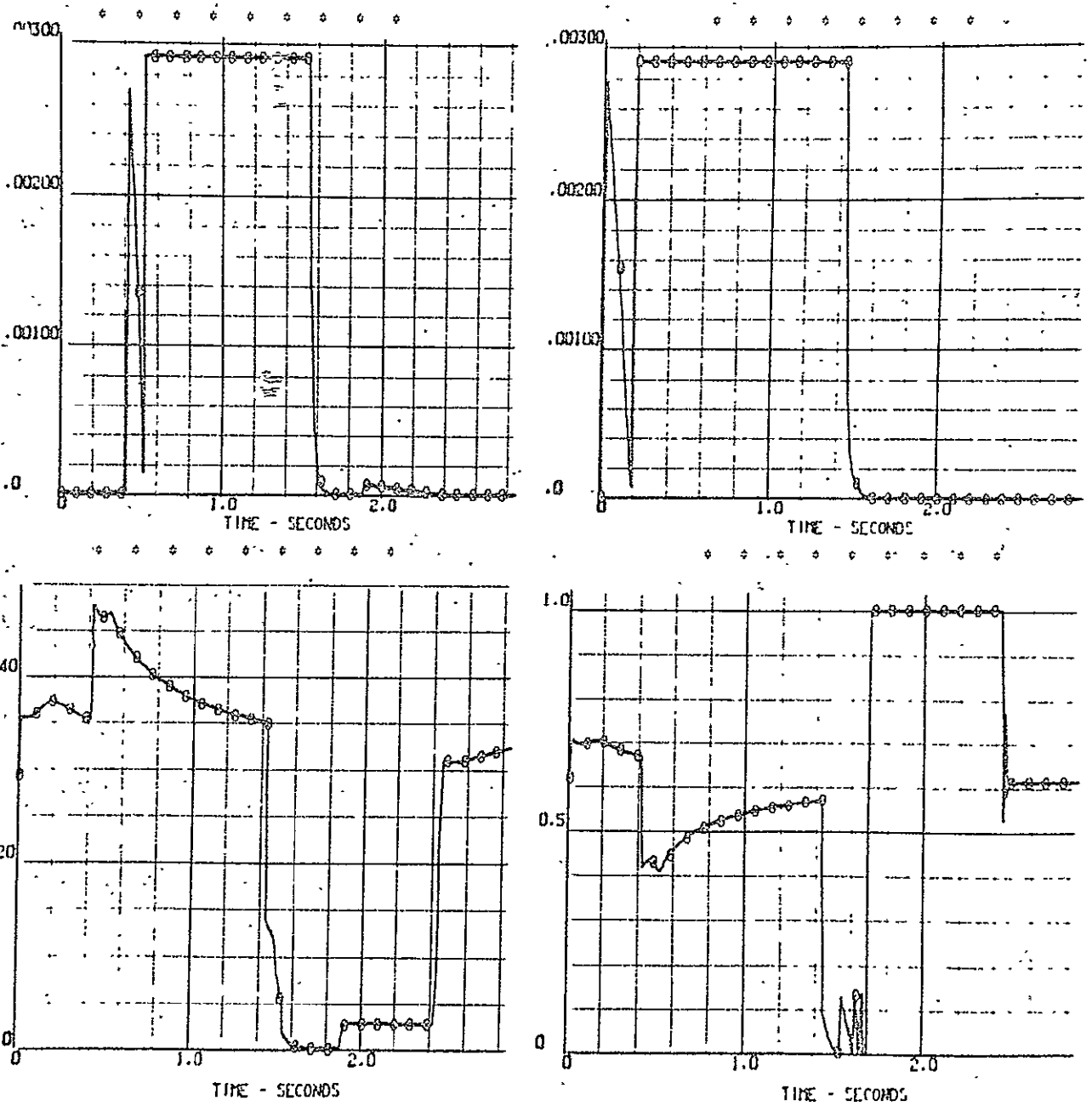


Figure C-1A - Graphical Output of Apollo Descent Engine LM-3 Flight Anomaly.

NOT REPRODUCIBLE

DATE: 01.12.71
TIME: 11.29.07

APOLLO DESCENT ENGINE
LM-3 FLIGHT ANOMALY

DATA CORRELATION

0107 022

4 FUEL PRESSURE SEGMENT NO. 1.
X FUEL PRESSURE SEGMENT NO. 2.

0 FUEL PRESSURE SEGMENT NO.

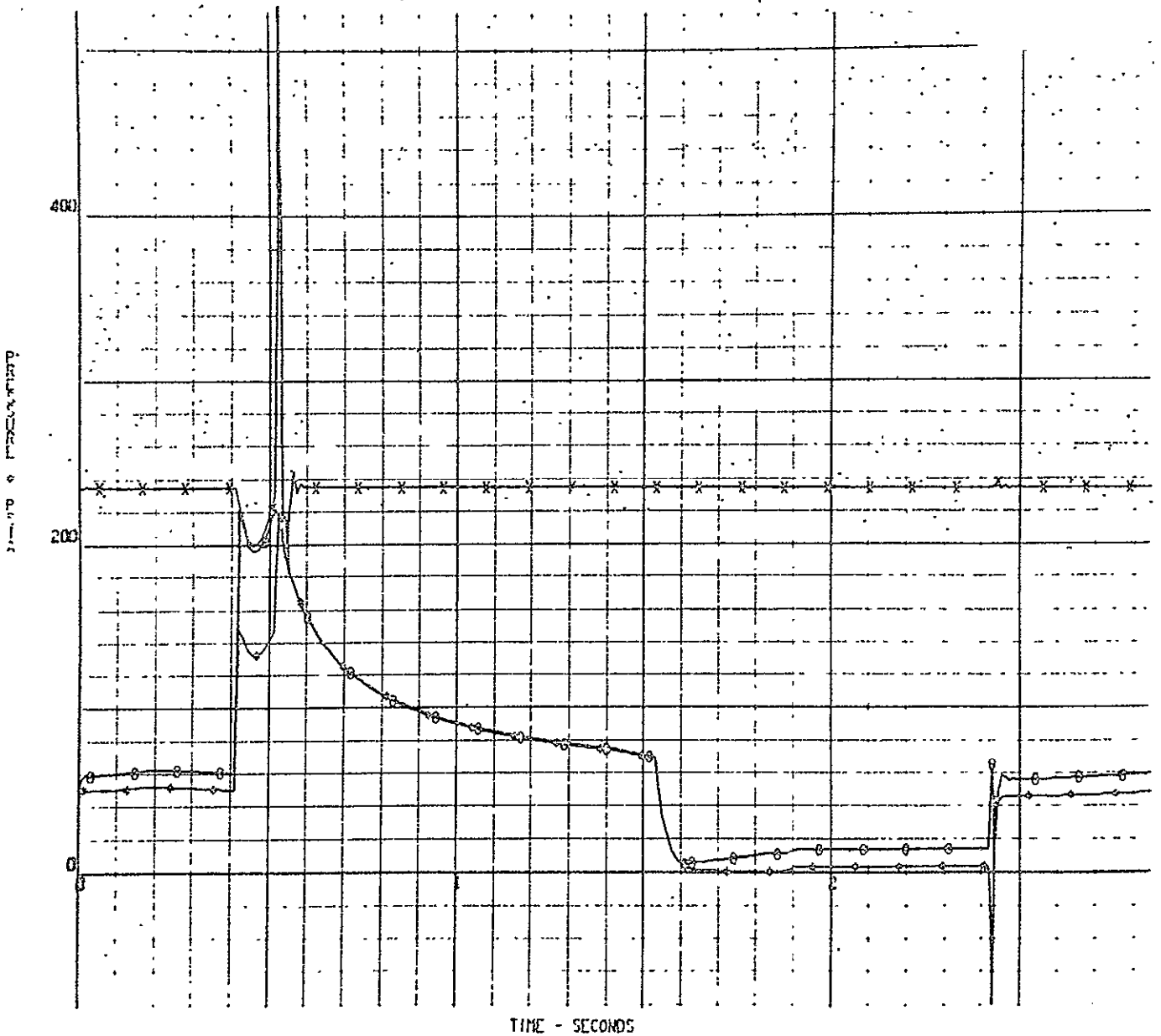


Figure C-1B - Graphical Output of Apollo Descent Engine LM-3 Flight Anomaly.

CPTE 61 1271
TIME 11.20.00

APOLLO DESCENT ENGINE
LM-3 FLIGHT ANOMALY

DATA CORRELATION

31151

* OXIDIZER PRESSURE SEGMENT NO. 1.
X OXIDIZER PRESSURE SEGMENT NO. 9.

0 OXIDIZER PRESSURE SEGMENT NO. 9.

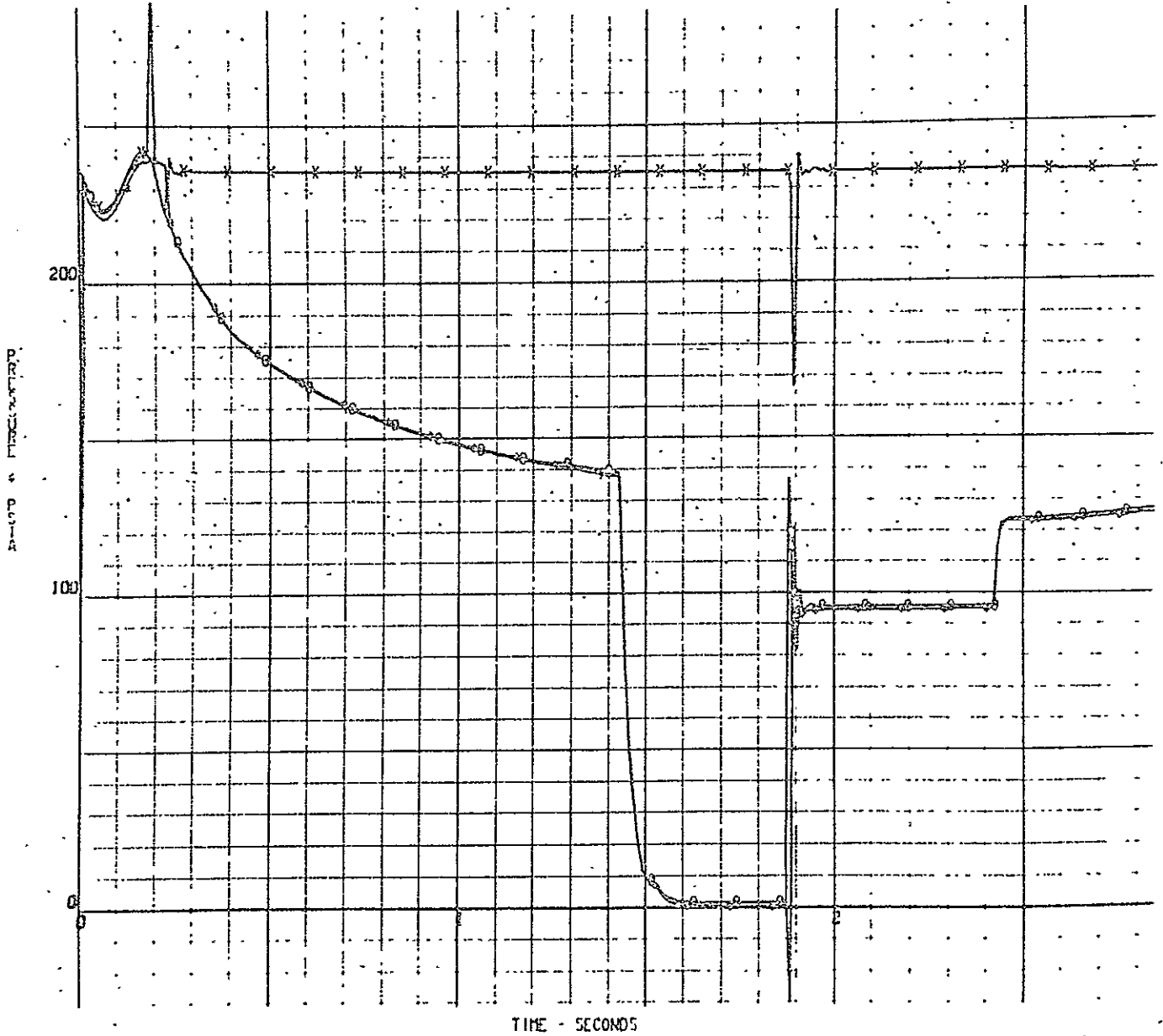


Figure C-1C - Graphical Output of Apollo Descent Engine LM-3 Flight Anomaly.

DATE: 01/11/71
TIME: 11:20:07

APOLLO DESCENT ENGINE
LM-3 FLIGHT ANOMALY

DATA CORRELATION

3195

FUEL FLOW SEGMENT NO. 1

FUEL FLOW SEGMENT NO. 2

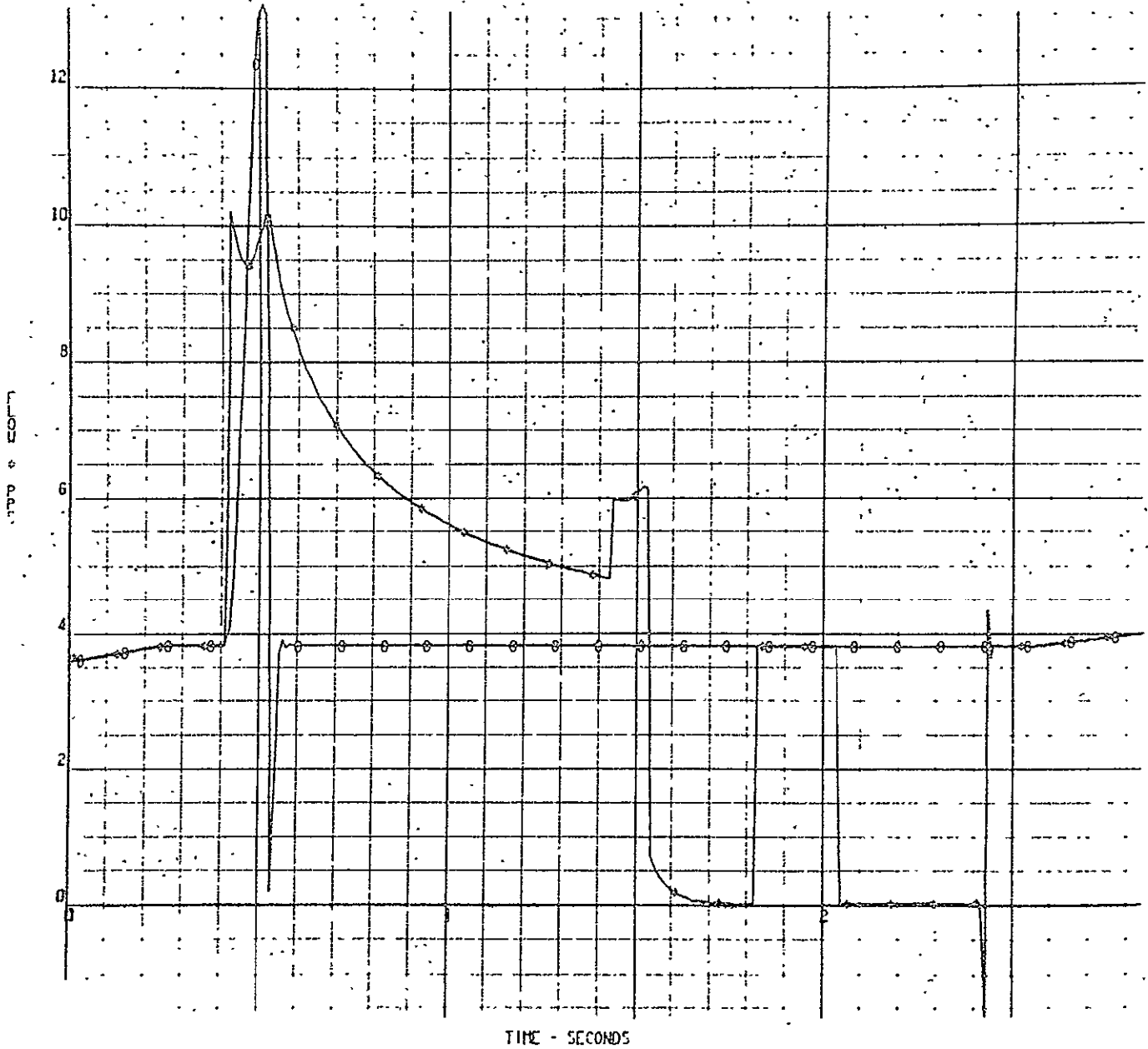


Figure C-1D - Graphical Output of Apollo Descent Engine LM-3 Flight Anomaly.

NOT REPRODUCIBLE

APOLLO DESCENT ENGINE
LM-3 FLIGHT ANOMALY
OXIDIZER FLOW SEGMENT NO. 1.

DATA CORRELATION

OXIDIZER FLOW SEGMENT NO.

31/11/68

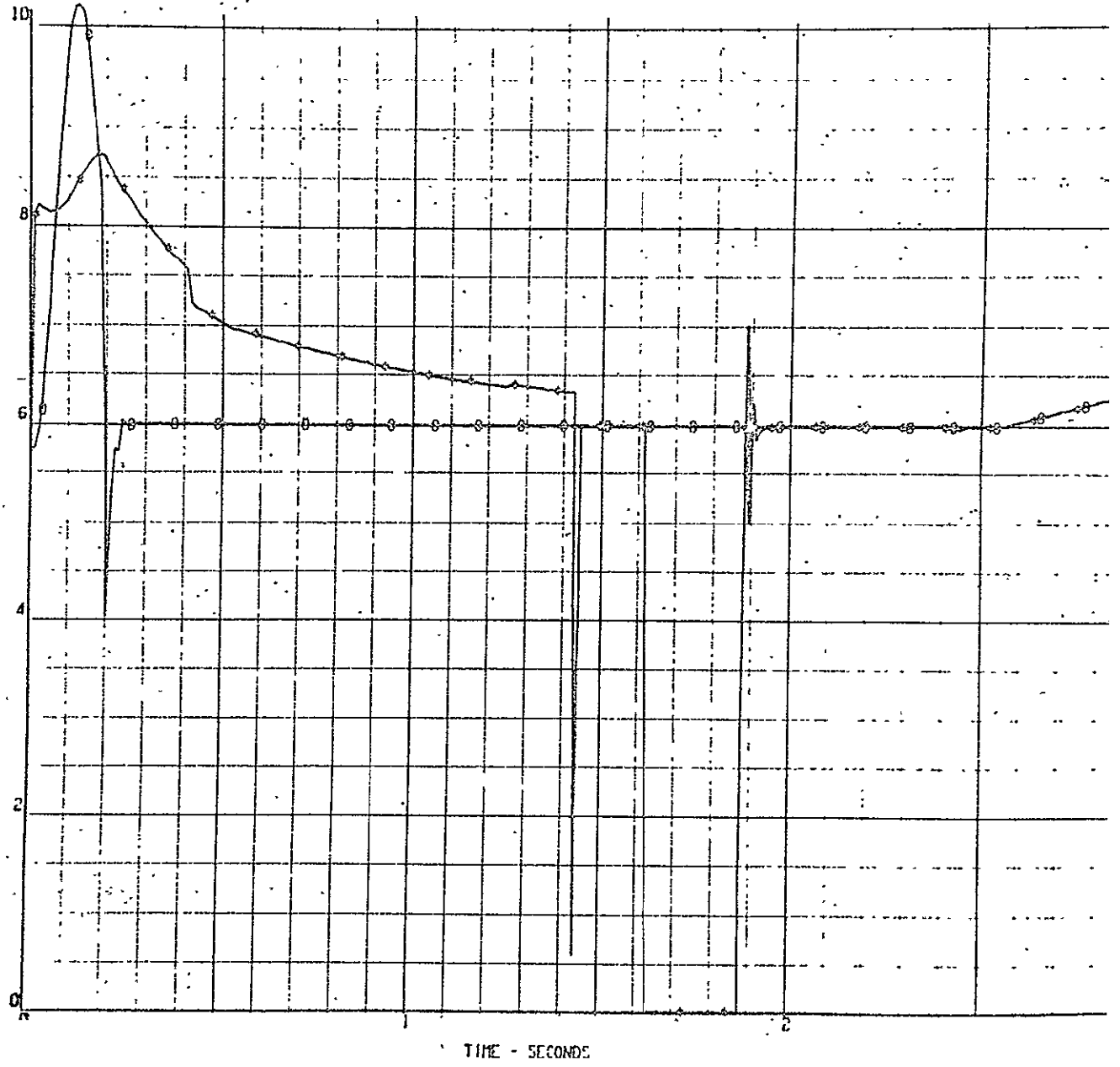


Figure C-1E - Graphical Output of Apollo Descent Engine LM-3 Flight Anomaly.

