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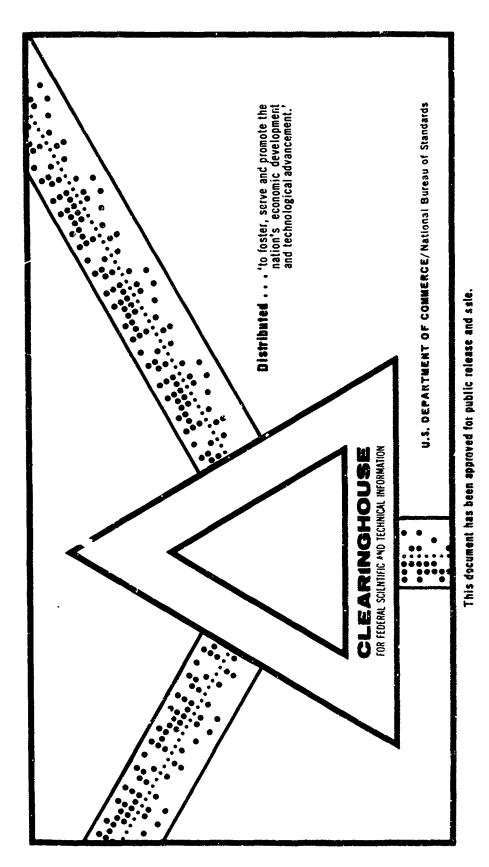
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EXTENSION OF HUMAN DESCRIBING FUNCTION MODELS TO STEP PLUS RANDOM APPEARING INPUTS

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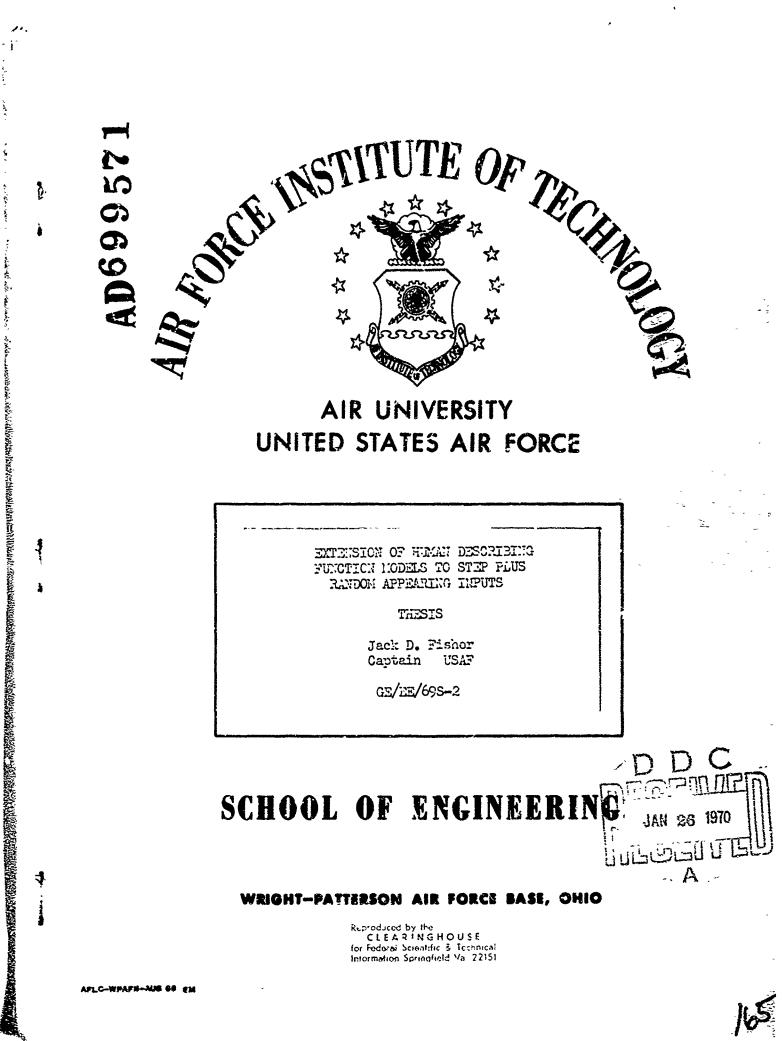
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THESIS

Presented to the Faculty of the School of Engineering

The Air Force Institute of Technology

Air University

in Partial Fulfillment of the

Requirements for the

Master of Science Degree

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by

Jack D. Fisher, B.S.E.E. Captain USAF

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### Preface

This study is an attempt to determine human operator models used in predicting the performance of human trackers when operating control systems with Gaussian noise plus step inputs. Performance measurements of human trackers operating control systems can be used to establish the parameters of the describing function r dol. Therefore, a major portion of this thesis deals with the collection and analysis of data from tracker controlled systems with Gaussian inputs, with step inputs, and with combined step and Gaussian inputs.

I wish to express my appreciation to Ronald O. Anderson, Control Analysis Group Leader, Air Force Flight Dynamics Laboratory for his sponsorship, interest, and continued assistance throughout all phases of this study. Special thanks is given to Paul E. Pietrzak of the Control Criteria Branch, Air Force Flight Dynamics Laboratory for his help with the analog simulations and for recording the Gaussian inputs on reproducable magnetic tape. Appreciation is extended to Major Russell A. Hannen for his understanding guidance and helpful suggestions. I am indebted to my three classmates, Captains Allan H. Dickson, Ronald L. Shillcutt, and John R. Starkie for their interest and their many hours of assistance as tracking subjects. Also, thanks is given to Lieutenant Commander Robert H. Wehr for inking several figures.

Finally, I wish to extend my appreciation and love to my wife and four children for their patience, understanding and encouragement.

Jack D. Fisher

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## List of Symbols

a	Break frequency (radians per second)
Cm	Control system output of the model system (volta)
ср	Control system output of the piloted system (volts)
e	Control system total error (volts)
ဓာ္မ	Control system error of the piloted system (volts)
Ð	Control system error of the model system (volts)
es	Control system error due to the step input (volts)
Øg	Control system error due to the random noise input (volts)
<sup>3</sup>	Kean squared error (volts squared)
গ্	Variance of the random noise input (volts squared)
50	Variance of the output (volts squared)
IAE	Time integral of absolute error (volts-seconds)
IES	Time integral of error squared (volts <sup>2</sup> -seconds)
ITAZ	Time integral of time weighted absolute error(volts-seconds <sup>2</sup> )
ITES	Time integral of time weighted error squared(volts <sup>2</sup> -seconds <sup>2</sup> )
x	KpK
K	Controlled element gain
× <sub>F</sub>	Human tracker gain
K <sub>N</sub>	System gain at $s = 0$ .
rs	Step input to the control system (volts)
r	Total input to the control system (volts)
ુદ્ધ	Gaussian input to the control system (volts)
*	Pure time delsy constant (seconds)
۲	Effective time delay constant (seconds)

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- TI Lag time constant (seconds)
- Load time constant (seconds)
- TN Neuromuscular lag (seconds)
- Yc Controlled element transfer function
- Yp Human pilot describing transfer function

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#### ABSTRACT

A study was made of describing function models of human trackers while operating control systems with Gaussian plus step inputs. The parameters in the describing function model were adjusted using existing parameter adjustment rules and experimental data. Four performance measures were determined from the experimental data to assess their usefulness in adjusting the parameters of human pilot describing function models.

The experiments were run using three subjects with varied levels of flying experience. Each subject was given the single task of controlling a system with one of three different controlled elements; X, K/S, K/S<sup>2</sup>. Data were collected on each subject for each system with a single step input, Gaussian input, and Gaussian plus step input. Comparisons of the output of the piloted systems and the model systems were made, and suggestions for applications to the controlled element dynamics were offered.

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EXTENSION OF HUMAN DESCRI\_\_NG FUNCTION MODELS TO STEP PLUS RANDOM APPEARING INPUTS

### I. Introduction

#### Back round

In the past several years, interest has been generated in monmachine systems with particular emphasis on determining the role and response of man in the system. Mathematical models, which imitate humar behavior during a particular task, have been developed. Men such as Elkind, Manuer, and Graham have gained distinction in the growing area of human response modeling. The United States Air Force has an obvious interest in this area becaus: of the relationship between man, the pilot, and the machine, the airplane.

The Air Force Flight Dynamics Laboratory at Wright-Patterson Air Force Base has been conducting in-house studies and contracting for research in the area of human response. Of particular interest at present is the development of a model that would predict the response of a pilot in a one-step landing system. A one-step landing system would allow a pilot, flying along a glide path towards a runway, to make one major change in his flight path before touchdown. A prediction of the proper altitude at which to make this change is dependent on the characteristics of the aircraft and the response of the pilot. The mathematical equations representing the aircraft characteristics are known, since the formulation of appropriate

transfer functions is normally accomplished during the design and construction of the aircraft. The mathematical equations representing the responses of the pilot in particular tasks are being developed as data is accurulated from the experiments of many individual in this field. Accurate models, which could predict pilot response, would be of benefit in performing handling qualities and manual control analysis during aircraft development, construction, and modification. Pilot models would also be useful for determining the feasibility of performing a particular aircraft menuver such as a one-step landing, without actually flying the aircraft.

In a one-step landing, although only one major change in flight path is needed, minor adjustments must be made to prevent the aircraft from being clown off the glide path by wind gusts. Human pilot describing function models have been developed for predicting pilot performance in controlling a single loop system in the presence of Genssian input signals, representing wind gusts. (Ref 9). Adjustment rules for setting the parameters of the model are well defined and used extensively. (Ref 11). Application of the describing function model has been applied to nonlinear systems (Ref 6), and to systems with step inputs (Ref 14). However, few data are presently available for determining pilot performance in a situation such as the one-step Landing system where the input to the system is a Gaussian random disturbance plus a command step signal. A preliminary study was done at the Air Force Flight Dynamics Laboratory (Ref 1 & 3). Also, a dual mode pilot model (surge model) has been proposed (Ref 5) and some results for rendom inputs plus "step-like discontinuities" are available. However, only the pure gain controlled element was

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considered, and the model is fairly complicated.

#### The Problem

An evaluation of the existing human pilot describing function model is necessary to determine how well, if at all, the model predicts the performance of a pilot in a system which has Gaussian plus step inputs. A determination of the best performance criteria to use in adjusting the model parameters is also necessary. The relationship between the performance measures and adjustment rules used for a system with Gaussian input and the measures and rules used for a system with step inputs should be determined. Therefore, the purpose of this thesis is to collect performance data by observing and modeling human subjects operating single axis control systems. The collection and analysis of these data will provide for a better understanding of performance and necessary model adjustments in systems which have Gaussian plus step signals applied.

## The Objectives

The objectives of this thesis are: (1) to collect, analyze, and correlate performance measure data of three subjects operating systems with Gaussian inputs, step inputs, and combined Gaussian plus step inputs, (2) to study the existing human pilot describing function model and determine a method of adjusting its parameters from accumulated data on actual pilot performance, (3) to develop techniques for combining the performance measure for a system with Gaussian input with the performance measure for a system with a step input to obtain the performance measure for a system with Gaussian plus step inputs, and (4) to evaluate the usefulness of the existing pilot

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model and adjustment rules for predicting the output of a manned system when Gaussian plus step signals are applied.

### Approach

The first stop was to collect data on the performance of three subjects operating a simple single axis compensatory tracking task. Each subject has a different level of flying proficiency, but each was given the same operating instructions. The experiments were sequenced from easy to difficult. Measurements were taken for three systems, excited first with step signals, then Gaussian signals, and then step and Gaussian signals.

The second step was to program the pilot describing function nodal on the analog computer so that data for determining the model characteristics could be collected. Graphs were prepared to show the effect of parameter variation on model performance. Root locus analysis was conducted to show trends in modeled system dynamics. The determination of model characteristics was accomplished so that a comparison with actual pilot performance would be possible.

The third step was the correlation of data. An attempt was made to match human performance with model performance by using appropriate model adjustments. The final step was to compare the system output of the adjusted model with the system output of the piloted model when operated simultaneously. Real time recordings were taken.

### Scope

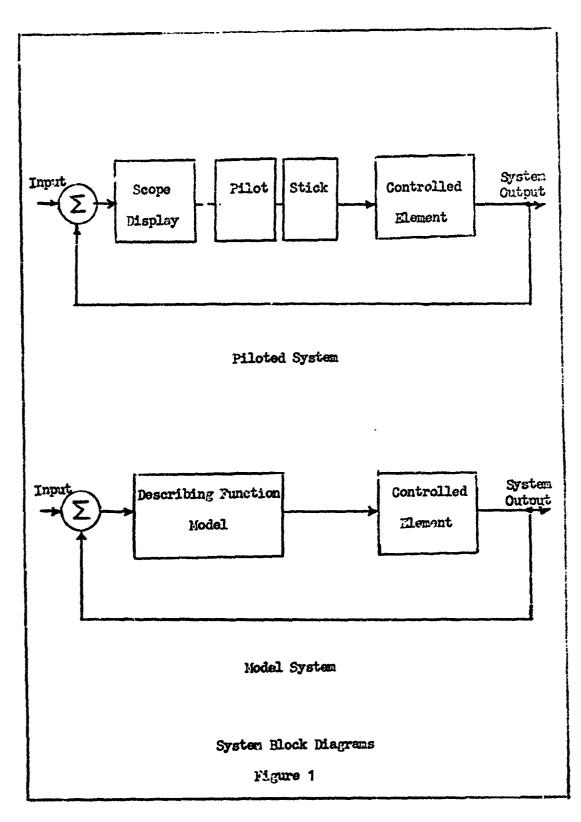
It should be emphasized that this thesis is not a study of the development of a new pilot model. The study is limited to the collection and analysis of data, the evaluation of the existing human

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describing function model with parameter variation, and the comparison of piloted and model systems with Gaussian plus step inputs. All experiments with human subjects and the model will be conducted for systems with one of three controlled elements and a single unity foedback loop. The analog computer is used in the simulation of both systems. A block diagram of the piloted and model systems is shown in Figure 1. Three controlled elements; K, K/S, and K/S<sup>2</sup> are used. No attempt was made to use aircraft dynamic equations.

Four performance measurements were studied: (1) the time integral of error squared, (2) the time integral of time weighted error squared, (3) the time integral of absolute error, and (4) the time integral of time weighted absolute error. A performance measurement is an evaluation of how well a system operates; how well the output follows the input, or how small the error can be maintained over a given time period. The time integral of error squared has been used successfully to evaluate the performance of human trackers in systems with Gaussian inputs. The purpose of studying additional performance measures was to evaluate their usefulness for systems with step, and Gaussian plus step inputs.

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#### II. Experimental Acoroach

#### <u>General</u>

The experiments were conducted in three phases. The same three subjects were used in each phase. Their flying experience is listed in Appendix F. The subjects were briefed on the purposes of the experiments. Their cooperation and interest through many hours of tests spread over several months was extremely high. All experiments were conducted in a single room with the subject seated in a student's chair. A force stick firaly attached to the chair armrest was the instrument which the subject used to affect changes on the system. The force stick is explained in Appendix A and it was used by the subject to correct for the system error. The error was displayed as a vertically displaced horizontal trace on a Tektronics oscilloscope. The subjects were told that the horizontal trace represented the pitch steering bar of an aircraft. They were instructed to keep the trace level with a guide line taped to the scope display. The force applied to the stick was electrically coupled to the controlled element of the system. The polarity of the stick control was set similiar to an aircraft stick; i.e. force applied away from the subject caused the horizontal trace on the scope to move up, and visa versa. It was emphasized to the subjects, especially the experienced pilots, that they should control the stick in a manner similiar to the method in which they hendled an actual aircraft control.

For each set of experiments, the subjects were allowed three practice runs. During these runs, the sensitivity of the stick was

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set for comfortable control and the brightness and focus of the horizontal oscilloscope trace were set for easy viewing. Distance between the subject and the scope display was set at five feet. The oscilloscope sensitivity was set for best utilization. It should be noted that changes of scope sensitivity within reasonable limits has very little effect on performance (Ref 14). The noise level in the room was approximately half of that which would be experienced in the cockpit of an aircraft. Subject 1 mentioned that he frequently talks during actual flying manuvers, and he asked if he would be permitted to talk during the experiments. To provide as much realism as possible, it was agreed that all subjects would be allowed to talk during the experiments if they wished. However, their performance was not discussed until all tests were completed on a particular system. On several occasions, superior performance by subject 1 was noted during tests in which he was talking frequently.

In each phase, three systems were tested. The first system tested had a pure gain controlled element, the second system had a single integrator with gain, and the third system included a doublo integrator with gain. The subjects completed the loop of the unity feedback control system by sensing the error on the scope and applying a correction to the controlled element with the force stick.

## Phase I - Step Input

During Phase I, tests were made on each of the three systems with a single one volt step input applied. The application of the step caused a two centimeter trace displacement on the oscilloscope when set at 0.5 volts/centimeter; therefore, the scope was set at

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0.5 volts/centimeter for all runs. The subjects were given warning to watch the scope display preceding the application of the step. The step was randomly applied within  $\circ$  time interval of thirty seconds. A maximum time of twenty seconds was given for the subjects to zero the error. The analog computer was then placed in hold and the readings were taken from the digital voltmeter. Also, real time recordings of the input, output, error, and force voltages were made. From these recordings, measurements were taken of the static time delay between the input of the step and the application of force to the stick. Twenty-five runs were made with each controlled element. For the K/S<sup>2</sup> controlled element, additional runs were occasionally necessary when the subject lost control due to over-reaction and oscilloscope display limitations. It was necessary to blas the stick voltage as shown in Appendix B due to a slight mechanical hystoresis.

### Phase II - Gaussian Input

During this phase of experimentation, the subjects were given a tracking task with Gaussian input applied to the system. Three, second order-filtered Gaussian signals (Appendix C) were used, one with a break frequency of 0.5 radians/second, another with a break frequency of 1.0 radians/second, and the third with a break frequency of 1.5 radians/second. To ensure that each run was of equal length, the automatic hold circuit of the analog computer was employed at exactly sixty seconds from the start of the run. Reuse of each of the three signals was accomplished by employing the Sangamo magnetic tape recorder/reproducer in loop operation. The production of the Gaussian signals is discussed in Appendix C. To avoid criticism that the

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subjects would learn the nature of the three signals, the input was switched after each sixty second trial. Occasionally, first orderfiltered signals were applied from the tape to prevent over familiarity with the three, second order-filtered signals used for the data collection.

For the signal with the 1.5 radians/second break frequency and the signal with the 0.5 radians/second break frequency, nine oneminute tests were made for each of the three controlled elements. For the signal with a 1.0 radian/second break frequency, only four oneminute tests were accomplished.

### Phase III - Gaussian Plus Step Inputs

The third phase of the experiment was completed using two of the three Gaussian signals used in Phase II; the 1.5 radians/second signal and the 0.5 radians/second signal. A 1, 3, or 5 volt step was applied at some random time within the first twenty seconds of the run. Five tests for each signal applied to each of the three systems were accomplished. Therefore, each subject performed a total of ninty tests during this phase. As mentioned before, the subjects worked the easiest system first and progressed to the more difficult system. All runs were sixty seconds long. The time lapse between the beginning of the run and the application of the step was measured with a hand stop watch.

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#### Performance Measures

The following performance measures were used to evaluate each experiment:

(1)  $\int e^2 dt$ (2)  $\int te^2 dt$ (3)  $\int IeI dt$ (4)  $\int tiel dt$ 

The measures were programmed on the analog computer as discussed in Appendix B. One difficulty occurred with the multipliers used on the analog; non-linearity of the diodes when operated near zero volts, resulted in erroneous readings for  $\int te^2 dt$  during some experiments in Phase II and Phase III. Time was represented by volts, so it was necessary to start the time at ten rather than zero. This was accomplished by applying an initial condition of ten volts to the timing integrator. The timing problem made it impossible to read  $\int te^2 dt$  and  $\int tie! dt$  directly. The following development indicates how these measures were determined. Since

$$\int_{2}^{T} (t + 10) e^{2} dt = \int_{2}^{1} te^{2} dt + 10 \int_{2}^{1} e^{2} dt ,$$

tlarefore

$$\int_{c}^{T} e^{2} dt = \int_{c}^{T} (t + 10) e^{2} dt - 10 \int_{c}^{T} e^{2} dt.$$

Similarly,

$$\int_{c}^{T} \text{iel } dt = \int_{0}^{T} (t + 10) \text{ jel } dt - 10 \int_{0}^{T} \text{iel } dt.$$

One objective of this study was to determine if a linear relationship existed between the measures recorded for the piloted systems with separate step and Gaussian inputs, and the measures

recorded for the piloted systems with combined Gaussian plus step inputs. The following hypothesis was formulated for each performance measure.

IES

$$\int_{c}^{T} (\mathbf{e}_{g} + \mathbf{e}_{g})^{2} dt = \int_{c}^{T} (\mathbf{e}_{g}^{2} + 2\mathbf{e}_{g}\mathbf{e}_{g} + \mathbf{e}_{g}^{2}) dt$$
$$= \int_{c}^{T} \mathbf{e}_{g}^{2} dt + \int_{c}^{T} 2\mathbf{e}_{g}\mathbf{e}_{g} dt + \int_{c}^{T} \mathbf{e}_{g}^{2} dt$$

If the term  $\int_{0}^{\overline{t}} 2e_{s}e_{g} dt$  is small enough to ignore, then the additive relationship  $\int_{0}^{\overline{t}} (e_{s} + e_{g})^{2} dt = \int_{0}^{\overline{t}} 2 dt + \int_{0}^{\overline{t}} e_{g}^{2} dt$  results.

$$\frac{\text{ITES}}{\int_0^T t(e_s + e_g)^2} dt = \int_0^T t(e_s^2 + 2e_s e_g + e_g)^2 dt$$
$$= \int_0^T te_s^2 dt + \int_0^T 2te_s e_g dt + \int_0^T te_g^2 dt$$

If the assumption is made that  $\int_{c}^{T} 2te_{g}e_{g} dt$  is very small, then  $\int_{a}^{T} t(e_{g} + e_{g})^{2} dt$  will approximately equal  $\int_{a}^{T} te_{g}^{2} dt + \int_{a}^{T} te_{g}^{2} dt$ . However, knowledge of the time when the step input is applied, is required to determine the value  $\int_{a}^{T} te_{g}^{2} dt$ . It appears that the complications involved in determining this value would eliminate the use of this performance measure for determining model parameter values in a system with Gaussian plus step inputs.

IAE

 $\int_{o}^{T} \log + \log l \, dt \leq \int_{o}^{T} (\log l + \log l) \, dt$ 

If the assumption is made that the error due to the step input is rormally of the same polarity as the error due to the Caussian signal than the absolute value of the sum will equal the sum of the absolute values. If the subject was maintaining the error at an extremely low level when the step was applied, then equality of the above might be possible. Although the assumptions for equality were doubted before experimentation, the measurements were taken to clarify the issue.

TTAE

 $\int_{a}^{T} tie_{s} + e_{g} i dt \leq \int_{a}^{T} tie_{s} i dt + \int_{a}^{T} tie_{g} i dt$ 

The same assumption must be made for this measure as made for the IAE. The time-varying aspect of this relationship further increases the computational difficulties in using this measure to determine the parameters of a model system forced with Gaussian plus step signals. However, the ITAE is possibly a good performance measure for a system with step inputs.

#### III. Describing Function Model and Analog Simulation

## The Eristing Model

The human pilot acts, in general, as a nonlinear and time-varying device in a control system. To develop a model to respond in a manner similar to that of a pilot, is a difficult task. However, a human describing function model has been developed which simulates pilot responses in a control system when random Gaussian signals are applied. (Ref 11). The general quasi-linear model appears as a LaPlace transformed equation.

$$Y_{p}(s) = \frac{K_{p}e^{T'S}(T_{L}S + 1)}{(T_{T}S + 1)(T_{N}S + 1)}$$

with S = jw since this is a describing function. The pure time delay is represented by  $\in -T^{T}S$ , the gain by K<sub>p</sub>, the general lead term as T<sub>L</sub>, the general lag term as T<sub>I</sub>, and the first-order lag time constant approximation of the neuromuscular system as T<sub>N</sub>. The neuromuscular lag approximation is often eliminated and the pure time delay term, T' is modified to include the neuromuscular time constant. The result is an effective time delay term  $\in -TS$ , where  $\Upsilon = T' + T_{N}$ . The simplified version of the pilot describing function model, represented in LaPlace transform, is

$$Y_{p}(s) = \frac{K_{p} e^{-\tilde{t}s} (T_{L}S + 1)}{(T_{I}S + 1)}$$

The model parameters, T,  $T_L$ ,  $T_I$ , and  $K_p$  are appropriately adjusted for the type of system being controlled. In a control system, where the controlled element is pure gain, the lead time constant, if any, is extremely small in relationship to the lag term, and thus can be

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climinated. Much the cont olled element is K/S, the lead and lag time constants are equal or zero, and with a K/S<sup>2</sup> controlled element, the lag, if any, is small in relation to the lead time constant and can be eliminated. The specific model form is shown with the corresponding controlled element in Table 1.

#### Table 1

#### The Simplified Models

Controlled Element	Model
K	$\mathbf{Y}_{p} = \frac{K_{D} \in \mathbf{\widehat{1S}}}{(\mathbf{T}_{\underline{1}}\mathbf{S} + 1)}$
K/S	$\mathbf{x}_p = \mathbf{x}_p \in \mathbf{\hat{TS}}$
x/s <sup>2</sup>	$\mathbf{x}_{\mathbf{p}} = \mathbf{p} (\mathbf{T}_{\mathbf{L}}\mathbf{S} + 1) \boldsymbol{\epsilon}^{-\mathbf{T}\mathbf{S}}$

The model parameters not only depend on the type of system, but the type of input and on the existance of physical nonlinearities. Adjustment rules governing the model operation have been developed. (Ref 11:18). Since the first consideration of the human operator is to maintain stability, the model parameters must be set for stable operation. The second consideration of the human operator is the maintenance of good low frequency operation by generating lag, if necessary. After adjusting for good low frequency operation, the pilot then generates lead, if necessary, to improve high frequency

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response. With the parameters,  $T_{I}$ ,  $T_{L}$ , and T, partially adjusted, the gain,  $K_{p}$ , is then set to the optimum operating level. It is thought that the operator adjusts gain to minimize the mean-squared error. The formulated rules also include certain invariance properties. First, the operator adjusts his gain to compensate for variations of the controlled element gain, thus over-all system gain remains relatively constant. Second, system cross-over frequency is invariant with changes of input bendwidth, provided the input bandwidth is less than the cross-over frequency. Third, when the bandwidth increase 'o, and goes beyond, the cross-over frequency, the operator, varies operation to maintain stability and good low frequency response. This appears as a reduction in operator gain and lead, and is known as regression.

#### Model Simulation

Assuming that the existing model was applicable to the experiments performed in this study, a method f r identifying the appropriate model values was necessary. To facilitate matching the model with the subjects, the model was simulated on the analog computer, and a series of tests were run to determine changes in the mean-squared error, as the parameter settings were varied. To program the analog computer, it was necessary to use an approximation to the pure time delay. The first order Pade' approximation was chosen, because of its constant amplitude characteristics for all frequencies. However, the phase difference between the Pade' approximation, and the actual time delay, becomes pronounced as frequency is increased. The LaPlace transform of the Pade' approximation is (1 - 0.5TS).

A root locus study was conducted to determine the appropriate parameter settings for the analog simulated model. Settings causing unstable operation were identified. The root loci of both the model with Pade' approximation and the human describing function with pure time delay were computed. Loci diagrams are shown in Figures 2-33. The plots were programmed on the IBM 7094 Digital Computer and drawn on the Cal-Comp plotter. The parameter settings used for each plot wore chosen from a range of values considered in previous studies (Ref 11), and are listed in Table 2. The title for the human describing function model plots with pure time delay was shortened to "Human Describing Kodel." The title for the simulated model plots using the Pade' approximation is "Analog Simulated Model."

The gain for optimum operation of the model, minimum mean errorsquared of the simulated model with a second order filtered Gaussian input having a break frequency of 1.5 radians per second, is identified on both the analog simulated plots and the human describing function plots. The following observations were made from the root locus study: At the gain setting for minimum mean error-squared of the simulated model,

1) the undamped natural angular frequency of the human describing function was less than that of the simulated model,

2) the damping factor of the human describing function was less than the damping factor of the pure gain controlled element model with small lag constants, and greater than the damping factor of the model with larger lag constants,

3) for large lead constants in the system with the K/S<sup>2</sup> controlled element, the damping factor was greater for the simulated model, and for small lead constants, the damping factor was greater, and

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Figures	Type System	Time Delay	Lead	Lag
2 & 3	K	0.2	0.0	5.0
4 & 5	K	0,2	0.0	3.0
6 & 7	K	0.2	0.0	1.0
829	ĸ	0.3	0.0	5.0
10 & 11	K	0.3	0.0	3.0
12 & 13	K.	0.3	0.0	1.0
14 & 15	ĸ/s	0.2	0.0	0.0
16 & 17	K/S	0.3	0.0	0.0
18 & 19	K/S <sup>2</sup>	0.2	0.5	0.0
20 & 21	K/S <sup>2</sup>	0.2	1.0	0.0
22 & 23	K/S <sup>2</sup>	0.2	3.0	0.0
24 & 25	K/S <sup>2</sup>	0.2	5.0	0.0
26 & 27	K/S <sup>2</sup>	0.3	0.5	0.0
28 & 29	K/S <sup>2</sup>	0.3	1.0	0.0
30 & 31	ĸ/s <sup>2</sup>	0.3	3.0	0.0
32 & 33	K/S <sup>2</sup>	0.3	5.0	0.0

Table 2

A List of The Root Locus Figures

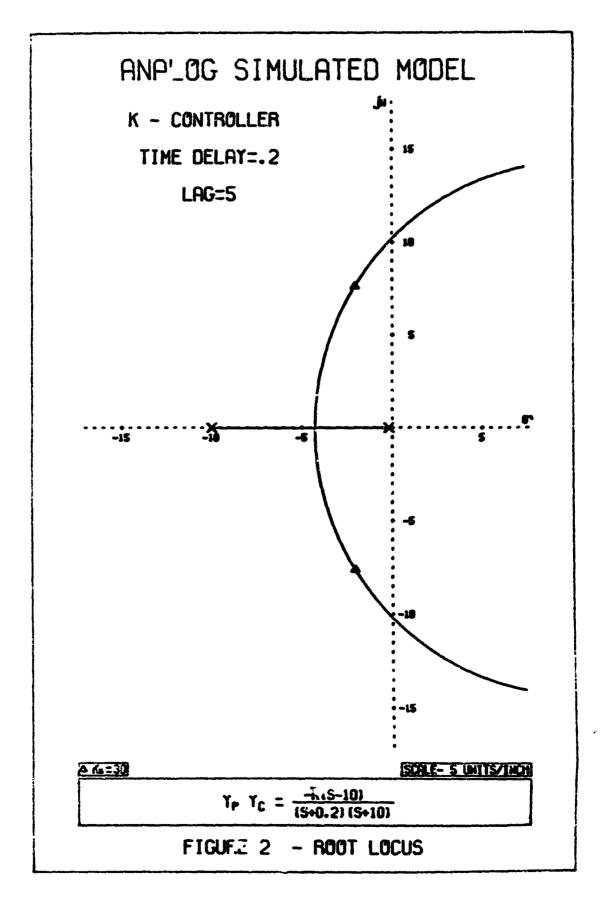
4) at low frequencies, the model is a good representation of the human describing function model.

These results may be of some value to investigators who have used, or are using, the Pade: approximation.

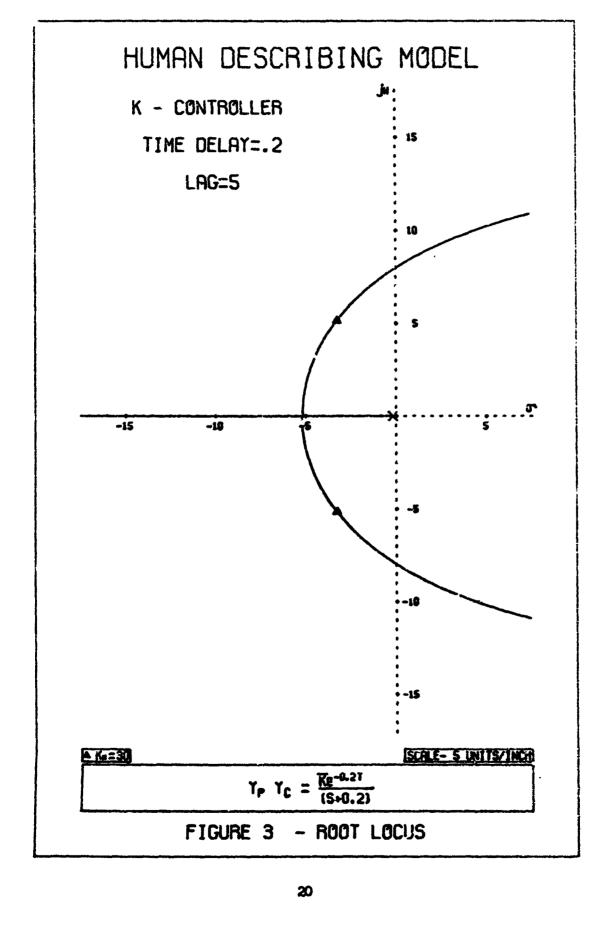
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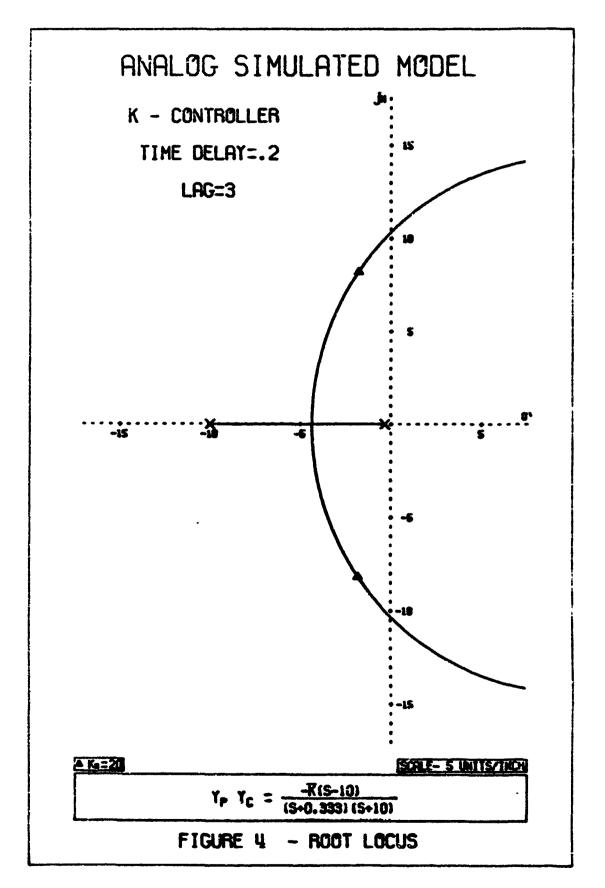


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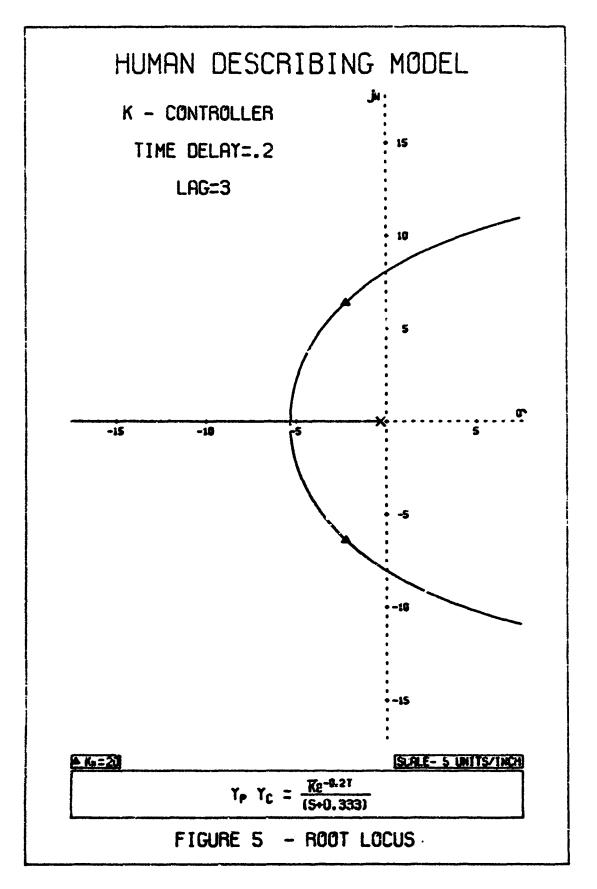


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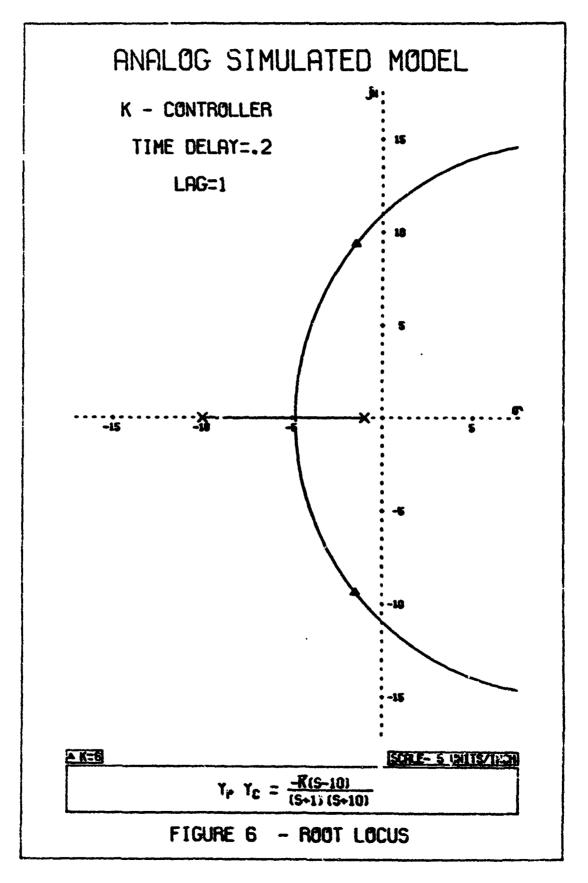


