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SSME Dynamics

(NASA-CR-144132) SSME MODEL, ENGINE DYNAMIC CHARACTERISTICS RELATED TO POGO (Rocketdyne) 160 p HC $6.75 CSCL 21H

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FOREWORD

This document was prepared by Rocketdyne Division, Rockwell International, under Contract NAS8-27980, to satisfy requirements of Data Procurement Document 341, Data Requirement No. SE-236-8.

ABSTRACT

This report presents a linear model of the Space Shuttle Main Engine for use in Pogo studies. A digital program is included from which engine transfer functions are determined relative to the engine operating level.

CONTENTS

ILLUSTRATIONS

TABLES

SSME ENGINE MODEL

SCOPE

This document provides a set of linear differential equations which describe the response of SSME engine parameters to variations in independent interface variables. The model provides adequate accuracy and frequency range for use in Pogo studies of the Space Shuttle Vehicle.

APPLICABLE SUPPORTING DOCUMENTS

The following documents, of the exact issue shown, form a part of this document to the extent specified herein:

- RL00001 - Engine Balance and Dynamic Model (Revision E, February 1973)
- DVS-SSME-101A - Design Verification Specification Space Shuttle Main Engine, Volume II, 20 July 1973
- RC1010 - Computer Program Requirements Document, Controller (Revision D, February 1973).

NOMENCLATURE

<u>Variables</u>

A	=	area, in.^{2}
C	=	fluid compliance, in.^{2}
DW	=	weight flowrate, lb/sec
F	=	oxidizer fraction in combustion process, dimensionless
g	=	gravity constant, 386.4 in./sec^2
H	=	specific enthalpy, Btu/lb
ℓ	=	length, inches
L	=	inertance, sec^2/in.
P	=	total pressure, psia
PR	=	pressure ratio

R = resistance to flow, $sec^2/in.^5$

S_{XX} = rotational speed, rad/sec

S = differential operator, sec^{-1}

T = temperature, R

TW1 = hot-gas wall temperature, R

TW2 = ambient wall temperature, R

V = volume, $in.^3$

W = weight, lb

X = actuator piston position

$\Gamma(X)$ = function of X

η = turbine speed parameter

θ = percent of total valve travel, dimensionless; valve angular position, degree

Δ = operator for small variation

μ = viscosity, $lb\text{-}sec/in.^2$

ρ = density, $lb\text{-}in.^3$

τ = time constant, sec

$\mathcal{T}$ = torque, in.-lb

Φ = normalized flow variable

α = normalized area ratio $A/\bar{A}$

χ = normalized stroke ratio, $X/\bar{X}$

DQ = heat flux, Btu/sec

A( ) = coefficient in linear model

BXX = coefficient in nonlinear model evaluated at EPL

SUBSCRIPTS

c = combustion chamber

C = thrust chamber

CN = thrust chamber nozzle

CCV = coolant control valve

CIES = combustion injector end static

FI = main fuel injector

FN = fixed nozzle or primary nozzle heat exchanger

FP = fuel preburner
FS = low-pressure fuel pump inlet
F1 = low-pressure fuel turbopump
F2 = high-pressure fuel turbopump
FD1 = downstream of low-pressure fuel pump
FD2 = downstream of high-pressure fuel pump
FPF = fuel preburner fuel
FPO = fuel preburner oxidizer
FPV = fuel preburner oxidizer valve
FP1 = low-pressure fuel pump
FP2 = high-pressure fuel pump
FT1 = low-pressure fuel turbine
FT2 = high-pressure fuel turbine
FNBP = primary nozzle bypass
FPOI = fuel preburner oxidizer injector
FT1D = low-pressure fuel turbine discharge
FT2D = high-pressure fuel turbine discharge
MC = main chamber heat exchanger
MFV = main fuel valve
MFVD = main fuel valve downstream
MOV = main oxidizer valve
OI = main oxidizer injector
OP = oxidizer preburner
OS = low-pressure oxidizer pump inlet
OS1 = high-pressure oxidizer pump inlet
O1 = low-pressure oxidizer turbopump
O2 = high-pressure oxidizer turbopump
OD1 = downstream of low-pressure oxidizer pump
OD2 = downstream of high-pressure oxidizer pump
OD3 = downstream of high-pressure oxidizer pump preburner boost stage
OPF = oxidizer preburner fuel
OPO = oxidizer preburner oxidizer
OPV = oxidizer preburner oxidizer valve
OP1 = low-pressure oxidizer pump

OP2 = high-pressure oxidizer pump (primary)

OP3 = high-pressure oxidizer pump preburner boost stage

OT1 = low-pressure oxidizer turbine

OT2 = high-pressure oxidizer turbine

OPOI = oxidizer preburner oxidizer injector

OTPR = oxidizer tank pressurization

PR = pressure ratio

POS = preburner common supply pressure

T = temperature

TC = thrust chamber

V = vapor pressure

W1 = hot-gas wall

W2 = ambient wall

(3) = high-pressure fuel pump discharge

(4) = fixed nozzle heat exchanger

(5) = main chamber heat exchanger

(9) = preburner fuel supply

ENGINE CYCLE DESCRIPTION

The engine flow schematic is shown in Fig. 1. Significant features are as follows. Two turbopumps are used in series in both the fuel and oxidizer system with an additional high-pressure stage on the shaft of the main high-pressure oxidizer pump to supply preburner oxidizer flow. A topping cycle is used in which most of the fuel is burned with about 10 percent of the oxidizer in the preburners. The preburner flow drives the turbines of the high-pressure fuel and oxidizer turbopump. The fuel-rich flow is subsequently burned with the remainder of the oxidizer in the main combustion chamber.

The low-pressure fuel turbopump is powered with fuel which has been heated in the coolant passages of the thrust chamber. This gas is then mixed with the fuel-rich turbine drive gases. The low-pressure oxidizer turbopump is driven with liquid oxygen from the high-pressure oxidizer pump discharge and is discharged back into the flow stream of the low-pressure oxidizer pump.

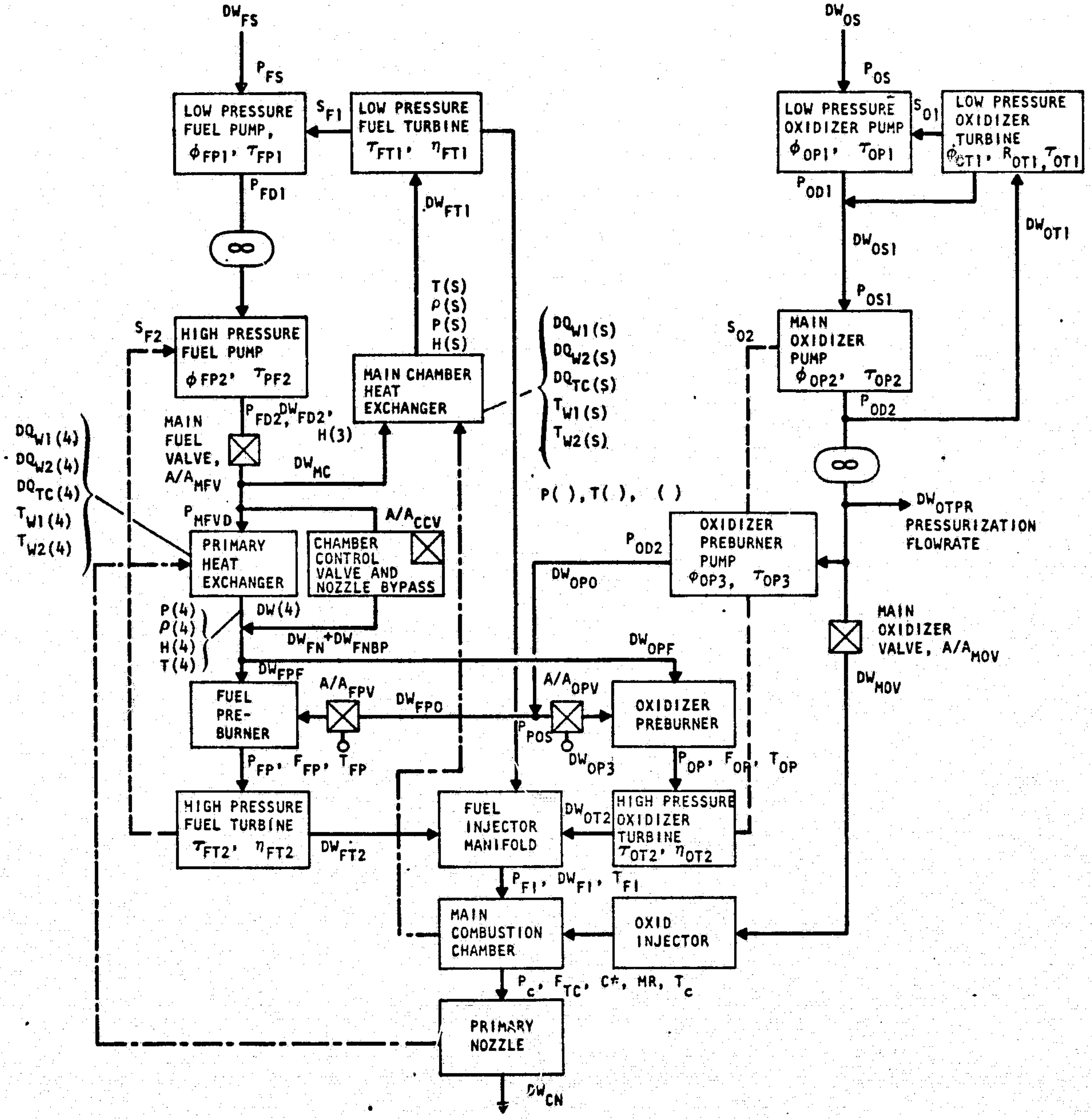

Figure 1. SSME Flow Schematic

The system is controlled by use of three scheduled valves and two closed loop control valves. The main oxidizer, main fuel, and coolant control valves are scheduled as a function of command thrust level. The closed loop controls sense fuel and oxidizer flowrate as well as thrust chamber pressure and vary oxidizer flow to the two preburners to accurately control engine thrust and mixture ratio. The resolution required for steady-state control is such that low level oscillations may pass undetected through the engine system with no response from the engine control system.

Information concerning analytical descriptions of components and system processes are contained in RL0001, Engine Balance and Dynamic Model, Ref. 1. Complete information in engine balance points may be obtained from DVS-SSME-101, Design Verification Specification, Space Shuttle Main Engine, Ref. 2. Details of the controller performance are contained in RC1010, Computer Progress Requirements Document, Controller, Ref. 3. Significant information from each of the reference documents (using the latest revisions at the time of this publication) are also contained in this report.

NONLINEAR MODEL

The equations for the nonlinear model shown in Table 1 are basically those in Ref. 1. The only modifications which can be presently justified are those which add local fluid compliance. Where possible the exact form and nomenclature of Ref. 1 is used. Note that Equation 42 and 43 are additional equations to include fluid inertia between the low-pressure and high-pressure oxidizer pump and to include high-pressure pump compliance.

Numbering for the nonlinear equations is related to the reduced linear equation set. All equation numbers which have an alphabetical suffix indicate that the dependent variable associated with that equation was eliminated in the linear equation set.

Coefficients for the nonlinear equation set are labeled as BXX. These were obtained directly from Ref. 1 and are included as Table 2 along with required balance data for a typical EPL (109 percent) engine and coefficients for nonlinear equations, based on Ref. 1 EPL power balance. These values are based on the EPL (109 percent) and need not be changed for subsequent runs at different power levels.

Functional characteristics of components shown in Figures 2 through 22 are taken directly from Ref. 1. Note that most of the functions are in a form such that they are normalized to the 109 percent thrust level (EPL).

TABLE 1. SSME NONLINEAR ENGINE MODEL EQUATIONS

Low-Pressure Fuel Pump

$$\phi_{FP1} = B11\ (DW_{FD2}/S_{F1}) \quad (1a)$$

$$P_{FD1} = P_{FS} + B12\ (S_{F1})^2\ \Gamma_{P_{FP1}}\ (\phi_{FP1}) \quad (1)$$

$$T_{FP1} = B13\ (S_{F1})^2\ \Gamma_{T_{FP1}}\ (\phi_{FP1}) \quad (1b)$$

Low-Pressure Fuel Turbopump Speed

$$S_{F1} = B14 \int (T_{FT1} - T_{FP1})\ dt; \quad (2)$$

Low-Pressure Fuel Turbine

$$T_{FT1} = B16\ [P(5)]\ \Gamma_{T_{FT1}} \left\{ [P_{FI}/P(5)]^{FT1S},\ \eta_{FT1} \right\} \quad (2a)$$

$$\eta_{FT1} = B15 \left[S_{F1}/\sqrt{T(5)} \right] \quad (2b)$$

$$DW_{FT1} = \left\{ B17 \left[P(5) - P_{FI} \right] \rho(5) \right\}^{1/2} \quad (2c)$$

High-Pressure Fuel Pump

$$\phi_{FP2} = B18\ (DW_{FD2}/S_{F2}) \quad (3a)$$

$$P_{FD2} = P_{FD1} + B19\ (S_{F2})^2\ \Gamma_{P_{FP2}}\ (\phi_{FP2}) \quad (3c)$$

$$T_{FP2} = B20\ (S_{F2})^2\ \Gamma_{T_{FP2}}\ (\phi_{FP2}) \quad (3b)$$

$$DW_{FD2} = B21 \int \left[P_{FD2} - P_{MFVD} - B22\ (DW_{FD2}/[A/\bar{A}]_{MFV})^2 \right] dt \quad (3)$$

$$[A/\bar{A}]_{MFV} = \Gamma_{MFV}\ [X/\bar{X}]_{MFV} \quad (3d)$$

TABLE 1. (Continued)

High-Pressure Fuel Turbopump Speed

$$S_{F2} = B23 \int (T_{FT2} - T_{FP2})\ dt; \tag{4}$$

$$H(3) = B103\ (T_{FP2})\ (S_{F2}) \tag{4a}$$

High-Pressure Fuel Turbine

$$DW_{FT2} = B24\ (P_{FP})\ \Gamma_{PR}\ [(P_{FI}/P_{FP})^{1/2}] \Big/ (T_{FP})^{1/2} \tag{4b}$$

$$T_{FT2} = B26\ (P_{FP})\ \Gamma_{T_{FT2}}\ [(P_{FI}/P_{FP})^{FT2S},\ \eta_{FT_2}] \tag{4c}$$

$$\eta_{FT2} = B25\ [S_{F2}] \tag{4d}$$

$$\Gamma_{PR}\ (PR) = [PR^{2/1.4} - PR^{2.4/1.4}]^{1/2} \tag{4e}$$

Low-Pressure Oxidizer Pump

$$\phi_{OP1} = (B27/S_{01})\ (DW_{OS1} - DW_{OT1}) \tag{5a}$$

$$P_{OD1} = P_{OS} + B28\ (S_{01})^2\ \Gamma_{P_{OP1}}(\phi_{OP1}) \tag{5}$$

$$DW_{OS} = B31 \int [P_{OT} - P_{OS} - B32(DW_{OS})]\ dt \tag{5b}$$

$$P_{OS} = B33 \int (DW_{OS} - DW_{OS1} + DW_{OT1})\ dt \tag{5c}$$

$$T_{OP1} = B34\ (S_{01})^2\ \Gamma_{T_{OP1}}(\phi_{OP1}) \tag{5d}$$

TABLE 1. (Continued)

$$DW_{OTPR} = B106\ P_{OD2} \tag{5e}$$

$$DW_{OS1} = B115\int[P_{OD1} - P_{OS1}]dt \tag{42}$$

Low-Pressure Oxidizer Turbopump Speed

$$S_{O1} = B35\int(T_{OT1} - T_{OP1})\ dt; \tag{6}$$

Low-Pressure Oxidizer Pump Turbine

$$T_{OTI} = B36(DW_{OT1})^2\Gamma_{T_{OT1}}\ (\phi_{OT1}) \tag{7a}$$

$$DW_{OT1} = [(P_{OD2} - P_{OD1}) / (B37 + R_{OT1})]^{1/2} \tag{7}$$

$$R_{OT1} = \Gamma_{R_{OT1}}(\phi_{OT1}) \tag{7b}$$

$$\phi_{OT1} = B38\ (S_{O1}/DW_{OT1}) \tag{7c}$$

High-Pressure Oxidizer Pump

$$P_{OS1} = B116\int[DW_{OS1} - DW_{MOV} - DW_{OT1} - DW_{OP3} - DW_{OTPR}]dt \tag{43}$$

$$\phi_{OP2} = (B39/S_{O2})\ (DW_{MOV} + DW_{OT1} + DW_{OP3} + DW_{OTPR}) \tag{8a}$$

$$P_{OD2} = P_{OS1} + B40\ \left[(S_{O2})^2\ \Gamma_{P_{OP2}}\ (\phi_{OP2})\right] \tag{8}$$

$$T_{OP2} = B41\ (S_{O2})^2\ \Gamma_{T_{OP2}}(\phi_{OP2}) \tag{8b}$$

TABLE 1. (Continued)

High-Pressure Oxidizer Turbopump Speed

$$S_{O2} = B42\int (T_{OT2} - T_{OP2} - T_{OP3})\ dt; \tag{9}$$

High-Pressure Oxidizer Pump Preburner Boost Stage

$$\phi_{OP3} = B43\ (DW_{OP3}/S_{O2}) \tag{10a}$$

$$T_{OP3} = B44\ (S_{O2})^2 \Gamma_{T_{OP3}} (\phi_{OP3}) \tag{10b}$$

$$P_{OD3} = B45\ (S_{O2})^2\ \Gamma_{P_{OP3}} (\phi_{OP3}) + P_{OD2} \tag{10c}$$

$$DW_{OP3} = B46\int \left[P_{OD3} - P_{POS} - B104(DW_{OP3})^2\right] dt \tag{10}$$

High-Pressure Oxidizer Turbine

$$T_{OT2} = B29\ (P_{OP})\ \Gamma_{T_{OT2}} \left[(P_{FI}/P_{OP})^{EOT2S}, \eta_{OT2}\right] \tag{10d}$$

$$\eta_{OT2} = B47\ \left[S_{O2}\right] \tag{10e}$$

$$DW_{OT2} = B48\ (P_{OP})\ \Gamma_{PR} \left[(P_{FI}/P_{OP})^{1/2}\right] \Big/ \sqrt{T_{OP}} \tag{11}$$

Preburner Oxidizer Supply Pressure

$$P_{POS} = B49\int (DW_{OP3} - DW_{FPO} - DW_{OPO})\ dt \tag{12}$$

Fuel Preburner Fuel Flow

$$DW_{FPF} = B50\int \left\{P(9) - P_{FP} - \left[B51/\rho(9)\right]\ (DW_{FPF})^2\right\} dt \tag{13}$$

TABLE 1. (Continued)

Fuel Preburner Oxidizer Flow

$$DW_{FPO} = B52\int\left[P_{POS} - P_{FP} - B53\ (DW_{FPO}/[A/\bar{A}]_{FPV})^2 - B54(DW_{FPO})^2\right]dt \qquad (14)$$

$$[A/\bar{A}]_{FPV} = \Gamma_{FPV}\ ([X/\bar{X}]_{FPV}) \qquad (14a)$$

Fuel Preburner Combustor

$$P_{FP} = B56\int (DW_{FPF} + DW_{FPO} - B111\ DW_{FT2})\ dt \qquad (15)$$

$$F_{FP} = DW_{FPO} / (DW_{FPO} + DW_{FPF}) \qquad (15a)$$

$$T_{FP} = \Gamma_T(F_{FP}) + B112\ [T(9)] \qquad (15b)$$

Oxidizer Preburner Fuel Flow

$$DW_{OPF} = B57\int\left\{P(9) - P_{OP} - [B58/\ \rho(9)]\ (DW_{OPF})^2\right\}dt \qquad (16)$$

Oxidizer Preburner Oxidizer Flow

$$DW_{OPO} = B59\int\left[P_{POS} - P_{OP} - B60\ (DW_{OPO})^2 - B61\ (DW_{OPO}/[A/\bar{A}]_{OPV})^2\right]dt \qquad (17)$$

$$[A/\bar{A}]_{OPV} = \Gamma_{OPV}\ ([X/\bar{X}]_{OPV}) \qquad (17a)$$

Oxidizer Preburner Combustor

$$P_{OP} = B63\int(DW_{OPF} + DW_{OPOI} - B107\ DW_{OT2})\ dt \qquad (18)$$

$$F_{OP} = DW_{OPO} / (DW_{OPO} + DW_{OFF}) \qquad (18a)$$

$$T_{OP} = \Gamma_T(F_{OP}) + B113\ [T(9)] \qquad (18b)$$

TABLE 1. (Continued)

Main Chamber Fuel Injector

$$P_{FI} = B64 \int (DW_{FT1} + DW_{OT2} + DW_{FT2} - B108\ DW_{FI})\ dt \qquad (19)$$

$$DW_{FI} = B65\ (P_{FI})\ \Gamma_{PR}\ [P_C/P_{FI}] \Big/ \sqrt{T_{FI}} \qquad (20)$$

$$T_{FI} = B66\ (T_{FP}) + B67\ (T_{OP}) + B68\ [T(5)] \qquad (20a)$$

Main Chamber Oxidizer Injector

$$DW_{MOV} = B69 \int \left[P_{OD2} - P_C - B70\ (DW_{MOV} / [A/\bar{A}]_{MOV})^2 - B71 (DW_{MOV})^2 \right] dt \qquad (21)$$

$$[A/\bar{A}]_{MOV} = \Gamma_{MOV}\ ([X/\bar{X}]_{MOV}) \qquad (21a)$$

Thrust Chamber

$$P_{CIES} = B114\ P_c \qquad (22a)$$

$$P_C = B72 \int (B109\ DW_{FI} + DW_{MOV} - DW_{CN})\ dt \qquad (22)$$

$$F_{TC} = (DW_{MOV} + DW_{OP3}) / (DW_{MOV} + DW_{FI}) \qquad (23)$$

$$DW_{CN} = B73\ (P_C/C^*) \qquad (23a)$$

$$C^* = 35000 + 210500\ F_{TC} - 173500\ (F_{TC})^2 \qquad (23b)$$

$$MR = (DW_{OTPR} + DW_{MOV} + DW_{OP3})/DW_{FD2} \qquad (23c)$$

$$T_C = \Gamma_T\ (F_{TC}) \qquad (23d)$$

TABLE 1. (Continued)

Main Chamber Regenerative Cooling Element

$$P(5) = B74\int\left[DQ_{W1}(5) + DQ_{W2}(5) + H(3)\ DW_{MC} - H(5)\ DW_{FT1}\right]dt \quad (24)$$

$$H(5) = B101\ [T(5)] \quad (24a)$$

$$DW_{MC} = B75\int\left\{P_{MFVD} - P(5) - [B76/\rho(5)]\ (DW_{MC})^2\right\}dt \quad (25)$$

$$\rho(5) = B77\int\left[DW_{MC} - DW_{FT1}\right]dt \quad (26)$$

$$T(5) = B78\ [P(5)/\rho(5)] \quad (27)$$

$$DQ_{W1}(5) = B79\ [1.0 + 0.002\ T(5)]\ [T_{W1}(5) - T(5)]\ (DW_{MC})^{0.8} \quad (27a)$$

$$DQ_{W2}(5) = B80\ [1.0 + 0.002\ T(5)]\ [T_{W2}(5) - T(5)]\ (DW_{MC})^{0.8} \quad (27b)$$

$$DQ_{TC}(5) = B81\ [T_C - T_{W1}(5)]\ (DW_{CN})^{0.8} \quad (27c)$$

$$T_{W1}(5) = B82\int[DQ_{TC}(5) - DQ_{W1}(5)]\,dt \quad (28)$$

$$T_{W2}(5) = B83\int[-DQ_{W2}(5)]\,dt \quad (29)$$

Fixed Nozzle Regenerative Cooling Element

$$P(4) = B84\int[DQ_{W1}(4) + DQ_{W2}(4) - H(4)\ DW(4) + H(3)\ DW_{FN}]dt \quad (30)$$

$$DW_{FN} = B85\int[P_{MFVD} - P(4) - B86\ (DW_{FN})^2]dt \quad (31)$$

$$\rho(4) = B87\int[DW_{FN} - DW(4)]dt \quad (32)$$

$$T(4) = B88\ [P(4)/\rho(4)] \quad (33)$$

TABLE 1. (Concluded)

$$DQ_{W1}(4) = B89 \left[T_{W1}(4) - T(4)\right] [1.0 + 0.002\ T(4)] (DW_{FN})^{0.8} \quad (33a)$$

$$DQ_{W2}(4) = B90 \left[T_{W2}(4) - T(4)\right] [1.0 + 0.002\ T(4)]\ (DW_{FN})^{0.8} \quad (33b)$$

$$H(4) = B102\ [T(4)] \quad (33c)$$

$$DQ_{TC}(4) = B91 \left[T_C - T_{W1}(4)\right]\ (DW_{CN})^{0.8}$$

$$T_{W1}(4) = B92 \int \left[DQ_{TC}(4) - DQ_{W1}(4)\right] dt \quad (34)$$

$$T_{W2}(4) = B93 \int \left[-DQ_{W2}(4)\right] dt \quad (35)$$

<u>Fixed Nozzle Inlet, Discharge and Bypass</u>

$$DW(4) = B94 \int \left\{P(4) - P(9) - [B95/\rho(4)] [DW(4)]^2\right\} dt \quad (36)$$

$$P(9) = B96 \int \left[DW(4) + DW_{FNBP} - DW_{OPF} - DW_{FPF}\right] dt \quad (37)$$

$$P_{MFVD} = B97 \int (B110\ DW_{FD2} - DW_{FN} - DW_{MC} - DW_{FNBP})\ dt \quad (38)$$

$$DW_{FNBP} = B98 \int \left[P_{MFVD} - P(9) - (B99)\ (DW_{FNBP}/\ [A/\bar{A}]_{CCV})^2\right] dt \quad (39)$$

$$[A/\bar{A}]_{CCV} = \Gamma_{CCV}\ ([X/\bar{X}]_{CCV}) \quad (39a)$$

$$T(9) = B100\ [P(9)/\rho(9)] \quad (40)$$

$$\rho(9) = \left[DW_{FNBP} + DW(4)\right] / \left[DW(4)/\rho(4) + B105\ DW_{FNBP}\right] \quad (41)$$

TABLE 2. COEFFICIENTS FOR NONLINEAR MODEL EQUATIONS

B11	=	$(\bar{\phi}_{FP1})\ (\bar{S}_{F1})/\overline{DW}_{FD2}$
B12	=	$(\bar{P}_{FD1} - (\bar{P}_{FS})/(\bar{S}_{F1})^2$
B13	=	$\bar{\Upsilon}_{FP1}/(\bar{S}_{F1})^2$
B14	=	$1.0/G_{F1}$
B15	=	$\bar{\eta}_{FT1}\ \sqrt{\bar{T}(5)}/\bar{S}_{F1}$
B16	=	$\bar{\Upsilon}_{FT1} \Big/ \left\{ \left[\bar{\Gamma}_{\Upsilon_{FT1}}\right] \quad \left[\bar{P}(5)\right] \right\}$
B17	=	$\left\{\left[\bar{P}(5) - \bar{P}_{FI}\right] \quad \bar{\rho}(5)/(\overline{DW}_{FT1})^2\right\}^{-1}$
B18	=	$(\bar{\phi}_{FP2})\ (\bar{S}_{F2})/\overline{DW}_{FD2}$
B19	=	$(\bar{P}_{FD2} - \bar{P}_{FD1})/(\bar{S}_{F2})^2$
B20	=	$\bar{\Upsilon}_{FP2}/(\bar{S}_{F2})^2$
B21	=	2500.0
B22	=	$\left[\bar{P}_{FD2} - \bar{P}_{MFVD}\right] \left(\left[\overline{A/\bar{A}}\right]_{MFV}\right)^2 \Big/ (\overline{DW}_{FD2})^2$
B23	=	$1.0/G_{F2}$
B24	=	$\overline{DW}_{FT2} \sqrt{\bar{T}_{FP}} \Big/ \left\{\bar{P}_{FP}\ \Gamma_{PR}\ \left[(\bar{P}_{F1}/\bar{P}_{FP})^{1/2}\right]\right\}$
B25	=	$\bar{\eta}_{FT2}/\bar{S}_{F2}$
B26	=	$(\bar{\Upsilon}_{FT2}) \Big/ (\bar{\Gamma}_{\Upsilon_{FT2}})\ \bar{P}_{FP}$
B27	=	$(\bar{\phi}_{OP1})\ (\bar{S}_{O1})/(\overline{DW}_{MOV} + \overline{DW}_{OP3})$
B28	=	$(\bar{P}_{OD1} - \bar{P}_{OS})/(\bar{S}_{O1})^2$
B29	=	$(\bar{\Upsilon}_{OT2}) \Big/ (\bar{\Gamma}_{\Upsilon_{OT2}})\ \bar{P}_{OP}$
B30	=	$\bar{W}_{OI} - 1.0$

TABLE 2. (Continued)

B31	=	$1.0/\left[\ell/Ag\right]_{OS}$
B32	=	$(\bar{P}_{OT} - \bar{P}_{OS})/\overline{DW}_{OS}$
B33	=	150.0 in^{-2}
B34	=	$\bar{\tau}_{OP1}/(\bar{S}_{O1})^2$
B35	=	$1.0/G_{O1}$
B36	=	$\bar{\tau}_{OT1}\Big/\left[(\overline{DW}_{OT1})^2\,\Gamma_{\Upsilon_{OT1}}\,(\phi_{OT1})\right]$
B37	=	$(\bar{P}_{OD2} - \bar{P}_{OD1})/(\overline{DW}_{OT1})^2 - \bar{\Gamma}_{R_{OT1}}$
B38	=	$(\bar{\Phi}_{OT1})\,(\overline{DW}_{OT1})/\bar{S}_{O1}$
B39	=	$(\bar{\Phi}_{OP2})\,(\bar{S}_{O2})/(\overline{DW}_{MOV} + \overline{DW}_{OT1} + \overline{DW}_{OP3})$
B40	=	$(\bar{P}_{OD2} - \bar{P}_{OD1})/(\bar{S}_{O2})^2$
B41	=	$\bar{\tau}_{OP2}/(\bar{S}_{O2})^2$
B42	=	$1.0/G_{O2}$
B43	=	$(\bar{\Phi}_{OP3})\,(\bar{S}_{O2})/\overline{DW}_{OP3}$
B44	=	$\bar{\tau}_{OP3}/(\bar{S}_{O2})^2$
B45	=	$(\bar{P}_{OD3} - \bar{P}_{OD2})/(\bar{S}_{O2})^2$
B46	=	$100.0 \text{ in}^2/\text{sec}^2$
B47	=	$\bar{\eta}_{OT2}/\bar{S}_{O2}$
B48	=	$\overline{DW}_{OT2}\sqrt{\bar{T}_{OP}}\Big/\left\{\bar{P}_{OP}\,\Gamma_{PR}\left[(\bar{P}_{FI}/\bar{P}_{OP})^{1/2}\right]\right\}$
B49	=	38120.0 in^{-2}
B50	=	$66.675 \text{ in}^2/\text{sec}^2$
B51	=	$\left[\bar{P}(9) - \bar{P}_{FP}\right]\left[\bar{\rho}(9)\right]/(\overline{DW}_{FPF})^2$

TABLE 2. (Continued)

B52	=	$50.0\ \text{in}^2/\text{sec}^2$
B53	=	$(\bar{P}_{POS} - \bar{P}_{FPOI})\ (\overline{[A/\bar{A}]}_{FPV})^2/(\overline{DW}_{FPO})^2$
B54	=	$(\bar{P}_{FPOI} - \bar{P}_{FP})/(\overline{DW}_{FPO})^2$
B55	=	$1.0/\bar{W}_{FPOI}$
B56	=	$1378.0\ \text{in}^{-2}$
B57	=	$100\ \text{in}^2/\text{sec}^2$
B58	=	$\left[\bar{P}(9) - \bar{P}_{OP}\right]\left[\bar{\rho}(9)\right]/(\overline{DW}_{OPF})^2$
B59	=	$10.0\ \text{in}^2/\text{sec}^2$
B60	=	$(\bar{P}_{OPOI} - \bar{P}_{OP})/(\overline{DW}_{OPO})^2$
B61	=	$(\bar{P}_{POS} - \bar{P}_{OPOI})\ (\overline{[A/\bar{A}]}_{OPV})^2/(\overline{DW}_{OPO})^2$
B62	=	$1.0/\bar{W}_{OPOI}$
B63	=	$35000.0\ \text{in}^{-2}$
B64	=	$3949.0\ \text{in.}^{-2}$
B65	=	$\overline{DW}_{FI}\sqrt{\bar{T}_{FI}}/\left[P_{FI}\ \Gamma_{PR}\ (P_C/P_{FI})\right]$
B66	=	0.5055
B67	=	0.2563
B68	=	0.2400
B69	=	$50.0\ \text{in}^2/\text{sec}^2$
B70	=	$(\bar{P}_{OD2} - \bar{P}_{OI})\ (\overline{[A/\bar{A}]}_{MOV})^2/(\overline{DW}_{MOV})^2$
B71	=	$(\bar{P}_{OI} - \bar{P}_{C})/(\overline{DW}_{MOV})^2$
B72	=	$6838.0\ \text{in}^{-2}$
B73	=	$(\overline{DW}_{CN})\ \bar{C}^*/\bar{P}_C$

TABLE 2. (Continued)

B74	=	$3.812\ lb/(Btu\ in^2)$
B75	=	$483.75\ in^2/sec^2$
B76	=	$\left[\bar{P}_{MFVD} - \bar{P}(5)\right]\left[\bar{\rho}(5)\right]/\left[\overline{DW}_{MC}\right]^2$
B77	=	$0.001\ in^{-3}$
B78	=	$\left[\bar{T}(5)\right]\left[\bar{\rho}(5)\right]/\bar{P}(5)$
B79	=	$\overline{DQ}_{W1}(5)/\left\{\left[1+0.002\ \bar{T}(5)\right]\left[\bar{T}_{W1}(5) - \bar{T}(5)\right]\ (\overline{DW}_{MC})^{0.8}\right\}$
B80	=	2.0(B79)
B81	=	$\overline{DQ}_{TC}(5)/\left\{\left[\bar{T}_C - \bar{T}_{W1}(5)\right]\left[\overline{DW}_{CN}\right]^{0.8}\right\}$
B82	=	0.31 °R/Btu
B83	=	0.0825 °R/Btu
B84	=	$2.544\ lb/(Btu\ in^2)$
B85	=	$218.0\ in^2/sec^2$
B86	=	$\left[\bar{P}_{MFVD} - \bar{P}(4)\right]/(\overline{DW}_{FN})^2$
B87	=	$0.0005\ in^{-3}$
B88	=	$\left[\bar{T}(4)\right]\left[\bar{\rho}(4)\right]/\bar{P}(4)$
B89	=	$\overline{DQ}_{W1}(4)/\left\{\left[\bar{T}_{W1}(4) - \bar{T}(4)\right]\left[1.0+0.002\ \bar{T}(4)\right]\ (\overline{DW}_{FN})^{0.8}\right\}$
B90	=	2.0 (B89)
B91	=	$\overline{DQ}_{TC}(4)/\left\{\left[\bar{T}_C - \bar{T}_{W1}(4)\right]\ (\overline{DW}_{CN})^{0.8}\right\}$
B92	=	0.1668 or/Btu
B93	=	0.0834 R/Btu
B94	=	$21.19\ in^2/sec^2$
B95	=	$\left[\bar{P}(4) - \bar{P}(9)\right]\left[\bar{\rho}(4)\right]/\left[\overline{DW}(4)\right]^2$
B96	=	$81600\ in^{-2}$
B97	=	$32000\ in^{-2}$
B98	=	$20.0\ in^2/sec^2$

TABLE 2. (Continued)

B99	=	$\left[\bar{P}_{MFVD} - \bar{P}(9)\right] \left(\overline{[A/\bar{A}]}_{CCV}\right)^2 / \left(\overline{DW}_{FNBP}\right)^2$
B100	=	$\left[\bar{T}(9)\right]\left[\bar{\rho}(9)\right] / \bar{P}(9)$
B101	=	$\bar{H}(5)/\bar{T}(5)$
B102	=	$\bar{H}(4)/\bar{T}(4)$
B103	=	$\bar{H}(3)/\left[\bar{T}_{FP2}\left(\bar{S}_{F2}\right)\right]$
B104	=	$\left(\bar{P}_{OD3} - \bar{P}_{POS}\right) / \left(\overline{DW}_{OP3}\right)^2$
B105	=	$\left\{\left[\overline{DW}_{FNBP} + \overline{DW}(4)\right] / \rho(9) - \left[\overline{DW}(4)/\rho(4)\right]\right\} / \overline{DW}_{FNBP}$
B106	=	$\overline{DW}_{OTPR}/\bar{P}_{OD2}$
B107	=	$\left(\overline{DW}_{OPF} + \overline{DW}_{OPOI}\right)/\overline{DW}_{OT2}$
B108	=	$\left(\overline{DW}_{FT1} + \overline{DW}_{FT2} + \overline{DW}_{OT2}\right)/\overline{DW}_{FI}$
B109	=	$\left(\overline{DW}_{CN} - \overline{DW}_{OI}\right)/\overline{DW}_{FI}$
B110	=	$\left(\overline{DW}_{FN} + \overline{DW}_{MC} + \overline{DW}_{FNBP}\right)/\overline{DW}_{FD2}$
B111	=	$\left(\overline{DW}_{FPF} + \overline{DW}_{FPOI}\right)/\overline{DW}_{FT2}$
B112	=	$\left[\bar{T}_{FP} - \Gamma_T\left(\bar{F}_{FP}\right)\right] / \bar{T}(9)$
B113	=	$\left[\bar{T}_{OP} - \Gamma_T\left(\bar{F}_{OP}\right)\right] / \bar{T}(9)$
B114	=	$\bar{P}_{CIES}/\bar{P}_c$
B115	=	$1/L_{OS1} = 76.9231 \text{ in.}^2/\text{sec}^2$
B116	=	$1/C_2 \approx 1000 \text{ in.}^{-2}$

TABLE 2. (Continued)

REQUIRED BALANCE DATA FOR A TYPICAL EPL (109% POWER) ENGINE

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THE NUMBER OF THE INPUT VARIABLE IS:  2
STEADY-STATE VALUES FOR ENGINE PARAMETERS