DATE 01/11/71
TIME 1 23:49

APOLLO DESCENT ENGINE
LM-3 FLIGHT ANOMALY

DATA CORRELATION

3107 22

* FUEL FLOW SEGMENT NO. 7.

0 OXIDIZER FLOW SEGMENT NO. 7.

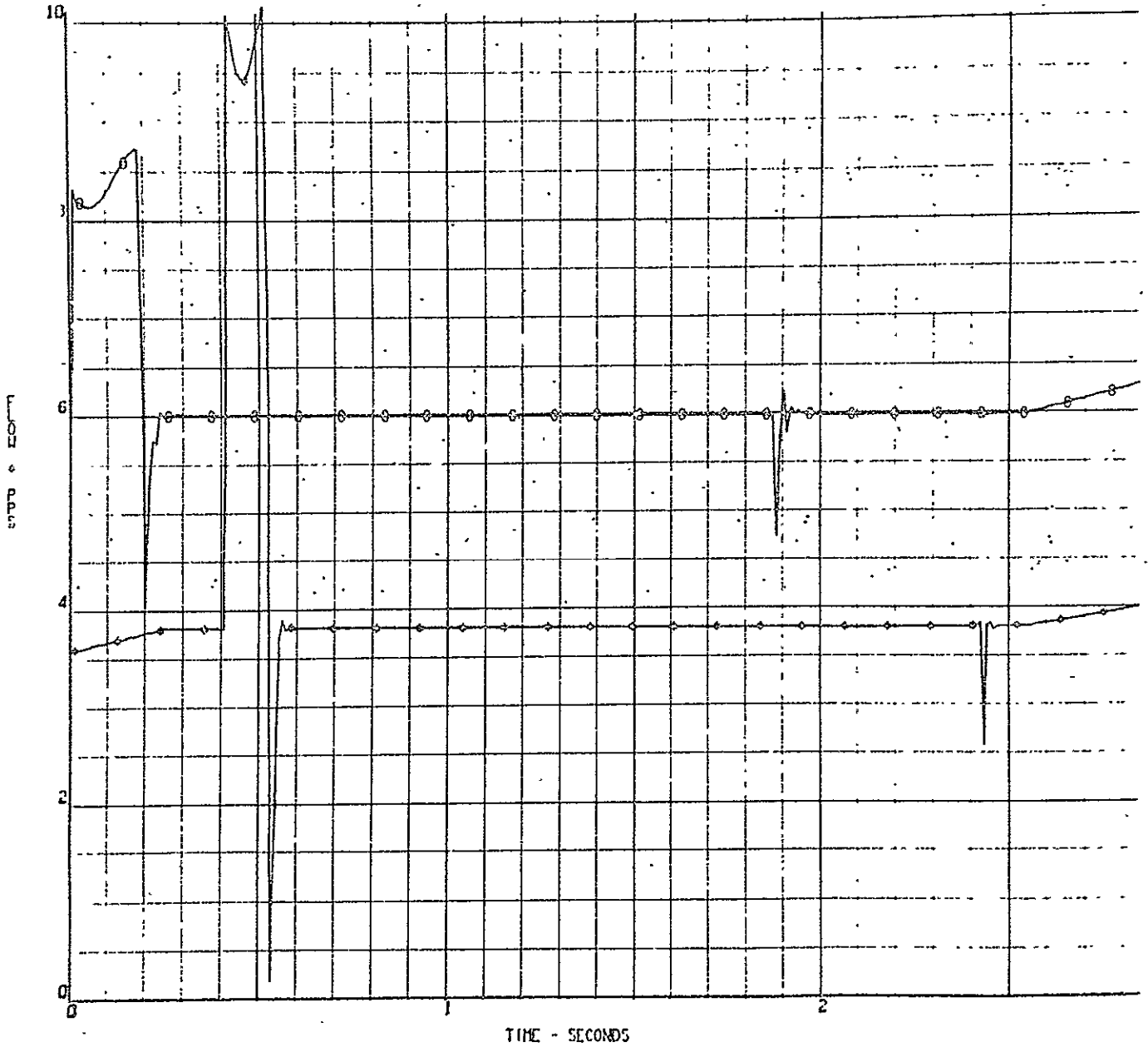


Figure C-1F - Graphical Output of Apollo Descent Engine LM-3 Flight Anomaly.

TABLE C-III

DESCENT ENGINE LM-3 ANOMALY PROGRAM OUTPUT LISTINGS

APOLLO DESCENT ENGINE

DATE 01/13/71

TIME 1: 9.33

DATA CORRELATION

LM-3 FLIGHT ANOMALY

FUEL FEEDSYSTEM PARAMETERS

* SEGMENT NO.	* DATA STATE	* PRESSURE PSIA	* FLOW PPS	* ACOUSTIC VELOCITY IN / SEC	* AREA SQ. IN.	* LENGTH INCHES	* RESISTANCE SEC**2/IN**5	* DISOLVED GAS LBS G / LB L
1	FULL	45.00	3.5700	48889.0	2.5000	10.20	0.1120E-03	0.0
2	FULL	45.00	3.5700	48889.0	2.5000	10.20	0.1604E-01	0.0
3	FULL	43.67	3.5437	48889.0	0.0	0.0	0.6680E-02	0.0
4	FULL	46.25	3.5437	48889.0	2.5000	10.20	0.1120E-03	0.0
5	FULL	45.00	3.5700	48889.0	2.5000	13.00	0.1430E-03	0.0
6	FULL	45.00	3.5700	48889.0	2.5000	15.00	0.1650E-03	0.0
7	FULL	45.00	3.5700	48889.0	2.5000	12.20	0.1340E-03	0.0
8	FULL	45.00	3.5700	48889.0	0.0	0.0	0.0	0.0
9	FULL	235.00	3.5700	48889.0	2.9200	11.00	0.1210E-03	0.0
10	FULL	235.00	3.5700	48889.0	2.9200	13.00	0.1430E-03	0.0
11	FULL	235.00	3.5700	48889.0	2.9200	15.00	0.1650E-03	0.0
12	FULL	235.00	3.5700	48889.0	2.9200	17.00	0.1870E-03	0.0
13	FULL	235.00	3.5700	48889.0	2.9200	19.00	0.2090E-03	0.0
14	FULL	235.00	3.5700	48889.0	2.9200	21.00	0.2310E-03	0.0
15	FULL	235.00	3.5700	48889.0	2.9200	23.00	0.2530E-03	0.0
16	FULL	235.00	3.5700	48889.0	2.9200	20.00	0.2200E-03	0.0
17	FULL	235.00	3.5700	48889.0	2.9200	17.00	0.1870E-03	0.0
18	FULL	235.00	3.5700	51152.3	3.2200	11.00	0.1150E-03	0.0
19	FULL	235.00	3.5700	51152.3	3.2200	15.00	0.1570E-03	0.0
20	FULL	235.00	3.5700	51152.3	3.2200	19.00	0.1990E-03	0.0
21	FULL	235.00	3.5700	51152.3	3.2200	17.00	0.1780E-03	0.0
22	FULL	235.00	3.5700	51152.3	3.2200	10.20	0.1070E-03	0.0
23	FULL	235.00	3.5700	60000.0	0.0	0.0	0.0	0.0

DATE 01/13/71 TIME 1: 9.33
 APOLLO DESCENT ENGINE

DATA CORRELATION

LM-3 FLIGHT ANOMALY

OXIDIZER FEEDSYSTEM CONSTANTS

* SEGMENT NO.	* DATA STATE	* PRESSURE PSIA	* FLOW PPS	* ACOUSTIC VELOCITY IN. / SEC	* AREA SQ. IN.	* LENGTH INCHES	* RESISTANCE SEC**2/IN**5	* DISOLVED GAS LBS G / LB L
1	FULL	105.00	5.7300	34613.9	2.9200	7.00	0.3900E-04	0.0
2	FULL	105.00	5.7300	34613.9	2.9200	7.40	0.4200E-04	0.0
3	FULL	104.57	5.7160	34613.9	0.0	0.0	0.1293E-02	0.0
4	FULL	105.38	5.7160	34613.9	2.9200	7.00	0.3900E-04	0.0
5	FULL	105.00	5.7300	34613.9	2.9200	9.00	0.5100E-04	0.0
6	FULL	105.00	5.7300	34613.9	2.9200	11.00	0.6200E-04	0.0
7	FULL	105.00	5.7300	34613.9	2.9200	15.00	0.8400E-04	0.0
8	FULL	105.00	5.7300	34613.9	0.0	0.0	0.0	0.0
9	FULL	236.00	5.7300	34613.9	2.9200	11.00	0.6200E-04	0.0
10	FULL	236.00	5.7300	34613.9	2.9200	13.00	0.7300E-04	0.0
11	FULL	236.00	5.7300	34613.9	2.9200	15.00	0.8400E-04	0.0
12	FULL	236.00	5.7300	34613.9	2.9200	17.00	0.9600E-04	0.0
13	FULL	236.00	5.7300	34613.9	2.9200	19.00	0.1070E-03	0.0
14	FULL	236.00	5.7300	34613.9	2.9200	21.00	0.1240E-03	0.0
15	FULL	236.00	5.7300	34613.9	2.9200	23.00	0.1290E-03	0.0
16	FULL	236.00	5.7300	34613.9	2.9200	20.00	0.1120E-03	0.0
17	FULL	236.00	5.7300	34613.9	2.9200	17.00	0.9600E-04	0.0
18	FULL	236.00	5.7300	34896.7	4.4200	11.00	0.1150E-03	0.0
19	FULL	236.00	5.7300	34896.7	4.4200	15.00	0.1560E-03	0.0
20	FULL	236.00	5.7300	34896.7	4.4200	19.00	0.1970E-03	0.0
21	FULL	236.00	5.7300	34896.7	4.4200	17.00	0.1760E-03	0.0
22	FULL	236.00	5.7300	34896.7	4.4200	10.00	0.1040E-03	0.0
23	FULL	236.00	5.7300	40500.0	0.0	0.0	0.0	0.0

APOLLO DESCENT ENGINE DATE 01/13/71 TIME 1: 9.33

DATA CORRELATION

LM-3 FLIGHT ANOMALY

* * * * FEEDSYSTEM CONFIGURATION * * * *

FUEL

OXIDIZER

INDEX INLET * * * BRANCHES * * * INLET * * * BRANCHES * * *

CAPPED SEGMENTS

0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0,

FUEL ICRDER ARRAY

*

NSEGF = 22

2 5 6 7 10 11 12 13 14 15 16 17 18 19 20 21 22

OXIDIZER IORDER ARRAY

*

NSEGO = 22

2 5 6 7 10 11 12 13 14 15 16 17 18 19 20 21 22

CUTOFF SEGMENTS

FUEL

OXIDIZER

FUEL VALVE TABLE									
INDEX	SEGMENT	*	*	VALUES					
1	323	235.000000	0.0	235.000000	10.000000	0.0	0.0	0.0	0.0
2	3	0.440000	10.000000	0.0	0.0	0.0	0.0	0.0	0.0
3	108	0.046646	0.0	0.049781	0.250000	0.049781	2.549999	0.058009	3.549999
4	201	0.195483	0.0	0.203234	0.250000	0.203234	2.549999	0.223938	3.549999

OXIDIZER VALVE TABLE									
INDEX	SEGMENT	*	*	VALUES					
1	323	236.000000	0.0	236.000000	10.000000	0.0	0.0	0.0	0.0
2	3	1.000000	10.000000	0.0	0.0	0.0	0.0	0.0	0.0
3	108	0.059659	0.0	0.063405	0.250000	0.063405	2.549999	0.074018	3.549999
4	201	0.092893	0.0	0.098459	0.250000	0.098459	2.549999	0.112530	3.549999

FUEL FUNGEN TABLE

OXIDIZER FUNGEN TABLE

CAVITATING VENTURI DATA

INDEX NO.	FUEL				OXIDIZER			
	1	2	3	4	1	2	3	4
SEGMENT NO.	8.	0.	0.	0.	8.	0.	0.	0.
UPSTREAM AREA - SQ. IN.	2.919999	0.0	0.0	0.0	2.919999	0.0	0.0	0.0
THROAT AREA - SQ. IN.	0.046646	0.0	0.0	0.0	0.059659	0.0	0.0	0.0
PRESSURE RECOVERY RATIO	0.100000	0.0	0.0	0.0	0.100000	0.0	0.0	0.0

ORIFICE DATA

ACCUMULATOR DATA

INJECTOR MANIFOLD DATA

FUEL

OXIDIZER

INDEX NO.	1	2	3	4	1	2	3	4
SEGMENT NO.	1.000000	0.0	0.0	0.0	1.000000	0.0	0.0	0.0
MANIFOLD VOLUME - CU. IN.	45.0000	0.0	0.0	0.0	30.0000	0.0	0.0	0.0
ORIFICE LENGTH - INCHES	0.375000	0.0	0.0	0.0	0.250000	0.0	0.0	0.0
INJECTOR C-SUB-D*A - SQIN	0.195489	0.0	0.0	0.0	0.092893	0.0	0.0	0.0
FLAME POINT DISTANCE-IN.	1.000000	0.0	0.0	0.0	0.500000	0.0	0.0	0.0

COMBUSTION CHAMBER DATA

INDEX NO.	1	2	3	4
CHAMBER PRESSURE - PSIA	29.3508	0.0	0.0	0.0
OXIDIZER FLOWRATE - PPS	5.7300	0.0	0.0	0.0
FUEL FLOWRATE - PPS	3.5700	0.0	0.0	0.0
OXIDIZER FRACTION	0.616129	0.0	0.0	0.0
THROAT AREA - SQ. IN.	54.400	0.0	0.0	0.0
CHAMBER VOLUME - CU. IN.	2557.000	0.0	0.0	0.0
NOZZLE EXIT AREA - SQ. IN.	0.0	0.0	0.0	0.0
THRUST COEFFICIENT	1.70000	0.0	0.0	0.0
ENGINE AMBIENT PRESSURE - PSIA	0.0	0.0	0.0	0.0
ENGINE THRUST - POUNDS	2714.36	0.0	0.0	0.0

NOT REPRODUCIBLE

COMBUSTION DATA

BASE PRESSURE = 150.0 PSIA

CSTAR CORRECTION = 0.008453

GAS CONSTANT CORRECTION = 0.027790

EFFICIENCY CORRECTION = 0.0

OX. FRACTION	GAS CONSTANT	CSTAR / G	EFFICIENCY
-0.0050	-2.0000E 05	15.000	0.8160
0.0	2.9300E 05	41.500	0.8180
0.0200	2.8200E 06	115.000	0.8260
0.0400	3.0400E 06	131.500	0.8330
0.0600	3.0700E 06	132.900	0.8410
0.1000	3.1300E 06	134.700	0.8560
0.2000	3.2400E 06	138.000	0.8890
0.2500	3.2800E 06	139.800	0.9030
0.3000	3.4200E 06	142.600	0.9200
0.3500	3.8700E 06	148.800	0.9330
0.4500	4.6000E 06	165.000	0.9590
0.5000	4.8800E 06	171.300	0.9670
0.5500	5.0300E 06	175.800	0.9740
0.6000	5.0200E 06	178.100	0.9780
0.6500	4.8600E 06	176.800	0.9730
0.7000	4.5500E 06	171.100	0.9650
0.8000	3.6300E 06	152.000	0.9220

0.9000	2.2700E 06	116.600	0.8590
0.9800	3.7000E 05	58.700	0.8010
1.0000	1.3300E 05	29.400	0.7870
1.0050	1.0000E 04	21.000	0.7810

APOLLO DESCENT ENGINE DATE 01/13/71 TIME 1: 9.33

DATA CORRELATION

LM-3 FLIGHT ANOMALY

* INPUT DATA CONSTANTS	* FUEL	* OXIDIZER
ENTRAINED GAS - LBS GAS / LB LIQUID	0.0	0.0
PROPELLANT DENSITY - POUNDS / CUBIC INCH	0.03250	0.05200
LIQUID TEMPERATURE - DEGREES RANKINE	530.0	530.0
PROPELLANT ACOUSTIC VELOCITY - INCHES / SECOND	60000.0	40500.0
VAPOR PRESSURE CURVE FIT CONSTANTS - CON1	8.3446E-03	8.9489E-03
(LOG(PVAP) = CON1 * TEMP + CON2)		
- CON2	-4.1095E 00	-3.6294E 00
PROPELLANT MOLECULAR WEIGHT	41.8	92.0
PRESSURANT GAS MOLECULAR WEIGHT	4.0	4.0
RATIO OF SPECIFIC HEATS - PRESSURANT GAS	1.670	1.670
RATIO OF SPECIFIC HEATS - PROPELLANT VAPOR	1.050	1.100
DISSOLVED GAS EVOLUTION TIME CONSTANT - 1/SEC.	1.0000E 01	1.0000E 01
DISSOLVED GAS CONCENTRATION - LBS GAS / LB LIQ / PSI	8.8889E-06	2.0526E-05
PROPELLANT TANK ULLAGE - CUBIC INCHES	0.0	0.0
PROPELLANT TANK INITIAL PRESSURE - PSIA	0.0	0.0
PRESSURANT GAS BOTTLE VOLUME - CUBIC INCHES	0.0	0.0
PROPELLANT LIQUID HEAT CAPACITY - BTU / LB / DEGREE R	6.9100E-01	3.6800E-01
PRESSURANT - LOW PRESSURE C-SUB-V	7.5000E-01	7.5000E-01
PRESSURANT - HIGH PRESSURE C-SUB-V	0.0	0.0
PRESSURANT - HIGH PRESSURE C-SUB-P	0.0	0.0
PRESSURANT - HIGH PRESSURE GAMMA	0.0	0.0

APOLLO DESCENT ENGINE

DATE 01/13/71

TIME 1: 9.33

DATA CORRELATION

LM-3 FLIGHT ANOMALY

0.0	45.00000	3.57000	105.00000	5.73000	0.0	0.0	29.35081	0.61613
0.009520	49.31779	3.63240	228.43883	8.09291	0.0	0.00277	35.44040	0.69459
0.019040	48.62859	3.57788	227.67528	8.18606	0.0	0.00263	35.30196	0.70172
0.028560	48.58351	3.58324	224.93532	8.16350	0.0	0.00249	35.36827	0.69501
0.038080	48.65289	3.59402	222.69366	8.13516	0.0	0.00236	35.37247	0.69306
0.047600	48.68669	3.60218	221.03070	8.11646	0.0	0.00223	35.37219	0.69305
0.057120	48.75662	3.61199	220.00687	8.11209	0.0	0.00210	35.40588	0.69233
0.066640	48.84312	3.62094	219.76390	8.12414	0.0	0.00196	35.47252	0.69170
0.076159	48.97234	3.63001	220.22563	8.15105	0.0	0.00183	35.57130	0.69156
0.085679	49.11687	3.63891	221.33151	8.19077	0.0	0.00168	35.69341	0.69224
0.095199	49.29662	3.64792	222.96249	8.24298	0.0	0.00154	35.84180	0.69320
0.104718	49.49413	3.65698	225.02791	8.30315	0.0	0.00138	36.01118	0.69421
0.114238	49.69658	3.66600	227.40985	8.36955	0.0	0.00122	36.19298	0.69511
0.123757	49.91176	3.67498	229.89093	8.43797	0.0	0.00106	36.38097	0.69640
0.133277	50.12143	3.68412	232.27435	8.50504	0.0	0.00089	36.56490	0.69763
0.142796	50.32883	3.69312	234.43968	8.56630	0.0	0.00072	36.74274	0.69904
0.152316	50.51500	3.70230	236.16504	8.61946	0.0	0.00055	36.90083	0.69997
0.161836	50.67857	3.71146	237.38156	8.66097	0.0	0.00039	37.03899	0.70006
0.171355	50.81709	3.72058	237.95345	8.68886	0.0	0.00023	37.15358	0.70017
0.180875	50.93237	3.72970	237.88286	8.70499	0.0	0.00007	37.24138	0.69994
0.190394	51.00427	3.73923	238.38390	8.68863	0.0	0.00290	37.28096	0.69915
0.199914	50.97186	3.74827	234.76157	8.63495	0.0	0.00290	37.22531	0.69726
0.209433	50.87590	3.75750	229.73552	8.54396	0.0	0.00290	37.09698	0.69461
0.218953	50.77402	3.76646	225.33345	8.46498	0.0	0.00290	36.97643	0.69202
0.228473	50.72232	3.77562	221.73227	8.40386	0.0	0.00290	36.89278	0.69002
0.237992	50.68373	3.78452	218.73947	8.35326	0.0	0.00290	36.82809	0.68815
0.247512	50.65202	3.79352	215.85083	8.30560	0.0	0.00290	36.76985	0.68658
0.257031	50.59436	3.79920	213.14182	8.25047	0.0	0.00290	36.69038	0.68509
0.266551	50.46255	3.79781	210.56270	8.19260	0.0	0.00290	36.57112	0.68309
0.276070	50.34724	3.79797	208.10571	8.13725	0.0	0.00290	36.45024	0.68148
0.285590	50.23056	3.79774	205.76585	8.08422	0.0	0.00290	36.33270	0.68059
0.295110	50.11543	3.79783	203.53221	8.03333	0.0	0.00290	36.21519	0.67936
0.304629	50.00722	3.79789	201.39925	7.98448	0.0	0.00290	36.10760	0.67765
0.314149	49.89748	3.79776	199.35912	7.93747	0.0	0.00290	36.00258	0.67643
0.323668	49.79588	3.79780	197.40587	7.89226	0.0	0.00290	35.90224	0.67504
0.333188	49.70132	3.79788	195.53416	7.84872	0.0	0.00290	35.80086	0.67392
0.342708	49.60472	3.79781	193.73900	7.80675	0.0	0.00290	35.70547	0.67282
0.352227	49.50908	3.79775	192.01541	7.76627	0.0	0.00290	35.61232	0.67190
0.361747	49.41369	3.79785	190.35738	7.72717	0.0	0.00290	35.52309	0.67066