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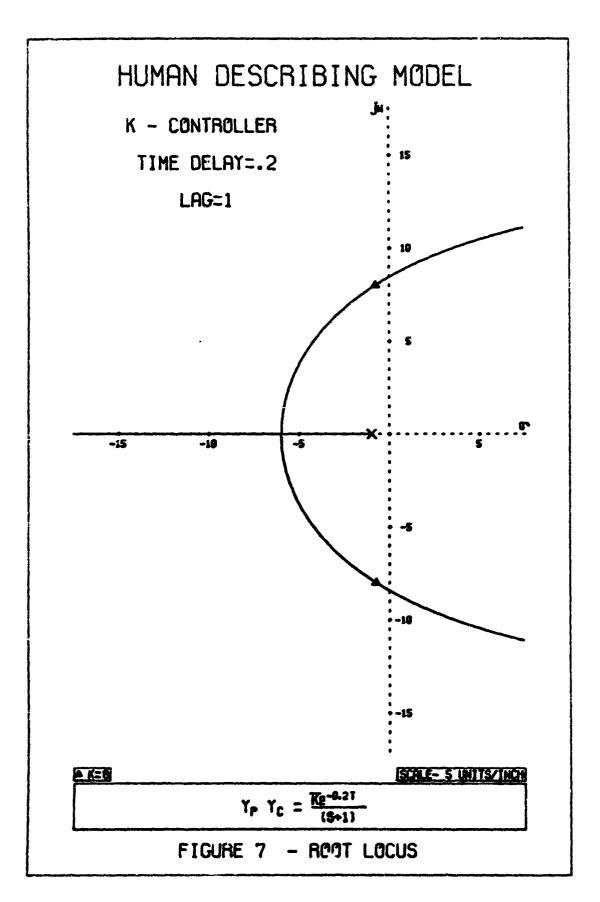
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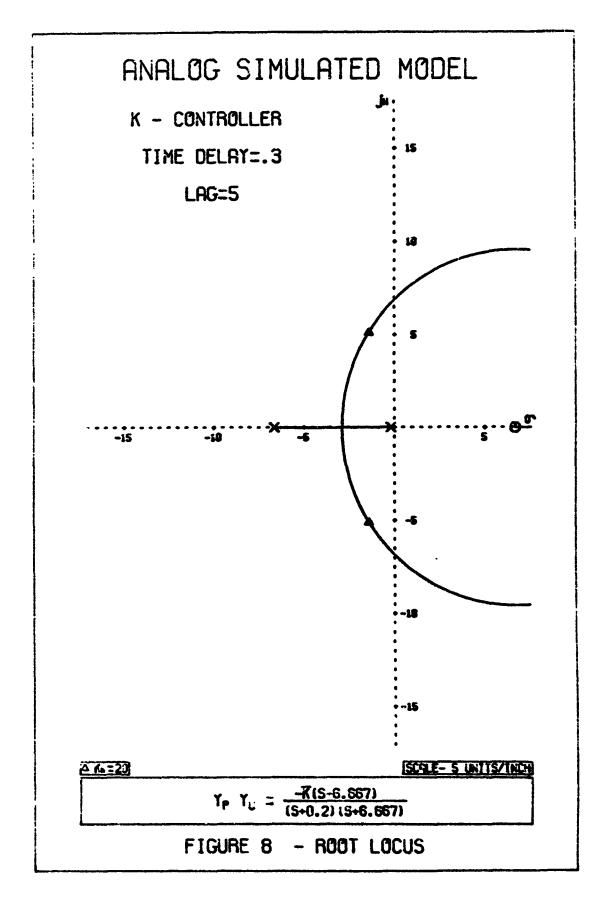
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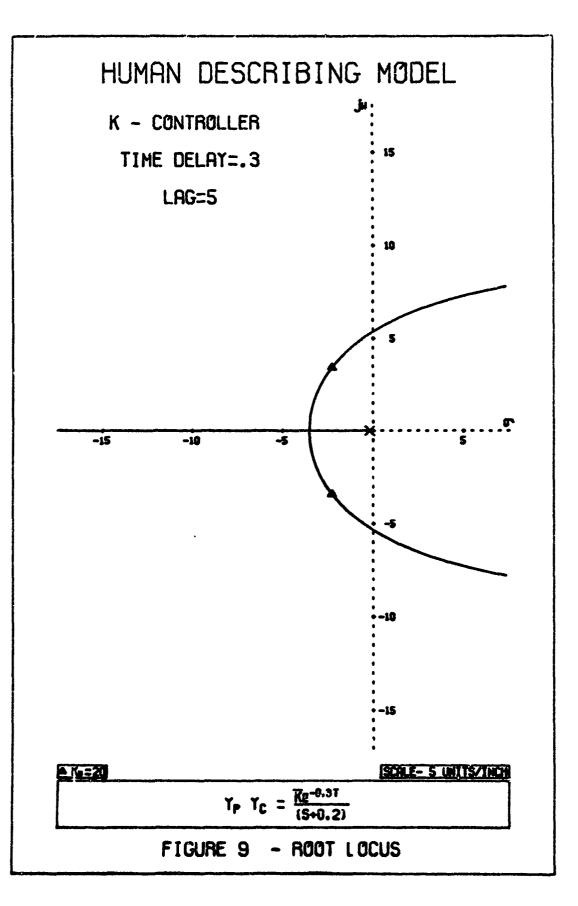


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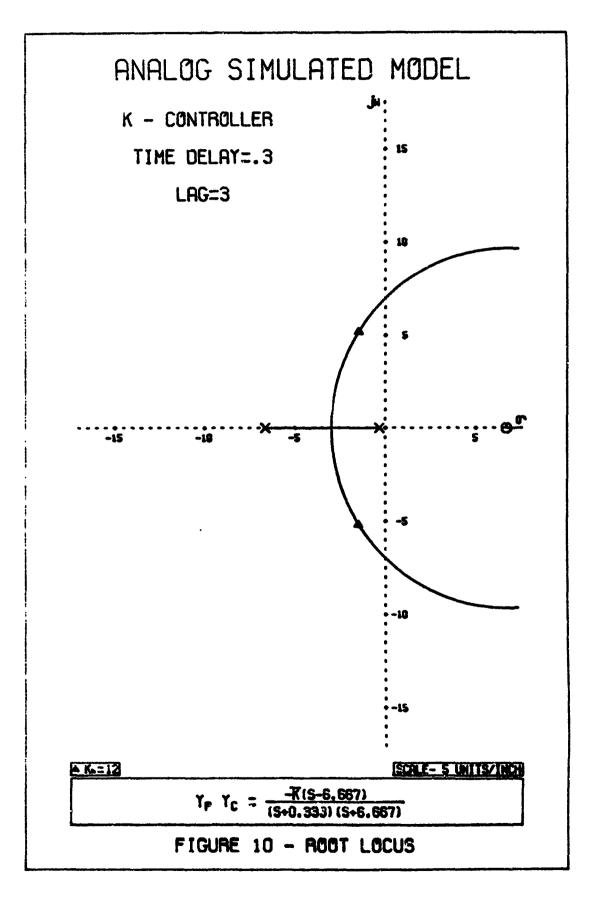
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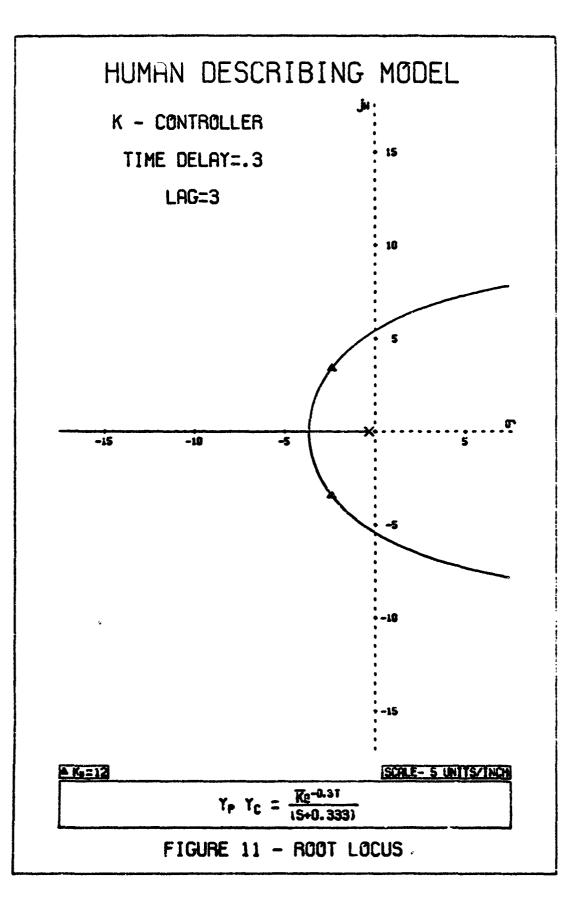
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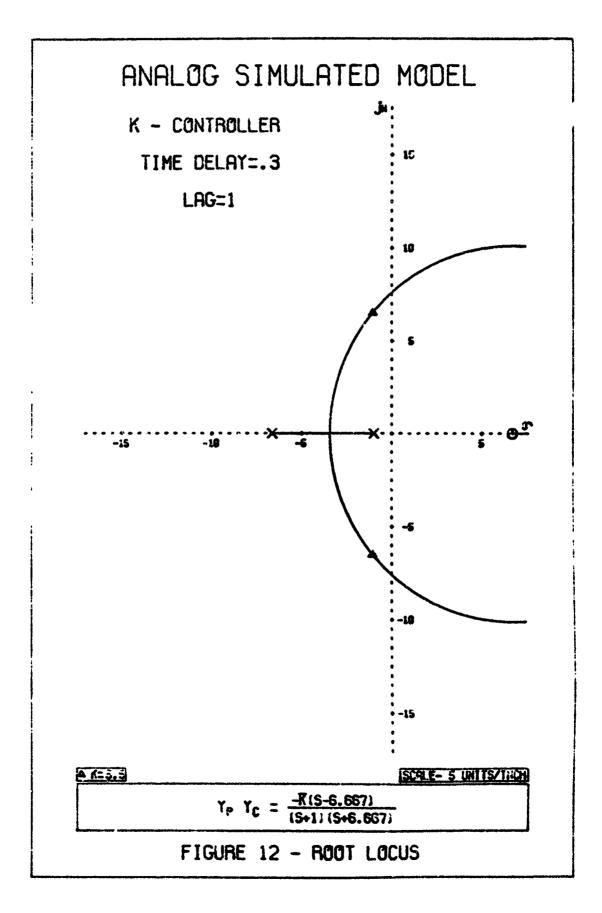
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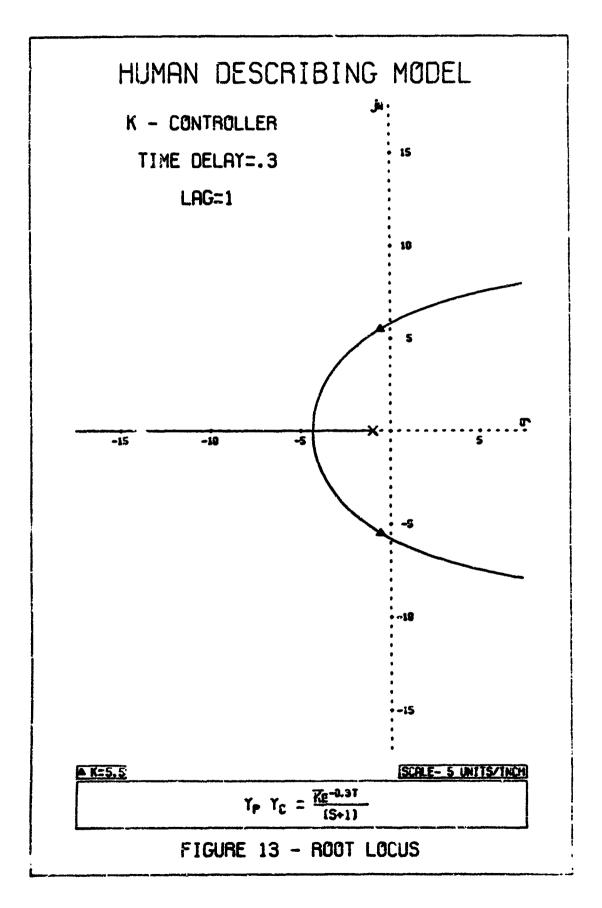
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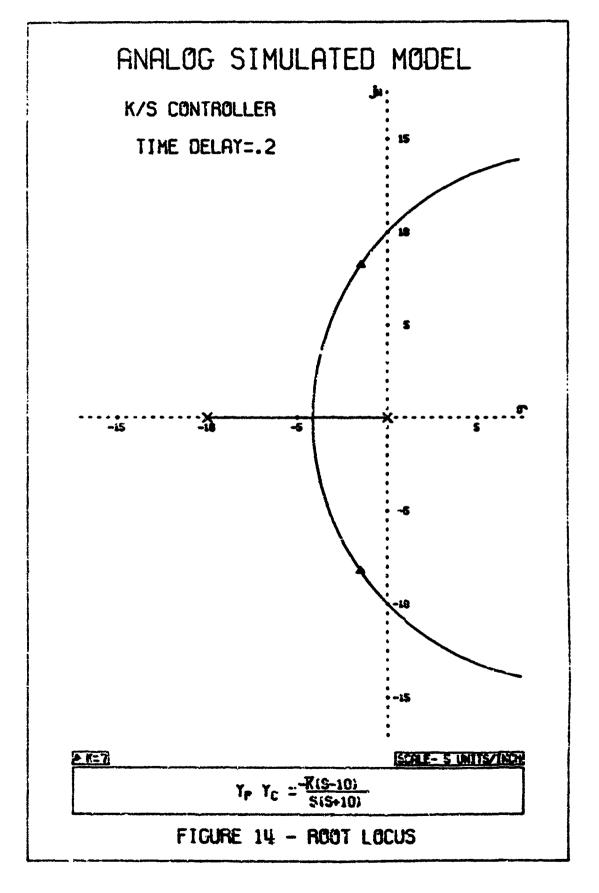


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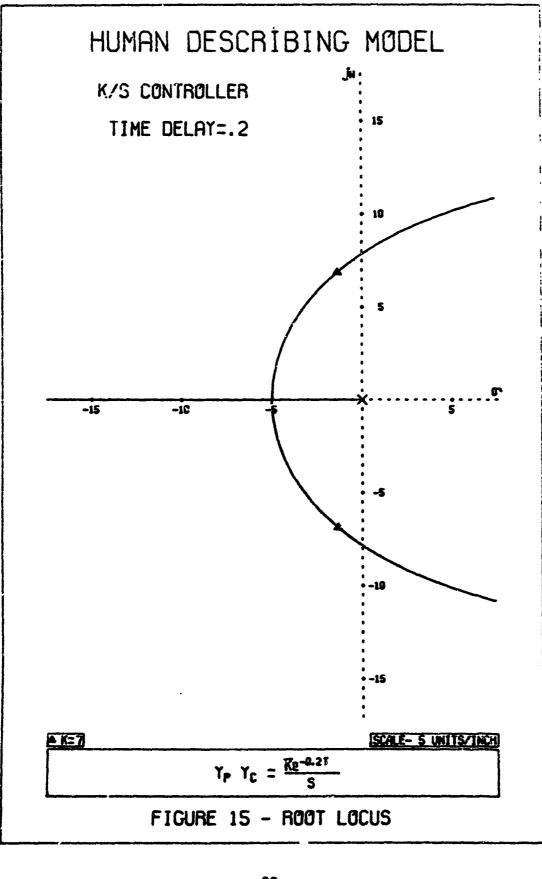
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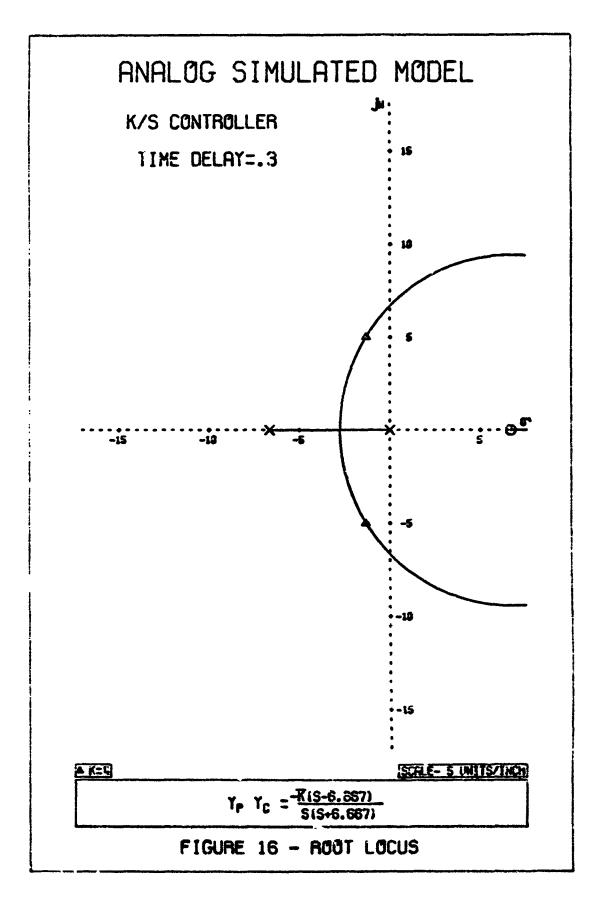
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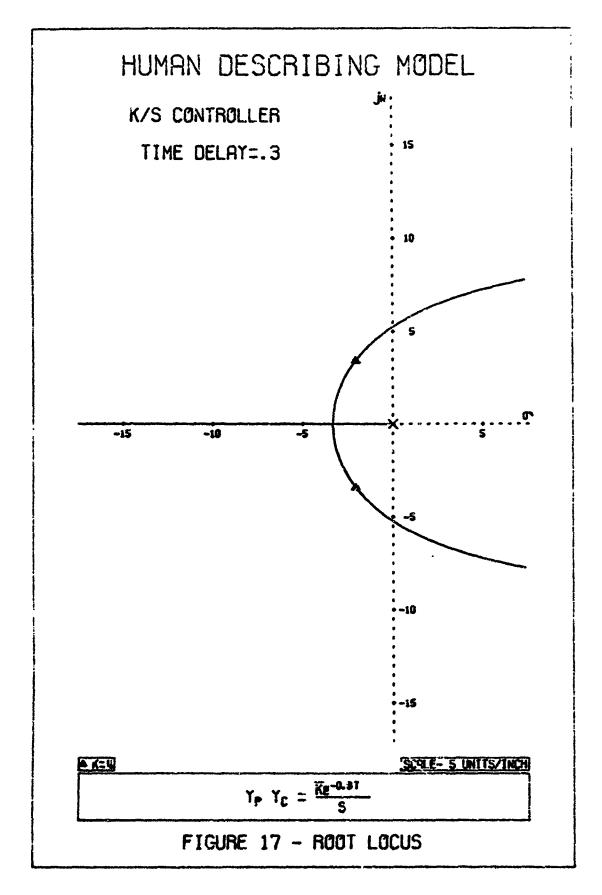
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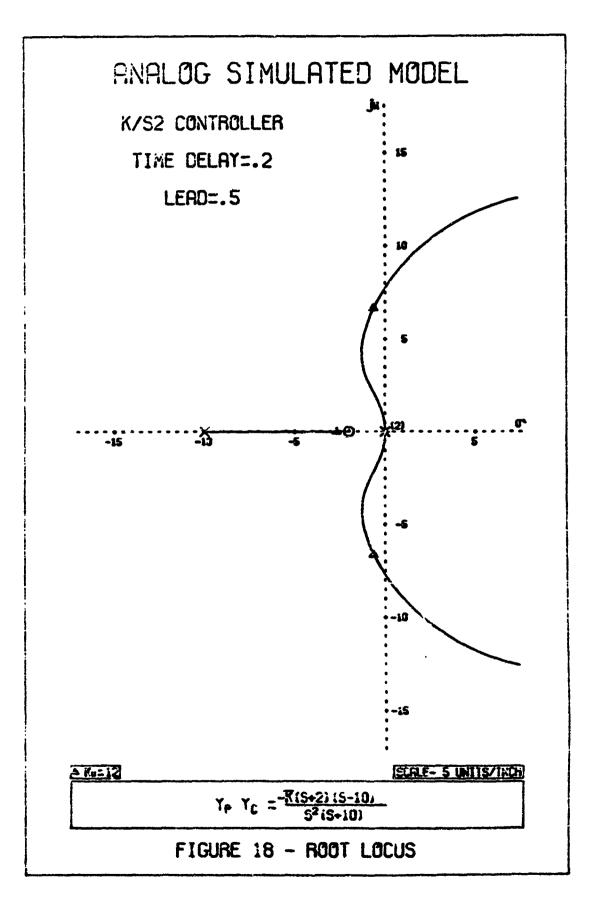


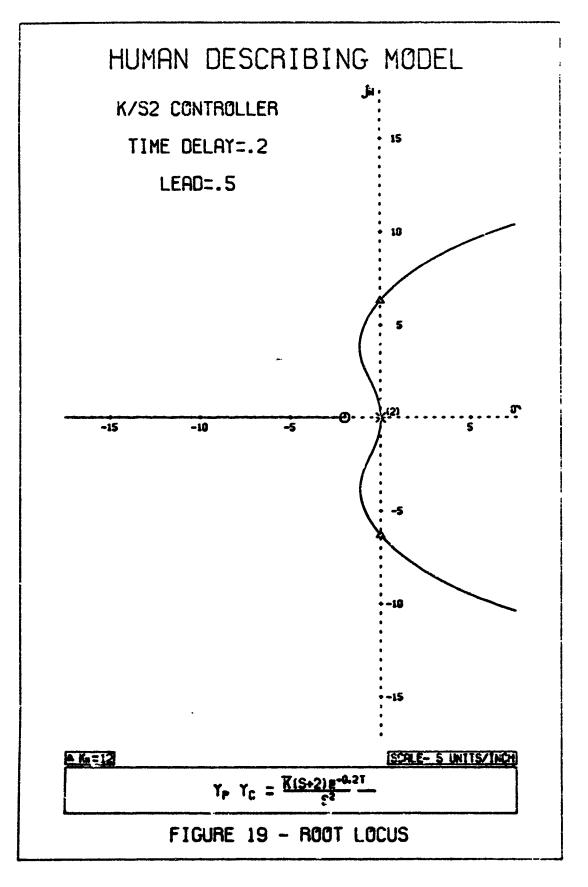
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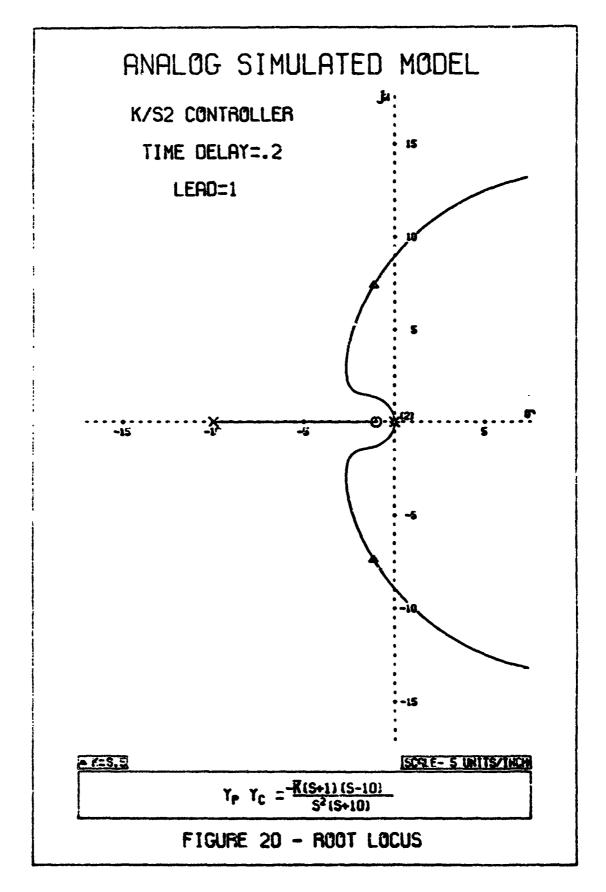
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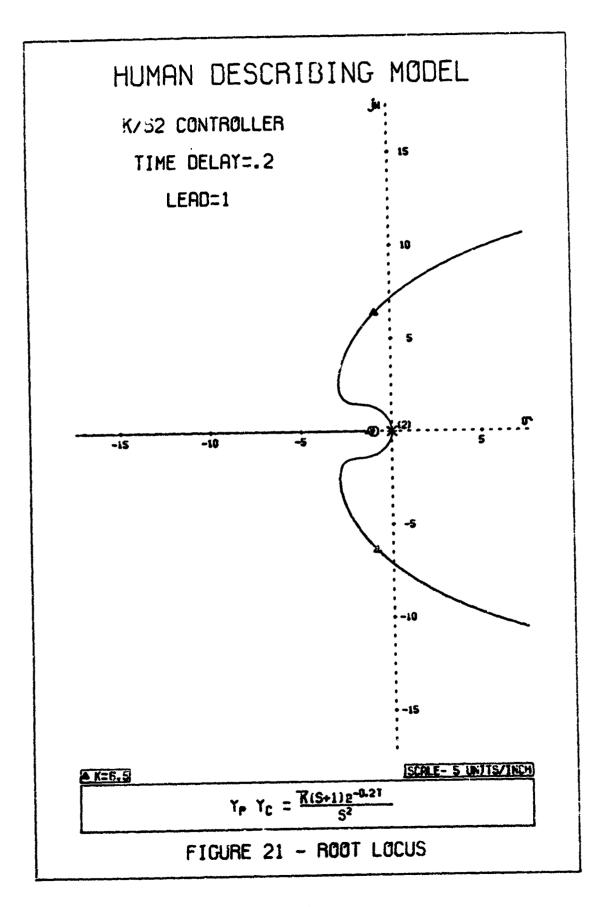


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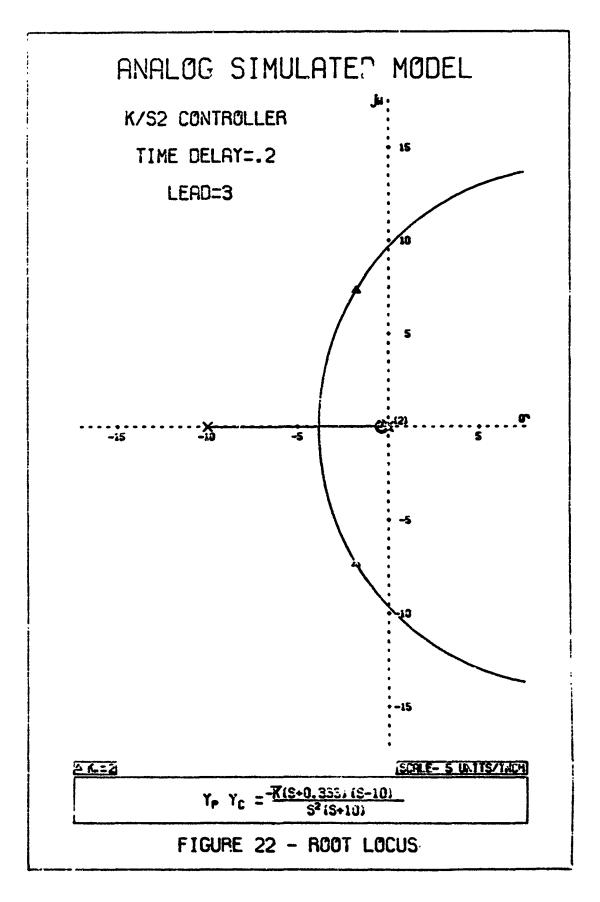


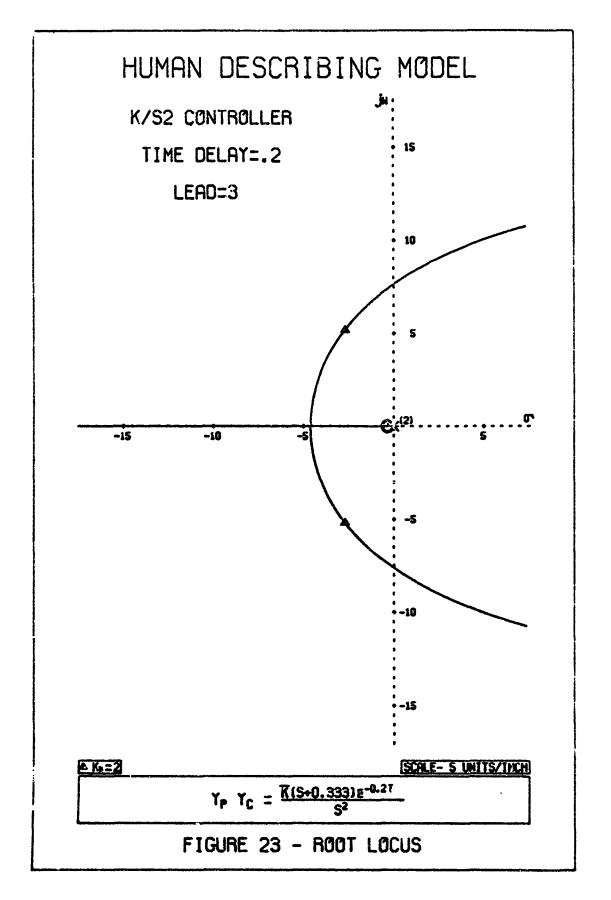
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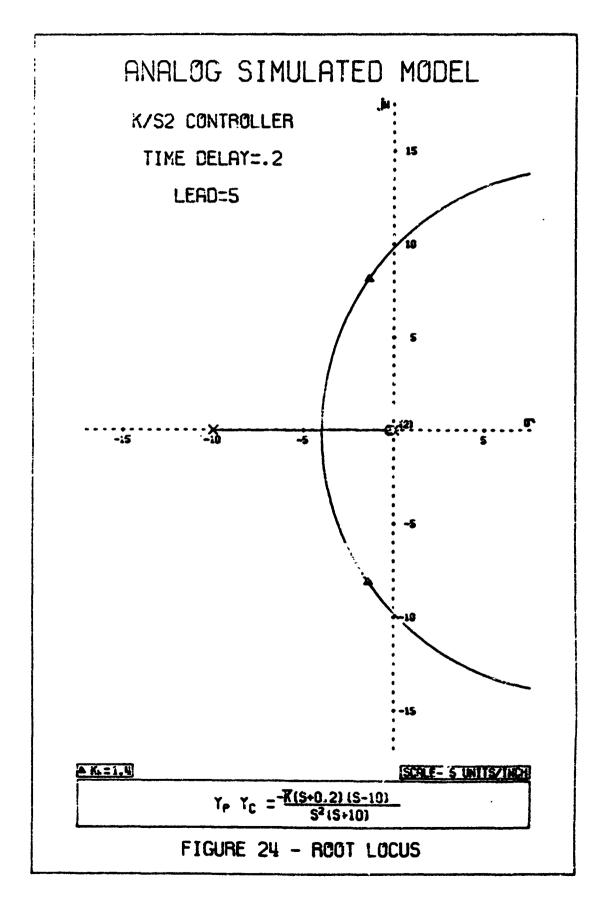


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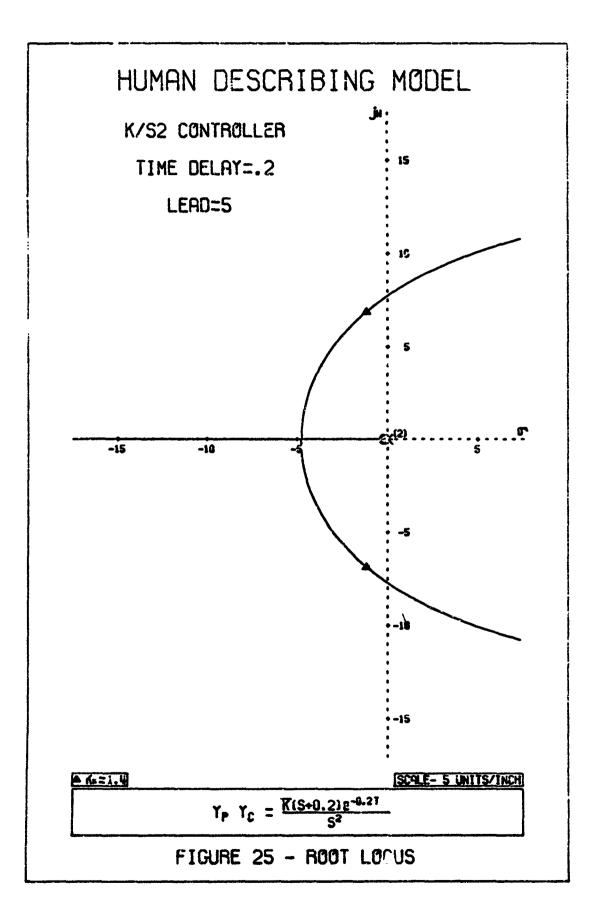




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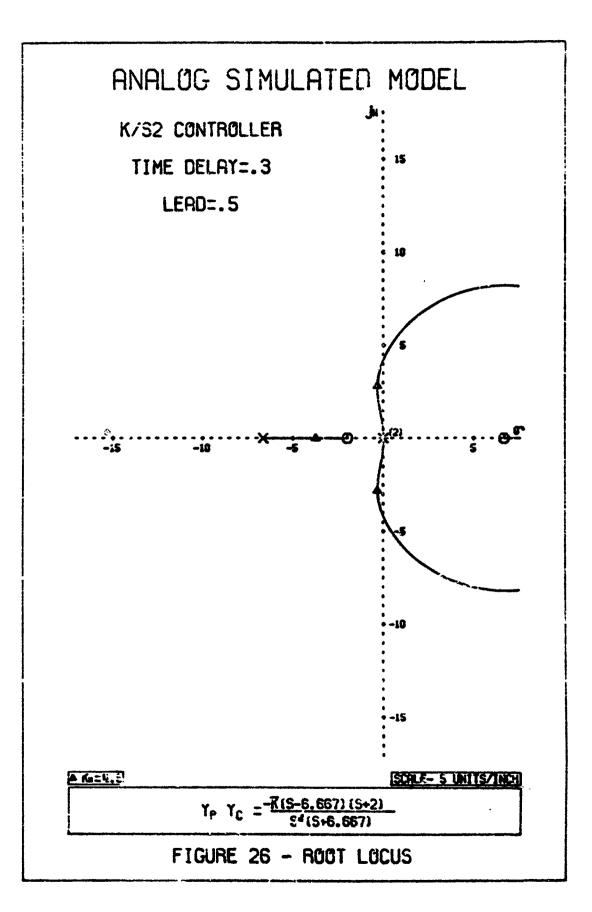


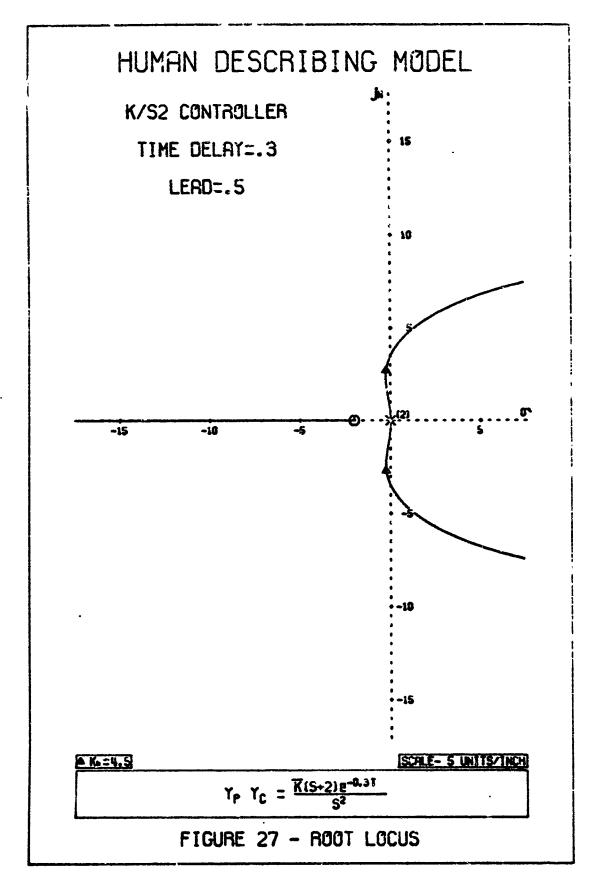
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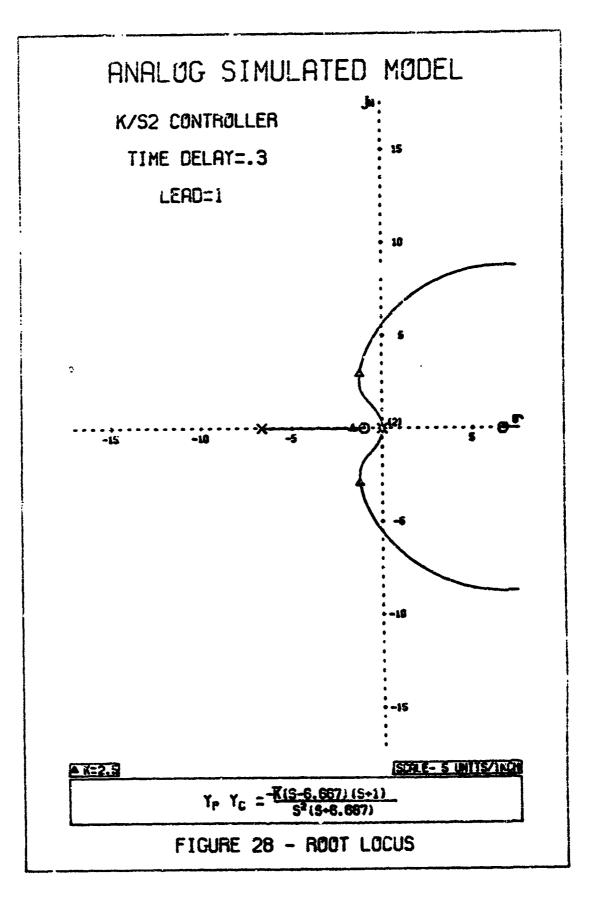
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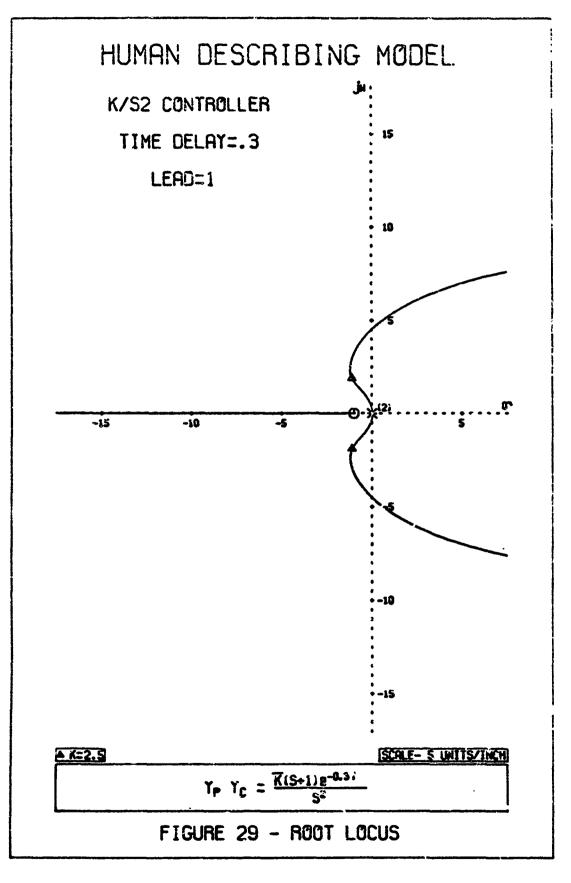