A/A(CCV)=  1.000E+00 A/A(FPV)=  3.307E-01 A/A(MFV)=  1.000E+00 A/A(MOV)=  1.000E+00 A/A(OPV)=  3.680E-01
C*      =  8.816E+04 DQ(TC4) =  7.223E+04 DQ(TC5) =  4.935E+04 DQ(W14) =  7.223E+04 DQ(W15) =  4.935E+04
DQ(W24) =  0.0       DQ(W25) =  0.0       DW(4)   =  4.189E+01 DW(5)   =  3.524E+01 DW(CN)  =  1.120E+03
DW(FI)  =  2.627E+02 DW(FN)  =  4.189E+01 DW(MC)  =  3.524E+01 DW(OI)  =  8.543E+02 DW(OS)  =  9.615E+02
DW(CCV) =  8.019E+01 DW(FD2) =  1.602E+02 DW(FPF) =  8.315E+01 DW(FPO) =  7.930E+01 DW(FT1) =  3.524E+01
DW(FT2) =  1.624E+02 DW(MOV) =  8.543E+02 DW(OPF) =  3.893E+01 DW(OPO) =  2.613E+01 DW(OF3) =  1.054E+02
DW(OT1) =  1.740E+02 DW(OT2) =  6.359E+01 DW(FNBP)=  8.019E+01 DW(FPCI)=  7.930E+01 DW(OPOI)=  2.613E+01
DW(OTPR)=  1.300E+00 E(FPO)  =  1.000E+00 E(OPO)  =  1.000E+00 E(OT2S) =  9.450E-01 F(TC)   =  8.592E-01
FT1S    =  5.696E-01 FT2S    =  9.559E-01 G(F1)   =  1.162E+00 GF2     =  3.176E+00 G(O1)   =  2.662E+00
G(O2)   =  1.092E+00 H(3)    =  4.423E+02 H(4)    =  2.167E+03 H(4)    =  1.843E+03 F(4)    =  6.794E+03
P(5)    =  5.143E+03 P(9)    =  6.650E+03 P(C)    =  3.330E+03 P(CIES) =  3.233E+03 P(FI)   =  5.662E+03
P(FP)   =  5.940E+03 P(FS)   =  3.000E+01 P(OI)   =  4.293E+03 P(OP)   =  5.929E+03 P(OS)   =  1.000E+02
P(OT)   =  1.180E+02 P(FD1)  =  2.520E+02 P(FD2)  =  7.066E+03 P(OD1)  =  4.441E+02 P(OD2)  =  5.170E+03
P(OD3)  =  8.484E+03 P(POS)  =  8.457E+03 P(FPOI) =  7.210E+03 P(MFVD) =  6.939E+03 P(OPOI) =  6.976E+03
R(FP)   =  4.633E+03 R(OP)   =  5.034E+03 S(F1)   =  1.638E+03 S(F2)   =  3.922E+03 S(O1)   =  5.709E+02
S(O2)   =  3.262E+03 T(4)    =  6.793E+02 T(5)    =  5.445E+02 T(9)    =  3.038E+02 T(C)    =  6.221E+03
T(F1)   =  1.535E+03 T(FP)   =  1.991E+03 T(OP)   =  1.544E+03 TW1(4)  =  1.260E+03 TW1(5)  =  1.330E+03
TW2(4)  =  6.793E+02 TW2(5)  =  5.445E+02 W(OI)   =  4.400E+01 W(FPOI) =  2.640E+00 W(OPOI) =  1.500E+00
ETA(FT1)=  1.660E+02 ETA(FT2)=  4.150E+02 ETA(OT2)=  3.775E+02 RHO(4)  =  1.475E-03 RHO(5)  =  1.402E-03
RHO(9)  =  1.715E-03 UP(FP1) =  1.153E+04 UP(FP2) =  1.296E+05 UP(FT1) =  1.153E+04 UP(FT2) =  1.296E+05
UP(OP1) =  2.015E+04 UP(OP2) =  5.230E+04 UP(OP3) =  4.045E+03 UP(OT1) =  2.015E+04 UP(OT2) =  5.643E+04
PHI(FP1)=  1.000E+00 PHI(FP2)=  1.000E+00 PHI(OP1)=  1.000E+00 PHI(OP2)=  1.000E+00 PHI(OP3)=  1.000E+00
PHI(OT1)=  4.400E-01 GM(LOI) =  1.000E+00 GM(PFP1)=  1.000E+00 GM(TFP1)=  1.000E+00 GM(TFT1)=  1.530E-02
GM(PFP2)=  1.000E+00 GM(TFP2)=  1.000E+00 GM(TFT2)=  1.936E-02 GM(POP1)=  1.000E+00 GM(TOP1)=  1.000E+00
GM(TOT1)=  7.050E-01 GM(ROT1)=  1.625E-01 GM(POP2)=  1.000E+00 GM(TOP2)=  1.000E+00 GM(TOP3)=  1.000E+00
GM(POP3)=  1.000E+00 GM(TOT2)=  2.502E-02 GM(FPV) =  1.534E-01 GM(OPV) =  4.340E-01 GM(MOV) =  1.000E+00
GM(MFV) =  1.000E+00 GM(CCV) =  1.000E+00
PARTIAL DERIVATIVES
GM(PFP1)/PHI(FP1)    = -1.000E+00 GM(TFP1)/PHI(FP1)    =  1.000E-01 GM(TFT1)/ETA(FT1)    = -6.000E-05
GM(TFT1)/P(FI)/P(5)  = -1.500E-01 GM(PFP2)/PHI(FP2)    = -5.000E-01 GM(TFP2)/PHI(FP2)    =  4.000E-01
GM(TFT2)/ETA(FT2)    = -3.000E-01 GM(TFT2)/P(FI)/P(FP)= -5.000E-05 GM(POP1)/PHI(OP1)    = -1.000E+00
GM(TOT1)/PHI(OT1)    = -1.200E+00 GM(TOP1)/PHI(OP1)    =  0.0       GM(ROT1)/PHI(OT1)    =  1.000E+00
GM(POP2)/PHI(OP2)    = -1.000E+00 GM(TOP2)/PHI(OP2)    =  3.000E-01 GM(TOP3)/PHI(OP3)    =  3.000E-01
GM(TOT2)/ETA(OT2)    = -5.000E-05 GM(TOT2)/P(FI)/P(OP)= -1.000E-01 GM(POP3)/PHI(OP3)    = -5.000E-01
GM(T)/F(OP)          =  4.300E+03 GM(PP)/P(FI)/P(OP)   =  0.0       GM(T)/F(OP)          =  4.200E+03
GM(P)/P(FI)/P(FP)    =  0.0       GM(PR)/P(C)/P(FI)    =  0.0       GM(TR)/F(TC)         =  7.000E+03
GM(MFV)/X/X(MFV)     =  2.000E+01 GM(FPV)/X/X(FPV)     =  2.000E+01 GM(OPV)/X/X(OPV)     =  2.000E+00
GM(MOV)/X/X(MOV)     =  2.000E+01 GM(CCV)/X/X(CCV)     =  5.000E+00
DW(OS1) =  1.135E+03 P(OS1)  =  4.441E+02
```

TABLE 2. (Concluded)

COEFFICIENTS FOR NONLINEAR EQUATIONS BASED ON REF. 1 EPL POWER BALANCE

VECTOR OF COEFFICIENTS CORRESPONDING TO THE ABOVE STEADY-STATE VALUES,B11 THROUGH B116.

1.0225E+01	1.3553E-01	4.2974E-03	8.6059E-01	2.3648E+00	1.4653E+02	5.9809E+02	2.4482E+01	4.4311E-04	8.4254E-03
2.5000E+03	5.0265E-05	3.1486E-01	5.6132E+00	1.0581E-01	3.9764E+10	5.9485E-01	1.0556E-03	1.3371E+10	4.3000E+01
1.0000E+00	1.8721E-02	1.5000E+02	6.1824E-02	3.7566E-01	2.1455E+00	-6.4062E-03	1.3410E-01	2.8772E+00	4.4414E-04
4.9226E-03	9.1575E-01	3.0940E+01	3.8015E-04	3.1145E-04	1.0000E+02	1.1573E-01	9.1222E-02	3.8120E+04	6.6675E+01
1.7612E-04	5.0000E+01	2.1686E-02	2.0196E-01	3.7879E-01	1.3780E+03	1.0000E+02	8.1589E-04	1.0000E+01	1.5334E+00
2.9375E-01	6.6667E-01	3.5000E+04	3.9490E+03	3.5393E-02	5.0550E-01	2.5630E-01	2.4300E-01	5.0000E+01	1.2017E-03
1.1270E+00	6.8380E+03	2.9642E+04	3.8120E+00	4.8375E+02	2.0276E-03	1.0000E-03	1.4843E-04	1.7401E+00	3.4862E+03
3.6694E-02	3.1000E-01	8.2503E-02	2.5440E+00	2.1800E+02	8.2632E-02	5.0000E-04	1.4746E-04	2.6572E+00	5.2800E+00
5.2949E-02	1.6680E-01	6.3400E-02	2.1190E+01	1.2104E-04	8.1600E+04	3.2000E+04	2.0000E+01	4.4942E-02	7.8348E-05
3.3848E+00	3.1900E+00	8.7017E-07	2.4293E-03	5.3353E+02	2.5145E-04	1.0263E+00	9.9383E-01	1.0104E+00	9.8202E-01
1.0000E+00	9.9991E-01	9.9846E-01	9.7963E-01	7.6923E+01	1.0000E+03				

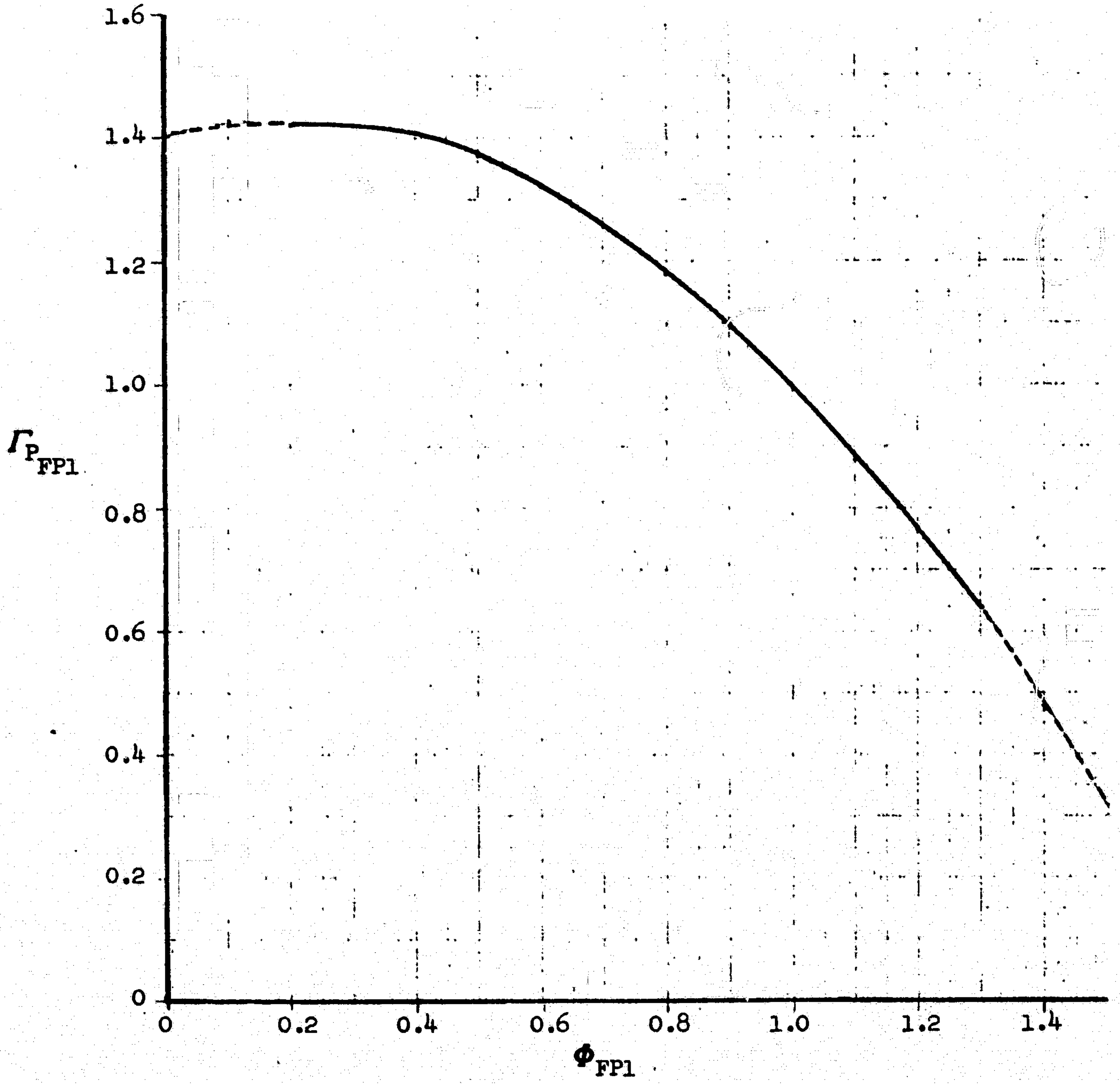


Figure 2. Low-Pressure Fuel Pump Pressure Rise Characteristics

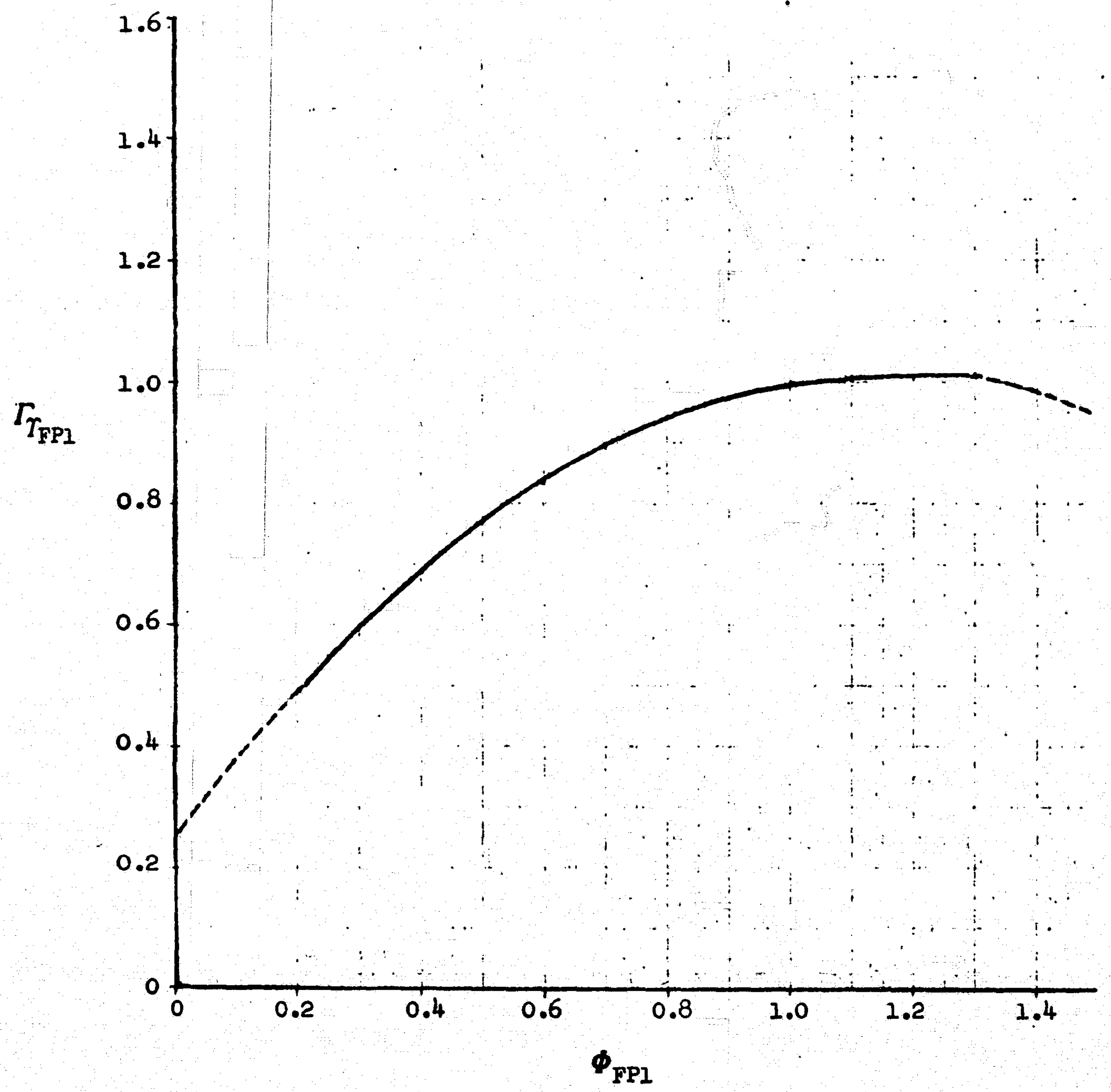


Figure 3. Low-Pressure Fuel Pump Torque Characteristics

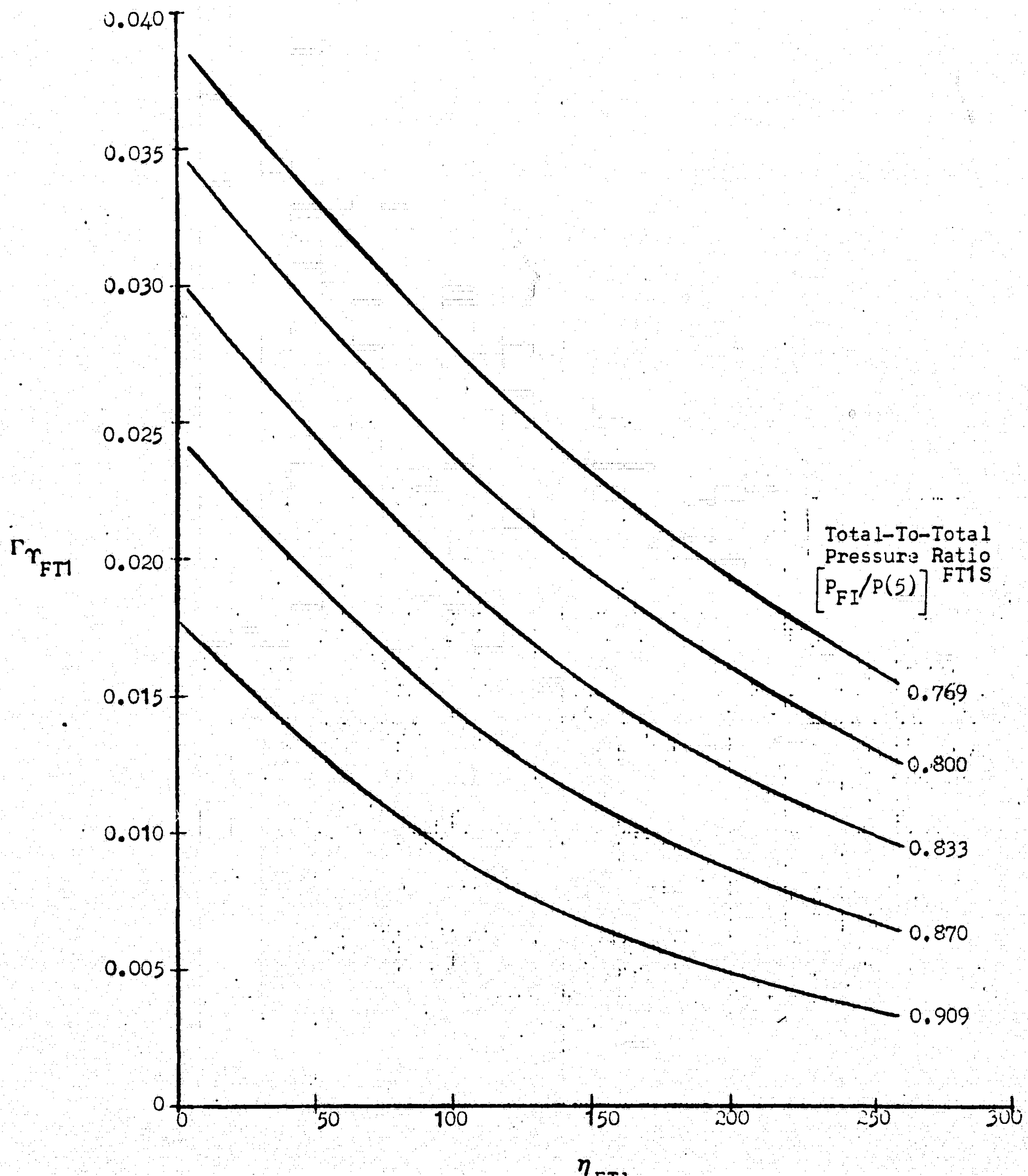


Figure 4. Low-Pressure Fuel Turbine Torque Characteristics

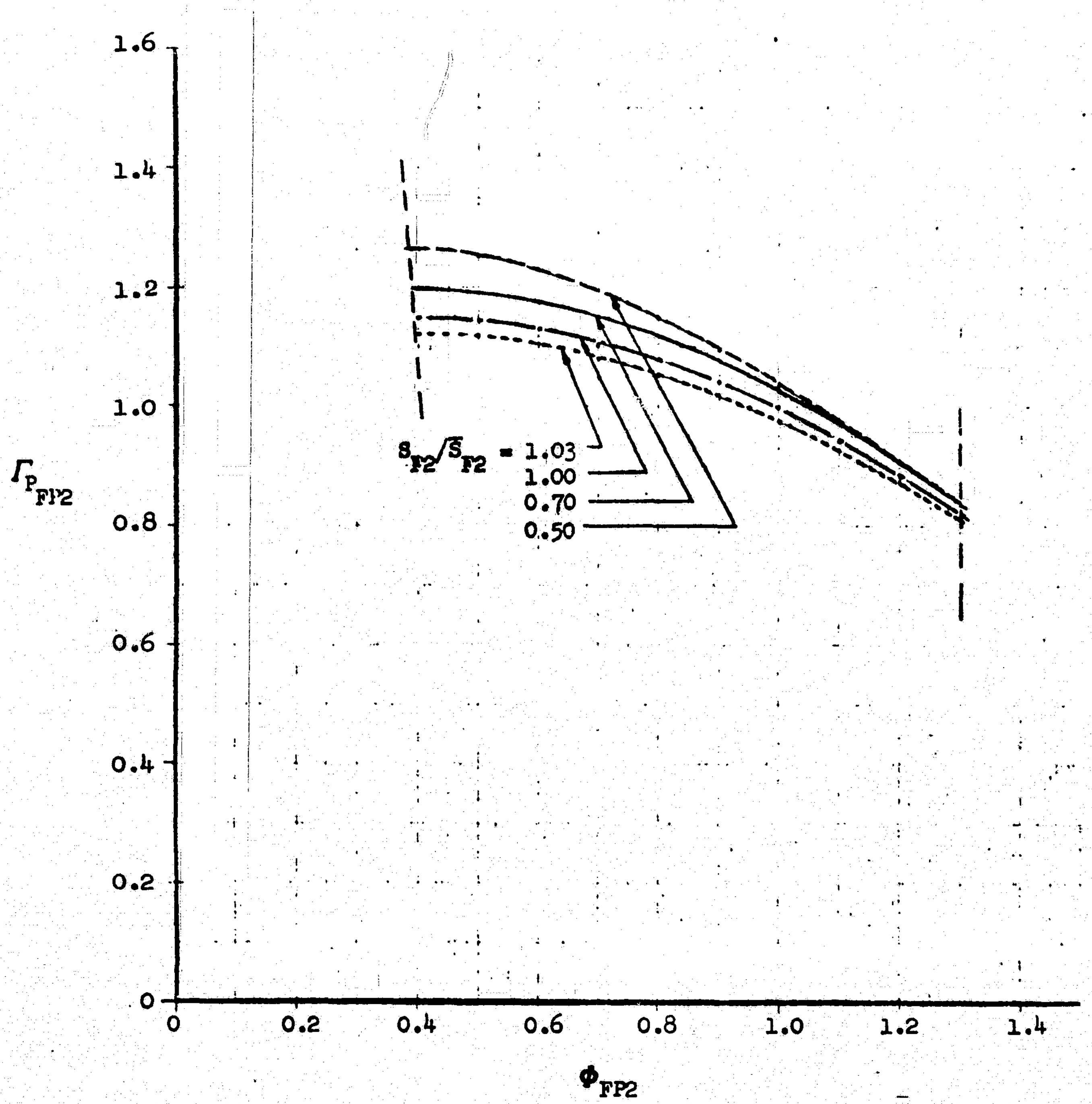


Figure 5. High-Pressure Fuel Pump Pressure Rise Characteristics

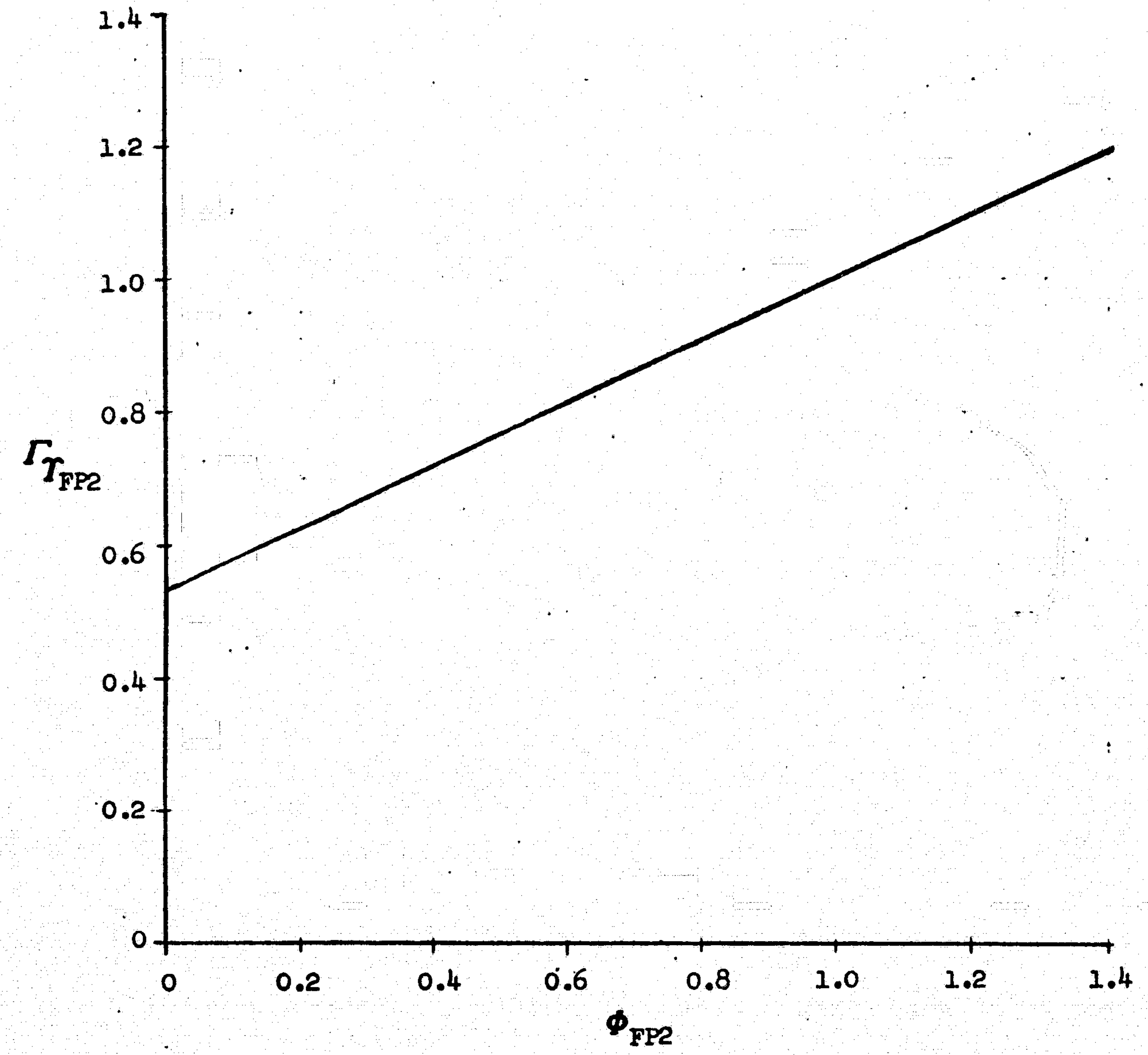


Figure 6. High-Pressure Fuel Pump Torque Characteristics

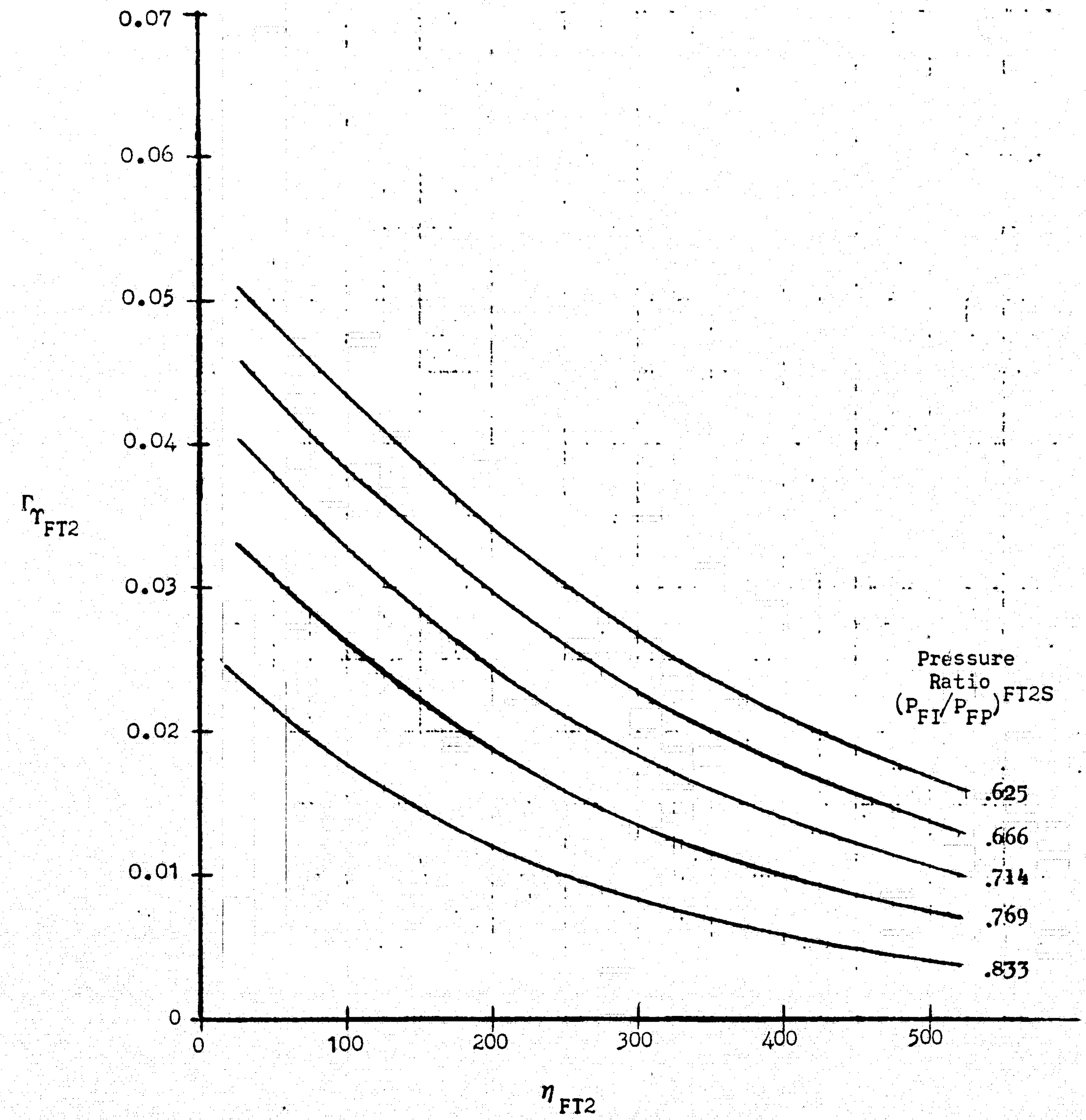


Figure 7. High-Pressure Fuel Turbine Torque Characteristics

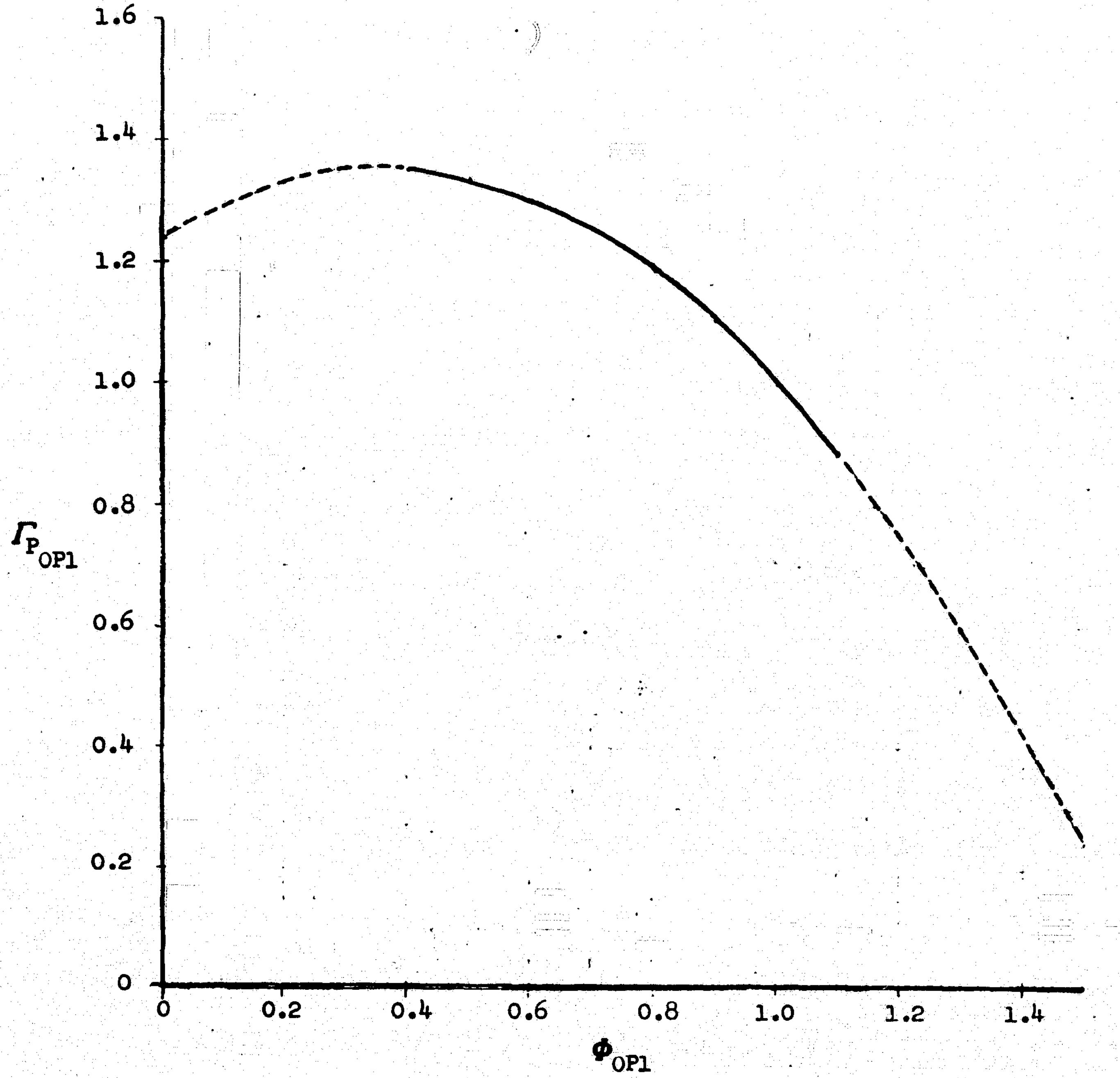


Figure 8. Low-Pressure Oxidizer Pump Pressure Rise Characteristics

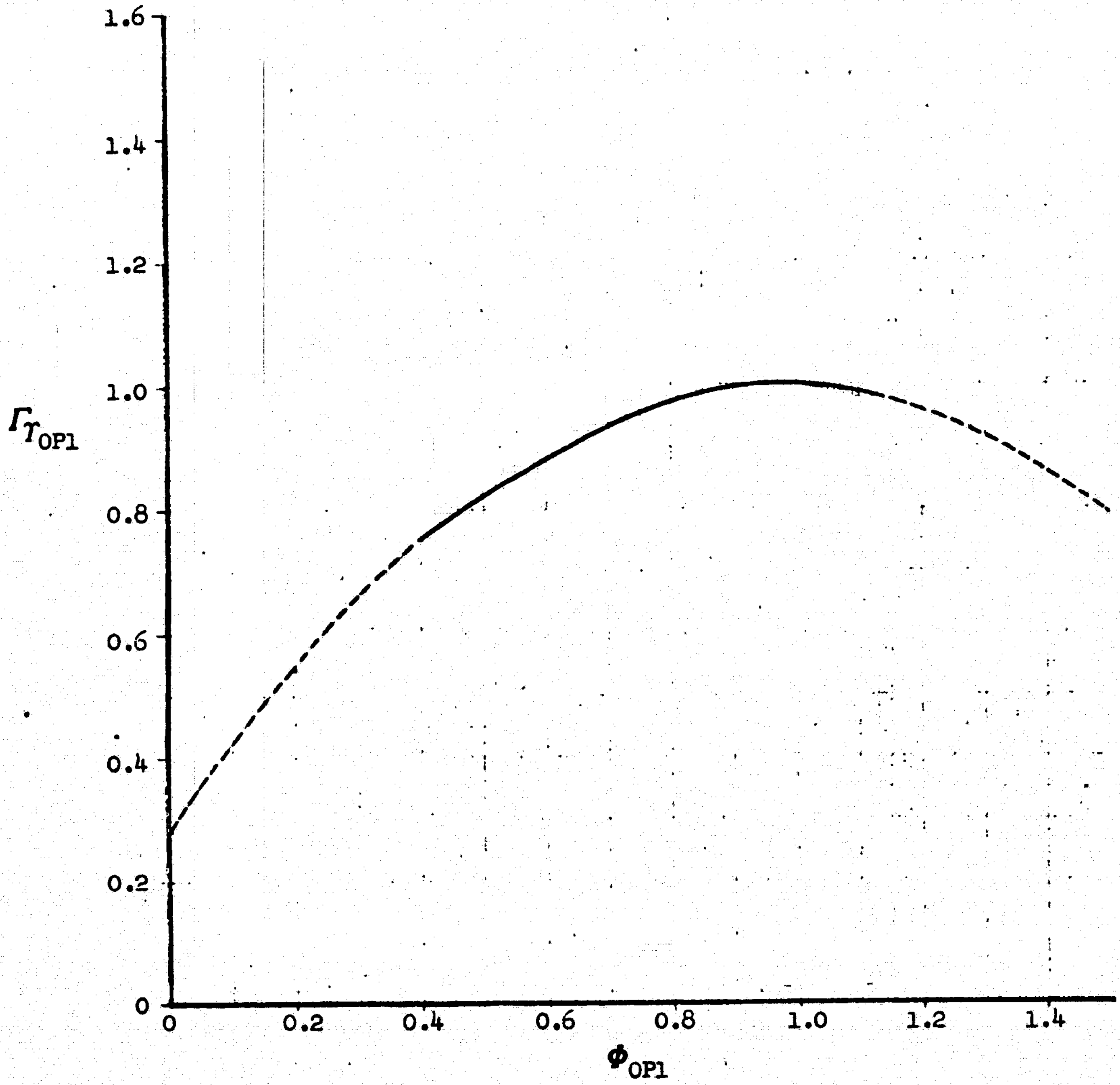


Figure 9. Low-Pressure Oxidizer Pump Torque Characteristics

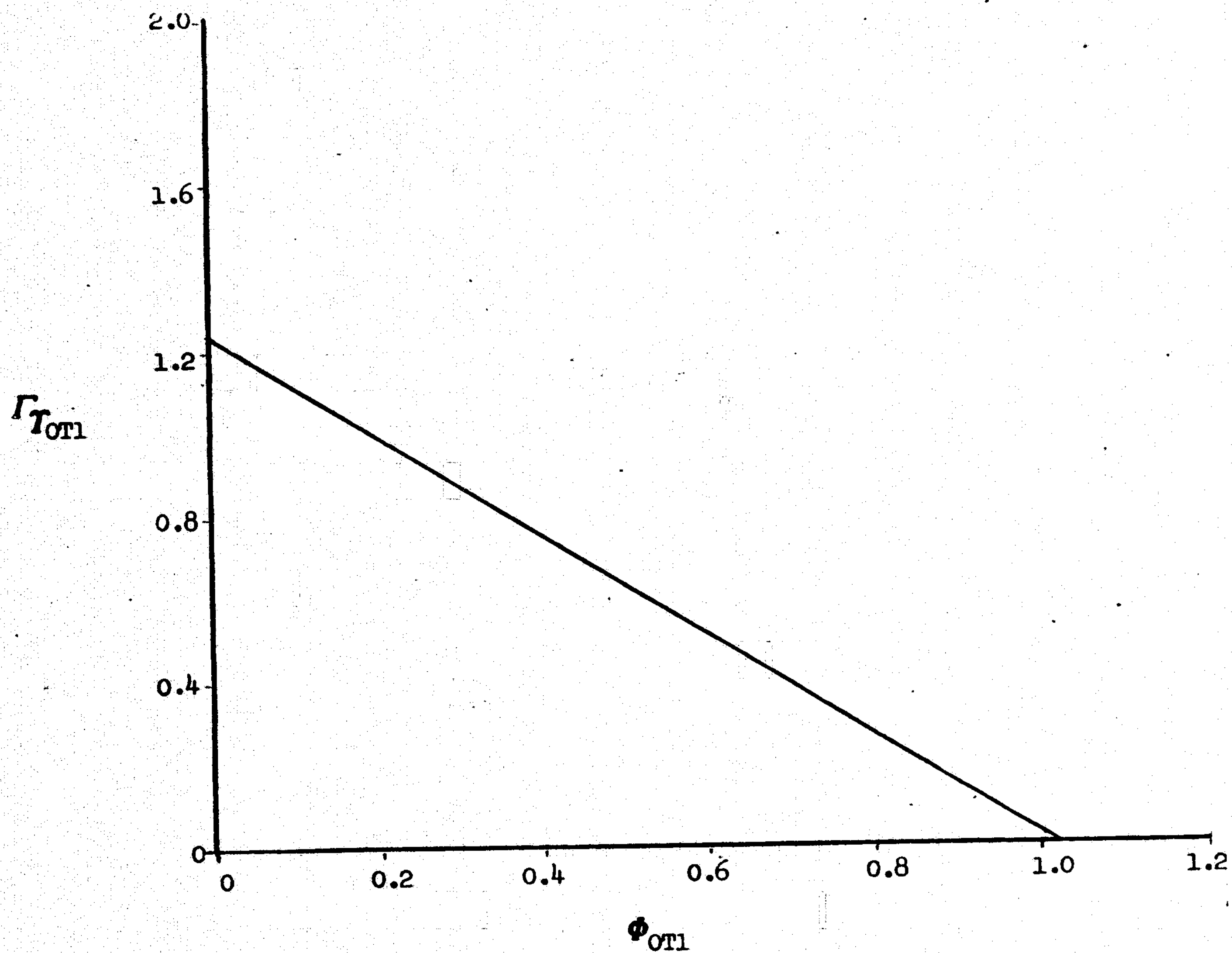


Figure 10. Low-Pressure Oxidizer Turbine Torque Characteristics

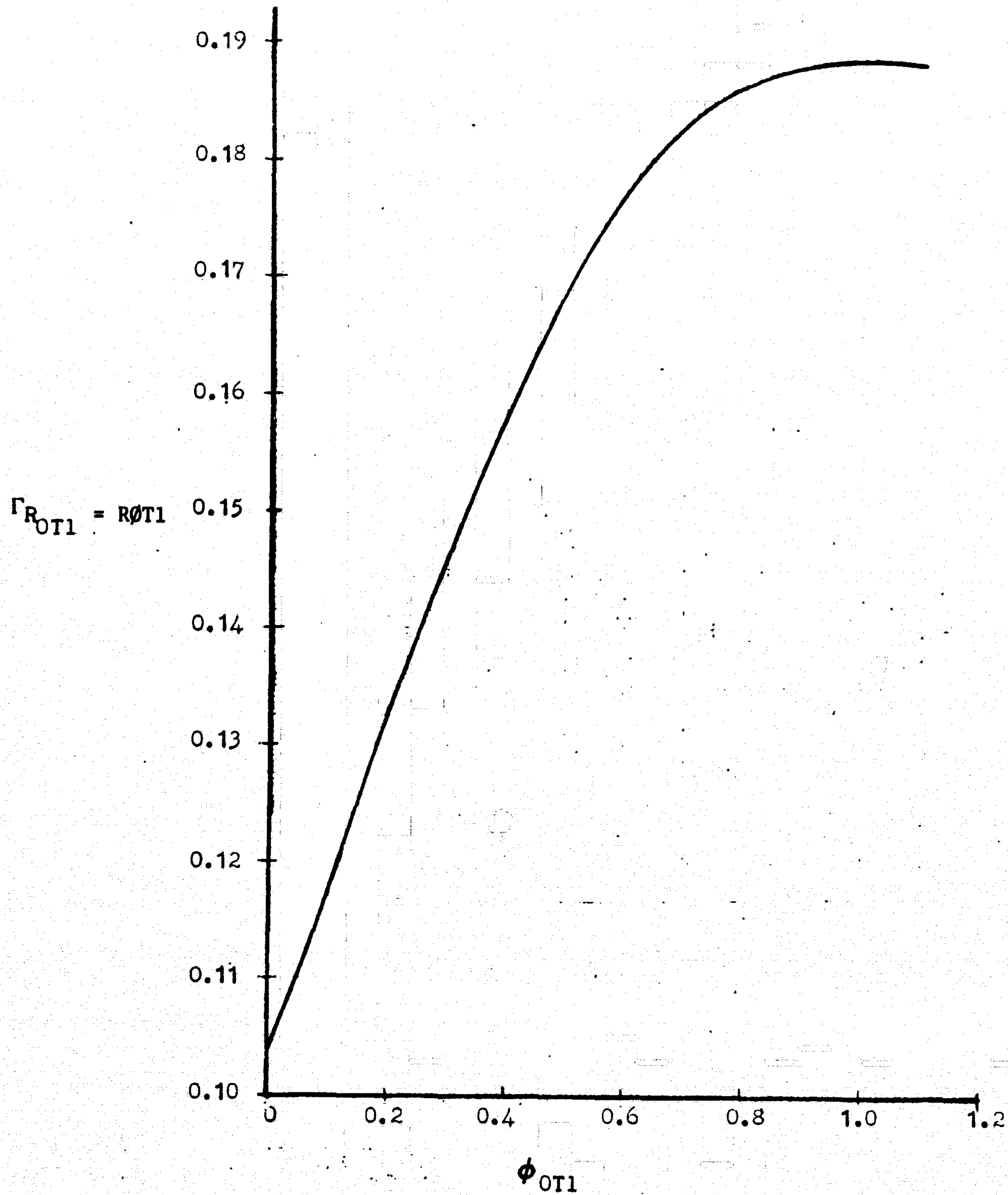


Figure 11. Low-Pressure Oxidizer Pump Resistance Characteristics

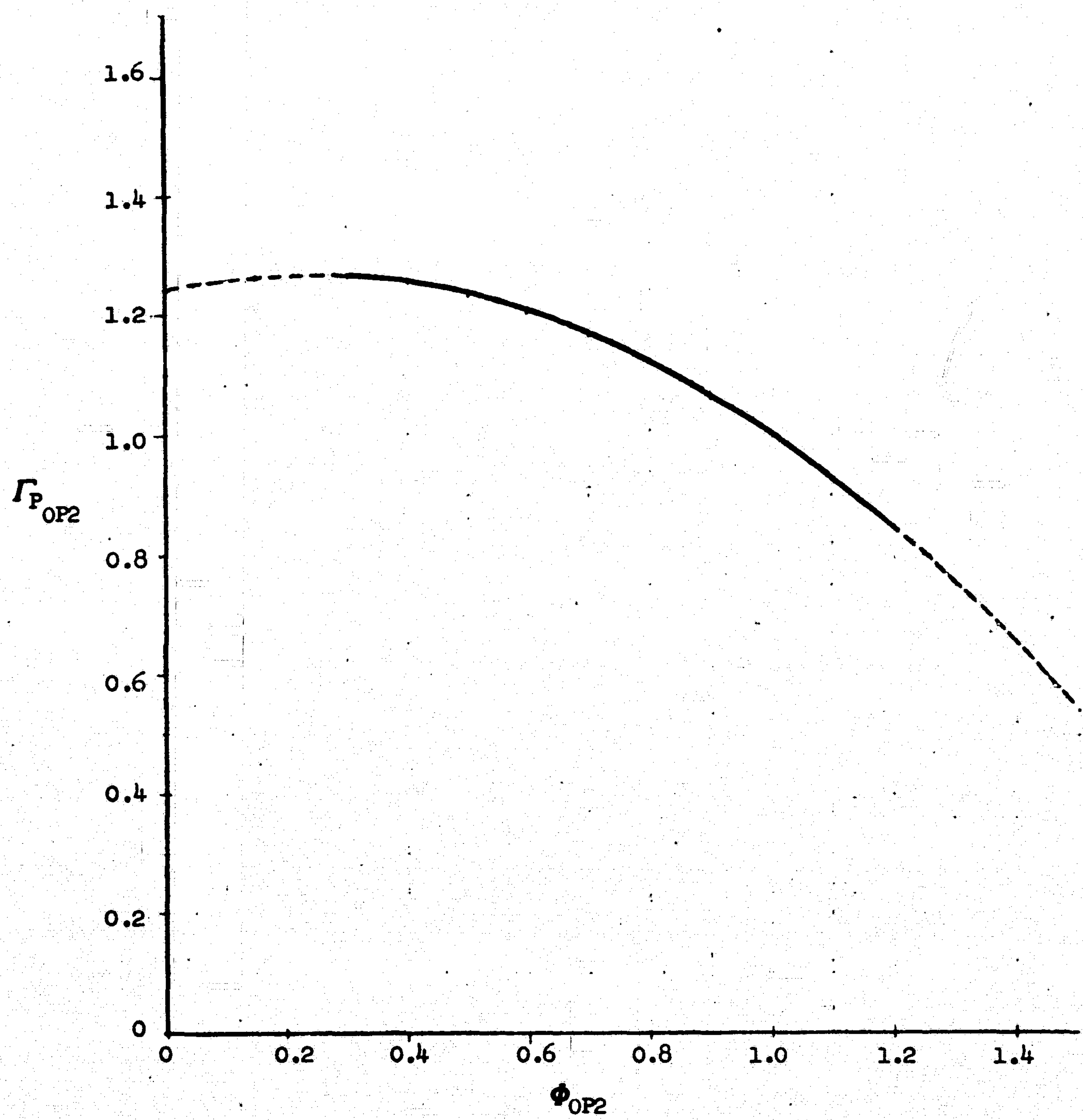


Figure 12. High-Pressure Oxidizer Pump (Main) Pressure Rise Characteristics

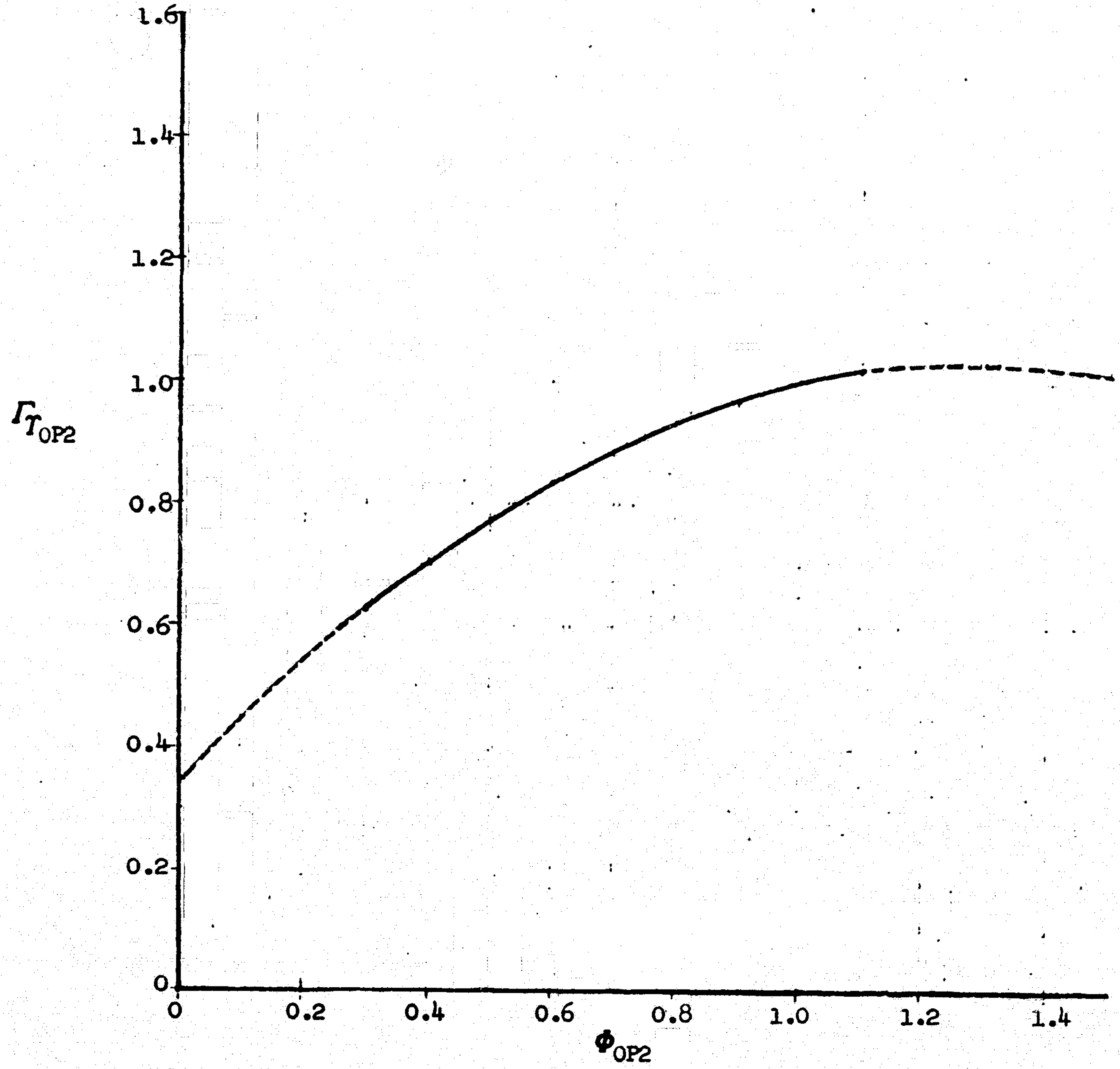


Figure 13. High-Pressure Oxidizer Pump (Main) Torque Characteristics

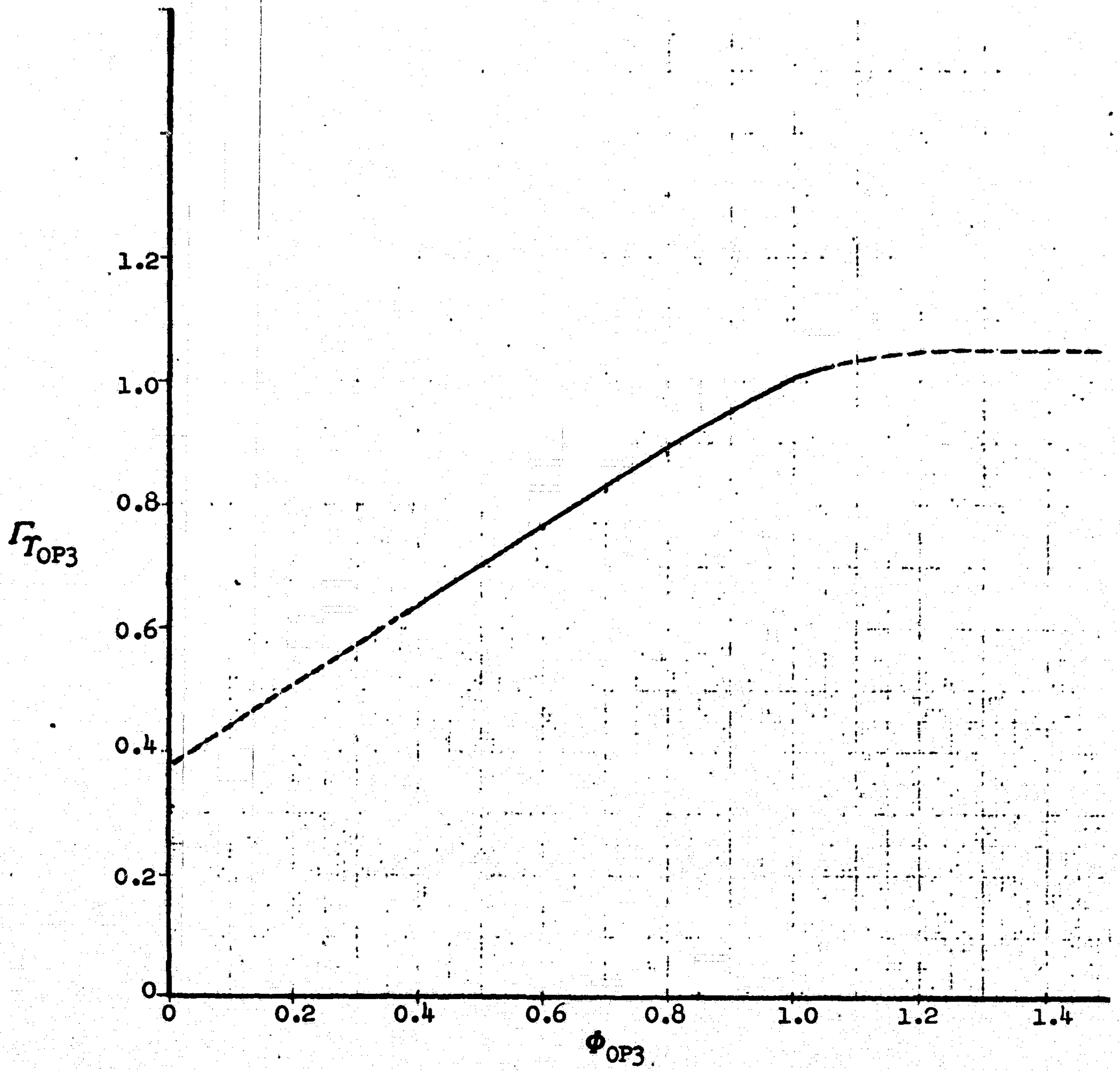


Figure 14. High-Pressure Oxidizer Pump Preburner Boost Stage Torque Characteristics

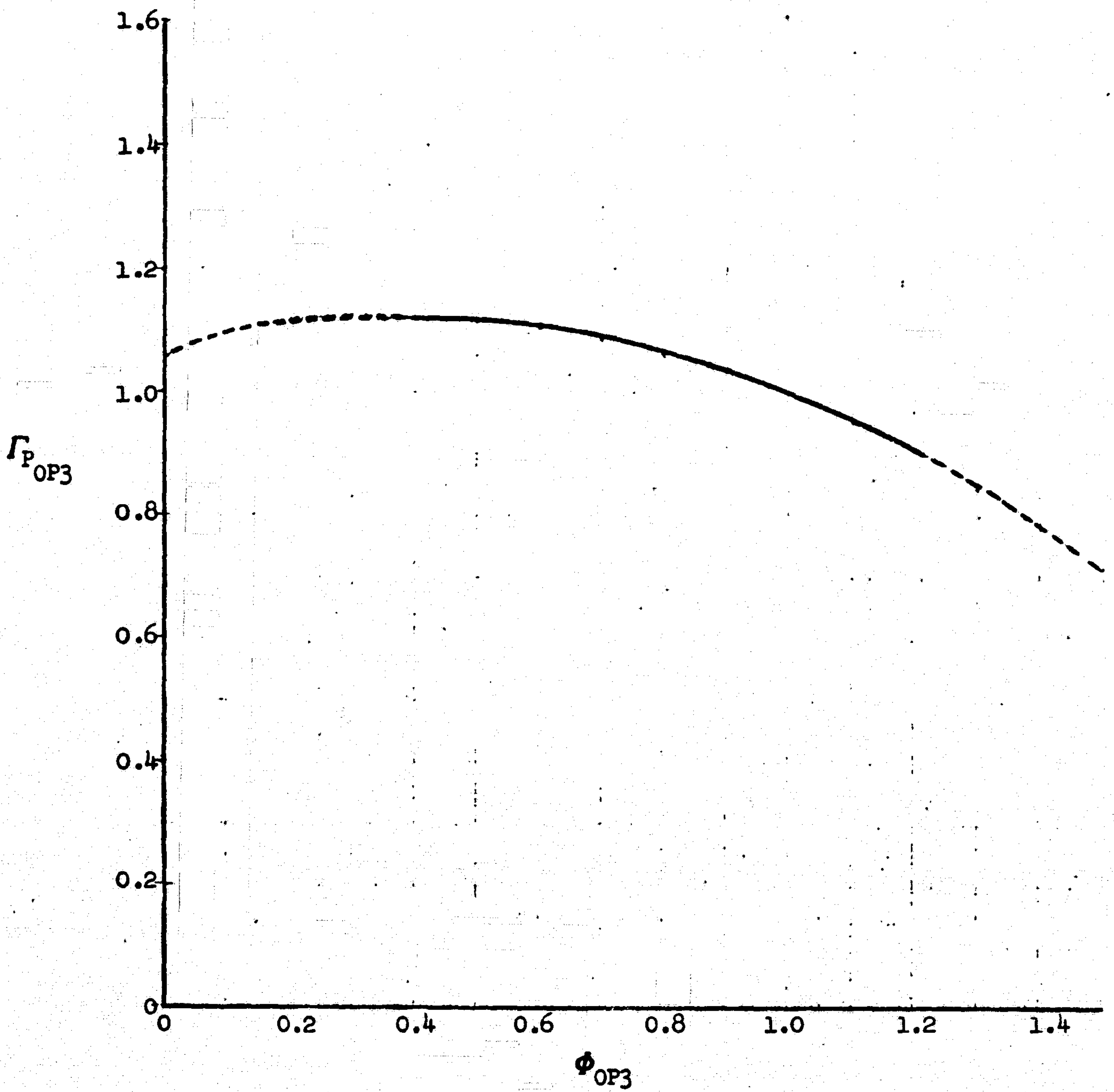


Figure 15. High-Pressure Oxidizer Pump Preburner Boost Stage Pressure Rise Characteristics

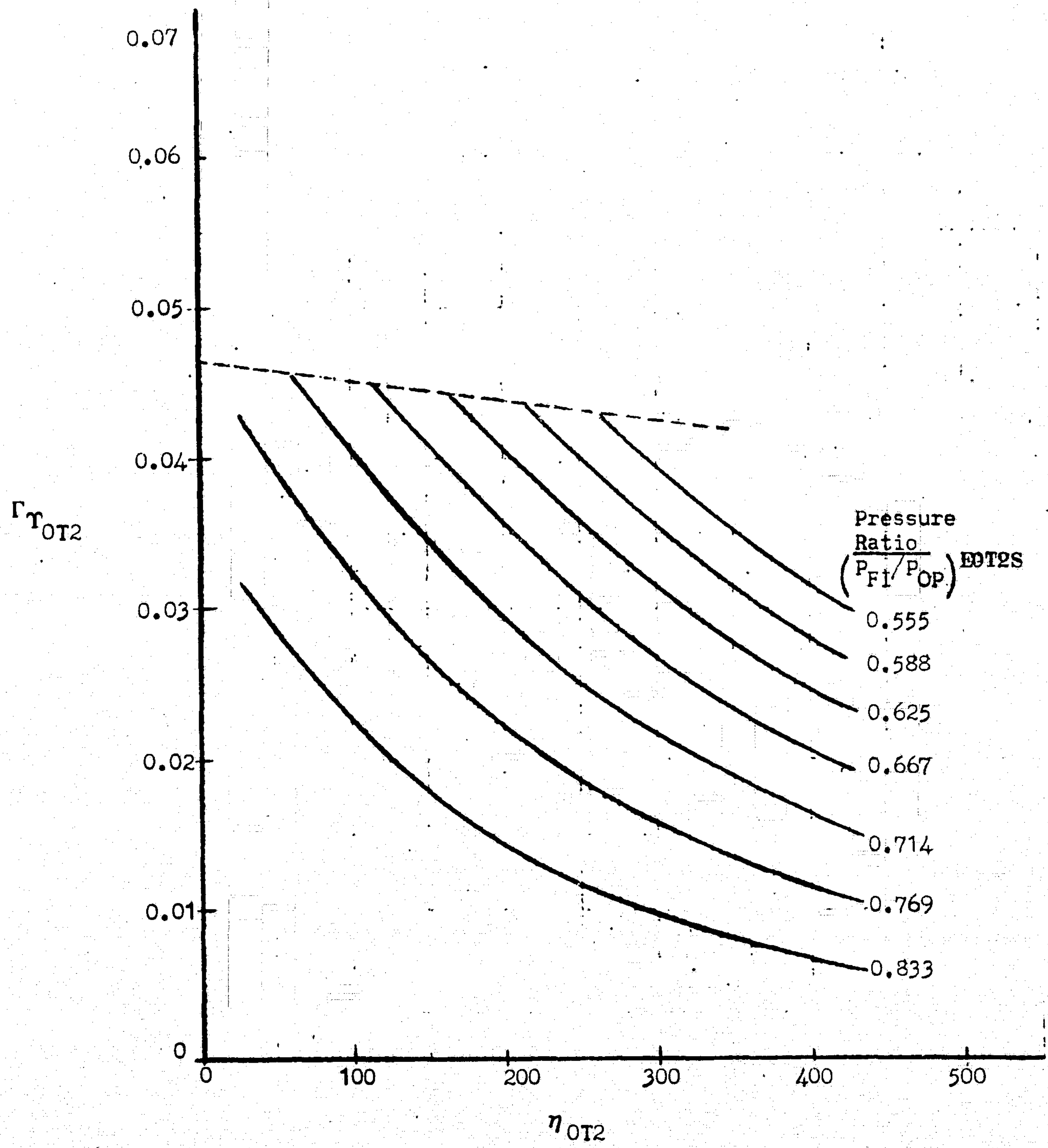
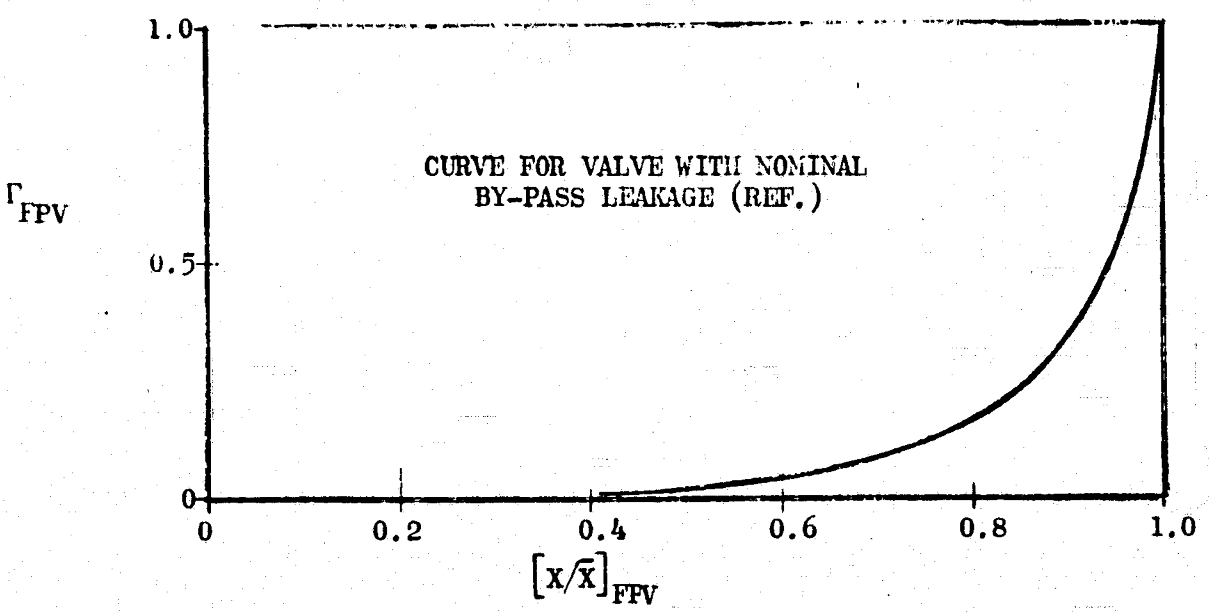


Figure 16. High-Pressure Oxidizer Turbine Torque Characteristic



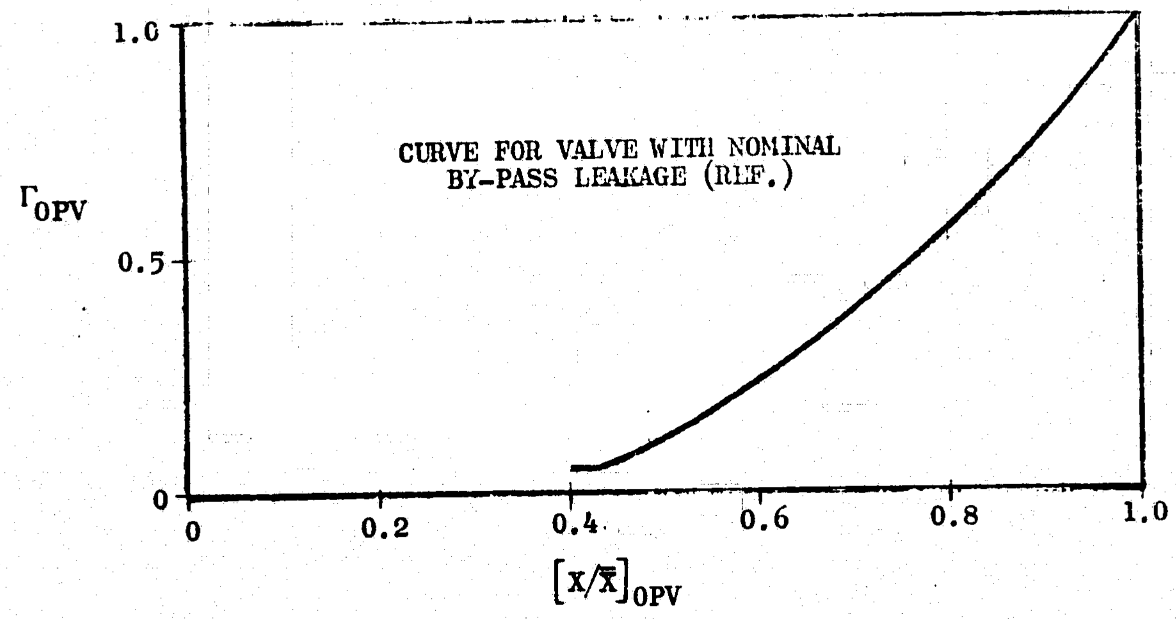
A resistance of 1.71875 x 10^{-4} Sec^2/In^5 was used in series with RF_v values listed below to obtain Γ_{FPV}

1000 RF_v	Γ_{FPV}	$[\theta/\bar{\theta}]_{FPV}$
0.0000	1.0000	1.0000
0.2441	0.6428	0.9688
0.5721	0.4806	0.9375
1.0373	0.3770	0.9063
1.7632	0.2980	0.8750
2.9811	0.2335	0.8438
4.8906	0.1843	0.8125
7.8665	0.1462	0.7813
12.0122	0.1188	0.7500
18.1261	0.0969	0.7188
27.6590	0.0786	0.6875
41.8487	0.0640	0.6563
67.0422	0.0506	0.6250
117.7405	0.0382	0.5938
228.3827	0.0274	0.5625
522.1774	0.0181	0.5313
1094.5552	0.0126	0.5000
3648.5732	0.0068	0.4688
5043.4377	0.0058	0.4503

Figure 17. Fuel Preburner Oxidizer Valve Effective Area vs Position Characteristic

Curve for Minimum By-Pass Leakage		Curve for Maximum By-Pass Leakage		
1000 RF_v	Γ_{FPV}	1000 RF_v	Γ_{FPV}	$[\theta/\bar{\theta}]_{FPV}$
0.0000	1.0000	0.0000	1.0000	1.0000
0.2444	0.6426	0.2438	0.6430	0.9688
0.5732	0.4803	0.5711	0.4810	0.9375
1.0399	0.3766	1.0346	0.3774	0.9063
1.7693	0.2976	1.7572	0.2985	0.8750
2.9950	0.2330	2.9673	0.2340	0.8438
4.9209	0.1837	4.8605	0.1848	0.8125
7.9307	0.1456	7.8031	0.1468	0.7813
12.1381	0.1182	11.8883	0.1194	0.7500
18.3687	0.0963	17.8883	0.0976	0.7188
28.1349	0.0779	27.1951	0.0792	0.6875
42.7715	0.0633	40.9555	0.0646	0.6563
68.9958	0.0498	65.1704	0.0513	0.6250
122.5059	0.0374	113.2478	0.0389	0.5938
241.9623	0.0266	215.9150	0.0282	0.5625
572.3822	0.0173	452.9515	0.0195	0.5315
1438.8170	0.0109	874.3861	0.0140	0.5000
5531.1564	0.0056	2598.6158	0.0081	0.4688
8535.5497	0.0045	3380.3136	0.0071	0.4503

Figure 17. (Concluded)

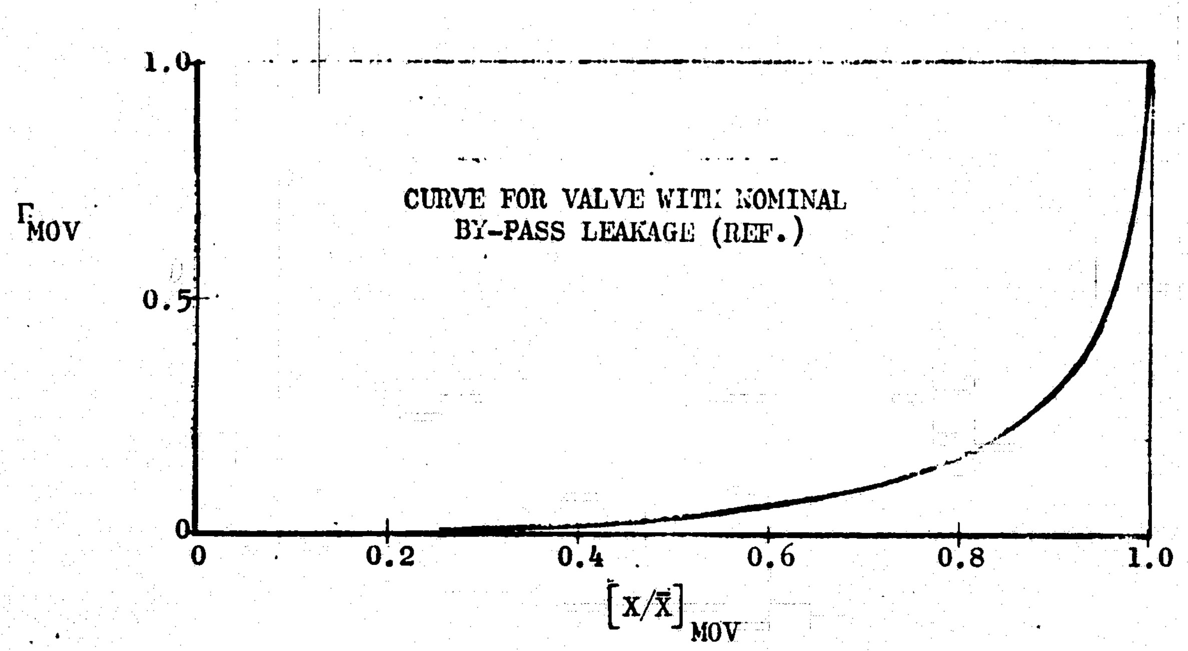


1000 RF_v	Γ_{OPV}	$[\theta/\bar{\theta}]_{OPV}$
10.26	1.00000	1.0000
13.11	0.88494	0.9688
16.33	0.79268	0.9375
20.17	0.71339	0.9063
24.76	0.64382	0.8750
30.33	0.58171	0.8438
37.18	0.52544	0.8125
45.72	0.47380	0.7813
56.59	0.42587	0.7500
70.74	0.38092	0.7188
89.65	0.33835	0.6875
115.85	0.29764	0.6563
153.80	0.25833	0.6250
212.19	0.21993	0.5938
310.08	0.18193	0.5625
496.75	0.14374	0.5313
937.19	0.10465	0.5000
2460.56	0.06459	0.4688
2618.31	0.06261	0.4503

Figure 18. Oxidizer Preburner Oxidizer Valve Effective Area vs Position Characteristic

Curve for Minimum By-Pass Leakage		Curve for Maximum By-Pass Leakage		
1000 RF_v	Γ_{0PV}	1000 RF_v	Γ_{0PV}	$[\theta/\tilde{\theta}]_{0PV}$
11.14	1.00000	9.48	1.00000	1.0000
13.93	0.89431	12.33	0.87666	0.9688
17.52	0.79735	15.24	0.78853	0.9375
21.81	0.71459	18.68	0.71233	0.9063
26.99	0.64235	22.77	0.64516	0.8750
33.32	0.57813	27.69	0.58497	0.8438
41.17	0.52012	33.70	0.53028	0.8125
51.06	0.46702	41.13	0.47998	0.7813
63.79	0.41784	50.50	0.43320	0.7500
80.57	0.37180	62.54	0.38926	0.7188
103.37	0.32825	78.43	0.34760	0.6875
135.55	0.28664	100.08	0.30772	0.6563
183.32	0.24648	130.78	0.26919	0.6250
259.27	0.20726	176.76	0.23154	0.5938
392.61	0.16842	251.00	0.19431	0.5625
666.01	0.12931	384.79	0.15693	0.5313
1401.46	0.08915	671.61	0.11879	0.5000
4718.96	0.04858	1501.70	0.07944	0.4688
5004.70	0.04717	1598.92	0.07699	0.4503

Figure 18. (Concluded)



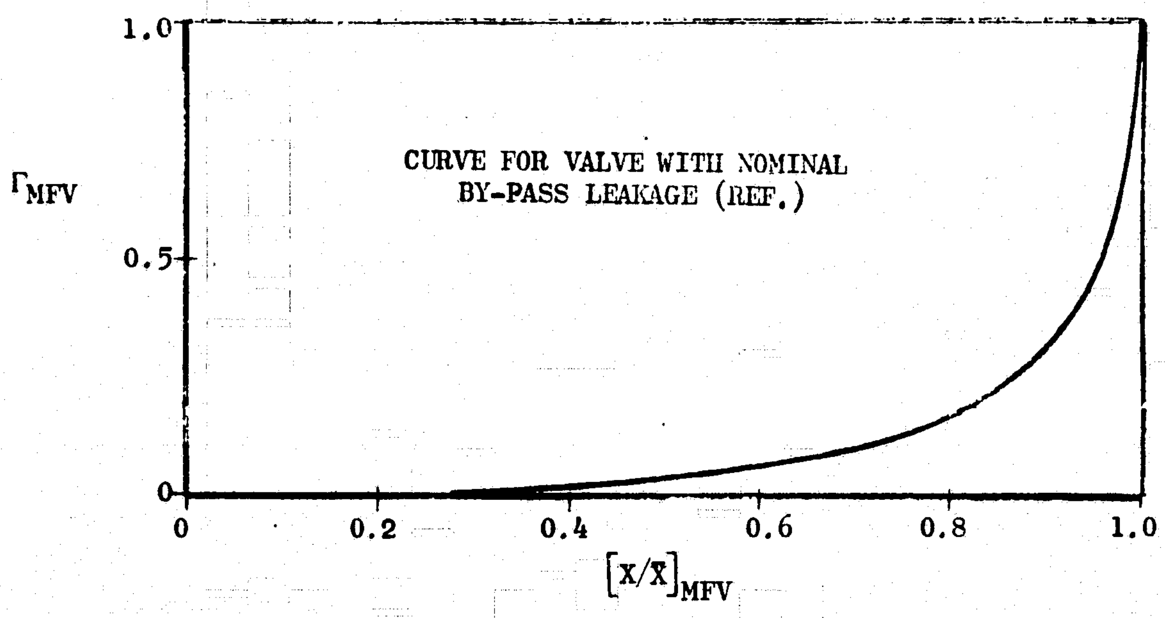
A resistance of 3.414×10^{-6} Sec^2/In^5 was used in series with RF_v Values listed below to obtain Γ_{MOV}.

1000 RF_v	Γ_{MOV}	$[\theta/\bar{\theta}]_{MOV}$
0.0000	1.0000	1.0000
0.0062	0.5960	0.9706
0.0148	0.4335	0.9412
0.0244	0.3502	0.9118
0.0377	0.2883	0.8824
0.0566	0.2386	0.8529
0.0829	0.1989	0.8235
0.1242	0.1636	0.7941
0.1790	0.1368	0.7647
0.2608	0.1137	0.7353
0.3586	0.0971	0.7059
0.5016	0.0822	0.6765
0.6824	0.0706	0.6471
0.9387	0.0602	0.6176
1.2987	0.0512	0.5882
1.8086	0.0434	0.5588
2.6280	0.0360	0.5294
4.0420	0.0291	0.5000
6.6206	0.0227	0.4706
11.6623	0.0171	0.4412
23.3579	0.0121	0.4118
56.8137	0.0078	0.3824
116.8515	0.0055	0.3529
389.9630	0.0030	0.3235

Figure 19. Main Oxidizer Valve Effective Area vs Position Characteristic

Curve for Minimum By-Pass Leakage		Curve for Maximum By-Pass Leakage		
1000 RF_v	Γ_{MOV}	1000 RF_v	Γ_{MOV}	$[\theta/\bar{\theta}]_{MOV}$
0.0000	1.0000	0.0000	1.0000	1.0000
0.0062	0.5959	0.0062	0.5961	0.9706
0.0148	0.4333	0.0147	0.4336	0.9412
0.0245	0.3500	0.0244	0.3504	0.9118
0.0377	0.2881	0.0376	0.2885	0.8824
0.0567	0.2384	0.0564	0.2388	0.8529
0.0831	0.1987	0.0827	0.1991	0.8235
0.1245	0.1634	0.1238	0.1638	0.7941
0.1797	0.1366	0.1784	0.1370	0.7647
0.2620	0.1134	0.2597	0.1139	0.7353
0.3606	0.0969	0.3567	0.0974	0.7059
0.5048	0.0820	0.4983	0.0825	0.6765
0.6877	0.0703	0.6771	0.0708	0.6471
0.9476	0.0599	0.9300	0.0605	0.6176
1.3136	0.0509	1.2841	0.0515	0.5882
1.8338	0.0431	1.7839	0.0437	0.5588
2.6736	0.0357	2.5836	0.0363	0.5294
4.1318	0.0287	3.9550	0.0294	0.5000
6.8157	0.0224	6.4337	0.0230	0.4706
12.1364	0.0168	11.2154	0.0174	0.4412
24.7647	0.0117	22.0677	0.0124	0.4118
55.0170	0.0079	42.4986	0.0089	0.3824
134.7548	0.0051	94.4583	0.0060	0.3529
573.9549	0.0024	275.0235	0.0035	0.3235

Figure 19. (Concluded)



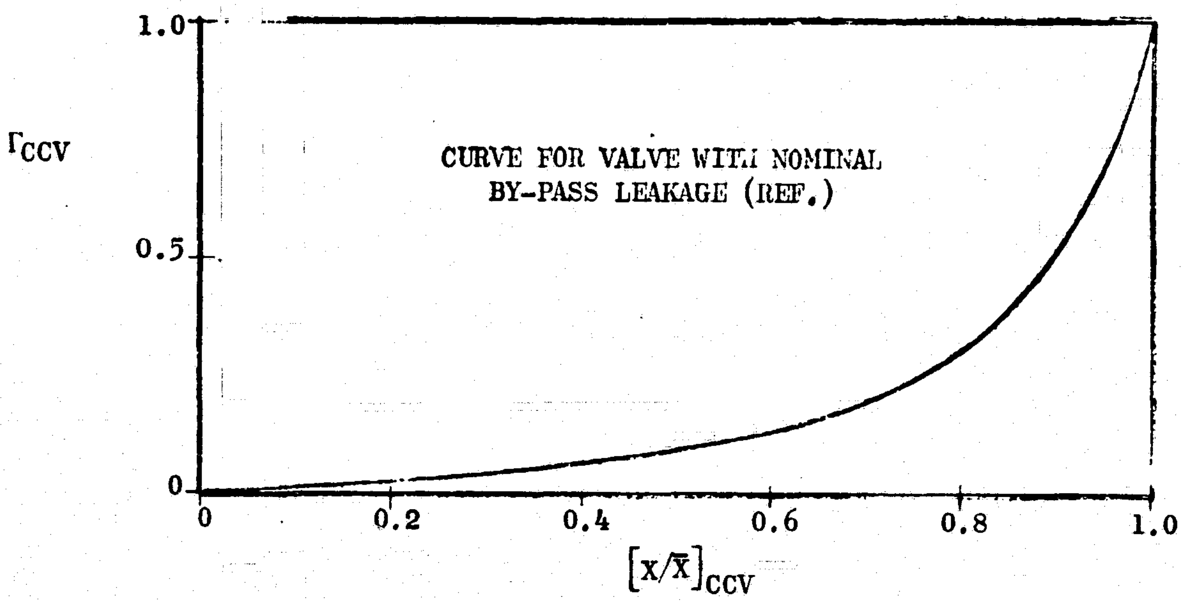
A resistance of 3.4135×10^{-6} Sec^2/In^5 was used in series with RF_v values listed below to obtain Γ_{MFV}.

10000 RF_v	Γ_{MFV}	$[\theta/\bar{\theta}]_{MFV}$
0.0000	1.0000	1.0000
0.0062	0.5959	0.9706
0.0148	0.4333	0.9412
0.0245	0.3500	0.9118
0.0377	0.2881	0.8824
0.0567	0.2384	0.8529
0.0831	0.1987	0.8235
0.1245	0.1634	0.7941
0.1797	0.1366	0.7647
0.2620	0.1134	0.7353
0.3606	0.0969	0.7059
0.5048	0.0820	0.6765
0.6877	0.0703	0.6471
0.9476	0.0599	0.6176
1.3136	0.0509	0.5882
1.8338	0.0431	0.5588
2.6736	0.0357	0.5294
4.1318	0.0287	0.5000
6.8157	0.0224	0.4706
12.1364	0.0168	0.4412
24.7647	0.0117	0.4118
62.4854	0.0074	0.3824
148.2311	0.0048	0.3529
595.4925	0.0024	0.3235

Figure 20. Main Fuel Valve Effective Area vs Position Characteristics

Curve for Minimum By-Pass Leakage		Curve for Maximum By-Pass Leakage		
$1000\ RF_v$	Γ_{MFV}	$1000\ RF_v$	Γ_{MFV}	$[\theta/\bar{\theta}]_{MFV}$
0.0000	1.0000	0.0000	1.0000	1.0000
0.0062	0.5957	0.0062	0.5960	0.9706
0.0148	0.4332	0.0148	0.4335	0.9412
0.0245	0.3499	0.0244	0.3502	0.9118
0.0378	0.2879	0.0377	0.2883	0.8824
0.0568	0.2382	0.0566	0.2386	0.8529
0.0833	0.1985	0.0829	0.1989	0.8235
0.1249	0.1631	0.1242	0.1636	0.7941
0.1803	0.1363	0.1790	0.1368	0.7647
0.2632	0.1132	0.2608	0.1137	0.7353
0.3625	0.0966	0.3586	0.0971	0.7059
0.5082	0.0817	0.5016	0.0822	0.6765
0.6931	0.0700	0.6824	0.0706	0.6471
0.9566	0.0596	0.9387	0.0602	0.6176
1.3287	0.0506	1.2987	0.0512	0.5882
1.8595	0.0428	0.8086	0.0434	0.5588
2.7204	0.0354	2.6280	0.0360	0.5294
4.2247	0.0284	4.0420	0.0291	0.5000
7.0195	0.0220	6.6206	0.0227	0.4706
12.6401	0.0164	11.6623	0.0171	0.4412
26.3025	0.0114	23.3579	0.0121	0.4118
69.0507	0.0070	52.5852	0.0081	0.3824
198.7157	0.0041	116.8515	0.0055	0.3529
1019.5109	0.0018	389.9630	0.0030	0.3235

Figure 20. (Concluded)



A resistance of 2.205×10^{-5} Sec^2/In^5 was used in series with RF_v values listed below to obtain Γ_{CCV}.

1000 RF_v	Γ_{CCV}	$[\theta/\bar{\theta}]_{CCV}$
0.0000	1.0000	1.0000
0.0173	0.7489	0.9563
0.0434	0.5806	0.9125
0.0860	0.4518	0.8688
0.1524	0.3555	0.8250
0.2422	0.2888	0.7813
0.3820	0.2336	0.7375
0.5891	0.1899	0.6938
0.8961	0.1550	0.6500
1.3206	0.1281	0.6063
1.9055	0.1070	0.5625
2.7345	0.0894	0.5188
3.9210	0.0748	0.4750
5.6980	0.0621	0.4313
8.0138	0.0524	0.3875
11.3647	0.0440	0.3438
16.8862	0.0361	0.3000
26.6630	0.0287	0.2563
44.4762	0.0223	0.2125
80.9009	0.0165	0.1688
167.2343	0.0115	0.1250
410.1394	0.0073	0.0813
1186.7226	0.0043	0.0375
1557.6401	0.0038	0.0052

Figure 21. Coolant Control Valve Effective Area vs Position Characteristics

Curve for Minimum By-Pass Leakage		Curve for Maximum By-Pass Leakage		
1000 RF_v	Γ_{CCV}	1000 RF_v	Γ_{CCV}	$[\theta/\bar{\theta}]_{CCV}$
0.0000	1.0000	0.0000	1.0000	1.0000
0.0173	0.7487	0.0172	0.7491	0.9563
0.0435	0.5801	0.0433	0.5810	0.9125
0.0863	0.4512	0.0857	0.4524	0.8688
0.1532	0.3547	0.1517	0.3562	0.8250
0.2437	0.2880	0.2408	0.2896	0.7813
0.3850	0.2327	0.3790	0.2345	0.7375
0.5951	0.1890	0.5833	0.1909	0.6938
0.9076	0.1540	0.8848	0.1559	0.6500
1.3419	0.1271	1.2998	0.1292	0.6063
1.9436	0.1059	1.8685	0.1080	0.5625
2.8022	0.0884	2.6692	0.0905	0.5188
4.0412	0.0737	3.8061	0.0759	0.4750
5.9161	0.0609	5.4918	0.0632	0.4313
8.3911	0.0512	7.6615	0.0536	0.3875
12.0265	0.0428	10.7559	0.0452	0.3438
18.1362	0.0348	15.7612	0.0374	0.3000
29.2634	0.0274	24.3944	0.0301	0.2563
50.4002	0.0209	39.5384	0.0236	0.2125
96.5107	0.0151	68.7933	0.0179	0.1688
218.7066	0.0100	132.0051	0.0129	0.1250
646.9507	0.0058	283.0306	0.0088	0.0813
2904.8830	0.0028	640.8195	0.0059	0.0375
4818.1147	0.0021	760.2137	0.0054	0.0052

Figure 21. (Concluded)

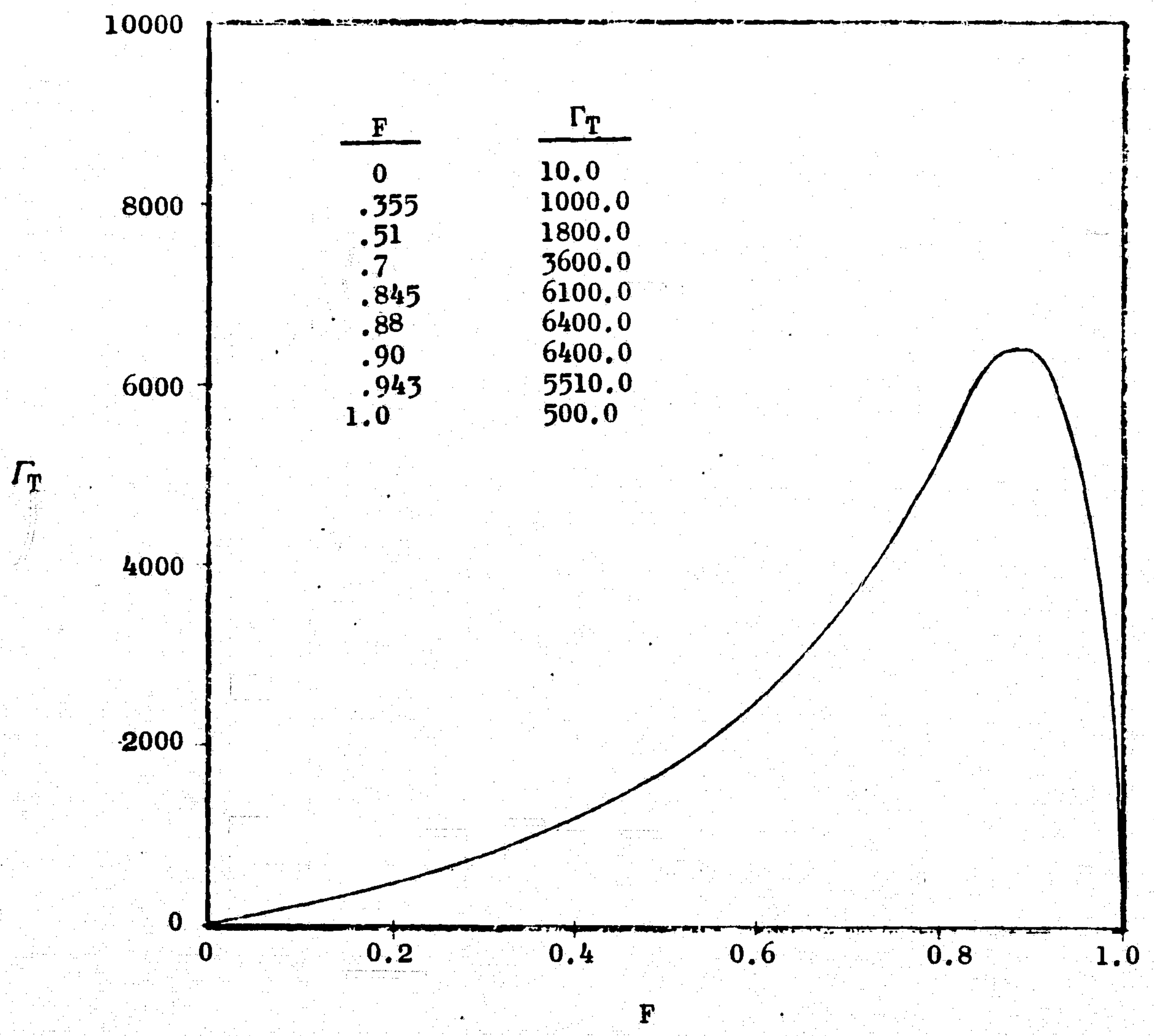


Figure 22. Combustion Temperature Function vs Oxidizer Fraction (F)

LINEAR MODEL

Linerization of the basic equations was accomplished by considering the effect of small variations in each independent variable in each equation. Where functional variations were required, the slope of the functional characteristic was used. Integral equations were rewritten in their differential form and the differential operator "S" was used.

The linearized equations were then reduced by eliminating variables which were not required for display in the final solutions and which could be eliminated in a straightforward manner. All dependant variables which were defined in the non-linear model by an equation numbered with an alphabetical suffix were eliminated. (If necessary the frequency response of any of these variables can be constructed using solutions from the variables which were retained.) It should be noted that each variable variation has retained its units, e.g., its variation is directly in psi, lb/sec, etc.

The complete linearized set of equations is presented in a matrix format in Fig. 23. The coefficients in the matrix are generally dependent on operating level and are presented in Table 3.

In order to determine the frequency response of the system, a general-purpose digital computer program was modified specifically for use on the SSME linear model. The coefficient values are calculated from parameter values and function slopes which are input to the program. Input data also define those variables requiring derivative columns, specifies the size of the matrix, defines the frequency span of interest, and specifies which frequency responses are to be generated. Listings of the main and subprograms are contained in Appendixes A and B.

The pertinent output from the frequency response program is contained in a later section of this report for the 109-percent power level (EPL). For power levels other than EPL, other engine balance data must be used. Sufficient information to generate the coefficients is found in Appendix C, although it is currently not in a convenient form.

A - MATRIX OF OUTPUT VARIABLES

	1 ΔP_{FD1}	2 ΔS_{F1}	3 ΔDW_{FD2}	4 ΔS_{F2}	5 ΔP_{OD1}	6 ΔS_{O1}	7 ΔDW_{OT1}	8 ΔP_{OD2}	9 ΔS_{O2}	10 ΔDW_{OP3}	11 ΔDW_{OT2}	12 ΔP_{POS}	13 ΔDW_{FPF}	14 ΔDW_{FPO}	15 ΔP_{FP}	16 ΔDW_{OPF}	17 ΔDW_{OPO}	18 ΔP_{OP}	19 ΔP_{FI}	20 ΔDW_{FI}	21 ΔDW_{MOV}	22 ΔP_{C}	23 ΔF_{TC}	24 $\Delta P(5)$	25 ΔDW_{MC}	26 $\Delta P(5)$	27 $\Delta T(5)$	28 $\Delta T_{W1}(5)$	29 $\Delta T_{W2}(5)$	30 $\Delta P(4)$	31 ΔDW
1	a	a	a																												
2		d	a																a					a			a				
3	a		d	a																											
4			a	d											a				a												
5					a	a	a																								
6						d	a																								
7					a	a	a	a																							
8							a	a	a	a											a										
9							a	a	d	a								a	a		a										
10								a	a	d		a																			
11											a					a	a	a	a												
12										a		d		a			a														
13													d		a																
14												a		d	a																
15													a	a	d				a												
16																d		a													
17												a					d	a													
18											a					a	a	d													
19											a		a	a	a				d	a				a		a					
20													a	a		a	a		a	a		a					a				
21								a													d	a									
22																				a	a	d	a								
23										a										a	a		a								
24			a	a															a					d	a	a	a	a	a		
25																								a	d	a					
26																			a					a	a	d					
27																								a		a	a				
28																						a	a		a		a	d			
29																											a		d		
30			a	a																										d	a
31																														a	d
32																															a
33																														a	
34																						a	a								a
35																															
36																														a	
37													a			a															
38			a																						a						a
39																															
40																															
41																															
42					a																										
43							a	a		a											a										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

a--INDICATES AN ALGEBRAIC COEFFICIENT
d--INDICATES A COEFFICIENT OF THE FORM S + a

2

R - MATRIX OF (7) INPUT VARIABLES

