DEVELOPMENT OF WEAPON DELIVERY MODELS AND ANALYSIS PROGRAMS

Volume III. Testing and Demonstration of the Armament Delivery Analysis Programming System (ADAPS)

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FOREWORD

This document is the third of three volumes of the final report of a study conducted for the United States Air Force under Contract F33615-71-C-1059, "Development of Weapon Delivery Models and Analysis Programs". Approximately one man year of effort was covered by the contract. It was initiated under Project No. 8219, "Stability and Control Investigations", Task No. 821904, "Flight Control System Analysis," and administered by the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. Major Harvey M. Paskin (FGC), and Mr. Alonzo J. Connors (FGC) were project engineers.

The technical work reported was conducted by the Research Department of the Systems and Research Division of Honeywell Inc. Dr. A. Ferit Konar was the principal investigator; Mr. M.D. Ward was the programmer analyst. Dr. G.B. Skelton and Dr. E.E. Yore were project managers. Technical consultation was provided by Dr. Gunter Stein and Mr. C.R. Stone of Honeywell Inc.

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The investigators in this study would like to thank Major Harvey H. Paskin for his enthusiastic support, for his technical leadership, and for his assistance in obtaining bomb data. The investigators would also like to thank Mr. Alonzo J. Connors for providing direction and assistance in testing the analysis programs.

This technical report was reviewed and is approved.

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ABSTRACT

The testing and use of ADAPS is demonstrated by performing an analysis with a specified iron bomb (M117) and a representative tactical fighter-bomber aircraft (F4). The demonstration example revealed no appreciable performance difference between the time-invariant and time-varying optimal controllers for the weapon delivery process. The contribution matrix of an iron bomb indicated that the major contributors to the CEP are the velocity and the attitude-state errors at release.

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SECTION I

INTRODUCTION

This volume demonstrates the testing and use of the computer programs documented in Volume II by performing an analysis with a specified iron bomb (M117) and a representative tactical fighter-bomber aircraft (F4).

A typical delivery trajectory is chosen to be 40 degrees dive angle, 400 knots release velocity and 4000 feet release altitude. The measure of weapon delivery performance is chosen to be the CEP at impact.

First a typical data preparation and the input/output to the simulator and the linearizer (ADAP1) are treated. Then aircraft, weapon, and controller design software tests are described in that order.

Succeeding sections treat controller design, comparisons of stationary and nonstationary controllers, and variance contribution and critical-parameter identification in that order. A final section summarizes the conclusions drawn from the demonstration example.

SECTION II
DATA PREPARATION

The major effort in data preparation for ADAPS is in punching cards for the parameter inputs and the aerodynamic tables.

Typical parameter inputs for an aircraft are shown in Table I, and weapon parameter inputs are shown in Table II. The representations of the airframe and the weapon aerodynamic tables in ADAPS are shown in Tables III and IV. Figure 1 shows the card images of the input data to ADAP 1 for the demonstration example. Figure 2 shows the A-Array dump output of the nonlinear trajectory data.

Table I. Typical Parameter Inputs for Aircraft

A(I)	Quantity	Mnemonic	Symbol	Description	Initial Value	Units
002	-13809.0	X	x_e	Range from target		ft
004	12000.0	H	h	Altitude		ft
016	422.5	VEL	V_a	Total velocity		ft/sec
026	0.03665	---	α	---		rad
029	0.03665	AL	α_a	Total angle of attack		rad
031	-0.5614	TH	θ	Pitch angle		rad
043	-0.001745	Q	q	Pitch rate		rad/sec
090	32.17	G	g	Gravity		ft/sec
115	38.67	B	b	Wing open		ft
116	16.04	C	c	Wing mean aerodynamic chord		ft
117	530.0	S	s	Wing area		ft^2
121	0.1	YDS	δ_s	Stabilator deflection		deg
122	0.00133	DELDS	$\Delta\delta_s$	Stabilator increment		deg/sec
131	100.0	N	N	No. of integration steps		---
132	1.0		ΔT	Time interval		sec
134	1.0	DTOUT		Output time interval		sec
140	0.7	YDSPU	δs_{pu}	Stabilator deflection during pull-up		deg
141	7720	YTH(1)		Effective thrust output for engine 1		lbs
142	7720	YTH(2)		Effective thrust output for engine 2		lbs
156	10000.0	H1	h_1	Stabilator profile altitude breakpoint 1		ft
157	0.00075	DELDS1	$\Delta\delta_{s1}$	Stabilator increment 1		deg
170	12.0	NX, ANX	n_x	Number of nonlinear states		---
171	4.0	NU, ANU	n_u	Number of controls		---
172	6.0	NW, ANW	n_w	Number of disturbances		---
201	10.0	DX(1)	δ_u	Perturbation magnitude for u		ft/sec
202	5.0	DX(2)	δv	v		ft/sec
203	5.0	DX(3)	δw	w		ft/sec
204	0.01	DX(4)	δp	p		rad/sec
205	0.01	DX(5)	δq	q		rad/sec
206	0.01	DX(6)	δr	r		rad/sec
207	0.02	DX(7)	$\delta\theta$	θ		rad
208	0.02	DX(8)	$\delta\phi$	ϕ		rad
209	0.02	DX(9)	$\delta\psi$	ψ		rad
210	20.0	DX(10)	δx_e	x_e		ft
211	20.0	DX(11)	δy_e	y_e		ft
212	20.0	DX(12)	δh_e	h_e		ft
213	10.0		$\delta\dot{u}$	$\dot{u}$		ft/sec^2
214	5.0		$\delta\dot{v}$	$\dot{v}$		ft/sec^2
215	5.0		$\delta\dot{w}$	$\dot{w}$		ft/sec^2
216	0.01		$\delta\dot{p}$	$\dot{p}$		rad/sec^2
217	0.01		$\delta\dot{q}$	$\dot{q}$		rad/sec^2

Table I. Typical Parameter Inputs for Aircraft (continued)

A(1)	Quantity	Mnemonic	Symbol	Description	Initial Value	Units
218	0.01		$\delta\dot{r}$	Perturbation magnitude for $\dot{r}$		rad/sec^2
221	0.05	DU(1)	$\delta(\delta_a)$	δ_a		deg
222	0.05	DU(2)	$\delta(\delta_s)$	δ_s		deg
223	0.05	DU(3)	$\delta(\delta_r)$	δ_r		deg
224	0.05	DU(4)	$\delta(\delta_{sp})$	δ_{sp}		deg
231	5.0	DW(1)	δu_a	u_a		ft/sec
232	5.0	DW(2)	δv_a	v_a		ft/sec
233	5.0	DW(3)	δw_a	w_a		ft/sec
234	0.01	DW(4)	δp_a	p_a		rad/sec
235	0.01	DW(5)	δq_a	q_a		rad/sec
236	0.01	DW(6)	δr_a	r_a		rad/sec
256	0.2	KQDOT	$K_{\dot{q}}$	Trim stabilator gain on $\dot{q}$		deg/rad/sec^2
257	- 0.25	KQ	K_q	Trim stabilator gain on q		deg/rad/sec
258	0.1	KGAMDT	$K_{\dot{\gamma}}$	Trim stabilator gain on $\dot{\gamma}$		deg/rad/sec
259	- 0.3	KGAM	K_γ	Trim stabilator gain on γ		deg/rad
260	- 0.6981	GAMN	γ_o	Initial flight-path angle		rad
261	1.0	TINT	---	---		---
270	0.1047	QPU	q_{pu}	Pull-up pitch axis		rad/sec
274	4000.0	HP	h_p	Pull-up altitude		ft
283	30.0	TMAX	t_{max}	Maximum simulation time		sec
290	0.5236	PSIB	$\bar{\psi}$	Mean wind azimuth angle		rad
291	0.5236	THETAB	$\bar{\theta}$	Mean wind elevation angle		rad
292	2000.0	HNAUT	h_o	Reference altitude for mean wind		ft
293	30.0	VBNAUT	$\bar{V}_o$	Reference mean wind magnitude		ft/sec
391	1.0	EA(1, 1)	e_{a11}	Accelerometer alignment matrix direction cosines		
395	1.0	EA(2, 2)	e_{a22}			
399	1.0	EA(3, 3)	e_{a33}			
400	1.0	EV(1, 1)	e_{v11}	Velocity sensor alignment matrix direction cosines		
404	1.0	EV(2, 2)	e_{v22}			
408	1.0	EV(3, 3)	e_{v33}			
409	1.0	ECOMEG(1, 1)	$e_{\Omega 11}$	Attitude gyros, alignment matrix direction cosines		
413	1.0	ECOMEG(2, 2)	$e_{\Omega 22}$			
417	1.0	ECOMEG(3, 3)	$e_{\Omega 33}$			
418	1.0	EOMEGD(1, 1)	$e_{\dot{\omega} 11}$			
422	1.0	EOMEGD(2, 2)	$e_{\dot{\omega} 22}$			
426	1.0	EOMEGD(3, 3)	$e_{\dot{\omega} 33}$			
427	1.0	EOMEG(1, 1)	$e_{\omega 11}$			
431	1.0	EOMEG(2, 2)	$e_{\omega 22}$			
435	1.0	EOMEG(3, 3)	$e_{\omega 33}$			
501	- 313.5	XEX(1)	X_{ex}	X-coordinate of the thrust exit for engine 1		ft
502	- 313.5	XEX(2)		X-coordinate of the thrust exit for engine 2		ft
506	23.83	YEX(1)	Y_{ex}	Y-coordinate of the thrust exit for engine 1		ft
507	- 23.83	YEX(2)		Y-coordinate of the thrust exit for engine 2		ft
511	- 32.41	ZEX(1)	Z_{ex}	Z-coordinate of the thrust exit for engine 1		ft
512	- 32.41	ZEX(2)		Z-coordinate of the thrust exit for engine 2		ft
517	2.0	ANEX	N_{ex}	Number of thrust exits		

Table I. Typical Parameter Inputs for Aircraft (concluded)

A(1)	Quantity	Mnemonic	Symbol	Description	Initial Value	Units
559	20.0	XTH(1)	---	Thrust of engine 1		percent
560	20.0	XTH(2)	---	Thrust of engine 2		percent
579	- 316.0	XCA	---	X-coordinate of the moment reference center		ft
582	- 0.25	YAB(1)	---	Thrust vector azimuth bias for engine 1		deg
583	0.25	YAB(2)	---	Thrust vector azimuth bias for engine 2		deg
587	5.25	YEB(1)	---	Thrust vector elevation bias for engine 1		deg
588	5.25	YEB(2)	---	Thrust vector elevation bias for engine 2		deg
646	40.0	YDSB	δ_{sb}	Speed brakes deflection		deg
716	40420.0	WT	wt	Weight of the aircraft		lbs
901	7.0	AI(1)	u(loc)	State component location of u		
902	8.0	AI(2)	v(loc)	State component location of v		
903	9.0	AI(3)	w(loc)	State component location of w		
904	42.0	AI(4)	p(loc)	State component location for p		
905	43.0	AI(5)	q(loc)	q		
906	44.0	AI(6)	r(loc)	r		
907	31.0	AI(7)	θ(loc)	θ		
908	32.0	AI(8)	ϕ(loc)	ϕ		
909	33.0	AI(9)	ψ(loc)	ψ		
910	2.0	AI(10)	x_e(loc)	x_e		
911	3.0	AI(11)	y_e(loc)	y_e		
912	4.0	AI(12)	h_e(loc)	h_e		
913	17.0	AI(13)	$\dot{u}$(loc)	$\dot{u}$		
914	18.0	AI(14)	$\dot{v}$(loc)	$\dot{v}$		
915	19.0	AI(15)	$\dot{w}$(loc)	$\dot{w}$		
916	45.0	AI(16)	$\dot{p}$(loc)	$\dot{p}$		
917	46.0	AI(17)	$\dot{q}$(loc)	$\dot{q}$		
918	47.0	AI(18)	$\dot{r}$(loc)	$\dot{r}$		
919	39.0	AI(19)	$\dot{\theta}$(loc)	$\dot{\theta}$		
920	40.0	AI(20)	$\dot{\phi}$(loc)	$\dot{\phi}$		
921	41.0	AI(21)	$\dot{\psi}$(loc)	$\dot{\psi}$		
922	13.0	AI(22)	$\dot{x}_e$(loc)	$\dot{x}_e$		
923	14.0	AI(23)	$\dot{y}_e$(loc)	$\dot{y}_e$		
924	15.0	AI(24)	$\dot{h}_e$(loc)	$\dot{h}_e$		
925	123.0	AI(25)	δ_a(loc)	δ_a		
926	121.0	AI(26)	δ_s(loc)	δ_s		
927	125.0	AI(27)	δ_r(loc)	δ_r		
928	645.0	AI(18)	δ_{sp}(loc)	δ_{sp}		
929	101.0	AI(29)	u_g(loc)	Disturbance input location for u_g		
930	102.0	AI(30)	v_g(loc)	v_g		
931	103.0	AI(31)	w_g(loc)	w_g		
932	104.0	AI(32)	p_g(loc)	p_g		
933	105.0	AI(33)	q_g(loc)	q_g		
934	106.0	AI(34)	r_g(loc)	r_g		
995	2.0	SAC		Aircraft switch in Main		
996	2.0	SW		Weapon switch in Main		
998	1.00	ACWS		Aircraft weapon switch in wind filter		

Table II. Typical Parameter Inputs for Weapon

A(I)	Quantity	Mnemonic	Symbol	Description	Initial Value	Units
002	-4081.0	X	x_e	Range from target at release		ft
004	3995.0	H	h	Altitude		ft
007	858.1	U	u	Velocity along x_b axis		ft/sec
009	- 21.84	W	w	Velocity along z_b axis		ft/sec
031	- 0.7158	TH	θ	Pitch attitude		rad
043	- 0.01135	Q	q	Pitch rate		rad/sec
083	5.6	IX	I_x	Moment of inertia about x axis		slug ft^2
084	41.4	IY	I_y	Moment of inertia about y axis		slug ft^2
085	41.4	IZ	I_z	Moment of inertia about z axis		slug ft^2
090	32.17	G	g	Gravity		ft/sec^2
091	25.6	MASS	m	Mass		slug
115	1.33	B	b	Wing span of bomb		ft
131	100.0	N	N	No. of integration steps		
132	1.0		ΔT	Time interval		sec
134	1.0	DTOUT	---	Output interval		sec
147	2.0	TAPEUNIT	---	---		
170	12.0	NX	n_x	No. of weapon states		
171	2.0	NU	n_u	No. of control inputs		
172	3.0	NW	n_w	No. of distribution inputs		
201	2.0	DX(1)	δu	Perturbation magnitude for u		ft/sec
202	2.0	DX(2)	δv	v		ft/sec
203	2.0	DX(3)	δw	w		ft/sec
204	0.004	DX(4)	δp	p		rad/sec
205	0.004	DX(5)	ψq	q		rad/sec
206	0.004	DX(6)	δr	r		rad/sec
207	0.004	DX(7)	$\delta\theta$	θ		rad/sec
208	0.004	DX(8)	$\delta\phi$	ϕ		rad
209	0.004	DX(9)	$\delta\psi$	ψ		rad
210	20.0	DX(10)	δx_e	x_e		ft
211	20.0	DX(11)	δy_e	y_e		ft
212	20.0	DX(12)	δh_e	h_e		ft
221	2.0	DU(1)	$\delta(\delta_a)$	δ_a		deg
222	2.0	DU(2)	$\delta(\delta_s)$	δ_s		deg
231	2.0	DW(1)	δu_a	u_a		ft/sec
232	2.0	DW(2)	δv_a	v_a		ft/sec
233	2.0	DW(3)	δw_a	w_a		ft/sec
261	1.0	TINT	---	---		---

Table II. Typical Parameter Inputs for Weapon (concluded)

A(I)	Quantity	Mnemonic	Symbol	Description	Initial Value	Units
290	0.5236	PSIB	ψ	Mean wind azimuth angle		rad
291	0.5236	THETAB	θ	Mean wind elevation angle		rad
292	2000.0	HNAUT	h_o	Reference altitude for mean wind		ft
293	30.0	VBNAUT	v_o	Reference mean wind magnitude		ft/sec
294	1.33	BMBD	b_d	Bomb diameter		ft
901	7.0	AI(1)	u(loc)	State component location of u		
902	8.0	AI(2)	v(loc)	v		
903	9.0	AI(3)	w(loc)	w		
904	42.0	AI(4)	p(loc)	p		
905	43.0	AI(5)	q(loc)	q		
906	44.0	AI(6)	r(loc)	r		
907	31.0	AI(7)	θ(loc)	θ		
908	32.0	AI(8)	ϕ(loc)	ϕ		
909	33.0	AI(9)	ψ(loc)	ψ		
910	2.0	AI(10)	$x_{e(loc)}$	x_e		
911	3.0	AI(11)	$y_{e(loc)}$	y_e		
912	4.0	AI(12)	$h_{e(loc)}$	h_e		
913	17.0	AI(13)	$\dot{u}$(loc)	$\dot{u}$		
914	18.0	AI(14)	$\dot{v}$(loc)	$\dot{v}$		
915	19.0	AI(15)	$\dot{w}$(loc)	$\dot{w}$		
916	45.0	AI(16)	$\dot{p}$(loc)	$\dot{p}$		
917	46.0	AI(17)	$\dot{q}$(loc)	$\dot{q}$		
918	47.0	AI(18)	$\dot{r}$(loc)	$\dot{r}$		
919	39.0	AI(19)	$\dot{\theta}$(loc)	$\dot{\theta}$		
920	40.0	AI(20)	$\dot{\phi}$(loc)	$\dot{\phi}$		
921	41.0	AI(21)	$\dot{\psi}$(loc)	$\dot{\psi}$		
922	13.0	AI(22)	$\dot{x}_e$(loc)	$\dot{x}_e$		
923	14.0	AI(23)	$\dot{y}_e$(loc)	$\dot{y}_e$		
924	15.0	AI(24)	$\dot{h}_e$(loc)	$\dot{h}_e$		
925	263.0	AI(25)	δx	Canted fin longitudinal input		deg
926	264.0	AI(26)	δy	Canted fin lateral input		deg
927	101.0	AI(27)	u_g	Gust disturbance input		ft/sec
928	102.0	AI(28)	v_g	Gust disturbance input		ft/sec
929	103.0	AI(29)	w_g	Gust disturbance input		ft/sec
995	2.0	SAC		Aircraft switch in main		
996	2.0	SW		Weapon switch in main		
997	1.0	ACWS		A/C weapon switch in wind filter		

Table III. Representation of Aircraft Coefficients in Stability Axes

Coefficient	Look-Up Representation	Mnemonic	Units
$C_L(M_a, h, \alpha^o_w)$	F1(1, 2, 3)	CL	
$C_{z_q}(h, M_a)$	F2(2, 1)	CZQ	per radian
$C_{z_{\dot{\alpha}}}(h, M_a)$	F3(2, 1)	CZALDT	per radian
$C_{L_{\delta_s}}(h, \alpha^o_w, M_a)$	F4(2, 3, 1)	CLDS	per degree
$C_{L_{\delta_{sp}}}(h, M_a)$	F5(2, 1)	CLDSP	per degree
$C_{L_{\delta_a}}(h, M_a)$	F6(2, 1)	CLDA	per degree
$C_{L_{\delta_{sb}}}(\alpha^o_w, M_a)$	F7(3, 1)	CLDSB	per degree
$C_{L_{\delta_{lg}}}(\alpha^o_w)$	F8(3)	CLDLG	
$C_D(Pow, M_a C_L)$	F9(4, 1, 5)	CD	
$C_D(\delta^o_{sb}, C_L, M_a)$	F10(6, 5, 1)	CDDSB	
$C_{D_{\delta_{lg}}}(CL)$	F11(5)	CDDLG	
$C_{mca}(M_a, h, \alpha^o_w)$	F12(1, 2, 3)	CMCA	
$C_{m_q}(h, M_a)$	F13(2, 1)	CMQ	per radian
$C_{m_{\dot{\alpha}}}(h, M_a)$	F14(2, 1)	CMALDT	per radian

Table III. Representation of Aircraft Coefficients in Stability Axes (continued)

Coefficient	Look-Up Representation	Mnemonic	Units
$C_{m_{\delta_s}}(h, \alpha^{o}_{w}, M_a)$	F15(2, 3, 1)	CMDS	per degree
$C_{m_{\delta_{sp}}}(\alpha^{o}_{w}, h, M_a)$	F16(3, 2, 1)	CMDSP	per degree
$C_{m_{\delta_a}}(\alpha^{o}_{w}, h, M_a)$	F17(3, 2, 1)	CMDA	per degree
$C_{m_{\delta_{sb}}}(M_a, \alpha^{o}_{w})$	F18(3, 1)	CMDSB	per degree
$C_{m_{\delta_{lg}}}(\alpha^{o}_{w})$	F19(3)	CMDLG	
$C_{y_\beta}(\alpha^{o}_{w}, h, M_a)$	F20(3, 2, 1)	CYBET	per degree
$C_{y_r}(\alpha^{o}_{w}, h, M_a)$	F21(3, 2, 1)	CYR	per radian
$C_{y_p}(h, \alpha^{o}_{w}, M_a)$	F22(2, 3, 1)	CYP	per radian
$C_{y_{\delta_{sp}}}(M_a)$	F23(1)	CYDSP	per degree
$C_{y_{\delta_a}}(M_a)$	F24(1)	CYDA	per degree
$C_{y_{\delta_r}}(h, M_a)$	F25(2, 1)	CYDR	per degree
$C_{n_\beta}(\alpha^{o}_{w}, h, M_a)$	F26(3, 2, 1)	CNBET	per degree
$C_{n_r}(M_a, h, \alpha^{o}_{w})$	F27(3, 2, 1)	CNR	per radian

Table III. Representation of Aircraft Coefficients in Stability Axes (continued)

Coefficient	Look-Up Representation	Mnemonic	Units
$C_{n_p}(h, \alpha^{o}_{w}, M_a)$	F28(2, 3, 1)	CNP	per radian
$C_{n_{\delta_{sp}}}(\alpha^{o}_{w}, M_a)$	F29(3, 1)	CNDSP	per degree
$C_{n_{\delta_a}}(\alpha^{o}_{w}, h, M_a)$	F30(3, 2, 1)	CNDA	per degree
$C_{n_{\delta_r}}(h, M_a)$	F31(2, 1)	CNDR	per degree
$C_{l_\beta}(\alpha^{o}_{w}, h, M_a)$	F32(3, 2, 1)	CLLBET	per degree
$C_{l_r}(\alpha^{o}_{w}, h, M_a)$	F33(3, 2, 1)	CLLR	per radian
$C_{l_p}(\alpha^{o}_{w}, h, M_a)$	F34(3, 2, 1)	CLLP	per radian
$C_{l_{\delta_{sp}}}(\alpha^{o}_{w}, h, M_a)$	F35(3, 2, 1)	CLLDSP	per degree
$C_{l_{\delta_a}}(\alpha^{o}_{w}, h, M_a)$	F36(3, 2, 1)	CLLDA	per degree
$C_{l_{\delta_r}}(\alpha^{o}_{w}, h, M_a)$	F37(3, 2, 1)	CLLDR	per degree
$X_{c.g.}(Y_{trm}, W_T)$	F45(10, 15)	XCG	inches
$Z_{c.g.}(Y_{trm}, W_T)$	F46(10, 15)	ZCG	inches
$I_x(Y_{trm}, W_T)$	F47(10, 15)	IX	$slug/ft^2$
$I_y(Y_{trm}, W_T)$	F48(10, 15)	IY	$slug/ft^2$

Table III. Representation of Aircraft Coefficients in Stability Axes (concluded)

Coefficient	Look-Up Representation	Mnemonic	Units
$I_z(Y_{trm}, W_T)$	F49(10, 15)	IZ	$slug/ft^2$
$I_{xz}(Y_{trm}, W_T)$	F50(10, 15)	IXZ	$slug/ft^2$
$\rho(h)$	F53(2)	RHO	lbs/ft^3
a(h)	F54(2)	SOS	ft/sec
Argument	**Look-Up Representation**	**Mnemonic**	**Units**
M	V(1)	MACH	
h	V(2)	H	feet
α^o_w	V(3)	AL+1°	degrees
Power	V(4)	POW	per unit
C_L	V(5)	CL	
δ_{sb}	V(6)	YDSB	degree
δ_s	V(7)	YDS	degree
Y_{trm}	V(10)	YTRM	degree
W_T	V(15)	WT	lbs

Table IV. Representation of Bomb Aerodynamic Coefficients in Cross-Velocity Axes

Coefficient	Look-Up Representation	Mnemonic	Units.
$C_N(\hat{\alpha}^o, M_a)$	F75(3, 1)	CN	
$C_{N_\delta}(\hat{\alpha}^o, M_a)$	F76(3, 1)	CNDEL	per degree
$C_A(M_a)$	F77(1)	CA	
$C_m(\hat{\alpha}^o, M_a)$	F78(3, 1)	CM	per degree
$C_{m_q}(\hat{\alpha}^o, M_a)$	F79(3, 1)	CMQ	per degree
$C_{m_\delta}(\hat{\alpha}^o, M_a)$	F80(3, 1)	CMDEL	per degree
Argument	**Look-Up Representation**	**Mnemonic**	**Units**
M	V(1)	MACH	
h	V(2)	H	feet
$\hat{\alpha}^o$	V(3)	ALFH	degrees

```
1
C 03/23/72
C  H0= 12000 FT,V0=250 KNTS
C INTEGRATION AND LINEARIZATION OF AIRPLANE
C NOMINAL PERTURBATION
C 40 DEGREE DIVE ANGLE
PCC
   2 -.1381E+05   4 +.1200E+05  16 +.4225E+03  26 +.3665E-01  29 +.3665E-01
  31 -.6614E+00  43 -.1745E-02  90 +.3217E+02 115 +.3867E+02 116 +.1604E+02
 117 +.5300E+03 121 +.1000E+00 122 +.1330E-02 131 +.1000E+03 132 +.1000E+01
 134 +.1000E+01 140 +.7000E+00 141 +.7720E+04 142 +.7720E+04 156 +.1000E+05
 157 +.7500E-03 170 +.1200E+02 171 +.4000E+01 172 +.6000E+01 201 +.1000E+02
 202 +.5000E+01 203 +.5000E+01 204 +.1000E-01 205 +.1000E-01 206 +.1000E-01
 207 +.2000E-01 208 +.2000E-01 209 +.2000E-01 210 +.2000E+02 211 +.2000E+02
 212 +.2000E+02 213 +.1000E+02 214 +.5000E+01 215 +.5000E+01 216 +.1000E-01
 217 +.1000E-01 218 +.1000E-01 221 +.5000E-01 222 +.5000E-01 223 +.5000E-01
 224 +.5000E-01 231 +.5000E+01 232 +.5000E+01 233 +.5000E+01 234 +.1000E-01
 235 +.1000E-01 236 +.1000E-01 256 +.2000E+00 257 -.3000E+00 258 +.1000E+00
 259 -.3000E+00 260 -.6981E+00 261 +.1000E+01 270 +.1047E+00 274 +.4000E+04
 283 +.3000E+02 290 +.5236E+00 291 +.5236E+00 292 +.2000E+04 293 +.3000E+02
 391 +.1000E+01 395 +.1000E+01 399 +.1000E+01 400 +.1000E+01 404 +.1000E+01
 408 +.1000E+01 409 +.1000E+01 413 +.1000E+01 417 +.1000E+01 418 +.1000E+01
 422 +.1000E+01 426 +.1000E+01 427 +.1000E+01 431 +.1000E+01 435 +.1000E+01
 501 -.3135E+03 502 -.3135E+03 506 +.2383E+02 507 -.2383E+02 511 -.3241E+02
 512 -.3241E+02 517 +.2000E+01 559 +.2000E+02 560 +.2000E+02 579 -.3162E+03
 582 -.2500E+00 583 +.2500E+00 587 +.5250E+01 588 +.5250E+01 646 +.4000E+02
 716 +.4042E+05 901 +.7000E+01 902 +.8000E+01 903 +.9000E+01 904 +.4200E+02
 905 +.4300E+02 906 +.4400E+02 907 +.3100E+02 908 +.3200E+02 909 +.3300E+02
 910 +.2000E+01 911 +.3000E+01 912 +.4000E+01 913 +.1700E+02 914 +.1800E+02
 915 +.1900E+02 916 +.4500E+02 917 +.4600E+02 918 +.4700E+02 919 +.3900E+02
 920 +.4000E+02 921 +.4100E+02 922 +.1300E+02 923 +.1400E+02 924 +.1500E+02
 925 +.1230E+03 926 +.1210E+03 927 +.1250E+03 928 +.6450E+03 929 +.1010E+03
 930 +.1020E+03 931 +.1030E+03 932 +.1040E+03 933 +.1050E+03 934 +.1060E+03
 995 +.2000E+01 996 +.2000E+01 998 +.1000E+01
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1

```
RUN
    3    1 1    2 2    3 3    1
  1            0.5       0.9
  2            0.0  20000.0
  3           -4.0       8.0      16.0      20.0
              -.22       .44       .78       .80
              -.22       .47       .82       .85
              -.25       .46       .74       .80
              -.27       .51       .82       .89
 -1
    2    5 2    4 1           2
  5            0.0  15000.0
  4            0.6       0.95
             -2.25     -2.15
             -2.40     -2.35
 -1
    2    5 2    6 1           3
  5
  6            0.6       0.8       0.95
              -.66      -.62      -.79
              -.72      -.71      -.86
 -1
    3    7 2    8 3    9 1    4
  7            0.0  20000.0
  8            6.0      12.0      16.0      20.0
  9            0.4       0.9
             .0069     .0057
             .0067     .0052
             .0064     .0046
             .0058     .0030
             .0071     .0064
             .0068     .0059
             .0065     .0050
             .0059     .0032
 -1
    2   10 2   11 1           5
 10            0.0  25000.0
 11            0.4       1.1
           -.00040   -.00040
           -.00055   -.00055
 -1
    2   10 2   12 1           6
 10
 12            0.4       0.7       1.05
             .00260    .00180    .00055
             .00270    .00220    .00140
 -1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  2  14 3  13 1          7
14          0.0      4.0      8.0     12.0
13          0.5      0.7      0.9
          .00135   .00145   .00295
          .00305   .00295   .00220
          .00100   .00105   .00100
          .00020   .00020  -.00030
-1
  1  15 3                  8
15         -4.0      4.0     12.0     14.0     16.0     20.0
          -.0140   -.0145   -.0155   -.0175   -.0230   -.0460
-1
  3  16 4  17 1  18 5   9
16          0.0      1.0
17          0.4      0.8      1.0
18          0.0      0.1      0.2
          .0180    .0190    .0225
          .0185    .0200    .0230
          .0360    .0380    .0430
          .0105    .0115    .0150
          .0105    .0115    .0150
          .0275    .0290    .0335
-1
  3  19 6  21 5  20 1  10
19          0.0     20.0     40.0
21          0.3      0.7      0.9
20         0.15     0.30     0.45      1.0
            0.0      0.0      0.0      0.0
            0.0      0.0      0.0      0.0
            0.0      0.0      0.0      0.0
          .0095    .0100    .0130    .0190
          .0090    .0100    .0130    .0210
          .0085    .0100    .0125    .0195
          .0250    .0250    .0300    .0395
          .0235    .0245    .0290    .0410
          .0225    .0240    .0295    .0400
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  1  22 5                    11
22          -.2        .2         .4         .6        .7      .775
          .0194     .0165      .0146      .0118     .0090     .0030
-1
  3  30 1  31 2  32 3  12
30           0.5        0.8       0.95
31           0.0 10000.0  30000.0
32          -4.0        6.0       10.0       18.0
            .025      -.014      -.026      -.025
            .026      -.015      -.028      -.028
            .028      -.016      -.029      -.031
            .023      -.011      -.021      -.028
            .030      -.015      -.025      -.032
            .034      -.018      -.029      -.038
            .029      -.026      -.032      -.052
            .034      -.035      -.040      -.063
            .039      -.041      -.048      -.07
-1
  2  33 2  34 1           13
33           0.0 15000.0
34           0.6        0.8
           -2.30      -2.25
           -2.45      -2.40
-1
  2  33 2  35 1           14
33
35           0.6        0.8       0.95
            -.97       -.95     -1.16
           -1.08      -1.03     -1.23
-1
  3  36 2  37 3  38 1  15
36           0.0 20000.0
37           6.0       12.0       16.0       20.0
38           0.4        0.6        0.9
          -.0100     -.0093     -.0083
          -.0097     -.0089     -.0075
          -.0092     -.0082     -.0065
          -.0085     -.0072     -.0044
          -.0102     -.0099     -.0094
          -.0099     -.0094     -.0084
          -.0095     -.0087     -.0071
          -.0092     -.0076     -.0047
-1
  3  39 3  40 2  42 1  16
39           0.0        8.0       16.0
40           0.0 15000.0
42           0.4        0.8       0.95
          .00012     .00018     .00035
          .00013     .00021     .00039
          .00006     .00015     .00030
          .00007     .00018     .00034
          .00003     .00018     .00036
          .00003     .00018     .00036
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  3  39 3  40 2  41 1  17
39
40
41          0.5      0.7      0.9
        -.00097 -.00091 -.00103
        -.00101 -.00096 -.00111
        -.00080 -.00081 -.00096
        -.00085 -.00086 -.00105
        -.00066 -.00076 -.00104
        -.00070 -.00080 -.00110
-1
  2  43 3  44 1         18
43          0.0      4.0      8.0     12.0
44          0.5     0.75     1.0
       0.00009 0.00009 -.00002
       -.00001 -.00016 0.00030
       0.00022 0.00022 0.00056
       0.00038 0.00040 0.00107
-1
  1  45 3               19
45        -8.0     -4.0      4.0     16.0     20.0
         .0026    .0020    .0003 -0.0030 -0.0043
-1
  3  39 3  40 2  46 1  20
39
40
46           .2       .8      1.0
        -.0114  -.0120  -.0124
        -.0114  -.0120  -.0125
        -.0105  -.0111  -.0108
        -.0105  -.0111  -.0112
        -.0096  -.0101  -.0098
        -.0096  -.0101  -.0100
-1
  3  39 3  40 2  46 1  26
39
40
46
        .00195  .00200  .00230
        .00195  .00205  .00240
        .00200  .00215  .00210
        .00200  .00215  .00225
        .00180  .00190  .00190
        .00180  .00190  .00200
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  3  39 3  40 2  47 1  32
39
40
47          0.4       0.8       1.0
         -.00055 -.00060 -.00063
         -.00055 -.00060 -.00065
         -.00135 -.00115 -.00105
         -.00140 -.00135 -.00125
         -.00 92 -.00075 -.00075
         -.00 97 -.00103 -.00100
-1
  3  48 3  40 2  47 1  21
48          0.0       4.0       8.0      12.0
40
47
            .295      .320      .325
            .295      .320      .330
            .295      .310      .315
            .295      .310      .320
            .280      .300      .305
            .280      .300      .320
            .275      .295      .295
            .275      .295      .310
-1
  3  48 3  40 2  47 1  27
48
40
47
           -.230     -.250     -.270
           -.230     -.250     -.275
           -.225     -.240     -.255
           -.225     -.240     -.260
           -.220     -.230     -.245
           -.220     -.230     -.245
           -.220     -.225     -.245
           -.220     -.225     -.245
-1
  3  49 3  40 2  50 1  33
49         -4.0       0.0       4.0       8.0      12.0      16.0
40
50            .4        .7        .95
           -.012     -.017     -.016
            .008     -.008     -.006
            .029      .035      .041
            .030      .037      .044
            .012      .076      .083
            .012      .081      .087
            .012      .096      .113
            .012      .097      .114
            .032      .107      .140
            .032      .109      .141
            .089      .110      .156
            .090      .111      .159
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  3   40 2   51 3   52 1   22
40
51          -12.0      -8.0        .0       8.0      12.0      16.0
52             .4         .8
             -.38       -.25
             -.39       -.35
             -.02       -.03
              .36        .27
              .35        .22
              .03        .00
             -.39       -.28
             -.40       -.37
             -.01       -.02
              .38        .30
              .34        .25
              .02        .00
-1
  3   40 2   51 3   53 1   28
40
51
53             .4        1.0
             .008       .032
             .060       .072
             .012       .023
            -.036      -.022
             .014      -.010
             .124       .070
            -.004       .048
             .072       .072
             .014       .020
            -.040      -.030
             .020      -.000
             .164       .084
-1
  3   54 3   55 2   56 1   34
54             0.0        4.0        8.0      12.0
55             0.0 10000.0 20000.0
56              .5         .9
            -.200      -.170
            -.210      -.185
            -.215      -.205
            -.210      -.165
            -.220      -.180
            -.225      -.205
            -.220      -.150
            -.230      -.165
            -.235      -.180
            -.200      -.115
            -.205      -.125
            -.215      -.135
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  1  57 1                  23
57          0.3      1.2      1.4      2.0
      -.000060-.000060-.000130-.000060
-1
  1  58 1                  24
58          0.3      1.2      1.4      1.6      2.0
      -.000165-.000165-.000030 .0000200.000020
-1
  2  40 2  59 1            25
40
59          0.0      0.4      0.8
         .00223   .00205   .00171
         .00223   .00210   .00184
-1
  2  60 3  61 1            29
60          0.0      8.0     16.0
61          0.5      0.9
        .000055 .000068
        .000022 .000017
       -.000011-.0000 4
-1
  3  60 3  40 2  62 1  30
60
40
62          0.4      0.9
       -.000048-.000037
       -.000048-.000037
       -.000114-.000077
       -.000116-.000083
       -.000181-.000160
       -.000184-.000165
-1
  2  40 2  63 1            31
40
63          0.0      0.4      0.8
       -.00140 -.00130 -.00101
       -.00140 -.00134 -.00111
-1
  3  70 3  71 2  72 1  35
70          0.0      4.0      8.0     12.0
71          0.0 10000.0 20000.0
72          0.3       .6       .8       .95
       .000119 .000129 .000143 .000160
       .000122 .000136 .000158 .000178
       .000124 .000142 .000169 .000198
       .000157 .000152 .000148 .000160
       .000162 .000162 .000163 .000180
       .000167 .000167 .000174 .000200
       .000121 .000124 .000120 .000110
       .000123 .000131 .000128 .000126
       .000126 .000136 .000143 .000140
       .000062 .000 62 .000062 .000059
       .000065 .000 68 .000068 .000070
       .000067 .000 71 .000073 .000076
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  3  70 3  71 2  73 1  36
70
71
73          0.3      0.6      0.8      1.0
          .00053   .00039   .00023   .00000
          .00055   .00043   .00029   .00008
          .00057   .00047   .00035   .00015
          .00051   .00040   .00023  -.00001
          .00054   .00044   .00031   .00009
          .00057   .00048   .00034   .00019
          .00058   .00039   .00023  -.00001
          .00060   .00043   .00030   .00007
          .00062   .00047   .00035   .00014
          .00042   .00033   .00019  -.00001
          .00045   .00037   .00024   .00005
          .00047   .00041   .00029   .00013
-1
  3  74 3  75 2  76 1  37
74          0.0      4.0     12.0     16.0
75          0.0 15000.0
76         0.0       0.4      0.8
         .000225  .000220  .000210
         .000225  .000225  .000225
         .000110  .000106  .000104
         .000110  .000108  .000110
        -.000110-.000109-.000110
        -.000110-.000109-.000115
        -.000225-.000220-.000210
        -.000225-.000225-.000225
-1
  2  23 7  24 8          38
23        -21.0    -11.0     -1.0      7.0
24          0.0      2.0      3.0      4.0
          0.115    -.057    -.140    -.230
          0.077    -.110    -.197    -.284
          0.022    -.133    -.231    -.304
          -.014    -.176    -.245    -.304
-1
  2  23 7  24 8          39
23
24
            .315     .157     .078      0.0
            .298     .150     .075      0.0
            .267     .134     .066      0.0
            .234     .119     .057      0.0
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  2  23 7  24 8          40
23
24
             .87    -0.24    -0.48    -0.68
             .40    -0.55    -0.91    -1.28
            0.13    -0.92    -1.46    -2.12
           -0.13    -1.28    -2.00    -2.90
-1
  1  23 7                 41
23
           4.95     5.20     5.05     4.55
-1
  1  25 9                 42
25        -10.38   -.0001    .0001   10.38
          -11.55   -2.31     2.31    11.55
-1
  2  2812  2711           43
28          -8.0      8.0
27          -3.0     -1.5      1.5      3.0
           -75.0    -25.0     60.0    130.0
          -130.0    -60.0     25.0     75.0
-1
  1  64 1                 44
64           0.2      0.4      0.65     1.0      1.2      2.0
            0.21     0.36     0.45     0.39     0.43     0.61
-1
  2  6510  6615           45
65           0.0    100.
66       32000.0 37500.0 43000.0
           317.4    317.9    325.4
           317.4    317.9    325.4
-1
  2  6510  6615           46
65
66
             24.5     28.4     28.7
             23.7     26.7     27.3
-1
  2  6510  6615           47
65
66
          21900.   24097.   27432.
          23492.   26572.   29917.
-1
  2  6510  6615           48
65
66
         121000. 126665. 138521.
         123716. 128976. 140844.
-1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
   2  6510  6615          49
  65
  66
         137000. 143576. 157697.
         139989. 146129. 160250.
  -1
   2  6510  6615          50
  65
  66
           3600.0  3801.  5880.
           3539.   3782.  5959.
  -1
   1  6713                51
  67          0.0    50.0 50.0001   100.0
         .000217 .000239 .000389 .000540
  -1
   1  6714                52  51
  -1
   1  68 2                53
  68    0.0      10000.  20000.  30000.  40000.  50000.  60000.
        .002377 .001755 .001266 .0008893.0005851.0003618.0002237
  -1
   1  69 2                54
  69    0.0      10000.  20000.  30000.  37000.  60000.
        1117.    1078.   1037.   995.    969.    969.
  -1
  -1
C 03/23/72
C  INTEGRATION AND LINERIZATION OF WEAPON M117 DATA
C DOUBLE NOMINAL PERTURBATION
PCC
   2 -.4081E+04   4 +.3995E+04   7 +.8581E+03   9 -.2184E+02  31 -.7158E+00
  43 -.1135E-01  83 +.5600E+01  84 +.4140E+02  85 +.4140E+02  90 +.3217E+02
  91 +.2560E+02 115 +.1330E+01 131 +.1000E+03 132 +.1000E+01 134 +.1000E+01
 147 +.2000E+01 170 +.1200E+02 171 +.2000E+01 172 +.3000E+01 201 +.2000E+01
 202 +.2000E+01 203 +.2000E+01 204 +.4000E-02 205 +.4000E-02 206 +.4000E-02
 207 +.4000E-02 208 +.4000E-02 209 +.4000E-02 210 +.2000E+02 211 +.2000E+02
 212 +.2000E+02 221 +.2000E+01 222 +.2000E+01 231 +.2000E+01 232 +.2000E+01
 233 +.2000E+01 261 +.1000E+01 290 +.5236E+00 291 +.5236E+00 292 +.2000E+04
 293 +.3000E+02 294 +.1330E+01 901 +.7000E+01 902 +.8000E+01 903 +.9000E+01
 904 +.4200E+02 905 +.4300E+02 906 +.4400E+02 907 +.3100E+02 908 +.3200E+02
 909 +.3300E+02 910 +.2000E+01 911 +.3000E+01 912 +.4000E+01 913 +.1700E+02
 914 +.1800E+02 915 +.1900E+02 916 +.4500E+02 917 +.4600E+02 918 +.4700E+02
 919 +.3900E+02 920 +.4000E+02 921 +.4100E+02 922 +.1300E+02 923 +.1400E+02
 924 +.1500E+02 925 +.2630E+03 926 +.2640E+03 927 +.1010E+03 928 +.1020E+03
 929 +.1030E+03 995 +.2000E+01 996 +.2000E+01 997 +.1000E+01
RUN
   1   1 1                 77
   1    0.0     0.80    0.95    1.0     1.1     1.2     1.3     1.5
        0.12    0.11    0.11    0.14    0.27    0.30    0.29    0.28
  -1
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (continued)

```
  2    2 1    3 3          75
 2     0.0      0.40      0.80      1.20      1.50
 3     0.0      4.0       8.0       12.0      16.0      20.0      24.0
       0.0      0.24      0.62      1.02      1.59      2.04      2.70
       0.0      0.24      0.62      1.02      1.57      2.04      2.66
       0.0      0.24      0.63      1.08      1.60      2.08      2.62
       0.0      0.33      0.74      1.19      1.64      2.28      3.32
       0.0      0.35      0.71      1.17      1.83      2.63      3.71
-1
  2    4 1    5 3          76
 4     0.0      0.40      0.80      1.20      1.50
 5     0.0      16.0      20.0      24.0
       0.0      0.0       0.0       -.09
       0.0      0.0       0.0       -.09
       0.0      -.03      -.08      -.23
       0.0      -.10      -.13      -.15
       0.0      -.06      -.09      -.11
-1
  2    6 1    7 3          78
 6     0.0      0.40      0.80      1.2       1.5
 7     0.0      4.0       8.0       12.0      16.0      20.0      24.0
       0.0      -.30      -.77      -1.65     -2.52     -3.56     -4.02
       0.0      -.30      -.77      -1.65     -2.52     -3.56     -4.02
       0.0      -.24      -.98      -1.72     -2.49     -3.25     -3.60
       0.0      -.37      -1.04     -1.67     -2.17     -2.63     -3.14
       0.0      -.27      -.63      -1.10     -1.57     -2.07     -2.58
-1
  2    8 1    9 3          80
 8     0.0      0.5       0.9       1.3       1.5
 9     0.0      10.       16.0      20.0      24.0
       0.0      0.0       0.0       -.08      -.42
       0.0      0.0       0.0       -.08      -.42
       0.0      -.03      -.08      -.27      -.66
       0.0      -.04      -.10      -.16      -.47
       0.0      -.04      -.08      -.12      -.33
-1
  2   10 1   11 3          79
10     0.0      0.6       0.9       1.20      1.50
11     0.0      10.0      20.0      30.0
       -75.0    -94.0     -125.0    -143.0
       -75.0    -94.0     -125.0    -143.0
       -80.0    -175.0    -200.0    -240.0
       -158.0   -200.0    -215.0    -230.0
       -155.0   -170.0    -180.0    -195.0
-1
  1   68 2                53
68     0.0      10000.    20000.    30000.    40000.    50000.    60000.
       .002377  .001755   .001266   .0008893  .0005851  .0003618  .0002237
-1
  1   69 2                54
69     0.0      10000.    20000.    30000.    37000.    60000.
       1117.    1078.     1037.     995.      969.      969.
-1
-1
STO
```

Figure 1. Typical Parameter and Table Inputs to ADAP 1 (concluded)

LIST OF NON-ZERO ELEMENTS IN A(1). THRU. A(1000)

1	1.0000E+00	2	-1.3476E+04	4	1.1718E+04	5	4.2214E-01	6	1.0709E+03	7	4.5165E+02	9	1.9763E+01		
10	4.5165E+02	12	1.9763E+01	13	3.4457E+02	15	-2.9221E+02	16	4.5209E+02	17	2.9207E+01	19	2.1321E+00		
20	9.5323E+00	22	-2.4214E+01	26	3.6650E-02	28	-7.0336E-01	29	4.3728E-02	31	-6.5963E-01	37	1.8874E-03		
43	2.0050E-03	46	-4.4957E-03	48	-6.1422E-01	49	7.8913E-01	51	1.0000E+00	53	1.0000E+00	54	7.9022E-01		
56	-6.1282E-01	58	1.0000E+00	60	6.1282E-01	62	7.9022E-01	70	1.7053E+02	71	-3.3982E+03	73	-2.9011E+04		
78	3.3492E+03	81	2.0050E-03	83	2.5868E+04	84	1.3296E+05	85	1.5107E+05	88	4.9048E+03	89	1.0000E-02		
90	3.2170E+01	91	1.2565E+03	92	6.9848E-01	93	-3.2089E-01	95	4.7348E-01	108	-2.9202E+02	111	1.5375E+04		
112	-1.4128E+03	114	1.6709E-03	115	3.8670E+01	116	1.6040E+01	117	5.3000E+02	121	2.3300E-01	122	1.3300E-03		
131	1.0000E+02	132	1.0000E+00	134	1.0000E+00	138	1.0000E+00	140	7.0000E-01	141	7.7200E+03	142	7.7200E+03		
145	1.0000E+00	146	1.0000E+03	148	-4.6626E+03	150	-2.8835E+04	152	-1.0387E+04	156	1.0000E+04	157	7.5000E-04		
163	-3.2387E-01	165	6.6408E-04	167	1.9399E-03	170	1.2000E+01	171	4.0000E+00	172	6.0000E+00	201	1.0000E+01		
202	5.0000E+00	203	5.0000E+00	204	1.0000E-02	205	1.0000E-02	206	1.0000E-02	207	2.0000E-02	208	2.0000E-02		
209	2.0000E-02	210	2.0000E+01	211	2.0000E+01	212	2.0000E+01	213	1.0000E+01	214	5.0000E+00	215	5.0000E+00		
216	1.0000E-02	217	1.0000E-02	218	1.0000E-02	221	5.0000E-02	222	5.0000E-02	223	5.0000E-02	224	5.0000E-02		
231	5.0000E+00	232	5.0000E+00	233	5.0000E+00	234	1.0000E-02	235	1.0000E-02	236	1.0000E-02	256	2.0000E-01		
257	-3.0000E-01	258	1.0000E-01	259	-3.0000E-01	260	-6.9810E-01	261	1.0000E+00	265	2.5000E-03	266	5.0000E-03		
270	1.0470E-01	274	4.0000E+03	283	3.0000E+01	288	4.6953E+01	290	5.2360E-01	291	5.2360E-01	292	2.0000E+03		
293	3.0000E+01	295	1.3369E+01	296	2.0331E+01	297	-4.0155E+01	298	4.0885E+02	299	-2.0331E+01	300	5.5637E+01		
301	4.1312E+02	302	5.1510E+00	303	5.1510E+00	304	5.1510E+00	305	3.4426E-02	306	3.4426E-02	307	3.4426E-02		
308	8.3905E+00	309	8.3905E+00	310	1.1187E+01	311	4.2222E+02	313	1.5481E+01	315	-1.7450E-03	317	-6.6140E-01		
320	1.7301E+01	322	7.2862E+00	324	4.7374E-02	326	1.8295E+04	328	-1.3768E+00	329	-9.6593E+01	331	-2.2482E-02		
391	1.0000E+00	395	1.0000E+00	399	1.0000E+00	400	1.0000E+00	404	1.0000E+00	408	1.0000E+00	409	1.0000E+00		
413	1.0000E+00	417	1.0000E+00	418	1.0000E+00	422	1.0000E+00	426	1.0000E+00	427	1.0000E+00	431	1.0000E+00		
435	1.0000E+00	501	-3.1350E+02	502	-3.1350E+02	506	2.3830E+01	507	-2.3830E+01	511	-3.2410E+01	512	-3.2410E+01		
517	2.0000E+00	558	2.5000E-05	559	2.0000E+01	560	2.0000E+01	574	7.7200E+03	575	7.7200E+03	579	-3.1620E+02		
581	-2.8559E+01	582	-2.5000E-01	583	2.5000E-01	587	5.2500E+00	588	5.2500E+00	593	9.9580E-01	594	-9.1501E-02		
595	-2.5563E-01	596	9.9580E-01	597	-9.1501E-02	598	-2.5563E-01	601	-3.9470E+03	611	3.2188E+02	612	2.8559E+01		
646	4.0000E+01	661	2.6708E+02	700	-3.7794E+01	703	-4.0299E+01	705	-2.5758E-01	706	2.5054E+00	709	1.0814E-01		
712	1.1488E-01	716	4.0420E+04	801	2.0374E-01	802	-2.3672E+00	803	-7.0688E-01	804	6.9775E-03	805	-4.7032E-04		
806	2.5988E-03	807	2.8394E-03	808	-1.4469E-02	809	2.2527E-02	810	2.9062E-02	811	1.6465E-02	812	-4.7896E-03		
813	-2.4172E+00	814	-1.0560E+00	815	-1.0066E-02	816	1.0638E-04	817	-9.3021E-04	818	2.3905E-06	819	4.0532E-04		
820	-1.1228E-02	821	2.9589E-01	822	1.5542E-01	823	-6.0000E-05	824	-1.6500E-04	825	2.0739E-03	826	2.0147E-03		
827	-2.2647E-01	828	-9.1984E-03	829	4.0544E-05	830	-7.6677E-05	831	-1.3180E-03	832	-9.1711E-04	833	1.8600E-02		
834	-2.1962E-01	835	1.5858E-04	836	5.0534E-04	837	1.2202E-04	901	7.0000E+00	902	8.0000E+00	903	9.0000E+00		
904	4.2000E+01	905	4.3000E+01	906	4.4000E+01	907	3.1000E+01	908	3.2000E+01	909	3.3000E+01	910	2.0000E+00		
911	3.0000E+00	912	4.0000E+00	913	1.7000E+01	914	1.8000E+01	915	1.9000E+01	916	4.5000E+01	917	4.6000E+01		
918	4.7000E+01	919	3.9000E+01	920	4.0000E+01	921	4.1000E+01	922	1.3000E+01	923	1.4000E+01	924	1.5000E+01		
925	1.2300E+02	926	1.2100E+02	927	1.2500E+02	928	6.4500E+02	929	1.0100E+02	930	1.0200E+02	931	1.0300E+02		
932	1.0400E+02	933	1.0500E+02	934	1.0600E+02	995	2.0000E+00	996	2.0000E+00	998	1.0000E+00				

Figure 2. Typical A-Array Dump Output From ADAP 1 During Simulation

SECTION III
TESTING THE AIRCRAFT SOFTWARE

Aircraft software testing consisted of the following:

- Level-flight simulation and the linear data generation
- 40-degree dive and pull-up trajectory generation (with no thrust)
- 40-degree dive trajectory generation (with 75 percent of total thrust)
- Frozen-point spectrum analysis of the linear data

LEVEL FLIGHT

First, the main program was written to generate a level flight. This was accomplished by algebraic trimming and using the trimmed data in the aircraft flying mode. During level flight, linear data was obtained as shown in Figure 3.