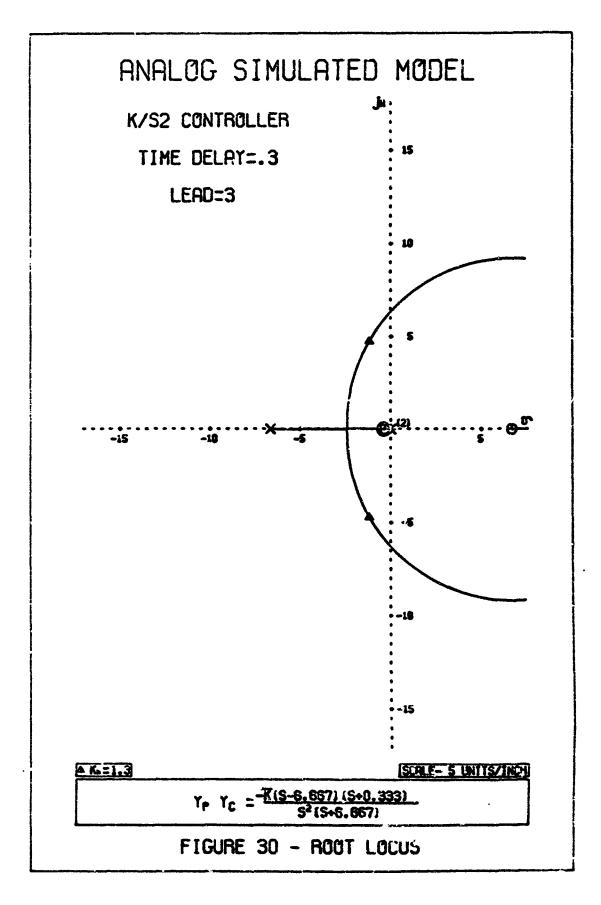


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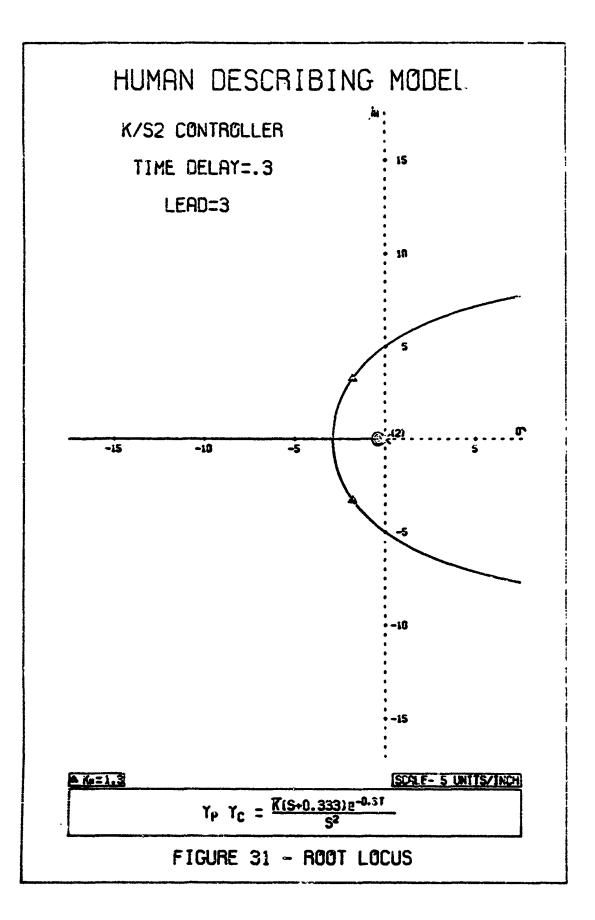
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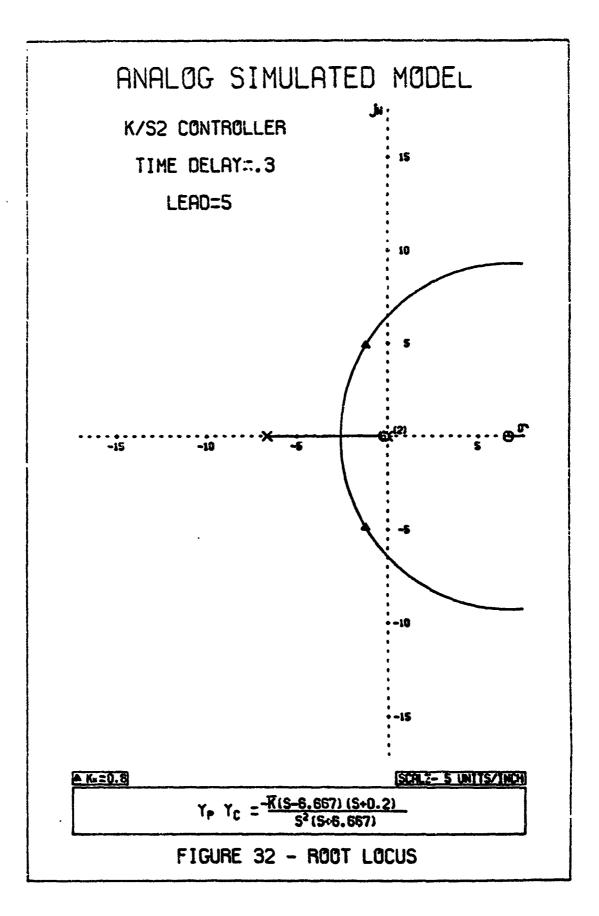
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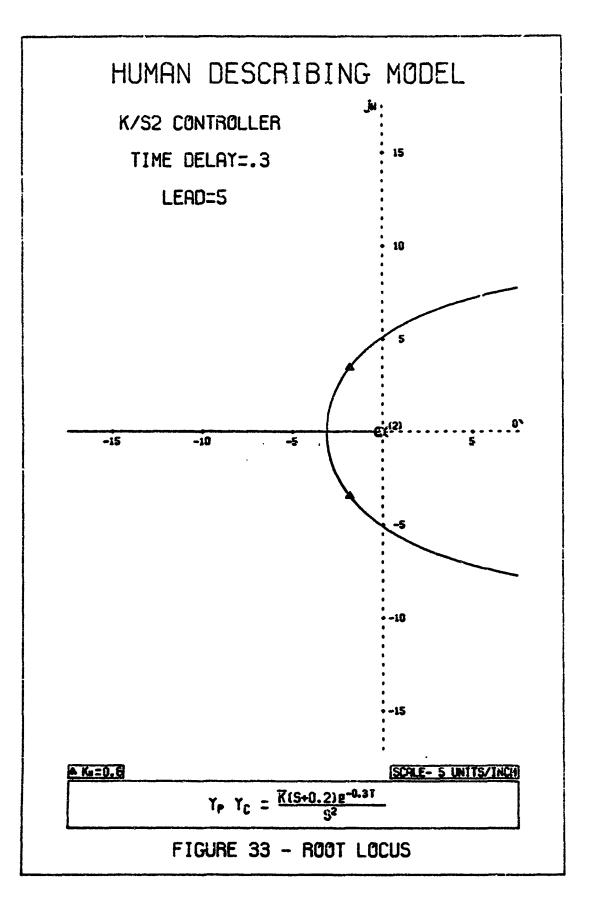
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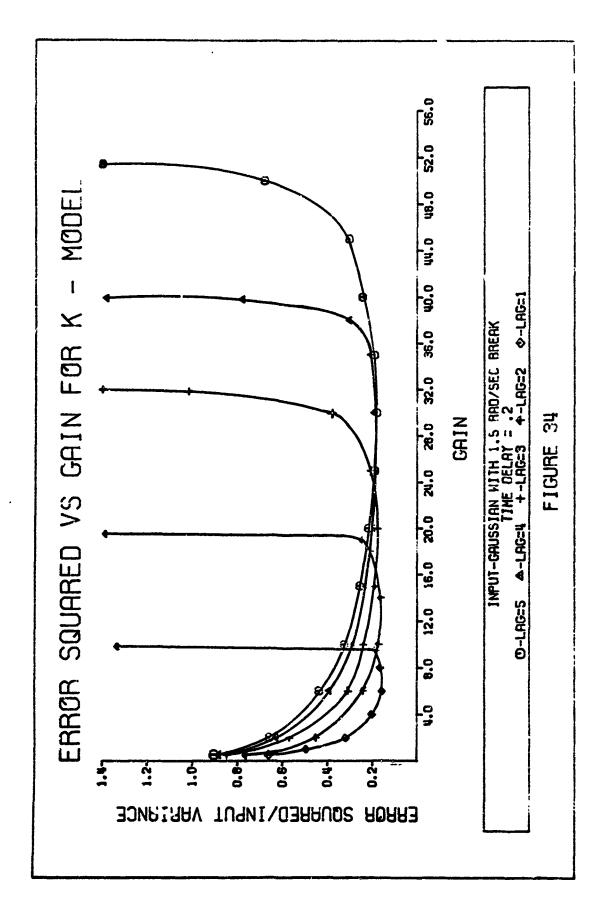


## Variations in Model Characteristics

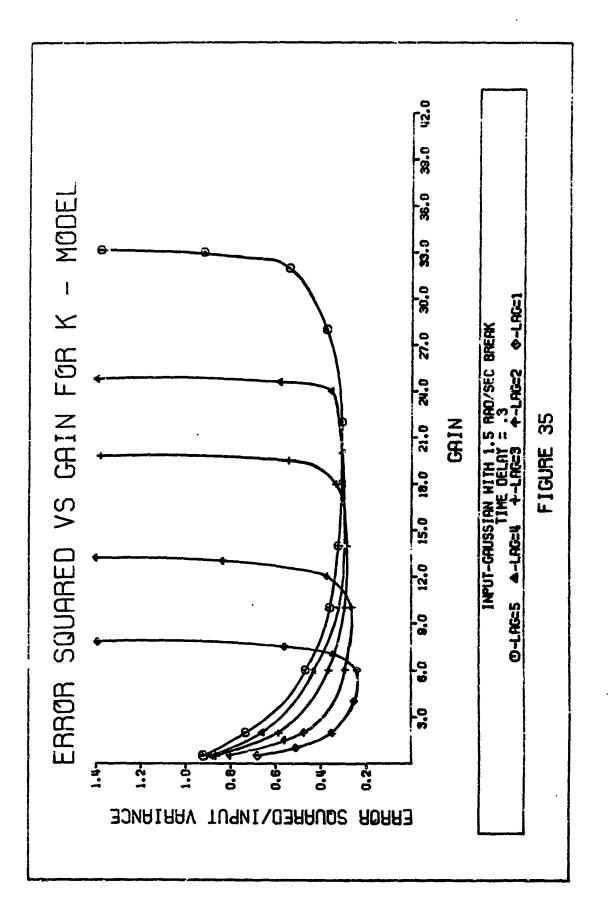
A set of characteristic curves was developed to show the effects of parameter variations on the performance of the analog simulated model. The input signal used was Gaussian white noise through a second order filter (Appendix C) with a break frequency of 1.5 radians por second. The mean squared error (called error squared in the following) divided by the input variance was plotted against the model system gain. The data used to plot the curves were obtained on the analog computer.

The system with a pure gain controlled element was prepared first. Five curves, representing gain variations for five different lag time constants are shown in Figure 34. The values of lag selected are consistent with values necessary for good low frequency response. If the time delay and lag time constant are known, the gain necessary for minimum error squared can be easily determined from the appropriate characteristic curve. The gain which causes model instability is also found easily by observing the rapid rise in the error squared as gain is increased, In Figure 34, the delay time is 0.2 seconds. Similar curves were plotted in Figure 35, but the time delay was increased to 0.3 seconds. As the time delay is increased, the gain for minimum error squared decreases and the minimum error squared increases. The gain for unstable operation varies inversely with the time delay. However, it was observed that the gain for minimum error squared and the gain for unstable operation vary directly with the lag time constant. Therefore, an increase in the time delay and an increase in the lag time constant would have a balancing effect in the gain for minimum error squared but an additive effect on the value of minimum error squared.

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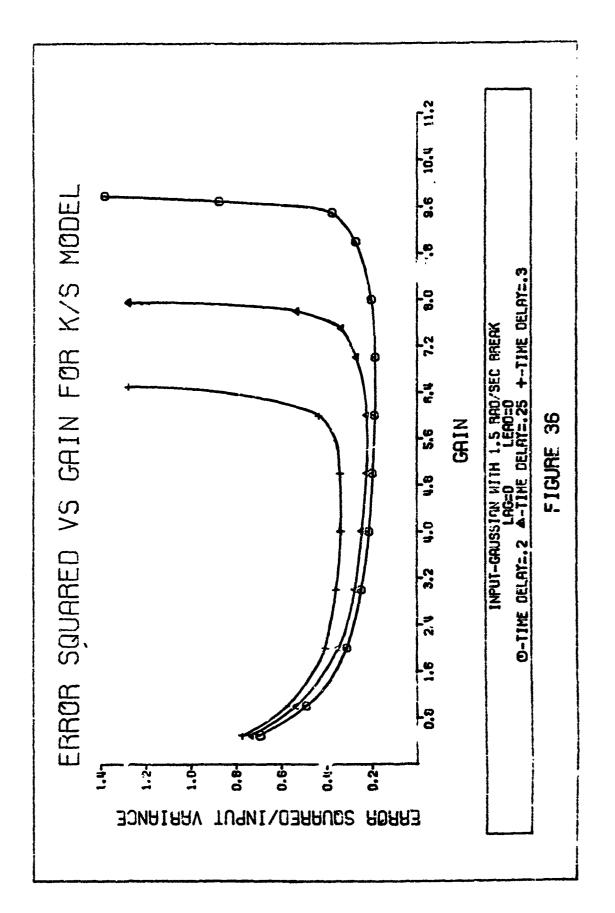


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Three curves, showing error squared versus gain, were plotted in Figure 35. Three different time delays were used, 0.2 seconds, 0.25 seconds, and 0.3 seconds. As the time delay was increased, the gain for minimum error squared and the gain for unstable operation decreased. As expected, the minimum error squared increased with an increase in the time delay.

The characteristic curves for the analog simulation of the model used with a  $X/S^2$  controlled element are shown in Figure 36 and Figure 37. The gain for minimum error squared varies inversely with the lead time constant and the delay time. The minimum error squared increases with an increase in the time delay, but decreases with an increase in the lead time constant.

Use of the existing adjustment rules, the root locus diagrams, ind the model characteristic curves reduces the guess-work required in predicting the model parameters for proper system response with random appearing inputs. To determine model parameters for step and random inputs, the piloted system output and appropriate performance measures must be obtained through experimentation. The necessary experimental results are discussed in the next chapter.

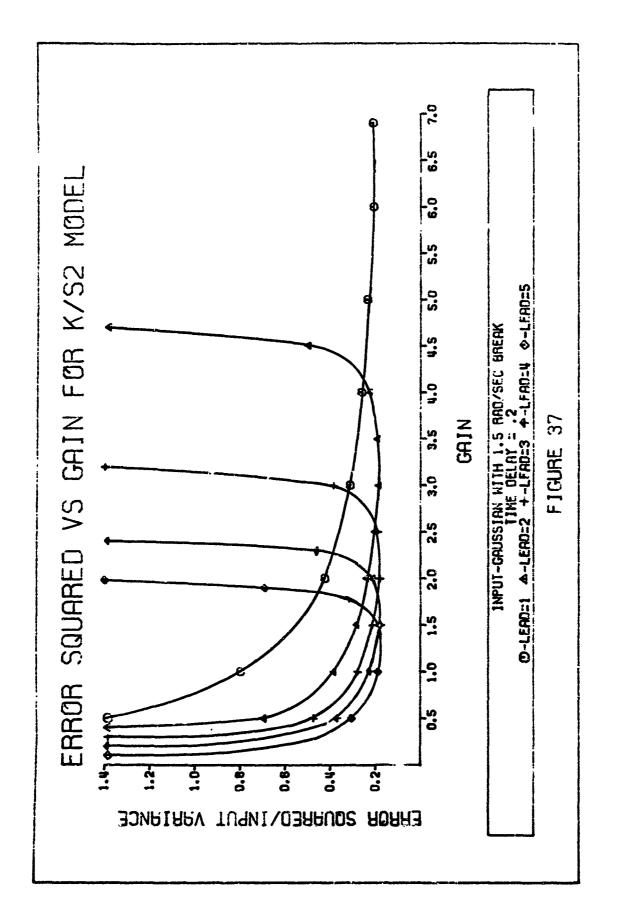


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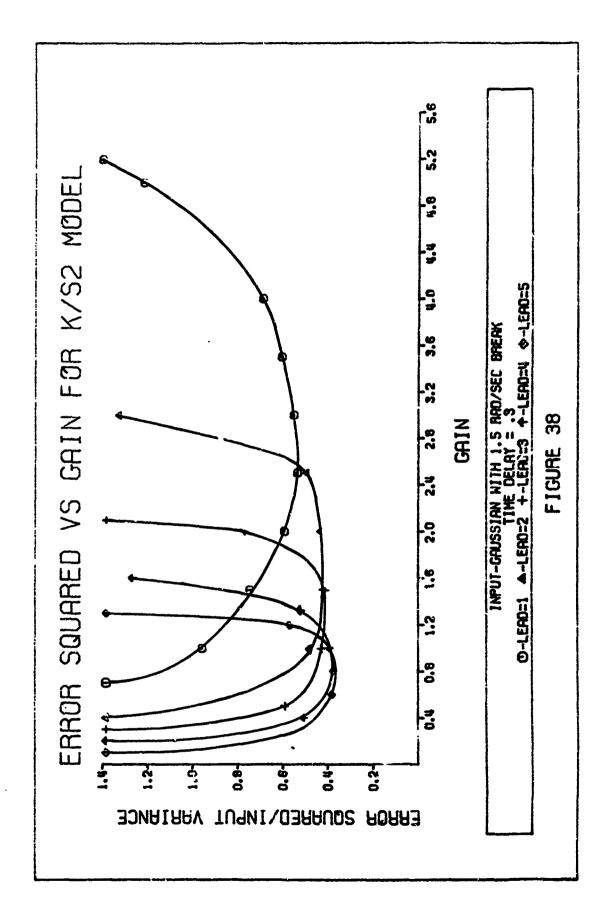
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#### IV. Experimental Results

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In this chapter, the data collected from each experimental phase are analyzed, and observations and results are presented. The details of the experimental procedures were proviously presented in Chapter II. The use of the performance measures for setting model parameters is discussed at the end of this chapter.

### Phase I - Step Input

Four performance measures were taken for each step input. A time recording of the output, the error, and the force stick movement was nade for each trial run. The average static delay time, the time between the application of the step and the first movement of the force stick, was computed for all tests. All data are listed in Appendix D. The average delay time for the three subjects was anyroximately 0.26 seconds, which approximately agrees with the results of Reference 14. The low individual average delay time of 0.23 seconds was noted for subject 1 while operating the K/S2 controlled system. The high average of 0.32 seconds was computed for subject 3 on the K/S<sup>2</sup> controlled system. The absence of any trends in the static time delay values, indicates that the reaction time of the individual subject was more related to his alertness on the dy of the test than on the controlled element used. The only conclusion that can be nade from the computed date, is that flying experience and a small static delay time apparently are related.

Correlation coefficients for each performance measure, and for the static delay time were computed from the data collected on the

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## Table 3

## Correlation Coefficients of Experimental Data For Systems With K Controlled Elements and Step Inputs

Subject 1						
	IES	ITES	IAE	ITAE	Time Delay	
IES	1.000	•935	.796	.173	•934	
ITES		1.000	.800	.237	•924	
IAE			1.000	.728	•753	
ITAE				1.000	•171	
		Subje	st 2			
	IES	ITES	IAE	ITAE	Time Delay	
IZS	1.000	.748	•721	.000	.714	
ITES		1.000	.639	•044	.623	
IAE			1,000	.676	.284	
ITAE				1.000	332	
		Subje	st 3			
	IZS	ITES	IAE	ITAB	Time Delay	
IES	1.000	•389	.436	•119	•813	
ITES		1.000	•943	•901	•099	
IAE			1.000	.941	.143	
ITAE				1,000	164	
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## Table 4

NAME OF THE PARTY

Correlation Coefficients of Experimental Data For Systems With K/S Controlled Llements and Step Inputs

Subject 1							
	IES	ITES	IAE	ITAE	Time Delay		
IES	1.000	•904	,829	•000	•507		
ITES		1.000	•831	.083	•523		
IAE			1.000	•545	•326		
ITAE				1.000	188		
		Subje	ct 2				
	IES	ITES	IAE	ITAE	Time Delay		
IES	1.000	•959	.714	085	•455		
ITES		1,000	.827	.122	•473		
IAE			1.000	•634	.423		
ITAE				1,000	.0?6		
		Subje	ct 3				
	IES	ITES	IAE	ITAE	Time Delay		
IES	1.000	•980	.940	•783	•303		
ITES		1.000	.976	.873	.260		
IAE	•		1.000	.947	.241		
ITAE				1.000	.157		

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Notes

## Tuble 5

## Correlation Coefficients of Experimental Data For Systems With K/S<sup>2</sup> Controlled Flaments and Step Inputs

IES         ITES         IAE         ITAE         Time Delay           TTS         1.000         .929         .880         .639         .394           ITTS         1.000         .955         .791         .534           IAE         1.000         .894         .514           IAE         1.000         .894         .514           IAE         1.000         .894         .514           IAE         1.000         .474           Subject 2           IES         ITES         IAE         ITAE           IES         1.000         .894         .779         .388         .038           ITES         1.000         .960         .740         .147           IAE         1.000         .960         .740         .147           IAE         1.000         .875         .205           ITAE         1.000         .875         .205           ITAE         ITS         IAE         ITME Delay           IES         ITS         IAE         ITME Delay           IES         1.000         .798         .370        007           ITES         1.000         .799         <	Subject 1							
ITES       1.000       .955       .791       .534         IAE       1.000       .894       .514         ITAE       1.000       .894       .514         ITAE       1.000       .474         Subject 2         IES       ITES       IAE       ITAE       Time Delay         IES       1.000       .894       .779       .388       .038         ITES       1.000       .960       .740       .147         IAE       1.000       .960       .740       .147         IAE       1.000       .875       .205         ITAE       ITES       IAE       ITES         Subject 3       IES       1.000       .251         IES       1.000       .690       .798       .370      107         ITES       1.000       .720       .638      015         <	1	IES	ITES	IAE	ITAB	Time Delay		
IAE       1.000       .894       .514         ITAE       1.000       .474         Subject 2         IES       ITES       IAE       ITAE       Time Delay         IES       1.000       .894       .779       .388       .038         ITES       1.000       .894       .779       .388       .038         ITES       1.000       .960       .740       .147         IAE       1.000       .960       .740       .147         IAE       1.000       .960       .740       .147         IAE       1.000       .251       .205       .205         ITAE       ITES       IAE       ITAE       Time Delay         IES       1.000       .6798       .370      107         ITES       1.000       .798       .370      015         IAE       1.000       .799      094       .094	I2S	1.000	.929	<b>.</b> 880	•639	•394		
ITAE       1.000       .474         Subject 2       Subject 2         IES       ITES       IAE       ITAE       Time Delay         IES       1.000       .894       .779       .388       .038         ITES       1.000       .960       .740       .147         IAE       1.000       .960       .740       .147         IAE       1.000       .960       .740       .147         IAE       1.000       .251       .205       .205         ITAE       Subject 3       .205       .205         IES       ITES       IAE       ITAE       Time Delay         .251       .205       .205       .205         ITAE       .200       .875       .205         IES       ITES       IAE       ITAE       Time Delay         .251       .205       .205       .205       .205         .200       .370       .201       .251         .2100       .370       .201       .251         .225       .225       .225       .225         .225       .225       .225       .225         .225       .225       .225       .22	ITES		1.000	•955	•791	•534		
Subject 2           IES         ITES         IAE         ITAE         Time Delay           IES         1.000         .894         .779         .388         .038           ITES         1.000         .960         .740         .147           IAE         1.000         .960         .740         .147           IAE         1.000         .960         .740         .147           IAE         1.000         .875         .205           ITAE         1.000         .875         .205           ITAE         1.000         .875         .205           ITAE         IES         ITES         ITES         .205           ITAE         1.000         .875         .205           ITAE         IES         1.000         .251           Subject 3         IES         ITES         IAE         Time Delay           IES         1.000         .690         .798         .370        007           ITES         1.000         .720         .638        015           IAE         1.000         .799        094	IAE			1.000	•894	•514		
IES         ITES         IAE         ITAE         Time Delay           IES         1.000         .894         .779         .388         .038           ITES         1.000         .960         .740         .147           IAE         1.000         .960         .740         .147           IAE         1.000         .875         .205           ITAE         1.000         .875         .205           ITAE         1.000         .875         .205           ITAE         1.000         .251         .251           Subject 3           IIES         ITES         ITES         IAE         ITME         Time Delay           IES         1.000         .690         .798         .370        107           ITES         1.000         .720         .638        015           IAE         1.000         .799        094	ITAE				1.000	•474		
IES       1.000       .894       .779       .388       .038         ITES       1.000       .960       .740       .147         IAE       1.000       .875       .205         ITAE       Subject 3       .251         IES       ITES       IAE       ITAE         IES       ITES       IAE       ITAE       Time Delay         IES       1.000       .690       .798       .370      107         ITES       1.000       .720       .638      015         IAE       1.000       .739      094			Subje	ct 2				
ITES       1.000       .960       .740       .147         IAE       1.000       .875       .205         ITAE       1.000       .875       .205         ITAE       1.000       .251         Subject 3         ITES         IES       ITES       IAE       ITAE       Time Delay         IES       1.000       .690       .798       .370      107         ITES       1.000       .720       .638      015         IAE       1.000       .799      094		IES	ITES	IAB	ITAE	Time Delay		
IAE     1.000     .875     .205       ITAE     1.000     .251       Subject 3       IES     ITES     IAE     ITAE     Time Delay       IES     1.000     .690     .798     .370    107       ITES     1.000     .720     .638    015       IAE     1.000     .799    094	IES	1.000	<b>.</b> 894	.779	•388	.038		
ITAE     1.000     .251       Subject 3       IES     ITES     IAE     ITAE     Time Delay       IES     1.000     .690     .798     .370    107       ITES     1.000     .720     .638    015       IAE     1.000     .799    094	ITES		1.000	•960	.740	.147		
Subject 3           IES         ITES         IAE         ITAE         Time Delay           IES         1.000         .690         .798         .370        107           ITES         1.000         .720         .638        015           IAE         1.000         .799        094	IAE			1.000	.875	•205		
IES         ITES         IAE         ITAE         Time Delay           IES         1.000         .690         .798         .370        107           ITES         1.000         .720         .638        015           IAE         1.000         .799        094	ITAE				1.000	•251		
IES       1.000       .690       .798       .370      107         ITES       1.000       .720       .638      015         IAE       1.000       .799      094			Subjec	rt 3				
ITES     1.000     .720     .638    015       IAE     1.000     .799    094		IES	ITES	IAE	ITAE	Time Delay		
IAE 1.000	IES	1,000	•690	•798	.370	107		
	ITES		1.000	.720	•638	015		
ITAE 1.000078	IAE			1.000	•799	094		
	ITAE		1.000	078				

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twenty-five runs made by each subject operating each of the controlled elements. The coefficients were computed by using the data from Tables D-1 through D-6 of Appendix D in the equation,

Correlation Coefficient =  $\frac{E[X_1X_2] - \overline{X}_1\overline{X}_2}{\sqrt{E[(X_1 - \overline{X}_1)^2]*E[(X_2 - \overline{X}_2)^2]}}$ The computed coefficients are presented in Tables 3 through 5. A decrease in the correlation between the time delay and the performance measures was noted as the order of the controlled element was increased. Of the four performance measures taken, the IES and the ITES were better correlated to the static delay time. In general, the correlations were highest for the subjects with flying experience. It should be noted that minimum time has also been suggested as a performance measure (Ref 12:68). However, observed pilot conservations (Ref 1) seems to rule out this measure.

The correlation between each of the performance measures was computed and also shown in Tables 3 through 5. If high correlation existed between any two performance measures, the more difficult to compute could be eliminated from the useful list of measures. The correlations between the IES and the ITES, between the IES and IAE, and between the ITES and the IAE were all found to be relatively high. Since minimizing the IES is included as an adjustment rule of the existing human describing function model with random inputs, and because the IES is relatively easy to compute and measure, this performance measure was given priority consideration over the other measures. Therefore, the ITES and the IAE were eliminated as practical performance measures for a system with step inputs.

The correlation between the IES and the ITAE was found to be relatively low, even negative in some cases. An investigation of the model system with step inputs was undertaken to determine whether the gain should be set for the minimum ITAE or for minimum IES. From a study of time recordings of the system outputs, the following observations were made:

1) The experienced pilots were conservative in operating the force stick. The result is an overdamped system output.

2) Setting the gain of the human describing function model for minimum error squared, results in an underdamped system output.

3) Setting the gain of the human describing function model for minimum ITAE results in a slightly overdamped system output.

4) Therefore, setting the gain of the model for minimum ITAE resulted in a better match of the model system output with the experienced piloted system output.

5) Setting the gain of the model below the value necessary for minimum IES, gave the same results as setting the gain of the model for minimum ITAE (Approximately 85% of gain for minimum IES).

6) Subject 3, who had no flying experience, was less conservative than the other two subjects. The output from systems operated by Subject 3 showed less dampening than the experienced pilot system output.

7) Setting the gain of the model with a pure gain controlled element slightly below the gain for minimum IES resulted in a relatively good match of the unexperienced piloted system and the model system output.

8) Subject 3 had difficulty maintaining control of the system with  $(. K/S^2 \text{ controlled element.}$  His erratic behavior made comparison with the model difficult.

It should be remembered that human response is, in general, time varying, and therefore a perfect match between the output of the model system and the output of the piloted system is impossible. Regression (Ref 11:19) due to the high frequency components of a step input is offered as a possible reason why the human subjects operate the system at a gain below the value necessary for minimum error squared. The damped effects of a reduced gain can be observed in the real time recordings shown in Appendix E. Operating a model system at the gain setting for minimum ITAE results in a greater dampening effect than operating at the gain setting for minimum IES (Ref 19:48), and provides a close match between the model system output and the piloted system output. Therefore, the ITAE is proposed as a useful performance measure for systems with step inputs.

## Phase II - Gaussian Inout

The experiments conducted during this phase were accomplished to establish a set of values to be used in Phase III. However, correlation coefficients were computed to compare performance measures. In almost all cases, the correlation among the four performance measures was extremely high, averaging above 0.85. As might be expected, the two subjects with flying experience performed better than the subject with no flying experience. In several cases, the error squared was so small that invalid readings, resulting from nonlinear operation of the multiplier used to obtain the ITES, were

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recorded. Therefore, the ITES was eliminated as a useful performance measure.

In an attempt to match the model system and the experienced piloted system outputs, the gain of the model was adjusted very slightly below the value of gain necessary for minimum error squared. When the Gaussian with a high filtered break frequency was used, a smoothing tendency was noted in the outputs of the systems controlled by the experienced pilots. (Appendix E). Also, the more experienced pilots appeared to introduce more lead into the system with the  $K/S^2$ controlled element. A lead time constant of four was assumed for the experienced pilots, whereas a lead time constant of about one was assumed for the subject with no flying experience. Summarising the results of this phase, the existing adjustment rules were verified with the small exception that the experienced pilots appeared to operate with a gain very slightly below the gain necessary for rinimum error squared. See the real time recordings in Appendix E,

#### Phase III - Gaussian Plus Step Inouts

The data collected during this phase were analyzed and compared with the data from previous phases. Each performance measure was analyzed separately. It should be noted that the step time in Tables D-16 through D-33 was the time interval between the beginning of the run and the application of the step.

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The values of IES were averaged and the variance was computed for each set of five, one minute runs. The IES for the 3 wilt step was determined by multiplying the IES for the 1 wolt step in Tables D-1

through D-6 by 9. A multiplier of 25 was used to obtain the IES for the 5 volt step. To verify these values, several sample measurements were taken with 3 and 5 volt steps actually applied to the system. The averaged  $\int e_3^2$  dt for each of the 1, 3, and 5 wolt step inputs was added to the averaged  $\int e_g^2 dt$  for the Gaussian inputs; then, the sum was compared with the averaged  $\int e^2 dt$  computed during this phase. The results for each subject operating each of the three controlled elements are shown in Table 6. The absolute difference between the surmed value and the combined value of the system with Gaussian plus step inputs was compared with the combined standard deviation of the three error measures. For the cases where the absolute difference was less than the combined standard deviation, the assumption, that the  $\int 2e_{\mathbf{s}}e_{\mathbf{g}}$  dt term was small enough to be neglected, was considered volid. Values satisfying this validity test are marked with an asterick in Table 6. From the calculations and comparisons, the following observations were made:

1) For most of the cases tested, the  $\int e_g^2 dt + \int e_8^2 dt$  was within one standard deviation of the  $\int e^2 dt$ .

2) In general, the  $\int e^2 dt$  was slightly more than the  $\int e_g^2 dt + \int e_g^2 dt due to the ammission of <math>\int 2e_g e_g dt$ .

3) Because the experienced pilots were able to maintain a small error for the Gaussian input, the continuous time multiplication of the error due to the Gaussian input with the error due to the step input was maintained at a very low level.

From the above observations, the assumption that the sum of the  $\int e_g^2 dt$  and the  $\int e_g^2 dt$  will fairly well predict the  $\int e^2 dt$  for a system with Gaussian plus step inputs, is validated.

## Tatle 6

Comparison of IES For The Step Input and IES For The Gaussian Input With IES For The Combined Step and Gaussian Input

System	(o <sup>a</sup> i)	Sub	For 1 <b>v</b>	For 1 wolt step For 3 wolt step		For 5 walt step		
			Summed	Combined	Summed	Combined	Summed	Combined
K	0.5 (1.44)	1 2 3	3.412 4.221 13.862	3.552 4.421* 17.011*	6.700 8.061 17.006	9.048 7.604* 34.964*	12.301 15.741 23.294	18.785 16.28 <del>5</del> * 51.032
K	1.5 (0.56)	1 2 3	5.258 6.848 9.049	6.486* 7.604* 10.400*	8 <b>.276</b> 10.688 12.193	10.248 11.707* 19.112	15.177 18.368 18.481	18.987 18.752* 39.558
K/S	0.5 (1.44)	1 2 3	5.324 6.472 12.695	5•592* 7•684* 12•787*	9.804 12.232 21.583	7.752 14.266* 20.141*	18.764 23.752 39.359	15.720 27.328* 45.514*
K/S	1•5 (0•56)	1 2 3	6.005 11.201 15.465	5.979* 13.084* 15.640*	10.485 16.961 24.353	9.196* 17.918* 25.975*	19.445 28.481 42.129	18.082* 34.722* 43.568*
ĸ/s <sup>2</sup>	0.5 (1.44)	1 2 3	39•357 36•291 42•406	41.918* 41.575* 50.859*	44 <b>.</b> 929 45.147 54.310	51.884* 43.775* 66.821*	55.873 62.869 78.118	63.261* 61.719* 87.768*
k/s <sup>2</sup>	1.5 (0.56)	1 2 3	45.924 42.234 58.709	51.646# 50.309# 65.600#	51.396 51.090 70.613	55.832* 59.863* 89.966*	62.340 68.802 94.421	71.259* 82.943* 96.966*
* Ind	* Indicates that the two values are within one standard deviation							

of the computed data.

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It should be noted that the "additive results" appear to work over a wide range for  $\int e_{g}^{2} dt \approx \int e_{g}^{2} dt$ . A general range of values is indicated from the data collected for Subject 1. Cases r aged from:

 $0.245 (K, 1v) \leq \int e_8^2 dt \leq (0.913)(25) (K/S^2, 5v)$ 

2.450 (X,a=0.5) 
$$\leq \int e_g^2 dt \leq 51.3$$
 (K/S<sup>2</sup>,a=1.5)

IAE

and

The values of IAE were averaged and the variance was computed for each set of five, one minute runs. To obtain the IAE for a 3 volt step, the IAE for a 1 volt step was multiplied by 3, and to obtain the IAE for a 5 volt step, the IAE for a 1 volt step was multiplied by 5. The averaged  $\int |e_g|$  it for each of the 1, 3, and 5 wolt step inputs was added to the averaged  $\int |e_g|$  dt for the Gaussian inputs; then, the sum was compared with the averaged fiel dt computed during this phase. The results for each subject operating each of the three controlled elements are shown in Table 7. The absolute difference between the surmed value and the combined value of the system with Gaussian plus step inputs was compared with the combined standard deviation of the three error measures. For the cases where the absolute different was less than the combined standard deviation, the assumption, that  $\int |e| dt$ approximately equals  $\int |e_{S}| dt + \int |e_{g}| dt$ , was considered valid. Values satisfying this validity test are marked with an asterick in Table 7. From the calculations and comperisons, the following observations were made:

1) For most of the cases tested, the  $\int |e_g| dt + \int |e_g| dt$  was within one standard deviation of the  $\int |e| dt$ .

## Table 7

Comparison of IAE For The Step Input and IAE For The Gaussian Input With IAE For The Combined Step and Gaussian Input

System	(0 <sup>a</sup> i)	Sub	For 1 ve	olt step	For 3 wolt step		For 5 volt step	
			Summed	Combined	Summed	Combined	Summed	Combined
ĸ	0•5 (1•44)	1 2 3	11.319 11.602 20.914	13.695 11.722* 21.762*	12.660 13.264 22.780	15.448 12.531* 27.434*	13.955 14.926 24.446	16.888 14.720* 34.065
x	1.5 (0.56)	1 2 3	15.313 15.608 18.497	15 <b>.</b> 343* 16 <b>.</b> 091* 19 <b>.</b> 295*	16.631 17.270 20.263	16.937* 18.036* 23.442*	17.949 18.932 22.129	17.844* 18.709* 27.082*
K/S	0.5 (1.44)	1 2 3	13.195 15.250 23.177	12.947* 15.880* 23.208*	14.997 17.364 26.575	12.676 18.322* 23.126*	16.799 19.478 29.973	13.501 19.836* 27.503*
K/S	1.5 (0.56)	1 2 3	15.049 20.505 24.022	14. <i>5</i> 94* 21.206* 23.625*	16.851 22.619 27.400	15.821* 22.522* 28.366*	18.653 24.733 30.818	17.019* 25.688* 31.040*
k/s <sup>2</sup>	0.5 (1.44)	1 2 3	37.753 35.983 40.017	39.221* 37.316* 42.543*	39.367	42.865* 39.512* 46.411*	42.777 42.751 50.965	42,008* 42,811* 49,402*
K/S <sup>2</sup>	1.5 (0.50)	1 2 3	40.329 36.401 47.612	41.918* 41.493 48.383*	39.785	42.733* 44.651 56.693*	45.353 43.169 58.560	44.232* 48.421* 55.084*
* Indicates that the two values are within one standard deviation of the computed data.								

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2) In general, the fieldt was slightly less than the fiegl dt +  $\int |e_{g}| dt$  as would be expected from the mathematical relationship,  $\int |e_{g}| dt \leq \int (|e_{g}| + |e_{g}|) dt$ .

3) If the error due to the Gaussian input was maintained at a low level when the step was applied, the sum of the individual IAEs would equal the combined IAE. However, the same relationship would be true if the step error was of the same polarity as the error of the Gaussian was when the step was applied.

From the above observations, the assumption that the sum of  $\int |e_s| dt$ and  $\int |e_s| dt$  will fairly well predict  $\int |e| dt$  for a system with Gaussian plus step inputs, is validated.

A study of the correlation coefficients between the IAE and the IES of a system with step plus Gaussian inputs demonstrated that the two measures perform the same evaluation of the subject's performance. In almost all cases, the correlation coefficient was above 0.85. Therefore, it was determined that the IES was a better performance measure to use because of its acceptance as a measure of performance for system with Gaussian inputs.

#### **ITES**

As mentioned before, the ITES was impossible to determine for some runs, because the error squared was maintained at a very low level causing nonlinear operation of the analog multiplier circuit. Therefore, the ITES was eliminated from consideration as a useful performance measure of piloted systems with Gaussian plus step inputs.

#### ITAE

Computational difficulties : n determining the effects of time on

this performance measure prohibit its usefulness.

From the analysis of all data, the conclusion is made that the IES is the best performance measure to use in evaluating the operation of the piloted system with Gaussian plus step inputs.

### Adjusting the Model Parameters

The final step in this study was to adjust the parameters of the analog simulated model, and record the outputs of the model and piloted systems when both were operated simultaneously. One major difficulty in properly matching the piloted and model system outputs for step inputs was the distortion caused by the use of the Pade' approximation of the real time delay. The phase difference at high frequencies between the Pade' approximation and the real time delay resulted in a dip in the model output when there should have been none. This distortion 'as especially apparent for the model system with the pure gain controlled element.

Despite the difficulties associated with the Pade' approximation in the analog simulated system, the following parameter setting were determined:

1) The lag time constant was set at 3 seconds for the model with a pure gain controlled element. This value was previously determined by others (Ref 11:46), and was found to provide the proper lag for the experiments of this study.

2) The time delay was determined from data collected during Phase I to be approximately 0.3 seconds for all models with step inputs. From earl er studies (Ref 11), the time delay for the K and K/S systems with random inputs is 0.2 seconds, and the time delay for the  $K/S^2$ 

system with random inputs is 0.4 seconds. An overall compromise for the step plus Gaussian case is the selection of a time delay of 0.3seconds.

3) The lead time constant for the model with the  $K/S^2$  controlled element was selected between 1 and 5 seconds. For a model used to predict the response of an experienced pilot, the lead time constant was set at 4 seconds, and for the response prediction of the subject with no flying experience, the lead time constant was set at 1 second.

4) The best gain setting for a system with step inputs was found to be for minimum ITAE or approximately 85% below the setting for minimum IES. For Gaussian plus small step inputs, the gain setting should be slightly below the value for minimum error squared. As the step is increased in relationship to the Gaussian input, the gain should be decreased toward the value which would provide minimum ITAE for a single step input. This technique for setting the gain of a system with step plus Gaussian inputs is more applicable for predicting the response of an experienced pilot than for predicting the response of an unexperienced pilot. The subject with no flying experience appeared to always operate cluse to the gain setting necessary for minimum IES in respect to time history responses.

Real time recordings of the piloted system and model system outputs and errors are shown in Appendix E.

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## V. Summary and Conclusions

The conclusions, supported by the analysis of data collected during the experimental study, are summarized in this chapter. First, it was found that the existing human describing function model is useful in predicting the response of a pilot in systems with Gaussian plus one step inputs. He use of the existing adjustment rules, model characteristic curves, and performance data on human trackers was necessary to adjust the model parameters for proper model prediction of the actual pilot response.