Row	26 $\Delta P(5)$	27 $\Delta T(5)$	28 $\Delta T_{W1}(5)$	29 $\Delta T_{W2}(5)$	30 $\Delta P(4)$	31 ΔDW_{FN}	32 $\Delta P(4)$	33 $\Delta T(4)$	34 $\Delta T_{W1}(4)$	35 $\Delta T_{W2}(4)$	36 $\Delta DW(4)$	37 $\Delta P(9)$	38 ΔP_{MFVD}	39 ΔDW_{FNBP}	40 $\Delta T(9)$	41 $\Delta P(9)$	42 ΔDW_{OS1}	43 ΔP_{OS1}
1																		
2		a																
3													a					
4																		
5																	a	
6																	a	
7																		
8																		a
9																		
10																		
11															a			
12																		
13												a				a		
14																		
15															a			
16												a				a		
17																		
18																		
19	a														a			
20		a													a			
21																		
22																		
23																		
24	a	a	a	a														
25	a												a					
26	d																	
27	a	a																
28		a	d															
29		a		d														
30					d	a		a	a	a	a							
31					a	d							a					
32						a	d				a							
33					a		a	a										
34						a		a	d									
35								a		d								
36					a		a				d	a						
37											a	d		a				
38						a							d	a				
39												a	a	d				
40												a			a	a		
41							a				a			a		a		
42																	d	a
43																	a	d

Row	1 ΔP_{FS}	2 ΔP_{OS}	3 $\Delta X/X_{MFV}$	4 $\Delta X/X_{MOV}$	5 $\Delta X/X_{FPV}$	6 $\Delta X/X_{OPV}$	7 $\Delta X/X_{CCV}$
1	a						
2							
3			a				
4							
5		a					
6							
7							
8							
9							
10							
11							
12							
13							
14					a		
15							
16							
17						a	
18							
19							
20							
21				a			
22							
23							
24							
25							
26							
27							
28							
29							
30							
31							
32							
33							
34							
35							
36							
37							
38							
39							a
40							
41							
42							
43							

Figure 23. Input-Output Variables Matrix

TABLE 3. LINEAR ENGINE MODEL MATRIX COEFFICIENTS

$$A(1,1) = 1$$

$$B(1,2) = P_{FS} - P_{FD1}$$

$$C(1,2) = \frac{\left(\partial\Gamma_{P_{FP1}} / \partial\phi_{FP1}\right)\phi_{FP1}}{\Gamma_{P_{FP1}}}$$

$$A(1,2) = \frac{B(1,2)}{S_{F1}} \left[2 - C(1,2)\right]$$

$$A(1,3) = B(1,2) \left[\frac{C(1,2)}{DW_{FD2}}\right]$$

$$B(2,2) = \frac{\left(\partial\Gamma_{\tau_{FP1}} / \partial\phi_{FP1}\right)\phi_{FP1}}{\Gamma_{\tau_{FP1}}}$$

$$C(2,2) = \frac{\left(\partial\Gamma_{\tau_{FT1}} / \partial\eta_{FT1}\right)\eta_{FT1}}{\Gamma_{\tau_{FT1}}}$$

$$A(2,2) = S - \frac{B14}{S_{F1}} \left\{\tau_{FP1} \left[-2 + B(2,2)\right] + \tau_{FT1}\, C(2,2)\right\}$$

$$A(2,3) = B14 \left[\frac{B(2,2)}{DW_{FD2}}\right] \tau_{FP1}$$

$$B(2,19) = B14\ \tau_{FT1} \frac{\left\{\partial\Gamma_{\tau_{FT1}} / \partial\left[\left(P_{FI}/P(5)\right)^{FT1S}\right]\right\}}{\Gamma_{\tau_{FT1}}} FT1S \left[\frac{P_{FI}}{P(5)}\right]^{FT1S}$$

$$A(2,19) = -\left[\frac{B(2,19)}{P_{FI}}\right]$$

$$A(2,24) = \frac{1}{P(5)} \left[B(2,19) - B14\,\tau_{FT1}\right]$$

$$A(2,27) = B14\ (\tau_{FT1}) \left[\frac{C(2,2)}{2\cdot T(5)}\right]$$

$$A(3,1) = -B21$$

$$B(3,3) = \frac{\left(\partial\Gamma_{P_{FP2}} \big/ \partial\phi_{FP2}\right)\phi_{FP2}}{\Gamma_{P_{FP2}}}$$

$$A(3,3) = S - B21\ (P_{FD2} - P_{FD1}) \left[\frac{B(3,3)}{DW_{FD2}}\right] + 2 \left[\frac{(B21)(B22)\ DW_{FD2}}{(A/\bar{A})^2_{MFV}}\right]$$

$$A(3,4) = -B21 \left[\frac{P_{FD2} - P_{FD1}}{S_{F2}}\right] \left[2 - B(3,3)\right]$$

$$A(3,38) = B21$$

$$B(4,3) = \frac{\left(\partial\Gamma_{\tau_{FP2}} \big/ \partial\phi_{FP2}\right)\left(\phi_{FP2}\right)}{\Gamma_{\tau_{FP2}}}$$

$$A(4,3) = B23\ \frac{(\tau_{FP2})\ B(4,3)}{DW_{FD2}}$$

$$B(4,4) = \frac{\partial\Gamma_{\tau_{FT2}} \big/ \partial\eta_{FT2}}{\Gamma_{\tau_{FT2}}}$$

$$A(4,4) = S + B23 \left[\frac{(\tau_{FP2})\left(2 - B(4,3)\right)}{S_{F2}} - (\tau_{FT2})\ B(4,4)(B25)\right]$$

$$B(4,15) = \left\{\frac{\partial\Gamma_{\tau_{FT2}} \big/ \partial\left[(P_{FI}/P_{FP})^{FT2S}\right]}{\Gamma_{\tau_{FT2}}}\right\} (FT2S) \left(\frac{P_{FI}}{P_{FP}}\right)^{FT2S}$$

TABLE 3. (Continued)

$$A(4,15) = -\frac{B23\ (\tau_{FT2})}{P_{FP}}\ [1 - B(4,15)]$$

$$A(4,19) = -B23 \left[\frac{\tau_{FT2}}{P_{FI}}\right] B(4,15)$$

$$A(5,5) = 1$$

$$B(5,6) = \frac{\left(\partial\Gamma_{P_{OP1}} \big/ \partial\phi_{OP1}\right)\ \phi_{OP1}}{\Gamma_{P_{OP1}}}$$

$$A(5,6) = -\frac{(P_{OD1} - P_{OS})}{S_{O1}}\ [2 - B(5,6)]$$

$$A(5,42) = -\frac{(P_{OD1} - P_{OS})\ B(5,6)}{DW_{MOV} + DW_{OP3}}$$

$$A(5,7) = -A(5,42)$$

$$B(6,6) = \frac{\left(\partial\Gamma_{\tau_{OT1}} \big/ \partial\phi_{OT1}\right)\ \phi_{OT1}}{\Gamma_{\tau_{OT1}}}$$

$$C(6,6) = \frac{\left(\partial\Gamma_{\tau_{OP1}} \big/ \partial\phi_{OP1}\right)\ \phi_{OP1}}{\Gamma_{\tau_{OP1}}}$$

TABLE 3. (Continued)

$$A(6,6) = S - \frac{B35}{S_{01}} \left[(\tau_{OT1})\ B(6,6) - (2)(\tau_{OP1}) + (\tau_{OP1})\ C(6,6)\right]$$

$$A(6,7) = - \frac{B35}{DW_{OT1}} \ (\tau_{OT1})\ [2 - B(6,6)]\ -A(6,42)$$

$$A(6,10) = B35\ (\tau_{OP1})\ \ C(6,6) \Big/ \left[DW_{MOV} + DW_{OP3} + DW_{OTPR}\right]$$

$$A(7,5) = \frac{DW_{OT1}}{2(P_{OD2} - P_{OD1})}$$

$$B(7,6) = \frac{\left(DW_{OT1}\right) \left(\partial\Gamma_{R_{OT1}} \Big/ \partial\phi_{OT1}\right) \phi_{OT1}}{2\left(B37 + R_{OT1}\right)}$$

$$A(7,6) = \frac{B(7,6)}{S_{01}}$$

$$A(7,7) = 1 - \frac{B(7,6)}{DW_{OT1}}$$

$$A(7,8) = -A(7,5)$$

$$A(8,43) = -1$$

$$B(8,7) = \frac{\left(\partial\Gamma_{P_{OP2}} \Big/ \partial\phi_{OP2}\right)}{\Gamma_{P_{OP2}}}$$

TABLE 3. (Continued)

$$A(8,7) = -\frac{B(8,7)(\phi_{OP2})(P_{OD2}-P_{OD1})}{DW_{MOV} + DW_{OT1} + DW_{OP3} + DW_{OTPR}}$$

$$A(8,8) = 1 + A(8,10)(B106)$$

$$A(8,9) = \frac{(P_{OD1}-P_{OD2})\left[2-B(8,7)(\phi_{OP2})\right]}{S_{02}}$$

$$A(8,10) = A(8,21) = A(8,7)$$

$$B(9,7) = \frac{\left(\partial\Gamma_{\tau_{OP2}}/\partial\phi_{OP2}\right)\left(\phi_{OP2}\right)}{\Gamma_{\tau_{OP2}}}$$

$$C(9,7) = \frac{\tau_{OP2}}{DW_{MOV} + DW_{OT1} + DW_{OP3} + DW_{OTPR}}$$

$$A(9,7) = +B(9,7)\ [C(9,7)]\ (B42)$$

$$B(9,9) = \frac{\left(\partial\Gamma_{\tau_{OP3}}/\partial\phi_{OP3}\right)\ \phi_{OP3}}{\Gamma_{\tau_{OP3}}}$$

$$C(9,9) = \frac{\left(\partial\Gamma_{\tau_{OT2}}/\partial\eta_{OT2}\right)\ \eta_{OT2}}{\Gamma_{\tau_{OT2}}}$$

$$A(9,9) = S - \frac{B42}{S_{02}}\left\{(\tau_{OT2})\ C(9,9)-\tau_{OP2}\left[2-B(9,7)\right]-\tau_{OP3}\left[2-B(9,9)\right]\right\}$$

$$A(9,10) = A(9,7) + \frac{(\tau_{OP3})\ B(9,9)(B42)}{DW_{OP3}}$$

$$A(9,18) = -\frac{\tau_{OT2}}{P_{OP}}\ \frac{\left\{\Gamma_{\tau_{OT2}} - \left[\partial\Gamma_{\tau_{OT2}} \Big/ \partial\left((P_{FI}/P_{OP})^{EOT2S}\right)\right](EOT2S\left(\frac{P_{FI}}{P_{OP}}\right)^{EOT2S}\right\}}{\Gamma_{\tau OT2}}\ B42$$

$$A(9,19) = -\frac{B42\ \Gamma_{OT2}}{\Gamma_{OT2}\ P_{FI}}\ \left\{\frac{\partial\Gamma}{2PR}\left(\frac{P_{FI}}{P_{OP}}\right)^{EOT2S}\ EOT2S\right\}$$

$$A(9,21) = A(9,7)$$

$$A(10,8) = -B46$$

$$B(10,9) = \frac{\left(\partial\Gamma_{P_{OP3}} \Big/ \partial\phi_{OP3}\right)\ \phi_{OP3}}{\Gamma_{P_{OP3}}}$$

$$A(10,9) = -B46\left[\frac{(P_{OD3}-P_{OD2})}{S_{02}}\right][2-B(10,9)]$$

$$A(10,10) = S + B46\left[2(B104)(DW_{OP3}) - \frac{(P_{OD3}-P_{OD2})B(10,9)}{DW_{OP3}}\right]$$

$$A(10,12) = B46$$

$$A(11,11) = 1$$

$$B(11,16) = \frac{DW_{OT2}}{2T_{OP}}\left[(\partial\Gamma_T/\partial F_{OP})(F_{OP})(1-F_{OP})\right]$$

$$A(11,16) = -\frac{B(11,16)}{DW_{OPF}}$$

$$A(11,17) = \frac{B(11,16)}{DW_{OPO}}$$

TABLE 3. (Continued)

$$B(11,18) = \frac{\partial \Gamma_{PR}/\partial \left[(P_{FI}/P_{OP})^{1/2}\right]}{2\Gamma_{PR}\left[(P_{FI}/P_{OP})^{1/2}\right]} \left(\frac{P_{FI}}{P_{OP}}\right)^{1/2}$$

$$A(11,18) = \frac{DW_{OT2}}{P_{OP}} \; [B(11,18) - 1]$$

$$A(11,19) = -\frac{DW_{OT2}}{P_{FI}} \; [B(11,18)]$$

$$A(11,40) = \frac{B113 \; (DW_{OT2})}{2(T_{OP})}$$

$$A(12,10) = -B49$$

$$A(12,12) = S$$

$$A(12,14) = B49$$

$$A(12,17) = B49$$

$$B(13,13) = \frac{(B50)(B51)DW_{FPF}^{\;2}}{\rho(9)}$$

$$A(13,13) = S + B(13,13) \big/ DW_{FPF}$$

$$A(13,15) = B50$$

$$A(13,37) = -B50$$

$$A(13,41) = -B(13,13) \big/ \rho(9)$$

$$A(14,12) = -B52$$

TABLE 3. (Continued)

$$B(14,14) = 2(B53)\left[\frac{DW_{FPO}}{(A/\bar{A})_{FPV}}\right]^2$$

$$A(14,14) = S + B52\left[\frac{B(14,14)}{DW_{FPO}} + 2(B54)(DW_{FPO})\right]$$

$$A(14,15) = B52$$

$$B(15,13) = \frac{DW_{FT2}\ (\partial\Gamma_T/\partial F_{FP})[F_{FP}(1-F_{FP})]}{2(T_{FP})}$$

$$A(15,13) = -B56\left[1 - \frac{(B111)B(15,13)}{DW_{FPF}}\right]$$

$$A(15,14) = -B56\left[1 + \frac{(B111)B(15,13)}{DW_{FPO}}\right]$$

$$B(15,15) = \frac{DW_{FT2}\left[\partial\Gamma_{PR}/\partial(P_{FI}/P_{FP})^{1/2}\right]}{2\Gamma_{PR}\left[(P_{FI}/P_{FP})^{1/2}\right]}\left(\frac{P_{FI}}{P_{FP}}\right)^{1/2}$$

$$A(15,15) = S + \frac{(B56)(B111)}{P_{FP}}[DW_{FT2}-B(15,15)]$$

$$A(15,19) = \frac{(B56)(B111)B(15,15)}{P_{FI}}$$

$$A(15,40) = -(B56)(B111)(B112)\left[\frac{DW_{FT2}}{2T_{FP}}\right]$$

$$B(16,16) = \frac{(B57)(B58)(DW_{OPF})}{\rho(9)}$$

$$A(16,16) = S + (2)\ B(16,16)$$

$A(16,18) = B57$

$A(16,37) = -B57$

$A(16,41) = -B(16,16)\ (DW_{OPF}) \Big/ \rho(9)$

$A(17,12) = -B59$

$$B(17,17) = 2(B61) \left[\frac{DW_{OPO}}{(A/\bar{A}_{OPV})} \right]^2$$

$$A(17,17) = S + (B59) \left[2(B60)(DW_{OPO}) + \frac{B(17,17)}{DW_{OPO}} \right]$$

$A(17,18) = B59$

$A(18,11) = (B63)(B107)$

$A(18,16) = -B63$

$A(18,17) = -B63$

$A(18,18) = S$

$A(19,11) = -B64$

$$A(19,13) = -\ \frac{(B64)\ B(15,13)}{DW_{FPF}}$$

$$A(19,14) = (B64) \left[\frac{B(15,13)}{DW_{FPO}} \right]$$

$$A(19,15) = -\ \frac{B64}{P_{FP}}\ [DW_{FT2} - B(15,15)]$$

TABLE 3. (Continued)

$$B(19,19) = \frac{DW_{FT1}}{2(P(5)-P_{FI})}$$

$$A(19,19) = S + B64 \left[B(19,19) - \frac{B(15,15)}{P_{FI}}\right]$$

$$A(19,20) = (B64)(B108)$$

$$A(19,24) = -(B64)\ B(19,19)$$

$$A(19,26) = -\frac{(B64)(DW_{FT1})}{(2)\rho(5)}$$

$$A(19,40) = \frac{(B64)(B112)(DW_{FT2})}{(2)T_{FP}}$$

$$B(20,13) = \left[\frac{DW_{FI}}{2T_{FI}}\right] (\partial\Gamma_T/\partial F_{FP})(F_{FP})(1-F_{FP})$$

$$A(20,13) = -\frac{(B66)\ B(20,13)}{DW_{FPF}}$$

$$A(20,14) = \frac{(B66)\ B(20,13)}{DW_{FPO}}$$

$$B(20,16) = \left[\frac{DW_{FI}}{2T_{FI}}\right] (\partial\Gamma_T/\partial F_{OP})(F_{OP})(1-F_{OP})$$

$$A(20,16) = -\frac{(B67)\ B(20,16)}{DW_{OPF}}$$

$$A(20,17) = \frac{(B67)\ B(20,16)}{DW_{OPO}}$$

$$B(20,19) = \frac{DW_{FI}\ [\partial\Gamma_{PR}/\partial(P_c/P_{FI})]P_c}{\Gamma_{PR}(P_c/P_{FI})}$$

$$A(20,19) = -\frac{DW_{FI} - B(20,19)}{P_{FI}}$$

$$A(20,20) = 1$$

$$A(20,22) = -\frac{B(20,19)}{P_c}$$

$$A(20,27) = \frac{(B68)(DW_{FI})}{2T_{FI}}$$

$$A(20,40) = DW_{FI}\ [B66\ (B112) + B67\ (B113)]/2\ T_{FI}$$

$$A(21,8) = -B69$$

$$B(21,21) = 2(B70)\left[\frac{DW_{MOV}}{(A/\bar{A})_{MOV}}\right]^2$$

$$A(21,21) = S + B69\left[\frac{B(21,21)}{DW_{MOV}} + 2\ (B71)(DW_{MOV})\right]$$

$$A(21,22) = B69$$

$$A(22,20) = -B72\ (B109)$$

$$A(22,21) = -B72$$

$$A(22,22) = S + B72\left[\frac{DW_{CN}}{P_c}\right]$$

$$B(22,23) = \frac{210500-347000(F_{TC})}{c^*}$$

$$A(22,23) = -B72\ (DW_{CN})\ B(22,\ 23)$$

$$B(23,10) = \frac{1}{DW_{MOV}+DW_{FI}}$$

TABLE 3. (Continued)

$$A(23,10) = -B(23,10)$$

$$A(23,20) = B(23,10)\ F_{TC}$$

$$A(23,21) = -B(23,10)\ (1 - F_{TC})$$

$$A(23,23) = 1$$

$$A(24,3) = -\frac{B74\ (DW_{MC})\ H(3)\ [B(4,3)]}{DW_{FD2}}$$

$$A(24,4) = -\frac{B74(DW_{MC})\ H(3)\ [3-B(4,3)]}{S_{F2}}$$

$$A(24,19) = -(B74)\ H(5)\ [B(19,19)]$$

$$A(24,24) = S - A(24,19)$$

$$B(24,25) = \left[\frac{0.8}{DW_{MC}}\right] [DQ_{W1}(5) + DQ_{W2}(5)]$$

$$A(24,25) = -B74\ [H(3) + B(24,25)]$$

$$A(24,26) = (B74)\ H(5) \left[\frac{DW_{FT1}}{(2)\rho(5)}\right]$$

$$B(24,27) = \frac{0.002}{1.0 + (0.002)\ T(5)}$$

$$C(24,27) = \frac{1}{T_{W1}(5)-T(5)}$$

$$D(24,27) = B\ (80)\ [1 + 0.002T(5)]\ [DW_{MC}]^{0.8}$$

TABLE 3. (Continued)

$$A(24,27) = -B74\left\{ DQ_{W1}(5)[B\ (24,27)-C(24,27)]+DQ_{W2}(5)[B(24,27)-B101DW_{FT1}-D(24,27)]\right\}$$

$$A(24,28) = -B74\ [DQ_{W1}(5)][C(24,27)]$$

$$A(24,29) = -B74\ [D(24,27)]$$

$$A(25,24) = B75\ [D(24,27)]$$

$$B(25,25) = B75(B76)\left[\frac{DW_{MC}}{\rho(5)}\right]$$

$$A(25,25) = S + [B(25,25)]\ 2$$

$$A(25,26) = -B75\ (B76)\left(\frac{DW_{MC}}{\rho(5)}\right)^2$$

$$A(25,38) = -B75$$

$$B(26,19) = B77\ [B(19,19)]$$

$$A(26,19) = -B(26,19)$$

$$A(26,24) = B(26,19)$$

$$A(26,25) = -B77$$

$$A(26,26) = S + \frac{B77\ (DW_{FT1})}{(2)\rho(5)}$$

$$A(27,24) = [T(5)]/P(5)$$

$$A(27,26) = [T(5)]/\rho(5)$$

TABLE 3. (Continued)

$A(27,27) = 1$

$B(28,22) = B82\ [DQ_{TC}(5)]$

$A(28,22) = -0.8\ \frac{[B(28,22)]}{P_c}$

$B(28,23) = \frac{1}{T_C - T_{W1}(5)}$

$A(28,23) = B82\ [DQ_{TC}(5)][(0.8)B(22,23) - \partial\Gamma_T/\partial F_{TC}(B28,23)]$

$B(28,25) = (B82)\ DQ_{W1}(5)$

$A(28,25) = \frac{(0.8)\ B(28,25)}{DW_{MC}}$

$A(28,27) = B(28,25)\ [B(24,27) - C(24,27)]$

$A(28,28) = S + B(28,22)\ B(28,23) + B(28,25)\ C(24,27)$

$A(29,27) = -(B83)(D(24,27))$

$A(29,29) = S + B83\ [D(24,27)]$

$B(30,3) = B84\ [H(3)]$

$C(30,3) = B(30,3)(DW_{FN})$

TABLE 3. (Continued)

$$A(30,3) = -C(30,3)B(4,3)/DW_{FP2}$$

$$A(30,4) = \frac{-C(30,3)}{S_{F2}} [3 - B(4,3)]$$

$$A(30,30) = S$$

$$B(30,31) = B84 \; [DQ_{W1}(4)]$$

$$C(30,31) = B84 \; [DQ_{W2}(4)]$$

$$A(30,31) = -B(30,3) - \frac{0.8}{DW_{FN}} \; [B(30,31) + C(30,31)]$$

$$B(30,33) = \frac{0.002}{1.0 + (0.002)\; T(4)}$$

$$C(30,33) = \frac{1}{T_{W1}(4) - T(4)}$$

$$D(30,33) = B90(1 + 0.002\; T(4))\; DW_{FN}^{0.8}$$

$$A(30,33) = -B(30,31)[B(30,33)-C(30,33)]-C(30,31)[B(30,33)]-B84(D(30,33)+B102 \cdot DW(4))$$

$$A(30,34) = -B(30,31)\; [C(30,33)]$$

$$A(30,35) = -B84\; [D(30,33)]$$

$$A(30,36) = B84\; (B102)\; [T(4)]$$

$$A(31,30) = B85$$

$$A(31,31) = S + 2(B85)(B86)(DW_{FN})$$

$A(31,38) = -B85$

$A(32,31) = -B87$

$A(32,32) = S$

$A(32,36) = B87$

$A(33,30) = -\frac{T(4)}{P(4)}$

$A(33,32) = \frac{T(4)}{\rho(4)}$

$A(33,33) = S$

$B(34,22) = B92\ [DQ_{TC}(4)]$

$A(34,22) = -\frac{(0.8)\ B(34,22)}{P_c}$

$B(34,23) = \frac{1}{T_C - T_{W1}(4)}$

$A(34,23) = -B(34,22)\ [B(34,23)(\partial\Gamma_T/\partial F_{TC}) - (0.8)\ B(22,23)]$

$B(34,31) = B92\ [DQ_{W1}(4)]$

$A(34,31) = \frac{(0.8)\ B(34,31)}{DW_{FN}}$

$A(34,33) = B(34,31)\ [B(30,33) - C(30,33)]$

$A(34,34) = S + B(34,22)\ B(34,23) + B(34,31)\ C(30,33)$

$A(35,33) = -B93\ [D(30,33)]$

$A(35,35) = S + D(30,33)\ B93$

$A(36,30) = -B94$

$$B(36,32) = \frac{(B95)[DW(4)]^2}{\rho(4)}$$

$$A(36,32) = -\frac{B(36,32)}{\rho(4)}\ (B94)$$

$$A(36,36) = S + \frac{(2)(B94)\ B(36,32)}{DW(4)}$$

$A(36,37) = B94$

$A(37,13) = A(37,16) = B96$

$A(37,36) = -B96$

$A(37,37) = S$

$A(37,39) = -B96$

$A(38,3) = -B97(B110)$

$A(38,25) = A(38,31) = A(38,39) = B97$

$A(38,38) = S$

$A(39,37) = B98$

$A(39,38) = -B98$

$$B(39,39) = 2\ (B98)(B99)\left[\frac{DW_{FNBP}}{(A/\overline{A}_{CCV})}\right]^2$$

TABLE 3. (Continued)

$$A(39,39) = S + B(39,39)/DW_{FNBP}$$

$$A(40,41) = \frac{T(9)}{\rho(9)}$$

$$A(40,37) = -\frac{T(9)}{P(9)}$$

$$A(40,40) = 1$$

$$B(41,32) = \frac{\rho(9)}{DW(4) + (B105)[\rho(4)](DW_{FNBP})}$$

$$A(41,32) = -\frac{B(41,32)\ [DW(4)]}{\rho(4)}$$

$$B(41,36) = \frac{\rho(9)}{DW_{FNBP} + DW(4)}$$

$$A(41,36) = -B(41,36) + B(41,32)$$

$$A(41,39) = -B(41,36) + (B105)\ B(41,32)\ \rho(4)$$

$$A(41,41) = 1$$

$$A(42,42) = S$$

$$A(42,5) = -B(115)$$

$$A(42,45) = B(115)$$

$$A(43,43) = S$$

$$A(43,42) = -B116$$

$$A(43,7) = B116$$

TABLE 3. (Concluded)

$$A(43,10) = B116$$

$$A(43,21) = B116$$

$$A(43,8) = (B106)(B116)$$

$$R(1,1) = 1$$

$$R(5,2) = 1$$

$$R(3,3) = \frac{(2)(B21)(B22)DW_{FD2}{}^{2}[\partial\Gamma_{MFV}/\partial(X/\bar{X}_{MFV})]}{(A/\bar{A})_{MFV}{}^{3}}$$

$$R(14,5) = B52\ [B(14,14)]\ [\partial\Gamma_{FPV}/\partial(X/\bar{X})_{FPV}]/\left(\frac{A}{\bar{A}}\right)_{FPV}$$

$$R(17,6) = \frac{2(B59)\ B(17,17)\ [\partial\Gamma_{OPV}/\partial(X/\bar{X}_{OPV})]}{(A/\bar{A}_{OPV})}$$

$$R(21,4) = \frac{(B69)\ B(21,21)\ [\partial\Gamma_{MOV}/\partial(X/\bar{X}_{MOV})]}{(A/\bar{A}_{MOV})}$$

$$R(39,7) = \frac{B(39,39)\ [\partial\Gamma_{CCV}/\partial(X/\bar{X}_{CCV})]}{(A/\bar{A}_{CCV})}$$

ENGINE CONTROLLER MODEL

The engine is controlled and throttled in response to vehicle commands by a controller which includes a digital computer. Three valves are directly driven (open loop) in response to the vehicle input. Two additional valves contain feedback signals from the engine flowrates and thrust chamber pressure and provide a vernier adjustment on thrust level as well as control of engine mixture ratio.

A schematic of the engine closed loop control logic (from Ref. 3) is shown in Fig. 24 along with linear block diagram. Table 4 lists the coefficients required in the linear block diagram as a function of thrust level.

Nominal resistance for the scheduled valves as well as the closed loop control valves is contained in the tables of engine balance information. The resistance (R) is defined in the following equation:

$$R = \frac{\rho \Delta P}{w^2}$$

In the engine balance information the units of R are sec^2-$in.^{-2}$-ft^{-3}. In the dynamic model the units of R are sec^2-$in.^{-5}$. The valve resistances as obtained from the engine balances are listed in Table 5 .

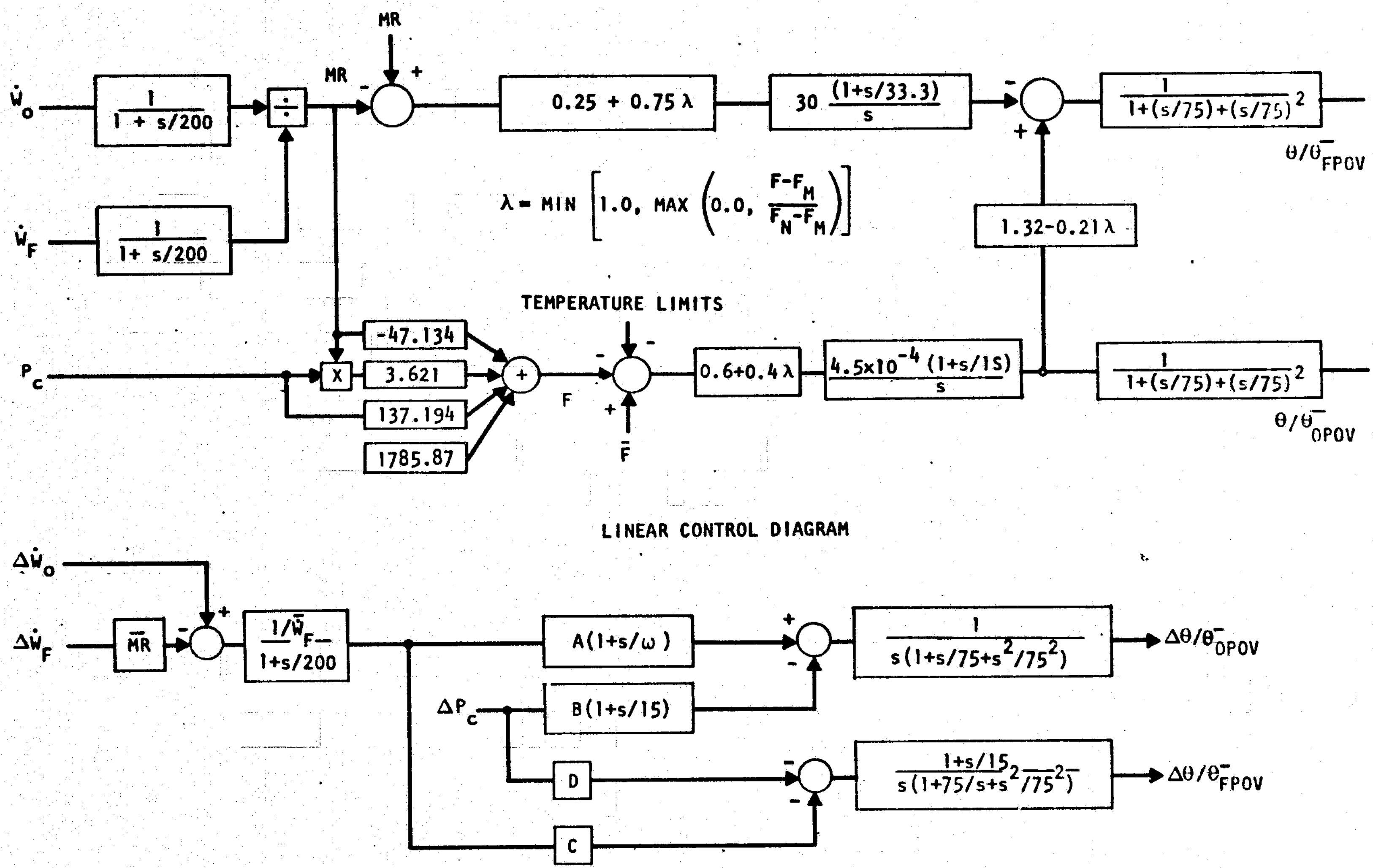


Figure 24. SSME Mainstage Control (Preburner Oxidizer Valve)

TABLE 4. LINEAR CONTROL SYSTEM COEFFICIENTS

Power Level, λ	ω	A	B	C	D
$\geq$1.0	28.15	35.35	0.07938	4.819	0.07152
0.9	27.92	32.98	0.07765	4.164	0.06865
0.8	27.69	30.61	0.07579	3.547	0.06579
0.7	27.43	28.22	0.07382	2.968	0.06293
0.6	27.13	25.83	0.07173	2.429	0.06007
0.5	26.79	23.43	0.06951	1.928	0.05721

TABLE 5. CONTROL VALVE RESISTANCES(1) AS A FUNCTION OF THRUST LEVEL

Thrust Level, percent	R_{FPOV}	R_{OPOV}	R_{MOV}	R_{MFV}	R_{CCV}
109 (EPL)	14.26	171.97	0.00471	0.00469	0.03570
100 (EPL)	26.82	258.59	0.00472	0.00469	0.03570
75	87.99	652.00	0.06117	0.06950	0.55000
60	164.46	1126.30	0.20000	0.24600	2.23000
50	266.90	1621.50	0.40006	0.50000	5.00000

(1)Units of resistance valves are sec^2 $in.^{-2}$ ft^{-3}

FREQUENCY DOMAIN SOLUTIONS OF LINEAR MODEL

Initial results from the frequency response routine are contained in this section (Table 6). The first sheet of output contains operating point and function slope information which has been read into the program. On the second sheet the BXX values (as described in the nonlinear model section of this report) are shown. Input number 2 denotes that P_{OS} (low pressure oxidizer pump inlet pressure) was chosen as an input for this case.

The column identification vector coding is as follows: the numeral one indicates a zero derivative column for the first variable (P_{FD1}) while the (+) indicates that a complete response for that variable will be computed. The zero in the second column indicates that column represents the first derivative (d/dt S_{F1}) of the third column. Column three represents S_{F1}, but its frequency response will not be computed due to use of (-). The identification vector continues with a ±1 representing each variable indicated in the matrix of linear equations and zeros used where derivatives are required. The last entry in the vector is the input column and is always -1.

Following the identification vector is the complete matrix of coefficients for the system of linear differential equations.

After solution of the system at the lowest frequency specified by input data (0.1 Hz for this case) the value of all dependent variables is listed. Variables are numbered as listed in Fig. 23. Magnitudes are normalized to a unit value of the input variable. For the representative case, variable 42 (DW_{OS1}) indicates that at 0.1 Hz a 1-psi oscillation in P_{OS} results in 0.0844-lb/sec oscillation in flowrate with a phase of 359.74 degrees (-0.26 degree) with respect to the input.

Following the lowest-frequency solution is tabulated response information for all required parameters expressed as decibels and degrees-of-phase shift.

A plotting routine is included with the frequency-response program and samples of this output will be included when the system solution is completely checked out.

TABLE 6. INITIAL SOLUTION FOR 109-PERCENT POWER LEVEL

