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I am submitting herewith a thesis written by John H. E. Stelling III entitled "Application of Singular Value Decomposition and Nonlinear Feedback Control to a Multispace Problem." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Chemical Engineering.

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APPLICATION OF SINGULAR VALUE DECOMPOSITION AND NONLINEAR FEEDBACK CONTROL TO A MULTISPACE PROBLEM

A Thesis

Presented for the

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DEDICATION

This thesis is dedicated to two individuals who have had the greatest influence on my interests in science and research: my grandfather, Col. C. F. Myers, Jr., and my teacher, Dr. George B. Savitsky.

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ABSTRACT

Much has been written to indicate the desirability of process operation at or near an unstable steady state. A new control philosophy has been applied successfully to a first order experimental system to provide stable operation using a nonlinear feedback control device, a relay with hysteresis. Based on these encouraging results, the present study undertook to examine application of this control concept to a higher order system, the 2-azobisisobutyronitrile initiated bulk polymerization of styrene in a continuous flow stirred tank reactor.

The tenth order model developed for this polymerization system was studied using singular value decomposition, a mathematical analysis relatively new to the field of engineering applications. This process resulted in a simplification of the model to a lower order through a quantitative approach, improving on the qualitative arguments previously employed. A further application of singular value decomposition indicated specific control loops to be examined for best response to a step input change.

Tsypkin's analysis, used when examining a relay control mechanism, was shown to be the necessary technique for design of the nonlinear control element for higher order systems, as the added complexity led to improper conclusions based on the standard Van Heerden graphical analysis approach. Due to the highly exothermic nature of the free radical polymerization process, control of the reactor temperature by inlet monomer concentration was shown to yield satisfactory process control about the unstable steady state. Period and amplitude of the oscillation as predicted by Tsypkin's analysis compared very well with those resulting from the nonlinear simulation. Several new phenomena not previously observed in the application of this nonlinear scheme are reported. Other results of Tsypkin's analysis of control strategies pointed toward interesting possibilities in the area of pushing (use of large relay drive levels) control theory.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The study of process control has become increasingly important in the years since World War II. Many of the questions regarding stability have been approached through investigations into process dynamics.

Through these studies of the process dynamics, it became obvious that many processes, spanning a wide variety of industrially significant reactions, exhibited steady state multiplicity, that is, more than a single unique set of operating conditions for any particular set of process parameters. For lumped-parameter systems having more than one stable steady state, there will be at least one unstable steady state. Quite often, it is the unstable steady state at which operation is desired, for example the lower steady state may have low yields associated with it and the upper steady state may represent an impractical operating condition or even perhaps a "runaway" condition. The unstable steady state may then be the logical compromise to obtain good yields and reasonable operating conditions.

Conventional linear control strategies have been applied successfully to a large number of industrially significant processes, but there is impetus to implement new methods of process control. A novel approach to process control could provide stability of a periodic nature in a region about the unstable steady state. Furthermore, this idea of control "about" a steady state could yield some desirable product qualities unattainable with linear control.

This concept of nonlinear feedback control was set forth and mathematically investigated by Bruns, et. al., [23,24,25] and very recently by Matsubara and Onogi [27]. In a related study, Paredes [28,62] demonstrated the idea on an experimental system. Part of this work endeavored to investigate the nonlinear feedback control for a multispace complex process, a free radical polymerization reactor. Equally important in this current study was a survey of currently accepted models of the process. A comparison of the model used in this work and others was made to emphasize the role of process modeling and model simplification.

A new analysis technique in the field of engineering, singular value decomposition, was employed to study reactor modeling and control. Through the implementation of singular value decomposition, the process model was simplified to a reduced order using a quantitative approach rather than the qualitative "feel" generally employed for this purpose. Further application of singular value decomposition yielded an insight into the possible control strategies used to maintain process operation near the unstable steady state.

CHAPTER I

LITERATURE SURVEY

Background Information

In a 1918 study by Liljenroth [1], the concept of a stability analysis in reaction engineering is first indicated, employing a Van Heerden [2] type of approach. Liljenroth used experimental data on the study of an ammonia oxidation burner (platinum wire gauze) to show that ammonia conversion to nitric oxide varied in a sigmoidal relationship with temperature; that is, a so-called "conversion curve" was constructed that was S-shaped. Further, he showed that the burner temperature was linearly related to the conversion, yielding his "heat of reaction line." By plotting both of these curves together, Liljenroth indicated the steady states of operation as the intersections of the lines. Even though he suggested the possibility of unstable steady states, he had observed none experimentally.

Van Heerden [2], in 1953, used a similar graphical approach to that of Liljenroth in his analysis of autothermic reactors. His ideas were more mathematically based by examining the system of interest from an energy balance standpoint. He viewed the energy balance as being comprised of a heat generation contribution and a heat removal contribution. In the graphical analysis, the heat generation curve was sigmoidal in shape and the heat removal curve linear. His reasoning was that, at the intersections of these two curves, steady state conditions existed.

Van Heerden further indicated the "slope condition" of stability based on this graphical analysis. Now, it is well-known that the slope condition represents necessary and sufficient criteria for a single variable system and only a necessary condition for stability of multivariable systems [55,56,57]. Van Heerden [3] extended these concepts to the analysis of exothermic processes in continuous flow stirred-tank reactors (CSTRs) and various plug flow reactor (PFR) configurations.

Even though the mathematical analyses of Poincare [4], Lyapunov [5], and Minorsky [6] had been available, it was not until 1955 that these methods were applied by Bilous and Amundson [7] in the reaction engineering field. The idea of using perturbation theory of the linearized system was employed for an irreversible exothermic reaction occuring in a CSTR (continuous flow stirred tank reactor), a process described by two ordinary differential equations. Their results for the linearized system were then compared with analog "reaction paths" or phase plots developed from the nonlinear equations.

In 1958, Aris and Amundson [8,9,10] investigated the stability problem in a now-classical series of papers. The problems of stability and transient behavior were mathematically theorized for the CSTR model used by Bilous and Amundson. Of equal significance was their presentation of stability analyses for the various modes of linear control (i.e. proportional, proportional-integral, *etc.*) applied to systems at the unstable steady state.

These initial investigations provided a firm base from which an ever-increasing volume of work has been accomplished. The following survey is but a brief review of some recent work which is central to the current research.

Recent Publications

Concepts and analyses illustrated by Van Heerden, Aris, Amundson, and others have stood to encourage much investigative work in the area of process dynamics and control. Through subsequent studies, much has been learned about steady state multiplicity and oscillatory chemical reactor behavior. Implementation of applicable control schemes to unstable systems has been a result of this work.

Chemical reactors have generally been designed under steady state conditions [37,51,52,53], with no regard to transient behavior. Since transients are encountered at reactor start-up and shutdown, as well as with any perturbation in operating parameters, these effects could well influence reactor performance and should, therefore, be considered. Further, steady state multiplicity and, thus, unstable steady states need to be accounted for in these designs.

In a review of practical applications of reactor stability, Schmeal and Barkelew [11] drew from their industrial setting various problems encountered in the operation of continuous stirred-tank reactors (the autocatalytic effect in the hydration of olefins to alcohols using sulfuric acid as catalyst), imperfectly mixed reactors, and packed bed reactors. Also discussed were the various effects of steady state multiplicity in slurry reactions, two-phase reactions, and metal-fluid reactions.

Similarly, ElNashaie, Marek and Ray [12] investigated the problem of catalyst deactivation in dispersed catalytic reactors. Their work showed that for some ranges of catalyst activity multiple steady states could occur. In their example they found when in a region of multiple steady states, operation at the unstable steady state was indicated as nearer optimal based on the moderate operating temperature. Even though the upper steady state gave higher productivity initially, the higher operating temperature caused more rapid deactivation of the catalyst and a shift from a region of steady state multiplicity to a region of a single unproductive lower steady state. Therefore, operation at the unstable steady state provided a better time-averaged yield with slowly increasing moderate productivity and moderate decay rate.

Reaction multiplicity is common in biological and enzyme systems [58,59,60]. Bruns, et al., [13] presented a mathematical investigation of an enzymatic reaction exhibiting an inhibited substrate reaction mechanism. A stable oscillatory state was shown for the case of a unique steady state. For the case of steady state multiplicity, oscillatory behavior was observed outside the region of asymptotic stability. Stelling, et al., [61] used this same system to illustrate, via numerical simulation, limit cycle amplitude reduction by employing a relay with hysteresis as a feedback controller.

Chemical oscillations were found by Franck [15] to depend heavily upon complex kinetic mechanisms: coupling between reactions and various transport phenomena. Gilles, et al., [16] expanded on this concept in their study of the catalytic fixed bed reactor for an endothermic reaction with self-inhibiting or self-accelerating steps. They included simulations of the dehydrogenation of alcohol on an oxide catalyst.

Ivanov, et al., [14] present investigations in the area of steady state multiplicity and stable limit cycles for a catalytic reaction system coupled to an adsorption process. In their study, periodic oscillatory behavior is correlated to the system kinetic and model parameters.

Knorr and O'Driscoll [17] used batch reactor data on the bulk polymerization of styrene to demonstrate mathematically the possible existence of multiple steady states in an isothermal CSTR. Through a Van Heerden-type approach using the steady state mass balance, they show that the middle steady state is necessarily unstable. In the case of the polymerization reactor, operation at or near the unstable steady state is desirable since little or no product is made at the lower steady state and, at the upper steady state, the so-called "gel effect" causes the product to be of undesirable characteristics. To attain operation at the intermediate conversion level, Knorr and O'Driscoll suggest an oscillating monomer feed concentration and reactor recycling.

In related work Ray [18] examined the effect on molecular weight distributions of sinusoidal perturbations in monomer feed concentrations for continuous stirred-tank reactors. Laurence and Vasudevan [19] used very slow forced oscillations of feed concentrations of monomer and initiator to study the time-averaged effects on the molecular weight distributions. An experimental study of periodic operation of a styrene polymerization reactor using open loop on-off control of initiator feed was presented by Spitz, et al., [20]. Additional experimental studies of forced periodic open loop operation of polymerization reactors are cited in the literature.

Bruns, et al., [23,24,25] propose operation of a system near its unstable steady state using a nonlinear feedback control element. Matsubara and Onogi [27] recently showed for an example that, for performance at an unstable steady state, the nonlinear relay control should be used for stability reasons and that this novel controller is superior to the conventional linear controller in performance for this case. In an experimental study, Paredes [28,62] successfully applied the nonlinear feedback control element to maintain process operation near an unstable steady state in the bis-trichloromethyl-trisulfide-aniline reaction system in a CSTR [54].

These articles represent but a few of many regarding the phenomenon of steady state multiplicity. Further examples may be found in a comprehensive review of multiplicity by Schmitz [29].

CHAPTER II

REACTION SYSTEM

Introduction

Polymerization is the process by which molecular units known as monomers are combined to form aggregates known as polymers. Since the kinetic mechanism of the polymerization process is very complex, much effort in recent years has gone into the characterization of these processes so that consistent product properties might be maintained [30-39]. The example of interest in this research is the chain growth free radical polymerization in a CSTR of styrene with initiation by 2-azobisisobutyronitrile (AIBN).

In polymerization reactions, there exists an essentially infinite number of individual chemical species (free radicals and polymers of varying chain lengths). Therefore, the kinetic expressions describing the polymerization process comprise an infinite set. This number of expressions is effectively reduced to a finite set through the use of number chain length distributions for radical and polymer species. To attain these distribution descriptions, basically these methods have been employed: generating function technique, stepwise algebraic substitution technique, continuous variable technique, and discrete variable technique [40,41,42]. Perhaps the simplest method to apply is the discrete variable technique which makes use of Z-transformations [19,22,41].

Polymerization Kinetics

Free radical unipolymerization kinetics may be described by essentially five mechanisms: free radical generation, polymerization initiation, propagation, chain transfer, and termination. Each mechanism will be discussed individually before combining all the steps to yield the full polymerization reactor model used in this research. In every case, the discussion will be directed toward the free radical polymerization of styrene initiated by AIBN. The ensuing discussion is the result of modeling due to [30-50].

Free Radical Generation. Free radicals are generated when covalent bonds of monomer or free radical-producing agents are homolytically broken. The lower the energy required to break these bonds, the more stable the resulting free radical is; some free radicals may be so stable that they may not be capable of initiating polymerization. The methods of introducing this dissociation energy requirement are varied: electrochemically, chemically (redox systems), photochemically, or thermally.

Of interest in this research is free radical generation by initiator decomposition and by thermal decomposition of the monomer:

$$I \xrightarrow{k_1} 2\,R_1 \qquad \text{Initiator Decomposition} \qquad (2.1)$$

$$3M \xrightarrow{k_2} 2\,R_1 + M \qquad \text{Monomer Decomposition} \qquad (2.2)$$

where:

I	initiator
M	monomer
R_1	single unit free radical
k_1, k_2	rate constants

The thermal decomposition method, naturally, is increasingly important as the reaction temperature is increased, and, in fact, becomes the predominant radical generating mechanism above 120°C [63]. These free radicals are available to initiate polymerization with monomer, polymer, or another radical.

One problem encountered with an initiator is the so-called "cage effect" that essentially eliminates available radicals through reaction with itself. Consider the case of AIBN as the initiator:

$$\mathrm{Me{-}\underset{CN}{\overset{Me}{C}}{-}N{=}N{-}\underset{CN}{\overset{Me}{C}}{-}Me} \longrightarrow 2\,\mathrm{Me{-}\underset{CN}{\overset{Me}{C}}\cdot} + N_2 \qquad (2.3)$$

$$\longrightarrow \mathrm{Me{-}\underset{CN}{\overset{Me}{C}}{-}\underset{CN}{\overset{Me}{C}}{-}Me}$$

As the two radicals are formed, they may recombine as shown if they are not sterically blocked from doing so or if they do not have the opportunity to diffuse away from one another. To take this cage effect into account, an initiator efficiency is generally employed in the rate expressions involving initiator-initiated polymerization [43-47].

Initiation of Polymerization. Initiation occurs when a free radical reacts with another species. The most desired of these initiation reactions is that involving radical and monomer:

$$R\cdot + M \text{ -----> } RM\cdot \tag{2.4}$$

where: $R\cdot$ any free radical

M monomer

$RM\cdot$ a new free radical of increased length

but, as discussed earlier, undesired reactions may occur:

$$R\cdot + Y \text{ -----> Non-polymeric products} \tag{2.5}$$

The efficiency factor, f, is used in the current study to describe that number of free radicals actually initiating polymerization. In this way both the cage effect and side reactions are accounted for with the resulting initiation rate expression is:

$$r_i = 2k_1fI + 2k_2M^3 \tag{2.6}$$

The particular correlation for the efficiency factor, f, is the same as that used by Spitz [22].

Propagation. Propagation is that step where monomer units are added to a free radical of undetermined length to form a free radical of increased chain length:

$$R_j + M \xrightarrow{k_3} R_{j+1} \qquad j>0 \tag{2.7}$$

The rate of formation due to propagation for chain length growth from j-1 to j is given by:

$$r_p = k_3 M(R_{j-1} - R_j) \tag{2.8}$$

Transfer Reactions. A transfer reaction is one in which something is transferred from one chemical species to another. Transfer reactions may involve the transfer of a chemical site (the site of kinetic activity) or the transfer of radical activity. Dependent upon the relative activity of the resultant radical species, a transfer reaction may be viewed as a termination reaction, an acceleration reaction, an inhibition or retardation step, or a straight transfer from one polymer chain to another. Further complications are included since transfer reactions may occur with any species (monomer, polymer, solvent, etc.). Due to these properties, transfer reactions are often used to control polymer product propertites, such as molecular weight.

For this particular system of interest, transfer to monomer is the predominant transfer reaction:

$$R_j + M \xrightarrow{k_4} R_1 + P_j \tag{2.9}$$

where: P_j polymer of length j

and the rate of transfer for radicals of length j is given by:

$$r_{tr} = k_4 M(R_j - R_j \delta(j-1)) \tag{2.10}$$

where: $\delta(j-1)$ dirac delta function

Termination of Chain Growth. Termination is that step or reaction mechanism which effectively halts chain length growth through propagation. Common forms of termination are illustrated by:

1. Coupling: $R_n^{\cdot} + R_m^{\cdot} \text{ -----> } P_n\text{--}P_m$ (2.11)
2. Disproportionation: $R_n^{\cdot} + R_m^{\cdot} \text{ -----> } R_n^{\cdot\cdot} + R_m$ (2.12)

Other mechanisms for termination of polymerization include termination with monomer and through transfer reactions.

Most specifically for the styrene system under study, termination is by radical recombination:

$$R_j + R_k \xrightarrow{k_5} P_{j+k} \tag{2.13}$$

CSTR Model Development

With the kinetic expressions previously given, individual species balances may be written for the CSTR model where no polymer is fed to the reactor and constant reactor volume is assumed:

$$\text{Initiator:} \frac{dI}{dt} = \frac{(I_o - I)}{\theta} - k_1 I \tag{2.14}$$

Monomer: $$\frac{dM}{dt} = \frac{(M_o - M)}{\Theta} - 2k_2M^3 - k_3M\Sigma R_j - k_4M\Sigma R_j \quad (2.15)$$

Radical: $$\frac{dR_j}{dt} = -\frac{R_j}{\Theta} + (2k_1fI + 2k_2M^3)\delta(j-1)$$

$$+ k_3M(R_{j-1} - R_j)$$

$$+ k_4M(R_j\delta(j-1) - R_j) - k_5R_j\Sigma R_k \quad (2.16)$$

Polymer: $$\frac{dP_j}{dt} = -\frac{P_j}{\Theta} + k_4MR_j + \frac{k_5}{2}\Sigma R_{j-k}R_k \quad (2.17)$$

where: I_o initiator feed concentration

M_o monomer feed concentration

Θ reactor residence time

Through the use of Z-transformations, as previously described, differential equations for the moments of free radical distribution and of polymer distribution may be written [19,22,41]:

$$\frac{d\sigma_0}{dt} = -\frac{\sigma_0}{\Theta} + (2k_1fI + 2k_2M^3) - k_5\sigma_0^2 \quad (2.18)$$

$$\frac{d\sigma_1}{dt} = -\frac{\sigma_1}{\Theta} + (2k_1fI + 2k_2M^3) + (k_3 + k_4)M\sigma_0$$

$$- k_4M\sigma_1 - k_5\sigma_0\sigma_1 \quad (2.19)$$

$$\frac{d\sigma_2}{dt} = -\frac{\sigma_2}{\Theta} + (2k_1fI + 2k_2M^3) + (k_3 + k_4)M\sigma_0$$

$$+ 2k_3M\sigma_1 - k_4M\sigma_2 - k_5\sigma_0\sigma_2 \quad (2.20)$$

$$\frac{d\mu_0}{dt} = -\frac{\mu_0}{\Theta} + k_4M(\sigma_0 - R_1) + k_5\frac{\sigma_0^2}{2} \quad (2.21)$$

$$\frac{d\mu_1}{dt} = -\frac{\mu_1}{\Theta} + k_4M(\sigma_1 - R_1) + k_5\sigma_0\sigma_1 \quad (2.22)$$

$$\frac{d\mu_2}{dt} = -\frac{\mu_2}{\Theta} + k_4M(\sigma_2 - R_1) + k_5(\sigma_0\sigma_2 + \sigma_1^2) \quad (2.23)$$

where: σ_0 0th moment of radical distribution

σ_1 1st moment of radical distribution

σ_2 2nd moment of radical distribution

μ_0 0th moment of polymer distribution

μ_1 1st moment of polymer distribution

μ_2 2nd moment of polymer distribution

The moments of radical distribution are generally written to describe radicals of all chain lengths. But, in the initial development of this model, special consideration was given to the single-unit-length radical since it was involved in reactions that other radicals were not associated with (ie. thermal initiation, initiator decomposition, transfer reactions). The rate equation for this species is given by:

$$\frac{dR_1}{dt} = -\frac{R_1}{\Theta} + (2k_1fI + 2k_2M^3) - (k_3 + k_4)MR_1 + k_4M\sigma_0 - k_5\sigma_0R_1 \qquad (2.24)$$

Under normal circumstances, that is, single precision reaction dynamics studies, the R_1 term is left out entirely since its effect is not noted to any significant digit. Even though the effect of this term still appears to be negligible under the current double precision considerations, an analysis discussed later in Chapter IV indicates that this term should be retained. Using the derived moment expressions, and including the consideration of the single-unit-length radical R_1, the monomer balance equation may be rewritten as:

$$\frac{dM}{dt} = \frac{(M_o - M)}{\theta} - 2k_2M^3 - (k_3 + k_4)M\sigma_0 + k_4MR_1 \tag{2.25}$$

Since this study involves the case of the nonisothermal CSTR, an energy balance must be included to describe temperature transients. In general, this balance is given by:

$$\frac{d(V\rho C_pT)}{dt} = \frac{V\rho_o C_{po}(T_o - T_r) - V\rho C_p(T - T_r)}{\theta}$$

$$- UA_H(T - T_c) + V\Sigma(-\Delta H_i)r_i \tag{2.26}$$

where:

ΔH_i	heat of reaction for reaction i
V	reactor volume
ρ	density of reaction mixture
C_p	heat capacity of reaction mixture
T_o	inlet temperature
T_r	reference temperature
T_c	coolant temperature
U	overall heat transfer coefficient
A_H	heat transfer area

Assumptions commonly made regarding this energy balance are:

1. constant volume reactor: a standard practice for liquid-phase reaction sytems;

2. average coolant temperature: a standard practice described by Aris [53];

3. constant density and heat capacity: although it is known that these properties do change over the entire range of operating conditions possible, the additional complexity encountered in the inclusion of variable properties in this model would not enhance the results of this study. The common approach used has been to assume constant density and heat capacity.

4. significant heats of reaction for only thermal initiation, propagation, and transfer reactions[20-22];

yielding the following energy balance:

$$\frac{dT}{dt} = \frac{(T_0 - T)}{\Theta} - \frac{UA_H(T - T_c)}{V\rho C_p} + \frac{((-\Delta H_2)k_2M^3 + (-\Delta H_3)k_3M\sigma_0 + (-\Delta H_4)k_4M\sigma_0)}{\rho C_p} \qquad (2.27)$$

Thus, the complete model describing the system under study is given by the ten ordinary differential equations written as (2.14), (2.18)-(2.25), and (2.27).

Phenomena of High Temperature and High Conversion

In general, the total rate of propagation is expected to decrease in some closely-linear relationship to monomer conversion. However, observations indicate that this total rate of reaction frequently will increase, pass through a maximum, and then decrease. This behavior is due to diffusion-related effects and is called the gel effect or the Trommsdorf effect. The gel effect, occuring at high conversions where the monomer concentration is low and the polymer concentration is high, is exhibited as an increase in the rate of polymerization resulting from the combination of essentially immobile polymer chains and diffusion-mobile monomer units.

An additional diffusion-related effect is noted at even higher conversions due to the very high viscosities encountered. Due to the higher viscosity and even lower monomer concentration, the combination of monomer and polymer free radicals is slowed and the rate of polymerization decreases again. This phenomenon is known as the glass effect.

Gel and glass effects have been studied and modeled [43-50] with the resulting correlations showing the effects in terms of the propagation and termination reaction rate constants. The correlation of Hui and Hamielec [47] has been included as part of the model used in this research, and is given as:

$$k_5 = k_{50}(\exp(Ax + Bx^2 + Cx^3))^{-2} \tag{2.28}$$

where: $A = 2.57 - .00505T$

$B = 9.56 - .0176T$

$C = -3.03 + .00785T$

$x = (M_o - M)/M_o$

k_{50} = rate constant at zero conversion

k_5 = rate constant at actual conversion.

Summary of Model Parameters

It was the intention of this study to choose a process of some industrial importance. Concurrent with this thinking was the selection of parameter values such that the results of this work might have some correlation to a real situation. These model parameter values are noted in TABLE 2-1.

TABLE 2-1. MODEL PARAMETER VALUES

PARAMETER	VALUE	REFERENCE
ρ	11.5 gmol/l	81
C_p	33.5 cal/gmol	81
U	0.0005 cal/sec-cm^2-^{o}K	82
V	1000 l	
θ	10080 sec	
I_o	0.0106 gmol/l	
M_o	4.81 gmol/l	
$-\Delta H_2$	10000.	26
$-\Delta H_3$	16680.	26
$-\Delta H_4$	16680.	26
k_1'	1.580 E15	26
k_2'	2.190 E 5	26
k_3'	1.050 E 7	26
k_4'	2.310 E-6	26
k_5'	1.255 E 9	26
E_1	30800.	26
E_2	27441.	26
E_3	7067.	26
E_4	12671.	26
E_5	1677.	26
f	exp(-2x)	20,22

I = 1 to 5

$k(I) = k(I)' \times EXP(-E_I / 1.987 / T)$

$k(5) = k(5) / (EXP(Ax + Bx^2 + Cx^3))^2$

CHAPTER III

STEADY STATES AND STABILITY

This section deals with the determination of steady states for any particular set of system parameters and the analysis of the resulting steady state operating conditions as regards stability. The term stability, here and in the remainder of the thesis, will mean local asymptotic stability unless otherwise noted. The problem of control at the unstable steady state and the stability of the resulting controlled process will be addressed later.

General Introduction

In the analysis of any dynamic system, the question of stability of a steady state becomes important; this is especially the case for systems involving steady state multiplicity. The criteria for determination of stability is well established [53,55,56,57,64] and will not be elaborated here. There are many available references which present the development of these criteria for a second order system [56,57,64]. In lieu of reiterating this development, some general comments pertaining to their results and the logical extensions to higher order systems will be made.

As referenced earlier, Van Heerden [2] presented a graphical approach to stability analysis which involved separation of the energy balance into heat generation and heat removal curves. Intersections of these curves represent steady state conditions and the "slope condition" for stability was established. For the single variable problem, this slope condition is necessary and sufficient; but, for higher order systems, the slope condition is only a necessary condition for stability.

Local asymptotic stability (eg. that steady state where transients in an arbitrarily small region about the state die out as time progresses) analysis represents necessary and sufficient criteria for stability of higher order systems. Local stability is based on the linearized system about the steady state of interest, where the equations may be written as:

$$Y = AX \tag{3.1}$$

where: Y vector of derivatives of X

X vector of perturbation variables

A matrix containing the linearization coefficients evaluated at the steady state of interest: Jacobian matrix.

For an n^{th} order system described as above, the characteristic equation is given by:

$$\det(A - \lambda I) = 0 \tag{3.2}$$

where: I identity matrix

λ roots of characteristic equation or eigenvalues

Another representation of the characteristic equation is in the form of an n^{th} order polynomial:

$$b_0\lambda^n + b_1\lambda^{n-1} + \cdots + b_{n-1}\lambda + b_n = 0. \tag{3.3}$$

In order to have local asymptotic stability, the eigenvalues of the Jacobian matrix (the roots of the characteristic equation) must have negative real parts. In the case of instability, the eigenvectors corresponding to the positive eigenvalues will indicate the source(s) of the instability.

Another way of expressing the necessary and sufficient conditions for local stability is the Routh-Hurwitz criteria. That is, the successive determinants defined by

$$\Delta_1 = b_1,\ \Delta_2 = \begin{vmatrix} b_1 & b_0 \\ b_3 & b_2 \end{vmatrix},\ \Delta_3 = \begin{vmatrix} b_1 & b_0 & 0 \\ b_3 & b_2 & b_1 \\ b_5 & b_4 & b_3 \end{vmatrix}, \tag{3.4}$$

$$\Delta_r = \begin{vmatrix} b_1 & b_0 & 0 & 0 & 0 & 0 & 0 \\ b_3 & b_2 & b_1 & b_0 & 0 & 0 & 0 \\ b_5 & b_4 & b_3 & b_2 & b_1 & b_0 & 0 \\ \cdot & \cdot & & & & & \\ b_{2n-1} & b_{2n-2} & \cdot & \cdot & \cdot & \cdot & b_n \end{vmatrix} \tag{3.5}$$

must all be positive for an n^{th} order system.

With the advent of high-speed computers and available mathematical techniques, the second method of Lyapunov and Krasovskii's theorem [5,57,65] have been applied for stability analyses. This method of analysis acts as a sufficient, but not necessary, condition for stability of the steady state. It gives additional information as it identifies a specific region where asymptotic stability applies. This method has been found, in general, to be very conservative for the actual region of stability is usually considerably larger than that indicated by the Lyapunov function. An example of a second order system is presented by Berger and Perlmutter [66,67].

Literature: Stability of Polymerization Reactors

As noted in the literature survey, much effort has gone into investigating the dynamics of the free radical polymerization of styrene, with particular interest in the steady state multiplicity of the system. There has been some effort put forth in examining the stability of these systems. Basically, there are two types of stability problems encountered in this class of reactions. Concentration stability is due to the auto-acceleration nature of the polymerization reaction and may present itself even under isothermal conditions. Temperature or thermal stability involves both the auto-acceleration effects and the exothermic effects of the polymerization process. This review is intended only as a brief introduction to the available publications on the topic.

Warden and Amundson [35] applied the Routh-Hurwitz criteria to a monomer-terminated addition polymerization with first order initiation step in a nonisothermal CSTR. Their system was described by three ordinary differential equations. They also investigated regions of stability for various modes of linear control applied to the system. One result of their study was that the unstable steady state could always be made stable using proportional control based on the reactor temperature and several manipulated variables. Ranges of parameter values for the various modes of control were indicated for stable control of the average molecular weight and of the total polymer concentration.

Knorr and O'Driscoll [17] used a Van Heerden-type analysis using the steady state mass balance (monomer) equation to determine steady state multiplicity. They note that multiple steady states exist for the styrene polymerization CSTR for both nonisothermal and isothermal cases. Much of their work deals with the phenomena occuring at higher temperatures and higher conversions. In his dissertation, Knorr [49] gives far more detail of the stability problems with suggestions for control. Also, he examines the additional complexities associated with the copolymerization process.

Shastry and Fan [37] depart from the classical analysis techniques using linearization to apply Lyapunov's second or direct method to determine regions of stability. Their studies used simplified kinetic models to examine the temperature stability of homopolymerization in two tanks in series and of copolymerization in a single CSTR.

A study of dynamic behavior in free radical polymerization reactors, where oscillatory phenomena is possible, is presented by Jaisinghani and Ray [48]. Polymethymethacrylate and polystyrene systems were studied using simplified dimensionless equations. Lowering the order of their model to two ordinary differential equations, they used bifurcation theory to determine that unstable limit cycles are possible at the upper steady state only. More detail on the polystyrene system is available in the thesis by Jaisinghani [50]. One of the interesting results is that there was no qualitative changes in their simulations either with or without the initiator dynamics. Quantitative analyses predicting this result arrived at in their numerical study is presented later in Chapter IV.

With this basic review of stability, in general, and of some of the existing literature concerning dynamics and steady state stability of polymerization reactors, the problem of steady state multiplicity and stability analysis of the specific system of interest will be investigated.

Analysis of the Reaction System

Steady States. The search for steady state multiplicity for the reaction system under study was done through a Van Heerden-type approach of the nonisothermal system. All time-dependent derivatives (equations 2.14,2.18-2.25,2.27) were set equal to zero and the resulting equations solved for the steady state operating conditions:

$$I = I_o/(1 + k_1\Theta) \tag{3.6}$$

$$\sigma_0 = \frac{-1 + \sqrt{1 + 8k_5(k_1fI + k_2M^3)\Theta^2}}{2k_5\Theta} \tag{3.7}$$

$$\sigma_1 = \frac{2(k_1fI + k_2M^3) + (k_3 + k_4)M\sigma_0}{1/\Theta + k_4M + k_5\sigma_0} \tag{3.8}$$

$$\sigma_2 = \sigma_1\left[1 + \frac{2k_3M}{1/\Theta + k_4M + k_5\sigma_0}\right] \tag{3.9}$$

$$R_1 = \frac{2(k_1fI + k_2M^3) + k_4M\sigma_0}{1/\Theta + (k_3 + k_4)M\sigma_0 - k_5\sigma_0} \tag{3.10}$$

$$\mu_0 = \Theta\left[k_4M(\sigma_0 - R_1) + \frac{k_5\sigma_0^2}{2}\right] \tag{3.11}$$

$$\mu_1 = \Theta\left[k_4M(\sigma_1 - R_1) + k_5\sigma_0\sigma_1\right] \tag{3.12}$$

$$\mu_2 = \Theta\left[k_4M(\sigma_2 - R_1) + k_5(\sigma_0\sigma_2 + \sigma_1^2)\right] \tag{3.13}$$

$$0 = (M_o - M)/\Theta - 2k_2M^3 - (k_3 + k_4)M\sigma_0 + k_4MR_1 \tag{3.14}$$

$$0 = \frac{\sum(-\Delta H_i) r_i}{\rho C_p} - \left[\frac{(T - T_o)}{\theta} + \frac{UA_H(T - T_c)}{V\rho C_p}\right] = Q_g - Q_r \quad (3.15)$$

By assuming temperatures, values for the remaining nine variables were determined [Program UTKVHA.FOR, Appendix A]. Monomer concentration was solved through an iterative procedure using equations (3.6), (3.7), (3.10) and (3.14), using an error specification of 10^{-14} for the monomer balance [eqn. (3.14)]. Heat generation [Q_g] and heat removal [Q_r] curves as functions of temperature were constructed as shown in FIGURE 3-1. Intersections indicate steady state conditions and the slope condition is evident as a necessary condition for stability. It is important to note the the Van Heerden Analysis is only valid <u>at</u> the steady states. This point is vividly demonstrated by the control studies of Chapter VI.

The heat generation curve is the sigmoidally-shaped curve shown in the figure. The auto-acceleration effect is evidenced by the very steep nature of this curve. The inclusion of the gel and glass effects for higher temperatures and conversions is noted by the sharp increase and subsequent decrease in the generation curve. From this graphical analysis, the middle steady state would be unstable based on the slope condition. Stability of the other steady states must be determined through an eigenvalue analysis.

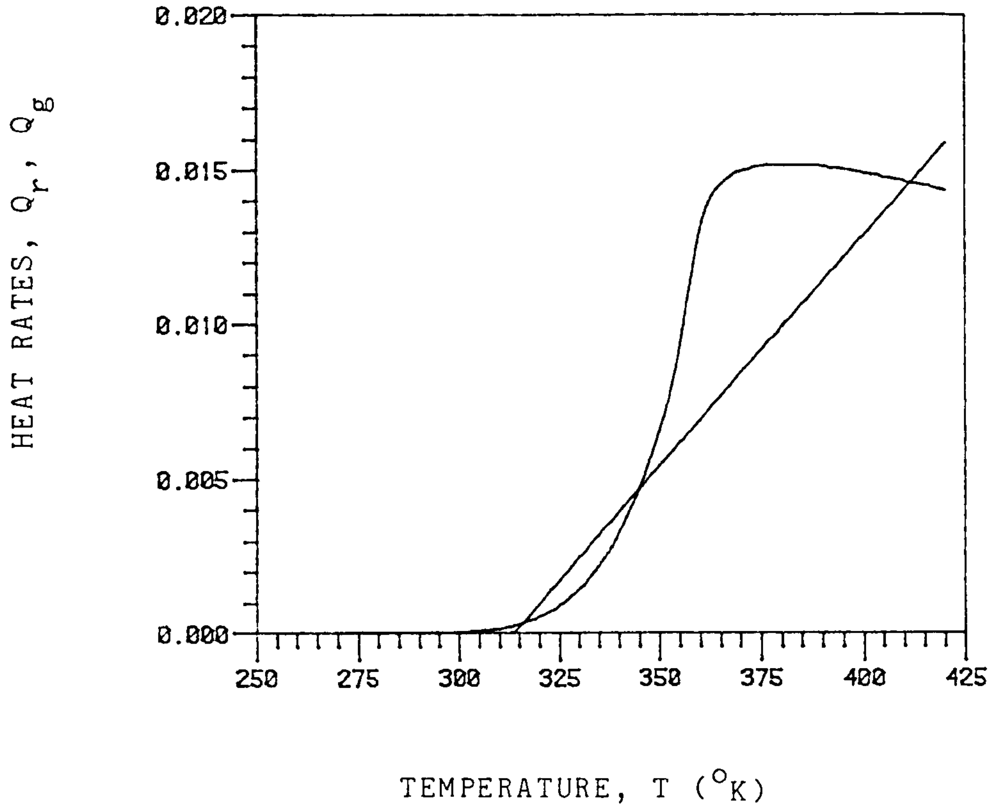


FIGURE 3-1. VAN HEERDEN DIAGRAM: STANDARD CASE

Determination of the actual steady state conditions is done, again, through the Van Heerden approach outlined above. A trial-and-error solution via subroutine of program UTKVHA.FOR is made for the temperature of the state using the five equations involved in the solution of the energy balance (T, M, I, R_1 and σ_0). When mass and energy balance error criteria[10^{-14}] are met for equations (3.14) and (3.15), all variables are then calculated. These values, as noted in TABLE 3-1 for the standard case used here, are subsequently used for further analyses. Variable numbers shown in TABLE 3-1 are consistent with the order of variables used in analyses throughout this thesis.

Eigenvalue Analysis. To determine stability of the lower and upper steady states and to verify the instability of the middle steady state, an eigenvalue analysis was done at each steady state. Thus, the local asymptotic stability of the various steady states was determined.

Using the values of the steady state conditions determined above, the coefficients of the linearized model are calculated and stored as the Jacobian matrix. These coefficients are derived by taking the partial derivatives of each nonlinear ordinary differential equation, Y_i, with respect to each state variable, X_i, such that the entries in the Jacobian matrix A are:

TABLE 3-1. STEADY STATE VALUES AND EIGENVALUES: STANDARD CASE

VARIABLE		STEADY STATE LOWER	MIDDLE	HIGH
T	1	315.9	345.1	411.6
M	2	4.721	3.598	0.4038
μ_0	3	0.9637 E-4	0.2614 E-2	0.8324 E-2
μ_1	4	0.8880 E-1	0.1217 E+1	0.4409 E+1
μ_2	5	0.1300 E+3	0.9028 E+3	0.4525 E+4
I	6	0.01052	0.007081	0.1513 E-4
σ_0	7	0.1375 E-7	0.9523 E-7	0.5837 E-6
σ_1	8	0.6938 E-5	0.2443 E-4	0.2565 E-3
σ_2	9	0.6995 E-2	0.1251 E-1	0.2252 E 0
R_1	10	0.0274 E-9	0.3738 E-9	0.1330 E-8
EIGENVALUES:				
		-0.9921 E-4	-0.9921 E-4	-0.9921 E-4
		-0.9921 E-4	-0.9921 E-4	-0.9921 E-4
		-0.9921 E-4	-0.9921 E-4	-0.9921 E-4
		-0.9345 E-4	0.2894 E-3	-0.6880 E-1
		-0.1002 E-3	-0.1108 E-3	-0.5234 E-3
			0.1681 E-4i	
		-0.1133 E-3	-0.1108 E-3	-0.2063 E-3
			-0.1681 E-4i	
		-0.1270 E+1	-0.4940 E+1	-0.1706 E+1
		-0.1270 E+1	-0.4940 E+1	-0.1706 E+1
		-0.2297 E+1	-0.8861 E+1	-0.1153 E+1
		-0.6407 E+3	-0.1267 E+4	-0.7495 E+3

$$a_{ij} = \frac{\partial Y_i}{\partial X_j} \tag{3.16}$$

This procedure was done analytically for the specific styrene polymerization system studied. Eigenvalues of this matrix are then determined by means of a package routine [Program OLDSVD.FOR, Appendix A] from the Scientific Subroutine Package (SSP). This being a very stiff system, ie. eigenvalues are very widely separated by orders of magnitude, double precision routines were employed. As a result, no eigenvectors were determined since standard routines require complex arithmetic which is unavailable on the DECsystem-10 machine used for computations.

Some of the interesting results, as noted in TABLE 3-1, from the eigenanalyses performed were:

1. verification of stiffness of the polymerization system,

2. verification of instability of the middle steady state,

3. determination of stability of upper and lower steady states, and

4. repetition of roots (eigenvalues): at each steady state investigated, there were two sets of repeated roots (two roots equal and three roots equal).

To gain some insight into the global stability of this system for the chosen set of model parameters, simulations of the nonlinear system were made around each steady state. These simulations showed that no limit cycles exist and confirmed the eigenvalue analyses. No open-loop phase plane plots or time traces are reproduced in this paper.

CHAPTER IV

SINGULAR VALUE DECOMPOSITION ANALYSES

General Background

Singular value decomposition, also referred to in this work as SVD, is a linear algebra analysis tool that is applicable to matrices describing stable linear systems. Even though singular value decomposition has been established since 1889 (by Sylvester for real square matrices), significant engineering applications have been slow to develop. In fact, there have been very few applications of singular value decomposition in the engineering area. The main interest, here, in singular value decomposition is directed toward model simplification/reduction and identification of control loops.

For very stiff systems, that is, systems with widely-separated eigenvalues, variables or combinations of variables may be seen as fast, while others are slow in the general comparison. Through a complete eigenvalue analysis, these variables or combinations may be determinable. If, for example, the macroscopic time element is of primary interest, the common procedure for handling fast variables is to ignore their transients as noted in FIGURE 4-1 and make a quasi-steady state assumption (pseudo-steady state assumption); that is, assume that the fast variables are always in a steady state relationship with the remainder of the process variables retained as dynamic.

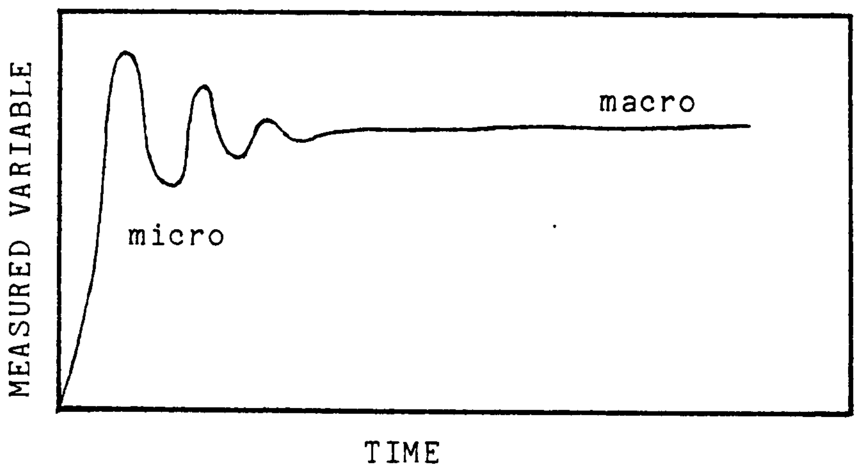


FIGURE 4-1. FAST VS. SLOW VARIABLES: TIME RELATIONSHIPS

A major stumbling block is often encountered when repeated eigenvalues exist; the interpretation of the eigenvalue analysis becomes quite difficult.

This is the basic problem associated with modal control [55], although additional transformations will often alleviate the confusion involved in modal analysis. Singular value decomposition uses a variation of eigenvalue analysis which greatly simplifies systems analysis, even in the case of repeated eigenvalues. For the particular research problem of interest, three varieties of singular value decomposition analyses were employed to examine the steady state process, the dynamic process, and the controlled process. Before discussing each of these analyses, a brief overview of the procedure used will be presented.