40-DEGREE DIVE AND PULLUP TRAJECTORY

The main program was modified to generate a 40-degree dive trajectory for the linearization. This maneuver was accomplished by a proportional-plus-derivative controller from the flight-path angle to the stabilator as shown in Figure 4, with the gain values $K_\gamma = -3.0$, and $K_{\dot{\gamma}} = 2$ (subroutine PILOT).

The trajectory flown with zero thrust is shown in Figure 5. With a 40-degree dive, the exact crash point on the ground is 11,918 feet versus ADAP's result of 11,940 feet. The stabilator, angle-of-attack and flight-path angle profiles during a 40-degree dive maneuver are shown in Figure 6. As shown, the maximum deviation from the nominal flight path angle is about 0.1 degree. Figure 7 shows the time variation of various elements in the linear system matrix. As can be seen, the time variations during dive are in the form of

$$A(t) = A_o + A_1 t$$

This fact should be exploited to reduce computations in nonstationary optimization processes.

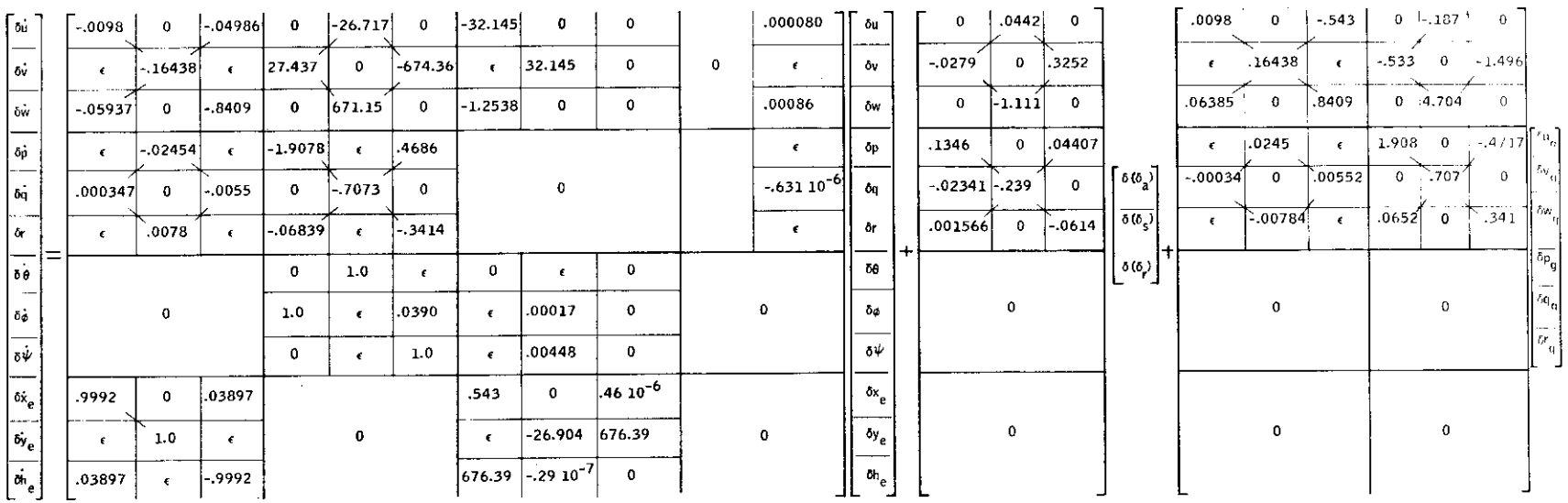


Figure 3. Linear Data for Level Flight

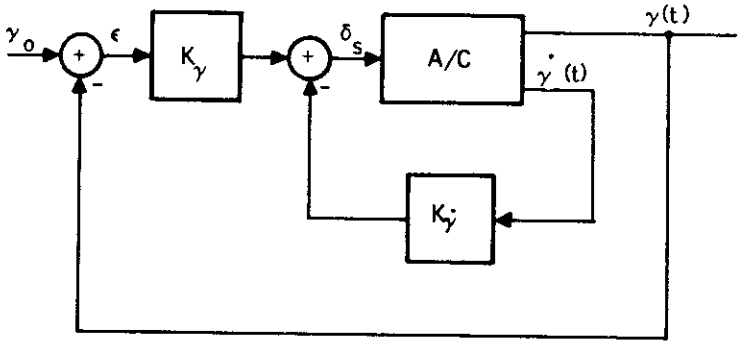


Figure 4. Flight-Path-Angle Controller for Trim

Next, the main program was modified to generate the pull-up nominal trajectory. A similar-type controller was used to obtain a constant pitch-up. The gain values were $K_q = -0.3$ and $K_{\dot{q}} = 0.2$. Figure 8 shows the flown nominal trajectory. Figure 9 shows the nominal flight-path angle flown. Figures 10 and 11 show respectively the nominal elevator profile and linear data for the pitching moment coefficient of the stabilator. Results can be refined further. For the purpose of linearization they were found to be satisfactory.

The 40-degree dive trajectory which has been obtained by using no thrust as discussed above, was modified by introducing 75 percent of the full thrust (i.e., 2 x 7720 pounds) into the program. The initial speed of the airplane was also modified from 400 knots down to 250 knots. Evidently this flight condition is very close to what a pilot does during dive bombing.

The flight-path angle was maintained within ±1 degree using the stabilator profile with two line segments.

The nonlinear dive trajectory was flown, and the linear data were generated and plotted against time as shown in Figures 12 through 48.

The majority of the time-varying data can be represented by straight lines. Some of the linear data (with smaller relative magnitudes) show rapid changes as functions of time. These can be attributed to two sources: (a) approximate trim profile and initial conditions and (b) straight-line approximation in the nonlinear aerodynamic data.

Smoother data can be obtained by using a better stabilator profile and a higher-order approximation to aerodynamic table functions. These are refinements, however.

The program listing for the plotting data is given in Figure 49. This is followed by typical trajectory input data in Figure 50. The plots of important trajectory variables are shown in Figures 51 through 59.

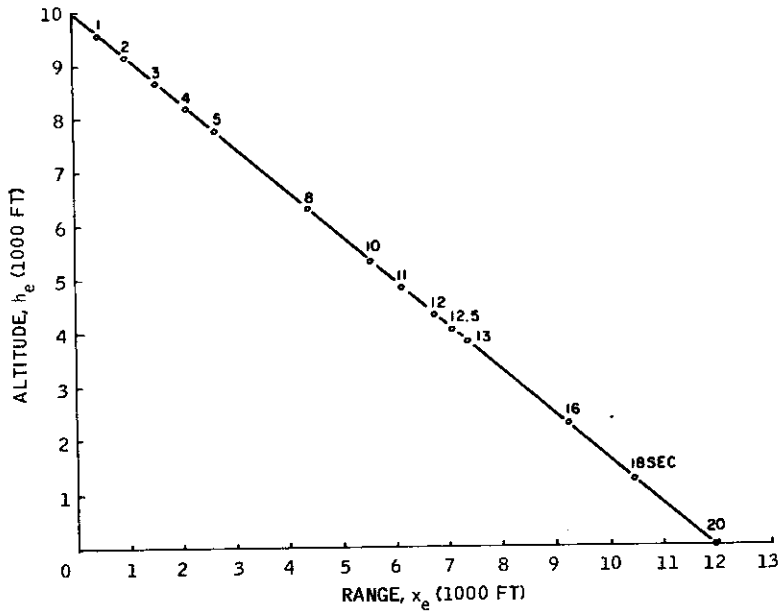


Figure 5. Zero-Thrust, 40-degree Dive Trajectory

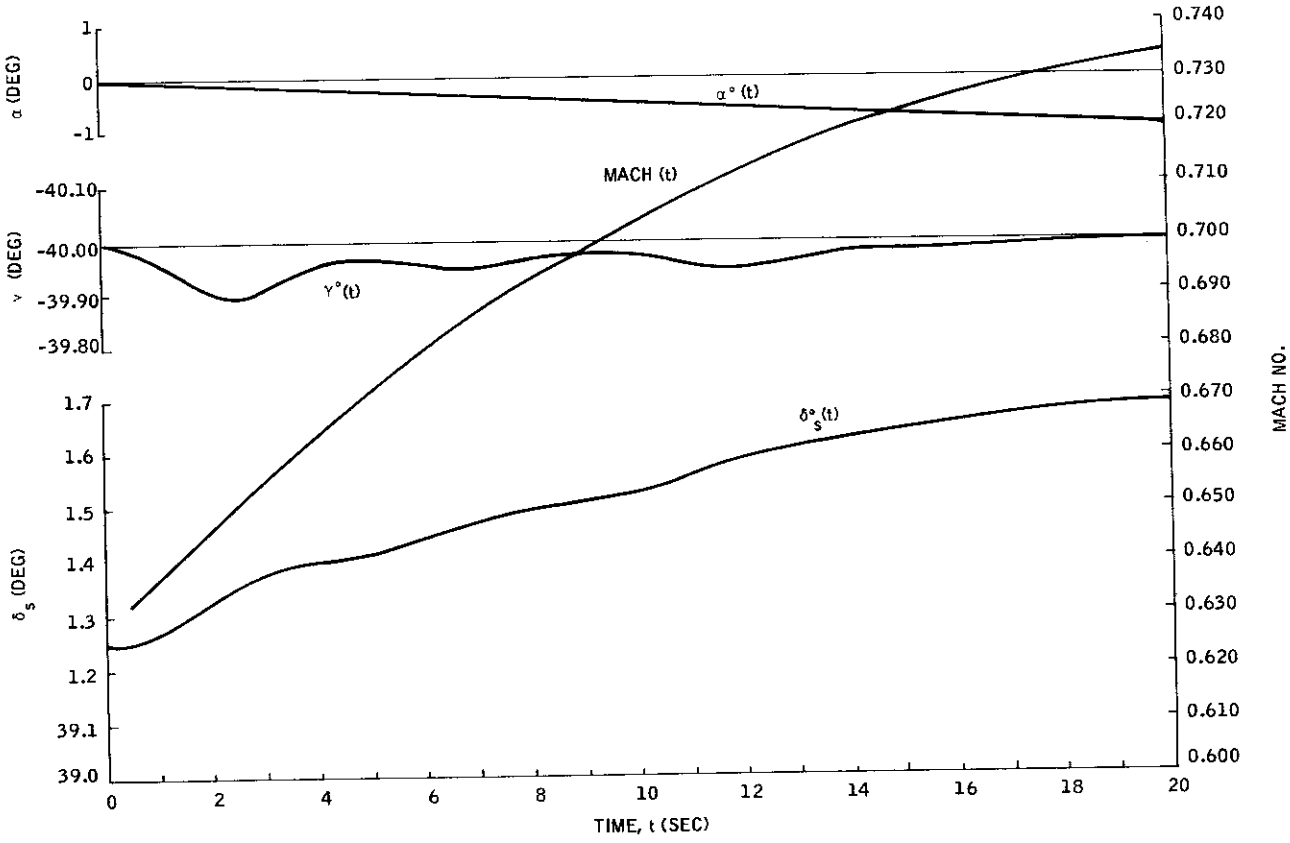


Figure 6. Stabilator, Angle-of-Attack and Flight-Path-Angle Profiles During Dive

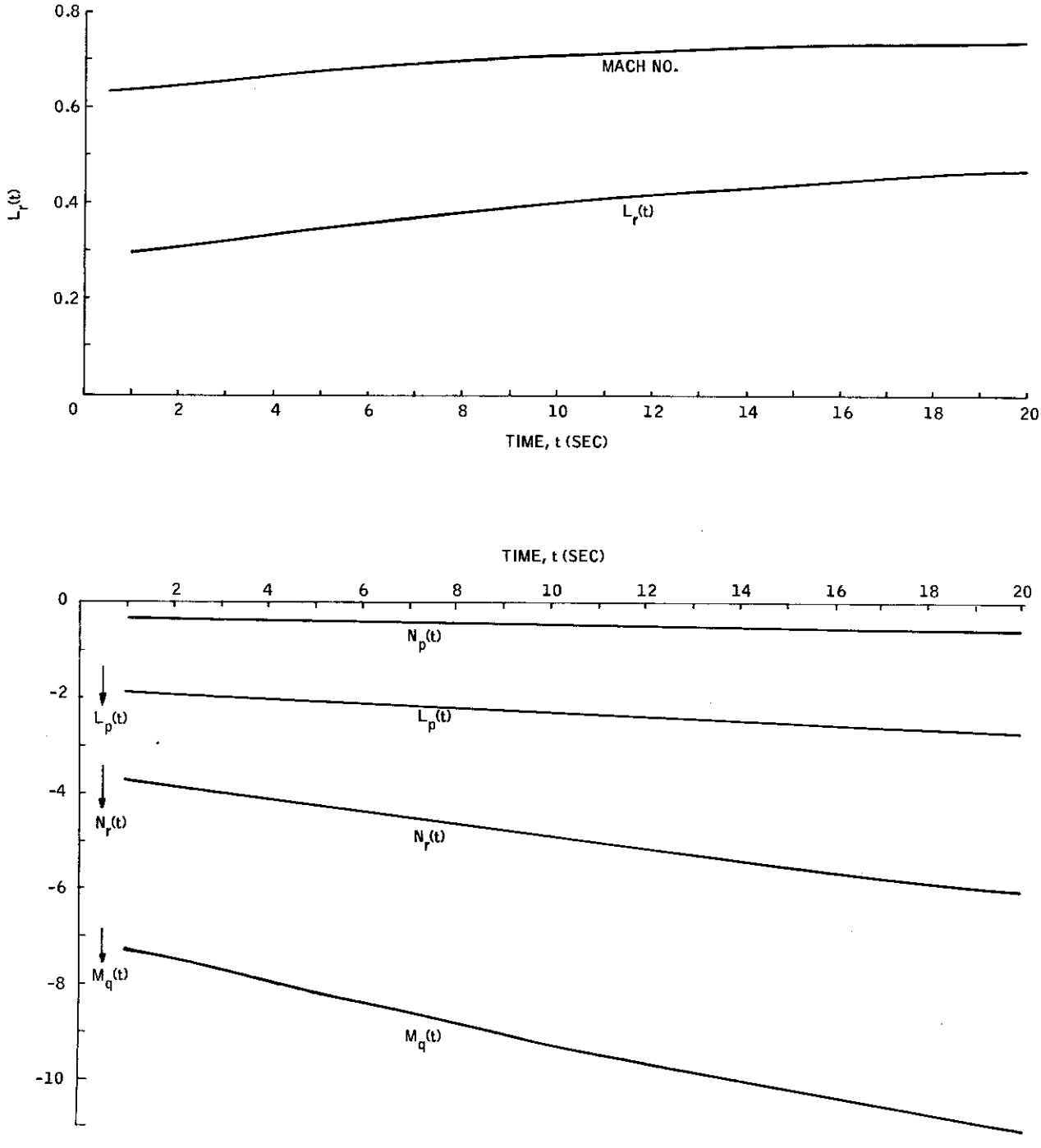


Figure 7. Linear Data for 40-degree Dive

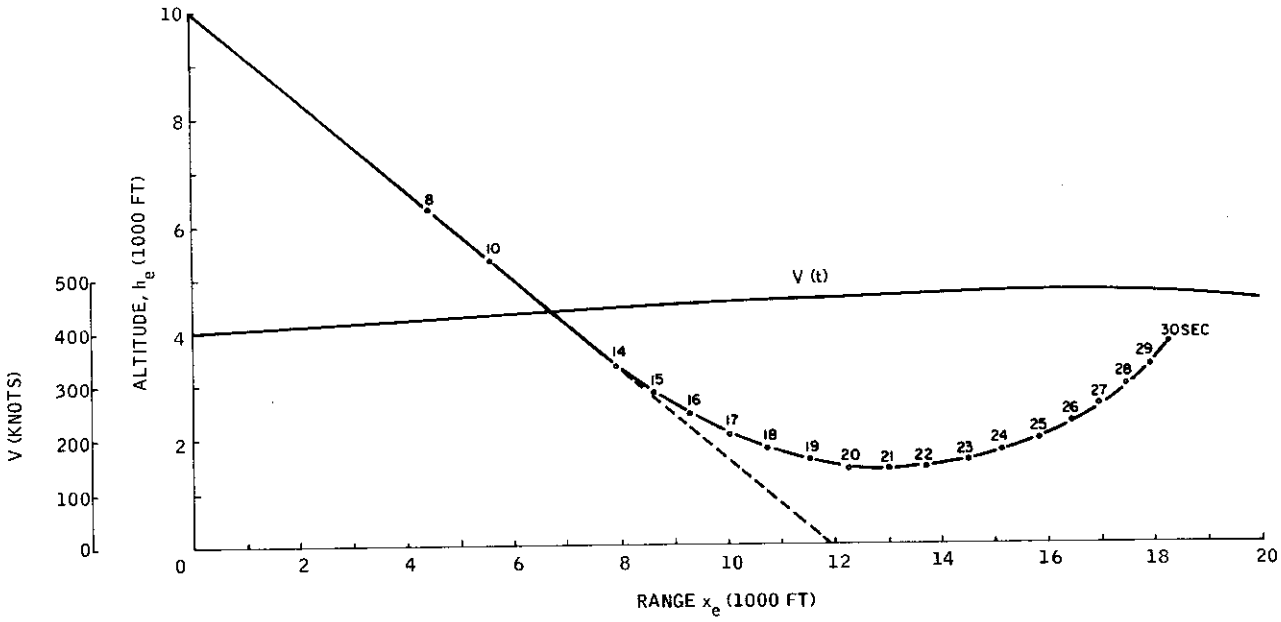


Figure 8. Dive and Pullup Trajectory

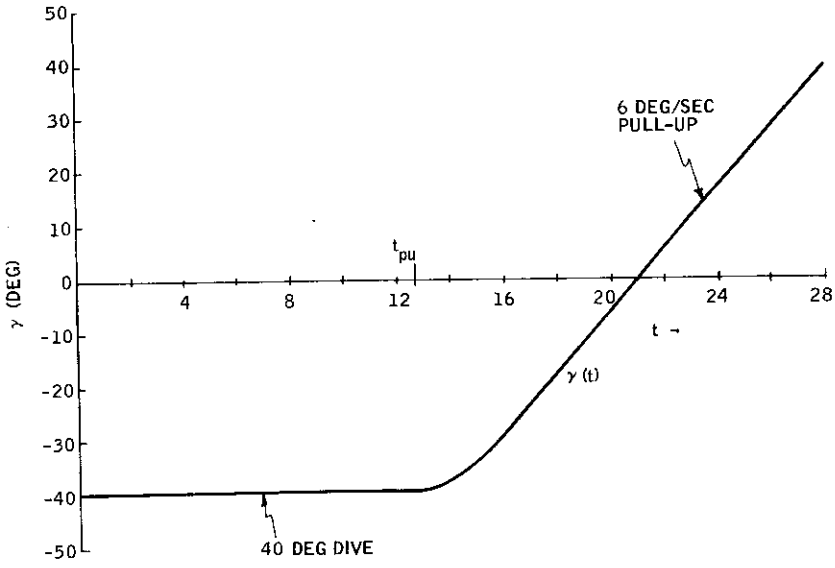


Figure 9. Flight-Path Angle versus Time in Dive and Pullup

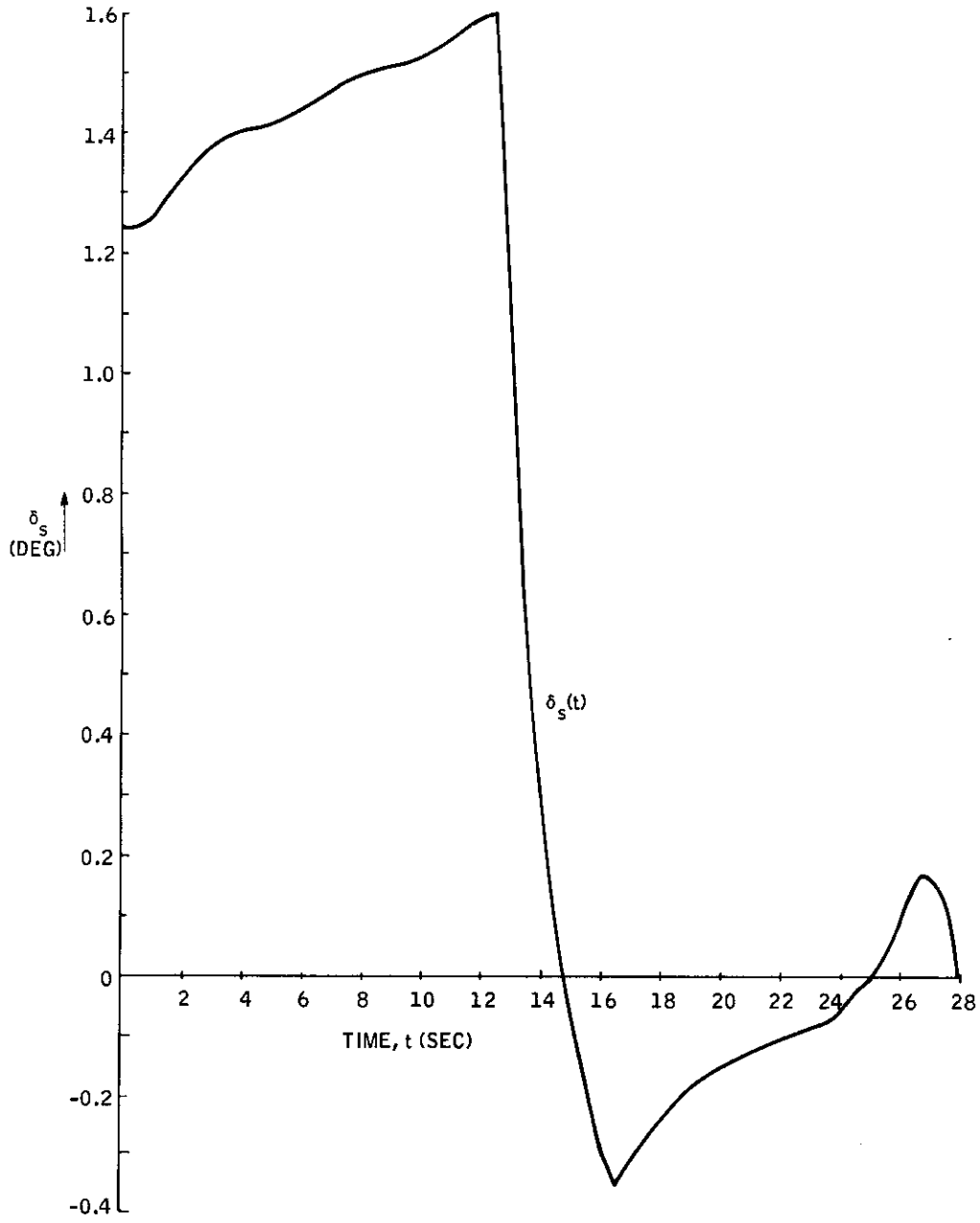


Figure 10. Stabilator Profile During Dive and Pull-up Maneuver Trim

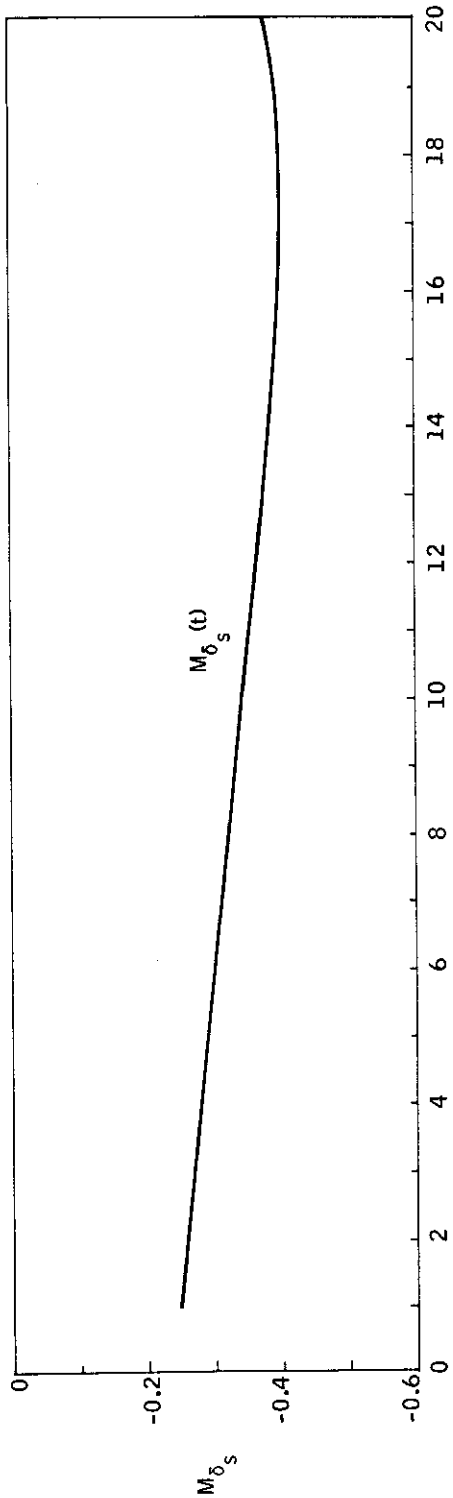
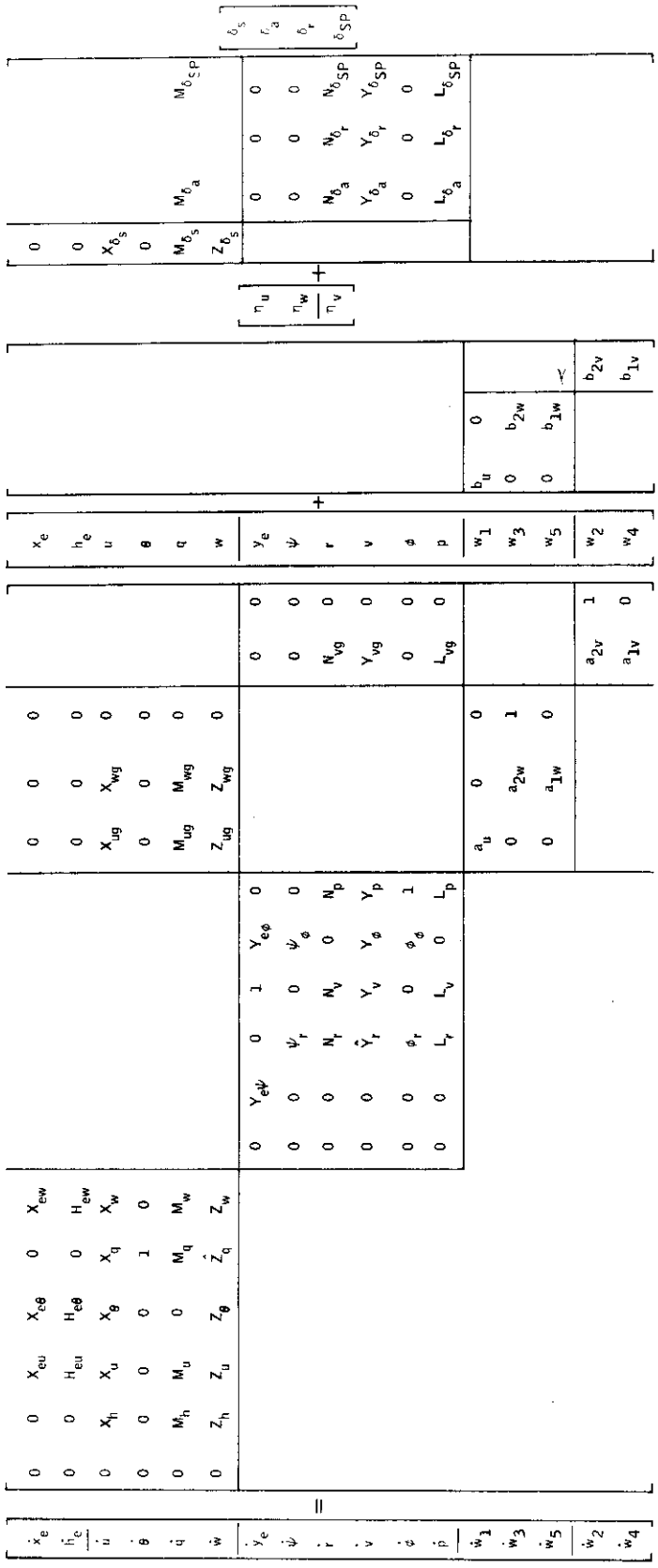