Second, the adjustment rule, stating that human subjects attempt to minimize their mean squared error, should be modified slightly to account for the conservative response of an experienced pilot when he is operating a control device in a manner similar to the way he operates an aircraft control. The gain of a model representing an experienced pilot in a system with step inputs, should be set to a value that is approximately 85% of the value necessary for minimum mean squared error. The decrease in gain of the model will provide increased dampening, thus, indicating the conservative nature of pilot response.

Third, it was found that operating a system with step inputs at minimum ITAE was similar to operating a system with the gain set at 85% of the value necessary for minimum IES. Therefore, use of the minimum ITAE is recommended for adjusting the gain of a model in a system with step inputs.

A technique suggested for the adjustment of model gain in a system with step plus Gaussian inputs is to reduce the gain below the

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> value necessary for minimum IES as the step innert is increased in relationship with the Gaussian input. For a small step in relation to the random input, the gain should be set between 90% and 95% of the value necessary for minimum IES. For a large step in relation to the random input, the gain should be set between 85% and 90% of the value necessary for minimum IES. This technique is especially useful for predicting the response of an experienced pilot.

Finally, the summed values of the IES found from the system with step inputs and the IES found from the system with Gaussian inputs is a relatively close approximation of the IES of a system with step plus Gaussian inputs. There is every reason to believe that the results of this study could be applied to systems composed of aircraft-like dynamics.

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#### VI. <u>Recommendations</u>

The following recommendations are suggested for expanding the results of this study.

1) Verify that the same technique of reducing gain can be used for systems having controlled elements representing actual aircraft dynamics, and step plus random signals applied.

2) Study the effects of applying random signals plus other deterministic signals such as ramps or sine waves.

3) Study the effects of applying an additional Gaussian signal, simulating pilot remnant, directly to the controlled element. Perhaps, a pilot remnant input with the step plus random input pilot model could be used to predict repeatability aspects of the responses.

4) Investigate the use of delay tapes to replace the Pade: approximation of the pure time delay in the analog model simulation of a system with step inputs.

5) Conduct further statistical studies to determine the response differences between experienced pilots and non-pilots, when performing specialized tasks related to aircraft control.

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#### Appendix $\Lambda$

### Ecuipment Description

## Analog Computer

Use of an Applied Dynamics Analog Computer, Model AD-2-64 PB, was made throughout this investigation. This is a precision electronics differential analyzer capable of solving both linear and nonlinear ordinary differential equations. It contains 64 operational amplifiers, 24 of which may be used as integrators. The unit also contains 80 coefficient pots, 16 electronic multipliers, 8 diode function generators, and 20 special diode networks. (Ref 2).

### Digital Voltmeter

A Nonlinear System, Model 4206 Digital Voltmeter was used. This unit was installed as a part of the AD-54PB computer and featured automatic range and polarity control. The meter has a 10 megohm input impedance and an accuracy of  $\pm$  0.02 percent of full scale and a resolution of  $\pm$  0.01 percent of full scale on each range. (Ref 16).

#### Hand Control

A Measurements Systems, Model 435 Hand Control, mounted in a student's chair, was used for the pilot tracking portion of this investigation. This is an a.e. powered force-stick tranducer which produces phase reversing a.c. voltages converted to d.c. proportional to applied force in two axes. Its essential features are zero backlash, low hysteresis, and drift, and linear output vs. force applied. (Ref 13).

#### Magnetic Tape Recorder/Reproducer

A Sangamo Electric Company, Model 4784 Magnetic Tape Recorder/ Reproducer was used to reproduce several 60 second gaussian noise signals for input to the analog computer. The Recorder/Reproducer is a seven channel, eight speed magnetic tape device with the capability of reel to reel or loop operation. The system consists of six major assemblies: A control panel, an a.c. control box, a power supply drawer, a tape transport panel, a vacuum panel, and a plug-in module chasis. An important feature is the employment of a unique vacuum tensioning and cleaning system to maintain precise tape tension at the head while cleaning the tape to reduce drop outs and oxide buildup. (Ref 17).

#### Ncise Generator

An Elgenco Model 311A Noise Generator was used to produce the signals which were stored on magnetic tape for reuse throughout the experiment. This unit is a stable source of random noise of mean less than 50 millivolts. Its output has an amplitude probability distribution that is Gaussian to less than plus or minus one percent and the output spectrum is uniform to plus or minus 0.1 db from 0 to 35 cycles per second. (Ref 7).

#### Oscilloscope

In this investigation a Tektronics Type R435A Oscilloscope was used to present tracking error. This oscilloscope together with a type CA plug-in preamplifier provided rise time capability of 0.023 microseconds with a band pass from d.c. to 15 megacycles per second. The oscilloscope has a usable viewing area of 6x10

centimeters with a range of 0.05 volts per centimeter to 20 volts per centimeter. (Ref 18).

### Recorder

Real time recordings were made with a Beckman, Type SC-2 Dynograph, Direct Writing Recorder. This is an eight channel unit capable of recording bi-polar signals on rectilinear paper with a sensitivity of 50 millivolts per division to 10 volts per division. Input impedance is 1 megohr and frequency response is flat from d.c. to 42 cycles per second. (Ref 4).

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#### Appendix B

#### Analog Computer Program

The analog computer was used for all experiments. Both the piloted system and the model system, along with all performance measures, were programed on one analog board. The analog schematic for both the piloted systems and the model systems is shown in Figure B-1. The input circuit, the timing circuit, and the automatic sixty second hold circuit, are shown in Figure B-2. Figure B-3 is the schematic of all performance measure circuitry. Switches available on the computer were used extensively to change controlled elements, and the signals applied.

#### Systems

The schematic of the piloted system is pictured in the top half of Figure B-1. The schematic for the model system is shown in the bottom half of Figure B-1. Since a pure time delay in the form  $e^{-15}$ is impossible to program, a first order Pade' approximation was selected because it presents zero db gain at all frequencies. (Ref 15:218)

Separate program sections were prepared for each controlled element and combined with the pilot model. The controlled element represented by K is programed together with the lag term of the pilot model. In all cases the controlled element gain was chosen to be unity. The combined term is  $K_p/(T_1S + 1)$ . For the controlled element K/S, the combined term is  $K_p/S$ , and for the controlled element,  $K_p/S^2$ , the combined term is  $K_p(T_1S + 1)/S^2$ ,

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Table 1 indicates the potentiometer settings for both systems. The rumbers inclosed in the triangles indicate the line connections on the strip recorder.

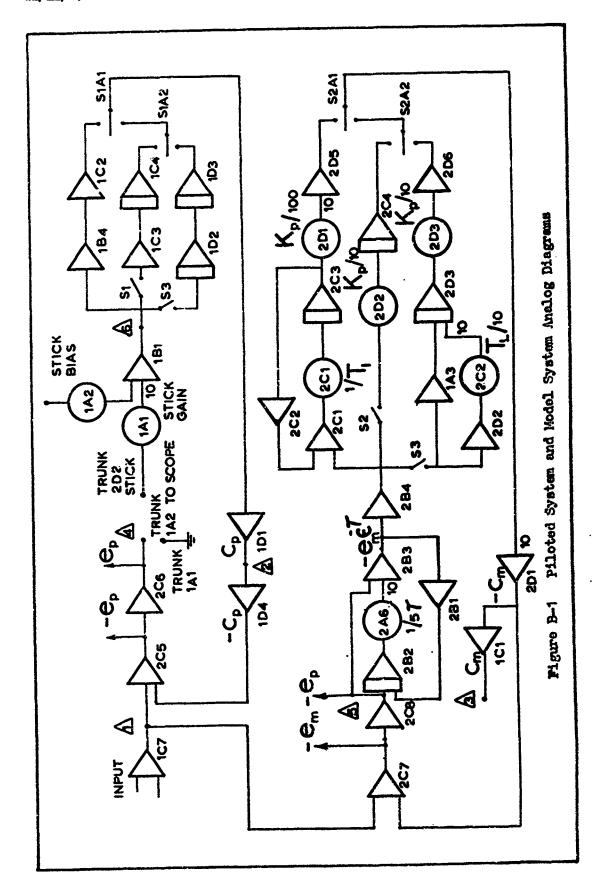
#### Timing, Hold, and Input

The timing circuit is set for linear operation by the application of a 10 volt initial condition to the integrator. One volt represents one second. The sixty second hold circuit is also a timing circuit. Both the hold circuit and the timing circuit were checked often during experimentation to insure synchronous, accurate operation. The input circuit was designed so that circuit changes between experiments were minimized. The potentioneter settings are shown in Table B-2.

#### Performance Measures

Performance data were collected from the circuitry represented by the schematic in Figure B-3. The diode multipliers with the most linear characteristics were selected for the experiments. Known voltages were input into each performance measure circuit for a one minute interval, and the circuits were calibrated by using potentiometers.

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## Table B-1

Quantity	Potentiometer	Sample Setting	
Stick Gain	1&1	1.000	
Stick Bias	142	.003	
1/57	246	.667	
1/T <sub>I</sub>	201	•333	
T <sub>L</sub> /10	202	•300	
K <sub>p</sub> /100 K <sub>p</sub> /10 K <sub>p</sub> /10	201	.120	
к <sub>р</sub> /10	21)2	•450	
Kp/10	203	•130	

## Potentiometer Values for Figure B-1

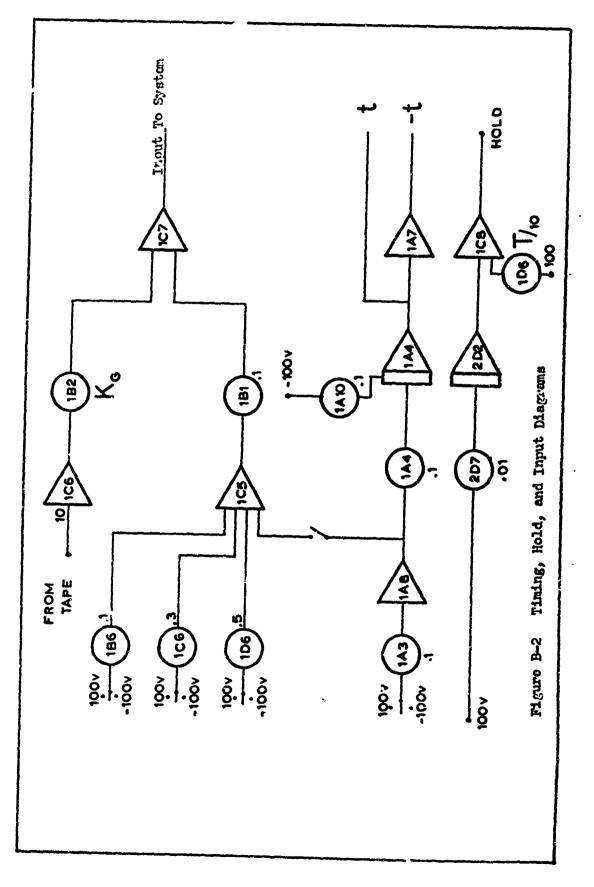
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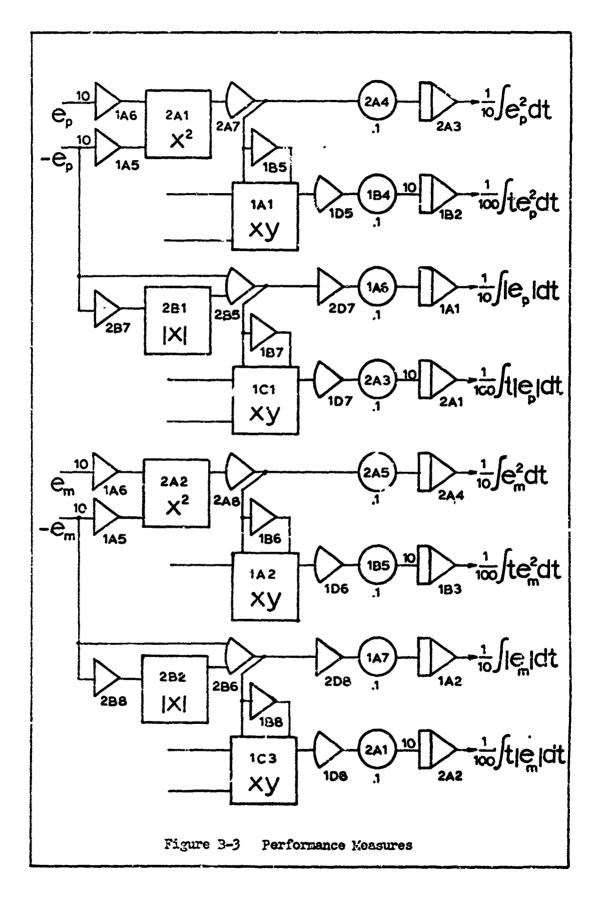
## Table B-2

# Potentiometer Values for Figure B-2

Quentity	Potenticmeter	Setting
t/10	143	.100
t/10	184	.100
to/100	1410	.100
t/100	207	.010
t <sub>h</sub> /100	1D6	.600
r <sub>s</sub> /10	1B6	.100
r <sub>s</sub> /10	106	.300
r <sub>s</sub> /10	1D6	.500
r <sub>3</sub> /10	1B1	.100
r <sub>s</sub> /10 B <sub>g</sub> /10	1B2	Variable .272 or .562

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## Table B-3

## Potentiometer Values for Figure B-3

Quantity	Potentiometer	Approximate Setting
IAE <sub>m</sub> /10	1A6	<b>•</b> 100
IAEp/10	187	.100
ITESm/100	1B4	.100
ITESp/100	1B5	<b>.</b> 100
ITAEm/100	241	.100
ITAEp/100	243	.100
IESm/10	244	.100
7.55p/10	245	<b>.</b> 100

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### Appendix C

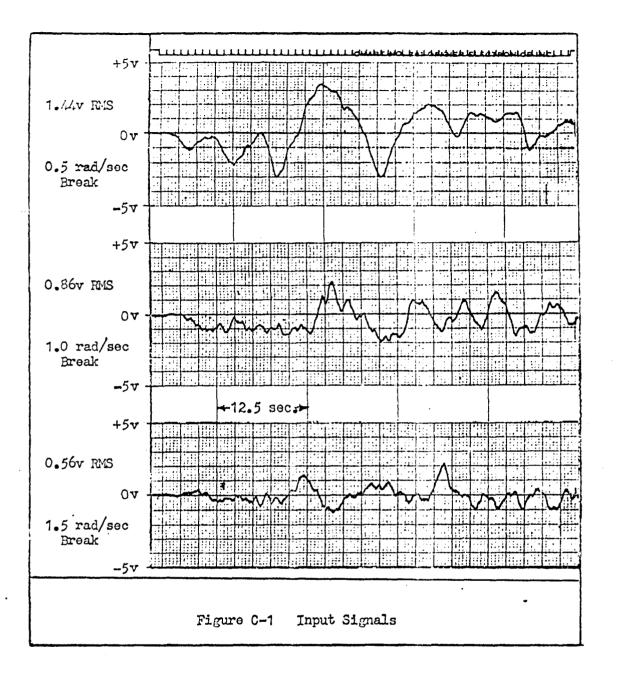
### Analog Gaussian Input Tape Recordings

The signal recordings used in the Phase II and III experiments are shown in Figure C-1. The following procedure was used to obtain these signals. First, white noise from the Elgenco Model 311A Noise Generator was fed to a second order filter, which was programmed on the analog computer. Then, the filtered Gaussian signal was processed through a fader and reproduced on the appropriate tape channel of the Sangamo Model 4784 Magnetic Tape Recorder/Reproducer. Fading was accomplished to eliminate step signals at the beginning of the input tape.

The equation used to program the second order filter is

$$y(s) = \frac{K x(s)}{(S+a)^2} ,$$

where y(s) represents the Gaussian output, and x(s) represents the white noise input. The analog schematic of the filter is shown in Figure C-2, and the potentiometer settings are shown in Table C-1.

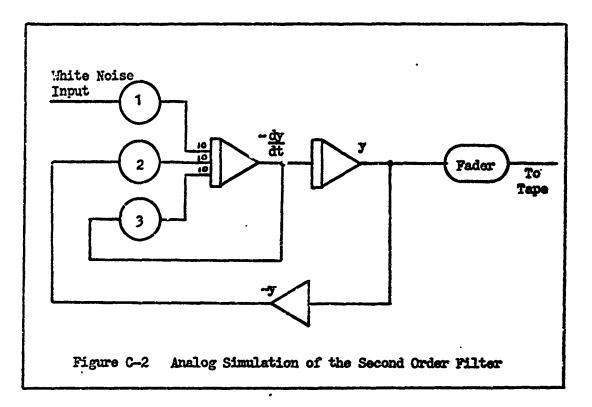


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Table C-1

Potentioneter Settings for Figure C-2

Quantity	Pot.	Settings For The Following Break Frequencies				
		0.5 rad/sec	1.0 rad/sec	1.5 rad/sec		
K/10a <sup>2</sup>	1	Gain/10	Gain/10	Gain/10		
23/10	3	•100	•200	.300		
a <sup>2</sup> /10	2	.025	.100	•225		

#### Appendix D

### Experimental Data

A listing of all data is presented here to save those who wish to continue research on this topic many tedious hours of laboratory time. The data also provide model designers with a first step comparison of their model system performance with piloted system performance.

The mean, variance, and standard deviation were computed, and these values are presented with the experimental measurements. Tables D-1 through D-6 list data gathered and analyzed during Phase I of the study. The first column is measured in volts<sup>2</sup>-seconds, the second column in volts<sup>2</sup>-seconds<sup>2</sup>, the third column in volts-seconds, the fourth column in volts-seconds<sup>2</sup>, and the last column, the delay time, is measured in tenths of a second. Tables D-7 through D-24 list data gathered and analyzed during Phase II, and Tables D-25 through D-33 list data gathered and analyzed during Phase III. The step time, the interval between the beginning of the run and the archication of the step in the Phase III experiments, is measured in seconds. The same four units of measure are used for the first four columns in Tables D-7 through D-33 as were used in Tables D-1 through D-6.

A "O." appearing in any of the tables, indicates that no measurement was taken, or that the measurement was invalid due to multiplier nonlinearity.

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Table D-1

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	IES	ITES	IAE	ITAE	OELAY TIM
	0.740	0.940	1.112	2.550	5.9
	0.319	0.239	0.535	1.430	2.9
	0.430	0.372	0.635	1.270	3.2
	0.341	0.253	0.592	1.560	2.5
	0.402	0.324 0.356	0.653 0.686	1.590	3.8
	0.462 0.448	0.372	0.798	2.120	3.1
	0.300	0.141	0.463	1.070	2.2
	0.400	0.240	0.631	1.520	2.9
	0.255	0.149	0.515	1.580	2.3
	0.245	0.042	0.603	2.270	2.2
DATA	0.334	0.146	0.546	1.470	2.4
	0.307	0.183	0.560	1.560	2.5
	0.299	0.102	0.747	2.650	2.2
	0.295	0.198 0.239	0.475 0.756	1.080 2.530	2.5
	0.318	0.225	0.625	1.870	2.5
	0.362	0.222	0.778	2.450	3.0
	0.407	0.389	0.783	2.210	3.5
	0.281	0.194	0.632	2.060	2.2
	0.300	0.212	0.672	2.160	2.2
	0.340	0.083	0.532	1.320	2.6
	0.427	0.399	0.754	1-920	4.0
	0.454	0.373 0.180	0.792 0.600	2.070 2.260	3.8
	0.227	0.100	0.000		
IEAN	0.361	0.259	0.659	2.841	2.9
		A 074	A A18	0 717	1 6.7
SUBJECT 1 - A	0.010 0.102 PERFORMANCE MEA	0.024 0.154 SURES FOR K/S (	0.018 0.136	0.217 0.465	0.7
ARIANCE STO. DEV. SUBJECT 1 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA LT STEP IES	0.154 SURES FOR K/S ( 17ES	0.136		0.6 DELAY TE
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP 1ES 0.576	0.154 SURES FOR K/S ( 17ES 0.525	0.136 CONTROLLER 14E 0.924	0.465	0.6 DELAY TI 2.5
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612	0.154 SURES FOR K/S ( 17ES 0.525 0.582	0.136 CONTROLLER 14E 0.924 1.105	0.465 [[74E 2.440 3.390	0.6 DELAY TI 2.5 2.6
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637	0.136 CONTROLLER 14E 0.924 1.105 0.969	0.465 [74E 2.440 3.390 2.150	0.6 DELAY TE 2.5 2.6 2.3
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP 1ES 0.576 0.612 0.684 0.583	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553	0.136 CONTROLLER 14E 0.924 1.105 0.969 1.019	0.465 <u>ITAE</u> 2.440 3.390 2.150 2.810	0-6 DELAY TI 2-5 2-6 2-3 2-1
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684	0.154 SURES FOR K/S ( 1TES 0.525 0.582 0.637 0.553 0.696	0.136 CONTROLLER 1AE 0.924 1.105 0.969 1.019 1.040	0.465 <u>ITAE</u> 2.440 3.390 2.150 2.810 2.550	0-6 DELAY TI 2-5 2-6 2-3 2-1 2-0
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553	0.136 CONTROLLER 14E 0.924 1.105 0.969 1.019	0.465 <u>ITAE</u> 2.440 3.390 2.150 2.810	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2
SUBJECT 1 - A	0.102 PERFORMANCE NEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785	0.154 SURES FOR K/S ( 1TES 0.525 0.582 0.637 0.553 0.696 0.982	0.136 CONTROLLER 14E 0.924 1.105 0.969 1.019 1.040 1.200	0.465 <u>174E</u> 2.440 3.390 2.150 2.810 2.550 2.740	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1
SUBJECT 1 - A	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.645 0.645 0.785 0.693 0.658 0.716	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723	0.136 CONTROLLER 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032	0.465 [TAE 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 2.060	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3
TO. DEV.	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.645 0.645 0.785 0.693 0.658 0.716 0.695	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706	0.136 ONTROLLER 14E 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.956	0.445 174E 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 2.080 1.790	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740	0.136 ONTROLLER 14E 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.956 0.924	0.445 174E 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 2.080 1.790 1.640	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.956 0.924 0.904	0.445 174E 2.440 3.390 2.150 2.550 2.740 1.940 2.360 2.080 1.790 1.640 1.740	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.1 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614	0.154 SURES FOR K/S ( 1TES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625	0.136 CONTROLLER 1AE 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.926 0.924 0.924 0.926 0.926 0.925	0.465 174E 2.440 3.390 2.150 2.550 2.740 1.940 2.360 2.360 1.790 1.640 1.740 1.500	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.1 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614 0.526	0.154 SURES FOR K/S ( 1TES 0.525 0.525 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.740 0.612 0.625 0.488	0.136 CONTROLLER 14E 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.966 0.926 0.926 0.906 0.859 0.750	0.465 <u>174E</u> 2.440 3.390 2.150 2.350 2.740 1.940 2.360 2.080 1.790 1.640 1.740 1.500 1.420	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.1 2.3 2.9 2.1 2.5 2.6 2.5 2.6 2.8 2.0
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614	0.154 SURES FOR K/S ( 1TES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.966 0.924 0.924 0.924 0.924 0.924 0.924 0.959 0.750 0.846	0.465 174E 2.440 3.390 2.150 2.550 2.740 1.940 2.360 2.360 1.790 1.640 1.740 1.500	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.1 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.645 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614 0.526 0.571 0.613 0.532	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693	0.136 CONTROLLER 14E 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.966 0.926 0.926 0.906 0.859 0.750	0.465 ITAE 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 2.080 1.790 1.640 1.500 1.420 1.660	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 9 2.1 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.5 2.6 2.3 2.9 2.5 2.5 2.5 2.5 2.5 2.5 2.6 2.3 2.9 2.5 2.5 2.5 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.5 2.5 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.5 2.5 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.662 0.614 0.526 0.571 0.613 0.532 0.378	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.603 0.580 0.696 0.696 0.696 0.696	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.966 0.924 0.924 0.906 0.859 0.750 0.866 0.876 0.979 0.800	0.445 174E 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 2.080 1.790 1.640 1.740 1.500 1.420 1.660 1.653 2.550 2.440	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5 2.6 2.8 2.0 2.3 3.3 2.3 2.1
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614 0.526 0.571 0.613 0.532 0.378 0.415	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.580 0.580 0.580 0.580	0.136 ONTROLLER IAE 0.924 1.019 1.040 1.200 0.986 1.022 1.032 0.956 0.924 0.906 0.859 0.750 0.846 0.876 0.979 0.800 0.752	0.445 174E 2.440 3.390 2.150 2.350 2.740 1.940 2.360 2.360 2.080 1.790 1.640 1.740 1.650 1.650 2.550 2.440 1.652	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.5 2.6 2.8 2.0 2.3 3.3 2.3 3.3 2.1 2.5 2.6 2.8 2.0 2.3 3.3 2.3 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.3 3.3 2.7 2.5 2.6 2.3 3.3 2.7 2.7 2.5 2.6 2.5 2.6 2.5 2.6 2.3 3.3 2.7 2.7 2.5 2.6 2.5 2.6 2.5 2.6 2.7 2.5 2.6 2.7 2.7 2.5 2.6 2.7 2.7 2.7 2.7 2.7 2.7 2.7 2.7
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 G.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.6675 0.6675 0.6614 0.526 0.571 0.613 0.532 0.378 0.415 0.354	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.696 0.413 0.372 0.395	0.136 CONTROLLER 1 AE 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.966 0.924 0.904 0.859 0.750 0.846 0.876 0.979 0.800 0.752 0.822	0.445 174E 2.440 3.390 2.150 2.550 2.740 1.940 2.360 2.080 1.790 1.640 1.740 1.500 1.420 1.650 2.550 2.440 1.653 2.550	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.1 2.3 2.5 2.6 2.8 2.0 2.3 3.3 2.3 2.3 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.0 3.2 2.9 2.1 2.3 2.1 2.9 2.1 2.5 2.6 2.5 2.6 2.3 3.2 2.9 2.1 2.5 2.6 2.3 2.1 2.9 2.1 2.5 2.6 2.5 2.6 2.3 3.2 2.9 2.1 2.5 2.5 2.6 2.3 2.1 2.9 2.1 2.5 2.5 2.6 2.5 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.5 2.6 2.3 3.3 2.3 2.3 2.5 2.5 2.6 2.5 2.5 2.5 2.6 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.665 0.642 0.614 0.526 0.571 0.613 0.532 0.378 0.415 0.354 0.415	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.695 0.488 0.693 0.580 0.488 0.693 0.580 0.488 0.693 0.580 0.488 0.693 0.580 0.488 0.693 0.580 0.695 0.488 0.693 0.580 0.695 0.488 0.693 0.580 0.695 0.488 0.693 0.580 0.695 0.488 0.693 0.580 0.695 0.488 0.693 0.580 0.695 0.695 0.693 0.695 0.695 0.695 0.747 0.674 0.723 0.706 0.747 0.625 0.625 0.693 0.695 0.697 0.747 0.674 0.723 0.706 0.747 0.674 0.625 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.695 0.488 0.488 0.489 0.472	0.136 ONTROLLER CONTROLLER 0.924 1.105 0.949 1.019 1.040 1.200 0.986 1.022 1.032 0.986 0.924 0.924 0.926 0.925 0.859 0.859 0.859 0.8750 0.846 0.979 0.800 0.752 0.822 0.800	0.445 ITAE 2.440 3.390 2.150 2.810 2.550 2.740 1.940 1.940 1.740 1.640 1.640 1.650 2.550 2.440 1.650 2.550 2.440	0.6 OELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 9 2.1 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 3.3 2.1 2.3 2.3 2.1 2.3 2.1 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.9 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 2.5 2.6 2.3 2.5 2.6 2.3 2.3 2.1 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614 0.526 0.571 0.613 0.532 0.378 0.415 0.354 0.415 0.426	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.696 0.488 0.693 0.580 0.696 0.488 0.695 0.485	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.966 0.924 0.926 0.926 0.926 0.926 0.926 0.859 0.859 0.859 0.876 0.979 0.800 0.752 0.822 0.822 0.800 0.766	0.445 ITAE 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 1.790 1.640 1.760 1.650 1.650 2.550 2.440 1.655 2.550 2.440 1.920 2.700 2.270 2.030	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5 2.6 2.8 2.8 2.0 2.3 3.3 2.1 2.2 2.0 2.5 2.6 2.3 2.1 2.3 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.3 2.5 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.5 2.6 2.3 3.3 2.1 2.2 2.0 2.3 3.3 2.1 2.2 2.0 2.3 2.1 2.2 2.0 2.3 2.1 2.2 2.5 2.6 2.6 2.6 2.3 2.1 2.2 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
TO. DEV. SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.665 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614 0.526 0.571 0.613 0.532 0.378 0.415 0.354 0.426 0.396	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.696 0.413 0.372 0.375 0.472 0.445 0.444	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.966 0.924 0.906 0.859 0.750 0.846 0.876 0.979 0.800 0.752 0.822 0.822 0.926 0.736	0.445 ITAE 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 1.790 1.640 1.790 1.640 1.650 2.550 2.440 1.655 2.550 2.440 1.655 2.550 2.440 1.655 2.550 2.440 1.655 2.550 2.440 1.920 2.700 2.270 2.030 2.020	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5 2.6 2.8 2.0 2.3 3.3 2.3 2.1 2.2 2.0 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.1 2.5 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.5 2.6 2.3 2.1 2.1 2.3 2.1 2.3 2.1 2.5 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.1 2.5 2.5 2.6 2.5 2.6 2.3 2.1 2.5 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.5 2.6 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.614 0.526 0.571 0.613 0.532 0.378 0.415 0.354 0.415 0.426	0.154 SURES FOR K/S ( 17ES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.696 0.488 0.693 0.580 0.696 0.488 0.695 0.485	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.966 0.924 0.926 0.926 0.926 0.926 0.926 0.859 0.859 0.859 0.876 0.979 0.800 0.752 0.822 0.822 0.800 0.766	0.445 ITAE 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 1.790 1.640 1.760 1.650 1.650 2.550 2.440 1.655 2.550 2.440 1.920 2.700 2.270 2.030	0.6 DELAY TE 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5 2.6 2.3 2.9 2.5 2.6 2.3 3.3 2.1 2.2 2.0 2.1 2.3 2.1 2.5 2.6 2.3 2.1 2.3 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.5 2.6 2.3 2.1 2.3 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.5 2.6 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.6 2.5 2.5 2.5 2.5 2.5 2.5 2.5 2.5
D. 1	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 G.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.6675 0.6675 0.6614 0.526 0.571 0.613 0.532 0.378 0.415 0.415 0.425	0.154 SURES FOR K/S ( 1TES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.693 0.580 0.696 0.413 0.372 0.395 0.472 0.485 0.444 0.388 0.501	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.040 1.200 0.986 1.022 1.032 0.986 0.924 1.022 1.032 0.986 0.924 0.996 0.959 0.750 0.846 0.876 0.979 0.800 0.752 0.822 0.800 0.752 0.822 0.926 0.752 0.822 0.926 0.752 0.822 0.926 0.752 0.822 0.926 0.752 0.822 0.956 0.752 0.822 0.956 0.752 0.859 0.752 0.822 0.859 0.752 0.822 0.822 0.822 0.859 0.752 0.822 0.859 0.752 0.822 0.926 0.752 0.859 0.752 0.822 0.859 0.752 0.822 0.859 0.752 0.822 0.859 0.752 0.822 0.956 0.752 0.822 0.956 0.752 0.822 0.859 0.752 0.822 0.859 0.752 0.822 0.859 0.752 0.822 0.859 0.752 0.859 0.752 0.822 0.859 0.752 0.822 0.956 0.752 0.859 0.752 0.822 0.752 0.752 0.859 0.752 0.822 0.859 0.752 0.852 0.859 0.752 0.852 0.859 0.752 0.852 0.859 0.752 0.852 0.859 0.752 0.852 0.859 0.752 0.852 0.859 0.752 0.859 0.752 0.852 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859 0.752 0.859	0.445 174E 2.440 3.390 2.150 2.310 2.550 2.740 1.940 2.360 2.360 1.790 1.640 1.790 1.640 1.640 1.650 2.550 2.440 1.655 2.550 2.700 2.700 2.700 2.270 2.030 2.020 1.920 1.930	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5 2.6 2.3 2.9 2.1 2.3 2.9 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.4 2.3 2.4 2.5 2.6 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.1 2.3 2.5 2.6 2.3 2.1 2.3 2.9 2.5 2.6 2.3 2.1 2.3 2.5 2.6 2.3 2.1 2.3 2.5 2.6 2.3 2.5 2.6 2.3 2.1 2.3 2.5 2.6 2.3 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.8 2.0 2.3 3.3 2.3 2.1 2.2 2.5 2.6 2.8 2.0 2.3 3.3 2.1 2.2 2.0 2.1 2.2 2.5 2.6 2.8 2.0 2.3 3.3 2.1 2.2 2.0 2.1 2.2 2.5 2.6 2.6 2.8 2.0 2.1 2.2 2.5 2.6 2.6 2.8 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.6 2.6 2.6 2.6 2.6 2.6 2.6
SUBJECT 1 - 1 INPUT - 1 VOL	0.102 PERFORMANCE MEA T STEP IES 0.576 0.612 0.684 0.583 0.645 0.785 0.693 0.658 0.716 0.695 0.675 0.642 0.613 0.571 0.613 0.532 0.378 0.415 0.415 0.426 0.396 0.367	0.154 SURES FOR K/S ( 1TES 0.525 0.582 0.637 0.553 0.696 0.982 0.747 0.674 0.723 0.706 0.740 0.612 0.625 0.488 0.603 0.580 0.696 0.413 0.372 0.395 0.444 0.388	0.136 ONTROLLER IAE 0.924 1.105 0.969 1.019 1.060 1.200 0.986 1.022 1.032 0.966 0.924 0.906 0.859 0.750 0.846 0.876 0.979 0.800 0.752 0.822 0.800 0.752 0.822 0.800 0.756 0.736 0.736 0.698	0.445 174E 2.440 3.390 2.150 2.810 2.550 2.740 1.940 2.360 2.080 1.790 1.640 1.640 1.640 1.650 2.550 2.440 1.655 2.550 2.440 1.655 2.550 2.440 1.920 2.020 1.920	0.6 DELAY TI 2.5 2.6 2.3 2.1 2.0 3.2 2.9 2.1 2.3 2.9 2.5 2.6 2.8 2.0 2.3 2.3 2.3 2.3 2.1 2.2 2.6 2.3 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.5 2.6 2.3 2.1 2.5 2.5 2.6 2.3 2.1 2.5 2.6 2.3 2.1 2.5 2.5 2.6 2.3 2.1 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.3 2.5 2.6 2.5 2.6 2.3 2.5 2.6 2.3 2.3 2.1 2.2 2.5 2.6 2.3 2.3 2.1 2.2 2.5 2.6 2.3 2.3 2.1 2.2 2.5 2.6 2.3 2.3 2.1 2.2 2.0 2.5 2.6 2.3 2.3 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.0 2.1 2.2 2.4 2.4 2.4

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<u>GE/EE/695-2</u>

Table	<b>D-2</b>
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	165	ITES	IAE	ITAE	DELAY TIM
	0.688	0.896	1.174	3.120	2.4
	0.54=	0.651	1.145	3.760	2.1
	0.894	1.322	1.672	5.240	2.0
	0.716	1.296	1.608	5.580	2.7
	0.801	1.195	1.396	4.040	2.2
	0.593	0.800	1.109	3.120	2.1
	0.787	1.048	1.260	3.120	2.1
	0.739	1.117	1.298	3.520	2.5
	0.879	1.451	1.596	5.020	2.7
	0.659	1.107	1.404	4.710	2.5
	0.534	0.687	1.021	2.910	2.1
DATA	0.791	1.053	1.229	2.920	2.3
1	0.500	0.729	1.103	3.650	2.6
	0.668	1.128	1.282	3.740	2.8
	0.785	1.081	1.520	4.960	2.6
	0.872	1.221	1.439	3.930	2.2
	0.913	1.524	1.635	5.110	2.4
	0.700	1.620	1.844	6.280	2.5
	0.709	0,867	1.046	2.120	2.6
i	0.454	0.474	0,920	2.700	2.1
	0.602	0.303	1.059	2.830	2.0
	0.526	0.614	0.999	2.600	2.2
	0.509	0.590	0.908	4.160	2.1
1	0.530	0.681	0.960	2.330	2.0
	0.441	0.516	0.781	1.990	1-8
MEAN	0.684	0.979	1.256	3.738	2.3
VARIANCE	0.021	0.101	0.075	1.272	0.1
STD. DEV.	0.146	0.317	0.273	1.128	0.3