Mathematical Procedure

In control theory, the linearized model of the nonlinear system is often used so that linear analysis techniques can be employed. This provides important information and insight into the dynamic behavior of the corresponding nonlinear system. The classical example is the determination of local asymptotic stability of the steady states of a nonlinear system. Thus, the linearized model of the nonlinear system is used here. This exercise results in a system described in a linear algebra form:

$$Y = AX + BP \tag{4.1}$$

where:

- Y — vector of state variable derivatives
- X — state variable vector
- P — input variable vector
- A — Jacobian matrix
- B — matrix containing coefficients of model linearized with respect to P.

Now consider, for example, only an open loop system given by:

$$Y = AX. \tag{4.2}$$

Having now a simple linear algebra problem, singular value decomposition can be applied to matrix A.

In general, for any matrix D, singular value decomposition is basically an eigenvalue analysis of a transformation of the matrix D. The decomposition results in a reordered system given by:

$$D = V \Sigma U^H \tag{4.3}$$

where: Σ diagonal matrix containing singular values σ_1, $\sigma_2, \ldots$

V matrix containing orthonormal columns(eigenvectors of DD^H)

U matrix containing orthonormal columns(eigenvectors of $D^H D$).

The values given by $\sigma_1^2, \sigma_2^2, \ldots$ are the non-zero eigenvalues of $D^H D$. Columns of matrix V are known as <u>left singular vectors of D</u> and the columns of U are known as the <u>right singular vectors of D</u>. The resulting system is an orthogonal geometric representation of the original linearized model; that is, inputs and outputs are described as elliptical surfaces given by the matrices U (output) and V (input) respectively. The relative magnitudes of each vector (<u>ie</u>. its length) of both U and V are given by the corresponding singular values.

To digress briefly on the topic of geometric representation: the outputs of the system may be viewed as an elliptical surface where the axes of the ellipsoid are given by U . In this way, all axes are perpendicular to one another and the relative importance of each orthogonal direction (comprised of one or a combination of the original state variables) is given by the singular values corresponding to each vector. The larger the singular value is, the more significant is that particular coordinate direction. The same argument is made for the inputs of the system, with axes described by V. Moore [69] develops these concepts for a third order system, with special emphasis on the geometric analogy, and indicates the extensions to higher order problems.

The method of applying singular value decomposition is via the QR algorithm iteration scheme. Stewart [68] gives a thorough explanation of the mechanics of the QR algorithm and its use in singular value decomposition and eigenvalue analysis. The particular routine employed in this research is a Householder bidiagonalization with QR variant, a FORTRAN version of an ALGOL routine due to Golub and Reinsch [72].

This presentation is meant only as a brief introduction to singular value analysis. Stewart [68] gives a summary and additional references. Moore [69] indicates the applications to control problems in general. He also makes some application of this analysis to the problems of controllability, observability and model reduction [70,71]. The implementation of singular value decomposition routines and the information contained in the analysis results are detailed below in terms of the styrene polymerization model.

SVD of the Jacobian Matrix

The first application of singular value decomposition to this research was directed toward the problem of model reduction/simplification. The distinction made, in this work, between model reduction and model simplification is: reduction indicates that variables are eliminated entirely, whereas simplification infers that the variables are retained, as in the case of pseudo-steady state variables. This is of particular interest since the system of equations used here are difficult and time-consuming to integrate (stiff differential equations and a 10th order model). Of initial importance is the reduction of order of the open loop system by model simplification, described as:

$$Y = AX \tag{4.2}$$

where: Y vector of state variable derivatives

A Jacobian matrix

X state variables vector

Singular value decomposition of the Jacobian matrix yields information about the derivatives and which internal or,in this case, state variables affect the derivatives. For example, TABLE 4-1 is a typical singular value decomposition analysis of the Jacobian matrix, this one representing the tenth order model at the unstable steady state. Each singular value is associated with its corresponding columns of matrices U and V; ie. SV(1) corresponds to the first column of both U and V. Further, each row of U represents an output variable and its contributions to the orthogonal column vectors(the first row is the contributions to the column vectors of U due to the first output variable, etc.) and, similarly, each row of V represents an input variable and its contributions to the orthogonal column vectors in V. For the analysis of the Jacobian matrix, the derivatives are the input variables and the state variables are the output variables. Thus, refering to TABLE 4-1, the first singular value SV(1), being of the largest magnitude, is indicative of the fastest derivative as given as the major component of the corresponding vector of matrix V (the seventh variable, or σ_0). In other words, for this steady state, the total number of free radicals is changing faster than any of the other state variables as the system is perturbed slightly from the steady state. This is physically consistent with the expected behavior. And, this rate of change has its

TABLE 4-1. RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: TENNM2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 15-SEP-79
TIME: 10:22 02.3

INPUT STEADY STATE VALUES

T= .345124D+03	RO= .952324D-07	PO= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-08	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.823598D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.339271D+04
LAMBDA(3)=	-.494021D+01	.000000D+00	SV(3)=	.126731D+04
LAMBDA(4)=	-.494021D+01	.000000D+00	SV(4)=	.420314D+00
LAMBDA(5)=	-.992063D-04	.000000D+00	SV(5)=	.171922D-03
LAMBDA(6)=	-.126731D+04	.000000D+00	SV(6)=	.124738D-03
LAMBDA(7)=	-.886090D+01	.000000D+00	SV(7)=	.839815D-04
LAMBDA(8)=	.289422D-03	.000000D+00	SV(8)=	.494396D-05
LAMBDA(9)=	-.110818D-03	.168102D-04	SV(9)=	.992063D-04
LAMBDA(10)=	-.110818D-03	-.168102D-04	SV(10)=	.740037D-09

MATRIX U - ORTHONORMALIZED COLUMNS

.6013D-01	-.3084D-02	-.1822D-04	.9976D+00	.2672D-02	.3229D-01	.5580D-03	-.1144D-01	-.5070D-04	.1696D-03
-.1533D-02	.7867D-04	-.4019D-03	-.2544D-01	.9024D-01	.6425D+00	.6704D+00	-.3590D+00	-.4100D-05	-.6026D-03
.5998D-05	-.3263D-06	.4023D-03	.9951D-04	-.3293D-03	-.1515D-02	.1505D-02	-.1774D-05	.1000D+01	-.2345D-11
.1380D-02	-.1527D-02	.4014D-03	.2286D-01	-.5625D-01	-.7163D+00	.6952D+00	.4155D-03	-.2152D-02	-.5571D-08
.7066D+00	-.7062D+00	-.3354D-04	-.4479D-01	.4491D-03	.9381D-03	-.4782D-03	.8999D-03	.2293D-05	-.7458D-05
.9179D-20	.5492D-15	-.5509D-14	-.2127D-08	-.8527D+00	.1749D+00	.1110D+00	.3053D+00	-.1825D-03	.3696D+00
-.1076D-04	.5519D-06	.3260D-08	-.1785D-03	.3424D+00	-.6767D-01	-.4194D-01	-.1149D+00	.7322D-04	.9291D+00
.1535D-03	.1448D-02	.4355D-06	.2578D-02	.3798D+00	.1946D+00	.2307D+00	.8744D+00	.7398D-04	-.7243D-02
-.7051D+00	-.7080D+00	-.3265D-04	.4029D-01	.4490D-03	.9378D-03	-.4783D-03	.8999D-03	.2292D-05	-.7458D-05
.5987D-06	-.4622D-04	.1000D+01	-.1452D-05	.5889D-04	.5469D-03	-.1037D-04	-.1450D-03	-.4015D-03	-.2395D-06

MATRIX V - ORTHOGONAL MATRIX

.3841D-09	-.4517D-06	.2812D-08	-.1007D-03	.6993D-02	-.1545D-01	-.2058D-01	.9975D+00	.5551D-04	.1805D-01
.1118D-06	-.9319D-05	.2498D-07	-.1031D-01	-.1566D+00	-.8085D+00	-.5668D+00	-.2306D-01	.3318D-05	-.7400D-03
-.7225D-15	.9540D-14	-.3150D-10	-.2349D-07	.1900D-03	.1205D-02	-.1778D-02	.3622D-04	-.1000D+01	.3143D-06
-.1662D-12	.4465D-10	-.3143D-10	-.5396D-05	.3246D-01	.5697D+00	-.8212D+00	-.8338D-02	.2152D-02	.7469D-03
-.8511D-10	.2065D-07	.2625D-11	.1057D-04	-.2591D-03	-.7461D-03	.5649D-03	-.1806D-01	-.2293D-05	.9998D+00
-.5099D-10	-.1241D-07	.4701D-07	.6050D-05	.9871D+00	-.1469D+00	-.6276D-01	-.1047D-01	.1219D-03	-.7366D-05
.1000D+01	-.2113D-03	-.4663D-06	.8468D-05	.4156D-08	.2148D-07	.1500D-07	.9847D-09	-.1686D-12	.2637D-10
-.2113D-03	-.1000D+01	-.1236D-03	-.2548D-05	.1448D-05	.7565D-05	.5307D-05	-.2365D-06	-.5754D-10	.1943D-07
.8467D-05	.2642D-05	-.3450D-08	-.9999D+00	.1619D-02	.8331D-02	.5849D-02	.1368D-03	-.2721D-07	.1638D-04
-.4402D-06	.1236D-03	-.1000D+01	.3503D-08	.4233D-07	-.2812D-07	-.1782D-07	.1772D-08	.3740D-10	.3209D-10

greatest effect on the fifth(μ_2) and the ninth(σ_2) state variables, as indicated by the principal components of the first column of matrix U. This analysis procedure is followed for each singular value. As an added note, should an input vector and an output vector be equivalent, it would represent an eigenvector and the corresponding singular value would also be an eigenvalue of the original matrix (for this example note SV(3) and SV(9)).

The results of singular value decomposition of the Jacobian matrix for each steady state for various order models are given in Appendix B (along with eigenvalues). These analyses indicate that, for the lower and middle steady states, there are basically four variables with significantly faster derivatives than the remaining variables, as shown by consideration of the four larger singular values. These faster variables are the four free-radical oriented terms (σ_0, σ_1, σ_2 and R_1) and are noted as the principal components of the left singular vectors (V) of the four major singular values. Those state variables affected most strongly by these fast variables are given in the right singular vectors (U) which correspond to the same singular values(T, μ_2, σ_2 and R_1). For this analysis at the upper steady state, the initiator derivative joins the other four as fast in comparison to the other state variable derivatives.

This establishes a criteria and specific numerical reasoning for determination of which variables were considered to be fast. This method of examining stiff systems is a superior approach to the intuitive "feel" used previously. Although numerically crude at this stage of development, additional research could be done to quantify the procedure further. These analyses verify the standard procedure for handling of the radical distribution moment equations, that is, quasi-steady state assumption. But, it should be noted here that, in some instances, the quasi-steady state assumption may be inappropriate, since dynamics of the fast variables may have great influence on the total system dynamics. In such cases, singular value decomposition could be used to separate fast and slow variables for integration on separate time frames.

An interesting result of this particular analysis is the changing character of the initiator derivative. In many cases, the initiator equation is handled through the quasi-steady state assumption [31]. And, in fact, one study showed no pathological differences in system dynamics when the initiator dynamics were included and when initiator dynamics were ignored [48,50]. This analysis indicates regions where the initiator dynamics should be retained for numerical reasons.

The singular value decomposition analysis of the Jacobian matrix at the steady state yielded information concerning the derivatives of the state variables. This is especially helpful in the handling of stiff problems as are often encountered in polymerization processes of this class. The option of quasi-steady state assumption is left open to the researcher, dependent upon the time frame of interest (microscopic or macroscopic) and the option of an SVD-approach to integration is also available. Next an investigation of the dynamic system is to be made.

Grammian Analyses

Generalizations. The problem of model reduction/simplification has long been studied in the field of engineering in order to obtain systems of lower order that enable analysis by simpler means. One method, continued fraction inversion, is an accepted means of handling systems described in the Laplace domain [55,73-79]. This method of model reduction is also applicable to system analysis based on time or frequency response data. The analysis procedure described here is an application of singular value decomposition for model reduction of linear systems using time domain response data.

The preceding section dealt with an analysis which yielded information concerning the open loop derivatives of the system: determination of fast and slow variables in a relative sense. But, for model reduction, the dynamic system must be investigated. This is accomplished by examining the dynamic response of the system in terms of a grammian, as defined by [69,70,71]:

$$W^2_{H_{t_1}} = \int_0^{t_1} H'(t)H(t)dt \tag{4.4}$$

where: W^2 grammian

$H(t)$ impulse response matrix

H_{t_1} map: $R^m \dashrightarrow e^r[0,t_1]$

The grammian is a symmetric matrix that is positive semidefinite ($\underline{\omega}'W^2\underline{\omega}>0$ for all $\underline{\omega}$) and that has a unique symmetric square root $W = W'$. Since this integration could be cumbersome, and does not allow for any on-line control applications, a better method of developing the grammian is through a response matrix, comprised of response values of the output variables, at consistent time intervals, due to perturbations in each of the state variables:

$$W^2 = R'R \tag{4.5}$$

where: R N x n response matrix

N dimension of system

n number of samples at interval h

Using this technique, large quantities of data (accumulated on-line or through simulation) may be handled yielding the singular value decomposition of the actual dynamic system. Additional advantages, which will not be explored in this research, for this method include the ability to examine changing singular values and vectors which would give insight into problems such as dead time.

Once the grammian is supplied, the model reduction becomes an application of decomposition to a matrix reduction problem [68-71]. Model reduction involves the elimination of those variables which do not affect the overall nature of the matrix and may be examined from a Frobenius norm approach. A major concern in a grammian analysis is the normalization of variables such that equal or appropriate weight is given each variable in the decomposition process. This aspect of singular value decomposition is not highly developed and the normalization process is, therefore, the result of experience and "feel" for the system under investigation, rather than a simple mechanical procedure. This is an area where additional theoretical results are needed. In the application of this analysis to the present problem, several normalization procedures were used to provide some insight to the effects of the normalization scheme.

Normalization. Four sets of grammian analyses were conducted on the response data collected from simulations with response values recorded as:

1. perturbation variables about the steady state of interest;

2. variables normalized with respect to the steady state of interest;

3. variables normalized with respect to the expected range of values (inlet conditions to those at the upper steady state), where conversion was taken as the normalized variable for monomer; and

4. variables normalized as in No. 3, but (M/M_o) was taken as the normalized monomer variable.

Perturbation variables proved inappropriate since the numerical magnitude of the variables was not masked, causing larger-valued variables such as temperature and the second moment of polymer distribution to appear to be of supreme importance and the remaining variables to be insignificant. This showed the need for some form of normalization. Normalization with respect to the steady state was also somewhat unsatisfactory as it tended to enhance the importance of the faster variables. Basically, this resulted from the fast increase of the radical quantities in comparison to their steady state values. The sets of analyses conducted with the range-normalized variables seemed to give the most understandable and reliable results. These procedures allowed each variable to range from zero to unity, giving each variable an equal weight in the decomposition analysis. The latter of these tests, with monomer normalized as (M/M_o), yielded the most reasonable information since monomer, not conversion, is taken as the state variable in this polymerization model.

Analysis and Results. Grammian analyses [Program GRAM.FOR, Appendix A] were conducted for each steady state, even though the analysis procedure has been proved for stable systems only. Response values were collected from simulations at set time intervals with initial conditions taken as perturbations of 5% away from the values for the steady state studied in all variables. These perturbations were defined in terms of the dimensional values. Various tests were made where the dynamic model was represented by five, nine and ten ordinary differential equations. The lower order models retained the remaining variables under the quasi-steady state assumption; that is, although reduced order dynamic models were used, the system grammian was still described by ten variables. Additionally, various sampling time intervals were used. A summary of runs made is tabulated in TABLE 4-2. Singular value decomposition analyses of the grammians are located in Appendix C. In all runs given in this work, the number of samples, n, taken for the response matrix was ten.

TABLE 4-2. SUMMARY OF GRAMMIAN ANALYSIS RUNS

RUN	STEADY STATE	TIME INTERVAL sec.	MODEL ORDER	NORMALIZATION 1	2	3	4
2	MID	0.01	10	*			
3	MID	10.0	9	*	*	*	*
5	MID	100.0	5	*	*	*	*
6	LOW	100.0	5	*	*	*	*
7	LOW	100.0	9	*	*	*	*
8	HI	100.0	5	*	*	*	*

Run No. 2 was discarded since numerical problems were encountered in simulating the single unit radical equation (instability in integration): values for R_1 began oscillating between positive and negative values. For all other runs, the quasi-steady state assumption was employed for R_1 dynamics, a seemingly reasonable assumption since this would be a fast variable of minute proportion in comparison to the other state variables. This was the only problem encountered in the simulation process. The interpretation of the analysis results is done in the same manner as was done for the analysis of the Jacobian matrix decomposition with the difference that input variables are now state variables as well as the output variables being state variables.

The most striking element in these analyses is that only <u>one</u> major singular value resulted from the decompositions performed. Based on the most reasonable normalization technique (No. 4), the vector corresponding to the major singular value has significant contributions due to every variable. The radical distribution moments appear to enjoy a larger role at the upper steady state, explainable by the overproduction of free radicals at the elevated temperatures (glass effect).

Based on the grammian analyses conducted, all variables should be kept as part of the simulation model, even though decomposition of the Jacobian matrix indicates some variables are faster. This seeming contradiction can really be viewed as an explanation for the quasi-steady state assumption. One disclaimer that should be made here concerns the retention of R_1 in the full model, as indicated by the grammian analysis. It has been noted that no essential differences in analysis or simulation results can be seen for models including R_1 and for models that do not include R_1. Although the results of these tests indicate retention in the model, it was felt that this may have stemmed from the normalization process whereby the actual magnitude of the variables is masked from the analysis machinery. In reality, despite its importance in a reaction mechanism sense, the magnitude of R_1 makes its effect on the other variables negligible. These conflicting results cannot be justified with the numerical analysis presented here. Further investigation of this observation is beyond the scope of this work. Understanding of this apparent shortcoming would certainly provide a guide to future use of this decomposition application.

Two additional results of merit involve comparison of grammian decompositions for matrices constructed from samples of different time intervals for the same steady state. Results of grammian analyses with different time intervals were similar; further extended time frames may begin to differences as the macroscopic scale is approached. Similarly, common analysis results are given from grammians constructed from the response data of the different order dynamic models tested. This fact tends to reinforce the proposed model simplification via quasi-steady state assumption, and verifies the contention of Jaisinghani [50] that initiator dynamics do not affect system pathology (in the 5-equation model, the initiator was considered to be a pseudo-steady state variable). This theory is supported by the relatively small contributions of the initiator to the resultant vectors of the major singular value.

Through singular value decomposition of the Jacobian matrices and the grammian analyses, the complete ten-equation model describing the styrene polymerization process under investigation is not reduced. Instead, the model is simplified through the quasi-steady state assumption. The dynamics of the radical-oriented variables have been eliminated to leave a model consisting of five dynamic variables (T, M, μ_0, μ_1, μ_2) and five quasi-steady state variables (I, σ_0, σ_1, σ_2, R_1). These results are based on analyses for the middle steady state since it represents the state around which the nonlinear control will be investigated in Chapter VI.

Input Response Analyses

An insight into the controlled process may also be gained through another application of singular value decomposition. For the controlled process described by:

$$Y = AX + BP \tag{4.1}$$

the process, at steady state, is:

$$X = -A^{-1}BP. \tag{4.6}$$

It is this new matrix defined by $(-A^{-1}B)$ that will give indications of most responsive control based on unit step changes in the control variable. Again, normalization of the control variables is of utmost importance since a step change will reflect the normalization employed.

For the styrene polymerization process examined here, the following five possible control variables were chosen as those available in an actual physical setting:

1. residence time Θ (basically an indication of flow rate);

2. inlet monomer concentration, M_o;

3. inlet initiator concentration, I_o;

4. average coolant temperature, T_c; and

5. inlet temperature, T_o.

These control variables were normalized with respect to the range of values to be considered as probable changes in the control parameter; the construction of the B-matrix reflected this considerartion through row multiplication by the desired range for each control variable. The B-matrix was constructed from the coefficients of the linearized system of equations (linearized with respect to the control variables), evaluated at the steady state:

$$b_{ij} = \frac{\partial Y_i}{\partial P_j} \tag{4.7}$$

where: b_{ij} = i-th row, j-th column entry of B

Y_i = i-th derivative

P_j = j-th input variable.

Singular value decomposition analyses were conducted [Program RESVDN.FOR, Appendix A] at each steady state and normalization of control variables were such that a reasonable step change was simulated. Also, various order models were tested.

For interpretation of an input response analysis, the matrix supplied to the decomposition routine is N x 5, where N is the model dimension studied and five represents the five system inputs (Θ, M_o, I_o, T_c, and T_o). Referring to TABLE 4-3 (Input Response Analysis of the Ninth Order Model), note there are five singular values, as indicated by the five non-zero entries, with five corresponding columns in matrices U and V. Each vector of U is comprised of nine components (dynamic state variables) and each vector of V is comprised of five components (system inputs). Scaling factors indicate the relative magnitudes of the "unit step changes" in each input to the system; for example, a unit step change in residence time Θ for this analysis is actually a change of 2000 seconds. Now, for a unit step change in all input variables, the third input (I_o) is shown as having the largest effect as given by its role as the principal component of the vector in V corresponding to the largest singular value SV(1). And, as before in the other decomposition analyses, the fifth output (μ_2) is seen as the state variable most affected by the unit step inputs. This

TABLE 4-3. RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: R92.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 21-AUG-79
TIME: 09:31 22.6

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00
-.3591D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.2397D-07	-.1263D+04	.0000D+00	.0000D+00
.3578D-08	.2214D-06	-.9921D-04	.0000D+00	.0000D+00	-.2397D-07	.4940D+01	.0000D+00	.0000D+00
.1923D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	-.2397D-07	.1136D+04	.4940D+01	.0000D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	-.2397D-07	.5819D+06	.2273D+04	.4940D+01
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01

INPUT MATRIX M & SINGULAR VALUES

.5900D-03	.0000D+00	.0000D+00	.9963D-03	.2480D-02	SV(1)=	0.212225123713279646D+04
-.2386D-04	.9921D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.773769321274946038D+01
.5145D-07	-.1655D-06	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.185024218665259416D+00
.2395D-04	-.8493D-04	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.126412786018915772D+01
.1777D-01	-.6527D-01	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.353273935950016119D-19
-.6928D-07	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.000000000000000000D+00
.1875D-11	.1999D-06	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.000000000000000000D+00
.4809D-09	.8480D-04	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.000000000000000000D+00
.2462D-06	.4349D-01	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

.1690D-01	.9991D+00	-.3434D-01	.1901D-01	.5966D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.6896D-03	-.2806D-01	-.2869D+00	.9575D+00	-.5841D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5010D-06	-.1201D-03	-.3936D-02	-.1365D-02	.4529D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.7876D-03	-.2742D-01	-.9571D+00	-.2877D+00	-.2011D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.9999D+00	-.1689D-01	.1136D-02	.5657D-03	.1972D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1694D-04	-.1408D-02	-.2226D-01	.5426D-03	.8631D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3178D-10	-.3121D-08	-.1578D-06	-.4786D-07	-.5575D-06	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1987D-07	-.2211D-06	-.2068D-04	-.5909D-05	-.3263D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1619D-04	.1842D-03	-.4368D-03	.2417D-03	-.2223D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.2785D-01	-.4561D+00	.8895D+00	.3191D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2074D+00	-.4276D+00	-.2288D+00	.8496D+00	.5943D-16	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9343D+00	-.3273D+00	-.1387D+00	.2600D-01	.4077D-17	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1076D+00	.2641D+00	.1381D+00	.1964D+00	-.9279D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2678D+00	.6574D+00	.3438D+00	.4889D+00	.3728D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

process is carried through for each singular value. Finally, the nearly-zero singular value SV(5) indicates a repetition of input variables, as is the case for control via temperature manipulation (T_c and T_o) and can be noted also by the entries in the B-matrix.

The results of the input response decomposition analysis are given in Appendix D. For all the tests made, only four singular values are of importance, indicating a repetition of input variables. This is obviously the case for control via either T_c or T_o would yield a common control response. More importantly, though, is the indication of primary control variables (as given by the first singular value and vector). Inlet temperature (T_o), inlet initiator concentration (I_o) and residence time (Θ) are shown to be primary control variables and inlet monomer concentration (M_o) is seen as the dominant secondary control variable for the case of the middle steady state. Since all of these variables play major roles in each of the singular values, it is difficult to determine precisely <u>the</u> single dominating control variable, if indeed one is better that the rest.

A further extention of this analysis is to examine each control variable individually to obtain a general indication as to which state variables are most affected by a step change in each control variable. Generalized results of this procedure are given in TABLE 4-4.

TABLE 4-4. INDIVIDUAL CONTROL VARIABLE TEST RESULTS

CONTROL VARIABLE	STATE VARIBLES AFFECTED		
	LOW	MID	HI
θ	μ_2	μ_2	μ_2
M_o	μ_2	μ_2	μ_2-T
I_o	μ_2	μ_2	μ_2
T_c	μ_2-T	μ_2	μ_2
T_o	μ_2-T	μ_2	μ_2

The second moment of polymer distribution is indicated as that state variable most affected by step changes in control parameters, but this quantity is hardly measurable (although it may yet be attainable through the use of a filter). Dependent upon the region of interest, inlet monomer concentration or one of the temperature parameters may prove to be adequate as manipulated variables since reactor temperature, an easily measured quantity, is seen to have strong, desirable dependence, as indicated by its role as the second most affected variable in these analyses.

Conclusions

Through various applications of singular value decomposition, the model for the styrene polymerization process has been simplified to five dynamic equations (T, M, μ_0, μ_1, μ_2) and five varibles resulting from pseudo-steady state assumptions (I, σ_0, σ_1, σ_2, R_1). The application of these linear algebra techniques has taken some of the guess-work out of model simplification/reduction and given some insight into the differences between these two results. Although theoretically limited to stable, linear systems, the techniques employed here, when applied to the unstable regions, yielded similar and anticipated results. The required theoretical extentions would be a fruitful area for continued research.

Some of the important uses of singular value decomposition are listed here:

1. Jacobian matrix analysis yields information of system derivatives and the state variables affected by changes in those derivatives;

2. grammian analysis highlights dynamic situations by giving information on the relative importance of the dynamic variables for the time frames desired; and

3. input response analysis indicates possible control strategies based on the relative response values and vectors resultant from step changes in the control parameters.

As a result, singular value decomposition is an area of analysis relatively new in the field of engineering and offers interesting possibilities for new applications:

1. new technique for handling of stiff differential equations;

2. improvement and advantage over modal control analysis;

3. on-line analysis directed toward multivariable control problems; and

4. decoupling in multivariable control problems.

CHAPTER V

STYRENE POLYMERIZATION MODELS

Introduction and Generalizations

In the development of the reaction system model used in this research, it became evident that the free-radical polymerization of styrene had been the subject of much published research. Consequently, many approaches to the modeling of the process have been used, often tailoring the modeling efforts to suit the specific needs and goals of the study undertaken. Studies of reaction dynamics would required a more simplified model than those studies concerned with the resultant polymer properties, since polymer distribution moments have no dynamic effect on the polymerization process.

Similarly, mathematical studies have oftentimes been conducted in terms of dimensionless variables to obtain more generalized solutions, as compared to those conducted in association with experimental results, where the modeling has been left in dimensioned form as a point of correlation. Other differences in modeling include: isothermal vs. nonisothermal studies, bulk vs. solution polymerization, compensation for volumetric changes, and correlations for properties (density, heat capacity, gel effect and glass effect).

This chapter is meant to direct attention to a few of the other modeling efforts found in the literature and to point out some of the similarities and differences encountered.

Comparison of Modeling

The standard approach to modeling is by writing species material balances and an energy balance (if dealing with a nonisothermal case). In the case of a polymerization process, this procedure results in an infinite series of equations for free radical and polymer species of varying chain length. Application of moments of distributions of free radical and polymer reduce this infinite series of equations to a finite set, generally given by three moments of distribution of free radical and three moments of distribution of polymer.

Laurence and Vasudevan [19] conducted a study on the time-averaged effects on molecular weight distributions of very slow oscillations of the feed concentrations of monomer and initiator. Their model was that of an isothermal CSTR described by eight equations (moment equations, monomer and initiator equations). The variables were normalized with respect to their steady state values and dimensionless equations were subsequently derived. The system under study was the solution polymerization (benzene as solvent) of styrene, as described kinetically by initiator decomposition, propagation and termination mechanisms.

Hamielec, et al., [43-46] presented a series of articles on polymer properties and molecular weight distributions concerning free-radical polymerization in batch reactors, CSTRs, and various configurations of CSTRs. Again, solution polymerization (benzene as solvent) of styrene was studied, but a correction for solvent effects was included for the transfer and termination reactions. No correction, however, was made for thermally-induced polymerization, and, although viscosity effects were evident in their experimental work, they were not accounted for in the model. Pseudo-steady state assumptions were made for handling radical distribution moments.

In a later paper, Hui and Hamielec [47] explored the problems of gel and glass effects for thermally-induced bulk polymerization of styrene. Their model, for this study, ignored initiation and transfer reactions, employed the method of moments to reduce the number of equations involved, and was simplified through quasi-steady state assumptions applied to free radical moments of distribution. Also included in this model were compensations for volumetric changes. The result of their work was a correlation involving the propagation and termination reaction rate constants to compensate for gel and glass effects encountered at high temperatures and conversions.

In an earlier study of control of addition polymerization reactors, Warden and Amundson [35] developed a model for a nonisothermal CSTR. Their model was simplified to only three equations since their major concern was the reaction dynamics and control of these dynamics. Reduction to only three equations maintained the desired integrity of the model while allowing them to apply more easily the Routh-Hurwitz criteria for stability to their control study.

Spitz, *et al.*, [20] investigated the bulk free radical polymerization of styrene initiated by AIBN in an experimental study. Their modeling efforts were focused on the comparison of theoretical prediction and experimental results of open loop on-off periodic control of inlet initiator concentration. Their model [20,21,22] consisted of nine equations writen in dimensioned form, where the following applied:

1. pseudo-steady state assumption for moments of radical distribution;

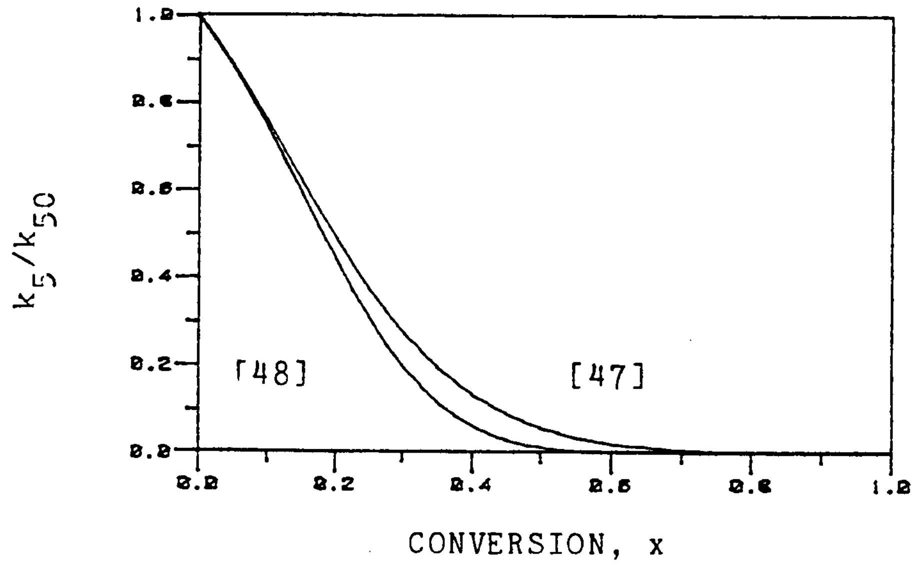
2. compensation for initiator cage effect; and

3. gel and glass effects through correlations due to [47].

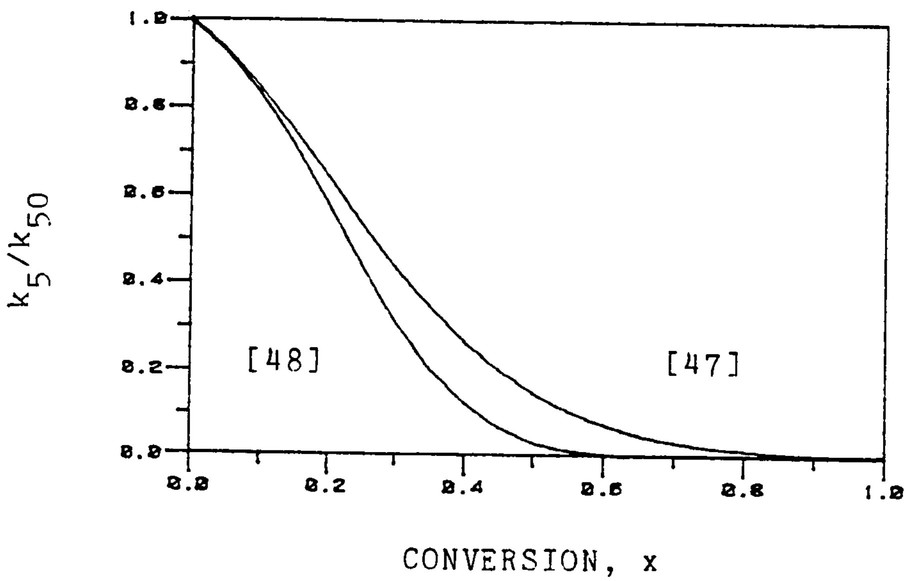
For the nonisothermal portion of their study, variation of heat capacity was considered as a function of polymer chain length.

In a more recent paper by Jaisinghani and Ray [48], reactor dynamics of free radical polymerization were studied. Their model, since polymer properties were inconsequential, consisted only of four equations (initiator, monomer, temperature and zeroeth moment of radical distribution). Further simplification resulted from the quasi-steady state assumption applied to the radical moment equation. In order to examine the process more generally, the remaining equations were made dimensionless. Other features of their model include a constant heat capacity and a heat of reaction for only the propagation reaction. Thermally-initiated polymerization was ignored.

Probably the most significant difference in this model is the change in the correlation for the gel and glass effects. Since their study employed the use of bifurcation theory to test for limit cycles, the data used by Hui and Hamielec [47] was refit to another mathematical correlation to simplify the differentiation demanded by the analysis technique. Although the correlation is intended to yield a similar compensatory effect, for the polystyrene system examined, this did not seem to be the case as noted in FIGURE 5-1.



A. 40°C



B. 120°C

FIGURE 5-1. COMPARISON OF CORRELATIONS

Understandably, variations are noted in the simulation results, as seen by the temperature-time traces of FIGURE 5-2.

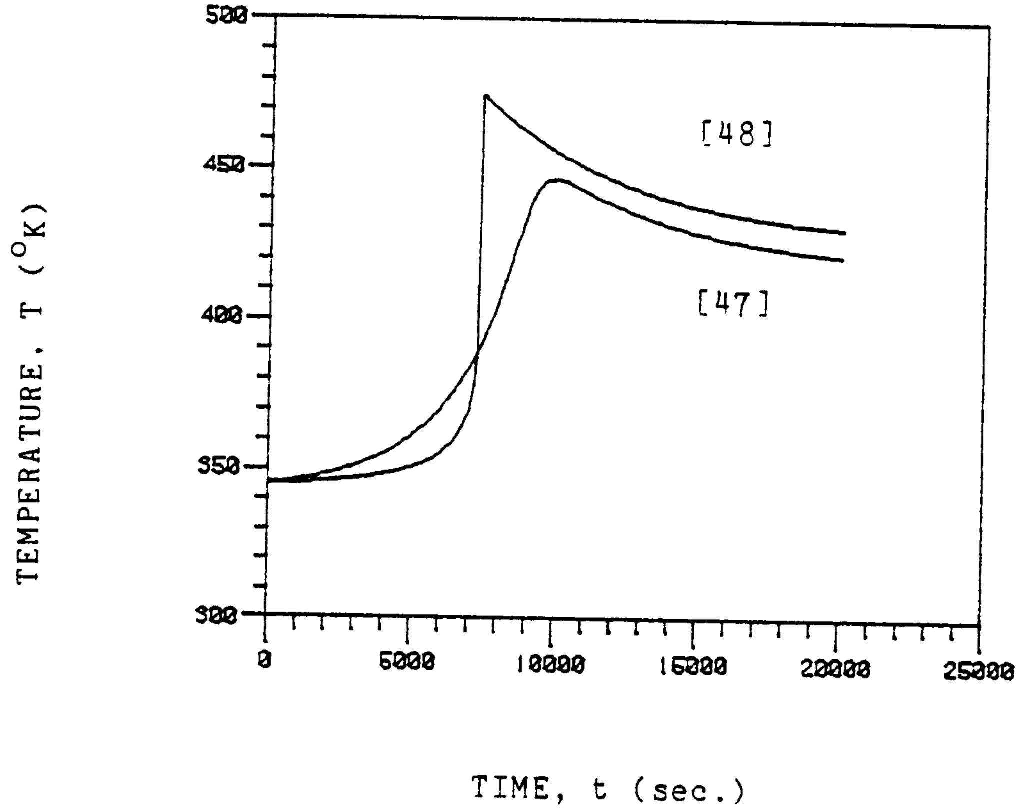


FIGURE 5-2. COMPARISON OF MODELS: SIMULATION

Even with these differences, however, the same reactor pathology is maintained for both correlations. Since reactor dynamics only were of interest, their work included some interesting studies of the influence of initiator dynamics. Again, they saw no pathological changes in the overall reactor dynamics due to initiator dynamics (included or ignored).

Summary

All models investigated were developed in similar manners, but some of the major differences have been outlined. A greater majority of differences in models results from the intent of the specific research. All models applied the pseudo-steady state assumption to some extent (depending upon the study) for simplification, although none had concrete reasoning for this assumption. Prior studies have relied on intuitive reasoning for this simplification, whereas this work has presented a quantitative approach through singular value decomposition. No other models included a single unit free radical equation or variable although many used it as a starting point in their model development. Retention of the R_1 equation for this study has been explained earlier.

Other features included and neglected in this model are:

1. no compensation for solvent as in solution polymerization;

2. consideration of thermal initiation (monomer decomposition) to free radicals;

3. constant heat capacity and density;

4. consideration of heats of reaction for thermal initiation, propagation and transfer reactions;

5. compensation for gel and glass effects through the correlation due to Hui and Hamielec [47]; and

6. compensation for the cage effect of the initiator, as given by Spitz, *et al.*, [20,22].

CHAPTER VI

THE CONTROL PROBLEM

General Introduction

The desirability of process operation at or near an unstable steady state has given way to designs of control systems to meet this need. Conventional linear feedback control systems are directed toward maintaining the unstable steady state conditions. In some cases, this conventional approach may prove difficult to implement or, for other reasons, an alternative concept may be desired. One such approach [23-25,27,28,62] will be examined here as it is applied to the styrene polymerization CSTR under investigation.

A thorough and rigorous development of the design procedures will not be presented as these may be found elsewhere [23,28,65]. Instead, an intuitive description of the nonlinear feedback control stategy will be given along with an "applied" approach to the nonlinear control element (relay) design. To initiate the study of the relay control scheme for a specified control loop (having chosen the measured and manipulated variables), the effects of the change in the manipulated variable on the process steady

<u>state behavior</u> was studied through Van Heerden diagrams. This showed how the generation and removal characteristics were modified due to changes in the manipulated input. It also provided some "feel" for the suitability of the linearization of the process as required by the current analysis and design procedures, especially in terms of the manipulated variable.

Then the nonlinear control element for the nonlinear system is formally analyzed by applying Tsypkin's method to the linearized model. This design method yields both amplitude and period of the resultant cyclic solution of the controlled process.

The control objective of this section is the illustration that a nonlinear feedback control element (relay) may be applied successfully to the AIBN-initiated styrene polymerization carried out in a CSTR. In order to force this part of the research to remain within reasonable bounds for this thesis, the following constraints were placed on the study:

1. Of the many new and intriguing results and characteristics in behavior not reported in other studies of nonlinear control for unstable reactor operation, only a selected few were investigated in detail.

2. Stability analysis of the predicted periodic solutions was not carried out.

3. No attempts were made to examine the effects of the implemented control strategy on the various properties of the polymer product.

Many of the details leading to the results, trends, and conclusions reported in this portion of the thesis are given in Applied Control Laboratories Report Number 7903 [85].

Tsypkin's Analysis

When the nonlinear feedback control element under consideration is a relay, an analysis procedure set forth by Tsypkin allows treatment of the control element exactly [23,65,83]. Basically there are two sets of conditions which must be satisfied in this procedure:

1. the switching conditions, which yield the predicted frequency Ω_o of the periodic solution, and

2. the continuity condition, which requires checking the waveform, and thus, gives the anticipated amplitude of the resulting oscillation.

The switching conditions are necessary conditions for an oscillation, while the switching conditions and the continuity conditions taken together constitute necessary and sufficient conditions for an oscillation.

Bruns [23] presents the switching and continuity conditions for a symmetric relay with hysteresis (memory), as shown in FIGURE 6-1, for the case where the relay is in a negative feedback loop. These conditions are rewritten here for the same relay considered in a positive feedback loop, where time zero is taken as a time when the relay changes to a positive drive level. The switching conditions are:

Passive: $x(n\tau_0^-)=-\delta \qquad \dot{x}(n\tau_0^-)< 0 \qquad (6.1a)$

$x(\alpha n\tau_0^-)=\delta \qquad \dot{x}(\alpha n\tau_0^-)> 0$

Active: $x(n\tau_0^-)=\delta \qquad \dot{x}(n\tau_0^-)> 0 \qquad (6.1b)$

$x(\alpha n\tau_0^-)=-\delta \qquad \dot{x}(\alpha n\tau_0^-)< 0$

and the continuity conditions are:

Passive: $x(t) < \delta \qquad n\tau_0 \leq t < \alpha n\tau \qquad (6.2a)$

$x(t) > -\delta \qquad n\ _0 \leq t < (n+1)\tau_0$

Active: $x(t) > -\delta \qquad n\ _0 \leq t < \alpha n\tau \qquad (6.2b)$

$x(t) < \delta \qquad n\ _0 \leq t < (n+1)\tau_0$

where: $\tau_0^- = \lim_{\epsilon \to 0} (\tau_0 - \epsilon)$ = time of switch to D^+

δ = half-bandwidth, deviation from reference

x = independent controlled variable

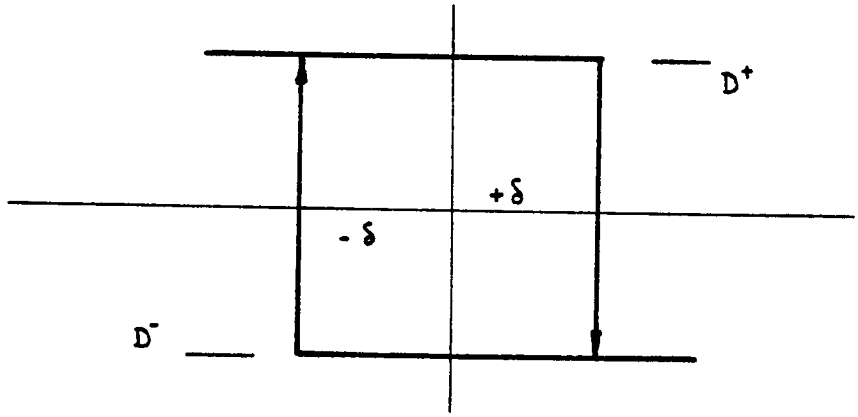


FIGURE 6-1. ACTIVE RELAY WITH HYSTERESIS.