Figure 11. Pitching Moment Coefficient of the Stabilator Along the Nominal Path



$$\dot{x} = F x + G_1 u + G_2 \bar{v} + G_3 \eta \,, \quad G_2 = G_3$$

Figure 12. Augmented Aircraft and Reduced-Wind Dynamics

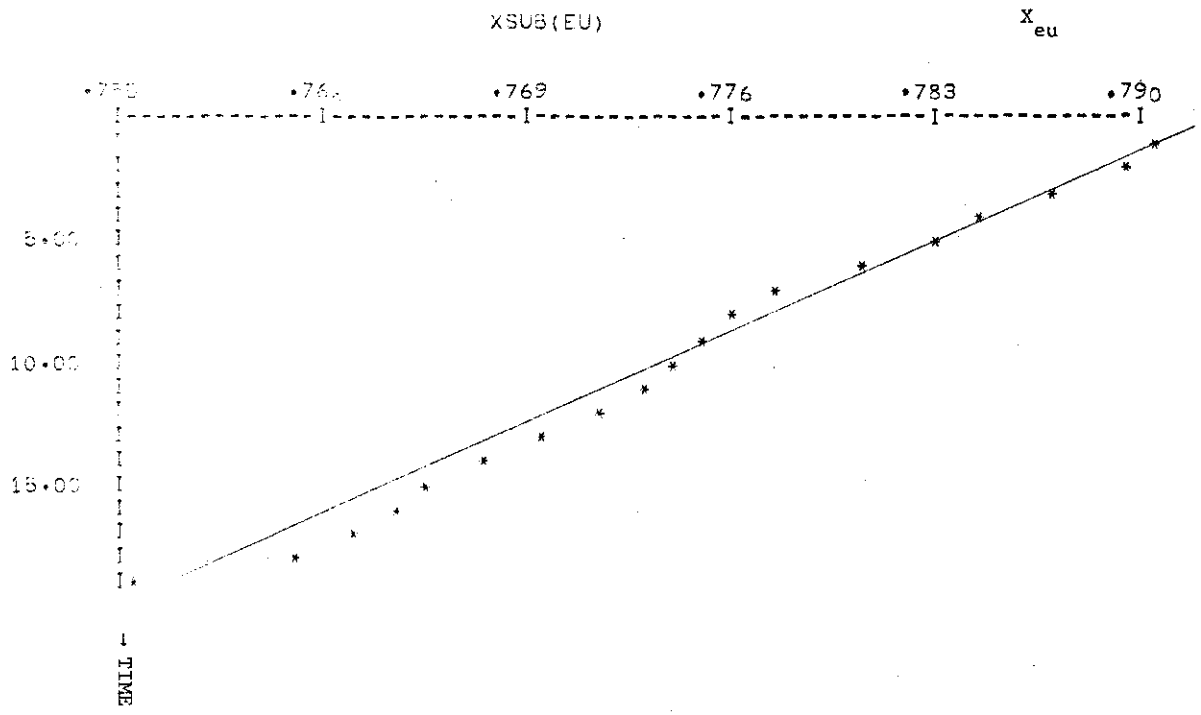


Figure 13. X_{eu} versus Time

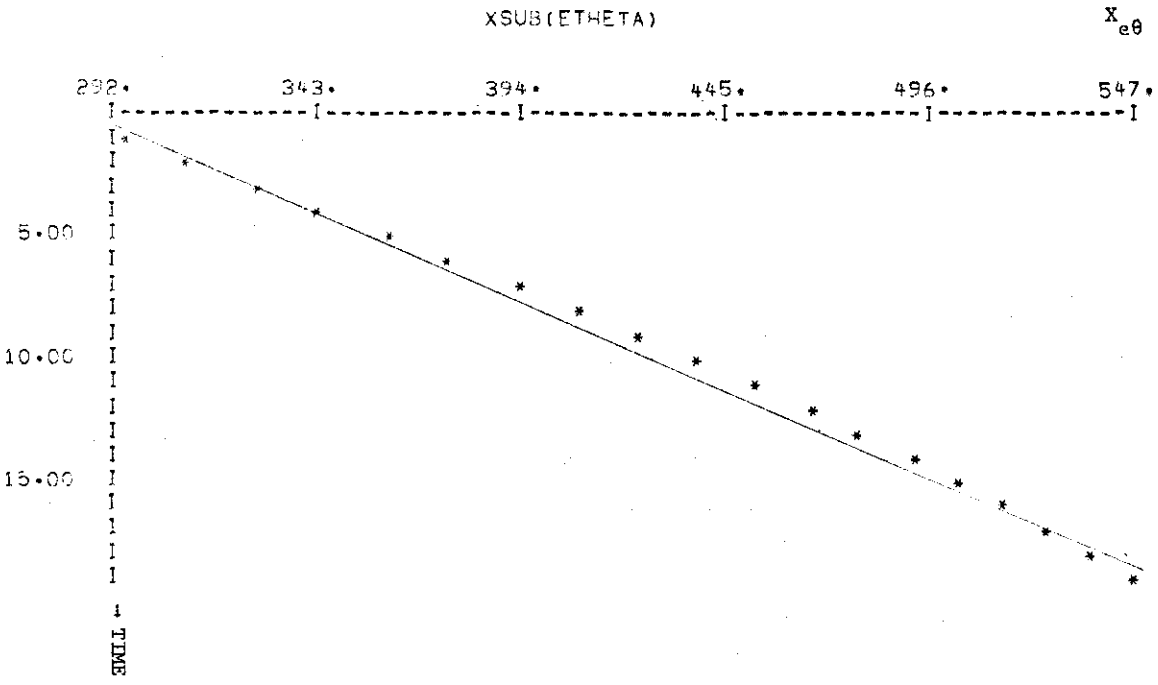


Figure 14. $X_{e\theta}$ versus Time

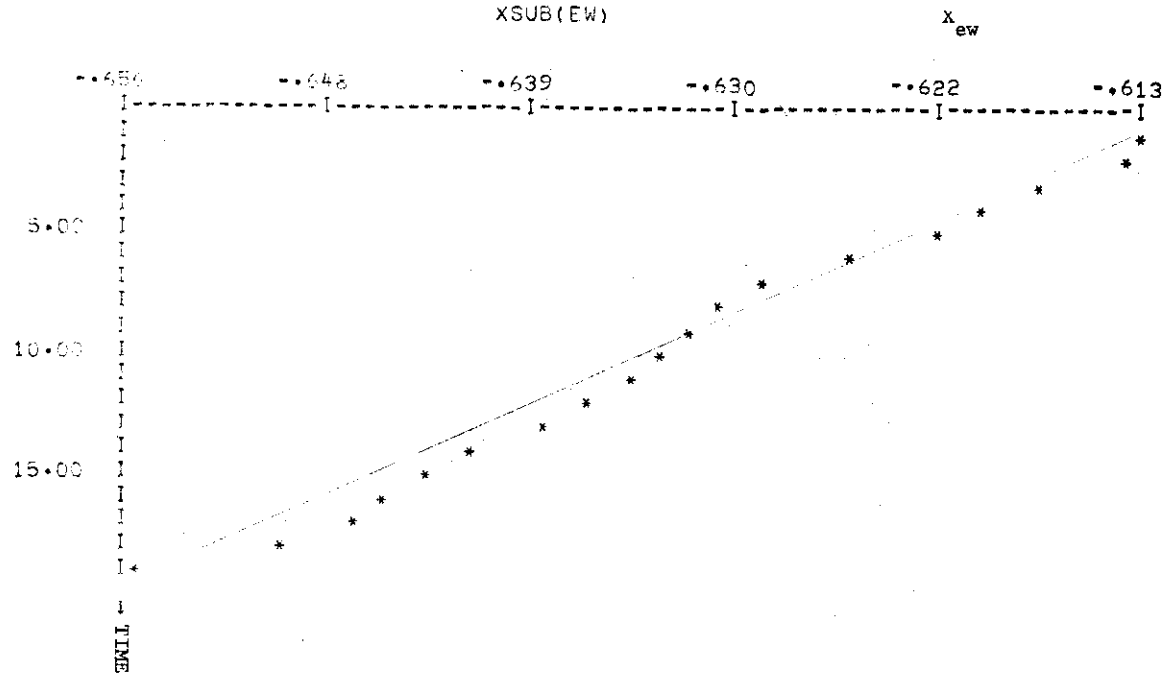


Figure 15. X_{ew} versus Time

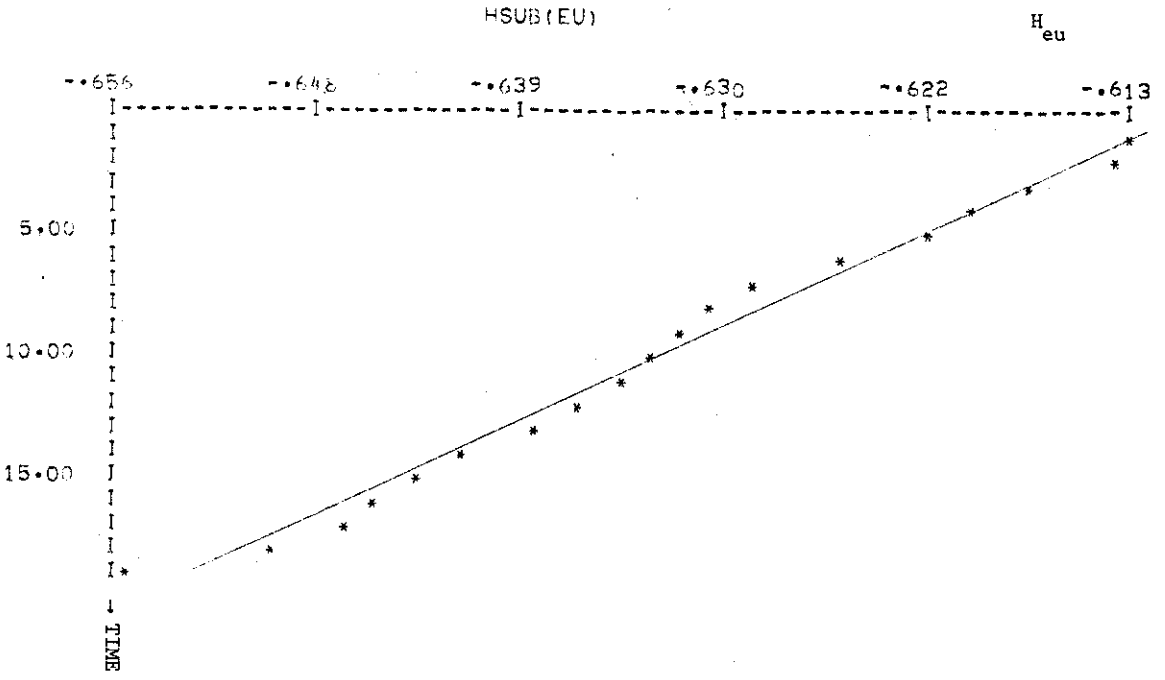


Figure 16. H_{eu} versus Time

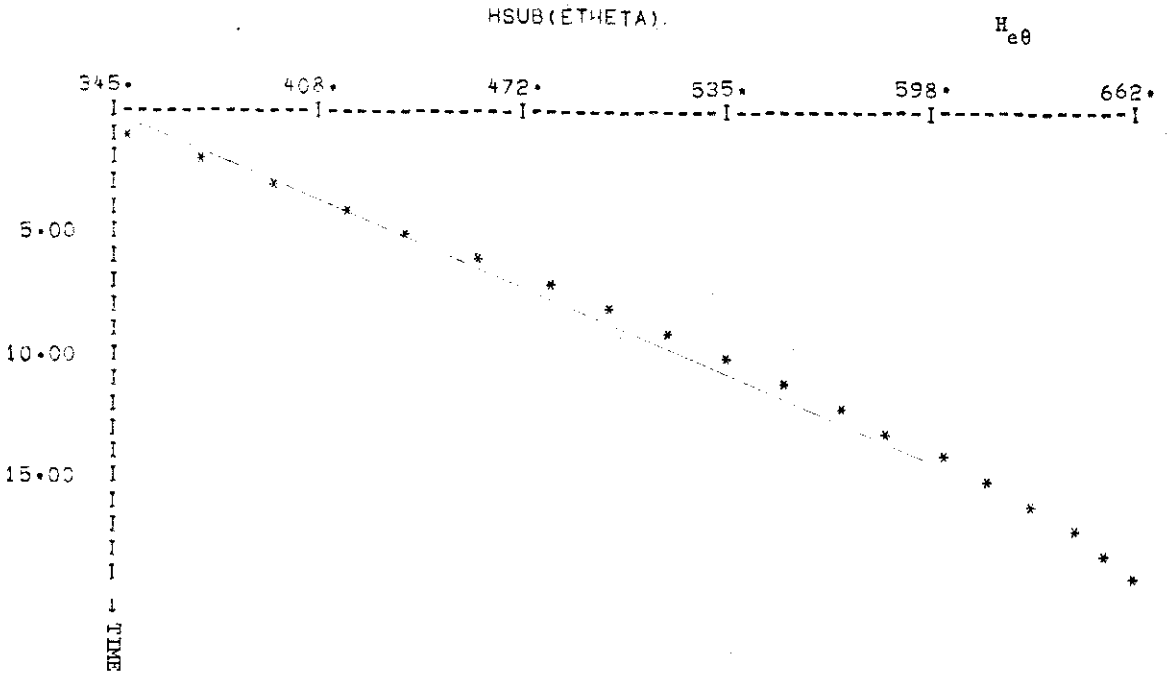


Figure 17. $H_{e\theta}$ versus Time

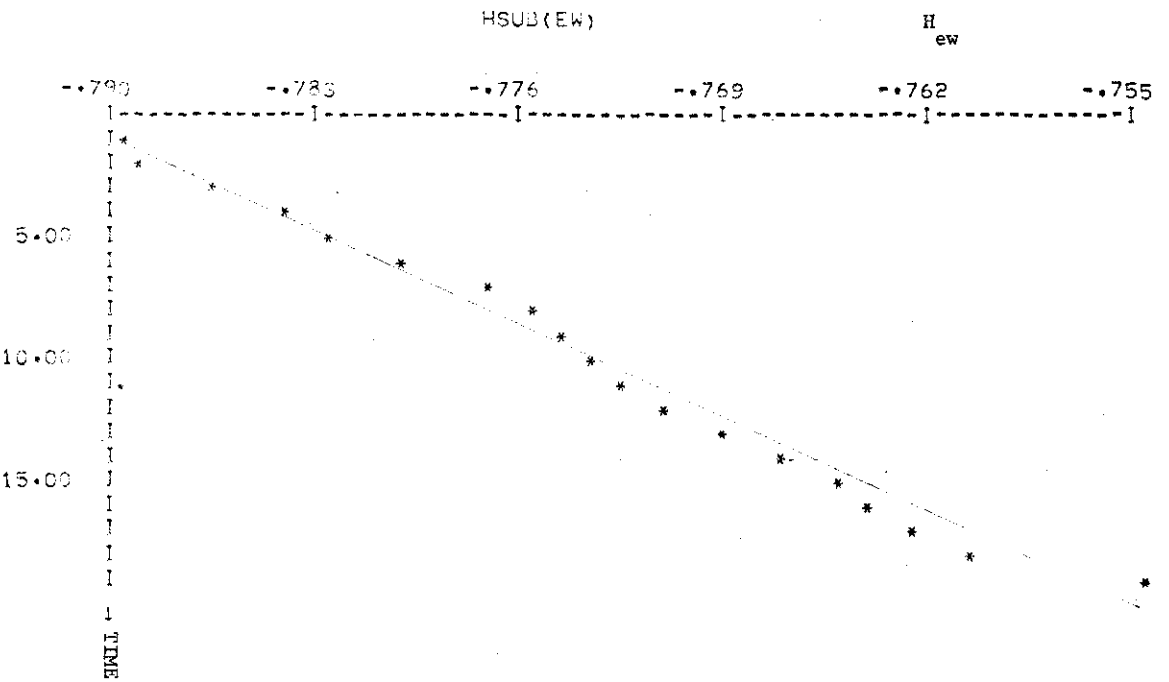


Figure 18. H_{ew} versus Time

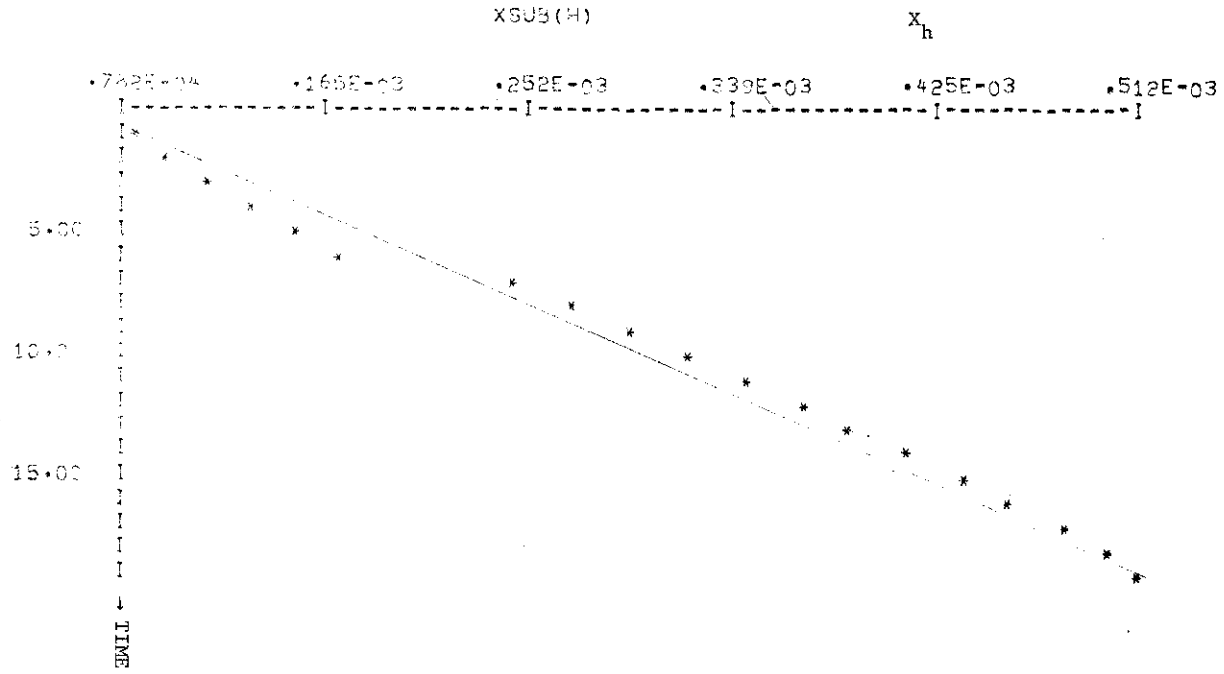


Figure 19. X_h versus Time

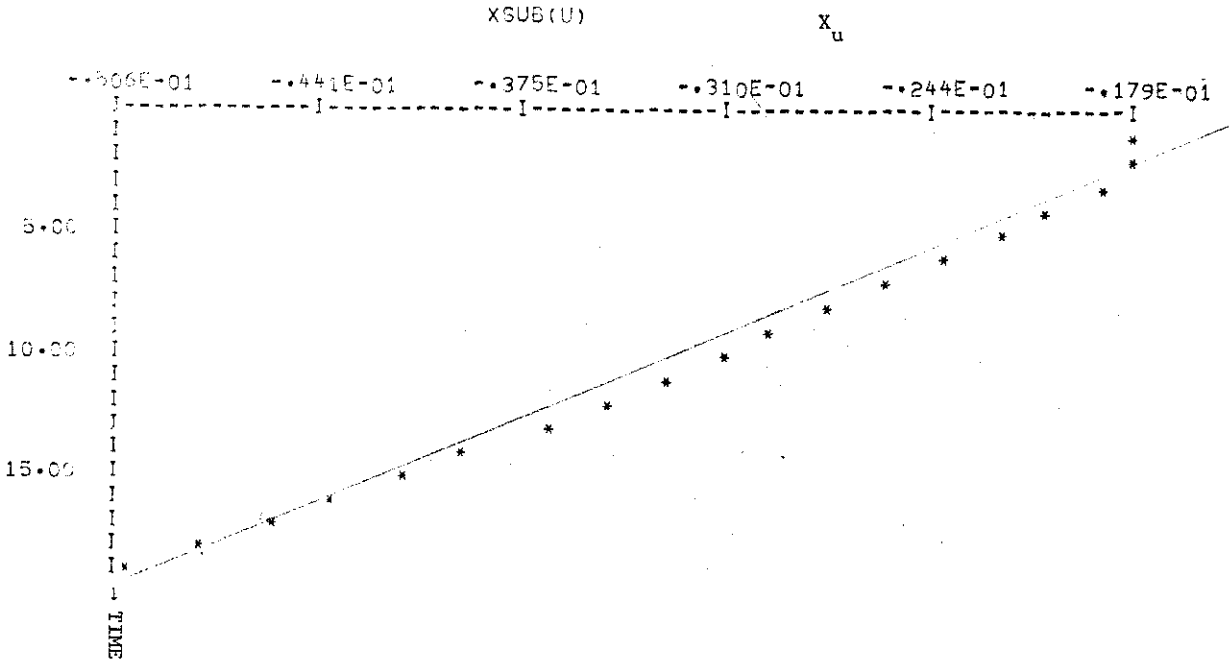


Figure 20. X_u versus Time

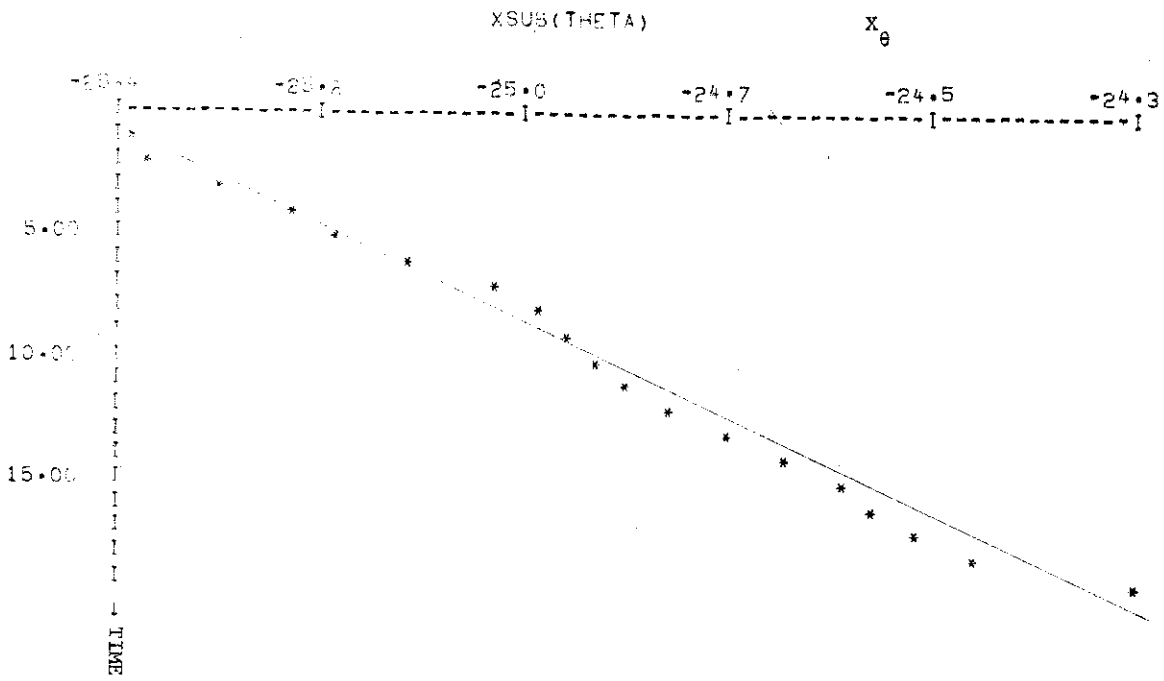


Figure 21. X_θ versus Time

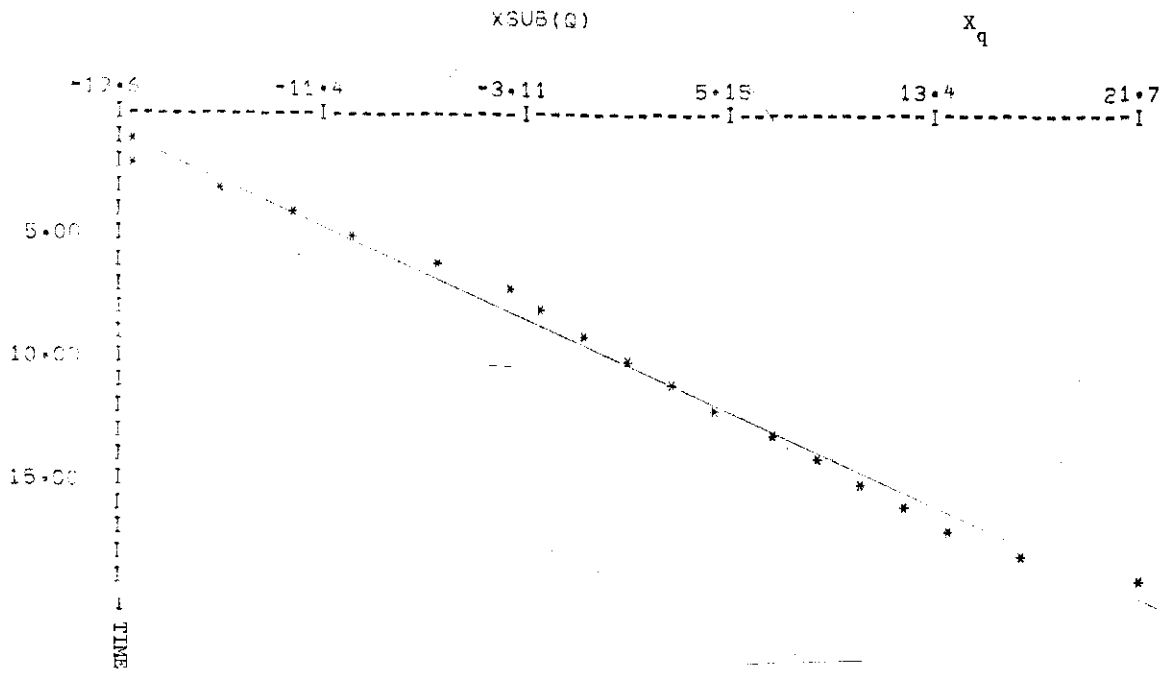


Figure 22. X_q versus Time

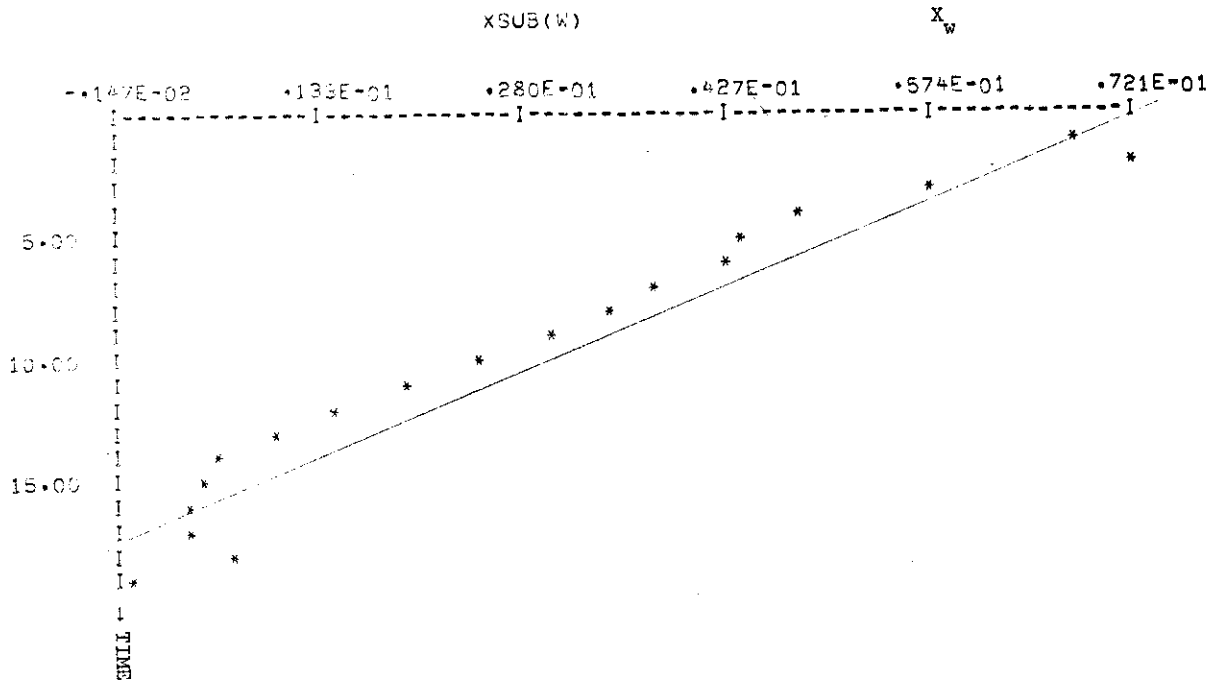


Figure 23. X_w versus Time

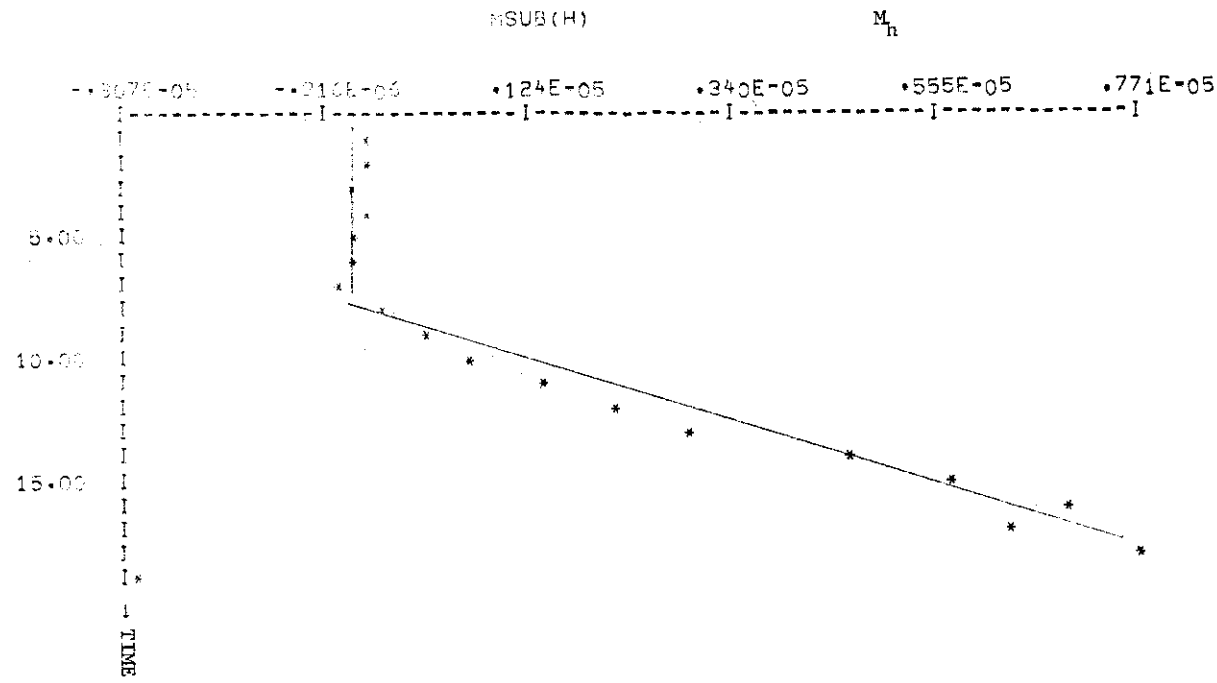


Figure 24. M_h versus Time

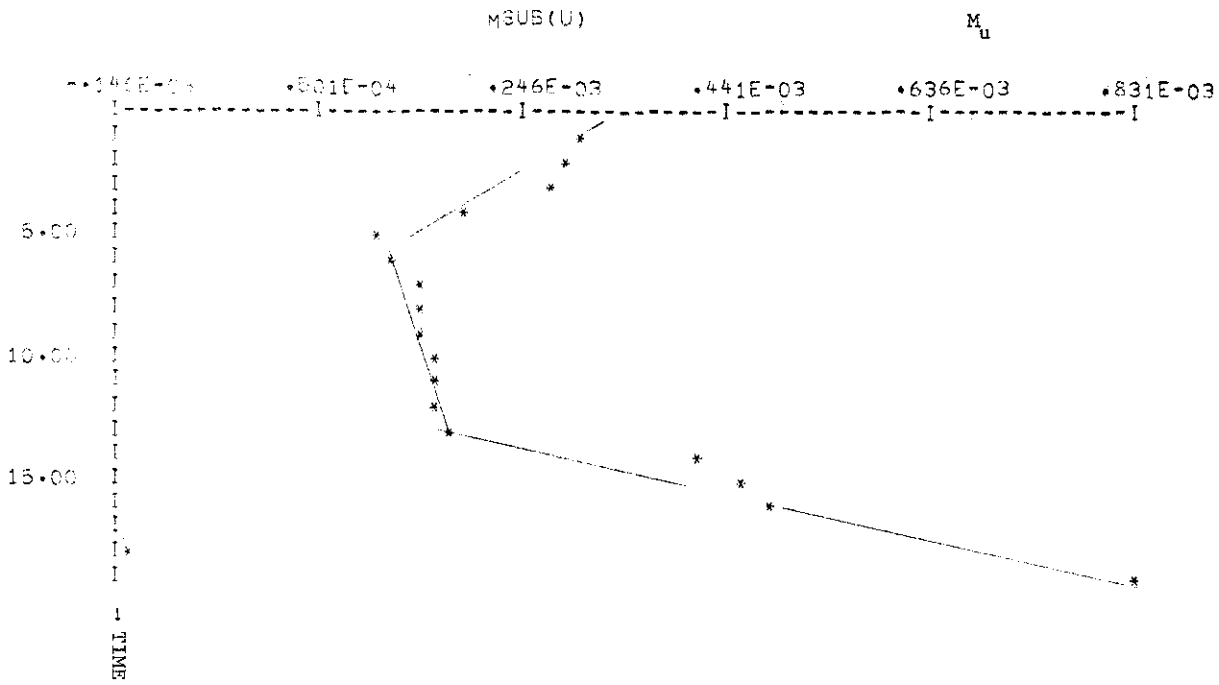


Figure 25. M_u versus Time

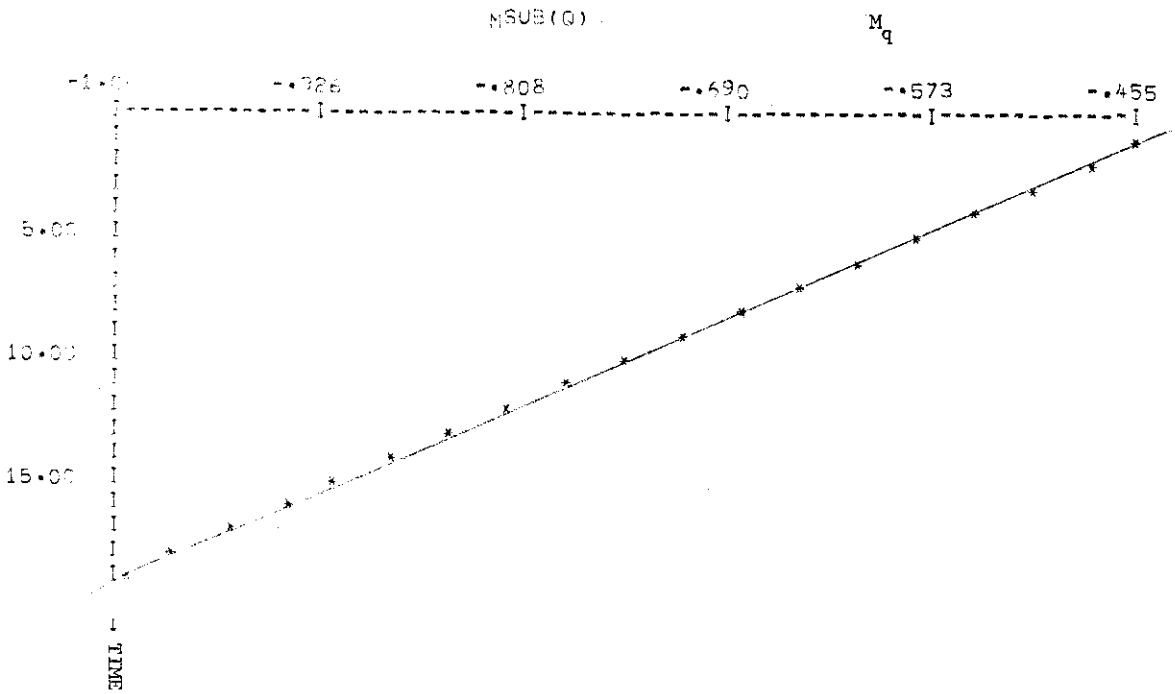


Figure 26. M_q versus Time

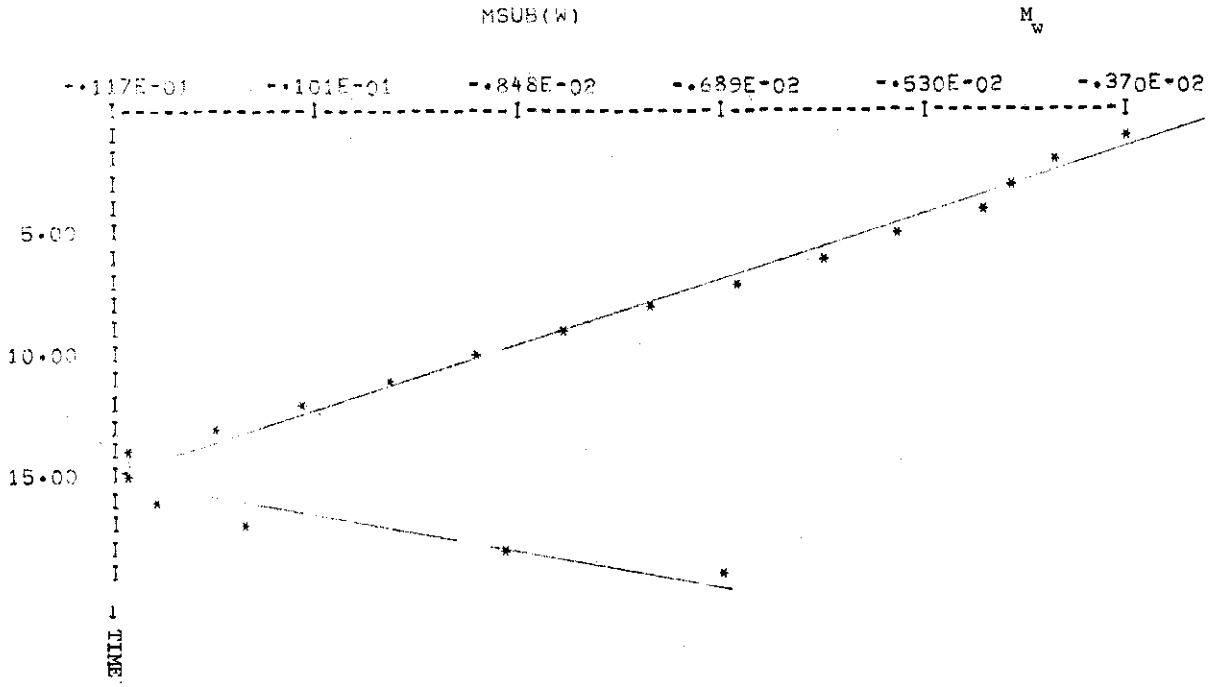


Figure 27. M_w versus Time

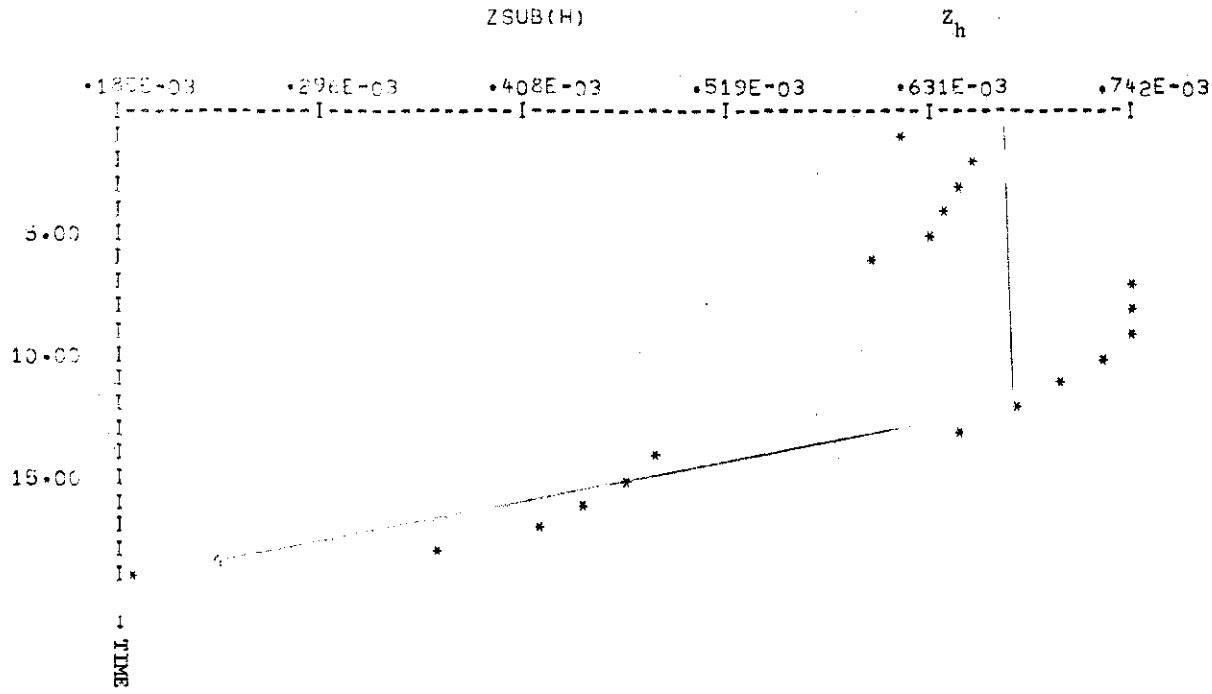


Figure 28. Z_h versus Time

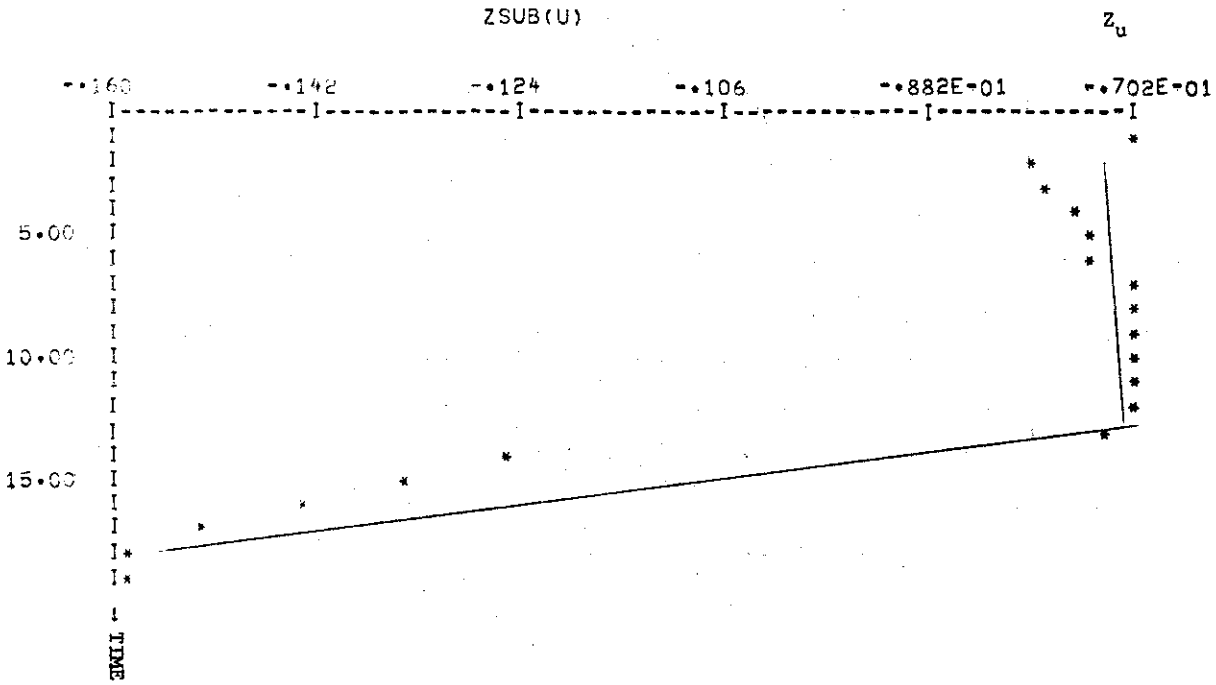


Figure 29. Z_u versus Time

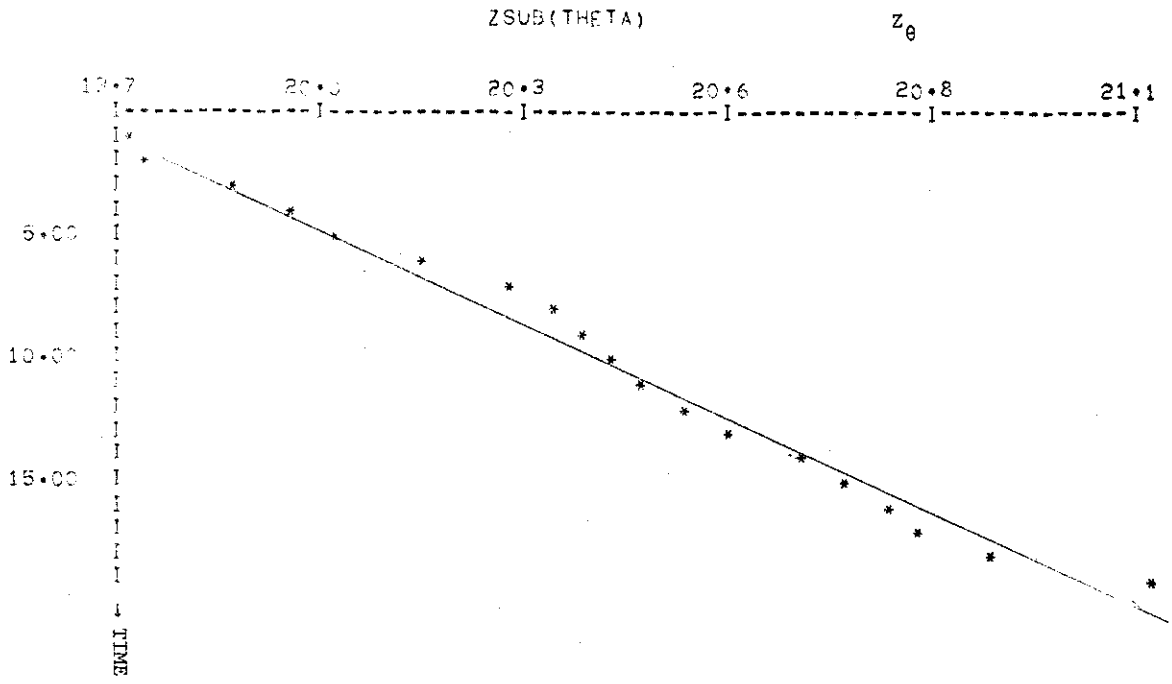


Figure 30. Z_θ versus Time

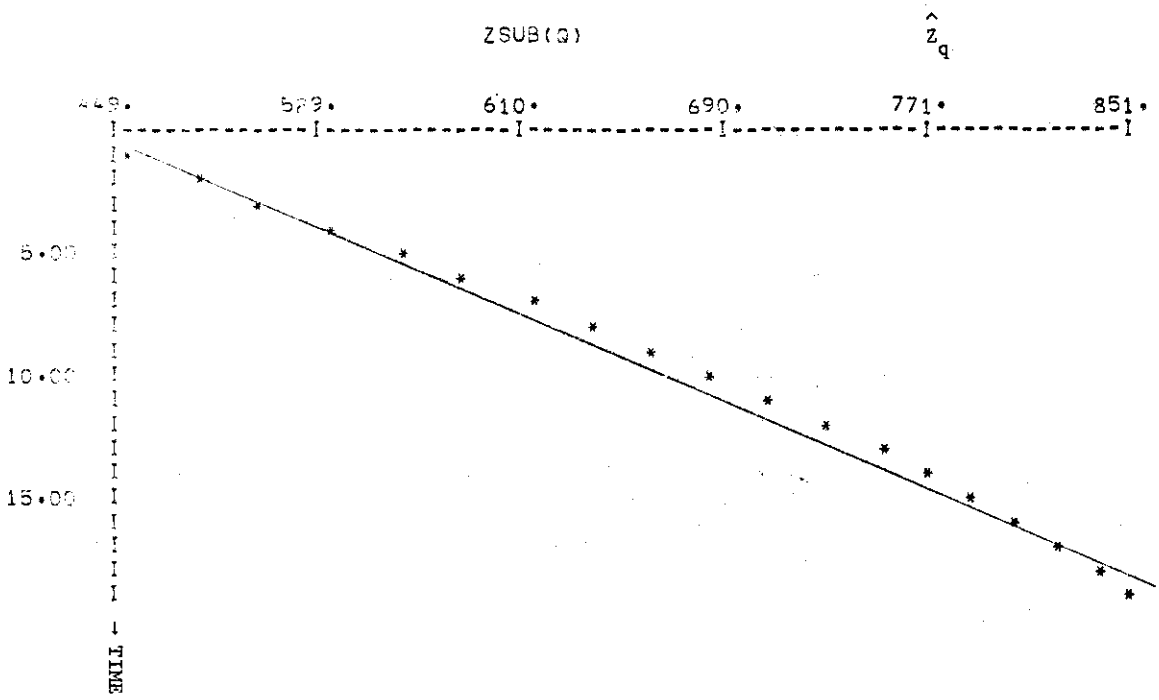


Figure 31. $\hat{Z}_q$ versus Time

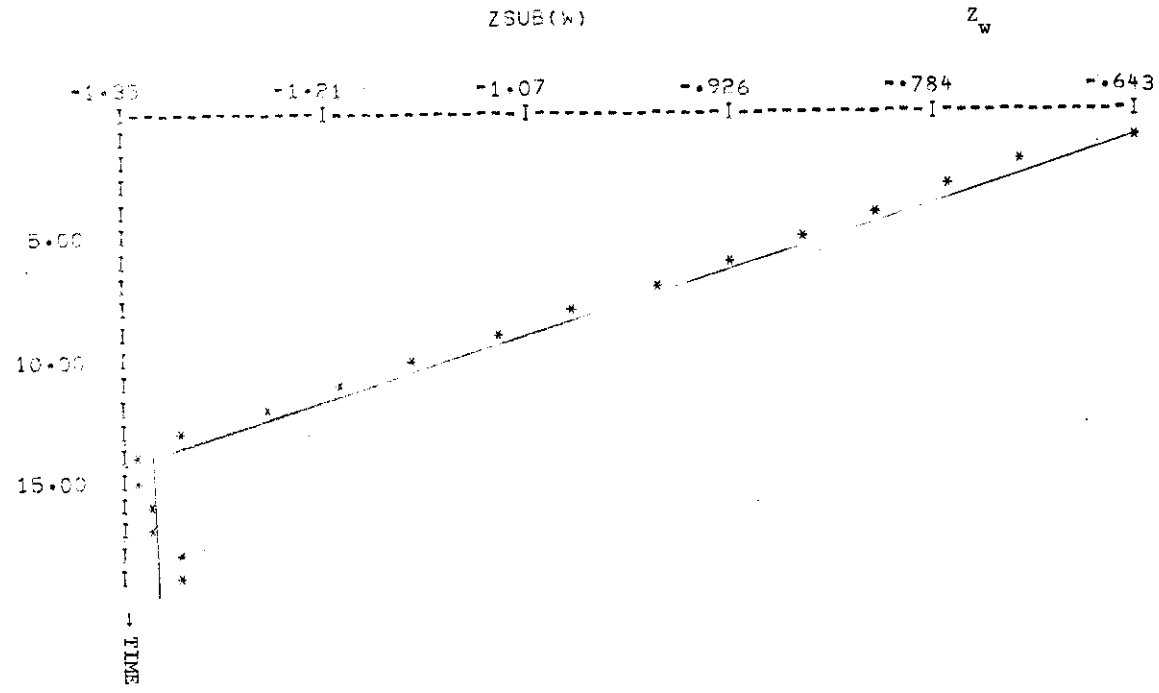


Figure 32. Z_w versus Time

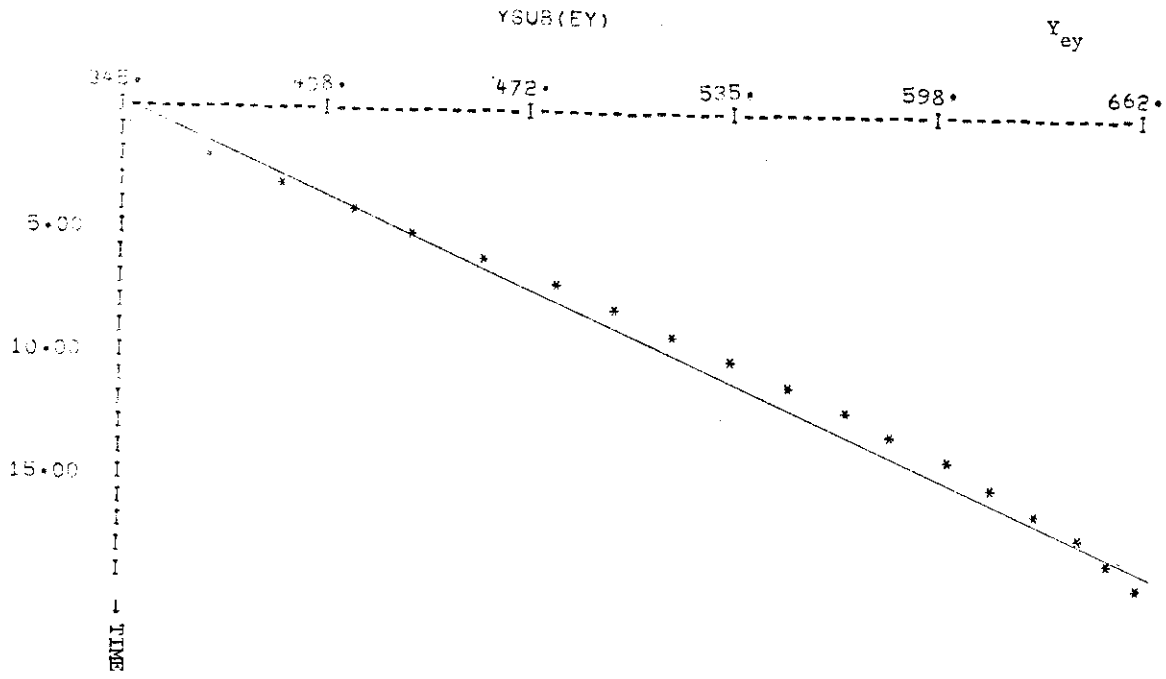


Figure 33. Y_{ey} versus Time

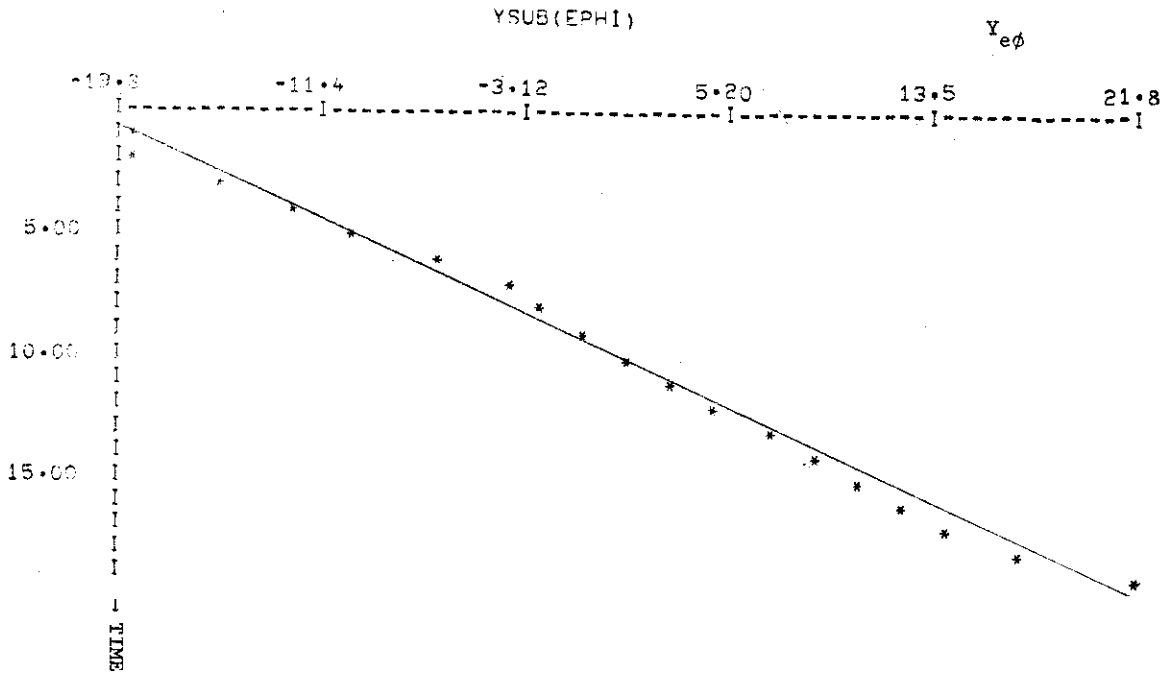


Figure 34. $Y_{e\phi}$ versus Time

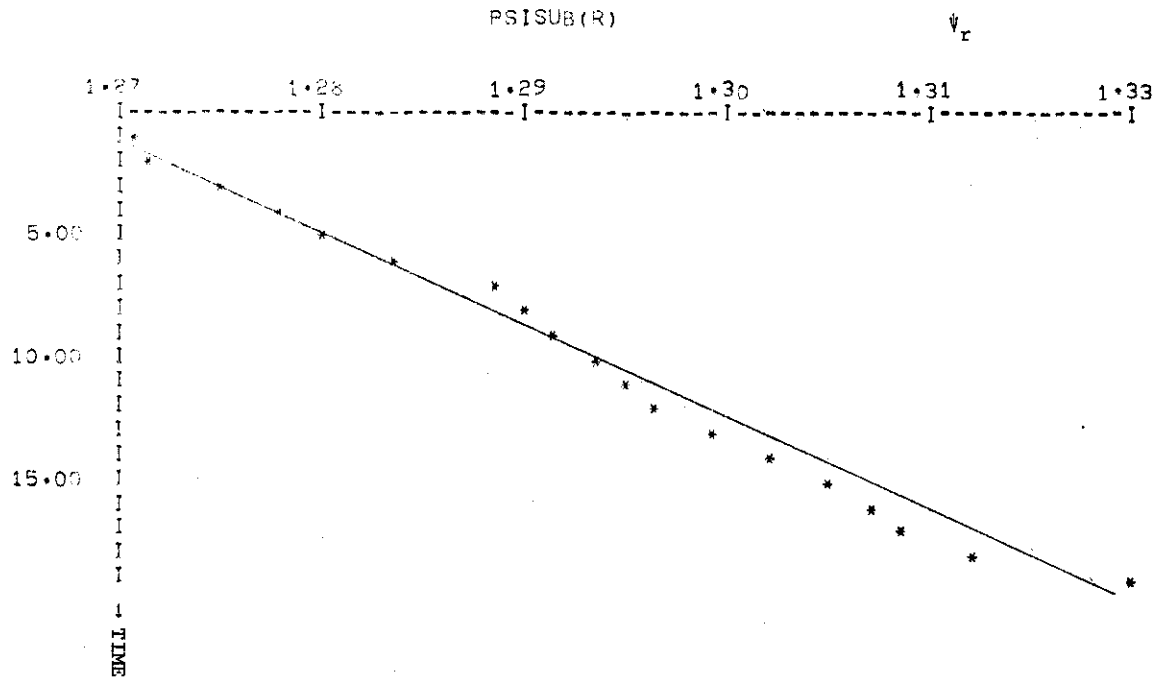


Figure 35. ψ_r versus Time

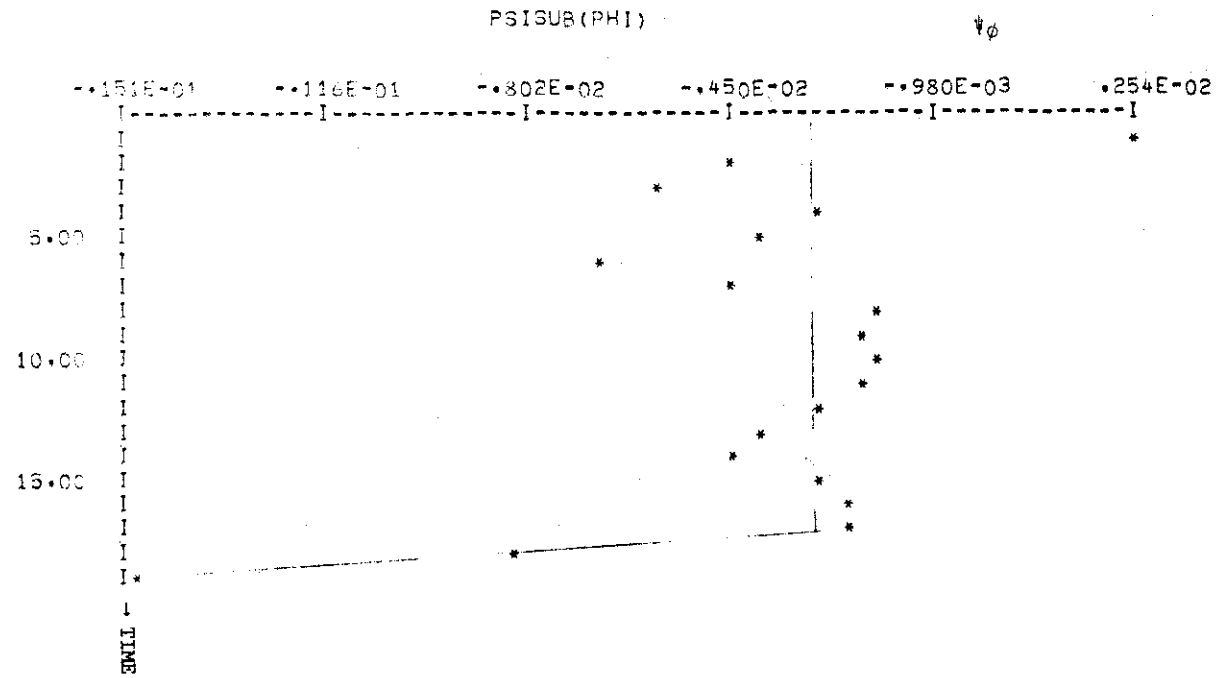


Figure 36. ψ_ϕ versus Time

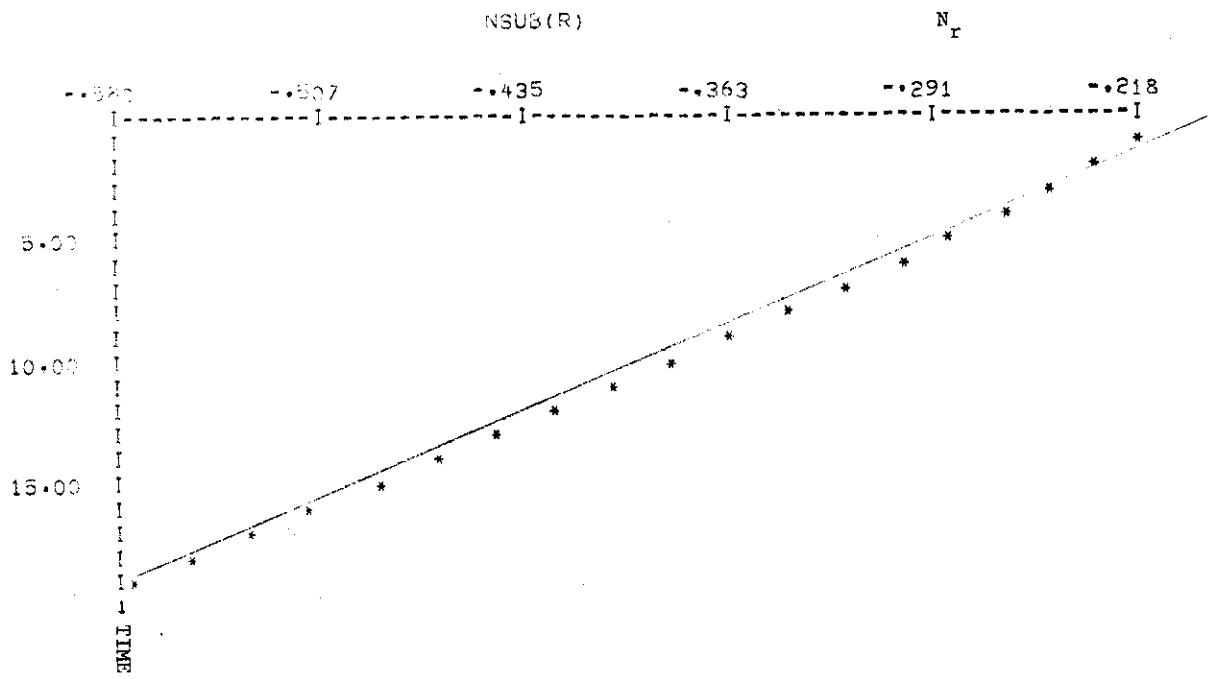


Figure 37. N_r versus Time

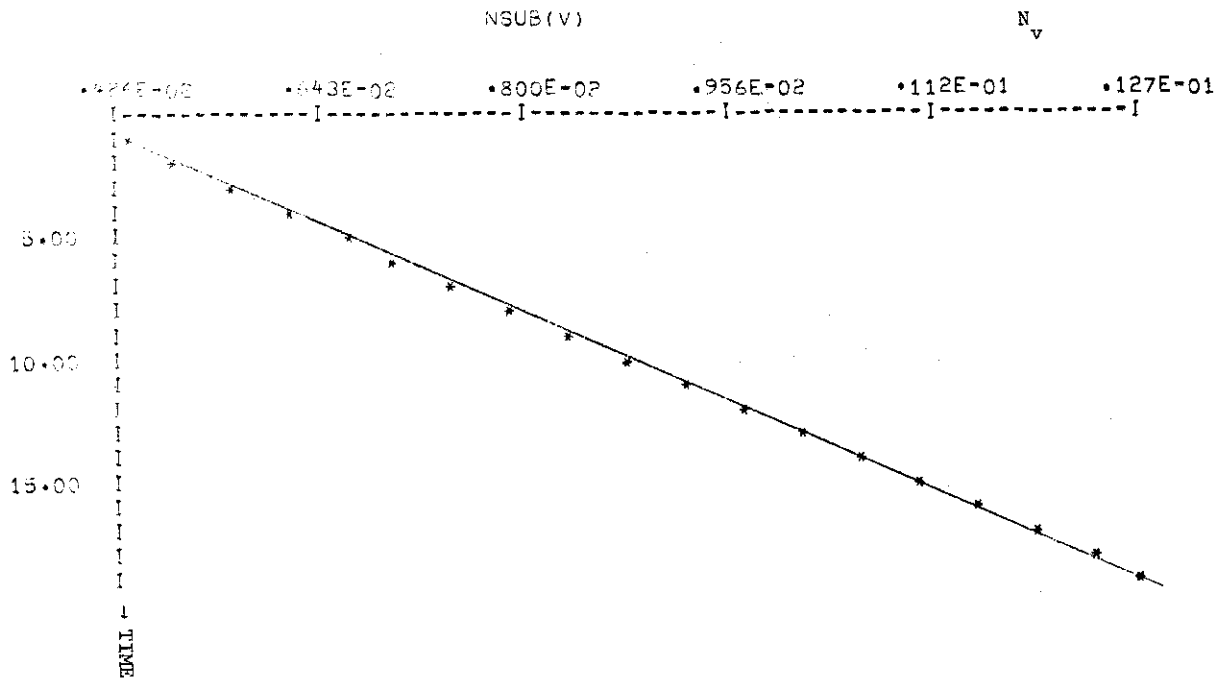


Figure 38. N_v versus Time

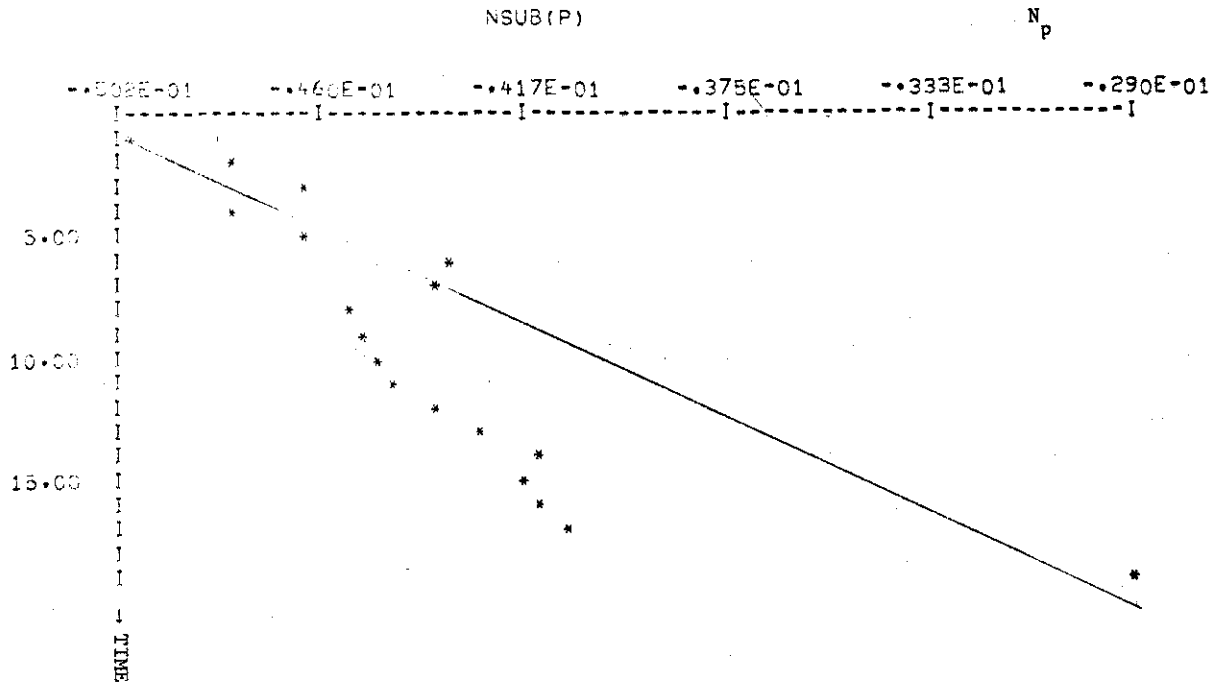


Figure 39. N_p versus Time

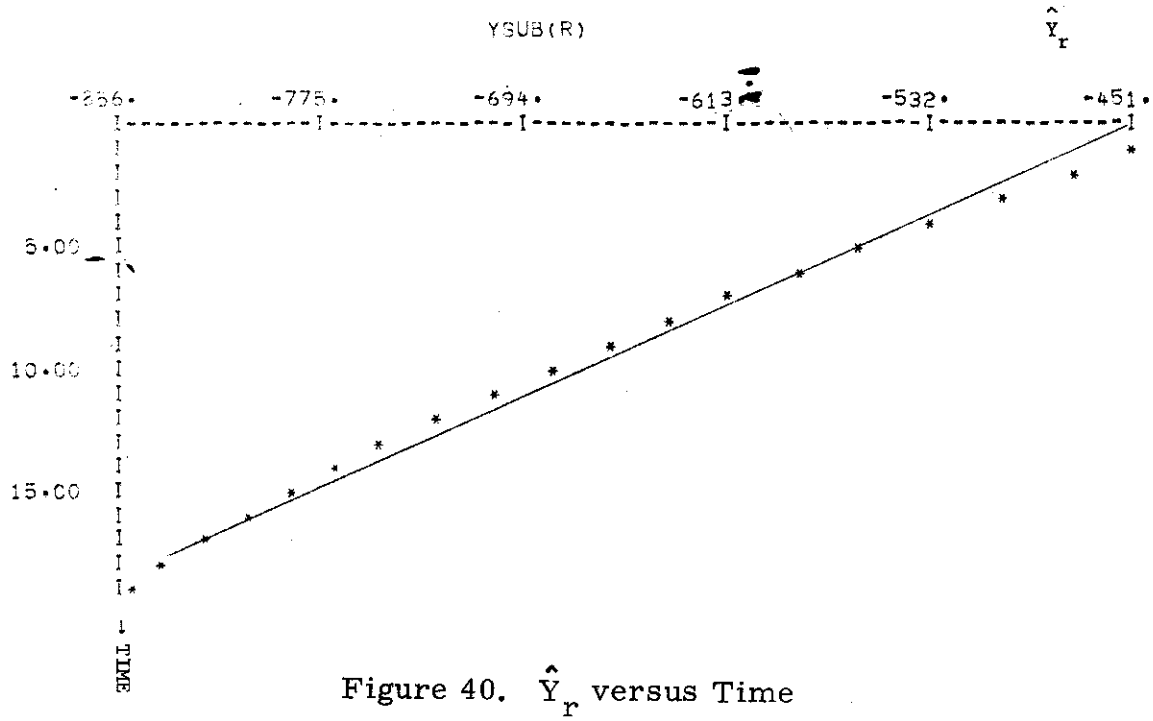


Figure 40. $\hat{Y}_r$ versus Time

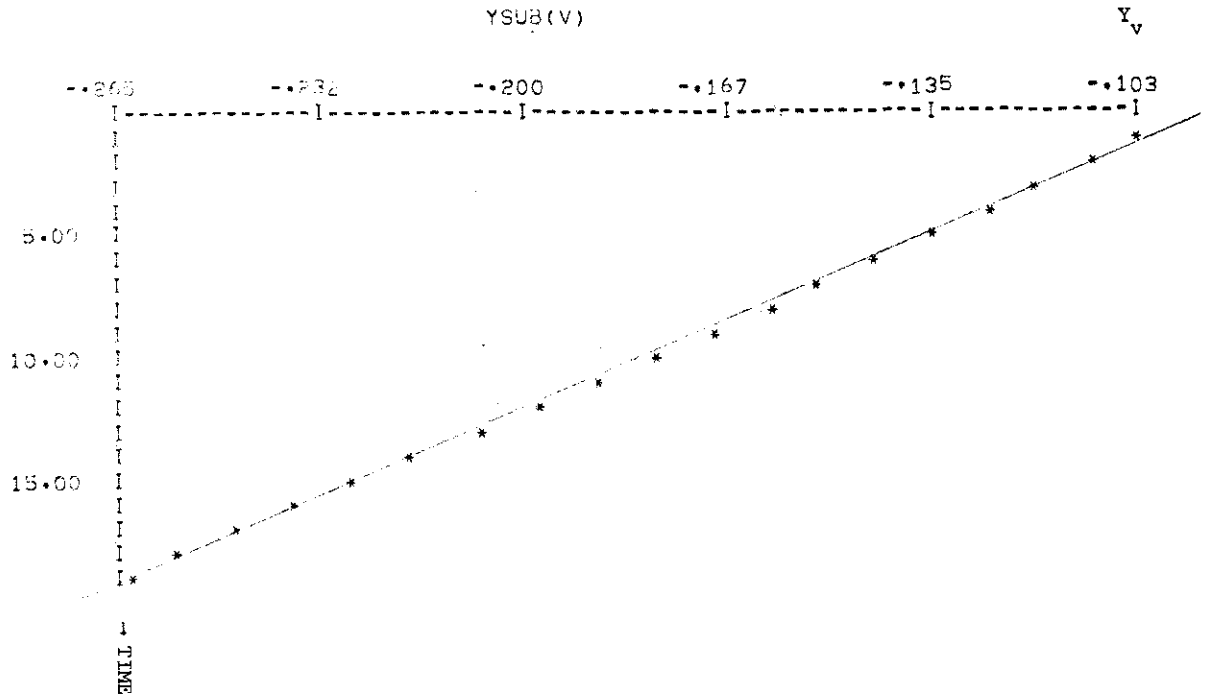


Figure 41. Y_v versus Time

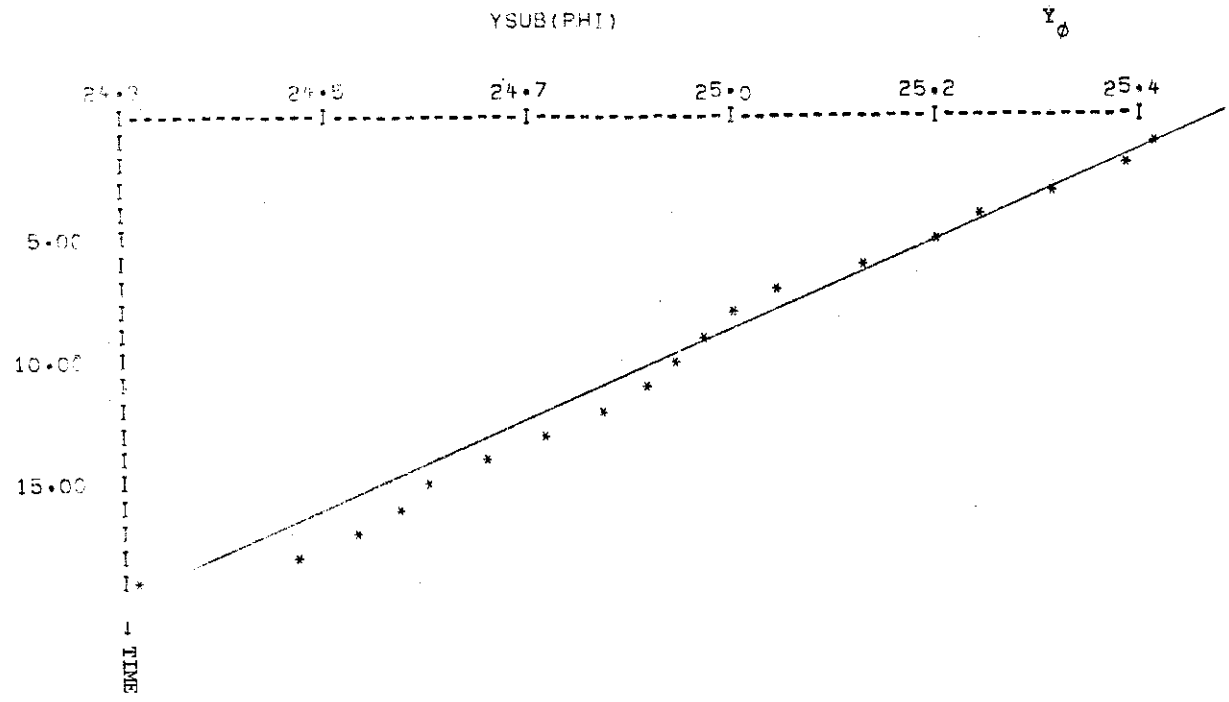


Figure 42. Y_ϕ versus Time

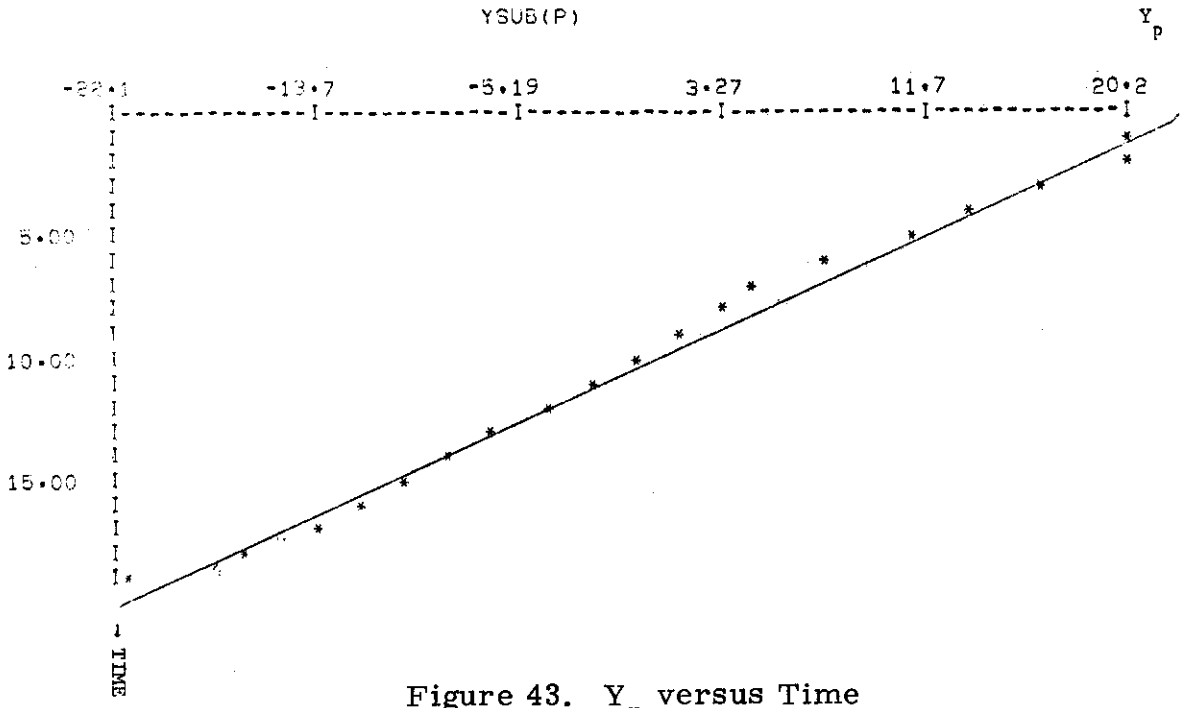


Figure 43. Y_p versus Time

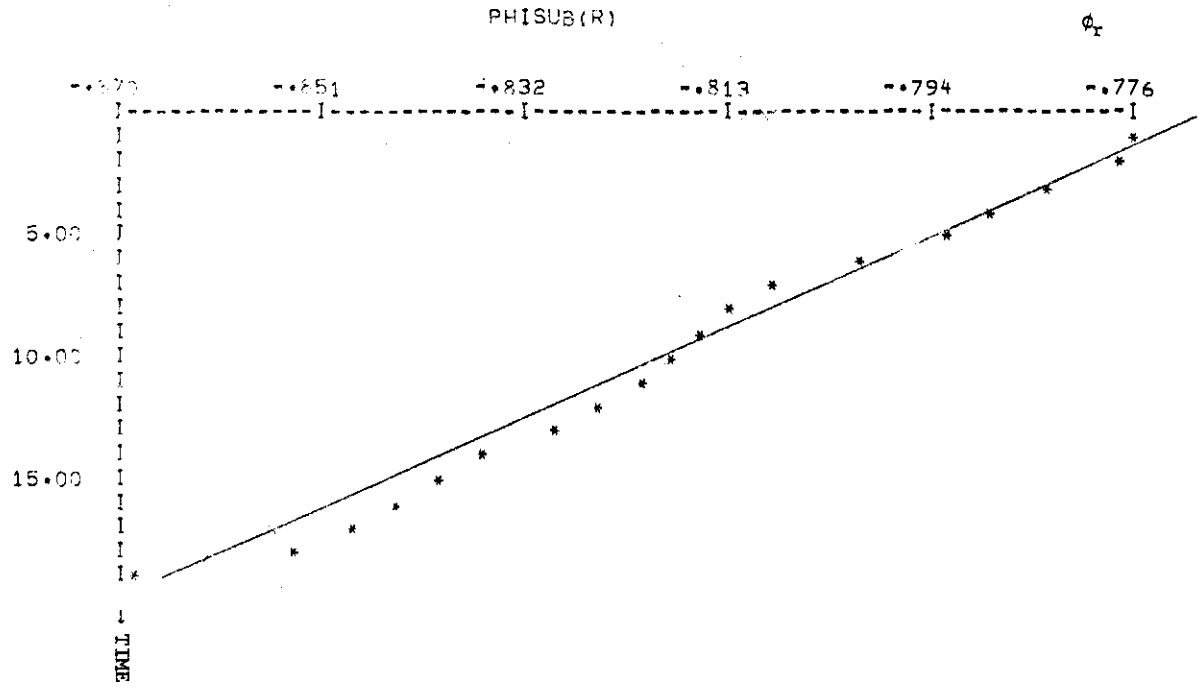


Figure 44. ϕ_r versus Time

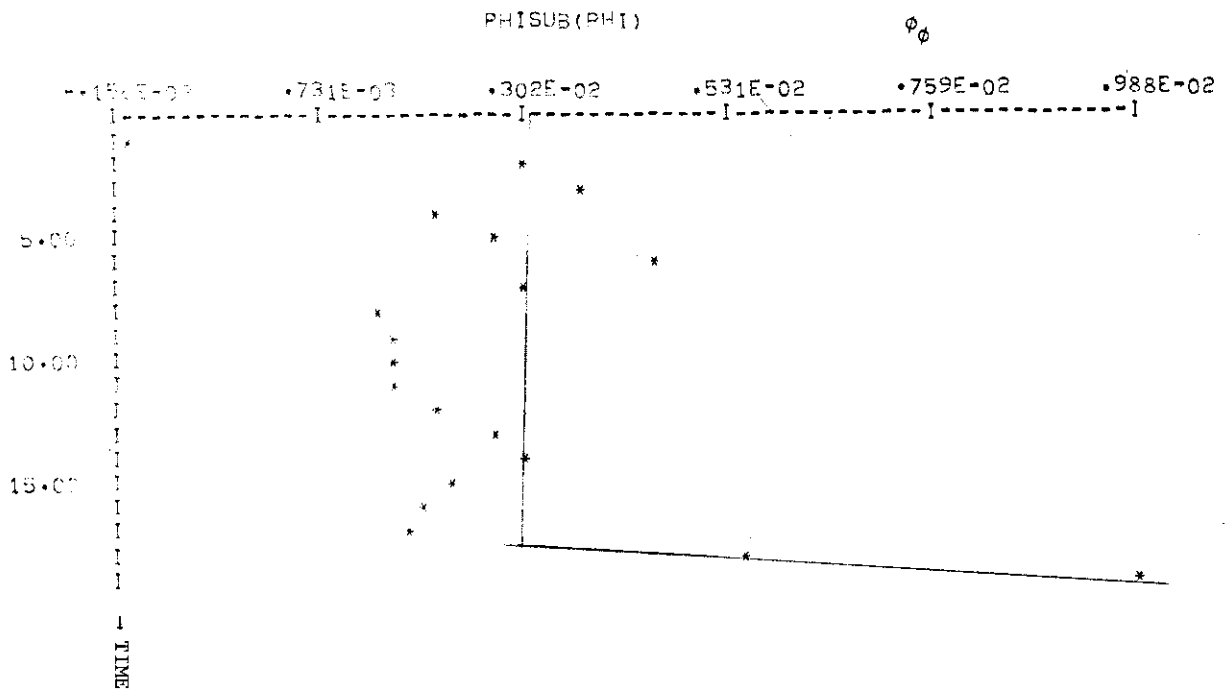


Figure 45. ϕ_ϕ versus Time

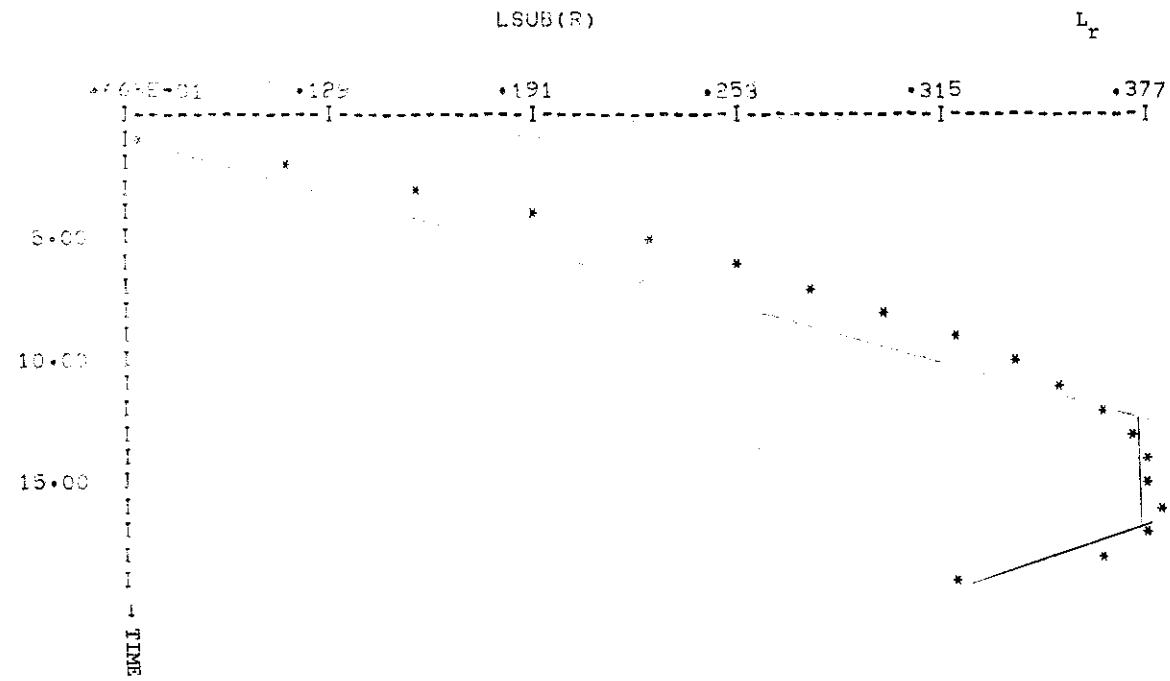


Figure 46. L_r versus Time

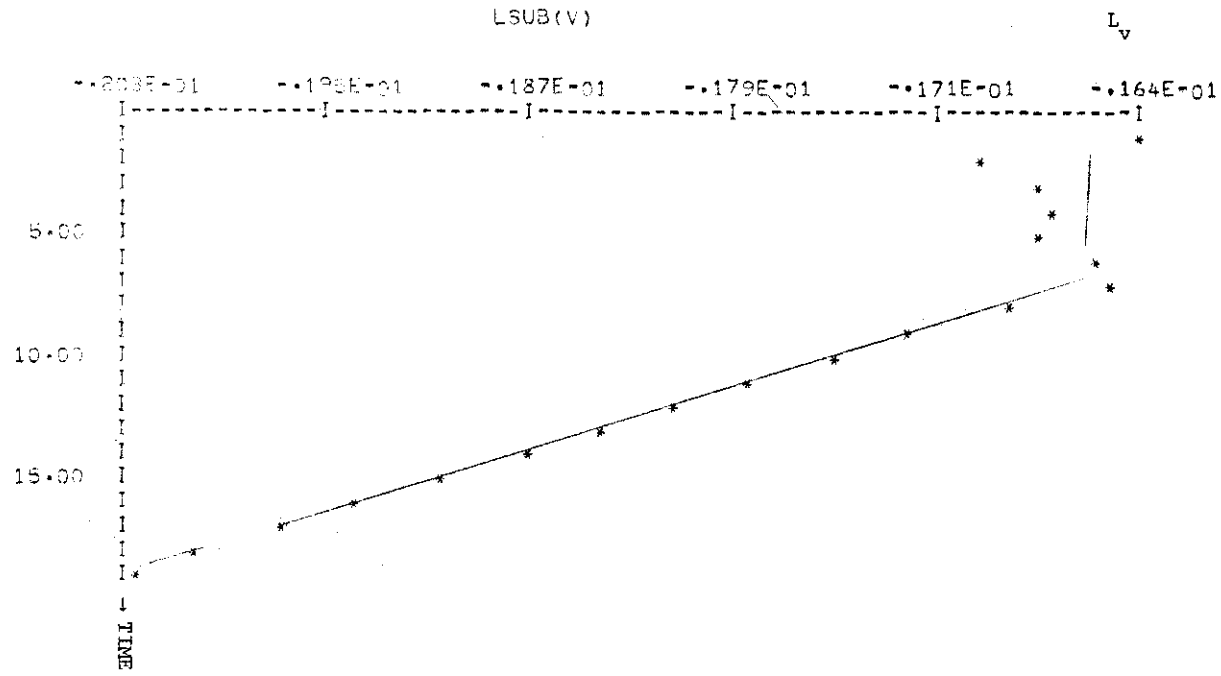


Figure 47. L_v versus Time

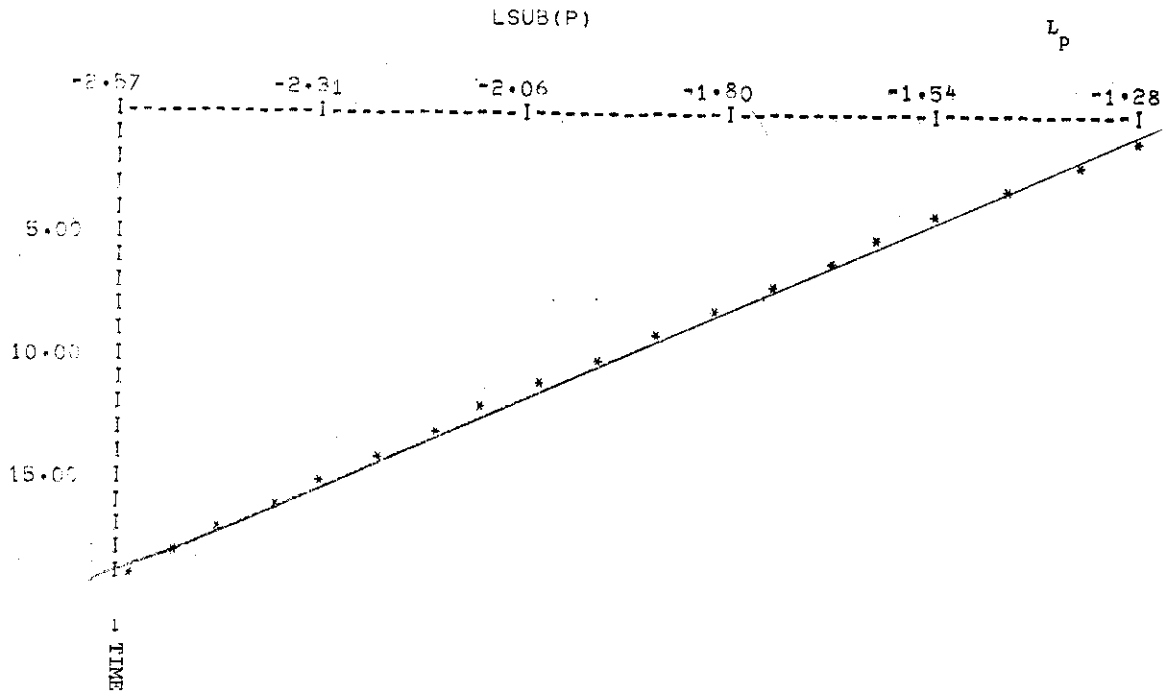


Figure 48. L_p versus Time

```
$FORTRAN LS,G0
     1:        DIMENSION A(1000),IDX(20),IORD(20,8),YY(40,20),XX(40),AB(6)
     2:        READ(5,1)NG
     3:        DO 3 I=1,NG
     4:      3 READ(5,2)IDX(I),(IORD(I,J),J=1,8)
     5:      1 FORMAT(I2)
     6:      2 FORMAT(I4,8(A4))
     7:    999 PAUSE
     8:        READ(5,998)NDP
     9:    998 FORMAT(I2)
    10:        REWIND 2
    11:        DO 4 I=1,NDP
    12:        READ(2)A
    13:        XX(I)=A(1)
    14:        DO 5 J=1,NG
    15:        JJ=IDX(J)
    16:      5 YY(I,J)=A(JJ)
    17:      4 CONTINUE
    18:        DO 100 L=1,NG
    19:        XMAX=-1.E+20
    20:        XMIN=+1.E+20
    21:        DO 10 I=1,NDP
    22:        XMAX=AMAX(XMAX,YY(I,L))
    23:     10 XMIN=AMIN(XMIN,YY(I,L))
    24:        R=XMAX-XMIN
    25:        WRITE(9,200)(IORD(L,K),K=1,8)
    26:   200 FORMAT(1H1,25X,8A4)
    27:        AB(1)=XMIN
    28:        DO 11 M=1,5
    29:     11 AB(M+1)=AB(M)+R/5.
    30:        WRITE(9,201)(AB(M),M=1,6)
    31:   201 FORMAT(//6G14.3)
    32:        WRITE(9,202)
    33:   202 FORMAT(8X,'I',5('----------I'))