NOT REPRODUCIBLE

0.371266	49.33585	3.79778	188.76250	7.68939	0.0	0.00290	35.43817	0.66914
0.380786	49.24661	3.79782	187.22783	7.65284	0.0	0.00290	35.35016	0.66818
0.390305	49.16454	3.79773	185.74931	7.61757	0.0	0.00290	35.26964	0.66730
0.399825	49.08356	3.79763	184.32466	7.58340	0.0	0.00290	35.18906	0.66644
0.409345	49.00835	3.79774	182.95044	7.55031	0.0	0.00290	35.11284	0.66508
0.418864	147.73988	10.17029	181.73790	7.20564	0.00268	0.00290	47.52788	0.41477
0.428384	141.68512	9.89465	180.72684	7.16799	0.00244	0.00290	47.42796	0.42055
0.437903	136.84225	9.65762	179.74239	7.15230	0.00222	0.00290	47.03304	0.42528
0.447423	133.63075	9.49962	178.78270	7.13494	0.00201	0.00290	46.72502	0.42890
0.456942	131.92651	9.41679	177.84750	7.11577	0.00180	0.00290	46.50720	0.43047
0.466462	131.62459	9.40629	176.93852	7.09488	0.00158	0.00290	46.37560	0.43003
0.475982	132.58829	9.46155	176.05577	7.07244	0.00135	0.00290	46.32443	0.42775
0.485501	134.67046	9.57351	175.20033	7.04874	0.00109	0.00290	46.34169	0.42410
0.495021	137.68742	9.73131	174.37204	7.02408	0.00080	0.00290	46.41800	0.41940
0.504540	141.37759	9.91959	173.57115	6.99891	0.00048	0.00290	46.53511	0.41383
0.514060	145.34169	10.11831	172.79709	6.97381	0.00014	0.00290	46.67070	0.40814
0.523579	217.63217	10.11975	172.05228	6.95064	0.00290	0.00290	46.67332	0.40713
0.533099	203.29704	9.76155	171.32133	6.94404	0.00290	0.00290	46.19984	0.41559
0.542619	190.92575	9.36194	170.60013	6.94003	0.00290	0.00290	45.63452	0.42567
0.552138	182.49608	9.08299	169.88960	6.93232	0.00290	0.00290	45.21306	0.43280
0.561658	175.70482	8.86210	169.19110	6.92257	0.00290	0.00290	44.86960	0.43853
0.571177	169.60103	8.66237	168.50581	6.91229	0.00290	0.00290	44.55580	0.44380
0.580697	164.14761	8.47942	167.83400	6.90180	0.00290	0.00290	44.26163	0.44865
0.590217	159.20113	8.31144	167.17500	6.89155	0.00290	0.00290	43.96881	0.45326
0.599736	154.70978	8.15693	166.52847	6.88164	0.00290	0.00290	43.67845	0.45758
0.609256	150.60008	8.01356	165.89398	6.87163	0.00290	0.00290	43.40285	0.46158
0.618775	146.82716	7.88009	165.27116	6.86158	0.00290	0.00290	43.14000	0.46542
0.628295	143.34691	7.75538	164.66055	6.85152	0.00290	0.00290	42.88922	0.46904
0.637814	140.12543	7.63851	164.06071	6.84144	0.00290	0.00290	42.64920	0.47247
0.647334	137.13293	7.52869	163.47244	6.83138	0.00290	0.00290	42.41827	0.47564
0.656854	134.34470	7.42523	162.89525	6.82136	0.00290	0.00290	42.19742	0.47880
0.666373	131.73915	7.32753	162.32922	6.81141	0.00290	0.00290	41.98538	0.48176
0.675893	129.29819	7.23507	161.77373	6.80150	0.00290	0.00290	41.78113	0.48458
0.685412	127.00571	7.14742	161.22849	6.79166	0.00290	0.00290	41.58421	0.48720
0.694932	124.84772	7.06416	160.69327	6.78190	0.00290	0.00290	41.39409	0.48977
0.704451	122.81227	6.98493	160.16829	6.77223	0.00290	0.00290	41.21037	0.49230
0.713971	120.88855	6.90942	159.65262	6.76263	0.00290	0.00290	41.03275	0.49462
0.723491	119.06705	6.83736	159.14629	6.75313	0.00290	0.00290	40.86073	0.49690
0.733010	117.33958	6.76849	158.64902	6.74373	0.00290	0.00290	40.69412	0.49909
0.742530	115.69849	6.70255	158.16167	6.73442	0.00290	0.00290	40.53339	0.50120
0.752049	114.13734	6.63935	157.68298	6.72519	0.00290	0.00290	40.37764	0.50318
0.761569	112.64999	6.57872	157.21329	6.71608	0.00290	0.00290	40.22743	0.50516
0.771088	111.23105	6.52001	156.75174	6.70700	0.00290	0.00290	40.08006	0.50705

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0.780608	100.87570	6.46458	156.29849	6.69820	0.00290	0.00290	39.93741	0.50887
0.790124	108.57716	6.41074	155.85384	6.68944	0.00290	0.00290	39.79782	0.51064
0.799647	107.33607	6.35881	155.41628	6.68076	0.00290	0.00290	39.66252	0.51235
0.809167	106.14462	6.30875	154.98680	6.67221	0.00290	0.00290	39.53058	0.51401
0.818686	105.00163	6.26047	154.56497	6.66376	0.00290	0.00290	39.40111	0.51555
0.828206	103.90410	6.21385	154.15103	6.65547	0.00290	0.00290	39.27556	0.51709
0.837726	102.84914	6.16881	153.74379	6.64725	0.00290	0.00290	39.15327	0.51855
0.847245	101.83426	6.12527	153.34390	6.63915	0.00290	0.00290	39.03433	0.52008
0.856765	100.85713	6.08314	152.95059	6.63116	0.00290	0.00290	38.91713	0.52156
0.866284	99.91554	6.04236	152.56422	6.62327	0.00290	0.00290	38.80299	0.52296
0.875804	99.00758	6.00285	152.18457	6.61550	0.00290	0.00290	38.69133	0.52424
0.885323	98.13138	5.96456	151.81123	6.60782	0.00290	0.00290	38.58284	0.52561
0.894843	97.28522	5.92741	151.44449	6.60026	0.00290	0.00290	38.47626	0.52674
0.904363	96.46750	5.89137	151.08339	6.59279	0.00290	0.00290	38.37241	0.52805
0.913882	95.67677	5.85637	150.72865	6.58542	0.00290	0.00290	38.27061	0.52934
0.923402	94.91170	5.82237	150.38000	6.57816	0.00290	0.00290	38.17111	0.53051
0.932921	94.17097	5.78932	150.03691	6.57100	0.00290	0.00290	38.07338	0.53152
0.942441	93.45343	5.75719	149.69888	6.56392	0.00290	0.00290	37.97758	0.53271
0.951960	92.75797	5.72594	149.36745	6.55697	0.00290	0.00290	37.88409	0.53381
0.961480	92.08350	5.69551	149.04103	6.55009	0.00290	0.00290	37.79333	0.53486
0.971000	91.42905	5.66590	148.71983	6.54332	0.00290	0.00290	37.70326	0.53592
0.980519	90.79375	5.63705	148.40364	6.53664	0.00290	0.00290	37.61516	0.53692
0.990039	90.17676	5.60892	148.09274	6.53004	0.00290	0.00290	37.52885	0.53785
0.999558	89.57722	5.58152	147.78680	6.52354	0.00290	0.00290	37.44461	0.53888
1.009065	88.99443	5.55476	147.48560	6.51709	0.00290	0.00290	37.36360	0.53975
1.018571	88.42775	5.52895	147.18930	6.51093	0.00290	0.00290	37.27437	0.54113
1.028077	87.87631	5.50325	146.89760	6.50454	0.00290	0.00290	37.20201	0.54159
1.037583	87.33966	5.47835	146.61037	6.49833	0.00290	0.00290	37.12546	0.54247
1.047090	86.81702	5.45419	146.32784	6.49236	0.00290	0.00290	37.04430	0.54335
1.056596	86.30797	5.43048	146.04971	6.48635	0.00290	0.00290	36.97076	0.54420
1.066102	85.81201	5.40747	145.77608	6.48055	0.00290	0.00290	36.89040	0.54408
1.075608	85.32855	5.38466	145.50627	6.47459	0.00290	0.00290	36.82564	0.54585
1.085114	84.85715	5.36251	145.24075	6.46883	0.00290	0.00290	36.75453	0.54665
1.094621	84.39725	5.34102	144.97963	6.46322	0.00290	0.00290	36.68321	0.54743
1.104127	83.94862	5.31973	144.72198	6.45760	0.00290	0.00290	36.61502	0.54821
1.113633	83.51074	5.29904	144.46854	6.45210	0.00290	0.00290	36.54691	0.54897
1.123139	83.08310	5.27881	144.21877	6.44669	0.00290	0.00290	36.47937	0.54971
1.132645	82.66557	5.25978	143.97289	6.44126	0.00290	0.00290	36.41583	0.55045
1.142152	82.25763	5.23919	143.73080	6.43587	0.00290	0.00290	36.35402	0.55168
1.151658	81.85909	5.22015	143.49210	6.43063	0.00290	0.00290	36.29306	0.55186
1.161164	81.46947	5.20153	143.25685	6.42552	0.00290	0.00290	36.22941	0.55255
1.170671	81.08859	5.18310	143.02522	6.42036	0.00290	0.00290	36.17027	0.55366
1.180177	80.71613	5.16525	142.79642	6.41537	0.00290	0.00290	36.11090	0.55389

NOT REPRODUCIBLE

1.189683	80.35176	5.14763	142.57191	6.41042	0.00290	0.00290	36.04843	0.55555
1.199189	77.99525	5.13043	142.35028	6.40552	0.00290	0.00290	35.99474	0.55519
1.208695	79.63629	5.11341	142.13139	6.40062	0.00290	0.00290	35.93980	0.55581
1.218202	79.30476	5.09698	141.91599	6.39596	0.00290	0.00290	35.88069	0.55644
1.227708	78.97034	5.08062	141.70406	6.39121	0.00290	0.00290	35.82811	0.55704
1.237214	78.64276	5.06404	141.49504	6.38657	0.00290	0.00290	35.77422	0.55763
1.246720	78.32189	5.04914	141.28891	6.38209	0.00290	0.00290	35.71751	0.55823
1.256227	78.00774	5.02943	141.08099	6.40594	0.00290	0.00290	35.74405	0.56004
1.265733	77.70097	5.01319	140.88655	6.40046	0.00290	0.00290	35.70915	0.56069
1.275239	77.40025	4.99852	140.65562	6.39566	0.00290	0.00290	35.65733	0.56123
1.284745	77.10550	4.98413	140.44850	6.39096	0.00290	0.00290	35.60606	0.56176
1.294251	76.81636	4.97003	140.24428	6.38634	0.00290	0.00290	35.55481	0.56238
1.303758	76.53281	4.95615	140.04311	6.38177	0.00290	0.00290	35.50499	0.56287
1.313264	76.25453	4.94252	139.84462	6.37726	0.00290	0.00290	35.45581	0.56335
1.322770	75.98157	4.92920	139.64861	6.37287	0.00290	0.00290	35.40585	0.56378
1.332276	75.71367	4.91598	139.45531	6.36842	0.00290	0.00290	35.35922	0.56428
1.341783	75.45064	4.90307	139.26508	6.36411	0.00290	0.00290	35.31148	0.56476
1.351289	75.19252	4.89040	139.07744	6.35987	0.00290	0.00290	35.26413	0.56524
1.360795	74.93953	4.87798	138.89258	6.35570	0.00290	0.00290	35.21719	0.56571
1.370301	74.69110	4.86574	138.71027	6.35158	0.00290	0.00290	35.16946	0.56617
1.379807	74.44710	4.85346	138.53061	6.34737	0.00290	0.00290	35.12978	0.56662
1.389314	74.20737	4.84189	138.35306	6.34346	0.00290	0.00290	35.08202	0.56705
1.398820	73.97185	4.83008	138.17780	6.33942	0.00290	0.00290	35.03914	0.56751
1.408326	73.74040	4.81836	138.00494	6.33535	0.00290	0.00290	34.99976	0.56794
1.417832	73.51294	4.80714	137.83492	6.33153	0.00290	0.00290	34.95631	0.56836
1.427339	73.28934	4.79612	137.66702	6.32777	0.00290	0.00290	34.91075	0.56879
1.436845	72.92488	5.94715	104.49968	0.59439	0.00290	0.00216	13.85638	0.09072
1.446351	72.45435	5.95930	73.39148	5.98556	0.00290	0.00149	13.20605	0.07494
1.455857	71.99005	5.95514	51.13937	5.98573	0.00290	0.00101	12.83199	0.06097
1.465364	71.53313	5.94618	35.34193	5.98567	0.00290	0.00068	12.55883	0.04794
1.474870	71.08311	5.94428	24.21518	5.98563	0.00290	0.00046	12.14790	0.03544
1.484376	70.63719	5.96726	16.62215	5.98561	0.00290	0.00031	11.22489	0.02392
1.493882	70.18860	6.02324	11.90716	5.98575	0.00290	0.00021	9.64833	0.01543
1.503388	69.73370	6.08011	9.06422	5.98573	0.00290	0.00016	8.07006	0.01035
1.512895	69.27528	6.11113	7.32079	5.98557	0.00290	0.00013	7.00963	0.00702
1.522401	68.81763	6.15510	6.18886	5.98575	0.00290	0.00010	5.57320	0.00031
1.531907	68.37039	6.12565	6.45008	5.98569	0.00290	0.00010	5.72206	0.00023
1.541413	49.12-23	0.70087	4.25853	5.98561	0.00206	0.00007	1.90195	0.12718
1.550920	33.98061	0.53141	2.67619	5.98562	0.00141	0.00004	1.41206	0.10893
1.560426	23.40826	0.43041	1.68245	5.98563	0.00096	0.00003	1.12596	0.09108
1.569932	16.05890	0.37654	1.10324	5.98575	0.00065	0.00002	0.89947	0.07034
1.579438	10.97062	0.32623	0.79557	5.98562	0.00044	0.00001	0.71680	0.05544
1.588944	7.46229	0.26734	0.61581	5.98562	0.00030	0.00001	0.57652	0.04209

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1.598451	5.05361	0.21825	0.49003	5.98557	0.00020	0.00001	0.46408	0.03567
1.607957	3.40702	0.18262	0.31271	5.98575	0.00013	0.00000	0.19399	0.0
1.617463	2.28636	0.14195	0.24719	5.98566	0.00009	0.00000	0.34503	0.12381
1.626969	1.52708	0.11398	0.28586	0.00642	0.00006	0.00000	0.27530	0.09699
1.636476	1.01502	0.09676	0.18226	0.01642	0.00004	0.00000	0.11305	0.0
1.645982	0.67133	0.07935	0.09755	0.01133	0.00002	0.00000	0.06462	0.0
1.655488	0.44177	0.05338	0.16369	0.0	0.00002	0.00000	0.16722	0.13526
1.664994	0.28920	0.04912	0.09607	0.01239	0.00001	0.00000	0.05670	0.0
1.674500	0.18831	0.04000	0.04732	0.00716	0.00001	0.00000	0.03415	0.0
1.684007	0.12195	0.03168	0.02751	0.00297	0.00000	0.00000	0.02524	0.0
1.693513	0.07854	0.02529	0.01948	0.00317	0.00000	0.00000	0.01690	1.00000
1.703019	0.05028	0.02171	0.00899	0.00401	0.00000	0.00000	0.00487	1.00000
1.712525	0.03201	0.01782	0.00364	0.00295	0.00000	0.00000	0.00141	1.00000
1.722032	0.02025	0.01435	0.00139	0.00196	0.00000	0.00000	0.00041	1.00000
1.731538	0.01273	0.01144	0.00050	0.00123	0.00000	0.00000	0.00012	1.00000
1.741044	0.00795	0.00907	0.00017	0.00073	0.00000	0.00000	0.00003	1.00000
1.750550	0.00494	0.00715	0.00005	0.00041	0.00000	0.00000	0.00001	1.00000
1.760056	0.00304	0.00562	0.00002	0.00022	0.00000	0.00000	0.00000	1.00000
1.769563	0.00186	0.00440	0.00000	0.00011	0.00000	0.00000	0.00000	1.00000
1.779069	0.00113	0.00343	0.00000	0.00005	0.00000	0.00000	0.00000	1.00000
1.788575	0.00068	0.00266	0.00000	0.00003	0.00000	0.00000	0.00000	1.00000
1.798081	0.00041	0.00206	0.00000	0.00003	0.00000	0.00000	0.00000	1.00000
1.807588	0.00024	0.00159	0.00000	0.00003	0.00000	0.00000	0.00000	1.00000
1.817094	0.00014	0.00122	0.00000	0.00004	0.00000	0.00000	0.00000	1.00000
1.826600	0.00008	3.79741	0.00000	0.00004	0.00000	0.00000	0.00000	1.00000
1.836106	0.00005	3.79747	0.00000	0.00004	0.00000	0.00000	0.00000	1.00000
1.845613	0.00003	3.79740	0.00000	0.00005	0.00000	0.00000	0.00000	1.00000
1.855119	0.00002	3.79747	0.00000	0.00006	0.00000	0.00000	0.00000	1.00000
1.864625	0.00001	3.79748	0.00000	0.00008	0.00000	0.00000	0.00000	1.00000
1.874131	0.00000	3.79747	0.00001	0.00014	0.00000	0.00000	0.00000	1.00000
1.883637	0.23246	3.79745	136.91151	7.01107	0.00001	0.00000	1.21709	1.00000
1.893144	1.41512	3.79748	83.21832	5.70503	0.00004	0.00000	2.31546	1.00000
1.902650	2.53294	3.79741	101.09247	6.21704	0.00006	0.00000	2.60976	1.00000
1.912156	2.73083	3.79738	92.22765	5.84604	0.00007	0.00000	2.73082	1.00000
1.921662	2.74347	3.79749	92.19870	5.95217	0.00007	0.00000	2.74141	1.00000
1.931169	2.75735	3.79746	94.30188	5.97154	0.00006	0.00000	2.75678	1.00000
1.940675	2.75812	3.79746	94.47144	5.98306	0.00006	0.00000	2.75742	1.00000
1.950181	2.75908	3.79747	94.33897	5.97788	0.00006	0.00000	2.75832	1.00000
1.959687	2.76035	3.79740	94.30124	5.97615	0.00006	0.00000	2.75963	1.00000
1.969193	2.75990	3.79745	94.72241	5.98649	0.00006	0.00000	2.75932	1.00000
1.978700	2.76005	3.79747	94.86380	5.99245	0.00006	0.00000	2.75944	1.00000
1.988206	2.76000	3.79749	94.81567	5.99014	0.00006	0.00000	2.75950	1.00000
1.997712	2.76005	3.79738	94.66464	5.98584	0.00006	0.00000	2.75947	1.00000