To analyze the switching conditions, a Tsypkin's locus $T(j\Omega_o)$ is constructed in the complex plane by considering all values of Ω_o for the Tsypkin function according to:

$$T(j\Omega_o) = \frac{-1}{\Omega_o}\dot{x}\left[\frac{\pi^-}{\Omega_o}\right] - jx\left[\frac{\pi^-}{\Omega_o}\right] \tag{6.3}$$

or: $$T(j\Omega_o) = \frac{4D}{\pi}\sum\left[\operatorname{Re} G_1(jk\Omega_o) + j\frac{1}{k}\operatorname{Im} G_1(jk\Omega_o)\right] \tag{6.4}$$

Thus the switching conditions may be rewritten to yield the following form for a relay considered in a positive feedback sense:

Passive: $$\operatorname{Im}[T(j\Omega_o)] = \sum \frac{1}{k}\operatorname{Im}[G_1(jk\Omega_o)] = \frac{\pi}{4}\left[G_s(\infty) + \frac{\delta}{D}\right] \tag{6.5}$$

$$\operatorname{Re}[T(j\Omega_o)] = \sum \operatorname{Re}[G_1(jk\Omega_o)] > \frac{\pi}{4\Omega_o}\lim sG_1(s) \tag{6.6}$$

Active: $$\operatorname{Im}[T(j\Omega_o)] = \sum \frac{1}{k}\operatorname{Im}[G_1(jk\Omega_o)] = \frac{\pi}{4}\left[G_s(\infty) - \frac{\delta}{D}\right] \tag{6.7}$$

$$\operatorname{Re}[T(j\Omega_o)] = \sum \operatorname{Re}[G_1(jk\Omega_o)] < \frac{\pi}{4\Omega_o}\lim sG_1(s) \tag{6.8}$$

To simplify handling of these series summations, some closed forms have been provided by Gelb and VanderVelde [83]. Armed with these closed forms of summations, Tsypkin's analysis becomes a cookbook procedure that can be applied to any linear process described as a partial fraction expansion in the Laplace domain. For a given bandwidth 2δ and drive level D, a frequency of oscillation Ω_0 is sought using the switching condition on the variable (eqn. 6.5 or eqn. 6.7). All real positive solutions that are found are candidate solutions. Any candidate frequency Ω_0 is then tested for the switching condition of the derivative (eqn. 6.6 or eqn. 6.8).

Finally, for the solution to satisfy necessary and sufficient conditions and, thus, be a valid solution, the continuity conditions must be met. Again, the expressions for the waveform are written in terms of infinite series involving the process transfer function, with Gelb and VanderVelde providing the required closed forms to reduce the generation of the waveform to a numerical procedure.

Polymerization Process

Since this direct approach to Tsypkin's analysis was taken, it became necessary to examine the problem of obtaining transfer functions for the various control strategies under investigation, as well as allowing the flexibility of examining different order models of the process. Due to the multiple input-multiple output nature of the system, the solution was approached by developing a generalized numerical package. Note that, for the tenth order model with five possible manipulated variables, fifty transfer functions would be needed to describe the reactor fully. Further, such a package would facilitate analysis of simplified models as well as being a general tool in the analysis of other systems.

A subroutine package due to Melsa and Jones [80] was revised by Stelling [84] to allow for the construction of the resolvent matrix Φ, based on the input Jacobian matrix A, where:

$$\Phi = \mathrm{adj}\,(sI - A) \tag{6.9}$$

and each element φ_{ij} of Φ is a polynomial which represents the numerator of the open loop transfer function. Cross-multiplication of the resolvent matrix with the input coefficient matrix B, as given by (4.7), yields the numerator of the closed loop transfer function for each of the fifty possible control strategies.

The denominator of the transfer function is given as the product of the eigenvalue terms, given by $(s-\lambda_1)(s-\lambda_2)\cdots$; thus, the partial fraction expansion of the desired loop transfer function is derived through another subroutine package from Melsa and Jones [80], as modified for this work by Stelling [84]. Again, since this is all done numerically, it becomes a simple process to examine any of the feasible control schemes for the considered process.

Applied Tsypkin's Analysis

For the purpose of this initial study, five control loops were surveyed with regard to Tsypkin's design procedure:

1. second moment of polymer distribution controlled by flow rate manipulation (residence time), D=2000 seconds;

2. second moment of polymer distribution controlled by manipulation of average coolant temperature, D=20^{o}K;

3. second moment of polymer distribution controlled by manipulation of inlet initiator concentration, D=0.01 and .004 moles/liter;

4. reactor temperature maintained through inlet monomer concentration manipulation, D=1.5 moles/liter; and

5. monomer concentration controlled by manipulation of inlet monomer concentration, D=1.5 moles/liter.

Singular value decomposition involved in input response analyses indicated control of the second moment of polymer distribution and of reactor temperature. Control of monomer concentration was also indicated as the most probable secondary control variable. These particular control strategies and drive levels were chosen due to the seeming linearity of the system with regard to the control variables as given by the Van Heerden analysis. Tsypkin's analysis was conducted for these loops using the fifth order model and simulation verification was also done using the fifth order model.

Based on the results of the input response analyses conducted using singular value decomposition, control of the second moment of polymer distribution was tested (cases 1, 2, and 3). Only Tsypkin's analysis was performed on these loops with some interesting results. For Case 1, the acceptable ranges for half-bandwidths given by the switching conditions was $10 \leq \delta \leq 125$, with corresponding oscillation periods of 1164-32442 seconds. The lower frequency oscillations exhibited increasingly nonlinear behavior.

For Case 3, where average coolant temperature with a drive level of $20^{\circ}K$ was used to control the second moment of polymer distribution, Tsypkin's analysis indicated that the desired relay should be a passive relay (positive feedback sense); this is contrary to that which would be anticipated from the Van Heerden diagram. An important concept is emphasized by this revelation; that is, for higher order systems (strictly for any system other than first order [25]), the Van Heerden approach will only yield information about the steady states and not give reliable insight into the dynamics involved. This same phenomenon would be expected in the use of phase plane analysis where dynamics up to only second order are correctly represented [24]. Thus the approach using Tsypkin's analysis is the appropriate analysis to implement in predicting the system's dynamic response and relay design. Here it should be pointed out that the limiting factor is the use of the linearized model.

Case 3 provided further unexpected results as Tsypkin's analysis predicted that, for the chosen drive levels, there were no relay designs, active or passive, which lead to oscillatory behavior. Solutions were found for Ω_0 according to the switching condition of the variable, but these solutions failed the derivative test.

The specific control loop indicated by the input response anaylses discussed in Chapter IV was control of the second moment of polymer distribution by inlet initiator concentration. For inlet initiator drive levels that would provide multiple steady states, no solutions corresponding to realistic bandwidths solutions were determined that would provide a stable periodic solution. But, as the drive level was increased to the point that only a unique steady state existed for at least one drive level, some rather interesting results were found: for a small region of narrow half-bandwidths ($0<\delta\leq 8$), two solutions for the frequency of oscillation were found. This phenomenon has not been reported in previous applications of this kind and immediately raises the intriguing question of stability of oscillation for the two cases. Further investigation into the control problem exhibited here is obviously indicated, and could be aided somewhat by results given by Spitz, <u>et al</u>., [20,22] in their studies involving forced periodic control. Since this interesting phenomenon falls outside the central scope of this thesis, the suggested studies will be left for future research.

Controlling reactor temperature by manipulating inlet monomer concentration at a drive level of D=1.5 moles/liter proved to give stable control for $\delta_{max} = 12^{o}K$ using an active relay element (positive feedback loop). For this

Case 4, simulation of the nonlinear equations was also implemented. This procedure would normally be the final step in all detailed designs. This simulation showed the bandwidth was further restricted when applying the relay control to the nonlinear system; δ_{max} was reduced to a value of about $9^{O}K$. It should be noted that the resulting stable oscillation for the nonlinear system for $\delta=5$, as shown by the simulation in FIGURE 6-2, is very much first order in character; this phenomenon can be explained by:

1. five variables are taken as pseudo-steady state variables;

2. moments of polymer distribution do not enter into monomer or temperature dynamics; and

3. monomer concentration for stable oscillations is, in essence, at steady state.

Period and total amplitude of the resulting oscillations as predicted by Tsypkin's analysis were verified by the simulation results as being quite good and are indicated in TABLE 6-1.

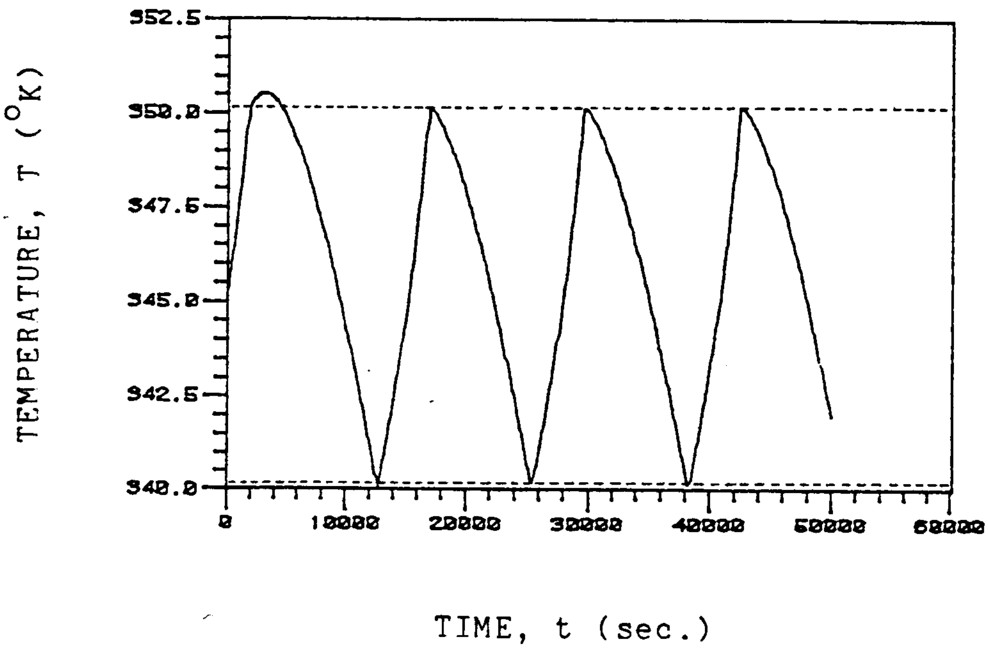


FIGURE 6-2. ACTIVE RELAY CONTROL: CASE 4 (D = 1.5, δ = 5.)

TABLE 6-1. COMPARISON OF SIMULATION AND TSYPKIN RESULTS FOR CASE 4: D = 1.5

	BANDWIDTH	TSYPKIN	SIMULATION
PERIOD, sec.	5	13004	12803
	9	29970	35570
AMPLITUDE	5	10	10
	9	18	20.9

As the bandwidth was increased to its maximum value of 18°C, the character of the resulting oscillation drifted from that of first order exhibited for a bandwidth of 10°C (δ=5.). An overshoot of almost 3°C occurred at the upper switching level with none seen at the lower switching level for this maximum bandwidth.

One of the more interesting cases examined was Case 5, control of monomer concentration by inlet monomer concentration. A passive relay (positive feedback loop) was indicated for implementation through the Van Heerden approach; this is reversed from control relays for the other state variables since monomer is the one function that decreases with increasing temperature. When applied in the Tsypkin analysis design, the passive relay surprisingly would not satisfy any of the switching conditions. This again illustrates the absence of dynamic information in the Van Heerden diagram. Normally, the limiting case for relay design is $\delta = 0$, or the case of the "ideal" relay. This case also failed to meet the switching criteria.

Upon closer examination of this unique problem, it was noticed that, beginning at the unstable steady state, if a step increase of inlet monomer concentration was made, the reactor monomer concentration would initially increase, then decrease as the reactor temperature would rise rapidly. Conversely, if a step decrease in inlet monomer concentration was made, reactor monomer concentration would initially decrease. This phenomenon is sometimes called wrong way behavior and has been noted in other processes. Wrong way behavior presents special problems in the design of process control systems. This situation of wrong way behavior is dramatically illustrated in FIGURE 6-3.

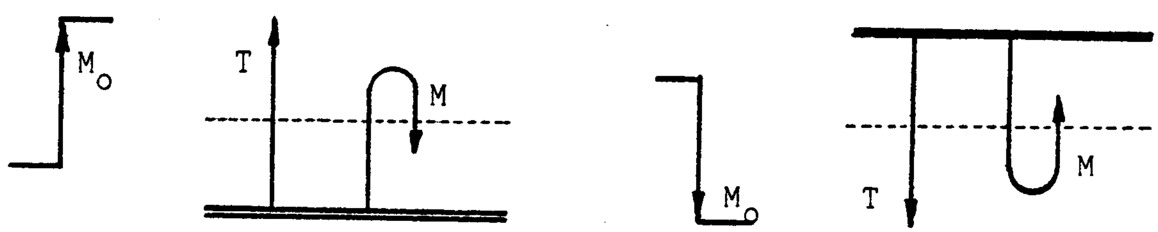


FIGURE 6-3. RESPONSE TO STEP CHANGES IN INLET MONOMER

The linearized system used for Tsypkin's design also demonstrated the wrong way behavior seen in the nonlinear simulations, reinforcing the contention that control design for higher order systems cannot be done through the Van

Heerden diagram. Thus, based on Tsypkin results, an active relay (positive feedback loop) was employed for Case 5. This turnabout from the design implied by the Van Heerden approach to the design given by Tsypkin's analysis can be noted by studying the changing character of the relay from passive to active as shown in FIGURE 6-4.

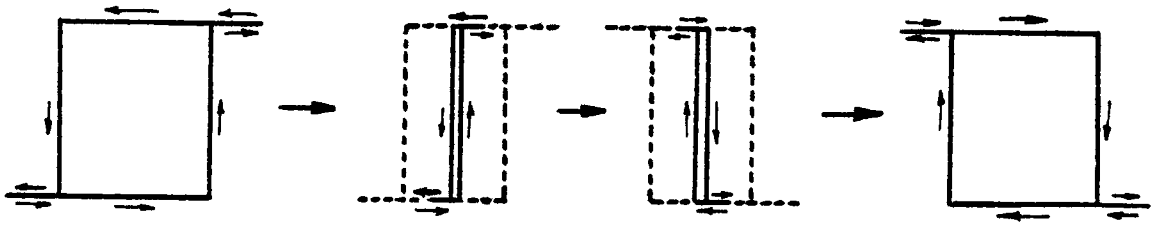


FIGURE 6-4. PASSIVE TO ACTIVE CHARACTER OF RELAY

Basing a Tsypkin design on controlling monomer concentration using inlet monomer concentration with the active relay gave still further interesting results. Solutions were found for frequency of oscillation, based on the switching condition on the variable, that did not satisfy the switching condition on the derivative. This case is an example of the problems arising when discontinuities in the derivative are encountered, and can be noted mathematically by the finite value taken by $\lim_{s \to \infty} sG_1(s)$. It is more easily recognised intuitively from FIGURE 6-3:

1. values falling within the indicated gap would satisfy the switching condition of the variable; and

2. of each pair of values within the gap, only one value has the proper sign on the derivative to satisfy that switching condition.

So, under "normal" conditions, the frequency of oscillation given by Tsypkin's analysis is expected to be greater than that attainable through simulation due to nonlinearities. But, in this case, before simulation is attempted, the range of allowable frequencies is reduced due to the switching criteria on the derivative. This range is noted in TABLE 6-2.

TABLE 6-2. ILLUSTRATION OF FREQUENCY LIMITATION DUE TO SWITCHING CRITERIA OF TSYPKIN'S ANALYSIS FOR CASE 5: D = 1.5

BANDWIDTH	PERIOD	$RE[T(j\Omega_o)]$		$\frac{\pi}{4\Omega_o} \lim_{s \to \infty} sG_1(s)$	CHECKS
0.10	1200	0.0054	$<$	0.033	*
0.25	3030	0.0333	$<$	0.084	*
0.50	6333	0.1308	$<$	0.176	*
1.00	20667	0.7545	$>$	0.574	
1.06	36370	1.3984	$>$	1.016	

The nonlinear simulation of Case 5, as shown in FIGURE 6-5, indicates that control is lost for this strategy due to the extreme asymmetry of the system. The process is far more temperature-dependent than it is dependent upon monomer concentration. As seen in FIGURE 6-5, temperature increased with time, finally reacting monomer at a rate fast enough to force loss of control based on the monomer concentration. The stable oscillations indicated by Knorr [49] for the open loop forced oscillation situation are for the isothermal CSTR. Based on these discoveries, control of the reactor temperature yielded the better control (Case 4).

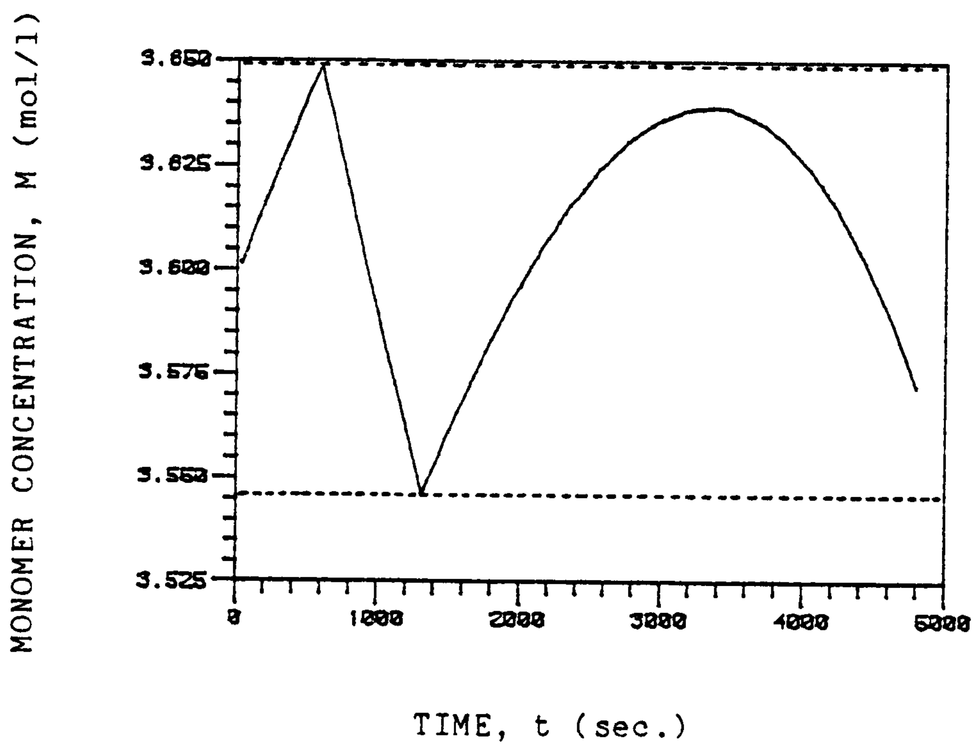


FIGURE 6-5. ILLUSTRATION OF CASE 5 CONTROL USING AN ACTIVE RELAY: D=1.5, δ=0.05

Conclusions

Based on these initial investigations, the following important conclusions were drawn.

1. Relay control is applicable to the AIBN-initiated styrene polymerization process modeled.

2. Relay design for higher order systems must be done using Tsypkin's analysis since the Van Heerden and phase plane approaches do not give any indication of the actual dynamic behavior.

3. Longer period-borderline case studies(such as Case 4, D=1.5, δ=9.) showed an overshoot at the upper switching level, resulting from the combination of the longer period of oscillation, wider bandwidth, and the highly exothermic nature of the polymerization process.

4. Although Tsypkin's analysis may indicate a reasonable stable oscillation the nonlinear simulations could well prove that the actual stable oscillations possible are for unrealistic bandwidths.

5. For the nonisothermal CSTR under control of monomer concentration by inlet monomer concentration manipulation, the stability of the oscillations

predicted by Tsypkin's analysis was not tested, but, based on the nonlinear simulations attempted, these oscillations were unstable.

Out of this survey there are indicated other avenues that should be investigated:

1. control based on inlet initiator concentration;
2. control of various polymer properties, either as state variables or calculated variables; and
3. time-averaged effects of relay control on the various polymer properties.

CHAPTER VII

RECOMMENDATIONS FOR FUTURE STUDY

There are many areas that could be explored using this present work as a base. Quite a large number of difficulties were encountered due to the ill-conditioning of the system, that is, due to the widely spread range in magnitudes of values for all the variables used. This problem is particularly evident from the condition numbers for the various order models, as given in TABLE 7-1. The condition number of a matrix is merely the largest singular value divided by the smallest singular value, with a condition number of unity representative of a singular matrix. To further investigate this styrene polymerization model, as a complete model of ten dynamic equations, normalization of state variables to dimensionless form is indicated.

TABLE 7-1. CONDITION NUMBERS FOR MODELS

MODEL ORDER	CONDITION NUMBER
2	1.886 E02
5	3.851 E04
6	4.762 E08
7	1.805 E14
9	1.666 E11
10	1.113 E15

Further refinements to the styrene polymerization model employed in this study could be made to better represent the process over a large region of operating conditions. More specifically, correlations for the changing nature of the density and the heat capacity could be included, as well as adding the influence of the solvent in the solution polymerization process. Also much remains to be done in the way of examining the various models presented in the literature; simulations could indicate differences not readily detected in the survey approach used in this thesis.

A large amount of research is open to investigation in the engineering applications area of singular value decomposition. For the system investigated, the conflicting results concerning the use of the single unit radical in the model should be studied further. This could, perhaps, best be accomplished through the normalization techniques employed. Following this line of study, a quantitative guideline for normalization could well be developed, possibly involving time scaling employed in the grammian analyses. The same techniques applied in this study could be applied to other systems of interest. In order to apply these techniques to unstable processes, the required theory needs to be formalized. The analysis tool could be modified to allow an effective method of integrating the stiff differential equations used here, or for any system of stiff equations. And, singular value decomposition could easily be applied in other process control areas, such as decoupling problems and on-line analysis directed toward multivariable control.

Some of the unexpected, and previously unreported, results found in this research deserve further investigation:

1. multiple solutions for the pushing control example of polymer properties controlled by inlet initiator concentration;

2. asymmetry of resultant oscillations and comparison to predictions by Tsypkin's analysis; and

3. wrong way behavior noted in the case of monomer controlled through inlet monomer concentration manipulation.

Specific to the nonlinear control problem addressed in this research, the most promising new area of investigation would be in the application of nonsymmetric relays (unequal bandwidths, unequal drive levels, or a combination of these features) to the feedback control system. Since there are many severe nonlinearities encountered in this system, especially near the unstable steady state, nonsymmetric relays could provide some compensation for these effects and allow better control. This idea should be included in the analysis of the effects of relay control on the time-averaged polymer properties. Finally, since this research represents merely a mathematical study, the ideas investigated should be experimentally verified.

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APPENDICES

APPENDIX A

FORTRAN PROGRAMMING

FORTRAN compiler listings for the following programs are given in this appendix:

1. UTKVHA.FOR - Van Heerden analysis and steady state solutions;

2. OLDSVD.FOR - eigenvalue analysis and SVD of the Jacobian matrix;

3. GRAM.FOR - grammian analysis of the dynamic system by SVD; and

4. RESVDN.FOR - analysis of input responses for full and simplified models.

Eigenvalues found using OLDSVD.FOR were determined by means of matrix routines from the Scientific Subroutine Package (SSP) supplied by the International Business Machines Corporation. Singular value decomposition was done using the FORTRAN version of an ALGOL routine by Golub and Reinsch [72].

Simulations of the nonlinear system of equations were done using a variable step size, variable order Adams-Moulton predictor-corrector routine. Also tested was a Gear method, specifically applicable to systems of stiff ordinary differential equations. The routine used was subroutine DVOGER from the International Mathematical and Statistical Libraries, Inc.

```
MAIN.    UTKVHA.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       10:08   PAGE 1

C        PROGRAM FOR STEADY STATE VALUES VS TEMPERATURE
C        TO EXAMINE THE EFFECTS OF VARIOUS 'CONTROLLABLE'
C        PARAMETERS ON THE 'STABILITY' OF THE SYSTEM...
C
C        PGM BY JOHN STELLING III.........REV./06.04.79
C
C.......
         IMPLICIT REAL*8 (A-H,O-Z)
C.......
         REAL*8 M,MI,MIO,MOLD,MBAL,MPRE
         REAL TI,QGI,QRI,MI,P2
         REAL*8 IFILE,JFILE,SFILE
         COMMON/AREA1/R,CAGE,MIO,RKO(5),RK(5),EN(5),CONV
         COMMON/AREA2/DH(5),DHO(5),BI,TREF,TI
         COMMON/AREASS/DHO,IT,TC,GV,UAV,RHOCP,V2,CP,CI,ERROR
C.......
         WRITE(5,1000)
 1000    FORMAT( 3X,'VAN HEERDEN DATA OUTPUT FILE NAME: ',$)
         READ(5,1500)IFILE
 1500    FORMAT( A10)
         WRITE(5,1600)
 1600    FORMAT( 3X,'STEADY STATE RESULTS TO LINE PRINTER: ',$)
         READ(5,1500)SFILE
         WRITE(5,2000)
 2000    FORMAT( 3X,'PLOTTER DATA FILE NAME: ',$)
         READ(5,1500)JFILE
C.......
         OPEN(UNIT=23,ACCESS='SEQOUT',FILE=JFILE)
         OPEN(UNIT=20,ACCESS='SEQOUT',FILE=IFILE)
         OPEN(UNIT=25,ACCESS='SEQOUT',FILE=SFILE)
         OPEN(UNIT=21,ACCESS='SEQIN',FILE='SSPIN.DAT')
C        INITIALIZATION OF VALUES
         DELOP=+1.
         ISOL=0
         R=1.987
         IT=2000
         ERROR=1.0-14
         TST=270.15
         TC=310.15
         TI=315.15
         TREF=298.15
         MIO=4.81
         GV=10080.
C.
C.
         BI=4.45
         CI=.0106
         U=.0005
         AREA=38383.
         V=1000.
         CALL INPUT(TC,TI,MIO,CI,GV)
         CP=33.5
         RHO=11.5
                 UAV=U*AREA/V
                 RHOCP=RHO*CP
                 V2=UAV/RHOCP
```

```
            DM0=.05
C           READ IN BASE VALUES
            READ(21,*) (RKO(I),I=1,5)
            READ(21,*) (EN(I),I=1,5)
            READ(21,*) (DHO(I),I=1,5)
C
            WRITE(25,3000)SFILE
 3000       FORMAT('1',5X,'VAN HEERDEN STEADY STATE TEST: ',A10)
            WRITE(25,3001)GV,MIO,CI,TI,TC
 3001       FORMAT('0',5X,'CONTROL PARAMETERS:'/11X,'RESIDENCE TIME: ',
     1      3X,F/11X,'INLET MONOMER',4X,F/11X,'INLET INITIATOR',2X,F/11X,
     2      'T-INLET',10X,F/11X,'T-COOLANT',8X,F)
C           STEP TEMPERATURES
            DO 20 J=1,150
            T=TST+1.*FLOAT(J)
C*******HEATS OF REACTION*******
                    CPDELT=CP*(T-TREF)
                    DO 22 IRXN=2,4
   22       DH(IRXN)=DHO(IRXN)-CPDELT
C*****************************
            DM=DM0
            DO 30 K=1,5
   30       RK(K)=RKO(K)*EXP(-EN(K)/R/T)
            RKZ5=RK(5)
            C=CI/(1.+RK(1)*GV)
            A1=2.57-.00505*T
            A2=9.56-.0176*T
            A3=-3.03+.00785*T
            M=MIO+DM0
            MPRE=0.
            DO 135 I=1,IT
            M=M-DM
            IF(M)531,531,541
  531       FLAG=1.0
            M=MIO
  541       CONTINUE
            CONV=(MIO-M)/MIO
            CAGE=2.
            EFF=EXP(-CAGE*CONV)
            RK(5)=RKZ5/(EXP((A1+(A2+A3*CONV)*CONV)*CONV))**2
            F=1.+8.*RK(5)*(RK(1)*EFF*C+RK(2)*M**3)*GV*GV
            G=2.*GV*RK(5)
            RO=(-1.+SQRT(F))/G
C*******
            RAD=2*(RK(1)*EFF*C+RK(2)*M**3)+RK(4)*M*R0
            RAD=RAD/(1/GV+M*(RK(3)+RK(4))-RK(5)*R0)
C*******
            MBAL=(MIO-M)/GV-2.*RK(2)*M**3-(RK(3)+RK(4))*M*R0
     1      +RK(4)*M*RAD
            CRIT=MBAL*MPRE
            MPRE=MBAL
            IF(FLAG.EQ.1.0)GO TO 33
            IF(CRIT) 115,125,125
  115       DM=-.1*DM
            GO TO 135
  125       IF(ABS(MBAL).LE.ERROR) GO TO 33
```

```
 135    CONTINUE
        WRITE(20,900)
 900    FORMAT ( 3X,'MONOMER BALANCE ITERATION WENT 2000....')
  33    CONTINUE
        FLAG=0.
        Z=2.*EFF*RK(1)*C+2.*RK(2)*M**3+(RK(3)+RK(4))*M*R0
        R1=Z/(1./GV+RK(5)*R0+RK(4)*M)
        P0=(RK(4)*M*(R0-RAD)+RK(5)/2.*R0**2)*GV
        P1=(RK(4)*M*(R1-RAD)+RK(5)*R0*R1)*GV
C       HEAT GENERATION AND REMOVAL CALCULATIONS
C.
        QR=(T-TI)/GV-V2*(TC-T)
C.
        QG=(DH(2)*RK(2)*M*M+R0*(DH(3)*RK(3)+DH(4)*RK(4)))*M/RHOCP
        DELQ=QG-QR
              TEST=DELQ*DELQP
        IF(TEST)9011,9012,9013
 9011   CALL UTKSS(T,DELQ,ISOL)
              GOTO 9013
 9012   ISOL=ISOL+1
        WRITE(25,8000)DELQ,MBAL,QG,QR
        WRITE(25,8001)T,M,C
        WRITE(25,8002)P0,P1,P2
        WRITE(25,8003)R0,R1,R2
        WRITE(5,8004)ISOL,T,M,P2
 8000   FORMAT('-',5X,'DELQ= ',D14.8,2X,'MBAL= ',D14.8/8X,
     1  'QG= ',D14.8,2X,'QR= ',D14.8)
 8001   FORMAT(' ',5X,'STEADY STATE PROPERTIES:'/8X,'T= ',D14.8,3X,
     1  'M= ',D14.8,3X,'I= ',D14.8)
 8002   FORMAT(' ',6X,'P0= ',D14.6,2X,'P1= ',D14.8,2X,'P2= ',D14.8)
 8003   FORMAT(' ',6X,'R0= ',D14.8,2X,'R1= ',D14.8,2X,'R2= ',D14.8)
 8004   FORMAT( 3X,'STEADY STATE #',I2,/6X,'T= ',D/6X,'M= ',D/5X,'P2= ',D)
              DELQP=-DELQP
              GOTO 9014
 9013   DELQP=DELQ
 9014         CONTINUE
        R2=R1+(2.*RK(3)*M*R1)/(1./GV+RK(4)*M+RK(5)*R0)
        P2=(RK(4)*M*(R2-RAD)+RK(5)*(R0*R2+R1**2))*GV
        CALL RESULT(C,M,R0,R1,R2,P0,P1,P2,T,20)
        WRITE(20,100) MBAL,QR,QG,DELQ
        WRITE(20,200) RAD
 200    FORMAT(' ',10X,'RADICAL CONCN IS: ',D20.14)
 100    FORMAT (' ',6X,'MBAL=',E12.6,2X,'QR=',E12.6,2X,'QG=',E12.6,
     1  2X,'DELQ=',E12.6)
C*******
              T1=T
              M1=M
              P21=P2
              QR1=QR
              QG1=QG
C*******
        WRITE(23) T1,QR1,QG1,M1,P21
  20    CONTINUE
        CLOSE(UNIT=23,ACCESS='SEQOUT',FILE=JFILE)
        CLOSE(UNIT=21,ACCESS='SEQIN',FILE='SSPIN.DAT')
        CLOSE(UNIT=20,ACCESS='SEQOUT',FILE=IFILE)
```

```
MAIN.    UTKVHA.FOR       FORTRAN V.5A(621) /KI    19-SEP-79        10:08    PAGE 1-3

00169           CLOSE(UNIT=25,ACCESS='SEQOUT',FILE=SFILE)
00170           STOP
00171           END


COMMON BLOCKS

/AREA1/(+46)
R        +0      CAGE     +2      MIO      +4      RKO      +6      RK       +20
EN       +32     CUNV     +44

/AREA2/(+32)
DH       +0      DHO      +12     BI       +24     TREF     +26     TI       +30

/AREASS/(+23)
DMO      +0      II       +2      TC       +3      GV       +5      UAV      +7
RHOCP    +11     V2       +13     CP       +15     CI       +17     ERROR    +21


SUBPROGRAMS CALLED

UTKSS    INPUT   FLOAT.   DEXP.   RESULT  DABS.
DSQRT.

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*P21     1       *AREA    3       *Z       5       *EFF     7        T1      11
*T       12      *CPDELT  14      *RKZ5    16      *K       20      *QG      21
*A3      23      *ISOL    25      %MI              *QR      26       P2      30
 MPRE    31      *FLAG    33      *A2      35      *V       37       SFILE   41
*PI      43       MI      45       JFILE   46       M       50      *J       52
*G       53      *TST     55       .S0006  57      *CRIT    60       .S0005  62
*AI      63       .S0004  65      *R2      66      *DM      70       .S0003  72
*IRXN    73       .S0002  74       .S0001  75      *PO      76       .S0000  100
*DELQP   101     *U       103     *RI      105     *RHO     107     *DELQ    111
 IFILE   113     *TEST    115     *I       117     *F       120     *C       122
*RO      124      UGI     126     %MOLD            *RAD     127      MBAL    131
 QRI     133

TEMPORARIES

 .Q0000 401      .Q0001 402

MAIN.     NO ERRORS DETECTED
```

```
      SUBROUTINE UTKSS(TEM,DELQ1,ISOL)
C     PROGRAM FOR STEADY STATE VALUES VS TEMPERATURE
C.......
      IMPLICIT REAL*8 (A-H,O-Z)
C.......
      REAL*8 M,MI,MIO,MOLD,MBAL,MPRE
      COMMON/AREA1/R,CAGE,MIO,RKO(5),RK(5),EN(5),CONV
      COMMON/AREA2/DH(5),DHO(5),BI,TREF,TI
      COMMON/AREASS/DMO,IT,TC,GV,UAV,RHOCP,V2,CP,CI,ERROR
              ISOL=ISOL+1
      DT=-.5
      DELQP=DELQ1
      T=TEM+DT
      DO 201 J=1,500
      DM=DMO
      DO 30 K=1,5
 30   RK(K)=RKO(K)*EXP(-EN(K)/R/T)
      RKZ5=RK(5)
      C=CI/(1.+RK(1)*GV)
      A1=2.57-.00505*T
      A2=9.56-.0176*T
      A3=-3.03+.00785*T
      M=MIO+DMO
      MPRE=0.
      DO 135 I=1,IT
      M=M-DM
      IF(M)531,531,541
 531  FLAG=1.0
      M=MIO
 541  CONTINUE
      CONV=(MIO-M)/MIO
      CAGE=2.
      EFF=EXP(-CAGE*CONV)
      RK(5)=RKZ5/(EXP((A1+(A2+A3*CONV)*CONV)*CONV))**2
      F=1.+8.*RK(5)*(RK(1)*EFF*C+RK(2)*M**3)*GV*GV
      G=2.*GV*RK(5)
      RO=(-1.+SQRT(F))/G
C.......
      RAD=2*(RK(1)*EFF*C+RK(2)*M**3)+RK(4)*M*RO
      RAD=RAD/(1/GV+M*(RK(3)+RK(4))-RK(5)*RO)
C.......
      MBAL=(MIO-M)/GV-2.*RK(2)*M**3-(RK(3)+RK(4))*M*RO
     1 +RK(4)*M*RAD
      CRIT=MBAL*MPRE
      MPRE=MBAL
      IF(FLAG.EQ.1.0)GO TO 33
      IF(CRIT) 115,125,125
 115  DM=-.1*DM
      GO TO 135
 125  IF(ABS(MBAL).LE.ERROR) GO TO 33
 135  CONTINUE
      WRITE(20,1001)
 1001 FORMAT ( 3X,'MONOMER BALANCE ITERATION WENT 750....')
 33   CONTINUE
      FLAG=0.
      Z=2.*EFF*RK(1)*C+2.*RK(2)*M**3+(RK(3)+RK(4))*M*RO
```

```
              R1=Z/(1./GV+RK(5)*R0+RK(4)*M)
              P0=(RK(4)*M*(R0-RAD)+RK(5)/2.*R0**2)*GV
              P1=(RK(4)*M*(R1-RAD)+RK(5)*R0*R1)*GV
C*******HEATS OF REACTION*******
                        CPDELT=CP*(T-TREF)
                        DO 22 IRXN=2,4
      22      DH(IRXN)=DHO(IRXN)-CPDELT
C*****************************
C*******TEMPERATURE BALANCE CALCULATIONS*******
              QR=(T-TI)/GV-V2*(TC-T)
              QG=(DH(2)*RK(2)*M*M+R0*(DH(3)*RK(3)+DH(4)*RK(4)))*M/RHOCP
C*********************************************
              DELQ=QG-QR
C             TEMPERATURE ITERATION LOGIC
                        TEST=DELQ*DELQP
              DELQP=DELQ
              IF(ABS(DELQ).LE.ERROR)GO TO 301
              IF(ISOL.EQ.1)GOTO 9040
              IF(ISOL.EQ.3)GOTO 9040
              IF(TEST)9031,301,9033
    9031      DT=-.5*DT
    9033      T=T+DT
                        GOTO 201
    9040      T=(QG+TI/GV+TC*V2)/(1./GV+V2)
    201       CONTINUE
    301       CONTINUE
              R2=R1+(2.*RK(3)*M*R1)/(1./GV+RK(4)*M+RK(5)*R0)
              P2=(RK(4)*M*(R2-RAD)+RK(5)*(R0*R2+R1**2))*GV
              WRITE(25,8000)DELQ,MBAL,QG,QR
              WRITE(25,8001)T,M,C
              WRITE(25,8002)P0,P1,P2
              WRITE(25,8003)R0,R1,R2
              WRITE(5,8004)ISOL,T,M,P2
    8000      FORMAT('-',5X,'DELQ= ',D14.8,2X,'MBAL= ',D14.8/8X,
         1    'QG= ',D14.8,2X,'QR= ',D14.8)
    8001      FORMAT(' ',5X,'STEADY STATE PROPERTIES:'/8X,'T= ',D14.8,3X,
         1    'M= ',D14.8,3X,'I= ',D14.8)
    8002      FORMAT(' ',6X,'P0= ',D14.6,2X,'P1= ',D14.8,2X,'P2= ',D14.8)
    8003      FORMAT(' ',6X,'R0= ',D14.8,2X,'R1= ',D14.8,2X,'R2= ',D14.8)
    8004      FORMAT( 3X,'STEADY STATE #',I2,/6X,'T= ',D/6X,'M= ',D/5X,'P2= ',D)
    C***      WRITE(22,*)C,M,R0,R1,R2,P0,P1,P2,T,RAD
              RETURN
              END
```