```
THE NUMBER OF THE INPUT VARIABLE IS:  2
STEADY-STATE VALUES FOR ENGINE PARAMETERS

A/A(CCV)=  1.000E+00 A/A(FPV)=  3.307E-01 A/A(MFV)=  1.000E+00 A/A(MOV)=  1.000E+00 A/A(OPV)=  3.680E-01
C*      =  8.816E+04 DQ(TC4) =  7.223E+04 DQ(TC5) =  4.935E+04 DQ(W14) =  7.223E+04 DQ(W15) =  4.935E+04
DQ(W24) =  0.0       DQ(W25) =  0.0       DW(4)   =  4.189E+01 DW(5)   =  3.524E+01 DW(CN)  =  1.120E+03
DW(FI)  =  2.627E+02 DW(FN)  =  4.189E+01 DW(MC)  =  3.524E+01 DW(CI)  =  8.543E+02 DW(CS)  =  9.615E+02
DW(CCV) =  8.019E+01 DW(FD2) =  1.602E+02 DW(FPF) =  8.315E+01 DW(FPO) =  7.930E+01 DW(FT1) =  3.524E+01
DW(FT2) =  1.624E+02 DW(MOV) =  8.543E+02 DW(OPF) =  3.893E+01 DW(CPO) =  2.613E+01 DW(OP3) =  1.054E+02
DW(OT1) =  1.740E+02 DW(OT2) =  6.339E+01 DW(FNBP)=  8.019E+01 DW(FPOI)=  7.930E+01 DW(OPOI)=  2.613E+01
DW(OTPR)=  1.300E+00 E(FPO)  =  1.000E+00 E(OPC)  =  1.000E+00 E(OT2S) =  9.458E-01 F(TC)   =  8.592E-01
FT1S    =  5.698E-01 FT2S    =  9.559E-01 G(F1)   =  1.162E+00 GF2     =  3.176E+00 G(O1)   =  2.662E+00
G(O2)   =  1.092E+00 H(3)    =  4.423E+02 H(4)    =  2.167E+03 H(4)    =  1.843E+03 P(4)    =  6.794E+03
P(5)    =  5.143E+03 P(9)    =  6.650E+03 P(C)    =  3.330E+03 P(CIES) =  3.233E+03 P(FI)   =  3.662E+03
P(FP)   =  5.940E+03 P(FS)   =  3.000E+01 P(OI)   =  4.293E+03 P(CP)   =  5.929E+03 P(CS)   =  1.000E+02
P(OT)   =  1.180E+02 P(FD1)  =  2.520E+02 P(FD2)  =  7.068E+03 P(OD1)  =  4.441E+02 P(OD2)  =  5.170E+03
P(OD3)  =  8.484E+03 P(POS)  =  8.457E+03 P(FPCI) =  7.210E+03 P(MFVO) =  6.939E+03 P(OPOI) =  6.976E+03
R(FP)   =  4.633E+03 R(OP)   =  5.084E+03 S(F1)   =  1.638E+03 S(F2)   =  3.922E+03 S(O1)   =  5.709E+02
S(O2)   =  3.262E+03 T(4)    =  6.793E+02 T(5)    =  5.445E+02 T(9)    =  3.038E+02 T(C)    =  6.221E+03
T(FI)   =  1.535E+03 T(FP)   =  1.391E+03 T(OP)   =  1.544E+03 TW1(4)  =  1.260E+03 TW1(5)  =  1.330E+03
TW2(4)  =  6.793E+02 TW2(5)  =  5.445E+02 W(OI)   =  4.400E+01 W(FPOI) =  2.640E+00 W(OPOI) =  1.500E+00
ETA(FT1)=  1.660E+02 ETA(FT2)=  4.150E+02 ETA(OT2)=  3.775E+02 RHO(4)  =  1.475E-03 RHO(5)  =  1.402E-03
RHO(9)  =  1.715E-03 UP(FP1) =  1.153E+04 UP(FP2) =  1.296E+05 UP(FT1) =  1.153E+04 UP(FT2) =  1.296E+05
UP(OP1) =  2.015E+04 UP(OP2) =  5.238E+04 UP(OP3) =  4.045E+03 UP(OT1) =  2.015E+04 UP(OT2) =  5.643E+04
PHI(FP1)=  1.000E+00 PHI(FP2)=  1.000E+00 PHI(OP1)=  1.000E+00 PHI(OP2)=  1.000E+00 PHI(OP3)=  1.000E+00
PHI(OT1)=  4.400E-01 GM(EOI) =  1.000E+00 GM(PFP1)=  1.000E+00 GM(TFP1)=  1.000E+00 GM(TFT1)=  1.533E-02
GM(PFP2)=  1.000E+00 GM(TFP2)=  1.000E+00 GM(TFT2)=  1.936E-02 GM(POP1)=  1.000E+00 GM(TOP1)=  1.000E+00
GM(TOT1)=  7.050E-01 GM(POT1)=  1.625E-01 GM(POP2)=  1.000E+00 GM(TOP2)=  1.000E+00 GM(TOP3)=  1.000E+00
GM(POP3)=  1.000E+00 GM(TOT2)=  2.502E-02 GM(FPV) =  1.534E-01 GM(OPV) =  4.340E-01 GM(MOV) =  1.000E+00
GM(MFV) =  1.000E+00 GM(CCV) =  1.000E+00
PARTIAL DERIVATIVES
GM(PFP1)/PHI(FP1)   = -1.000E+00 GM(TFP1)/PHI(FP1)    =  1.000E-01 GM(TFT1)/ETA(FT1)   = -6.000E-05
GM(TFT1)/P(FI)/P(5) = -1.500E-01 GM(PFP2)/PHI(FP2)    = -5.000E-01 GM(TFP2)/PHI(FP2)   =  4.000E-01
GM(TFT2)/ETA(FT2)   = -3.000E-01 GM(TFT2)/P(FI)/P(FP)= -5.000E-05 GM(POP1)/PHI(OP1)   = -1.000E+00
GM(TOT1)/PHI(OT1)   = -1.200E+00 GM(TOP1)/PHI(OP1)    =  0.0       GM(POT1)/PHI(OT1)   =  1.000E+00
GM(POP2)/PHI(OP2)   = -1.000E+00 GM(TOP2)/PHI(OP2)    =  3.000E-01 GM(TOP3)/PHI(OP3)   =  3.000E-01
GM(TOT2)/ETA(OT2)   = -5.000E-05 GM(TOT2)/P(FI)/P(OP)= -1.000E-01 GM(POP3)/PHI(OP3)   = -5.000E-01
GM(T)/F(OP1         =  4.000E+03 GM(PR)/P(FI)/P(OP)   =  0.0       GM(T)/F(OP)         =  4.200E+03
GM(P)/P(FI)/P(FP)   =  0.0       GM(PP)/P(C)/P(FI)    =  0.0       GM(TR)/F(TC)        =  7.000E+03
GM(MFV)/X/X(MFV)    =  2.000E+01 GM(FPV)/X/X(FPV)     =  2.000E+01 GM(OPV)/X/X(OPV)    =  2.000E+00
GM(MOV)/X/X(MOV)    =  2.000E+01 GM(CCV)/X/X(CCV)     =  5.000E+00
DW(OS1) =  1.135E+03 P(OS1)  =  4.441E+02
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TABLE 6. (Continued)

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VECTOR OF COEFFICIENTS CORRESPONDING TO THE ABOVE STEADY-STATE VALUES,B11 THROUGH B116.
 1.0225E+01 1.3553E-01 4.2974E-03 8.6059E-01 2.3648E+00 1.4653E+02 5.9809E+02 2.4482E+01 4.4311E-04 8.4254E-03
 2.5000E+03 5.0265E-03 3.1486E-01 5.6132E+00 1.0581E-01 3.9764E+10 5.9485E-01 1.0558E-03 1.3371E+10 4.3000E+01
 1.0000E+00 1.8721E-02 1.5000E+02 6.1824E-02 3.7566E-01 2.1455E+00-6.4062E-03 1.3410E-01 2.8772E+00 4.4414E-04
 4.9226E-03 9.1575E-01 3.0940E+01 3.8015E-04 3.1145E-04 1.0000E+02 1.1573E-01 9.1222E-02 3.8120E+04 6.6675E+01
 1.7612E-04 5.0000E+01 2.1686E-02 2.0196E-01 3.7879E-01 1.3780E+03 1.0000E+02 8.1589E-04 1.0000E+01 1.5334E+00
 2.9375E-01 6.6667E-01 3.5000E+04 3.9490E+03 6.5698E-02 5.0550E-01 2.5630E-01 2.4000E-01 5.0000E+01 1.2017E-03
 1.3192E-03 6.8380E+03 2.9642E+04 3.8120E+00 4.8375E+02 2.0276E-03 1.0000E-03 1.4843E-04 1.7401E+00 3.4802E+00
 3.6694E-02 3.1000E-01 8.2500E-02 2.5440E+00 2.1800E+02 8.2632E-02 5.0000E-04 1.4748E-04 2.6572E+00 5.2800E+00
 5.2949E-02 1.6680E-01 8.3400E-02 2.1190E+01 1.2104E-04 8.1600E+04 3.2000E+04 2.0000E+01 4.4942E-02 7.8348E-05
 3.3848E+00 3.1900E+00 8.7017E-07 2.4290E-03 5.3353E+02 2.5145E-04 1.0263E+00 9.9383E-01 1.0104E+00 9.8202E-01
 1.0000E+00 9.9991E-01 9.9846E-01 9.7083E-01 7.6923E+01 1.0000E+03

INPUT COLUMN VECTOR FOR INPUT NUMBER  2
 0.0         0.0         0.0         0.0         1.000E+00   0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0

COLUMN IDENTIFICATION VECTOR
 1 0-1 0-1 0-1 1 0 1 1 1 0 1 0 1-1 0-1 0-1 0-1 0 1 0-1 0-1 0 1 0-1-1 0 1 0 1-1 0
-1 0-1 0-1-1 0-1 0-1 0-1 0-1 0-1-1 0-1 0-1 0-1 0-1 0 1 0-1-1-1 0 1 0 1-1