2.007218	2.76005	3.79737	94.66719	5.98538	0.00005	0.00000	2.75949	1.00000
2.016725	2.76002	3.79746	94.66652	5.98518	0.00005	0.00000	2.75948	1.00000
2.026231	2.76000	3.79737	94.65710	5.98421	0.00005	0.00000	2.75949	1.00000
2.035737	2.75995	3.79738	94.71306	5.98627	0.00005	0.00000	2.75945	1.00000
2.045243	2.76007	0.00246	94.67384	5.98528	0.00005	0.00000	2.75948	1.00000
2.054749	2.76005	0.00248	94.70193	5.98650	0.00005	0.00000	2.75946	1.00000
2.064255	2.76007	0.00248	94.66641	5.98555	0.00005	0.00000	2.75948	1.00000
2.073762	2.76007	0.00247	94.67241	5.98551	0.00005	0.00000	2.75948	1.00000
2.083268	2.76005	0.00247	94.68085	5.98584	0.00004	0.00000	2.75946	1.00000
2.092774	2.76006	0.00250	94.68202	5.98550	0.00004	0.00000	2.75947	1.00000
2.102281	2.76002	0.00250	94.69304	5.98609	0.00004	0.00000	2.75945	1.00000
2.111787	2.76015	0.00247	94.67873	5.98571	0.00004	0.00000	2.75947	1.00000
2.121293	2.76007	0.00186	94.67995	5.98580	0.00004	0.00000	2.75947	1.00000
2.130799	2.76013	0.00286	94.67513	5.98558	0.00004	0.00000	2.75947	1.00000
2.140306	2.76002	0.00224	94.68227	5.98581	0.00004	0.00000	2.75947	1.00000
2.149812	2.76009	0.00258	94.68678	5.98580	0.00004	0.00000	2.75947	1.00000
2.159318	2.76010	0.00199	94.67126	5.98542	0.00003	0.00000	2.75947	1.00000
2.168824	2.76012	0.00281	94.68579	5.98584	0.00003	0.00000	2.75947	1.00000
2.178330	2.76003	0.00216	94.67053	5.98550	0.00003	0.00000	2.75947	1.00000
2.187837	2.75998	0.00271	94.68059	5.98592	0.00003	0.00000	2.75947	1.00000
2.197343	2.76016	0.00276	94.67805	5.98575	0.00003	0.00000	2.75947	1.00000
2.206849	2.76017	0.00277	94.68213	5.98582	0.00003	0.00000	2.75947	1.00000
2.216355	2.75991	0.00230	94.68576	5.98596	0.00003	0.00000	2.75947	1.00000
2.225862	2.76015	0.00225	94.68112	5.98571	0.00003	0.00000	2.75947	1.00000
2.235368	2.75997	0.00237	94.68796	5.98590	0.00002	0.00000	2.75947	1.00000
2.244874	2.76018	0.00215	94.68552	5.98575	0.00002	0.00000	2.75947	1.00000
2.254380	2.76008	0.00200	94.68420	5.98571	0.00002	0.00000	2.75947	1.00000
2.263886	2.75988	0.00232	94.67963	5.98579	0.00002	0.00000	2.75947	1.00000
2.273393	2.76002	0.00254	94.68384	5.98570	0.00002	0.00000	2.75947	1.00000
2.282899	2.76015	0.00260	94.68315	5.98576	0.00002	0.00000	2.75947	1.00000
2.292405	2.75991	0.00257	94.68056	5.98556	0.00002	0.00000	2.75947	1.00000
2.301911	2.75993	0.00238	94.68344	5.98590	0.00002	0.00000	2.75947	1.00000
2.311418	2.75997	0.00223	94.68283	5.98587	0.00001	0.00000	2.75947	1.00000
2.320924	2.76009	0.00250	94.68071	5.98567	0.00001	0.00000	2.75947	1.00000
2.330430	2.76005	0.00255	94.67781	5.98580	0.00001	0.00000	2.75947	1.00000
2.339936	2.76015	0.00269	94.68216	5.98597	0.00001	0.00000	2.75947	1.00000
2.349442	2.76004	0.00288	94.68260	5.98591	0.00001	0.00000	2.75947	1.00000
2.358949	2.76006	0.00253	94.68147	5.98590	0.00001	0.00000	2.75947	1.00000
2.368455	2.76005	0.00248	94.68349	5.98584	0.00001	0.00000	2.75947	1.00000
2.377961	2.75997	0.00252	94.68204	5.98576	0.00001	0.00000	2.75947	1.00000
2.387467	2.75996	0.00237	94.67607	5.98562	0.00000	0.00000	2.75947	1.00000
2.396974	2.75998	0.00250	94.68411	5.98600	0.00000	0.00000	2.75947	1.00000
2.406480	2.76005	0.00254	94.68244	5.98584	0.00000	0.00000	2.75947	1.00000

NOT REPRODUCIBLE

2.415986	2.76006	0.00251	94.67673	5.98583	0.00000	0.00000	2.75947	1.00000
2.425492	-30.66464	-1.63764	96.22690	5.93615	0.00000	0.00000	6.66314	0.99956
2.434999	44.07652	4.32693	113.36687	6.00126	0.00000	0.00000	21.40753	0.52305
2.444505	40.78467	3.63535	119.46930	5.95245	0.00000	0.00000	27.66904	0.76751
2.454011	43.86487	3.81515	121.89024	5.96880	0.00000	0.00000	30.95140	0.57989
2.463517	44.83527	3.79188	122.68692	5.98791	0.00000	0.00000	30.78554	0.60648
2.473023	44.82657	3.79997	122.82758	5.98387	0.00000	0.00000	30.96376	0.61001
2.482530	44.81838	3.79795	122.83914	5.98635	0.00000	0.00000	30.88091	0.61658
2.492036	44.84357	3.79825	122.84042	5.98555	0.00000	0.00000	30.92923	0.61030
2.501542	44.83057	3.79883	122.83104	5.98613	0.00000	0.00000	30.90839	0.61188
2.511048	44.80327	3.79730	122.83876	5.98596	0.00000	0.00000	30.91344	0.61147
2.520555	44.81662	3.79821	122.83731	5.98582	0.00000	0.00000	30.90816	0.61284
2.530061	44.80006	3.79751	122.83232	5.98568	0.00000	0.00000	30.90663	0.61184
2.539567	44.79773	3.79757	122.82333	5.98564	0.00000	0.00000	30.90160	0.61285
2.549073	44.79648	3.79741	122.83298	5.98575	0.00000	0.00000	30.90616	0.61183
2.558579	44.82555	3.80136	122.81122	5.99171	0.00000	0.00000	30.92693	0.61189
2.568086	44.89204	3.80768	122.87373	6.00061	0.00000	0.00000	30.96994	0.61184
2.577592	44.95564	3.81335	122.98723	6.01068	0.00000	0.00000	31.02087	0.61188
2.587098	45.02435	3.81949	123.07317	6.01967	0.00000	0.00000	31.07523	0.61080
2.596604	45.08571	3.82525	123.15143	6.02946	0.00000	0.00000	31.11887	0.61188
2.606111	45.15004	3.83130	123.24602	6.03860	0.00000	0.00000	31.16641	0.61188
2.615617	45.21970	3.83732	123.33867	6.04841	0.00000	0.00000	31.21832	0.61076
2.625123	45.27736	3.84309	123.42419	6.05774	0.00000	0.00000	31.26506	0.61190
2.634629	45.35005	3.84911	123.50943	6.06703	0.00000	0.00000	31.31270	0.61214
2.644135	45.41766	3.85508	123.59967	6.07676	0.00000	0.00000	31.36269	0.61300
2.653642	45.48045	3.86093	123.69771	6.08615	0.00000	0.00000	31.41780	0.61191
2.663148	45.54631	3.86700	123.79279	6.09571	0.00000	0.00000	31.46449	0.61191
2.672654	45.60490	3.87276	123.87175	6.10492	0.00000	0.00000	31.50735	0.61302
2.682160	45.67915	3.87885	123.96664	6.11458	0.00000	0.00000	31.56276	0.61192
2.691667	45.74190	3.88480	124.04599	6.12394	0.00000	0.00000	31.61058	0.61193
2.701173	45.80750	3.89068	124.14313	6.13371	0.00000	0.00000	31.66020	0.61193
2.710679	45.87244	3.89645	124.23012	6.14271	0.00000	0.00000	31.71143	0.61258
2.720185	45.93668	3.90257	124.31462	6.15234	0.00000	0.00000	31.75731	0.61192
2.729692	46.00394	3.90856	124.41168	6.16216	0.00000	0.00000	31.80713	0.61194
2.739198	46.06892	3.91451	124.49950	6.17145	0.00000	0.00000	31.85594	0.61195
2.748704	46.13039	3.92043	124.58733	6.18086	0.00000	0.00000	31.90442	0.61194
2.758210	46.19542	3.92625	124.66116	6.19010	0.00000	0.00000	31.95387	0.61195
2.767716	46.26239	3.93222	124.76077	6.20018	0.00000	0.00000	32.00266	0.61195
2.777223	46.32802	3.93824	124.85143	6.20974	0.00000	0.00000	32.05219	0.61197
2.786729	46.39655	3.94421	124.94276	6.21908	0.00000	0.00000	32.10120	0.61197
2.796235	46.45752	3.94944	125.02733	6.22833	0.00000	0.00000	32.15047	0.61195
2.805741	46.52184	3.95597	125.11058	6.23765	0.00000	0.00000	32.19925	0.61196
2.815248	46.59120	3.96204	125.20461	6.24721	0.00000	0.00000	32.24974	0.61197

2.824754	46.65633	3.96782	125.28084	6.25660	0.00000	0.00000	32.29793	0.6119
2.834260	46.71561	3.97383	125.37421	6.26633	0.00000	0.00000	32.34665	0.6119
2.843766	46.78151	3.97975	125.45218	6.27540	0.00000	0.00000	32.39557	0.6120

IHC9001 EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

IHC2171 FIDCS - END OF DATA SET ON UNIT 5

TRACEBACK ROUTINE CALLED FROM ISN	REG. 14	REG. 15	REG. 0	REG. 1
FRONL#	0006A1DC	0007D158	0000A414	00069920
MAIN	000106CE	010698A0	FFFFFF2E	000AEFF8

ENTRY POINT= 010698A0

APPENDIX D

SE5-5 PRESSURIZATION MODEL

SE-5 PRESSURIZATION MODEL

The SE-5 pressurization system is shown schematically at the right. The necessary input data for simulation of the system is listed below:

B(5), B(6) - Liquid Temp

Assume $70^{\circ}\text{F} - 530^{\circ}\text{R}$

B(15), B(16) - Pressurant

Molecular wt. 28 - GN_2

B(17), B(18) - Ratio of Specific

Heat - Propellant Tank Pressure Level

- 1.4

B(30) - Pressurant Bottle

Volume - 886 in^3

B(31) - Fuel Heat Capacity

- $0.7 \text{ BTU/lb}^{\circ}\text{F}$

B(32) - Oxidizer Heat Capacity

- $0.369 \text{ BTU/lb}^{\circ}\text{F}$

B(33), B(34) - Pressurant C_v - Propellant Tank

Pressure - $0.172 \text{ BTU/lb}^{\circ}\text{F}$

B(36) - Pressurant Bottle C_v - $0.185 \text{ BTU/lb}^{\circ}\text{F}$

B(38) - Pressurant Bottle C_p - $0.330 \text{ BTU/lb}^{\circ}\text{F}$

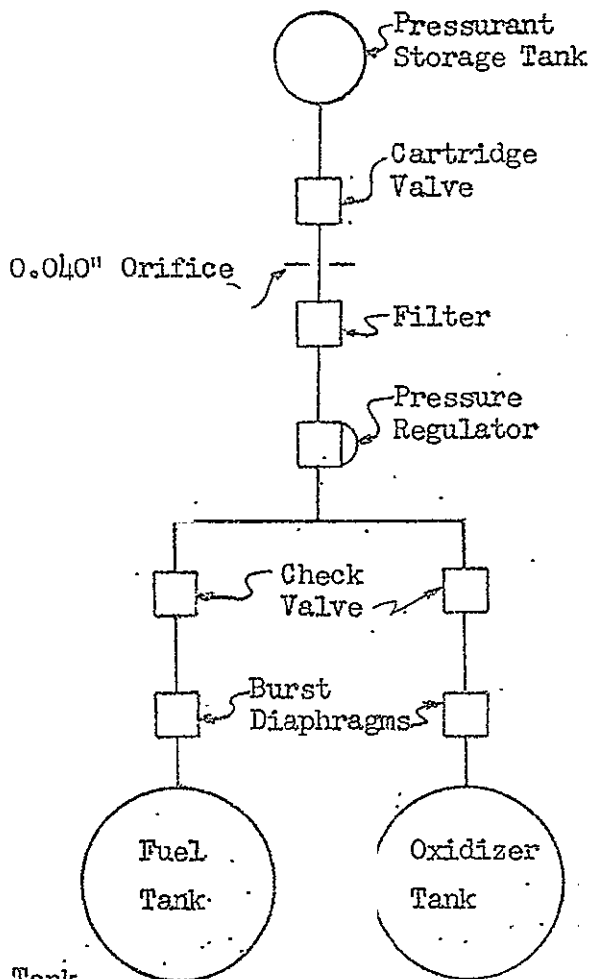
B(40) - Pressurant Bottle γ - 1.781

Regulator Constants

B(42) - Gain = $1.0 \text{ in}^2/\text{psi}$

B(44) - Lockup = 209 psia

B(46) - Maximum Flow Area = 0.004 - Estimate



	<u>Fuel</u>	<u>Oxidizer</u>
Propellant Flowrate - PPS	0.2656	0.4258
Density - lbs/in ³	0.0315	0.052
q - in ³ /sec	8.43	8.22
Q = 16.65 x 60 = 999.00 in ³ /min		
= 999 x $\frac{208}{14.7}$ x $\frac{1}{1728}$ = 8.2 SCFM		

$$\dot{m} = \frac{p q}{RT} = \frac{208 \times 16.65}{\frac{18544}{28} \times 530} = 0.00985 \text{ pps}$$

Using Orifice Valve Calculator; C_DA = 0.0011 in²

$$\dot{m} = 0.00985, P_1 = 375, P_2 = 208, T = 530^\circ R$$

B(48) Pressurant Compressibility Factor - 1.15

$$P_r = \frac{4700}{492} = 9.55 \quad T_r = \frac{530}{277} = 1.91$$

B(50) Heat Input to Pressurant Tank - 0

B(52) Heat Input to Propellant Tank - 0

B(54) Regulator Sense Pressure Flag - 8

B(62) Effective Flow Area - Regulator to Fuel

$$\begin{aligned} \text{Tank} &= 0.00546 \text{ in}^2 \\ R &= 43.2 \text{ sec}^2/\text{in}^5 \\ C_D A &= \frac{1}{27.8 \sqrt{R}} = 0.00546 \end{aligned}$$

NOT REPRODUCIBLE

B(63) Effective Area ΔP 1-2 - 0.00396 in²
 Cartridge Valve ΔP = 30 psi @ 7 SCFM
 P_{in} = 100 psia, C_DA = 0.00396

B(64) Effective Area ΔP 6-7 - 0.000815 in²
 Orifice - 0.040 dia,

B(66) Effective Area - Regulator to Oxidizer Tank
 R = 25.8, C_DA = 0.00710

B(68) Laminar Flow Filter Constant

$$\frac{\dot{q} \sqrt{T}}{\text{psi}} = \frac{0.009 \times \sqrt{530}}{10} = 0.023$$

The gas pressures, temperatures, and flows at time zero must also be provided as input data:

E(13)	P(1,1,1)	,	E(22)	P(1,2,1)	-
E(14)	P(2,1,1)	,	E(23)	P(2,2,1)	-
E(15)	P(3,1,1)	,	E(24)	P(3,2,1)	-
E(16)	P(4,1,1)	,	E(25)	P(4,2,1)	-
E(17)	P(5,1,1)	,	E(26)	P(5,2,1)	-
E(18)	P(6,1,1)	,	E(27)	P(6,2,1)	-
E(19)	P(7,1,1)	,	E(28)	P(7,2,1)	-
E(20)	P(8,1,1)	,	E(29)	P(8,2,1)	16.0 psia
E(21)	P(9,1,1)	,	E(30)	P(9,2,1)	16.0 psia
E(31)	P(1,1,2)	,	E(40)	P(1,2,2)	4700 psia
E(37)	P(7,1,2)	,	E(46)	P(7,2,2)	4700 psia
E(38)	P(8,1,2)	,	E(47)	P(8,2,2)	16.0 psia
E(39)	P(9,1,2)	,	E(48)	P(9,2,2)	16.0 psia
E(49)	T(1,1,1)	,	E(58)	T(1,2,1)	-
E(55)	T(7,1,1)	,	E(64)	T(7,2,1)	-
E(56)	T(8,1,1)	,	E(65)	T(8,1,1)	530 °R
E(57)	T(9,1,1)	,	E(66)	T(9,1,1)	530 °R
E(67)	T(1,1,2)	,	E(76)	T(1,2,2)	530 °R
E(75)	T(9,1,2)	,	E(84)	T(9,2,2)	530 °R
E(85) - E(120)	-	Flow	-	0.0	initially

Figure D-1 shows the configuration of the fluid system. To calculate the priming transient it will be necessary to divide the system into segments. To minimize computer time it will be necessary to increase the length of certain elements. A computer time increment of 0.2 ms. will be used and minimum segment lengths calculated. Effective acoustic velocity is:

$$a_e = \left[\frac{1}{\frac{1}{a_l^2} + \frac{\rho}{g} \cdot \frac{Dc}{EE}} \right]^{1/2}$$

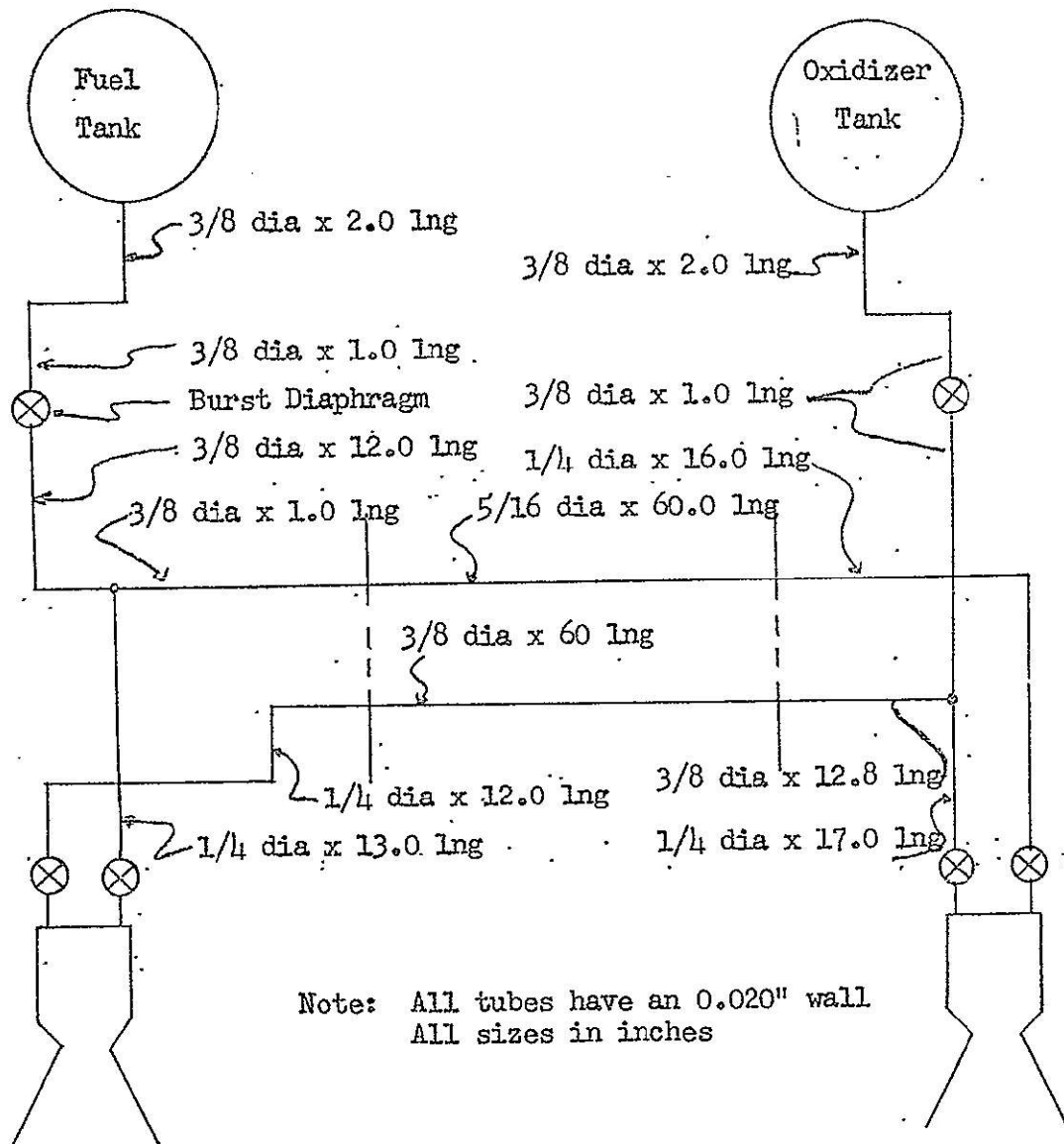


FIGURE D-1 - SE-5 Feed System

The feed system contains three different sizes of tubing each with a 0.020 in. wall

Tube Size	\bar{D}	$\frac{D_c}{eE}$
1/4	.230	3.4883×10^{-7}
5/16	.2925	4.4362×10^{-7}
3/8	.355	5.3842×10^{-7}

	Fuel	Oxidizer
Acoustic Velocity - a_ℓ	63,100	39,450
Density - ρ	0.0315	0.052
1/4" Tube $\left\{ \begin{array}{l} a_\ell \\ \text{Min. Length} \end{array} \right.$	59,802 11.96	38,082 7.61
5/16" Tube $\left\{ \begin{array}{l} a_\ell \\ \text{Min. Length} \end{array} \right.$	58,991 11.80	37,734 7.55
3/8" Tube $\left\{ \begin{array}{l} a_\ell \\ \text{Min. Length} \end{array} \right.$	58,213 11.65	37,396 7.48

The segmentation of the feed system is shown on the next page. On the inside the segment length and sizes are correct except the 1.0 in. length of 3/8" line will be assumed to be 5/16", and the length of line between the tank and burst diaphragm has been increased to 12.0 in. The resistances are those used in the engine balance, except they are distributed in the model.