COMMON BLOCKS

```
/AREA1/(+46)
R       +0      CAGE    +2      MIO     +4      RKO     +6      RK      +20
EN      +32     CONV    +44

/AREA2/(+32)
DH      +0      DHO     +12     BI      +24     TREF    +26     TI      +30

/AREASS/(+23)
DHO     +0      II      +2      TC      +3      GV      +5      UAV     +7
```

```
UTKSS   UTKVHA.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       10:08   PAGE 1-2

RHOCP   +11     V2      +13     CP      +15     CI      +17     ERROR   +21

SUBPROGRAMS CALLED

DEXP.   DABS.   DSQRT.

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*Z      1       *EFF    3       *TEM    5       *T      7       *CPDELT 11
*RKZ5   13      *K      15      *QG     16      *A3     20      %HI
*ISOL   22      *JR     23      *P2     25       HPRE   27      *FLAG   31
*DT     33      *A2     35      *P1     37       H      41      *J      43
*G      44      *CRIT   46      *A1     50      *R2     52       .S0003 54
*DM     55      *DELQ1  57      *IRXN   61       .S0002 62       .S0001 63
*P0     64       .S0000 66      *DELQP  67      *R1     71      *DELQ   73
*TEST   75      *I      77      *F      100     *C      102     *R0     104
%HOLD           *RAD    106      MBAL   110

TEMPORARIES

 .A0016 224      .Q0000 225      .Q0001 226

UTKSS     NO ERRORS DETECTED
```

```
INPUT    UTKVHA.FOR       FORTRAN V.5A(621) /KI    19-SEP-79        10:08    PAGE 1

                SUBROUTINE INPUT(TC,TI,MIO,CI,GV,RHOIN,CPIN)
      C
                IMPLICIT REAL*8 (A-H,O-Z)
                REAL*8 MIO
      C
                WRITE(5,3000)TC,TI,MIO,CI,GV
       3000     FORMAT( 3X,'CURRENT INLET CONDITIONS:'/10X,'1-TC= ',F/
           1    10X,'2-TI= ',F/10X,'3-MO= ',F/10X,'4-IO= ',F/10X,
           2    '5-THETA= ',F/4X,'WHICH VARIABLE TO BE CHANGED?-- ',$)
                READ(5,*)IND
                IF(IND.EQ.1)GOTO 3001
                IF(IND.EQ.2)GOTO 3004
                IF(IND.EQ.3)GOTO 3006
                IF(IND.EQ.4)GOTO 3008
                IF(IND.EQ.5)GOTO 3010
                GOTO 3003
       3001     WRITE(5,3002)TC
       3002     FORMAT( 3X,'CURRENT TC= ',F,2X,'NEW TC= ',$)
                READ(5,*)TC
                GOTO 3003
       3004     WRITE(5,3005)TI
       3005     FORMAT( 3X,'CURRENT TI= ',F,2X,'NEW TI= ',$)
                READ(5,*)TI
                GOTO 3003
       3006     WRITE(5,3007)MIO
       3007     FORMAT( 3X,'CURRENT MO= ',F,2X,'NEW MO= ',$)
                READ(5,*)MIO
                GOTO 3003
       3008     WRITE(5,3009)CI
       3009     FORMAT( 3X,'CURRENT IO= ',F,2X,'NEW IO= ',$)
                READ(5,*)CI
                GOTO 3003
       3010     WRITE(5,3011)GV
       3011     FORMAT( 3X,'CURRENT THETA= ',F,2X,'NEW THETA= ',$)
                READ(5,*)GV
       3003     CONTINUE
                RETURN
                END

SUBPROGRAMS CALLED


SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

 MIO     1        *CI     3       *IND     5      %RHOIN        %CPIN
*TI      6        *TC     10      *GV      12

TEMPORARIES

 .A0016 123

INPUT      NO ERRORS DETECTED
```

```
RESULT  UTKVHA.FOR      FORTRAN V.5A(621) /KI    19-SEP-79        10:08    PAGE 1

                SUBROUTINE RESULT(IN,M,R0,R1,R2,P0,P1,P2,T,KP)
        C.
        C.      THIS ROUTINE ALLOWS DATA TO BE WRITTEN THAT IS COMMON TO
        C.      MANY OF THE PROGRAMS USED IN THIS POLYSTYRENE SIMULATION
        C.      STUDY..
        C.
        C.      PGM BY JS3..........1/01-25-79
        C.
        C.......
                IMPLICIT REAL*8 (A-H,O-Z)
        C.......
                COMMON/AREA1/R,CAGE,MIO,RKO(5),RK(5),EN(5),CONV
                REAL*8 IN,M,MIO
        C.
                DPN=P1/P0
                DPW=P2/P1
                ZP=DPW/DPN
                VIS=DEXP(-1.06-8.348*DLOG(1.-CONV)+.565*DLOG(DPW))
        C.
                WRITE(KP,100)T,IN,M,DPN,DPW,VIS,ZP
         100    FORMAT ('0',4X,'T=',D12.6,2X,'IN=',D12.6,3X,'M=',D12.6,
              1 2X,'DPN=',D12.6,2X,'DPW=',D12.6,2X,'VIS=',D12.6,2X,'ZP=',
              2 F6.3)
                WRITE(KP,110)CONV,R0,R1,R2,P0,P1,P2
         110    FORMAT (' ',1X,'CONV=',D12.6,2X,'R0=',D12.6,2X,'R1=',D12.6,2X,
              1 'R2=',D12.6,3X,'P0=',D12.6,3X,'P1=',D12.6,2X,'P2=',D12.6)
        C.
                RETURN
                END

COMMON BLOCKS

/AREA1/(+46)
R        +0      CAGE    +2      MIO     +4      RKO     +6      RK      +20
EN       +32     CONV    +44

SUBPROGRAMS CALLED

DLOG.   DEXP.

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*T       1       *P2     3       *VIS    5       *DPW    7       *P1     11
 M       13      *ZP     15      *R2     17      *P0     21      *KP     23
 IN      24      *R1     26      *DPN    30      *R0     32

TEMPORARIES

 .A0016 111     .Q0000 112     .Q0001 113     .Q0002 114     .Q0003 115

RESULT    NO ERRORS DETECTED
```

```
MAIN.     OLDSVD.FOR      FORTRAN V.5A(621) /KI`  19-SEP-79       10:07    PAGE 1

      C.        PROGRAM IS FOR THE SOLUTION OF THE EIGENVALUES AND EIGENVECTORS
      C.        OF POLYSTYRENE SYSTEM BY USING:
      C.                DATINT--->DATA INTERFACE ROUTINE
      C.                RRC------->REACTION RATE CONSTANT ROUTINE
      C.                HCDEN---->CP,RHO,&DELTA H ROUTINE
      C.                DJAKE---->JACOBIAN MATRIX ROUTINE
      C.                HSBG----->SSP TRIANGULATE ROUTINE
      C.                ATEIG---->SSP EIGENVALUE ROUTINE
      C.                OUTTA---->DATA OUTPUT ROUTINE
      C.                SVD------>SINGLE VALUE DECOMPOSITION ROUTINE
      C.                UTTA----->DATA OUTPUT ROUTINE
      C.
      C.        PGM BY JS3..........1/01-25-79
      C.                  ..........2/03-10-79
      C.                  ..........3/05.04.79
      C.
                IMPLICIT REAL*8 (A-H,O-Z)
                REAL*8 WK(20),DW(10,10),PW(10,10),Y(1,10)
                REAL*8 DR(10),DI(10),IN,YI(1,10)
      C.......
                REAL*8 SW(10,10),U(10,10),V(10,10),Q(10),WKAREA(10)
      C.......
                DIMENSION IANA(10)
                COMPLEX IFILE,JFILE
                COMMON/AREA2/DH(5),DHO(5),BI,TREF,TI
                COMMON/AREAI/IY,IM
                COMMON/AREAD/KDAT
                COMMON/OUTP/IFILE,JFILE
      C.......
                WRITE(5,1000)
       1000     FORMAT( 3X,'EIGENVALUE ANALYSIS RUN NAME: ',$)
                READ(5,1500)IFILE
       1500     FORMAT( 2A5)
                WRITE(5,2000)
       2000     FORMAT( 3X,'INPUT DATA FROM FILE NAME: ',$)
                READ(5,1500)JFILE
      C.......
                OPEN(UNIT=20,FILE=IFILE,ACCESS='SEQOUT')
      C.......
      C.
                KDAT=1
                IY=1
      C.
      C
                CALL DATINT(1,YI)
      C
                        KDAT=2
      C
                        Y(1,1)=YI(1,9)
                        Y(1,2)=YI(1,2)
                        Y(1,3)=YI(1,6)
                        Y(1,4)=YI(1,7)
                        Y(1,5)=YI(1,8)
                        Y(1,6)=YI(1,1)
                        Y(1,7)=YI(1,3)
                        Y(1,8)=YI(1,4)
```

```
                     Y(1,9)=YI(1,5)
                     Y(1,10)=YI(1,10)
C.
             N=IM
             IZ=IM
C.
             CALL RRC(YI(1,2),YI(1,9),EFF)
C*******HEAT OF REACTION CALCULATIONS*******
                     CP=33.5
                     RHO=11.5
                     CPDELT=CP*(YI(1,9)-TREF)
                     DO 22 IRXN=2,4
   22        DH(IRXN)=DHO(IRXN)-CPDELT
C*******************************************
C
             VALUE1=RHO*CP
C
             CALL DJAKE(Y,PW,VALUE1,EFF)
C.
             CALL MODRED(PW,IM)
 5002        CONTINUE
             DO 10 I=1,IN
             DO 20 J=1,IM
C*******
             SW(I,J)=PW(I,J)
C*******
   20        DW(I,J)=PW(I,J)
   10        CONTINUE
C.
             CALL HSBG(IZ,DW,10)
             CALL ATEIG(IZ,DW,DR,DI,IANA,10)
                     DO 5050 IOT=1,IM
 5050        WRITE(21,*)DR(IOT),DI(IOT)
C*******
C>>>>>        CALL LSVALR(SW,10,10,10,10,1,WKAREA,Q,U,V)
             CALL SVD(10,IM,IM,SW,Q,.TRUE.,U,.TRUE.,V,IERR,WKAREA)
C*******
C.
C.           TYPE OUT DATA + 'GO TO LPT ?'
C.
             WRITE(5,100)
  100        FORMAT( 3X,'EIGENVALUES & SINGULAR VALUES:')
             DO 30 I=1,IM
             WRITE(5,110) I,DR(I),DI(I),I,Q(I)
  110        FORMAT( 9X,'D(',I2,')=',D12.6,2X,D12.6,3X,'Q(',I2,')=',D12.6)
   30        CONTINUE
C
                     WRITE(5,9999)IERR,IERR
 9999        FORMAT( 3X,'ERROR MESSAGE #',I2,'-HALT ON SV#',I2)
C.
             WRITE(5,120)
  120        FORMAT( 3X,'DO YOU WANT TO GO TO THE PRINTER ? - NO(0)!YES(1)')
             READ(5,*)IND
             IF(IND.EQ.0)GOTO 40
C.
             CALL OUTTA(PW,DR,DI,YI,U,V,Q)
```

```
MAIN.   OLDSVD.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       10:07   PAGE 1-2

        C.
          40    CONTINUE
        C.
          50    CONTINUE
        C.......
                CLOSE(UNIT=20,FILE=IFILE,ACCESS='SEQOUT')
        C.......
                STOP
                END

COMMON BLOCKS

/AREA2/(+32)
DH      +0      DHO     +12     BI      +24     TREF    +26     TI      +30

/AREAI/(+2)
IY      +0      IM      +1

/AREAD/(+1)
KDAT    +0
/OUTP/(+4)
IFILE   +0      JFILE   +2

SUBPROGRAMS CALLED

MODRED  ATEIG   RMC     HSBG    OUTTA   DJAKE
SVD     DATINT

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*IOT    1       *EFF    2       *CPDELT 4       Q       6       YI      32
*N      56      UI      57      Y       103     *CP     127     V       131
 WKAREA 441     %WK             *J      465     .S0004  466     *IZ     467
 .S0003 470     .S0002  471     *IRXN   472     .S0001  473     *IERR   474
 .S0000 475     SW      476     %IN             DR      1006    PW      1032
*IND    1342    U       1343    *RHO    1653    IANA    1655    DW      1667
*I      2177    *VALUEI 2200

TEMPORARIES


MAIN.   NO ERRORS DETECTED
```

```
OUTTA    OLDSVD.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       10:07    PAGE 1

              SUBROUTINE OUTTA(PW,ZR,ZI,Y,U,V,Q)
      C.
      C.      ROUTINE WRITES OUT RESULTS OF EIGENVALUE PROGRAM
      C.
      C.      PGM BY JS3...........1/01-25-79
      C.                 ...........2/03-10-79
      C.                 ...........3/06.06.79
      C.
              IMPLICIT REAL*8 (A-H,O-Z)
              COMPLEX IFILE,JFILE
              REAL*8 PW(10,10),Y(1,10),ZR(10),ZI(10)
              REAL*8 U(10,10),V(10,10),Q(10)
              REAL DAY(2),HR,SEC
              COMMON/AREAI/IY,IM
              COMMON/OUTP/IFILE,JFILE
      C.
              WRITE(20,100)
        100   FORMAT('1',4X,'RESULTS OF SVD AND EIGENVALUE ANALYSES'/5X,
          1   '---SVD OF JACOBIAN MATRIX---')
                      CALL DATE(DAY)
                      CALL TIME(HR,SEC)
      C
      C*******************************************************************
              WRITE(20,1500)IFILE
              WRITE(20,1600)JFILE,Y(1,9),Y(1,3),Y(1,6)
       1500   FORMAT('0',4X,'EIGENVALUE ANALYSIS RUN NAME: ',2A5,10X,
          1   'INPUT STEADY STATE VALUES---->')
       1600   FORMAT(' ',4X,'INPUT DATA FOR ANALYSIS FROM: ',2A5,10X,
          1   'I=',D12.6,4X,'RO=',D12.6,4X,'PO=',D12.6)
      C*******************************************************************
              WRITE(20,130)Y(1,1),Y(1,4),Y(1,7),DAY,Y(1,2),Y(1,5)
          1   ,Y(1,8),HR,SEC,Y(1,10)
        130   FORMAT(' ',54X,'I=',D12.6,4X,'R1=',D12.6,4X,'P1=',D12.6/
          1   5X,'DATE: ',2A5,34X,'M=',D12.6,4X,'R2=',D12.6,4X,'P2=',D12.6/
          2   5X,'TIME: ',2A5,32X,'RAD=',D12.6)
      C.
              WRITE(20,120)
        120   FORMAT ('0',4X,'JACOBIAN MATRIX VALUES---->'/)
              DO 10 I=1,IM
              WRITE(20,140) (PW(I,J),J=1,IM)
        140   FORMAT (' ',6X,10(D10.4,2X))
         10   CONTINUE
      C.
              WRITE(20,150)
        150   FORMAT('0',4X,'EIGENVALUES & SINGLE VALUES---->'/24X,'REAL',
          1   10X,'IMAG')
              DO 20 I=1,IM
              WRITE(20,160)I,ZR(I),ZI(I),I,Q(I)
        160   FORMAT (' ',8X,'LAMBDA(',I2,')=',2X,D12.6,2X,D12.6,10X,'Q(',
          1   I2,')=',2X,D12.6)
         20   CONTINUE
      C.
              WRITE(20,1209)
       1209   FORMAT('0',4X,'MATRIX U - ORTHONORMALIZED COLUMNS'/)
              DO 109 I=1,IM
              WRITE(20,140) (U(I,J),J=1,IM)
```

```
OUTTA   OLDSVD.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       10:07   PAGE 1-1

         109    CONTINUE
        C
                WRITE(20,1509)
         1509   FORMAT('0',4X,'MATRIX V - ORTHOGONAL MATRIX'/)
                        DO 209 I=1,IM
         209    WRITE(20,140)(V(I,J),J=1,IM)
        C.
                RETURN
                END

COMMON BLOCKS

/AREA1/(+2)
IY      +0      IM      +1

/OUTP/(+4)
IFILE   +0      JFILE   +2

SUBPROGRAMS CALLED

DATE    TIME

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

 Q      1       ZR      2       HR      3       Y       4       V       5
*J      6       .S0006  7       .S0005  10      .S0004  11      .S0003  12
 DAY    13      .S0002  15      .S0001  16      .S0000  17      SEC     20
 PW     21      U       22      ZI      23      *I      24

TEMPORARIES

 .A0016 240

OUTTA    NO ERRORS DETECTED
```

```
              SUBROUTINE MODRED(A,IM)
      C
      C       REDUCTION OF JACOBIAN MATRIX BASED ON JACOBIAN MATRIX
      C
              REAL*8 A(10,10),ROWCON
              IMI=IM
              WRITE(5,5000)
       5000   FORMAT( 3X,'MODEL REDUCTION INFORMATION'/5X,
          1   'WHAT ORDER MODEL DO YOU WANT TO EXAMINE? - ',$)
              READ(5,*)NELIM
              IF(NELIM.EQ.IM)GOTO 5001
                      NELIM=IMI-NELIM
                      DO 30 ICT=1,NELIM
              IELIM=IMI+1-ICT
                      DO 10 I=1,IM
              ROWCON=A(I,IELIM)/A(IELIM,IELIM)
                      DO 10 J=1,IM
         10   A(I,J)=A(I,J)-ROWCON*A(IELIM,J)
              IM=IM-1
         30           CONTINUE
              GOTO 5002
       5001   WRITE(5,5003)
       5003   FORMAT( 5X,'YOU WANTED THE WHOLE MODEL !')
       5002   RETURN
              END
```

SUBPROGRAMS CALLED

SCALARS AND ARRAYS "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

```
*NELIM  1        ROWCON 2       *ICT     4      *IMI     5      *J      6
 A      7        .S0002 10      .S0001  11      .S0000  12      *IELIM  13
*I      14      *IM     15
```

TEMPORARIES

```
 .A0016 46
```

MODRED   NO ERRORS DETECTED

```
MAIN.     GRAM.FOR        FORTRAN V.5A(621) /KI    19-SEP-79        10:07    PAGE 1

C                     GRAM.FOR
C
C             PROGRAM IS FOR THE SINGULAR VALUE DECOMPOSITION OF A
C             GRAMMIAN MATRIX OF THE DYNAMIC MODEL - GRAMMIAN IS
C             GENERATED BY CROSS-MULTIPLICATION OF THE RESPONSE
C             MATRIX WITH ITS TRANSPOSE....
C
C             SUBROUTINES USED:
C                     GRAMMY----GENERATES GRAMMIAN FROM RFILE
C                     SVD-------SINGULAR VALUE DECOMPOSITION
C                     OUTTA-----DATA OUTPUT ROUTINE
C
C             PGMD JOHN STELLING III..........16.JUN.79
C
              IMPLICIT REAL*8 (A-H,O-Z)
              REAL*8 PW(10,10)
C.......
              REAL*8 SW(10,10),U(10,10),V(10,10),Q(10),WKAREA(10)
C.......
              COMMON/AREA1/IY,IM
C*******READ IN INFORMATION*******
              WRITE(5,1000)
 1000         FORMAT( 3X,'DIMENSION OF SYSTEM: ',$)
              READ(5,*)IM
              N=IM
C*********************************
              CALL GRAMMY(PW,IM)
C.
              DO 10 I=1,IM
              DO 20 J=1,IM
C.......
   20         SW(I,J)=PW(I,J)
C.......
   10         CONTINUE
C.
C.......
C>>>>>        CALL LSVALR(SW,10,10,10,10,1,WKAREA,Q,U,V)
              CALL SVD(IM,IM,IM,SW,Q,.TRUE.,U,.TRUE.,V,IERR,WKAREA)
C.......
C.
C.            TYPE OUT DATA + 'GO TO LPT ?'
C.
              WRITE(5,100)
  100         FORMAT( 3X,'SINGULAR VALUES OF DYNAMIC MODEL:')
              DO 30 I=1,IM
              WRITE(5,110) I,Q(I)
  110         FORMAT( 9X,'SV(',I2,')= ',D)
   30         CONTINUE
C
                      WRITE(5,9999)IERR,IERR
 9999         FORMAT( 3X,'ERROR MESSAGE #',I2,'-HALT ON SV#',I2)
C.
              WRITE(5,120)
  120         FORMAT( 3X,'DO YOU WANT TO GO TO THE PRINTER ? - NO(0)!YES(1)',$)
              READ(5,*)IND
              IF(IND.EQ.0)GOTO 40
```

```
MAIN.   GRAM.FOR        FORTRAN V.5A(621) /KI   19-SEP-79       10:07   PAGE 1-1

C.
                CALL OUTTA(PW,U,V,Q)
C.
     40         CONTINUE
C.
                STOP
                END

COMMON BLOCKS

/AREAI/(+2)
IY      +0      IM      +1

SUBPROGRAMS CALLED

GRAMMY  OUTTA   SVD

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

 Q      1       *N      25      V       26      WKAREA 336      *J      362
 .S0002 363      .S0001 364     *IERR   365     .S0000 366       SW     367
 PW     677     *IND    1207     U      1210    *I      1520

TEMPORARIES


MAIN.   NO ERRORS DETECTED
```

```
OUTTA   GRAM.FOR        FORTRAN V.5A(621) /KI   19-SEP-79       10:07   PAGE 1

              SUBROUTINE OUTTA(PW,U,V,Q)
        C.
        C.    ROUTINE WRITES OUT RESULTS OF EIGENVALUE PROGRAM
        C.
        C.    P.M BY JS3...........1/01-25-79
        C.               ...........2/03-10-79
        C.               ...........3/06.06.79
        C.
              IMPLICIT REAL*8 (A-H,O-Z)
              COMMON/AREA1/IY,IM
              REAL*8 U(IM,IM),V(IM,IM),Q(IM),PW(IM,IM)
        C.
              WRITE(3,120)
         120  FORMAT ('0',4X,'GRAMMIAN MATRIX VALUES---->'/)
              DO 10 I=1,IM
              WRITE(3,140) (PW(I,J),J=1,IM)
         140  FORMAT (' ',6X,10(D10.4,2X))
          10  CONTINUE
        C.
              WRITE(3,150)
         150  FORMAT('-',4X,'SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION'//)
              DO 20 I=1,IM
              WRITE(3,160)I,Q(I)
         160  FORMAT(' ',10X,'SV(',I2,')= ',2X,D)
          20  CONTINUE
        C.
              WRITE(3,1209)
        1209  FORMAT('0',4X,'MATRIX U - ORTHONORMALIZED COLUMNS'/)
              DO 109 I=1,IM
              WRITE(3,140) (U(I,J),J=1,IM)
         109  CONTINUE
        C
              WRITE(3,1509)
        1509  FORMAT('0',4X,'MATRIX V - ORTHOGONAL MATRIX'/)
                     DO 209 I=1,IM
         209  WRITE(3,140)(V(I,J),J=1,IM)
        C.
              RETURN
              END

COMMON BLOCKS

/AREA1/(+2)
IY      +0      IM      +1

SUBPROGRAMS CALLED

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

 .I0010 1        U      2        V     3       *J      4      .S0006 5
 .S0005 6       .S0004 7        .S0003 10      .S0002 11      .S0001 12
```

```
OUTTA   GRAM.FOR        FORTRAN V.5A(621) /KI   19-SEP-79       10:07   PAGE 1-1

 .S0000 13      PW      14      U       15      .I0007 16       .I0006 17
 .I0005 20      .I0004 21       .I0003 22       .I0002 23       .I0001 24
.I      25      .I0000 26

TEMPORARIES

 .A0016 110

OUTTA      NO ERRORS DETECTED
```

```
          SUBROUTINE GRAMMY(GM,IM)
C
C         ROUTINE CALLS IN RESPONSE DATA FILE AND RETURNS TO
C         MAIN PROGRAM THE GRAMMIAN MATRIX FOR THE DYNAMIC MODEL.
C
C         PUMD JOHN STELLING III...........16.JUN.79
C
          IMPLICIT REAL*8 (A-H,O-Z)
          REAL*8 GM(IM,IM),A(10,100),RFILE
          REAL DAY(2),HR,SEC
C
C*******READ IN DATA FILE INFORMATION*******
          WRITE(5,1000)
 1000     FORMAT( 3X,'DATA FILE CONTAINING THE RESPONSE MATRIX: ',$)
          READ(5,1500)RFILE
 1500     FORMAT( A10)
          OPEN(UNIT=1,FILE=RFILE,ACCESS='SEQIN')
C******************************************
C
                  IRV=0
C
C*******READ IN RESPONSE DATA FROM RFILE*******
                  DO 10 I=1,400
          READ(1,END=20)T,(A(J,I),J=1,10)
          IRV=IRV+1
   10             CONTINUE
   20             CONTINUE
C******************************************
C
                  IRV=IRV/10
C
          WRITE(5,2000)IRV
 2000     FORMAT( 3X,'NUMBER OF RESPONSE VALUES: ',I3)
C
          WRITE(3,3000)RFILE,IRV
 3000     FORMAT('1',10X,'SVD ANALYSIS OF THE DYNAMIC MODEL'/16X,
     1    'DATA FILE CONTAINING THE RESPONSE MATRIX: ',A10/16X,
     2    'NUMBER OF RESPONSE VALUES: ',I3)
C
                  CALL DATE(DAY)
                  CALL TIME(HR,SEC)
          WRITE(3,3299)DAY,HR,SEC
 3299     FORMAT('0',15X,'DATE & TIME OF ANALYSIS: ',2A5,5X,2A5)
C
                  IRV=IRV*IM
C
C*******GRAMMIAN BY CROSS-MULTIPLICATION*******
                  DO 30 I=1,IM
                  DO 40 J=1,IM
          SUM=0.
                  DO 50 I1=1,IRV
                  DO 60 J1=1,IRV
          SUM=SUM+A(I,I1)*A(J,J1)
   60             CONTINUE
   50             CONTINUE
          GM(I,J)=SUM
```

```
GRAMMY  GRAM.FOR        FORTRAN V.5A(621) /KI   19-SEP-79       10:07   PAGE 1-1

        40           CONTINUE
        30           CONTINUE
     C*****************************************************
     C
             RETURN
             END

SUBPROGRAMS CALLED

DATE
TIME

SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*IRV      1      *I       2      HR       4      *J1      5      *J       6
 .S0005   7      GM       10     .S0004   11     *SUM     12     .S0003   14
 DAY      15     A        17     .S0002   3737   .S0001   3740   .S0000   3741
 SEC      3742   MFILE    3743   .I0002   3745   *I1      3746   .I0001   3747
*I        3750   .I0000   3751   *IM      3752

TEMPORARIES

 .A0016 4044

GRAMMY    NO ERRORS DETECTED
```

```
MAIN.     RESVON.FOR       FORTRAN V.5A(621) /KI    19-SEP-79        13:14    PAGE 1

          C.        PROGRAM IS FOR THE SOLUTION OF THE EIGENVALUES AND EIGENVECTORS
          C.        OF POLYSTYRENE SYSTEM BY USING:
          C.                DATINT--->DATA INTERFACE ROUTINE
          C.                RRC------->REACTION RATE CONSTANT ROUTINE
          C.                DJAKE---->JACOBIAN MATRIX ROUTINE
          C.                HSBG----->SSP TRIANGULATE ROUTINE
          C.                ATEIG---->SSP EIGENVALUE ROUTINE
          C.                OUTTA---->DATA OUTPUT ROUTINE
          C.                SVD------>SINGLE VALUE DECOMPOSITION ROUTINE
          C.                UTTA----->DATA OUTPUT ROUTINE
          C.
          C.        PGM BY JS3..........1/01-25-79
          C.                  ..........2/03-10-79
          C.                  ..........3/05.04.79
          C.
                    IMPLICIT REAL*8 (A-H,O-Z)
                    REAL*8 WK(20),DW(10,10),PW(10,10),Y(1,10)
                    REAL*8 IN,YI(1,10),WAREA(10),BU(10),B(10,10),BSW(10,10)
          C.......
                    REAL*8 SW(10,10),U(10,10),V(10,10),Q(10),WKAREA(10)
          C.......
                    DIMENSION IANA(10) ,
                    COMPLEX IFILE,JFILE
                    COMMON/AREA2/DH(5),DHO(5),BI,TREF,TI
                    COMMON/AREA1/IY,IM
                    COMMON/AREAD/KDAT
                    COMMON/OUTP/IFILE,JFILE
          C.......
                    WRITE(5,1000)
           1000    .FORMAT( 3X,'INPUT RESPONSE ANALYSIS RUN NAME: ',$)
                    READ(5,1500)IFILE
           1500     FORMAT( 2A5)
                    WRITE(5,2000)
           2000     FORMAT( 3X,'INPUT DATA FROM FILE NAME: ',$)
                    READ(5,1500)JFILE
          C.......
                    OPEN(UNIT=20,FILE=IFILE,ACCESS='SEQOUT')
          C.......
          C.
                    KDAT=1
                    IY=1
          C.
          C
                    CALL DATINT(1,YI)
          C
                            KDAT=2
          C
                            Y(1,1)=YI(1,9)
                            Y(1,2)=YI(1,2)
                            Y(1,3)=YI(1,6)
                            Y(1,4)=YI(1,7)
                            Y(1,5)=YI(1,8)
                            Y(1,6)=YI(1,1)
                            Y(1,7)=YI(1,3)
                            Y(1,8)=YI(1,4)
                            Y(1,9)=YI(1,5)
```

```
                    Y(1,10)=YI(1,10)
C.
            N=IM
            IZ=IM
C.
            CALL RRC(YI(1,2),YI(1,9),EFF)
C*******HEAT OF REACTION CALCULATIONS*******
                    CP=33.5
                    RHO=11.5
                    CPDELT=CP*(YI(1,9)-TREF)
                    DO 22 IRXN=2,4
   22       DH(IRXN)=DHO(IRXN)-CPDELT
C*********************************************
C
            VALUE1=RHO*CP
C
            CALL DJAKE(Y,PW,VALUE1,EFF)
C.
C****       CALL HSBG(IZ,DW,10)
C****       CALL ATEIG(IZ,DW,DR,DI,IANA,10)
C*******.
            CALL RUMAT(Y,WAREA,EFF,B)
            CALL MODRED(PW,IM,10,B,5)
C.
            DO 10 I=1,IM
            DO 20 J=1,IM
C*******.
            SW(I,J)=-PW(I,J)
C*******.
   20       DW(I,J)=PW(I,J)
   10       CONTINUE
                    DO 15 I=1,IM
C****       BU(I)=WAREA(I)
   15               WAREA(I)=1.
            CALL MINV(SW,10,IM,DETERM,WAREA)
C*******CROSS-MULTIPLICATION FOR A'XB MATRIX**********
                    DO 60 I=1,IM
                    DO 62 J=1,5
            SUM=0.
                    DO 64 I1=1,IM
   64       SUM=SUM+SW(I,I1)*B(I1,J)
   62       BSW(I,J)=SUM
   60               CONTINUE
C*************************************************
C>>>>>      CALL LSVALR(SW,10,10,10,1,WKAREA,Q,U,V)
            CALL SVD(10,IM,5,BSW,Q,.TRUE.,U,.TRUE.,V,IERR,WKAREA)
C*******.
C.
C.          TYPE OUT DATA + 'GO TO LPT ?'
C.
            WRITE(5,100)
  100       FORMAT( 3X,'EQUIVALENT INPUT VECTOR & SINGULAR VALUES:')
            DO 30 I=1,IM
            WRITE(5,110) I,BU(I),I,Q(I)
  110       FORMAT( 9X,'BXU(',I2,')=',D20.14,10X,'SV(',I2,')=',D20.14)
   30       CONTINUE
```

```
MAIN.   RESVON.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       13:14   PAGE 1-2

        C
                        WRITE(5,9999)IERR,IERR
         9999   FORMAT( 3X,'ERROR MESSAGE #',I2,'-HALT ON SV#',I2)
        C.
                WRITE(5,120)
          120   FORMAT( 3X,'DO YOU WANT THIS PRINTED?-NO/0:YES/1 ',$)
                READ(5,*)IND
                IF(IND.EQ.0)GOTO 40
        C.
                CALL OUTTA(PW,B,YI,U,V,Q)
        C.
          40    CONTINUE
        C.
          50    CONTINUE
        C.......
                CLOSE(UNIT=20,FILE=IFILE,ACCESS='SEQOUT')
        C.......
                STOP
                END


COMMON BLOCKS

/AREA2/(+32)
DH      +0      DHO     +12     BI      +24     TREF    +26     TI      +30

/AREA1/(+2)
IY      +0      IM      +1

/AREAD/(+1)
KDAT    +0
/OUTP/(+4)
IFILE   +0      JFILE   +2


SUBPROGRAMS CALLED

MODRED  BUMAT   RMC     OUTTA   DJAKE   MINV
SVD     DATINT

SCALARS AND ARRAYS   "*". NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*EFF    1       *LPDELT 3       Q       5       YI      31      *N      55
 B      56       *AREA  366     Y       412     *CP     436      V      440
 *KAREA 750     %*K             *J      774     BSW     775     .S0007 1305
 .S0006 1306     .S0005 1307    *SUM    1310    .S0004 1312     *IZ    1313
 .S0003 1314     .S0002 1315    *IRXN   1316    .S0001 1317     *IERR  1320
 .S0000 1321     SW     1322    %IN             PW      1632    *IND   2142
 U      2143    *HHO    2453    %IANA           DW      2455    *I1    2765
*I      2766     *U     2767    *DETERM 3013    *VALUE1 3015
```

```
MAIN.   RESVDN.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       13:14   PAGE 1-3

TEMPORARIES

MAIN.     NO ERRORS DETECTED
```

```
        SUBROUTINE OUTTA(PW,B,Y,U,V,Q)
C.
C.      ROUTINE WRITES OUT RESULTS OF EIGENVALUE PROGRAM
C.
C.      PGM BY JS3...........1/01-25-79
C.               ...........2/03-10-79
C.               ...........3/06.06.79
C.
        IMPLICIT REAL*8 (A-H,O-Z)
        COMPLEX IFILE,JFILE
        REAL*8 PW(10,10),Y(1,10),B(10,10)
        REAL*8 U(10,10),V(10,10),Q(10)
        REAL DAY(2),HR,SEC
        COMMON/AREA1/IY,IM
        COMMON/OUTP/IFILE,JFILE
        COMMON/NEW1/UFACT(5)
C.
                CALL DATE(DAY)
                CALL TIME(HR,SEC)
C
        WRITE(20,100)
  100   FORMAT('1',4X,'RESULTS OF SVD OF INPUT RESPONSE ANALYSIS')
C*********************************************************************
        WRITE(20,1500)IFILE
        WRITE(20,1600)JFILE,Y(1,9),Y(1,3),Y(1,6)
 1500   FORMAT('0',4X,'INPUT RESPONSE ANALYSIS RUN NAME: ',2A5,10X,
     1  'INPUT STEADY STATE VALUES---->')
 1600   FORMAT(' ',4X,'INPUT DATA FOR ANALYSIS FROM: ',2A5,10X,
     1  'I=',D12.6,4X,'R0=',D12.6,4X,'P0=',D12.6)
C*********************************************************************
        WRITE(20,130)Y(1,1),Y(1,4),Y(1,7),DAY,Y(1,2),Y(1,5)
     1  ,Y(1,8),HR,SEC,Y(1,10)
  130   FORMAT(' ',54X,'I=',D12.6,4X,'R1=',D12.6,4X,'P1=',D12.6/
     1  5X,'DATE: ',2A5,34X,'M=',D12.6,4X,'R2=',D12.6,4X,'P2=',D12.6/
     2  5X,'TIME: ',2A5,32X,'RAD=',D12.6)
C.
        WRITE(20,120)
  120   FORMAT ('0',4X,'JACOBIAN MATRIX VALUES---->'/)
        DO 10 I=1,IM
        WRITE(20,140) (PW(I,J),J=1,IM)
  140   FORMAT (' ',6X,10(D10.4,2X))
   10   CONTINUE
C.
        WRITE(20,150)
  150   FORMAT('0',4X,'INPUT MATRIX B & SINGULAR VALUES---->')
        DO 20 I=1,IM
        WRITE(20,160)(B(I,J),J=1,5),I,Q(I)
  160   FORMAT(' ',6X,5(D10.4,2X),4X,'SV(',I2,')= ',D)
   20   CONTINUE
C.
        WRITE(20,1209)
 1209   FORMAT('0',4X,'MATRIX U - ORTHONORMALIZED COLUMNS'/)
        DO 109 I=1,IM
        WRITE(20,140) (U(I,J),J=1,IM)
  109   CONTINUE
C
```

```
OUTTA   RESVDN.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       13:14   PAGE 1-1

                WRITE(20,1509)
         1509   FORMAT('0',4X,'MATRIX V - ORTHOGONAL MATRIX'/)
                        DO 209 I=1,IM
          209   WRITE(20,140)(V(I,J),J=1,IM)
        C.
                WRITE(20,189)(UFACT(I),I=1,5)
          189   FORMAT('0',4X,'SCALING FACTORS: THETA/',F8.3,2X,'MO/',F7.3,
            1   2X,'IO/',F7.3,2X,'TC/',F7.3,2X,'TO/',F7.3)
                RETURN
                END


COMMON BLOCKS

/AREAI/(+2)
IY      +0      IM      +1

/OUTP/(+4)
IFILE   +0      JFILE   +2

/NEW1/(+12)
UFACT   +0

SUBPROGRAMS CALLED

DATE    TIME

SCALARS AND ARRAYS  "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

 Q       1       M       2       HR      3       Y       4       V       5
*J       6      .S0007   7      .S0006  10      .S0005  11      .S0004  12
 .S0003 13       DAY    14      .S0002  16      .S0001  17      .S0000  20
 SEC    21       MW     22       U      23      .S0010  24      *I      25

TEMPORARIES

 .A0016 246

OUTTA    NO ERRORS DETECTED
```

```
      SUBROUTINE DJAKE(YP,PW,VALUE1,EFF)
C
C     THIS SUBROUTINE IS TO BE USED TO 'CHECK' UVA AND THE
C     WAY THEY CALCULATE THEIR EIGENVALUES FOR THE PSSA MODEL.
C
C     PROGRAM BY JS3.........................1/05.01.79
C                   .........................2/05.04.79
C
      IMPLICIT REAL*8 (A-H,O-Z)
C
      REAL*8 YP(IY,IM),IN,IO,MIO,M,PW(IM,IM)
C
      COMMON/AREA1/R,CAGE,MIO,RKO(5),RK(5),EN(5),CONV
      COMMON/AREA2/DH(5),DHO(5),BI,TREF,TI
      COMMON/AREA3/TC,THETA,U,AREA,V,UAV,RCPIN,CP
      COMMON/AREAI/IY,IM
      COMMON/AREARK/A1,A2,A3
      COMMON/AREAR5/RK5M
C
      T=YP(1,1)
      M=YP(1,2)
      PO=YP(1,3)
      PI=YP(1,4)
      PC=YP(1,5)
      IN=YP(1,6)
      RO=YP(1,7)
      RI=YP(1,8)
      RC=YP(1,9)
      RAD=YP(1,10)
C
      THIN=-1./THETA
      RK5M=2.*RK(5)*(A1+2.*A2*CONV+3.*A3*CONV**2)/MIO
      RT2=R*T**2
      RK5T=RK(5)*EN(5)/RT2+2.*RK(5)*(.00505+(.0176-.00785*CONV)
     1 *CONV)*CONV
C.
      RK1T=RK(1)*EN(1)/RT2
      RK2T=RK(2)*EN(2)/RT2
      RK3T=RK(3)*EN(3)/RT2
      RK4T=RK(4)*EN(4)/RT2
C
      DHT=-CP
C.
      DIF1=T-TC
      DIF2=T-TREF
      VAL=UAV/VALUE1
      FM=-EFF/MIO*CAGE
C************************************************************
            QPOLT=RK(3)*DH(3)+RK(4)*DH(4)
            QINT0=2*(EFF*IN*RK1T+M*M*M*RK2T)
            QINT1=M*RO*(RK3T+RK4T)
            QINT2=M*RK4T+RO*RK5T
            QINM0=2*(RK(1)*IN*FM+3*RK(2)*M*M)
            QINM1=RO*(RK(3)+RK(4))
            QINM2=RK(4)+RO*RK5M
            QRI0=M*(RK(3)+RK(4))
```

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DJAKE   RESVDN.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       13:14   PAGE 1-1

C***********************************************************************
C.
C.       NOW. THE PARTIAL DERIVATIVES, LINE BY LINE.........
C.
C.       INITIALIZE MATRIX TO ZERO
C.
         DO 10 I=1,IM
         DO 20 J=1,IM
   20    PW(I,J)=0.
   10    CONTINUE
C
C*******DTEMDT
C
         PW(1,1)=THIN+(M*R0*(DH(3)*RK3T+DH(4)*RK4T+RK(3)*DHT)+
     1   2*M**3*RK2T*DH(2)-UAV)/VALUE1
         PW(1,2)=(R0*QPOLT+6*M*M*RK(2))/VALUE1
         PW(1,7)=M*QPOLT/VALUE1
C
C*******DHDT
C
         PW(2,1)=M*(RAD*RK4T-2*M*M*RK2T)-QINT1
         PW(2,2)=THIN-6*RK(2)*M*M-QINM1+RK(4)*RAD
         PW(2,7)=-QR10
         PW(2,10)=RK(4)*M
C
C*******DR0DT
C
         PW(3,1)=R0*(M*RK4T+R0/2*RK5T)-M*RAD*RK4T
         PW(3,2)=R0*(RK(4)+R0/2*RK5M)-RK(4)*RAD
         PW(3,3)=THIN
         PW(3,7)=RK(4)*M+RK(5)*R0
         PW(3,10)=-RK(4)*M
C
C*******DR1DT
C
         PW(4,1)=R1*(M*RK4T+R0*RK5T)-M*RAD*RK4T
         PW(4,2)=R1*(RK(4)+R0*RK5M)-RK(4)*RAD
         PW(4,4)=THIN
         PW(4,7)=RK(5)*R1
         PW(4,8)=PW(3,7)
         PW(4,10)=PW(3,10)
C
C*******DR2DT
C
         PW(5,1)=R2*(M*RK4T+R0*RK5T)+R1*R1*RK5T-M*RAD*RK4T
         PW(5,2)=R2*(M*RK4T+R0*RK5M)+R1*R1*RK5M-RK(4)*RAD
         PW(5,5)=THIN
         PW(5,7)=RK(5)*R2
         PW(5,8)=2*PW(4,7)
         PW(5,9)=PW(3,7)
         PW(5,10)=PW(3,10)
C
C*******DINDT
C
         PW(6,1)=-IN*RK1T
         PW(6,6)=THIN-RK(1)
```

```
C
C*******DWODT
C
      PW(7,1)=QINT0-RK5T*R0*R0
      PW(7,2)=QINM0-RK5M*R0*R0
      PW(7,6)=2*RK(1)*EFF
      PW(7,7)=THIN-2*RK(5)*R0
C
C*******DW1DT
C
      PW(8,1)=QINT0+QINT1-R1*QINT2
      PW(8,2)=QINM0+QINM1-R1*QINM2
      PW(8,6)=PW(7,6)
      PW(8,7)=QR10-R1*RK(5)
      PW(8,8)=THIN-PW(3,7)
C
C*******DW2DT
C
      PW(9,1)=QINT0+QINT1-R2*QINT2+2*M*R1*RK3T
      PW(9,2)=QINM0+QINM1-R2*QINM2+2*R1*RK(3)
      PW(9,6)=PW(7,6)
      PW(9,7)=QR10-RK(5)*R2
      PW(9,8)=2*RK(3)*M
      PW(9,9)=PW(8,8)
C
C*******DWADDT
C
      PW(10,1)=QINT0+QINT1-RAD*(QINT2+M*RK3T)
      PW(10,2)=QINM0+QINM1-RAD*(QINM2+RK(3))
      PW(10,6)=PW(7,6)
      PW(10,7)=RK(4)*M-RK(5)*RAD
      PW(10,10)=PW(8,8)-RK(3)*M
C
      RETURN
      END
```

COMMON BLOCKS

```
/AREA1/(+46)
R       +0      CAGE    +2      MIO     +4      RKO     +6      RK      +20
EN      +32     CONV    +44

/AREA2/(+32)
DH      +0      DWO     +12     BI      +24     TREF    +26     TI      +30

/AREA3/(+20)
TC      +0      THETA   +2      U       +4      AREA    +6      V       +10
UAV     +12     RCPIN   +14     CP      +16

/AREAI/(+2)
IY      +0      IM      +1

/AREARK/(+6)
A1      +0      A2      +2      A3      +4
```

```
DJAKE   RESVDN.FOR      FORTRAN V.5A(621) /KI   19-SEP-79       13114   PAGE 1-3

/AREARS/(+2)
RK5M    +0

SUBPROGRAMS CALLEU


SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*EFF     1       *T       3       *RK5T    5       *QPOLT   7       *DIF2    11
*RK2T    13      *W2      15      *DIF1    17      *QINT2   21      *QINM2   23
*THIN    25      *W1      27       M       31      *J       33      %IO
*QINT1   34      *WK3T    36      *QR10    40      *RT2     42      *R2      44
*QINM1   46       .S0001  50       .S0000  51      *P0      52       IN      54
 PW      56      *QINTO   57      *R1      61      *QINMO   63       .I0005  65
 .I0004  66      *VAL     67       .I0003  71      *RK4T    72       .I0002  74
 .I0001  75      *I       76       .I0000  77       YP      100     *FM      101
*R0      103     *WHT     105     *RAD     107     *VALUE1  111     *RK1T    113

TEMPORARIES

 .A0016  115

DJAKE     NO ERHOHS DETECTED
```

```
      SUBROUTINE BUMAT(Y,BU,EFF,B)
C
C             SUBROUTINE BUMAT(Y,BU,EFF,B)
C
C     SUBROUTINE SUPPLIES THE CROSS-PRODUCT VECTOR OF THE B MATRIX
C     AND THE PROCESS INPUT VECTOR U (DEVIATION VARIABLES).....
C
C     PGMD BY JOHN STELLING III...........1/06.29.79
C
C
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 MIO,IO,Y(1,10),BU(10),B(10,10),U(5)
      REAL*8 MIOI,IOI
C
      COMMON/AREA1/R,CAGE,MIO,RKO(5),RK(5),EN(5),CONV
      COMMON/AREA2/DH(5),DHO(5),BI,TREF,TI
      COMMON/AREA3/TC,THETA,UCAP,AREA,V,UAV,RCPIN,CP
      COMMON/AREA5/IO
      COMMON/AREAH5/RK5M
      COMMON/NEW1/UFACT(5)
C
      DATA UFACT/2000.,1.,.04,20.,25./
C
              WRITE(5,8888)(I,UFACT(I),I=1,5)
 8888 FORMAT( 3X,'SCALING FACTORS FOR INPUTS: '/5(2X,'UFACT(',
     1 I1,')= ',F/))
              DO 8886 I=1,5
      WRITE(5,8885)
 8885 FORMAT( 3X,'CHANGE WHICH VARIABLE?(0 FOR NO CHANGE)- ',$)
      READ(5,*)IINPUT
              IF(IINPUT.EQ.0)GOTO 8887
      WRITE(5,8889)IINPUT
 8889 FORMAT( 3X,'UFACT(',I1,')= ',$)
      READ(5,*)UFACT(IINPUT)
 8886         CONTINUE
 8887         CONTINUE
C
C*******B-MATRIX FORMULATION*************************
              THIN=1/THETA
              THIN2=THIN*THIN
C
              DO 10 I=1,10
              DO 20 J=1,5
   20 B(I,J)=0.
   10         CONTINUE
C
              DO 30 I=1,10
   30 B(I,1)=Y(1,I)*THIN2
C
      B(1,1)=B(1,1)-TI*THIN2
      B(2,1)=B(2,1)-MIO*THIN2
      B(6,1)=B(6,1)-IO*THIN2
C
      B(1,4)=UAV/RCPIN
      B(1,5)=THIN
      B(2,2)=THIN
```