    34:        JJ=5
    35:        DO 300 J=1,NDP
    36:        LL=(YY(J,L)-XMIN)*70./R
    37:        IF(J.NE.JJ) GOTO 400
    38:        T=XX(J)
    39:        JJ=JJ+5
    40:        WRITE(9,203)T,LL
    41:   203 FORMAT(F6.2,'  I',NX,'*')
    42:        GOTO 300
    43:   400 WRITE(9,204)LL
    44:   204 FORMAT(6X,'  I',NX,'*')
    45:   300 CONTINUE
    46:   100 CONTINUE
    47:        GOTO 999
    48:        END
```

Figure 49. Plotting Data Program Listing

```
1
C 03/23/72
C  H0= 12000 FT,V0=250 KNTS
C INTEGRATION AND LINEARIZATION OF AIRPLANE
C NOMINAL PERTURBATION
C 40 DEGREE DIVE ANGLE
PCC
   2 -.1381E+05   4 +.1200E+05  16 +.4225E+03  26 +.3665E-01  29 +.3665E-01
  31 -.6614E+00  43 -.1745E-02  90 +.3217E+02 115 +.3867E+02 116 +.1604E+02
 117 +.5300E+03 121 +.1000E+00 122 +.1330E-02 131 +.1000E+03 132 +.1000E+01
 134 +.1000E+01 140 +.7000E+00 141 +.7720E+04 142 +.7720E+04 156 +.1000E+05
 157 +.7500E-03 170 +.1200E+02 171 +.4000E+01 172 +.6000E+01 201 +.1000E+02
 202 +.5000E+01 203 +.5000E+01 204 +.1000E-01 205 +.1000E-01 206 +.1000E-01
 207 +.2000E-01 208 +.2000E-01 209 +.2000E-01 210 +.2000E+02 211 +.2000E+02
 212 +.2000E+02 213 +.1000E+02 214 +.5000E+01 215 +.5000E+01 216 +.1000E-01
 217 +.1000E-01 218 +.1000E-01 221 +.5000E-01 222 +.5000E-01 223 +.5000E-01
 224 +.5000E-01 231 +.5000E+01 232 +.5000E+01 233 +.5000E+01 234 +.1000E-01
 235 +.1000E-01 236 +.1000E-01 256 +.2000E+00 257 -.3000E+00 258 +.1000E+00
 259 -.3000E+00 260 -.6981E+00 261 +.1000E+01 270 +.1047E+00 274 +.4000E+04
 283 +.3000E+02 290 +.5236E+00 291 +.5236E+00 292 +.2000E+04 293 +.3000E+02
 391 +.1000E+01 395 +.1000E+01 399 +.1000E+01 400 +.1000E+01 404 +.1000E+01
 408 +.1000E+01 409 +.1000E+01 413 +.1000E+01 417 +.1000E+01 418 +.1000E+01
 422 +.1000E+01 426 +.1000E+01 427 +.1000E+01 431 +.1000E+01 435 +.1000E+01
 501 -.3135E+03 502 -.3135E+03 506 +.2383E+02 507 -.2383E+02 511 -.3241E+02
 512 -.3241E+02 517 +.2000E+01 559 +.2000E+02 560 +.2000E+02 579 -.3162E+03
 582 -.2500E+00 583 +.2500E+00 587 +.5250E+01 588 +.5250E+01 646 +.4000E+02
 716 +.4042E+05 901 +.7000E+01 902 +.8000E+01 903 +.9000E+01 904 +.4200E+02
 905 +.4300E+02 906 +.4400E+02 907 +.3100E+02 908 +.3200E+02 909 +.3300E+02
 910 +.2000E+01 911 +.3000E+01 912 +.4000E+01 913 +.1700E+02 914 +.1800E+02
 915 +.1900E+02 916 +.4500E+02 917 +.4600E+02 918 +.4700E+02 919 +.3900E+02
 920 +.4000E+02 921 +.4100E+02 922 +.1300E+02 923 +.1400E+02 924 +.1500E+02
 925 +.1230E+03 926 +.1210E+03 927 +.1250E+03 928 +.6450E+03 929 +.1010E+03
 930 +.1020E+03 931 +.1030E+03 932 +.1040E+03 933 +.1050E+03 934 +.1060E+03
 995 +.2000E+01 996 +.2000E+01 998 +.1000E+01
```

Figure 50. Typical Aircraft Trajectory Input Data

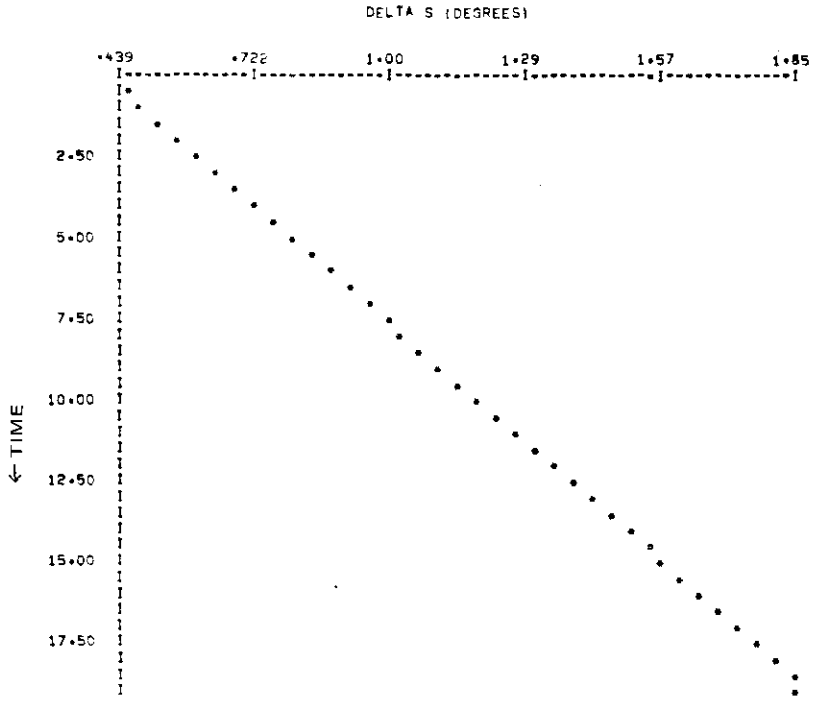


Figure 51. δ_s versus Time

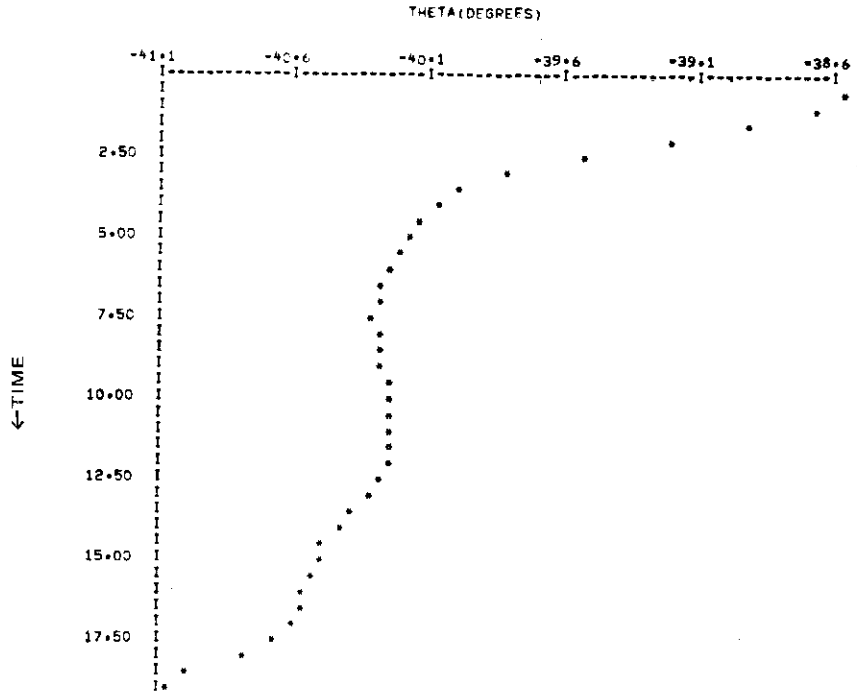


Figure 52. θ versus Time

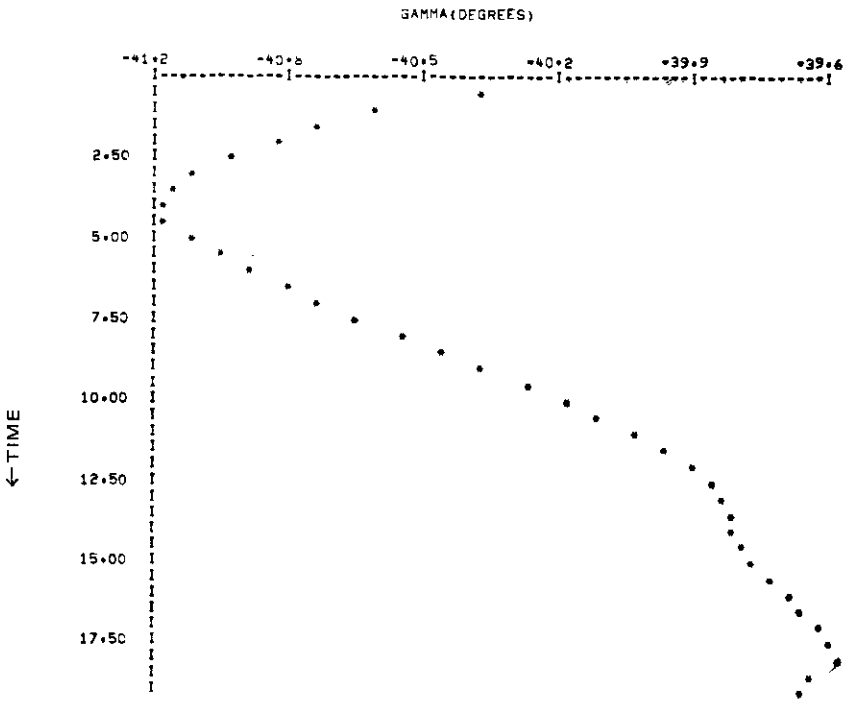


Figure 53. γ versus Time

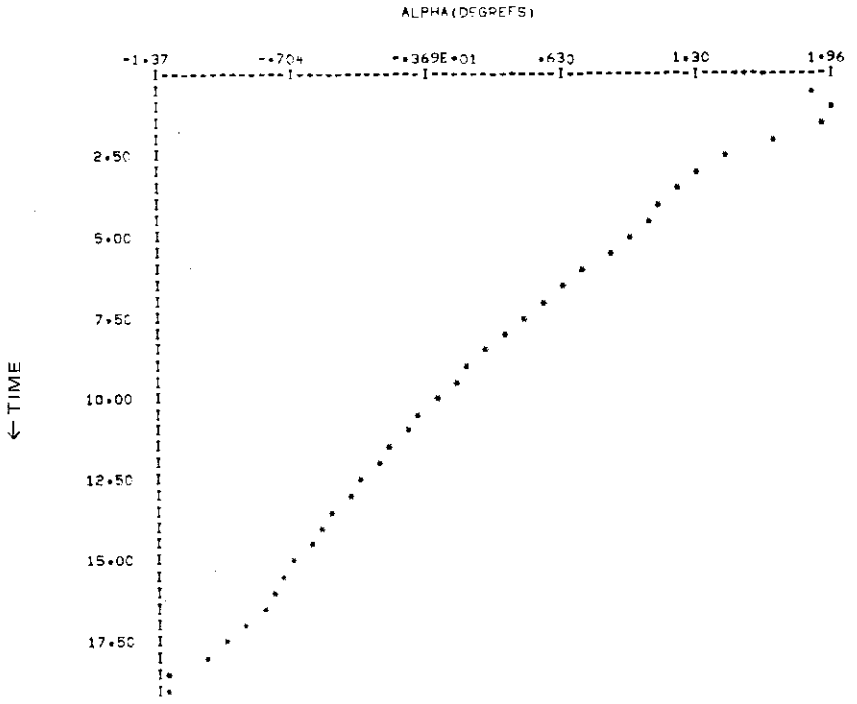


Figure 54. α versus Time

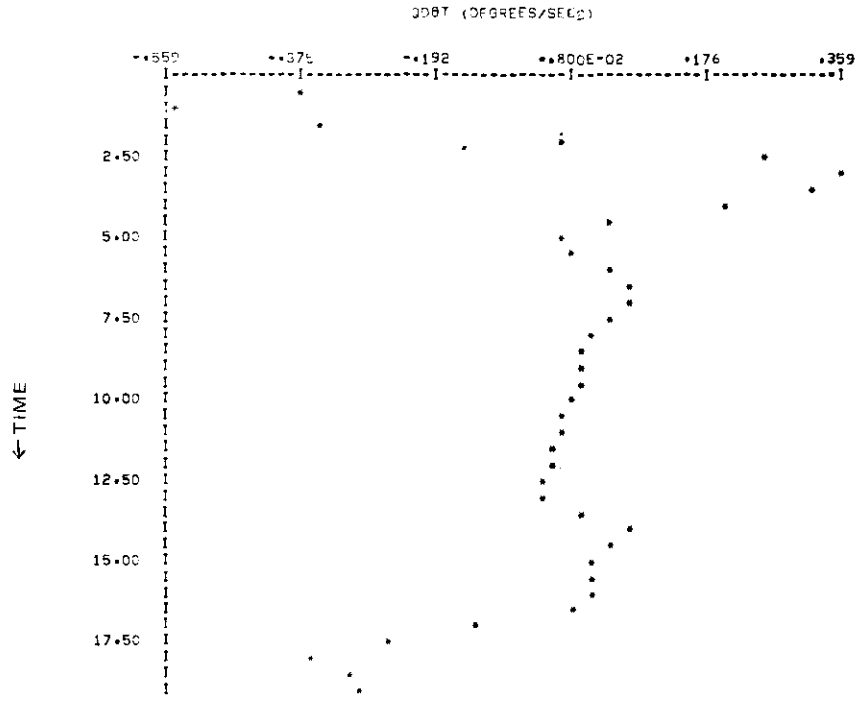


Figure 55. $\dot{q}$ versus Time

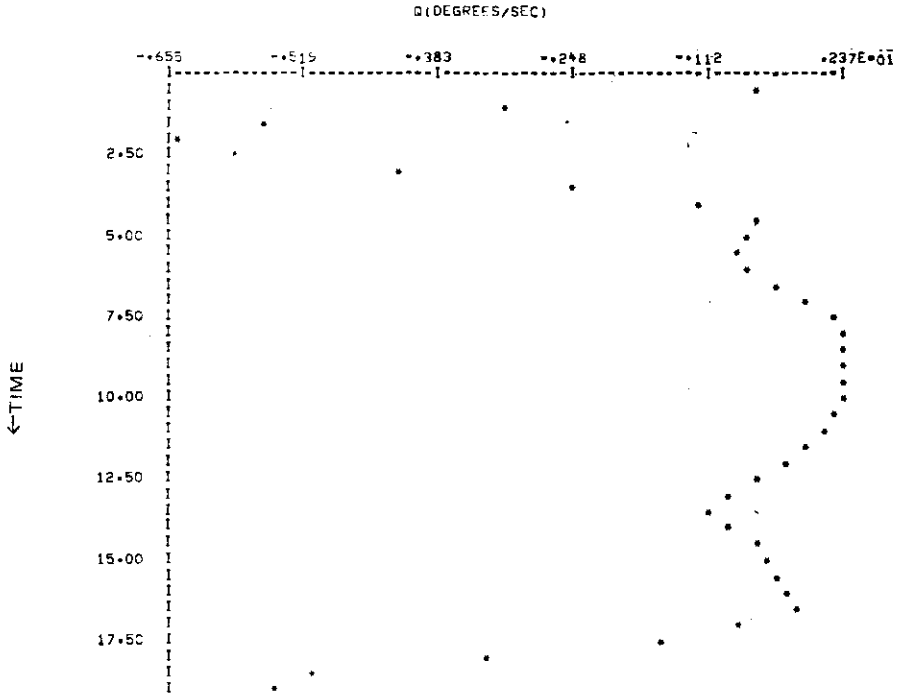


Figure 56. q versus Time

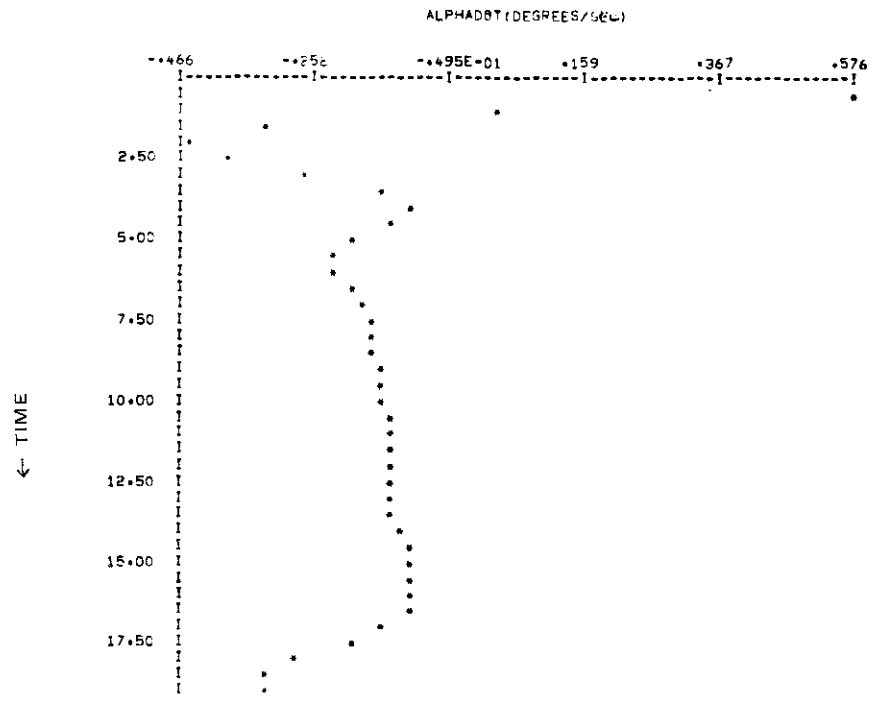


Figure 57. $\dot{\alpha}$ versus Time

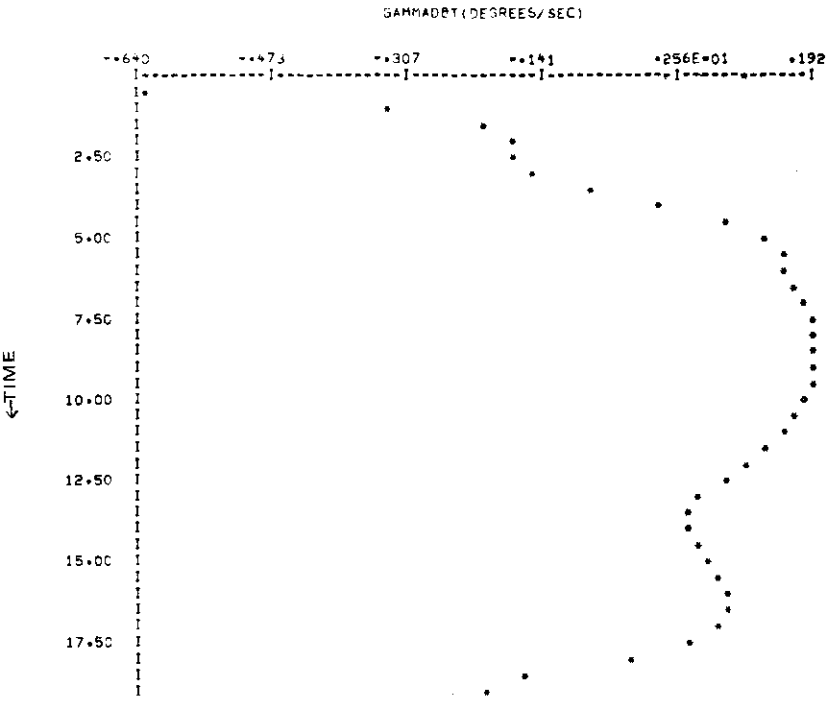


Figure 58. $\dot{\gamma}$ versus Time

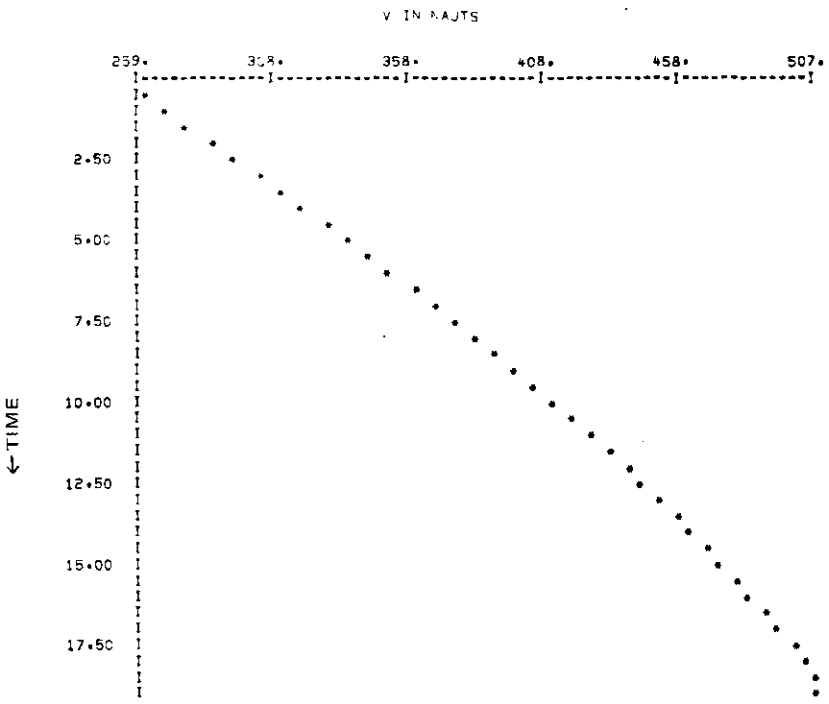


Figure 59. V versus Time

FROZEN-POINT SPECTRUM ANALYSIS OF THE LINEAR DATA

The linear aircraft data was then subjected to a frozen-point eigenvalue analysis. The eigenvalues were separated into the longitudinal and lateral channels. By properly partitioning the longitudinal matrix, the phugoid, and the short-period modes as well as the altitude and range modes were identified. Similarly the lateral matrix was partitioned, and the dutch-roll, the roll convergence and the spiral modes were identified. The matrices were partitioned as shown in Volume I, Figure 31.