The oxidizer system is similar to the fuel system modeling except for the segment between the burst diaphragm and tee. To meet model requirements it will be given a length of 8.0 inches. 7.0 inches of the 3/8" and 1/4" lines will be included in this segment so that total system volume is not changed.

$$A = \frac{(8 \times 0.0881 + 7 \times 0.0346)}{8} = 0.1184 \text{ in}^2$$

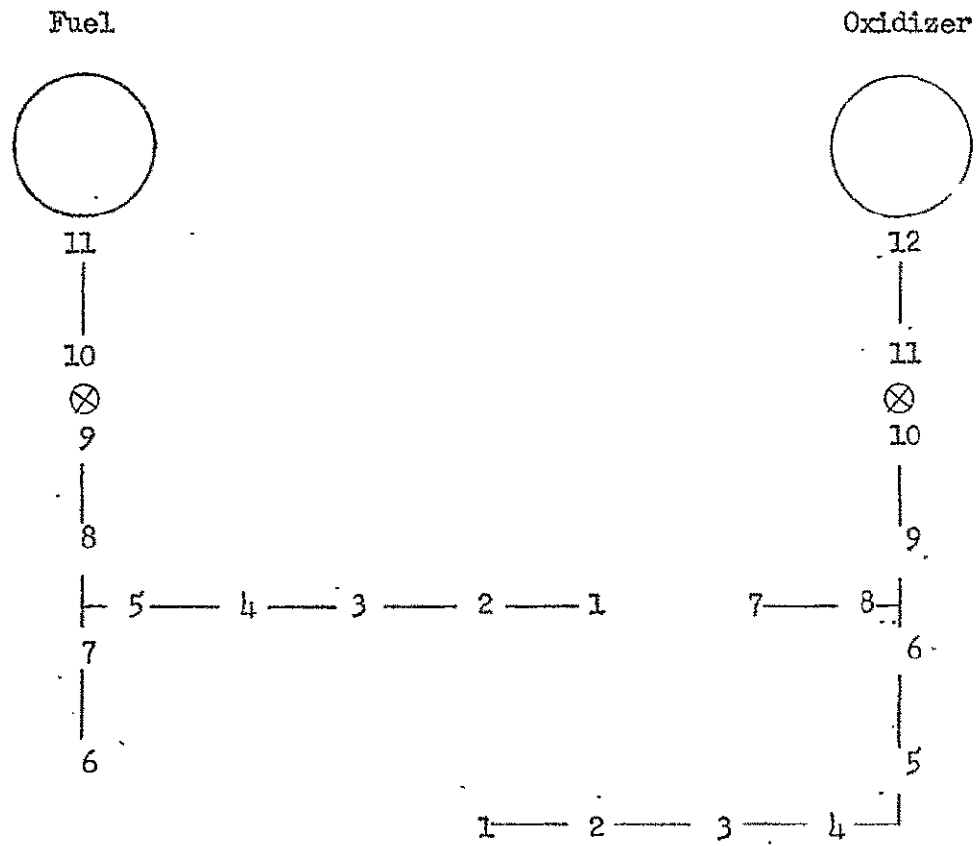
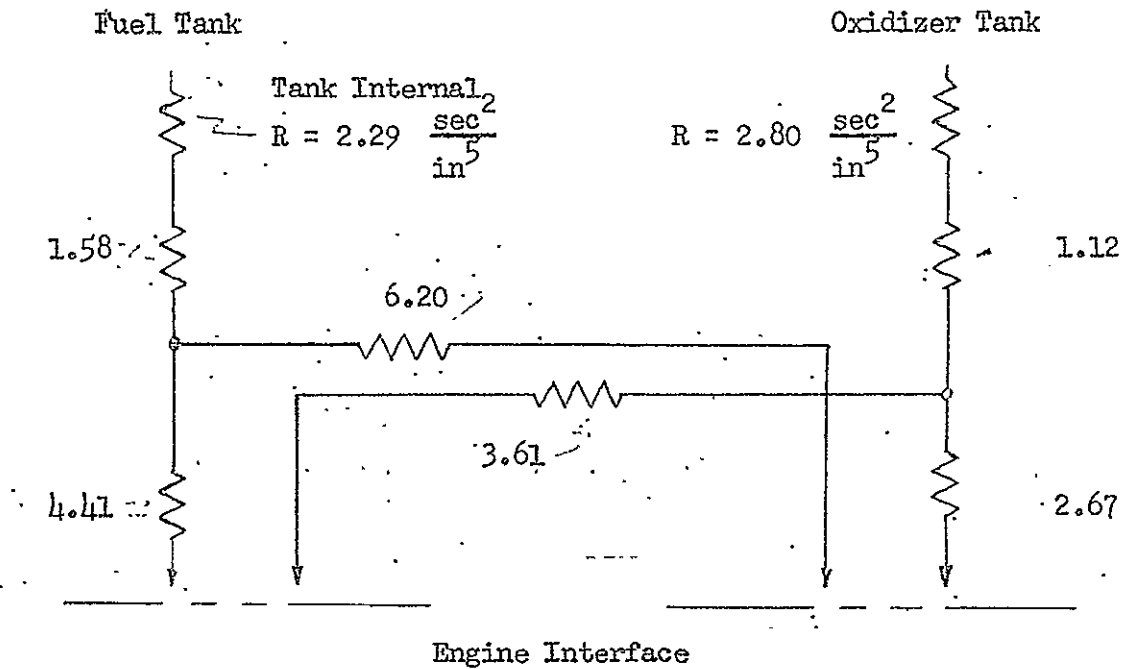


Figure D-2 - SE5-5 Pressurization System Model Segmentation

TABLE D-I - SE-5 MODEL FEED SYSTEM PARAMETERS

Segment No.	F u e l				O x i d i z e r			
	Length	Area	Compliance	Resistance	Length	Area	Compliance	Resistance
1	16.0	0.0346	3.4883×10^{-7}	2.6464	12.0	0.0346	3.4883×10^{-7}	1.8649
2	15.0	0.0583	4.4362×10^{-7}	0.8739	15.0	0.0881	5.3842×10^{-7}	.3596
3	19.0	0.0583	4.4362×10^{-7}	1.1069	17.0	0.0881	5.3842×10^{-7}	.4075
4	27.0	0.0583	4.4362×10^{-7}	1.5728	19.0	0.0881	5.3842×10^{-7}	.4554
5	-	-	-	-	14.8	0.0881	5.3842×10^{-7}	.3547
6	13.0	0.0346	3.4883×10^{-7}	4.41	-	-	-	-
7	-	-	-	-	10.0	0.0346	3.4883×10^{-7}	1.5706
8	12.0	0.0881	5.3842×10^{-7}	1.435	-	-	-	-
9	Valve	-	-	-	8.0	0.1184	5.3842×10^{-7}	0.145
10	12.0	0.0881	5.3842×10^{-7}	1.435	Valve	-	-	-
11	Tank	-	-	-	8.0	0.0881	5.3842×10^{-7}	2.92
12	-	-	-	-	Tank	-	-	-

Resistance data was obtained from an engine balance. The values shown below will be distributed throughout the system.



The burst diaphragm resistance is $1.0 \frac{\text{sec}^2}{\text{in}^5}$; its effective area is:

$$C_D A = \frac{1}{27.807 \sqrt{1}} = 0.03596$$

The resistance in the fuel line between tank and tee is:

$$R = 2.29 + 1.58 = 3.87 = 2.87 \text{ sec}^2/\text{in}^5$$

The resistance of the crossover line will be distributed on the basis of length and area

$$6.20 = 61.0 R_{5/16} + 16 R_{1/4}, \quad R_{1/4} = \left(\frac{0.0583}{0.0346} \right)^2 R_{5/16}$$

$$R_{5/16} = \frac{6.20}{61 + 16 \cdot \left(\frac{583}{346} \right)^2} = 0.05826 \frac{\text{sec}^2}{\text{in}^5} / \text{in}$$

$$R_{1/4} = 0.05826 \times \left(\frac{583}{346} \right)^2 = 0.1653 \frac{\text{sec}^2}{\text{in}^5} / \text{in}$$

The resistance in the oxidizer system will be calculated in a similar fashion.

Between the tank and burst diaphragm

$$R = 2.80 + 1.12 - 1.00 = 2.92$$

Crossover Line

$$3.61 = 72.8 R_{3/8} + 12.0 R_{1/4} \quad R_{1/4} = \left(\frac{0.0881}{0.0346} \right)^2 R_{3/8}$$

$$R_{3/8} = \frac{3.61}{72.8 + 12.0 \times \left(\frac{881}{346} \right)^2} = 0.02397 \frac{\text{sec}^2}{\text{in}^5} / \text{in}$$

$$R_{1/4} = 0.02397 \times 6.483 = 0.1554 \frac{\text{sec}^2}{\text{in}^5} / \text{in}$$

The resistance between the "T" and engine is

$$R' = \frac{2.67}{17} = 0.1570 \frac{\text{sec}^2}{\text{in}^5} / \text{in}$$

The resistance of the composite line is the parallel combination of 0.1679 and 1.0994, or 0.1456.

A listing of the input data deck is shown in Table D-II. Table D-III shows the pictorial output, and Table D-IV presents the output listing.

TABLE D-II

SE5-5 PRESSURIZATION MODEL INPUT DATA

2	1	10	0.0346	0.0583	0.0583	0.0583	0.0	0000100,
0.0346			0.0	0.0881	0.0	0.0881		0000200,
2	121	10	16.0	15.0	19.0	27.0	0.0	0000300,
3.0			0.0	12.0	0.0	12.0		0000400,
2	241	10	3.4883E-07	4.4362E-07	4.4362E-07	4.4362E-07	0.0	0000500,
3.4883E-07			0.0	5.3842E-07	0.0	5.3842E-07		0000600,
2	361	10	2.6464	0.8739	1.1069	1.5728	0.0	0000700,
4.41			0.0	1.435	0.0	1.435		0000800,
2	61	11	0.0346	0.0881	0.0881	0.0881	0.0881	0000900,
0.0			0.0346	0.0	0.1184	0.0	0.0881	0001000,
2	181	11	12.0	15.0	17.0	19.0	14.8	0001100,
0.0			10.0	0.0	8.0	0.0	8.0	0001200,
2	301	11	3.4883E-07	5.3842E-07	5.3842E-07	5.3842E-07	5.3842E-07	0001300,
0.0			3.4883E-07	0.0	5.3842E-07	0.0	5.3842E-07	0001400,
2	421	11	1.8649	0.3596	0.4075	0.4554	0.3547	0001500,
0.0			1.5706	0.0	0.1456	0.0	2.92	0001600,
3	201	9	409.0	0.0	1.0	0.001	0.001	0001700,
0.05			0.002	0.05	160.0			0001800,
-3	301	9	410.0	0.0	1.0	0.001	0.001	0001900,
0.05			0.002	0.05	160.0			0002000,

\$D1 ICMT=3, IPR=3, IST=1, NSEGF=10, NSEGO=11, DELT=0.0002, ID=1000000,
 LFF=9*1,51*0, LFO=10*1,50*0, ICAPFU=1,6,3*0, ICAPOX=1,7,3*0, ID=1000100,
 IORF=2,3,4,57*0, IORO=2,3,4,5,56*0, ID=1000200,
 IBRAN(1,1,1)=8, IBRAN(1,2,1)=5, IBRAN(1,3,1)=7, ID=1000300,
 IBRAN(1,1,2)=9, IBRAN(1,2,2)=6, IBRAN(1,3,2)=8, ID=1000400,
 ICAP=1, ITANK=8, ID=1000500,
 B(3)=0.0315, B(4)=0.052, B(5)=530, B(6)=530, ID=1000600,
 B(7)=63100, B(8)=39450, B(9)=0.0107745, B(10)=-5.81014, ID=1000700,
 B(11)=0.0089489, B(12)=-3.62944, B(13)=46.075, B(14)=92.016, ID=1000800,
 B(15)=28.0, B(16)=28.0, B(17)=1.4, B(18)=1.4, ID=1000900,
 B(25)=340, B(26)=340, B(27)=16, B(28)=16, B(30)=886, ID=1001000,
 B(31)=0.7, B(32)=0.369, B(33)=0.172, B(34)=0.172, ID=1001100,
 B(36)=0.185, B(38)=0.33, B(39)=1.781, B(40)=1.781, B(42)=0.004, ID=1001200,
 B(44)=209, ID=1001220,
 B(46)=0.004, B(48)=1.15, B(50)=0, B(52)=0, B(54)=8, ID=1001300,
 B(62)=0.00546, B(63)=0.00396, B(64)=0.000815, B(65)=0.004, ID=1001400,
 B(66)=0.0071, B(68)=0.023, B(90)=50, ID=1001500,
 E=19*0,2*16,7*0,2*16,7*4700,2*16,7*4700,2*16,7*0,2*530,7*0,20*530, ID=1001600,
 114*0, E(85)=0, ID=1001700,
 PF(10)=16, PF(11)=16, PO(11)=16, PO(12)=16, ID=1001800,
 IPI=1,6,11,3*0,101,107,112,3*0,211,205,207,3*0,312,308,306,9*0, ID=1001900,
 IWI=11,211,112,312,401,402,403,404, ID=1002000,

```
VARIS=5,200,5,112,5,40,5,47,12*0,  
INDEX=12,  
B(25)=20, B(26)=20, B(62)=0.01092, B(66)=0.0142,  
END  
5-5 TANK PRESSURIZATION TRANSIENT
```

```
ID=1002100,  
ID=1008800,  
ID=1009000,  
1100000,  
1100100,  
1100200,  
PROGRAM CHECKOUT 1100300,
```

PROGRAM CHECKOUT

DATE 12/14/70
TIME 12:13:03

SE5-5 TANK PRESSURIZATION TRANSIENT

11/24/70
12:13:03

PROGRAM CHECKOUT

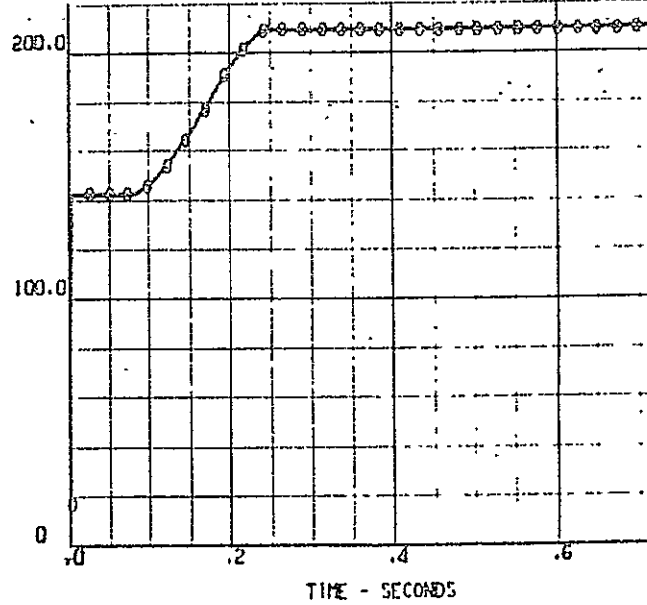
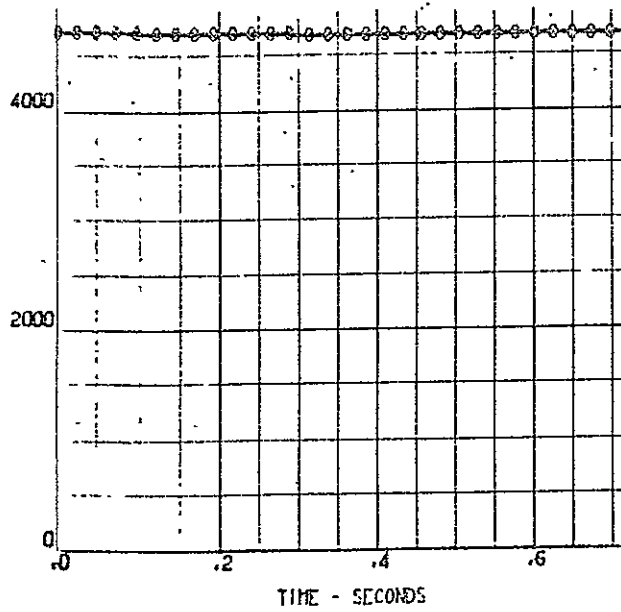
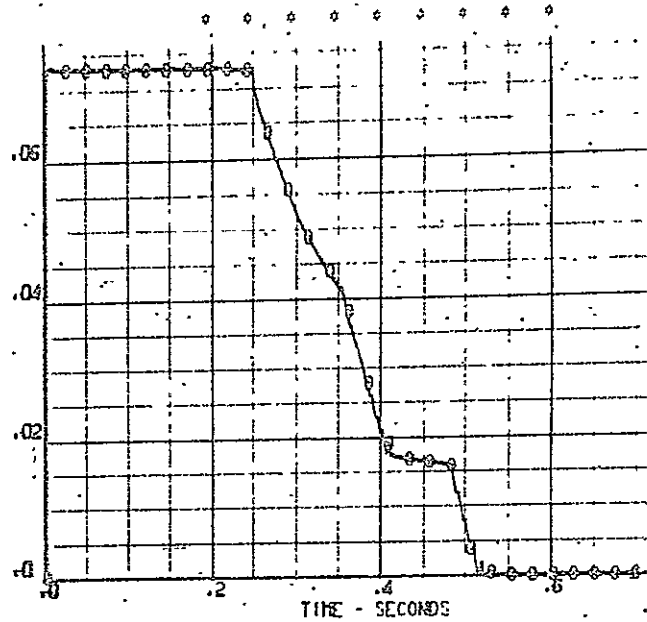
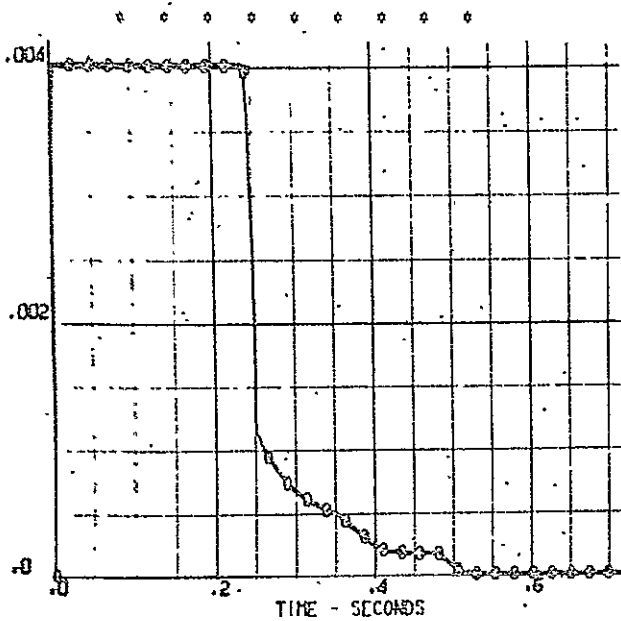


Figure D-3A - Graphical Output of SE5-5 Pressurization System Model.