```
            B(6,3)=THIN
      C
                        FVAL=-2.*RK(1)*Y(1,6)*Y(1,2)*EFF*CAGE/MIO/MIO
                        RK5MIO=-RK5M*Y(1,2)/MIO
      C
            B(3,2)=RK5MIO*Y(1,7)*Y(1,7)/2.
            B(4,2)=RK5MIO*Y(1,7)*Y(1,8)
            B(5,2)=RK5MIO*(Y(1,7)*Y(1,9)+Y(1,8)*Y(1,8))
            B(7,2)=FVAL-2.*B(3,2)
            B(8,2)=FVAL-B(4,2)
            B(9,2)=FVAL-RK5MIO*Y(1,7)*Y(1,9)
            B(10,2)=FVAL-RK5MIO*Y(1,7)*Y(1,10)
      C*******************************************************************
      C*******SCALING OF THE B-MATRIX**************************************
                        DO 70 J=1,5
                        DO 80 I=1,10
         80 B(I,J)=B(I,J)*UFACT(J)
         70             CONTINUE
      C*******************************************************************
      C*******WRITE OUT THE B-MATRIX***************************************

                        NPASS=NPASS+1
      C**   WRITE(3,1000)NPASS
       1000 FORMAT('0',4X,'B-MATRIX FOR STEADY STATE NO. ',I2)
                        DO 35 I=1,10
         35 WRITE(21)(B(I,J),J=1,5)
      C**   35          WRITE(3,1001)(B(I,J),J=1,5)
       1001 FORMAT(' ',5(3X,D10.4))
      C*******************************************************************
      C*******U-VECTOR FORMULATION*****************************************
            DO 40 I=1,5
         40 U(I)=0.
                        GOTO 8989
            WRITE(5,3000)THETA,MIO,IO,TC,TI
       3000 FORMAT( 3X,'CURRENT INLET CONDITIONS:'/10X,'1-THETA= ',F/
          1 10X,'2-MO= ',F/10X,'3-IO= ',F/10X,'4-TC= ',F/10X,
          2 '5-TO= ',F/4X,'WHICH VARIABLE TO BE CHANGED?-- ',$)
            READ(5,*)IND
            IF(IND.EQ.1)GOTO 3010
            IF(IND.EQ.2)GOTO 3006
            IF(IND.EQ.3)GOTO 3008
            IF(IND.EQ.4)GOTO 3001
            IF(IND.EQ.5)GOTO 3004
            GOTO 3003
       3001 WRITE(5,3002)TC
       3002 FORMAT( 3X,'CURRENT TC= ',F,2X,'NEW TC= ',$)
            READ(5,*)TC1
            U(IND)=TC-TC1
            GOTO 3003
       3004 WRITE(5,3005)TI
       3005 FORMAT( 3X,'CURRENT TI= ',F,2X,'NEW TI= ',$)
            READ(5,*)TI1
            U(IND)=TI-TI1
            GOTO 3003
       3006 WRITE(5,3007)MIO
       3007 FORMAT( 3X,'CURRENT MO= ',F,2X,'NEW MO= ',$)
```

```
                READ(5,*)MIO1
                U(IND)=MIO-MIO1
                GOTO 3003
        3008    WRITE(5,3009)IO
        3009    FORMAT( 3X,'CURRENT IO= ',F,2X,'NEW IO= ',$)
                READ(5,*)IO1
                U(IND)=IO-IO1
                GOTO 3003
        3010    WRITE(5,3011)THETA
        3011    FORMAT( 3X,'CURRENT THETA= ',F,2X,'NEW THETA= ',$)
                READ(5,*)THETA1
                U(IND)=THETA-THETA1
        3003    CONTINUE
      C
                WRITE(5,1002)IND,U(IND)
        1002    FORMAT( 3X,'U(',I2,')=',F,2X,'READY,SET,GO....')
      C*****************************************************************
      C*******CROSS-MULTIPLICATION FOR VECTOR****************
                        DO 50 I=1,10
                SUM=0.
                        DO 60 J=1,5
          60    SUM=B(I,J)*U(J)+SUM
          50    BU(I)=SUM
      C
        8989            CONTINUE
                RETURN
                END
```

COMMON BLOCKS

```
/AREA1/(+46)
R        +0      CAGE     +2      MIO      +4      RKO      +6      RK       +20
EN       +32     CONV     +44

/AREA2/(+32)
DH       +0      DHO      +12     BI       +24     TREF     +26     TI       +30

/AREA3/(+20)
TC       +0      THETA    +2      UCAP     +4      AREA     +6      V        +10
UAV      +12     RLPIN    +14     CP       +16

/AREA5/(+2)
IO       +0
/AREAR5/(+2)
RKSM     +0
/NEW1/(+12)
UFACT    +0
```

SUBPROGRAMS CALLED

```
SCALARS AND ARRAYS   "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

*THIN2  1       *EFF     3      B        5      IO1     6       *THETA1 10
 Y      12      *WPASS  13      *THIN   14      *J      16       .S0007 17
 .S0006 20      *II1    21       .S0005 23      *SUM    24       .S0004 26
 .S0003 27       .S0002 30       .S0001 31      *TC1    32       .S0000 34
*IINPUT 35      *IND    36      MIO1    37       U      41       .S0013 53
 .S0012 54       .S0011 55       .S0010 56      *FVAL   57      *I      61
 HU     62      *HKSMIO 63

TEMPORARIES

 .A0016 256

BUMAT     NO ERRORS DETECTED
```

```
                  SUBROUTINE MODRED(A,IM,IC,B,ID)
      C
      C           REDUCTION OF JACOBIAN MATRIX BASED ON JACOBIAN MATRIX
      C
                  REAL*8 A(10,10),ROWCON,B(10,10)
                  IMI=IM
                  WRITE(5,5000)
       5000       FORMAT( 3X,'MODEL REDUCTION INFORMATION'/5X,
            1     'WHAT ORDER MODEL DO YOU WANT TO EXAMINE? - ',$)
                  READ(5,*)NELIM
                  IF(NELIM.EQ.IM)GOTO 5001
                          NELIM=IMI-NELIM
                          DO 30 ICT=1,NELIM
                  IELIM=IMI+1-ICT
                          DO 50 I=1,IM
                  ROWCON=A(I,IELIM)/A(IELIM,IELIM)
                          DO 10 J=1,IC
         10       A(I,J)=A(I,J)-ROWCON*A(IELIM,J)
                          DO 40 J=1,ID
         40       B(I,J)=B(I,J)-B(IELIM,J)*ROWCON
         50               CONTINUE
                  IM=IM-1
         30               CONTINUE
                  GOTO 5002
       5001       WRITE(5,5003)
       5003       FORMAT( 5X,'YOU WANTED THE WHOLE MODEL !')
       5002       RETURN
                  END
```

SUBPROGRAMS CALLED

SCALARS AND ARRAYS "*" NO EXPLICIT DEFINITION - "%" NOT REFERENCED

```
*NELIM   1     ROWCON  2     *ICT     4      B       5     *IMI     6
*ID      7     *J     10     .S0003  11      A      12     .S0002  13
.S0001  14     .S0000 15     *IC     16     *IELIM  17     *I      20
*IM     21
```

TEMPORARIES

```
.A0016 52
```

MODRED NO ERRORS DETECTED

APPENDIX B

ANALYSES:

EIGENVALUES AND SVD OF THE JACOBIAN MATRIX

The twelve sets of results given in this appendix represent the examination of the three steady states for tenth, ninth, sixth, and fifth order models. The model and steady state focused in each test is indicated in the EIGENVALUE ANALYSIS RUN NAME:

1. the first four characters represent the model tested, and

2. the fifth character (L,M,H) represents the low, middle or high steady state.

TABLE B-1 gives the cross reference between state variables discussed in the text of the thesis and the INPUT STEADY STATE VALUES variables indicated on each analysis sheet.

TABLE B-1. CROSS REFERENCE OF VARIABLES

INPUT VARIABLE	VARIABLE NUMBER	STATE VARIABLE
T	1	T
M	2	M
P0	3	μ_0
P1	4	μ_1
P2	5	μ_2
I	6	I
R0	7	σ_0
R1	8	σ_1
R2	9	σ_2
RAD	10	R_1

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: TENNL2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 15-SEP-79
TIME: 10:21 15.3

INPUT STEADY STATE VALUES

T= .315942D+03	R0= .137505D-07	P0= .963715D-04
I= .105175D-01	R1= .693849D-05	P1= .887989D-01
M= .472135D+01	R2= .699538D-02	P2= .130049D+03
RAD= .273483D-10		

JACOBIAN MATRIX VALUES

-.1367D-03	.7777D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2670D+05	.0000D+00	.0000D+00	.0000D+00
-.3134D-06	-.1011D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.6396D+03	.0000D+00	.0000D+00	.1214D+00
.1748D-09	.4034D-08	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.1270D+01	.0000D+00	.0000D+00	-.1214D+00
.1228D-06	.3893D-05	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.5794D+03	.1270D+01	.0000D+00	-.1214D+00
.1586D-03	.5674D-02	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5841D+06	.1159D+04	.1270D+01	-.1214D+00
-.1272D-08	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.9998D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2315D-06	-.1392D-07	.0000D+00	.0000D+00	.0000D+00	.1501D-05	-.2297D+01	.0000D+00	.0000D+00	.0000D+00
.1931D-06	-.2037D-05	.0000D+00	.0000D+00	.0000D+00	.1501D-05	.6018D+02	-.1270D+01	.0000D+00	.0000D+00
.1927D-03	-.2044D-02	.0000D+00	.0000D+00	.0000D+00	.1501D-05	-.5835D+06	.1279D+04	-.1270D+01	.0000D+00
.3153D-06	.1852D-05	.0000D+00	.0000D+00	.0000D+00	.1501D-05	.1191D+00	.0000D+00	.0000D+00	-.6407D+03

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.826077D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.172374D+04
LAMBDA(3)=	-.126974D+01	.000000D+00	SV(3)=	.640712D+03
LAMBDA(4)=	-.126974D+01	.000000D+00	SV(4)=	.580690D-01
LAMBDA(5)=	-.992063D-04	.000000D+00	SV(5)=	.698781D-06
LAMBDA(6)=	-.640712D+03	.000000D+00	SV(6)=	.679449D-09
LAMBDA(7)=	-.229656D+01	.000000D+00	SV(7)=	.994186D-04
LAMBDA(8)=	-.934526D-04	.000000D+00	SV(8)=	.990496D-04
LAMBDA(9)=	-.113321D-03	.000000D+00	SV(9)=	.100007D-03
LAMBDA(10)=	-.100183D-03	.000000D+00	SV(10)=	.992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

-.3232D-01	-.1574D-02	-.4591D-05	.9990D+00	.2335D-02	-.5350D-04	-.3227D-01	-.8666D-03	-.8059D-04	.3713D-04
.7742D-03	.3771D-04	-.1894D-03	-.2392D-01	.2994D-02	.1146D-03	-.7225D+00	-.6910D+00	-.3511D-02	-.2108D-03
-.1537D-05	-.7892D-07	.1895D-03	.4750D-04	.4679D-06	-.1032D-06	.3216D-03	-.3384D-04	.1773D-03	-.1000D+01
-.7014D-03	-.7707D-03	.1893D-03	.2166D-01	.2043D-03	-.1009D-05	.6906D+00	-.7229D+00	.1350D-02	.2479D-03
-.7071D+00	-.7067D+00	-.1550D-04	-.2400D-01	-.5209D-03	-.6830D-05	-.3608D-03	.3753D-03	-.8531D-05	-.1310D-06
-.1555D-21	.3580D-16	-.3655D-15	-.1013D-08	-.1482D-01	-.1520D-01	-.3503D-02	-.1484D-02	.9998D+00	.1762D-03
.2780D-05	.1354D-06	.3948D-09	-.8592D-04	.1334D-01	-.9998D+00	-.1652D-05	-.2701D-04	-.1501D-01	-.2556D-05
-.7285D-04	.7331D-03	.1043D-06	.2266D-02	-.9998D+00	-.1311D-01	-.2045D-02	-.2197D-02	-.1503D-01	-.3607D-05
.7063D+00	-.7075D+00	-.1512D-04	.2173D-01	-.5209D-03	-.6829D-05	-.3607D-03	.3754D-03	-.8529D-05	-.1310D-06
-.1443D-06	-.2150D-04	.1000D+01	-.4099D-05	.6273D-06	.2322D-07	-.2678D-03	.5990D-05	-.9533D-06	.1894D-03

MATRIX V - ORTHOGONAL MATRIX

.3443D-10	-.1440D-06	.4848D-09	-.2345D-02	-.9962D+00	.7386D-01	.4623D-01	.3814D-02	.5078D-04	-.5183D-04
-.6607D-08	-.1487D-05	.2833D-08	-.1729D-02	.3600D-01	-.2671D-02	.7231D+00	.6897D+00	.3537D-02	.2117D-03
.1846D-15	.4542D-14	-.2935D-10	-.8115D-07	-.6643D-04	.4925D-05	-.3209D-03	.3389D-04	-.1759D-03	.1000D+01
.8423D-13	.4436D-10	-.2931D-10	-.3701D-04	-.2901D-01	.2673D-02	-.6891D+00	.7240D+00	-.1339D-02	-.2479D-03
.8492D-10	.4067D-07	.2399D-11	.4101D-04	.7395D-01	.9973D+00	.3601D-03	-.3759D-03	.8462D-05	.1310D-06
.1283D-11	-.6154D-09	.2342D-08	.6179D-06	.1162D-03	-.8360D-06	.3483D-02	.1470D-02	-.1000D+01	-.1748D-03
-.1000D+01	-.1016D-03	-.1102D-06	.2172D-05	-.5205D-08	.3859D-09	-.1990D-08	-.1993D-08	-.1034D-10	-.7440D-12
.1016D-03	-.1000D+01	-.5783D-04	-.6619D-06	.9442D-07	.3381D-07	-.1083D-05	-.1027D-05	-.4656D-08	-.3075D-09
-.2173D-05	.6646D-06	-.7374D-09	-.1000D+01	.2278D-02	-.1278D-03	-.1333D-02	-.1229D-02	-.6803D-05	-.3167D-06
.1043D-06	.5783D-04	-.1000D+01	.7694D-09	-.3868D-09	.2869D-10	.2163D-08	.1998D-08	-.2332D-08	-.2916D-10

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: TENNM2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 15-SEP-79
TIME: 10:22 02.3

INPUT STEADY STATE VALUES

T= .3451240+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-06	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.823598D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.339271D+04
LAMBDA(3)=	-.494021D+01	.000000D+00	SV(3)=	.126731D+04
LAMBDA(4)=	-.494021D+01	.000000D+00	SV(4)=	.420314D+00
LAMBDA(5)=	-.992063D-04	.000000D+00	SV(5)=	.171922D-03
LAMBDA(6)=	-.126731D+04	.000000D+00	SV(6)=	.124738D-03
LAMBDA(7)=	-.886090D+01	.000000D+00	SV(7)=	.839815D-04
LAMBDA(8)=	.289422D-03	.000000D+00	SV(8)=	.494396D-05
LAMBDA(9)=	-.110818D-03	.168102D-04	SV(9)=	.992063D-04
LAMBDA(10)=	-.110818D-03	-.168102D-04	SV(10)=	.740037D-09

MATRIX U - ORTHONORMALIZED COLUMNS

.6013D-01	-.3084D-02	-.1822D-04	.9976D+00	.2672D-02	.3229D-01	.5580D-03	-.1144D-01	-.5070D-04	.1696D-03
-.1533D-02	.7867D-04	-.4019D-03	-.2544D-01	.9024D-01	.6425D+00	.6704D+00	-.3590D+00	-.4100D-05	-.6026D-03
.5998D-05	-.3263D-06	.4023D-03	.9951D-04	-.3293D-03	-.1515D-02	.1505D-02	-.1774D-05	.1000D+01	-.2345D-11
.1380D-02	-.1527D-02	.4014D-03	.2286D-01	-.5625D-01	-.7163D+00	.6952D+00	.4155D-03	-.2152D-02	-.5571D-08
.7066D+00	-.7062D+00	-.3354D-04	-.4479D-01	.4491D-03	.9381D-03	-.4782D-03	.8999D-03	.2293D-05	-.7458D-05
.9179D-20	.5492D-15	-.5509D-14	-.2127D-08	-.8527D+00	.1749D+00	.1110D+00	.3053D+00	-.1825D-03	.3698D+00
-.1076D-04	.5519D-06	.3260D-08	-.1785D-03	.3424D+00	-.6767D-01	-.4194D-01	-.1149D+00	.7322D-04	.9291D+00
.1535D-03	.1448D-02	.4355D-06	.2578D-02	.3798D+00	.1946D+00	.2307D+00	.8744D+00	.7398D-04	-.7243D-02
-.7051D+00	-.7080D+00	-.3265D-04	.4029D-01	.4490D-03	.9378D-03	-.4783D-03	.8999D-03	.2292D-05	-.7458D-05
.5987D-06	-.4622D-04	.1000D+01	-.1452D-05	.5889D-04	.5469D-03	-.1037D-04	-.1450D-03	-.4015D-03	-.2395D-06

MATRIX V - ORTHOGONAL MATRIX

.3841D-09	-.4517D-06	.2812D-08	-.1007D-03	.6993D-02	-.1545D-01	-.2058D-01	.9995D+00	.5551D-04	.1805D-01
.1118D-06	-.9319D-05	.2498D-07	-.1031D-01	-.1566D+00	-.8085D+00	-.5668D+00	-.2306D-01	.3318D-05	-.7400D-03
-.7225D-15	.9540D-14	-.3150D-10	-.2349D-07	.1900D-03	.1205D-02	-.1778D-02	.3622D-04	-.1000D+01	.3143D-06
-.1662D-12	.4465D-10	-.3143D-10	-.5396D-05	.3246D-01	.5697D+00	-.8212D+00	-.8338D-02	.2152D-02	.7469D-03
-.8511D-10	.2065D-07	.2625D-11	.1057D-04	-.2591D-03	-.7461D-03	.5649D-03	-.1806D-01	-.2293D-05	.9998D+00
-.5099D-10	-.1241D-07	.4701D-07	.6050D-05	.9871D+00	-.1469D+00	-.6276D-01	-.1047D-01	.1219D-03	-.7366D-05
.1000D+01	-.2113D-03	-.4663D-06	.8468D-05	.4156D-08	.2148D-07	.1500D-07	.9847D-09	-.1686D-12	.2637D-10
-.2113D-03	-.1000D+01	-.1236D-03	-.2548D-05	.1448D-05	.7565D-05	.5307D-05	-.2365D-06	-.5754D-10	.1943D-07
.8467D-05	.2642D-05	-.3450D-08	-.9999D+00	.1619D-02	.8331D-02	.5849D-02	.1368D-03	-.2721D-07	.1638D-04
-.4402D-06	.1236D-03	-.1000D+01	.3503D-08	.4233D-07	-.2812D-07	-.1782D-07	.1772D-08	.3740D-10	.3209D-10

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: TENNH2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 15-SEP-79
TIME: 10:22 50.6

INPUT STEADY STATE VALUES

T= .411555D+03	R0= .583692D-06	P0= .832444D-02
I= -.151281D-04	R1= .256499D-03	P1= .440938D+01
M= .403754D+00	R2= .225177D+00	P2= .452538D+04
RAD= .133030D-08		

JACOBIAN MATRIX VALUES

.1203D-03	.3620D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2504D+05	.0000D+00	.0000D+00	.0000D+00
-.9191D-05	-.1182D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.7489D+03	.0000D+00	.0000D+00	.1129D+01
.3009D-07	.1995D-05	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.1705D+01	.0000D+00	.0000D+00	-.1129D+01
.1559D-04	.1039D-02	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.2531D+03	.1705D+01	.0000D+00	-.1129D+01
.1575D-01	.4337D+00	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.2222D+06	.5062D+03	.1705D+01	-.1129D+01
-.9610D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.6951D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2011D-07	-.8719D-06	.0000D+00	.0000D+00	.0000D+00	.2222D-01	-.1152D+01	.0000D+00	.0000D+00	.0000D+00
-.6370D-05	.4303D-04	.0000D+00	.0000D+00	.0000D+00	.2222D-01	.4958D+03	-.1706D+01	.0000D+00	.0000D+00
-.5622D-02	.3863D-01	.0000D+00	.0000D+00	.0000D+00	.2222D-01	-.2215D+06	.1496D+04	-.1706D+01	.0000D+00
.9201D-05	.1080D-02	.0000D+00	.0000D+00	.0000D+00	.2222D-01	.1128D+01	.0000D+00	.0000D+00	-.7495D+03

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.314719D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.141774D+04
LAMBDA(3)=	-.170552D+01	.000000D+00	SV(3)=	.749482D+03
LAMBDA(4)=	-.170552D+01	.000000D+00	SV(4)=	.191731D+00
LAMBDA(5)=	-.992063D-04	.000000D+00	SV(5)=	.762891D-01
LAMBDA(6)=	-.115313D+01	.000000D+00	SV(6)=	.394236D-03
LAMBDA(7)=	-.749480D+03	.000000D+00	SV(7)=	.700260D-04
LAMBDA(8)=	-.687955D-01	.000000D+00	SV(8)=	.992062D-04
LAMBDA(9)=	-.523354D-03	.000000D+00	SV(9)=	.516353D-05
LAMBDA(10)=	-.206349D-03	.000000D+00	SV(10)=	.263630D-09

MATRIX U - ORTHONORMALIZED COLUMNS

-.7956D-01	.3900D-01	.1430D-03	-.9954D+00	.8368D-02	-.2230D-02	.1231D-01	.1510D-03	.3461D-01	-.4659D-04
.2380D-02	-.1167D-02	.1503D-02	.2977D-01	-.6906D-03	-.2434D+00	-.2506D+00	.1352D-04	.9365D+00	-.9551D-03
-.5419D-05	.3279D-05	-.1507D-02	-.6662D-04	.4395D-03	-.5674D-02	.5488D-02	-.1000D+01	.1265D-04	.1876D-10
-.8042D-03	.1598D-02	-.1504D-02	-.9992D-02	.7743D-03	.7202D+00	-.6936D+00	-.7890D-02	.1947D-02	.8353D-09
-.7060D+00	.7032D+00	.2901D-03	.8398D-01	-.4708D-03	-.1142D-02	.4062D-04	.6594D-05	-.2861D-03	.2657D-05
-.1095D-13	-.5456D-09	.2749D-08	.2408D-02	.9111D+00	-.1804D+00	-.1866D+00	.3987D-03	-.9589D-01	.3054D+00
.3661D-05	-.1794D-05	-.7458D-08	-.7241D-03	-.2913D+00	.5964D-01	.6170D-01	-.1274D-03	.3279D-01	.9522D+00
-.1575D-02	-.4308D-03	.1051D-05	-.2055D-01	-.2914D+00	-.6212D+00	-.6460D+00	-.1509D-03	-.3339D+00	.3119D-02
.7037D+00	.7099D+00	.2953D-03	-.2844D-01	-.1738D-03	-.1143D-02	.4058D-04	.6593D-05	-.2861D-03	.2657D-05
-.3591D-05	.4150D-03	-.1000D+01	-.6653D-04	-.2157D-05	-.1442D-02	.6594D-03	.1519D-02	.1409D-02	-.1443D-05

MATRIX V - ORTHOGONAL MATRIX

-.4792D-07	.4998D-05	-.8424D-08	.7104D-02	-.4781D-04	.1421D-01	-.3541D-01	-.5384D-03	-.9992D+00	-.5488D-02
-.8958D-06	.2355D-03	-.1256D-05	-.3925D-02	.1066D-02	.9833D+00	.1816D+00	.9922D-05	.7514D-02	.3137D-03
.1708D-14	-.2295D-12	.1995D-09	.3447D-07	-.5715D-06	.1428D-02	-.7775D-02	.1000D+01	-.2430D-03	-.7058D-05
.2535D-12	-.1118D-09	.1990D-09	.5170D-05	-.1007D-05	-.1812D+00	.9827D+00	.7890D-02	-.3740D-01	-.3143D-03
.2226D-09	-.4920D-07	-.3840D-10	-.4345D-04	.6122D-06	.2874D-03	-.5755D-04	-.6580D-05	.5498D-02	-.1000D+01
.4958D-07	.1113D-04	-.2964D-04	-.6642D-02	-.1000D+01	.1023D-02	.1880D-03	-.5683D-06	.8504D-05	.6435D-08
-.1000D+01	.2208D-02	.4280D-05	-.7616D-05	.2395D-07	-.1422D-05	-.2624D-06	-.1116D-10	-.6054D-08	-.4271D-09
.2208D-02	.1000D+01	.7818D-03	.9182D-05	.1080D-04	-.2316D-03	-.4258D-04	.3925D-09	.3283D-05	-.9566D-07
-.7639D-05	-.8203D-05	-.1194D-07	.9999D+00	-.6638D-02	.3766D-02	.9606D-03	.3785D-05	.7129D-02	-.3232D-05
.2554D-05	-.7818D-03	.1000D+01	-.1970D-06	-.2965D-04	.1446D-05	.2664D-06	-.2102D-09	-.1205D-08	.3842D-09

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: NINEL2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 20-AUG-79
TIME: 17:58 19.3

INPUT STEADY STATE VALUES

T= .3159420D+03	R0= .1375050D-07	P0= .9637150D-04
I= .1051750D-01	R1= .6938490D-05	P1= .8879890D-01
M= .4721350D+01	R2= .6995380D-02	P2= .1300490D+03
RAD= .2734830D-10		

JACOBIAN MATRIX VALUES

-.1367D-03	.7777D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2670D+05	.0000D+00	.0000D+00
-.3134D-06	-.1011D-03	.0000D+00	.0000D+00	.0000D+00	.2844D-09	-.6396D+03	.0000D+00	.0000D+00
.1150D-09	.3683D-08	-.9921D-04	.0000D+00	.0000D+00	-.2844D-09	.1270D+01	.0000D+00	.0000D+00
.1227D-06	.3893D-05	.0000D+00	-.9921D-04	.0000D+00	-.2844D-09	.5794D+03	.1270D+01	.0000D+00
.1586D-03	.5674D-02	.0000D+00	.0000D+00	-.9921D-04	-.2844D-09	.5841D+06	.1159D+04	.1270D+01
-.1272D-08	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.9998D-04	.0000D+00	.0000D+00	.0000D+00
.2315D-08	-.1392D-07	.0000D+00	.0000D+00	.0000D+00	.1501D-05	-.2297D+01	.0000D+00	.0000D+00
.1931D-06	-.2037D-05	.0000D+00	.0000D+00	.0000D+00	.1501D-05	.6018D+02	-.1270D+01	.0000D+00
.1927D-03	-.2044D-02	.0000D+00	.0000D+00	.0000D+00	.1501D-05	-.5835D+06	.1279D+04	-.1270D+01

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.826077D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.172374D+04
LAMBDA(3)=	-.992063D-04	.000000D+00	SV(3)=	.580690D-01
LAMBDA(4)=	-.229656D+01	.000000D+00	SV(4)=	.698781D-06
LAMBDA(5)=	-.126974D+01	.000000D+00	SV(5)=	.679449D-09
LAMBDA(6)=	-.126974D+01	.000000D+00	SV(6)=	.994186D-04
LAMBDA(7)=	-.113321D-03	.000000D+00	SV(7)=	.990496D-04
LAMBDA(8)=	-.934526D-04	.000000D+00	SV(8)=	.100007D-03
LAMBDA(9)=	-.100183D-03	.000000D+00	SV(9)=	.992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

-.3232D-01	-.1574D-02	-.9990D+00	-.2335D-02	.5350D-04	.3227D-01	.8658D-03	.8059D-04	.3675D-04
.7742D-03	.3770D-04	.2392D-01	-.2994D-02	-.1154D-03	.7225D+00	.6909D+00	.3511D-02	-.2196D-03
-.1537D-05	-.7484D-07	-.4750D-04	-.4679D-06	.1000D-06	-.3335D-03	.3347D-04	-.1774D-03	-.1000D+01
-.7014D-03	-.7707D-03	-.2166D-01	-.2043D-03	.1856D-06	-.6906D+00	.7229D+00	-.1350D-02	.2558D-03
-.7071D+00	-.7067D+00	.2400D-01	.5209D-03	.6830D-05	.3608D-03	-.3753D-03	.8531D-05	-.1351D-06
-.1563D-21	.3580D-16	.1013D-08	.1482D-01	.1521D-01	.3503D-02	.1484D-02	-.9998D+00	.1762D-03
.2780D-05	.1354D-06	.8592D-04	-.1334D-01	.9998D+00	.1653D-05	.2815D-04	.1501D-01	-.2560D-05
-.7285D-04	.7331D-03	-.2266D-02	.9998D+00	.1311D-01	.2045D-02	.2197D-02	.1503D-01	-.3633D-05
.7063D+00	-.7075D+00	-.2173D-01	.5209D-03	.6829D-05	.3607D-03	-.3754D-03	.8529D-05	-.1351D-06

MATRIX V - ORTHOGONAL MATRIX

.3443D-10	-.1440D-06	.2345D-02	.9962D+00	-.7386D-01	-.4623D-01	-.3812D-02	-.5078D-04	-.5128D-04
-.6607D-08	-.1487D-05	.1729D-02	-.3600D-01	.2671D-02	-.7232D+00	-.6897D+00	-.3537D-02	.2206D-03
.1846D-15	.4308D-14	.8115D-07	.6643D-04	-.4925D-05	.3328D-03	-.3353D-04	.1759D-03	.1000D+01
.8423D-13	.4436D-10	.3701D-04	.2901D-01	-.2673D-02	.6891D+00	-.7241D+00	.1339D-02	-.2558D-03
.8492D-10	.4067D-07	-.4101D-04	-.7395D-01	-.9973D+00	-.3601D-03	.3759D-03	-.8462D-05	.1351D-06
.1283D-11	-.6153D-09	-.6179D-06	-.1162D-03	.8360D-06	-.3483D-02	-.1470D-02	.1000D+01	-.1748D-03
-.1000D+01	-.1016D-03	-.2172D-05	.5205D-08	-.3859D-09	.1990D-08	.1992D-08	.1034D-10	-.7683D-12
.1016D-03	-.1000D+01	.6619D-06	-.9442D-07	-.3381D-07	.1083D-05	.1027D-05	.4657D-08	-.3208D-09
-.2173D-05	.6646D-06	.1000D+01	-.2278D-02	.1278D-03	.1333D-02	.1229D-02	.6803D-05	-.3329D-06

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: NINEM2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 20-AUG-79
TIME: 17:55 51.2

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00
-.3591D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.2397D-07	-.1263D+04	.0000D+00	.0000D+00
.3578D-08	.2214D-06	-.9921D-04	.0000D+00	.0000D+00	-.2397D-07	.4940D+01	.0000D+00	.0000D+00
.1923D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	-.2397D-07	.1136D+04	.4940D+01	.0000D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	-.2397D-07	.5819D+06	.2273D+04	.4940D+01
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.823598D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.339271D+04
LAMBDA(3)=	-.992063D-04	.000000D+00	SV(3)=	.420314D+00
LAMBDA(4)=	-.886090D+01	.000000D+00	SV(4)=	.171922D-03
LAMBDA(5)=	-.494021D+01	.000000D+00	SV(5)=	.124738D-03
LAMBDA(6)=	-.494021D+01	.000000D+00	SV(6)=	.839815D-04
LAMBDA(7)=	.223301D-03	.000000D+00	SV(7)=	.494396D-05
LAMBDA(8)=	-.110630D-03	.000000D+00	SV(8)=	.740037D-09
LAMBDA(9)=	-.448839D-04	.000000D+00	SV(9)=	.992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

.6013D-01	-.3084D-02	-.9976D+00	.2672D-02	.3229D-01	-.5580D-03	.1144D-01	.1696D-03	-.5069D-04
-.1533D-02	.7865D-04	.2544D-01	.9024D-01	.6425D+00	-.6704D+00	.3590D+00	-.6026D-03	-.3872D-05
.5998D-05	-.3077D-06	-.9951D-04	-.3294D-03	-.1515D-02	-.1505D-02	.1805D-05	-.2398D-11	.1000D+01
.1380D-02	-.1527D-02	-.2286D-01	-.5625D-01	-.7163D+00	-.6952D+00	-.4155D-03	-.5571D-08	-.2153D-02
.7066D+00	-.7062D+00	.4479D-01	.4491D-03	.9381D-03	.4782D-03	-.8999D-03	-.7456D-05	.2293D-05
.9179D-20	.5490D-15	.2127D-08	-.8527D+00	.1749D+00	-.1110D+00	-.3053D+00	.3698D+00	-.1824D-03
-.1076D-04	.5519D-06	.1785D-03	.3424D+00	-.6767D-01	.4194D-01	.1149D+00	.9291D+00	.7318D-04
.1535D-03	.1448D-02	-.2578D-02	.3798D+00	.1946D+00	-.2307D+00	-.8744D+00	-.7243D-02	.7414D-04
-.7051D+00	-.7080D+00	-.4029D-01	.4490D-03	.9378D-03	.4783D-03	-.8999D-03	-.7458D-05	.2293D-05

MATRIX V - ORTHOGONAL MATRIX

.3841D-09	-.4517D-06	.1007D-03	.6993D-02	-.1545D-01	.2058D-01	-.9995D+00	.1805D-01	.5551D-04
.1118D-06	-.9319D-05	.1031D-01	-.1566D+00	-.8085D+00	.5668D+00	.2306D-01	-.7400D-03	.2920D-05
-.7225D-15	.8996D-14	.2349D-07	.1901D-03	.1205D-02	.1778D-02	-.3623D-04	.3143D-06	-.1000D+01
-.1662D-12	.4465D-10	.5396D-05	.3246D-01	.5697D+00	.8212D+00	.8338D-02	.7469D-03	.2153D-02
-.8511D-10	.2065D-07	-.1057D-04	-.2591D-03	-.7461D-03	-.5649D-03	.1806D-01	.9998D+00	-.2293D-05
-.5101D-10	-.1240D-07	-.6050D-05	.9871D+00	-.1469D+00	.6276D-01	.1047D-01	-.7366D-05	.1218D-03
.1000D+01	-.2113D-03	-.8468D-05	.4156D-08	.2148D-07	-.1500D-07	-.9847D-09	.2637D-10	-.1580D-12
-.2113D-03	-.1000D+01	.2548D-05	.1448D-05	.7565D-05	-.5307D-05	.2365D-06	.1943D-07	-.5382D-10
.8467D-05	.2642D-05	.9999D+00	.1619D-02	.8331D-02	-.5849D-02	-.1368D-03	.1638D-04	-.2311D-07

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: NINEH2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 20-AUG-79
TIME: 17:58 59.5

INPUT STEADY STATE VALUES

T= .411555D+03	R0= .583692D-06	P0= .832444D-02
I= .151281D-04	R1= .256499D-03	P1= .440938D+01
M= .403754D+00	R2= .225177D+00	P2= .452538D+04
RAD= .133030D-08		

JACOBIAN MATRIX VALUES

.1203D-03	.3620D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2504D+05	.0000D+00	.0000D+00
-.9177D-05	-.1180D-02	.0000D+00	.0000D+00	.0000D+00	.3349D-04	-.7489D+03	.0000D+00	.0000D+00
.1623D-07	.3678D-06	-.9921D-04	.0000D+00	.0000D+00	-.3349D-04	.1704D+01	.0000D+00	.0000D+00
.1558D-04	.1038D-02	.0000D+00	-.9921D-04	.0000D+00	-.3349D-04	.2531D+03	.1705D+01	.0000D+00
.1575D-01	.4337D+00	.0000D+00	.0000D+00	-.9921D-04	-.3349D-04	.2222D+06	.5062D+03	.1705D+01
-.9610D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.6951D-01	.0000D+00	.0000D+00	.0000D+00
.2011D-07	-.8719D-06	.0000D+00	.0000D+00	.0000D+00	.2222D-01	-.1152D+01	.0000D+00	.0000D+00
-.6370D-05	.4303D-04	.0000D+00	.0000D+00	.0000D+00	.2222D-01	.4958D+03	-.1706D+01	.0000D+00
-.5622D-02	.3863D-01	.0000D+00	.0000D+00	.0000D+00	.2222D-01	-.2215D+06	.1496D+04	-.1706D+01

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.314719D+06
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.141774D+04
LAMBDA(3)=	-.992063D-04	.000000D+00	SV(3)=	.191731D+00
LAMBDA(4)=	-.170552D+01	.000000D+00	SV(4)=	.762891D-01
LAMBDA(5)=	-.170552D+01	.000000D+00	SV(5)=	.394236D-03
LAMBDA(6)=	-.115313D+01	.000000D+00	SV(6)=	.700260D-04
LAMBDA(7)=	-.687955D-01	.000000D+00	SV(7)=	.992064D-04
LAMBDA(8)=	-.523354D-03	.000000D+00	SV(8)=	.516353D-05
LAMBDA(9)=	-.206349D-03	.000000D+00	SV(9)=	.263630D-09

MATRIX U - ORTHONORMALIZED COLUMNS

-.7956D-01	.3900D-01	.9954D+00	-.8368D-02	.2230D-02	.1231D-01	.1511D-03	-.3461D-01	.4659D-04
.2380D-02	-.1166D-02	-.2977D-01	.6906D-03	.2434D+00	-.2506D+00	.1499D-04	-.9365D+00	.9551D-03
-.5413D-05	.2654D-05	.6652D-04	-.4395D-03	.5672D-02	.5489D-02	-.1000D+01	-.1265D-04	-.1876D-10
-.8042D-03	.1597D-02	.9992D-02	-.7743D-03	-.7202D+00	-.6936D+00	-.7891D-02	-.1947D-02	-.8353D-09
-.7060D+00	.7032D+00	-.8398D-01	.4708D-03	.1142D-02	.4062D-04	.6593D-05	.2861D-03	-.2657D-05
-.1097D-13	-.5445D-09	-.2408D-02	-.9111D+00	.1804D+00	-.1866D+00	.3981D-03	.9589D-01	-.3054D+00
.3661D-05	-.1794D-05	.7241D-03	.2913D+00	-.5964D-01	.6170D-01	-.1272D-03	-.3279D-01	-.9522D+00
-.1575D-02	-.4308D-03	.2055D-01	.2914D+00	.6212D+00	-.6460D+00	-.1530D-03	.3339D+00	-.3119D-02
.7037D+00	.7099D+00	.2844D-01	.1738D-03	.1143D-02	.4058D-04	.6593D-05	.2861D-03	-.2657D-05

MATRIX V - ORTHOGONAL MATRIX

-.4792D-07	.4998D-05	-.7104D-02	.4781D-04	-.1421D-01	-.3541D-01	-.5386D-03	.9992D+00	.5488D-02
-.8958D-06	.2355D-03	.3925D-02	-.1066D-02	-.9833D+00	.1816D+00	.1076D-04	-.7514D-02	-.3137D-03
.1706D-14	-.1857D-12	-.3442D-07	.5715D-06	-.1427D-02	-.7776D-02	.1000D+01	.2431D-03	.7058D-05
.2535D-12	-.1118D-09	-.5170D-05	.1007D-05	.1812D+00	.9827D+00	.7891D-02	.3740D-01	.3143D-03
.2226D-09	-.4920D-07	.4345D-04	-.6122D-06	-.2874D-03	-.5755D-04	-.6580D-05	-.5498D-02	.1000D+01
.4965D-07	.1110D-04	.6642D-02	.1000D+01	-.1023D-02	.1888D-03	-.5674D-06	-.8504D-05	-.6435D-08
-.1000D+01	.2209D-02	.7616D-05	-.2395D-07	.1422D-05	-.2624D-06	-.1237D-10	.6054D-08	.4271D-09
.2208D-02	.1000D+01	-.9182D-05	-.1080D-04	.2316D-03	-.4258D-04	.1967D-09	-.3283D-05	.9566D-07
-.7639D-05	-.8203D-05	-.9999D+00	.6638D-02	-.3766D-02	.9606D-03	.3789D-05	-.7129D-02	.3232D-05

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RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: SIXXL2.DAT          INPUT STEADY STATE VALUES
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT          T= .315942D+03    RO= .137505D-07    PO= .963715D-04
                                                  I= .105175D-01    R1= .693849D-05    P1= .887989D-01
DATE: 20-AUG-79                                   M= .472135D+01    R2= .699538D-02    P2= .130049D+03
TIME: 18:02 08.7                                RAD= .273483D-10

JACOBIAN MATRIX VALUES

  -.1098D-03  -.8410D-04   .0000D+00   .0000D+00   .0000D+00   .1745D-01
  -.9582D-06  -.9719D-04   .0000D+00   .0000D+00   .0000D+00  -.4180D-03
   .1395D-08  -.4014D-08  -.9921D-04   .0000D+00   .0000D+00   .8294D-06
   .9606D-06  -.2021D-05   .0000D+00  -.9921D-04   .0000D+00   .4195D-03
   .8392D-03  -.9846D-03   .0000D+00   .0000D+00  -.9921D-04   .7883D-01
  -.1272D-08   .0000D+00   .0000D+00   .0000D+00   .0000D+00  -.9998D-04

EIGENVALUES & SINGLE VALUES
                        REAL          IMAG
    LAMBDA( 1)=   -.992063D-04   .000000D+00         SV( 1)=    .807475D-01
    LAMBDA( 2)=   -.992063D-04   .000000D+00         SV( 2)=    .320968D-03
    LAMBDA( 3)=   -.992063D-04   .000000D+00         SV( 3)=    .446854D-07
    LAMBDA( 4)=   -.113322D-03   .000000D+00         SV( 4)=    .908456D-04
    LAMBDA( 5)=   -.934533D-04   .000000D+00         SV( 5)=    .992480D-04
    LAMBDA( 6)=   -.100183D-03   .000000D+00         SV( 6)=    .992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

   .2161D+00   .9646D+00   .3518D-02   .1486D+00  -.2624D-01  -.6227D-05
  -.5161D-02  -.1526D+00  -.7597D-02   .9857D+00  -.7063D-01  -.4492D-05
   .1027D-04   .3040D-04   .2189D-08   .1320D-03   .1712D-02   .1000D+01
   .5195D-02   .1460D-01   .1192D-05   .7373D-01   .9972D+00  -.1717D-02
   .9763D+00  -.2144D+00   .4492D-03  -.2805D-01   .1278D-03  -.2852D-07
  -.1238D-02  -.4457D-02   .1000D+01   .6978D-02  -.4455D-03  -.1235D-07

MATRIX V - ORTHOGONAL MATRIX

   .9853D-02  -.8899D+00  -.7291D-01  -.4483D+00   .4044D-01   .4125D-05
  -.1212D-01   .4510D+00   .2640D-02  -.8897D+00   .6982D-01   .4492D-05
  -.1262D-07  -.9395D-05  -.4861D-05  -.1441D-03  -.1711D-02  -.1000D+01
  -.6382D-05  -.4514D-02  -.2646D-02  -.8052D-01  -.9967D+00   .1717D-02
  -.1200D-02   .6626D-01  -.9973D+00   .3064D-01  -.1278D-03   .2852D-07
   .9999D+00   .1432D-01  -.4460D-03  -.6335D-02   .4417D-03   .1220D-07
```

RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: SIXXM2.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 20-AUG-79
TIME: 18:03 20.1

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

.2609D-03	-.2143D-02	.0000D+00	.0000D+00	.0000D+00	.3330D+00
-.1072D-04	-.4455D-04	.0000D+00	.0000D+00	.0000D+00	-.8491D-02
.3146D-07	-.1231D-06	-.9921D-04	.0000D+00	.0000D+00	.3319D-04
.1077D-04	-.5483D-04	.0000D+00	-.9921D-04	.0000D+00	.8551D-02
.4542D-02	-.4511D-01	.0000D+00	.0000D+00	-.9921D-04	.8918D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03

EIGENVALUES & SINGLE VALUES

	REAL	IMAG		
LAMBDA(1)=	-.992063D-04	.000000D+00	SV(1)=	.953012D+00
LAMBDA(2)=	-.992063D-04	.000000D+00	SV(2)=	.138329D-01
LAMBDA(3)=	.289434D-03	.000000D+00	SV(3)=	.136659D-04
LAMBDA(4)=	-.992063D-04	.000000D+00	SV(4)=	.200129D-08
LAMBDA(5)=	-.110818D-03	.168101D-04	SV(5)=	.992584D-04
LAMBDA(6)=	-.110818D-03	-.168101D-04	SV(6)=	.992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

-.3491D+00	-.9362D+00	.3200D-01	.4585D-03	.2582D-01	-.2639D-04
.8899D-02	.3098D-01	.9995D+00	-.1630D-02	.4918D-02	-.1426D-05
-.3480D-04	-.9979D-04	.2005D-04	-.6441D-11	-.3092D-02	.1000D+01
-.8966D-02	-.2403D-01	.5744D-02	-.1503D-07	-.9996D+00	-.3094D-02
-.9370D+00	.3493D+00	-.2484D-02	-.2017D-04	-.7604D-05	.2283D-05
.1557D-03	.4868D-03	.1614D-02	.1000D+01	-.3838D-05	.9780D-08

MATRIX V - ORTHOGONAL MATRIX

-.4561D-02	.9700D-01	-.9942D+00	.1818D-01	-.4152D-01	.1643D-04
.4514D-01	-.9942D+00	-.9706D-01	-.7450D-03	-.3879D-02	.1426D-05
.3622D-08	.7157D-06	-.1455D-03	.3193D-06	.3090D-02	-.1000D+01
.9333D-06	.1723D-03	-.4170D-01	.7450D-03	.9991D+00	.3094D-02
.9754D-04	-.2505D-02	.1803D-01	.9998D+00	.7600D-05	-.2283D-05
-.9990D+00	-.4537D-01	.1557D-03	-.1904D-04	.1527D-04	-.1156D-07

```
RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: SIXXH2.DAT          INPUT STEADY STATE VALUES
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT          T= .411555D+03    RO= .583692D-06    PO= .832444D-02
                                                  I= .151281D-04    R1= .256499D-03    P1= .440938D+01
DATE: 20-AUG-79                                   M= .403754D+00    R2= .225177D+00    P2= .452538D+04
TIME: 18:02 45.6                                RAD= .133030D-08

JACOBIAN MATRIX VALUES

   .5575D-03    .1725D-01    .0000D+00    .0000D+00    .0000D+00    .4830D+03
  -.2225D-04   -.6135D-03    .0000D+00    .0000D+00    .0000D+00   -.1445D+02
   .4597D-07   -.9216D-06   -.9921D-04    .0000D+00    .0000D+00    .3283D-01
   .2228D-04    .5141D-03    .0000D+00   -.9921D-04    .0000D+00    .1447D+02
   .1282D-01    .8191D-01    .0000D+00    .0000D+00   -.9921D-04    .1126D+05
  -.9610D-07    .0000D+00    .0000D+00    .0000D+00    .0000D+00   -.6951D-01

EIGENVALUES & SINGLE VALUES
                   REAL            IMAG
    LAMBDA( 1)=  -.992063D-04    .000000D+00          SV( 1)=    .112750D+05
    LAMBDA( 2)=  -.992063D-04    .000000D+00          SV( 2)=    .137396D-01
    LAMBDA( 3)=  -.992063D-04    .000000D+00          SV( 3)=    .551066D-05
    LAMBDA( 4)=  -.523485D-03    .000000D+00          SV( 4)=    .863205D-09
    LAMBDA( 5)=  -.688381D-01    .000000D+00          SV( 5)=    .993197D-04
    LAMBDA( 6)=  -.206357D-03    .000000D+00          SV( 6)=    .992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

  -.4284D-01    .9980D+00   -.3689D-01   -.1525D-03    .2983D-01    .1858D-03
   .1281D-02   -.3695D-01   -.9993D+00   -.3127D-02    .2028D-02   -.1407D-05
  -.2912D-05   -.8458D-04   -.5204D-05    .1014D-07   -.3410D-02    .1000D+01
  -.1283D-02    .2971D-01   -.3129D-02    .2210D-08   -.9995D+00   -.3406D-02
  -.9991D+00   -.4287D-01    .3044D-03    .8701D-05    .7194D-05   -.6509D-05
   .6165D-05    .3705D-04   -.3131D-02    .1000D+01    .1089D-04    .1386D-07

MATRIX V - ORTHOGONAL MATRIX

  -.1138D-05    .5939D-03    .9984D+00   -.5470D-02   -.5632D-01   -.9825D-04
  -.7324D-05    .1000D+01   -.5792D-03    .3128D-03    .2476D-03    .1398D-05
   .2562D-13    .6107D-06    .9369D-04   -.7047D-05    .3406D-02   -.1000D+01
   .1129D-10   -.2145D-03    .5632D-01   -.3159D-03    .9984D+00    .3406D-02
   .8791D-08    .3096D-03   -.5480D-02   -.1000D+01   -.7186D-05    .6509D-05
  -.1000D+01   -.7324D-05   -.1132D-05   -.4855D-08    .6230D-07    .1017D-09
```

```
RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: FIVEL2.DAT          INPUT STEADY STATE VALUES
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT           T= .3159420+03     R0= .1375050D-07     P0= .963715D-04
                                                   I= .1051750D-01    R1= .6938490D-05     P1= .8879890D-01
DATE: 20-AUG-79                                    M= .4721350D+01    H2= .6995380D-02     P2= .1300490D+03
TIME: 18:05 05.7                                 RAD= .2734830D-10

JACOBIAN MATRIX VALUES

   -.1100D-03  -.8410D-04   .0000D+00   .0000D+00   .0000D+00
   -.9528D-06  -.9719D-04   .0000D+00   .0000D+00   .0000D+00
    .1384D-08  -.4014D-08  -.9921D-04   .0000D+00   .0000D+00
    .9552D-06  -.2021D-05   .0000D+00  -.9921D-04   .0000D+00
    .8382D-03  -.9846D-03   .0000D+00   .0000D+00  -.9921D-04

EIGENVALUES & SINGLE VALUES
                    REAL           IMAG
     LAMBDA( 1)=  -.9920630D-04   .0000000D+00         SV( 1)=   .1298970D-02
     LAMBDA( 2)=  -.9920630D-04   .0000000D+00         SV( 2)=   .1522440D-03
     LAMBDA( 3)=  -.1146060D-03   .0000000D+00         SV( 3)=   .5323250D-05
     LAMBDA( 4)=  -.9920630D-04   .0000000D+00         SV( 4)=   .9920510D-04
     LAMBDA( 5)=  -.9258980D-04   .0000000D+00         SV( 5)=   .9920630D-04

MATRIX U - ORTHONORMALIZED COLUMNS

   -.5340D-02   .9083D+00  -.4183D+00   .6040D-02  -.1048D-19
    .5644D-01   .4179D+00   .9067D+00   .2783D-02  -.9854D-19
    .3056D-05   .1761D-04  -.1534D-06  -.2656D-02  -.1000D+01
    .1667D-02   .6620D-02  -.8547D-04  -.1000D+01   .2656D-02
    .9984D+00  -.1878D-01  -.5350D-01   .1545D-02  -.1375D-05

MATRIX V - ORTHOGONAL MATRIX

    .6446D+00  -.7622D+00   .5865D-01  -.3300D-02   .0000D+00
   -.7607D+00  -.6472D+00  -.5024D-01  -.2809D-02  -.1663D-19
   -.2334D-06  -.1147D-04   .2859D-05   .2656D-02   .1000D+01
   -.1273D-03  -.4314D-02   .1593D-02   .1000D+01  -.2656D-02
   -.7625D-01   .1224D-01   .9970D+00  -.1545D-02   .1375D-05
```

```
RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: FIVEM2.DAT          INPUT STEADY STATE VALUES
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT          T= .345124D+03   RO= .952324D-07   PO= .261393D-02
                                                  I= .708052D-02   R1= .244300D-04   P1= .121652D+01
DATE: 20-AUG-79                                   M= .359771D+01   R2= .125096D-01   P2= .902797D+03
TIME: 18:04 13.3                                RAD= .373847D-09

JACOBIAN MATRIX VALUES

  .1590D-03  -.2143D-02   .0000D+00   .0000D+00   .0000D+00
 -.8120D-05  -.4455D-04   .0000D+00   .0000D+00   .0000D+00
  .2130D-07  -.1231D-06  -.9921D-04   .0000D+00   .0000D+00
  .8157D-05  -.5483D-04   .0000D+00  -.9921D-04   .0000D+00
  .4269D-02  -.4511D-01   .0000D+00   .0000D+00  -.9921D-04

EIGENVALUES & SINGLE VALUES
                  REAL            IMAG
   LAMBDA( 1)=  -.992063D-04   .000000D+00         SV( 1)=   .453647D-01
   LAMBDA( 2)=   .223833D-03   .000000D+00         SV( 2)=   .992619D-04
   LAMBDA( 3)=  -.992063D-04   .000000D+00         SV( 3)=   .454253D-04
   LAMBDA( 4)=  -.109381D-03   .000000D+00         SV( 4)=   .117801D-05
   LAMBDA( 5)=  -.992063D-04   .000000D+00         SV( 5)=   .992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

 -.4735D-01  -.1650D-01   .9619D+00  -.2688D+00   .7040D-17
 -.9608D-03  -.4650D-02   .2690D+00   .9631D+00  -.2474D-16
 -.2745D-05   .3252D-02   .5568D-04   .1477D-06  -.1000D+01
 -.1220D-02   .9998D+00   .1710D-01   .4985D-04   .3252D-02
 -.9989D+00  -.4349D-03  -.4588D-01   .1181D-01  -.1225D-05

MATRIX V - ORTHOGONAL MATRIX

 -.9416D-01   .3742D-01  -.9898D+00  -.9987D-01   .0000D+00
  .9956D+00   .3541D-02  -.9384D-01  -.7263D-02  -.4844D-21
  .6004D-06  -.3250D-02  -.1216D-03  -.1244D-04   .1000D+01
  .2669D-05  -.9993D+00  -.3735D-01  -.4198D-02  -.3252D-02
  .2184D-02   .4346D-03   .1002D+00  -.9950D+00   .1225D-05
```

```
RESULTS OF SVD AND EIGENVALUE ANALYSES
---SVD OF JACOBIAN MATRIX---

EIGENVALUE ANALYSIS RUN NAME: FIVEM2.DAT        INPUT STEADY STATE VALUES
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT         T= .4115550+03   R0= .5836920-06   P0= .8324440-02
                                                 I= .1512810-04   R1= .2564990-03   P1= .4409380+01
DATE: 20-AUG-79                                  M= .4037540+00   R2= .2251770+00   P2= .4525380+04
TIME: 18:05 41.1                               RAD= .1330300-08

JACOBIAN MATRIX VALUES

 -.1103D-03   .1725D-01   .0000D+00   .0000D+00   .0000D+00
 -.2281D-05  -.6135D-03   .0000D+00   .0000D+00   .0000D+00
  .5857D-09  -.9216D-06  -.9921D-04   .0000D+00   .0000D+00
  .2281D-05   .5141D-03   .0000D+00  -.9921D-04   .0000D+00
 -.2753D-02   .8191D-01   .0000D+00   .0000D+00  -.9921D-04

EIGENVALUES & SINGLE VALUES
                      REAL           IMAG
    LAMBDA( 1)=  -.992063D-04   .000000D+00          SV( 1)=   .837543D-01
    LAMBDA( 2)=  -.992063D-04   .000000D+00          SV( 2)=   .460588D-03
    LAMBDA( 3)=  -.516666D-03   .000000D+00          SV( 3)=   .275364D-06
    LAMBDA( 4)=  -.207054D-03   .000000D+00          SV( 4)=   .991166D-04
    LAMBDA( 5)=  -.992063D-04   .000000D+00          SV( 5)=   .992063D-04

MATRIX U - ORTHONORMALIZED COLUMNS

 -.2059D+00  -.9764D+00   .4869D-01   .4346D-01  -.2501D-18
  .7320D-02   .4817D-01   .9988D+00  -.2120D-02  -.5667D-17
  .1100D-04   .6677D-04  -.6574D-08   .1552D-02  -.1000D+01
 -.6135D-02  -.4318D-01   .6909D-05  -.9990D+00  -.1553D-02
 -.9785D+00   .2061D+00  -.2773D-02  -.2897D-02  -.1500D-05

MATRIX V - ORTHOGONAL MATRIX

  .3244D-01  -.9984D+00  -.4442D-01   .9175D-02   .0000D+00
 -.9995D+00  -.3245D-01  -.2832D-03   .3084D-03  -.1690D-21
 -.1303D-07  -.1438D-04   .2368D-05  -.1553D-02   .1000D+01
  .7266D-05   .9300D-02  -.2489D-02   .1000D+01   .1553D-02
  .1159D-02  -.4438D-01   .9990D+00   .2900D-02   .1500D-05
```

APPENDIX C

GRAMMIAN ANALYSES

The singular value decomposition analyses of the dynamic model, or grammian analyses, for three forms of normalization discussed in Chapter IV (techniques 2, 3, and 4) are given in this appendix. The sixth character of the DATA FILE of each analysis indicates the run number, as given also in TABLE 4-2 on page 52.

The first set of five analysis results (pages 160-164) were done according to normalization technique 2. Likewise, normalization technique 3 was used for the analyses given on pages 165-169 and normalization technique 4 was used for the final set of analyses (pages 170-174).

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: GRAM03.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 11-JUL-79 16:20 48.7

GRAMMIAN MATRIX VALUES

.3025D+00	.1983D+00	.8195D+00	.4980D+00	.3241D+00	.1520D+00	.2848D+02	.3283D+01	-.1211D+02	.7359D+02
.1983D+00	.1300D+00	.5372D+00	.3264D+00	.2124D+00	.9965D-01	.1867D+02	.2152D+01	-.7938D+01	.4824D+02
.8195D+00	.5372D+00	.2220D+01	.1349D+01	.8780D+00	.4119D+00	.7715D+02	.8895D+01	-.3281D+02	.1994D+03
.4980D+00	.3264D+00	.1349D+01	.8198D+00	.5335D+00	.2503D+00	.4688D+02	.5405D+01	-.1994D+02	.1211D+03
.3241D+00	.2124D+00	.8780D+00	.5335D+00	.3472D+00	.1629D+00	.3051D+02	.3518D+01	-.1297D+02	.7884D+02
.1520D+00	.9965D-01	.4119D+00	.2503D+00	.1629D+00	.7640D-01	.1431D+02	.1650D+01	-.6086D+01	.3698D+02
.2848D+02	.1867D+02	.7715D+02	.4688D+02	.3051D+02	.1431D+02	.2681D+04	.3091D+03	-.1140D+04	.6928D+04
.3283D+01	.2152D+01	.8895D+01	.5405D+01	.3518D+01	.1650D+01	.3091D+03	.3564D+02	-.1314D+03	.7987D+03
-.1211D+02	-.7938D+01	-.3281D+02	-.1994D+02	-.1297D+02	-.6086D+01	-.1140D+04	-.1314D+03	.4848D+03	-.2946D+04
.7359D+02	.4824D+02	.1994D+03	.1211D+03	.7884D+02	.3698D+02	.6928D+04	.7987D+03	-.2946D+04	.1790D+05

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.52819222552710425 3D-15
SV(2)= 0.21107153111663930 6D+05
SV(3)= 0.42585177364467338 0D-14
SV(4)= 0.66337070551214288 2D-15
SV(5)= 0.22630682313702746 0D-15
SV(6)= 0.25926865611980760 1D-16
SV(7)= 0.12075126367206218 1D-16
SV(8)= 0.57057987002485071 4D-17
SV(9)= 0.55012120149815192 5D-17
SV(10)= 0.22574773761957116 0D-17

MATRIX U - ORTHONORMALIZED COLUMNS

.1025D-01	.3786D-02	-.2494D-01	-.7403D+00	-.6135D+00	.6265D-01	.1741D+00	-.6790D-01	.1266D+00	.1411D+00
-.1931D-02	.2481D-02	.6289D-02	.5324D+00	-.4042D+00	.1319D+00	.1116D+00	-.4707D+00	.7888D-01	.5436D+00
-.2515D-01	.1026D-01	-.2568D-01	-.7635D-01	-.8292D-01	.6586D+00	-.6585D+00	.4502D-01	-.3327D+00	.7603D-01
.5399D-02	.6232D-02	.3712D-03	-.1142D+00	-.2348D-01	-.2935D+00	.2817D-01	-.5620D+00	-.7313D+00	-.2207D+00
-.2321D-02	.4056D-02	-.2222D-01	.1834D+00	-.2352D+00	.3567D+00	.1035D+00	-.3020D+00	.3035D+00	-.7676D+00
.2491D-02	.1903D-02	.8173D-02	-.1586D+00	.1233D+00	-.3734D+00	-.6373D+00	-.4350D+00	.4735D+00	.2302D-01
-.9317D+00	.3564D+00	-.6359D-01	-.6615D-02	.2933D-02	-.2065D-01	.1922D-01	-.3238D-02	.8116D-02	.1540D-02
.2922D-01	.4109D-01	-.1388D+00	-.2944D+00	.6143D+00	.4284D+00	.3220D+00	-.4138D+00	.1248D+00	.2002D+00
-.1242D+00	-.1516D+00	.9687D+00	-.6315D-01	.6873D-01	.9029D-01	.4295D-01	-.6326D-01	.1568D-01	.1423D-01
.3390D+00	.9209D+00	.1907D+00	.8054D-02	-.1176D-01	-.3028D-02	-.7746D-02	.1638D-01	-.5207D-03	-.5254D-02

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.3786D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9394D-05	.2481D-02	.1299D-01	.7046D-03	.7480D-02	.1880D+00	-.1974D+00	.7507D+00	-.1285D+00	-.5877D+00
-.3882D-04	.1026D-01	.3644D-01	-.7266D-01	.2167D+00	.3748D+00	-.8130D+00	-.5464D-02	.6756D-01	.3747D+00
-.2359D-04	.6232D-02	.5960D-01	.1493D-01	.2340D-01	.7803D+00	.2985D+00	-.2245D+00	.4399D+00	-.2320D+00
-.1535D-04	.4056D-02	.2306D-01	.7369D-02	-.2740D-01	.1979D+00	-.1512D+00	-.5172D+00	-.7196D+00	-.3890D+00
-.7202D-05	.1903D-02	.9519D-02	.2228D-01	-.3453D-01	.4048D+00	.3851D+00	.3440D+00	-.5132D+00	.5517D+00
-.1349D-02	.3564D+00	-.3046D+00	-.7885D+00	-.3946D+00	.4705D-01	-.1879D-01	-.1761D-02	.1483D-01	.4669D-02
-.1556D-03	.4109D-01	.5079D+00	.2335D+00	-.8069D+00	.3421D-01	-.1628D+00	.7212D-02	.5312D-01	.6461D-01
.5737D-03	-.1516D+00	-.8013D+00	.4288D+00	-.3570D+00	.9318D-01	-.1139D+00	-.1032D-01	.3501D-01	.2484D-01
-.3486D-02	.9209D+00	-.3763D-01	.3659D+00	.1276D+00	-.1607D-01	.3221D-02	-.2139D-03	-.1502D-02	-.1046D-02

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: GRMA05.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 11-JUL-79 16:22 52.9

GRAMMIAN MATRIX VALUES

.6658D+00	-.3601D+00	.4327D+01	.2584D+01	.1175D+01	-.8743D+01	.3150D+02	.7041D+01	-.1215D+02	.6176D+02
-.3601D+00	.1948D+00	-.2341D+01	-.1398D+01	-.6355D+00	.4730D+01	-.1704D+02	-.3809D+01	.6571D+01	-.3341D+02
.4327D+01	-.2341D+01	.2813D+02	.1679D+02	.7636D+01	-.5683D+02	.2048D+03	.4576D+02	-.7896D+02	.4014D+03
.2584D+01	-.1398D+01	.1679D+02	.1003D+02	.4559D+01	-.3393D+02	.1223D+03	.2732D+02	-.4714D+02	.2396D+03
.1175D+01	-.6355D+00	.7636D+01	.4559D+01	.2073D+01	-.1543D+02	.5559D+02	.1242D+02	-.2144D+02	.1090D+03
-.8743D+01	.4730D+01	-.5683D+02	-.3393D+02	-.1543D+02	.1148D+03	-.4137D+03	-.9246D+02	.1595D+03	-.8110D+03
.3150D+02	-.1704D+02	.2048D+03	.1223D+03	.5559D+02	-.4137D+03	.1491D+04	.3332D+03	-.5748D+03	.2922D+04
.7041D+01	-.3809D+01	.4576D+02	.2732D+02	.1242D+02	-.9246D+02	.3332D+03	.7446D+02	-.1285D+03	.6531D+03
-.1215D+02	.6571D+01	-.7896D+02	-.4714D+02	-.2144D+02	.1595D+03	-.5748D+03	-.1285D+03	.2217D+03	-.1127D+04
.6176D+02	-.3341D+02	.4014D+03	.2396D+03	.1090D+03	-.8110D+03	.2922D+04	.6531D+03	-.1127D+04	.5728D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.91905728240445998 5D-15
SV(2)= 0.76709690574998751 2D+04
SV(3)= 0.14870608595715749 4D-13
SV(4)= 0.38936605683018750 4D-14
SV(5)= 0.10738480533730300 9D-14
SV(6)= 0.31014476581755160 8D-14
SV(7)= 0.20402802181439888 3D-15
SV(8)= 0.23861188857085845 7D-15
SV(9)= 0.76374143770535479 5D-16
SV(10)= 0.35053308825852794 3D-17

MATRIX U - ORTHONORMALIZED COLUMNS

.4195D-01	.9316D-02	.5930D-01	.4844D-01	.2785D+00	.2245D-01	.3352D+00	-.7897D-03	-.8518D+00	-.2761D+00
-.6711D-03	-.5039D-02	.2162D-01	-.1819D-01	.1847D-01	-.1106D-01	-.4131D-01	-.2754D-01	-.3169D+00	.9465D+00
.2099D-02	.6055D-01	-.4541D+00	.5947D+00	-.2196D+00	.3937D+00	.1547D+00	.4548D+00	-.1309D-01	.4662D-01
.3618D-01	.3615D-01	.1670D+00	-.5075D+00	-.6162D+00	.4949D+00	.2817D+00	.2563D-02	-.8845D-01	-.1280D-01
.4512D-01	.1644D-01	.9697D-01	-.1236D+00	-.1663D+00	.1904D-01	-.7967D+00	.4343D+00	-.3231D+00	-.1313D+00
-.1868D+00	-.1223D+00	-.2127D+00	.2066D+00	-.6510D+00	-.5360D+00	-.1481D-01	-.3100D+00	-.2234D+00	-.6998D-01
.6328D+00	.4408D+00	-.5333D+00	-.2868D+00	.6029D-02	-.1875D+00	-.1908D-02	-.5371D-01	-.2066D-01	-.1405D-02
.1795D+00	.9852D-01	.2829D-01	.3175D+00	-.3258D-02	.4836D+00	-.3589D+00	-.6960D+00	-.8224D-01	-.5164D-01
-.5449D+00	-.1700D+00	-.6352D+00	-.3780D+00	.2063D+00	.2022D+00	-.1374D+00	-.1425D+00	-.6647D-01	-.2811D-01
-.4799D+00	.8641D+00	.1363D+00	.4629D-01	-.1285D-01	-.4455D-01	.1444D-02	-.5570D-02	-.6684D-02	-.5697D-03

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.9316D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.4695D-04	-.5039D-02	.3712D-02	-.1787D-01	.3161D-02	.1904D-01	.4422D-01	-.1444D+00	.6108D+00	-.7768D+00
-.5641D-03	.6055D-01	-.6795D-01	.2793D-01	-.1596D+00	.8044D-01	-.3931D-01	-.7344D+00	-.5667D+00	-.3114D+00
-.3368D-03	.3615D-01	.2829D-01	.2746D+00	-.3406D+00	.3824D+00	.5545D+00	.4383D+00	-.2902D+00	-.2766D+00
-.1532D-03	.1644D-01	-.1594D-01	-.1489D-01	-.1151D+00	-.4079D+00	-.5472D+00	.4669D+00	-.3625D+00	-.4133D+00
.1140D-02	-.1223D+00	.1944D-01	-.8762D+00	-.3172D+00	-.1639D+00	.2910D+00	.3931D-01	-.5401D-01	-.1748D-01
-.4107D-02	.4408D+00	-.7651D+00	.5233D-01	.8303D-01	-.3605D+00	.2828D+00	.1906D-01	.1716D-01	.9831D-02
-.9179D-03	.9852D-01	-.1408D+00	.1605D+00	-.8464D+00	.3730D-01	-.2876D+00	-.9055D-01	.2934D+00	.2236D+00
.1584D-02	-.1700D+00	.3867D+00	.3371D+00	-.1460D+00	-.7228D+00	.3771D+00	-.1402D+00	.2287D-01	.4240D-01
-.8051D-02	.8641D+00	.4891D+00	-.1160D+00	.8137D-02	.4907D-03	-.5865D-02	.1985D-02	.1696D-01	.1208D-01

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: GRMA06.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 11-JUL-79 16:24 54.2

GRAMMIAN MATRIX VALUES

.2353D+00	.2100D+00	.2433D+01	.1285D+01	.6477D+00	-.3080D+00	.9789D+01	.2428D+01	-.1787D+01	.2287D+02
.2100D+00	.1874D+00	.2171D+01	.1147D+01	.5780D+00	-.2749D+00	.8737D+01	.2166D+01	-.1595D+01	.2041D+02
.2433D+01	.2171D+01	.2516D+02	.1329D+02	.6697D+01	-.3185D+01	.1012D+03	.2510D+02	-.1848D+02	.2364D+03
.1285D+01	.1147D+01	.1329D+02	.7020D+01	.3538D+01	-.1682D+01	.5347D+02	.1326D+02	-.9762D+01	.1249D+03
.6477D+00	.5780D+00	.6697D+01	.3538D+01	.1783D+01	-.8477D+00	.2694D+02	.6681D+01	-.4919D+01	.6293D+02
-.3080D+00	-.2749D+00	-.3185D+01	-.1682D+01	-.8477D+00	.4031D+00	-.1281D+02	-.3177D+01	.2339D+01	-.2993D+02
.9789D+01	.8737D+01	.1012D+03	.5347D+02	.2694D+02	-.1281D+02	.4073D+03	.1010D+03	-.7435D+02	.9513D+03
.2428D+01	.2166D+01	.2510D+02	.1326D+02	.6681D+01	-.3177D+01	.1010D+03	.2504D+02	-.1844D+02	.2359D+03
-.1787D+01	-.1595D+01	-.1848D+02	-.9762D+01	-.4919D+01	.2339D+01	-.7435D+02	-.1844D+02	.1358D+02	-.1737D+03
.2287D+02	.2041D+02	.2364D+03	.1249D+03	.6293D+02	-.2993D+02	.9513D+03	.2359D+03	-.1737D+03	.2222D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.321555228845165193D-16
SV(2)= 0.270256577190275315D+04
SV(3)= 0.306568932105981443D-14
SV(4)= 0.344413570769409231D-15
SV(5)= 0.325677039605329972D-15
SV(6)= 0.196726577570881233D-15
SV(7)= 0.133384328595727645D-16
SV(8)= 0.120274124836701158D-15
SV(9)= 0.117551791256372672D-16
SV(10)= 0.978175140253688254D-17

MATRIX U - ORTHONORMALIZED COLUMNS

.3837D-02	-.9331D-02	-.1445D+00	.3429D-01	.1912D-01	-.1233D+00	.4214D+00	-.2044D+00	-.2021D+00	.8379D+00
.1774D+00	-.8328D-02	-.2040D+00	-.3295D+00	-.6614D+00	.5452D+00	-.2067D+00	-.1201D+00	.4145D-01	.1573D+00
.3927D+00	-.9649D-01	-.3580D+00	.7482D+00	-.1108D+00	.1038D+00	-.4976D-01	.3492D+00	-.4086D-02	.3178D-01
-.9882D-01	-.5097D-01	-.1400D+00	-.2060D+00	-.2803D+00	-.1941D-01	.7537D+00	.4449D+00	-.5191D-02	-.2841D+00
-.3039D-01	-.2568D-01	.9798D-01	.1972D+00	.3290D-01	.1684D+00	.2728D+00	-.2887D+00	.8726D+00	.3561D-01
-.1305D+00	.1221D-01	.1833D+00	-.1860D+00	-.4764D-01	-.1706D+00	-.3028D+00	.6946D+00	.3591D+00	.4243D+00
-.8017D+00	-.3982D+00	-.3653D+00	.1883D+00	-.9641D-01	.4740D-01	-.1532D+00	-.5025D-01	-.1508D-01	-.1028D-02
.1290D+00	-.9626D-01	-.5351D-01	.2947D-01	-.5352D+00	-.7705D+00	-.1035D+00	-.2356D+00	.1279D+00	-.8777D-01
-.2300D+00	.7087D-01	.7336D+00	.4030D+00	-.4032D+00	.1428D+00	.8868D-01	.2448D-02	-.2204D+00	.4491D-01
.2727D+00	-.9067D+00	.2684D+00	-.1257D+00	.9843D-01	.5191D-01	.3220D-01	.5287D-02	-.4181D-01	.2049D-01

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	-.9331D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.7771D-04	-.8328D-02	-.2111D-02	-.1246D+00	-.1147D+00	.1952D+00	-.3683D+00	.2917D-01	.6597D+00	-.6012D+00
-.9004D-03	-.9649D-01	-.1093D+00	.6457D+00	.1146D+00	.6916D+00	.1585D+00	-.1979D+00	.6730D-01	.3777D-01
-.4756D-03	-.5097D-01	.1960D+00	-.5184D+00	.3091D+00	.4576D+00	.4632D+00	.4050D+00	.7931D-01	.1999D-01
-.2397D-03	-.2568D-01	-.2925D-01	.2420D+00	.4353D-01	-.3482D+00	.6390D+00	-.5515D-02	-.6647D-01	-.6357D+00
.1140D-03	.1221D-01	.3922D-02	.1949D+00	.4264D+00	-.3727D+00	.1620D+00	.7707D-02	.6750D+00	.3990D+00
-.3622D-02	-.3882D+00	.8921D+00	.1755D+00	.1031D-01	-.6189D-01	-.1143D+00	-.5314D-01	-.4133D-01	-.3408D-01
-.8983D-03	-.9626D-01	.2208D-01	-.4064D+00	.9132D-02	.5853D-01	.2115D+00	-.8765D+00	.8841D-01	.2766D-01
.6614D-03	.7087D-01	-.5317D-01	-.2049D-01	.8325D+00	-.2565D-01	-.3593D+00	-.1170D+00	-.2896D+00	-.2671D+00
-.8461D-02	-.9067D+00	-.3869D+00	-.7628D-01	.3569D-01	-.7799D-01	-.5702D-01	.1050D+00	-.2103D-01	.1454D-01

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: GRAM07.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 11-JUL-79 16:27 18.9

GRAMMIAN MATRIX VALUES

.2363D+00	.2096D+00	.2580D+01	.1330D+01	.6510D+00	.2122D+00	.1036D+02	.2467D+01	-.1973D+01	.2472D+02
.2096D+00	.1860D+00	.2289D+01	.1180D+01	.5775D+00	.1883D+00	.9190D+01	.2188D+01	-.1750D+01	.2193D+02
.2580D+01	.2289D+01	.2818D+02	.1453D+02	.7109D+01	.2318D+01	.1131D+03	.2694D+02	-.2155D+02	.2699D+03
.1330D+01	.1180D+01	.1453D+02	.7489D+01	.3665D+01	.1195D+01	.5832D+02	.1389D+02	-.1111D+02	.1392D+03
.6510D+00	.5775D+00	.7109D+01	.3665D+01	.1794D+01	.5847D+00	.2854D+02	.6796D+01	-.5436D+01	.6810D+02
.2122D+00	.1883D+00	.2318D+01	.1195D+01	.5847D+00	.1906D+00	.9305D+01	.2216D+01	-.1772D+01	.2220D+02
.1036D+02	.9190D+01	.1131D+03	.5832D+02	.2854D+02	.9305D+01	.4542D+03	.1081D+03	-.8650D+02	.1084D+04
.2467D+01	.2188D+01	.2694D+02	.1389D+02	.6796D+01	.2216D+01	.1081D+03	.2575D+02	-.2060D+02	.2580D+03
-.1973D+01	-.1750D+01	-.2155D+02	-.1111D+02	-.5436D+01	-.1772D+01	-.8650D+02	-.2060D+02	.1648D+02	-.2064D+03
.2472D+02	.2193D+02	.2699D+03	.1392D+03	.6810D+02	.2220D+02	.1084D+04	.2580D+03	-.2064D+03	.2586D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)=	0.26043002491433466 4D-15
SV(2)=	0.31203653531937802 7D+04
SV(3)=	0.29568027952686628 8D-14
SV(4)=	0.11097850482220186 8D-14
SV(5)=	0.20883970237025930 5D-15
SV(6)=	0.18546508413017019 9D-15
SV(7)=	0.45503561798813874 0D-16
SV(8)=	0.57108700905775612 3D-17
SV(9)=	0.18615991840682032 6D-16
SV(10)=	0.15972340045007889 3D-16

MATRIX U - ORTHONORMALIZED COLUMNS

.1204D-01	.8702D-02	.8519D-02	.6446D-01	-.2068D+00	.1360D+00	.1680D+00	-.4398D+00	-.4111D+00	.7373D+00
-.1461D-01	.7720D-02	-.1023D+00	-.7839D-01	.2890D+00	-.1588D+00	-.3687D-01	.7776D+00	-.2103D+00	.4735D+00
-.3880D-01	.9502D-01	-.3619D+00	-.8401D+00	-.1257D+00	.3232D+00	.2147D-01	-.1318D-01	.1671D+00	.6266D-01
-.3736D-01	.4899D-01	-.1751D+00	-.2191D+00	.6599D+00	-.4600D+00	.3233D+00	-.3602D+00	-.1674D+00	-.9074D-01
.4545D-01	.2398D-01	.4333D-01	-.1735D+00	-.7310D-01	.9821D-01	-.3051D+00	.3822D-01	-.8350D+00	-.3982D+00
.1544D-01	.7816D-02	-.1002D-01	-.6911D-01	.1957D+00	-.2009D+00	-.8740D+00	-.2610D+00	.1692D+00	.2355D+00
.8775D+00	.3815D+00	-.2391D+00	.1310D+00	.5776D-01	.7689D-01	.7674D-02	.2841D-02	.2575D-01	-.1120D-01
.1778D+00	.9084D-01	.8256D+00	-.2726D+00	.3299D+00	.2888D+00	.5557D-01	-.3131D-02	.6294D-01	.7015D-01
-.1900D+00	-.7266D-01	-.2921D+00	.3148D+00	.5150D+00	.7077D+00	-.6993D-01	-.4721D-01	-.1787D-01	-.2847D-01
-.3959D+00	.9103D+00	.4145D-01	.1021D+00	-.3864D-01	-.1435D-01	-.1974D-01	.1496D-01	-.6741D-03	-.8832D-02

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.8702D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.6718D-04	.7720D-02	.2210D-02	-.2120D-01	.7027D-01	-.3118D+00	-.2675D+00	-.4828D-02	.8391D+00	-.3487D+00
-.8269D-03	.9502D-01	.7481D-02	-.6310D+00	.5037D+00	.2251D+00	-.5104D+00	.3652D-01	-.7862D-01	.1426D+00
-.4263D-03	.4899D-01	.3386D-02	-.1109D+00	-.4688D-01	-.7645D+00	-.2473D+00	-.3044D+00	-.4497D+00	-.2063D+00
-.2086D-03	.2398D-01	-.2259D-01	-.1167D+00	-.1642D-01	.4390D+00	.1020D+00	-.4455D+00	-.1220D+00	-.7540D+00
-.6801D-04	.7816D-02	-.1497D-01	-.2677D-01	-.2393D-01	.4131D-01	.7012D-01	-.8323D+00	.2387D+00	.4921D+00
-.3320D-02	.3815D+00	-.9167D+00	.1034D+00	.7239D-02	.1310D-01	-.5139D-01	.1940D-01	-.4910D-02	.1344D-01
-.7905D-03	.9084D-01	-.2069D-01	-.5362D+00	-.8205D+00	.6409D-01	-.8979D-01	.9537D-01	.7545D-01	.6096D-01
.6323D-03	-.7266D-01	.7119D-01	.5105D+00	-.2549D+00	.2620D+00	-.7613D+00	-.7247D-01	-.9844D-01	.3035D-01
-.7922D-02	.9103D+00	.3917D+00	.1262D+00	.8472D-02	.1740D-01	.3530D-01	.8061D-02	.1313D-01	.5510D-02

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: GRMA08.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 11-JUL-79 16:30 22.5

GRAMMIAN MATRIX VALUES

.4120D+01	-.1020D+03	.2230D+02	.1083D+02	.2643D+01	-.9364D+02	.3499D+03	.5639D+02	-.7870D+02	.9993D+03
-.1020D+03	.2523D+04	-.5520D+03	-.2680D+03	-.6540D+02	.2317D+04	-.8660D+04	-.1395D+04	.1948D+04	-.2473D+05
.2230D+02	-.5520D+03	.1207D+03	.5862D+02	.1431D+02	-.5069D+03	.1894D+04	.3053D+03	-.4261D+03	.5410D+04
.1083D+02	-.2680D+03	.5862D+02	.2846D+02	.6945D+01	-.2461D+03	.9197D+03	.1482D+03	-.2068D+03	.2626D+04
.2643D+01	-.6540D+02	.1431D+02	.6945D+01	.1695D+01	-.6006D+02	.2244D+03	.3617D+02	-.5048D+02	.6409D+03
-.9364D+02	.2317D+04	-.5069D+03	-.2461D+03	-.6006D+02	.2128D+04	-.7953D+04	-.1282D+04	.1789D+04	-.2271D+05
.3499D+03	-.8660D+04	.1894D+04	.9197D+03	.2244D+03	-.7953D+04	.2972D+05	.4789D+04	-.6684D+04	.8487D+05
.5639D+02	-.1395D+04	.3053D+03	.1482D+03	.3617D+02	-.1282D+04	.4789D+04	.7717D+03	-.1077D+04	.1368D+05
-.7870D+02	.1948D+04	-.4261D+03	-.2068D+03	-.5048D+02	.1789D+04	-.6684D+04	-.1077D+04	.1503D+04	-.1909D+05
.9993D+03	-.2473D+05	.5410D+04	.2626D+04	.6409D+03	-.2271D+05	.8487D+05	.1368D+05	-.1909D+05	.2423D+06

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)=	0.92759778947532317 7D-14
SV(2)=	0.27914833069594890 9D+06
SV(3)=	0.13961436723967797 9D-12
SV(4)=	0.33122958506129740 0D-13
SV(5)=	0.31071457695506932 6D-13
SV(6)=	0.14975181473107238 0D-13
SV(7)=	0.20556985915797218 9D-13
SV(8)=	0.85213836145874224 5D-15
SV(9)=	0.68222447011800495 6D-15
SV(10)=	0.16950946975159406 5D-17

MATRIX U - ORTHONORMALIZED COLUMNS

.1430D-02	.3842D-02	-.1304D+00	.6847D-01	-.9620D-02	-.7628D-01	.8994D-01	-.5983D+00	-.7653D+00	.1435D+00
-.7562D-01	-.9507D-01	-.1781D+00	-.5928D+00	-.7734D+00	-.5490D-02	-.5448D-01	-.1418D-01	-.3122D-02	.2789D-01
-.3668D-01	.2080D-01	-.3122D+00	.3098D+00	-.1717D+00	.7154D+00	.1338D+00	-.3698D+00	.3261D+00	.5043D-01
.1033D-01	.1010D-01	.5207D-01	-.1167D+00	.7718D-01	-.4859D+00	.7111D-01	-.6597D+00	.5186D+00	-.1796D+00
.1110D-02	.2464D-02	-.3651D-01	.2085D-01	-.4475D-01	.1233D+00	.2010D-01	.1228D-01	-.1930D+00	-.9712D+00
-.2661D+00	-.8732D-01	-.6513D+00	-.4185D+00	.5214D+00	.5842D-01	-.2146D+00	.2511D-01	.1381D-01	-.8502D-02
.8888D+00	.3263D+00	-.1973D+00	-.1595D+00	.5351D-01	.5355D-01	-.1820D+00	-.1581D-01	.8480D-02	.4518D-02
-.5002D-01	.5258D-01	-.5220D+00	.5714D+00	-.2979D+00	-.4337D+00	-.3113D+00	.1424D+00	.3542D-01	-.2103D-01
-.9285D-01	-.7339D-01	.3337D+00	.1628D-01	-.6176D-02	.1909D+00	-.8883D+00	-.2206D+00	-.8236D-02	-.7513D-02
-.3477D+00	.9318D+00	.5267D-01	-.8081D-01	-.2932D-01	.1496D-01	-.1854D-01	-.1129D-02	-.1387D-01	.3859D-02

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.3842D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3653D-03	-.9507D-01	.1183D+00	-.8151D-01	-.2706D+00	-.9171D+00	-.2323D+00	-.3541D-01	-.1736D-01	-.2163D-01
-.7990D-04	.2080D-01	.2580D-01	.1051D-01	-.1006D+00	-.2401D-01	.3231D+00	-.9194D-01	-.8748D+00	-.3317D+00
-.3879D-04	.1010D-01	.1177D-01	.7633D-01	-.1120D+00	-.4453D-01	.1238D+00	.9176D+00	-.1540D+00	.3135D+00
-.9467D-05	.2464D-02	-.1160D-02	.8133D-02	-.1494D-01	-.5055D-03	.8585D-02	-.3560D+00	-.2939D+00	.8869D+00
.3355D-03	-.8732D-01	.1460D+00	.6331D+00	.2341D+00	.7538D-01	-.6654D+00	.4677D-01	-.2478D+00	-.5827D-01
-.1254D-02	.3263D+00	-.9179D+00	.9817D-01	.3905D-01	-.1389D+00	-.1279D+00	.1090D-01	-.6079D-01	-.1696D-01
-.2020D-03	.5258D-01	-.1891D-01	-.4742D+00	-.5620D+00	.343				