MATRIX OF COEFFICIENTS
EQUATION   1
 1.000E+00   0.0        -4.366E-01   0.0         1.386E+00   0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
```

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 2									
0.0	1.000E+00	1.545E+01	0.0	6.194E+00	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.247E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1.081E+01	0.0	0.0	0.0	0.0	-5.931E+00	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 3									
-2.500E+03	0.0	0.0	1.000E+00	5.721E+04	0.0	-1.086E+04	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	2.500E+03	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 4									
0.0	0.0	0.0	0.0	1.019E+02	1.000E+00	6.693E+04	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-6.880E+00	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.733E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 5									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E+00	0.0	-1.808E+00
-2.629E-01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	2.629E-01	0.0	0.0					
EQUATION 6									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E+00	3.645E+01
-1.196E+02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 7									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.841E-02	0.0	4.296E-01
-4.094E-01	-1.841E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 8									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.164E+00	1.001E+00	0.0	-4.346E+00	0.0	4.164E+00	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	4.164E+00	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-1.000E+00					
EQUATION 9									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.268E+01	0.0	1.000E+00	3.868E+01	0.0	2.322E+01	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-2.960E+01	0.0	3.382E+01	0.0	0.0	1.268E+01	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 10									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	-1.000E+02	0.0	-2.540E+02	1.000E+00	1.623E+03	0.0	0.0	1.000E+02	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 11									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	1.000E+00	0.0	0.0	0.0

ORIGINAL PAGE IS OF POOR QUALITY

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	-5.069E-01	0.0	7.552E-01	0.0
-1.759E-02	0.0	1.117E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.050E-02
0.0	0.0	0.0	0.0	0.0					

EQUATION 12

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-3.812E+04	0.0	1.000E+00	0.0	0.0
0.0	0.0	3.812E+04	0.0	0.0	0.0	0.0	0.0	3.812E+04	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 13

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E+00
1.139E+03	0.0	0.0	0.0	6.668E+01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-6.668E+01	0.0	0.0	0.0	0.0	0.0
-2.760E+07	0.0	0.0	0.0	0.0					

EQUATION 14

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.000E+01	0.0
0.0	1.000E+00	3.174E+03	0.0	5.000E+01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 15

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-6.685E+02	0.0	-2.122E+03	1.000E+00	6.185E+01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-3.920E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-5.621E+01
0.0	0.0	0.0	0.0	0.0					

EQUATION 16

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.000E+00	3.704E+03	0.0	0.0	0.0
1.000E+02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-1.000E+02	0.0	0.0	0.0	0.0	0.0
-4.204E+07	0.0	0.0	0.0	0.0					

EQUATION 17

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.000E+01	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.000E+00	1.935E+03	0.0
1.000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 18

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	3.592E+04	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-3.500E+04	0.0	-3.500E+04	1.000E+00
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 19

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-3.949E+03	0.0	0.0	0.0
-2.033E+03	0.0	2.132E+03	0.0	-3.874E+01	0.0	0.0	0.0	0.0	0.0
0.0	1.000E+00	1.593E+02	3.925E+03	0.0	0.0	0.0	0.0	0.0	0.0
-4.698E+01	0.0	0.0	0.0	-4.963E+07	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.611E+02
0.0	0.0	0.0	0.0	0.0					

EQUATION 20

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-5.459E-01	0.0	5.724E-01	0.0	0.0	0.0	-5.416E-01	0.0	8.068E-01	0.0
0.0	0.0	-3.930E-01	1.000E+00	0.0	0.0	0.0	3.533E-01	0.0	0.0
0.0	0.0	0.0	0.0	0.0	2.054E-02	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.515E-02

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0					
EQUATION 21									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	-5.000E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	1.000E+00	2.154E+02	0.0	5.000E+01	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 22									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-6.909E+03	0.0	-6.838E+03	1.000E+00	2.299E+03	7.612E+06	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 23									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-8.953E-04	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	7.692E-04	0.0	-1.261E-04	0.0	0.0	1.000E+00	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 24									
0.0	0.0	0.0	0.0	-1.484E+02	0.0	-3.939E+01	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-8.359E+01	0.0	0.0	0.0	0.0	0.0	0.0	1.000E+00
8.359E+01	0.0	-5.957E+03	0.0	8.829E+07	9.931E+02	0.0	-2.395E+02	0.0	-4.790E+02
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 25									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.837E+02	1.000E+00	4.931E+04	0.0	-6.197E+08	0.0	0.0	0.0	0.0	0.0

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-4.837E+02	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 26									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-1.190E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.190E-05	0.0	-1.200E-03	1.000E+00	1.257E+01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 27									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-1.059E-01	0.0	0.0	0.0	3.884E+05	1.000E+00	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 28									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-3.675E+00	-3.406E+04	0.0
0.0	0.0	3.473E+02	0.0	0.0	-4.829E+00	1.000E+00	2.260E+01	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 29									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-1.037E+01	0.0	0.0	1.000E+00	1.037E+01
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 30									
0.0	0.0	0.0	0.0	-1.177E+02	0.0	-3.125E+01	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.000E+00	0.0	0.0	-4.634E+03	0.0	0.0	1.129E+03	0.0	-3.164E+02	0.0
-6.288E+02	0.0	5.513E+03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 31

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	2.180E+02	1.000E+00	1.509E+03	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-2.180E+02	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 32

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	-5.000E-04	1.000E+00	0.0	0.0	0.0	0.0	0.0
0.0	0.0	5.000E-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 33

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	-9.999E-02	0.0	0.0	0.0	4.605E+05	1.000E+00	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 34

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-2.894E+00	-2.658E+04	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	2.301E+02	0.0	0.0	-1.053E+01	1.000E+00	2.318E+01	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					

EQUATION 35

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE 6. (Continued)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	-2.061E+01	0.0	0.0	1.000E+00
2.061E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 36									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	-2.119E+01	0.0	0.0	0.0	-2.069E+06	0.0	0.0	0.0	0.0
0.0	1.000E+00	1.457E+02	0.0	2.119E+01	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 37									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8.160E+04	0.0	0.0	0.0	0.0	0.0	8.160E+04	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-8.160E+04	1.000E+00	0.0	0.0	0.0	0.0	-8.160E+04	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 38									
0.0	0.0	0.0	0.0	-3.142E+04	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	3.200E+04	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	3.200E+04	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.000E+00	0.0	0.0	3.200E+04	0.0
0.0	0.0	0.0	0.0	0.0					
EQUATION 39									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	2.000E+01	0.0	-2.000E+01	1.000E+00	1.442E+02	0.0
0.0	0.0	0.0	0.0	0.0					

TABLE 6. (Continued)

EQUATION 40									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-4.568E-02	0.0	0.0	0.0	0.0	1.000E+00
1.771E+05	0.0	0.0	0.0	0.0					
EQUATION 41									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-4.639E-01	0.0	0.0	0.0	0.0
0.0	0.0	2.286E-06	0.0	0.0	0.0	0.0	0.0	-1.194E-06	0.0
1.000E+00	0.0	0.0	0.0	0.0					
EQUATION 42									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-7.692E+01	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	1.000E+00	0.0	0.0	7.692E+01					
EQUATION 43									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1.000E+03	2.515E-01	0.0	0.0	0.0	1.000E+03	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	1.000E+03	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	-1.000E+03	1.000E+00	0.0					

TABLE 6. (Continued)

VARIABLE MAGNITUDES USING A FREQUENCY OF 6.283187E-01 RPS.

VARIABLE NUMBER	MAGNITUDE	PHASE
1	6.727383E-03	3.494810E+02
2	4.161231E-03	2.164516E+02
3	5.718917E-03	1.783759E+02
4	2.895568E-05	3.588359E+02
5	9.327574E-01	3.599717E+02
6	2.386025E-02	1.806697E+02
7	7.273261E-03	1.816573E+02
8	5.377407E-01	3.597559E+02
9	1.005701E-02	1.867650E+02
10	4.935801E-03	3.596545E+02
11	2.374519E-04	1.762432E+02
12	4.322969E-01	3.593574E+02
13	3.417070E-03	1.781637E+02
14	3.701375E-03	3.596160E+02
15	1.973379E-01	3.590364E+02
16	1.477818E-03	1.787783E+02
17	1.234404E-03	3.594397E+02
18	1.934429E-01	3.592329E+02
19	1.476374E-01	3.598643E+02
20	7.624395E-03	1.779238E+02

TABLE 6. (Continued)

21	8.662844E-02	3.595225E+02
22	1.646162E-01	3.599062E+02
23	2.118244E-05	3.591072E+02
24	1.431544E-01	3.596162E+02
25	7.145805E-04	1.687396E+02
26	5.332581E-08	1.645468E+02
27	3.557504E-02	3.509197E+02
28	7.702231E-02	3.555178E+02
29	3.550988E-02	3.474512E+02
30	1.525686E-01	3.580305E+02
31	2.155631E-03	1.788057E+02
32	1.011164E-07	1.709824E+02
33	6.171294E-02	3.529413E+02
34	9.410328E-02	3.555601E+02
35	6.168429E-02	3.502952E+02
36	2.141571E-03	1.754413E+02
37	1.575053E-01	3.583081E+02
38	1.376471E-01	3.579438E+02
39	2.758109E-03	1.805816E+02
40	1.516938E-02	3.540654E+02
41	4.522501E-08	1.702554E+02
42	8.442771E-02	3.597444E+02
43	9.327551E-01	3.599292E+02

TABLE 6. (Continued)

FREQUENCY			VARIABLE 1			VARIABLE 5			VARIABLE 6			VARIABLE 7			VARIABLE 8	
RPS	CPS		DECIBELS	PHASE		DECIBELS	PHASE		DECIBELS	PHASE		DECIBELS	PHASE		DECIBELS	PHASE
6.28E-01	1.00E-01	/	-43.44	349.48	/	-0.60	359.97	/	-32.45	180.67	/	-42.77	181.66	/	-5.39	359.76
9.42E-01	1.50E-01	/	-43.65	344.38	/	-0.60	359.96	/	-32.43	180.97	/	-42.75	182.46	/	-5.40	359.66
1.26E+00	2.00E-01	/	-43.79	339.56	/	-0.61	359.94	/	-32.41	181.25	/	-42.73	183.23	/	-5.41	359.58
1.88E+00	3.00E-01	/	-44.33	330.32	/	-0.61	359.92	/	-32.37	181.70	/	-42.68	184.66	/	-5.45	359.49
2.51E+00	4.00E-01	/	-44.93	322.58	/	-0.61	359.90	/	-32.33	182.04	/	-42.62	185.98	/	-5.48	359.50
3.77E+00	6.00E-01	/	-46.17	309.68	/	-0.61	359.85	/	-32.25	182.46	/	-42.53	188.37	/	-5.54	359.71
5.03E+00	8.00E-01	/	-47.48	299.24	/	-0.61	359.81	/	-32.22	182.75	/	-42.45	190.61	/	-5.58	0.04
6.28E+00	1.00E+00	/	-48.40	291.81	/	-0.61	359.77	/	-32.20	183.01	/	-42.39	192.79	/	-5.59	0.39
9.42E+00	1.50E+00	/	-50.46	274.67	/	-0.61	359.67	/	-32.22	183.76	/	-42.26	198.26	/	-5.59	1.19
1.26E+01	2.00E+00	/	-51.55	260.11	/	-0.60	359.57	/	-32.30	184.69	/	-42.13	203.71	/	-5.55	1.81
1.88E+01	3.00E+00	/	-52.88	229.20	/	-0.60	359.36	/	-32.51	187.00	/	-41.81	214.35	/	-5.43	2.59
2.51E+01	4.00E+00	/	-53.82	198.86	/	-0.59	359.16	/	-32.77	189.73	/	-41.40	224.32	/	-5.32	2.94
3.77E+01	6.00E+00	/	-54.94	146.38	/	-0.56	358.78	/	-33.34	195.69	/	-40.50	241.66	/	-5.14	2.99
5.03E+01	8.00E+00	/	-55.23	106.58	/	-0.54	358.46	/	-33.97	201.72	/	-39.66	255.77	/	-4.99	2.63
6.28E+01	1.00E+01	/	-55.18	78.48	/	-0.51	358.20	/	-34.69	207.58	/	-39.02	267.47	/	-4.84	1.99
9.42E+01	1.50E+01	/	-55.41	31.92	/	-0.45	357.76	/	-36.93	221.71	/	-38.39	290.56	/	-4.34	359.28
1.26E+02	2.00E+01	/	-55.31	0.81	/	-0.42	357.51	/	-39.90	237.40	/	-39.12	311.22	/	-3.54	355.25
1.57E+02	2.50E+01	/	-54.68	337.04	/	-0.42	357.32	/	-43.72	263.97	/	-41.12	340.90	/	-2.35	350.05

TABLE 6. (Continued)

FREQUENCY		VARIABLE 9		VARIABLE 10		VARIABLE 15		VARIABLE 18		VARIABLE 21	
RPS	CPS	DECIBELS	PHASE	DECIBELS	PHASE	DECIBELS	PHASE	DECIBELS	PHASE	DECIBELS	PHASE
6.28E-01	1.00E-01	-39.95	186.77	-46.13	359.65	-14.10	359.04	-14.27	359.23	-21.25	359.52
9.42E-01	1.50E-01	-39.60	189.24	-46.16	359.53	-14.12	358.60	-14.29	358.89	-21.26	359.31
1.26E+00	2.00E-01	-39.21	190.96	-46.20	359.46	-14.15	358.20	-14.32	358.59	-21.28	359.13
1.88E+00	3.00E-01	-38.36	192.16	-46.29	359.52	-14.22	357.55	-14.39	358.15	-21.33	358.87
2.51E+00	4.00E-01	-37.66	191.50	-46.37	359.80	-14.28	357.07	-14.46	357.88	-21.38	358.74
3.77E+00	6.00E-01	-36.64	187.25	-46.53	0.92	-14.40	356.49	-14.58	357.72	-21.47	358.76
5.03E+00	8.00E-01	-36.05	182.13	-46.62	2.34	-14.48	356.12	-14.66	357.80	-21.54	358.97
6.28E+00	1.00E+00	-35.72	177.12	-46.65	3.87	-14.52	355.82	-14.70	357.93	-21.57	359.24
9.42E+00	1.50E+00	-35.42	166.11	-46.58	7.47	-14.54	354.85	-14.72	358.09	-21.58	359.85
1.26E+01	2.00E+00	-35.43	156.80	-46.38	10.50	-14.51	353.58	-14.68	357.95	-21.55	0.25
1.88E+01	3.00E+00	-35.66	141.37	-45.86	14.95	-14.44	350.35	-14.58	356.93	-21.42	0.51
2.51E+01	4.00E+00	-36.02	129.00	-45.31	17.78	-14.42	346.56	-14.51	355.34	-21.27	0.21
3.77E+01	6.00E+00	-36.62	115.23	-44.34	20.73	-14.57	338.63	-14.50	351.56	-21.03	358.69
5.03E+01	8.00E+00	-36.99	96.18	-43.53	21.70	-14.96	330.87	-14.59	348.04	-20.83	356.50
6.28E+01	1.00E+01	-37.24	84.65	-42.83	21.53	-15.23	323.52	-14.70	344.56	-20.65	353.89
9.42E+01	1.50E+01	-37.72	61.23	-41.36	18.22	-16.16	306.58	-14.85	336.09	-20.17	346.08
1.26E+02	2.00E+01	-38.16	40.05	-39.98	12.73	-16.86	291.25	-14.65	327.48	-19.48	336.94
1.57E+02	2.50E+01	-38.34	18.03	-38.45	6.12	-17.15	277.03	-14.00	319.43	-18.49	326.80

TABLE 6. (Concluded)

FREQUENCY		VARIABLE 22		VARIABLE 38		VARIABLE 42		VARIABLE 43		VARIABLE **	
RPS	CPS	DECIBELS	PHASE	DECIBELS	PHASE	DECIBELS	PHASE	DECIBELS	PHASE	DECIBELS	PHASE
6.28E-01	1.00E-01	-15.67	359.91	-17.22	357.94	-21.47	359.74	-0.60	359.93	0.0	0.0
9.42E-01	1.50E-01	-15.67	359.86	-17.27	356.99	-21.49	359.65	-0.60	359.89	0.0	0.0
1.26E+00	2.00E-01	-15.67	359.82	-17.33	356.12	-21.51	359.59	-0.61	359.86	0.0	0.0
1.88E+00	3.00E-01	-15.67	359.76	-17.49	354.68	-21.57	359.61	-0.61	359.79	0.0	0.0
2.51E+00	4.00E-01	-15.67	359.71	-17.65	353.59	-21.64	359.78	-0.61	359.73	0.0	0.0
3.77E+00	6.00E-01	-15.66	359.59	-17.95	352.30	-21.74	0.48	-0.61	359.61	0.0	0.0
5.03E+00	8.00E-01	-15.64	359.45	-18.17	351.62	-21.81	1.40	-0.61	359.49	0.0	0.0
6.28E+00	1.00E+00	-15.62	359.26	-18.32	351.17	-21.83	2.40	-0.60	359.37	0.0	0.0
9.42E+00	1.50E+00	-15.57	358.67	-18.53	350.08	-21.81	4.78	-0.60	359.06	0.0	0.0
1.26E+01	2.00E+00	-15.52	357.96	-18.61	348.63	-21.70	6.87	-0.59	358.75	0.0	0.0
1.88E+01	3.00E+00	-15.43	356.23	-18.69	344.86	-21.39	10.25	-0.56	358.11	0.0	0.0
2.51E+01	4.00E+00	-15.37	354.27	-18.79	340.52	-21.03	12.81	-0.52	357.44	0.0	0.0
3.77E+01	6.00E+00	-15.33	350.14	-19.13	331.58	-20.29	16.62	-0.42	356.06	0.0	0.0
5.03E+01	8.00E+00	-15.33	345.99	-19.58	323.09	-19.57	19.58	-0.29	354.66	0.0	0.0
6.28E+01	1.00E+01	-15.32	341.79	-20.07	315.09	-18.84	22.11	-0.14	353.22	0.0	0.0
9.42E+01	1.50E+01	-15.17	330.66	-21.17	296.73	-16.99	27.23	0.39	349.47	0.0	0.0
1.26E+02	2.00E+01	-14.71	318.60	-21.91	279.84	-15.08	30.93	1.12	345.32	0.0	0.0
1.57E+02	2.50E+01	-13.90	305.65	-22.19	263.70	-13.03	33.09	2.10	340.46	0.0	0.0

REFERENCES

1. RL00001-Engine Balance and Dynamic Model, Revision E, February 1973.
2. DVS-SSME-101-Design Verification Specification Space Shuttle Main Engine, Volume II, Revision A, 20 July 1973.
3. RC1010-Computer Program Requirements Document, Controller, Revision D, 16 February 1973.

APPENDIX A

DESCRIPTION OF THE COEFFICIENT EVALUATION PROGRAM

In the discussion of the nonlinear engine equations, coefficient expressed by BXX were contained in many of the equations. These are functions of component design and represent physical processes and/or geometry. Using engine balance information (from models which include many sophistications not required in the frequency response model), the subsystems can be described quite accurately for small variations about the balance point. The balance point data is therefore read into the program as well as slopes of empirical relations at the balance point.

Some of the BXX values are not functions of operating point, but represent dynamic parameters such as compliance or inertance. These values are contained in the program itself.

After computing the values of BXX which are balance point dependent, the entire set is listed as output, as well as the entire input list. The linear coefficients are then calculated from the BXX values and operating point and slope data. These are automatically transferred to their proper location in the frequency response program.

A coefficient "KOLI" discussed in the input data section of Appendix B selects which of the input variables is to be used and calculates the coefficient for that variable while setting all other inputs to zero.

Multiple cases in general require multiple individual runs except in the case where only the input variable is changed. Each setup requires full information concerning the balance point.

A listing of "EVALAB," the coefficient evaluation program is contained in this appendix (Table A-1).

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TABLE A-1. EVALAB COEFFICIENT EVALUATION PROGRAM

```
LEVEL 2  ( NOV 72 )                               OS/360  FORTRAN H EXTENDED              DATE 73.264/19.53.40

REQUESTED OPTIONS: MAP,DECK,LIST,XREF,OPT=2

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(2) LINECOUNT(40) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC LIST DECK OBJECT MAP NOFORMAT GOSTMT XREF ALC NOANSF NOTERMINAL FLAG(I)

   ISN 0002             SUBROUTINE EVALAB                                                         00006000
   ISN 0003             DIMENSION A(50,200),V(170),B(120)                                         00006010
   ISN 0004             DIMENSION FTAB(9),GTAB(9)                                                 00006015
   ISN 0005             DATA FTAB/0.0,0.355,0.51,0.7,0.845,0.88,0.9,0.943,1.0/                    00006016
   ISN 0006             DATA GTAB/10.0,1000.0,1800.0,3600.0,6100.0,6400.0,6400.0,5510.0,          00006017
                       1500.0/                                                                    00006018
   ISN 0007             COMMON ICRT,A,IDV(200)  /EVAL/ TITLE(18)                                  00006019
   ISN 0008             NAMELIST /VNOM/ V,KOLI,IDV,SCALE,ID                                       00006020
   ISN 0009             WRITE(6,1)  TITLE                                                         00006030
   ISN 0010           1 FORMAT('1',18A4)                                                          00006040
   ISN 0011             SCALE    = 1.0                                                            00006045
   ISN 0012             READ(5,VNOM,END=32)                                                       00006050
   ISN 0013             WRITE(6,2) KOLI                                                           00006060
   ISN 0014           2 FORMAT('1THE NUMBER OF THE INPUT VARIABLE IS:',I3)                        00006070
   ISN 0015             IF(INFLAG.EQ.123)      GO TO 10                                           00006080
                C       COMPUTE NOMINAL VALUES                                                    00006090
   ISN 0017             B(11)    = V(106)*V(73)/V(22)                                             00006100
   ISN 0018             B(12)    = (V(62)-V(57))/V(73)                                            00006110
   ISN 0019             B(13)    = V(97)/V(73)**2                                                 00006120
   ISN 0020             B(14)    = 1.0/V(43)                                                      00006130
   ISN 0021             B(15)    = V(91)*SQRT(V(78))/V(73)                                        00006140
   ISN 0022             B(16)    = V(99)/(V(115)*V(51))                                           00006150
   ISN 0023             B(17)    = V(25)**2/((V(51)-V(55))*V(95))                                 00006160
   ISN 0024             B(18)    = V(107)*V(74)/V(22)                                             00006170
   ISN 0025             B(19)    = (V(63)-V(62))/V(74)**2                                         00006180
   ISN 0026             B(20)    = V(98)/V(74)**2                                                 00006190
   ISN 0027             B(21)    = 2500.0                                                         00006200
   ISN 0028             B(22)    = (V(63)-V(69))*V(3)**2/V(22)**2                                 00006210
   ISN 0029             B(23)    = 1.0/V(44)                                                      00006220
   ISN 0030             PR       = SQRT(V(55)/V(56))                                              00006230
   ISN 0031             GAMPR    = SQRT(PR**(2.0/1.4)-PR**(2.4/1.4))                              00006240
   ISN 0032             B(24)    = V(26)*SQRT(V(82))/(V(56)*GAMPR)                                00006250
   ISN 0033             B(25)    = V(92)/V(74)                                                    00006260
```

TABLE A-1. (Continued)

```
LEVEL 2  ( NOV 72 )              EVALAB          OS/360  FORTRAN H EXTENDED              DATE 73.264/19.53.40

    ISN 0034          B(26)     = V(100)*V(56)/V(118)                                    00006270
    ISN 0035          B(27)     = V(108)*V(75)/(V(27)+V(30))                             00006280
    ISN 0036          B(28)     = (V(64)-V(60))/V(75)**2                                 00006290
    ISN 0037          B(29)     = V(105)*V(59)/V(127)                                    00006300
    ISN 0038          B(30)     = V(38)-1.0                                              00006310
    ISN 0039          B(31)     = 1.0                                                    00006320
    ISN 0040          B(32)     = (V(61)-V(60))/V(20)                                    00006330
    ISN 0041          B(33)     = 150.0                                                  00006340
    ISN 0042          B(34)     = V(101)/V(75)**2                                        00006350
    ISN 0043          B(35)     = 1.0/V(45)                                              00006360
    ISN 0044          B(36)     = V(104)/(V(121)*V(111)*V(31)**2)                        00006370
    ISN 0045          B(37)     = (V(65)-V(64))/V(31)**2-V(122)                          00006380
    ISN 0046          B(38)     = V(111)*V(31)/V(75)                                     00006390
    ISN 0047          B(39)     = V(109)*V(76)/(V(27)+V(31)+V(30))                       00006400
    ISN 0048          B(40)     = (V(65)-V(64))/V(76)**2                                 00006410
    ISN 0049          B(41)     = V(102)/V(76)**2                                        00006420
    ISN 0050          B(42)     = 1.0/V(46)                                              00006430
    ISN 0051          B(43)     = V(110)*V(76)/V(30)                                     00006440
    ISN 0052          B(44)     = V(103)/V(76)**2                                        00006450
    ISN 0053          B(45)     = (V(66)-V(65))/V(76)**2                                 00006460
    ISN 0054          B(46)     = 100.0                                                  00006470
    ISN 0055          B(47)     = V(93)/V(76)                                            00006480
    ISN 0056          PR        = SQRT(V(55)/V(59))                                      00006490
    ISN 0057          GAMPR     = SQRT(PR**(2.0/1.4)-PR**(2.4/1.4))                      00006500
    ISN 0058          B(48)     = V(32)*SQRT(V(83))/V(59)*GAMPR                          00006510
    ISN 0059          B(49)     = 38120.0                                                00006520
    ISN 0060          B(50)     = 66.675                                                 00006530
    ISN 0061          B(51)     = (V(52)-V(56))*V(96)/V(23)**2                           00006540
    ISN 0062          B(52)     = 50.0                                                   00006550
    ISN 0063          B(53)     = (V(67)-V(68))*(V(2)/V(24))**2                          00006560
    ISN 0064          B(54)     = (V(68)-V(56))/V(24)**2                                 00006570
    ISN 0065          B(55)     = 1.0/V(89)                                              00006580
    ISN 0066          B(56)     = 1378.0                                                 00006590
    ISN 0067          B(57)     = 100.0                                                  00006600
    ISN 0068          B(58)     = (V(52)-V(59))*V(96)/V(28)**2                           00006610
    ISN 0069          B(59)     = 10.0                                                   00006620
    ISN 0070          B(60)     = (V(70)-V(59))/V(29)**2                                 00006630
    ISN 0071          B(61)     = (V(67)-V(70))*(V(5)/V(29))**2                          00006640
```

TABLE A-1. (Continued)

```
LEVEL 2  ( NOV 72 )              EVALAB          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.40

      ISN 0072          B(62)    = 1.0/V(90)                                                      00006650
      ISN 0073          B(63)    = 35000.0                                                        00006660
      ISN 0074          B(64)    = 3949.0                                                         00006670
      ISN 0075          PR       = V(53)/V(55)                                                    00006672
      ISN 0076          GAMPR    = (PR**(2.0/1.4)-PR**(2.4/1.4))                                  00006674
      ISN 0077          B(65)    = V(16)*SQRT(V(81))/V(55)*GAMPR                                  00006680
      ISN 0078          B(66)    = 0.5055                                                         00006690
      ISN 0079          B(67)    = 0.2563                                                         00006700
      ISN 0080          B(68)    = 0.24                                                           00006710
      ISN 0081          B(69)    = 50.0                                                           00006720
      ISN 0082          B(70)    = (V(65)-V(58))*(V(4)/V(27))**2                                  00006730
      ISN 0083          B(71)    = (V(58)-V(53))/V(27)**2                                         00006740
      ISN 0084          B(72)    = 6838.0                                                         00006750
      ISN 0085          B(73)    = V(15)*V(6)/V(53)                                               00006760
      ISN 0086          B(74)    = 3.812                                                          00006770
      ISN 0087          B(75)    = 483.75                                                         00006780
      ISN 0088          B(76)    = (V(69)-V(51))*V(95)/V(18)**2                                   00006790
      ISN 0089          B(77)    = 0.001                                                          00006800
      ISN 0090          B(78)    = V(78)*V(95)/V(51)                                              00006810
      ISN 0091          B(79)    = V(10)/((1.0+0.002*V(78))*(V(85)-V(78))*V(18)**0.8)             00006820
      ISN 0092          B(80)    = 2.0*B(79)                                                      00006830
      ISN 0093          B(81)    = V(8)/((V(80)-V(85))*V(15)**0.8)                                00006840
      ISN 0094          B(82)    = 0.31                                                           00006850
      ISN 0095          B(83)    = 0.0825                                                         00006860
      ISN 0096          B(84)    = 2.544                                                          00006870
      ISN 0097          B(85)    = 218.0                                                          00006880
      ISN 0098          B(86)    = (V(69)-V(50))/V(17)**2                                         00006890
      ISN 0099          B(87)    = 0.0005                                                         00006900
      ISN 0100          B(88)    = V(77)*V(94)/V(50)                                              00006902
      ISN 0101          B(89)    = V(9)/((V(84)-V(77))*(1.0+0.002*V(77))*V(17)**0.8)              00006904
      ISN 0102          B(90)    = 2.0*V(89)                                                      00006906
      ISN 0103          B(91)    = V(7)/((V(80)-V(84))*V(15)**0.8)                                00006908
      ISN 0104          B(92)    = 0.1668                                                         00006910
      ISN 0105          B(93)    = 0.0834                                                         00006912
      ISN 0106          B(94)    = 21.19                                                          00006914
      ISN 0107          B(95)    = (V(50)-V(52))*V(94)/V(13)**2                                   00006916
      ISN 0108          B(96)    = 81600.0                                                        00006918
      ISN 0109          B(97)    = 32000.0                                                        00006920
```

TABLE A-1. (Continued)

```
LEVEL 2  ( NOV 72 )              EVALAB          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.40

    ISN 0110             B(98)   = 20.0                                                        00006922
    ISN 0111             B(99)   = (V(69)-V(52))*(V(1)/V(33))**2                               00006924
    ISN 0112             B(100)  = V(79)*V(96)/V(52)                                           00006926
    ISN 0113             B(101)  = V(49)/V(78)                                                 00006928
    ISN 0114             B(102)  = V(48)/V(77)                                                 00006930
    ISN 0115             B(103)  = V(47)/(V(98)*V(74))                                         00006932
    ISN 0116             B(104)  = (V(66)-V(67))/V(30)**2                                      00006934
    ISN 0117             B(105)  =((V(33)+V(13))/V(96)-V(13)/V(94))/V(33)                      00006936
    ISN 0118             B(106)  = V(36)/V(65)                                                 00006938
    ISN 0119             B(107)  = (V(28)+V(35))/V(32)                                         00006940
    ISN 0120             B(108)  = (V(25)+V(26)+V(32))/V(16)                                   00006942
    ISN 0121             B(109)  = (V(15)-V(19))/V(16)                                         00006944
    ISN 0122             B(110)  = (V(17)+V(18)+V(33))/V(22)                                   00006946
    ISN 0123             B(111)  = (V(23)+V(34))/V(26)                                         00006948
    ISN 0124             FOXD    = V(24)/(V(24)+V(23))                                         00006950
    ISN 0125             IRET    = 1                                                           00006952
    ISN 0126             GO TO 5                                                               00006954
    ISN 0127           3 B(112)  = (V(82)-GAMMT)/V(79)                                         00006956
    ISN 0128             FOXD    = V(35)/(V(35)+V(28))                                         00006958
    ISN 0129             IRET    = 2                                                           00006960
    ISN 0130             GO TO 5                                                               00006961
    ISN 0131           4 B(113)  = (V(83)-GAMMT)/V(79)                                         00006962
    ISN 0132             B(114)  = V(54)/V(53)                                                 00006963
    ISN 0133             B(115)  = 76.9231                                                     00006964
    ISN 0134             B(116)  = 1000.0                                                      00006965
    ISN 0135             GO TO 9                                                               00006966
    ISN 0136           5 DO  6 I=2,10                                                          00006968
    ISN 0137             IF(FOXD.GT.FTAB(I))   GO TO 6                                         00006970
    ISN 0139             GAMMT    = GTAB(I-1)+(FOXD-FTAB(I-1))*(GTAB(I)-GTAB(I-1))/            00006972
                        1(FTAB(I)-FTAB(I-1))                                                   00006974
    ISN 0140             GO TO(3,4),IRET                                                       00006976
    ISN 0141           6 CONTINUE                                                              00006978
    ISN 0142             WRITE(6,7)  FOXD                                                      00006980
    ISN 0143           7 FORMAT(' OXIDIZER FRACTION EXCEEDS ONE',1PE12.3)                      00006982
                 C       PRINT V VECTOR AND B VECTOR                                           00007910
    ISN 0144           9 WRITE(6,91)                                                           00007920
    ISN 0145          91 FORMAT(' STEADY-STATE VALUES FOR ENGINE PARAMETERS')                  00007930
    ISN 0146             WRITE(6,27) (V(I),I=1,60)                                             00007940
```

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TABLE A-1. (Continued)

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LEVEL 2  ( NOV 72 )             EVALAB            CS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.40

      ISN 0147              WRITE(6,29) (V(I),I=61,120)                                         00007942
      ISN 0148              WRITE(6,30) (V(I),I=121,163)                                        00007944
      ISN 0149           93 FORMAT(1H0,1P10E11.4)                                               00007950
      ISN 0150              WRITE(6,95)                                                         00007960
      ISN 0151           95 FORMAT('1VECTOR OF COEFFICIENTS CORRESPONDING TO THE ABOVE STEADY-00007970
                            1STATE VALUES,B11 THROUGH B116.')                                   00007980
      ISN 0152              WRITE(6,93) (B(I),I=11,116)                                         00007990
      ISN 0153              A(1,1)  = 1.0                                                       00008000
      ISN 0154              B12     = V(57)-V(62)                                               00008010
      ISN 0155              C12     = V(133)*V(106)/V(113)                                      00008020
      ISN 0156              A(1,3)  = B12*(2.0-C12)/V(73)                                       00008030
      ISN 0157              A(1,5)  = B12*C12/V(22)                                             00008040
      ISN 0158              B22     = V(134)*V(106)/V(114)                                      00008050
      ISN 0159              C22     = V(135)*V(91)/V(115)                                       00008060
      ISN 0160              A(2,2)  = 1.0                                                       00008070
      ISN 0161              A(2,3)  = -B(14)/V(73)*(V(97)*(B22-2.0)+V(99)*C22)                  00008080
      ISN 0162              A(2,5)  = B(14)*B22*V(97)/V(22)                                     00008090
      ISN 0163              B219    = B(14)*V(99)*V(136)*V(41)*(V(55)/V(51))**V(41)/V(115)      00008100
      ISN 0164              A(2,33) = -B219/V(55)                                               00008110
      ISN 0165              A(2,41) = (B219-B(14)*V(99))/V(51)                                  00008120
      ISN 0166              A(2,46) = B(14)*V(99)*C22/(2.0*V(78))                               00008130
      ISN 0167              A(3,1)  = -B(21)                                                    00008140
      ISN 0168              B33     = V(137)*V(107)/V(116)                                      00008150
      ISN 0169              A(3,4)  = 1.0                                                       00008160
      ISN 0170              A(3,5)  = -B(21)*((V(63)-V(62))*B33/V(22)-2.0*B(22)*V(22)/V(3)**2)00008170
      ISN 0171              A(3,7)  = -B(21)*(V(63)-V(62))*(2.0-B33)/V(74)                      00008180
      ISN 0172              A(3,67) = B(21)                                                     00008185
      ISN 0173              B43     = V(138)*V(107)/V(117)                                      00008190
      ISN 0174              A(4,5)  = B(23)*V(98)*B43/V(22)                                     00008200
      ISN 0175              B44     = V(139)/V(118)                                             00008210
      ISN 0176              A(4,6)  = 1.0                                                       00008220
      ISN 0177              A(4,7)  = B(23)*(V(98)*(2-B43)/V(74)-V(100)*B44*B(25))              00008230
      ISN 0178              B415    =(V(140)*V(42)*(V(55)/V(56))**V(42))/V(118)                 00008240
      ISN 0179              A(4,25) = -B(23)*V(100)*(1.0-B415)/V(56)                            00008250
      ISN 0180              A(4,33) = -B(23)*V(100)*B415/V(55)                                  00008260
      ISN 0181              A(5,8)  = 1.0                                                       00008270
      ISN 0182              B56     = V(141)*V(108)/V(119)                                      00008280
      ISN 0183              A(5,10) = -(V(64)-V(60))*(2.0-B56)/V(75)                            00008290
```

TABLE A-1. (Continued)

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LEVEL 2  ( NOV 72 )              EVALAB             OS/360  FORTRAN H EXTENDED                  DATE 73.264/19.53.40

     ISN 0184          A(5,11) = (V(64)-V(60))*B56/(V(162)+V(31))                               00008300
     ISN 0185          A(5,73) = -A(5,11)                                                       00008310
     ISN 0186          B66     = V(142)*V(111)/V(121)                                           00008320
     ISN 0187          C66     = V(143)*V(108)/V(120)                                           00008330
     ISN 0188          A(6,9)  = 1.0                                                            00008340
     ISN 0189          A(6,10) = -B(35)*(V(104)*B66-2.0*V(101)+V(101)*C66)/V(75)                00008350
     ISN 0190          A(6,73) = B(35)*V(101)*C66/(V(27)+V(30)+V(36))                           00008370
     ISN 0191          A(6,11) = -B(35)*V(104)*(2.0-B66)/V(31)-A(6,73)                          00008380
     ISN 0192          A(7,8)  = V(31)/(2.0*(V(65)-V(64)))                                      00008390
     ISN 0193          B76     = V(31)*V(144)*V(111)/(2.0*(B(37)+V(122)))                       00008400
     ISN 0194          A(7,10) = B76/V(75)                                                      00008410
     ISN 0195          A(7,11) = 1.0-B76/V(31)                                                  00008420
     ISN 0196          A(7,12) = -A(7,8)                                                        00008430
     ISN 0197          B87     = V(145)/V(123)                                                  00008450
     ISN 0198          B88     = V(27)+V(30)+V(31)+V(36)                                        00008460
     ISN 0199          A(8,11) = -B87*V(109)*(V(65)-V(163))/B88                                 00008470
     ISN 0200          A(8,12) = 1.0+B(106)*A(8,11)                                             00008480
     ISN 0201          A(8,14) = (V(64)-V(65))*(2.0-B87*V(109))/V(76)                           00008490
     ISN 0202          A(8,16) = A(8,11)                                                        00008500
     ISN 0203          A(8,36) = A(8,11)                                                        00008510
     ISN 0204          A(8,75) = -1.0                                                           00008515
     ISN 0205          B97     = V(146)*V(109)/V(124)                                           00008520
     ISN 0206          C97     = V(102)/B88                                                     00008530
     ISN 0207          A(9,11) = B(42)*B97*C97                                                  00008540
     ISN 0208          B99     = V(147)*V(110)/V(125)                                           00008550
     ISN 0209          C99     = B(47)*V(76)*V(148)/V(127)                                      00008560
     ISN 0210          A(9,13) = 1.0                                                            00008570
     ISN 0211          A(9,14) = -B(42)*(V(105)*C99-V(102)*(2.0-B97)-V(103)*                    00008580
                      1          (2.0-B99))/V(76)                                               00008590
     ISN 0212          A(9,16) = A(9,11)+B(42)*V(103)*B99/V(30)                                 00008600
     ISN 0213          A(9,31) = -B(42)*V(105)*(1.0*V(127)-V(149)*V(39)*(V(55)/V(59))           00008610
                      1         **V(39))/(V(59)*V(127))                                         00008620
     ISN 0214          A(9,33) = -B(42)*V(105)*V(149)*V(39)*(V(55)/V(59))**V(39)/               00008630
                      1(V(55)*V(127))                                                           00008635
     ISN 0215          A(9,36) = A(9,11)                                                        00008640
     ISN 0216          A(10,12)= -B(46)                                                         00008650
     ISN 0217          B109    = V(150)*V(110)/V(126)                                           00008660
     ISN 0218          A(10,14)= -B(46)*(V(66)-V(65))*(2.0-B109)/V(76)                          00008670
```

TABLE A-1. (Continued)

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LEVEL 2  ( NOV 72 )            EVALAB          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.40

     ISN 0219          A(10,15)= 1.0                                                     00008680
     ISN 0220          A(10,16)= B(46)*(2.0*B(104)*V(30)-(V(66)-V(65))*B109/V(30))       00008690
     ISN 0221          A(10,19)= B(46)                                                   00008700
     ISN 0222          A(11,17)= 1.0                                                     00008710
     ISN 0223          FOP     = V(35)/(V(35)+V(28))                                     00008720
     ISN 0224          FFOP    = V(151)*FOP*(1.0-FOP)                                    00008730
     ISN 0225          B1116   = V(32)*FFOP/(2.0*V(83))                                  00008740
     ISN 0226          A(11,27)= -B1116/V(28)                                            00008750
     ISN 0227          A(11,29)= B1116/V(29)                                             00008760
     ISN 0228          PR      = (V(55)/V(59))**.5                                       00008770
     ISN 0229          GAMPR   = (PR**(2.0/1.4)-PR**(2.4/1.4))**.5                       00008780
     ISN 0230          DGAMPR  = (2.0*PR**(.6/1.4)-2.4*PR**(1.0/1.4))/(2.8*GAMPR)        00008785
     ISN 0231          B1118   = DGAMPR*PR/(2.0*GAMPR)                                   00008790
     ISN 0232          A(11,31)= V(32)*(B1118-1.0)/V(59)                                 00008800
     ISN 0233          A(11,33)= -V(32)*B1118/V(55)                                      00008810
     ISN 0234          A(11,70)= B(113)*V(32)/(2.0*V(83))                                00008820
     ISN 0235          A(12,16)= -B(49)                                                  00008830
     ISN 0236          A(12,18)= 1.0                                                     00008840
     ISN 0237          A(12,23)= B(49)                                                   00008850
     ISN 0238          A(12,29)= B(49)                                                   00008860
     ISN 0239          B1313   = B(50)*B(51)*V(23)**2/V(96)                              00008870
     ISN 0240          A(13,20)= 1.0                                                     00008880
     ISN 0241          A(13,21)= 2.0*B1313/V(23)                                         00008890
     ISN 0242          A(13,25)= B(50)                                                   00008900
     ISN 0243          A(13,65)= -B(50)                                                  00008910
     ISN 0244          A(13,71)= -B1313/V(96)                                            00008920
     ISN 0245          A(14,19)= -B(52)                                                  00008930
     ISN 0246          B1414   = 2.0*B(53)*(V(24)/V(2))**2                               00008940
     ISN 0247          A(14,22)= 1.0                                                     00008950
     ISN 0248          A(14,23)= B(52)*(B1414/V(24)+2.0*B(54)*V(24))                     00008960
     ISN 0249          A(14,25)= B(52)                                                   00008970
     ISN 0250          FFP     = V(24)/(V(24)+V(23))                                     00008980
     ISN 0251          FFFP    = V(153)*FFP*(1.0-FFP)                                    00008990
     ISN 0252          B1513   = V(26)*FFFP/(2.0*V(82))                                  00009000
     ISN 0253          A(15,21)= -B(56)*(1.0-B(111)*B1513/V(23))                         00009010
     ISN 0254          A(15,23)= -B(56)*(1.0+B(111)*B1513/V(24))                         00009020
     ISN 0255          PRF     = (V(55)/V(56))**.5                                       00009030
     ISN 0256          GAMPRF  = (PRF**(2.0/1.4)-PRF**(2.4/1.4))**.5                     00009040
```

TABLE A-1. (Continued)

```
LEVEL 2  ( NOV 72 )              EVALAB          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.40

  ISN 0257              DGAMPR   = (2.0*PRF**(.6/1.4)-2.4*PRF**(1.0/1.4))/(2.8*GAMPRF)     00009045
  ISN 0258              B1515    = V(26)*DGAMPR*PRF/(2.0*GAMPRF)                           00009050
  ISN 0259              A(15,24)= 1.0                                                      00009060
  ISN 0260              A(15,25)= B(56)*B(111)*(V(26)-B1515)/V(56)                         00009070
  ISN 0261              A(15,33)= B(56)*B(111)*B1515/V(55)                                 00009080
  ISN 0262              A(15,70)= -B(56)*B(111)*B(112)*V(26)/(2.0*V(82))                   00009090
  ISN 0263              B1616    =  B(57)*B(58)*V(28)/V(96)                                00009100
  ISN 0264              A(16,26)= 1.0                                                      00009110
  ISN 0265              A(16,27)= 2.0*B1616                                                00009120
  ISN 0266              A(16,31)= B(57)                                                    00009130
  ISN 0267              A(16,65)= -B(57)                                                   00009140
  ISN 0268              A(16,71)= -B1616*V(28)/V(96)                                       00009150
  ISN 0269              A(17,19)= -B(59)                                                   00009160
  ISN 0270              B1717    = 2.0*B(61)*(V(29)/V(5))**2                               00009170
  ISN 0271              A(17,28)= 1.0                                                      00009180
  ISN 0272              A(17,29)= B(59)*(2.0*B(60)*V(29)+B1717/V(29))                      00009190
  ISN 0273              A(17,31)= B(59)                                                    00009200
  ISN 0274              A(18,17)= B(63)*B(107)                                             00009210
  ISN 0275              A(18,27)= -B(63)                                                   00009220
  ISN 0276              A(18,29)= -B(63)                                                   00009230
  ISN 0277              A(18,30)= 1.0                                                      00009240
  ISN 0278              A(19,17)= -B(64)                                                   00009250
  ISN 0279              A(19,21)= -B(64)*B1513/V(23)                                       00009260
  ISN 0280              A(19,23)= B(64)*B1513/V(24)                                        00009270
  ISN 0281              A(19,25)= -B(64)*(V(26)+B1515)/V(56)                               00009280
  ISN 0282              B1919    = V(25)/(2.0*(V(51)-V(55)))                               00009290
  ISN 0283              A(19,32)= 1.0                                                      00009300
  ISN 0284              A(19,33)= B(64)*(B1919-B1515/V(55))                                00009310
  ISN 0285              A(19,34)= B(64)*B(108)                                             00009320
  ISN 0286              A(19,41)= -B(64)*B1919                                             00009330
  ISN 0287              A(19,45)= -B(64)*V(25)/(2.0*V(95))                                 00009340
  ISN 0288              A(19,70)= B(64)*B(112)*V(26)/(2.0*V(82))                           00009350
                  C     SEE THE COMPUTATION OF B1513 FOR DEFINITION OF FFFP                00009360
  ISN 0289              B2013    =  V(16)*FFFP/(2.0*V(81))                                 00009370
  ISN 0290              A(20,21)= -B(66)*B2013/V(23)                                       00009380
  ISN 0291              A(20,23)= B(66)*B2013/V(24)                                        00009390
                  C     SEE THE COMPUTATION OF B1116 FOR DEFINITION OF FFOP                00009400
  ISN 0292              B2016    = V(16)*FFOP/(2.0*V(81))                                  00009410
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TABLE A-1. (Continued)

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LEVEL 2 ( NOV 72 )              EVALAB          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.40

  ISN 0293      A(20,27)= -B(67)*B2016/V(28)                                          00009420
  ISN 0294      A(20,29)= B(67)*B2016/V(29)                                           00009430
  ISN 0295      PRF      = V(53)/V(55)                                                00009432
  ISN 0296      GAMPRF   = (PRF**(2.0/1.4)-PRF**(2.4/1.4))**.5                        00009434
  ISN 0297      DGAMPR   = (2.0*PRF**(.6/1.4)-2.4*PRF**(1.0/1.4))/(2.8*GAMPRF)        00009435
  ISN 0298      B2019    = V(16)*DGAMPR*PRF/GAMPRF                                    00009440
  ISN 0299      A(20,33)= -(V(16)-B2019)/V(55)                                        00009450
  ISN 0300      A(20,34)= 1.0                                                         00009460
  ISN 0301      A(20,38)= -B2019/V(53)                                                00009470
  ISN 0302      A(20,46)= B(68)*V(16)/(2.0*V(81))                                     00009480
  ISN 0303      A(20,73)= V(16)*(B(66)*B(112)+B(67)*B(113))/(2.0*V(81))               00009485
  ISN 0304      A(21,12)= -B(69)                                                      00009490
  ISN 0305      B2121    = 2.0*B(70)*(V(27)/V(4))**2                                  00009500
  ISN 0306      A(21,35)= 1.0                                                         00009510
  ISN 0307      A(21,36)= B(69)*(B2121/V(27)+2.0*B(71)*V(27))                         00009520
  ISN 0308      A(21,39)= B(69)                                                       00009530
  ISN 0309      A(22,34)= -B(72)*B(109)                                               00009540
  ISN 0310      A(22,36)= -B(72)                                                      00009550
  ISN 0311      A(22,37)= 1.0                                                         00009560
  ISN 0312      A(22,38)= B(72)*V(15)/V(53)                                           00009570
  ISN 0313      B2223    = (210500-347000*V(40))/V(6)                                 00009580
  ISN 0314      A(22,39)= -B(72)*V(15)*B2223                                          00009590
  ISN 0315      B2310    = 1.0/(V(27)+V(16))                                          00009600
  ISN 0316      A(23,16)= -B2310                                                      00009610
  ISN 0317      A(23,34)= B2310*V(40)                                                 00009620
  ISN 0318      A(23,36)= -B2310*(1.0-V(40))                                          00009630
  ISN 0319      A(23,39)= 1.0                                                         00009640
  ISN 0320      A(24,5)  = -B(74)*V(18)*V(47)*B43/V(22)                               00009650
  ISN 0321      A(24,7)  = -B(74)*V(18)*V(47)*(3.0-B43)/V(74)                         00009660
  ISN 0322      A(24,33)= -B(74)*V(49)*B1919                                          00009670
  ISN 0323      A(24,40)= 1.0                                                         00009680
  ISN 0324      A(24,41)= -A(24,33)                                                   00009690
  ISN 0325      B2425    = 0.8*(V(10)+V(12))/V(18)                                    00009700
  ISN 0326      A(24,43)= -B(74)*(V(47)+B2425)                                        00009710
  ISN 0327      A(24,45) = B(74)*V(49)*V(25)/(2.0*V(95))                              00009720
  ISN 0328      B2427    = 0.002/(1.0+0.002*V(78))                                    00009730
  ISN 0329      C2427    = 1.0/(V(85)-V(78))                                          00009740
  ISN 0330      D2427    = B(80)*(1.0+.002*V(78))*V(18)**0.8                          00009750
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TABLE A-1. (Continued)

```
LEVEL 2  ( NOV 72 )            EVALAB          OS/360  FORTRAN H EXTENDED          DATE 73.264/19.53.40

   ISN 0331          A(24,46)= -B(74)*(V(10)*(B2427-C2427)+V(12)*B2427-B(101)*V(25)-   00009760
                    1          D2427)                                                   00009770
   ISN 0332          A(24,48)= -B(74)*V(10)*C2427                                       00009780
   ISN 0333          A(24,50)= -B(74)*D2427                                             00009790
   ISN 0334          A(25,41)= B(75)                                                    00009800
   ISN 0335          B2525    = B(75)*B(76)*V(18)/V(95)                                 00009810
   ISN 0336          A(25,42)= 1.0                                                      00009820
   ISN 0337          A(25,43)= 2.0*B2525                                                00009830
   ISN 0338          A(25,45)= -B(75)*B(76)*(V(18)/V(95))**2                            00009840
   ISN 0339          A(25,67)= -B(75)                                                   00009850
   ISN 0340          B2619    = B(77)*B1919                                             00009860
   ISN 0341          A(26,33)= -B2619                                                   00009870
   ISN 0342          A(26,41)= B2619                                                    00009880
   ISN 0343          A(26,43)= -B(77)                                                   00009890
   ISN 0344          A(26,44)= 1.0                                                      00009900
   ISN 0345          A(26,45)= B(77)*V(25)/(2.0*V(95))                                  00009910
   ISN 0346          A(27,41)= -V(78)/V(51)                                             00009920
   ISN 0347          A(27,45)= V(78)/V(95)                                              00009930
   ISN 0348          A(27,46)= 1.0                                                      00009940
   ISN 0349          B2822    = B(82)*V(8)                                              00009950
   ISN 0350          A(28,38)= -0.8*B2822/V(53)                                         00009960
   ISN 0351          B2823    = 1.0/(V(80)-V(85))                                       00009970
   ISN 0352          A(28,39)= B(82)*V(8)*(0.8*B2223-V(156)*B2823)                      00009980
   ISN 0353          B2825    = B(82)*V(10)                                             00009990
   ISN 0354          A(28,43)= 0.8*B2825/V(18)                                          00010000
   ISN 0355          A(28,46)= B2825*(B2427-C2427)                                      00010010
   ISN 0356          A(28,47)= 1.0                                                      00010020
   ISN 0357          A(28,48)= B2822*B2823+B2825*C2427                                  00010030
   ISN 0358          B2925    = B(83)*V(12)                                             00010040
   ISN 0359          A(29,43)= 0.8*B2925/V(18)                                          00010050
   ISN 0360          A(29,46)= B2925*B2427-B(83)*D2427                                  00010060
   ISN 0361          A(29,49)= 1.0                                                      00010070
   ISN 0362          A(29,50)= B(83)*D2427                                              00010080
   ISN 0363          B303     = B(84)*V(47)                                             00010090
   ISN 0364          C303     = B303*V(17)                                              00010100
   ISN 0365          A(30,5)  = -C303*B43/V(22)                                         00010200
   ISN 0366          A(30,7)  = -C303*(3.0-B43)/V(74)                                   00010210
   ISN 0367          A(30,51)= 1.0                                                      00010220
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TABLE A-1. (Continued)