The program listing for the eigenvalue analysis is given in Figure 60. The short-period mode and the phugoid mode of the airframe during dive are plotted in Figures 61 and 62, respectively at 1-second data time points. The dutch-roll mode, the spiral mode, and the roll convergence mode are similarly plotted in Figures 63, 64 and 65.

```
FORTRAN LS,G0
    1:       DIMENSION D(12,12),ISH(12),FU(4,4),FU1(3,3),FU2(2,2),FL(6,6)
    2:       DIMENSION FL1(2,2),FL2(4,4),F(12,12),FH(12,12)
    3:       DIMENSION A(50)
    4:       LW=9
    5:       KK=16
    6:       READ(5,1001) ISH
    7:  1001 FORMAT(1212)
    8:       DO 10 L=1,KK
    9:       READ(2)F
   10:       DO 4001 I=1,12
   11:       DO 4001 J=1, 12
   12:       IF(ABS(F(I,J)).GT..00000001) GOTO 4001
   13:       F(I,J)=0.
   14:  4001 CONTINUE
   15:       DO 300 I=1,12
   16:       DO 300 J=1,12
   17:   300 FH(I,J)= F(I,J)
   18:       CALL SHUF(FH,12,12,1,ISH,12,12,D)
   19:       FH(1,8)=0.
   20:       FH(1,11)=0.
   21:       FH(4,5)=1.1
   22:       FH(7,10)=1.1
   23:       FH(11,12)=1.1
   24:       FH(2,11)=0.
   25:  4000 FORMAT(1H1/7X,1CH F MATRIX /)
   26:       WRITE(LW,4000)
   27:       CALL MP(12,12,12,12,FH,9)
   28:       ICOT=0
   29:       DO 4022 I=1,12
   30:       DO 4022 J=1,12
   31:       IF((FH(I,J).EQ.0.).OR.(FH(I,J).EQ.1.)) GOTO 4022
   32:       ICOT=ICOT+1
   33:       A(ICOT)=FH(I,J)
   34:  4022 CONTINUE
   35:       WRITE(3)A
   36:       DO 4002 I=1,4
   37:       II=I+2
   38:       DO 4002 J=1,4
   39:       JJ=J+2
   40:  4002 FU(I,J)=FH(II,JJ)
   41:       DO 4003 I=1,3
   42:       II=I+1
   43:       DO 4003 J=1,3
   44:       JJ=J+1
   45:  4003 FU1(I,J)=FU(II,JJ)
   46:       DO 4004 J=1,2
   47:       JJ=J+1
   48:       DO 4004 I=1,2
   49:       II=I+1
   50:  4004 FU2(I,J)=FU1(II,JJ)
   51:       DO 4005 I=1,6
   52:       II=I+6
   53:       DO 4005 J=1,6
   54:       JJ=J+6
   55:  4005 FL(I,J)=FH(II,JJ)
   56:       DO 4006 I=1,4
   57:       DO 4006 J=1,4
   58:  4006 FL2(I,J)=FL(I,J)
   59:       DO 4007 I=1,2
```

Figure 60. Eigenvalue Analysis Program Listing

```
      II=I+2
      DO 4007 J=1,2
      JJ=J+2
 4007 FL1(I,J)=FL2(II,JJ)
      WRITE(9,4008)
      CALL MP(4,4,4,4,FU,9)
      CALL ROOT(FU,4)
      WRITE(9,4009)
      CALL MP(3,3,3,3,FU1,9)
      CALL ROOT(FU1,3)
      WRITE(9,4010)
      CALL MP(2,2,2,2,FU2,9)
      CALL ROOT(FU2,2)
      WRITE(9,4011)
      CALL MP(6,6,6,6,FL,9)
      CALL ROOT(FL,6)
      WRITE(9,4012)
      CALL MP(4,4,4,4,FL2,9)
      CALL ROOT(FL2,4)
      WRITE(9,4013)
      CALL MP(2,2,2,2,FL1,9)
      CALL ROOT(FL1,2)
 4008 FORMAT(1H1/7X,10HF11 MATRIX/)
 4009 FORMAT(///7X,15HF11(3X3) MATRIX/)
 4010 FORMAT(///7X,15HF11(2X2) MATRIX/)
 4011 FORMAT(1H1/7X,10HF22 MATRIX/)
 4012 FORMAT(///7X,15HF22(4X4) MATRIX/)
 4013 FORMAT(///7X,15HF22(2X2) MATRIX/)
   10 CONTINUE
      END
```

```
      SUBROUTINE ROOT(A,NX)
      DIMENSION A(NX,NX),RR(40)
      LWR=9
      CALL HESSEN(NX,A,NX)
      CALL QRCALL(NX,A,RR,MM,NX)
      WRITE(LWR,900)
  900 FORMAT(///5X,23H      REAL              IMAG/)
      MN=MM/2
      DO 901 K=1,MN
      I=2*K-1
      II=2*K
  901 WRITE(LWR,802)RR(I),RR(II)
  802 FORMAT(2E20.8)
      RETURN
      END
```

Figure 60. Eigenvalue Analysis Program Listing (concluded)

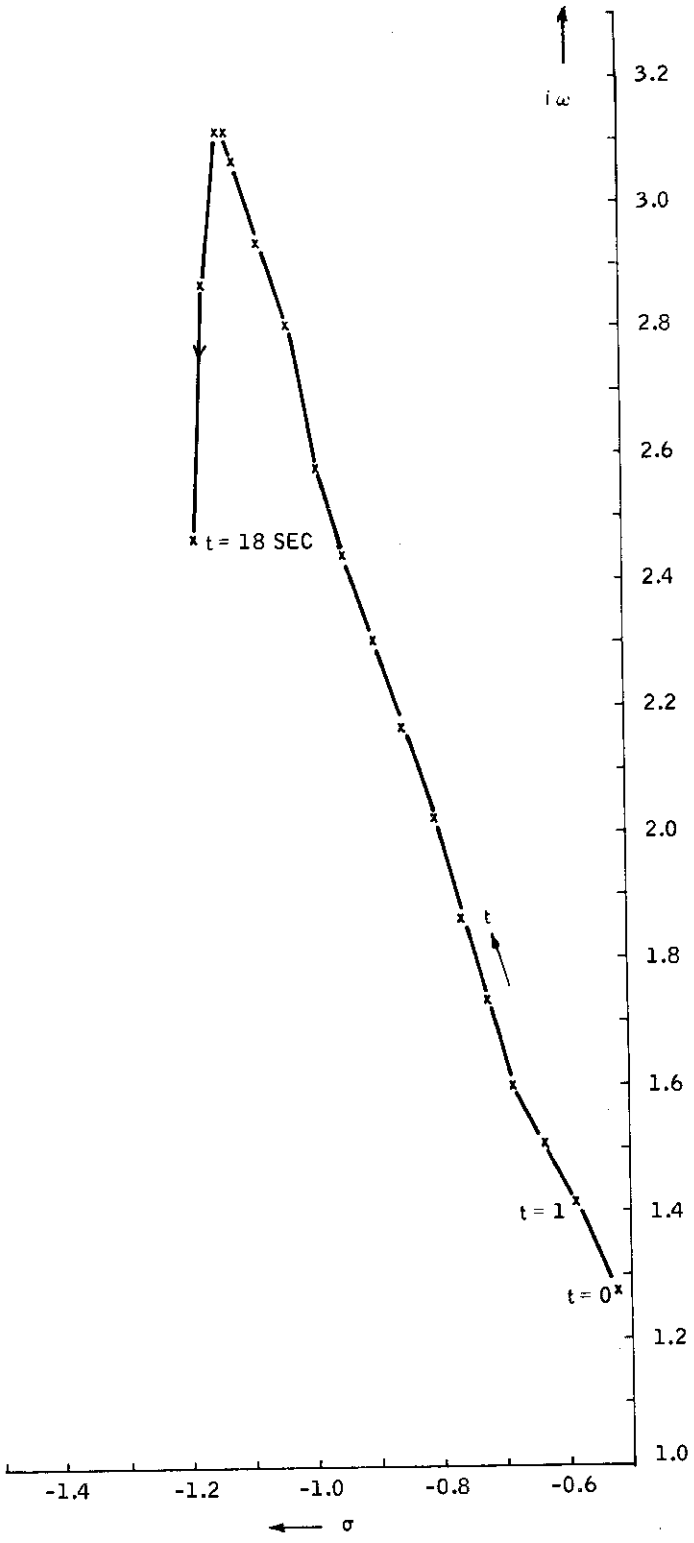


Figure 61. Short-Period Mode of Airframe During Dive

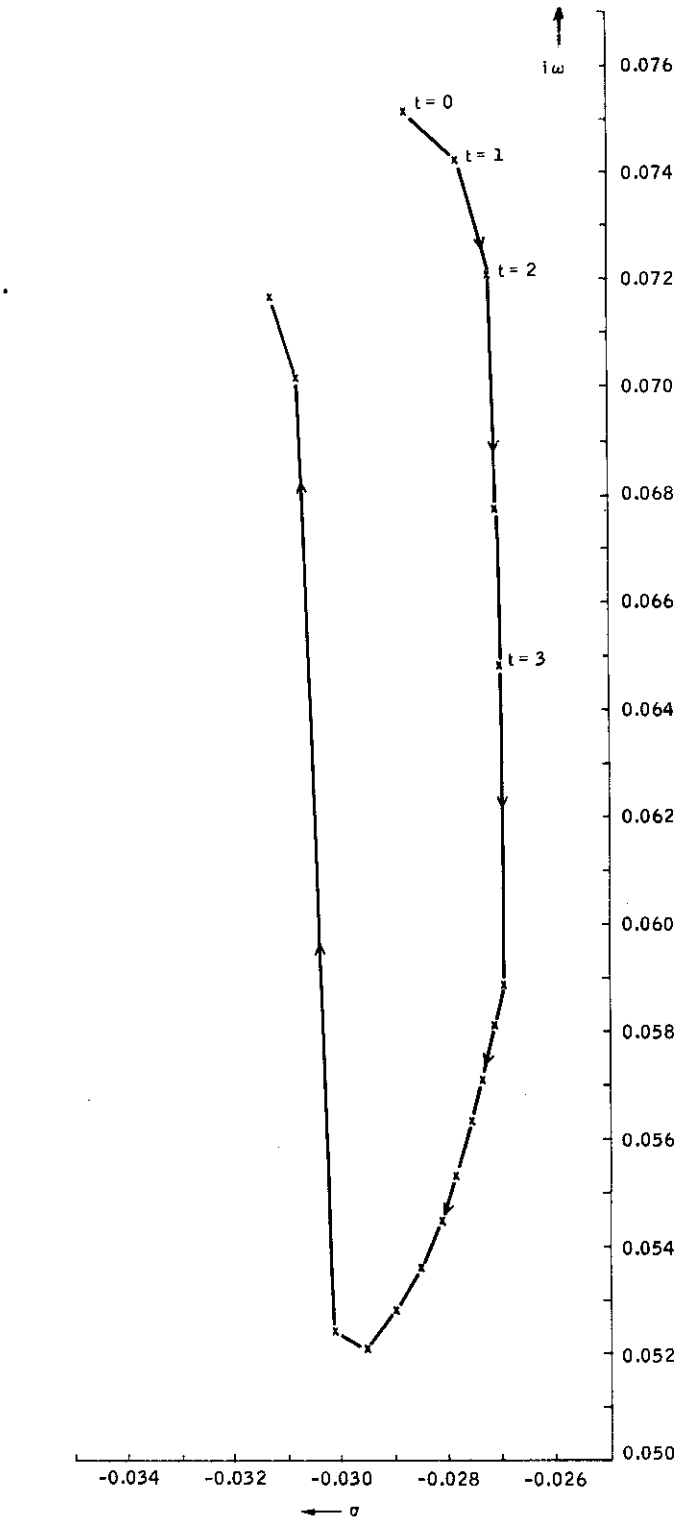


Figure 62. Phugoid Mode of Airframe During Dive

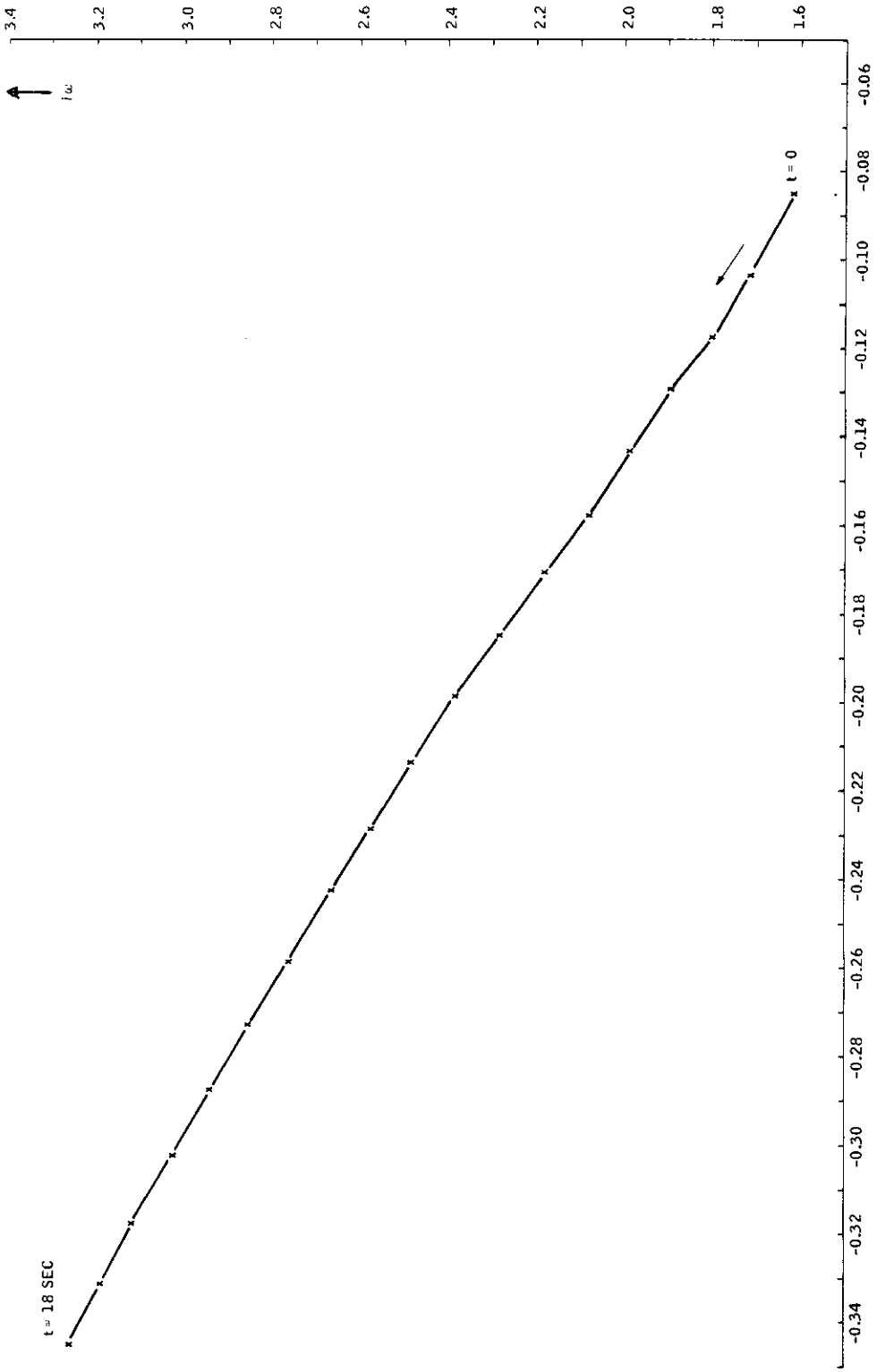


Figure 63. Dutch-Roll Mode of Airframe During Dive

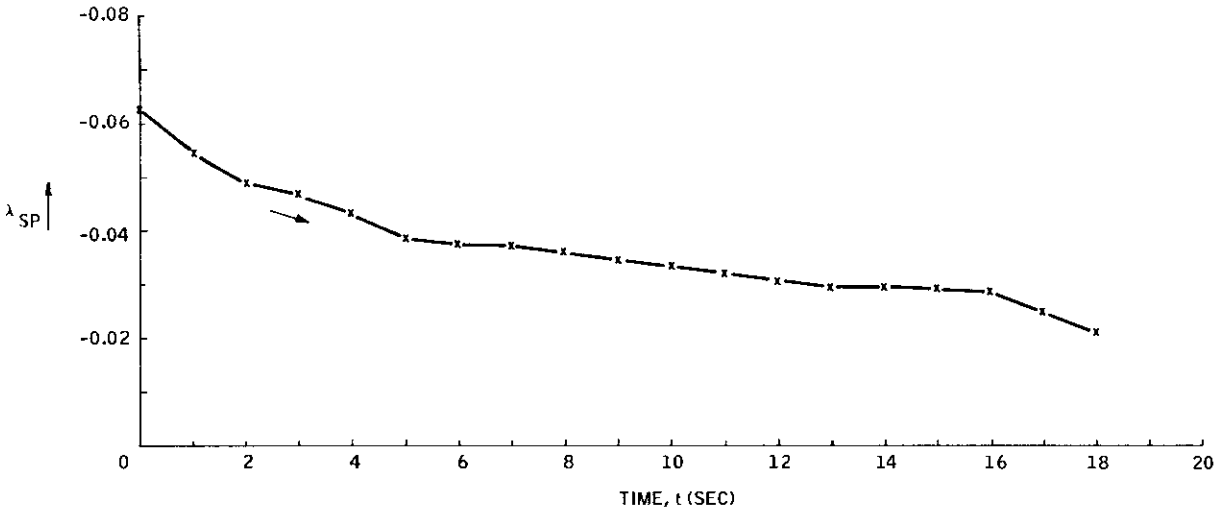


Figure 64. Spiral Mode of Airframe versus Time During Dive

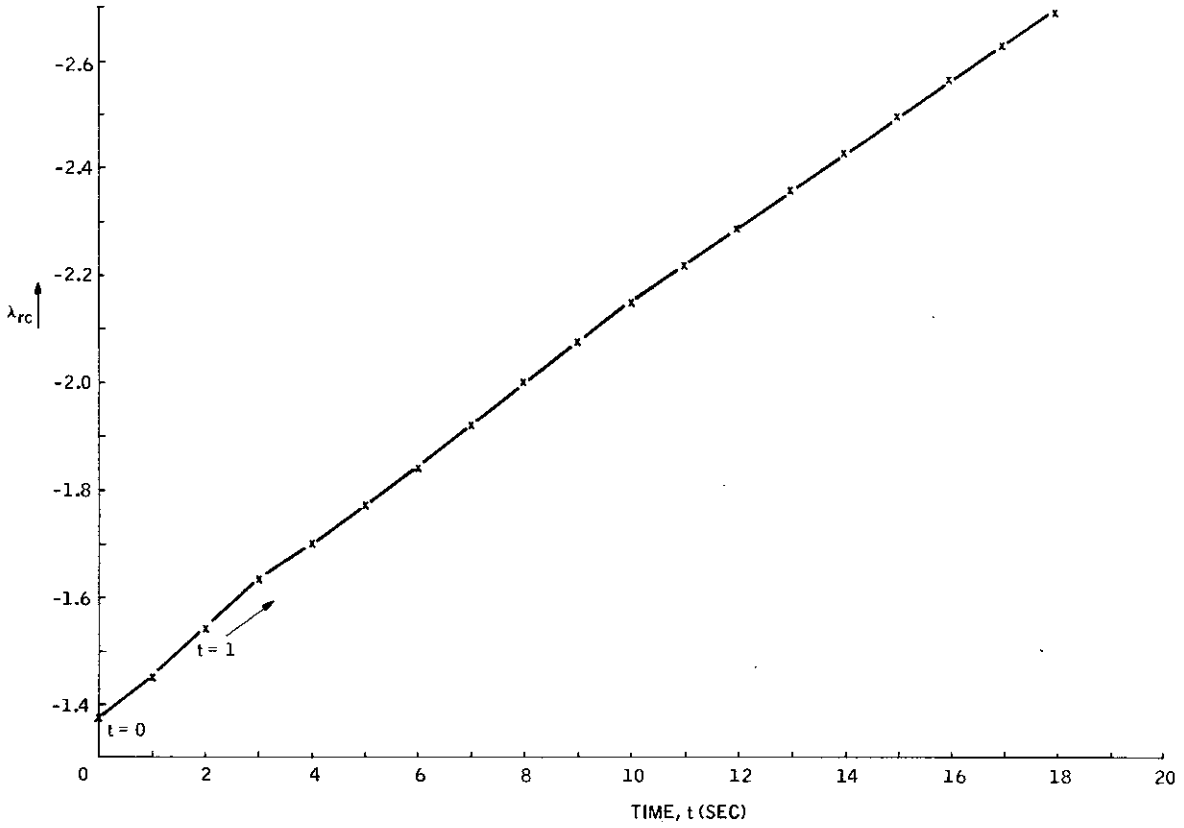


Figure 65. Roll-Convergence Mode of Airframe versus Time During Dive

SECTION IV
TESTING THE WEAPON AND GUST FILTER SOFTWARE

First, a main program was written to generate the weapon's nonlinear trajectory. The M117 bomb was dropped from a specified altitude with a specified velocity and dive angles. The results obtained from the program were checked against bombtable TH 61 A1-3-2/NAVAIR 00-130-ASR-2. Table V shows these checks. The results were found to be satisfactory. Next, the main program was modified to include linearization at specified time intervals during the weapon trajectory generation with different perturbation magnitudes. Almost the same linearization matrices (F, G) are obtained by doubling and halving the nominal perturbations. Figure 66 shows the pitch-axis variables during fall.

The lateral response was also checked by two experiments, one starting with the side velocity of v = 20 feet, with $\psi = 0$, and the other by v = 0 and ψ = 10-degree azimuth angle in bomb orientation.

The linear data obtained from the nominal initial condition were subjected to the frozen-point spectrum (eigenvalue) analysis. The short-period and the dutch-roll modes of the M117 were found to be stable at all frozen-time points. The phugoid mode and the spiral mode became slightly unstable at some points of the free fall. Figures 67 and 68 show the longitudinal and the lateral eigenvalues of the weapon.

The gust filter, which is a part of WINDK, was checked out by integrating numerically its covariance differential equation with a unity covariance input until steady state is reached. The result was found to be

$$\lim_{t\to\infty} E \begin{bmatrix} u_g^2 \\ v_g^2 \\ w_g^2 \end{bmatrix} = \frac{1}{\pi} \begin{bmatrix} \sigma_u^2 \\ \sigma_v^2 \\ \sigma_w^2 \end{bmatrix}$$

A brief analysis was presented in Section IV of Volume I to justify the result. This shows that, in order to obtain a variance σ^2 at the output of the Dryden filter, the input noise η must have a variance

$$\sigma_\eta^2 = \pi$$

instead of the usually assumed value of unity.

The pole locations of the roll, pitch and yaw gust filters for the aircraft are inversely proportional to wingspan b. The corresponding term for the weapon would be its diameter. When weapon diameter is used in place of wingspan, the magnitudes of the poles of the roll pitch, and yaw filters become excessively large. Numerical integration (i.e., non-real-time simulation) of these extremely fast dynamics requires a very small integration step size.

For small weapons, the space gradient effects of wind gust, (i.e., roll, pitch and yaw filters) are small. For this reason, these filters are omitted in the simulation of weapons in ADAPS.

The overall state of the weapon and wind dynamics are defined as

$$(x', w') \triangleq (\delta x_e, \delta h_e, \delta u, \delta\theta, \delta q, \delta w | \delta y, \delta\psi, \delta r, \delta v | w_1, w_3, w_5 | w_2, w_4)$$

in which the roll dynamics of the weapon and the roll-pitch-yaw dynamics of wind gust are omitted.

Table V. Comparison of Trajectory Data Obtained from ADAP 1 and Bombtable

FC	Rlse Alt Above Burst (ft)	Eject Vel (ft/sec)	Dive Angle (deg)	Rlse Vel (kts)	Time of Fall (sec)	Horiz Range (ft)	Impact Angle (deg)	Impact Vel (ft/sec)	Source of Data
1	4000	0	40	400	7.40	3740	52.6	814	Bombtable
					7.37	3749	51.7	817.6	ADAP 1
2	4000	0	30	400	8.60	4900	46.7	810	Bombtable
					8.57	4907	46.8	813.5	ADAP 1

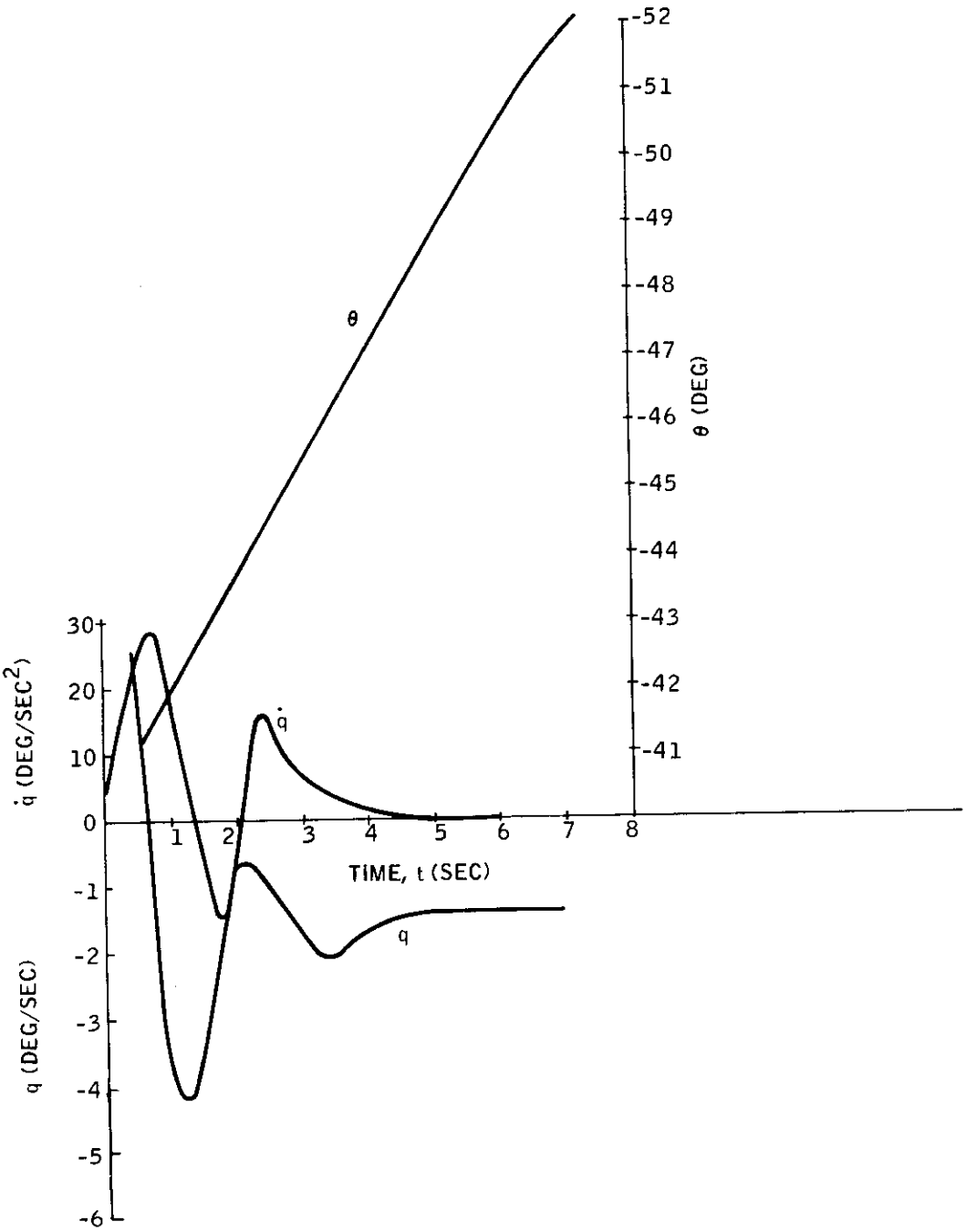


Figure 66. Weapon Pitch-Axis Variables During Fall

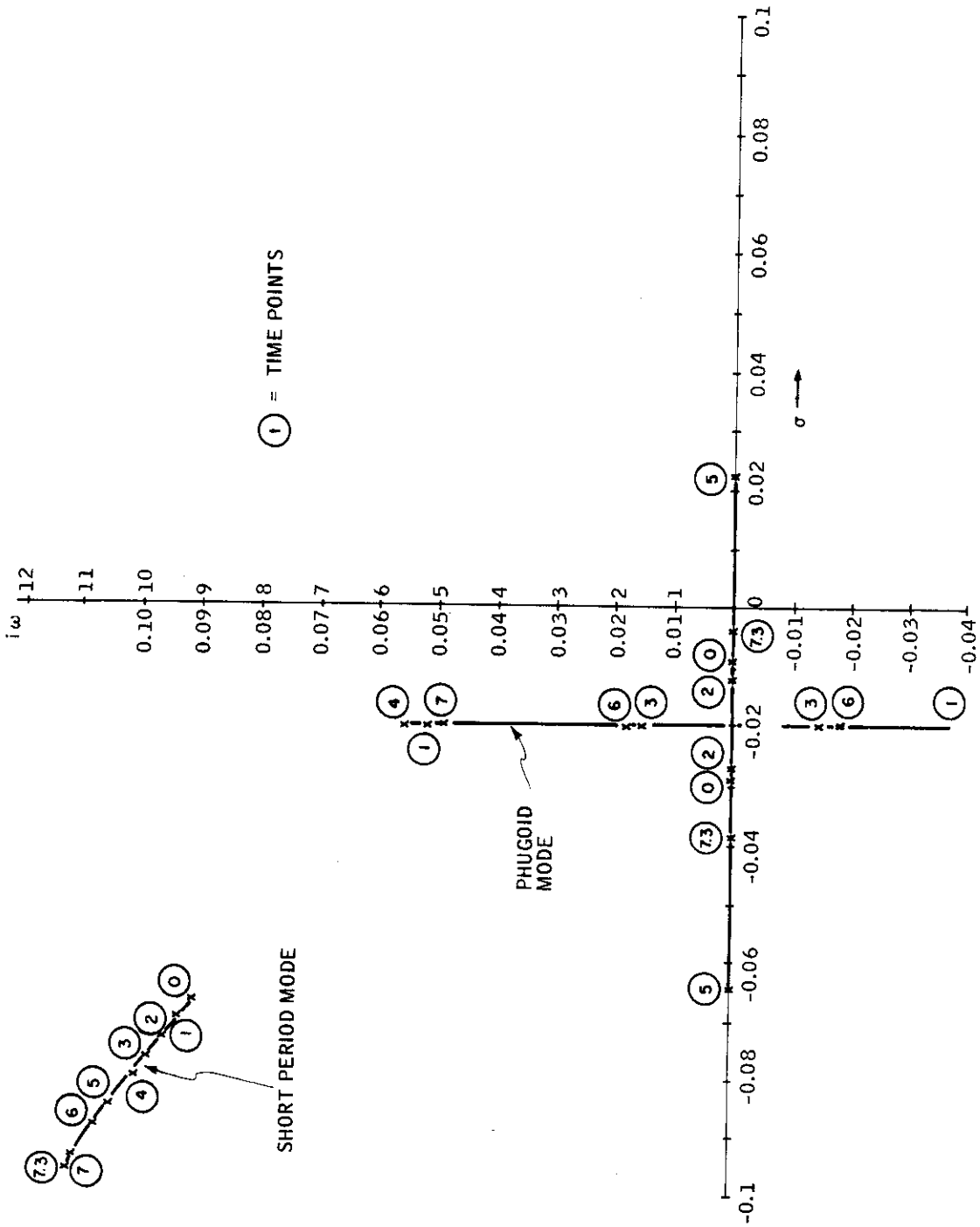


Figure 67. Spectrum of Frozen Point - Longitudinal Matrix of M117

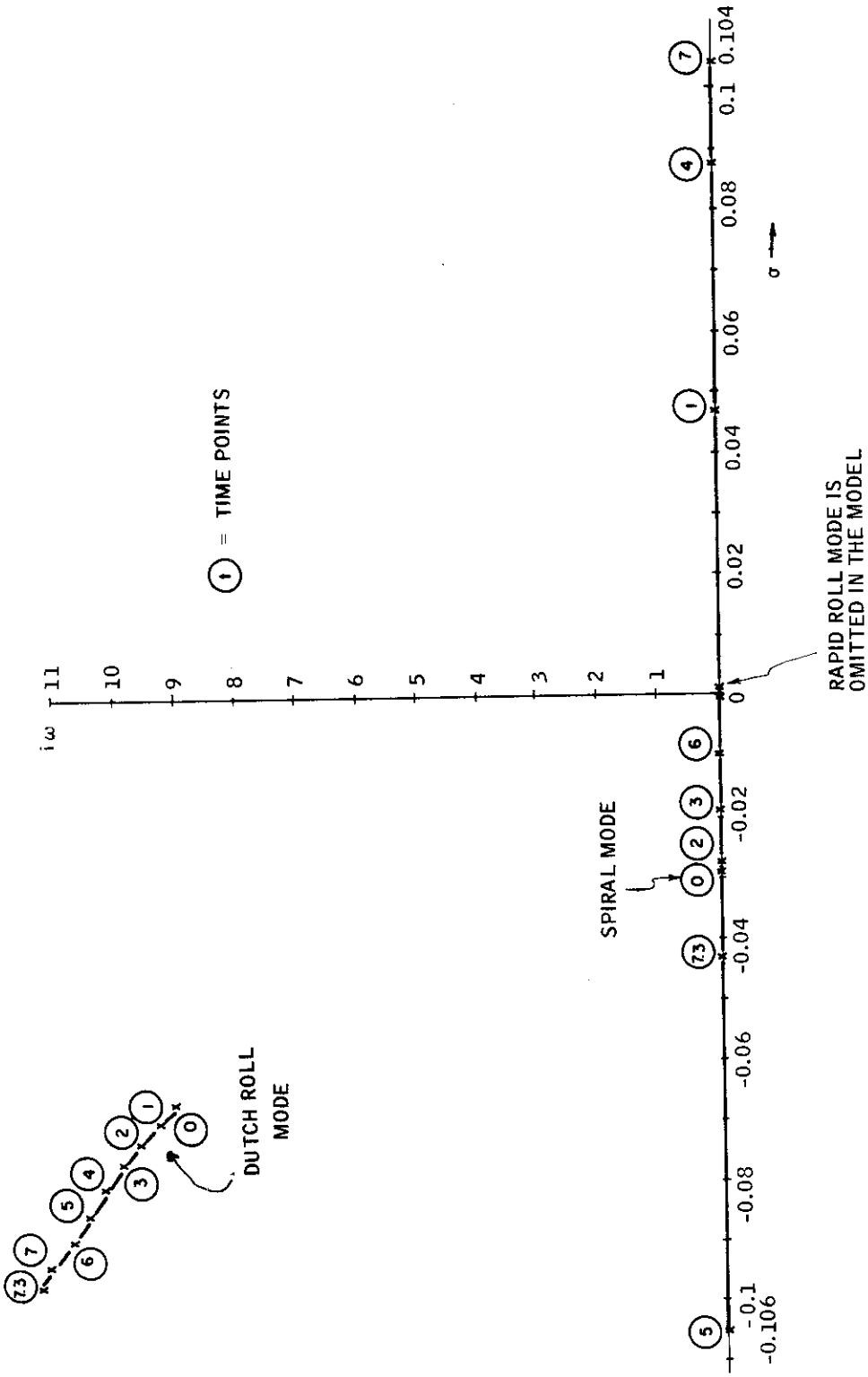


Figure 68. Spectrum of Frozen Point - Lateral Matrix of M117

SECTION V
TESTING THE CONTROLLER DESIGN SOFTWARE

The nonstationary optimization program (DISCOP) was debugged using a dynamical system (catalytic cracker) with a known solution. This known solution was for the continuous controller. The sample time of DISCOP which essentially computes discrete controller had to be reduced to 0.001 to approximate the continuous controller. The same steady-state gains were produced by DISCOP.

The second test was conducted for a system described by a set of proper identity matrices. Feedback and estimator gains were computed by DISCOP. The results were identical with the known answers.

The stationary optimization program DIAK was tested similarly. Simple system matrices were used, and the costate, optimal controller gains, minimum estimation error covariance, optimal estimator gains and the total covariance matrices were computed and checked against known answers.

SECTION VI
CONTROLLER DESIGN

The linear data obtained from ADAP 1, as previously described, were used for controller design.

The first run was made to determine how much improvement in performance would be obtained by using a controller. For this, first the performance corresponding to the airframe with no controller was evaluated, and the CEP at impact was computed. This was compared against performance with the optimal controller. As expected, a large improvement in the performance (reducing the CEP) was obtained.

To establish the adequacy or inadequacy of the stationary analysis, first a nonstationary optimization program was run, and the CEP at impact was computed with the time-varying controller gains. Next, a time point, nine seconds, was chosen within the airplane flight time interval $0 \leq t \leq 19$ seconds. The linear data of the 9-second time point were used for computing the time-invariant (i.e., steady-state) optimal gains. Subsequently, the CEP at impact was computed with these fixed gains.

In these two iterations it was assumed that the aircraft states were measured completely but imperfectly and the wind states together with the aircraft states had to be estimated. The control points were assumed to be the ailerons, the stabilator, the spoilers and the rudder. The gains corresponding to stationary and nonstationary designs for the 9-second data points are shown in Tables VI, VII and VIII.

No appreciable difference in performance was noticed betwen the two results. The performance results are summarized in Table IX. On the basis of this experiment, the performance obtained from the fixed-gain optimal system is thought to be satisfactory. We emphasize that the performance computations are based on the actual physical time-varying, finite-time system with a variable or fixed set of gains in it. The steady-state variances of the position and the attitude states of the closed-loop system corresponding to some of the frozen-point linear data are finite but considerably different than that of finite time covariances. This is due to low damping of the position and attitude integrators by the optimal controller.

The output of the performance evaluator (ADAP 3) corresponding to the free airframe is shown in Figure 69. Figure 70 shows the performance outputs with the nonstationary optimal controller. The performance outputs for the fixed-gain optimal controller are shown in Figure 71.

The controller weights corresponding to the stabilator, aileron, rudder and the spoiler were all the same, and the value used in the example was 10^4. Since the bomb dynamics did not have the roll states p and ϕ, no weightings were computed for these variables when using the impact covariance matrix. The weighting values used for these variables were selected to be:

$$q_\phi = 10^3, \quad q_p = 10^2$$

Table VI. Feedback Gains from Longitudinal States at 9 Seconds

Control	x_e (ft)	h_e (ft)	u (ft/sec)	θ (rad)	q (rad/sec)	w (ft/sec)	Optimization
δ_s (deg)	0.00121	0.00106	0.00545	10.437	1.864	-0.0130	Nonstationary
	0.00124	0.00108	0.00551	10.559	1.863	-0.0133	Stationary
δ_a (deg)	0.000104	0.00009	0.00039	0.86642	0.15553	-0.00106	Nonstationary
	0.000097	0.00008	0.00031	0.76507	0.13655	-0.00094	Stationary
δ_r (deg)	0.000015	0.000013	0.00011	0.15521	0.02688	-0.00020	Nonstationary
	0.000021	0.000018	0.00015	0.21582	0.03684	-0.00028	Stationary
δ_{sp} (deg)	-0.00003	-0.00002	-0.00016	-0.2787	-0.04918	-0.000352	Nonstationary
	-0.00003	-0.00003	-0.00020	-0.32738	-0.05687	-0.000421	Stationary

Table VII. Feedback Gains from Lateral States at 9 Seconds

Control	y_e (ft)	ψ (rad)	r (rad/sec)	v (rad/sec)	ϕ (rad)	p (rad/sec)	Optimization
δ_s	0.000079	0.6950	0.1603	0.00105	0.1488	0.06737	Nonstationary
(deg)	0.000070	0.7030	0.2224	0.00099	0.2093	0.09943	Stationary
δ_a	-0.00137	-11.412	-2.4919	-0.01759	-2.3055	-1.037	Nonstationary
(deg)	-0.00134	-11.548	-3.0831	-0.1721	-2.8890	-1.3530	Stationary
δ_r	0.001056	8.3445	1.7659	0.01298	1.600	0.7163	Nonstationary
(deg)	0.00099	8.077	2.0522	0.01224	1.8752	0.8731	Stationary
δ_{sp}	-0.00058	-4.8339	-1.0511	-0.0074	-0.9702	-0.4362	Nonstationary
(deg)	-0.000571	-4.868	-1.2917	-0.0072	-1.2073	-0.5650	Stationary

Table VIII. Feedback Gains from Wind States at 9 Seconds

Control	w_1 (ft/sec)	w_3 (ft/sec)	w_5	w_2 (ft/sec)	w_4	Optimization
δ_s	-0.00204	-0.00048	-0.00217	0.000037	0.000145	Nonstationary
(deg)	-0.00215	-0.00075	-0.00157	0.000151	0.000650	Stationary
δ_a	-0.00013	-0.00003	-0.00013	-0.00051	-0.00185	Nonstationary
(deg)	-0.00008	-0.00001	-0.00012	-0.00217	-0.00582	Stationary
δ_r	-0.00005	-0.00001	-0.00006	0.00027	0.001181	Nonstationary
(deg)	-0.00008	-0.00003	-0.000001	0.00135	0.00324	Stationary
δ_{sp}	0.00006	0.000016	0.000075	-0.00021	-0.00077	Nonstationary
(deg)	0.00009	0.000038	0.000044	0.00090	-0.00239	Stationary

Table IX. Performance Summary for Different Runs

Description of Run	Variances at the Nominal Impact Time			Variances at the Horizontal Impact Plane		Horizontal CEP	Variances at the Vertical Impact Plane		Vertical CEP
	σ_x^2	σ_y^2	σ_h^2	$\tilde{\sigma}_x^2$	$\tilde{\sigma}_y^2$	CEP_h	$\tilde{\sigma}_h^2$	$\tilde{\sigma}_y^2$	CEP_v
Free airframe	58430	59212	17099	111550	59212	337.7	143940	59212	364.29
Nonstationary optimal controller	17386	1052	19412	2225.9	1052.8	27.77	201.5	1052.8	28.96
Fixed-gain optimal controller	17581	870	22343	658.76	870.0	32.27	849.98	870.0	34.31

INITIAL COVARIANCE OF BOMB

```
ROW   1
 .33478E 05  .80399E 04  .28117E 03  .26896E 01  .48895E-01 -.34751E 00  .12140E 02 -.28100E-13  .72533E-14  .44572E-12
-.52562E 01 -.43002E 01  .43174E 00  .00000E 00  .00000E 00
ROW   2
 .80399E 04  .70049E 04 -.89702E 02  .71480E 00 -.45088E-01  .11704E 01  .39441E-09  .23204E-13 -.59896E-14 -.36807E-12
-.19701E 02 -.22112E 01 -.12014E 00  .00000E 00  .00000E 00
ROW   3
 .28117E 03 -.89702E 02  .33195E 02  .18539E-01  .22762E-02  .23915E 00 -.10616E-10 -.62459E-15  .16122E-15  .99072E-14
 .20555E 01 -.35162E 00  .37054E-01  .00000E 00  .00000E 00
ROW   4
 .26896E 01  .71480E 00  .18539E-01  .23372E-03  .37864E-05  .11196E-01  .81913E-14  .48192E-18 -.12440E-18 -.76442E-17
-.52964E-02  .83308E-02  .69035E-03  .00000E 00  .00000E 00
ROW   5
 .48895E-01 -.45088E-01  .22762E-02  .37864E-05  .11804E-04  .15403E-02  .32787E-14  .19290E-18 -.49791E-19 -.30597E-17
-.23661E-02  .26876E-02  .46213E-03  .00000E 00  .00000E 00
ROW   6
-.34751E 00  .11704E 01  .23915E 00  .11196E-01  .15403E-02  .16497E 02  .37896E-11  .22296E-15 -.57551E-16 -.35365E-14
-.13524E 00  .90336E 01  .72884E 00  .00000E 00  .00000E 00
ROW   7
 .12140E 02  .39441E-09 -.10616E-10  .81913E-14  .32787E-14  .37896E-11  .27398E 05  .30982E 01  .27916E-02 -.21837E 02
 .00000E 00  .00000E 00  .00000E 00  .15381E 01 -.22529E 00
ROW   8
-.28100E-13  .23204E-13 -.62459E-15  .48192E-18  .19290E-18  .22296E-15  .30982E 01  .43224E-03 -.15450E-05 -.23888E-01
 .00000E 00  .00000E 00  .00000E 00 -.13414E-01 -.11648E-02
ROW   9
 .72533E-14 -.59896E-14  .16122E-15 -.12440E-18 -.49791E-19 -.57551E-16  .27916E-02 -.15450E-05  .10762E-03 -.44409E-03
 .00000E 00  .00000E 00  .00000E 00 -.36721E-02 -.61270E-03
ROW  10
 .44572E-12 -.36807E-12  .99072E-14 -.76442E-17 -.30597E-17 -.35365E-14 -.21837E 02 -.23888E-01 -.44409E-03  .21057E 02
 .00000E 00  .00000E 00  .00000E 00  .93049E 01  .77086E 00
ROW  11
-.52562E 01 -.19701E 02  .20555E 01 -.52964E-02 -.23661E-02 -.13524E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .98318E 01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
ROW  12
-.43002E 01 -.22112E 01 -.35162E 00  .83308E-02  .26876E-02  .90336E 01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .95895E 01  .82433E 00  .00000E 00  .00000E 00
ROW  13
 .43174E 00 -.12014E 00  .37054E-01  .69035E-03  .46213E-03  .72884E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .82433E 00  .90732E-01  .00000E 00  .00000E 00
ROW  14
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .15381E 01 -.13414E-01 -.36721E-02  .93049E 01
 .00000E 00  .00000E 00  .00000E 00  .95895E 01  .82433E 00
ROW  15
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00 -.22529E 00 -.11648E-02 -.61270E-03  .77086E 00
 .00000E 00  .00000E 00  .00000E 00  .82433E 00  .90732E-01
```