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NORM03.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 13-JUL-79 11:11 23.8

GRAMMIAN MATRIX VALUES

.4480D+04	.1669D+04	.4560D+04	.4830D+04	.5350D+04	.2210D+04	.5036D+04	.6018D+04	.6404D+04	.2296D+04
.1669D+04	.6217D+03	.1699D+04	.1799D+04	.1993D+04	.8233D+03	.1876D+04	.2242D+04	.2385D+04	.8552D+03
.4560D+04	.1699D+04	.4642D+04	.4916D+04	.5446D+04	.2250D+04	.5126D+04	.6126D+04	.6518D+04	.2337D+04
.4830D+04	.1799D+04	.4916D+04	.5207D+04	.5768D+04	.2383D+04	.5429D+04	.6488D+04	.6903D+04	.2475D+04
.5350D+04	.1993D+04	.5446D+04	.5768D+04	.6389D+04	.2639D+04	.6014D+04	.7187D+04	.7647D+04	.2741D+04
.2210D+04	.8233D+03	.2250D+04	.2383D+04	.2639D+04	.1090D+04	.2484D+04	.2969D+04	.3159D+04	.1132D+04
.5036D+04	.1876D+04	.5126D+04	.5429D+04	.6014D+04	.2484D+04	.5661D+04	.6764D+04	.7198D+04	.2580D+04
.6018D+04	.2242D+04	.6126D+04	.6488D+04	.7187D+04	.2969D+04	.6764D+04	.8083D+04	.8601D+04	.3084D+04
.6404D+04	.2385D+04	.6518D+04	.6903D+04	.7647D+04	.3159D+04	.7198D+04	.8601D+04	.9152D+04	.3281D+04
.2296D+04	.8552D+03	.2337D+04	.2475D+04	.2741D+04	.1132D+04	.2580D+04	.3084D+04	.3281D+04	.1176D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.8613241973401503110-13
SV(2)= 0.4650302302253422830+05
SV(3)= 0.9108027871040696280-13
SV(4)= 0.7672726603301140510-13
SV(5)= 0.5117297439627882980-13
SV(6)= 0.7540460760846262670-13
SV(7)= 0.3125248235213901160-13
SV(8)= 0.1175831374841313980-13
SV(9)= 0.1561689640375304730-13
SV(10)= 0.3647653629816392800-14

MATRIX U - ORTHONORMALIZED COLUMNS

-.5892D+00	-.3104D+00	.2672D+00	-.2615D+00	-.4617D+00	.1073D+00	.1192D+00	.1793D+00	-.3816D+00	.8405D-02
-.2019D-01	-.1156D+00	.8022D-02	-.1301D+00	-.4617D+00	-.1806D+00	.1793D+00	-.4868D+00	.5633D+00	.3703D+00
-.3304D+00	-.3159D+00	-.2053D+00	-.2207D+00	.5447D+00	.4461D+00	-.7991D-01	-.2376D-01	.2133D+00	.3899D+00
.2272D+00	-.3346D+00	-.3764D+00	-.5322D+00	.1522D+00	-.2840D+00	.2660D+00	-.2800D+00	-.2958D+00	-.2665D+00
-.2927D+00	-.3707D+00	-.3834D+00	.3577D+00	.1873D-01	-.5251D+00	-.9071D-02	.3945D+00	.2501D+00	-.8775D-01
.1657D+00	-.1531D+00	-.1335D+00	-.9502D-01	-.1887D+00	-.1716D+00	-.8252D+00	-.6580D-01	-.2611D+00	.3220D+00
.3607D+00	-.3489D+00	-.3623D+00	.1991D+00	-.4096D+00	.5932D+00	.3900D-01	.1323D+00	.6950D-01	-.1837D+00
.5110D-01	-.4169D+00	.2450D+00	.6010D+00	.1737D+00	-.2817D-01	.1555D+00	-.4423D+00	-.3537D+00	.1626D+00
.4273D+00	-.4436D+00	.5917D+00	-.2121D+00	.1277D+00	-.1045D+00	-.1068D-01	.3695D+00	.2476D+00	.2000D-01
-.2517D+00	-.1590D+00	.1964D+00	.5612D-03	.5931D-01	.8607D-01	-.4118D+00	-.3772D+00	.2866D+00	-.6840D+00

MATRIX V - ORTHOGONAL MATRIX

.9506D+00	-.3104D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3775D-01	-.1156D+00	-.1101D+00	-.2059D+00	-.2674D+00	-.1411D+00	.2129D+00	.1641D+00	-.8179D-01	.8720D+00
-.1032D+00	-.3159D+00	-.6088D+00	.2429D+00	-.1180D+00	.2808D+00	.4075D+00	-.8091D-01	-.4033D+00	-.1787D+00
-.1093D+00	-.3346D+00	-.2962D+00	-.2452D+00	-.1627D+00	-.4432D+00	-.1203D+00	.5758D+00	.2346D+00	-.3230D+00
-.1210D+00	-.3707D+00	-.2154D+00	-.3066D+00	.7773D+00	.4183D-01	-.1935D+00	-.1811D+00	.2678D-01	.1750D+00
-.4999D-01	-.1531D+00	-.1150D+00	-.3419D+00	-.4638D+00	-.1807D+00	-.3850D+00	-.6549D+00	-.1110D+00	-.8233D-01
-.1139D+00	-.3489D+00	.2745D+00	.5898D+00	.1092D+00	-.5872D+00	-.4667D-01	-.1200D+00	-.2522D+00	.7153D-01
-.1361D+00	-.4169D+00	.1226D+00	.3051D+00	-.2203D+00	.5431D+00	-.5162D+00	.1876D+00	.1753D+00	.1538D+00
-.1449D+00	-.4436D+00	.6086D+00	-.3826D+00	-.7178D-01	.1679D+00	.4295D+00	.1972D-02	-.1093D+00	-.1889D+00
-.5193D-01	-.1590D+00	-.9600D-01	.2004D+00	-.5587D-01	-.4997D-01	.3679D+00	-.3518D+00	.8101D+00	.3903D-01

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NORM05.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 13-JUL-79 11:20 41.4

GRAMMIAN MATRIX VALUES

.4354D+04	.1685D+04	.4417D+04	.4720D+04	.5263D+04	.2663D+04	.5106D+04	.5916D+04	.6286D+04	.3341D+04
.1685D+04	.6520D+03	.1709D+04	.1827D+04	.2037D+04	.1031D+04	.1976D+04	.2289D+04	.2433D+04	.1293D+04
.4417D+04	.1709D+04	.4480D+04	.4788D+04	.5339D+04	.2701D+04	.5180D+04	.6001D+04	.6377D+04	.3389D+04
.4720D+04	.1827D+04	.4788D+04	.5118D+04	.5706D+04	.2887D+04	.5536D+04	.6414D+04	.6815D+04	.3622D+04
.5263D+04	.2037D+04	.5339D+04	.5706D+04	.6362D+04	.3219D+04	.6172D+04	.7151D+04	.7599D+04	.4038D+04
.2663D+04	.1031D+04	.2701D+04	.2887D+04	.3219D+04	.1629D+04	.3123D+04	.3618D+04	.3845D+04	.2043D+04
.5106D+04	.1976D+04	.5180D+04	.5536D+04	.6172D+04	.3123D+04	.5988D+04	.6938D+04	.7373D+04	.3918D+04
.5916D+04	.2289D+04	.6001D+04	.6414D+04	.7151D+04	.3618D+04	.6938D+04	.8038D+04	.8541D+04	.4539D+04
.6286D+04	.2433D+04	.6377D+04	.6815D+04	.7599D+04	.3845D+04	.7373D+04	.8541D+04	.9077D+04	.4823D+04
.3341D+04	.1293D+04	.3389D+04	.3622D+04	.4038D+04	.2043D+04	.3918D+04	.4539D+04	.4823D+04	.2563D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.32477046128664026lD-12
SV(2)= 0.48260718459633152OD+05
SV(3)= 0.26929133357390315lD-12
SV(4)= 0.13701779331500887 3D-12
SV(5)= 0.24156317686804122lD-12
SV(6)= 0.76567871146151543 7D-13
SV(7)= 0.11044609343967171 9D-12
SV(8)= 0.61866166225732665 7D-13
SV(9)= 0.71636731794994959 2D-13
SV(10)= 0.34979520015064842 2D-13

MATRIX U - ORTHONORMALIZED COLUMNS

-.3101D+00	-.3004D+00	-.8196D-01	.1861D+00	-.4608D+00	-.1572D+00	-.1080D+00	-.4446D+00	.3833D+00	-.4230D+00
-.2594D-01	-.1162D+00	.1630D+00	.1275D+00	.9324D-01	-.3565D+00	.1164D+00	.6768D-01	.6296D+00	.6266D+00
.4050D+00	-.3647D+00	.2452D-01	-.6041D+00	-.2798D+00	-.3675D+00	-.3245D+00	-.1110D+00	-.1612D+00	.1436D+00
.1747D+00	-.3256D+00	.7353D-01	-.2680D-01	-.8165D-01	.5915D+00	-.3934D+00	.4429D+00	.3799D+00	-.7468D-01
-.2695D+00	-.3631D+00	.3997D+00	.2500D+00	-.4252D+00	.1552D+00	.1252D+00	.7562D-01	-.4683D+00	.3574D+00
-.9250D-01	-.1837D+00	-.1395D-01	-.1756D+00	-.1307D+00	-.3432D+00	.4754D+00	.6510D+00	.4131D-01	-.3745D+00
-.9833D-01	-.3523D+00	-.4714D+00	.4165D+00	.2846D+00	-.3215D+00	-.4132D+00	.2226D+00	-.2521D+00	.4930D-01
.1989D+00	-.4081D+00	.5715D+00	.1004D+00	.5467D+00	-.8653D-01	.6622D-01	-.2114D+00	-.3977D-01	-.3166D+00
-.3850D+00	-.4337D+00	-.3535D+00	-.4543D+00	.3020D+00	.2974D+00	.2874D+00	-.2030D+00	.1123D-01	.1695D+00
.6558D+00	-.2305D+00	-.3563D+00	.3165D+00	-.1586D+00	.1489D+00	.4640D+00	-.1558D+00	-.1197D-02	.5283D-01

MATRIX V - ORTHOGONAL MATRIX

.9538D+00	-.3004D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3660D-01	-.1162D+00	-.1520D-01	-.1058D+00	.4506D-01	-.3041D+00	.3656D+00	-.6186D+00	.5969D+00	.8102D-01
-.9594D-01	-.3047D+00	.3340D+00	-.4476D+00	-.4709D+00	.5006D+00	.1510D+00	-.1005D+00	-.3437D-02	-.2841D+00
-.1025D+00	-.3256D+00	.1490D+00	.1043D+00	.3625D+00	-.1486D+00	-.2442D+00	.2353D+00	.3359D+00	-.6849D+00
-.1143D+00	-.3631D+00	-.3920D+00	-.4778D+00	-.3807D-01	-.3024D+00	-.5131D+00	-.2249D+00	-.2505D+00	.6000D-01
-.5785D-01	-.1837D+00	-.1311D+00	-.3137D+00	-.1742D+00	-.2549D+00	.2679D+00	.7070D+00	.3150D+00	.2847D+00
-.1109D+00	-.3523D+00	-.5251D+00	.1103D+00	.2839D+00	.2092D+00	.5672D+00	-.8827D-02	-.3177D+00	-.1695D+00
-.1285D+00	-.4081D+00	.6194D+00	.1242D+00	.1389D+00	-.3669D+00	.1768D+00	-.2541D-01	-.4149D+00	.2447D+00
-.1366D+00	-.4337D+00	-.1647D+00	.6431D+00	-.4878D+00	.9098D-01	-.2117D+00	-.2446D-01	.1818D+00	.1671D+00
-.7257D-01	-.2305D+00	.9329D-01	-.9821D-01	.5247D+00	.5400D+00	-.2259D+00	.7605D-02	.2507D+00	.4924D+00

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NORM06.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 13-JUL-79   11:23 34.7

GRAMMIAN MATRIX VALUES

.9522D+04	.1384D+03	.9640D+04	.9557D+04	.9474D+04	.1375D+03	.9482D+04	.9481D+04	.9466D+04	.9463D+04
.1384D+03	.2011D+01	.1401D+03	.1389D+03	.1377D+03	.1998D+01	.1378D+03	.1378D+03	.1376D+03	.1375D+03
.9640D+04	.1401D+03	.9758D+04	.9674D+04	.9591D+04	.1392D+03	.9599D+04	.9598D+04	.9583D+04	.9580D+04
.9557D+04	.1389D+03	.9674D+04	.9591D+04	.9508D+04	.1380D+03	.9516D+04	.9515D+04	.9500D+04	.9497D+04
.9474D+04	.1377D+03	.9591D+04	.9508D+04	.9426D+04	.1368D+03	.9434D+04	.9433D+04	.9418D+04	.9415D+04
.1375D+03	.1998D+01	.1392D+03	.1380D+03	.1368D+03	.1984D+01	.1369D+03	.1369D+03	.1367D+03	.1366D+03
.9482D+04	.1378D+03	.9599D+04	.9516D+04	.9434D+04	.1369D+03	.9442D+04	.9441D+04	.9426D+04	.9423D+04
.9481D+04	.1378D+03	.9598D+04	.9515D+04	.9433D+04	.1369D+03	.9441D+04	.9440D+04	.9425D+04	.9422D+04
.9466D+04	.1376D+03	.9583D+04	.9500D+04	.9418D+04	.1367D+03	.9426D+04	.9425D+04	.9411D+04	.9407D+04
.9463D+04	.1375D+03	.9580D+04	.9497D+04	.9415D+04	.1366D+03	.9423D+04	.9422D+04	.9407D+04	.9404D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.31176575243071501 2D-12
SV(2)= 0.75998125172327212 4D+05
SV(3)= 0.33548168392971203 5D-12
SV(4)= 0.19876932669333043 7D-12
SV(5)= 0.34690721948475856 5D-12
SV(6)= 0.96882381316085479 5D-13
SV(7)= 0.15314052573380685 6D-12
SV(8)= 0.11514764240291330 7D-12
SV(9)= 0.30767070867141114 3D-15
SV(10)= 0.70055156773675646 7D-16

MATRIX U - ORTHONORMALIZED COLUMNS

-.7656D+00	-.3540D+00	-.1827D+00	.2875D+00	-.1093D+00	.2042D+00	.2825D+00	-.1961D+00	.2373D-01	-.7124D-02
-.1224D-02	-.5144D-02	-.2898D-02	.1160D-02	-.2115D-02	-.1886D-01	-.3127D-01	.5990D-01	.6367D+00	-.7679D+00
.2514D+00	-.3583D+00	-.3650D+00	-.5698D+00	.2600D+00	.4820D-01	.4641D+00	-.2504D+00	.5046D-01	.4031D-02
.6316D-01	-.3552D+00	.7128D+00	-.1565D+00	.5293D-02	.5246D+00	.1204D+00	.2179D+00	-.2848D-02	-.3811D-02
.1127D+00	-.3522D+00	-.4118D+00	.1167D+00	-.1189D+00	.5946D-02	-.8449D-03	.8121D+00	-.7931D-01	.1714D-02
-.2739D-02	-.5110D-02	-.1229D-02	.1616D-01	-.9458D-02	-.8791D-02	-.2981D-01	.6714D-01	.7642D+00	.6404D+00
.2417D+00	-.3525D+00	.1065D+00	.5840D+00	.6427D+00	-.1929D+00	-.7758D-02	-.1205D+00	.3192D-02	-.1011D-02
.3672D+00	-.3524D+00	.1238D+00	.2216D+00	-.6935D+00	-.3049D+00	.1710D+00	-.2704D+00	.1597D-01	-.3773D-02
-.3638D+00	-.3519D+00	.2625D+00	-.3977D+00	.8272D-01	-.6493D+00	-.2773D+00	.1017D+00	-.3035D-01	.1113D-01
.9152D-01	-.3518D+00	-.2452D+00	-.7733D-01	-.7294D-01	.3584D+00	-.7630D+00	-.2928D+00	-.2254D-02	.7826D-03

MATRIX V - ORTHOGONAL MATRIX

.9353D+00	-.3540D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1947D-02	-.5144D-02	.2074D-02	-.3231D-02	.6544D-02	.5047D-02	-.7469D-02	.5238D-02	.9930D+00	-.1173D+00
-.1356D+00	-.3583D+00	-.1988D+00	.4367D-01	.4562D-01	-.5680D+00	-.6079D+00	.3429D+00	-.5348D-02	.9672D-04
-.1345D+00	-.3552D+00	.6658D-01	-.2463D-01	-.7035D+00	-.3543D+00	.2710D+00	-.3955D+00	.6187D-02	-.1737D-01
-.1333D+00	-.3522D+00	-.8345D-01	-.1918D+00	.5065D+00	-.2940D+00	.6634D+00	.1768D+00	-.1677D-02	-.1147D-01
-.1934D-02	-.5110D-02	-.3865D-02	.5522D-02	-.3985D-02	-.1507D-01	.1381D-01	-.7444D-02	.1175D+00	.9928D+00
-.1334D+00	-.3525D+00	-.6803D+00	-.3427D+00	-.1019D+00	.5074D+00	-.7993D-01	-.5954D-01	-.3322D-02	.5536D-02
-.1334D+00	-.3524D+00	.9042D-02	.8059D+00	-.8376D-01	.3163D+00	.1493D+00	.2812D+00	-.1123D-02	-.1891D-02
-.1332D+00	-.3519D+00	.6567D+00	-.4208D+00	-.1202D+00	.3157D+00	-.1141D+00	.3504D+00	-.6905D-02	.1217D-01
-.1331D+00	-.3518D+00	.2344D+00	.1292D+00	.4631D+00	.8988D-01	-.2740D+00	-.6994D+00	-.3987D-02	.3876D-03

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NORM07.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 13-JUL-79 11:06 14.9

GRAMMIAN MATRIX VALUES

.9522D+04	.1385D+03	.9639D+04	.9556D+04	.9474D+04	.3371D+02	.9479D+04	.9481D+04	.9467D+04	.9455D+04
.1385D+03	.2016D+01	.1402D+03	.1390D+03	.1378D+03	.4905D+00	.1379D+03	.1379D+03	.1377D+03	.1376D+03
.9639D+04	.1402D+03	.9758D+04	.9674D+04	.9590D+04	.3413D+02	.9596D+04	.9597D+04	.9584D+04	.9572D+04
.9556D+04	.1390D+03	.9674D+04	.9590D+04	.9508D+04	.3384D+02	.9513D+04	.9515D+04	.9501D+04	.9489D+04
.9474D+04	.1378D+03	.9590D+04	.9508D+04	.9426D+04	.3354D+02	.9431D+04	.9433D+04	.9419D+04	.9408D+04
.3371D+02	.4905D+00	.3413D+02	.3384D+02	.3354D+02	.1194D+00	.3356D+02	.3357D+02	.3352D+02	.3348D+02
.9479D+04	.1379D+03	.9596D+04	.9513D+04	.9431D+04	.3356D+02	.9437D+04	.9438D+04	.9425D+04	.9413D+04
.9481D+04	.1379D+03	.9597D+04	.9515D+04	.9433D+04	.3357D+02	.9438D+04	.9440D+04	.9426D+04	.9414D+04
.9467D+04	.1377D+03	.9584D+04	.9501D+04	.9419D+04	.3352D+02	.9425D+04	.9426D+04	.9413D+04	.9401D+04
.9455D+04	.1376D+03	.9572D+04	.9489D+04	.9408D+04	.3348D+02	.9413D+04	.9414D+04	.9401D+04	.9389D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.197359495965125139D-12
SV(2)= 0.759765132477834408D+05
SV(3)= 0.521316858382380613D-13
SV(4)= 0.115479608411434804D-12
SV(5)= 0.106399682680523194D-12
SV(6)= 0.448952291870176315D-13
SV(7)= 0.451442456187554653D-13
SV(8)= 0.822658632112234239D-13
SV(9)= 0.410049876693856349D-16
SV(10)= 0.822505977484516012D-18

MATRIX U - ORTHONORMALIZED COLUMNS

.3634D+00	-.3540D+00	-.2080D+00	.4034D-01	.2466D+00	.4168D+00	-.4273D+00	.5290D+00	.2701D-01	.5999D-02
.2563D-02	-.5151D-02	.2267D-01	.2533D-01	-.3144D-01	-.1361D-01	.3376D-01	.8767D-02	.9572D+00	-.2833D+00
-.6009D+00	-.3584D+00	-.1158D+00	.1052D+00	.2592D+00	-.3519D+00	-.5223D+00	-.1471D+00	.2190D-01	-.3444D-02
.3286D+00	-.3553D+00	.3543D+00	-.5855D+00	.3255D+00	-.2536D-01	-.2872D-01	-.4354D+00	.1947D-01	-.5911D-03
-.3109D+00	-.3522D+00	-.3986D+00	-.5356D+00	-.1265D+00	-.4683D-01	.4566D+00	.3267D+00	-.6516D-03	.2418D-02
.2741D-03	-.1253D-02	.6189D-02	.1021D-01	-.9349D-02	-.1106D-01	.1046D-01	-.3160D-02	.2827D+00	.9590D+00
-.2626D+00	-.3524D+00	.7368D+00	.8497D-01	-.3853D+00	.1787D+00	.7425D-02	.2743D+00	-.3295D-01	.2795D-02
-.1100D+00	-.3525D+00	-.2679D+00	.2751D+00	-.1691D+00	.5972D+00	.1532D+00	-.5546D+00	.1038D-03	.8151D-04
.4438D+00	-.3520D+00	-.1895D+00	.1067D+00	-.6078D+00	-.4770D+00	-.1607D+00	-.9255D-01	-.2277D-01	-.3767D-02
.1553D+00	-.3515D+00	.8825D-01	.5124D+00	.4500D+00	-.2885D+00	.5336D+00	.1036D+00	-.2785D-01	-.2735D-02

MATRIX V - ORTHOGONAL MATRIX

.9352D+00	-.3540D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1950D-02	-.5151D-02	.4252D-02	-.2012D-02	.5639D-02	.1493D-01	-.1045D-01	.1433D+00	.9741D+00	.1738D+00
-.1357D+00	-.3584D+00	.2893D+00	.4574D+00	.2177D+00	-.5059D+00	.4908D+00	.1265D+00	-.1093D-01	.8951D-02
-.1345D+00	-.3553D+00	.2778D+00	-.9160D-01	.1781D+00	.7757D+00	.2852D+00	.2306D+00	-.4588D-01	-.8165D-02
-.1333D+00	-.3522D+00	.1280D+00	-.6719D-01	.5080D+00	-.1615D-01	-.3781D+00	-.6544D+00	.8759D-01	-.4999D-02
-.4745D-03	-.1253D-02	-.2822D-03	-.2621D-02	.2190D-02	.8386D-02	-.6250D-02	-.2449D-01	-.1723D+00	.9847D+00
-.1334D+00	-.3524D+00	-.3973D+00	.5838D+00	-.4804D+00	.2418D+00	-.7642D-01	-.2507D+00	.3604D-01	-.4800D-03
-.1334D+00	-.3525D+00	-.4598D+00	-.6022D+00	-.1289D+00	-.1777D+00	.4553D+00	-.1659D+00	.3073D-01	.3693D-02
-.1332D+00	-.3520D+00	.5472D+00	-.2724D+00	-.5801D+00	-.1883D+00	-.3230D+00	.9040D-01	-.1547D-01	-.6946D-03
-.1331D+00	-.3515D+00	-.3925D+00	-.1509D-01	.2807D+00	-.1280D+00	-.4661D+00	.6188D+00	-.9535D-01	-.4447D-02

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NORM08.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 13-JUL-79 11:26 38.6

GRAMMIAN MATRIX VALUES

.7508D+02	-.8303D+03	.9522D+02	.4623D+02	.1128D+02	-.8658D+03	.1494D+04	.2407D+03	-.3360D+03	.4266D+04
-.8303D+03	.9182D+04	-.1053D+04	-.5112D+03	-.1248D+03	.9575D+04	-.1652D+05	-.2662D+04	.3715D+04	-.4717D+05
.9522D+02	-.1053D+04	.1207D+03	.5862D+02	.1431D+02	-.1098D+04	.1894D+04	.3053D+03	-.4261D+03	.5410D+04
.4623D+02	-.5112D+03	.5862D+02	.2846D+02	.6945D+01	-.5331D+03	.9197D+03	.1482D+03	-.2068D+03	.2626D+04
.1128D+02	-.1248D+03	.1431D+02	.6945D+01	.1695D+01	-.1301D+03	.2244D+03	.3617D+02	-.5048D+02	.6409D+03
-.8658D+03	.9575D+04	-.1098D+04	-.5331D+03	-.1301D+03	.9985D+04	-.1723D+05	-.2776D+04	.3874D+04	-.4919D+05
.1494D+04	-.1652D+05	.1894D+04	.9197D+03	.2244D+03	-.1723D+05	.2972D+05	.4789D+04	-.6684D+04	.8487D+05
.2407D+03	-.2662D+04	.3053D+03	.1482D+03	.3617D+02	-.2776D+04	.4789D+04	.7717D+03	-.1077D+04	.1368D+05
-.3360D+03	.3715D+04	-.4261D+03	-.2068D+03	-.5048D+02	.3874D+04	-.6684D+04	-.1077D+04	.1503D+04	-.1909D+05
.4266D+04	-.4717D+05	.5410D+04	.2626D+04	.6409D+03	-.4919D+05	.8487D+05	.1368D+05	-.1909D+05	.2423D+06

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.43825640307774774000-13
SV(2)= 0.29373440405334408700+06
SV(3)= 0.31823461556356576000-12
SV(4)= 0.17003692136636231500-12
SV(5)= 0.49823107678389568500-13
SV(6)= 0.30626502279609910300-13
SV(7)= 0.13271716538607312300-13
SV(8)= 0.18915034413132344000-14
SV(9)= 0.19002149477957708600-14
SV(10)= 0.50795478357585042100-17

MATRIX U - ORTHONORMALIZED COLUMNS

.1170D-01	.1599D-01	.7370D-01	.5815D-01	.5573D-02	.5147D+00	.7457D+00	.2775D+00	-.3046D+00	-.2123D-02
-.2411D+00	-.1768D+00	.5733D+00	-.8206D-01	.7523D+00	-.2489D-01	-.3945D-01	-.5038D-01	-.6631D-01	.7816D-02
.4634D-01	.2028D-01	-.1237D+00	-.4003D-01	.1852D-01	-.4790D+00	-.1826D-01	.2531D-01	-.8652D+00	-.3356D-01
.9122D-02	.9843D-02	-.2545D-01	-.4000D-01	.8829D-01	-.3321D+00	-.1635D-01	.9114D+00	.2176D+00	.3396D-01
.6967D-02	.2402D-02	-.3316D-02	.5537D-03	-.1050D-01	.3391D-02	-.6361D-02	-.2555D-01	-.4058D-01	.9987D+00
-.4158D+00	-.1844D+00	-.2556D+00	.8452D+00	.1086D+00	-.3150D-01	-.1860D-01	.1572D-01	-.8642D-02	.3208D-02
.7059D+00	.3181D+00	.3555D+00	.5109D+00	.8038D-01	-.3364D-01	-.7402D-01	.2332D-02	-.7072D-02	-.4532D-02
.4391D-01	.5126D-01	-.6743D-01	.4269D-03	.1008D+00	-.5968D+00	.6579D+00	-.2958D+00	.3227D+00	.1217D-01
-.3169D+00	-.7154D-01	.6735D+00	.1056D+00	-.6247D+00	-.1894D+00	.4555D-01	.2657D-01	-.2850D-01	-.1553D-02
-.4073D+00	.9083D+00	-.6196D-02	-.1474D-01	.8401D-01	.2453D-01	-.3159D-01	-.3909D-02	-.1022D-01	.7281D-03

MATRIX V - ORTHOGONAL MATRIX

.9999D+00	.1599D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2827D-02	-.1768D+00	.1428D+00	.6880D+00	-.2588D+00	-.7506D-01	-.4748D+00	-.2090D+00	-.3644D+00	.2122D-01
-.3242D-03	.2028D-01	-.2540D-02	.1355D+00	-.5916D+00	.2395D+00	.4157D-01	.7442D+00	.1352D+00	.9101D-02
-.1574D-03	.9843D-02	-.2515D-02	.1694D+00	-.3945D+00	.1324D+00	.1162D+00	-.5213D+00	.7085D+00	-.1040D+00
-.3841D-04	.2402D-02	.1981D-02	-.1716D-01	.6624D-02	-.7010D-02	-.1090D-01	.4222D-01	-.1039D+00	-.9934D+00
.2948D-02	-.1844D+00	-.1980D+00	.1055D+00	.3500D+00	.8708D+00	-.1840D+00	-.1173D-01	.2916D-01	-.8005D-02
-.5086D-02	.3181D+00	.9055D+00	.4785D-01	.1590D+00	.2127D+00	.4964D-01	.3173D-01	.5090D-01	-.3212D-02
-.8196D-03	.5126D-01	.5362D-01	-.3848D+00	.7903D-02	-.1216D+00	-.8440D+00	.1016D+00	.3298D+00	-.1313D-01
.1144D-02	-.7154D-01	-.6200D-01	.5282D+00	.5282D+00	-.3117D+00	.2487D-01	.3399D+00	.4672D+00	-.3839D-01
-.1452D-01	.9083D+00	-.3373D+00	.1971D+00	.2359D-01	.6321D-01	-.9972D-01	-.4421D-01	-.7508D-01	.4899D-02

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NOR103.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 16-JUL-79 14:07 05.1

GRAMMIAN MATRIX VALUES

.4480D+04	.5025D+04	.4560D+04	.4830D+04	.5350D+04	.2210D+04	.5036D+04	.6018D+04	.6404D+04	.2296D+04
.5025D+04	.5635D+04	.5114D+04	.5417D+04	.6000D+04	.2479D+04	.5648D+04	.6749D+04	.7181D+04	.2575D+04
.4560D+04	.5114D+04	.4642D+04	.4916D+04	.5446D+04	.2250D+04	.5126D+04	.6126D+04	.6518D+04	.2337D+04
.4830D+04	.5417D+04	.4916D+04	.5207D+04	.5768D+04	.2383D+04	.5429D+04	.6488D+04	.6903D+04	.2475D+04
.5350D+04	.6000D+04	.5446D+04	.5768D+04	.6389D+04	.2639D+04	.6014D+04	.7187D+04	.7647D+04	.2741D+04
.2210D+04	.2479D+04	.2250D+04	.2383D+04	.2639D+04	.1090D+04	.2484D+04	.2969D+04	.3159D+04	.1132D+04
.5036D+04	.5648D+04	.5126D+04	.5429D+04	.6014D+04	.2484D+04	.5661D+04	.6764D+04	.7198D+04	.2580D+04
.6018D+04	.6749D+04	.6126D+04	.6488D+04	.7187D+04	.2969D+04	.6764D+04	.8083D+04	.8601D+04	.3084D+04
.6404D+04	.7181D+04	.6518D+04	.6903D+04	.7647D+04	.3159D+04	.7198D+04	.8601D+04	.9152D+04	.3281D+04
.2296D+04	.2575D+04	.2337D+04	.2475D+04	.2741D+04	.1132D+04	.2580D+04	.3084D+04	.3281D+04	.1176D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)=	0.9844518297551274290D-13
SV(2)=	0.5151622842353854060D+05
SV(3)=	0.9016884419292091260D-13
SV(4)=	0.7118857656224595110D-13
SV(5)=	0.5142466566540258200D-13
SV(6)=	0.1133772848184849750D-12
SV(7)=	0.1280008947592676230D-13
SV(8)=	0.4998789564030968790D-13
SV(9)=	0.3595169421769443050D-13
SV(10)=	0.1223525124188093480D-13

MATRIX U - ORTHONORMALIZED COLUMNS

-.4423D+00	.2949D+00	.1670D+00	.1855D+00	-.3622D+00	.1661D+00	.6073D+00	.3560D+00	-.2740D-01	.5873D-02
-.5083D+00	.3307D+00	.9381D-01	.2491D+00	.1199D+00	-.4488D+00	-.2746D+00	-.3085D+00	-.4013D+00	-.1183D+00
-.1775D+00	.3002D+00	-.4976D+00	.1672D+00	.5433D+00	.2327D+00	-.4137D-01	.1930D+00	.1089D+00	.4502D+00
.2196D+00	.3179D+00	.1532D+00	-.1316D+00	.2305D+00	.6114D+00	.1156D-01	-.9798D-01	-.5109D+00	-.3349D+00
-.1891D+00	.3522D+00	-.2907D+00	-.3525D+00	-.5332D+00	.2689D+00	-.2934D+00	-.3570D+00	.2364D+00	.7363D-01
.2369D+00	.1455D+00	-.5288D+00	.3477D+00	-.8499D-02	-.1379D+00	.3326D+00	-.2476D+00	.1871D+00	-.5442D+00
.3410D+00	.3315D+00	-.2839D+00	-.2648D+00	-.2227D+00	-.3953D+00	-.1047D+00	.5290D+00	-.3550D+00	.2065D-01
.9832D-01	.3961D+00	.2720D+00	-.5023D+00	.3367D+00	-.3061D+00	.3938D+00	-.2378D+00	.2856D+00	.8274D-01
.4565D+00	.4215D+00	.3808D+00	.5347D+00	-.1597D+00	.1755D-01	-.2083D+00	-.4145D-01	.2236D+00	.2495D+00
-.2002D+00	.1511D+00	.1690D+00	-.6923D-01	.1823D+00	.3620D-01	-.3844D+00	.4521D+00	.4657D+00	-.5478D+00

MATRIX V - ORTHOGONAL MATRIX

.9555D+00	.2949D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1021D+00	.3307D+00	.5122D+00	.8018D-02	-.5771D+00	.2569D+00	.6638D-02	.9718D-02	-.4397D+00	-.1588D+00
-.9264D-01	.3002D+00	-.4248D+00	-.3480D+00	-.3406D+00	-.6202D-01	.5379D+00	.3554D+00	.8680D-01	.2381D+00
-.9812D-01	.3179D+00	-.4384D+00	.3634D+00	-.9468D-01	.4901D-01	.1612D+00	-.4305D+00	.1112D+00	-.5744D+00
-.1087D+00	.3522D+00	-.1153D+00	.2872D-01	.5795D+00	.6320D+00	.3697D-01	.1654D+00	-.2711D+00	.1120D+00
-.4490D-01	.1455D+00	-.8879D-01	.1824D+00	-.1735D+00	.1276D+00	-.5187D+00	.6318D+00	.4108D+00	-.2288D+00
-.1023D+00	.3315D+00	.3093D+00	-.5697D+00	.1148D+00	.1183D+00	-.8231D-01	-.3265D+00	.5598D+00	-.7434D-01
-.1223D+00	.3961D+00	-.1965D+00	-.2792D+00	.1587D+00	-.5541D+00	-.4428D+00	-.2837D-02	-.4233D+00	-.6411D-01
-.1301D+00	.4215D+00	.3872D+00	.5155D+00	.2121D+00	-.4011D+00	.2560D+00	.1034D+00	.2100D+00	.2519D+00
-.4664D-01	.1511D+00	-.2442D+00	.2106D+00	-.3044D+00	.1736D+00	-.3819D+00	-.3800D+00	.8834D-01	.6709D+00

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NOR105.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 16-JUL-79 14:14 16.9

GRAMMIAN MATRIX VALUES

.4354D+04	.4914D+04	.4417D+04	.4720D+04	.5263D+04	.2663D+04	.5106D+04	.5916D+04	.6286D+04	.3341D+04
.4914D+04	.5545D+04	.4984D+04	.5327D+04	.5940D+04	.3005D+04	.5763D+04	.6676D+04	.7095D+04	.3770D+04
.4417D+04	.4984D+04	.4480D+04	.4788D+04	.5339D+04	.2701D+04	.5180D+04	.6001D+04	.6377D+04	.3389D+04
.4720D+04	.5327D+04	.4788D+04	.5118D+04	.5706D+04	.2887D+04	.5536D+04	.6414D+04	.6815D+04	.3622D+04
.5263D+04	.5940D+04	.5339D+04	.5706D+04	.6362D+04	.3219D+04	.6172D+04	.7151D+04	.7599D+04	.4038D+04
.2663D+04	.3005D+04	.2701D+04	.2887D+04	.3219D+04	.1629D+04	.3123D+04	.3618D+04	.3845D+04	.2043D+04
.5106D+04	.5763D+04	.5180D+04	.5536D+04	.6172D+04	.3123D+04	.5988D+04	.6938D+04	.7373D+04	.3918D+04
.5916D+04	.6676D+04	.6001D+04	.6414D+04	.7151D+04	.3618D+04	.6938D+04	.8038D+04	.8541D+04	.4539D+04
.6286D+04	.7095D+04	.6377D+04	.6815D+04	.7599D+04	.3845D+04	.7373D+04	.8541D+04	.9077D+04	.4823D+04
.3341D+04	.3770D+04	.3389D+04	.3622D+04	.4038D+04	.2043D+04	.3918D+04	.4539D+04	.4823D+04	.2563D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)=	0.34583699677835709 6D-12
SV(2)=	0.53153967422473423 0D+05
SV(3)=	0.31981114123454593 7D-12
SV(4)=	0.18152046650809481 7D-12
SV(5)=	0.12686346574367876 5D-12
SV(6)=	0.23262576468645561 0D-12
SV(7)=	0.57432650201187460 1D-13
SV(8)=	0.33677149359370772 9D-12
SV(9)=	0.52419174358438569 8D-13
SV(10)=	0.12626754886707357 4D-12

MATRIX U - ORTHONORMALIZED COLUMNS

-.3338D+00	-.2862D+00	.5991D-01	-.3661D+00	.4376D-01	-.6189D+00	.6422D-01	.2022D+00	-.4457D+00	-.2012D+00
.3304D+00	-.3230D+00	.1582D+00	.4468D+00	-.1525D+00	-.4592D+00	.3709D+00	-.4066D+00	.3694D-01	.1529D+00
.3910D+00	-.2903D+00	-.2614D-01	.3838D+00	-.1749D+00	.1067D+00	-.1829D+00	.5512D+00	-.1598D+00	-.4584D+00
.1189D+00	-.3103D+00	-.1301D+00	-.8483D-01	-.1662D+00	.2511D+00	-.4704D+00	-.4084D+00	-.5689D+00	.2510D+00
-.3052D+00	-.3460D+00	-.4018D+00	-.1140D+00	-.6729D+00	.7649D-01	.1327D+00	.1088D+00	.3308D+00	.1233D+00
-.1021D+00	-.1751D+00	-.9500D-02	.4384D-01	.1234D+00	-.3088D+00	-.6622D+00	-.2624D+00	.5071D+00	-.2860D+00
-.8753D-01	-.3357D+00	.5847D+00	.2774D-02	.8013D-01	.6382D-01	-.1878D+00	.3803D+00	.1670D+00	.5653D+00
.1494D+00	-.3889D+00	-.5831D+00	-.2631D-01	.6246D+00	.1203D-01	.1250D+00	.1349D+00	.1029D+00	.2259D+00
-.4439D+00	-.4132D+00	.2472D+00	.1620D+00	.2222D+00	.4560D+00	.2684D+00	-.2583D+00	-.1819D-01	-.3853D+00
.5309D+00	-.2196D+00	.2219D+00	-.6856D+00	-.5145D-01	.1349D+00	.1568D+00	-.1135D+00	.2129D+00	-.2168D+00

MATRIX V - ORTHOGONAL MATRIX

.9582D+00	-.2862D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9648D-01	-.3230D+00	.3532D-01	.9217D-01	.4344D+00	-.1939D+00	-.3933D+00	.5044D+00	.1391D+00	.4710D+00
-.8672D-01	-.2903D+00	-.4537D+00	.3016D+00	-.1668D+00	-.3134D-01	.3432D+00	-.3646D+00	.5254D-03	.5760D+00
-.9268D-01	-.3103D+00	-.2471D+00	-.3626D+00	.4588D+00	.2518D-01	.3617D+00	.9884D-01	-.5599D+00	-.1934D+00
-.1033D+00	-.3460D+00	.2861D+00	.3934D+00	.1216D+00	-.2902D+00	.4854D+00	.8591D-01	.3766D+00	-.3863D+00
-.5229D-01	-.1751D+00	.1534D+00	.4725D+00	-.3511D+00	-.2350D+00	-.2559D+00	.9455D-01	-.6720D+00	-.1241D+00
-.1003D+00	-.3357D+00	.4344D+00	-.1166D+00	.2653D+00	.2917D-01	-.3036D+00	-.7143D+00	-.2613D-01	.2606D-01
-.1162D+00	-.3889D+00	-.5690D+00	-.1197D+00	-.2024D+00	-.8394D-01	-.4208D+00	-.5319D-01	.2664D+00	-.4454D+00
-.1234D+00	-.4132D+00	.3357D+00	-.5069D+00	-.5673D+00	.7484D-01	.1583D+00	.2290D+00	.4390D-01	.1934D+00
-.6559D-01	-.2196D+00	.3600D-01	.3259D+00	.4222D-01	.8988D+00	-.3582D-01	.1449D+00	.1369D-01	-.8862D-01

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NOR106.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 16-JUL-79 14:20 32.9

GRAMMIAN MATRIX VALUES

.9522D+04	.9620D+04	.9640D+04	.9557D+04	.9474D+04	.1375D+03	.9482D+04	.9481D+04	.9466D+04	.9463D+04
.9620D+04	.9718D+04	.9738D+04	.9654D+04	.9571D+04	.1389D+03	.9579D+04	.9578D+04	.9563D+04	.9560D+04
.9640D+04	.9738D+04	.9758D+04	.9674D+04	.9591D+04	.1392D+03	.9599D+04	.9598D+04	.9583D+04	.9580D+04
.9557D+04	.9654D+04	.9674D+04	.9591D+04	.9508D+04	.1380D+03	.9516D+04	.9515D+04	.9500D+04	.9497D+04
.9474D+04	.9571D+04	.9591D+04	.9508D+04	.9426D+04	.1368D+03	.9434D+04	.9433D+04	.9418D+04	.9415D+04
.1375D+03	.1389D+03	.1392D+03	.1380D+03	.1368D+03	.1984D+01	.1369D+03	.1369D+03	.1367D+03	.1366D+03
.9482D+04	.9579D+04	.9599D+04	.9516D+04	.9434D+04	.1369D+03	.9442D+04	.9441D+04	.9426D+04	.9423D+04
.9481D+04	.9578D+04	.9598D+04	.9515D+04	.9433D+04	.1369D+03	.9441D+04	.9440D+04	.9425D+04	.9422D+04
.9466D+04	.9563D+04	.9583D+04	.9500D+04	.9418D+04	.1367D+03	.9426D+04	.9425D+04	.9411D+04	.9407D+04
.9463D+04	.9560D+04	.9580D+04	.9497D+04	.9415D+04	.1366D+03	.9423D+04	.9422D+04	.9407D+04	.9404D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.34051161767396899 3D-12
SV(2)= 0.85714519185205465 9D+05
SV(3)= 0.36899925768812583 1D-12
SV(4)= 0.20440623167555523 5D-12
SV(5)= 0.37987251962910686 4D-12
SV(6)= 0.25076968988110174 5D-12
SV(7)= 0.14613070914062416 6D-12
SV(8)= 0.22347751492873090 9D-12
SV(9)= 0.12276851858281530 4D-12
SV(10)= 0.14094308628839764 5D-15