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SAULT WALK

	IES	ITES	IAE	ITAE	DELAY TIME
	0.456	0.474	0.786	2.120	2.8
	0.471 ·	0.357	0.792	2.110	2.9
	0.475	0.391 J.710	0.929	1.710	3.2
	0.430	0.337	0.780	2.210	2.2
	0.509	0.495	0.860	2.190	3.2
	0.421	0.356	0.809	2.420	2.2
	0.400	0.367	0.750	2.130	2.4
DATA	0.382	0.380	0.603	2.600	2.3
	0.465 0.476	0.410 0.477	0.822	2.140 2.350	2.3
	0.507	0.474	0.826	1.920	2.9
	0.540	J. 56%	0.868	1.960	3.2
	0.432	0.439	0.806	2.220	2.5
	0.508	0. 549	0.873	2.180	2.6
	0.596	0.632	0.866	1.670	4.5
	0.587	0.643	0.953	2.260	3.2
	0.516	0.514	0.864	2.150	3.0
	0.505	0.921 0.361	0.833	1.750 1.110	3.4
	0.413	0.415	0.722	1.820	2.7
	0.367	0.342	0.656	1.690	2.9
	0.572	0.729	1.071	3.040	3.1
	0.405	0.444	0.832	2.470	2.4
	0.506	0.519	1.004	2.980	2.8
NEAN	0.480	0.492	0.\$31	2.126	2.8
MADTANCE					
ARIANCE STD. DEV.	0.004	0.020	0.009	0-164	0.2
STD. DEV.	0.067 ERFORMANCE MEA	0.141	0.094	0.164 0.406	0.2 0.5
STD. DEV.	0.067 ERFORMANCE MEAN T STEP	0-141 SURES FOR K/S (	0.094	0.406	0.5
STD. DEV.	0.067 ERFORMANCE MEAN T STEP	0.141 SURES FOR K/S ( ITES	0.094 CONTROLLER IAE	0.406	0.5
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973	0.141 SURES FOR K/S ( 1TES 1.228	0.094 CONTROLLER IAE 1.436	0.406	0.5 DELAY TIM 2.9
STD. DEV.	0.067 ERFORMANCE MEA: T STEP IES 0.973 0.816	0.141 SURES FOR K/S ( 1TES 1.228 0.972	0.094 CONTROLLER IAE 1.436 1.151	0.406	0.5 DELAY TIM 2.9 2.6
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973	0.141 SURES FOR K/S ( 1TES 1.228	0.094 CONTROLLER IAE 1.436	0.406	0.5 DELAY TIM 2.9
STD. DEV.	0.067 ERFORMANCE MEA: T STEP IES 0.973 0.816 0.763	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.840	0.094 CONTROLLER I.434 1.151 1.090	0.406 <u>ITAE</u> 3.130 2.210 2.030	0.5 DELAY TIM 2.9 2.6 2.5
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815	0-141 SURES FOR K/S ( 17ES 1-228 0-972 0-972 0-972 0-972 0-972 0-972 0-972 0-972	0.094 CONTROLLER I.436 1.151 1.090 0.954 1.031 1.090	0.406 ITAE 3-130 2.210 2.030 1.740 2.370 1.800	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.5 2.6 3.0
STD. DEV.	0.067 ERFORMANCE MEAS T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651	0.141 SURES FOR K/S ( 1.228 0.972 0.840 0.682 0.702 0.942 0.942 0.657	0.094 CONTROLLER I.436 1.151 1.090 0.954 1.031 1.090 9.875	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.400 1.370	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.840 0.662 0.702 0.942 0.657 0.798	0.094 CONTROLLER 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.400 1.370 2.140	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.5 2.6 3.0 2.9 3.0
STD. DEV.	0.067 ERFORMANCE MEA: T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691	0.141 SURES FOR K/S ( 1.228 0.972 0.840 0.662 0.702 0.942 0.657 0.798 0.769	0.094 CONTROLLER 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1
STD. DEV.	0.067 ERFORMANCE MEA: T STEP 1ES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.440 0.440 0.462 0.702 0.942 0.457 0.798 0.769 0.514	0.094 CONTROLLER 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930	0.406 <u>ITAE</u> 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.089	0.5 DELAV TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.815 0.631 0.815 0.651 0.739 0.691 0.551 0.720	0-141 SURES FOR K/S ( 17ES 1.228 0.972 0.440 0.682 0.702 0.942 0.657 0.798 0.769 0.514 0.837	0.094 IAE 1.434 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.090 2.160	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.8
STD. DEV.	0.067 ERFORMANCE MEA: T STEP 1ES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.440 0.440 0.462 0.702 0.942 0.457 0.798 0.769 0.514	0.094 CONTROLLER 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930	0.406 <u>ITAE</u> 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.089	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.6 3.0
STD. DEV.	0.067 ERFORHANCE HEAT T STEP IES 0.973 0.815 0.631 0.815 0.651 0.739 0.651 0.739 0.651 0.720 0.718	0-141 SURES FOR K/S ( 17ES 1-228 0.972 0.940 0.642 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809	0.094 CONTROLLER I.436 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.140 1.570 2.080 1.600	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.8
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.755 0.651	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.840 0.682 0.702 0.942 0.657 0.708 0.769 0.514 0.837 0.809 0.534 0.862 0.868	0.094 CONTROLLER I.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.092	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.400 1.370 2.140 1.570 2.099 2.160 1.600 3.470 2.300 2.300 2.440	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.6 3.0 2.1 2.8 3.0 2.1 2.6 3.0 2.9 3.0 2.9 3.3 2.6
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.757 0.65° 0.622	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.440 0.682 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809 0.514 0.837 0.809 0.534 0.862 0.658 0.590	0.094 CONTROLLER I.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.038 1.128 1.092 0.852	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.600 1.370 2.140 1.570 2.080 2.160 1.600 3.470 2.300 2.440 1.370	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.0 2.1 2.8 3.0 2.9 3.3 2.6 2.9
STD. DEV.	0.067 ERFORMANCE MEA: T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.755 0.65 <sup>°</sup> : 0.65 <sup>°</sup> : 0.622 0.675	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.840 0.682 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809 0.514 0.837 0.809 0.534 0.862 6.888 0.590 0.721	0.094 IAE 1.434 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.092 0.852 0.941	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.570 2.140 1.570 2.089 2.160 1.600 3.470 2.300 2.440 1.370 1.370 1.610	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.8 3.0 2.9 3.0 2.1 2.6 3.0 2.9 3.0 2.9 3.3 2.6 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.1 3.0 2.9 3.3 2.6 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 3.0 3.0 3.0 3.0 3.0 3.0
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.815 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.755 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.940 0.462 0.702 0.942 0.657 0.769 0.769 0.514 0.837 0.809 0.534 0.842 0.868 0.590 0.721 0.800	0.094 IAE 1.434 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.092 0.852 0.941 1.096	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.140 1.600 3.470 2.300 2.440 1.370 1.610 2.130	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.0 2.9 3.0 2.9 3.3 2.6 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.1 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.3 2.6 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 2.9 3.3 3.0 3.0 3.0 2.9 3.3 3.0 3.0 3.0 3.0 3.0 3.0 3.0
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.675 0.631 0.815 0.651 0.739 0.651 0.739 0.651 0.720 0.718 0.411 0.758 0.622 0.675 0.622 0.675 0.745 0.705	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.942 0.642 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809 0.534 0.842 0.809 0.534 0.862 0.868 C.590 0.721 0.80C 0.746	0.094 IAE 1.436 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.038 1.128 1.092 0.852 0.941 1.096 0.966	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.140 1.570 2.080 2.140 1.600 3.470 2.300 2.440 1.370 1.610 2.130 1.630	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.8 3.0 2.9 3.3 2.6 2.9 3.3 2.6 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 2.6 3.0 2.9 2.6 3.0 2.9 2.6 3.0 2.9 3.3 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 2.9 3.0 2.9 3.0 2.9 3.0 3.0 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 2.9 3.0 2.9 2.9 2.9 2.9 2.9 3.0 2.9 2.9 2.9 2.9 3.0 2.9 2.9 3.0 2.9 2.9 3.0 2.9 2.9 2.9 2.9 2.9 2.9 2.9 2.9 2.9 2.9
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.815 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.755 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655 0.655	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.940 0.462 0.702 0.942 0.657 0.769 0.769 0.514 0.837 0.809 0.534 0.842 0.868 0.590 0.721 0.800	0.094 IAE I.436 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.044 `.949 0.930 1.082 0.983 1.038 1.128 1.092 0.852 0.941 1.096 0.966 1.148	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.140 1.570 2.080 2.160 1.600 3.470 2.300 2.440 1.370 1.610 2.130 1.630 1.980	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.5 2.6 3.0 2.9 3.0 2.1 3.8 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 3.0 2.9 3.1 3.0 2.8 4.2
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.752 0.655 0.622 0.675 0.675 0.745 0.705 0.841	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.942 0.662 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809 0.534 0.862 C.690 0.721 0.900 0.746 0.969	0.094 IAE 1.436 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.038 1.128 1.092 0.852 0.941 1.096 0.966	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.140 1.570 2.080 2.140 1.600 3.470 2.300 2.440 1.370 1.610 2.130 1.630	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.8 3.0 2.9 3.3 2.6 2.9 3.3 2.6 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 2.6 3.0 2.9 2.6 3.0 2.9 2.6 3.0 2.9 3.3 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 2.9 3.0 2.9 3.0 2.9 3.0 3.0 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 2.9 3.0 3.0 3.0 2.9 3.0 2.9 3.0 3.0 2.9 3.0 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 3.0 2.9 2.9 3.0 2.9 2.9 2.9 2.9 2.9 3.0 2.9 2.9 2.9 2.9 3.0 2.9 2.9 3.0 2.9 2.9 3.0 2.9 2.9 2.9 2.9 2.9 2.9 2.9 2.9 2.9 2.9
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.755 0.655 0.622 0.675 0.622 0.675 0.745 0.745 0.745 0.728 0.897 0.656	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.840 0.662 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809 0.534 0.837 0.809 0.534 0.862 0.668 0.590 0.721 0.869 0.746 0.969 0.816	0.094 IAE I.436 1.436 1.151 1.090 0.954 1.031 1.090 9.875 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.092 0.852 0.941 1.096 0.966 1.148 1.176	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.090 2.140 1.570 2.090 2.160 1.600 3.470 2.300 2.440 1.370 1.610 1.370 1.630 1.980 2.740	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.0 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.1 3.0 2.8 4.2 4.4
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.815 0.631 0.815 0.651 0.720 0.718 0.411 0.755 0.65: 0.622 0.65: 0.622 0.675 0.745 0.745 0.745 0.745 0.745 0.745 0.897 0.656 0.611	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.940 0.6482 0.702 0.942 0.657 0.769 0.769 0.514 0.837 0.809 0.534 0.862 6.688 6.590 0.721 0.800 0.746 0.949 0.816 1.074 0.773 0.602	0.094 IAE 1.434 1.151 1.090 0.954 1.031 1.090 0.954 1.031 1.090 0.955 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.092 0.983 1.038 1.128 1.092 0.966 1.148 1.176 1.165 1.118 0.834	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.160 1.600 3.470 2.300 2.440 1.610 2.130 1.630 1.630 1.980 2.740 1.840 2.740 1.840	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.0 2.1 2.8 3.0 2.9 3.3 3.0 2.9 3.3 2.6 2.9 3.1 3.0 2.9 3.1 3.0 2.8 4.2 4.4 4.4 4.4
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.755 0.655 0.622 0.675 0.622 0.675 0.745 0.745 0.745 0.728 0.897 0.656	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.440 0.662 0.702 0.942 0.657 0.798 0.769 0.514 0.83? 0.809 0.514 0.83? 0.809 0.514 0.83? 0.809 0.514 0.83? 0.809 0.514 0.862 0.809 0.514 0.862 0.965 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.809 0.534 0.862 0.809 0.534 0.862 0.9721 0.809 0.514 0.862 0.809 0.514 0.862 0.809 0.514 0.862 0.809 0.514 0.862 0.809 0.721 0.809 0.721 0.809 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.721 0.800 0.774 0.775 0.775 0.775 0.778 0.778 0.779 0.772 0.809 0.7721 0.800 0.774 0.775 0.775 0.775 0.775 0.777 0.771 0.807 0.775 0.775 0.772 0.721 0.800 0.774 0.775 0.775 0.775 0.775 0.772 0.7721 0.800 0.774 0.816 1.074 0.773	0.094 IAE 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.082 0.949 0.930 1.082 0.983 1.082 0.983 1.082 0.983 1.092 0.852 0.941 1.096 0.966 1.148 1.176 1.165 1.118	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.500 1.370 2.140 1.570 2.089 2.140 1.570 2.089 2.140 1.600 3.470 2.300 2.440 1.370 1.610 2.130 1.630 1.980 2.740 1.640 2.750	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 4.2 4.2 4.4 4.4 4.4
STD. DEV.	0.067 ERFORHANCE HEA: T STEP IES 0.973 0.815 0.631 0.815 0.651 0.720 0.718 0.411 0.755 0.65: 0.622 0.65: 0.622 0.675 0.745 0.745 0.745 0.745 0.745 0.745 0.897 0.656 0.611	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.940 0.6482 0.702 0.942 0.657 0.769 0.769 0.514 0.837 0.809 0.534 0.862 6.688 6.590 0.721 0.800 0.746 0.949 0.816 1.074 0.773 0.602	0.094 IAE 1.434 1.151 1.090 0.954 1.031 1.090 0.954 1.031 1.090 0.955 1.084 `.949 0.930 1.082 0.983 1.038 1.128 1.092 0.983 1.038 1.128 1.092 0.966 1.148 1.176 1.165 1.118 0.834	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.160 1.600 3.470 2.300 2.440 1.610 2.130 1.630 1.630 1.980 2.740 1.840 2.740 1.840	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.0 2.1 2.8 3.0 2.9 3.3 3.0 2.9 3.3 2.6 2.9 3.1 3.0 2.9 3.1 3.0 2.8 4.2 4.4 4.4 4.4
STD. DEV.	0.067 ERFORMANCE MEAN T STEP IES 0.973 0.816 0.763 0.675 0.631 0.815 0.651 0.739 0.691 0.551 0.720 0.718 0.411 0.758 0.655 0.622 0.675 0.745 0.745 0.745 0.745 0.745 0.745 0.745 0.897 0.656 0.611 0.951	0.141 SURES FOR K/S ( 17ES 1.228 0.972 0.942 0.642 0.702 0.942 0.657 0.798 0.769 0.514 0.837 0.809 0.534 0.842 0.868 C.590 0.721 0.80C 0.746 0.946 0.942 0.953 0.869 0.721 0.80C 0.746 0.969 0.516 1.074 0.975 0.9602 1.196	0.094 IAE 1.436 1.436 1.151 1.090 0.954 1.031 1.090 0.875 1.084 `.949 0.930 1.082 0.983 1.082 1.082 0.983 1.038 1.128 1.095 0.952 0.941 1.096 0.966 1.148 1.176 1.165 1.118 0.834 3.214	0.406 ITAE 3.130 2.210 2.030 1.740 2.370 1.800 1.370 2.140 1.570 2.080 2.160 1.600 3.470 2.300 2.160 1.600 3.470 2.300 2.160 1.370 2.300 2.160 1.370 2.130 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.980 2.740 1.630 1.740 2.740 1.630 1.740 2.740 1.740 2.140 1.670 2.160 1.670 2.160 1.670 2.160 1.670 2.440 1.740 2.160 1.770 2.740 1.740 2.740 1.740 2.740 1.740 2.740 1.740 2.740 1.740 2.740 1.740 1.740 2.740 1.7	0.5 DELAY TIM 2.9 2.6 2.5 2.5 2.5 2.6 3.0 2.9 3.0 2.1 2.8 3.0 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.6 2.9 3.3 2.5 2.5 2.5 2.6 3.0 2.9 3.3 3.0 2.9 3.3 2.6 3.0 3.0 2.9 3.3 2.6 3.0 2.9 3.3 2.6 3.0 3.0 2.9 3.3 2.6 3.0 2.9 3.3 3.0 2.9 3.3 3.0 3.0 2.9 3.3 3.0 2.9 3.3 3.0 3.0 3.0 3.0 3.0 3.0 3.0

Table D-3

.

5

Table D-4

	IES	ITES	IAE	ITAE	DELAY TIM
	1.184	1.590	1.669	3.632	2.7
	1.206	1.770	1.779	4.170	2.2
	1.052	1.620	1.781	4.830	2.6
	0.944	1.240	1.492	3.770	2.9
	1.244	2.040	1.962	5.280	2.5
	1.034	1.350	1.398	2.790	2.1
	0.968	1.280	1.430	3.330	2.2
	1.358	2.470	2.220	5.700	2.3
	1.212	1.860	1.826	4.460	2.0
	1.135	1.740	1.712	4.140	2.1
	0.923	2.310	1.642	4.780	2.2
DATA	0.928	1.270	1.530	4.040	2.6
	1.246	1.760	1.720	3.610	2.5
	0.934	1.260	1.490	3.790	2.2
	1.181	1.670	1.708	3.860	3.5
	1.118	1.720	1.742	4.380	2.7
	1.282	1.860	1.786	3.940	2.0
	0.899	1.250	1.528	4.170	2.6
	1.132	1.550	1.562	3.220	3.0
	1.009	1.330	1.486	3.550	2.0
	1.223	1.780	1.802	4.200	2.5
	1.180	2.230	2.112	6.660	3.5
	0.985	1.38C	1.552	3.920	2.6
	1 .210	1.820	1.792	4.130	2.4
	1.084	1.500	1.586	3.570	2.1
NEAN	1.107	1.626	1.692	4.194	2.5
VARIANCE	0.017	0.100	0.039	0.816	0.2
STD. DEV.	0.129	0.316	0.198	0.903	0.4

Table	D-5
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	IES	1165	IAF	ITAE	DELAY TIN
ا جو مورد اندی پر بالا ترجیع کا پر	0.367	0.168	0.626	1.880	3.3
	0.362	0.279	0.621	1.500	3.5
	0.280	0.170	0.584	1.940	2.8
	0.354	0-280	0.584	1.590	2.9
	0.552	0.492	0.853	2.090	5.0
	0.613 0.620	0.751	0.969	2.390 2.800	4.0
	0.389	0.450	0.880	3.100	3.0
i	0.474	0.590	1.007	3.450	3.8
	0.361	0.370	0.703	2.200	2.8
	0.433	0.510	0.880	2.880	3.6
DATA	0.377	0.28C	0.639	1.710	2.8
	0.371	0.370	9.747	2.380	2.4
	0.390	0.480	0.992	3.830	2.3
	0.365	0.712	0.963	3.850	2.2
	0.366 0.374	0.821	0.966	3.920	2.2
	0.461	1.144	1.376	6.249 6.280	2.4
	0.298	0.644	0.986	3.740	3.0
	0.302	0.280	0.688	2.420	2.5
	0.303	0.267	0.810	3.160	2.5
	0.331	0.552	0.941	3.830	2.2
	0.468	0.944	1.328	5.570	2.6
	0.334	0.512	0.864	3.300	2.5
	0.252	0.236	0.536	1.720	2.2
HEAN	0.393	0.514	0.583	3.111	3.0
VARIANCE	0.009	0.069	0.960	1.756	0.7
			*****		
STD. DEV. SUBJECT 3 - P INPUT - 1 VOL	0.093 PERFORMANCE MEAS T STEP	0.262	0.245	1.325	0-8
SUBJECT 3 - P	PERFORMANCE MEAS		0.245		
SUBJECT 3 - P	ERFORMANCE NEAS	SURES FOR K/S C	0.245	1.325 	0.8 
SUBJECT 3 - P	ERFORMANCE MEAS T STEP IES	SURES FOR K/S C	0.245 ONTROLLER	ITAE	DELAY TIM
SUBJECT 3 - P	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.613	SURES FOR K/S C 17ES 2.970 2.700 2.400	0.245 DATROLLER <u>IAE</u> 2.690 2.280 2.089	ITAE 9.640 6.160 5.470	DELAY TIM 3.0 4.0 3.2
SUBJECT 3 - P	ERFORMANCE MEAS T STEP 1.457 1.535 1.613 1.200	URES FOR K/S C ITES 2.970 2.700 2.400 1.890	0.245 DATROLLER 1AE 2.690 2.280 2.089 1.956	<u>ITAE</u> 9.640 6.160 5.470 5.520	DELAY TIM 3.0 4.0 2.2 3.1
SUBJECT 3 - P	ERFORMANCE MEAS T STEP 1.457 1.535 1.413 1.200 0.817	URES FOR K/S C <u>ITES</u> 2.970 2.700 2.40C 1.890 1.607	0.245 CONTROLLER 2.690 2.280 2.089 1.956 1.332	<u>ITAE</u> 9.640 6.160 5.470 5.520 3.370	OELAY TIM 3.0 4.0 2.2 3.1 3.4
SUBJECT 3 - P	ERFORMANCE MEAS T STEP 1.457 1.535 1.413 1.200 0.817 1.388	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247	0.245 CONTROLLER 2.690 2.280 2.089 1.956 1.332 1.943	<u>ITAE</u> 9.640 6.160 5.670 5.520 3.370 4.510	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3
SUBJECT 3 - P	ERFDRMANCE MEAS T STEP 1.457 1.535 1.413 1.200 0.817 1.388 1.076	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420	0.245 DAYROLLER 1AE 2.690 2.280 2.089 1.956 1.332 1.943 1.577	<u>ITAE</u> 9.640 6.160 5.470 5.520 3.370 4.510 3.790	DELAY TIM 3.0 4.0 3.2 3.1 3.4 4.3 4.1
SUBJECT 3 - P	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230	0.245 ONTROLLER 1AE 2.690 2.280 2.089 1.956 1.332 1.953 1.577 2.072	<u>ITAE</u> 9.640 6.160 5.670 5.520 3.370 4.510 3.790 5.800	DELAY TIM 3.0 4.0 3.2 3.1 3.4 4.3 4.1 2.8
SUBJECT 3 - P	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330 0.944	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239	0.245 ONTROLLER <u>IAE</u> 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373	<u>ITAE</u> 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010	DELAY TIM 3.0 4.0 3.2 3.1 3.4 4.3 4.3 4.1 2.8 2.7
SUBJECT 3 - P	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330	URES FOR K/S C ITES 2.970 2.700 2.400 1.890 1.C07 2.247 1.420 2.230 1.239 2.140	0.245 DATROLLER 1AE 2.690 2.280 2.089 1.956 1.332 1.956 1.577 2.072 1.373 1.956	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239	0.245 ONTROLLER <u>IAE</u> 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373	<u>ITAE</u> 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C	0.245 DATROLLER 1AE 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 3.010 3.000 4.230	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760	0.245 D.	ITAE 9.640 6.160 5.670 5.520 3.370 4.510 3.790 5.800 3.010 5.800 3.010 5.800 3.010 5.800 3.010 5.800 3.010 5.800 4.230 3.690 4.910 4.950	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110	0.245 ONTROLLER 1AE 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.645 1.603 1.824 1.945	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800 3.010 5.000 4.230 3.690 4.910 4.950 5.150	DELAY TIM 3.0 4.0 3.2 3.1 3.4 4.3 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.3
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444	SURES FOR K/S C ITES 2.970 2.700 2.400 1.890 1.607 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480	0.245 DATROLLER 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646 1.411 1.603 1.824 1.945 2.138	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800 3.010 5.000 4.230 3.690 4.910 4.950 5.150 5.150 5.570	DELAY TIM 3-0 4-0 2-2 3-1 3-4 4-3 4-1 2-8 2-7 2-7 2-5 2-8 2-9 3-0 3-3 3-0
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS I STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.63C	0.245 IAE 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646 1.411 1.603 1.824 1.945 2.138 1.613	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800 4.230 3.690 4.910 4.950 5.150 5.570 3.750	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS I STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.63C 2.140	0.245 DATROLLER IAE 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646 1.411 1.603 1.824 1.945 2.138 1.613 1.878	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800 3.010 5.000 4.230 3.690 4.910 4.950 5.150 5.150 5.570 3.750 4.210	DELAY TIM 3-0 4-0 2-2 3-1 3-4 4-3 4-1 2-8 2-7 2-7 2-5 2-8 2-9 3-0 3-3 3-0 2-6 2-8
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.63C 2.14C 0.934	0.245 D.	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 3.010 3.000 4.230 3.690 4.910 4.950 5.150 5.570 3.750 4.210 2.440	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.6 3.1
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS I STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.60 2.140 0.934 1.159	0.245 D.	ITAE 9.640 6.160 5.670 5.520 3.370 4.510 3.790 5.800 3.010 5.800 5.800 5.800 5.800 3.010 5.8000 5.8000 5.8000 5.8000 5.8000 5.8000 5.8000 5.80000 5.80000000000	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.8 3.1 3.4 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.0 3.3 3.0 3.0 3.0 3.0 3.0
SUBJECT 3 - P	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355 0.823 0.887	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.63C 2.14C 0.934	0.245 IAE 2.690 2.280 2.089 1.956 1.332 1.943 1.943 1.977 2.072 1.373 1.956 1.641 1.603 1.824 1.945 2.138 1.613 1.878 1.189 1.372 1.355	ITAE           9.640           6.160           5.470           5.520           3.370           4.510           3.790           5.800           3.010           3.000           4.230           3.690           4.910           4.950           5.150           5.570           3.750           3.350           3.210	DELAY TIM 3.0 4.0 3.2 3.1 3.4 4.3 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.6 3.1 3.4 4.3 4.3 4.3 4.3 4.3 4.3 4.3
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355 0.823 0.887 0.895	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.126 1.224 1.760 2.110 2.480 1.63C 2.140 0.934 1.159 1.108	0.245 D.	ITAE 9.640 6.160 5.670 5.520 3.370 4.510 3.790 5.800 3.010 5.800 5.800 5.800 5.800 3.010 5.8000 5.8000 5.8000 5.8000 5.8000 5.8000 5.8000 5.80000 5.80000000000	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.8 3.1 3.4 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.0 3.3 3.0 3.0 3.0 3.0 3.0
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS T STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355 0.823 0.887 0.895 1.012	JTES           2.970           2.700           2.40C           1.890           1.607           2.247           1.420           2.30           1.239           2.140           1.58C           1.124           1.760           2.110           2.480           1.63C           2.140           1.380	0.245 ONTROLLER 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646 1.441 1.603 1.824 1.945 2.138 1.613 1.878 1.189 1.372 1.355 1.534	ITAE           9.640           6.160           5.470           5.520           3.370           4.510           3.790           5.800           3.010           5.000           4.230           3.690           4.910           4.950           5.150           5.570           3.750           4.210           3.350           3.210           3.740	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.6 3.1 3.4 4.3 4.3 4.3 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0 2.6 3.1 3.4 4.3 4.3 4.3 4.3 4.3 4.3 4.3
SUBJECT 3 - P INPUT - 1 VOL	ERFORMANCE MEAS I STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355 0.823 0.887 0.887 0.895 1.012 0.839	URES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C 1.124 1.760 2.110 2.480 1.63C 2.14C 0.934 1.159 1.108 1.380 1.380 1.065	0.245 ONTROLLER 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646 1.411 1.603 1.824 1.945 2.138 1.613 1.878 1.189 1.372 1.355 1.534 1.291	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800 4.910 4.950 5.150 5.150 5.570 3.750 4.210 2.440 3.350 3.210 3.740 3.090	DELAY TIM 3-0 4-0 3-2 3-1 3-4 4-3 4-1 2-8 2-7 2-7 2-5 2.6 2-9 3-0 3-3 3-0 2-6 2-8 3+1 3-8 2-7 2-7 2-7 2-5 2.9 3-0 2-6 2-9 3-1 3-8 2-7 2-7 2-7 2-5 2.9 3-0 2-7 2-7 2-7 2-7 2-7 2-7 2-7 2-7
DATA	ERFORMANCE MEAS I STEP IES 1.457 1.535 1.613 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355 0.823 0.887 0.895 1.012 0.839 1.072	URES FOR K/S C ITES 2.970 2.700 2.400 1.890 1.C07 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.630 2.140 0.934 1.159 1.108 1.380 1.380 1.065 1.500	0.245 IAE 2.690 2.280 2.089 1.956 1.332 1.943 1.577 2.072 1.373 1.956 1.646 1.411 1.603 1.824 1.945 2.138 1.613 1.878 1.189 1.372 1.355 1.534 1.291 1.545	ITAE 9.640 6.160 5.470 5.520 3.370 4.510 3.790 5.800 3.010 5.800 4.230 3.690 4.910 4.950 5.150 5.150 5.150 5.570 3.750 4.210 2.440 3.350 3.210 3.740 3.090 3.470	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.8 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5 2.8 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0
SUBJECT 3 - P INPUT - 1 VOL	PERFORMANCE MEAS T STEP IES 1.457 1.535 1.413 1.200 0.817 1.388 1.076 1.330 0.944 1.311 1.072 0.887 0.867 1.136 1.289 1.444 1.128 1.355 0.823 0.823 0.895 1.012 0.839 1.072 0.599	SURES FOR K/S C ITES 2.970 2.700 2.40C 1.890 1.607 2.247 1.420 2.230 1.239 2.140 1.58C 1.126 1.224 1.760 2.110 2.480 1.63C 2.14C 0.934 1.159 1.108 1.380 1.065 1.50C 0.649	0.245 D.245 D.245 D.245 D.245 D.245 D.260 2.089 1.956 1.332 1.943 1.943 1.977 2.072 1.373 1.956 1.645 1.641 1.603 1.824 1.945 2.138 1.613 1.878 1.189 1.355 1.534 1.291 1.555 0.874	ITAE           9.640           6.160           5.470           5.520           3.370           4.510           3.790           5.800           3.010           5.000           4.230           3.690           4.910           4.950           5.150           5.570           3.750           3.210           3.740           3.090           3.470           3.740	DELAY TIM 3.0 4.0 2.2 3.1 3.4 4.3 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.8 3.1 3.4 4.1 2.8 2.7 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.8 2.9 3.0 3.0 2.6 2.8 2.7 2.7 2.5 2.8 2.9 3.0 3.0 2.6 2.8 2.9 3.0 3.3 3.0 2.6 2.7 2.5 2.5 2.8 2.9 3.0 3.0 2.6 2.7 2.7 2.5 2.8 2.9 3.0 3.0 2.6 2.7 2.5 2.8 2.9 3.0 3.3 3.0 2.6 2.7 2.7 2.5 2.8 2.9 3.0 3.0 3.0 3.0 3.0 3.0 3.0 3.0

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Table I	)6
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	165	ITES	IAE	ITAE	DELAY TIM
	1.489	2.630	2.470	7.330	3.8
	1.558	3.510	3.050	10.950	3.5
	2.092	6.020	3.709	13.510	3.1
	1.524	2.470	2.160	5.120	2.5
	1.385	2.800	2.680	9.240	3.3
	1.492	2.72C	2.438	7.100	3.0
	1.122	1.720	2.116	6.920	2.5
	1.229	3.400	2.833	13.810	2.6
	1.458	4.810	3.263	19.190	3.3
	1.555	2.890	2.758	8.310	2.4
	1.323	2.290	2.460	8.060	3.7
DATA	1.520	2.590	2.736	9.050	4.0
f f	0.904	1.200	1.828	6.200	3.5
	1.120	1.650	2.448	7.250	3.2
1	1.208	1.940	2.276	7.820	3.4
1	1.130	2.910	2.141	7.110	3.5
1	1.544	4.06C	2.506	7.340	3.4
1	1.879	2.980	3.438	11.860	3.1
.	1.595	4.460	2.634	7.940	3.6
1	2.005	3.710	3.320	10.560	2.9
1	1.803	2.940	3.310	11.400	3.2
	1.626	3.030	2.606	7.740	3.3
ļ	1.362	3.030	3.129	12.390	3.2
t	1.642	3.860	3.216	11.990	3.1
	1.626	3.530	2.893	9.660	3.0
HEAN	1.488	3.086	2.737	9.534	3.2
VARIANCE	0.076	1.059	0.217	9.172	0.2
STD. DEV.	0.276	1.029	0.465	3.029	0.4

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### Table D-7

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	IES	ITES	IAE	I ITAE
	3.396	0.	11.280	392.000
	3.144	0.	11.320	416.480
	3.000	0.	1.0.768	384.720
DATA	2.928	0.	10.800	368.240
•	3.816	0.	11.048	391.040
	2.748	0.	10.352	364.360
	2.454	0.	9.280	333.520
	3.378	0.	11.568	415.600
	2.592	0.	9.520	296-160
YEAN	3.051	0.	10.660	374.124
VARIANCE	0.166	-0.	0.569	1335.189
STD. DEV.	0.408	~0.	0.755	36.540
	1ES 5.920	17ES 74.560	IAE 13.941	1 516.240
ومشروب بالمتقاد بسائل والمترج والمراجع	IES	ITES	IAE	ITAE
0474	1	52.880	13.590	479.680
DATA	5.344	67.680	14.400	503.640
	6.920	121.920	15.345	567.540
FEAN	5.865	79.260	14.319	521.775
	0 433	667.992	0.433	135.543
VARIANCE	0.432	00/.772	0.433	1 1370 543
	0.658	25.846	0.658	
STD. DEV.	0.658 ERFORMANCE MEASU	25.846 RES FOR K CONTROL WITH 1.5 RADIAN	0.658 LER CUT-OFF	27.121
STD. DEV.	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN IES	25.846 RES FOR K CONTROL WITH 1.5 RADIAN	0.658 LER CUT-OFF IAE	27.121 ITAE
STD. DEV.	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN IES 4.896	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640	0.658 LER CJT-OFF IAE 13.392	27.121 <u>ITAE</u> 487.830
STD. DEV.	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN IES 4.896 6.680	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120	0.658 LER CUT-OFF IAE 13.392 15.471	27.121 <u>ITAE</u> 487.830 548.190
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN <u>IES</u> 4.896 6.680 6.728	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560	0.658 LER CJT-OFF IAE 13.392 15.471 15.660	27.121 <u>ITAE</u> 487.830 548.190 551.700
STD. DEV.	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN <u>IES</u> 4.896 6.680 6.728 7.432	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920	0.658 LER CJT-OFF IAE 13.392 15.471 15.660 16.272	27.121 <u>ITAE</u> 487.800 548.190 551.700 591.930
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN <u>IES</u> 4.896 6.680 6.728 7.432 6.496	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600	0.658 LER CJT-OFF IAE 13.392 15.471 15.660 16.272 16.110	27.121 <u>ITAE</u> 487.800 548.190 551.700 591.930 569.790
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN <u>IES</u> 4.896 6.680 6.728 7.432	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600 111.520	0.658 LER CJT-OFF IAE 13.392 15.471 15.660 16.272 16.110 15.930	27.121 <u>ITAE</u> 487.800 548.190 551.700 591.930 569.790
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN 1ES 4.896 6.680 6.728 7.432 6.496 6.928 5.144	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600 111.520 53.760	0.658 LER CJT-OFF IAE 13.392 15.471 15.660 16.272 16.110 15.930 13.653	<u>ITAE</u> 487.800 548.190 551.700 591.930 569.790 569.790 600.030
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN <u>IES</u> 4.896 6.680 6.728 7.432 6.496 6.928	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600 111.520 53.760 7.120	0.658 LER CUT-OFF IAE 13.392 15.471 15.660 16.272 16.110 15.930 13.653 12.474	17AE 487.800 551.700 591.930 569.790 600.030 448.110
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN 1ES 4.896 6.680 6.728 7.432 6.496 6.928 5.144	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600 111.520 53.760	0.658 LER CJT-OFF IAE 13.392 15.471 15.660 16.272 16.110 15.930 13.653	27.12) ITAE 487.80( 548.19( 551.70( 591.93( 569.79( 569.79( 600.03( 448.11)
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN IES 4.896 6.680 6.728 7.432 6.496 6.928 5.144 4.400	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600 111.520 53.760 7.120	0.658 LER CUT-OFF IAE 13.392 15.471 15.660 16.272 16.110 15.930 13.653 12.474	27.121 <u>ITAE</u> 487.830 548.190 551.700 591.930 569.790 569.790
STD. DEV. SUBJECT 1 - PE INPUT56 VC	0.658 ERFORMANCE MEASU DLT RMS GAUSSIAN IES 4.896 6.680 6.728 7.432 6.496 6.928 5.144 4.400 4.640	25.846 RES FOR K CONTROL WITH 1.5 RADIAN ITES 28.640 95.120 96.560 113.920 85.600 111.520 53.760 7.120 24.160	0.658 LER CUT-OFF IAE 13.392 15.471 15.660 16.272 16.110 15.930 13.653 12.474 12.924	17AE 487.80( 548.19( 551.70( 591.93( 569.79) 569.79( 600.03( 448.11) 475.20(

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Table D-8

•	IES	ITES	IAE	ITAE
المكار بالمجيرات والبنان المتهجين بتعلمينيا ويها	5.300	0.	12.960	446.000
	4.540	0.	12.130	416.900
	5.200	0.	12.600	429.800
CATA	4.650	0.	12.000	416.100
	4.400	0.	12.150	416.600
	4.940	0.	12.420	414.000
	5.110	0.	12.860	430.600
	4.160	0.	11.520	399.200
	4.580	0.	12.010	412.100
FEAN	4.764	0.	12.294	420.144
VARIANCE	0.136	-0.	0.187	161.297
STD. DEV.	0.369	-0.	0.433	12.700

#### SUBJECT 1 - PERFORMANCE MEASURES FOR K/S CONTROLLER INPUT - .86 VOLT RHS GAUSSIAN WITH 1 RADIAN CUT-OFF

	IES	ITES	IAE	ITAE
	11.344	244.320	18.909	633.150
DATA	10.672	243.040	18.666	630.630
	11.208	266.880	19.620	671.310
	10-024	219.680	18.576	626.760
FEAN	10.812	243-480	18.943	640.462
VARTANCE	0.270	278.725	0.168	322.371
STD. DEV.	0.520	16.695	0.410	17.955

### SUBJECT 1 - PERFORMANCE MEASURES FOR K/S CONTROLLER INPUT - .56 VOLT RMS GAUSSIAN WITH 1.5 RADIAN CUT-OFF

	IES	ITES	IAE	ITAE
	4.938	70.620	13.696	466.240
	5.916	124.140	14.832	525.360
	4.728	80.160	13.168	475.280
DATA	5.460	93.420	14.376	502.480
	5.934	133.860	14.816	534.880
	6.384	143.820	15.224	538.800
	5.676	118.680	13.904	501.920
	5.088	86.640	13.872	490.480
	4.884	77.280	13.440	463.120
FEAN	5.445	103.180	14.148	499.840
VARIANCE	0.290	655.796	0.436	730.715
STD. DEV.	0.538	25.609	0.660	27.032

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Table D-9

	IES	ITES	IAE	ITAE
	44.415	1363.050	36.140	1176.600
	47.349	1496.610	42.500	1310.000
	30.402	1051.380	33.040	1125.600
DATA	41.220	1297.800	37.290	1220.100
	38.709	1204.110	35.850	1155.500
	31.950	1028.700	34.150	1132.500
	36.216	1272.240	36.090	1199.100
	35.604	1265.760	35.100	1221.000
	43.092	1504.080	38.310	1317.900
YEAN	38.773	1275.970	36.497	1206.478
VARIANCE	29.248	25071.236	6.675	4343.153
STD. DEV.	5.408	158.339	2.584	65.903
	1ES 58.860	2313.400	1AE 44.050	1574.500
	IES	ITES	IAE	ITAE
	4			
DATA	67.200	2414.000 2019.600	49.710 45.760	1641.900
	61.700	2015.000	46.750	1496.500
	£ Contractions of the second s	1	1	1
YEAN	62.450	2190.500	46.567	1544.825
	62.450 9.045	2190.500 31266.062	46.567 4.225	
YEAN VARIANCE STD. DEV.				4697.500
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ	31266.062	4.225 2.055	4697.500
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ DLT RMS GAUSSIA IES	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES	4.225 2.055 ROLLER CUT-OFF	4697.500 68.538
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ DLT RMS GAUSSIA <u>IES</u> 47.730	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.700	4.225 2.055 ROLLER CUT-OFF IAE 38.950	1355.500
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ OLT RMS GAUSSIA <u>IES</u> 47.730 38.000	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.700 1360.000	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490	4697.500 68.538 1355.500 1305.100
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ DLT RMS GAUSSIA <u>IES</u> 47.730 38.000 27.210	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.700 1360.000 887.900	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800	4697.500 68.538 1355.500 1305.100 1121.000
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ DLT RMS GAUSSIA IES 47.730 38.000 27.210 53.400	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.7C0 1360.000 887.900 1996.000	4.225 2.055 ROLLER CUT-DFF IAE 38.950 37.490 32.800 42.320	4697.500 68.538 1355.500 1305.100 1121.000 1452.800
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ DLT RMS GAUSSIA IES 47.730 38.000 27.210 53.400 48.410	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.7C0 1360.000 887.900 1996.000 2040.900	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800 42.320 39.460	4697.500 68.538 1355.500 1305.100 1121.000 1452.800 1462.400
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ OLT RMS GAUSSIA 1ES 47.730 38.000 27.210 53.400 48.410 51.310	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.7C0 1360.000 887.900 1996.000 2040.900 1899.900	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800 42.320 39.460 39.710	4697.500 68.538 1355.500 1305.100 1121.000 1452.800 1462.400 1410.900
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ OLT RMS GAUSSIA 1ES 47.730 38.000 27.210 53.400 48.410 51.310 44.680	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.700 1360.000 887.900 1996.000 2040.900 1899.900 1728.200	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800 42.320 39.460 39.710 38.320	4697.500 68.538 1355.500 1305.100 1121.000 1452.800 1462.400 1410.900 1358.890
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ OLT RMS GAUSSIA 1ES 47.730 38.000 27.210 53.400 48.410 51.310	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.7C0 1360.000 887.900 1996.000 2040.900 1899.900	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800 42.320 39.460 39.710	4697.500 68.538 1355.500 1305.100 1121.000 1452.800 1462.400 1410.900 1358.800 1466.100
VARIANCE STD. DEV. SUBJECT 1 - PI INPUT56 VI	9.045 3.008 ERFORMANCE MEAL DLT RMS GAUSSIA <u>IES</u> 47.730 38.000 27.210 53.400 48.410 51.310 44.680 50.130	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.7C0 1360.000 887.900 1996.000 2040.900 1899.900 1728.200 1859.7C0	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800 42.320 39.460 39.710 38.320 42.690	4697.500 68.538 1355.500 1305.100 1121.000 1452.800 1462.400 1410.900 1358.800 1466.100 1351.800
VARIANCE STD. DEV. SUBJECT 1 - PI	9.045 3.008 ERFORMANCE MEAJ DLT RMS GAUSSIA <u>IES</u> 47.730 38.000 27.210 53.400 48.410 51.310 44.680 50.130 46.290	31266.062 176.822 URES FOR K/S2 CONT N WITH 1.5 RADIAN ITES 1753.7C0 1360.000 887.900 1996.000 2040.900 1899.900 1728.200 1859.7C0 1625.100	4.225 2.055 ROLLER CUT-OFF IAE 38.950 37.490 32.800 42.320 39.460 39.710 38.320 42.690 39.920	4697.500 68.538 1355.500 1305.100 1121.000 1452.800 1462.400 1410.900