DATE 12/14/70
TIME 12:23:03

SE5-5 TANK PRESSURIZATION TRANSIENT

NOT REPRODUCIBLE

1
12/14/70

* FUEL PRESSURE SEGMENT NO. 1.
X FUEL PRESSURE SEGMENT NO. 11.

PROGRAM CHECKOUT

0 FUEL PRESSURE SEGMENT NO. 6.

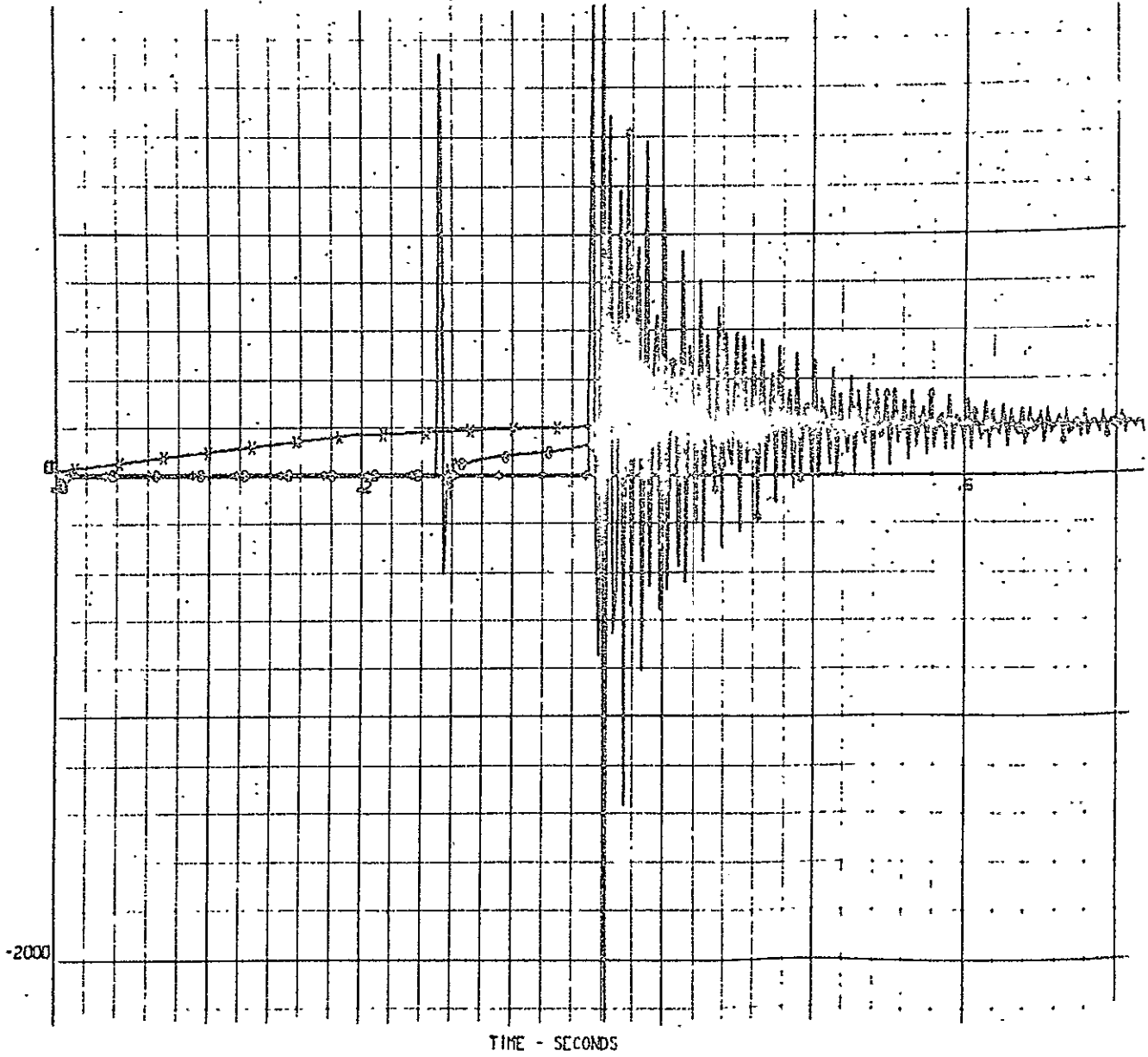


Figure D-3B - Graphical Output of SE5-5 Pressurization System Model.

DATE 10/14/70
TIME 11:23.03

SE5-5 TANK PRESSURIZATION TRANSIENT

10/14/70 11:23

PROGRAM CHECKOUT

* OXIDIZER PRESSURE SEGMENT NO. 1
X OXIDIZER PRESSURE SEGMENT NO. 12

o OXIDIZER PRESSURE SEGMENT NO.

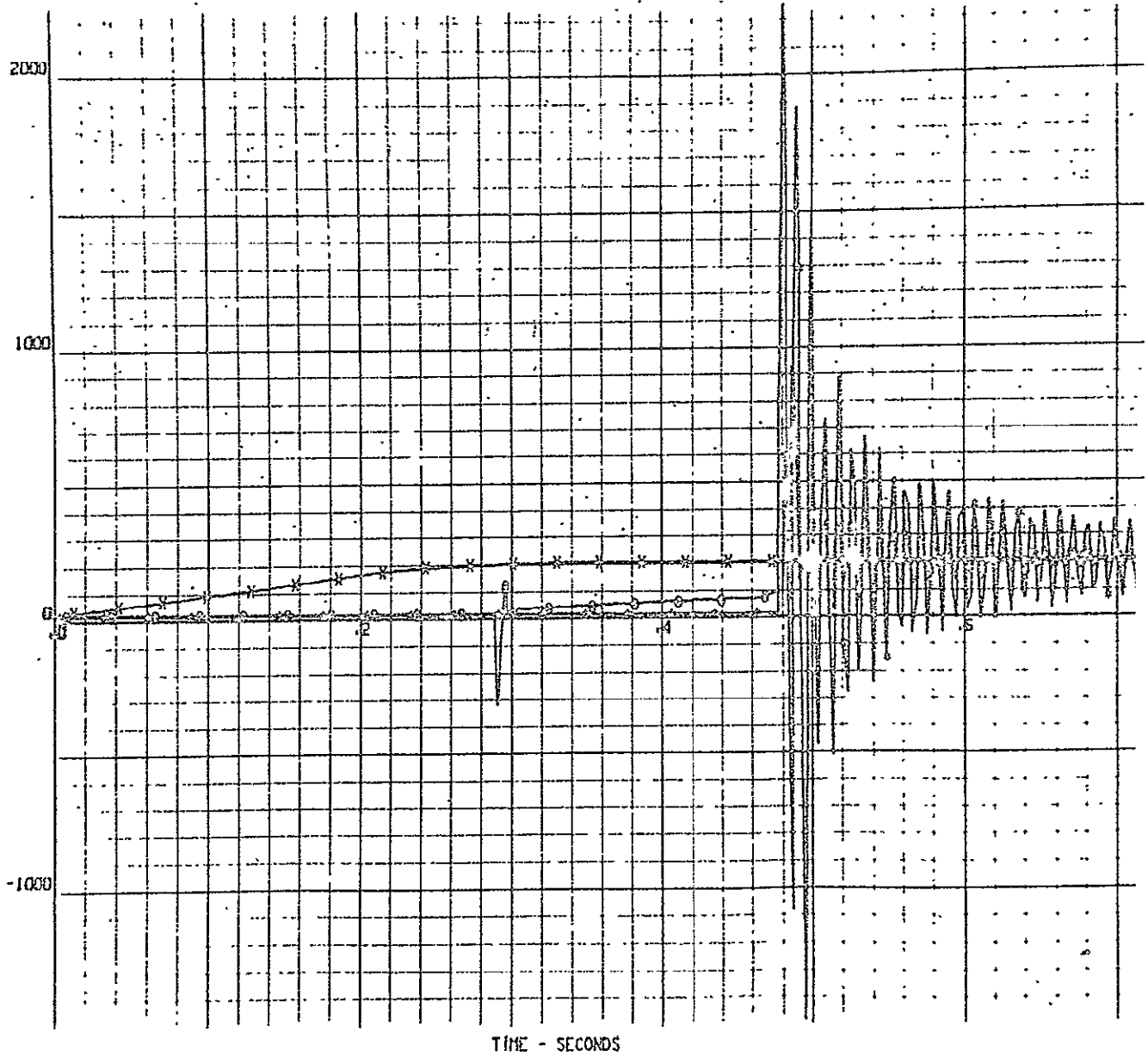


Figure D-3C - Graphical Output of SE5-5 Pressurization System Model.

1 JUL 1973
TIME 12:23:23

SES-C TANK PRESSURIZATION TRANSIENT

1
12/18/73

PROGRAM CHECKOUT

* FUEL FLOW SEGMENT NO. 11.
X FUEL FLOW SEGMENT NO. 7.

o FUEL FLOW SEGMENT NO.

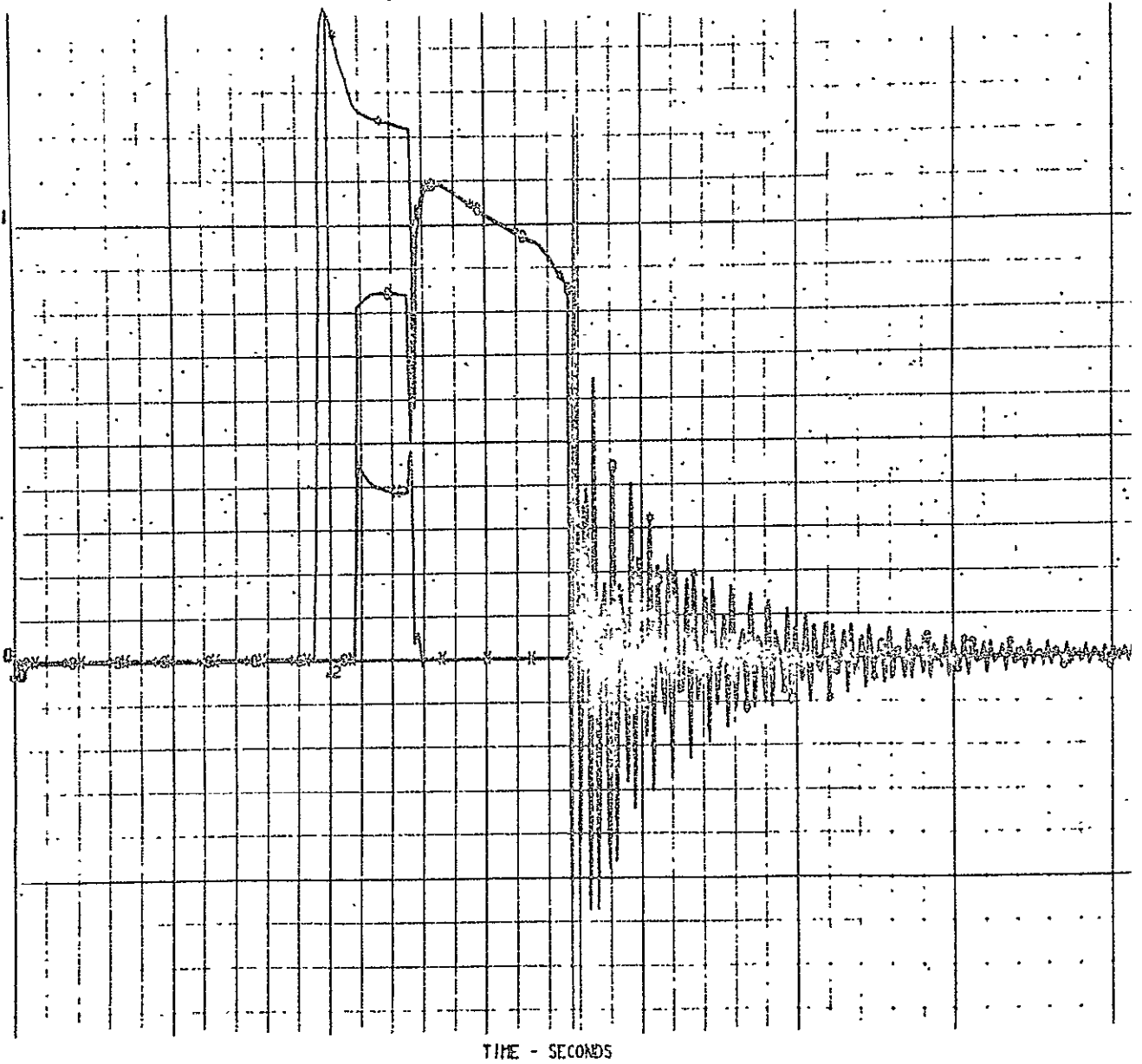


Figure D-3D - Graphical Output of SE5-5 Pressurization System Model.

DATE 1-18-70
TIME 12:23:43

SES-5 TANK PRESSURIZATION TRANSIENT

NOT REPRODUCIBLE

12/18/70

PROGRAM CHECKOUT

* OXIDIZER FLOW SEGMENT NO. 12.
X OXIDIZER FLOW SEGMENT NO. 6.

o OXIDIZER FLOW SEGMENT NO. 3.

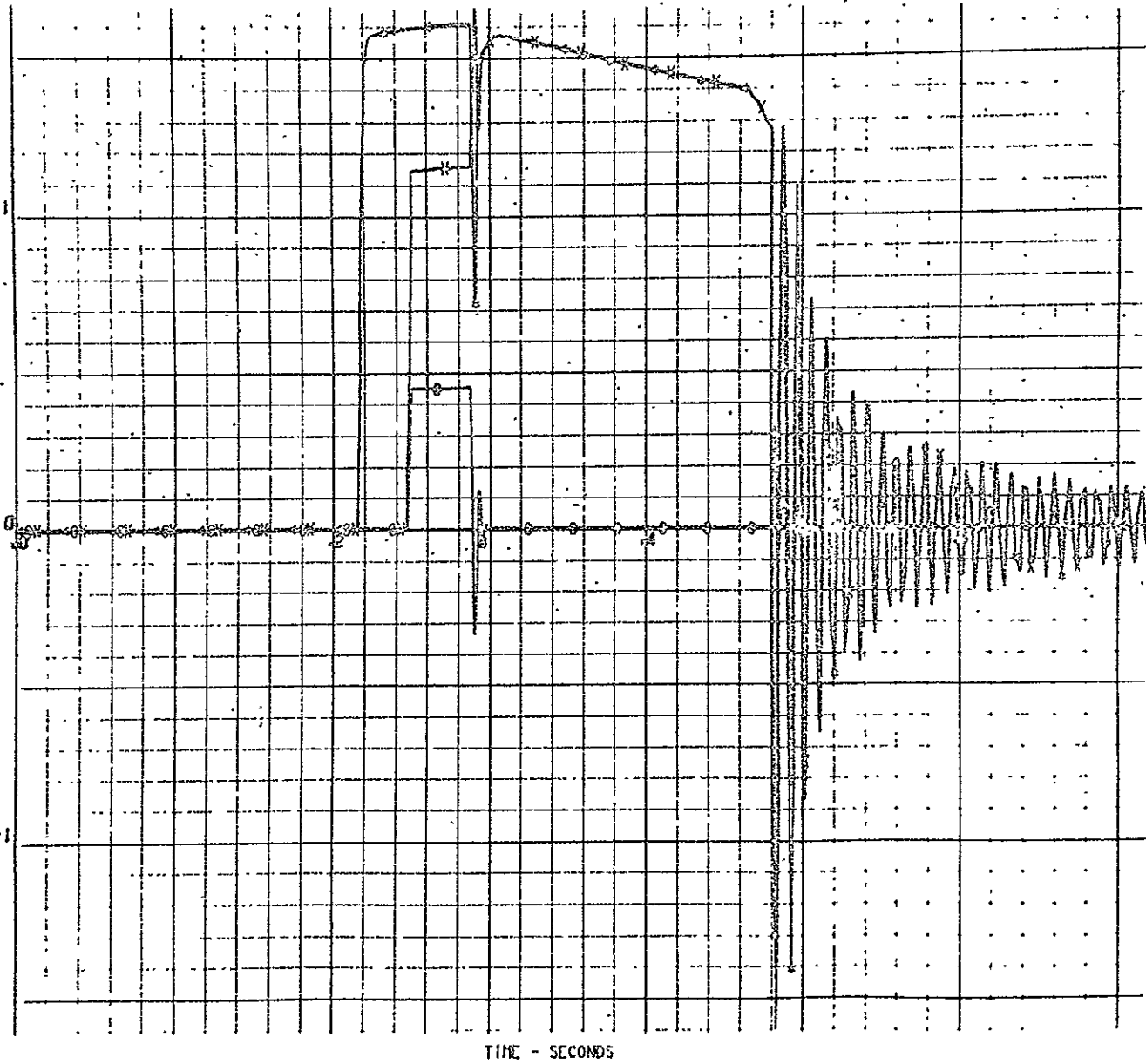


Figure D-3E - Graphical Output of SE5-5 Pressurization System Model.