Figure 69. Performance Evaluator Output - Free Airframe

```
      XSUBF MATRIX T=     4.28

RBW   1
 .60294E 00 -.62304E 00  .17836E 00 -.26569E-04  .18072E-03 -.34479E-01 -.69096E-09 -.10555E-11 -.95899E-12  .46555E-09
 .20729E 00 -.91954E-02  .23553E-01  .46546E-09  .19755E-08
RBW   2
-.62304E 00  .68361E 00 -.19133E 00 -.33500E-04  .15761E-03 -.30660E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
-.21632E 00 -.85040E-02  .16660E-01  .00000E 00  .00000E 00
RBW   3
 .17936E 00 -.19133E 00  .62515E-01 -.10596E-04 -.65221E-05 -.11883E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .43977E 00 -.29561E-02 -.40228E-02  .00000E 00  .00000E 00
RBW   4
-.26569E-04 -.33500E-04 -.10596E-04  .42610E-04  .91194E-05  .41113E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .23447E-04  .10552E-01  .14673E-01  .00000E 00  .00000E 00
RBW   5
 .18072E-03  .15761E-03 -.65221E-05  .91194E-05  .58511E-02  .14627E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .43567E-04  .10938E 00  .44073E 00  .00000E 00  .00000E 00
RBW   6
-.34479E-01 -.30660E-01 -.11883E-01  .41113E-01  .14627E-01  .39676E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .17814E-01  .10315E 02  .14602E 02  .00000E 00  .00000E 00
RBW   7
-.69096E-09  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .36046E-01 -.36601E-03  .36531E-03  .24418E 00
 .00000E 00  .00000E 00  .00000E 00  .19077E 00  .61763E-02
RBW   8
-.10555E-11  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00 -.36601E-03  .25254E-03  .75961E-04 -.16194E 00
 .00000E 00  .00000E 00  .00000E 00 -.10390E 00 -.59320E-01
RBW   9
-.95899E-12  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .36531E-03  .75961E-04  .74214E-02 -.57265E-01
 .00000E 00  .00000E 00  .00000E 00 -.18401E 00 -.14661E 00
RBW  10
 .46555E-09  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .24418E 00 -.16194E 00 -.57265E-01  .10386E 03
 .00000E 00  .00000E 00  .00000E 00  .66839E 02  .38155E 02
RBW  11
 .20729E 00 -.21632E 00  .43977E 00  .23447E-04  .43567E-04  .17814E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .64663E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
RBW  12
-.91954E-02 -.85040E-02 -.29561E-02  .10552E-01  .10938E 00  .10315E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .17072E 02  .49839E 02  .00000E 00  .00000E 00
RBW  13
 .23553E-01  .16660E-01 -.40228E-02  .14673E-01  .44073E 00  .14602E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .49839E 02  .17389E 03  .00000E 00  .00000E 00
RBW  14
 .46546E-09  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .19077E 00 -.10390E 00 -.18401E 00  .66839E 02
 .00000E 00  .00000E 00  .00000E 00  .71744E 02  .42611E 02
RBW  15
 .19755E-08  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .61763E-02 -.59320E-01 -.14661E 00  .38155E 02
 .00000E 00  .00000E 00  .00000E 00  .42611E 02  .27159E 02
```

Figure 69. Performance Evaluator Output - Free Airframe (continued)

PHI(T ,TR) MATRIX

ROW 1									
.10000E 01	.20172E-02	.49408E 01	.33662E 04	.45008E 01	-.40420E 01	.00000E 00	.18626E-05	.37485E-08	.28731E-08
.10066E 00	.24574E 00	.26640E 00	-.74333E-09	-.27066E-08					
ROW 2									
.00000E 00	.99811E 00	-.35517E 01	.40640E 04	.54825E 01	-.46249E 01	.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.78244E-01	-.24596E 00	-.34527E 00	.00000E 00	.00000E 00					
ROW 3									
.00000E 00	.91130E-03	.90393E 00	-.12584E 03	-.18119E 00	.12189E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.29157E-01	.62774E-01	.84009E-01	.00000E 00	.00000E 00					
ROW 4									
.00000E 00	.59815E-07	.23798E-03	.84406E 00	.11545E-02	-.98675E-03	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.48130E-05	.55006E-05	-.12574E-04	.00000E 00	.00000E 00					
ROW 5									
.00000E 00	.16224E-07	.15072E-04	-.23961E-01	.70367E-04	.24306E-04	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.47820E-06	.44600E-05	.46416E-06	.00000E 00	.00000E 00					
ROW 6									
.00000E 00	-.12225E-05	-.47817E-03	.37410E 00	.17895E-01	-.28395E-03	.00000E 00	.00000E 00	.00000E 00	.00000E 00
-.16530E-05	.20554E-05	-.23702E-02	.00000E 00	.00000E 00					
ROW 7									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.10000E 01	.40807E 04	.83505E 01	.62797E 01
.00000E 00	.00000E 00	.00000E 00	-.66498E-01	.51312E-01					
ROW 8									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.10000E 01	.20402E-02	.15393E-02
.00000E 00	.00000E 00	.00000E 00	.23327E-04	-.94337E-04					
ROW 9									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.90220E-04	.29210E-05
.00000E 00	.00000E 00	.00000E 00	-.36273E-04	.17760E-03					
ROW 10									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	-.16245E-01	.12281E-03
.00000E 00	.00000E 00	.00000E 00	-.25326E-01	.77299E-01					
ROW 11									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.41583E-01	.00000E 00	.00000E 00	.00000E 00	.00000E 00					
ROW 12									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.00000E 00	.58537E-03	-.35228E-02	.00000E 00	.00000E 00					
ROW 13									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.00000E 00	.37087E-04	-.19146E-01	.00000E 00	.00000E 00					
ROW 14									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.00000E 00	.00000E 00	.00000E 00	-.24884E-01	.76153E-01					
ROW 15									
.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.00000E 00	.00000E 00	.00000E 00	-.28808E-01	.18673E-01					

Figure 69. Performance Evaluator Output - Free Airframe (continued)

X(T) MATRIX

ROW 1
•58430E 05 •22643E 05 •19296E 02 •31226E 01 -•77186E-01 •10357E 01 •12140E 02 •75918E-09 -•80676E-12 •59646E-09
-•26856E 00 -•16955E-01 -•24906E-01 •59308E-09 •21799E-08

ROW 2
•22643E 05 •17099E 05 -•31187E 03 •13041E 01 -•39556E-01 •60687E 00 •55182E-09 •25651E-13 -•18315E-17 •59068E-16
-•22392E 01 -•11548E-01 -•59551E-02 •00000E 00 •00000E 00

ROW 3
•19296E 02 -•31187E 03 •26491E 02 -•34648E-02 •69077E-03 -•29250E-01 -•12102E-10 -•56255E-15 •40167E-19 -•12954E-17
•55526E 00 -•30532E-02 -•43378E-02 •00000E 00 •00000E 00

ROW 4
•31226E 01 •13041E 01 -•34648E-02 •21577E-03 •47371E-05 •41174E-01 •83351E-15 •38745E-19 -•27665E-23 •89220E-22
-•13475E-03 •10551E-01 •14668E-01 •00000E 00 •00000E 00

ROW 5
-•77186E-01 -•39556E-01 •69077E-03 •47371E-05 •58512E-02 •14625E-01 -•31782E-15 -•14774E-19 •10549E-23 -•34020E-22
•50171E-04 •10938E 00 •44073E 00 •00000E 00 •00000E 00

ROW 6
•10357E 01 •60687E 00 -•29250E-01 •41174E-01 •14625E-01 •39676E 02 •81958E-14 •38098E-18 -•27202E-22 •87729E-21
•17691E-01 •10315E 02 •14602E 02 •00000E 00 •00000E 00

ROW 7
•12140E 02 •55182E-09 -•12102E-10 •83351E-15 -•31782E-15 •81958E-14 •59212E 05 •47316E 01 •19951E-03 •11420E 00
•00000E 00 •00000E 00 •00000E 00 •61455E-01 -•10313E 00

ROW 8
•75918E-09 •25651E-13 -•56255E-15 •38745E-19 -•14774E-19 •38098E-18 •47316E 01 •66117E-03 •75954E-04 -•16197E 00
•00000E 00 •00000E 00 •00000E 00 -•10393E 00 -•59349E-01

ROW 9
-•80676E-12 -•18315E-17 •40167E-19 -•27665E-23 •10549E-23 -•27202E-22 •19951E-03 •75954E-04 •74214E-02 -•57262E-01
•00000E 00 •00000E 00 •00000E 00 -•18400E 00 -•14660E 00

ROW 10
•59646E-09 •59068E-16 -•12954E-17 •89220E-22 -•34020E-22 •87729E-21 •11420E 00 -•16197E 00 -•57262E-01 •10386E 03
•00000E 00 •00000E 00 •00000E 00 •66842E 02 •38160E 02

ROW 11
-•26856E 00 -•22392E 01 •55526E 00 -•13475E-03 •50171E-04 •17691E-01 •00000E 00 •00000E 00 •00000E 00 •00000E 00
•64689E 02 •00000E 00 •00000E 00 •00000E 00 •00000E 00

ROW 12
-•16955E-01 -•11548E-01 -•30532E-02 •10551E-01 •10938E 00 •10315E 02 •00000E 00 •00000E 00 •00000E 00 •00000E 00
•00000E 00 •17572E 02 •49839E 02 •00000E 00 •00000E 00

ROW 13
-•24906E-01 -•59551E-02 -•43378E-02 •14668E-01 •44073E 00 •14602E 02 •00000E 00 •00000E 00 •00000E 00 •00000E 00
•00000E 00 •49839E 02 •17389E 03 •00000E 00 •00000E 00

ROW 14
•59308E-09 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •61455E-01 -•10393E 00 -•18400E 00 •66842E 02
•00000E 00 •00000E 00 •00000E 00 •71747E 02 •42616E 02

ROW 15
•21799E-08 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 -•13013E 00 -•59349E-01 -•14660E 00 •38160E 02
•00000E 00 •00000E 00 •00000E 00 •42616E 02 •27167E 02

Figure 69. Performance Evaluator Output - Free Airframe (continued)

```
XSUBM / L3 MATRIX

ROW   1
 .11159E 04  .00000E 00  .65675E 03  .42706E 01 -.45969E-01  .44558E 01 -.12140E 02  .75921E-09  .38592E-12  .79234E-09
-.22399E 01 -.27182E-01  .16359E 03  .81810E 02  .21799E-08
ROW   2
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
ROW   3
 .65674E 03  .00000E 00  .21420E 02  .28156E-01 -.88335E-04 -.66701E-02 -.98856E-09  .59411E-16  .32507E-14  .53389E-12
 .50097E 00 -.33332E-02  .44148E 00  .22298E 00  .00000E 00
ROW   4
 .42706E 01  .00000E 00  .28156E-01  .21577E-03  .70217E-05  .41274E-01 -.12563E-10  .38745E-19  .41260E-16  .67763E-14
-.13475E-03  .10551E-01  .20328E-01  .28301E-02  .00000E 00
ROW   5
-.45969E-01  .00000E 00 -.88335E-04  .70217E-05  .58511E-02  .14625E-01  .93131E-13  .30164E-19 -.30372E-18 -.49882E-16
 .46248E-04  .10938E 00  .44069E 00 -.20833E-04  .00000E 00
ROW   6
 .44558E 01  .00000E 00 -.66701E-02  .41274E-01  .14625E-01  .39677E 02 -.18407E-10  .23447E-17  .60616E-16  .99554E-14
 .17520E-01  .10315E 02  .14610E 02  .41579E-02  .00000E 00
ROW   7
 .12140E 02  .00000E 00 -.98856E-09 -.12563E-10  .93131E-13 -.18407E-10  .59212E 05  .47316E 01  .19951E-03  .11420E 00
 .21572E-10  .11126E-12 -.71256E-09  .61455E-01 -.13013E 00
ROW   8
 .75921E-09  .00000E 00  .59411E-16  .38745E-19  .30164E-19  .23447E-17  .47316E 01  .66117E-03  .75954E-04 -.16197E 00
 .00000E 00  .00000E 00  .11134E-15 -.10393E 00 -.59349E-01
ROW   9
 .38592E-12  .00000E 00  .32507E-14  .41260E-16 -.30372E-18  .60616E-16  .19951E-03  .75954E-04  .74214E-02 -.57262E-01
-.70844E-16 -.36538E-18  .23480E-14 -.18400E 00 -.14660E 00
ROW   10
 .79234E-09  .00000E 00  .53389E-12  .67763E-14 -.49882E-16  .99554E-14  .11420E 00 -.16197E 00 -.57262E-01  .10386E 03
-.11635E-13 -.60008E-16  .38562E-12  .66842E 02  .38160E 02
ROW   11
-.22399E 01  .00000E 00  .50097E 00 -.13475E-03  .46248E-04  .17520E-01  .21572E-10  .00000E 00 -.70844E-16 -.11635E-13
 .64680E 02  .00000E 00 -.97190E-02 -.48595E-02  .00000E 00
ROW   12
-.27182E-01  .00000E 00 -.33332E-02  .10551E-01  .10938E 00  .10315E 02  .11126E-12  .00000E 00 -.36538E-18 -.60008E-16
 .00000E 00  .17272E 02  .49839E 02 -.25063E-04  .00000E 00
ROW   13
 .16359E 03  .00000E 00  .44148E 00  .20328E-01  .44069E 00  .14610E 02 -.71256E-09  .11134E-15  .23480E-14  .38562E-12
-.97190E-02  .49839E 02  .17422E 03  .16106E 00  .00000E 00
ROW   14
 .81810E 02  .00000E 00  .22298E 00  .28301E-02 -.20833E-04  .41579E-02  .61455E-01 -.10393E 00 -.18400E 00  .66842E 02
-.48595E-02 -.25063E-04  .16106E 00  .71828E 02  .42616E 02
ROW   15
 .21799E-08  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00 -.13013E 00 -.59349E-01 -.14660E 00  .38160E 02
 .00000E 00  .00000E 00  .00000E 00  .42616E 02  .27167E 02

CEP HORIZONTAL=  .33773675E 03 CEP VERTICAL=  .16410525E 03
```

Figure 69. Performance Evaluator Output - Free Airframe (continued)

XSUBV WIG MATRIX

ROW 1
•00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00
•00000E 00 •00000E 00 •00000E 00 •00000E 00 •00000E 00

ROW 2
•00000E 00 •14393E 06 -•27416E 04 •48510E 01 -•30437E 00 -•59573E 01 •13790E 02 •86239E-09 -•41155E-11 •15212E-09
-•25442E 01 -•30208E-01 -•43890E 03 -•21944E 03 •24761E-08

ROW 3
•00000E 00 -•27416E 04 •69752E 02 -•89467E-01 •59807E-02 •80491E-01 -•33436E 00 -•20910E-10 •79363E-13 -•70431E-11
•56266E 00 -•25862E-02 •78356E 01 •39196E 01 -•60039E-10

ROW 4
•00000E 00 •48510E 01 -•89467E-01 •21577E-03 -•14766E-05 •40903E-01 •34172E-10 •38745E-19 -•11222E-15 -•18431E-13
-•13475E-03 •10551E-01 -•72738E-03 -•76976E-02 •00000E 00

ROW 5
•00000E 00 -•30437E 00 •59807E-02 -•14766E-05 •58518E-02 •14639E-01 -•24158E-04 -•15108E-14 •85581E-17 -•45055E-16
•50706E-04 •10938E 00 •44169E 00 •47691E-03 -•43379E-14

ROW 6
•00000E 00 -•59573E 01 •80491E-01 •40903E-01 •14639E-01 •39677E 02 -•10557E-02 -•66017E-13 •21554E-15 -•27990E-13
•17715E-01 •10315E 02 •14622E 02 •99724E-02 -•18956E-12

ROW 7
•00000E 00 •13790E 02 -•33436E 00 •34172E-10 -•24158E-04 -•10557E-02 •59212E 05 •47316E 01 •19951E-03 •11420E 00
-•29389E-11 -•18554E-12 -•59854E-01 •31528E-01 -•13013E 00

ROW 8
•00000E 00 •86239E-09 -•20910E-10 •38745E-19 -•15108E-14 -•66017E-13 •47316E 01 •66117E-03 •75954E-04 -•16197E 00
•00000E 00 •00000E 00 -•37430E-11 -•10393E 00 -•59349E-01

ROW 9
•00000E 00 -•41155E-11 •79363E-13 -•11222E-15 •85581E-17 •21554E-15 •19951E-03 •75954E-04 •74214E-02 -•57262E-01
•96517E-17 •60933E-18 •14332E-13 -•18400E 00 -•14660E 00

ROW 10
•00000E 00 •15212E-09 -•70431E-11 -•18431E-13 -•45055E-16 -•27990E-13 •11420E 00 -•16197E 00 -•57262E-01 •10386E 03
•15852E-14 •10007E-15 -•12402E-11 •66842E 02 •38160E 02

ROW 11
•00000E 00 -•25442E 01 •56266E 00 -•13475E-03 •50706E-04 •17715E-01 -•29389E-11 •00000E 00 •96517E-17 •15852E-14
•64680E 02 •00000E 00 •13241E-02 •66205E-03 •00000E 00

ROW 12
•00000E 00 -•30208E-01 -•25862E-02 •10551E-01 •10938E 00 •10315E 02 -•18554E-12 •00000E 00 •60933E-18 •10007E-15
•00000E 00 •17572E 02 •49840E 02 •41796E-04 •00000E 00

ROW 13
•00000E 00 -•43890E 03 •78356E 01 -•72738E-03 •44169E 00 •14622E 02 -•59854E-01 -•37430E-11 •14332E-13 -•12402E-11
•13241E-02 •49840E 02 •17531E 03 •71022E 00 -•10748E-10

ROW 14
•00000E 00 -•21944E 03 •39196E 01 -•76976E-02 •47691E-03 •99724E-02 •31528E-01 -•10393E 00 -•18400E 00 •66842E 02
•66205E-03 •41796E-04 •71022E 00 •72102E 02 •42616E 02

ROW 15
•00000E 00 •24761E-08 -•60039E-10 •00000E 00 -•43379E-14 -•18956E-12 -•13013E 00 -•59349E-01 -•14660E 00 •38160E 02
•00000E 00 •00000E 00 -•10748E-10 •42616E 02 •27167E 02

CEP HORIZONTAL= •13410529E 03 CEP VERTICAL= •36429105E 03

Figure 69. Performance Evaluator Output - Free Airframe (continued)

WEIGHTING MATRIx GH

RθW 1
•15708E 01 •13834E 01 •28494E 01 •10908E 05 •14651E 02 -•12745E 02 •00000E 00 •29258E-05 •58881E-08 •45131E-08
•49917E-01 •45377E-01 -•59003E-01 -•11676E-08 -•42515E-08

RθW 2
•13834E 01 •12184E 01 •25095E 01 •96064E 04 •12903E 02 -•11224E 02 -•30208E-10 •24535E-05 •49334E-08 •37850E-08
•43962E-01 •40404E-01 -•51964E-01 -•10263E-08 -•37458E-08

RθW 3
•28494E 01 •25095E 01 •51689E 01 •19787E 05 •26578E 02 -•23119E 02 •10750E-09 •57462E-05 •11579E-07 •88619E-08
•90550E-01 •83222E-01 -•10703E 00 -•21252E-08 -•77067E-08

RθW 4
•10908E 05 •96064E 04 •19787E 05 •75742E 08 •10174E 06 -•88499E 05 -•12300E-06 •19815E-01 •39860E-04 •30567E-04
•34662E 03 •31857E 03 -•40971E 03 -•80998E-05 -•29529E-04

RθW 5
•14651E 02 •12903E 02 •26578E 02 •10174E.06 •13666E 03 -•11887E 03 -•16593E-09 •26613E-04 •53534E-07 •41053E-07
•46559E 00 •42791E 00 -•55033E 00 -•10880E-07 -•39663E-07

RθW 6
-•12745E 02 -•11224E 02 -•23119E 02 -•88499E 05 -•11887E 03 •10340E 03 •13998E-09 -•23168E-04 -•46604E-07 -•35738E-07
-•40500E 00 -•37222E 00 •47872E 00 •94642E-08 •34502E-07

RθW 7
•00000E 00 -•30208E-10 •10750E-09 -•12300E-06 -•16593E-09 •13998E-09 •31416E 01 •12820E 05 •26234E 02 •19728E 02
•23681E-11 •74441E-11 •10450E-10 -•20891E 00 •16120E 00

RθW 8
•29258E-05 •24535E-05 •57462E-05 •19815E-01 •26613E-04 -•23168E-04 •12820E 05 •52313E 08 •10705E 06 •80505E 05
•10264E-06 •11583E-06 -•67259E-07 -•85249E 03 •65781E 03

RθW 9
•58881E-08 •49334E-08 •11579E-07 •39860E-04 •53534E-07 -•46604E-07 •26234E 02 •10705E 06 •21907E 03 •16474E 03
•20689E-09 •23413E-09 -•13391E-09 -•17445E 01 •13461E 01

RθW 10
•45131E-08 •37850E-08 •88619E-08 •30567E-04 •41053E-07 -•35738E-07 •19728E 02 •80505E 05 •16474E 03 •12389E 03
•15829E-09 •17856E-09 -•10390E-09 -•13119E 01 •10123E 01

RθW 11
•49917E-01 •43962E-01 •90550E-01 •34662E 03 •46559E 00 -•40500E 00 •23681E-11 •10264E-06 •20689E-09 •15829E-09
•15863E-02 •14579E-02 -•18750E-02 -•37262E-10 -•13498E-09

RθW 12
•45377E-01 •40404E-01 •83222E-01 •31857E 03 •42791E 00 -•37222E 00 •74441E-11 •11583E-06 •23413E-09 •17856E-09
•14579E-02 •13399E-02 -•17232E-02 -•34597E-10 -•12379E-09

RθW 13
-•59003E-01 -•51964E-01 -•10703E 00 -•40971E 03 -•55033E 00 •47872E 00 •10450E-10 -•67259E-07 -•13391E-09 -•10390E-09
-•18750E-02 -•17232E-02 •22163E-02 •43164E-10 •16023E-09

RθW 14
-•11676E-08 -•10263E-08 -•21252E-08 -•80998E-05 -•10880E-07 •94642E-08 -•20891E 00 -•85249E 03 -•17445E 01 -•13119E 01
-•37262E-10 -•34597E-10 •43164E-10 •13892E-01 -•10720E-01

RθW 15
-•42515E-08 -•37458E-08 -•77067E-08 -•29529E-04 -•39663E-07 •34502E-07 •16120E 00 •65781E 03 •13461E 01 •10123E 01
-•13498E-09 -•12379E-09 •16023E-09 -•10720E-01 •82717E-02

Figure 69. Performance Evaluator Output - Free Airframe (continued)

```
        WEIGHTING MATRIX QV

ROW   1
 .20266E 01  .17550E 01  .36766E 01  .14074E 05  .18904E 02 -.16444E 02  .34379E-10  .39155E-05  .78844E-08  .60391E-08
 .64407E-01  .58194E-01 -.76130E-01 -.15089E-08 -.54839E-08
ROW   2
 .17350E 01  .15720E 01  .32380E 01  .12295E 05  .16649E 02 -.14483E 02  .69350E-13  .33251E-05  .66915E-08  .51290E-08
 .56723E-01  .52192E-01 -.67048E-01 -.13268E-08 -.48312E-08
ROW   3
 .36766E 01  .32380E 01  .66694E 01  .25530E 05  .34293E 02 -.29830E 02  .16986E-09  .75413E-05  .15200E-07  .11630E-07
 .11684E 00  .10738E 00 -.13810E 00 -.27442E-08 -.99423E-08
ROW   4
 .14074E 05  .12295E 05  .25530E 05  .97729E 08  .13127E 06 -.11419E 06  .11573E-06  .26687E-01  .53722E-04  .41163E-04
 .44724E 03  .41105E 03 -.52865E 03 -.10469E-04 -.38086E-04
ROW   5
 .18904E 02  .16649E 02  .34293E 02  .13127E 06  .17633E 03 -.15338E 03  .15473E-09  .35843E-04  .72154E-07  .55286E-07
 .60074E 00  .55212E 00 -.71009E 00 -.14062E-07 -.51158E-07
ROW   6
-.16444E 02 -.14483E 02 -.29830E 02 -.11419E 06 -.15338E 03  .13342E 03 -.13896E-09 -.31197E-04 -.62801E-07 -.48119E-07
-.52257E 00 -.48028E 00  .61768E 00  .12233E-07  .44500E-07
ROW   7
 .34379E-10  .69350E-13  .16986E-09  .11573E-06  .15473E-09 -.13896E-09  .31416E 01  .12820E 05  .26234E 02  .19728E 02
 .34606E-11  .84482E-11  .91586E-11 -.20891E 00  .16120E 00
ROW   8
 .39155E-05  .33251E-05  .75413E-05  .26687E-01  .35843E-04 -.31197E-04  .12820E 05  .52313E 08  .10705E 06  .80505E 05
 .13409E-06  .14473E-06 -.10443E-06 -.85249E 03  .65781E 03
ROW   9
 .78844E-08  .66915E-08  .15200E-07  .53722E-04  .72154E-07 -.62801E-07  .26234E 02  .10705E 06  .21907E 03  .16474E 03
 .27032E-09  .29243E-09 -.20889E-09 -.17445E 01  .13461E 01
ROW  10
 .60391E-08  .51290E-08  .11630E-07  .41163E-04  .55286E-07 -.48119E-07  .19728E 02  .80505E 05  .16474E 03  .12389E 03
 .20678E-09  .22313E-09 -.16122E-09 -.13119E 01  .10123E 01
ROW  11
 .64407E-01  .56723E-01  .11684E 00  .44724E 03  .60074E 00 -.52257E 00  .34606E-11  .13409E-06  .27032E-09  .20678E-09
 .20467E-02  .18811E-02 -.24193E-02 -.48106E-10 -.17414E-09
ROW  12
 .59134E-01  .52192E-01  .10738E 00  .41105E 03  .55212E 00 -.48028E 00  .84482E-11  .14473E-06  .29243E-09  .22313E-09
 .18811E-02  .17298E-02 -.22839E-02 -.44563E-10 -.15978E-09
ROW  13
-.76130E-01 -.67048E-01 -.13810E 00 -.52865E 03 -.71009E 00  .61768E 00  .91586E-11 -.10443E-06 -.20889E-09 -.16122E-09
-.24193E-02 -.22839E-02 -.28596E-02  .55981E-10  .20652E-09
ROW  14
-.15089E-08 -.13268E-08 -.27442E-08 -.10469E-04 -.14062E-07  .12233E-07 -.20891E 00 -.85249E 03 -.17445E 01 -.13119E 01
-.48106E-10 -.44563E-10  .55981E-10  .13892E-01 -.10720E-01
ROW  15
-.54839E-08 -.48312E-08 -.99423E-08 -.38086E-04 -.51158E-07  .44500E-07  .16120E 00  .65781E 03  .13461E 01  .10123E 01
-.17414E-09 -.15978E-09  .20652E-09 -.10720E-01  .82717E-02

        QH(1,1) =  .15707963E 01 QH(7,7) =  .31415926E 01 QV(2,2) =  .15707963E 01 QV(7,7) =  .31415926E 01


        JSUBH=  .36124401E 06 JSUBV=  .41210889E 06


        APPROXIMATE CEPH=  .33909813E 03 APPROXIMATE CEPV=  .36218550E 03

*STOP* 00000000
```

Figure 69. Performance Evaluator Output - Free Airframe (concluded)

INITIAL COVARIANCE OF BOMB

```
ROW   1
 1.1231E+04 -1.2100E+04  6.2666E+02 -1.2345E-01  2.8161E-01 -1.9587E+01  5.1099E+01  1.2963E-02  3.0050E-03  1.7084E+00
-2.7736E-01 -1.7128E+00 -1.7599E-01  1.5678E+00 -3.1939E-03
ROW   2
-1.2100E+04  1.3132E+04 -6.7626E+02  1.2800E-01 -3.0198E-01  1.7482E+01 -4.4949E+01 -5.5781E-04 -5.0576E-03 -1.3407E+01
-1.7670E+00 -1.1718E+00 -1.3584E-01 -1.3042E+01 -3.8957E+00
ROW   3
 6.2666E+02 -6.7626E+02  3.5253E+01 -7.1777E-03  1.5715E-02 -1.0999E+00  3.3424E+00 -1.9828E-03  3.9143E-04  1.9876E+00
 3.6175E-01 -1.2104E-01 -1.0527E-02  1.9570E+00  6.5051E-01
ROW   4
-1.2345E-01  1.2800E-01 -7.1777E-03  6.5725E-06 -2.8379E-06  4.1604E-03 -2.4884E-03  2.8134E-06  1.7130E-07 -1.6643E-03
-6.9085E-04  3.4602E-03  5.0477E-04 -1.6427E-03 -8.5289E-04
ROW   5
 2.8161E-01 -3.0198E-01  1.5715E-02 -2.8379E-06  1.1033E-05  3.0757E-04  8.9617E-04  2.7456E-06  4.6916E-07 -1.5797E-03
-8.9391E-04  1.2425E-03  2.4739E-04 -1.5909E-03 -9.3084E-04
ROW   6
-1.9587E+01  1.7482E+01 -1.0999E+00  4.1604E-03  3.0757E-04  4.1791E+00 -2.0236E-02 -2.3719E-04  4.6128E-05  1.2378E-01
 1.0549E-02  3.7253E+00  5.5411E-01  1.3357E-01  3.3837E-02
ROW   7
 5.1099E+01 -4.4949E+01  3.3424E+00 -2.4884E-03  8.9617E-04 -2.0236E-02  7.2908E+02 -1.7118E-01 -2.5842E-03  3.1442E+01
 1.3947E+00  1.0625E-02  5.8381E-04  3.3863E+01  6.7822E+00
ROW   8
 1.2963E-02 -5.5781E-04 -1.9828E-03  2.8134E-06  2.7456E-06 -2.3719E-04 -1.7118E-01  1.8891E-04 -1.0990E-05 -7.6143E-02
-7.8881E-03  3.7539E-06  2.5662E-07 -7.3660E-02 -1.9230E-02
ROW   9
 3.0050E-03 -5.0576E-03  3.9143E-04  1.7130E-07  4.6916E-07  4.6128E-05 -2.5842E-03 -1.0990E-05  3.2515E-05  8.8942E-03
-7.5286E-04  2.1750E-07  2.4026E-08  7.4394E-03  8.2861E-04
ROW  10
 1.7084E+00 -1.3407E+01  1.9876E+00 -1.6643E-03 -1.5797E-03  1.2378E-01  3.1442E+01 -7.6143E-02  8.8942E-03  5.2942E+01
 5.4030E+00 -2.2603E-05 -2.2352E-06  5.0479E+01  1.3201E+01
ROW  11
-2.7736E-01 -1.7670E+00  3.6175E-01 -6.9085E-04 -8.9391E-04  1.0549E-02  1.3947E+00 -7.8881E-03 -7.5286E-04  5.4030E+00
 3.0539E+00  0.          0.          5.4414E+00  3.1353E+00
ROW  12
-1.7128E+00 -1.1718E+00 -1.2104E-01  3.4602E-03  1.2425E-03  3.7253E+00  1.0625E-02  3.7539E-06  2.1750E-07 -2.2603E-05
 0.          3.9854E+00  6.1008E-01  0.          0.
ROW  13
-1.7599E-01 -1.3584E-01 -1.0527E-02  5.0477E-04  2.4739E-04  5.5411E-01  5.8381E-04  2.5662E-07  2.4026E-08 -2.2352E-06
 0.          6.1008E-01  9.5997E-02  0.          0.
ROW  14
 1.5678E+00 -1.3042E+01  1.9570E+00 -1.6427E-03 -1.5909E-03  1.3357E-01  3.3863E+01 -7.3660E-02  7.4394E-03  5.0479E+01
 5.4414E+00  0.          0.          5.0062E+01  1.3141E+01
ROW  15
-3.1939E-03 -3.8957E+00  6.5051E-01 -8.5289E-04 -9.3084E-04  3.3837E-02  6.7822E+00 -1.9230E-02  8.2861E-04  1.3201E+01
 3.1353E+00  0.          0.          1.3141E+01  4.6854E+00
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller

XSUBF MATRIX T= 6.28

```
ROW   1
 6.0311E-01 -6.2324E-01  1.7942E-01 -2.6614E-05  1.8083E-04 -3.4524E-02  0.          0.          0.          0.
 2.0731E-01 -9.2023E-03  2.3380E-02  0.          0.
ROW   2
-6.2324E-01  6.8373E-01 -1.9140E-01 -3.3545E-05  1.5779E-04 -3.0701E-02  0.          0.          0.          0.
-2.1635E-01 -8.5157E-03  1.6501E-02  0.          0.
ROW   3
 1.7942E-01 -1.9140E-01  6.2541E-02 -1.0609E-05 -6.5417E-06 -1.1895E-02  0.          0.          0.          0.
 4.4026E-01 -2.9560E-03 -4.0483E-03  0.          0.
ROW   4
-2.6614E-05 -3.3545E-05 -1.0609E-05  4.2656E-05  9.0988E-06  4.1159E-02  0.          0.          0.          0.
 2.3477E-05  1.0554E-02  1.4753E-02  0.          0.
ROW   5
 1.8083E-04  1.5779E-04 -6.5417E-06  9.0988E-06  5.8585E-03  1.4616E-02  0.          0.          0.          0.
 4.3630E-05  1.0945E-01  4.4101E-01  0.          0.
ROW   6
-3.4524E-02 -3.0701E-02 -1.1895E-02  4.1159E-02  1.4616E-02  3.9722E+01  0.          0.          0.          0.
 1.7845E-02  1.0318E+01  1.4680E+01  0.          0.
ROW   7
 0.          0.          0.          0.          0.          0.          3.6046E-02 -3.6658E-04  3.6599E-04  2.4455E-01
 0.          0.          0.          1.9104E-01  6.3304E-03
ROW   8
 0.          0.          0.          0.          0.          0.         -3.6658E-04  2.5303E-04  7.5903E-05 -1.6226E-01
 0.          0.          0.         -1.0409E-01 -5.9466E-02
ROW   9
 0.          0.          0.          0.          0.          0.          3.6599E-04  7.5903E-05  7.4368E-03 -5.7247E-02
 0.          0.          0.         -1.8420E-01 -1.4674E-01
ROW  10
 0.          0.          0.          0.          0.          0.          2.4455E-01 -1.6226E-01 -5.7247E-02  1.0407E+02
 0.          0.          0.          6.6961E+01  3.8250E+01
ROW  11
 2.0731E-01 -2.1635E-01  4.4026E-01  2.3477E-05  4.3630E-05  1.7845E-02  0.          0.          0.          0.
 6.4773E+01  0.          0.          0.          0.
ROW  12
-9.2023E-03 -8.5157E-03 -2.9560E-03  1.0554E-02  1.0945E-01  1.0318E+01  0.          0.          0.          0.
 0.          1.7082E+01  4.9928E+01  0.          0.
ROW  13
 2.3380E-02  1.6501E-02 -4.0483E-03  1.4753E-02  4.4101E-01  1.4680E+01  0.          0.          0.          0.
 0.          4.9928E+01  1.7422E+02  0.          0.
ROW  14
 0.          0.          0.          0.          0.          0.          1.9104E-01 -1.0409E-01 -1.8420E-01  6.6961E+01
 0.          0.          0.          7.1864E+01  4.2701E+01
ROW  15
 0.          0.          0.          0.          0.          0.          6.3304E-03 -5.9466E-02 -1.4674E-01  3.8250E+01
 0.          0.          0.          4.2701E+01  2.7225E+01
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (continued)

PHI(T +TR) MATRIX

```
ROW   1
 1.0000E+00  2.0176E-03  4.9408E+00  3.3664E+03  4.5009E+00 -4.0420E+00  0.          0.          0.          0.
 1.0066E-01  2.4572E-01  2.6649E-01  0.          0.
ROW   2
 0.          9.9810E-01 -3.5517E+00  4.0642E+03  5.4825E+00 -4.6249E+00  0.          0.          0.          0.
-7.8240E-02 -2.4594E-01 -3.4534E-01  0.          0.
ROW   3
 0.          9.1472E-04  9.0391E-01 -1.2583E+02 -1.8118E-01  1.2187E-01  0.          0.          0.          0.
 2.9155E-02  6.2769E-02  8.4039E-02  0.          0.
ROW   4
 0.          5.9640E-08  2.3799E-04  8.4406E-01  1.1545E-03 -9.8671E-04  0.          0.          0.          0.
 4.8137E-06  5.4981E-06 -1.2531E-05  0.          0.
ROW   5
 0.          1.5067E-08  1.5074E-05 -2.3965E-02  6.9076E-05  2.4303E-05  0.          0.          0.          0.
 4.7815E-07  4.5088E-06  8.9634E-08  0.          0.
ROW   6
 0.         -1.3757E-06 -4.7754E-04  3.7346E-01  1.7928E-02 -2.8430E-04  0.          0.          0.          0
-1.6720E-06  2.0238E-04 -2.3384E-03  0.          0.
ROW   7
 0.          0.          0.          0.          0.          0.          1.0000E+00  4.0808E+03  8.3505E+00  6.2797E+00
 0.          0.          0.         -6.6498E-02  5.1289E-02
ROW   8
 0.          0.          0.          0.          0.          0.          0.          1.0000E+00  2.0402E-03  1.5393E-03
 0.          0.          0.          2.3268E-05 -9.4067E-05
ROW   9
 0.          0.          0.          0.          0.          0.          0.          0.          8.9043E-05  2.9263E-06
 0.          0.          0.         -3.6236E-05  1.7733E-04
ROW  10
 0.          0.          0.          0.          0.          0.          0.          0.         -1.6275E-02  1.2180E+04
 0.          0.          0.         -2.5289E-02  7.7122E-02
ROW  11
 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 4.1541E-02  0.          0.          0.          0.
ROW  12
 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 0.          5.8236E-04 -3.4949E-03  0.          0.
ROW  13
 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 0.          3.6928E-03 -1.9028E-02  0.          0.
ROW  14
 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 0.          0.          0.         -2.4850E-02  7.5984E-02
ROW  15
 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 0.          0.          0.         -2.8771E-02  1.8529E-02
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (continued)

X(T) MATRIX

```
ROW   1
 1.7386E+04 -1.8291E+04  7.0681E+02  8.2831E-02  1.4714E-02 -4.2882E-01  1.4863E+02  2.2046E-02 -9.8227E-05 -1.0398E-01
 1.8410E-01 -9.7972E-03  1.7753E-02 -1.0270E-01 -1.5407E-01
ROW   2
-1.8291E+04  1.9412E+04 -7.4902E+02 -7.8475E-02 -1.5472E-02  3.8972E-01 -1.6255E+02 -2.3483E-02 -8.6551E-04 -7.9701E-02
-4.7178E-01 -8.7145E-03  1.2761E-02 -7.7058E-02  6.1022E-01
ROW   3
 7.0681E+02 -7.4902E+02  2.9194E+01  2.8493E-03  6.0628E-04 -2.8343E-02  7.0208E+00  9.0553E-04  6.8501E-05  6.8984E-03
 4.6114E-01 -2.9763E-03 -4.0496E-03  6.6824E-03 -4.6948E-02
ROW   4
 8.2831E-02 -7.8475E-02  2.8493E-03  4.4091E-05  9.1304E-06  4.1158E-02  8.6690E-04  5.4723E-07 -6.9391E-08 -1.9198E-05
 2.9608E-06  1.0554E-02  1.4752E-02 -1.8855E-05  1.8771E-05
ROW   5
 1.4714E-02 -1.5472E-02  6.0628E-04  9.1304E-06  5.8585E-03  1.4615E-02  1.4292E-04  7.6757E-09  3.2770E-09  6.2954E-07
 4.4612E-05  1.0945E-01  4.4101E-01  6.1617E-07 -1.5396E-06
ROW   6
-4.2882E-01  3.8972E-01 -2.8343E-02  4.1158E-02  1.4615E-02  3.9722E+01 -3.8893E-03 -3.4868E-07 -6.2795E-08 -1.0133E-05
 1.7827E-02  1.0318E+01  1.4680E+01 -9.8958E-06  3.4053E-05
ROW   7
 1.4863E+02 -1.6255E+02  7.0208E+00  8.6690E-04  1.4292E-04 -3.8893E-03  1.0528E+03  2.0300E-01  6.6348E-04 -1.3902E-01
 1.2160E-01  9.3751E-06  6.4515E-05 -1.8967E-01 -1.1692E+00
ROW   8
 2.2046E-02 -2.3483E-02  9.0553E-04  5.4723E-07  7.6757E-09 -3.4868E-07  2.0300E-01  3.3298E-04  7.5944E-05 -1.6229E-01
 1.0752E-05  1.2811E-09  8.9170E-09 -1.0412E-01 -5.9563E-02
ROW   9
-9.8227E-05 -8.6551E-04  6.8501E-05 -6.9391E-08  3.2770E-09 -6.2795E-08  6.6348E-04  7.5944E-05  7.4368E-03 -5.7234E-02
 1.5559E-05 -1.1858E-14 -8.8982E-14 -1.8419E-01 -1.4675E-01
ROW  10
-1.0398E-01 -7.9701E-02  6.8984E-03 -1.9198E-05  6.2954E-07 -1.0133E-05 -1.3902E-01 -1.6229E-01 -5.7234E-02  1.0408E+02
 4.3562E-03 -1.3467E-12 -1.0617E-11  6.6969E+01  3.8258E+01
ROW  11
 1.8410E-01 -4.7178E-01  4.6114E-01  2.9608E-06  4.4612E-05  1.7827E-02  1.2160E-01  1.0752E-05  1.5559E-05  4.3562E-03
 6.4778E+01  0.          0.          4.2794E-03 -4.0901E-03
ROW  12
-9.7972E-03 -8.7145E-03 -2.9763E-03  1.0554E-02  1.0945E-01  1.0318E+01  9.3751E-06  1.2811E-09 -1.1858E-14 -1.3467E-12
 0.          1.7082E+01  4.9928E+01  0.          0.
ROW  13
 1.7753E-02  1.2761E-02 -4.0496E-03  1.4752E-02  4.4101E-01  1.4680E+01  6.4515E-05  8.9170E-09 -8.8982E-14 -1.0617E-11
 0.          4.9928E+01  1.7422E+02  0.          0.
ROW  14
-1.0270E-01 -7.7058E-02  6.6824E-03 -1.8855E-05  6.1617E-07 -9.8958E-06 -1.8967E-01 -1.0412E-01 -1.8419E-01  6.6969E+01
 4.2794E-03  0.          0.          7.1872E+01  4.2709E+01
ROW  15
-1.5407E-01  6.1022E-01 -4.6948E-02  1.8771E-05 -1.5396E-06  3.4053E-05 -1.1692E+00 -5.9563E-02 -1.4675E-01  3.8258E+01
-4.0901E-03  0.          0.          4.2709E+01  2.7255E+01
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (continued)

VARIANCE CONTRIBUTION MATRIX

```
ROW   1
 1.3967E+04 -3.0378E+01  3.8530E+03 -5.1319E+02  1.5671E+00  1.0835E+02  0.          0.          0.          0.
-5.6223E-02 -1.1241E+00 -1.5779E-01  0.          0.
ROW   2
 0.          1.5917E+04  2.9273E+03  6.4919E+02 -2.0310E+00 -8.2459E+01  0.          0.          0.          0.
 4.8109E-01  1.2518E+00  2.7325E-01  0.          0.
ROW   3
 0.          0.          0.          0.          0.          0.          2.2605E+02  5.1167E+02  6.8812E-02  3.1760E+02
 0.          0.          0.         -3.1702E+00  5.4268E-01
```

NORMALIZED VARIANCE CONTRIBUTION MATRIX

```
ROW   1
 8.0340E+01 -1.7473E-01  2.2163E+01 -2.9519E+00  9.0141E-03  6.2326E-01  0.          0.          0.          0.
-3.2339E-04 -6.4661E-03 -9.0763E-04  0.          0.
ROW   2
 0.          8.2000E+01  1.5081E+01  3.3444E+00 -1.0463E-02 -4.2481E-01  0.          0.          0.          0.
 2.4784E-03  6.4490E-03  1.4077E-03  0.          0.
ROW   3
 0.          0.          0.          0.          0.          0.          2.1472E+01  4.8603E+01  6.5364E-03  3.0168E+01
 0.          0.          0.         -3.0114E-01  5.1548E-02
```


Figure 70. Performance Evaluator Output - With **Non**stationary Optimal Controller (continued)

```
        XSUBH WIG MATRIX

ROW   1
 2.2593E+02  0.          1.8274E+01  1.3745E-02 -1.0115E-03 -1.7771E-01  5.5295E+00  1.3728E-03 -8.6018E-04 -1.7414E-01
-2.3123E-01 -1.7469E-02 -5.1857E+00 -2.7779E+00  3.8314E-01
ROW   2
 0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 0.          0.          0.          0.          0.
ROW   3
 1.8274E+01  0.          4.2839E+00  9.4651E-04 -2.5647E-04 -4.0202E-02  3.0794E+00  3.3615E-04  4.7515E-05  4.9659E-03
 4.4970E-01 -3.1876E-03 -1.2119E+00 -5.9925E-01 -3.2152E-02
ROW   4
 1.3745E-02  0.          9.4651E-04  4.4091E-05  8.9930E-06  4.1152E-02  8.6690E-04  5.4723E-07 -6.9391E-08 -1.9198E-05
 2.9608E-06  1.0554E-02  1.4412E-02 -1.8916E-04  1.8771E-05
ROW   5
-1.0115E-03  0.         -2.5647E-04  8.9930E-06  5.8585E-0[illegible]  1.4617E-02 -1.4185E-04 -3.3463E-08  1.7607E-09  4.8991E-07
 4.3785E-05  1.0945E-01  4.4109E-01  4.0700E-05 -4.7059E-07
ROW   6
-1.7771E-01  0.         -4.0202E-02  4.1152E-02  1.4617E-02  3.9722E+01 -1.6333E-02 -2.1464E-06 -1.2905E-07 -1.6234E-05
 1.7791E-02  1.0318E+01  1.4688E+01  4.0550E-03  8.0768E-05
ROW   7
 3.[illegible]5E+00  0.          3.0794E+00  8.6690E-04 -1.4185E-04 -1.6333E-02  1.0528E+03  2.0322E-01  6.4[illegible]-04 -1.3902E-01
 1.2160E-01  9.3751E-06 -7.0548E-01 -5.4244E-01 -1.1692E+00
ROW   8
 1.3728E-03  0.          3.3010E-04  5.4723E-07 -3.3463E-08 -2.1464E-06  2.0300E-01  3.3298E-04  7.5944E-05 -1.6[illegible]9E-01
 1.0752E-05  1.28[illegible]-0[illegible] -1.0192E-04 -1.0417E-01 -5.9563E-02
ROW   9
-8.6018E-04  0.          4.7515E-05 -6.9391E-08  1.7607E-09 -1.2905E-07  6.6348E-04  7.5944E-05  7.4368E-03 -5.72[illegible]E-[illegible]
 1.5559E-05 -[illegible]8[illegible]E-[illegible] -3.7567E-06 -1.0417E-01 -1.4675E-01
ROW  10
-1.7414E-01  0.          4.9659E-03 -1.9198E-05  4.8991E-07 -1.6234E-05 -1.3902E-01 -1.6229E-01 -5.7234E-02  1.[illegible]E-0[illegible]
 4.3562E-03 -1.3467E-12 -3.4594E-04  6.6[illegible]E+01  3.8258E+01
ROW  11
-2.3123E-01  0.          4.4970E-01  2.9608E-06  4.3785E-05  1.7791E-02  1.2100E-01  1.0752E-05  1.5559E-05  4.[illegible]56E-0[illegible]
 6.4778E+01  0.         -2.0477E-03  3.2555E-03 -4.0901E-03
ROW  12
-1.7469E-02  0.         -3.1876E-03  1.0554E-02  1.0945E-01  1.0318E+01  9.3751E-06  1.2811E-09 -1.1858E-14 -1.3467E-12
 0.          1.7082E+01  4.9928E+01 -1.8912E-05  0.
ROW  13
-5.1857E+00  0.         -1.2119E+00  1.4412E-02  4.4109E-01  1.4688E+01 -7.0548E-01 -1.0192E-04 -3.7567E-06 -3.4594E-04
-2.0477E-03  4.9928E+01  1.7459E+02  1.8254E-01  2.6486E-03
ROW  14
-2.7779E+00  0.         -5.9925E-01 -1.8916E-04  4.0706E-05  4.0550E-03 -5.4244E-01 -1.0417E-01 -1.8419E-01  6.6969E+01
 3.2555E-03 -1.8912E-05  1.8254E-01  7.1963E+01  4.2710E+01
ROW  15
 3.8314E-01  0.         -3.2152E-02  1.8771E-05 -4.7059E-07  8.0768E-05 -1.1692E+00 -5.9563E-02 -1.4675E-01  3.8258E+01
-4.0901E-03  0.          2.6486E-03  4.2710E+01  2.7255E+01


     CEP HORIZONTAL= 2.77745770E+01
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (continued)