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# GE/22/695-2

# Table D-10

	IES	ITES	IAE	ITAE
	3.256	0.	10.052	310.800
	4.928	0.	13.398	377.230
	3.883	0.	10.633	331.380
ATA	3.536	0.	10.766	313.180
	4.713	0.	12.124	339.78
	4.367	0.	11.690	338.52
	4.070	0.	11.095	328.02
	2.486	0.	8.736	264.95
	2.431	0.	8.442	267.96
EAN	3.741	0.	10.771	319.09
VARIANCE	0.716	-0.	2.198	1118-41
STD. DEV.	0.846	-0.	1.483	33.44
	14.850	282.200	20,490	
	IES	ITES	IAE	ITAE
	14.850	282-100	20,490	678.50
DATA	9.180	130.200	18.160	618.90
	10.110	100-200	20.940	598.60
	8.600	71.200	28.120	566.90
YEAN	10.685	145.925	19.202	615-72
VARIANCE	6.073	6616.3?7	1.154	1656.98
	2.464	81.341	1.074	40.70
STD. DEV.				
SUBJECT 2 - PE		JRES FOR K CONTROL		
SUBJECT 2 - PE		JRES FOR K CONTROL WITH 1.5 RADIAN		ITAE
SUBJECT 2 - PE	LT RMS GAUSSIAN	JRES FOR K CONTROL	CUT-OFF IAE 14-200	
SUBJECT 2 - PE	LT RMS GAUSSIAN	JRES FOR K CONTROL WITH 1.5 RADIAN	CUT-OFF	ITAE
SUBJECT 2 - PE INPUT56 VO	IT RMS GAUSSIAN IES 5.620	JRES FOR K CONTROL WITH 1.5 RADIAN	CUT-OFF IAE 14-200	I TAE 512.50 522.70
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720	URES FOR K CONTROL WITH 1.5 RADIAN 1TES 15.900 48.800	CUT-OFF IAE 14.200 14.750	I TAE 512.500 522.700 501.700
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720 5.920	URES FOR K CONTROL WITH 1.5 RADIAN 1TES 15.900 48.800 1 15.300	CUT-OFF <u>IAE</u> 14.200 14.750 14.480	1 TAE 512.50
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720 5.920 6.320	URES FOR K CONTROL WITH 1.5 RADIAN 1TES 15.900 48.800 15.300 36.400	CUT-OFF <u>IAE</u> 14.200 14.750 14.480 14.950	ITAE 512-50 522-70 501-70 525-50
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720 5.920 6.320 6.760	URES FOR K CONTROL WITH 1.5 RADIAN 1TES 15.900 48.800 15.300 36.400 37.600	CUT-OFF IAE 14-200 14-750 14-480 14-950 15-870	I TAE 512-50 522-70 501-70 525-50 524-90
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720 5.920 6.320 6.320 6.760 5.240	URES FOR K CONTROL WITH 1.5 RADIAN 17ES 15.900 48.800 15.300 36.400 37.600 0. 118.100	CUT-OFF IAE 14-200 14.750 14.480 14.950 15.870 13.700	ITAE 512.50 522.70 501.70 525.50 524.90 466.10 539.20
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720 5.920 6.320 6.320 6.760 5.240 9.040	URES FOR K CONTROL WITH 1.5 RADIAN 17ES 15.900 48.800 15.300 36.400 37.600 0.	CUT-OFF IAE 14-200 14-750 14-480 14-950 15-870 13.700 16-590	ITAE 512-50 522-70 501-70 525-50 524-90 466-10
SUBJECT 2 - PE	LT RMS GAUSSIAN IES 5.620 6.720 5.920 6.320 6.320 6.760 5.240 9.040 6.040	URES FOR K CONTROL WITH 1.5 RADIAN 17ES 15.900 48.800 15.300 36.400 37.600 0. 118.100 10.200	CUT-OFF IAE 14-200 14-750 14-480 14-950 15-870 13-700 16-590 14-360	ITAE 512-50 522-70 501-70 525-50 524-90 466-10 539-20 486-40
SUBJECT 2 - PE INPUT56 VO	LT RMS GAUSSIAN IES 5.620 6.720 5.920 6.320 6.320 6.760 5.240 9.040 6.040 5.650	URES FOR K CONTROL WITH 1.5 RADIAN 1TES 15.900 48.800 15.300 36.400 37.600 0. 118.100 10.200 0.	CUT-OFF IAE 14-200 14-750 14-48C 14-950 15-870 13-700 16-590 14-360 14-090	<u>ITAE</u> 512.50 522.70 501.70 525.50 524.90 466.10 539.20 486.40 471.50

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#### Table D-11

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	IES	ITES	IAE	I TAE
1	5.420	0.	14.060	443.10
	5.500	0.	14.310	476.10
Ì	6.130	0.	14.700	467.80
DATA	5.960	0.	14.330	457.50
	7.520	44.200	15.780	505.10
	5.680	0.	14.260	466.00
i	<b>∔</b> •580	0.	12.610	428.000
1	5.790	0.	14.120	448.60(
	5.190	0.	13.570	455.90
FEAN	5.752	4.711	14.193	460.90
VARIANCE	0.576	192.952	0.637	427.27
STD. DEV.	0.759	13.891	0.798	20.67

#### SUBJECT 2 - PERFORMANCE MEASURES FOR K/S CONTROLLER INPUT - .86 VOLT RMS GAUSSIAN WITH 1 RADIAN CUT-OFF

	IES	ITES	IAE	ITAE
	18.900	461.700	26.990	859.100
CATA	21.860	616.400	28.580	964.200
	18.420	494.000	25.650	890.500
	23.140	660-200	29-180	987.200
#EAN	20.580	558.075	27.600	925.250
VARIANCE	3.920	6806.266	1.908	2734.578
STD. DEV.	1.980	82.500	1.381	52.293
				L

#### SUBJECT 2 - PERFORMANCE MEASURES FOR K/S CONTROLLER INPUT - .56 VOLT RPS GAUSSIAN WITH 1.5 RADIAN CUT-OFF

IES	ITES	IAE	ITAE
9.380	176.800	19.463	704.200
9.880	172.900	18.520	643.400
9.650	169.600	18.440	636.900
9.750	164.800	18.520	642-400
10.900	187.000	19.420	648.200
13.090	293.900	21.720	742.800
12.960	257.000	21.580	704.600
9.260	117.600	18-41C	596.400
9.460	132.300	18. ~20	620.000
10.431	185.767	19.445	659.878
2.051	2802.314	1.514	1966.865
1.432	52.93?	1.231	44.349
	9.330 9.880 9.650 9.750 10.900 13.090 12.960 9.260 9.260 9.460 10.481 2.051	9.330       176.800         9.880       172.900         9.650       169.600         9.750       164.800         10.900       187.000         13.090       293.900         12.960       257.000         9.460       132.300         10.481       185.767         2.051       2802.314	9.330         176.800         19.4CJ           9.880         172.900         18.520           9.650         169.600         18.440           9.750         164.800         18.520           10.900         187.000         19.420           13.090         293.900         21.72C           12.96C         257.000         21.580           9.260         117.690         18.41C           9.460         132.300         18.720           10.431         185.767         19.448           2.051         2802.314         1.514

### GE/33/695-2

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#### Table D-12

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	IES	ITES	IAE	ITAE
	37.110	1029.900	36.600	1126.000
	46.010	1489.900	38.550	1263.500
	34.780	974.200	35.080	1131.200
CATA	33.470	1007.300	35.090	1154.100
	36.290	1098.000	33.520	1083.800
	24.000	604.700	29.450	935.500
	39.340	1156-600	35.240	1175.600
	29.280	732.200	30.530	923.700
	36.470	1221.300	34.560	1204.400
FEAN	35.184	1034.900	24.291	1110.867
VARIANCE	33.768	60192-597	7.098	11696.139
STD. DEV.	5.811	245.342	2.564	108.149

SUBJECT 2 - PERFORMANCE MEASURES FOR K/S2 CONTROLLER INPUT - .86 VOLT RMS GAUSSIAN WITH 1 RADIAN CUT-OFF

	1ES	ITES	IAE	ITAE
	55.080	1914.200	45.250	1525.500
DATA	53.480	1600.200	44.950	1406.500
	50.600	1709.000	41.420	1438.800
	50.340	1649.600	44.010	1455.900
PEAN	52.375	1718.256	43.907	1456.675
VARIANCE	3.958	14282.687	2.272	1893.656
STD. DEV.	1.989	119.510	1.507	43.516

SUBJECT 2 - PERFORMANCE MEASURES FOR K/S2 CONTROLLER INPUT - .56 VOLT RPS GAUSSIAN WITH 1.5 GADIAN CUT-OFF

	IES	ITES	IAF	ITAE
	37.656	1223,040	33.060	1147.400
	40.416	1230.240	34-260	1115.400
	39.792	1337.280	35.380	1216.200
DATA	45.660	1629.000	36.190	1278.100
	37.204	1343.760	32.300	1181-000
	47.520	1792.800	36.640	1343.600
	41.412	1561.080	3' 580	1303.200
	37.380	1195.800	33.760	1147.400
	43.200	1690.800	34.610	1299.900
PEAN	41.127	1444.867	34.70%	1225-800
VARIANCE	12.262	45339.444	1.683	6074.958
STD. DEV.	3.502	212.931	1.297	77.942

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Table D-13

	166	1 1755 \$	IAE	1 TAE
	1ES 12.000	1TES 296-800	19.416	626.640
	20.550	522.500	21.372	679.080
	13-530	402.700	21.780	736.200
CATA	14.605	423.950	20.280	697.800
	13.720	407.800	18.972	650.880
	12.970	357.000	26.852	689.880
	12.390	324.250	19.800	649.800
•	11.960	324.800	19.842	672.780
	9.500	226.000	17.928	579.120
FEAN	13.469	365.089	20.031	664.687
VARIANCE	8.122	6538.587	1.297	1811.056
STD. DEV.	2.850	80.862	1.139	42.556
		RES FOR K CONTROL WITH 1 RADIAN CU		
	IES	ITES	IAE	ITAE
	7.500	196.450	15.505	570.150
DATA	8.490	241.000	16.814	614.460
	9.105	244.150	17.318	610-820
	11.690	371.100	19.320	714.000
FEAN	9.196	263.175	17.239	627.351
VARIANCE	2.401	4238.429	1.881	2804-86
•				
STD. DEV.	1.549	65.103	1.372	52.961
STD. DEV.	RFORMANCE MEASL	65-103 RES FOR K CONTROL WITH 1.5 RADIAN	LER	52.96]
STD. DEV.	RFORMANCE MEASU ILT RMS GAUSSIAN IES	RES FOR K CONTROL WITH 1.5 RADIAN ITES	LER CUT-OFF IAE	52.961
STD. DEV.	RFORMANCE MEASU ILT RMS GAUSSIAN IES 8.980	RES FOR K CONTROL WITH 1.5 RADIAN ITES 244.100	LER CUT-OFF IAE 18.060	<u>ITAE</u> 625.800
STD. DEV.	RFORMANCE MEASULT RMS GAUSSIAN IES 8.980 7.760	ITES FOR K CONTROL WITH 1.5 RADIAN ITES 244.100 197.700	LER CUT-OFF IAE 18.060 17.514	<u>ITAE</u> 625.800 615.860
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASU LT RMS GAUSSIAN IES 8.980 7.760 8.560	ITES FOR K CONTROL WITH 1.5 RADIAN ITES 244.100 197.700 192.700	LER CUT-OFF IAE 18.060 17.514 18.284	<u>ITAE</u> 625.800 615.860 588.560
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASU ILT RMS GAUSSIAN IES 8.980 7.760 8.560 6.960	ITES 244.100 192.700 173.400	LER CUT-OFF 18.060 17.514 18.284 15.134	<u>ITAE</u> 625.80 615.86 588.56 554.26
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASL LT RMS GAUSSIAN IES 8.980 7.760 8.560 6.960 11.340	ITES 244.100 192.700 173.400 343.200	LER CUT-OFF 18.060 17.514 18.284 15.134 20.510	<u>ITAE</u> 625.80 615.86 588.56 554.26 734.30
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASL LT RMS GAUSSIAN IES 8.980 7.760 8.560 6.960 11.340 11.815	ITES 244.100 192.700 173.400 343.200 370.950	LER CUT-OFF 18.060 17.514 18.284 15.134 20.510 20.685	<u>ITAE</u> 625.800 615.860 588.560 554.260 734.300 752.150
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASL ILT RMS GAUSSIAN IES 8.980 7.760 8.560 6.960 11.340 11.815 6.530	ITES 244.100 192.700 173.400 343.200 370.950 166.500	LER CUT-OFF 18.060 17.514 18.284 15.134 20.510 20.685 15.386	<u>ITAE</u> 625.800 615.860 588.560 554.260 734.300 752.150 577.64
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASL LT RMS GAUSSIAN IES 8.980 7.760 8.560 6.960 11.340 11.815	ITES 244.100 192.700 173.400 343.200 370.950	LER CUT-OFF 18.060 17.514 18.284 15.134 20.510 20.685 15.386 16.758	<u>ITAE</u> 625.80 615.86 588.56 554.26 734.30 752.15 577.64 592.62
STD. DEV.	RFORMANCE MEASU ILT RMS GAUSSIAM IES 8.980 7.760 8.560 6.960 11.340 11.815 6.530 8.430	RES FOR K CONTROL WITH 1.5 RADIAN ITES 244.100 197.700 192.700 173.400 343.200 370.950 166.500 223.100	LER CUT-OFF 18.060 17.514 18.284 15.134 20.510 20.685 15.386	<u>ITAE</u> 625.80 615.86 588.56 554.26 734.30 752.15
STD. DEV. SUBJECT 3 - PE INPUT55 VO	RFORMANCE MEASU IES 8.980 7.760 8.560 6.960 11.340 11.815 6.530 8.430 7.525	RES FOR K CONTROL WITH 1.5 RADIAN ITES 244.100 192.700 192.700 173.400 343.200 370.950 166.500 223.100 182.850	LER CUT-OFF 18.060 17.514 18.284 15.134 20.510 20.685 15.386 16.758 16.198	ITAE 625.80 615.86 588.56 554.26 734.30 752.15 577.64 592.62 565.32

Table D-14

	I IES	I ITES I	IAE	ITAE
	14.208	425.280	24.232	852.080
	14.526	314.940	23.440	710.400
	9.270	212.580	18.864	642.560
DATA	17.352	404.220	26.400	796.000
	10.368	240.780	20.688	676.320
	8-514	166.500	18.776	611.280
	11.460	274.800	22.512	743.680
	10.374	238.500 173.280	19.904 18.488	665.760
PEAN	11.584	272.320	21.478	702.533
VARIANCE	8.679	7703.470	6.989	5874.840
STD. DEV.	2.946	87.769	2.644	76.648
		URES FOR K/S CONTR N WITH 1 RADIAN CU		
				1
	<u>IES</u> 24.216	1TES 766.440	IAE 29.240	1009.200
CATA	17.628	480.120	25.960	756.400
	24.114	763-860	30.976	1027.040
	16.128	455.520	24.840	843.600
		4770720	246040	043.000
PEAN	20.521	616.485	27.754	
PEAN VARIANCE				909-060
	20.521	616.485	27.754	909.060 12884.352
VARIANCE STD. DEV. SUBJECT 3 - PE	20.521 13.553 3.682 RFORMANCE MEAS	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAM	27.754 6.075 2.465 OLLER CUT-OFF	909.060 12884.352 113.509
VARIANCE STD. DEV. SUBJECT 3 - PE	20.521 13.553 3.682 RFORMANCE MEAS LT RMS GAUSSIA IES	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAM	27.754 6.075 2.465 OLLER CUT-OFF IAE	909.060 12884.352 113.509 ITAE
VARIANCE STD. DEV. SUBJECT 3 - PE	20.521 13.553 3.682 RFORMANCE MEAS LT RMS GAUSSIA IES 13.884	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712	909.060 12884.352 113.509 <u>ITAE</u> 783.375
VARIANCE STD. DEV. SUBJECT 3 - PE	20.521 13.553 3.682 RFORMANCE MEAS LT RMS GAUSSIA IES	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAM	27.754 6.075 2.465 OLLER CUT-OFF IAE	909.060 12884.352 113.509 <u>ITAE</u> 783.375 655.425
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS LT RMS GAUSSIA IES 13.884 9.858	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007	909.060 12884.352 113.509 ITAE
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS LT RMS GAUSSIA IES 13.884 9.858 13.950	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740 404.220	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192	909.060 12884.352 113.509 113.509 113.509 113.509 113.509 13.375 655.425 744.825 851.325
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS LT RMS GAUSSIA IES 13.884 9.858 13.950 18.606	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740 404.220 596.940	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192 24.967	909.060 12884.352 113.509 <u>ITAE</u> 783.375 655.425 744.825
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS ILT RMS GAUSSIA IES 13.884 9.858 13.950 18.606 15.348 15.018 17.256	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740 404.220 596.940 507.120 405.720 460.440	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192 24.967 23.062 23.227 24.495	909.060 12884.352 113.509 113.509 113.509 113.509 113.509 13.375 655.425 744.825 851.325 807.375 748.725 764.550
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS ILT RMS GAUSSIA IES 13.884 9.858 13.950 18.606 15.348 15.018 17.256 16.746	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740 404.220 596.940 507.120 405.720 460.440 354.780	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192 24.967 23.062 23.227 24.495 26.100	909.060 12884.352 113.509 113.509 113.509 113.509 113.509 13.375 655.425 743.375 655.425 744.825 851.325 807.375 748.725 764.550 730.500
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS ILT RMS GAUSSIA IES 13.884 9.858 13.950 18.606 15.348 15.018 17.256	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740 404.220 596.940 507.120 405.720 460.440	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192 24.967 23.062 23.227 24.495	909.060 12884.352 113.509 113.509 113.509 113.509 783.375 655.425 744.825 851.325 807.375 748.725 764.550 730.500
VARIANCE STD. DEV. SUBJECT 3 - PE	20.521 13.553 3.682 RFORMANCE MEAS ILT RMS GAUSSIA IES 13.884 9.858 13.950 18.606 15.348 15.018 17.256 16.746	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAN ITES 442.800 280.740 404.220 596.940 507.120 405.720 460.440 354.780	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192 24.967 23.062 23.227 24.495 26.100	909.060 12884.352 113.509 113.509 113.509 113.509 113.509 113.509 113.509 13.375 655.425 744.825 851.325 807.375 746.725 764.550 730.500 616.050
VARIANCE STD. DEV. SUBJECT 3 - PE INPUT56 VO	20.521 13.553 3.682 RFORMANCE MEAS ILT RMS GAUSSIA IES 13.884 9.858 13.950 18.606 15.348 15.018 17.256 16.746 9.520	616.485 22177.758 148.922 URES FOR K/S CONTR N WITH 1.5 RADIAM ITES 442.800 280.740 404.220 596.94C 507.120 405.720 460.440 354.780 218.940	27.754 6.075 2.465 OLLER CUT-OFF IAE 21.712 18.007 22.192 24.967 23.062 23.227 24.495 26.100 17.145	909.060 12884.352 113.509 113.509 113.509 113.509 113.509 13.375 655.425 744.825 851.325 807.375 748.725

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Table D-15

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	IES	ITES	IAE	ITAE
	55.168	1535.520	43.128	807.120
	45.744	1395.360	38.214	1296.360
	51.072	1407.680	43.632	1277.280
DATA	34.664	1062.960	34.650	1133.100
	42.448	928.320	38.034	1010.160
	32.224	106.560	33.858	1065.420
	42.440	999.600	37.854	1054.260
	32.728	819.120	33.210	958.500
	31.776	940.640	32.940	1033.200
PEAN	40.918	1110.640	37.286	1076-60
VARIANCE	66.607	61466.458	14.483	20547-15
STD. DEV.	8.161	247.924	3.806	143.34

SUBJECT 3 - PERFORMANCE MEASURES FOR K/S2 CONTROLLER INPUT - .86 VOLT RMS GAUSSIAN WITH 1 RADIAN CUT-OFF

	1 IES	ITES	IAE	ITAE
	95.040	3044.800	55.161	1698.390
DATA	65.968	2267.520	49.473	1568.070
	72.872	2432.880	56.313	1771.470
	46.384	1484.960	39.582	1236.780
PEAN	70.066	2307.540	5G.132	1568.677
VARIANCE	302.301	309375.500	43.808	42026.594
STD. DEV.	17.387	556.215	6.619	205.004

SUBJECT 3 - PERFORMANCE MEASURES FOR K/S2 CONTROLLER INPUT - .56 VOLT RMS GAUSSIAN WITH 1.5 RADIAN CUT-OFF

	IES	ITES	IAE	ITAE
	37.600	1287.200	37.674	1285.560
	45.880	1636.400	40.059	1344.510
	44.080	1609.600	39.690	1358.100
DATA	40.048	1525.920	36.459	1284-210
	77.600	2382.400	55.620	1701.900
	47.224	1790.160	39.438	1396.620
	64.000	1821.600	48.330	1439.100
	58.400	1460.800	47.223	1288.'70
	100-160	2356-900	59.382	1511.280
PEAN	57.221	1763.431	44.875	1401.050
VARIANCE	376.394	128211.277	60.631	16544.694
STD. DEV.	19.401	358.066	7.787	128.626

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1	IES	ITES	IAE	ITAE	STEP TIME
	3.705	0.	13.916	393.263	6.0
DATA	3.579	0.	13.063	371.053	11.9
	3.495	0.	13.947	388.105	13.2
	3.568	0.	13.737	377-158	8.5
	3.411	0.	13.811	361.053	88.0
AEAN	3.552	0.	13.695	378.126	
VARIANCE	0.010	-0.	0-105	134.237	
STD. DEV.	0.098	-0.	0.325	11.586	
INPUT - 1.44	VOLT RHS GAUS	SIAN WITH .5 RA	DIAN CUT-OFF P	LUS 3 VOLT ST	TEP
	IES	ITES	IAE	ITAE	STEP TIME
	9.379	57.895	16.547	448.316	12-8
DATA	9.705	20.947	15.800	393.158	8.8
	8.168	13.053	14.547	391.579	11.0
	8.295	39.368	14.926	416.842	12.0
	9.695	24.947	15.421	398.842	7.0
MEAN	9.048	31.242	15.448	409.747	
VARIANCE	0.460	250.572	0.4#3	452.422	
	0.678	15.829	0.695	21.270	
STD. DEV.	0.8/6				i
		SIAN WITH .5 RA	DIAN CUT-OFF P	PLUS 5 VOLT ST	
	VOLT RHS GAUS	ITES	IAE	ITAE	STEP TIME
INPUT - 1.44	VOLT RMS GAUS: <u> IES</u> 22.011	1TES 237.158	IAE 17.221	1TAE 433.579	STEP TIME
INPUT - 1.44	VOLT RHS GAUS: 1ES 22.011 16.737	1TES 237.158 125.263	IAE 17.221 16.926	1TAE 433.579 460.632	STEP TIME 13-8 12-0
INPUT - 1.44	VOLT RHS GAUS: 1ES 22.011 16.737 15.221	17FS 237.158 125.263 93.474	IAE 17.221 16.926 15.768	1TAE 433.579 460.632 442.947	STEP TIME 13.8 12.0 10.0
INPUT - 1.44	VOLT RHS GAUS: 1ES 22.011 16.737	1TES 237.158 125.263	IAE 17.221 16.926	1TAE 433.579 460.632	STEP TIME 13-8 12-0
INPUT - 1.44 DATA	VOLT RHS GAUS: IES 22.011 16.737 15.221 21.432	ITES 237-158 125-263 93-474 128-105	IAE 17.221 16.926 15.768 17.789	<u>ITAE</u> 433.579 460.632 442.947 445.895	STEP TIME 13.8 12.0 10.0 8.2
STD. DEV. INPUT - 1.44 DATA NEAN VARIANCE	VOLT RHS GAUS: IES 22.011 16.737 15.221 21.432 18.526	ITES 237-158 125-263 93-474 128-105 90-526	IAE 17.221 16.926 15.768 17.789 16.737	1TAE 433.579 460.632 442.947 445.895 393.789	STEP TIME 13.8 12.0 10.0 8.2

Table D-.6

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Section.

## Table D-17

1	TES	ITES	IAE	ITAE	STEP TIM
	6.611	16.632	15.632	449.474	9.0
DATA	7.053	21.053	16.316	466.737	6.6
1	5.558	16.842	15.074	449.895	11.7
	6.400	12.000	15.337	470.421	12.3
	5.811	0.	14.358	417.579	14-2
MEAN	6.486	13.305	15.343	450.821	
VARIANCE	G.161	52.464	0.415	349.044	
STD. DEV.	0.401	7.243	9.644	18.663	

INPUT - .56 VOLT RMS GAUSSIAN WITH 1.5 RADIAK CUT-OFF PLUS 3 VOLT STEP

TES	ITES	IAE	ITAE	STEP TIM
11.747	117.474	17.537	488.421	12.8
10.284	75.263	17.411	475.368	12.2
11.495	85.474	13.916	510.421	4.3
9.347	37.263	15.884	436.316	9.6
8.368	20.316	14.937	429.368	7.6
10.248	67.158	14- 337	467.979	
1.630	1204.144	1.922	953.428	İ
1.277	34.701	1.386	30.874	
	11.747 10.284 11.495 9.347 8.368 10.248 1.630	11.747         117.474           10.284         75.263           11.495         85.474           9.347         37.263           8.368         20.316           10.248         67.158           1.630         1204.144	11.747       117.474       17.537         10.284       75.263       17.411         11.495       85.474       18.916         9.347       37.263       15.884         8.368       20.316       14.937         10.248       67.158       16.337         1.630       1204.144       1.922	11.747         117.474         17.537         488.421           10.284         75.263         17.411         475.368           11.495         85.474         18.916         510.421           9.347         37.263         15.884         436.316           8.368         20.316         14.937         429.368           10.248         67.158         16.337         467.979           1.630         1204.344         1.922         953.428

#### INPUT - .56 VOLT RHS GAUSSIAN WITH 1.5 RADIAN CUT-OFF PLUS 5 VOLT STEP

20.084	140.000	19.074	1 31 013	
		174VIT 1	474.947	1 7.2
19.705	190.000	18.905	475.263	12.7
19.853	136.105	16.989	443.368	8.4
18.611	81.#95	17.411	439.789	5.2
14.684	120.000	16.842	435.579	10.0
18.987	133.600	17.844	453.789	
1.583	1717.319	0.912	309.005	
1.258	34.890	0.955	17.579	}
	19.853 18.611 14.684 18.987 1.583	19.853       136.105         18.611       81.895         14.684       120.000         18.987       133.600         1.583       1717.319	19.853       136.105       16.989         18.611       81.795       17.411         16.684       120.000       16.842         18.987       133.600       17.844         1.583       1717.319       0.912	19.853         136.105         16.989         443.368           18.611         81.795         17.411         439.789           16.684         120.000         16.842         435.579           18.987         133.600         17.844         453.789           1.583         1717.319         0.912         309.005

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	IES	ITES	IAE	ITAE	STEP TIME
	5.600	0.	13.147	368.526	6.5
DATA	5.663	0.	12.832	352.632	6.9
	5.547	0.	13.242	372.842	14.8
	5.579	0.	12.800	356.737	8.8
	5.568	0.	12.716	358.000	16.7
EAN	5.592	0.	12.947	361.747	
ARIANCE	0.002	-0.	0.043	58.261	
STD. DEV.	0.943	-0.	G.208	7.633	
	TEC	TTEC	TAE	TTAE	
	IES	ITES	IAE	ITAE	STEP TIME
	7.158	0.	12.653	329.474	9.7
47 4	7 776		1 12 042 2		
ATA	7.779	0.	13.063	356.947	5.8
ATA	7.516	0.	12.221	331.158	13.3
ATA					
	7.516 8.000	0. 0.	12.221 12.979	331.158 348.316	13.3 10.1
(EAN)	7.516 8.000 8.305	0. 0. 0.	12.221 12.979 12.463	331.158 348.316 337.684	13.3 10.1
DATA HEAM VARIANCE STD. DEV.	7.516 8.000 8.305 7.752	0. 0. 0.	12.221 12.979 12.463 12.676	331.158 348.316 337.684 340.716	13.3 10.1
HEAH VARIANCE 5TD. DEV.	7.516 8.000 8.305 7.752 0.155 0.394	0. 0. 0. -0.	12.221 12.979 12.463 12.676 0.099 0.314	331.158 348.316 337.684 340.716 109.631 10.470	13.3 10.1 7.9
IEAM VARIANCE STD. DEV.	7.516 8.000 8.305 7.752 0.155 0.394 VOLT RMS GAUS	0. 0. 0. -0. -0. SIAN WITH .5 RA	12.221 12.979 12.463 12.676 0.099 0.314	331.158 348.316 337.684 340.716 109.631 10.470	13.3 10.1 7.9
IEAN ARIANCE TD. DEV.	7.516 8.000 8.305 7.752 0.155 0.394	0. 0. 0. -0. -0.	12.221 12.979 12.463 12.676 0.099 0.314	331.158 348.316 337.684 340.716 109.631 10.470	13.3 10.1 7.9
IEAN ARIANCE TD. DEV. NPUT - 1.44	7.516 8.000 8.305 7.752 0.155 0.394 VOLT KHS GAUS IES	0. 0. 0. -0. -0. SIAN WITH .5 RA	12.221 12.979 12.463 12.676 0.099 0.314 DIAN CUT-OFF	331.158 348.316 337.684 340.716 109.631 10.470 	13.3 10.1 7.9
IEAN ARIANCE TD. DEV. NPUT - 1.44	7.516 8.000 8.305 7.752 0.155 0.394 VOLT KHS GAUS <u>IES</u> 13.989 14.674 16.442	0. 0. 0. -0. -0. -0. SIAN WITH .5 RA ITES 64.316 16.842 71.684	12.221 12.979 12.463 12.676 0.099 0.314 DIAN CUT-OFF 1 14.2 13.379 13.221 14.232	331.158 348.316 337.684 340.716 109.631 10.470 PLUS 5 VOLT ST ITAE 337.526 335.579 360.737	13.3 10.1 7.9 IEP STEP TIME 11.5 5.2 7.7
EAM ARIANCE TD. DEV. NPUT - 1.44	7.516 8.000 8.305 7.752 0.155 0.394 VOLT KMS GAUS <u>IES</u> 13.989 14.674 16.442 17.547	0. 0. 0. -0. -0. -0. SIAN WITH .5 RA ITES 64.316 16.842 71.684 82.211	12.221 12.979 12.463 12.676 0.099 0.314 0.01AN CUT-OFF 1 14.2 13.379 13.221 14.232 14.232	331.158 348.316 337.684 340.716 109.631 10.470 2005 \$ VOLT \$1 <u>ITAE</u> 337.526 335.579 360.737 349.789	13.3 10.1 7.9 <b>IEP</b> <b>STEP TIME</b> 11.5 5.2 7.7 9.0
IEAN ARIANCE TD. DEV. NPUT - 1.44	7.516 8.000 8.305 7.752 0.155 0.394 VOLT KHS GAUS <u>IES</u> 13.989 14.674 16.442	0. 0. 0. -0. -0. -0. SIAN WITH .5 RA ITES 64.316 16.842 71.684	12.221 12.979 12.463 12.676 0.099 0.314 DIAN CUT-OFF 1 14.2 13.379 13.221 14.232	331.158 348.316 337.684 340.716 109.631 10.470 PLUS 5 VOLT ST ITAE 337.526 335.579 360.737	13.3 10.1 7.9 IEP STEP TIME 11.5 5.2 7.7
IEAM VARIANCE STD. DEV.	7.516 8.000 8.305 7.752 0.155 0.394 VOLT KMS GAUS <u>IES</u> 13.989 14.674 16.442 17.547	0. 0. 0. -0. -0. -0. SIAN WITH .5 RA ITES 64.316 16.842 71.684 82.211	12.221 12.979 12.463 12.676 0.099 0.314 0.01AN CUT-OFF 1 14.2 13.379 13.221 14.232 14.232	331.158 348.316 337.684 340.716 109.631 10.470 2005 \$ VOLT \$1 <u>ITAE</u> 337.526 335.579 360.737 349.789	13.3 10.1 7.9 <b>IEP</b> <b>STEP TIME</b> 11.5 5.2 7.7 9.0
IEAM VARIANCE STD. DEV.	7.516 8.000 8.305 7.752 0.155 0.394 VOLT RMS GAUS <u>IES</u> 13.989 14.674 16.442 17.547 25.947	0. 0. 0. 0. -0. -0. -0. SIAN WITH .5 RA <u>ITES</u> 64.316 16.842 71.684 82.211 100.947	12.221 12.979 12.463 12.676 0.099 0.314 DIAN CUT-OFF 1 IAE 13.379 13.221 14.232 14.232 14.232 14.232	331.158 348.316 337.684 340.716 109.631 10.470 PLUS 5 VOLT ST ITAE 337.526 335.579 360.737 349.789 303.789	13.3 10.1 7.9 <b>IEP</b> <b>STEP TIME</b> 11.5 5.2 7.7 9.0

# Table D-18

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# Table D-19

	IES	ITES	IAE	ITAE	STEP TIME
	6.232	0.	15.032	454.526	13.5
DATA	5.747	0.	14.168	439.474	10.0
-	5.937	0.	14.411	409.789	9.2
İ	6.263	G,	14.937	411.579	6.3
	5.716	0.	14.421	625.895	3.8
MEAN	5.979	G.	14.594	428.253	
VARIANCE	0.054	-0.	0.111	288.139	
STD. DEV.	0.232	-0.	0.333	16.975	
INPUT56 V	OLT RHS GAUSS	IAN WITH 1.5 R	ADIAN CUT-OFF	PLUS 3 VOLT S	TEP
1	IES	ITES	IAF	ITAE	STEP TIME
	8.947	25.474	14. 968	407.053	13,4
DATA	8.926	28.947	14.737	417.368	11.0
	8.211	27.263	16.095	449.579	8.8
1					
	10.063	31.474	16.505	436.842	6.0
					6.0 5.1
MEAN	10.063	31.474	16.505	436.842	
	10.063 9.832	31.474 41.158	16.505 16.800	436.842 454.211	
MEAN VARIANCE STD. DEV.	10.063 9.832 9.196	31.474 41.158 30.863	16.505 16.800 15.821	436.842 454.211 433.011	
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673	31.474 41.158 30.863 30.406	16.505 16.800 15.821 0.681 0.825	436.842 454.211 433.011 331.428 18.205	5.1
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 VOLT RMS GAUSS IES	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Re ITES	16.505 16.800 15.821 0.681 0.825 ADIAN CUT-OFF	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S ITAE	S.1 TEP STEP TIME
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 /OLT RHS GAUSS 1ES 18.474	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Rd ITES 178.632	16.505 16.800 15.821 0.481 0.825 ADIAN CUT-OFF	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S <u>ITAE</u> 468.632	5.1 TEP STEP TINE 13.9
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 70LT RHS GAUSS <u>1ES</u> 18.474 19.821	31.474 41.158 30.863 30.406 5.514 IAN WITH 1.5 Rd ITES 178.632 171.368	16.505 16.800 15.821 0.481 0.825 ADIAN CUT-OFF 1AE 16.084 18.421	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S ITAE 468.632 457.895	5.1 TEP STEP TINE 13.9 10.5
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 70LT RHS GAUSS <u>IES</u> 18.474 19.821 16.558	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Rd ITES 178.632 171.368 99.789	16.505 16.800 15.821 0.481 0.825 ADIAN CUT-OFF IAE 16.054 18.421 16.126	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S ITAE 468.632 457.895 481.263	5.1 TEP STEP TIME 13.9 10.5 8.2
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 0.673 0.673 0.673 0.673 <u>1ES</u> 18.474 19.821 16.558 16.484	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Rd ITES 178.632 171.368 99.789 82.842	16.505 16.800 15.821 0.681 0.825 ADIAN CUT-OFF 16.084 16.084 16.126 16.821	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S <u>ITAE</u> 468.632 457.895 461.263 482.526	5.1 TEP STEP TIME 13.9 10.5 8.2 6.8
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 70LT RHS GAUSS <u>IES</u> 18.474 19.821 16.558	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Rd ITES 178.632 171.368 99.789	16.505 16.800 15.821 0.481 0.825 ADIAN CUT-OFF IAE 16.054 18.421 16.126	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S ITAE 468.632 457.895 481.263	5.1 TEP STEP TIMI 13.9 10.5 8.2
VARIANCE STD. DEV. INPUT56 V DATA	10.063 9.832 9.196 0.452 0.673 0.673 0.673 0.673 0.673 <u>1ES</u> 18.474 19.821 16.558 16.484	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Rd ITES 178.632 171.368 99.789 82.842	16.505 16.800 15.821 0.681 0.825 ADIAN CUT-OFF 16.084 16.084 16.126 16.821	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S <u>ITAE</u> 468.632 457.895 461.263 482.526	5.1 TEP STEP TIMI 13.9 10.5 8.2 6.8
VARIANCE STD. DEV.	10.063 9.832 9.196 0.452 0.673 0.673 0.673 0.673 <u>1ES</u> 18.474 19.821 16.558 16.484 39.074	31.474 41.158 30.863 30.406 5.514 SIAN WITH 1.5 Ro <u>ITES</u> 178.632 171.368 99.789 82.842 100.000	16.505 16.800 15.821 0.681 0.825 ADIAN CUT-OFF IAE 16.084 18.421 16.126 16.821 17.642	436.842 454.211 433.011 331.428 18.205 PLUS 5 VOLT S ITAE 468.632 457.895 461.263 482.526 469.789	5.1 TEP STEP TIMI 13.9 10.5 8.2 6.8

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Table D-20

	I IES	ITES	IAE	ITAE	STEP TIM
	44.063	1006.737	41.453	1187.579	9.0
CATA	51.537	1486.737	41-642	1324-632	10.3
	27.242	680.842	32.211	917.895	12.5
	37.926	986.947	39.032	1108.632	8.1
	48.821	1347.895	41.768	1267.579	£.7
MEAN	41.918	1101.032	39.221	1161.263	
VARIANCE	75.218	81634.537	13.363	20136.637	
STD. DEV.	8.673	285.719	3.647	141.904	
INPUT - 1.44	VOLT RMS GAU	SSIAN WITH .5 RA	DIAN CUT-OFF	PLUS 3 VOLT S	150
	1 <u>ES</u>	1686-316	1AE 47.579	1344.211	<u>STEP TIM</u> 12.2
	46.568	1205.895	40,158	1167.695	8.0
	1 90.300				
	53.589	1504.105 756.316	43.789 34.168	1298.947 957.263	10.0
	53.589	1504.105	43.789	1298.947	
DATA 	53.589 33.211	1504.105 756.316	43.789 34.168	1298.947 957.263	10.0 8.4
MEAN	53.589 33.211 60.053	1504.105 756.316 1622.632	43.789 34.168 48.632	1298.947 957.263 1385.263	10.0 8.4
	53.589 33.211 60.053 51.884	1504.105 756.316 1622.632 1355.053	43.789 34.168 48.632 42.865	1298.947 957.263 1385.263 1230.716	10.0 8.4
MEAN VARIANCE STD. DEV.	53.589 33.211 60.053 51.884 129.170 11.365	1504.105 756.316 1622.632 1355.053 116856.899	43.789 34.168 48.632 42.865 27.858 5.278	1298.947 957.263 1385.263 1230.716 24028.875 155.012	10.0 8.4 4.8
MEAN VARIANCE STD. DEV.	53.589 33.211 60.053 51.884 129.170 11.365	1504.105 756.316 1622.632 1355.053 116856.899 341.843	43.789 34.168 48.632 42.865 27.858 5.278	1298.947 957.263 1385.263 1230.716 24028.875 155.012	10.0 8.4 4.8
HEAN VARIANCE STD. DEV. INPUT - 1.44	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU <u>IES</u> 64.232	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA	43.789 34.168 48.632 42.865 27.858 5.278	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S	10.0 8.4 4.8
HEAN VARIANCE STD. DEV. INPUT - 1.44	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU IES 64.232 47.305	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA ITES 1976.632 872.211	43.789 34.168 48.632 42.865 27.858 5.278 DIAN CUT-OFF IAE 43.074 34.958	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S <sup>*</sup> ITAE 1171.368 924.105	10.0 8.4 4.8 TEP
HEAN VARIANCE STD. DEV. INPUT - 1.44	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU IES 64.232 47.305 63.853	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA ITES 1476.632 872.211 1290.947	43.789 34.168 48.632 42.865 27.858 5.278 001AN CUT-OFF IAE 43.074 34.958 43.011	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S <sup>*</sup> <u>ITAE</u> 1171.368 924.105 1127.789	10.0 8.4 4.8 TEP STEP TIM 10.4 8.5 6.5
KEAN VARIANCE STD. DEV. ENPUT - 1.44	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU IES 64.232 47.305 63.853 47.884	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA ITES 1976.632 872.211 1290.947 808.526	43.789 34.168 48.632 42.865 27.858 5.278 01AN CUT-OFF IAE 43.074 34.958 43.011 38.347	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S <sup>-</sup> <u>ITAE</u> 1171.368 924.105 1127.789 980.737	10.0 8.4 4.8 TEP STEP TIM 10.4 8.5 6.5 4.2
HEAN VARIANCE STD. DEV. INPUT - 1.44	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU IES 64.232 47.305 63.853	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA ITES 1476.632 872.211 1290.947	43.789 34.168 48.632 42.865 27.858 5.278 001AN CUT-OFF IAE 43.074 34.958 43.011	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S <sup>*</sup> <u>ITAE</u> 1171.368 924.105 1127.789	10.0 8.4 4.8 TEP STEP TIM 10.4 8.5 6.5
MEAN VARIANCE STD. DEV.	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU IES 64.232 47.305 63.853 47.884	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA ITES 1976.632 872.211 1290.947 808.526	43.789 34.168 48.632 42.865 27.858 5.278 01AN CUT-OFF IAE 43.074 34.958 43.011 38.347	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S <sup>-</sup> <u>ITAE</u> 1171.368 924.105 1127.789 980.737	10.0 8.4 4.8 TEP STEP TIM 10.4 8.5 6.5 4.2
MEAN VARIANCE STD. DEV. INPUT - 1.44 DATA	53.589 33.211 60.053 51.884 129.170 11.365 VOLT RMS GAU <u>IES</u> 64.232 47.305 63.853 47.884 93.032	1504.105 756.316 1622.632 1355.053 116856.899 341.843 SSIAN WITH .5 RA ITES 1976.632 872.211 1290.947 R08.526 1962.316	43.789 34.168 48.632 42.865 27.858 5.278 01AN CUT-OFF IAE 43.074 34.958 43.011 38.347 50.653	1298.947 957.263 1385.263 1230.716 24028.875 155.012 PLUS 5 VOLT S <u>ITAE</u> 1171.368 924.105 1127.789 980.737 1308.210	10.0 8.4 4.8 TEP STEP TIM 10.4 8.5 6.5 4.2