MATRIX U - ORTHONORMALIZED COLUMNS

.6582D+00	-.3333D+00	-.3178D+00	.3031D+00	-.4104D-01	-.4948D+00	.6815D-01	.1072D+00	.1519D-02	.1464D-01
.2796D+00	-.3367D+00	.2608D-01	.1195D+00	-.2316D+00	.5476D+00	.7585D-01	-.6376D+00	.1662D+00	.1189D-01
-.3463D+00	-.3374D+00	-.4558D+00	-.5164D+00	.8785D-01	-.2919D+00	.2219D+00	-.2741D+00	.2726D+00	.1071D-01
-.8443D-01	-.3345D+00	.6126D+00	.3892D-01	.1087D-01	-.3005D+00	-.3451D+00	.1060D-01	.5424D+00	.1760D-01
-.1491D+00	-.3316D+00	-.3727D+00	.6260D-02	-.6059D-01	.1919D+00	-.7922D+00	.1343D+00	-.2055D+00	-.2327D-01
.1985D-02	-.4812D-02	-.1504D-02	.1754D-01	-.7857D-02	-.9668D-02	.1945D-01	-.5351D-02	.3748D-01	-.9988D+00
-.2803D+00	-.3319D+00	.2228D-01	.4846D+00	.7120D+00	.8581D-01	.1821D+00	-.6023D-01	-.1580D+00	.1028D-02
-.3638D+00	-.3319D+00	.2224D+00	.1602D+00	-.5573D+00	-.2450D+00	.2101D+00	-.6210D-01	-.5135D+00	-.4733D-02
.3522D+00	-.3313D+00	.3464D+00	-.6039D+00	.2779D+00	.1037D+00	.3801D-01	.1124D+00	-.4227D+00	-.2774D-01
-.6622D-01	-.3312D+00	-.7961D-01	.1176D-01	-.1960D+00	.4058D+00	.3385D+00	.6845D+00	.3048D+00	.1377D-01

MATRIX V - ORTHOGONAL MATRIX

.9428D+00	-.3333D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1190D+00	-.3367D+00	-.3964D+00	-.3888D-01	-.9102D-01	-.7944D+00	-.2567D+00	.7160D-01	.5586D-01	.1834D-01
-.1193D+00	-.3374D+00	-.1010D+00	-.1209D-01	.1653D+00	.8217D-01	.2458D+00	-.7297D+00	.4841D+00	.1717D-01
-.1183D+00	-.3345D+00	.2840D+00	-.1816D-01	-.6840D+00	-.8540D-01	.5047D+00	-.2481D-01	-.2498D+00	.1874D-01
-.1172D+00	-.3316D+00	-.2218D-01	-.3514D+00	.5244D+00	.2762D-01	.1316D+00	-.9739D-01	-.6706D+00	-.9130D-02
-.1701D-02	-.4812D-02	-.3113D-02	.7466D-02	-.1066D-01	-.2557D-01	.2058D-01	-.1308D-01	.9020D-02	-.9992D+00
-.1173D+00	-.3319D+00	-.6262D+00	-.1507D+00	-.2277D+00	.5566D+00	-.6340D-01	.2999D+00	.7334D-01	-.1376D-01
-.1173D+00	-.3319D+00	.9132D-01	.7833D+00	.8716D-02	.1619D+00	-.3707D+00	-.1358D+00	-.2683D+00	-.5151D-02
-.1171D+00	-.3313D+00	.5451D+00	-.4344D+00	-.9185D-01	.1194D+00	-.5674D+00	.4417D-01	.2094D+00	-.1560D-01
-.1171D+00	-.3312D+00	.2320D+00	.2226D+00	.4013D+00	-.5667D-01	.3713D+00	.5847D+00	.3594D+00	.3141D-02

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NOH107.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 16-JUL-79 14:26 22.5

GRAMMIAN MATRIX VALUES

.9522D+04	.9619D+04	.9639D+04	.9556D+04	.9474D+04	.3371D+02	.9479D+04	.9481D+04	.9467D+04	.9455D+04
.9619D+04	.9718D+04	.9738D+04	.9654D+04	.9571D+04	.3406D+02	.9576D+04	.9578D+04	.9564D+04	.9552D+04
.9639D+04	.9738D+04	.9758D+04	.9674D+04	.9590D+04	.3413D+02	.9596D+04	.9597D+04	.9584D+04	.9572D+04
.9556D+04	.9654D+04	.9674D+04	.9590D+04	.9508D+04	.3384D+02	.9513D+04	.9515D+04	.9501D+04	.9489D+04
.9474D+04	.9571D+04	.9590D+04	.9508D+04	.9426D+04	.3354D+02	.9431D+04	.9433D+04	.9419D+04	.9408D+04
.3371D+02	.3406D+02	.3413D+02	.3384D+02	.3354D+02	.1194D+00	.3356D+02	.3357D+02	.3352D+02	.3348D+02
.9479D+04	.9576D+04	.9596D+04	.9513D+04	.9431D+04	.3356D+02	.9437D+04	.9438D+04	.9425D+04	.9413D+04
.9481D+04	.9578D+04	.9597D+04	.9515D+04	.9433D+04	.3357D+02	.9438D+04	.9440D+04	.9426D+04	.9414D+04
.9467D+04	.9564D+04	.9584D+04	.9501D+04	.9419D+04	.3352D+02	.9425D+04	.9426D+04	.9413D+04	.9401D+04
.9455D+04	.9552D+04	.9572D+04	.9489D+04	.9408D+04	.3348D+02	.9413D+04	.9414D+04	.9401D+04	.9389D+04

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)=	0.202105417750570811D-12
SV(2)=	0.856925752877564528D+05
SV(3)=	0.100179065088326986D-12
SV(4)=	0.171859114087648232D-12
SV(5)=	0.947421990537079243D-13
SV(6)=	0.923329722966328071D-13
SV(7)=	0.578432283473441800D-13
SV(8)=	0.504136470480887194D-13
SV(9)=	0.737657732971045418D-13
SV(10)=	0.438585480151088921D-18

MATRIX U - ORTHONORMALIZED COLUMNS

.3299D+00	-.3333D+00	.2427D+00	.1452D+00	.1418D+00	-.1125D+00	.4609D-01	-.2637D+00	.7717D+00	.3850D-03
.1136D+00	-.3368D+00	-.8525D+00	.1985D+00	-.8587D-01	-.2155D+00	.2844D-01	-.2231D+00	-.5679D-01	.4398D-02
-.6045D+00	-.3374D+00	.6778D-01	.5373D-01	.5901D+00	-.2948D+00	.2575D+00	.9457D-01	-.5325D-01	.3138D-02
.3044D+00	-.3345D+00	.1009D+00	-.6831D+00	.2255D+00	.5360D-01	.6678D-02	-.3837D+00	-.3430D+00	.3581D-02
-.2983D+00	-.3317D+00	.2285D+00	-.1711D-02	-.6834D+00	.3389D-01	.4785D+00	-.2192D+00	-.6024D-01	-.2517D-02
.8266D-04	-.1180D-02	-.2681D-02	.1635D-03	.4290D-02	-.3622D-02	-.1032D-02	-.5208D-02	-.2268D-02	-.1000D+01
-.2840D+00	-.3318D+00	-.2093D+00	-.4765D+00	-.1856D+00	.2318D+00	-.3412D+00	.4415D+00	.3727D+00	-.3577D-02
-.1673D+00	-.3319D+00	.2612D+00	.3486D+00	-.9469D-01	-.2063D-01	-.7357D+00	-.2470D+00	-.2457D+00	.2007D-02
.4393D+00	-.3314D+00	.1873D+00	.7734D-01	-.1322D+00	-.4415D+00	.5226D-01	.6210D+00	-.2354D+00	-.1784D-02
.1722D+00	-.3310D+00	-.1674D-01	.3398D+00	.2131D+00	.7752D+00	.2033D+00	.1869D+00	-.1497D+00	-.2232D-02

MATRIX V - ORTHOGONAL MATRIX

.9428D+00	-.3333D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1191D+00	-.3368D+00	-.1690D+00	.2702D+00	-.3065D+00	.1479D+00	.2055D+00	.6868D+00	-.3570D+00	-.1170D+00
-.1193D+00	-.3374D+00	-.2900D+00	.3807D+00	.3070D+00	.2394D-01	.5898D+00	-.4469D+00	.2471D-02	.2131D-01
-.1183D+00	-.3345D+00	-.2202D+00	.2747D+00	-.5021D+00	.2314D+00	-.4488D+00	-.2563D+00	.4074D+00	.1070D+00
-.1173D+00	-.3317D+00	-.8683D-01	-.2071D+00	.5127D+00	.4674D+00	-.4504D+00	-.6294D-01	-.3531D+00	-.1141D+00
-.4173D-03	-.1180D-02	.2514D-03	.3586D-02	-.8526D-02	.8383D-02	-.2203D-01	.1351D-01	-.2860D+00	.9578D+00
-.1173D+00	-.3318D+00	.3556D+00	.3461D+00	.1141D+00	-.6739D+00	-.3335D+00	-.5618D-01	-.2101D+00	-.6455D-01
-.1173D+00	-.3319D+00	.5461D+00	-.3953D+00	-.4094D+00	.1604D+00	.2799D+00	-.3162D+00	-.2159D+00	-.5772D-01
-.1172D+00	-.3314D+00	-.5097D+00	-.6194D+00	-.4875D-01	-.4638D+00	.2603D-01	.6289D-01	.9849D-01	.3474D-01
-.1170D+00	-.3310D+00	.3833D+00	-.6345D-01	.3375D+00	.1022D+00	.1222D+00	.3894D+00	.6322D+00	.1879D+00

SVD ANALYSIS OF THE DYNAMIC MODEL
DATA FILE CONTAINING THE RESPONSE MATRIX: NOR108.DAT
NUMBER OF RESPONSE VALUES: 10

DATE & TIME OF ANALYSIS: 16-JUL-79 14:31 09.5

GRAMMIAN MATRIX VALUES

.7508D+02	-.3620D+02	.9522D+02	.4623D+02	.1128D+02	-.8658D+03	.1494D+04	.2407D+03	-.3360D+03	.4266D+04
-.3620D+02	.1745D+02	-.4591D+02	-.2229D+02	-.5439D+01	.4174D+03	-.7202D+03	-.1161D+03	.1620D+03	-.2057D+04
.9522D+02	-.4591D+02	.1207D+03	.5862D+02	.1431D+02	-.1098D+04	.1894D+04	.3053D+03	-.4261D+03	.5410D+04
.4623D+02	-.2229D+02	.5862D+02	.2846D+02	.6945D+01	-.5331D+03	.9197D+03	.1482D+03	-.2068D+03	.2626D+04
.1128D+02	-.5439D+01	.1431D+02	.6945D+01	.1695D+01	-.1301D+03	.2244D+03	.3617D+02	-.5048D+02	.6409D+03
-.8658D+03	.4174D+03	-.1098D+04	-.5331D+03	-.1301D+03	.9985D+04	-.1723D+05	-.2776D+04	.3874D+04	-.4919D+05
.1494D+04	-.7202D+03	.1894D+04	.9197D+03	.2244D+03	-.1723D+05	.2972D+05	.4789D+04	-.6684D+04	.8487D+05
.2407D+03	-.1161D+03	.3053D+03	.1482D+03	.3617D+02	-.2776D+04	.4789D+04	.7717D+03	-.1077D+04	.1368D+05
-.3360D+03	.1620D+03	-.4261D+03	-.2068D+03	-.5048D+02	.3874D+04	-.6684D+04	-.1077D+04	.1503D+04	-.1909D+05
.4266D+04	-.2057D+04	.5410D+04	.2626D+04	.6409D+03	-.4919D+05	.8487D+05	.1368D+05	-.1909D+05	.2423D+06

SINGULAR VALUES FROM GRAMMIAN DECOMPOSITION

SV(1)= 0.41672244414692020D-13
SV(2)= 0.28456992246046116 3D+06
SV(3)= 0.26037130715164764 9D-12
SV(4)= 0.13211006140969029 2D-12
SV(5)= 0.39042856440866369 8D-13
SV(6)= 0.63253460937606188 8D-14
SV(7)= 0.38472605481632329 3D-14
SV(8)= 0.16359577010992909 6D-15
SV(9)= 0.16927827950386403 0D-15
SV(10)= 0.10460013296271839 2D-16

MATRIX U - ORTHONORMALIZED COLUMNS

.9454D-02	.1624D-01	.9342D-01	.8231D-01	.1038D+00	-.3535D+00	.9060D+00	-.7343D-02	-.1657D+00	.7726D-02
-.2154D-01	-.7831D-02	.1416D-01	.5209D-02	.2619D-01	.1429D+00	-.1053D+00	.3292D+00	-.8533D+00	.3612D+00
.4859D-01	.2060D-01	-.1626D+00	-.1547D+00	-.6982D+00	.5024D+00	.2772D+00	-.2964D+00	-.1503D+00	-.1405D+00
.1039D-01	.1000D-01	-.3236D-01	-.4856D-01	-.2160D+00	.2192D+00	.1959D+00	.8176D+00	.3996D+00	.1877D+00
.7302D-02	.2441D-02	-.5955D-02	-.7281D-02	-.2835D-01	.3965D-01	.5359D-01	-.3565D+00	.2420D+00	.8994D+00
-.4373D+00	-.1873D+00	-.2397D+00	.8334D+00	-.1404D+00	.3986D-01	-.8773D-02	-.4493D-02	.1467D-01	-.2169D-02
.7406D+00	.3232D+00	.2555D+00	.5174D+00	-.7901D-01	.7324D-01	-.4923D-01	-.2900D-03	-.1022D-03	-.3882D-02
.4781D-01	.5208D-01	-.9984D-01	-.6068D-01	-.6136D+00	-.7372D+00	-.2129D+00	.8764D-01	-.5477D-01	.7364D-01
-.3339D+00	-.7268D-01	.9096D+00	.2942D-01	-.2238D+00	.4231D-01	-.4648D-01	-.2245D-01	.1721D-01	-.1051D-01
-.3787D+00	.9228D+00	-.5838D-01	-.3687D-02	.3256D-01	.2111D-01	-.1479D-02	-.5903D-02	.1521D-02	-.2412D-02

MATRIX V - ORTHOGONAL MATRIX

.9999D+00	.1624D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1272D-03	-.7831D-02	-.1765D-01	.3738D-01	.3980D-01	.8563D-02	-.3395D+00	-.8125D+00	.1982D+00	-.4263D+00
-.3346D-03	.2060D-01	-.5520D-02	-.9673D-02	.3240D+00	-.1646D+00	.8336D+00	-.3125D+00	-.2293D+00	-.1490D+00
-.1625D-03	.1000D-01	-.5932D-02	.2321D-01	.1388D+00	-.9364D-01	.1551D+00	-.2146D+00	.7109D+00	.6292D+00
-.3965D-04	.2441D-02	.2096D-02	-.1302D-01	.3966D-02	.1074D-01	.2106D+00	.3968D+00	.6329D+00	-.6304D+00
.3043D-02	-.1873D+00	-.1885D+00	.8260D+00	.4077D+00	.2597D+00	-.6808D-01	.9047D-01	-.2609D-01	-.3409D-02
-.5250D-02	.3232D+00	.9075D+00	.2669D+00	.1579D-01	.1855D-01	-.4529D-02	-.4625D-02	-.1104D-02	-.6359D-02
-.8460D-03	.5208D-01	.5678D-01	-.3277D+00	.1617D+00	.9185D+00	.1047D+00	-.6003D-01	.2133D-01	.4244D-01
.1181D-02	-.7268D-01	-.6625D-01	.3498D+00	-.8256D+00	.2285D+00	.3248D+00	-.1632D+00	.3340D-01	.3024D-01
-.1499D-01	.9228D+00	-.3645D+00	.1206D+00	-.5340D-02	.1711D-01	-.1629D-01	.1187D-01	-.6059D-02	-.3921D-02

APPENDIX D

INPUT RESPONSE ANALYSES

The input response analyses discussed in Chapter IV are given in this appendix. The cross reference of variable given in TABLE B-1 on page 146 is also applicable to these analysis results. Scaling factors for each process input is indicated at the base of each analysis. Run numbers are given as the fifth and sixth characters of the RUN NAME. Pertinent information about these runs are given in TABLE D-1.

TABLE D-1. INFORMATION ON INPUT RESPONSE ANALYSES

RUN NUMBER	STEADY STATE	MODEL	VARIABLE TESTED
1	L	10	*
2	M	10	*
3	H	10	*
4	M	10	Θ
5	M	10	M_o
6	M	10	I_o
7	M	10	T_c
8	M	10	T_Q
9	M	9	*
10	M	6	*
11	M	5	*

* all input variables tested.

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR01.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:47 53.4

INPUT STEADY STATE VALUES

T= .3159420D+03	R0= .1375050D-07	P0= .9637150D-04
I= .1051750D-01	R1= .6938490D-05	P1= .8879890D-01
M= .4721350D+01	R2= .6995380D-02	P2= .1300490D+03
RAD= .2734830D-10		

JACOBIAN MATRIX VALUES

-.1367D-03	.7777D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2670D+05	.0000D+00	.0000D+00	.0000D+00
-.3134D-06	-.1011D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.6396D+03	.0000D+00	.0000D+00	.1214D+00
.1748D-09	.4034D-08	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.1270D+01	.0000D+00	.0000D+00	-.1214D+00
.1228D-06	.3893D-05	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.5794D+03	.1270D+01	.0000D+00	-.1214D+00
.1586D-03	.5674D-02	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5841D+06	.1159D+04	.1270D+01	-.1214D+00
-.1272D-08	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.9998D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2315D-08	-.1392D-07	.0000D+00	.0000D+00	.0000D+00	.1501D-05	-.2297D+01	.0000D+00	.0000D+00	.0000D+00
.1931D-06	-.2037D-05	.0000D+00	.0000D+00	.0000D+00	.1501D-05	.6018D+02	-.1270D+01	.0000D+00	.0000D+00
.1927D-03	-.2044D-02	.0000D+00	.0000D+00	.0000D+00	.1501D-05	-.5835D+06	.1279D+04	-.1270D+01	.0000D+00
.3153D-06	.1852D-05	.0000D+00	.0000D+00	.0000D+00	.1501D-05	.1191D+00	.0000D+00	.0000D+00	-.6407D+03

INPUT MATRIX B & SINGULAR VALUES

.1560D-04	.0000D+00	.0000D+00	.9963D-03	.2480D-02	SV(1)=	0.2329547048449040050D+03
-.1745D-05	.9921D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.6472411626502575470D+01
.1897D-08	-.3613D-08	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.7950763829876927800D-01
.1748D-05	-.3446D-05	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.8191531632439825280D+00
.2560D-02	-.5516D-02	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.1028417005175144950D-18
-.1625D-08	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.0000000000000000000D+00
.2707D-12	.7833D-09	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.0000000000000000000D+00
.1366D-09	.3640D-05	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.0000000000000000000D+00
.1377D-06	.3676D-02	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.0000000000000000000D+00
.5383D-15	-.6428D-08	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.0000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

-.1052D+00	-.9886D+00	-.1808D-01	.1066D+00	-.1003D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.6457D-03	.1086D+00	-.1519D+00	.9823D+00	.1099D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2025D-05	.2049D-05	-.2000D-02	-.3209D-03	.9999D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1311D-02	.1026D-02	-.9489D+00	-.1501D+00	.8010D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9944D+00	.1047D+00	.3084D-02	-.1044D-01	-.1245D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.6356D-04	.2706D-02	-.2680D+00	-.2962D-01	-.8923D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1518D-09	.1507D-09	-.1746D-06	-.2492D-07	-.8469D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2620D-07	-.1633D-10	-.1149D-04	-.3886D-06	-.2873D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2442D-04	-.7679D-04	.6573D-01	.1191D-01	.5863D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.5008D-10	-.1672D-09	-.1097D-08	.2810D-08	-.7723D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

-.1166D+00	.4174D+00	.8286D+00	-.3544D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1541D+00	.7094D+00	-.8723D-01	.6822D+00	.1206D-18	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3810D+00	.4393D+00	-.5365D+00	-.6115D+00	.4264D-17	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3370D+00	-.1341D+00	.5000D-01	.6973D-01	-.9279D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.8390D+00	-.3339D+00	.1245D+00	.1736D+00	.3728D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR02.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:49 14.2

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-08	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

INPUT MATRIX B & SINGULAR VALUES

.5900D-03	.0000D+00	.0000D+00	.9963D-03	.2480D-02	SV(1)=	0.21222512371327964 6D+04
-.2386D-04	.9921D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.77376932127494802 8D+01
.5145D-07	-.1655D-06	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.16502421866525942 5D+00
.2395D-04	-.8493D-04	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.12641278601891581 2D+01
.1777D-01	-.6527D-01	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.77138085954530170 0D-19
-.6928D-07	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000 0D+00
.1875D-11	.1999D-06	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.00000000000000000 0D+00
.4809D-09	.8480D-04	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.00000000000000000 0D+00
.2462D-06	.4349D-01	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.00000000000000000 0D+00
.7359D-14	-.1299D-06	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.00000000000000000 0D+00

MATRIX U - ORTHONORMALIZED COLUMNS

.1690D-01	.9991D+00	-.3434D-01	.1901D-01	.5976D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.6896D-03	-.2806D-01	-.2869D+00	.9575D+00	-.5819D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5010D-06	-.1201D-03	-.3936D-02	-.1365D-02	.4514D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.7876D-03	-.2742D-01	-.9571D+00	-.2877D+00	-.2004D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.9999D+00	-.1689D-01	.1136D-02	.5657D-03	.1983D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1694D-04	-.1408D-02	-.2226D-01	.5426D-03	.8606D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3178D-10	-.3121D-08	-.1578D-06	-.4786D-07	-.1996D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1987D-07	-.2211D-06	-.2068D-04	-.5909D-05	-.4249D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1619D-04	.1842D-03	-.4368D-03	.2417D-03	-.2350D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2964D-10	.2069D-08	-.8577D-08	.2502D-07	-.3256D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.2785D-01	-.4561D+00	.8895D+00	.3191D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2074D+00	-.4276D+00	-.2288D+00	.8496D+00	.1482D-15	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9343D+00	-.3273D+00	-.1387D+00	.2600D-01	.9806D-17	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1076D+00	.2641D+00	.1381D+00	.1964D+00	-.9279D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2678D+00	.6574D+00	.3438D+00	.4889D+00	.3728D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR03.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:50 08.2

INPUT STEADY STATE VALUES

T= .4115550+03	R0= .5836920-06	P0= .8324440-02
I= .1512810-04	R1= .2564990-03	P1= .4409380+01
M= .4037540+00	R2= .2251770+00	P2= .4525380+04
RAD= .1330300-08		

JACOBIAN MATRIX VALUES

.1203D-03	.3620D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2504D+05	.0000D+00	.0000D+00	.0000D+00
-.9191D-05	-.1182D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.7489D+03	.0000D+00	.0000D+00	.1129D+01
.3009D-07	.1995D-05	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.1705D+01	.0000D+00	.0000D+00	-.1129D+01
.1559D-04	.1039D-02	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.2531D+03	.1705D+01	.0000D+00	-.1129D+01
.1575D-01	.4337D+00	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.2222D+06	.5062D+03	.1705D+01	-.1129D+01
-.9610D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.6951D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2011D-07	-.8719D-06	.0000D+00	.0000D+00	.0000D+00	.2222D-01	-.1152D+01	.0000D+00	.0000D+00	.0000D+00
-.6370D-05	.4303D-04	.0000D+00	.0000D+00	.0000D+00	.2222D-01	.4958D+03	-.1706D+01	.0000D+00	.0000D+00
-.5622D-02	.3863D-01	.0000D+00	.0000D+00	.0000D+00	.2222D-01	-.2215D+06	.1496D+04	-.1706D+01	.0000D+00
.9201D-05	.1080D-02	.0000D+00	.0000D+00	.0000D+00	.2222D-01	.1128D+01	.0000D+00	.0000D+00	-.7495D+03

INPUT MATRIX B & SINGULAR VALUES

.1898D-02	.0000D+00	.0000D+00	.9963D-03	.2480D-02	SV(1)=	0.46649013823410123 8D+04
-.8673D-04	.9921D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.25703062216632288 4D+02
.1639D-06	-.3075D-07	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.66702566813573634 0D-01
.8679D-04	-.2703D-04	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.58874731137367355 5D+00
.8908D-01	-.3560D-01	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.34775213937161515 3D-18
-.2084D-06	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000 0D+00
.1149D-10	.4977D-07	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.00000000000000000 0D+00
.5049D-08	.2702D-04	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.00000000000000000 0D+00
.4432D-05	.2373D-01	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.00000000000000000 0D+00
.2619D-13	-.1159D-07	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.00000000000000000 0D+00

MATRIX U - ORTHONORMALIZED COLUMNS

.4867D-02	.9995D+00	-.1323D-01	-.2771D-01	-.1057D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3040D-03	-.5769D-02	-.8959D+00	.3322D+00	-.2906D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.6864D-05	.1424D-03	.2438D-01	-.5363D-02	.8869D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3080D-03	.3142D-01	.3151D+00	.9428D+00	.1037D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1000D+01	-.4876D-02	-.3073D-03	-.5445D-04	-.6326D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5244D-08	-.1108D-05	.1185D-03	-.1025D-04	-.3855D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.4163D-09	.1552D-08	.2937D-05	-.3945D-06	-.9937D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.9524D-07	-.3036D-05	.8232D-03	-.8610D-04	-.2659D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.6546D-05	-.5933D-02	.3119D+00	.1124D-02	-.9470D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3776D-09	.3925D-08	-.1283D-05	.4775D-06	.4601D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.1362D+00	-.2925D+00	-.9238D+00	.2059D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.4335D-02	.6577D+00	-.3992D-01	.7522D+00	.1129D-17	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.9855D+00	.1080D+00	.8989D-01	-.9534D-01	-.1533D-18	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3774D-01	.2556D+00	-.1379D+00	-.2306D+00	-.9279D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9395D-01	.6363D+00	-.3432D+00	-.5741D+00	.3728D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR04.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:51 35.5

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-08	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

INPUT MATRIX B & SINGULAR VALUES

.5900D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(1)=	0.59217085166882931 6D+02
-.2385D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.0000000000000000000D+00
.5145D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.0000000000000000000D+00
.2395D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.0000000000000000000D+00
.1777D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.0000000000000000000D+00
-.6928D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(6)=	0.0000000000000000000D+00
.1875D-11	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.0000000000000000000D+00
.4809D-09	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.0000000000000000000D+00
.2462D-06	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.0000000000000000000D+00
.7359D-14	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.0000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

-.4277D-01	.2522D-03	-.3374D-05	-.2589D-03	.9991D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2522D-03	.1000D+01	.8159D-09	.6261D-07	-.2416D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3374D-05	.8159D-09	.1000D+01	-.8376D-09	.3232D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2589D-03	.6261D-07	-.8376D-09	.1000D+01	.2481D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.9991D+00	-.2416D-03	.3232D-05	.2481D-03	.4277D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5209D-05	-.1260D-08	.1685D-10	.1293D-08	-.4990D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2239D-09	.5416D-13	-.7245D-15	-.5560D-13	.2146D-09	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2486D-07	.6013D-11	-.8044D-13	-.6173D-11	.2382D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3988D-05	-.9643D-09	.1290D-10	.9900D-09	-.3820D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1159D-09	.2802D-13	-.3749D-15	-.2877D-13	.1110D-09	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 0.000 IO/ 0.000 TC/ 0.000 TO/ 0.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR05.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:52 45.6

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-06	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

INPUT MATRIX B & SINGULAR VALUES

.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(1)=	0.00000000000000000000D+00
.0000D+00	.9921D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.44023540991457540000D+03
.0000D+00	-.1655D-06	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.00000000000000000000D+00
.0000D+00	-.8493D-04	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.00000000000000000000D+00
.0000D+00	-.6527D-01	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000000D+00
.0000D+00	.1999D-06	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.00000000000000000000D+00
.0000D+00	.8480D-04	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.00000000000000000000D+00
.0000D+00	.4349D-01	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.00000000000000000000D+00
.0000D+00	-.1299D-06	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.00000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

.1000D+01	-.9442D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1780D-04	-.1885D-02	.1549D-05	-.3839D-03	-.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1462D-07	.1549D-05	.1000D+01	.5933D-09	.1546D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3624D-05	-.3838D-03	.5933D-09	.1000D+01	-.3831D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9442D-02	-.1000D+01	.1546D-05	-.3831D-03	.1885D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2728D-07	.2889D-05	-.4465D-11	.1107D-08	.2883D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.4376D-12	.4635D-10	-.7164D-16	.1776D-13	.4626D-10	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.8601D-10	-.9109D-08	.1408D-13	-.3490D-11	-.9092D-08	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1458D-06	-.1544D-04	.2386D-10	-.5915D-08	-.1541D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.7171D-12	-.7594D-10	.1174D-15	-.2910D-13	-.7580D-10	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	-.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/ 0.000 MO/ 1.000 IO/ 0.000 TC/ 0.000 TO/ 0.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR06.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:53 43.3

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-08	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

INPUT MATRIX B & SINGULAR VALUES

.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(1)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.19828411888987958 3D+04
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.00000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

-.9998D+00	-.1818D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1354D-04	.7450D-03	.3193D-06	.7451D-03	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5804D-08	-.3193D-06	.1000D+01	-.2377D-09	-.3191D-06	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1354D-04	-.7450D-03	-.2377D-09	.1000D+01	-.7445D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1818D-01	-.9998D+00	-.3191D-06	-.7445D-03	.7457D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.3461D-06	.1904D-04	.6075D-11	.1418D-07	.1903D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.4827D-12	-.2655D-10	-.8473D-17	-.1977D-13	-.2653D-10	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3531D-09	-.1942D-07	-.6198D-14	-.1446D-10	-.1941D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2984D-06	-.1642D-04	-.5239D-11	-.1222D-07	-.1641D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5774D-12	-.3176D-10	-.1014D-16	-.2365D-13	-.3174D-10	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/ 0.000 MO/ 0.000 IO/ 0.040 TC/ 0.000 TO/ 0.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR07.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:54 43.3

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-08	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

INPUT MATRIX B & SINGULAR VALUES

.0000D+00	.0000D+00	.0000D+00	.9963D-03	.0000D+00	SV(1)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.22828050096866214 9D+03
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.00000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

-.1000D+01	-.7941D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1150D-04	.1448D-02	.3501D-05	.1453D-02	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2780D-07	-.3571D-05	.1000D+01	-.5080D-08	-.3496D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1154D-04	-.1453D-02	-.5080D-08	.1000D+01	-.1451D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.7941D-02	-.1000D+01	-.3496D-05	-.1451D-02	.1450D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1929D-07	.2430D-05	.8494D-11	.3525D-08	.2426D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1028D-11	-.1294D-09	-.4525D-15	-.1878D-12	-.1293D-09	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2430D-09	-.3059D-07	-.1070D-12	-.4439D-10	-.3055D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1139D-06	-.1433D-04	-.5009D-10	-.2079D-07	-.1431D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1201D-12	.1513D-10	.5289D-16	.2195D-13	.1511D-10	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/ 0.000 MO/ 0.000 IO/ 0.000 TC/ 20.000 TO/ 0.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: SVDR08.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 17-SEP-79
TIME: 09:55 35.4

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00	.0000D+00
-.3593D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1263D+04	.0000D+00	.0000D+00	.5099D+00
.5040D-08	.2348D-06	-.9921D-04	.0000D+00	.0000D+00	.0000D+00	.4940D+01	.0000D+00	.0000D+00	-.5099D+00
.1924D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	.0000D+00	.1136D+04	.4940D+01	.0000D+00	-.5099D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	.0000D+00	.5819D+06	.2273D+04	.4940D+01	-.5099D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01	.0000D+00
.3633D-05	.3312D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.4925D+00	.0000D+00	.0000D+00	-.1267D+04

INPUT MATRIX B & SINGULAR VALUES

.0000D+00	.0000D+00	.0000D+00	.0000D+00	.2480D-02	SV(1)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.56826646111374416 9D+03
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.00000000000000000000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	SV(10)=	0.00000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

-.1000D+01	-.7941D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1150D-04	.1448D-02	.3501D-05	.1453D-02	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2780D-07	-.3501D-05	.1000D+01	-.5080D-08	-.3496D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1154D-04	-.1453D-02	-.5080D-08	.1000D+01	-.1451D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.7941D-02	-.1000D+01	-.3496D-05	-.1451D-02	.1450D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1929D-07	.2430D-05	.8494D-11	.3525D-08	.2426D-05	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1028D-11	-.1294D-09	-.4525D-15	-.1878D-12	-.1293D-09	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2430D-09	-.3059D-07	-.1070D-12	-.4439D-10	-.3055D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1138D-06	-.1433D-04	-.5009D-10	-.2079D-07	-.1431D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1201D-12	.1513D-10	.5289D-16	.2195D-13	.1511D-10	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.1000D+01	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/ 0.000 MO/ 0.000 IO/ 0.000 TC/ 0.000 TO/ 25.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: R92.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 21-AUG-79
TIME: 09:31 22.6

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

-.1860D-04	.1311D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.4952D+05	.0000D+00	.0000D+00
-.3591D-05	-.1326D-03	.0000D+00	.0000D+00	.0000D+00	.2397D-07	-.1263D+04	.0000D+00	.0000D+00
.3578D-08	.2214D-06	-.9921D-04	.0000D+00	.0000D+00	-.2397D-07	.4940D+01	.0000D+00	.0000D+00
.1923D-05	.1170D-03	.0000D+00	-.9921D-04	.0000D+00	-.2397D-07	.1136D+04	.4940D+01	.0000D+00
.1308D-02	.8761D-01	.0000D+00	.0000D+00	-.9921D-04	-.2397D-07	.5819D+06	.2273D+04	.4940D+01
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03	.0000D+00	.0000D+00	.0000D+00
.5000D-07	-.6179D-06	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.8861D+01	.0000D+00	.0000D+00
.1723D-05	-.8375D-04	.0000D+00	.0000D+00	.0000D+00	.5958D-04	.1264D+03	-.4940D+01	.0000D+00
.8603D-03	-.4274D-01	.0000D+00	.0000D+00	.0000D+00	.5958D-04	-.5807D+06	.2525D+04	-.4940D+01

INPUT MATRIX B & SINGULAR VALUES

.5900D-03	.0000D+00	.0000D+00	.9963D-03	.2480D-02	SV(1)=	0.2122251237132796460+04
-.2386D-04	.9921D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.7737693212749480380+01
.5145D-07	-.1655D-06	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.1850242186652594160+00
.2395D-04	-.8493D-04	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.1264127860189157720+01
.1777D-01	-.6527D-01	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.3532739359500161190-19
-.6928D-07	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.0000000000000000000D+00
.1875D-11	.1999D-06	.0000D+00	.0000D+00	.0000D+00	SV(7)=	0.0000000000000000000D+00
.4809D-09	.8480D-04	.0000D+00	.0000D+00	.0000D+00	SV(8)=	0.0000000000000000000D+00
.2462D-06	.4349D-01	.0000D+00	.0000D+00	.0000D+00	SV(9)=	0.0000000000000000000D+00

MATRIX U - ORTHONORMALIZED COLUMNS

.1690D-01	.9991D+00	-.3434D-01	.1901D-01	.5966D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.6896D-03	-.2806D-01	-.2869D+00	.9575D+00	-.5841D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.5010D-06	-.1201D-03	-.3936D-02	-.1365D-02	.4529D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.7876D-03	-.2742D-01	-.9571D+00	-.2877D+00	-.2011D-01	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.9999D+00	-.1689D-01	.1136D-02	.5657D-03	.1972D-04	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1694D-04	-.1408D-02	-.2226D-01	.5426D-03	.8631D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.3178D-10	-.3121D-08	-.1578D-06	-.4786D-07	-.5575D-06	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1987D-07	-.2211D-06	-.2068D-04	-.5909D-05	-.3263D-03	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.1619D-04	.1842D-03	-.4368D-03	.2417D-03	-.2223D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.2785D-01	-.4561D+00	.8895D+00	.3191D-02	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.2074D+00	-.4276D+00	-.2288D+00	.8496D+00	.5943D-16	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.9343D+00	-.3273D+00	-.1387D+00	.2600D-01	.4077D-17	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.1076D+00	.2641D+00	.1381D+00	.1964D+00	-.9279D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
-.2678D+00	.6574D+00	.3438D+00	.4889D+00	.3728D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: R62.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 21-AUG-79
TIME: 09:32 59.3

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

.2609D-03	-.2143D-02	.0000D+00	.0000D+00	.0000D+00	.3330D+00
-.1072D-04	-.4455D-04	.0000D+00	.0000D+00	.0000D+00	-.8491D-02
.3146D-07	-.1231D-06	-.9921D-04	.0000D+00	.0000D+00	.3319D-04
.1077D-04	-.5483D-04	.0000D+00	-.9921D-04	.0000D+00	.8551D-02
.4542D-02	-.4511D-01	.0000D+00	.0000D+00	-.9921D-04	.8918D+00
-.4544D-07	.0000D+00	.0000D+00	.0000D+00	.0000D+00	-.1485D-03

INPUT MATRIX B & SINGULAR VALUES

.5900D-03	.1117D-02	.0000D+00	.9963D-03	.2480D-02	SV(1)=	0.21222512368546545 9D+04
-.2386D-04	.7072D-04	.0000D+00	.0000D+00	.0000D+00	SV(2)=	0.77376930815421981 5D+01
.5145D-07	-.5405D-07	.0000D+00	.0000D+00	.0000D+00	SV(3)=	0.18502420097765583 8D+00
.2395D-04	.2835D-04	.0000D+00	.0000D+00	.0000D+00	SV(4)=	0.12641278232345558 0D+01
.1777D-01	.6336D-01	.0000D+00	.0000D+00	.0000D+00	SV(5)=	0.72991929383231515 6D-19
-.6928D-07	.0000D+00	.3968D-05	.0000D+00	.0000D+00	SV(6)=	0.00000000000000000 0D+00

MATRIX U - ORTHONORMALIZED COLUMNS

.1690D-01	.9991D+00	-.3434D-01	.1901D-01	.3628D-03	.0000D+00
-.6896D-03	-.2806D-01	-.2869D+00	.9575D+00	-.3739D-02	.0000D+00
.5010D-06	-.1201D-03	-.3936D-02	-.1365D-02	.8291D+00	.0000D+00
.7876D-03	-.2742D-01	-.9571D+00	-.2877D+00	-.1530D-01	.0000D+00
.9999D+00	-.1689D-01	.1136D-02	.5657D-03	.1239D-04	.0000D+00
-.1694D-04	-.1408D-02	-.2226D-01	.5426D-03	.5589D+00	.0000D+00

MATRIX V - ORTHOGONAL MATRIX

.2785D-01	-.4561D+00	.8895D+00	.3191D-02	.0000D+00	.0000D+00
.2074D+00	-.4276D+00	-.2288D+00	.8496D+00	.1121D-15	.0000D+00
-.9343D+00	-.3273D+00	-.1387D+00	.2600D-01	.7111D-17	.0000D+00
-.1076D+00	.2641D+00	.1381D+00	.1964D+00	.9279D+00	.0000D+00
-.2678D+00	.6574D+00	.3438D+00	.4889D+00	-.3728D+00	.0000D+00
.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00	.0000D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

RESULTS OF SVD OF INPUT RESPONSE ANALYSIS

INPUT RESPONSE ANALYSIS RUN NAME: R52.DAT
INPUT DATA FOR ANALYSIS FROM: SSIN02.DAT

DATE: 21-AUG-79
TIME: 09:33 34.4

INPUT STEADY STATE VALUES

T= .345124D+03	R0= .952324D-07	P0= .261393D-02
I= .708052D-02	R1= .244300D-04	P1= .121652D+01
M= .359771D+01	R2= .125096D-01	P2= .902797D+03
RAD= .373847D-09		

JACOBIAN MATRIX VALUES

.1590D-03	-.2143D-02	.0000D+00	.0000D+00	.0000D+00
-.8120D-05	-.4455D-04	.0000D+00	.0000D+00	.0000D+00
.2130D-07	-.1231D-06	-.9921D-04	.0000D+00	.0000D+00
.8157D-05	-.5483D-04	.0000D+00	-.9921D-04	.0000D+00
.4269D-02	-.4511D-01	.0000D+00	.0000D+00	-.9921D-04

INPUT MATRIX B & SINGULAR VALUES

.4347D-03	.1117D-02	.8896D-02	.9963D-03	.2480D-02	SV(1)=	0.21222512365501498OD+04
-.1990D-04	.7072D-04	-.2269D-03	.0000D+00	.0000D+00	SV(2)=	0.77376854063249536lD+01
.3597D-07	-.5405D-07	.8868D-06	.0000D+00	.0000D+00	SV(3)=	0.18497834599747669 9D+00
.1996D-04	.2835D-04	.2285D-03	.0000D+00	.0000D+00	SV(4)=	0.126412763715068945D+01
.1736D-01	.6336D-01	.2383D-01	.0000D+00	.0000D+00	SV(5)=	0.170213635175140873D-19

MATRIX U - ORTHONORMALIZED COLUMNS

.1690D-01	.9991D+00	-.3432D-01	.1901D-01	.1082D-04
-.6896D-03	-.2806D-01	-.2870D+00	.9575D+00	.1742D-03
.5010D-06	-.1201D-03	-.3937D-02	-.1365D-02	.1000D+01
.7876D-03	-.2742D-01	-.9573D+00	-.2877D+00	-.4165D-02
.9999D+00	-.1689D-01	.1136D-02	.5657D-03	.2717D-05

MATRIX V - ORTHOGONAL MATRIX

.2785D-01	-.4561D+00	.8895D+00	.3193D-02	.0000D+00
.2074D+00	-.4276D+00	-.2288D+00	.8496D+00	.1350D-16
-.9343D+00	-.3273D+00	-.1387D+00	.2600D-01	.1014D-17
-.1076D+00	.2641D+00	.1381D+00	.1964D+00	.9279D+00
-.2678D+00	.6574D+00	.3438D+00	.4889D+00	-.3728D+00

SCALING FACTORS: THETA/2000.000 MO/ 1.000 IO/ 0.040 TC/ 20.000 TO/ 25.000

VITA

John H. E. Stelling III was born on October 3, 1952 in Charleston, South Carolina to Mr. John H. E. Stelling Jr. and Mrs. Louise Myers Stelling.

He attended Porter-Gaud School where he graduated in June 1970.

He attended Clemson University from 1970 to May 1974 when he graduated with a B. S. in Chemical Engineering. He has worked as a technical trainee in Project Engineering for Tennessee Eastman Company in Kingsport, Tennessee. Upon completion of his undergraduate study, Mr. Stelling accepted a position in Research and Development with Dow Chemical USA in Plaquemine, Louisiana. He worked in the process development area of ethylene oxide research and was promoted to Research Engineer in March 1976.

In 1978, he accepted a teaching assistantship with the University of Tennessee where he graduated in December 1979 with an M. S. in Chemical Engineering.

Mr. Stelling is a member of The Honor Society of Phi Kappa Phi, Tau Beta Pi, Sigma Xi, and The American Institute of Chemical Engineers.