```
      XSUBV WIG MATRIX

ROW   1
 0.          0.          0.          0.          0.          0.          0.          0.          0.
 0.          0.          0.          0.          0.
ROW   2
 0.          2.9152E+02  1.3689E+01  1.5613E-02 -1.6596E-03 -2.2418E-01  6.2810E+00  1.5594E-03 -9.7708E-04 -1.9781E-01
-2.6266E-01 -1.9843E-02 -7.1558E+00 -3.7881E+00  4.3521E-01
ROW   3
 0.          1.3689E+01  3.4486E+00  5.6793E-04 -2.5260E-04 -3.6355E-02  2.9271E+00  2.9834E-04  7.1206E-05  9.7622E-03
 4.5607E-01 -2.7065E-03 -1.1285E+00 -5.5245E-01 -4.2704E-02
ROW   4
 0.          1.5613E-02  5.6793E-04  4.4091E-05  8.9656E-06  4.1150E-02  8.6690E-04  5.4723E-07 -6.9391E-08 -1.9198E-05
 2.9608E-06  1.0554E-02  1.4344E-02 -2.2305E-04  1.8771E-05
ROW   5
 0.         -1.6596E-03 -2.5260E-04  8.9656E-06  5.8585E-03  1.4618E-02 -1.5285E-04 -3.6195E-08  3.4724E-09  8.3645E-07
 4.4245E-05  1.0945E-01  4.4111E-01  4.9836E-05 -1.2330E-06
ROW   6
 0.         -2.2418E-01 -3.6355E-02  4.1150E-02  1.4618E-02  3.9722E+01 -1.6814E-02 -2.2658E-06 -5.4254E-08 -1.0910E-06
 1.7811E-02  1.0318E+01  1.4690E+01  4.7831E-03  4.7451E-05
ROW   7
 0.          6.2810E+00  2.9271E+00  8.6690E-04 -1.5285E-04 -1.6814E-02  1.0528E+03  2.0300E-01  6.6348E-04 -1.3902E-01
 1.2160E-01  9.3751E-06 -7.3274E-01 -5.5607E-01 -1.1692E+00
ROW   8
 0.          1.5594E-03  2.9834E-04  5.4723E-07 -3.6195E-08 -2.2658E-06  2.0300E-01  3.3298E-04  7.5944E-05 -1.6229E-01
 1.0752E-05  1.2811E-09 -1.0868E-04 -1.0417E-01 -5.9563E-02
ROW   9
 0.         -9.7708E-04  7.1206E-05 -6.9391E-08  3.4724E-09 -5.4254E-08  6.6348E-04  7.5944E-05  7.4368E-03 -5.7234E-02
 1.5559E-05 -1.1857E-14  4.8429E-07 -1.8419E-01 -1.4675E-01
ROW  10
 0.         -1.9781E-01  9.7622E-03 -1.9198E-05  8.3645E-07 -1.0910E-06 -1.3902E-01 -1.6229E-01 -5.7234E-02  1.0408E+02
 4.3562E-03 -1.3466E-12  5.1264E-04  6.6970E+01  3.8258E+01
ROW  11
 0.         -2.6266E-01  4.5607E-01  2.9608E-06  4.4245E-05  1.7811E-02  1.2160E-01  1.0752E-05  1.5559E-05  4.3562E-03
 6.4778E+01  0.         -9.0769E-04  3.8255E-03 -4.0901E-03
ROW  12
 0.         -1.9843E-02 -2.7065E-03  1.0554E-02  1.0945E-01  1.0318E+01  9.3751E-06  1.2811E-09 -1.1857E-14 -1.3466E-12
 0.          1.7082E+01  4.9928E+01  2.4152E-05  0.
ROW  13
 0.         -7.1558E+00 -1.1285E+00  1.4344E-02  4.4111E-01  1.4690E+01 -7.3274E-01 -1.0868E-04  4.8429E-07  5.1264E-04
-9.0769E-04  4.9928E+01  1.7464E+02  2.1177E-01  7.5962E-04
ROW  14
 0.         -3.7881E+00 -5.5245E-01 -2.2305E-04  4.9836E-05  4.7831E-03 -5.5607E-01 -1.0417E-01 -1.8419E-01  6.6970E+01
 3.8255E-03  2.4152E-05  2.1177E-01  7.1978E+01  4.2709E+01
ROW  15
 0.          4.3521E-01 -4.2704E-02  1.8771E-05 -1.2330E-06  4.7451E-05 -1.1692E+00 -5.9563E-02 -1.4675E-01  3.8258E+01
-4.0901E-03  0.          7.5962E-04  4.2709E+01  2.7255E+01


      CEP VERTICAL= 2.89696347E+01
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (continued)

```
      WEIGHTING MATRIX QH

ROW   1
 3.1416E+00  2.7668E+00  5.6989E+00  2.1816E+04  2.9303E+01 -2.5489E+01  0.          0.          0.          0.
 9.9846E-02  9.1745E-02 -1.1791E-01  0.          0.
ROW   2
 2.7668E+00  2.4367E+00  5.0190E+00  1.9214E+04  2.5807E+01 -2.2449E+01 -1.5104E-11 -6.1637E-08 -1.2613E-10 -9.4850E-11
 8.7934E-02  8.0800E-02 -1.0384E-01  1.0044E-12 -7.7468E-13
ROW   3
 5.6989E+00  5.0190E+00  1.0338E+01  3.9575E+04  5.3156E+01 -4.6238E+01  5.3748E-11  2.1933E-07  4.4882E-10  3.3752E-10
 1.8112E-01  1.6643E-01 -2.1389E-01 -3.5741E-12  2.7567E-12
ROW   4
 2.1816E+04  1.9214E+04  3.9575E+04  1.5150E+08  2.0349E+05 -1.7701E+05 -6.1502E-08 -2.5098E-04 -5.1358E-07 -3.8622E-07
 6.9336E+02  6.3711E+02 -8.1879E+02  4.0898E-09 -3.1544E-09
ROW   5
 2.9303E+01  2.5807E+01  5.3156E+01  2.0349E+05  2.7332E+02 -2.3775E+02 -8.2967E-11 -3.3857E-07 -6.9281E-10 -5.2101E-10
 9.3131E-01  8.5575E-01 -1.0998E+00  5.5171E-12 -4.2553E-12
ROW   6
-2.5489E+01 -2.2449E+01 -4.6238E+01 -1.7701E+05 -2.3775E+02  2.0681E+02  6.9987E-11  2.8560E-07  5.8443E-10  4.3950E-10
-8.1010E-01 -7.4438E-01  9.5665E-01 -4.6540E-12  3.5896E-12
ROW   7
 0.         -1.5104E-11  5.3748E-11 -6.1502E-08 -8.2967E-11  6.9987E-11  1.5708E+00  6.4101E+03  1.3117E+01  9.8642E+00
 1.1840E-12  3.7218E-12  5.2259E-12 -1.0446E-01  8.0565E-02
ROW   8
 0.         -6.1637E-08  2.1933E-07 -2.5098E-04 -3.3857E-07  2.8560E-07  6.4101E+03  2.6158E+07  5.3528E+04  4.0254E+04
 4.8316E-09  1.5188E-08  2.1326E-08 -4.2626E+02  3.2877E+02
ROW   9
 0.         -1.2613E-10  4.4882E-10 -5.1358E-07 -6.9281E-10  5.8443E-10  1.3117E+01  5.3528E+04  1.0953E+02  8.2371E+01
 9.8870E-12  3.1079E-11  4.3639E-11 -8.7225E-01  6.7276E-01
ROW  10
 0.         -9.4850E-11  3.3752E-10 -3.8622E-07 -5.2101E-10  4.3950E-10  9.8642E+00  4.0254E+04  8.2371E+01  6.1945E+01
 7.4352E-12  2.3372E-11  3.2817E-11 -6.5595E-01  5.0593E-01
ROW  11
 9.9846E-02  8.7934E-02  1.8112E-01  6.9336E+02  9.3131E-01 -8.1010E-01  1.1840E-12  4.8316E-09  9.8870E-12  7.4352E-12
 3.1733E-03  2.9158E-03 -3.7474E-03 -7.8734E-14  6.0726E-14
ROW  12
 9.1745E-02  8.0800E-02  1.6643E-01  6.3711E+02  8.5575E-01 -7.4438E-01  3.7218E-12  1.5188E-08  3.1079E-11  2.3372E-11
 2.9158E-03  2.6793E-03 -3.4433E-03 -2.4749E-13  1.9089E-13
ROW  13
-1.1791E-01 -1.0384E-01 -2.1389E-01 -8.1879E+02 -1.0998E+00  9.5665E-01  5.2259E-12  2.1326E-08  4.3639E-11  3.2817E-11
-3.7474E-03 -3.4433E-03  4.4253E-03 -3.4751E-13  2.6803E-13
ROW  14
 0.          1.0044E-12 -3.5741E-12  4.0898E-09  5.5171E-12 -4.6540E-12 -1.0446E-01 -4.2626E+02 -8.7225E-01 -6.5595E-01
-7.8734E-14 -2.4749E-13 -3.4751E-13  6.9461E-03 -5.3574E-03
ROW  15
 0.         -7.7468E-13  2.7567E-12 -3.1544E-09 -4.2553E-12  3.5896E-12  8.0565E-02  3.2877E+02  6.7276E-01  5.0593E-01
 6.0726E-14  1.9089E-13  2.6803E-13 -5.3574E-03  4.1321E-03
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (continued)

```
      WEIGHTING MATRIX QV

ROW   1
 4.0535E+00  3.5700E+00  7.3532E+00  2.8149E+04  3.7809E+01 -3.2889E+01  1.7190E-11  7.0147E-08  1.4354E-10  1.0795E-10
 1.2883E-01  1.1838E-01 -1.5214E-01 -1.1431E-12  8.8164E-13
ROW   2
 3.5700E+00  3.1441E+00  6.4760E+00  2.4791E+04  3.3299E+01 -2.8965E+01  3.4682E-14  1.4153E-10  2.8961E-13  2.1779E-13
 1.1346E-01  1.0426E-01 -1.3399E-01 -2.3063E-15  1.7788E-15
ROW   3
 7.3532E+00  6.4760E+00  1.3339E+01  5.1063E+04  6.8587E+01 -5.9660E+01  8.4930E-11  3.4658E-07  7.0921E-10  5.3334E-10
 2.3370E-01  2.1474E-01 -2.7598E-01 -5.6477E-12  4.3560E-12
ROW   4
 2.8149E+04  2.4791E+04  5.1063E+04  1.9548E+08  2.6256E+05 -2.2839E+05  5.7867E-08  2.3614E-04  4.8322E-07  3.6339E-07
 8.9463E+02  8.2205E+02 -1.0565E+03 -3.8481E-09  2.9680E-09
ROW   5
 3.7809E+01  3.3299E+01  6.8587E+01  2.6256E+05  3.5266E+02 -3.0677E+02  7.7368E-11  3.1572E-07  6.4606E-10  4.8585E-10
 1.2016E+00  1.1042E+00 -1.4190E+00 -5.1448E-12  3.9681E-12
ROW   6
-3.2889E+01 -2.8965E+01 -5.9660E+01 -2.2839E+05 -3.0677E+02  2.6684E+02 -6.9480E-11 -2.8353E-07 -5.8020E-10 -4.3632E-10
-1.0453E+00 -9.6046E-01  1.2344E+00  4.6203E-12 -3.5636E-12
ROW   7
 1.7190E-11  3.4682E-14  8.4930E-11  5.7867E-08  7.7368E-11 -6.9480E-11  1.5708E+00  6.4101E+03  1.3117E+01  9.8642E+00
 1.7303E-12  4.2238E-12  4.5808E-12 -1.0446E-01  8.0565E-02
ROW   8
 7.0147E-08  1.4153E-10  3.4658E-07  2.3614E-04  3.1572E-07 -2.8353E-07  6.4101E+03  2.6158E+07  5.3528E+04  4.0254E+04
 7.0610E-09  1.7236E-08  1.8693E-08 -4.2626E+02  3.2877E+02
ROW   9
 1.4354E-10  2.8961E-13  7.0921E-10  4.8322E-07  6.4606E-10 -5.8020E-10  1.3117E+01  5.3528E+04  1.0953E+02  8.2371E+01
 1.4449E-11  3.5271E-11  3.8252E-11 -8.7225E-01  6.7276E-01
ROW  10
 1.0795E-10  2.1779E-13  5.3334E-10  3.6339E-07  4.8585E-10 -4.3632E-10  9.8642E+00  4.0254E+04  8.2371E+01  6.1945E+01
 1.0866E-11  2.6524E-11  2.8766E-11 -6.5595E-01  5.0593E-01
ROW  11
 1.2883E-01  1.1346E-01  2.3370E-01  8.9463E+02  1.2016E+00 -1.0453E+00  1.7303E-12  7.0610E-09  1.4449E-11  1.0866E-11
 4.0944E-03  3.7623E-03 -4.8352E-03 -1.1506E-13  8.8746E-14
ROW  12
 1.1838E-01  1.0426E-01  2.1474E-01  8.2205E+02  1.1042E+00 -9.6046E-01  4.2238E-12  1.7236E-08  3.5271E-11  2.6524E-11
 3.7623E-03  3.4570E-03 -4.4429E-03 -2.8087E-13  2.1663E-13
ROW  13
-1.5214E-01 -1.3399E-01 -2.7598E-01 -1.0565E+03 -1.4190E+00  1.2344E+00  4.5808E-12  1.8693E-08  3.8252E-11  2.8766E-11
-4.8352E-03 -4.4429E-03  5.7099E-03 -3.0461E-13  2.3494E-13
ROW  14
-1.1431E-12 -2.3063E-15 -5.6477E-12 -3.8481E-09 -5.1448E-12  4.6203E-12 -1.0446E-01 -4.2626E+02 -8.7225E-01 -6.5595E-01
-1.1506E-13 -2.8087E-13 -3.0461E-13  6.9461E-03 -5.3574E-03
ROW  15
 8.8164E-13  1.7788E-15  4.3560E-12  2.9680E-09  3.9681E-12 -3.5636E-12  8.0565E-02  3.2877E+02  6.7276E-01  5.0593E-01
 8.8746E-14  2.1663E-13  2.3494E-13 -5.3574E-03  4.1321E-03

      QH(1,1) = 3.14159265E+00 QH(7,7) = 1.57079633E+00 QV(2,2) = 3.14159265E+00 QV(7,7) = 1.57079633E+00


      JSUBH= 2.36351968E+03 JSUBV= 2.56956184E+03


      APPROXIMATE CEPH= 2.74286653E+01 APPROXIMATE CEPV= 2.85992472E+01
```

Figure 70. Performance Evaluator Output - With Nonstationary Optimal Controller (concluded)

INITIAL COVARIANCE OF BOMB

```
ROW   1
 .11154E 05 -.12638E 05  .63510E 03 -.24038E 00  .59969E-01 -.64165E 02  .15566E 01 -.67844E+02  .86535E-03  .33890E 01
-.52492E-01 -.15947E 01 -.16677E 00  .32353E 01  .50064E 00
ROW   2
-.12638E 05  .14447E 05 -.72268E 03  .26913E 00 -.68796E-01  .68870E 02 -.25353E 01  .18539E+01 -.14010E-02 -.10935E 02
-.14521E 01 -.10338E 01 -.12511E 00 -.10520E 02 -.31578E 01
ROW   3
 .63510E 03 -.72268E 03  .61559E 02 -.13913E-01  .35444E-02 -.31677E 01  .29973E 00 -.31073E+02  .20176E-03  .19087E 01
 .35266E 00 -.12495E 00 -.10707E-01  .18814E 01  .62846E 00
ROW   4
-.24038E 00  .26913E 00 -.13913E-01  .11635E+04 -.11077E+05  .61717E-02 -.24546E+05  .50859E+06  .59567E-04 -.29678E-03
-.40438E-03  .37556E-02  .54321E-03 -.37802E-03 -.38652E-03
ROW   5
 .59969E-01 -.68796E-01  .35444E-02 -.11077E-05  .90486E-05  .10848E-02  .38080E-05 -.12340E-06  .22926E-04  .74967E-04
-.57603E-03  .13008E-02  .25611E-03 -.24147E-03 -.42903E-03
ROW   6
-.64165E 02  .68870E 02 -.31677E 01  .61717E-02  .10848E-02  .11310E 02  .84482E-01 -.79631E-03  .20121E-03  .52900E 00
 .94042E-01  .38007E 01  .56573E 00  .44957E 00  .15680E 00
ROW   7
 .15566E 01 -.25353E 01  .29973E 00 -.24546E-05  .38080E-05  .84482E-01  .13777E 03 -.24812E+01  .13157E-02  .10041E 02
 .50942E 00  .18754E-01  .13660E-02  .92413E 01  .19545E 01
ROW   8
-.67844E-02  .18539E-01 -.31073E-02  .50859E-06 -.12340E-06 -.79631E-03 -.24812E-01  .17177E+03 -.15223E-04 -.83426E-01
-.84643E-02  .22366E-04  .29879E-05 -.82740E-01 -.21252E-01
ROW   9
 .86535E-03 -.14010E-02  .20176E-03  .59567E-06  .22926E-06  .20121E-03  .13157E-02 -.15223E+04  .55923E-04  .76154E-02
-.88781E-03 -.24482E-05 -.29166E-06  .68818E-02  .61245E-03
ROW  10
 .33890E 01 -.10935E 02  .19087E 01 -.29678E-03  .74967E-04  .52900E 00  .10041E 02 -.83426E-01  .76154E-02  .56334E 02
 .54702E 01 -.69999E-02 -.12661E-02  .48723E 02  .12976E 02
ROW  11
-.52492E-01 -.14521E 01  .35266E 00 -.40438E-03 -.57603E-03  .94042E-01  .50942E 00 -.84643E+02 -.88781E-03  .54702E 01
 .30539E 01  .00000E 00  .00000E 00  .54414E 01  .31353E 01
ROW  12
-.15947E 01 -.10338E 01 -.12495E 00  .37556E-02  .13008E-02  .38007E 01  .15754E-01  .22366E-04 -.24482E-05 -.69999E-02
 .00000E 00  .30454E 01  .61508E 00  .00000E 00  .00000E 00
ROW  13
-.16677E 00 -.12511E 00 -.10707E-01  .54321E-03  .25611E-03  .56573E 00 -.13660E-02  .29879E-05 -.29166E-06 -.12661E-02
 .00000E 00  .61508E 00  .35997E-01  .00000E 00  .00000E 00
ROW  14
 .32353E 01 -.10520E 02  .18814E 01 -.37802E-03 -.24147E-03  .44957E 00  .92413E 01 -.82740E-01  .68818E-02  .48723E 02
 .54414E 01  .00000E 00  .00000E 00  .50062E 02  .13141E 02
ROW  15
 .50064E 00 -.31578E 01  .62846E 00 -.38652E-03 -.42903E-03  .15680E 00  .19545E 01 -.21252E-01  .61245E-03  .12976E 02
 .31353E 01  .00000E 00  .00000E 00  .13141E 02  .46854E 01
```

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller

```
      XSUBF MATRIX T=    6.28

ROW   1
 .60294E 00 -.62304E 00  .17936E 00 -.26569E-04  .18072E-03 -.34479E-01 -.69096E-09 -.10555E-11 -.95899E-12  .46555E-09
 .20729E 00 -.91954E-02  .23553E-01  .46546E-09  .19755E-08
ROW   2
-.62304E 00  .68351E 00 -.19133E 00 -.33500E-04  .15761E-03 -.30660E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
-.21632E 00 -.85040E-02  .16660E-01  .00000E 00  .00000E 00
ROW   3
 .17936E 00 -.19133E 00  .62515E-01 -.10596E-04 -.65221E-05 -.11883E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .43977E 00 -.29561E-02 -.40228E-02  .00000E 00  .00000E 00
ROW   4
-.26569E-04 -.33500E-04 -.10596E-04  .42610E-04  .91194E-05  .41113E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .23447E-04  .10552E-01  .14673E-01  .00000E 00  .00000E 00
ROW   5
 .18072E-03  .15761E-03 -.65221E-05  .91194E-05  .58511E-02 -.14627E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .43567E-04  .10938E 00  .44073E 00  .00000E 00  .00000E 00
ROW   6
-.34479E-01 -.30660E-01 -.11883E-01  .41113E-01 -.14627E-01  .39676E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .17814E-01  .10315E 02  .14602E 02  .00000E 00  .00000E 00
ROW   7
-.69096E-09  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .36046E-01 -.36601E-03  .36531E-03  .24418E 00
 .00000E 00  .00000E 00  .00000E 00  .19077E 00  .61763E-02
ROW   8
-.10555E-11  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00 -.36601E-03  .25254E-03  .75961E-04 -.16194E 00
 .00000E 00  .00000E 00  .00000E 00 -.10390E 00 -.59320E-01
ROW   9
-.95899E-12  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .36531E-03  .75961E-04  .74214E-02 -.57265E-01
 .00000E 00  .00000E 00  .00000E 00 -.18401E 00 -.14661E 00
ROW  10
 .46555E-09  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .24418E 00 -.16194E 00 -.57265E-01  .10386E 03
 .00000E 00  .00000E 00  .00000E 00  .66839E 02  .38155E 02
ROW  11
 .20729E 00 -.21632E 00  .43977E 00  .23447E-04  .43567E-04  .17814E-01  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .64663E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
ROW  12
-.91954E-02 -.85040E-02 -.29561E-02  .10552E-01  .10938E 00  .10315E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .17077E 02  .49839E 02  .00000E 00  .00000E 00
ROW  13
 .23553E-01  .16660E-01 -.40228E-02  .14673E-01  .44073E 00  .14602E 02  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .49839E 02  .17389E 03  .00000E 00  .00000E 00
ROW  14
 .46546E-09  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .19077E 00 -.10390E 00 -.18401E 00  .66839E 02
 .00000E 00  .00000E 00  .00000E 00  .71744E 02  .42611E 02
ROW  15
 .19755E-08  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .61763E-02 -.59320E-01 -.14661E 00  .38155E 02
 .00000E 00  .00000E 00  .00000E 00  .42611E 02  .27159E 02
```

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (continued)

```
      PRINT ,INV MATRIX

R0W   1
 •10000E 01  •00000E 00  •49428E 01  •33662E 04  •45008E 01 -•40420E 01  •00000E 00  •18626E-05  •37485E-08  •28731E-08
 •10000E 00  •24874E 00  •26440E 00 -•74838E-09 -•27066E-08
R0W   2
 •00000E 00  •99411E 01 -•95817E 01  •40640E 04  •54825E 01 -•46249E 01  •00000E 00  •00000E 00  •00000E 00  •00000E 00
-•76044E-01 -•24896E 00 -•34827E 00  •00000E 00  •00000E 00
R0W   3
 •00000E 00  •91130E-05  •90393E 00 -•12584E 03 -•18119E 00  •12189E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •29157E-01  •62774E-01  •84009E-01  •00000E 00  •00000E 00
R0W   4
 •00000E 00  •89915E-07  •29798E-03  •84406E 00  •11545E-02 -•98675E-03  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •48130E-05  •55006E-05 -•12574E-04  •00000E 00  •00000E 00
R0W   5
 •00000E 00  •16224E-07  •15072E-04 -•23961E-01  •70367E-04  •24306E-04  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •47220E-06  •44506E-06  •46416E-06  •00000E 00  •00000E 00
R0W   6
 •00000E 00 -•12325E-05 -•47817E-03  •37410E 00  •17395E-01 -•28395E-03  •00000E 00  •00000E 00  •00000E 00  •00000E 00
-•16830E-05  •20754E-04 -•23702E-02  •00000E 00  •00000E 00
R0W   7
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •10000E 01  •40807E 04  •83505E 01  •62797E 01
 •00000E 00  •00000E 00  •00000E 00 -•66498E-01  •51312E-01
R0W   8
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •10000E 01  •20402E-02  •15393E-02
 •00000E 00  •00000E 00  •00000E 00  •23327E-04 -•94337E-04
R0W   9
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •90220E-04  •29210E-05
 •00000E 00  •00000E 00  •00000E 00 -•36273E-04  •17763E-03
R0W  10
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00 -•16245E-01  •12281E-03
 •00000E 00  •00000E 00  •00000E 00 -•25326E-01  •77299E-01
R0W  11
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •41583E-01  •00000E 00  •00000E 00  •00000E 00  •00000E 00
R0W  12
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •00000E 00  •58537E-03 -•35228E-02  •00000E 00  •00000E 00
R0W  13
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •00000E 00  •37987E-02 -•19146E-01  •00000E 00  •00000E 00
R0W  14
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •00000E 00  •00000E 00  •00000E 00 -•24884E-01  •76153E-01
R0W  15
 •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00  •00000E 00
 •00000E 00  •00000E 00  •00000E 00 -•28808E-01  •18673E-01
```

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (continued)

X(T) MATRIX

ROW 1	.17581E 05	-.19446E 05	.42697E 03	.68743E-01	.18050E-01	-.52632E 00	-.71997E 01	-.22475E-02	.19893E-04	-.98300E-01	.21771E 00	-.26457E-02	.19109E-01	-.97367E-01	-.25019E 00
ROW 2	-.19446E 05	.22342E 05	-.90790E 03	-.37693E-03	-.21168E-01	.52717E 00	.69161E 01	.26820E-02	-.70174E-03	-.77932E-01	-.42517E 00	-.25110E-02	.14466E-01	-.75565E-01	.46341E 00
ROW 3	.42697E 03	-.90790E 03	.51796E 02	.44704E-02	.10929E-02	-.42241E-01	-.43696E 00	-.17867E-03	.63637E-04	.68008E-02	.45928E 00	-.29827E-02	-.40735E-02	.65926E-02	-.42710E-01
ROW 4	.68743E-01	-.37693E-03	.44704E-02	.51004E-04	.90335E-05	.41112E-01	-.64060E-04	.94615E-08	-.46616E-07	-.17209E-04	.94650E-05	.10552E-01	.14672E-01	-.16933E-04	.24253E-05
ROW 5	.18050E-01	-.21168E-01	.10929E-02	.90335E-05	.58511E-02	.14626E-01	-.88249E-05	-.43829E-08	.25636E-08	.57324E-06	.44344E-04	.10938E 00	.44073E 00	.56183E-06	-.10147E-05
ROW 6	-.52632E 00	.52717E 00	-.42241E-01	.41112E-01	.14626E-01	.39676E 02	.26792E-03	.11279E-06	-.49551E-07	-.90783E-05	.17799E-01	.10315E 02	.14602E 02	-.88792E-05	.24371E-04
ROW 7	-.71997E 01	.69161E 01	-.43696E 00	-.64060E-04	-.88249E-05	.26792E-03	.87005E 03	.18800E 00	.63833E-03	.57844E 00	.46916E-02	.17157E-04	.12649E-03	.51568E 00	.65401E 00
ROW 8	-.22475E-02	.26820E-02	-.17867E-03	.94615E-08	-.43829E-08	.11279E-06	.18800E 00	.30083E-03	.76003E-04	-.16185E 00	-.89158E-05	.31239E-08	.23087E-07	-.10382E 00	-.59121E-01
ROW 9	.19893E-04	-.70174E-03	.63637E-04	-.46616E-07	.25636E-08	-.49551E-07	.63833E-03	.76003E-04	.74214E-02	-.57252E-01	.15609E-04	.10226E-11	-.53392E-11	-.18399E 00	-.14662E 00
ROW 10	-.98300E-01	-.77932E-01	.68008E-02	-.17209E-04	.57324E-06	-.90783E-05	.57844E 00	-.16185E 00	-.57252E-01	.10387E 03	.43759E-02	.51123E-10	-.15445E-09	.66847E 02	.38163E 02
ROW 11	.21771E 00	-.42517E 00	.45928E 00	.94650E-05	.44344E-04	.17799E-01	.46916E-02	-.89158E-05	.15609E-04	.43759E-02	.64669E 02	.00000E 00	.00000E 00	.42980E-02	-.40839E-02
ROW 12	-.26457E-02	-.25110E-02	-.29827E-02	.10552E-01	.10938E 00	.10315E 02	.17157E-04	.31239E-08	.10226E-11	.51123E-10	.00000E 00	.17272E 02	.49839E 02	.00000E 00	.00000E 00
ROW 13	.19109E-01	.14466E-01	-.40735E-02	.14672E-01	.44073E 00	.14602E 02	.12649E-03	.23087E-07	-.53392E-11	-.15445E-09	.00000E 00	.49839E 02	.17399E 03	.00000E 00	.00000E 00
ROW 14	-.97367E-01	-.75565E-01	.65926E-02	-.16933E-04	.56183E-06	-.88792E-05	.51568E 00	-.10382E 00	-.18399E 00	.66847E 02	.42980E-02	.00000E 00	.00000E 00	.71752E 02	.42619E 02
ROW 15	-.25019E 00	.46341E 00	-.42710E-01	.24253E-05	-.10147E-05	.24371E-04	.65401E 00	-.59121E-01	-.14662E 00	.38163E 02	-.40839E-02	.00000E 00	.00000E 00	.42619E 02	.27188E 02

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (continued)

```
      XSUBH WIG MATRIX

RBW   1
 .65876E 03  .00000E 00  .33124E 02  .68411E-01 -.19283E-03 -.45090E-01 -.11111E 01  .11358E-03 -.59788E-03 -.16691E 00
-.15659E 00 -.17138E-01  .10030E 01  .32169E 00  .15778E 00
RBW   2
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
RBW   3
 .33124E 02  .00000E 00  .20904E 02  .44612E-02 -.61792E-04 -.57489E-01 -.26926E 00 -.11363E-03  .46622E-04  .49112E-02
 .44897E 00 -.31891E-02 -.15930E 01 -.78987E 00 -.31474E-01
RBW   4
 .68411E-01  .00000E 00  .44612E-02  .51004E-04  .90328E-05  .41112E-01 -.64060E-04  .94615E-08 -.46616E-07 -.17209E-04
 .94650E-05  .10552E-01  .14671E-01 -.17751E-04  .24253E-05
RBW   5
-.19283E-03  .00000E 00 -.61792E-04  .90328E-05  .58511E-02  .14628E-01  .32912E-05  .31561E-09  .13342E-08  .43672E-06
 .43599E-04  .10938E 00  .44081E 00  .39436E-04 -.20289E-06
RBW   6
-.45090E-01  .00000E 00 -.57489E-01  .41112E-01  .14628E-01  .39677E 02  .79738E-03  .31811E-06 -.10327E-06 -.15044E-04
 .17767E-01  .10315E 02  .14611E 02  .48414E-02  .59846E-04
RBW   7
-.11111E 01  .00000E 00 -.26926E 00 -.64060E-04  .32912E-05  .79738E-03  .87005E 03  .18800E 00  .63833E-03  .57844E 00
 .46916E-02  .17157E-04  .30145E-01  .53069E 00  .65401E 00
RBW   8
 .11358E-03  .00000E 00 -.11363E-03  .94615E-08  .31561E-09  .31811E-06  .18800E 00  .30083E-03  .76003E-04 -.16185E 00
-.89158E-05  .31239E-08  .11664E-04 -.10381E 00 -.59121E-01
RBW   9
-.59788E-03  .00000E 00  .46622E-04 -.46616E-07  .13342E-08 -.10327E-06  .63833E-03  .76003E-04  .74214E-02 -.57252E-01
 .15609E-04  .10226E-11 -.30458E-05 -.18399E 00 -.14662E 00
RBW  10
-.16691E 00  .00000E 00  .49112E-02 -.17209E-04  .43672E-06 -.15044E-04  .57844E 00 -.16185E 00 -.57252E-01  .10387E 03
 .43759E-02 -.51123E-10 -.33826E-03  .66847E 02  .38163E 02
RBW  11
-.15659E 00  .00000E 00  .44897E 00  .94650E-05  .43599E-04  .17767E-01  .46916E-02 -.89158E-05  .15609E-04  .43759E-02
 .64669E 02  .00000E 00 -.18454E-02  .33753E-02 -.40839E-02
RBW  12
-.17138E-01  .00000E 00 -.31891E-02  .10552E-01  .10938E 00  .10315E 02  .17157E-04  .31239E-08  .10226E-11  .51123E-10
 .00000E 00  .17222E 02  .49839E 02 -.18471E-04  .00000E 00
RBW  13
 .10030E 01  .00000E 00 -.15930E 01  .14671E-01  .44081E 00  .14611E 02  .30145E-01  .11664E-04 -.30458E-05 -.33826E-03
-.18454E-02  .49839E 02  .17432E 03  .21016E 00  .20114E-02
RBW  14
 .32169E 00  .00000E 00 -.78987E 00 -.17751E-04  .39436E-04  .48414E-02  .53069E 00 -.10381E 00 -.18399E 00  .66847E 02
 .33753E-02 -.18471E-04  .21016E 00  .71857E 02  .42620E 02
RBW  15
 .15778E 00  .00000E 00 -.31474E-01  .24253E-05 -.20289E-06  .59846E-04  .65401E 00 -.59121E-01 -.14662E 00  .38163E 02
-.40839E-02  .00000E 00  .20114E-02  .42620E 02  .27188E 02


CEP HORIZONTAL=  .32270323E 02 CEP VERTICAL=  .19892559E 02
```

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (continued)

```
      XSUBV EIG MATRIX

RBW   1
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
 .00000E 00  .00000E 00  .00000E 00  .00000E 00  .00000E 00
RBW   2
 .00000E 00  .84908E 03  .17016E 02  .77708E-01 -.17081E-02 -.11629E 00 -.12621E 01  .12901E+03 -.67914E-03 -.18959E 00
-.17788E 00 -.19468E-01 -.25500E 01 -.14792E 01  .17922E 00
RBW   3
 .00000E 00  .17016E 02  .19579E 02  .25770E-02 -.86290E-04 -.57550E-01 -.23866E 00 -.11676E+03  .63089E-04  .95083E-02
 .45328E 00 -.27170E-02 -.16945E 01 -.83566E 00 -.35819E-01
RBW   4
 .00000E 00  .77703E-01  .25770E-02  .51004E-04  .88967E-05 -.41106E-01 -.64060E-04  .94615E-08 -.46616E-07 -.17209E-04
 .94650E-05  .10552E-01  .14333E-01 -.18639E-03  .24253E-05
RBW   5
 .00000E 00 -.17031E-02 -.86290E-04  .88967E-05  .58511E-02 -.14628E-01  .55022E-05  .89600E-10  .25240E-08  .76886E-06
 .43911E-04  .10938E 00  .44082E 00  .42502E-04 -.51686E-06
RBW   6
 .00000E 00 -.11629E 00 -.57550E-01  .41106E-01  .14628E-01  .39677E 02  .89400E-03  .30823E-06 -.51281E-07 -.53023E-06
 .17781E-01  .10315E 02  .14612E 02  .50658E-02  .46126E-04
RBW   7
 .00000E 00 -.12621E 01 -.23866E 00 -.64060E-04  .55022E-05  .89400E-03  .87005E 03  .18800E 00  .63833E-03  .57844E 00
 .46916E-02  .17157E-04  .35623E-01  .53343E 00  .65401E 00
RBW   8
 .00000E 00  .12901E-03 -.11676E-03  .94615E-08  .89600E-10  .30823E-06  .18800E 00  .30083E-03  .76003E-04 -.16185E 00
-.89158E-05  .31239E-08  .11104E-04 -.10381E 00 -.59121E-01
RBW   9
 .00000E 00 -.67914E-03  .63089E-04 -.46616E-07  .25240E-08 -.51281E-07  .63833E-03  .76003E-04  .74214E-02 -.57252E-01
 .15609E-04  .10226E-11 -.98084E-07 -.18399E 00 -.14662E 00
RBW   10
 .00000E 00 -.18959E 00  .95083E-02 -.17209E-04  .76886E-06 -.53023E-06  .57844E 00 -.16185E 00 -.57252E-01  .10387E 03
 .43759E-02  .51123E-10  .48465E-03  .66848E 02  .38163E 02
RBW   11
 .00000E 00 -.17788E 00  .45328E 00  .94650E-05  .43911E-04  .17781E-01  .46916E-02 -.89158E-05  .15609E-04  .43759E-02
 .64663E 02  .00000E 00 -.10734E-02  .37613E-02 -.40839E-02
RBW   12
 .00000E 00 -.19468E-01 -.27170E-02  .10552E-01  .10938E 00  .10315E 02  .17157E-04  .31239E-08  .10226E-11  .51123E-10
 .00000E 00  .17078E 02  .40839E 02  .23778E-04  .00000E 00
RBW   13
 .00000E 00 -.25500E 01 -.16945E 01  .14333E-01  .44082E 00  .14612E 02  .35623E-01  .11104E-04 -.98084E-07  .48465E-03
-.10734E-02  .40839E 02  .17432E 03  .21411E 00  .12335E-02
RBW   14
 .00000E 00 -.14792E 01 -.83566E 00 -.18639E-03  .42502E-04  .50658E-02  .53343E 00 -.10381E 00 -.18399E 00  .66848E 02
 .37613E-02  .23778E-04  .21411E 00  .71859E 02  .42619E 02
RBW   15
 .00000E 00  .17922E 00 -.35819E-01  .24253E-05 -.51686E-06  .46126E-04  .65401E 00 -.59121E-01 -.14662E 00  .38163E 02
-.40839E-02  .00000E 00  .12335E-02  .42619E 02  .27188E 02


CER HORIZONTAL=  .1[illegible]59E 02 CER VERTICAL=  .34310937E 02
```

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (continued)

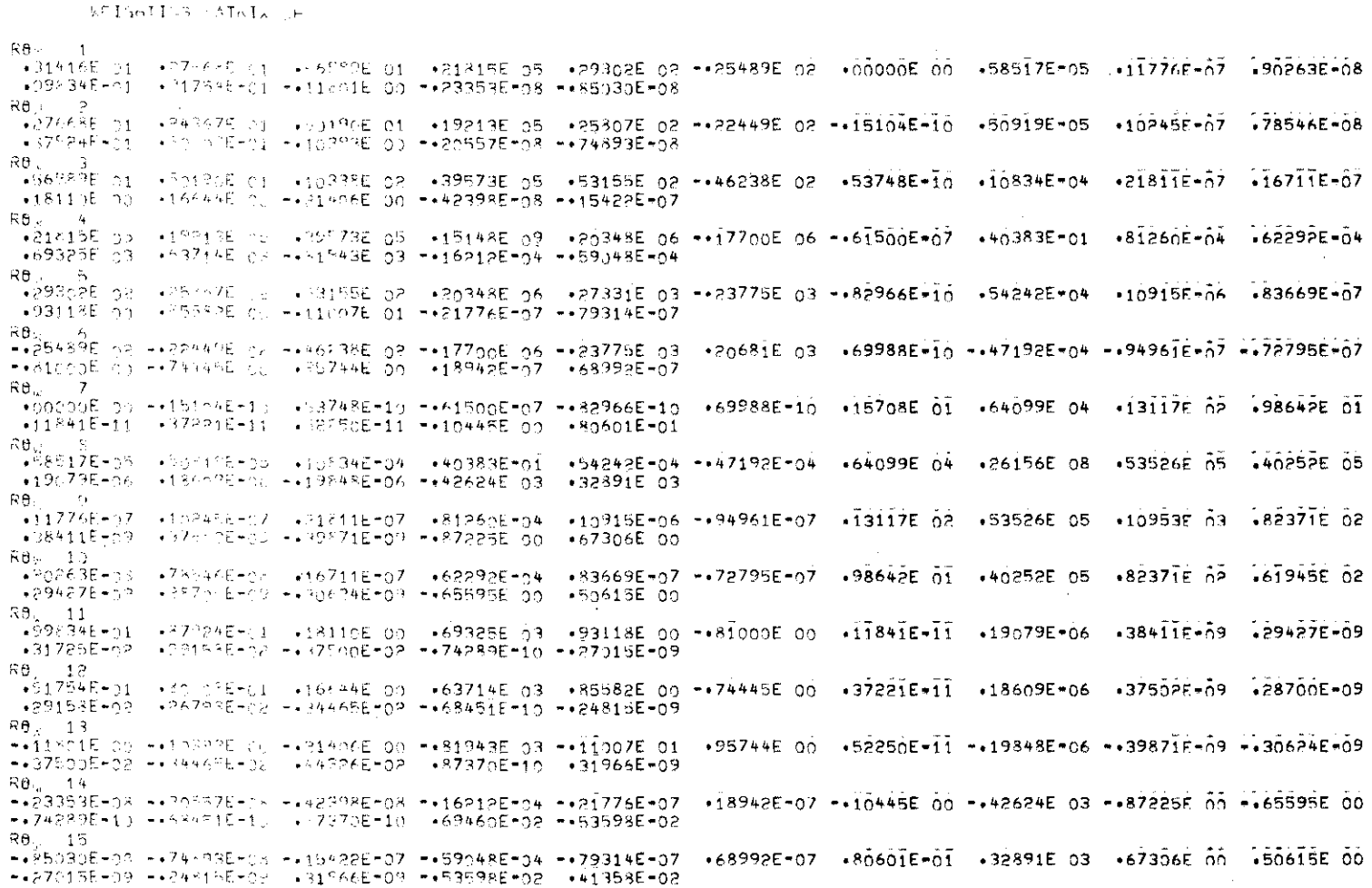


Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (continued)

```
      WEIGHTING MATRIX V

R0W   1
 .40535E 01  .35703E 01  .73532E 01  .28143E 05  .37309E 02 -.32889E 02  .17190E-10  .76205E-05  .15338E-07  .11754E-07
 .12881E 00  .11339E 00 -.15226E 00 -.30143E-08 -.10970E-07
R0W   2
 .35700E 01  .31441E 01  .64760E 01  .24790E 05  .33298E 02 -.28965E 02  .34675E-13  .66497E-05  .13382E-07  .10257E-07
 .11346E 00  .10497E 00 -.13410E 00 -.26537E-08 -.96624E-08
R0W   3
 .73532E 01  .64760E 01  .13339E 02  .51060E 05  .68585E 02 -.59660E 02  .84930E-10  .14043E-04  .28272E-07  .21660E-07
 .23367E 00  .21476E 00 -.27620E 00 -.54715E-08 -.19898E-07
R0W   4
 .28148E 05  .24790E 05  .51060E 05  .19546E 09  .26254E 06 -.22838E 06  .57864E-07  .52666E-01  .10599E-03  .81236E-04
 .89448E 03  .82209E 03 -.10573E 04 -.20927E-04 -.76181E-04
R0W   5
 .37309E 02  .33298E 02  .68585E 02  .26254E 06  .35265E 03 -.30676E 03  .77366E-10  .70740E-04  .14237E-06  .10912E-06
 .12015E 01  .11042E 01 -.14202E 01 -.28110E-07 -.10233E-06
R0W   6
-.32889E 02 -.28965E 02 -.59660E 02 -.22838E 06 -.30676E 03  .26684E 03 -.69479E-10 -.61543E-04 -.12386E-06 -.94930E-07
-.10451E 01 -.96055E 00  .12354E 01  .24452E-07  .89012E-07
R0W   7
 .17190E-10  .34675E-13  .84930E-10  .57864E-07  .77366E-10 -.69479E-10  .15708E 01  .64099E 04  .13117E 02  .98642E 01
 .17303E-11  .42241E-11  .45793E-11 -.10445E 00  .80601E-01
R0W   8
 .76205E-05  .66497E-05  .14043E-04  .52666E-01  .70740E-04 -.61543E-04  .64099E 04  .26156E 08  .53526E 05  .40252E 05
 .24700E-06  .23775E-06 -.26492E-06 -.42624E 03  .32891E 03
R0W   9
 .15338E-07  .13382E-07  .28272E-07  .10599E-03  .14237E-06 -.12386E-06  .13117E 02  .53526E 05  .10953E 03  .82371E 02
 .49730E-09  .47905E-09 -.53250E-09 -.87225E 00  .67306E 00
R0W  10
 .11754E-07  .10257E-07  .21660E-07  .81236E-04  .10912E-06 -.94930E-07  .98642E 01  .40252E 05  .82371E 02  .61945E 02
 .38097E-09  .36668E-09 -.40871E-09 -.65595E 00  .50615E 00
R0W  11
 .12881E 00  .11345E 00  .23367E 00  .89448E 03 -.12015E 01 -.10451E 01  .17303E-11  .24700E-06  .49730E-09  .38097E-09
 .40935E-02  .37622E-02 -.48386E-02 -.95867E-10 -.34856E-09
R0W  12
 .11839E 00  .10497E 00  .21476E 00  .82209E 03 -.11042E 01 -.96055E 00  .42241E-11  .23775E-06  .47905E-09  .36668E-09
 .37622E-02  .34577E-02 -.44470E-02 -.88283E-10 -.32021E-09
R0W  13
-.15226E 00 -.13410E 00 -.27620E 00 -.10573E 04 -.14202E 01  .12354E 01  .45793E-11 -.26492E-06 -.53250E-09 -.40871E-09
-.48386E-02 -.44470E-02  .57193E-02  .11288E-09  .41234E-09
R0W  14
-.30143E-08 -.26537E-08 -.54715E-08 -.20927E-04 -.28110E-07  .24452E-07 -.10445E 00 -.42624E 03 -.87225E 00 -.65595E 00
-.95867E-10 -.88283E-10  .11288E-09  .69460E-02 -.53598E-02
R0W  15
-.10970E-07 -.96624E-08 -.19898E-07 -.76181E-04 -.10233E-06  .89012E-07  .80601E-01  .32891E 03  .67306E 00  .50615E 00
-.34856E-09 -.32021E-09  .41234E-09 -.53598E-02  .41358E-02

      QH(1,1) =  .31415926E 01 QH(7,7) =  .15707963E 01 QV(2,2) =  .31415926E 01 QV(7,7) =  .15707963E 01


      JSUBH=  .34362248E 04 JSUBV=  .40369832E 04


      APPROXIMATE CEPH=  .33072410E 02 APPROXIMATE CEPV=  .35847059E 02

*STOP* 00000000
```

Figure 71. Performance Evaluator Output - With Fixed-Gain Optimal Controller (concluded)

SECTION VII
STATIONARY AND NONSTATIONARY GAINS AND SPECTRUMS

GAIN PLOTS

Plots of optimal controller gains corresponding to the aircraft states were made, one for the time-varying optimal gains and the other for the fixed-optimal gains for each frozen-time point linear data. The symbols for the controller gains are given in Table X. Figure 72 shows the program listing used for plotting the gains. The plots corresponding to nonstationary and stationary designs for each gain element are shown as Figure 73. The gain values are expressed as per-radian deflection. It is seen that the values for stationary and nonstationary designs are reasonably close to each other.

Table X. Symbols for Controller Gains Corresponding to Aircraft States

	δ_{xe}	δ_{he}	δ_{u}	δ_{θ}	δ_{q}	δ_{w}	δ_{ye}	δ_{ψ}	δ_{r}	δ_{v}	δ_{ϕ}	δ_{p}
δ_{s}	$K_{\delta s,xe}$	$K_{\delta s,he}$	$K_{\delta s,u}$	$K_{\delta s,\theta}$	$K_{\delta s,q}$	$K_{\delta s,w}$	$K_{\delta s,ye}$	$K_{\delta s,\psi}$	$K_{\delta s,r}$	$K_{\delta s,v}$	$K_{\delta s,\phi}$	$K_{\delta s,p}$
δ_{a}	$K_{\delta a,xe}$	$K_{\delta a,he}$	$K_{\delta a,u}$	$K_{\delta a,\theta}$	$K_{\delta a,q}$	$K_{\delta a,w}$	$K_{\delta a,ye}$	$K_{\delta a,\psi}$	$K_{\delta a,r}$	$K_{\delta a,v}$	$K_{\delta a,\phi}$	$K_{\delta a,p}$
δ_{r}	$K_{\delta r,xe}$	$K_{\delta r,he}$	$K_{\delta r,u}$	$K_{\delta r,\theta}$	$K_{\delta r,q}$	$K_{\delta r,w}$	$K_{\delta r,ye}$	$K_{\delta r,\psi}$	$K_{\delta r,r}$	$K_{\delta r,v}$	$K_{\delta r,\phi}$	$K_{\delta r,p}$
δ_{sp}	$K_{\delta sp,xe}$	$K_{\delta sp,he}$	$K_{\delta sp,u}$	$K_{\delta sp,\theta}$	$K_{\delta sp,q}$	$K_{\delta sp,w}$	$K_{\delta sp,ye}$	$K_{\delta sp,\psi}$	$K_{\delta sp,r}$	$K_{\delta sp,v}$	$K_{\delta sp,\phi}$	$K_{\delta sp,p}$