TABLE D-IV

SE5-5 PRESSURIZATION SYSTEM PROGRAM OUTPUT LISTINGS

DATE 12/18/70
SE5-5 TANK PRESSURIZATION TRANSIENT

TIME 12:21.35

PROGRAM CHECKOUT

* SEGMENT DATA NO.	* STATE	* PRESSURE PSIA	* FLOW PPS	* FUEL FEEDSYSTEM PARAMETERS			* RESISTANCE SEC**2/IN**5	* DISOLVED GAS LBS G / LB L
				ACOUSTIC VELOCITY IN / SEC	AREA SQ. IN.	LENGTH INCHES		
1	EMPTY	0.79	0.0	59801.9	0.0346	16.00	2.646	0.0
2	EMPTY	0.79	0.0	58991.5	0.0583	15.00	0.8739	0.0
3	EMPTY	0.79	0.0	58991.5	0.0583	19.00	1.107	0.0
4	EMPTY	0.79	0.0	58991.5	0.0583	27.00	1.573	0.0
5	EMPTY	0.79	0.0	58213.1	0.0	0.0	0.0	0.0
6	EMPTY	0.79	0.0	59801.9	0.0346	13.00	4.410	0.0
7	EMPTY	0.79	0.0	58213.1	0.0	0.0	0.0	0.0
8	EMPTY	0.79	0.0	58213.1	0.0881	12.00	1.435	0.0
9	EMPTY	0.79	0.0	63100.0	0.0	0.0	0.1000E 32	0.0
0	FULL	16.00	0.0	58213.1	0.0881	12.00	1.435	0.0
1	FULL	16.00	0.0	63100.0	0.0	0.0	0.0	0.0

SE5-5 TANK PRESSURIZATION TRANSIENT DATE 12/18/70 TIME 12:21:35

* SEGMENT DATA NO. STATE	* PRESSURE PSIA	* FLOW PPS	OXIDIZER FEEDSYSTEM CONSTANTS			PROGRAM CHECKOUT		* DISOLVED GAS LBS G / LB L
			ACUSTIC VELOCITY IN / SEC	AREA SQ. IN.	LENGTH INCHES	RESISTANCE SEC**2/IN**5		
1 EMPTY	12.99	0.0	38082.0	0.0346	12.00	1.865	0.0	
2 EMPTY	12.99	0.0	37395.7	0.0881	15.00	0.3596	0.0	
3 EMPTY	12.99	0.0	37395.7	0.0881	17.00	0.4075	0.0	
4 EMPTY	12.99	0.0	37395.7	0.0881	19.00	0.4554	0.0	
5 EMPTY	12.99	0.0	37395.7	0.0881	14.80	0.3547	0.0	
6 EMPTY	12.99	0.0	37395.7	0.0	0.0	0.0	0.0	
7 EMPTY	12.99	0.0	38082.0	0.0346	10.00	1.571	0.0	
8 EMPTY	12.99	0.0	37395.7	0.0	0.0	0.0	0.0	
9 EMPTY	12.99	0.0	37395.7	0.1184	8.00	0.1456	0.0	
10 EMPTY	12.99	0.0	39450.0	0.0	0.0	0.1000E 32	0.0	
11 FULL	16.00	0.0	37395.7	0.0881	8.00	2.920	0.0	
12 FULL	16.00	0.0	39450.0	0.0	0.0	0.0	0.0	

INDEX	SEGMENT	*	FUEL VALVE TABLE						
			VALUES						
1	409	0.0	1.000000	0.001000	0.001000	0.050000	0.002000	0.050000	160.000000

INDEX	SEGMENT	*	OXIDIZER VALVE TABLE						
			VALUES						
1	410	0.0	1.000000	0.001000	0.001000	0.050000	0.002000	0.050000	160.000000

FUEL FUNGEN TABLE
 OXIDIZER FUNGEN TABLE

CAVITATING VENTURI DATA
FUEL

OXIDIZER

ORIFICE DATA

ACCUMULATOR DATA

INJECTOR MANIFOLD DATA

	FUEL				OXIDIZER			
	1	2	3	4	1	2	3	4
INDEX NO.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SEGMENT NO.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MANIFOLD VOLUME - CU. IN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ORIFICE LENGTH - INCHES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INJECTOR C-SUB-D*A - SQIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLAME FRONT DISTANCE-IN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

COMBUSTION CHAMBER DATA

	1		2		3		4	
	1	2	1	2	1	2	1	2
INDEX NO.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHAMBER PRESSURE - PSIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OXIDIZER FLOWRATE - PPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FUEL FLOWRATE - PPS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OXIDIZER FRACTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
THROAT AREA - SQ. IN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHAMBER VOLUME - CU. IN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NOZZLE EXIT AREA - SQ. IN.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CRUST COEFFICIENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENGINE AMBIENT PRESSURE - PSIA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ENGINE THRUST - POUNDS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

COMBUSTION DATA

BASE PRESSURE = 0.0 PSIA
 CSTAR CORRECTION = 0.0
 OX. FRACTION 0.0
 GAS CONSTANT 0.0

GAS CONSTANT CORRECTION = 0.0
 EFFICIENCY CORRECTION = 0.0
 CSTAR / C 0.0
 EFFICIENCY 0.0

DATE 12/18/70
SF5-5 TANK PERFORMANCE TRANSCRIPT

TIME 12:21:35

PROGRAM CHECKOUT

INPUT DATA CONSTANTS

ENTRAINED GAS - LBS GAS / LB LIQUID
 PROPELLANT DENSITY - POUNDS / CUBIC INCH
 LIQUID TEMPERATURE - DEGREES RANKINE
 PROPELLANT ACOUSTIC VELOCITY - INCHES / SECOND
 VAPOUR PRESSURE CURVE FIT CONSTANTS - CCN1
 (LOG(PVAP) = CCN1 * TEMP + CCN2)
 - CCN2
 PROPELLANT MOLECULAR WEIGHT
 PRESSURANT GAS MOLECULAR WEIGHT
 RATIO OF SPECIFIC HEATS - PRESSURANT GAS
 RATIO OF SPECIFIC HEATS - PROPELLANT VAPOR
 DISSOLVED GAS EVOLUTION TIME CONSTANT - 1/SEC.
 DISSOLVED GAS CONCENTRATION - LBS GAS / LB LIQ / PSI
 PROPELLANT TANK ULLAGE - CUBIC INCHES
 PROPELLANT TANK INITIAL PRESSURE - PSIA
 PRESSURANT GAS BOTTLE VOLUME - CUBIC INCHES
 PROPELLANT LIQUID HEAT CAPACITY - BTU / LB / DEGREE R
 PRESSURANT - LOW PRESSURE C-SUB-V
 PRESSURANT - HIGH PRESSURE C-SUB-V
 PRESSURANT - HIGH PRESSURE C-SUB-P
 PRESSURANT - HIGH PRESSURE GAMMA
 PRESSURE REGULATOR GAIN - SQ. IN. / PSI
 PRESSURE REGULATOR LOCKUP PRESSURE - PSIA
 PRESSURE REGULATOR MAXIMUM FLOW AREA - SQ. IN.
 PRESSURANT GAS COMPRESSIBILITY FACTOR
 PRESSURANT GAS BOTTLE HEAT INPUT - BTU / SEC
 PROPELLANT TANK HEAT INPUT - BTU / SEC
 PRESSURE REGULATOR SENSE PRESSURE INDEX
 HEAT EXCHANGER NO. 1 COOLANT SEGMENT NO.
 HEAT EXCHANGER NO. 3 COOLANT SEGMENT NO.
 EQUIVALENT ORIFICE AREA - DELTA P 1-2 - SQ. IN.

FUEL	OXIDIZER
0.0	0.0
0.03150	0.05200
530.0	530.0
63100.0	39450.0
1.0774E-02	8.9489E-C3
-5.8101E 00	-3.6294E CC
46.1	92.0
28.0	28.0
1.400	1.400
0.0	0.0
0.0	0.0
0.0	0.0
2.0000E 01	2.0000E 01
.16.0	16.0
0.0	8.8600E 02
7.0000E-01	3.6900E-01
1.7200E-01	1.7200E-01
0.0	1.8500E-01
0.0	3.3000E-01
1.781	1.781
0.0	4.0000E-03
0.0	209.0
0.0	4.0000E-03
0.0	1.150
0.0	0.0
0.0	0.0
0.0	8.0
0.0	0.0
0.0	0.0
0.0	2.9600E-C3

EQUIVALENT ORIFICE AREA - DELTA P 6-7 - SQ. IN.	0.0	8.1500E-04
EQUIVALENT ORIFICE AREA - REGULATOR - SQ. IN.	0.0	4.0000E-03
EQUIVALENT ORIFICE AREA - DELTA P 8-9 - SQ. IN.	1.0920E-02	1.4200E-02
LAMINAR FLOW FILTER CONSTANT - IN**3 / (PSI*SEC)	0.0	2.3000E-02
HEAT EXCHANGER AREA CAPACITANCE - UNIT NO. 1	0.0	0
BTU / DEGREE R / SECOND		
UNIT NO. 2	0.0	0.0
UNIT NO. 3	0.0	0.0
PROPELLANT VAPOR C-SUB-P	0.0	0.0
HEAT SOAKBACK - BTU / LB SEC DEGREE R	0.0	0.0
SOAKBACK INJECTOR TEMPERATURE - DEGREES R	0.0	0.0
PROPELLANT HEAT OF VAPORIZATION - BTU / LB	0.0	50.0000

NOT REPRODUCIBLE

SF 5-5 TANK PRESSURIZATION TRANSIENT

DATE 12/18/70

TIME 12:21:35

PROGRAM CHECKOUT

0.0	16.00000	0.0	16.00000	0.0	0.0	0.0	4700.00000	16.00000
0.002400	17.77057	0.00009	17.66196	0.00015	0.00400	0.07285	4699.87986	141.58415
0.004800	19.64098	0.00010	19.39618	0.00016	0.00400	0.07285	4699.67578	141.59151
0.007200	21.51099	0.00011	21.13037	0.00015	0.00400	0.07285	4699.51563	141.59036
0.009600	23.38066	0.00011	22.86450	0.00014	0.00400	0.07285	4699.35547	141.58917
0.012000	25.24954	0.00011	24.59813	0.00014	0.00400	0.07282	4699.19141	141.58503
0.014400	27.11797	0.00010	26.33150	0.00014	0.00400	0.07282	4699.03125	141.58380
0.016800	28.98622	0.00010	28.06480	0.00014	0.00400	0.07282	4698.87109	141.58267
0.019200	30.85428	0.00010	29.79808	0.00014	0.00400	0.07282	4698.71094	141.58143
0.021600	32.72220	0.00009	31.53127	0.00014	0.00400	0.07282	4698.54688	141.58030
0.024000	34.59006	0.00009	33.26442	0.00014	0.00400	0.07282	4698.38672	141.57914
0.026400	36.45775	0.00009	34.99750	0.00014	0.00400	0.07282	4698.22656	141.57798
0.028800	38.32533	0.00009	36.73053	0.00014	0.00400	0.07282	4698.06641	141.57672
0.031200	40.19287	0.00009	38.46358	0.00014	0.00400	0.07282	4697.90234	141.57549
0.033600	42.06035	0.00009	40.19659	0.00014	0.00400	0.07282	4697.74219	141.57430
0.036000	43.92772	0.00009	41.92955	0.00014	0.00400	0.07282	4697.58203	141.57313
0.038400	45.79509	0.00009	43.66246	0.00014	0.00400	0.07282	4697.42187	141.57196
0.040800	47.66231	0.00009	45.39526	0.00014	0.00400	0.07280	4697.26171	141.47876
0.043200	49.52878	0.00009	47.12746	0.00014	0.00400	0.07280	4697.10156	141.47760
0.045600	51.39520	0.00009	48.85962	0.00014	0.00400	0.07280	4696.94140	141.47636
0.048000	53.26160	0.00009	50.59169	0.00014	0.00400	0.07280	4696.78124	141.47516
0.050400	55.12794	0.00009	52.32372	0.00014	0.00400	0.07280	4696.62108	141.47397
0.052800	56.99425	0.00009	54.05566	0.00014	0.00400	0.07280	4696.46092	141.47284
0.055200	58.86057	0.00009	55.78758	0.00014	0.00400	0.07280	4696.30076	141.47166
0.057600	60.72685	0.00009	57.51945	0.00014	0.00400	0.07280	4696.14060	141.47057
0.060000	62.59306	0.00009	59.25127	0.00014	0.00400	0.07280	4695.98044	141.46945
0.062400	64.45929	0.00009	60.98309	0.00014	0.00400	0.07280	4695.82028	141.46836
0.064800	66.32547	0.00009	62.71487	0.00014	0.00400	0.07280	4695.66012	141.46726
0.067199	68.19165	0.00009	64.44659	0.00014	0.00400	0.07280	4695.50000	141.46616
0.069599	70.05782	0.00009	66.17825	0.00014	0.00400	0.07280	4695.34000	141.46506
0.071999	71.92399	0.00009	67.90992	0.00014	0.00400	0.07278	4695.18000	141.46397
0.074398	73.78853	0.00009	69.64158	0.00014	0.00400	0.07278	4695.02000	141.46287
0.076798	75.65245	0.00009	71.37324	0.00014	0.00400	0.07278	4694.86000	141.46177
0.079198	77.51456	0.00009	73.10492	0.00014	0.00400	0.07278	4694.70000	141.46067
0.081597	79.37497	0.00009	74.83652	0.00014	0.00400	0.07278	4694.54000	141.45957
0.083997	81.23354	0.00009	76.56812	0.00014	0.00400	0.07276	4694.38000	142.25378
0.086397	83.09115	0.00009	78.30000	0.00014	0.00400	0.07277	4694.22000	142.64618
0.088796	84.94493	0.00009	80.03188	0.00014	0.00400	0.07278	4694.06000	143.03972
0.091196	86.79776	0.00009	81.76373	0.00014	0.00400	0.07277	4693.90000	143.43326

0.093506	88.64859	0.00009	83.52747	0.00014	0.00400	0.07277	4693.71094	144.12321
0.095995	90.49727	0.00009	85.26891	0.00014	0.00400	0.07276	4693.54688	144.72081
0.098395	92.34369	0.00009	87.01184	0.00014	0.00400	0.07276	4693.38672	145.36529
0.100795	94.18787	0.00009	88.75612	0.00014	0.00400	0.07276	4693.22656	146.05672
0.103195	96.02982	0.00009	90.50150	0.00014	0.00400	0.07276	4693.06250	146.79178
0.105594	97.86977	0.00009	92.24825	0.00014	0.00400	0.07275	4692.90234	147.54424
0.107994	99.70770	0.00009	93.99664	0.00014	0.00400	0.07276	4692.74219	148.37250
0.110394	101.54355	0.00009	95.74641	0.00014	0.00400	0.07276	4692.58203	149.22382
0.112793	103.37686	0.00009	97.49744	0.00014	0.00400	0.07275	4692.41797	150.06281
0.115193	105.20813	0.00009	99.24985	0.00014	0.00400	0.07273	4692.25781	150.97221
0.117593	107.03743	0.00009	101.00356	0.00014	0.00400	0.07275	4692.09766	151.93364
0.119992	108.86430	0.00009	102.75867	0.00014	0.00400	0.07275	4691.93359	152.90852
0.122392	110.68918	0.00009	104.51520	0.00014	0.00400	0.07273	4691.77734	153.87653
0.124792	112.51164	0.00009	106.27324	0.00014	0.00400	0.07274	4691.61328	154.91357
0.127191	114.33183	0.00009	108.03261	0.00014	0.00400	0.07275	4691.45313	155.97604
0.129591	116.15004	0.00009	109.79327	0.00014	0.00400	0.07273	4691.28906	157.02121
0.131991	117.96603	0.00009	111.55560	0.00014	0.00400	0.07274	4691.12891	158.12831
0.134390	119.78000	0.00009	113.31923	0.00014	0.00400	0.07272	4690.96875	159.22481
0.136790	121.59161	0.00009	115.08424	0.00014	0.00400	0.07274	4690.80469	160.38021
0.139190	123.40114	0.00009	116.85057	0.00014	0.00400	0.07273	4690.64844	161.53161
0.141589	125.20876	0.00009	118.61832	0.00014	0.00400	0.07273	4690.48438	162.69381
0.143989	127.01402	0.00009	120.38727	0.00014	0.00400	0.07271	4690.32422	163.86481
0.146389	128.81757	0.00009	122.15759	0.00014	0.00400	0.07271	4690.16406	165.08011
0.148789	130.61896	0.00009	123.92923	0.00014	0.00400	0.07272	4690.00000	166.30521
0.151188	132.41826	0.00009	125.70212	0.00014	0.00400	0.07273	4689.83984	167.55481
0.153588	134.21559	0.00009	127.47601	0.00014	0.00400	0.07271	4689.67578	168.79801
0.155988	136.01115	0.00009	129.25157	0.00014	0.00400	0.07272	4689.51953	170.07651
0.158387	137.80493	0.00009	131.02832	0.00014	0.00400	0.07272	4689.35547	171.34751
0.160787	139.59674	0.00009	132.80606	0.00014	0.00400	0.07272	4689.19531	172.64651
0.163187	141.38672	0.00009	134.58531	0.00014	0.00400	0.07272	4689.03516	173.95131
0.165586	143.17493	0.00009	136.36542	0.00014	0.00400	0.07271	4688.87109	175.25921
0.167986	144.96135	0.00009	138.14691	0.00014	0.00400	0.07271	4688.71094	176.59011
0.170386	146.74612	0.00009	139.92943	0.00014	0.00400	0.07270	4688.55078	177.93001
0.172785	148.52922	0.00009	141.71309	0.00014	0.00400	0.07270	4688.39063	179.28061
0.175185	150.31058	0.00009	143.49767	0.00014	0.00400	0.07270	4688.22656	180.64151
0.177585	152.09033	0.00009	145.28322	0.00014	0.00400	0.07270	4688.06641	182.01251
0.179984	153.86852	0.00009	147.06949	0.00014	0.00400	0.07270	4687.90625	183.39561
0.182384	155.64503	0.00009	148.85701	0.00014	0.00400	0.07269	4687.74219	184.78521
0.184784	157.42033	0.00009	150.64545	0.00014	0.00400	0.07269	4687.58203	186.18391
0.187183	159.19405	0.00009	152.43469	0.00014	0.00400	0.07269	4687.42188	187.59141
0.189583	160.96643	0.00009	154.22485	0.00014	0.00400	0.07269	4687.26172	189.00721
0.191983	162.73856	0.59272	156.01520	0.00014	0.00400	0.07270	4687.10156	190.39731
0.194382	163.51268	1.24681	157.81199	0.00014	0.00400	0.07267	4686.93750	191.50371

0.196782	164.2.111	1.45992	159.57915	0.00014	0.00400	0.07267	4686.77734	192.48814
0.199182	164.70403	1.48687	161.34431	0.00014	0.00400	0.07267	4686.61719	193.44467
0.201582	165.21213	1.46403	163.09717	0.00014	0.00400	0.07267	4686.45313	194.41002
0.203981	165.75175	1.42990	164.83774	0.00014	0.00400	0.07267	4686.29297	195.39310
0.206381	166.32805	1.39521	166.56624	0.00014	0.00400	0.07266	4686.13281	196.39500
0.208781	166.94005	1.36275	168.28325	0.00014	0.00400	0.07267	4685.97266	197.42305
0.211180	167.58421	1.33304	169.98889	0.00014	0.00400	0.07267	4685.81250	198.45996
0.213580	168.25845	1.30593	171.68349	0.00014	0.00400	0.07267	4685.65234	199.51164
0.215980	168.96031	1.28117	173.36710	0.00014	0.00400	0.07266	4685.48828	200.56560
0.218379	169.68654	1.26378	174.92839	0.95494	0.00400	0.07267	4685.32813	201.59096
0.220779	170.42517	1.25429	176.09386	1.47131	0.00400	0.07266	4685.16797	202.41309
0.223179	171.16685	1.24829	177.13181	1.55586	0.00400	0.07265	4685.00391	203.18089
0.225578	171.90834	1.24445	178.14113	1.56991	0.00400	0.07265	4684.84375	203.93884
0.227978	172.64857	1.24139	179.13597	1.57391	0.00400	0.07265	4684.68359	204.68858
0.230378	173.38708	1.23869	180.11938	1.57632	0.00400	0.07265	4684.52344	205.43332
0.232777	174.12354	1.23617	181.09187	1.57843	0.00400	0.07265	4684.35938	206.17393
0.235177	174.85815	1.23375	182.05330	1.58042	0.00400	0.07265	4684.20313	206.90970
0.237577	175.59050	1.23139	183.00427	1.58233	0.00400	0.07265	4684.03906	207.64104
0.239976	176.32077	1.22908	183.94466	1.58418	0.00396	0.07264	4683.87891	208.36737
0.242376	177.04886	1.22679	184.87492	1.58597	0.00365	0.07264	4683.71484	209.08948
0.244776	177.77451	1.22453	185.79524	1.58769	0.00304	0.07264	4683.55469	209.80699
0.247176	178.49791	1.22228	186.70540	1.58936	0.00218	0.07264	4683.39453	210.52007
0.249575	179.20889	1.22006	187.59407	1.59096	0.00123	0.07005	4683.23438	209.33612
0.251975	179.85262	1.21779	188.39528	1.59250	0.00113	0.06839	4683.07813	208.81329
0.254375	180.74188	0.58087	189.16403	1.59450	0.00108	0.06737	4682.92188	208.82698
0.256774	181.58008	1.04326	189.90193	1.59623	0.00104	0.06636	4682.76993	208.81808
0.259174	182.31180	1.01728	190.61029	1.59785	0.00100	0.06540	4682.62109	208.82156
0.261574	182.99248	1.08975	191.29002	1.59931	0.00097	0.06447	4682.46875	208.82141
0.263973	183.62793	1.07773	191.94080	1.60066	0.00094	0.06357	4682.31641	208.82338
0.266373	184.23465	1.09247	192.56511	1.60189	0.00091	0.06269	4682.16797	208.82617
0.268773	184.81567	1.09019	193.16394	1.60300	0.00089	0.06183	4682.04688	208.82634
0.271172	185.37657	1.09123	193.73604	1.60398	0.00086	0.06098	4681.92969	208.83154
0.273572	185.91975	1.08702	194.28349	1.60486	0.00084	0.06014	4681.80859	208.83092
0.275972	186.44710	1.08267	194.80676	1.60563	0.00082	0.05935	4681.69141	208.84004
0.278371	186.95941	1.07781	195.30696	1.60628	0.00080	0.05856	4681.57031	208.85284
0.280771	187.45799	1.07068	195.78421	1.60683	0.00078	0.05777	4681.44922	208.84573
0.283171	187.94366	1.06479	196.23827	1.60729	0.00077	0.05699	4681.33594	208.84517
0.285570	188.41597	1.05853	196.67101	1.60765	0.00075	0.05624	4681.21875	208.84735
0.287970	188.87607	1.05184	197.08356	1.60791	0.00073	0.05551	4681.10547	208.84970
0.290370	189.32387	1.04596	197.48495	0.72180	0.00072	0.05479	4680.99219	208.85590
0.292769	189.75984	1.03988	198.02055	1.49322	0.00070	0.05391	4680.87500	208.86011
0.295169	190.18425	1.03376	198.42757	1.48348	0.00069	0.05315	4680.76563	208.85976
0.297569	190.59688	1.02811	198.79716	1.52211	0.00067	0.05243	4680.65234	208.85951