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### Table D-21

		1000 1	TAE	ITAE	STEP TIME
	IES	1736.000	<u>IAE</u> 50.716	1534.947	13.8
	72.821	1488.105	40.926	1260.211	11.0
DATA	48.032 51.832	1803.789	41.695	1378.842	8.5
	43.905	1532.526	38.442	1297.684	4.7
	41.642	1521.474	37.611	1285-053	5.8
MEAN	51.546	1616.379	41.918	1351.347	
VARIANCE	124,296	16384.875	21.478	10009.175	
STD. DEV.	11.149	128.003	4.634	100.046	
INPUT56		SIAN WITH 1.5 RA			TEP
	IES	ITES	IAE	1321.584	14.3
	55.958	1768.842	43.832	1259.158	10.6
DATA	61.979	1654.421	43.663 39.232	1166-632	8.5
	46.147	1386.947			
		1 1454 694			
	52.337	1654.526	40.916	1224.526	6.2
	52.337 60.737	1654.526 1726.316	46-021	1365-053	4.4
MEAN					
	60.737	1726.316	46-021	1365-053	
VARIANCE	60.737 55.832	1726.316	46-021 42-733	1365.053	
VARIANCE STD. DEV.	60.737 55.832 26.626 5.160	1726.316 1640.210 17778.800	46.021 42.733 5.689 2.335	1365-053 1267-410 4908-687 70-062	4.4
VARIANCE STD. DEV.	60.737 55.832 26.626 5.160	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/	46.021 42.733 5.689 2.335	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE	4.4 TEP STEP TIM
VARIANCE STD. DEV. INPUT56	60.737 55.832 26.626 5.160 VOLT RMS GAUS IES 61.347	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ <u>1755</u> 1498.105	46.021 42.733 5.689 2.335 ADIAN CUT-OFF IAE 40.653	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 2171.76	4.4 TEP STEP TIN 13.3
VARIANCE STD. DEV.	60.737 55.832 26.626 5.160 VOLT RHS GAUS <u>IES</u> 61.347 76.000	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ <u>ITES</u> 1498.105 2130.526	46.021 42.733 5.689 2.335 ADIAN CUT-OFF IAE 40.653 65.789	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 1171.78 J 1349.474	4.4 TEP STEP TIN 13.3 7.8
VARIANCE STD. DEV. INPUT56	60.737 55.832 26.626 5.160 VOLT RHS GAUS IES 61.347 76.000 73.137	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ 1498.105 2130.526 1492.842	46.021 42.733 5.689 2.395 ADIAN CUT-OFF IAE 40.653 05.789 44.211	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 1171.78) 1349.474 1130.526	4.4 TEP STEP TIN 13-3 7.8 9.2
VARIANCE STD. DEV. INPUT56	60.737 55.832 26.626 5.160 VOLT RMS GAUS <u>IES</u> 61.347 76.000 73.137 52.021	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ <u>1775</u> 1498.105 2130.526 1492.842 940.316	46.021 42.733 5.689 2.395 ADIAN CUT-OFF 1AE 40.653 65.789 44.211 38.168	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 1171.78J 1349.474 1130.526 1035.158	4.4 TEP STEP TIM 13-3 7.4 9.2 4.5
VARIANCE STD. DEV. INPUT56	60.737 55.832 26.626 5.160 VOLT RHS GAUS IES 61.347 76.000 73.137	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ 1498.105 2130.526 1492.842	46.021 42.733 5.689 2.395 ADIAN CUT-OFF IAE 40.653 05.789 44.211	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 1171.78) 1349.474 1130.526	4.4 TEP STEP TIN 13.3 7.8 9.2
VARIANCE STD. DEV. INPUT56	60.737 55.832 26.626 5.160 VOLT RMS GAUS <u>IES</u> 61.347 76.000 73.137 52.021	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ <u>1775</u> 1498.105 2130.526 1492.842 940.316	46.021 42.733 5.689 2.395 ADIAN CUT-OFF 1AE 40.653 65.789 44.211 38.168	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 1171.78J 1349.474 1130.526 1035.158	4.4 TEP STEP TIM 13.3 7.8 9.2 4.5
VARIANCE STD. DEV. INPUT56 DATA	60.737 55.832 26.626 5.160 VOLT RMS GAUS IES 61.347 76.000 73.137 52.021 93.789	1726.316 1640.210 17778.800 133.337 SIAN WITH 1.5 R/ <u>17ES</u> 1498.105 2130.526 1492.842 990.316 1847.368	46.021 42.733 5.689 2.335 ADIAN CUT-OFF 1AE 40.653 65.789 44.211 38.166 52.337	1365.053 1267.410 4908.687 70.062 PLUS 5 VOLT S ITAE 1171.78) 1349.474 1130.526 1035.158 1285.053	4.4 TEP STEP TIM 13.3 7.8 9.2 4.5

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# Table D-22

1	IES	ITES	ÎÂE	1 TAE	STEP TIME
	4.558	0.	12.126	359.158	14.7
DATA	5.032	0.	12.526	363.684	10.2
	3.979	ō.	11.221	341.053	9.0
1	4.263	0.	11.363	365.895	8.0
	4.274	0.	11.368	355.158	4.2
HEAN	4.421	0.	11.722	356.989	
VARIANCE	e • 127	-0.	0.262	77.234	
STD. DEV.	0.356	-6.	0.512	4.788	
INPUT - 1.44	VOLT RHS GAUS	SIAN NITH .5 RA	DIAN CUT-OFF	PLUS 3 VOLT S	TEP
	165	ITES	IAE	ITAE	STEP TIM
	9.274	0.	12.947	363.474	9.1
DATA	7.642	0.	13.316	401.474	13.6
1	6.400	0.	11.674	350.526	7.2
1	6.895	0.	11.895	343.474	4.2
	7.811	0.	12.821	374.421	9.9
			12.531	366.674	
NEAN	7,604	9.	440731	1	
	7,604 0,957	9. -0.	0.403	416.056	
NEAN Variance Sto. Dev.				416.056 20.397	
VARIANCE Sto. Dev.	0.978	-0.	0.403 0.635	20.397	TEP
VARIANCE STO. DEV.	Q.957 Q.978 VOLT RPS GAUS	-0. -0. SIAN HITH .5 R/ ITES	0.403 0.635 ADIAN CUT-CFF IAE	20.397 PLUS 5 VOLT S	STEP TIM
VARIANCE STO. DEV. INPUT - 1.44	0.957 0.978 VOLT RPS GAUS	-0. -0. SIAN HITH .5 R/ ITES 226.000	0.403 0.635 ADIAN CUT-CFF IAE 16.442	20-397 PLUS 5 VOLT S <u>(TAE</u> 469-384	STEP TIM
VARIANCE STO. DEV. INPUT - 1.44	0.957 0.978 VOLT RPS GAUS <u>IES</u> 20.542 15.284	-0. -0. SIAN HITH .5 RA ITES 226.000 71.368	0.403 0.635 ADIAN CUT-CFF IAE 16.442 14.789	20.397 PLUS 5 VOLT \$ <u>îtae</u> 469.184 400.421	STEP TIMI 14-1 10-8
VARIANCE STO. DEV. INPUT - 1.44	0.957 0.978 VOLT RPS GAUS <u>IES</u> 20.542 15.284 13.747	-0. -0. SIAN HITH .5 R/ ITES 226.000 71.368 3.789	0.403 0.635 ADIAN CUT-CFF IAE 16.442 14.789 13.642	20.397 PLUS 5 VOLT S <u>îTAE</u> 469.184 400.421 365.474	STEP TIMI 14-1 10-8 6-0
VARIANCE STO. DEV. INPUT - 1.44	0.957 0.978 VOLT RPS GAUS <u>IES</u> 20.642 15.284 13.747 17.642	-0. -0. SIAN WITH .5 R/ ITES 226.000 71.368 3.789 56.632	0.403 0.635 ADIAN CUT-GFF IAE 16.442 14.789 13.642 15.011	20.397 PLUS 5 VOLT \$ <u>îTAE</u> 469.384 400.421 365.474 394.316	STEP TIM 14-1 10-8 6-0 7-0
VARIANCE STO. DEV. INPUT - 1.44	0.957 0.978 VOLT RPS GAUS <u>IES</u> 20.542 15.284 13.747	-0. -0. SIAN HITH .5 R/ ITES 226.000 71.368 3.789	0.403 0.635 ADIAN CUT-CFF IAE 16.442 14.789 13.642	20.397 PLUS 5 VOLT S <u>îTAE</u> 469.184 400.421 365.474	STEP TIMI 14-1 10-8 6-0
VARIANCE STO. DEV. INPUT - 1.44 GATA	0.957 0.978 VOLT RPS GAUS <u>IES</u> 20.642 15.284 13.747 17.642	-0. -0. SIAN WITH .5 R/ ITES 226.000 71.368 3.789 56.632	0.403 0.635 ADIAN CUT-GFF IAE 16.442 14.789 13.642 15.011	20.397 PLUS 5 VOLT \$ <u>îTAE</u> 469.384 400.421 365.474 394.316	STEP TIM 14-1 10-8 6-0 7-0
VARIANCE Sto. Dev.	0.957 0.978 VOLT RPS GAUS <u>IES</u> 20.642 15.284 13.747 17.642 14.116	-0. -0. -0. SIAN WITH .5 R/ <u>ITES</u> 226.000 71.368 3.789 56.632 52.737	0.403 0.635 ADIAN CUT-GFF <u>IAE</u> 16.442 14.789 13.642 15.011 13.716	20.397 PLUS 5 VOLT \$ <u><u>i</u>TAE 469.134 400.421 365.474 394.316 362.632</u>	STEP TIM 14-1 10-8 6-0 7-0

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# Table D-23

	tec 1	ITES	. 140	ITAE	STEP TIM
	1ES 7.326	42.316	15.953	507.789	13.5
DATA	8.505	85.053	17.411	557.263	10.1
-	8.242	70.000	17.053	534.842	8.8
	6.621	12.316	14.242	485.000	8.6
	7.326	51.579	15.789	507.579	4.5
MEAN	7.604	52,253	16.091	518.695	1
VARIANCE	0.468	616.991	1.239	611-944	
STD. DEV.	0.684	24,839	1.113	24.737	
INPUT56	VOLT RHS GAUSS	IAN WITH 1.5 RA	DIAN CUT-OFF	LUS 3 VOLT S	13P
	IES	ITES	TAE	ITAE	STEP TIN
	11.474	112.211	18.316	565.105	4.7
DATA	12.611	94.316	18.095	527.684	6.3
	10-442	89.368	17.505	541.263	8.4
	10.442	89.368 112.105	17.905	547.053	8.4
NEAN	11.242	112.105	17.905	547.053	10.5
MEAN VARIANCE	11.242 12.768	112.105 159.684	17.905 18.358	547.053 563.579	10.5
VARIANCE	11.242 12.768 11.707	112.105 159.684 113.537	17.905 18.358 18.036	547.053 563.579 549.137	10.5
VARIANCE Std. Dev.	11.242 12.768 11.707 0.763 0.873	112.105 159.684 113.537 617.390 24.847	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF	547.053 563.579 549.137 204.616 14.306	10.5 14.7 
VARIANCE Std. Dev.	11.242 12.768 11.707 0.763 0.873 VOLT RHS GAUSS	112.105 159.684 113.537 617.390 24.847 IAM WITH 1.5 RA	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF	547.053 563.579 549.137 204.616 14.304 PLUS 5 VOLT S ITAE	10.5 14.7 TEP STEP TIM
VARIANCE STO. DEV. INPUT56	11.242 12.768 11.707 0.763 0.873 VOLT RHS GAUSS <u>165</u> 14.421	112.105 159.684 113.537 617.390 24.847 144 WITH 1.5 RA 17ES 27.389	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF 1 IAE 18.525	547.053 563.579 549.137 204.616 14.304 PLUS 5 VOLT S ITAE 562.105	10.5 14.7 TEP <u>STEP TIM</u> 14.3
VARIANCE STO. DEV. INPUT56	11.242 12.768 11.707 0.763 0.873 VOLT RHS GAUSS <u>IES</u> 14.421 14.400	112.105 159.684 113.537 617.390 24.847 144 WITH 1.5 RA 11ES 27.389 34.116	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF 1 IAE 18.525 19.432	547.053 563.579 549.137 204.616 14.304 PLUS 5 VOLT S <u>ITAE</u> 562.105 534.105	10.5 14.7 14.7 TEP STEP f1M 14.3 11.7
VARIANCE STO. DEV. INPUT56	11.242 12.768 11.707 0.763 0.873 VOLT RHS GAUSS <u>165</u> 14.421 14.400 14.832	112.105 159.684 113.537 617.390 24.847 24.847 IAN WITH 1.5 RA ITES 27.389 34.116 22.579	17.905 18.358 18.036 0.097 0.311 0IAN CUT-OFF 1 IAE 18.525 19.432 18.663	547.053 563.579 549.137 204.616 14.304 PLUS 5 VOLT S ITAE 562.105 534.105 519.684	10.5 14.7 TEP STEP TIM 14-3 11.7 8.6
VARIANCE STO. DEV. INPUT56	11.242 12.768 11.707 0.763 0.873 VOLT RHS GAUSS <u>IES</u> 14.421 14.400	112.105 159.684 113.537 617.390 24.847 144 WITH 1.5 RA 11ES 27.389 34.116	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF 1 IAE 18.525 19.432	547.053 563.579 549.137 204.616 14.304 PLUS 5 VOLT S <u>ITAE</u> 562.105 534.105	10.5 14.7 14.7 TEP STEP f1M 14.3 11.7
VARIANCE STO. DEV. INPUT56 DATA	11.242 12.768 11.707 0.763 0.873 VOLT RHS GAUSS <u>165</u> 14.421 14.421 14.421 14.832 14.800	112.105 155.684 113.537 617.390 24.847 24.847 INTES 27.389 34.116 22.579 15.863	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF 1 18.525 19.432 18.663 17.663	547.053 563.579 549.137 204.616 14.304 PLUS 5 VOLT S <u>ITAE</u> 562.105 534.105 519.684 510.105	10.5 14.7 TEP STEP TIM 14.3 11.7 8.6 7.2
VARIANCE STO. DEV. INPUT56	11.242 12.768 11.707 0.763 0.873 0.873 VOLT RHS GAUSS <u>165</u> 14.421 14.400 14.832 14.800 15.305	112.105 159.684 113.537 617.390 24.847 24.847 IAN WITH 1.5 RA <u>ITES</u> 27.389 34.116 22.579 15.863 16.705	17.905 18.358 18.036 0.097 0.311 DIAN CUT-OFF 18.525 19.432 18.663 17.663 19.263	547.053 563.579 549.137 204.616 14.306 PLUS 5 VOLT S <u>ITAE</u> 562.105 534.105 519.684 510.105 543.789	10.5 14.7 TEP STEP TIM 14.3 11.7 8.6 7.2

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# Table D-24

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فمحمد البدر المرجعات برو	IES	ITES	146	IÎAE	STEP TIM
	7.811	55.789	15.958	477.263	13.7
DATA	7.411	48.632	16.000	476.421	10.2
	7.463	42.421	15.495	470.947	9.2
	8-305	74.947	16.400	496.000	7.2
	7.432	68.737	15.547	490.332	3.6
MEAN	7.684	58.105	15.880	482.753	
VARIANCE	0.118	147.559	0.110	89.184	
STD. DEV.	0.343	12.147	0.332	9.444	
INPUT - 1.44	VULT RHS GAU	SSIAN WITH .5 RA	DIAN CUT-OFF	PLUS 3 VOLT S	TEP
	IES	ITES	IAE	ITAE	STEP TIM
	16.600	200.316	19.389	532.632	15.0
DATA	13.074	125.263	17.516	472.000	11.4
	14.505	129.158	18.368	499.474	9.2
	15.516	145.895	19.116	526.526	6.2
<u> </u>	11.737	62.842	17.221	472.211	5.0
		132.695	18.322	500.558	
MEAN	14.286	1321073		1	
MEAN VARIANCE	14.286	1938.795	0.727	664.678	
VARIANCE			0.727 0.853	664.678 25,781	
VARIANCE STD. DEV.	2.977 1.725	1938.795 44.032	0.853 DIAN CUT-OFF	25,781	
VARIANCE STD. DEV.	2.977 1.725 VOLT RMS GAUS	1938.795 44.032 SIAN WITH .5 RA	0.853 DIAN CUT-OFF	25,781 PLUS 5 VOLT S	STEP TIN
VARIANCE STD. DEV.	2.977 1.725 VOLT RMS GAU	1938.795 44.032 SIAN WITH .5 RA <u>1TES</u> 238.842	0.853 DIAN CUT-OFF <u>IAE</u> 21.168	25,781 PLUS & VOLT S ITAE 495.684	STEP TIN
VARIANCE STD. DEV.	2.977 1.725 VOLT RMS GAUS <u>IES</u> 30.021 23.684	1938.795 44.032 SIAN WITH .5 RA <u>1TES</u> 238.842 111.053	0.853 DIAN CUT-OFF <u>IAE</u> 21.168 19.368	25,781 PLUS 5 VOLT S ITAE 495.684 467.053	STEP TIMI 7.4 4.2
VARIANCE STD. DEV.	2.977 1.725 VOLT RMS GAU	1938.795 44.032 SSIAH WITH .5 RA <u>1TES</u> 238.842 111.053 226.211	0.853 DIAN CUT-OFF <u>IAE</u> 21.168 19.368 19.358	25,781 PLUS 5 VOLT S ITAE 495.684 467.053 479.570	STEP TIMI 7.4 4.2 8.4
VARIANCE STD. DEV.	2.977 1.725 VOLT RMS GAUS IES 30.021 23.684 27.095	1938.795 44.032 SIAN WITH .5 RA <u>1TES</u> 238.842 111.053	0.853 DIAN CUT-OFF <u>IAE</u> 21.168 19.368	25,781 PLUS 5 VOLT S ITAE 495.684 467.053	STEP TINI 7.4 4.2
VARIANCE STD. DEV. INPUT - 1.44	2.977 1.725 VOLT RMS GAUS <u>IES</u> 30.021 23.684 27.095 25.042	1938.795 44.032 SSIAN WITH .5 RA <u>1TES</u> 238.842 111.053 226.211 256.316	0.853 DIAN CUT-OFF IAE 21.168 19.368 19.358 17.863	25.781 PLUS 5 VOLT S ITAE 495.684 467.053 479.57° 465.158	STEP TIM 7.4 4.2 8.4 11.7
VARIANCE STD. DEV.	2.977 1.725 VOLT RMS GAUS <u>IES</u> 30.021 23.684 27.095 25.042 30.800	1938.795 44.032 SIAN WITH .5 RA <u>ITES</u> 238.842 111.053 226.211 256.316 445.263	0.853 DIAN CUT-OFF <u>IAE</u> 21.168 19.368 19.358 17.863 21.421	25,781 PLUS 5 VOLT S ITAE 495.684 467.053 479.57^ 465.158 589.263	STEP TINI 7.4 4.2 8.4 11.7

#### Table D-25

	IES	ITES	IAE	ITAE	STEP TIM
	15.147	363.789	23.147	751,474	16.0
DATA	13.895	247.263	21.895	646.842	11.6
	11.716	218.737	20.084	630.947	10.0
	13.505	280.105	21.053	646.632	5.6
	11.158	194.842	19.853	595.474	3.2
MEAN	13.084	260.947	21.206	654.274	
VARIANCE	2.135	3456.483	1.471	2712.612	
STD. DEV.	1.461	58.792	1.213	52.083	
	the second second second second second second second second second second second second second second second s	اليوريس بمجمعه برعد استدام وجبت يردا والمرا		The second second second second second second second second second second second second second second second s	
INPUT56		IAN WITH 1.5 RA			
INPUT56	IES	ITES	IAE	ITAE	STEP TIN
	1ES 17.684	17ES 331.684	1AE 23.421	1TAE 719.895	STEP TIN
	IES 17.684 16.853	17ES ?31.684 231.684	IAE 23.421 22.168	1TAE 719.895 642.947	STEP T7.NI 4.7 5.9
INPUT56 1 DATA	1ES 17.684	17ES 331.684	1AE 23.421	1TAE 719.895	STEP TIN

IES	ITES	IAE	ITAE	STEP TINE
17.684 16.853 20.211 18.463 16.379	?31.684 231.684 324.737 341.684 277.263	23.421 22.168 22.895 22.453 21.674	719.895 642.947 664.316 655.579 617.158	4.7 5.9 8.8 11.6 14.4
17.913	301.411	22.52/	659.979	1
1.822	1705.489	0.359	1150.362	
1.350	41.298	0.599	33.917	
	17.684 16.853 20.211 18.463 16.379 17.913 1.822	17.684       ?31.684         16.853       231.684         20.211       324.737         18.463       341.684         16.379       277.263         17.918       301.411         1.822       1705.489	17.684       ?31.684       23.421         16.853       231.684       22.168         20.211       324.737       22.895         18.463       341.684       22.453         16.379       277.263       21.674         17.913       301.411       22.52/         1.822       1705.489       0.359	17.684       ?31.684       23.421       719.895         16.853       231.684       22.168       642.947         20.211       324.737       22.895       664.316         18.463       341.684       22.453       655.579         16.379       277.263       21.674       617.158         17.913       301.411       22.52.       659.979         1.822       1705.489       0.359       1150.362

INPUT - .56 VOLT RNS GAUSSIAN WITH 1.5 RADIAN CUT-OFF PLUS 5 VOLT STEP

	IES	ITES	TAE	ITAE	STEP TIME
	33.579	683.263	27.495	830.316	14.3
DATA	44.000	683.158	28.547	753.263	11.2
	32.000	402.526	24.253	639.579	9.2
	33.389	410.737	25.000	674.211	7.0
	30.642	251.053	23.147	577.158	4.5
MEAN	34.722	486.147	25.688	6 . 4 . 9 3	
VARIANCE	22.544	29123.315	4.086	7819.081	
STD. DEV.	4.759	170.656	2.021	88.426	1

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Table D-26

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SUBJECT 2 - PERFORMANCE MEASURES FOR K/S2 CONTROLLER INPUT - 1.44 VILT RPS GAUSSIAN WITH .5 RADIAN CUT-OFF PLUS 1 VOLT STEP STEP TIME ITES IES IAE ITAE 47.811 1671.368 39.811 1252.421 5.2 8.3 DATA 42.842 1356.842 37.432 1154.316 32.842 1003.158 33.558 1046.526 45.695 1543.053 -0.579 1300.526 11.5 38.684 1145.789 35.200 1056.421 16,4 NEAN 41.575 1344.042 37.316 1162.042 VARIANCE 28.416 60483.525 7.097 10381.137 STD. DEV. 5.331 245.934 2.664 101.888 INPUT - 1.44 VOLT RMS GAUSSIAN WITH .5 RADIAN CUT-OFF PLUS 3 VOLT STEP STEP TIME 14.4 10.4 8.7 1115.895 IES ITES IAE 42.032 1189.158 38.305 DATA 39.011 934.105 37.432 1018.316 49.568 1167.474 40.011 1065.158 58.084 1337.053 42.547 1169-263 6.5 46-042 1058.000 39.263 1057.895 5.7 MEAN 46.947 1143.158 39-512 1085.305 VARIANCE 43.775 17409.587 3.062 2725.900 STD. DEV. 6.616 131.945 1.750 52.210 INPUT - 1.44 VOLT RPS GAUSSIAN WITH .5 RADIAN CUT-OFF PLUS 5 VOLI STEP ITES IAE ITAE

1ES 49.684 STEP TIME 1382.105 38.716 1156.000 14.2 DATA 58.674 1458.526 41.221 1172.000 10.4 1235.895 52.411 40.558 1102.842 9.5 68.453 1403.895 44.926 1197.053 5.5 75.874 1567.579 48.632 1325.263 2.8 MEAN 61.019 1409.600 42.811 1190.632 VARIANCE 96.801 11662.600 12.546 5484.075 STO. DEV. 9.839 107.994 3.542 74.055

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# Table D-27

	165	I ITES	IAE	ITAE	STEP TIME
ويتحتق وتشبيهما التجاويرية المورية	51.789	1917.895	43.442	1274.000	3.4
DATA	65,547	2803.474	43.784	1533.684	6.9
	44.126	1617.684	39.084	1286.000	9.2
	40.989	1409.053	38.663	1261.789	10.0
	49.095	1637.684	42.484	1346.737	15.5
MEAN	50.309	1797.158	41.493	1340.442	
VARIANCE	72.191	259785.574	4.773	10189.375	1
STD. DEV.	8.497	509.692	2.185	100.942	
INPUT56	VOLT RHS GAUS	SIAN WITH 1.5 RA	DIAN CUT-OFF	PLUS 3 VOLT S	TEP
	<u>IES</u>	ITES	IAE	ITAE	STEP TIME
	56.274	1654.105	44.358	1293.263	11.3
CATA	53.411	1482.737	42.537	1223.053	14.2
	66.716	2213.895	43.853	1361.474	9.4
	63.947 58.968	1876.316 1652.421	48.147 44.358	1424.842	6.2 6.8
MEAN	59.863	1775.895	44.651	1319.179	
176.MI	1				
	23.792	63589.725	3.501	4707.425	
	23.792 4.878	63589.725 252.170	3.501 1.871	4707.425 68.611	
VARIANCE STD. DEV.	4.878		1.871	68.611	TEP
VARIANCE STD. DEV.	4.878	252.170 SIAN WITH 1.5 RA	1.871 DIAN CUT-OFF <u>746</u>	68.611 PLUS 5 VOLT ST	
VARIANCE STD. DEV. INPUT56	4.878 VOLT RMS GAUS	252.170 SIAN WITH 1.5 RA ITES 2772.632	1.871 DIAR CUT-OFF <u>146</u> 55.874	68.611 PLUS 5 VOLT 5 1745 1666.526	STEP TIME
VARIANCE STD. DEV.	4.878 VOLT RMS GAUS 1ES 98.421 79.484	252.170 SIAN WITH 1.5 RA <u>ITES</u> 2772.632 2469.368	1.871 DIAN CUT-OFF <u>14E</u> 55.874 49.895	68.611 PLUS 5 VOLT ST 17AE 1666.526 1569.474	STEP TIME 10.5 13.7
VARIANCE STD. DEV. INPUT56	4.878 VOLT RHS GAUS 1ES 98.421 79.484 58.358	252.170 SIAN WITH 1.5 RA <u>ITES</u> 2772.632 2469.368 3300.632	1.871 DIAN CUT-OFF <u>146</u> 55.874 49.895 38.979	68.611 PLUS 5 VOLT ST 17AE 1666.526 1569.474 1030.211	STEP TIME 10.5 13.7 8.4
VARIANCE STD. DEV. INPUT56	4.878 VOLT RHS GAUS 98.421 79.484 58.358 77.326	252.170 SIAN WITH 1.5 RA TTES 2772.632 2469.368 3300.632 1769.895	1.871 DIAN CUT-OFF <u>14E</u> 55.874 49.895 38.979 46.484	68.611 PLUS 5 VOLT ST ITAE 1666.526 1569.474 1030.211 1303.579	STEP TIME 10.5 13.7 8.4 7.0
VARIANCE STD. DEV. INPUT56 DATA	4.878 VOLT RMS GAUS 1ES 98.421 79.484 58.358 77.326 101.126	252.170 SIAN WITH 1.5 RA <u>ITES</u> 2772.632 2469.368 3300.632 1769.895 1898.210	1.871 DIAR CUT-OFF <u>14E</u> 55.874 49.895 38.979 46.484 50.874	68.611 PLUS 5 VOLT ST 1666.526 1569.474 1030.211 1303.579 1352.316	STEP TIME 10.5 13.7 8.4
VARIANCE STD. DEV. INPUT56 DATA	4.878 VOLT RHS GAUS 98.421 79.484 58.358 77.326	252.170 SIAN WITH 1.5 RA TTES 2772.632 2469.368 3300.632 1769.895	1.871 DIAN CUT-OFF <u>14E</u> 55.874 49.895 38.979 46.484	68.611 PLUS 5 VOLT ST ITAE 1666.526 1569.474 1030.211 1303.579	STEP TIMI 10.5 13.7 8.4 7.0
VARIANCE STD. DEV. INPUT56	4.878 VOLT RMS GAUS 1ES 98.421 79.484 58.358 77.326 101.126	252.170 SIAN WITH 1.5 RA <u>ITES</u> 2772.632 2469.368 3300.632 1769.895 1898.210	1.871 DIAR CUT-OFF <u>14E</u> 55.874 49.895 38.979 46.484 50.874	68.611 PLUS 5 VOLT ST 1666.526 1569.474 1030.211 1303.579 1352.316	STEP TIME 10.5 13.7 8.4 7.0

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STD. DEV.

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Table D-28

CATA MEAN VARIANCE STD. DEV.	IES         13.811         18.242         23.516         14.116         15.368         17.011         13.030	1TES 254.000 374.211 476.632 182.211 264.737 310.358 16680.670	IAE 22.274 22.695 22.926 19.926 20.989 21.762	ITAE 666.211 716.211 650.421 523.263 572.632 625.747	STEP TIME 15.8 11.8 3.6 9.4 5.7
MEAN VARIANCE	18.242 23.516 14.116 15.368 17.011	374.211 476.632 182.211 264.737 310.358	22.695 22.926 19.926 20.989 21.762	716.211 650.421 523.263 572.632	11.8 3.6 9.4
MEAN VARIANCE	23.516 14.116 15.368 17.011	476.632 182.211 264.737 310.358	22.926 19.926 20.989 21.762	650.421 523.263 572.632	3.6
VARIANCE	14.116 15.368 17.011	182.211 264.737 310.358	19.926 20.989 21.762	523.263 572.632	9.4
VARIANCE	15.368	264.737 310.358	20.989	572.632	5.7
VARIANCE				625.747	
	13.030	16680-670		1	
STD. DEV.			1.291	4750.791	
	3.610	103.347	1.136	68.926	
	IES	ITES	IAE	ITAE	STEP TIM
	IES	ITES	IAE	ITAE	STEP TIM
	63.968	1415.053	28.221	764.526	14.2
DATA	27.011	467.263	25.905	657.368	10.4
	18.032	210.632	20.653	532.947	9.0
	33.516	853.263	31.832	975.368	6.9
	32.295	624.421	30.558	829.153	3.9
MEAN	34.964	714-126	27.434	751.874	
VARIANCE	240.099	166630.437	15.608	22588.569	
STD. DEV.	15.495	408.204	3.951	150.295	

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### Table D-29

	IES	ITES	IAE	IT4E	STEP TIME
	9.811	189.053	11.747	562.737	3.9
DATA	9.263	134.947	17.695	514.421	7.2
	9.368	153.684	20.063	529.158	9.2
	13.579	238.842	22.747	634.716	11.0
	9.979	161.053	38.221	527.895	13.7
MEAN	16.400	175.516	19,295	553.705	
VARIANCE	2.597	1305-013	3.724	1878.331	
STD. DEV.	1.612	36.125	1.930	43.340	
	-	IAN WITH 1.5 RA		*	
	IES	ITES	IAE	ITAE	STEP TIM
	19.347	326.632	23.284	625.053	13.1
ÚATA	15.905	181.579	21.305	543.053	10.1
	14.442	222.000	21.495	591.295	8.9
	20.705	331.368	25.589	657.579	6.3
	25.158	354.316	25.537	670.105	4.3
MEAN	19.112	283.179	23.442	617.537	
VARIANCE	14.248	4667.246	3.476	2125.747	
STD. DEV.	3.775	68.317	1.365	46.106	
				1	
	IES	ITES	IAE	ITAE	STEP TIM
1	35.663	620.842	26.926	691.789	14.2
	33.003 1		28.738	770.316	11.4
DATA	40.337	737.684			
DATA		737.684	29.253	702.105	8.8
DATA	40.337			702.105	8.8
DATA	40.337 34.463	510.737	29.253		
DAT A	40.337 34.463 47.958	510.737 480.947	29.253 27.168	571.684	7.1
	40.337 34.463 47.958 39.368	510.737 480.947 288.000	29.253 27.168 23.305	571.684 527.684	7.1

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	IES	ITES	IAE	ITAE	I STEP TIME
·····	13.484	238.532	22.042	598.947	14.4
DATA	11.463	240,000	19.979	598.737	10.9
	14.021	295.368	21.684	634.421	7.4
	13.663	254.105	22.411	624.947	9.4
	11.305	230.737	29.926	467.158	5.2
MEAN	12.787	251.768	23.208	584.842	
VARIANCE	1.345	531.965	11.976	3661.622	
STO. DEV.	1.160	23.064	3.461	69.511	
INPUT - 1.44		SIAN WITH .5 RA			
	TES	ITES	IAE	ITAE	STEP TIM
	22.747	344.526	21.874	544.737	13.5
DATA	20.884	341.895	25.179 21.779	629.895 568.105	10.0
	18.621 24.726	238.947	25.432	581.158	7.0
	13.726	173.579	21.368	546.632	4.3
MEAN	20.141	277.916	23.126	574.105	
VARIANCE	14.366	4219.337	3.200	963.103	
STD. DEV.	3.790	64.956	1.789	31.034	
INPUT - 1.44	VƏLT RMS GAU	SSIAN WITH .5 RA	DIAN CUT-OFF	PLUS 5 VOLT S	TEP
	IES	ITES	IAF	ITAE	STEP TIM
	34.463	319.474	25.747	607.684	3.9
GATA	43.189	465.789	27.053	648.842	6.2
	35.326	450.842	24.411	571.158	9.2
	54.674	781.684	30.937	667.895	12.1
	59.916	1050.316	29.368	725.895	15.0
			27.503	644.295	1
MEAN	45.514	613.621	~ * * * 7 * 3		
MEAN VARIANCE	45.514 104.525	613.621 70764.269	5.624	2785.109	

# Table D-30

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	IES	ITES	IAE	ITAE	STEP TIM
	16.579	415.263	23.800	768.737	5.8
DATA	16.137	392.842	24.674	720.842	7.2
	12.937	300-421	21.105	654.316	10.3
	170179	340.842	25.200	684.009	11.2
	15.368	399.474	23.347	711.684	-13.0
MEAN	15.640	369.768	23.625	707.916	
VARIANCE	2.176	1826.072	2.007	1465.094	
STD. DEV.	1.475	42.733	1.417	38.277	

INPUT - .56 VOLT RHS GAUSSIAN WITH 1.5 RADIAN CUT-OFF PLUS 3 VOLT STEP

IES	ITES	IAE	ITAE	STEP TIME
21.442	478.211	25.779	771.789	4.6
27.589	415.263	28.926	726.316	7.4
26.095	421.579	28.958	707.789	10.1
28.095	553.789	28.989	771.158	12.0
26.653	566.526	29.179	790.316	16.1
25.975	487.074	28.366	753.474	
5.624	4057.719	1.681	966.031	
2.372	63.70C	1.297	31.081	1
	21.442 27.589 26.095 28.095 26.653 25.975 5.624	21.442         478.211           27.589         415.263           26.095         421.579           28.095         553.789           26.653         566.526           25.975         487.074           5.624         4057.719	21.442         478.211         25.779           27.589         415.263         28.926           26.095         421.579         28.958           28.095         553.789         28.989           26.653         566.526         29.179           25.975         487.074         28.366           5.624         4057.719         1.681	21.442         478.211         25.779         771.789           27.589         415.263         28.926         726.316           26.095         421.579         28.958         707.78%           28.095         553.789         28.989         771.158           26.653         566.526         29.179         790.316           25.975         487.074         28.366         753.474           5.624         4057.719         1.681         966.031

INPUT - .56 VOLT RMS GAUSSIAN WITH 1.5 RADIAN CUT-OFF PLUS 5 VOLT STEP

	IES	ITES	IAE	ITAE	STEP TIME
	41.726	757.474	28.737	757.263	13.0
DATA	38.600	608.947	30.832	729.158	1 11.1
	46.484	653.053	32.653	750.316	8.7
	42.821	600.842	32.684	781.579	6.2
	48.211	751.579	30.295	744.737	9.8
AEAN	43.568	674.379	31.040	752.611	
VARIANCE	11.738	4001.687	2.241	295.631	
STD. DEV.	3.426	67.936	1.497	17.194	

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# Table D-32

	100	ITES	IAE	ITAE	STEP TIME
والمراجع والبالي والمتحد والمتحد والمحاد	1/ <u>:</u> \$ 63.905	1612.526	48.168	1312.000	4.8
DATA	49.095	1455.368	41.747	1270.947	8.6
UA1 -	40.116	1133.579	37.853	1076.211	12.0
	53.032	1886.526	43.505	1367.053	22.5
	48.147	1372.210	41.442	1217.158	6.5
MEAN	50.859	1492.042	42.543	1248.674	
VARIANCE	60.161	62867.000	i1.283	9851.337	
STD. DEV.	7.756	250.733	3.359	99.254	
INPUT - 1.44	VOLT RHS GAUS	SSIAN WITH .5 RA	DIAN CUT-OFF	PLUS 3 VOLT ST	TEP
	IES	ITES	IAE	ITAE	STEP TIME
	74.442	4356.632	51.011	1424.632	12.3
DATA	88.126	4346.105	52.274	1348.842	10.4
	49.411	3679.579	41.737	1275.263	8.5
	60.989	3644.842	42.547	1049.263	5.3
	61.137	3837.053	44.484	1172.000	15.1
HEAN	66.821	3972.842	46.411	1254.000	
VARIANCE	176.298	99729.399	19.203	17440.725	
STD. DEV.	13.277	315.800	4.382	132.063	
				PLUS 5 VOLT S	TEP
INPUT - 1.44	VOLT RPS GAU	SSIAN WITH .5 "A	DIAN CUT-OFF		
INPUT - 1.44	165	ITES	IAE	ITAE	STEP TIME
	1E3 93.305	11ES 4279.579	IAE 52.126	1308-210	5.0
	165 93.305 90.726	11ES 4279.579 4207.474	IAE 52.126 51.147	ITAE 1308-210 1244-316	5.0
	1E3 93.305 90.726 76.284	11E5 4279.579 4207.474 3715.053	IAE 52.126 51.147 44.779	ITAE 1308-210 1244-316 1133-263	5.0 8.3 9.7
	163 93.305 90.726 76.284 104.379	11E5 4279.579 4207.474 3715.053 4295.158	<u>IAE</u> 52.126 51.147 44.779 53.389	<u>ITAE</u> 1308-210 1244-316 1133-263 1575-579	5.0 8.3 9.7 12.3
INPUT - 1.44 DATA	1E3 93.305 90.726 76.284	11E5 4279.579 4207.474 3715.053	IAE 52.126 51.147 44.779	ITAE 1308-210 1244-316 1133-263	5.0 8.3 9.7
	163 93.305 90.726 76.284 104.379	11E5 4279.579 4207.474 3715.053 4295.158	<u>IAE</u> 52.126 51.147 44.779 53.389	<u>ITAE</u> 1308-210 1244-316 1133-263 1575-579	5.0 8.3 9.7 12.3
DATA	163 93.305 90.726 76.284 104.373 74.147	11ES 4279.579 4207.474 3715.053 4295.158 3815.368	IAE 52-126 51-147 44-779 53-389 45-568	ITAE 1308.210 1244.316 1133.263 1575.579 1335.\$95	5.0 8.3 9.7 12.3