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LEVEL 2  ( NOV 72 )            EVALAB          OS/360  FORTRAN H EXTENDED            DATE 73.264/19.53.40

      ISN 0368          B3031    = B(84)*V(9)                                                  00010230
      ISN 0369          C3031    = B(84)*V(11)                                                 00010240
      ISN 0370          A(30,54)= -B303-0.8*(B3031+C3031)/V(17)                                00010250
      ISN 0371          B3033    = 0.002/(1.0+0.002*V(77))                                     00010260
      ISN 0372          C3033    = 1.0/(V(84)-V(77))                                           00010270
      ISN 0373          D3033    = B(90)*(1.0+.002*V(77))*V(17)**0.8                           00010280
      ISN 0374          A(30,57)= -B3031*(B3033-C3033)-C3031*B3033+B(84)*(D3033+B(102)         00010290
                       1         *V(13))                                                       00010300
      ISN 0375          A(30,59)= -B3031*C3033                                                 00010310
      ISN 0376          A(30,61)= -B(84)*D3033                                                 00010320
      ISN 0377          A(30,63)= B(84)*B(102)*V(77)                                           00010330
      ISN 0378          A(31,52)= B(85)                                                        00010340
      ISN 0379          A(31,53)= 1.0                                                          00010350
      ISN 0380          A(31,54)= 2.0*B(85)*B(86)*V(17)                                        00010360
      ISN 0381          A(31,67)= -B(85)                                                       00010370
      ISN 0382          A(32,54)= -B(87)                                                       00010380
      ISN 0383          A(32,55)= 1.0                                                          00010390
      ISN 0384          A(32,63)= B(87)                                                        00010400
      ISN 0385          A(33,52)= -V(77)/V(50)                                                 00010410
      ISN 0386          A(33,56)= V(77)/V(94)                                                  00010420
      ISN 0387          A(33,57)= 1.0                                                          00010430
      ISN 0388          B3422    = B(92)*V(7)                                                  00010440
      ISN 0389          A(34,38)= -0.8*B3422/V(53)                                             00010450
      ISN 0390          B3423    = 1.0/(V(80)-V(84))                                           00010460
      ISN 0391          A(34,39)= -B3422*(B3423*V(156)-0.8*B2223)                              00010470
      ISN 0392          B3431    = B(92)*V(9)                                                  00010480
      ISN 0393          A(34,54)= 0.8*B3431/V(17)                                              00010490
      ISN 0394          A(34,57)= B3431*(B3033-C3033)                                          00010500
      ISN 0395          A(34,58)= 1.0                                                          00010510
      ISN 0396          A(34,59)= B3422*B3423+B3431*C3033                                      00010520
      ISN 0397          B3533    = B(93)*V(11)                                                 00010530
      ISN 0398          A(35,54)= 0.8*B3533/V(17)                                              00010540
      ISN 0399          A(35,57)= B3533*B3033-B(93)*D3033                                      00010550
      ISN 0400          A(35,60)= 1.0                                                          00010560
      ISN 0401          A(35,61)= B(93)*D3033                                                  00010570
      ISN 0402          A(36,52)= -B(94)                                                       00010580
      ISN 0403          B3632    = B(95)*V(13)**2/V(94)                                        00010590
      ISN 0404          A(36,56)= -B3632*B(94)/V(94)                                           00010600
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TABLE A-1. (Continued)

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LEVEL 2  ( NOV 72 )              EVALAB          OS/360  FORTRAN H EXTENDED                 DATE 73.264/19.53.40

   ISN 0405          A(36,62)= 1.0                                                    00010610
   ISN 0406          A(36,63)= 2.0*B(94)*B3632/V(13)                                  00010620
   ISN 0407          A(36,65)= B(94)                                                  00010630
   ISN 0408          A(37,27)= B(96)                                                  00010640
   ISN 0409          A(37,21)= B(96)                                                  00010650
   ISN 0410          A(37,63)= -B(96)                                                 00010660
   ISN 0411          A(37,64)= 1.0                                                    00010670
   ISN 0412          A(37,69)= -B(96)                                                 00010680
   ISN 0413          A(38,5) = -B(97)*B(110)                                          00010690
   ISN 0414          A(38,43)= B(97)                                                  00010710
   ISN 0415          A(38,54)= B(97)                                                  00010720
   ISN 0416          A(38,66)= 1.0                                                    00010730
   ISN 0417          A(38,69)= B(97)                                                  00010735
   ISN 0418          A(39,65)= B(98)                                                  00010740
   ISN 0419          A(39,67)= -B(98)                                                 00010750
   ISN 0420         B3939    = 2.0*B(98)*B(99)*(V(33)/V(1))**2                        00010760
   ISN 0421          A(39,68)= 1.0                                                    00010770
   ISN 0422          A(39,69)= B3939/V(33)                                            00010780
   ISN 0423          A(40,71)= V(79)/V(96)                                            00010790
   ISN 0424          A(40,65)= -V(79)/V(52)                                           00010800
   ISN 0425          A(40,70)= 1.0                                                    00010810
   ISN 0426         B4132    = V(96)/(V(13)+B(105)*V(94)*V(33))                       00010820
   ISN 0427          A(41,56)= -B4132*V(13)/V(94)                                     00010830
   ISN 0428         B4136    = V(96)/(V(33)+V(13))                                    00010840
   ISN 0429          A(41,63)= -B4136+B4132                                           00010850
   ISN 0430          A(41,69)= -B4136+B(105)*B4132*V(94)                              00010860
   ISN 0431          A(41,71) = 1.0                                                   00010862
   ISN 0432          A(42,8) = -B(115)                                                00010863
   ISN 0433          A(42,72)= 1.0                                                    00010868
   ISN 0434          A(42,75)= B(115)                                                 00010869
   ISN 0435          A(43,11)= B(116)                                                 00010870
   ISN 0436          A(43,12)= B(106)*B(116)                                          00010871
   ISN 0437          A(43,16)= B(116)                                                 00010872
   ISN 0438          A(43,36)= B(116)                                                 00010873
   ISN 0439          A(43,74)= 1.0                                                    00010874
   ISN 0440          A(43,73)= -B(116)                                                00010875
               C     KOLI DETERMINES WHICH ONE OF SEVEN INPUT  PARAMETERS IS USED.    00010880
               C PUT ZERO IN A-MATRIX INPUT COLUMN 76 FOR MULTIPLE INPUT RUNS         00010882
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LEVEL 2  ( NOV 72 )              EVALAB           OS/360  FORTRAN H EXTENDED              DATE 73.264/19.53.40

      ISN 0441          10 DO 100 J=1,43                                                       00010884
      ISN 0442         100 A(J,76)=0.0                                                         00010886
      ISN 0443             GO TO (11,12,13,14,15,16,17),KOLI                                   00010890
      ISN 0444          11 A(1,76) = SCALE                                                     00010900
      ISN 0445             GO TO 18                                                            00010910
      ISN 0446          12 A(5,76) = SCALE                                                     00010920
      ISN 0447             GO TO 18                                                            00010930
      ISN 0448          13 A(3,76) = 2.0*B(21)*B(22)*V(157)*V(22)**2/V(3)**3*SCALE             00010940
      ISN 0449             GO TO 18                                                            00010950
      ISN 0450          14 A(21,76)= B(65)*B2121*V(160)/V(4)*SCALE                             00010960
      ISN 0451             GO TO 18                                                            00010970
      ISN 0452          15 A(14,76)= B(52)*B1414*V(158)/V(2)*SCALE                             00010980
      ISN 0453             GO TO 18                                                            00010990
      ISN 0454          16 A(17,76)= 2.0*B(59)*B1717*V(159)/V(5)*SCALE                         00011000
      ISN 0455             GO TO 18                                                            00011010
      ISN 0456          17 A(39,76)= B3939*V(161)/V(1)*SCALE                                   00011020
                   C                                                                           00011030
                   C       PRINT INPUT COLUMN. PRINT MATRIX A IF INFLAG ISN'T TWO.             00011040
                   C                                                                           00011050
      ISN 0457          18 WRITE(6,19) KOLI,(A(I,76),I=1,43)                                   00011060
      ISN 0458          19 FORMAT('0INPUT COLUMN VECTOR FOR INPUT NUMBER',I3/(1P10E11.3))      00011070
      ISN 0459             WRITE(6,20) (IDV(J),J=1,76)                                         00011080
      ISN 0460          20 FORMAT('0COLUMN IDENTIFICATION VECTOR'/(' ',40I2))                  00011090
      ISN 0461             IF(INFLAG.EQ.123)      GO TO 28                                     00011100
      ISN 0463             WRITE(6,21)                                                         00011110
      ISN 0464          21 FORMAT('0MATRIX OF COEFFICIENTS')                                   00011120
      ISN 0465             DO 24 I=1,43                                                        00011150
      ISN 0466          24 WRITE(6,26) I,(A(I,J),J=1,75)                                       00011160
      ISN 0467          26 FORMAT(' EQUATION',I3/(1P10E11.3))                                  00011170
      ISN 0468          27 FORMAT('0A/A(CCV)='1PE11.3,' A/A(FPV)='E11.3,' A/A(MFV)='E11.3,     00011180
                          1' A/A(MOV)='E11.3,' A/A(OPV)='E11.3/' C*       ='E11.3,' DQ(TC4) ='00011190
                          2E11.3,' DQ(TC5) ='E11.3,' DQ(W14) ='E11.3,' DQ(W15) ='E11.3/        00011200
                          3' DQ(W24) =',E11.3,' DQ(W25) =',E11.3,' DW(4)   =',E11.3,           00011210
                          4' DW(5)   =',E11.3,' DW(CN)  =',E11.3/' DW(FI)  =',E11.3,           00011230
                          5' DW(FN)  =',E11.3,' DW(MC)  =',E11.3,' DW(OI)  =',E11.3,           00011240
                          6' DW(OS)  =',E11.3/' DW(CCV) =',E11.3,' DW(FD2) =',E11.3,           00011250
                          7' DW(FPF) =',E11.3,' DW(FPC) =',E11.3,' DW(FT1) =',E11.3/           00011260
                          8' DW(FT2) =',E11.3,' DW(MOV) =',E11.3,' DW(OPF) =',E11.3,           00011270
```

TABLE A-1. (Continued)


```
         9' DW(OPO) =',E11.3,' DW(OP3) =',E11.3/' DW(OT1) =',E11.3,
         A' DW(OT2) =',E11.3,' DW(FNBP)=',E11.3,' DW(FPOI)=',E11.3,
         B' DW(OPOI)=',E11.3/' DW(OTPR)=',E11.3,' E(FPO)  =',E11.3,
         C' E(OPO)  =',E11.3,' E(OT2S) =',E11.3,' E(TC)   =',E11.3/
         D' FT1S    =',E11.3,' FT2S    =',E11.3,' G(FI)   =',E11.3,
         E' GF2     =',E11.3,' G(O1)   =',E11.3/' G(O2)   =',E11.3,
         F' H(3)    =',E11.3,' H(4)    =',E11.3,' H(4)    =',E11.3,
         G' P(4)    =',E11.3/' P(5)    =',E11.3,' P(9)    =',E11.3,
         H' P(C)    =',E11.3,' P(CIES) =',E11.3,' P(FI)   =',E11.3/
         I' P(FP)   =',E11.3,' P(FS)   =',E11.3,' P(OI)   =',E11.3,
         J' P(OP)   =',E11.3,' P(OS)   =',E11.3)
ISN 0469     29 FORMAT(' P(OT)   =',1PE11.3,' P(FO1)  =',E11.3,' P(FO2)  =',E11.3,
         1' P(OD1)  =',E11.3,' P(OD2)  =',E11.3/' P(OD3)  =',E11.3,
         2' P(POS)  =',E11.3,' P(FPCI) =',E11.3,' P(MFVD) =',E11.3,
         3' P(OPOI) =',E11.3/' R(FP)   =',E11.3,' R(OP)   =',E11.3,
         4' S(F1)   =',E11.3,' S(F2)   =',E11.3,' S(O1)   =',E11.3/
         5' S(O2)   =',E11.3,' T(4)    =',E11.3,' T(5)    =',E11.3,
         6' T(9)    =',E11.3,' T(C)    =',E11.3/' T(FI)   =',E11.3,
         7' T(FP)   =',E11.3,' T(OP)   =',E11.3,' TW1(4)  =',E11.3,
         8' TW1(5)  =',E11.3/' TW2(4)  =',E11.3,' TW2(5)  =',E11.3,
         9' W(OI)   =',E11.3,' W(FPOI) =',E11.3,' W(OPOI) =',E11.3/
         A' ETA(FT1)=',E11.3,' ETA(FT2)=',E11.3,' ETA(OT2)=',E11.3,
         B' RHO(4)  =',E11.3,' RHO(5)  =',E11.3/' RHO(9)  =',E11.3,
         C' UP(FP1) =',E11.3,' UP(FP2) =',E11.3,' UP(FT1) =',E11.3,
         D' UP(FT2) =',E11.3/' UP(OP1) =',E11.3,' UP(OP2) =',E11.3,
         E' UP(OP3) =',E11.3,' UP(OT1) =',E11.3,' UP(OT2) =',E11.3/
         F' PHI(FP1)=',E11.3,' PHI(FP2)=',E11.3,' PHI(OP1)=',E11.3,
         G' PHI(OP2)=',E11.3,' PHI(OP3)=',E11.3/' PHI(OT1)=',E11.3,
         H' GM(EOL) =',E11.3,' GM(PFP1)=',E11.3,' GM(TFP1)=',E11.3,
         I' GM(TFT1)=',E11.3/' GM(PFP2)=',E11.3,' GM(TFP2)=',E11.3,
         J' GM(TFT2)=',E11.3,' GM(PCP1)=',E11.3,' GM(TOP1)=',E11.3)
ISN 0470     30 FORMAT(' GM(TOT1)=',1PE11.3,' GM(ROT1)=',E11.3,' GM(POP2)=',E11.3,
         1' GM(TOP2)=',E11.3,' GM(TCP3)=',E11.3/' GM(PCP3)=',E11.3,
         2' GM(TOT2)=',E11.3,' GM(FPV) =',E11.3,' GM(OPV) =',E11.3,
         3' GM(MOV) =',E11.3/' GM(MFV) =',E11.3,' GM(CCV) =',E11.3/
         4' PARTIAL DERIVATIVES'/' GM(PFP1)/PHI(FP1)   ='E11.3,
         5' GM(TFP1)/PHI(FP1)   ='E11.3,' GM(TFT1)/ETA(FT1)   ='E11.3/
         6' GM(TFT1)/P(FI)/P(5) ='E11.3,' GM(PFP2)/PHI(FP2)   ='E11.3,
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TABLE A-1. (Concluded)

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LEVEL 2  ( NOV 72 )            EVALAB          OS/360  FORTRAN H EXTENDED                 DATE 73.264/19.53.40

                          7' GM(TFP2)/PHI(FP2)   ='E11.3/' GM(TFT2)/ETA(FT2)   ='E11.3,        00011660
                          8' GM(TFT2)/P(FI)/P(FP)='E11.3,' GM(POP1)/PHI(OP1)   ='E11.3/        00011670
                          9' GM(TOT1)/PHI(OT1)   ='E11.3,' GM(TCP1)/PHI(OP1)   ='E11.3,        00011680
                          A' GM(ROT1)/PHI(CT1)   ='E11.3/' GM(PCP2)/PHI(OP2)   ='E11.3,        00011690
                          B' GM(TOP2)/PHI(OP2)   ='E11.3,' GM(TOP3)/PHI(OP3)   ='E11.3/        00011700
                          C' GM(TOT2)/ETA(CT2)   ='E11.3,' GM(TOT2)/P(FI)/P(OP)='E11.3,        00011710
                          D' GM(POP3)/PHI(OP3)   ='E11.3/' GM(T)/F(CP1         ='E11.3,        00011720
                          E' GM(PR)/P(FI)/P(OP)  ='E11.3,' GM(T)/F(CP)         ='E11.3/        00011730
                          F' GM(P)/P(FI)/P(FP)   ='E11.3,' GM(PR)/P(C)/P(FI)   ='E11.3,        00011740
                          G' GM(TR)/F(TC)        ='E11.3/' GM(MFV)/X/X(MFV)    ='E11.3,        00011750
                          H' GM(FPV)/X/X(FPV)    ='E11.3,' GM(OPV)/X/X(OPV)    ='E11.3/        00011760
                          I' GM(MOV)/X/X(MOV)    ='E11.3,' GM(CCV)/X/X(CCV)    ='E11.3/        00011770
                          J' DW(OS1) =',E11.3,' P(OS1)  ='E11.3)                                00011780
    ISN 0471                 INFLAG  = 123                                                      00011830
    ISN 0472              28 RETURN                                                             00011840
    ISN 0473              32 CALL EXIT                                                          00011845
    ISN 0474                 STOP                                                               00011847
    ISN 0475                 END                                                                00011850
```

APPENDIX B

DESCRIPTION OF THE SSME ENGINE FREQUENCY RESPONSE PROGRAM

INTRODUCTION

The SSME Frequency Response Program is based on a production routine developed by Rocketdyne for the purpose of providing frequency analysis of a system of linear equations containing nth order derivations and constant coefficients. The program has the capacity of handling 50 equations with 100 coefficients each, and produces tabulated values and graphic plots of the gain and phase as a function of log frequency for specified variables with respect to the input variable. The frequency range is under input control, and can be spread or clustered as required.

METHOD

The basic assumption is made that a linear system may be presented with only one input, Y,

$$\begin{bmatrix} a_{11}s^2 + b_{11}s + c_{11} \cdots\cdots, & c_{1n}s^2 + b_{1n}s + c_{1n} \\ \vdots & \vdots \\ a_{n1}s^2 + t_{n1}s + c_{n1} \cdots\cdots & a_{nn}s^2 + b_{nn}s + c_{nn} \end{bmatrix} \cdot \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} = \begin{bmatrix} a_1 s^2 + b_1 s + c_1 \\ \vdots \\ a_n s^2 + b_n s + c_n \end{bmatrix} \cdot Y$$

which may be written as:

$$[a_{ij}s^2 + b_{ij}s + c_{ij}] \cdot [x_j] = [a_i s^2 + b_i s + c_i] \quad \cdot Y$$

NOTE: The form $[a_{ij}s^2 + b_{ij}s + c_{ij}] \cdot [x_j] = [a_i s^2 + b_i s + c_i] \cdot Y$ is simply an arrangement of all equations so that only the independent variable (Y) and its derivations appear on the right-hand side of the equation; the arrangement may be performed on any linear system of equations.

(For simplicity, the Laplace operator, S = d/dt, of higher than second order, is not shown, although higher orders are allowed in the program.

If the Laplace operator is defined as $S = j\omega$, where $j = \sqrt{-1}$ and ω is the frequency, the coefficient matrix may be rearranged to provide a real matrix and an imaginary matrix:

$$\left\{\left[-a_{ij}\omega^2 + c_{ij}\right] + j\omega\left[b_{ij}\right]\right\}\cdot\left[x_j\right] = \left\{\left[-a_i\omega^2 + c_i\right] + j\omega\left[b_i\right]\right\}\cdot Y$$

Values specified for frequency (ω) are then inserted [as requested by input cards] and the system is solved by a complex Gaussian elimination subroutine (COGAEL). The solutions for specified dependent variables at all required frequencies are the output of the program. The output contains (1) the values of all dependent variables at the lowest of the input frequencies (magnitude and phase), (2) values of specified dependent variables at each input frequency (db and phase), and (3) graphic plots of db and phase versus log frequency for the specified variables.

It should be noted that the values of the independent variables are normalized to a unit value of the input variable. That is if the frequency response of pump discharge flowrate (units of lb/sec) is determined with pump suction pressure as an input (lb/in.^{2}), the units of the variation in flow will be "x" lb/sec per psi. In this case, the term "db" is taken to be 20 log(x) where x is the peak-to-peak value of the output divided by the peak-to-peak value of the input with units as stated in the nomenclature list.

LANGUAGE

The program is written in the FORTRAN IV computer language. Graphical output is based on the Rockwell International S-C 4020 Simulation Routines which utilize a Stromberg-Data graphics S-C 4020 output device.

Reference to these routines may be found in Engineers' Computing Manual, Volume II, Section 225, System 360/FORTRAN, published by Rockwell International.

Listings of the frequency response program and subroutines COGAEL (the complex Gaussian elimination program) and TDPLOT (a plotting subroutine which interfaces with the S-C 4020) are included in this appendix (Table B-1 through B-3).

The coefficients for the frequency response program are dependent on the values used in the engine balance. An additional subroutine computes these values and is discussed in Appendix A.

Insertion of Data

The data input cards and their formats are presented in Fig. B-1. The format is self explanatory. The values required in namelist "V" are obtained from engine balance information. A set of values for the current 109 percent engine balance is shown in Table 2.

Restrictions of the Frequency Response Program

The following are the program restrictions:

1. The program using logarithmic frequency spacing will generate up to 8 decades plus 3 frequencies or a maximum of 60 frequencies.
2. The total number of frequencies input as spare frequencies plus those implied by the initial-final frequency range values cannot exceed 60. Zero is an illegal value for frequency.
3. A maximum of 50 equations and 100 columns (including the input column) can be solved with the present dimension statements. To ensure economical as well as accurate evaluation of the equation sets it is necessary to minimize the number of equations. (In this SSME engine evaluation, 95 equations were reduced to 43 by eliminating variables which were

algebraic and/or would not be measurable quantities in the engine test program. By algebraic elimination of these variables, the system effects remain, but the cost and accuracy of solution is improved.)

4. The data sheets must be filled out exactly as shown for the example shown in Fig. B-1. Numbers which are written with no decimal point are being read into an "I" format. These numbers must be positioned exactly as shown in the sample problem. Numbers which do contain a decimal point are being read in with an "12.0" format. These numbers can be positioned anywhere on the line in which they are written, provided a decimal point is supplied.

TABLE B-1. FREQUENCY RESPONSE ROUTINE

```
LEVEL 2  ( NOV 72 )                          OS/360  FORTRAN H EXTENDED                    DATE 73.264/19.53.01

REQUESTED OPTIONS: MAP,DECK,LIST,XREF,OPT=2

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(2) LINECOUNT(40) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC LIST DECK OBJECT MAP NOFORMAT GOSTMT XREF ALC NOANSF NOTERMINAL FLAG(I)

                C       FREQUENCY RESPONSE ROUTINE                                                   00000030
      ISN 0002          DIMENSION  OM(60),     OMSCPS(60),W(60),      CMS(60),    ID(200),           00000040
                       1           CP(50,102),LXI(3),      II(3),       JI(3),      C7(3),            00000045
                       2           C(50,200), TITLE(18), D(100),      XMAG(50),   NO(50),            00000050
                       3           XREAL(50), XIMAG(50), GAIN(60),    FAZE(60),   VARR(50),          00000060
                       4           VARI(50),  IDF(18),   PHAN(50,60),DECB(50,60)                     00000070
      ISN 0003          COMMON ICRT,C,ID  /EVAL/ TITLE                                               00000090
      ISN 0004          DELTA(Q001FL) =1.0 -ABS(Q001FL)/AMAX1(ABS(Q001FL),.146936794E-38) 00000100
      ISN 0005          UNIT(Q002FL) =0.5 + SIGN( 0.5,DELTA(Q002FL) + Q002FL*(1.0-DELTA(Q000000110
                       102FL)))                                                                      00000120
      ISN 0006          THETA(Q003FL,Q004FL) =(180.0*(1.0+UNIT(Q003FL)*(1.0-2.0*UNIT(Q004F00000130
                       1L)))+ SIGN(1.0,Q003FL*Q004FL)*  ATAN(((ABS(Q004FL)*(1.0-DELTA(Q00300000140
                       2FL))))/(ABS(Q003FL)+DELTA(Q003FL)))*(180.0/3.141593)) * (1.0-DELTA00000150
                       3(Q003FL))+ 180.0*DELTA(Q003FL)*(1.0-DELTA(Q004FL))*(.5 +UNIT(-Q00400000160
                       4FL))                                                                         00000170
      ISN 0007        1 READ(5,2)  TITLE                                                             00000180
      ISN 0008        2 FORMAT(18A4)                                                                 00000190
                C       IS NECESSARY TO ZERO MATRIX STORAGE SPACE                                    00000200
      ISN 0009       10 DO      2004                KK = 1, 50                                       00000210
      ISN 0010          DO 2001 LL=1,102                                                             00000220
      ISN 0011     2001 CP(KK,LL)=0.0                                                                00000230
      ISN 0012          DO 2002 LL=1,200                                                             00000250
      ISN 0013     2002 C(KK,LL)=0.0                                                                 00000260
      ISN 0014          DO 2004 LL=1,60                                                              00000310
      ISN 0015          PHAN(KK,LL)=0.0                                                              00000320
      ISN 0016     2004 DECB(KK,LL)=0.0                                                              00000330
      ISN 0017          READ(5,120)NW,NR,ICRT,KEQ,TRIG,IRPS,CMI,CMFL                                 00000340
      ISN 0018      120 FORMAT(I12,I12,I3,I9,F2.0,I10,2F12.0)                                        00000350
      ISN 0019          IF( NW .EQ. 0 )                 GO TO  1218                                  00000360
      ISN 0021          IF( NW .LE. 60 )                GO TO  1216                                  00000370
      ISN 0023          WRITE(6,122)                                                                 00000380
      ISN 0024      122 FORMAT(1H-, 'NUMBER OF SHUFFLED IN FREQUENCIES EXCEEDS 60')                  00000390
      ISN 0025          GO TO 9                                                                      00000400
```

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TABLE B-1. (Continued)

```
LEVEL 2 ( NOV 72 )                 MAIN          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.01

    ISN 0026       1216 READ(5,121)  (W(I), I=1,NW)                                         00000410
    ISN 0027        121 FORMAT(6F12.0)                                                      00000420
    ISN 0028       1218 IF( NR .LE. 200 )                      GO TO  1220                  00000430
    ISN 0030            WRITE(6,123)                                                        00000440
    ISN 0031        123 FORMAT(30H-NUMBER OF COLUMNS EXCEEDS 200)                           00000450
    ISN 0032            GO TO 9                                                             00000460
    ISN 0033       1220 CALL EVALAB                                                         00000470
    ISN 0034            IF(NSKIP.EQ.1234)      GO TO 60                                     00000480
    ISN 0036            IF( KEQ .LE. 50 )                      GO TO  1222                  00000490
    ISN 0038            WRITE(6,124)                                                        00000500
    ISN 0039        124 FORMAT(5X,'NUMBER OF EQUATIONS EXCEEDS 50')                         00000510
    ISN 0040            GO TO 9                                                             00000520
    ISN 0041       1222 IF( OMI )                              1666, 3, 1675                00000530
    ISN 0042          3 WRITE (6,115)                                                       00000540
    ISN 0043        115 FORMAT(' INITIAL FREQUENCY IS ZERO')                                00000545
    ISN 0044            GO TO 9                                                             00000550
    ISN 0045       1666 OMI=ABS(OMI)                                                        00000560
    ISN 0046       1667 OM(1)=OMI                                                           00000570
    ISN 0047            J=2                                                                 00000580
    ISN 0048       1668 OM(J)=2.0*OM(J-1)                                                   00000590
    ISN 0049            IF( OM(J) .GE. OMFL )                  GO TO  1670                  00000600
    ISN 0051            J = J+1                                                             00000610
    ISN 0052            GO TO 1668                                                          00000620
    ISN 0053       1670 OM(J)=OMFL                                                          00000630
    ISN 0054            NOM=J                                                               00000640
    ISN 0055            GO TO 17                                                            00000650
    ISN 0056       1675 J=1                                                                 00000660
    ISN 0057            N=0                                                                 00000670
    ISN 0058            M=-1                                                                00000680
    ISN 0059            T=-1.0                                                              00000690
    ISN 0060            R=0.1                                                               00000700
    ISN 0061          4 IF( OMI .GE. R )                       GO TO     8                  00000720
    ISN 0063            M = M - 1                                                           00000730
    ISN 0064            R=R/10.0                                                            00000740
    ISN 0065            GO TO 4                                                             00000750
    ISN 0066          8 K=1                                                                 00000760
                  C     NEW CARD--INITIALIZATION OF L                                       00000770
    ISN 0067            L=0                                                                 00000780
```

TABLE B-1. (Continued)


```
ISN 0068    12 OM(J)=UNIT(T)*(((2.0**L)*3.0*10.0**M)/2.0)+UNIT(-T)*(2.0**L)*10.0*
              1*M
ISN 0069       IF(T)24,24,23
ISN 0070    23 L=L+1
ISN 0071    24 T=-T
ISN 0072       IF(L-3)26,27,25
ISN 0073    27 IF(T)26,26,25
ISN 0074    25 L=0
ISN 0075       T=-1.0
ISN 0076       M=M+1
ISN 0077    26 GO TO(11,16),K
ISN 0078    11 IF(OM(1)-OMI)12,15,13
ISN 0079    13 OM(2)=OM(1)
ISN 0080       OM(1)=OMI
ISN 0081       J=3
ISN 0082       K=2
ISN 0083       GO TO 12
ISN 0084    15 OM(1)=OMI
ISN 0085       K=2
ISN 0086    16 J=J+1
ISN 0087       IF(OM(J-1)-OMFL)12,18,18
ISN 0088    18 OM(J-1)=OMFL
ISN 0089       NOM=J-1
ISN 0090    17 J=1
ISN 0091       IF(NW)28,28,29
ISN 0092    28 OMS(J)=OM(J)
ISN 0093       IF(OMS(J)-OMFL)30,32,32
ISN 0094    30 J=J+1
ISN 0095       IF(J-60)28,28,45
ISN 0096    29 N=0
ISN 0097       I=1
ISN 0098    35 K=J+N
ISN 0099       IF(OM(J)-W(I))20,34,34
ISN 0100    20 IF(J-NOM)33,33,34
ISN 0101    33 OMS(K)=OM(J)
ISN 0102       J=J+1
ISN 0103       GO TO 35
ISN 0104    34 OMS(K)=W(I)
```

TABLE B-1. (Continued)

```
LEVEL 2  ( NOV 72 )                MAIN          OS/360  FORTRAN H EXTENDED           DATE 73.264/19.53.01

ISN 0105           N=N+1                                                              00001170
ISN 0106           IF(I-NW)36,37,37                                                   00001180
ISN 0107       37  IF(J-NOM)31,31,380                                                 00001190
ISN 0108       31  W(I)=OMFL                                                          00001200
ISN 0109           GO TO 38                                                           00001210
ISN 0110       36  I=I+1                                                              00001220
ISN 0111           IF(J-NOM)38,38,35                                                  00001230
ISN 0112       38  IF(OMS(K)-OMFL)35,32,32                                            00001240
ISN 0113      380  OMFL=OMS(K)                                                        00001250
ISN 0114           IF(K-60)32,32,45                                                   00001260
ISN 0115       45  WRITE (6,117)                                                      00001270
ISN 0116      117  FORMAT(37H1THE NUMBER OF FREQUENCIES EXCEEDS 60)                   00001280
ISN 0117           GO TO 9                                                            00001290
ISN 0118       32  J=1                                                                00001300
ISN 0119      431  IF(IRPS)432,432,43                                                 00001310
ISN 0120      432  OMFLC=OMFL                                                         00001320
ISN 0121           OMFL=2.0*3.1415927*OMFL                                            00001330
ISN 0122       43  IF(IRPS)39,39,40                                                   00001340
ISN 0123       39  OMSCPS(J)=OMS(J)                                                   00001350
ISN 0124           OMS(J)=2.0*3.1415927*OMSCPS(J)                                     00001360
ISN 0125           GO TO 41                                                           00001370
ISN 0126       40  OMSCPS(J)=OMS(J)/(2.0*3.1415927)                                   00001380
ISN 0127       41  IF(OMS(J)-OMFL)        42,60,60                                    00001390
ISN 0128       42  J=J+1                                                              00001400
ISN 0129           GO TO 43                                                           00001410
ISN 0130       60  IW=1                                                               00001580
ISN 0131           KEJ=KEQ+1                                                          00001590
ISN 0132       75  DO 662 J=1,KEQ                                                     00001750
ISN 0133           IJ=J+KEQ                                                           00001760
ISN 0134           LS=0                                                               00001770
ISN 0135           LK=0                                                               00001780
ISN 0136           LF=0                                                               00001790
ISN 0137           DO 320 I=1,NR                                                      00001800
ISN 0138           IF(LK)7,62,610                                                     00001810
ISN 0139       62  IF(KEQ-LF)64,64,65                                                 00001820
ISN 0140       65  LF=LF+1                                                            00001830
ISN 0141           IM=KEQ+LF                                                          00001840
ISN 0142       67  IR=I+LS                                                            00001850
```

TABLE B-1. (Continued)

```
LEVEL 2  ( NOV 72 )                MAIN          OS/360  FORTRAN H EXTENDED                DATE 73.264/19.53.01

     ISN 0143             IF(ID(IR))69,68,69                                                      00001860
     ISN 0144          68 LS=LS+1                                                                 00001870
     ISN 0145             GO TO 67                                                                00001880
     ISN 0146          69 II=IR-1                                                                 00001890
     ISN 0147             LK=LS                                                                   00001900
     ISN 0148             CREAL=0.0                                                               00001910
     ISN 0149             CIMAG=0.0                                                               00001920
     ISN 0150             R=1.0                                                                   00001930
     ISN 0151             S=0.0                                                                   00001940
     ISN 0152             LS=LS+1                                                                 00001950
     ISN 0153          55 CREAL=CREAL + R*C(J,IR)*(OMS(IW)**S)                                    00001960
     ISN 0154             LS=LS-1                                                                 00001970
     ISN 0155             IF(LS)7,57,56                                                           00001980
     ISN 0156          56 CIMAG=CIMAG+R*C(J,II)*(OMS(IW)**(S+1.0))                                00001990
     ISN 0157             S=S+2.0                                                                 00002000
     ISN 0158             R=(-1.0)*R                                                              00002010
     ISN 0159             IR=IR-2                                                                 00002020
     ISN 0160             II=II-2                                                                 00002030
     ISN 0161             LS=LS-1                                                                 00002040
     ISN 0162             IF(LS)7,57,55                                                           00002050
     ISN 0163          57 CP(J,LF)=CREAL                                                          00002060
     ISN 0164             CP(J,IM)=CIMAG                                                          00002070
     ISN 0165             GO TO 61                                                                00002080
     ISN 0166          64 IR=I+LS                                                                 00002090
     ISN 0167             IF(ID(IR))70,71,70                                                      00002100
     ISN 0168          71 LS=LS+1                                                                 00002110
     ISN 0169             GO TO 64                                                                00002120
     ISN 0170          70 II=IR-1                                                                 00002130
     ISN 0171             LK=LS                                                                   00002140
     ISN 0172             DREAL=0.0                                                               00002150
     ISN 0173             DIMAG=0.0                                                               00002160
     ISN 0174             R=1.0                                                                   00002170
     ISN 0175             S=0.0                                                                   00002180
     ISN 0176             LS=LS+1                                                                 00002190
     ISN 0177         772 DREAL=DREAL+R*C(J,IR)*(OMS(IW)**S)                                      00002200
     ISN 0178             LS=LS-1                                                                 00002210
     ISN 0179             I=I+1                                                                   00002220
     ISN 0180             IF(LS)7,63,773                                                          00002230
```

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TABLE B-1. (Continued)

```
LEVEL 2  ( NOV 72 )                MAIN          OS/360  FORTRAN H EXTENDED              DATE 73.264/19.53.01

      ISN 0181        773 DIMAG=DIMAG+R*C(J,II)*(OMS(IW)**(S+1.0))                        00002240
      ISN 0182            S=S+2.0                                                          00002250
      ISN 0183            R=(-1.0)*R                                                       00002260
      ISN 0184            IR=IR-2                                                          00002270
      ISN 0185            II=II-2                                                          00002280
      ISN 0186            LS=LS-1                                                          00002290
      ISN 0187            IF(LS)7,63,772                                                   00002300
      ISN 0188         63 D(J)=DREAL                                                       00002310
      ISN 0189            D(IJ)=DIMAG                                                      00002320
      ISN 0190            GO TO 61                                                         00002330
      ISN 0191          7 WRITE (6,116)                                                    00002340
      ISN 0192        116 FORMAT(24H LS HAS A NEGATIVE VALUE)                              00002350
      ISN 0193            GO TO 9                                                          00002360
      ISN 0194        610 LK=LK-1                                                          00002370
      ISN 0195         61 CONTINUE                                                         00002380
      ISN 0196        320 CONTINUE                                                         00002390
      ISN 0197        662 CONTINUE                                                         00002400
      ISN 0198            IF(IW-1)303,303,305                                              00002710
      ISN 0199        303 WRITE (6,323)                                                    00002720
      ISN 0200            DO 304 I=1,KEQ                                                   00002730
      ISN 0201            IJ=I+KEQ                                                         00002740
      ISN 0202        304 WRITE (6,321) I,D(I),D(IJ),(CP(I,J),CP(I,J+KEQ),J=1,KEQ)         00002750
      ISN 0203        305 CONTINUE                                                         00002759
                    C                                                                      00002760
                    C     ADD D-VECTOR TO CP-MATRIX. SHIFT COLUMNS OF IMAG CP BY 1 TO RIGHT.00002761
                    C     REAL D INTO COL. KEQ+1. IMAG D INTO COL. 2KEQ+2.                 00002762
                    C                                                                      00002763
      ISN 0204            DO 202 I = 1,KEQ                                                 00002770
      ISN 0205            IN = 2*KEQ + 1 - I                                               00002775
      ISN 0206            INP1 = IN + 1                                                    00002780
      ISN 0207            DO 202 J = 1,KEQ                                                 00002785
      ISN 0208            CP(J,INP1) = CP(J,IN)                                            00002790
      ISN 0209        202 CONTINUE                                                         00002795
      ISN 0210            IN = KEQ + 1                                                     00002800
      ISN 0211            INN = 2*KEQ + 2                                                  00002805
      ISN 0212            DO 203 J = 1,KEQ                                                 00002810
      ISN 0213            CP(J,IN) = D(J)                                                  00002815
      ISN 0214            JN = J + KEQ                                                     00002820
```

TABLE B-1. (Continued)

```
LEVEL 2  ( NOV 72 )              MAIN          OS/360  FORTRAN H EXTENDED          DATE 73.264/19.53.01

  ISN 0215          CP(J,INN) = D(JN)                                                       00002825
  ISN 0216      203 CONTINUE                                                                00002830
              C                                                                             00002835
              C     CALL COGAEL TO TRIANGULARIZE THE COMPLEX MATRIX BY GAUSS. ELIMIN.       00002836
              C                                                                             00002837
  ISN 0217          CALL COGAEL(CP,KEQ)                                                     00002840
              C                                                                             00002845
              C     BACK SUBSTITUTE TO DETERMINE REAL AND IMAGINARY PART OF VARIABLES,      00002846
              C     THEN DETERMINE MAGNITUDE AND PHASE.                                     00002847
              C                                                                             00002848
  ISN 0218          NP1 = KEQ + 1                                                           00002855
  ISN 0219          NNP1 = 2*NP1                                                            00002860
  ISN 0220          XREAL(KEQ) = CP(KEQ,NP1)                                                00002865
  ISN 0221          XIMAG(KEQ) = CP(KEQ,NNP1)                                               00002870
  ISN 0222          XMAG(KEQ) = SQRT(XREAL(KEQ)**2 + XIMAG(KEQ)**2)                         00002871
  ISN 0223          FAZE(KEQ) = THETA(XREAL(KEQ),XIMAG(KEQ))                                00002872
  ISN 0224          DO 205 J = 2,KEQ                                                        00002875
  ISN 0225          JJ = KEQ - J + 1                                                        00002880
  ISN 0226          JJP1 = JJ + 1                                                           00002885
  ISN 0227          SUMR = 0.0                                                              00002890
  ISN 0228          SUMI = 0.0                                                              00002895
  ISN 0229          DO 206 K = JJP1,KEQ                                                     00002900
  ISN 0230          KN = K + KEQ + 1                                                        00002905
  ISN 0231          SUMR = SUMR + CP(JJ,K)*XREAL(K) - CP(JJ,KN)*XIMAG(K)                    00002910
  ISN 0232          SUMI = SUMI + CP(JJ,KN)*XREAL(K) + CP(JJ,K)*XIMAG(K)                    00002915
  ISN 0233      206 CONTINUE                                                                00002920
  ISN 0234          XREAL(JJ) = CP(JJ,NP1) - SUMR                                           00002925
  ISN 0235          XIMAG(JJ) = CP(JJ,NNP1) - SUMI                                          00002930
  ISN 0236          XMAG(JJ) = SQRT(XREAL(JJ)**2 + XIMAG(JJ)**2)                            00002935
  ISN 0237      205 FAZE(JJ) = THETA(XREAL(JJ),XIMAG(JJ))                                   00002940
  ISN 0238          IF (IW - 1) 82,82,83                                                    00002945
  ISN 0239       82 CONTINUE                                                                00002950
  ISN 0240          WRITE (6,52)OMS(1),(I,XMAG(I),FAZE(I),I=1,KEQ)                          00002960
  ISN 0241       52 FORMAT(67H1                          VARIABLE MAGNITUDES USING A FREQ00002970
                   1UENCY OF      1PE14.6,5H RPS./   1H0 84H                      VARIABL00002980
                   2E NUMBER               MAGNITUDE                    PHASE /(1H0 I2000002990
                   37,1P2E30.6))                                                            00003000
  ISN 0242          IF(TRIG)770,770,771                                                     00003040
```

TABLE B-1. (Continued)

```
LEVEL 2  ( NOV 72 )                MAIN          OS/360  FORTRAN H EXTENDED              DATE 73.264/19.53.01

   ISN 0243        770 WRITE (6,1001)                                                                00003050
   ISN 0244       1001 FORMAT(70 H1 THESE ARE INTERMEDIATE RESULTS PRODUCED AFTER EACH MA00003060
                      1TRIX INVERSION./53H0INPUT FREQUENCY IN RADIANS/SECOND AND CYCLES/S00003070
                      2ECOND./59H0         VARIABLE,GAIN(DB),PHASE(DEGREES)       VARIABLE,E00003080
                      3TC. )                                                                         00003090
   ISN 0245        323 FORMAT(37H1INITIAL VALUES OF COEFFICIENT MATRIX)                              00003100
   ISN 0246        321 FORMAT(//9H EQUATION,I3,5X,5HINPUT,1P2E17.3/(1P10E11.3))                      00003110
   ISN 0247        771 IV=1                                                                          00003130
   ISN 0248            J=1                                                                           00003140
   ISN 0249            DO 78 I=1,NR                                                                  00003150
   ISN 0250            IF(ID(I))79,80,81                                                             00003160
   ISN 0251         79 IV=IV+1                                                                       00003170
   ISN 0252         80 GO TO 78                                                                      00003180
   ISN 0253         81 NO(J)=IV                                                                      00003190
   ISN 0254            IV=IV+1                                                                       00003200
   ISN 0255            J=J+1                                                                         00003210
   ISN 0256         78 CONTINUE                                                                      00003220
   ISN 0257            NOPRT=J-1                                                                     00003230
   ISN 0258         83 DO 84 K=1,NOPRT                                                               00003240
   ISN 0259            JX=NO(K)                                                                      00003250
   ISN 0260            VARR(K) = XREAL(JX)                                                           00003330
   ISN 0261            VARI(K) = XIMAG(JX)                                                           00003340
   ISN 0262         84 CONTINUE                                                                      00003350
   ISN 0263         86 DO 87 I=1,NOPRT                                                               00003360
   ISN 0264         90 PHAN(I,IW)=THETA(VARR(I),VARI(I))                                             00003420
   ISN 0265         96 DECB(I,IW)=20.0*ALOG10(AMAX1(1.0E-30,SQRT(VARR(I)**2+VARI(I)**2)))00003510
   ISN 0266         87 CONTINUE                                                                      00003515
   ISN 0267            IF(TRIG)960,960,961                                                           00003520
   ISN 0268        960 WRITE (6,1000)OMS(IW),OMSCPS(IW),(NO(NOW),DECB(NOW,IW),PHAN(NOW,IW00003530
                      1),NOW=1,NOPRT)                                                                00003540
   ISN 0269       1000 FORMAT(//F20.4,F20.5//(I4,F8.2,F7.1,I4,F8.2,F7.1,I4,F8.2,F7.1,I4,F00003550
                      18.2,F7.1,I4,F8.2,F7.1))                                                       00003560
   ISN 0270        961 IF(OMS(IW)-OMFL)85,95,95                                                      00003570
   ISN 0271         85 IW=IW+1                                                                       00003580
   ISN 0272            GO TO 75                                                                      00003590
   ISN 0273         95 CONTINUE                                                                      00003600
   ISN 0274         53 FORMAT(21H1      FREQUENCY        5(13H    VARIABLE  I2,3H    )/21H0   00003610
                      1RPS       CPS       5(18H  DECIBELS   PHASE )/)                               00003620
```

TABLE B-1. (Continued)

```
LEVEL 2  ( NOV 72 )              MAIN          OS/360  FORTRAN H EXTENDED            DATE 73.264/19.53.01

   ISN 0275         54 FORMAT(1P2E10.2,5(2H / 0P2F8.2))                                      00003630
   ISN 0276            NZ=5                                                                  00003640
   ISN 0277            NY=1                                                                  00003650
   ISN 0278            NX=NOPRT                                                              00003660
   ISN 0279         97 IF(NX)100,100,98                                                      00003670
   ISN 0280         98 WRITE (6,53)(NC(I),I=NY,NZ)                                           00003680
   ISN 0281            DO 99 J=1,IW                                                          00003690
   ISN 0282            WRITE (6,54)(OMS(J),OMSCPS(J),(DECB(K,J),PHAN(K,J),K=NY,NZ))          00003700
   ISN 0283         99 CONTINUE                                                              00003710
   ISN 0284            NY=NY+5                                                               00003720
   ISN 0285            NZ=NZ+5                                                               00003730
   ISN 0286            NX=NX-5                                                               00003740
   ISN 0287            GO TO 97                                                              00003750
   ISN 0288        100 IW2=IW+2                                                              00003757
   ISN 0289            DO 400 J=1,NOPRT                                                      00003760
   ISN 0290            DO 102 K=1,IW2                                                        00003770
   ISN 0291            GAIN(K)=DECB(J,K)                                                     00003780
   ISN 0292            FAZE(K)=PHAN(J,K)                                                     00003790
   ISN 0293        102 CONTINUE                                                              00003800
   ISN 0294            IF(IRPS)104,104,103                                                   00003810
   ISN 0295        103 L=1                                                                   00003815
   ISN 0296            CALL TOPLOT(OMS,GAIN,IW,CMI,CMFL,L )                                  00003820
   ISN 0297            CALL PRINTV(-21,21H GAIN IN DECIBELS      , 400, 470)                 00003830
   ISN 0298            CALL PRINTV(-21,21H FREQUENCY IN RADIANS,400,005)                     00003840
   ISN 0299            L=2                                                                   00003845
   ISN 0300            CALL TOPLOT(OMS,FAZE,IW,CMI,CMFL,L )                                  00003850
   ISN 0301            CALL PRINTV(-21,21H PHASE IN DEGREES      ,400,995)                   00003870
   ISN 0302            GO TO 105                                                             00003880
   ISN 0303        104 L=1                                                                   00003885
   ISN 0304            CALL TOPLOT(OMSCPS,GAIN,IW,CMI,CMFLC,L )                              00003890
   ISN 0305            CALL PRINTV(-21,21H GAIN IN DECIBELS      , 400, 470)                 00003900
   ISN 0306            CALL PRINTV(-21,21H FREQUENCY IN CPS      ,400,005)                   00003910
   ISN 0307            L=2                                                                   00003915
   ISN 0308            CALL TOPLOT(OMSCPS,FAZE,IW,CMI,CMFLC, L )                             00003920
   ISN 0309            CALL PRINTV(-21,21H PHASE IN DEGREES      ,400,995)                   00003930
   ISN 0310        105 CALL PRINTV(-21,20H VARIABLE NUMBER      ,400,1010)                   00003940
   ISN 0311            PNO=NO(J)                                                             00003942
   ISN 0312            CALL LABLV (PNO,560,1010,4,2,3)                                       00003944
```

TABLE B-1. (Concluded)