0.299969	190.99842	1.02239	199.13144	1.56399	0.00066	0.05176	4680.53506	208.86090
0.302368	191.38911	1.01672	199.44215	1.56096	0.00065	0.05110	4680.43359	208.86176
0.304768	191.75909	1.01133	199.73471	1.56877	0.00064	0.05048	4680.32422	208.86433
0.307168	192.13849	1.00605	200.01030	1.56818	0.00062	0.04986	4680.21484	208.86624
0.309567	192.49759	1.00075	200.27110	1.56765	0.00061	0.04927	4680.10547	208.86761
0.311967	192.84686	0.99555	200.51877	1.56505	0.00060	0.04869	4680.00000	208.86943
0.314367	193.18610	0.99057	200.75326	1.56354	0.00059	0.04813	4679.88672	208.87100
0.316766	193.51579	0.98555	200.97639	1.56027	0.00059	0.04756	4679.78125	208.86186
0.319166	193.83635	0.98072	201.18777	1.55836	0.00058	0.04706	4679.67969	208.87950
0.321566	194.14725	0.97592	201.38795	1.55500	0.00057	0.04654	4679.57422	208.88078
0.323965	194.44954	0.97122	201.57838	1.55283	0.00056	0.04604	4679.46875	208.88206
0.326365	194.74306	0.96662	201.75842	1.54953	0.00055	0.04554	4679.36719	208.88334
0.328765	195.02802	0.96206	201.92903	1.54718	0.00054	0.04507	4679.26563	208.88200
0.331164	195.30438	0.95760	202.09087	1.54396	0.00054	0.04461	4679.16016	208.88255
0.333564	195.57291	0.95322	202.24445	1.54146	0.00053	0.04417	4679.05469	208.88760
0.335964	195.83440	0.94907	202.38954	1.53833	0.00052	0.04373	4678.95313	208.88547
0.338363	196.09238	0.94401	202.52731	1.53571	0.00052	0.04330	4678.84766	208.88696
0.340763	196.34901	0.92146	202.65813	1.53267	0.00051	0.04288	4678.75000	208.88762
0.343163	196.60526	0.90751	202.78181	1.52995	0.00050	0.04247	4678.64844	208.88724
0.345563	196.86200	0.89313	202.89894	1.52698	0.00050	0.04205	4678.55078	208.88264
0.347962	197.11925	0.87894	203.01012	1.52419	0.00049	0.04166	4678.45313	208.88901
0.350362	197.37701	0.86494	203.11563	1.52129	0.00049	0.04126	4678.35547	208.88910
0.352762	197.63440	0.85124	203.21555	1.51845	0.00048	0.04086	4678.25391	208.88596
0.355161	198.80928	0.855177	203.31152	1.51560	0.00046	0.03976	4678.15625	208.93616
0.357561	199.86101	1.24221	203.40324	1.51273	0.00045	0.03849	4678.05859	208.90244
0.359961	200.25768	0.39617	203.48854	1.50993	0.00044	0.03799	4677.96484	208.91922
0.362360	201.62379	0.34897	203.57169	1.50723	0.00042	0.03638	4677.87109	208.92479
0.364760	201.93552	0.35072	203.64915	1.50464	0.00041	0.03584	4677.77734	208.90866
0.367160	202.91301	0.54554	203.72412	1.50145	0.00039	0.03463	4677.67969	208.94421
0.369559	203.64601	0.64391	203.79497	1.49865	0.00038	0.03346	4677.58984	208.91438
0.371959	204.03487	0.57238	203.86163	1.49572	0.00037	0.03289	4677.50391	208.93933
0.374359	205.04324	0.12173	203.92780	1.49337	0.00035	0.03128	4677.42969	208.94312
0.376758	205.25328	0.08010	203.98923	1.49034	0.00034	0.03078	4677.36719	208.92674
0.379158	206.01613	0.47884	204.04898	1.48783	0.00033	0.02948	4677.30859	208.96744
0.381558	206.47769	0.44382	204.10602	1.48455	0.00031	0.02833	4677.25000	208.93137
0.383957	206.76717	0.46251	204.15938	1.48225	0.00031	0.02776	4677.19141	208.95660
0.386357	207.45169	0.17087	204.21223	1.47910	0.00029	0.02603	4677.13281	208.95833
0.388757	207.51503	0.05521	204.26071	1.47695	0.00028	0.02570	4677.07422	208.93800
0.391156	208.04970	0.28041	204.30930	1.47372	0.00027	0.02426	4677.01953	208.98903
0.393556	208.24900	0.40079	204.35449	1.47143	0.00025	0.02314	4676.96875	208.92654
0.395956	208.39641	0.34416	204.39728	1.46826	0.00025	0.02280	4676.91406	208.98061
0.398356	208.78182	0.22973	204.44084	1.46602	0.00022	0.02055	4676.86328	208.97537
0.400755	208.67622	0.02231	204.47858	1.46304	0.00023	0.02094	4676.81250	208.94020

0.403155	208.98993	-0.17903	204.51888	.46073	0.00021	0.01906	4676.75781	209.04103
0.405555	208.91972	0.32204	204.55684	.45778	0.00019	0.01748	4676.71094	208.92641
0.407954	208.93036	-0.30325	204.58852	.45538	0.00021	0.01911	4676.66406	208.99773
0.410354	209.10094	0.21316	204.62398	.45254	0.00019	0.01735	4676.61719	208.96182
0.412754	208.90656	-0.04011	204.65509	.45018	0.00019	0.01756	4676.57422	208.91562
0.415153	209.00850	-0.12854	204.68613	.44744	0.00018	0.01715	4676.52734	208.92046
0.417553	209.00555	0.23548	204.71550	.44529	0.00018	0.01715	4676.48047	208.95294
0.419953	208.99738	-0.27330	204.74403	.44244	0.00018	0.01718	4676.43359	208.99561
0.422352	209.10460	0.19837	204.77109	.43983	0.00018	0.01705	4676.38672	208.95688
0.424752	208.94583	-0.07924	204.79765	.43742	0.00018	0.01700	4676.33984	208.95216
0.427152	209.10260	-0.07623	204.82318	.43491	0.00018	0.01694	4676.29297	208.95593
0.429551	209.00294	0.18112	204.84778	.43236	0.00018	0.01690	4676.24609	208.95663
0.431951	209.01842	-0.23059	204.87166	.42999	0.00018	0.01685	4676.19922	208.95631
0.434351	209.09024	0.19357	204.89468	.42744	0.00018	0.01680	4676.15234	208.95595
0.436750	208.96330	-0.09459	204.91718	.42502	0.00018	0.01676	4676.10547	208.95776
0.439150	209.10181	-0.02898	204.93890	.42263	0.00018	0.01671	4676.05859	208.95660
0.441550	209.00070	0.13830	204.95979	.42012	0.00018	0.01667	4676.01172	208.95692
0.443950	209.03410	-0.19030	204.98051	.41773	0.00018	0.01663	4675.96484	208.95677
0.446349	209.07733	0.18211	205.00044	.41532	0.00018	0.01659	4675.92188	208.95645
0.448749	208.97787	-0.10670	205.01988	.41296	0.00018	0.01655	4675.87109	208.95657
0.451149	209.09886	0.00396	205.03900	.41059	0.00018	0.01651	4675.82422	208.95665
0.453548	209.00055	0.09738	205.05719	.40827	0.00018	0.01647	4675.77734	208.95734
0.455948	209.04720	-0.15840	205.07552	.40586	0.00018	0.01643	4675.73047	208.95782
0.458348	209.06747	0.16463	205.09298	.40357	0.00018	0.01640	4675.68359	208.95685
0.460747	208.99229	-0.11483	205.11018	.40123	0.00017	0.01636	4675.63672	208.95691
0.463147	209.09645	0.02731	205.12714	.39897	0.00017	0.01633	4675.58984	208.95729
0.465547	209.00255	0.06266	205.14366	.39687	0.00017	0.01629	4675.54297	208.95679
0.467946	209.05722	-0.12869	205.16359	.39487	0.00017	0.01625	4675.50000	208.95715
0.470346	209.05995	0.14674	205.18747	.39287	0.00017	0.01620	4675.44922	208.95772
0.472746	209.00525	-0.11610	205.21652	.39087	0.00017	0.01614	4675.40625	208.95851
0.475145	209.09268	0.04599	205.25063	.38887	0.00017	0.01607	4675.35938	208.95880
0.477545	209.00555	0.03506	205.29005	.38687	0.00017	0.01599	4675.31250	208.95926
0.479945	209.06511	-0.10050	205.33423	.38487	0.00017	0.01589	4675.26563	208.95953
0.482344	209.05408	0.12924	205.37901	.38287	0.00016	0.01498	4675.21875	209.00668
0.484744	209.01703	-0.11201	205.42379	.38087	0.00014	0.01303	4675.17578	209.01353
0.487144	209.08971	0.05937	205.46857	.37887	0.00013	0.01198	4675.13281	208.95454
0.489543	209.01045	0.01238	205.51335	.37687	0.00013	0.01187	4675.08984	208.97044
0.491943	209.07202	-0.07555	205.55813	.37487	0.00011	0.01071	4675.05078	209.02992
0.494343	209.05052	0.11111	205.60291	.37287	0.00009	0.00866	4675.01172	209.01761
0.496743	209.02007	-0.10729	205.64769	.37087	0.00008	0.00790	4674.97656	208.96564
0.499142	209.09641	0.06755	205.69247	.36887	0.00008	0.00789	4674.93750	208.99429
0.501542	209.01801	-0.01638	205.73725	.36687	0.00007	0.00651	4674.90625	209.01569
0.503942	209.09248	-0.05378	205.78203	.36487	0.00004	0.00400	4674.87109	209.02637

0.506341	209.06294	0.09309	208.74237	0.71149	0.00004	0.00386	4674.83984	208.95267
0.508741	209.05472	-0.09964	208.75320	-0.13086	0.00004	0.00426	4674.80859	209.00934
0.511141	209.09886	0.07193	209.03096	-0.65456	0.00002	0.00203	4674.77734	209.08879

AN ERROR OCCURRED IN THE BRANCH ITERATION IN SUBROUTINE TANK.
 PG(8,2,1) = 209.089 PG(8,2,2) = 209.105

AN ERROR OCCURRED IN THE BRANCH ITERATION IN SUBROUTINE TANK.
 PG(8,2,1) = 209.077 PG(8,2,2) = 209.115

0.513540	209.04453	-0.02110	209.12610	0.19830	0.0	0.0	4674.77344	209.04453
0.515940	209.10373	-0.03465	208.95190	0.60250	0.00000	0.00045	4674.77344	208.95477
0.518340	209.06882	0.07603	208.95546	-0.24713	0.00002	0.00210	4674.75391	209.01788

AN ERROR OCCURRED IN THE BRANCH ITERATION IN SUBROUTINE TANK.
 PG(8,2,1) = 209.069 PG(8,2,2) = 209.085

AN ERROR OCCURRED IN THE BRANCH ITERATION IN SUBROUTINE TANK.
 PG(8,2,1) = 209.066 PG(8,2,2) = 209.101

0.520739	209.08037	-0.09028	209.16132	-0.46577	0.0	0.0	4674.75000	209.08037
0.523139	209.11295	0.07333	209.18663	0.32781	0.0	0.0	4674.75000	209.11295
0.525539	209.06075	-0.03214	208.96654	0.31481	0.00000	0.0	4674.75000	208.96654
0.527938	209.11624	-0.01811	209.03989	-0.39601	0.00000	0.00043	4674.74609	209.04254
0.530338	209.07852	0.06002	209.23784	-0.19908	0.0	0.0	4674.74609	209.07852
0.532738	209.08865	-0.07996	209.18077	0.42986	0.0	0.0	4674.74609	209.08865
0.535137	209.11018	0.07218	208.99608	0.13227	0.0	0.0	4674.74609	208.99608
0.537537	209.06703	-0.04010	209.09993	-0.42651	0.0	0.0	4674.74609	209.06703
0.539937	209.11800	-0.00422	209.26099	-0.08507	0.0	0.0	4674.74609	209.11800
0.542337	209.07874	0.04519	209.15303	0.38840	0.0	0.0	4674.74609	209.07874
0.544736	209.09564	-0.06923	209.02161	0.01848	0.0	0.0	4674.74609	209.02161
0.547136	209.10820	0.06900	209.14735	-0.33890	0.0	0.0	4674.74609	209.10820
0.549536	209.07372	-0.04535	209.24994	0.06924	0.0	0.0	4674.74609	209.07372
0.551935	209.11891	0.00718	209.11162	0.29163	0.0	0.0	4674.74609	209.11162
0.554335	209.07999	0.03173	209.03868	-0.15367	0.0	0.0	4674.74609	209.03868
0.556735	209.10168	-0.05839	209.18541	-0.25292	0.0	0.0	4674.74609	209.10168
0.559134	209.10605	0.06431	209.23021	0.21364	0.0	0.0	4674.74609	209.10605
0.561534	209.07994	-0.04822	209.08278	0.21735	0.0	0.0	4674.74609	209.07994
0.563934	209.12009	0.01631	209.06505	-0.24293	0.0	0.0	4674.74609	209.06505
0.566333	209.08173	0.01979	209.20880	-0.17587	0.0	0.0	4674.74609	209.08173
0.568733	209.10638	-0.04774	209.20097	0.25359	0.0	0.0	4674.74609	209.10638
0.571133	209.10440	0.05853	209.06685	0.12335	0.0	0.0	4674.74609	209.06685
0.573532	209.09606	-0.04919	209.09866	-0.25640	0.0	0.0	4674.74609	209.08606
0.575932	209.12035	0.02331	209.22130	-0.06390	0.0	0.0	4674.74609	209.12035
0.578332	209.08470	0.00938	209.16815	0.25649	0.0	0.0	4674.74609	209.08479

NOT REPRODUCIBLE

NOT REPRODUCIBLE

C.580731	209.11150	-0.03756	209.06110	0.00444	0.0	0.0	4674.74609	209.06110
C.583131	209.10422	0.05200	209.13260	-0.25145	0.0	0.0	4674.74609	209.10422
C.585531	209.09256	-0.04832	209.22382	0.04792	0.0	0.0	4674.74609	209.09256
C.587931	209.12093	0.02836	209.13918	0.23868	0.0	0.0	4674.74609	209.12093
C.590330	209.08839	0.00050	209.06686	-0.09149	0.0	0.0	4674.74609	209.06686
C.592730	209.11592	-0.02803	209.16173	-0.21686	0.0	0.0	4674.74609	209.11592
C.595130	209.10469	0.04505	209.21519	0.12693	0.0	0.0	4674.74609	209.10469
C.597529	209.09897	-0.04622	209.11526	0.18772	0.0	0.0	4674.74609	209.09897
C.599929	209.12134	0.03166	209.08221	-0.15629	0.0	0.0	4674.74609	209.08221
C.602329	209.09216	-0.00685	209.18463	-0.15309	0.0	0.0	4674.74609	209.09216
C.604728	209.11963	-0.01930	209.19893	0.17967	0.0	0.0	4674.74609	209.11963
C.607128	209.10516	0.03794	209.09854	0.11532	0.0	0.0	4674.74609	209.09854
C.609528	209.10448	-0.04309	209.10382	-0.19649	0.0	0.0	4674.74609	209.10382
C.611927	209.12186	0.03343	209.20010	-0.07614	0.0	0.0	4674.74609	209.12186
C.614327	209.09634	-0.01275	209.17810	-0.20590	0.0	0.0	4674.74609	209.09634
C.616727	209.12279	-0.01148	209.09015	0.03722	0.0	0.0	4674.74609	209.09015
C.619126	209.10622	0.03091	209.12831	-0.20760	0.0	0.0	4674.74609	209.10622
C.621526	209.10962	-0.03919	209.20750	0.00021	0.0	0.0	4674.74609	209.10962
C.623926	209.12198	0.03390	209.15672	0.20182	0.0	0.0	4674.74609	209.12198
C.626325	209.10037	-0.01726	209.09058	-0.03555	0.0	0.0	4674.74609	209.09058
C.628725	209.12556	-0.00463	209.15237	-0.18898	0.0	0.0	4674.74609	209.12556
C.631125	209.10748	0.02413	209.20621	0.06809	0.0	0.0	4674.74609	209.10748
C.633524	209.11472	-0.03477	209.13728	0.17028	0.0	0.0	4674.74609	209.11472
C.635924	209.12303	0.03326	209.09886	-0.09749	0.0	0.0	4674.74609	209.09886
C.638324	209.10535	-0.02050	209.17332	-0.14694	0.0	0.0	4674.74609	209.10535
C.640724	209.12846	0.00123	209.19792	0.12267	0.0	0.0	4674.74609	209.12846
C.643123	209.11020	0.01775	209.12173	0.12082	0.0	0.0	4674.74609	209.11020
C.645523	209.11989	-0.03004	209.11267	-0.14279	0.0	0.0	4674.74609	209.11267
C.647923	209.12383	0.03173	209.18877	-0.09289	0.0	0.0	4674.74609	209.12383
C.650322	209.10968	-0.02259	209.18446	0.15650	0.0	0.0	4674.74609	209.10968
C.652722	209.13019	0.00608	209.11217	0.06418	0.0	0.0	4674.74609	209.11217
C.655122	209.11191	0.01189	209.13068	-0.16363	0.0	0.0	4674.74609	209.11191
C.657521	209.12357	-0.02518	209.19835	-0.03464	0.0	0.0	4674.74609	209.12357
C.659921	209.12448	0.02950	209.16899	0.16406	0.0	0.0	4674.74609	209.12448
C.662321	209.11401	-0.02365	209.10942	0.00499	0.0	0.0	4674.74609	209.10942
C.664720	209.13220	0.00996	209.15005	-0.15897	0.0	0.0	4674.74609	209.13220
C.667120	209.11453	0.00662	209.20142	0.02442	0.0	0.0	4674.74609	209.11453
C.669520	209.12907	-0.02037	209.15321	0.14897	0.0	0.0	4674.74609	209.12907
C.671919	209.12581	0.02675	209.11320	-0.05186	0.0	0.0	4674.74609	209.11320
C.674319	209.11877	-0.02384	209.16812	-0.13534	0.0	0.0	4674.74609	209.11877
C.676719	209.13419	0.01292	209.19800	0.07640	0.0	0.0	4674.74609	209.13419
C.679119	209.11749	0.00701	209.13916	0.11826	0.0	0.0	4674.74609	209.11749
C.681519	209.12178	-0.01572	209.12137	-0.00457	0.0	0.0	4674.74609	209.12178

0.683918	209.12738	0.02364	209.18256	-0.09860	0.0	0.0	4674.74609	209.12738
0.686318	209.12350	-0.02327	209.18921	0.11222	0.0	0.0	4674.74609	209.12350
0.688717	209.13591	0.01501	209.12888	0.07638	0.0	0.0	4674.74609	209.12888
0.691117	209.12109	-0.00193	209.13397	-0.12278	0.0	0.0	4674.74609	209.12109
0.693517	209.13531	-0.01135	209.19247	-0.05267	0.0	0.0	4674.74609	209.13531
0.695916	209.12852	0.02032	209.17702	0.12879	0.0	0.0	4674.74609	209.12852
0.698316	209.12756	-0.02211	209.12357	0.02784	0.0	0.0	4674.74609	209.12357
0.700716	209.13760	0.01632	209.14902	-0.13000	0.0	0.0	4674.74609	209.13760
0.703115	209.12437	-0.00518	209.19734	-0.00325	0.0	0.0	4674.74609	209.12437
0.705515	209.13824	-0.00733	209.16397	0.12712	0.0	0.0	4674.74609	209.13824
0.707915	209.13066	0.01693	209.12367	-0.02067	0.0	0.0	4674.74609	209.12367
0.710314	209.13194	-0.02046	209.16425	-0.11998	0.0	0.0	4674.74609	209.13194
0.712714	209.13977	0.01694	209.19682	0.04257	0.0	0.0	4674.74609	209.13977
0.715114	209.12836	-0.00777	209.15173	0.10939	0.0	0.0	4674.74609	209.12836
0.717513	209.14159	-0.00372	209.12865	-0.06219	0.0	0.0	4674.74609	209.12865

IHC9001 EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER 217

IHC2171 FIOCS - END OF DATA SET ON UNIT 5.

TRACEBACK ROUTINE CALLED FROM ISN	REG. 14	REG. 15	REG. 0	REG. 1
FRDL#	00C3A54C	0004B7F8	0000A414	00039C90
MAIN	0000DDIA	01039C10	FD000008	00079FF8

ENTRY POINT= 01039C10