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# Table D-33

	IES	ITES	IAE	ITAE	STEP TIME
	التوالية بالمحدية التكلية أحاد بمتعاد التهية التجر	2475.579	46.000	1525.263	17.7
	67.179 64.568	2145.855	50-274	1518.316	1.3.5
DATA	58.105	2075.842	45.105	1491.579	10.2
	55.684	2064.211	44.032	1424.947	7.5
	82.463	2797.474	53.205	1678.632	4.1
NEAN	65.600	2312.000	48.297	1527.747	
VARIANCE	\$8.484	81346.445	16.0.	6947.475	
STD. DEV.	9.407	285.213	4.101	83.352	
INPUT56		SIAN WITH 1.5 RA			TEP STEP TIM
	IES	17ES	1AE 52.305	1586.421	4.7
~~~	71.116	2297.263	52.305	1719.474	6.8
DATA	33,116	2725.684 2687.053	52.863	1595.579	9.5
	79.189 108.842	2446.316	61.347	1536,000	11.6
	97.568	3563,263	57.211	1808.947	14.7
KEAN	89.966	274 .916	56.693	1649.284	
VARIANCE	179.098	192592.199	13.023	10017.725	
•	23.383	438.853	3.609	100.089	
STD. DEV.					
STD. DEV. 	VOLT RMS GAUS	SIAN WITH 1.5 RA	ADIAN CUT-OFF	PLUS 5 VOLT S	TEP
	IES	ITES	IAE	ITAE	STEP TIM
	1ES 82.000	11ES 2051.579	IAE 49.179	17AE	STEP TIM
	1ES 82.000 102.832	ITES 2051.579 2985.368	IAE 49.179 58.484	ITAE 1375.579 1623.579	STEP TIM
 INPUT56	1ES 82.000 102.832 115.053	ITES 2051.579 2985.368 2338.947	IAE 49.179 58.484 60.179	ITAE 1375.579 1623.579 1438.210	STEP TIM 14.3 10.9 8.0
 INPUT56	1ES 82.000 102.832	ITES 2051.579 2985.368	IAE 49.179 58.484	ITAE 1375.579 1623.579	STEP TIM 14.3 10.9
	1ES 82.000 102.832 115.053 75.368	ITES 2051.579 2985.368 2338.947 1844.211	IAE 49.179 58.484 60.179 49.453	ITAE 1375.579 1623.579 1438.219 1356.000	STEP TIN 14.3 10.9 8.0 7.2
INPUT56 QATA	1ES 82.000 102.832 115.053 75.368 109.579	ITES 2051.579 2985.368 2338.947 1844.211 2393.684	IAE 49.179 58.484 60.179 49.453 58.126	ITAE 1375.579 1623.579 1438.210 1356.000 1511.364	STEP TIM 14.3 10.9 8.0 7.2

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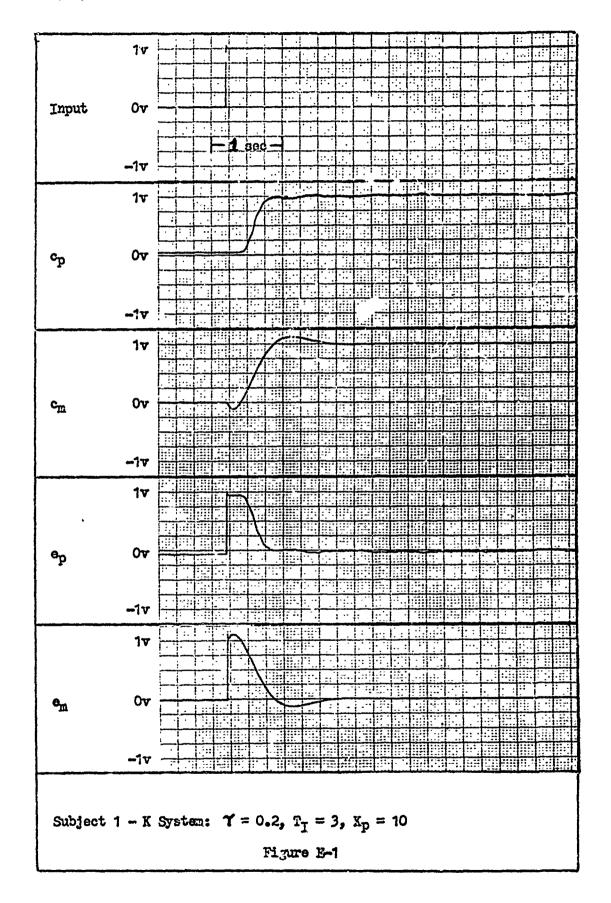
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#### Appendix E

# Real Time Recordings from the Analog Programs

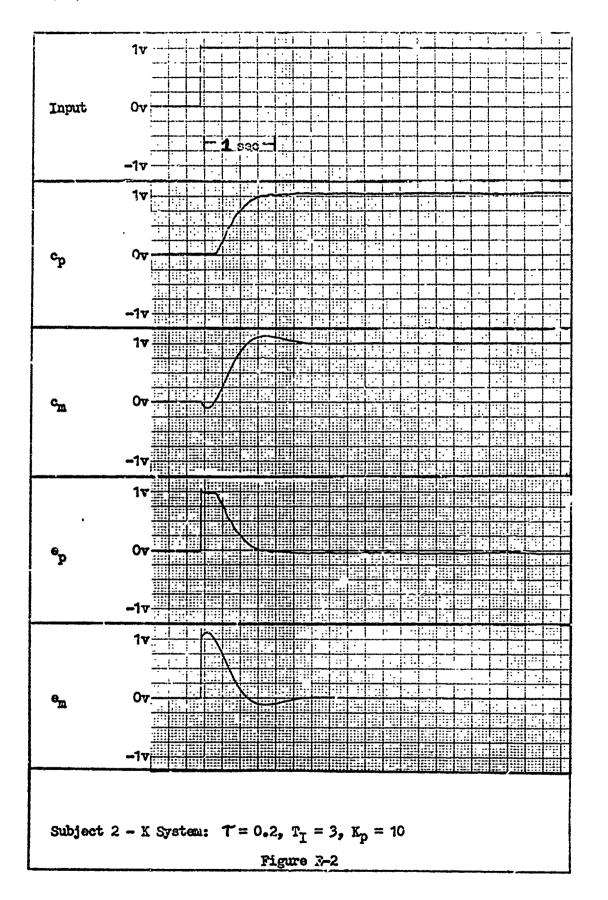
The following are real time recordings made with both piloted and model systems operating simultaneously. The input, output and error signals are shown. Figures E-1 through E-6 show the output and error with a step input. Figures E-7 through E-13 show the output and error with a Gaussian, and Figures E-14 through E-20 show the output and error with combined inputs.



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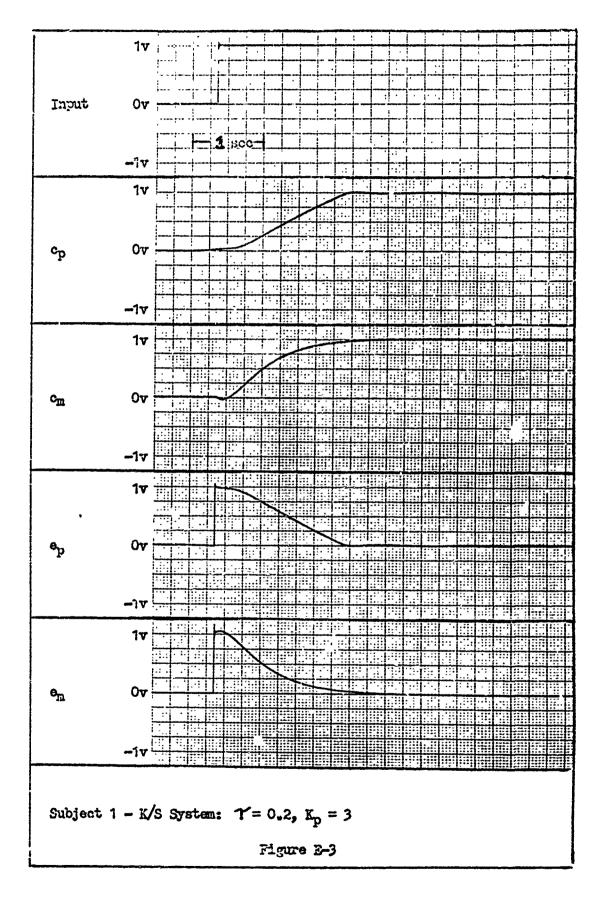
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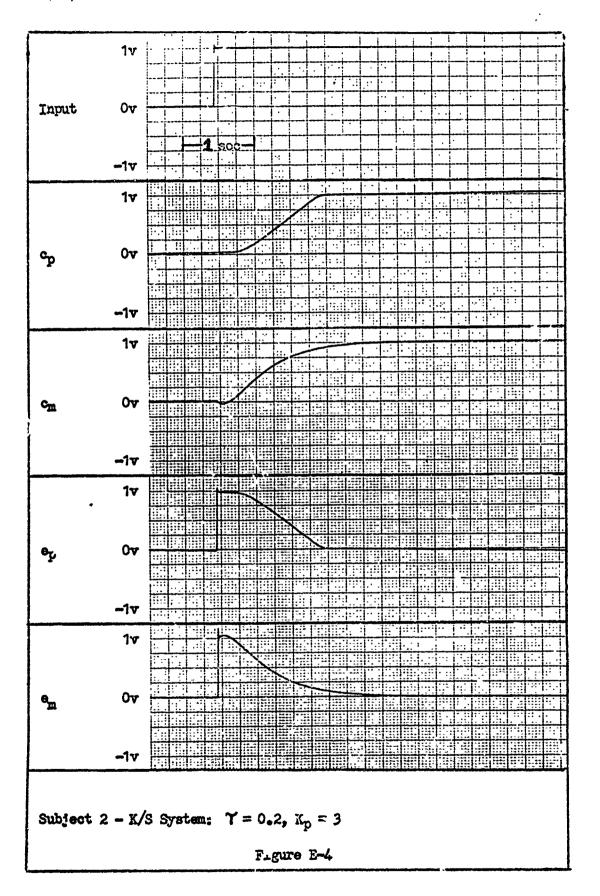
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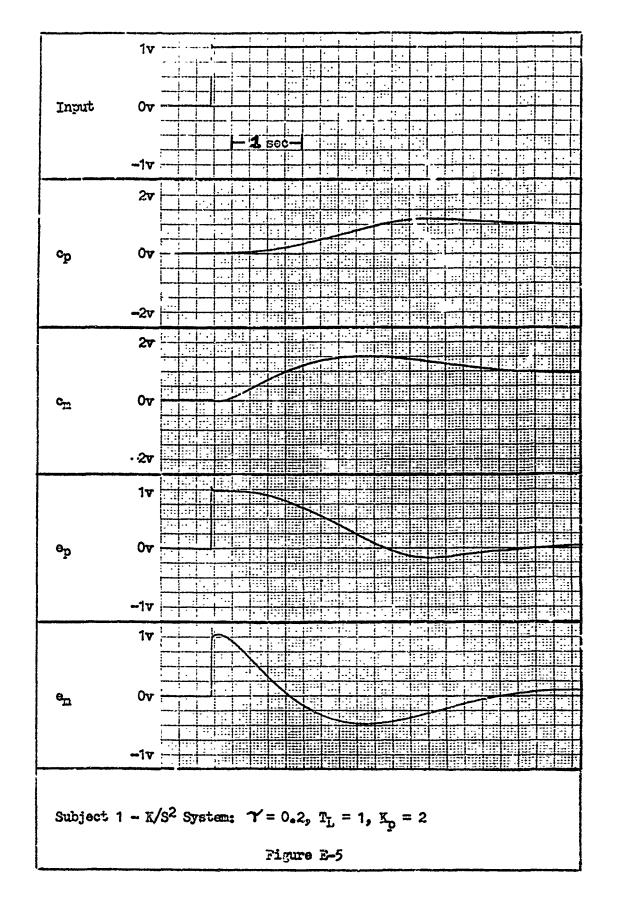


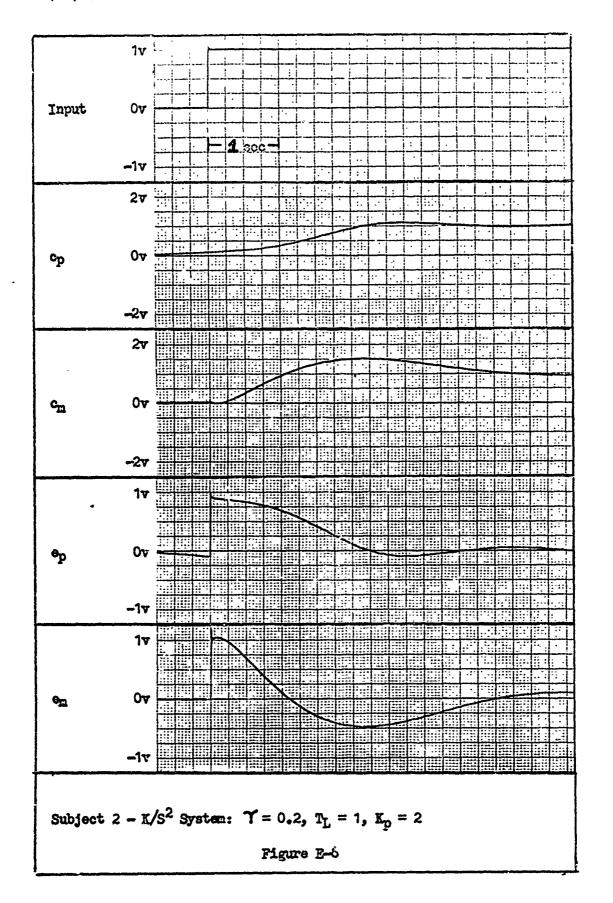
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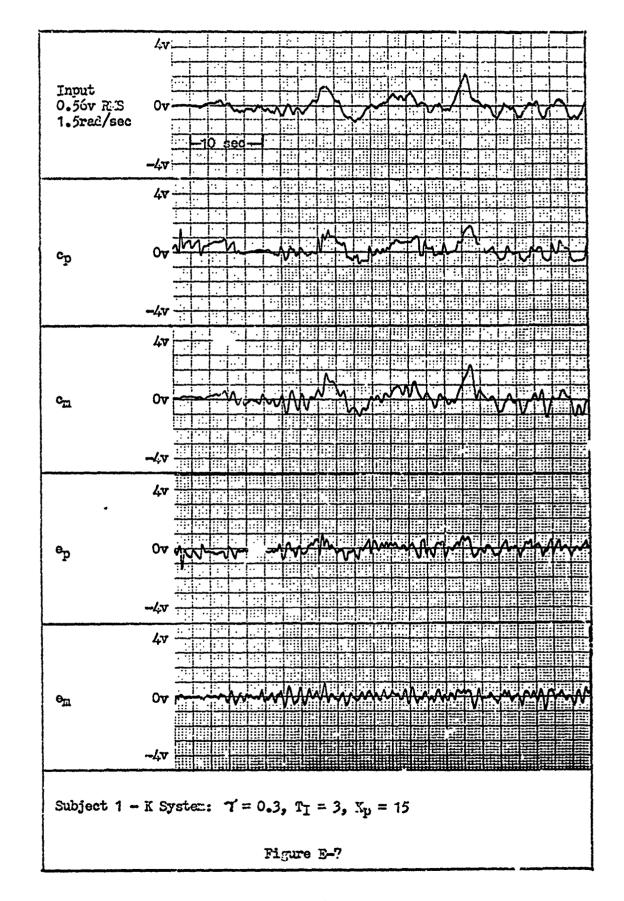


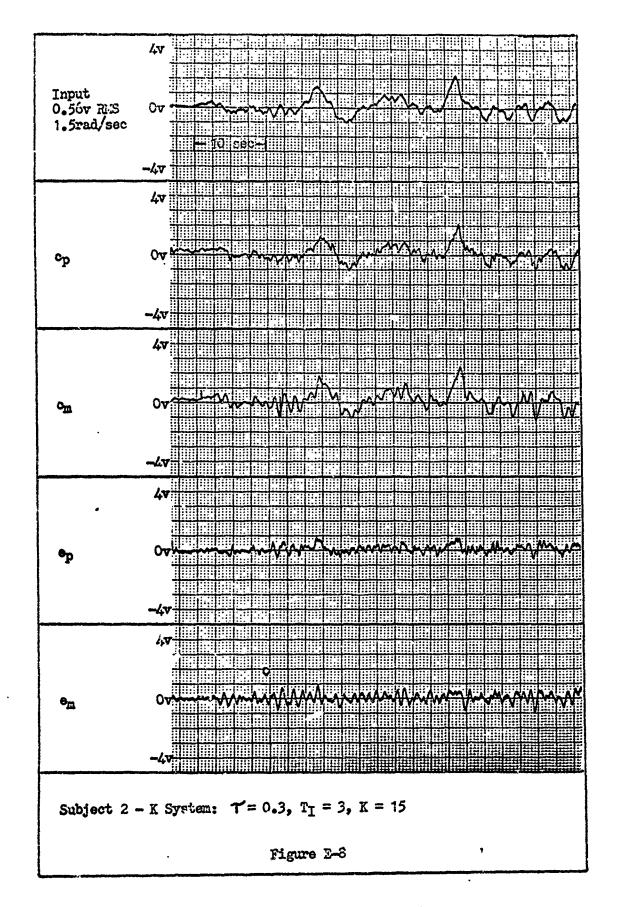
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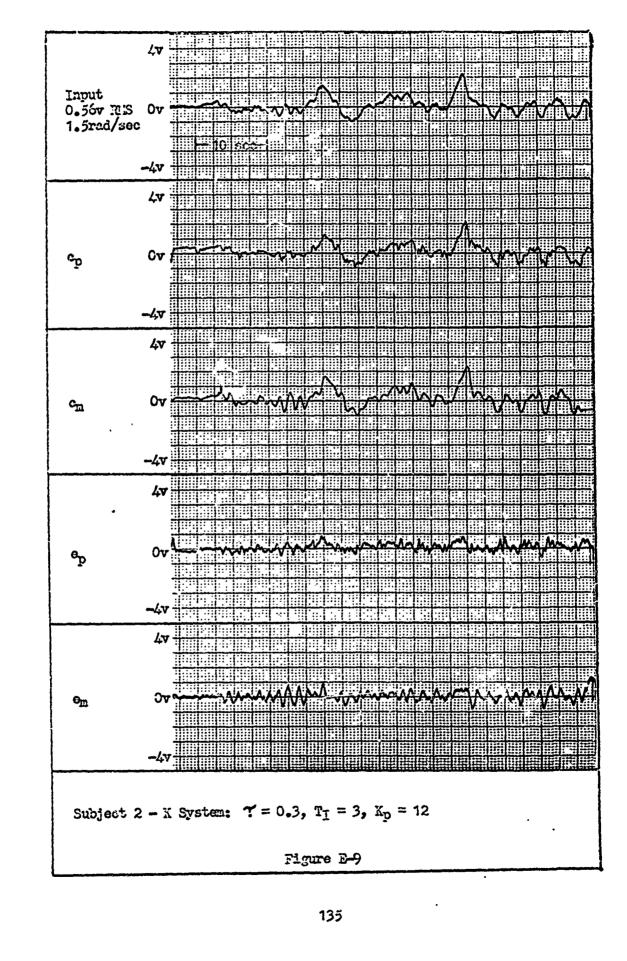
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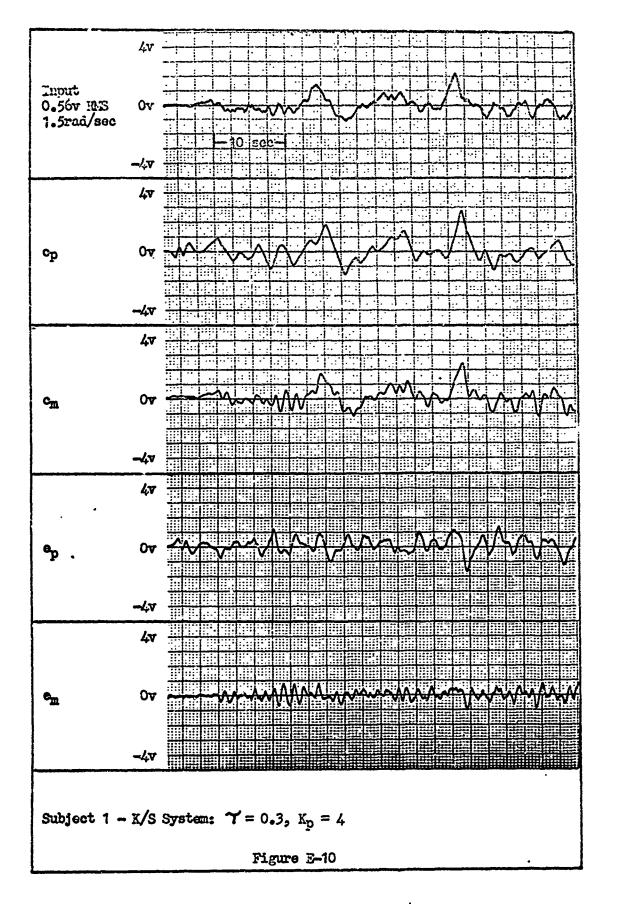
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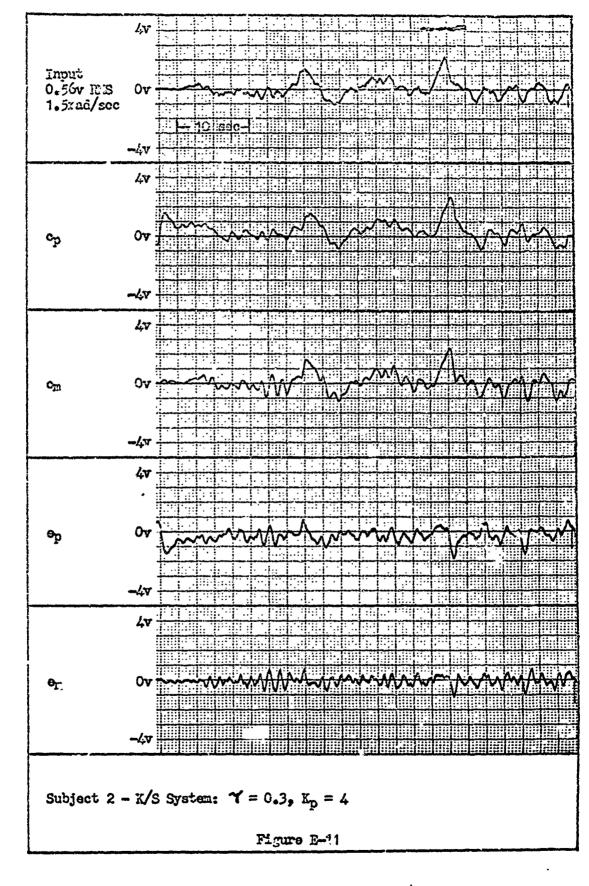




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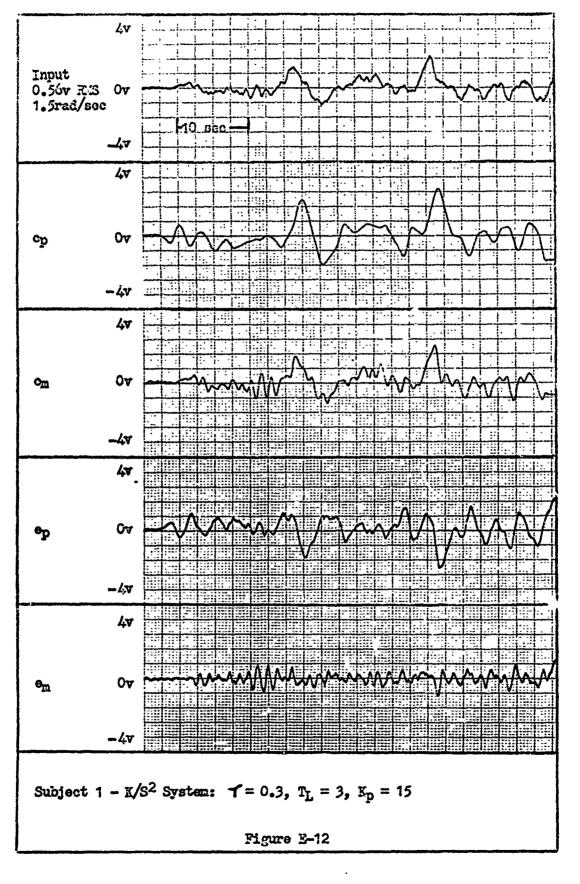
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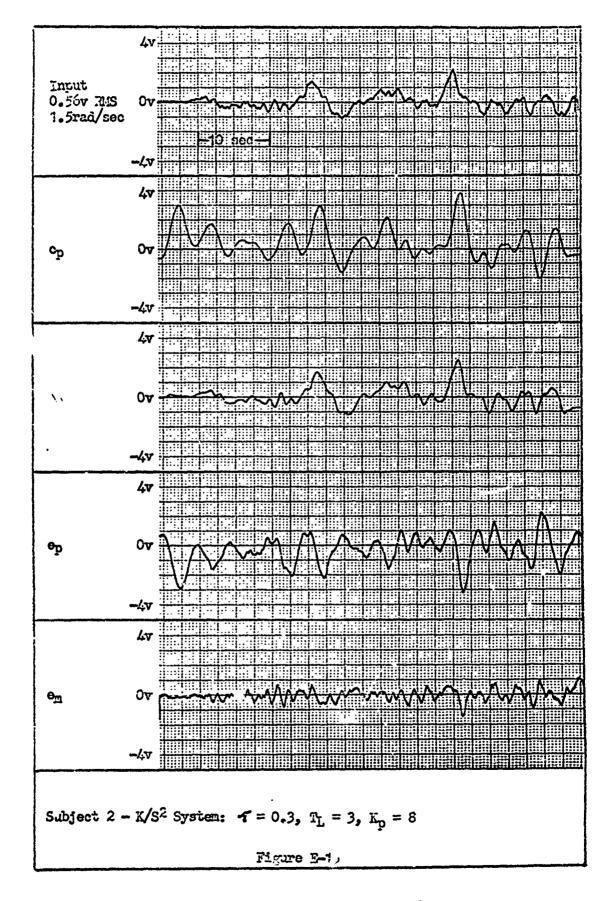




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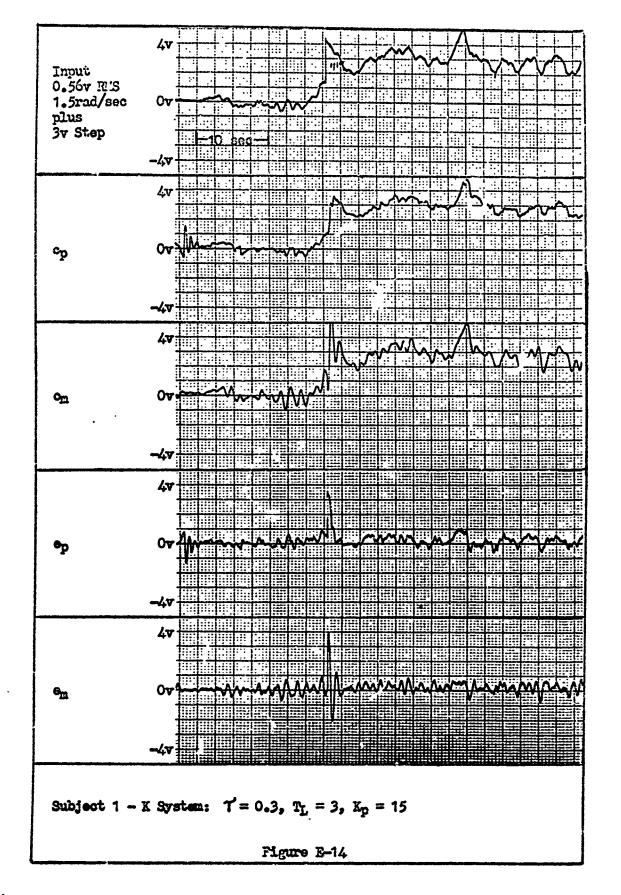


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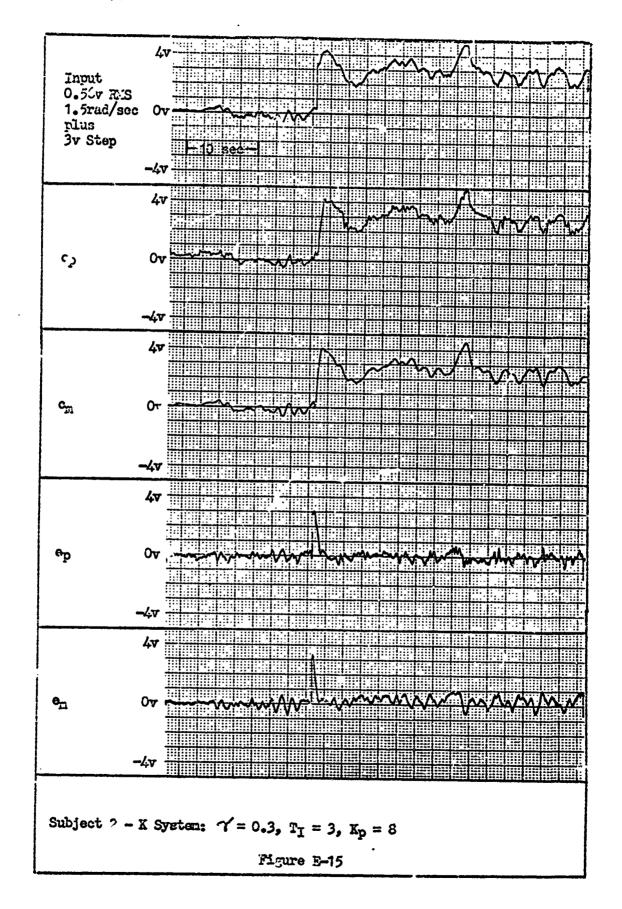


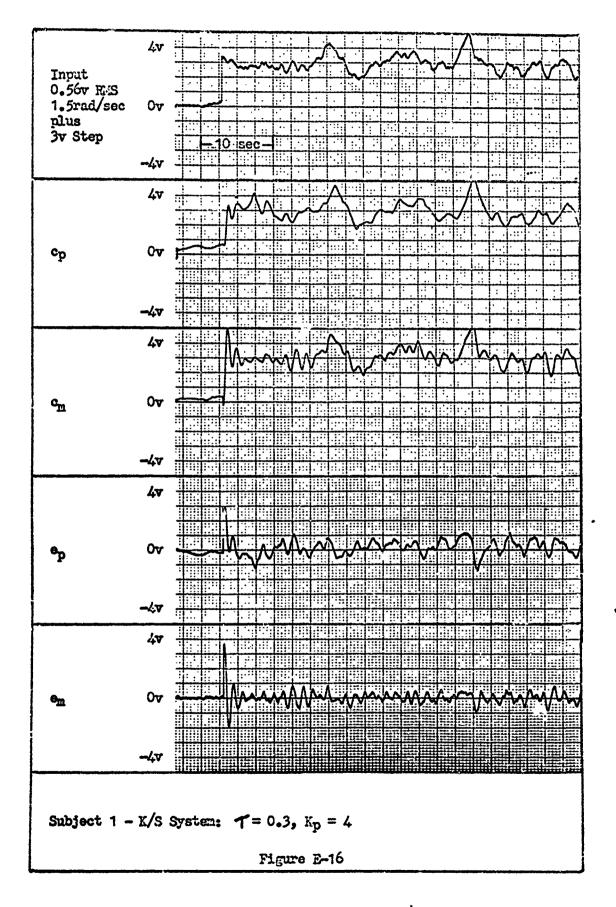
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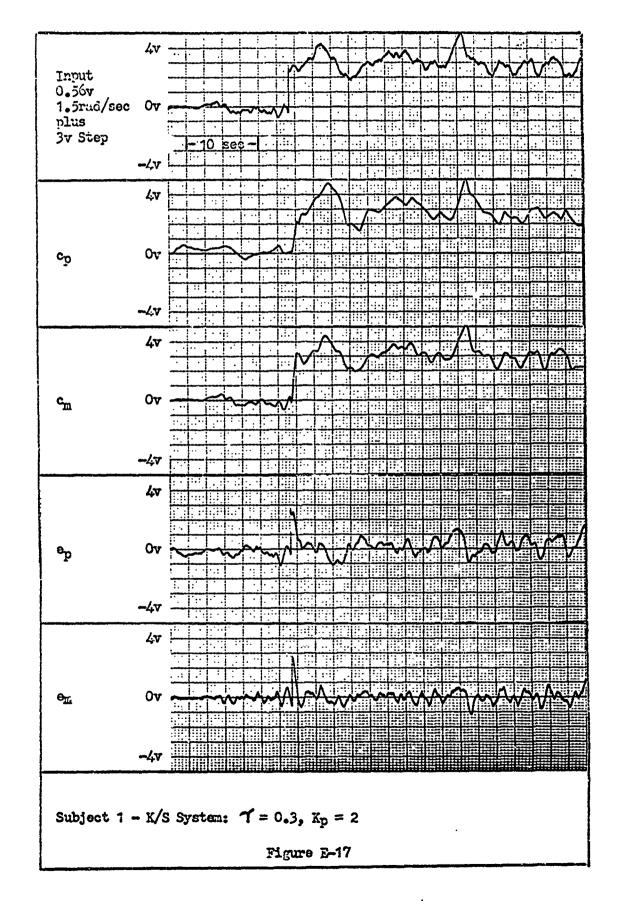
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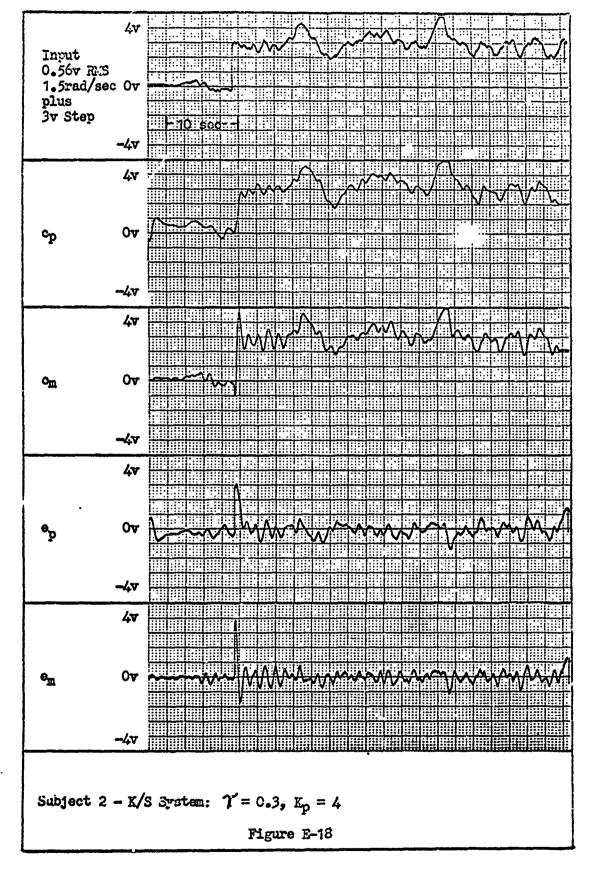






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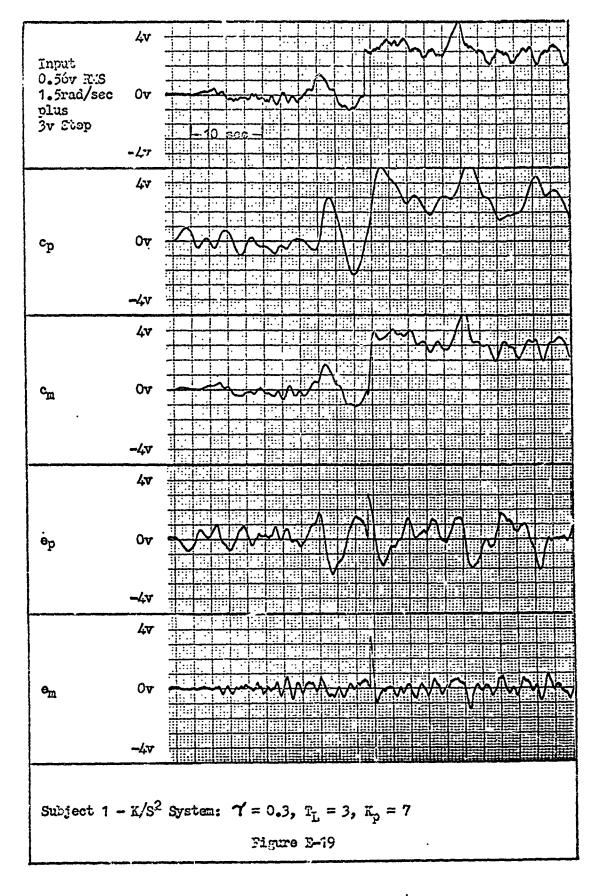




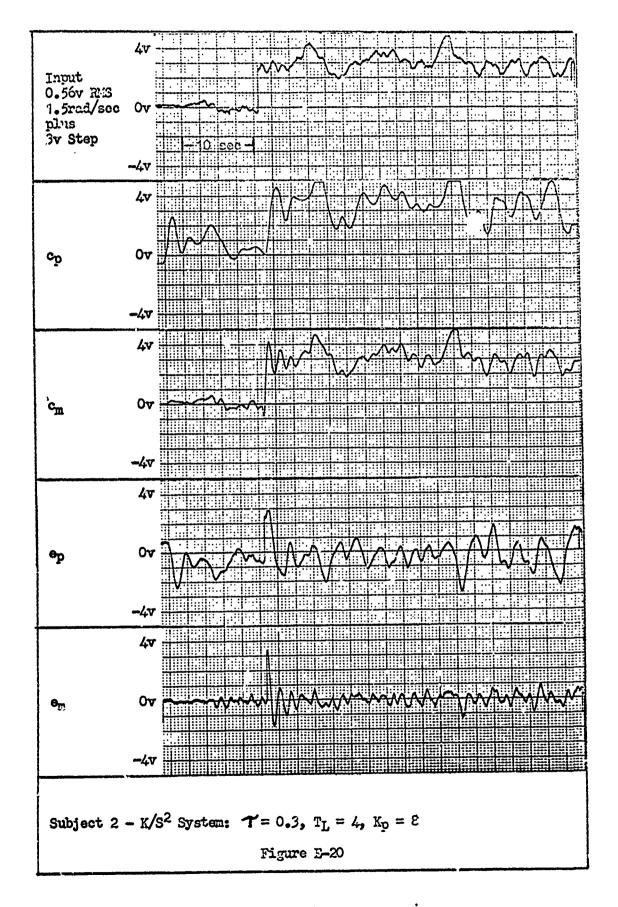
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#### Appendix 7 ·

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#### List of Tracking Subjects

#### Subject

### Excerience

- 1 USAF pilot with 9 years experience in tactical fighter and transport.
- 2 Private pilot with instrument training for his commercial license in single engine aircraft.
- 3 No flying experience.

Note: All subjects had limited task training with only three practice runs before data was taken.

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13. ABSTRACT								
A study was made of describing :	function mode	els of huma	n trackers while					
A study was made of describing function models of human trackers while operating control systems with Gaussian plus step inputs. The parameters in								
the describing function model were adjusted using existing parameter adjustment								
rules and experimental data. Four performance measures were determined from								
the experimental data to assess their usefulness in adjusting the parameters of								
human pilot describing function models.								
The experiments were run using three subjects with varied levels of								
flying experience. Each subject was given the single task of controlling a								
system with one of three different controlled elements; K, K/S, K/S <sup>2</sup> . Data								
were collected on each subject for each system with a single step input,								
Gaussian input, and Gaussian plus step input. Comparisons of the output of								
the piloted systems and the model systems were made, and suggestions for								
applications to the controlled element dynamics were offered.								
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