```
LEVEL 2  ( NOV 72 )              MAIN            OS/360  FORTRAN H EXTENDED              DATE 73.264/19.53.01

   ISN 0313        400 CONTINUE                                                                  00003959
   ISN 0314            NSKIP    = 1234                                                           00004010
   ISN 0315            GO TO 1220                                                                00004020
   ISN 0316          9 CALL EXIT                                                                 00004030
   ISN 0317            STOP                                                                      00004040
   ISN 0318            END                                                                       00004050
```

TABLE B-2. SUBROUTINE COGAEL

```
LEVEL 2  ( NOV 72 )                       OS/360  FORTRAN H EXTENDED          DATE 73.264/09.00.11

REQUESTED OPTIONS: MAP,DECK,LIST,XREF,OPT=2

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(2) LINECOUNT(40) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC LIST DECK OBJECT MAP NOFORMAT GOSTMT XREF ALC NOANSF NOTERMINAL FLAG(I)

  ISN 0002               SUBROUTINE COGAEL(A,N)
  ISN 0003               DIMENSION A(50,102)
                   C
                   C     GAUSSIAN ELIMINATION OF COMPLEX MATRIX.
                   C
  ISN 0004               NM1 = N - 1
  ISN 0005               NP1 = N + 1
  ISN 0006               ZZ = 10.0E-30
                   C
                   C     J IS THE COLUMN BEING ELIMINATED BELOW THE DIAGONAL.
                   C
  ISN 0007               DO      500                      J = 1, N
                   C
                   C     FIND MAXIMUM AMPLITUDE IN COLUMN AND BELOW THE DIAGONAL.
                   C
  ISN 0008               JMAX = J
  ISN 0009               JJ = J + NP1
  ISN 0010               CMAX = A(J,J)**2 + A(J,JJ)**2
  ISN 0011               JP1 = J + 1
  ISN 0012               IF( J - N )                      100, 145, 120
  ISN 0013           100 DO      110                      K = JP1, N
  ISN 0014               CCC = A(K,J)**2 + A(K,JJ)**2
  ISN 0015               IF( CCC .LE. CMAX )              GO TO   110
  ISN 0017               JMAX = K
  ISN 0018               CMAX = CCC
  ISN 0019           110 CONTINUE
                   C
                   C     INTERCHANGE ROWS IF REQUIRED TO OBTAIN MAXIMUM PIVOTAL ELEMENT.
                   C
  ISN 0020               IF( J - JMAX )                   130, 145, 120
  ISN 0021           120 WRITE(6,5)  J, JMAX
  ISN 0022             5 FORMAT('1 ERROR IN SUBROUTINE ** COGAEL **'/10X,'J AND JMAX EQUAL,
                        1 RESPECTIVE,'2I12)
```

TABLE B-2. (Continued)

```
LEVEL 2  ( NOV 72 )             COGAEL          OS/360  FORTRAN H EXTENDED                    DATE 73.264/09.00.11

    ISN 0023            CALL EXIT                                                                    C0003300
    ISN 0024        130 DO       140                    K = J, NP1                                   C0003400
    ISN 0025            KN = K + NP1                                                                 C0003500
    ISN 0026            HOLD = A(J,K)                                                                C0003600
    ISN 0027            A(J,K) = A(JMAX,K)                                                           C0003700
    ISN 0028            A(JMAX,K) = HOLD                                                             C0003800
    ISN 0029            HOLD = A(J,KN)                                                               C0003900
    ISN 0030            A(J,KN) = A(JMAX,KN)                                                         C0004000
    ISN 0031        140 A(JMAX,KN) = HOLD                                                            C0004100
                  C                                                                                  C0004300
                  C     DIVIDE PIVOT ROW BY PIVOT ELEMENT. PIVOT ELEMENT BECOMES 1.0.                C0004400
                  C                                                                                  C0004500
    ISN 0032        145 DO       160                    K = JP1, NP1                                 C0004700
    ISN 0033            KN = K + NP1                                                                 C0004800
    ISN 0034            IF( ABS(A(J,J)) .GT. ZZ )        GO TO   150                                 C0004900
    ISN 0036            IF( ABS(A(J,JJ)) .GT.ZZ )        GO TO   150                                 C0005000
    ISN 0038            DUM1 = A(J,J)                                                                C0005100
    ISN 0039            DUM2 = A(J,JJ)                                                               C0005200
    ISN 0040            WRITE(6,10)  DUM1,DUM2                                                       C0005300
    ISN 0041         10 FORMAT('1 MATRIX IS SINGULAR. EXIT FROM COGAEL. THE PIVOT ELEMENTSC0005400
                       1 ARE,' 1P2E13.6)                                                             C0005500
    ISN 0042            CALL EXIT                                                                    C0005600
    ISN 0043        150 REALA = (A(J,K)*A(J,J) + A(J,KN)*A(J,JJ)) / CMAX                             C0005700
    ISN 0044            VIMAG = (A(J,KN)*A(J,J) - A(J,K)*A(J,JJ))/CMAX                               C0005800
    ISN 0045            A(J,K) = REALA                                                               C0005900
    ISN 0046        160 A(J,KN) = VIMAG                                                              C0006000
                  C                                                                                  C0006200
                  C     ELIMINATE ELEMENTS BELOW DIAGONAL. THE ELEMENTS ELIMINATED ARE NOTC0006300
                  C     THEMSELVES CALCULATED.                                                       C0006400
                  C                                                                                  C0006500
    ISN 0047            IF( J - N )                     170, 600, 120                                C0006550
    ISN 0048        170 JP1 = J + 1                                                                  C0006600
    ISN 0049            DO       500                    I = JP1, N                                   C0006700
    ISN 0050            DO       500                    K = JP1, NP1                                 C0006800
    ISN 0051            KN = K + NP1                                                                 C0006900
    ISN 0052            REALA = A(I,K) - A(J,K)*A(I,J) + A(J,KN)*A(I,JJ)                             C0007000
    ISN 0053            VIMAG = A(I,KN) - A(J,KN)*A(I,J) - A(I,JJ)*A(J,K)                            C0007100
    ISN 0054            A(I,K) = REALA                                                               C0007200
```

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TABLE B-2. (Concluded)

```
LEVEL 2  ( NOV 72 )          COGAEL          OS/360  FORTRAN H EXTENDED                 DATE 73.264/C9.00.11

   ISN 0055        500 A(I,KN) = VIMAG                                                     COC07300
   ISN 0056        600 RETURN                                                              COC07500
   ISN 0057            END                                                                 COC07600
```

TABLE B-3. SUBROUTINE TDPLOT

```
LEVEL 2  ( NOV 72 )                              OS/360  FORTRAN H EXTENDED                 DATE 73.264/09.00.21

REQUESTED OPTIONS: MAP,DECK,LIST,XREF,OPT=2

OPTIONS IN EFFECT: NAME(MAIN) OPTIMIZE(2) LINECOUNT(40) SIZE(MAX) AUTODBL(NONE)
                   SOURCE EBCDIC LIST DECK OBJECT MAP NOFORMAT GOSTMT XREF ALC NOANSF NOTERMINAL FLAG(I)

   ISN 0002           SUBROUTINE  TDPLOT(W,Y,NFP,TL,XR,LL )                              00004660
   ISN 0003           DIMENSION W(60),Y(60)                                              00004670
   ISN 0004           COMMON  ICRT                                                       00004680
   ISN 0005           YMAX=Y(2)                                                          00004690
   ISN 0006           YMIN=Y(2)                                                          00004700
   ISN 0007           DO100J=3,NFP                                                       00004710
   ISN 0008           YMAX=AMAX1(YMAX,Y(J))                                              00004720
   ISN 0009           YMIN=AMIN1(YMIN,Y(J))                                              00004730
   ISN 0010       100 CONTINUE                                                           00004740
   ISN 0011           DY=AINT(2.0+(YMAX-YMIN)/10.0)                                      00004750
   ISN 0012           YT=DY*AINT(1.5+YMAX/DY)                                            00004760
   ISN 0013           YB=DY*AINT(YMIN/DY-1.5)                                            00004770
   ISN 0014           IF(W(2)/TL-10.1)201,201,5                                          00004780
   ISN 0015         5 XL=W(2)                                                            00004790
   ISN 0016           I=1                                                                00004800
   ISN 0017           GO TO 200                                                          00004810
   ISN 0018       201 YMAX=AMAX1(YMAX,Y(1))                                              00004820
   ISN 0019           YMIN=AMIN1(YMIN,Y(1))                                              00004830
   ISN 0020           XL=TL                                                              00004840
   ISN 0021           I=2                                                                00004850
   ISN 0022       200 CONTINUE                                                           00004860
   ISN 0023           K=0                                                                00004870
   ISN 0024           L=0                                                                00004880
   ISN 0025        10 L=L+1                                                              00004890
   ISN 0026           IF(L.GT.9)GO TO 30                                                 00004900
   ISN 0028           IF(10.0**K/XL.LE.1.0.AND.10.0**K/XL.GT.0.1)GO TO 20                00004910
   ISN 0030           IF(10.0**K/XL.GT.1.0)K=K-1                                         00004920
   ISN 0032           IF(10.0**K/XL.LE.0.1)K=K+1                                         00004930
   ISN 0034           GO TO 10                                                           00004940
   ISN 0035        20 XL=10.0**K                                                         00004950
   ISN 0036        30 K=0                                                                00004960
   ISN 0037           IF(LL-1) 31,31,60                                                  00004965
   ISN 0038        31 CALL CAMRAV(9)                                                     00004970
```

TABLE B-3. (Concluded)

```
LEVEL 2  ( NOV 72 )            TDPLOT          OS/360  FORTRAN H EXTENDED                DATE 73.264/09.00.21

  ISN 0039             IF(ICRT+1.LE.0)CALL CAMRAV(35)                                      00004980
  ISN 0041             IF(LL-1) 50,50,60                                                   00004981
  ISN 0042          50 CALL SETMIV(40,10,24,560)                                           00004982
  ISN 0043             GO TO 61                                                            00004984
  ISN 0044          60 CALL SETMIV(40,10,500, 70)                                          00004990
  ISN 0045          61 CALL SMXYV(1,0)                                                     00004995
  ISN 0046             CALL GRID1V(LL,XL,XR,YB,YT,1.0,DY,1,1,-1,-1, -2, -3)                00005000
  ISN 0047         180 GO TO(181,182),I                                                    00005010
  ISN 0048         181 CALL APLCTV(NFP-1,W(2),Y(2),1,1,1,44,IERR)                          00005020
  ISN 0049             GO TO 40                                                            00005030
  ISN 0050         182 CALL APLCTV(NFP,W(1),Y(1),1,1,1,44,IERR)                            00005040
  ISN 0051          40 K=K+1                                                               00005050
  ISN 0052             GO TO (180,180,180,190),K                                           00005060
  ISN 0053         190 IF(LL-1) 191,191,192                                                00005070
  ISN 0054         191 CALL LABLV(Y(1),600,470, 6, 2, 3)                                   00005075
  ISN 0055             GO TO 193                                                           00005080
  ISN 0056         192 CALL LABLV(Y(1),600,995,6,2,3)                                      00005085
  ISN 0057         193 RETURN                                                              00005086
  ISN 0058             END                                                                 00005090
```

FORTRAN FIXED 10 DIGIT DECIMAL DATA

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	1 IDENT IFICAT		TITLE CARD
13	IØN CARD		
25			
37			
49			
61			
IDENTIFICATION 73	1	80	

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	NW	I12	NW - NUMBER OF SPARE FREQUENCIES
13	NW	I12	NR - NUMBER OF COLUMNS
25	KEQ	I12	KEQ - NUMBER OF EQUATIONS
37	IRPS	12, I10	TRIG ≥ 1 MINIMIZES PRINTOUT, IRPS ≤0 CAPS, >0 RADIANS
49	ØMI	F12	OMI - INITIAL FREQUENCY: >0 LOGERITHMIC SPACING, <0 OCTAVE SPACING
61	ØMFL	F12	OMFL - FINAL FREQUENCY
IDENTIFICATION 73	2	80	

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	ω (1)	6F12.0	FREQUENCIES OTHER THAN INDICATED BY VALUES BY OMI, OMFL.
13	ω (2)		LOG SPACING GIVES 1.0, 1.5, 2, 3, 4, 6, 8, 10.. OVER FREQUENCY RANGE
25	.		OCTAVE SPACING GIVES, ØMI, 2 X ØMI, 4 X ØMI...
37	:		CARD MAY BE OMITTED OR MORE THAN ONE CARD MAY BE USED IF REQUIRED.
49			
61	ω (NW)		
IDENTIFICATION 73	3	80	

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	&VNØM V = X.,		INPUT BALANCE VALUES EXPRESSED AS A VECTOR
13	-XX, X - XXX, X-		USING "NAMELIST" FORMAT.
25	X, ...		$VNOM REQUIRED AT START OF NAMELIST.
37			
49			
61			
IDENTIFICATION 73	4	80	

Figure B-1. Data Input Card Format and Description

FORTRAN FIXED 10 DIGIT DECIMAL DATA

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	V (1 0) = X . X X X		CONTINUATION CARDS FOR ENGINE BALANCE VALUES
13	, X . . X X , ...		
25			
37			
49			
61			
IDENTIFICATION 73	5	80	

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	I D V = 1 , , 0 , - 1 ,		I.D. VECTOR CODE SHOWING WHICH COLUMNS REPRESENT
13	0 , . . .		DERIVATIVES (0), AND WHICH VARIABLES NEED (+1)
25			OR NEED NOT (-1) BE INCLUDED IN OUTPUT LISTS
37			NAME-LIST FORMAT USED.
49			
61			
IDENTIFICATION 73	6	80	

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	I D V (2 6) = 0 , -		CONTINUATION CARDS FOR ID VECTOR. "KØLI = 2 "
13	1 , . . . , I D V (N R		INDICATES INDEPENDENT VARIABLE (2) IS USED AS
25	) , K Ø L I = 2 ,		AN INPUT.
37	& E N D		#END - STATEMENT REQUIRED AT END OF NAMELIST
49			
61			
IDENTIFICATION 73	7	80	

Col.	NUMBER	FORMAT DESCRIPTION	DESCRIPTION
1	& V N Ø M K Ø L I =		CARD TYPE REQUIRED FOR ADDITIONAL FREQUENCY
13	1 , & E N D		RESPONSE RUN USING INPUT (1).
25			FOR SINGLE RUNS THIS CARD IS NOT REQUIRED
37			
49			
61			
IDENTIFICATION 73	1 0	80	

Figure B-1. (Concluded)

APPENDIX C

ENGINE BALANCE INFORMATION

Engine balance information for a 6.0 mixture ratio is presented. These data are copies of the following tables from DVS-SSME-101, Design Verification Specification, Space Shuttle Main Engine, Volume II.

DVS Table No.	Power Level, percent
IX	109
XII	100
XVII	75
XXII	60
XXVII	50

TABLE IX

ROCKETDYNE SSME (109%) EPL 6.0

ENGINE VARIABLES -		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	512299.		
MIXTURE RATIO - O/F		6.0000		
SPECIFIC IMPULSE	(SEC)	457.37		
ATMOSPHERIC PRESSURE	(PSIA)	0.0		
PROPELLENT FLOWRATE	(LB/SEC)	1123.28	962.81	160.47
PROPELLENT INLET TEMPERATURE	(DEG. R)		164.00	37.00
PROPELLENT INLET PRESSURE	(PSIA)		100.00	30.00
PROPELLENT INLET DENSITY	(LB/FT3)		70.94	4.41
PRESSURIZATION FLOWRATE	(LB/SEC)		2.41	0.77
PRESSURIZATION PRESSURE	(PSIA)		3566.03	3825.89
PRESSURIZATION TEMPERATURE	(DEG. R)		891.26	527.24
OVERBOARD LIQUID FLOWRATE	(LB/SEC)		0.13	0.0
OVERBOARD GAS FLOWRATE	(LB/SEC)	0.19		

THRUST CHAMBER VARIABLES		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	512299.		
MIXTURE RATIO - O/F		6.0175		
SPECIFIC IMPULSE	(LB/SEC)	457.51		
TOTAL FLOWRATE	(LB/SEC)	1119.77	960.20	159.57
IGNITER FLOWRATE	(LB/SEC)	1.74	0.72	1.02
NOZZLE STAGNATION PRESSURE	(PSIA)	3236.67		
INJECTOR END PRESSURE (STATIC)	(PSIA)	3214.30		
THRUST COEFFICIENT		1.9166		
CHARACTERISTIC VELOCITY	(FT/SEC)	7680.12		
GEOMETRIC THROAT AREA	(IN2)	63.41		
AERODYNAMIC THROAT AREA	(IN2)	62.58		
GEOMETRIC AREA RATIO	(AE/AT)	77.50		

		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	PRESSURE(PSIA) DISCHARGE	TEMP (DEGR)
CONTROL VALVE VARIABLES						
OXIDIZER PREBURNER OXIDIZER VALVE	R= 171.97	24.85	1500.73	8370.20	6869.46	209.59
FUEL PREBURNER OXIDIZER VALVE	R= 14.26	77.88	1221.83	8401.86	7180.03	209.59
SCHEDULED VALVE VARIABLES						
MAIN OXIDIZER VALVE	R= 0.00471	856.42	48.44	4899.59	4851.15	190.60
MAIN FUEL VALVE	R= 0.00469	157.54	23.22	6903.73	6880.51	99.90
COOLANT CONTROL VALVE	R= 0.03570	80.65	46.35	6780.32	6733.96	99.90

TABLE IX (Continued)

EPL TURBOMACHINERY VARIABLES		LOW PRESSURE OXIDIZER	LOW PRESSURE FUEL	HIGH PRESSURE OXIDIZER MAIN	HIGH PRESSURE OXIDIZER BOOST	HIGH PRESSURE FUEL
PUMP INLET FLOWRATE	(LB/SEC)	962.81	160.47	1136.26	122.50	160.47
PUMP INLET PRESSURE	(PSIA)	100.00	20.00	377.16	4911.50	192.60
PUMP INLET TEMPERATURE	(DEG. R)	164.00	37.00	169.32	190.60	39.67
PUMP INLET DENSITY	(LB/FT3)	70.9380	4.4072	70.3490	71.2636	4.3792
PUMP DISCHARGE FLOWRATE	(LB/SEC)	1136.39	160.47	1155.19	103.57	160.47
PUMP DISCHARGE PRESSURE	(PSIA)	442.13	259.04	5152.74	8434.77	7004.18
PUMP DISCHARGE TEMPERATURE	(DEG. R)	169.32	39.67	190.60	209.59	99.90
PUMP DISCHARGE DENSITY	(LB/FT3)	70.3490	4.4189	71.2636	70.7605	5.0061
PUMP TIP SPEED	(FT/SEC)	278.08	827.64	900.65	665.64	1939.58
PUMP HEAD RISE	(FT)	694.5	7409.1	9775.3	7119.4	194363.5
PUMP VOLUMETRIC FLOW-INLET	(GPM)	6091.6	16342.4	7249.4	652.3	16380.6
PUMP HEAD COEFFICIENT-PSI		0.2890	0.3480	0.3877	0.5170	1.6623
PUMP FLOW COEFFICIENT-PHI		0.2130	0.2390	0.1316	0.0617	0.1771
PUMP HORSEPOWER	(BHP)	1737.6	2946.9	25847.5	1917.5	76557.9
PUMP EFFICIENCY		0.6997	0.7335	0.7813	0.6992	0.7407
PUMP SPEED	(RPM)	5447.11	15806.83	31133.36		37354.67
TURBINE FLOWRATE	(LB/SEC)	172.57	34.67	63.08		161.65
TURBINE INLET PRESSURE	(PSIA)	4992.51	4774.06	5848.22		5880.32
TURBINE INLET TEMPERATURE	(DEG. R)	190.60	539.41	1478.90		1917.92
TURBINE DISCHARGE PRESSURE	(PSIA)	442.08	3974.45	3698.56		3729.93
TURBINE DISCHARGE TEMPERATURE	(DEG R)	169.41	527.24	1344.31		1754.21
TURBINE TIP SPEED	(FT/SEC)	142.60	510.38	1370.67		1660.87
TURBINE SPOUTING VELOCITY	(FT/SEC)	314.03	2365.05	4626.23		4597.49
TURBINE ISENTROPIC VELOCITY RATIO		0.4541	0.2140	0.2963		0.3613
TURBINE PRESSURE RATIO - TOTAL/TOTAL			1.2012	1.5812		1.5765
TURBINE TORQUE	(FT-LB)	1675.24	979.06	4683.99		10764.02
TURBINE HORSEPOWER	(BHP)	1737.4	2946.7	27765.7		76557.2
TURBINE EFFICIENCY		0.5987	0.5287	0.7279		0.7930
TURBINE SPEED	(RPM)	5447.11	15806.83	31133.36		37354.67

TABLE IX (Continued)

EPL

PREBURNER VARIABLES		FUEL PREBURNER OXIDIZER	FUEL PREBURNER FUEL	OXIDIZER PREBURNER OXIDIZER	OXIDIZER PREBURNER FUEL
INLET FLOWRATE (INCLUDING IGNITER)	(LB/SEC)	78.28	83.37	25.29	39.48
INLET PRESSURE	(PSIA)	7180.03	6492.89	6869.46	6406.42
INLET TEMPERATURE	(DEG R)	209.59	302.56	209.59	302.56
INJECTOR FLOWRATE	(LB/SEC)	77.38	82.17	24.50	36.36
INJECTOR INLET PRESSURE	(PSIA)	7134.70	6463.89	6847.65	6382.51
INJECTOR PRESSURE DROP	(PSI)	1237.28	566.47	979.50	514.36
INJECTOR END PRESSURE	(PSIA)	5897.42		5868.15	
GAS MIXTURE RATIO	(O/F)	0.9390		0.6692	
GAS FLOWRATE	(LB/SEC)	161.65		63.08	
GAS TEMPERATURE	(DEG R)	1917.92		1478.90	

	FLOWRATE (LB/SEC.)	DELTA P (PSI)	PRESSURE(PSIA) INLET	PRESSURE(PSIA) DISCHARGE	TEMPERATURE(DEG R) INLET	TEMPERATURE(DEG R) DISCHARGE
MAIN INJECTOR VARIABLES						
ORIFICE-OXIDIZER	855.99	1067.24	4281.54	3214.30	190.60	190.60
ORIFICE-HOT GAS	232.10	419.51	3633.81	3214.30	1576.06	1576.06
HOT GAS MIXTURE RATIO 0.8048						
PRIMARY(LOWER)FACEPLATE-FUEL	6.45	552.09	3766.39	3214.30	528.82	653.38
SECONDARY(UPPER)FACEPLATE-FUEL	3.96	132.58	3766.39	3633.81	528.82	579.88
BAFFLES-FUEL	20.99	600.93	3766.39	3165.46	528.82	697.28
ACOUSTIC CAVITY	0.51	552.09	3766.39	3214.30	528.82	528.82
COOLING CIRCUIT VARIABLES						
MAIN COMBUSTION CHAMBER	34.67	1644.15	6733.23	5089.09	99.90	539.41
MAIN CHAMBER NOZZLE	42.20	159.53	6771.46	6611.93	99.90	676.67
HIGH PRESSURE FUEL TURBINE	1.91	3274.25	7004.18	3729.93	99.90	100.18
OXIDIZER PREBURNER CASE	1.69	2683.95	6382.51	3698.56	302.56	302.56
OXIDIZER TURBINE END BEARING	4.78	4534.34	4911.50	377.16	190.60	190.60
PREBURNER PUMP BEARING	14.14	8057.61	8434.77	377.16	209.59	209.59
HOT GAS MANIFOLD - FUEL SIDE	19.58	72.09	3838.48	3766.39	527.24	528.68
HOT GAS MANIFOLD - OXIDIZER SIDE	14.31	35.27	3801.66	3766.39	527.24	529.00
TANK PRESSURIZATION SYSTEM VARIABLES						
HEAT EXCHANGER HOT GAS	64.57	47.36	3686.60	3639.24	1301.78	1299.53
HEAT EXCHANGER OXIDIZER INLET DUCT	2.41	65.69	4926.88	4860.98	190.60	190.60
PRIMARY HEATING COIL	1.71	1271.19	4860.98	3589.79	190.60	1268.65
BYPASS DUCT	0.70	1271.19	4860.98	3589.79	190.60	190.60
OXIDIZER TANK PRESSURIZATION DUCT	2.41	23.76	3589.79	3566.03	891.36	891.36
FUEL TANK PRESSURIZATION DUCT	0.77	148.57	3974.45	3825.69	527.24	527.24

TABLE IX (Continued)

EPL MISCELLANEOUS COMPONENTS	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	PRESSURE(PSIA) DISCHARGE	TEMP (DEG R)
OXIDIZER					
LOW PRESSURE PUMP DISCHARGE DUCT	1136.39	64.97	442.13	377.16	169.32
LOW PRESSURE TURBINE INLET DUCT	173.57	160.23	5152.74	4992.51	190.60
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 1	981.62	189.30	5152.74	4963.44	190.60
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 2	856.70	63.86	4963.44	4899.59	190.60
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 1	124.91	36.57	4963.44	4926.88	190.60
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 2	122.50	15.37	4926.88	4911.50	190.60
HIGH PRESSURE BOOST PUMP DISCHARGE DUCT	103.57	7.05	8434.77	8427.71	209.59
OXIDIZER PREBURNER INLET DUCT	25.29	57.52	8427.71	8370.20	209.59
OXIDIZER PREBURNER DOME	24.85	21.82	6869.46	6847.65	209.59
FUEL PREBURNER INLET DUCT	78.28	25.85	8427.71	8401.56	209.59
FUEL PREBURNER DOME	77.86	45.34	7180.03	7134.70	209.59
THRUST CHAMBER DOME	655.99	569.61	4851.15	4281.54	190.60
FUEL					
LOW PRESSURE PUMP DISCHARGE DUCT	160.47	66.43	259.04	192.60	39.67
LOW PRESSURE TURBINE INLET DUCT	34.67	195.72	4969.78	4774.06	539.41
LOW PRESSURE TURBINE DISCHARGE DUCT	33.89	100.08	3974.45	3874.37	527.24
HOT GAS MANIFOLD COOLANT DUCT-FUEL SIDE	19.58	35.89	3874.37	3838.48	527.24
HOT GAS MANIFOLD COOLANT DUCT-OXIDIZER SIDE	14.31	72.71	3874.37	3801.66	527.24
HIGH PRESSURE PUMP DISCHARGE DUCT	158.56	100.45	7004.18	6903.73	99.90
MAIN FUEL VALVE DISCHARGE DUCT	76.88	49.74	6880.51	6831.21	99.90
CHAMBER COOLING JACKET INLET DUCT	34.67	97.98	6831.21	6733.23	99.90
CHAMBER COOLING JACKET DISCHARGE MANIFOLD	34.67	119.30	5089.09	4969.78	539.41
FIXED NOZZLE COOLING JACKET INLET DUCT	42.20	59.74	6831.21	6771.46	99.90
COOLANT CONTROL VALVE INLET DUCT	80.65	100.19	6880.51	6780.32	99.90
COOLANT CONTROL VALVE DISCH DUCT & MIXER	80.65	170.96	6733.96	6563.00	99.90
FIXED NOZZLE COOLING JACKET DISCH DUCT & MIXE	42.20	48.93	6611.93	6563.00	676.67
PREBURNER SUPPLY DUCT	122.85	35.49	6563.00	6527.51	302.56
FUEL PREBURNER INLET DUCT	83.37	35.55	6528.43	6492.89	302.56
OXIDIZER PREBURNER INLET DUCT	39.48	122.16	6528.58	6406.42	302.56
FUEL PREBURNER INLET MANIFOLD	82.17	28.99	6492.89	6463.69	302.56
OXIDIZER PREBURNER INLET MANIFOLD	38.05	23.91	6406.42	6382.51	302.56

TABLE IX (Concluded)

EPL MISCELLANEOUS COMPONENTS		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
HOT GAS						
HIGH PRESSURE FUEL TURBINE INLET DUCT		161.65	17.10	5897.42	5880.32	1917.92
HIGH PRESSURE OXIDIZER TURBINE INLET DUCT		63.08	19.93	5868.15	5848.22	1478.90
HIGH PRESSURE FUEL TURBINE TURNAROUND DUCT		163.58	25.48	3729.93	3704.46	1741.64
HIGH PRESSURE OXIDIZER TURBINE DISCHARGE DUCT		64.57	11.96	3698.56	3686.60	1301.78
HOT GAS MANIFOLD-FUEL SIDE		163.58	64.53	3704.46	3639.94	1741.64
HOT GAS MANIFOLD-OXIDIZER SIDE		64.57	47.36	3686.60	3639.24	1301.78
MAIN INJECTOR POSTS-FUEL SIDE		163.58	6.12	3639.94	3633.81	1741.64
MAIN INJECTOR POSTS-OXIDIZER SIDE		64.57	5.43	3639.24	3633.81	1301.78
IGNITER SYSTEM						
MAIN CHAMBER						
OXIDIZER PRIMARY SUPPLY DUCT		0.29	418.05	4899.59	4481.54	190.60
OXIDIZER BYPASS DUCT		0.43	369.62	4851.15	4481.54	190.60
OXIDIZER IGNITOR CIRCUIT		0.72	1267.23	4481.54	3214.30	190.60
FUEL SUPPLY CIRCUIT		1.02	3666.20	6903.73	3214.30	99.90
MIXTURE RATIO - O/F	0.70					
OXIDIZER PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.44	1564.05	8370.20	6806.15	209.59
OXIDIZER BYPASS DUCT		0.35	54.58	6860.73	6806.15	209.59
OXIDIZER IGNITOR CIRCUIT		0.79	938.00	6806.15	5868.15	209.59
FUEL SUPPLY CIRCUIT		1.43	538.27	6406.42	5868.15	302.56
MIXTURE RATIO - O/F	0.55					
FUEL PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.41	1353.62	8401.86	7048.24	209.59
OXIDIZER BYPASS DUCT		0.49	100.86	7149.10	7048.24	209.59
OXIDIZER IGNITOR CIRCUIT		0.90	1150.82	7048.24	5897.42	209.59
FUEL SUPPLY CIRCUIT		1.20	595.46	6492.89	5897.42	302.56
MIXTURE RATIO - O/F	0.75					

* DATE 06/19/73 DATA READ 0.0167 BALANCE 7.6100 HEATEX 22.8967 TOTAL 23.1867

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TABLE XII

ROCKETDYNE SSME NPL 6.0

ENGINE VARIABLES - (100%)

		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	469998.		
MIXTURE RATIO - O/F		6.0000		
SPECIFIC IMPULSE	(SEC)	457.07		
ATMOSPHERIC PRESSURE	(PSIA)	0.0		
PROPELLENT FLOWRATE	(LB/SEC)	1031.23	883.91	147.32
PROPELLENT INLET TEMPERATURE	(DEG. R)		164.00	37.00
PROPELLENT INLET PRESSURE	(PSIA)		100.00	30.00
PROPELLENT INLET DENSITY	(LB/FT3)		70.94	4.41
PRESSURIZATION FLOWRATE	(LB/SEC)		2.25	0.70
PRESSURIZATION PRESSURE	(PSIA)		3238.90	3450.93
PRESSURIZATION TEMPERATURE	(DEG. R)		850.02	539.00
OVERBOARD LIQUID FLOWRATE	(LB/SEC)		0.12	0.0
OVERBOARD GAS FLOWRATE	(LB/SEC)	0.18		

THRUST CHAMBER VARIABLES

		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	469998.		
MIXTURE RATIO - O/F		6.0165		
SPECIFIC IMPULSE	(LB/SEC)	457.20		
TOTAL FLOWRATE	(LB/SEC)	1027.98	881.46	146.51
IGNITER FLOWRATE	(LB/SEC)	1.61	0.67	0.94
NOZZLE STAGNATION PRESSURE	(PSIA)	2968.63		
INJECTOR END PRESSURE (STATIC)	(PSIA)	2957.05		
THRUST COEFFICIENT		1.9171		
CHARACTERISTIC VELOCITY	(FT/SEC)	7673.02		
GEOMETRIC THROAT AREA	(IN2)	83.41		
AERODYNAMIC THROAT AREA	(IN2)	82.58		
GEOMETRIC AREA RATIO	(AE/AT)	77.50		

		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEGR)
CONTROL VALVE VARIABLES						
OXIDIZER PREBURNER OXIDIZER VALVE	R= 258.59	21.34	1662.96	7586.43	5923.46	205.92
FUEL PREBURNER OXIDIZER VALVE	R= 26.82	64.21	1561.91	7611.49	6049.58	205.92
SCHEDULED VALVE VARIABLES						
MAIN OXIDIZER VALVE	R= 0.00472	794.82	41.87	4409.38	4367.51	167.94
MAIN FUEL VALVE	R= 0.00469	144.61	19.74	6103.81	6084.07	93.11
COOLANT CONTROL VALVE	R= 0.03570	75.74	41.25	5994.91	5953.66	93.11

TABLE XII (Continued)

NPL 6.0 ROMACHINERY VARIABLES		LOW PRESSURE OXIDIZER	LOW PRESSURE FUEL	HIGH PRESSURE OXIDIZER MAIN	HIGH PRESSURE OXIDIZER BOOST	HIGH PRESSURE FUEL
PUMP INLET FLOWRATE	(LB/SEC)	683.91	147.32	1047.86	104.43	147.32
PUMP INLET PRESSURE	(PSIA)	100.00	30.00	359.84	4426.54	177.54
PUMP INLET TEMPERATURE	(DEG. R)	164.00	37.00	168.91	187.94	39.37
PUMP INLET DENSITY	(LB/FT3)	70.9380	4.4073	70.3937	71.2331	4.3850
PUMP DISCHARGE FLOWRATE	(LB/SEC)	1047.98	147.32	1065.83	86.45	147.32
PUMP DISCHARGE PRESSURE	(PSIA)	415.05	233.53	4624.22	7634.03	6189.21
PUMP DISCHARGE TEMPERATURE	(DEG. R)	168.91	39.37	187.94	205.92	93.11
PUMP DISCHARGE DENSITY	(LB/FT3)	70.3937	4.4184	71.2331	70.8058	4.9621
PUMP TIP SPEED	(FT/SEC)	262.70	773.74	845.47	624.85	1821.59
PUMP HEAD RISE	(FT)	639.5	6585.8	8723.4	6484.0	173192.7
PUMP VOLUMETRIC FLOW-INLET	(GPM)	5592.6	15002.7	6681.0	544.7	15028.2
PUMP HEAD COEFFICIENT-PSI		0.2982	0.3539	0.3926	0.5343	1.6793
PUMP FLOW COEFFICIENT-PHI		0.2070	0.2347	0.1292	0.0727	0.1730
PUMP HORSEPOWER	(BHP)	1466.0	2400.0	21297.5	1489.5	62239.3
PUMP EFFICIENCY		0.7002	0.7350	0.7804	0.6843	0.7453
PUMP SPEED	(RPM)	5145.86	14777.39	29225.78		35082.25
TURBINE FLOWRATE	(LB/SEC)	164.06	30.61	56.25		142.69
TURBINE INLET PRESSURE	(PSIA)	4481.01	4256.78	5163.50		5161.05
TURBINE INLET TEMPERATURE	(DEG. R)	167.94	550.71	1405.60		1726.83
TURBINE DISCHARGE PRESSURE	(PSIA)	414.91	3588.98	3357.69		3381.64
TURBINE DISCHARGE TEMPERATURE	(DEG R)	186.95	539.00	1283.31		1583.79
TURBINE TIP SPEED	(FT/SEC)	134.72	477.14	1286.69		1559.83
TURBINE SPOUTING VELOCITY	(FT/SEC)	296.91	2305.42	4450.77		4417.92
TURBINE ISENTROPIC VELOCITY RATIO		0.4537	0.2070	0.2891		0.3531
TURBINE PRESSURE RATIO - TOTAL/TOTAL			1.1861	1.5378		1.5262
TURBINE TORQUE	(FT-LB)	1498.27	852.96	4095.04		9318.00
TURBINE HORSEPOWER	(BHP)	1468.0	2399.9	22787.2		62241.0
TURBINE EFFICIENCY		0.5987	0.5221	0.7238		0.7910
TURBINE SPEED	(RPM)	5145.86	14777.39	29225.78		35082.25

TABLE XII (Continued)

NPL 6.0		FUEL PREBURNER		OXIDIZER PREBURNER	
REBURNER VARIABLES		OXIDIZER	FUEL	OXIDIZER	FUEL
INLET FLOWRATE (INCLUDING IGNITER)	(LB/SEC)	64.66	78.03	21.79	35.97
INLET PRESSURE	(PSIA)	6049.58	5734.29	5923.46	5659.23
INLET TEMPERATURE	(DEG R)	205.92	296.38	205.92	296.38
INJECTOR FLOWRATE	(LB/SEC)	63.90	76.90	21.11	33.15
INJECTOR INLET PRESSURE	(PSIA)	6018.78	5707.17	5907.39	5638.05
INJECTOR PRESSURE DROP	(PSI)	843.21	531.60	726.58	457.24
INJECTOR END PRESSURE	(PSIA)	5175.57		5180.80	
GAS MIXTURE RATIO	(O/F)	0.8287		0.6326	
GAS FLOWRATE	(LB/SEC)	142.69		56.25	
GAS TEMPERATURE	(DEG R)	1728.83		1405.60	

	FLOWRATE	DELTA P	PRESSURE(PSIA)		TEMPERATURE(DEG R)	
AIN INJECTOR VARIABLES	(LB/SEC)	(PSI)	INLET	DISCHARGE	INLET	DISCHARGE
ORIFICE-OXIDIZER	794.42	919.63	3876.68	2957.05	187.94	187.94
ORIFICE-HOT GAS	205.40	345.48	3302.53	2957.05	1448.60	1448.60
HOT GAS MIXTURE RATIO 0.7259						
PRIMARY(LOWER)FACEPLATE-FUEL	7.25	451.90	3408.94	2957.05	540.04	675.42
SECONDARY(UPPER)FACEPLATE-FUEL	3.36	106.41	3408.94	3302.53	540.04	596.10
BAFFLES-FUEL	18.86	505.63	3408.94	2903.32	540.04	714.98
ACOUSTIC CAVITY	0.44	451.90	3408.94	2957.05	540.04	540.04
OOLING CIRCUIT VARIABLES						
MAIN COMBUSTION CHAMBER	30.61	1434.07	5965.77	4531.71	93.11	550.71
MAIN CHAMBER NOZZLE	38.25	146.51	5993.28	5846.77	93.11	683.57
HIGH PRESSURE FUEL TURBINE	1.76	2807.57	6189.21	3381.64	93.11	93.30
OXIDIZER PREBURNER CASE	1.51	2280.35	5638.05	3357.69	296.38	296.38
OXIDIZER TURBINE END BEARING	4.53	4066.71	4426.54	359.84	187.94	187.94
PREBURNER PUMP BEARING	13.44	7274.19	7634.03	359.84	205.92	205.92
HOT GAS MANIFOLD - FUEL SIDE	17.28	62.36	3471.30	3408.94	539.00	539.84
HOT GAS MANIFOLD - OXIDIZER SIDE	12.63	30.51	3439.45	3408.94	539.00	540.32
NK PRESSURIZATION SYSTEM VARIABLES						
HEAT EXCHANGER HOT GAS	57.58	40.35	3347.49	3307.14	1242.43	1241.20
HEAT EXCHANGER OXIDIZER INLET DUCT	2.25	57.46	4437.72	4380.26	187.94	187.94
PRIMARY HEATING COIL	1.60	1119.86	4380.26	3260.40	187.94	1211.79
BYPASS DUCT	0.65	1119.86	4380.26	3260.40	187.94	187.94
OXIDIZER TANK PRESSURIZATION DUCT	2.25	21.49	3260.40	3238.90	850.02	850.02
FUEL TANK PRESSURIZATION DUCT	0.70	138.05	3588.98	3450.93	539.00	539.00

TABLE XII (Continued)

NPL 6.0 SCELLANEOUS COMPONENTS	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
OXIDIZER					
LOW PRESSURE PUMP DISCHARGE DUCT	1047.98	55.22	415.05	359.84	168.91
LOW PRESSURE TURBINE INLET DUCT	164.06	143.21	4624.22	4481.01	187.94
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 1	901.77	159.82	4624.22	4464.40	187.94
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 2	795.09	55.02	4464.40	4409.38	187.94
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 1	106.68	26.68	4464.40	4437.72	187.94
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 2	104.43	11.18	4437.72	4426.54	187.94
HIGH PRESSURE BOOST PUMP DISCHARGE DUCT	86.45	4.91	7634.03	7629.12	205.92
OXIDIZER PREBURNER INLET DUCT	21.79	42.70	7629.12	7586.43	205.92
OXIDIZER PREBURNER DOME	21.34	16.08	5923.46	5907.39	205.92
FUEL PREBURNER INLET DUCT	64.66	17.63	7629.12	7611.49	205.92
FUEL PREBURNER DOME	64.21	30.81	6049.58	6018.78	205.92
THRUST CHAMBER DOME	794.42	490.83	4367.51	3876.68	187.94
FUEL					
LOW PRESSURE PUMP DISCHARGE DUCT	147.32	56.00	233.53	177.54	39.37
LOW PRESSURE TURBINE INLET DUCT	30.61	170.81	4427.59	4256.78	550.71
LOW PRESSURE TURBINE DISCHARGE DUCT	29.91	86.63	3588.98	3502.35	539.00
HOT GAS MANIFOLD COOLANT DUCT-FUEL SIDE	17.28	31.05	3502.35	3471.30	539.00
HOT GAS MANIFOLD COOLANT DUCT-OXIDIZER SIDE	12.63	62.89	3502.35	3439.45	539.00
HIGH PRESSURE PUMP DISCHARGE DUCT	145.56	85.40	6189.21	6103.81	93.11
MAIN FUEL VALVE DISCHARGE DUCT	68.86	40.27	6084.07	6042.80	93.11
CHAMBER COOLING JACKET INLET DUCT	30.61	77.03	6042.80	5965.77	93.11
CHAMBER COOLING JACKET DISCHARGE MANIFOLD	30.61	104.12	4531.71	4427.59	550.71
FIXED NOZZLE COOLING JACKET INLET DUCT	38.25	49.52	6042.80	5993.28	93.11
COOLANT CONTROL VALVE INLET DUCT	75.74	89.16	6084.07	5994.91	93.11
COOLANT CONTROL VALVE DISCH DUCT & MIXER	75.74	154.63	5953.66	5799.02	93.11
FIXED NOZZLE COOLING JACKET DISCH DUCT & MIXE	38.25	47.75	5846.77	5799.02	683.57
PREBURNER SUPPLY DUCT	113.99	32.65	5799.02	5766.37	296.38
FUEL PREBURNER INLET DUCT	78.03	33.25	5767.54	5734.29	296.38
OXIDIZER PREBURNER INLET DUCT	35.97	108.24	5767.48	5659.23	296.38
FUEL PREBURNER INLET MANIFOLD	76.90	27.12	5734.29	5707.17	296.38
OXIDIZER PREBURNER INLET MANIFOLD	34.67	21.19	5659.23	5638.05	296.38

TABLE XII (Concluded)

NPL 6.0 MISCELLANEOUS COMPONENTS	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
HOT GAS					
HIGH PRESSURE FUEL TURBINE INLET DUCT	142.69	14.52	5175.57	5161.05	1728.83
HIGH PRESSURE OXIDIZER TURBINE INLET DUCT	56.25	17.31	5180.80	5163.50	1405.60
HIGH PRESSURE FUEL TURBINE TURNAROUND DUCT	144.46	20.98	3381.64	3360.65	1572.48
HIGH PRESSURE OXIDIZER TURBINE DISCHARGE DUCT	57.58	10.21	3357.69	3347.49	1243.43
HOT GAS MANIFOLD-FUEL SIDE	144.46	53.09	3360.65	3307.57	1572.48
HOT GAS MANIFOLD-OXIDIZER SIDE	57.58	40.35	3347.49	3307.14	1243.43
MAIN INJECTOR POSTS-FUEL SIDE	144.46	5.03	3307.57	3302.53	1572.48
MAIN INJECTOR POSTS-OXIDIZER SIDE	57.58	4.61	3307.14	3302.53	1243.43
IGNITER SYSTEM					
MAIN CHAMBER					
OXIDIZER PRIMARY SUPPLY DUCT	0.27	360.33	4409.38	4049.05	187.94
OXIDIZER BYPASS DUCT	0.40	318.46	4367.51	4049.05	187.94
OXIDIZER IGNITOR CIRCUIT	0.67	1092.00	4049.05	2957.05	187.94
FUEL SUPPLY CIRCUIT	0.94	3127.02	6103.81	2957.05	93.11
MIXTURE RATIO - O/F 0.71					
OXIDIZER PREBURNER					
OXIDIZER PRIMARY SUPPLY DUCT	0.46	1693.28	7586.43	5893.14	205.92
OXIDIZER BYPASS DUCT	0.23	23.89	5917.03	5893.14	205.92
OXIDIZER IGNITOR CIRCUIT	0.69	712.34	5893.14	5180.80	205.92
FUEL SUPPLY CIRCUIT	1.30	478.43	5659.23	5180.80	296.38
MIXTURE RATIO - O/F 0.53					
FUEL PREBURNER					
OXIDIZER PRIMARY SUPPLY DUCT	0.45	1622.87	7611.49	5988.63	205.92
OXIDIZER BYPASS DUCT	0.31	39.94	6028.56	5988.63	205.92
OXIDIZER IGNITOR CIRCUIT	0.76	813.06	5988.63	5175.57	205.92
FUEL SUPPLY CIRCUIT	1.12	558.72	5734.29	5175.57	296.38
MIXTURE RATIO - O/F 0.67					

RUN DATE 06/19/73 DATA READ 3.6933 BALANCE 10.5600 HEATEX 23.0067 TOTAL 23.3167

TABLE XVII

ROCKETDYNE SSME (75%)6.0

=NGINE VARIABLES –		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	352499.		
MIXTURE RATIO – O/F		6.0000		
SPECIFIC IMPULSE	(SEC)	456.27		
ATMOSPHERIC PRESSURE	(PSIA)	0.0		
PROPELLENT FLOWRATE	(LB/SEC)	775.00	664.28	110.71
PROPELLENT INLET TEMPERATURE	(DEG. R)		164.00	37.00
PROPELLENT INLET PRESSURE	(PSIA)		100.00	30.00
PROPELLENT INLET DENSITY	(LB/FT3)		70.94	4.41
PRESSURIZATION FLOWRATE	(LB/SEC)		1.88	0.53
PRESSURIZATION PRESSURE	(PSIA)		2548.37	2538.23
PRESSURIZATION TEMPERATURE	(DEG. R)		775.59	579.04
OVERBOARD LIQUID FLOWRATE	(LB/SEC)		0.09	0.0
OVERBOARD GAS FLOWRATE	(LB/SEC)	0.13		

'HRUST CHAMBER VARIABLES				
THRUST	(LB)	352499.		
MIXTURE RATIO – O/F		6.0166		
SPECIFIC IMPULSE	(LB/SEC)	456.40		
TOTAL FLOWRATE	(LB/SEC)	772.34	662.27	110.07
IGNITER FLOWRATE	(LB/SEC)	1.35	0.54	0.81
NOZZLE STAGNATION PRESSURE	(PSIA)	2224.44		
INJECTOR END PRESSURE (STATIC)	(PSIA)	2225.77		
THRUST COEFFICIENT		1.9189		
CHARACTERISTIC VELOCITY	(FT/SEC)	7652.57		
GEOMETRIC THROAT AREA	(IN2)	83.41		
AERODYNAMIC THROAT AREA	(IN2)	82.58		
GEOMETRIC AREA RATIO	(AE/AT)	77.50		

		FLOWRATE	DELTA P	PRESSURE(PSIA)		TEMP
'NTROL VALVE VARIABLES		(LB/SEC)	(PSI)	INLET	DISCHARGE	(DEGR)
OXIDIZER PREBURNER OXIDIZER VALVE	R= 652.00	13.97	1802.91	5724.84	3921.93	198.20
FUEL PREBURNER OXIDIZER VALVE	R= 87.99	38.66	1862.23	5737.17	3874.95	198.20
HEDULED VALVE VARIABLES						
MAIN OXIDIZER VALVE	R= 0.06117	608.44	318.63	3373.04	3054.41	182.69
MAIN FUEL VALVE	R= 0.06950	108.29	167.91	4553.67	4385.76	80.22
COOLANT CONTROL VALVE	R= 0.55000	47.33	255.45	4349.92	4094.47	80.22

TABLE XVII (Continued)

75% 6.0 URBOMACHINERY VARIABLES		LOW PRESSURE OXIDIZER	LOW PRESSURE FUEL	HIGH PRESSURE OXIDIZER MAIN	HIGH PRESSURE OXIDIZER BOOST	HIGH PRESSURE FUEL
PUMP INLET FLOWRATE	(LB/SEC)	664.26	110.71	805.43	69.09	110.71
PUMP INLET PRESSURE	(PSIA)	100.00	30.00	333.46	3388.63	164.56
PUMP INLET TEMPERATURE	(DEG. R)	164.00	37.00	168.26	182.69	38.97
PUMP INLET DENSITY	(LB/FT3)	70.9380	4.4075	70.4567	71.0669	4.4001
PUMP DISCHARGE FLOWRATE	(LB/SEC)	805.52	110.71	820.94	53.58	110.71
PUMP DISCHARGE PRESSURE	(PSIA)	366.05	196.18	3496.38	5745.54	4602.76
PUMP DISCHARGE TEMPERATURE	(DEG. R)	168.26	38.97	182.69	198.20	80.22
PUMP DISCHARGE DENSITY	(LB/FT3)	70.4567	4.4188	71.0669	70.6153	4.8587
PUMP TIP SPEED	(FT/SEC)	227.56	665.04	708.99	523.99	1525.20
PUMP HEAD RISE	(FT)	540.1	5377.0	6464.4	4775.7	130678.1
PUMP VOLUMETRIC FLOW-INLET	(GPM)	4203.0	11274.4	5130.8	338.4	11272.3
PUMP HEAD COEFFICIENT-PSI		0.3355	0.3912	0.4138	0.5596	1.8074
PUMP FLOW COEFFICIENT-PHI		0.1796	0.2052	0.1183	0.0538	0.1550
PUMP HORSEPOWER	(BHP)	942.3	1470.1	12276.9	746.5	35068.6
PUMP EFFICIENCY		0.6922	0.7363	0.7711	0.6232	0.7501
PUMP SPEED	(RPM)	4457.56	12701.30	24508.06		29373.93
TURBINE FLOWRATE	(LB/SEC)	141.24	21.78	39.91		99.21
TURBINE INLET PRESSURE	(PSIA)	3389.99	3075.99	3583.65		3544.92
TURBINE INLET TEMPERATURE	(DEG. R)	182.69	590.12	1284.60		1426.60
TURBINE DISCHARGE PRESSURE	(PSIA)	366.18	2650.04	2473.17		2485.06
TURBINE DISCHARGE TEMPERATURE	(DEG R)	182.03	579.04	1188.29		1317.10
TURBINE TIP SPEED	(FT/SEC)	116.70	410.11	1078.99		1306.03
TURBINE SPOUTING VELOCITY	(FT/SEC)	256.34	2181.83	4034.40		4006.21
TURBINE ISENTROPIC VELOCITY RATIO		0.4553	0.1880	0.2674		0.3260
TURBINE PRESSURE RATIO - TOTAL/TOTAL			1.1607	1.4490		1.4265
TURBINE TORQUE	(FT-LB)	1110.26	607.88	2790.94		6270.37
TURBINE HORSEPOWER	(BHP)	942.3	1470.1	13023.5		35065.9
TURBINE EFFICIENCY		0.5989	0.5019	0.7095		0.7795
TURBINE SPEED	(RPM)	4457.58	12701.30	24508.06		29373.93

TABLE XVII (Continued)

75% 6.0		FUEL PREBURNER OXIDIZER	FUEL PREBURNER FUEL	OXIDIZER PREBURNER OXIDIZER	OXIDIZER PREBURNER FUEL
EBURNER VARIABLES					
INLET FLOWRATE (INCLUDING IGNITER)	(LB/SEC)	39.14	60.07	14.44	26.53
INLET PRESSURE	(PSIA)	3874.95	3983.06	3921.93	3932.70
INLET TEMPERATURE	(DEG R)	198.20	294.05	198.20	294.05
INJECTOR FLOWRATE	(LB/SEC)	38.67	59.20	13.98	24.51
INJECTOR INLET PRESSURE	(PSIA)	3863.75	3962.41	3915.02	3917.87
INJECTOR PRESSURE DROP	(PSI)	309.59	408.25	319.66	322.51
INJECTOR END PRESSURE	(PSIA)	3554.16		3595.36	
GAS MIXTURE RATIO	(O/F)	0.6515		0.5672	
GAS FLOWRATE	(LB/SEC)	99.21		39.91	
GAS TEMPERATURE	(DEG R)	1426.60		1264.60	

	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE (PSIA) INLET	PRESSURE (PSIA) DISCHARGE	TEMPERATURE (DEG R) INLET	TEMPERATURE (DEG R) DISCHARGE
IN INJECTOR VARIABLES						
ORIFICE-OXIDIZER	608.20	540.28	2766.05	2225.77	182.69	182.69
ORIFICE-HOT GAS	144.14	211.50	2437.27	2225.77	1242.72	1242.72
HOT GAS MIXTURE RATIO 0.5909						
PRIMARY (LOWER) FACEPLATE-FUEL	4.98	298.02	2523.79	2225.77	579.44	735.93
SECONDARY (UPPER) FACEPLATE-FUEL	2.57	86.52	2523.79	2437.27	579.44	637.73
BAFFLES-FUEL	13.37	348.29	2523.79	2175.50	579.44	775.31
ACOUSTIC CAVITY	0.30	298.02	2523.79	2225.77	579.44	579.44
CLING CIRCUIT VARIABLES						
MAIN COMBUSTION CHAMBER	21.78	1040.77	4312.71	3271.94	80.22	590.12
MAIN CHAMBER NOZZLE	39.27	168.53	4299.13	4130.59	80.22	536.20
HIGH PRESSURE FUEL TURBINE	1.51	2117.70	4602.76	2485.06	80.22	80.52
OXIDIZER PREBURNER CASE	1.06	1444.70	3917.87	2473.17	294.05	294.05
OXIDIZER TURBINE END BEARING	3.93	3055.17	3388.63	333.46	182.69	182.69
PREBURNER PUMP BEARING	11.58	5412.08	5745.54	333.46	198.20	198.20
HOT GAS MANIFOLD - FUEL SIDE	12.26	43.72	2567.51	2523.79	579.04	579.08
HOT GAS MANIFOLD - OXIDIZER SIDE	8.96	21.38	2545.17	2523.79	579.04	579.94
K PRESSURIZATION SYSTEM VARIABLES						
HEAT EXCHANGER HOT GAS	40.84	26.25	2466.52	2440.27	1153.63	1151.27
HEAT EXCHANGER OXIDIZER INLET DUCT	1.86	40.08	3393.53	3353.45	182.69	182.69
PRIMARY HEATING COIL	1.32	788.15	3353.45	2565.30	182.69	1124.24
BYPASS DUCT	0.55	788.15	3353.45	2565.30	182.69	182.69
OXIDIZER TANK PRESSURIZATION DUCT	1.88	16.93	2565.30	2548.37	775.59	775.59
FUEL TANK PRESSURIZATION DUCT	0.53	111.81	2650.04	2538.23	579.04	579.04

TABLE XVII (Continued)

75% 6.0 SCELLANEOUS COMPONENTS	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	PRESSURE(PSIA) DISCHARGE	TEMP (DEG R)
OXIDIZER					
LOW PRESSURE PUMP DISCHARGE DUCT	805.52	32.59	366.05	333.46	168.26
LOW PRESSURE TURBINE INLET DUCT	141.24	106.38	3496.38	3389.99	182.69
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 1	679.70	91.01	3496.38	3405.37	182.69
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 2	608.73	32.33	3405.37	3373.04	182.69
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 1	70.97	11.83	3405.37	3393.53	182.69
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 2	69.09	4.90	3393.53	3388.63	182.69
HIGH PRESSURE BOOST PUMP DISCHARGE DUCT	53.58	1.89	5745.54	5743.65	198.20
OXIDIZER PREBURNER INLET DUCT	14.44	18.80	5743.65	5724.84	198.20
OXIDIZER PREBURNER DOME	13.97	6.91	3921.93	3915.02	198.20
FUEL PREBURNER INLET DUCT	39.14	6.48	5743.65	5737.17	198.20
FUEL PREBURNER DOME	38.66	11.20	3874.95	3863.75	198.20
THRUST CHAMBER DOME	608.20	288.36	3054.41	2766.05	182.69
FUEL					
LOW PRESSURE PUMP DISCHARGE DUCT	110.71	31.62	196.18	164.56	38.97
LOW PRESSURE TURBINE INLET DUCT	21.78	121.79	3197.78	3075.99	590.12
LOW PRESSURE TURBINE DISCHARGE DUCT	21.22	60.76	2650.04	2589.28	579.04
HOT GAS MANIFOLD COOLANT DUCT-FUEL SIDE	12.26	21.77	2589.28	2567.51	579.04
HOT GAS MANIFOLD COOLANT DUCT-OXIDIZER SIDE	8.96	44.11	2589.28	2545.17	579.04
HIGH PRESSURE PUMP DISCHARGE DUCT	109.20	49.09	4602.76	4553.67	80.22
MAIN FUEL VALVE DISCHARGE DUCT	61.04	32.33	4385.76	4352.83	80.22
CHAMBER COOLING JACKET INLET DUCT	21.78	40.13	4352.83	4312.71	80.22
CHAMBER COOLING JACKET DISCHARGE MANIFOLD	21.78	74.16	3271.94	3197.78	590.12
FIXED NOZZLE COOLING JACKET INLET DUCT	39.27	53.70	4352.83	4299.13	80.22
COOLANT CONTROL VALVE INLET DUCT	47.33	35.84	4385.76	4349.92	80.22
COOLANT CONTROL VALVE DISCH DUCT & MIXER	47.33	62.56	4094.47	4031.92	80.22
FIXED NOZZLE COOLING JACKET DISCH DUCT & MIXE	39.27	98.68	4130.59	4031.92	536.20
PREBURNER SUPPLY DUCT	86.60	24.17	4031.92	4007.74	294.05
FUEL PREBURNER INLET DUCT	60.07	25.30	4008.36	3983.06	294.05
OXIDIZER PREBURNER INLET DUCT	26.53	75.67	4008.38	3932.70	294.05
FUEL PREBURNER INLET MANIFOLD	59.20	20.65	3983.06	3962.41	294.05
OXIDIZER PREBURNER INLET MANIFOLD	25.57	14.83	3932.70	3917.87	294.05

TABLE XVII (Concluded)

75% 6.0		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
ISCELLANEOUS COMPONENTS						
HOT GAS						
HIGH PRESSURE FUEL TURBINE INLET DUCT		99.21	9.24	3554.16	3544.92	1426.60
HIGH PRESSURE OXIDIZER TURBINE INLET DUCT		39.91	11.72	3595.36	3583.65	1284.60
HIGH PRESSURE FUEL TURBINE TURNAROUND DUCT		100.73	12.70	2485.06	2472.36	1304.35
HIGH PRESSURE OXIDIZER TURBINE DISCHARGE DUCT		40.84	6.65	2473.17	2466.52	1153.63
HOT GAS MANIFOLD-FUEL SIDE		100.73	32.05	2472.36	2440.31	1304.35
HOT GAS MANIFOLD-OXIDIZER SIDE		40.84	26.25	2466.52	2440.27	1153.63
MAIN INJECTOR POSTS-FUEL SIDE		100.73	3.04	2440.31	2437.27	1304.35
MAIN INJECTOR POSTS-OXIDIZER SIDE		40.84	3.00	2440.27	2437.27	1153.63
NITER SYSTEM						
MAIN CHAMBER						
OXIDIZER PRIMARY SUPPLY DUCT		0.29	436.66	3373.04	2936.38	182.69
OXIDIZER BYPASS DUCT		0.24	118.03	3054.41	2936.38	182.69
OXIDIZER IGNITOR CIRCUIT		0.54	710.61	2936.38	2225.77	182.69
FUEL SUPPLY CIRCUIT		0.81	2159.99	4553.67	2225.77	80.22
MIXTURE RATIO - O/F	0.66					
OXIDIZER PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.47	1805.66	5724.84	3919.18	198.20
OXIDIZER BYPASS DUCT		-0.01	0.02	3919.17	3919.18	198.20
OXIDIZER IGNITOR CIRCUIT		0.46	323.82	3919.18	3595.36	198.20
FUEL SUPPLY CIRCUIT		0.96	337.34	3932.70	3595.36	294.05
MIXTURE RATIO - O/F	0.48					
FUEL PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.48	1869.82	5737.17	3867.35	198.20
OXIDIZER BYPASS DUCT		-0.01	0.05	3867.31	2867.35	198.20
OXIDIZER IGNITOR CIRCUIT		0.47	313.19	3867.35	3554.16	198.20
FUEL SUPPLY CIRCUIT		0.87	428.90	3983.06	3554.16	294.05
MIXTURE RATIO - O/F	0.54					

N DATE 06/19/73 DATA READ 0.0067 BALANCE 6.6833 HEATEX 22.1733 TOTAL 22.4733

TABLE XXII

ROCKETDYNE SSME (60%) 6.0

NGINE VARIABLES -		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	282000.		
MIXTURE RATIO - O/F		6.0000		
SPECIFIC IMPULSE	(SEC)	455.83		
ATMOSPHERIC PRESSURE	(PSIA)	0.0		
PROPELLENT FLOWRATE	(LB/SEC)	620.80	532.11	88.69
PROPELLENT INLET TEMPERATURE	(DEG. R)		164.00	37.00
PROPELLENT INLET PRESSURE	(PSIA)		100.00	30.00
PROPELLENT INLET DENSITY	(LB/FT3)		70.94	4.41
PRESSURIZATION FLOWRATE	(LB/SEC)		1.68	0.44
PRESSURIZATION PRESSURE	(PSIA)		2310.39	2039.88
PRESSURIZATION TEMPERATURE	(DEG. R)		784.19	611.47
OVERBOARD LIQUID FLOWRATE	(LB/SEC)		0.07	0.0
OVERBOARD GAS FLOWRATE	(LB/SEC)	0.11		

HRUST CHAMBER VARIABLES				
THRUST	(LB)	282000.		
MIXTURE RATIO - O/F		6.0157		
SPECIFIC IMPULSE	(LB/SEC)	455.96		
TOTAL FLOWRATE	(LB/SEC)	618.48	530.32	88.16
IGNITER FLOWRATE	(LB/SEC)	1.23	0.46	0.77
NOZZLE STAGNATION PRESSURE	(PSIA)	1778.46		
INJECTOR END PRESSURE (STATIC)	(PSIA)	1783.71		
THRUST COEFFICIENT		1.9201		
CHARACTERISTIC VELOCITY	(FT/SEC)	7640.39		
GEOMETRIC THROAT AREA	(IN2)	83.41		
AERODYNAMIC THROAT AREA	(IN2)	82.58		
GEOMETRIC AREA RATIO	(AE/AT)	77.50		

		FLOWRATE	DELTA P	PRESSURE(PSIA)		TEMP
ONTROL VALVE VARIABLES		(LB/SEC)	(PSI)	INLET	DISCHARGE	(DEGR)
OXIDIZER PREBURNER OXIDIZER VALVE	R=1126.30	10.98	1932.68	4955.29	3022.61	196.19
FUEL PREBURNER OXIDIZER VALVE	R= 164.46	29.28	2005.31	4963.44	2958.13	196.19
CHEDULED VALVE VARIABLES						
MAIN OXIDIZER VALVE	R= 0.20000	488.75	674.06	2994.13	2320.07	181.54
MAIN FUEL VALVE	R= 0.24600	86.47	385.04	3941.98	3556.94	77.03
COOLANT CONTROL VALVE	R= 2.23000	28.00	374.10	3544.00	3169.89	77.03

TABLE XXII (Continued)

60% 6.0 BOMACHINERY VARIABLES		LOW PRESSURE OXIDIZER	LOW PRESSURE FUEL	HIGH PRESSURE OXIDIZER MAIN	HIGH PRESSURE OXIDIZER BOOST	HIGH PRESSURE FUEL
PUMP INLET FLOWRATE	(LB/SEC)	532.11	88.69	663.09	55.60	88.69
PUMP INLET PRESSURE	(PSIA)	100.00	30.00	336.27	3004.14	168.68
PUMP INLET TEMPERATURE	(DEG. R)	164.00	37.00	168.45	181.54	39.00
PUMP INLET DENSITY	(LB/FT3)	70.9380	4.4076	70.4149	70.8750	4.4043
PUMP DISCHARGE FLOWRATE	(LB/SEC)	663.16	88.69	677.44	41.24	88.69
PUMP DISCHARGE PRESSURE	(PSIA)	358.37	188.98	3074.03	4968.33	3973.86
PUMP DISCHARGE TEMPERATURE	(DEG. R)	168.45	39.00	181.54	196.19	77.03
PUMP DISCHARGE DENSITY	(LB/FT3)	70.4149	4.4163	70.8750	70.3044	4.7733
PUMP TIP SPEED	(FT/SEC)	215.56	624.48	645.28	476.91	1383.13
PUMP HEAD RISE	(FT)	524.5	5143.7	5598.8	3990.7	113163.8
PUMP VOLUMETRIC FLOW-INLET	(GPM)	3366.7	9031.0	4226.5	261.2	9026.9
PUMP HEAD COEFFICIENT-PSI		0.3632	0.4244	0.4326	0.5645	1.9032
PUMP FLOW COEFFICIENT-PHI		0.1518	0.1751	0.1071	0.0457	0.1368
PUMP HORSEPOWER	(BHP)	761.7	1153.0	8941.4	518.1	24910.4
PUMP EFFICIENCY		0.6662	0.7194	0.7549	0.5776	0.7325
PUMP SPEED	(RPM)	4222.51	11926.80	22305.94		26637.88
TURBINE FLOWRATE	(LB/SEC)	131.04	17.56	31.50		77.81
TURBINE INLET PRESSURE	(PSIA)	2982.20	2472.77	2806.60		2764.69
TURBINE INLET TEMPERATURE	(DEG. R)	181.54	622.77	1301.48		1380.98
TURBINE DISCHARGE PRESSURE	(PSIA)	358.50	2138.40	1974.94		1983.24
TURBINE DISCHARGE TEMPERATURE	(DEG R)	180.92	611.47	1211.68		1262.85
TURBINE TIP SPEED	(FT/SEC)	110.54	385.10	982.04		1184.38
TURBINE SPOUTING VELOCITY	(FT/SEC)	239.10	2182.06	3907.11		3836.68
TURBINE ISENTROPIC VELOCITY RATIO		0.4623	0.1765	0.2513		0.3085
TURBINE PRESSURE RATIO - TOTAL/TOTAL			1.1564	1.4212		1.3940
TURBINE TORQUE	(FT-LB)	947.39	507.73	2227.35		4911.73
TURBINE HORSEPOWER	(BHP)	761.7	1153.0	9459.7		24911.6
TURBINE EFFICIENCY		0.5997	0.4682	0.6963		0.7689
TURBINE SPEED	(RPM)	4222.51	11926.80	22305.94		26637.88

TABLE XXII (Continued)

60% 6.0		FUEL PREBURNER		OXIDIZER PREBURNER	
REBURNER VARIABLES		OXIDIZER	FUEL	OXIDIZER	FUEL
INLET FLOWRATE (INCLUDING IGNITER)	(LB/SEC)	29.77	48.04	11.47	20.86
INLET PRESSURE	(PSIA)	2958.13	3113.42	3022.61	3075.46
INLET TEMPERATURE	(DEG R)	196.19	302.66	196.19	302.66
INJECTOR FLOWRATE	(LB/SEC)	29.41	47.35	11.10	19.27
INJECTOR INLET PRESSURE	(PSIA)	2951.67	3097.03	3018.32	3064.08
INJECTOR PRESSURE DROP	(PSI)	179.87	325.22	202.25	248.01
INJECTOR END PRESSURE	(PSIA)	2771.80		2816.07	
GAS MIXTURE RATIO	(O/F)	0.6198		0.5726	
GAS FLOWRATE	(LB/SEC)	77.81		31.50	
GAS TEMPERATURE	(DEG R)	1380.98		1301.48	

		FLOWRATE	DELTA P	PRESSURE(PSIA)		TEMPERATURE(DEG R)	
IN INJECTOR VARIABLES		(LB/SEC)	(PSI)	INLET	DISCHARGE	INLET	DISCHARGE
ORIFICE-OXIDIZER		488.66	349.71	2133.42	1783.71	181.54	181.54
ORIFICE-HOT GAS		113.76	163.09	1946.79	1783.71	1222.19	1222.19
HOT GAS MIXTURE RATIO	0.5679						
PRIMARY(LOWER)FACEPLATE-FUEL		4.02	249.68	2033.39	1783.71	612.37	774.57
SECONDARY(UPPER)FACEPLATE-FUEL		2.27	86.59	2033.39	1946.79	612.37	667.58
BAFFLES-FUEL		10.56	294.05	2033.39	1739.33	612.37	819.72
ACOUSTIC CAVITY		0.25	249.68	2033.39	1783.71	612.37	612.37
OLING CIRCUIT VARIABLES							
MAIN COMBUSTION CHAMBER		17.56	863.32	3498.74	2635.42	77.03	622.77
MAIN CHAMBER NOZZLE		40.89	189.74	3465.53	3275.79	77.03	447.18
HIGH PRESSURE FUEL TURBINE		1.45	1990.62	3973.86	1983.24	77.03	77.37
OXIDIZER PREBURNER CASE		0.83	1089.14	3064.08	1974.94	302.66	302.66
OXIDIZER TURBINE END BEARING		3.67	2667.87	3004.14	336.27	181.54	181.54
PREBURNER PUMP BEARING		10.69	4632.06	4968.33	336.27	196.19	196.19
HOT GAS MANIFOLD - FUEL SIDE		9.88	36.40	2069.79	2033.39	611.47	611.86
HOT GAS MANIFOLD - OXIDIZER SIDE		7.21	17.84	2051.22	2033.39	611.47	613.07
K PRESSURIZATION SYSTEM VARIABLES							
HEAT EXCHANGER HOT GAS		32.22	20.58	1969.73	1949.15	1176.94	1174.23
HEAT EXCHANGER OXIDIZER INLET DUCT		1.68	32.27	3007.33	2975.05	181.54	181.54
PRIMARY HEATING COIL		1.18	649.55	2975.05	2325.50	181.54	1147.11
BYPASS DUCT		0.50	649.55	2975.05	2325.50	181.54	181.54
OXIDIZER TANK PRESSURIZATION DUCT		1.68	15.11	2325.50	2310.39	784.19	784.19
FUEL TANK PRESSURIZATION DUCT		0.44	98.52	2138.40	2039.88	611.47	611.47

TABLE XXII (Continued)

60% 6.0 SCELLANEOUS COMPONENTS	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
OXIDIZER					
LOW PRESSURE PUMP DISCHARGE DUCT	663.16	22.10	358.37	336.27	168.45
LOW PRESSURE TURBINE INLET DUCT	131.04	91.83	3074.03	2982.20	181.54
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 1	546.40	58.97	3074.03	3015.06	181.54
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 2	489.12	20.93	3015.06	2994.13	181.54
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 1	57.28	7.73	3015.06	3007.33	181.54
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 2	55.60	3.18	3007.33	3004.14	181.54
HIGH PRESSURE BOOST PUMP DISCHARGE DUCT	41.24	1.13	4968.33	4967.20	196.19
OXIDIZER PREBURNER INLET DUCT	11.47	11.91	4967.20	4955.29	196.19
OXIDIZER PREBURNER DOME	10.98	4.29	3022.61	3018.32	196.19
FUEL PREBURNER INLET DUCT	29.77	3.76	4967.20	4963.44	196.19
FUEL PREBURNER DOME	29.28	6.45	2958.13	2951.67	196.19
THRUST CHAMBER DOME	488.66	186.65	2320.07	2133.42	181.54
FUEL					
LOW PRESSURE PUMP DISCHARGE DUCT	88.69	20.30	188.98	168.68	39.00
LOW PRESSURE TURBINE INLET DUCT	17.56	101.15	2573.92	2472.77	622.77
LOW PRESSURE TURBINE DISCHARGE DUCT	17.09	50.50	2138.40	2087.90	611.47
HOT GAS MANIFOLD COOLANT DUCT-FUEL SIDE	9.88	18.11	2087.90	2069.79	611.47
HOT GAS MANIFOLD COOLANT DUCT-OXIDIZER SIDE	7.21	36.68	2087.90	2051.22	611.47
HIGH PRESSURE PUMP DISCHARGE DUCT	87.23	31.88	3973.86	3941.98	77.03
MAIN FUEL VALVE DISCHARGE DUCT	58.45	30.17	3556.94	3525.65	77.03
CHAMBER COOLING JACKET INLET DUCT	17.56	26.91	3525.65	3498.74	77.03
CHAMBER COOLING JACKET DISCHARGE MANIFOLD	17.56	61.50	2635.42	2573.92	622.77
FIXED NOZZLE COOLING JACKET INLET DUCT	40.89	60.12	3525.65	3465.53	77.03
COOLANT CONTROL VALVE INLET DUCT	28.00	12.94	3556.94	3544.00	77.03
COOLANT CONTROL VALVE DISCH DUCT & MIXER	28.00	18.45	3169.89	3151.44	77.03
FIXED NOZZLE COOLING JACKET DISCH DUCT & MIXE	40.89	124.35	3275.79	3151.44	447.16
PREBURNER SUPPLY DUCT	68.90	18.97	3151.44	3132.48	302.66
FUEL PREBURNER INLET DUCT	48.04	20.07	3133.49	3113.42	202.66
OXIDIZER PREBURNER INLET DUCT	20.86	58.03	3133.49	3075.46	302.66
FUEL PREBURNER INLET MANIFOLD	47.35	16.39	3113.42	3097.03	302.66
OXIDIZER PREBURNER INLET MANIFOLD	20.10	11.37	3075.46	3064.08	302.66

TABLE XXII (Concluded)

60% 6.0 ISCELLANEOUS COMPONENTS		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
HOT GAS						
HIGH PRESSURE FUEL TURBINE INLET DUCT		77.81	7.12	2771.80	2764.69	1380.98
HIGH PRESSURE OXIDIZER TURBINE INLET DUCT		31.50	9.27	2816.07	2806.80	1301.48
HIGH PRESSURE FUEL TURBINE TURNAROUND DUCT		79.28	9.69	1983.24	1973.56	1264.90
HIGH PRESSURE OXIDIZER TURBINE DISCHARGE DUCT		32.22	5.21	1974.94	1969.73	1176.94
HOT GAS MANIFOLD-FUEL SIDE		79.28	24.45	1973.56	1949.11	1264.90
HOT GAS MANIFOLD-OXIDIZER SIDE		32.22	20.58	1969.73	1949.15	1176.94
MAIN INJECTOR POSTS-FUEL SIDE		79.28	2.32	1949.11	1946.79	1264.90
MAIN INJECTOR POSTS-OXIDIZER SIDE		32.22	2.35	1949.15	1946.79	1176.94
IGNITER SYSTEM						
MAIN CHAMBER						
OXIDIZER PRIMARY SUPPLY DUCT		0.37	690.01	2994.13	2304.11	161.54
OXIDIZER BYPASS DUCT		0.09	15.95	2320.07	2304.11	181.54
OXIDIZER IGNITOR CIRCUIT		0.46	520.41	2304.11	1783.71	161.54
FUEL SUPPLY CIRCUIT		0.77	1773.24	3941.98	1783.71	77.03
MIXTURE RATIO - O/F	0.60					
OXIDIZER PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.49	1928.90	4955.29	3026.40	196.19
OXIDIZER BYPASS DUCT		-0.11	5.50	3020.89	3026.40	196.19
OXIDIZER IGNITOR CIRCUIT		0.37	210.32	3026.40	2816.07	196.19
FUEL SUPPLY CIRCUIT		0.76	259.38	3075.46	2816.07	302.66
MIXTURE RATIO - O/F	0.49					
FUEL PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.49	2002.47	4963.44	2960.97	196.19
OXIDIZER BYPASS DUCT		-0.13	7.24	2953.72	2960.97	196.19
OXIDIZER IGNITOR CIRCUIT		0.36	189.16	2960.97	2771.80	196.19
FUEL SUPPLY CIRCUIT		0.69	341.61	3113.42	2771.80	302.66
MIXTURE RATIO - O/F	0.52					

UN DATE 06/19/73 DATA READ 0.0067 BALANCE 21.5400 HEATEX 33.1600 TOTAL 33.4533

TABLE XXVII

ROCKETDYNE SSME (50%) MPL 6.0

ENGINE VARIABLES -		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	235000.		
MIXTURE RATIO - O/F		6.0000		
SPECIFIC IMPULSE	(SEC)	455.57		
ATMOSPHERIC PRESSURE	(PSIA)	0.0		
PROPELLENT FLOWRATE	(LB/SEC)	517.77	443.80	73.97
PROPELLENT INLET TEMPERATURE	(DEG. R)		164.00	37.00
PROPELLENT INLET PRESSURE	(PSIA)		100.00	30.00
PROPELLENT INLET DENSITY	(LB/FT3)		70.94	4.41
PRESSURIZATION FLOWRATE	(LB/SEC)		1.53	0.38
PRESSURIZATION PRESSURE	(PSIA)		2214.59	1711.88
PRESSURIZATION TEMPERATURE	(DEG. R)		830.49	637.97
OVERBOARD LIQUID FLOWRATE	(LB/SEC)		0.06	0.0
OVERBOARD GAS FLOWRATE	(LB/SEC)	0.09		

HRUST CHAMBER VARIABLES		SYSTEM	OXIDIZER	FUEL
THRUST	(LB)	235000.		
MIXTURE RATIO - O/F		6.0150		
SPECIFIC IMPULSE	(LB/SEC)	455.70		
TOTAL FLOWRATE	(LB/SEC)	515.69	442.18	73.51
IGNITER FLOWRATE	(LB/SEC)	1.13	0.39	0.74
NOZZLE STAGNATION PRESSURE	(PSIA)	1480.91		
INJECTOR END PRESSURE (STATIC)	(PSIA)	1487.57		
THRUST COEFFICIENT		1.9215		
CHARACTERISTIC VELOCITY	(FT/SEC)	7630.20		
GEOMETRIC THROAT AREA	(IN2)	83.41		
AERODYNAMIC THROAT AREA	(IN2)	82.58		
GEOMETRIC AREA RATIO	(AE/AT)	77.50		

		FLOWRATE	DELTA P	PRESSURE(PSIA)		TEMP
NTROL VALVE VARIABLES		(LB/SEC)	(PSI)	INLET	DISCHARGE	(DEGR)
OXIDIZER PREBURNER OXIDIZER VALVE	R=1621.50	9.42	2056.67	4547.22	2490.55	196.30
FUEL PREBURNER OXIDIZER VALVE	R= 266.90	23.72	2147.74	4553.66	2405.93	196.30
HEDULED VALVE VARIABLES						
MAIN OXIDIZER VALVE	R= 0.40006	407.63	940.86	2802.91	1862.06	181.74
MAIN FUEL VALVE	R= 0.50000	71.82	550.17	3548.80	2998.63	76.30
COOLANT CONTROL VALVE	R= 5.00000	18.67	385.60	2992.68	2607.08	76.30

TABLE XXVII (Continued)

MPL 6.0 URBOMACHINERY VARIABLES		LOW PRESSURE OXIDIZER	LOW PRESSURE FUEL	HIGH PRESSURE OXIDIZER MAIN	HIGH PRESSURE OXIDIZER BOOST	HIGH PRESSURE FUEL
PUMP INLET FLOWRATE	(LB/SEC)	443.80	73.97	568.95	47.84	73.97
PUMP INLET PRESSURE	(PSIA)	100.00	30.00	341.64	2809.40	174.01
PUMP INLET TEMPERATURE	(DEG. R)	164.00	37.00	168.95	181.74	39.15
PUMP INLET DENSITY	(LB/FT3)	70.9380	4.4076	70.3266	70.6531	4.4031
PUMP DISCHARGE FLOWRATE	(LB/SEC)	569.01	73.97	582.64	34.15	73.97
PUMP DISCHARGE PRESSURE	(PSIA)	357.94	188.15	2858.99	4556.95	3571.27
PUMP DISCHARGE TEMPERATURE	(DEG. R)	168.95	39.15	181.74	196.30	76.30
PUMP DISCHARGE DENSITY	(LB/FT3)	70.3266	4.4115	70.6531	69.9471	4.6846
PUMP TIP SPEED	(FT/SEC)	210.88	606.79	609.01	450.10	1287.80
PUMP HEAD RISE	(FT)	523.6	5116.7	5154.5	3561.7	101812.7
PUMP VOLUMETRIC FLOW-INLET	(GPM)	2808.0	7532.1	3631.0	216.9	7533.5
PUMP HEAD COEFFICIENT-PSI		0.3788	0.4471	0.4471	0.5657	1.9752
PUMP FLOW COEFFICIENT-PHI		0.1294	0.1503	0.0975	0.0402	0.1227
PUMP HORSEPOWER	(BHP)	673.2	992.4	7267.4	410.1	19400.9
PUMP EFFICIENCY		0.6276	0.6934	0.7337	0.5392	0.7058
PUMP SPEED	(RPM)	4130.83	11588.89	21051.95		24801.93
TURBINE FLOWRATE	(LB/SEC)	125.20	14.91	26.12		64.25
TURBINE INLET PRESSURE	(PSIA)	2774.89	2085.64	2327.75		2276.17
TURBINE INLET TEMPERATURE	(DEG. R)	181.74	649.78	1382.40		1371.70
TURBINE DISCHARGE PRESSURE	(PSIA)	358.05	1802.54	1647.28		1653.28
TURBINE DISCHARGE TEMPERATURE	(DEG R)	181.09	637.97	1292.30		1279.50
TURBINE TIP SPEED	(FT/SEC)	108.14	374.19	926.83		1102.75
TURBINE SPOUTING VELOCITY	(FT/SEC)	229.84	2220.68	3904.13		3753.91
TURBINE ISENTROPIC VELOCITY RATIO		0.4705	0.1685	0.2374		0.2938
TURBINE PRESSURE RATIO - TOTAL/TOTAL			1.1571	1.4131		1.3768
TURBINE TORQUE	(FT-LB)	855.98	449.75	1915.43		4108.59
TURBINE HORSEPOWER	(BHP)	673.2	992.4	7677.6		19401.9
TURBINE EFFICIENCY		0.6004	0.4778	0.6824		0.7584
TURBINE SPEED	(RPM)	4130.83	11588.89	21051.95		24801.93

TABLE XXVII (Continued)

MPL 6.0		FUEL PREBURNER OXIDIZER	FUEL PREBURNER FUEL	OXIDIZER PREBURNER OXIDIZER	OXIDIZER PREBURNER FUEL
REBURNER VARIABLES					
INLET FLOWRATE (INCLUDING IGNITER)	(LB/SEC)	24.23	40.02	9.92	16.88
INLET PRESSURE	(PSIA)	2405.93	2571.95	2490.55	2542.62
INLET TEMPERATURE	(DEG R)	196.30	316.52	196.30	316.52
INJECTOR FLOWRATE	(LB/SEC)	23.92	39.44	9.59	15.59
INJECTOR INLET PRESSURE	(PSIA)	2401.67	2558.07	2487.38	2533.54
INJECTOR PRESSURE DROP	(PSI)	119.64	276.04	151.75	197.90
INJECTOR END PRESSURE	(PSIA)	2282.03		2335.63	
GAS MIXTURE RATIO	(O/F)	0.6056		0.6120	
GAS FLOWRATE	(LB/SEC)	64.25		26.12	
GAS TEMPERATURE	(DEG R)	1371.70		1382.40	

AIN INJECTOR VARIABLES		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	PRESSURE(PSIA) DISCHARGE	TEMPERATURE(DEG R) INLET	TEMPERATURE(DEG R) DISCHARGE
ORIFICE-OXIDIZER		407.67	244.17	1731.74	1487.57	181.74	181.74
ORIFICE-HOT GAS		94.43	135.77	1623.35	1487.57	1237.44	1237.44
HOT GAS MIXTURE RATIO	0.5658						
PRIMARY(LOWER)FACEPLATE-FUEL		3.42	222.47	1710.04	1487.57	639.82	804.32
SECONDARY(UPPER)FACEPLATE-FUEL		2.05	86.69	1710.04	1623.35	639.82	692.61
BAFFLES-FUEL		8.83	261.71	1710.04	1448.33	639.82	854.08
ACOUSTIC CAVITY		0.21	222.47	1710.04	1487.57	639.82	639.82
OCLING CIRCUIT VARIABLES							
MAIN COMBUSTION CHAMBER		14.91	724.52	2952.67	2228.15	76.30	649.78
MAIN CHAMBER NOZZLE		38.22	190.03	2918.43	2728.40	76.30	428.34
HIGH PRESSURE FUEL TURBINE		1.41	1917.99	3571.27	1653.28	76.30	76.69
OXIDIZER PREBURNER CASE		0.68	886.26	2533.54	1647.28	316.52	316.52
OXIDIZER TURBINE END BEARING		3.52	2467.75	2809.40	341.64	181.74	181.74
PREBURNER PUMP BEARING		10.17	4215.30	4556.95	341.64	196.30	196.30
HOT GAS MANIFOLD - FUEL SIDE		8.38	32.10	1742.14	1710.04	637.97	639.03
HOT GAS MANIFOLD - OXIDIZER SIDE		6.12	15.73	1725.77	1710.04	637.97	640.89
NK PRESSURIZATION SYSTEM VARIABLES							
HEAT EXCHANGER HOT GAS		26.71	17.50	1642.85	1625.35	1254.70	1251.46
HEAT EXCHANGER OXIDIZER INLET DUCT		1.53	26.79	2811.76	2784.97	181.74	181.74
PRIMARY HEATING COIL		1.06	556.51	2784.97	2228.46	181.74	1223.82
BYPASS DUCT		0.47	556.51	2784.97	2228.46	181.74	181.74
OXIDIZER TANK PRESSURIZATION DUCT		1.53	13.86	2228.46	2214.59	830.49	830.49
FUEL TANK PRESSURIZATION DUCT		0.38	90.66	1802.54	1711.88	637.97	637.97

TABLE XXVII (Continued)

MPL 6.0 MISCELLANEOUS COMPONENTS	FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
OXIDIZER					
LOW PRESSURE PUMP DISCHARGE DUCT	569.01	16.29	357.94	341.64	168.95
LOW PRESSURE TURBINE INLET DUCT	125.20	84.09	2858.99	2774.89	181.74
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 1	457.43	41.46	2858.99	2817.52	181.74
HIGH PRESSURE MAIN PUMP DISCH DUCT-SECT 2	408.06	14.61	2817.52	2802.91	181.74
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 1	49.37	5.76	2817.52	2811.76	181.74
HIGH PRESSURE BOOST PUMP INLET DUCT-SECTION 2	47.84	2.36	2811.76	2809.40	181.74
HIGH PRESSURE BOOST PUMP DISCHARGE DUCT	34.15	0.78	4556.95	4556.17	196.30
OXIDIZER PREBURNER INLET DUCT	9.92	8.95	4556.17	4547.22	196.30
OXIDIZER PREBURNER DOME	9.42	3.17	2490.55	2487.38	196.30
FUEL PREBURNER INLET DUCT	24.23	2.51	4556.17	4553.66	196.30
FUEL PREBURNER DOME	23.72	4.26	2405.93	2401.67	196.30
THRUST CHAMBER DOME	407.67	130.32	1862.06	1731.74	181.74
FUEL					
LOW PRESSURE PUMP DISCHARGE DUCT	73.97	14.14	188.15	174.01	39.15
LOW PRESSURE TURBINE INLET DUCT	14.91	88.68	2174.32	2085.64	649.78
LOW PRESSURE TURBINE DISCHARGE DUCT	14.51	44.45	1802.54	1758.10	637.97
HOT GAS MANIFOLD COOLANT DUCT-FUEL SIDE	8.38	15.96	1758.10	1742.14	637.97
HOT GAS MANIFOLD COOLANT DUCT-OXIDIZER SIDE	6.12	32.32	1758.10	1725.77	637.97
HIGH PRESSURE PUMP DISCHARGE DUCT	72.55	22.47	3571.27	3548.80	76.30
MAIN FUEL VALVE DISCHARGE DUCT	53.13	25.41	2998.63	2972.73	76.30
CHAMBER COOLING JACKET INLET DUCT	14.91	20.06	2972.73	2952.67	76.30
CHAMBER COOLING JACKET DISCHARGE MANIFOLD	14.91	53.82	2228.15	2174.32	649.78
FIXED NOZZLE COOLING JACKET INLET DUCT	38.22	54.30	2972.73	2918.43	76.30
COOLANT CONTROL VALVE INLET DUCT	18.67	5.95	2998.63	2992.68	76.30
COOLANT CONTROL VALVE DISCH DUCT & MIXER	18.67	2.83	2607.08	2604.26	76.30
FIXED NOZZLE COOLING JACKET DISCH DUCT & MIXE	38.22	124.14	2728.40	2604.26	428.34
PREBURNER SUPPLY DUCT	56.90	15.75	2604.26	2588.50	316.52
FUEL PREBURNER INLET DUCT	40.02	16.98	2588.93	2571.95	316.52
OXIDIZER PREBURNER INLET DUCT	16.88	46.32	2588.94	2542.62	316.52
FUEL PREBURNER INLET MANIFOLD	39.44	13.88	2571.95	2558.07	316.52
OXIDIZER PREBURNER INLET MANIFOLD	16.27	9.08	2542.62	2533.54	316.52

TABLE XXVII (Concluded)

MPL 6.0 SCELLANEOUS COMPONENTS		FLOWRATE (LB/SEC)	DELTA P (PSI)	PRESSURE(PSIA) INLET	DISCHARGE	TEMP (DEG R)
HOT GAS						
HIGH PRESSURE FUEL TURBINE INLET DUCT		64.25	5.86	2282.03	2276.17	1371.70
HIGH PRESSURE OXIDIZER TURBINE INLET DUCT		26.12	7.88	2335.63	2327.75	1382.40
HIGH PRESSURE FUEL TURBINE TURNAROUND DUCT		65.67	7.95	1653.28	1645.33	1255.68
HIGH PRESSURE OXIDIZER TURBINE DISCHARGE DUCT		26.71	4.43	1647.28	1642.85	1254.70
HOT GAS MANIFOLD-FUEL SIDE		65.67	20.07	1645.33	1625.25	1255.68
HOT GAS MANIFOLD-OXIDIZER SIDE		26.71	17.50	1642.85	1625.35	1254.70
MAIN INJECTOR POSTS-FUEL SIDE		65.67	1.90	1625.25	1623.35	1255.68
MAIN INJECTOR POSTS-OXIDIZER SIDE		26.71	2.00	1625.35	1623.35	1254.70
NITER SYSTEM						
MAIN CHAMBER						
OXIDIZER PRIMARY SUPPLY DUCT		0.43	937.58	2802.91	1865.33	181.74
OXIDIZER BYPASS DUCT		-0.04	3.27	1862.06	1865.33	181.74
OXIDIZER IGNITOR CIRCUIT		0.39	377.75	1[illegible]65.33	1487.57	181.74
FUEL SUPPLY CIRCUIT		0.74	1511.05	3548.80	1487.57	76.30
MIXTURE RATIO - O/F	0.53					
OXIDIZER PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.50	2045.52	4547.22	2501.70	196.30
OXIDIZER BYPASS DUCT		-0.17	12.41	2489.28	2501.70	196.30
OXIDIZER IGNITOR CIRCUIT		0.33	166.07	2501.70	2335.63	196.30
FUEL SUPPLY CIRCUIT		0.61	206.99	2542.62	2335.63	316.52
MIXTURE RATIO - O/F	0.54					
FUEL PREBURNER						
OXIDIZER PRIMARY SUPPLY DUCT		0.51	2133.76	4553.66	2419.90	196.30
OXIDIZER BYPASS DUCT		-0.20	16.88	2403.02	2419.90	196.30
OXIDIZER IGNITOR CIRCUIT		0.31	137.87	2419.90	2282.03	196.30
FUEL SUPPLY CIRCUIT		0.58	289.91	2571.95	2282.03	316.52
MIXTURE RATIO - O/F	0.54					

N DATE 06/19/73 DATA READ 0.0033 BALANCE 6.1567 HEATEX 17.9967 TOTAL 18.2867