```
▲FORTRAN LS,G9
     1:        DIMENSION XX(20),IORD(48,8),YY(20,48),AK(4,18,20),AB(6)
     2:        DIMENSION AKK(4,17)
     3:        READ(5,1)NG
     4:      1 FORMAT(I2)
     5:        DO 3 I=1,NG
     6:      3 READ(5,2)(IORD(I,J),J=1,8)
     7:      2 FORMAT(8(A4))
     8:        READ(5,998)NDP
     9:    998 FORMAT(I2)
    10:        DO 2022 L=1,20
    11:        READ(6)AKK
    12:        DO 3033 I=1,4
    13:        DO 3033 J=1,17
    14:   3033 AK(I,J,L)=AKK(I,J)
    15:   2022 CONTINUE
    16:        DO 2023 I=1,19
    17:   2023 XX(I)=I-1
    18:        XX(20)=18.97
    19:        DO 4 L=1,NDP
    20:        ICOT=0
    21:        DO 5 I=1,4
    22:        DO 5 J=1,12
    23:        ICOT=ICOT+1
    24:      5 YY(L,ICOT)=AK(I,J,L)/57.3
    25:      4 CONTINUE
    26:        DO 100 L=1,NG
    27:        XMAX=-1.E+20
    28:        XMIN=+1.E+20
    29:        DO 10 I=1,NDP
    30:        XMAX=AMAX(XMAX,YY(I,L))
    31:     10 XMIN=AMIN(XMIN,YY(I,L))
    32:        R=XMAX-XMIN
    33:        WRITE(9,200)(IORD(L,K),K=1,8)
    34:    200 FORMAT(1H1,25X,8A4)
    35:        AB(1)=XMIN
    36:        DO 11 M=1,5
    37:     11 AB(M+1)=AB(M)+R/5.
    38:        WRITE(9,201)(AB(M),M=1,6)
    39:    201 FORMAT(//6G14.3)
    40:        WRITE(9,202)
    41:    202 FORMAT(8X,'I',5('------------I'))
    42:        JJ=6
    43:        DO 300 J=1,NDP
    44:        LL=(YY(J,L)-XMIN)*70./R
    45:        IF(J.NE.JJ) GOTO 400
    46:        T=XX(J)
    47:        JJ=JJ+5
    48:        WRITE(9,203)T,LL
    49:    203 FORMAT(F6.2,'  I',NX,'*')
    50:        GOTO 300
    51:    400 WRITE(9,204)LL
    52:    204 FORMAT(6X,'  I',NX,'*')
    53:    300 CONTINUE
    54:    100 CONTINUE
    55:        END
```

Figure 72. Gain Plotting Program Listing

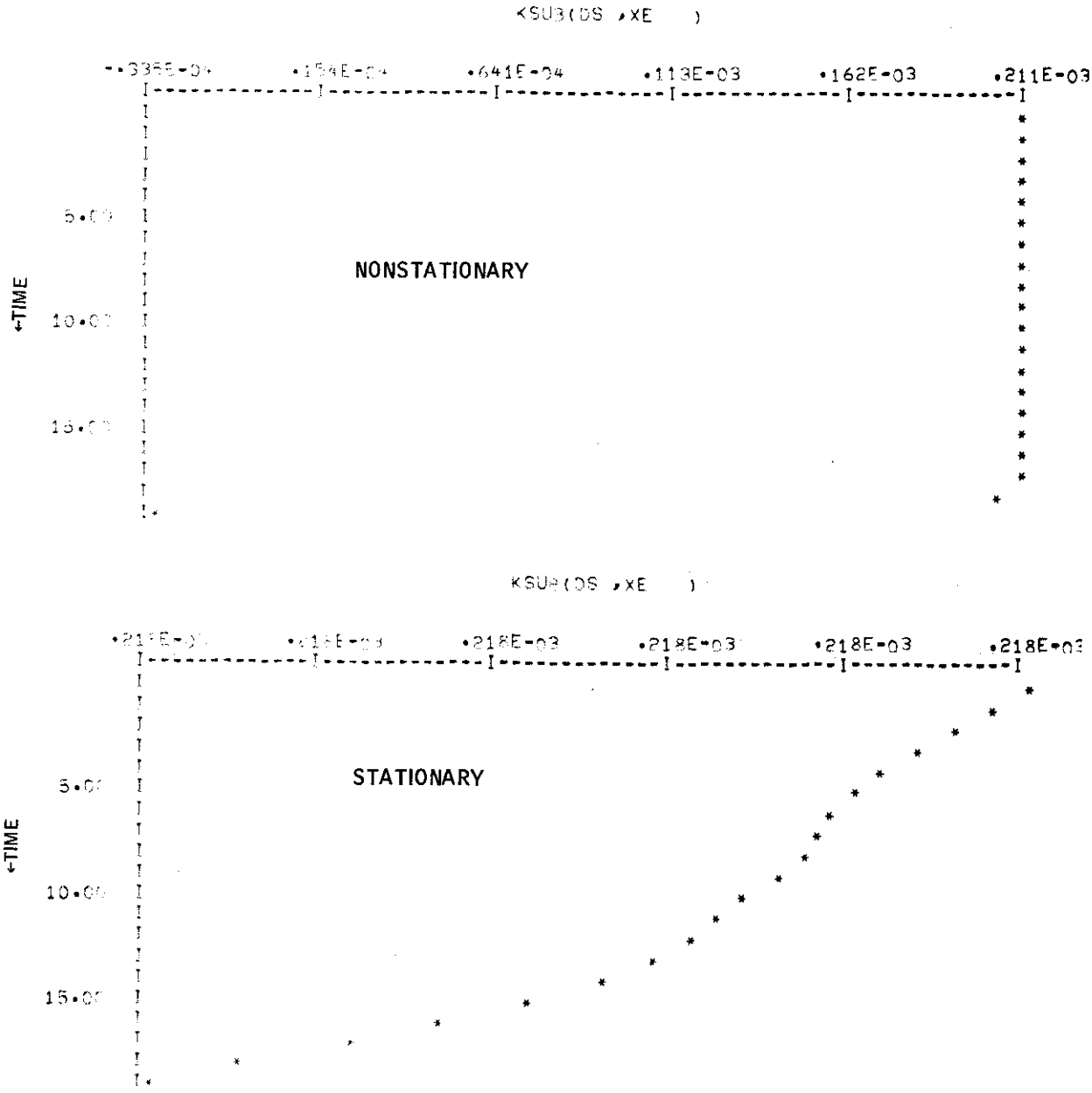


Figure 73. Optimal Controller Gain Plots versus Time

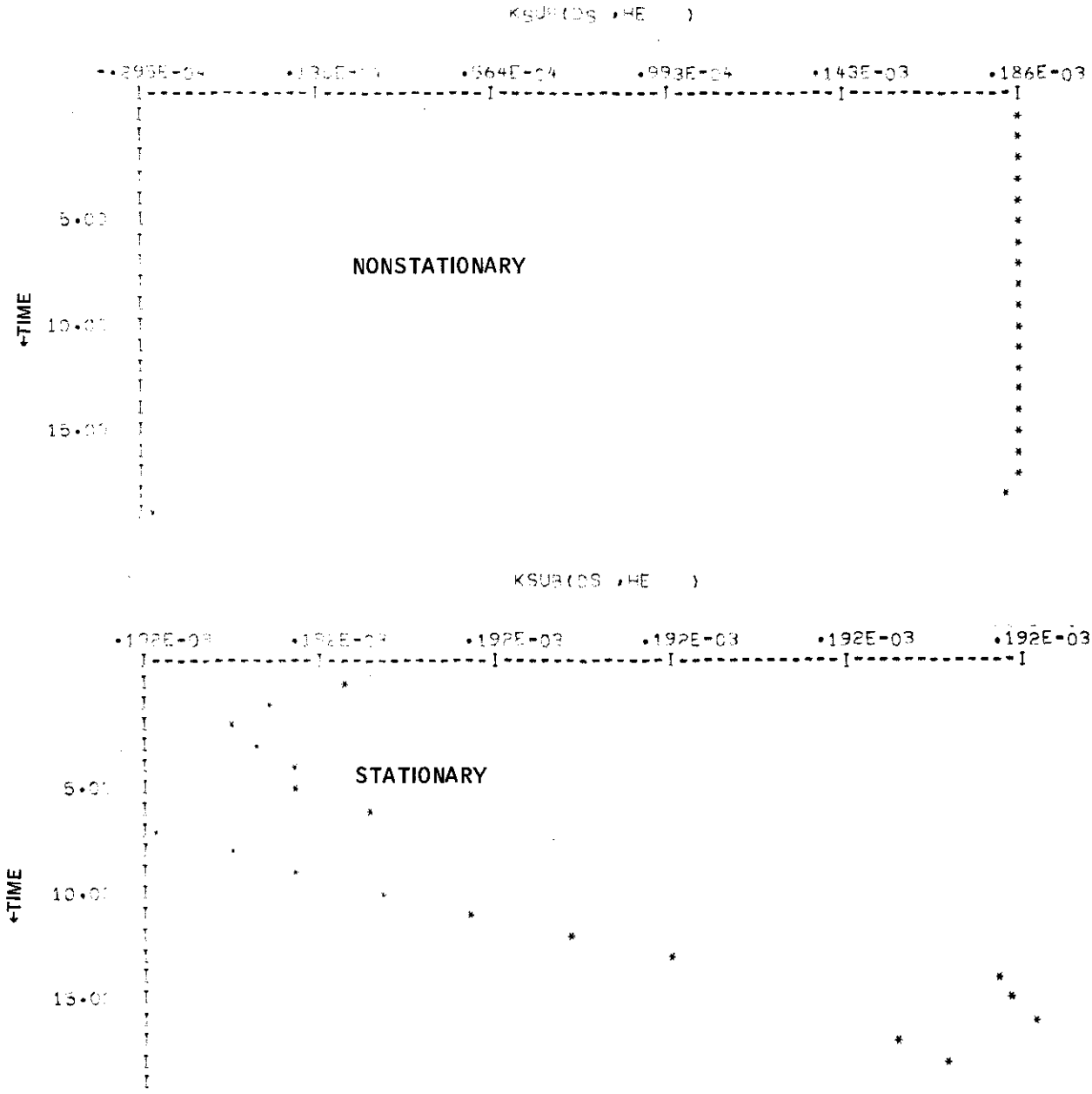


Figure 73. Optimal Controller Gain Plots (continued)

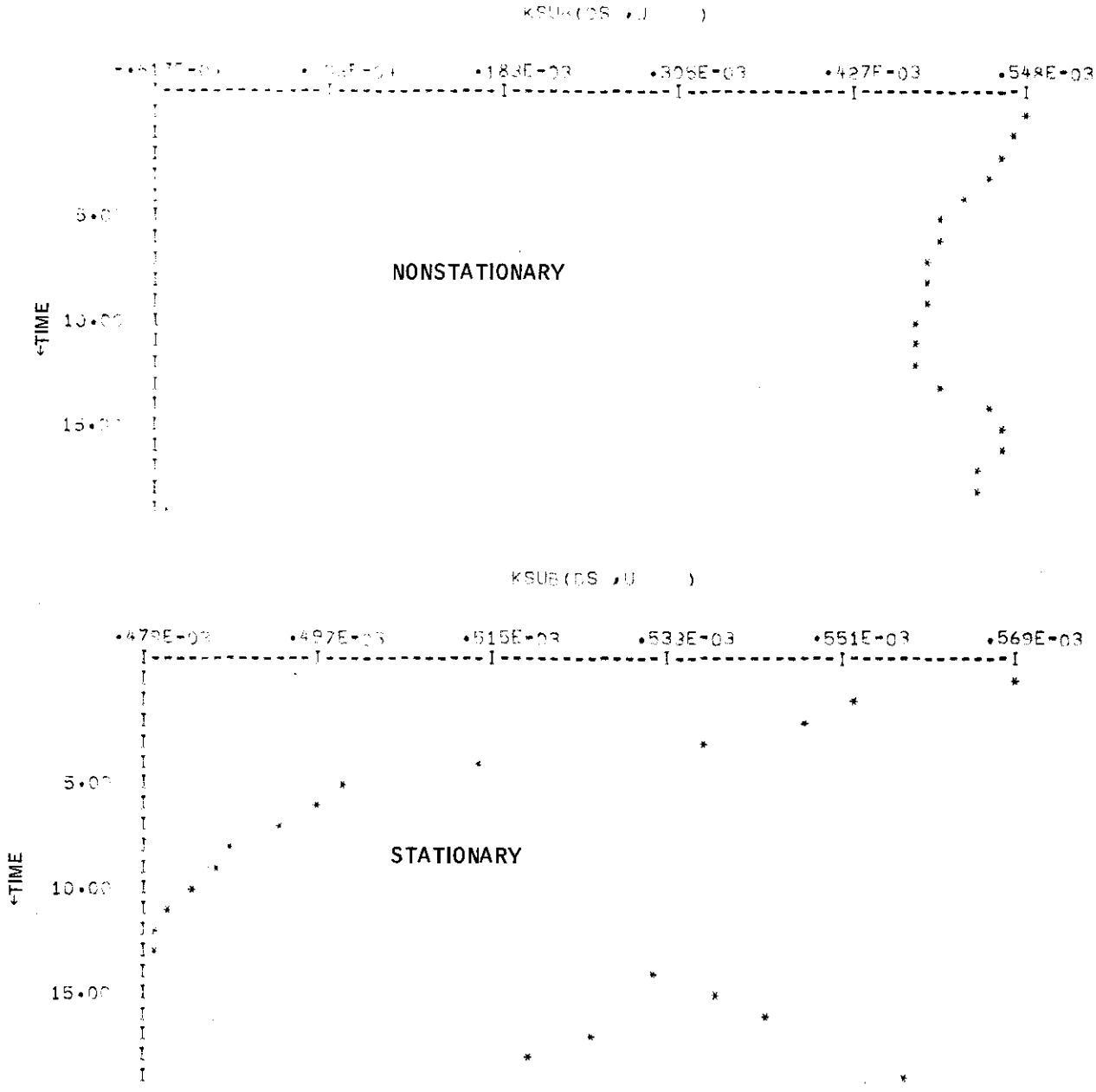


Figure 73. Optimal Controller Gain Plots (continued)

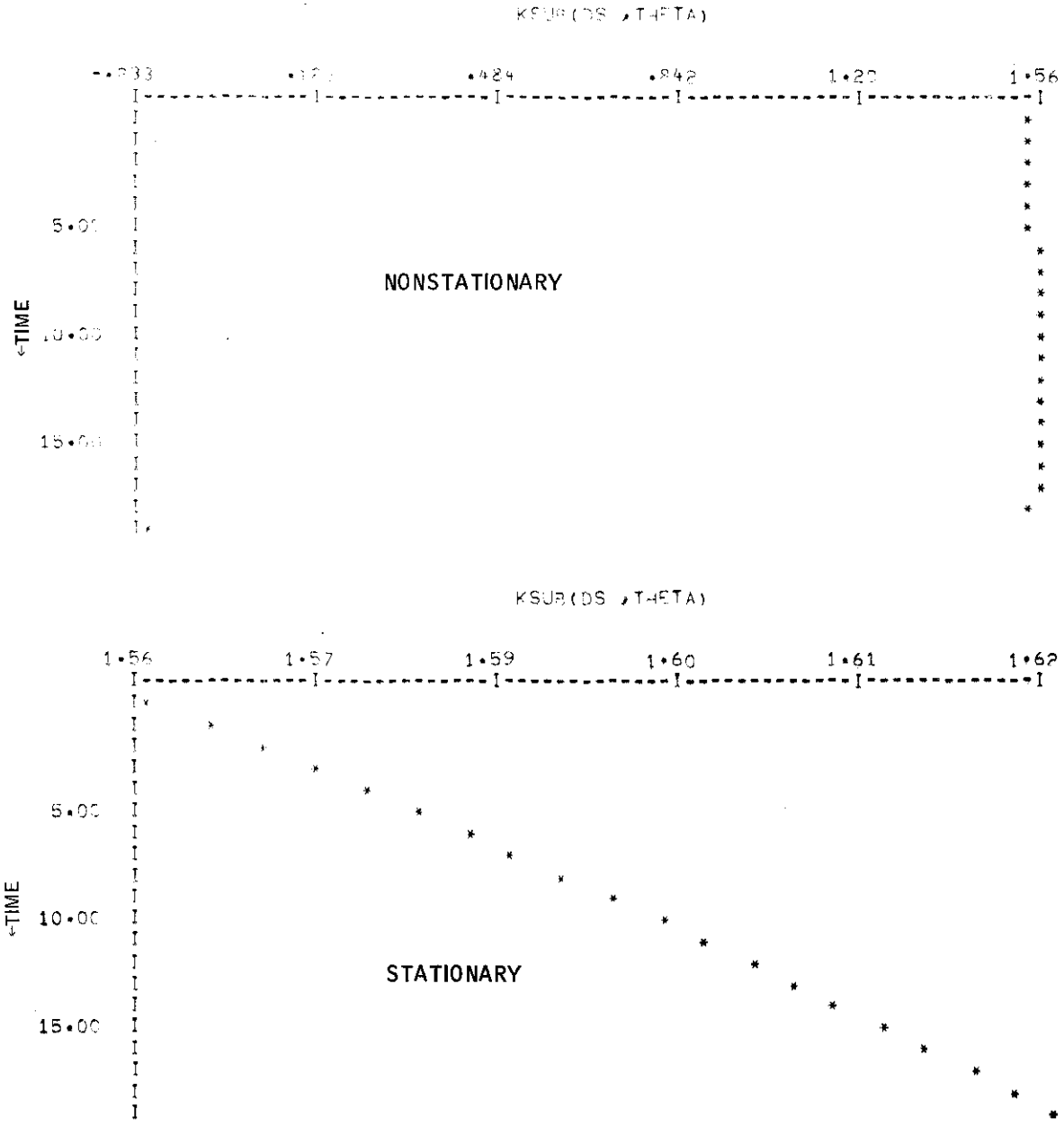


Figure 73. Optimal Controller Gain Plots (continued)

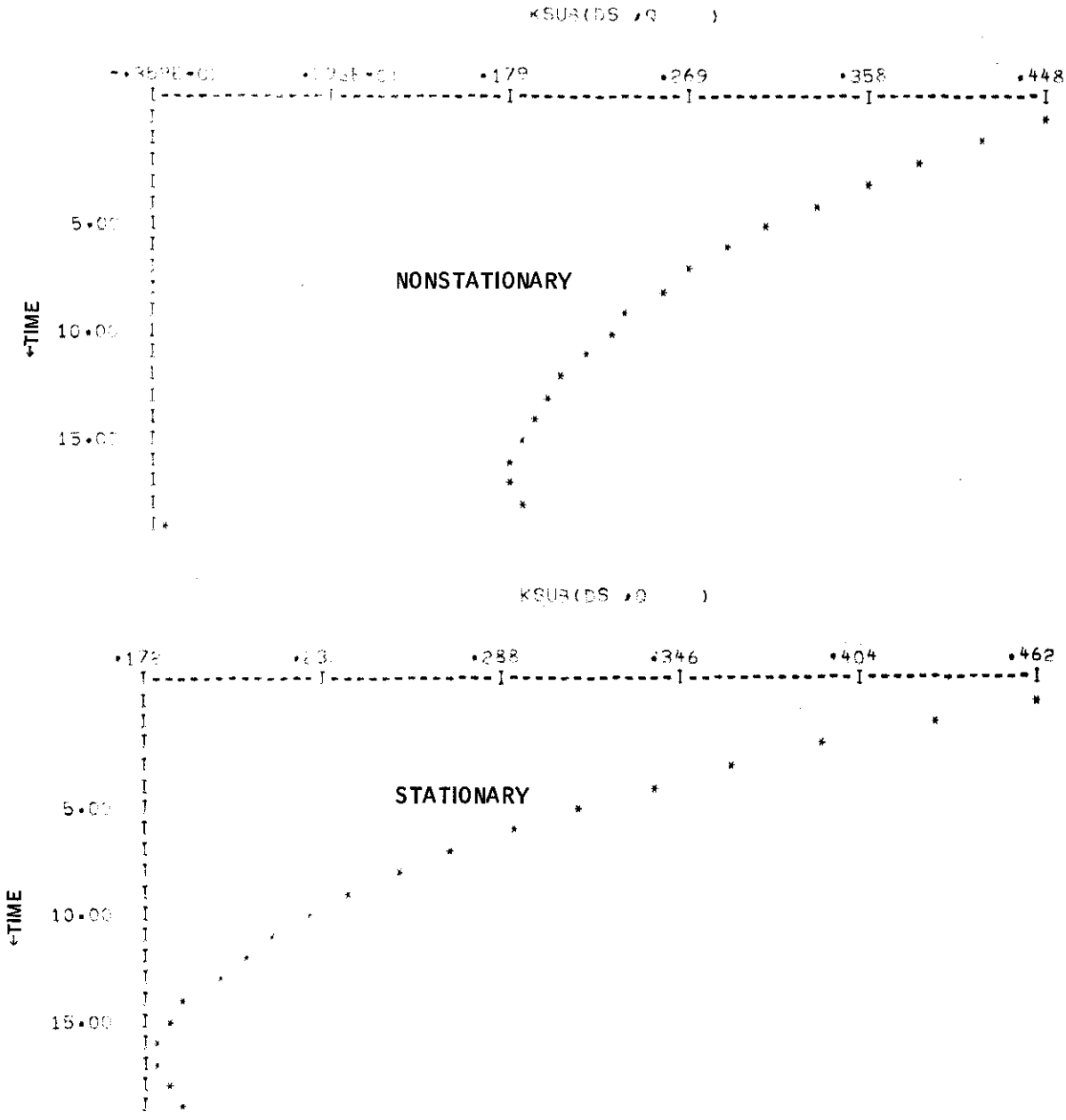


Figure 73. Optimal Controller Gain Plots (continued)

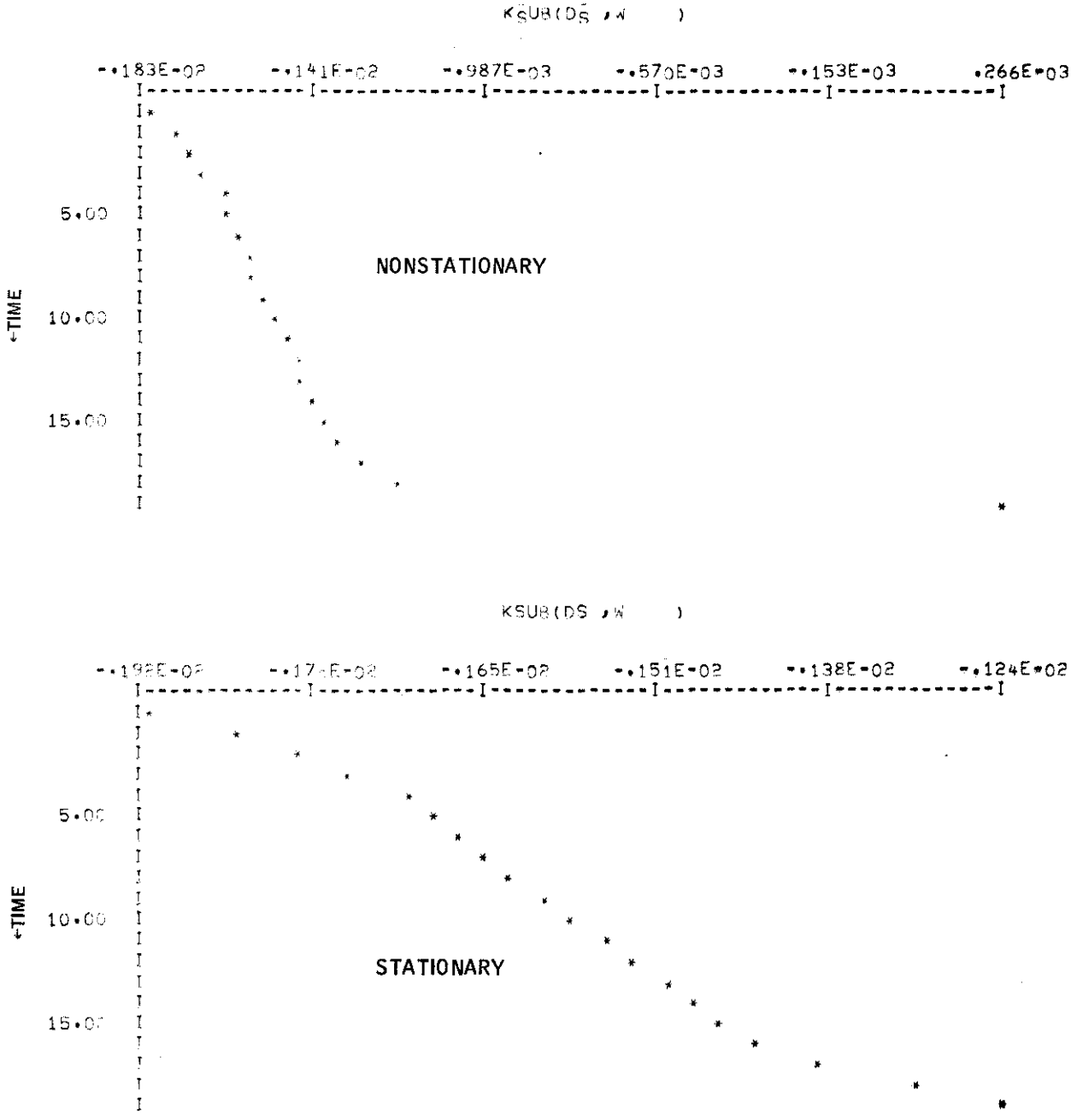


Figure 73. Optimal Controller Gain Plots (continued)

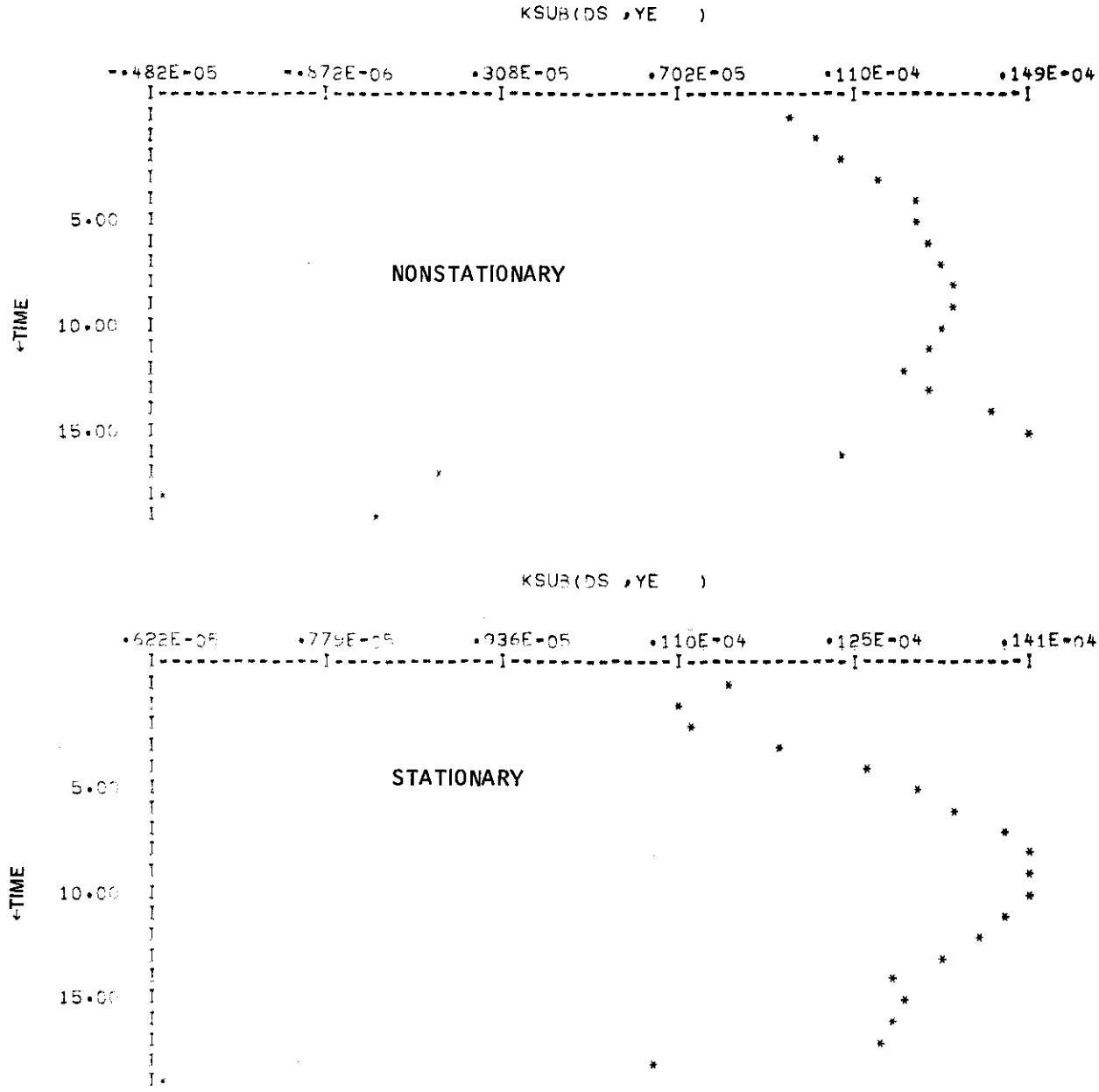


Figure 73. Optimal Controller Gain Plots (continued)

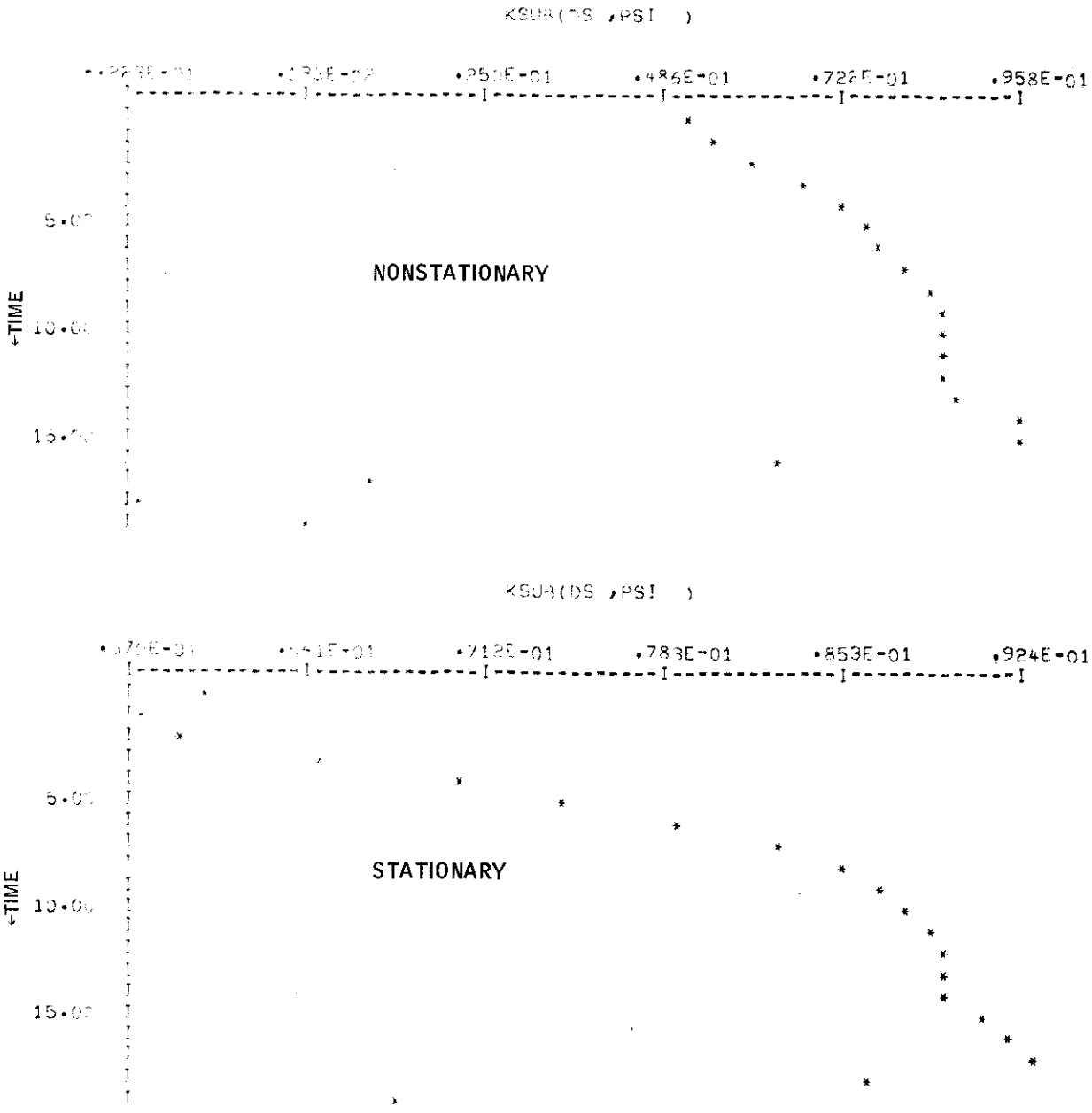


Figure 73. Optimal Controller Gain Plots (continued)

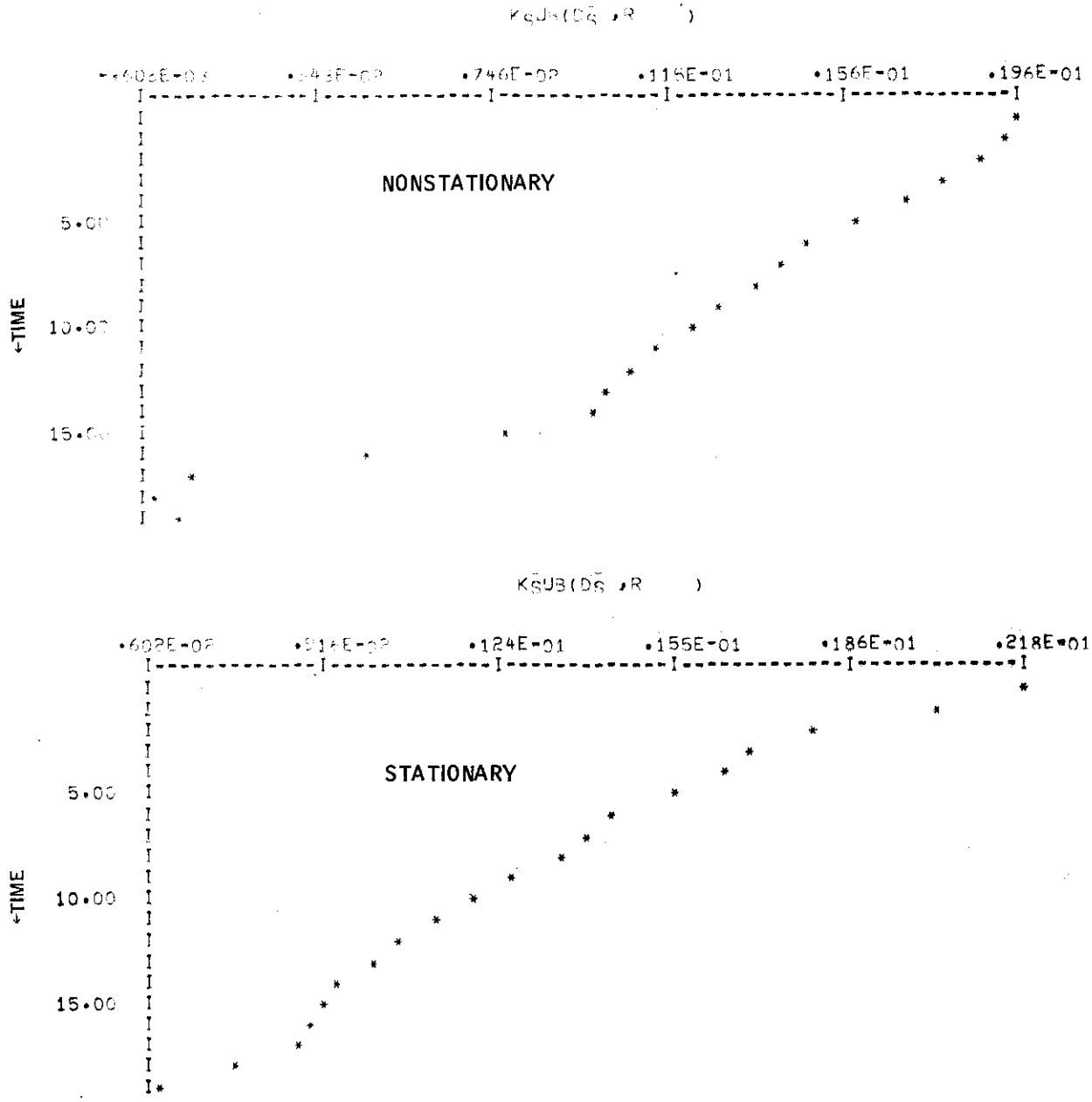


Figure 73. Optimal Controller Gain Plots (continued)

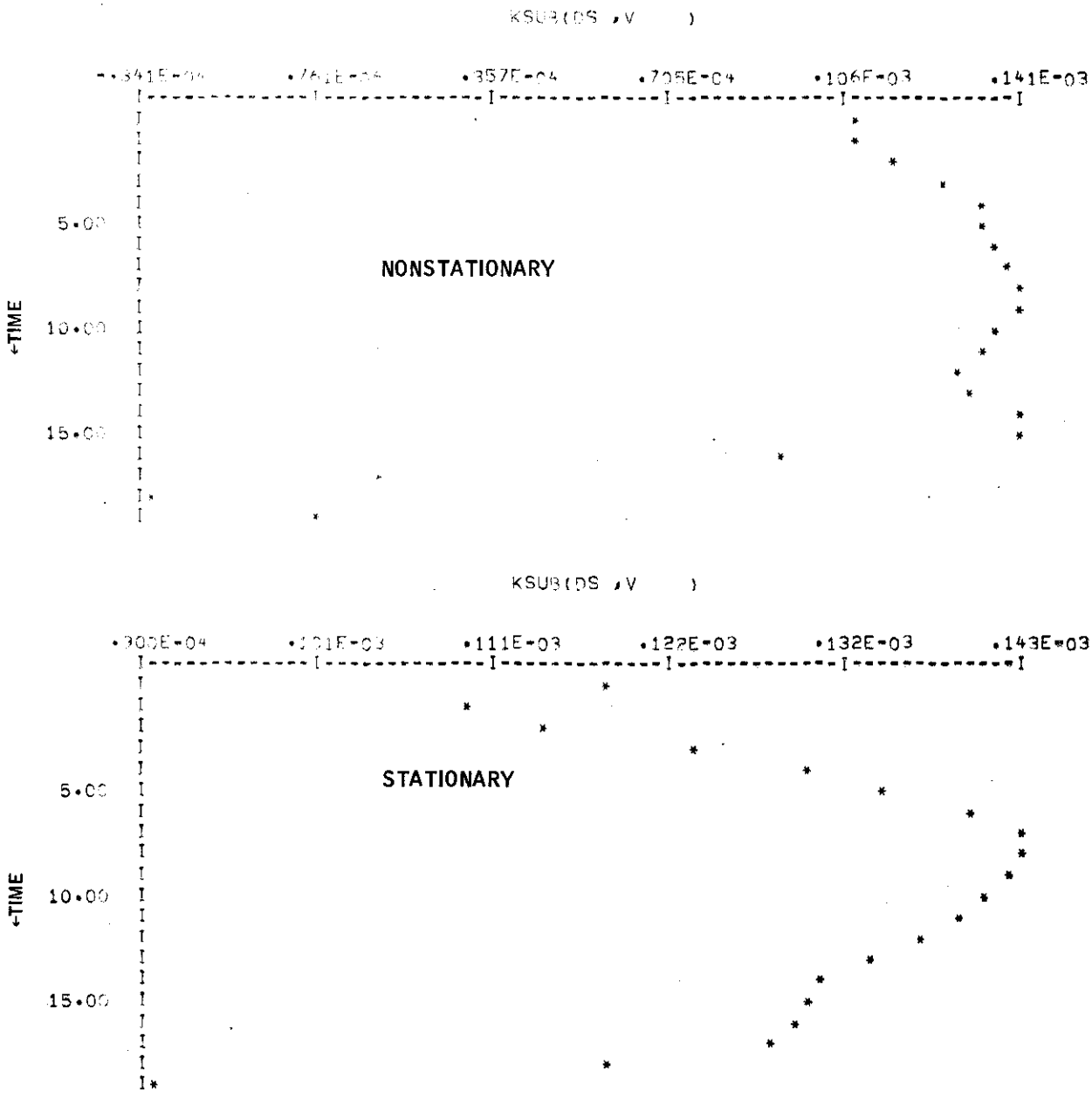


Figure 73. Optimal Controller Gain Plots (continued)

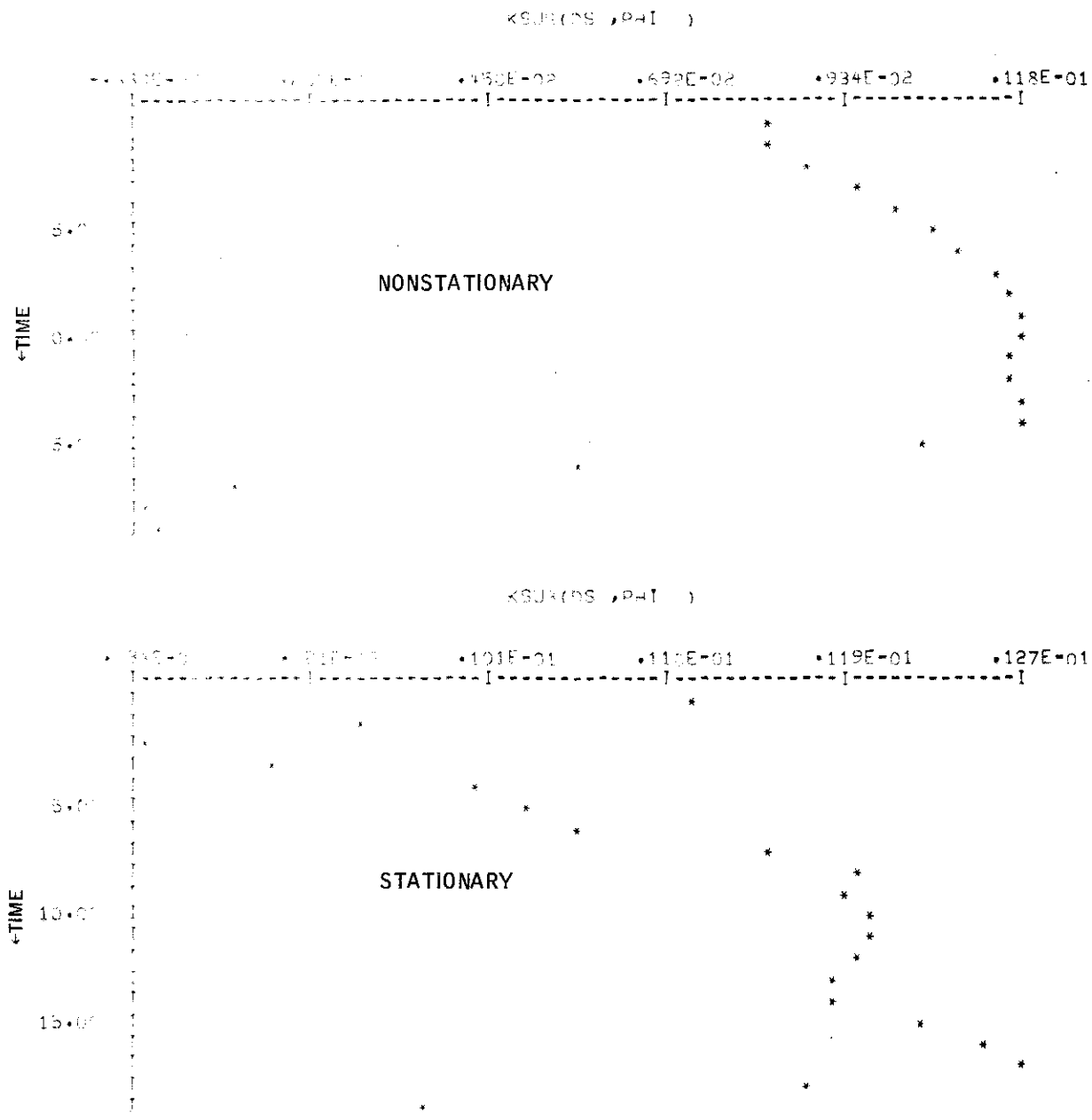


Figure 73. Optimal Controller Gain Plots (continued)

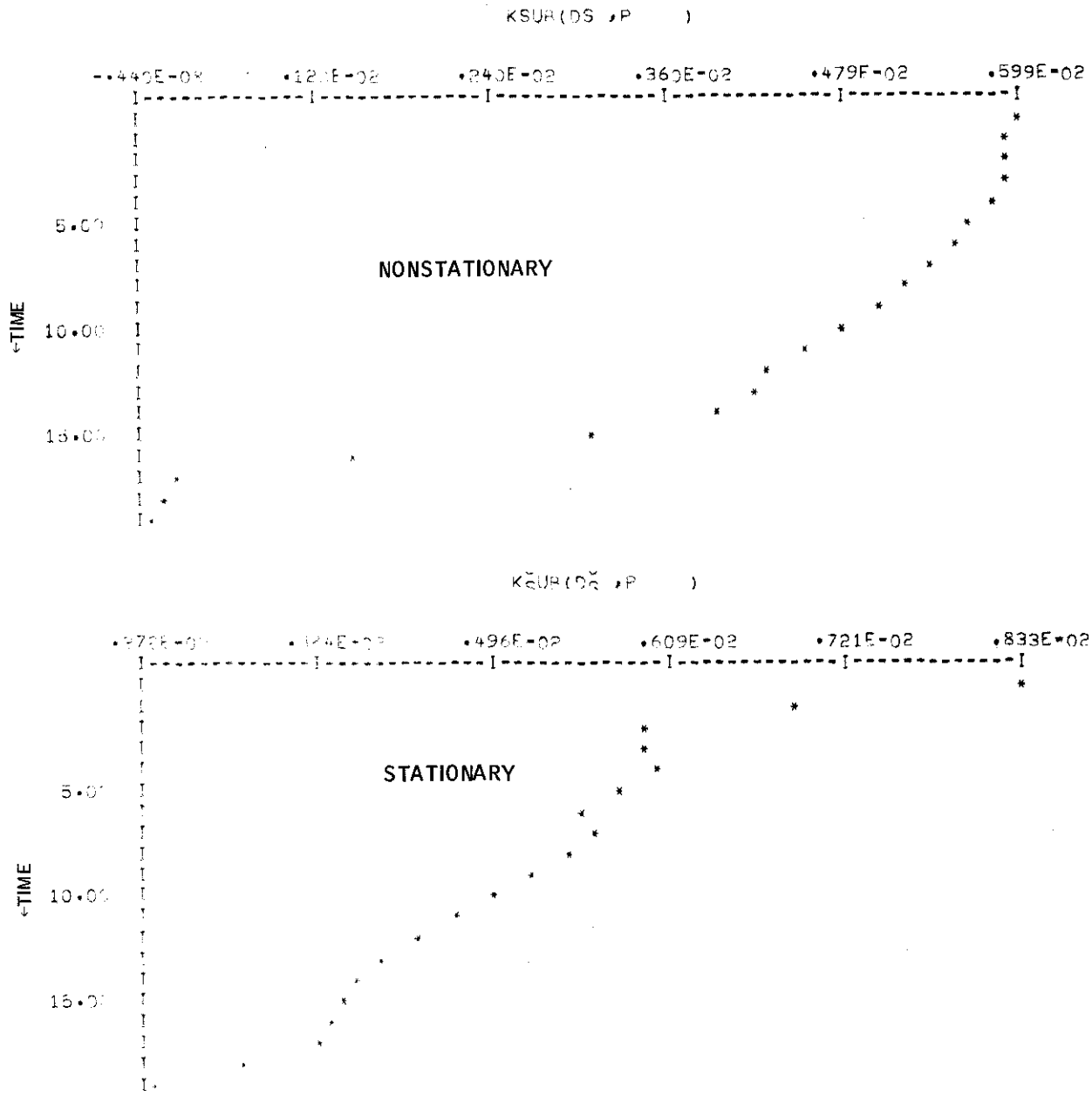


Figure 73. Optimal Controller Gain Plots (continued)

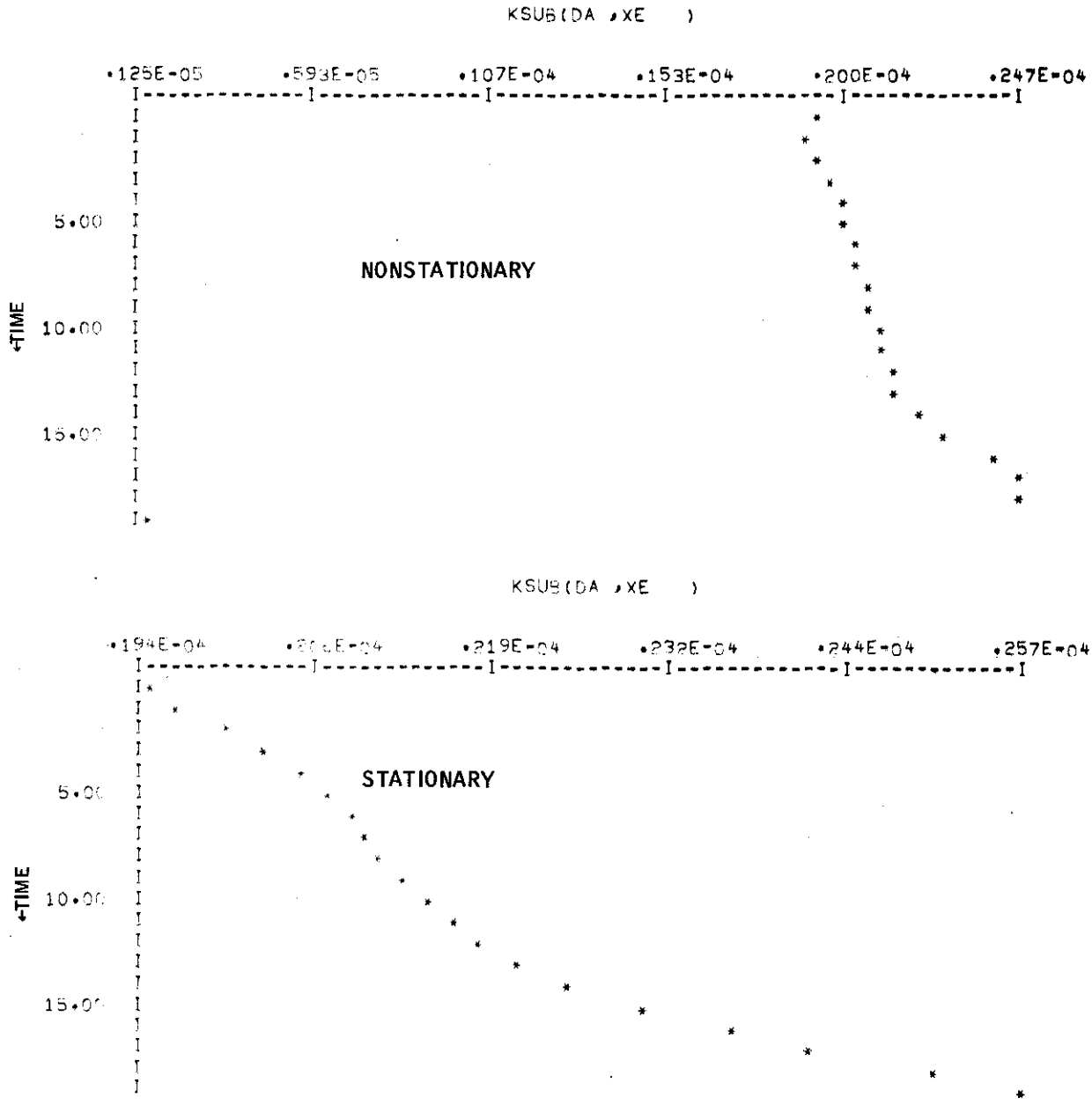


Figure 73. Optimal Controller Gain Plots (continued)

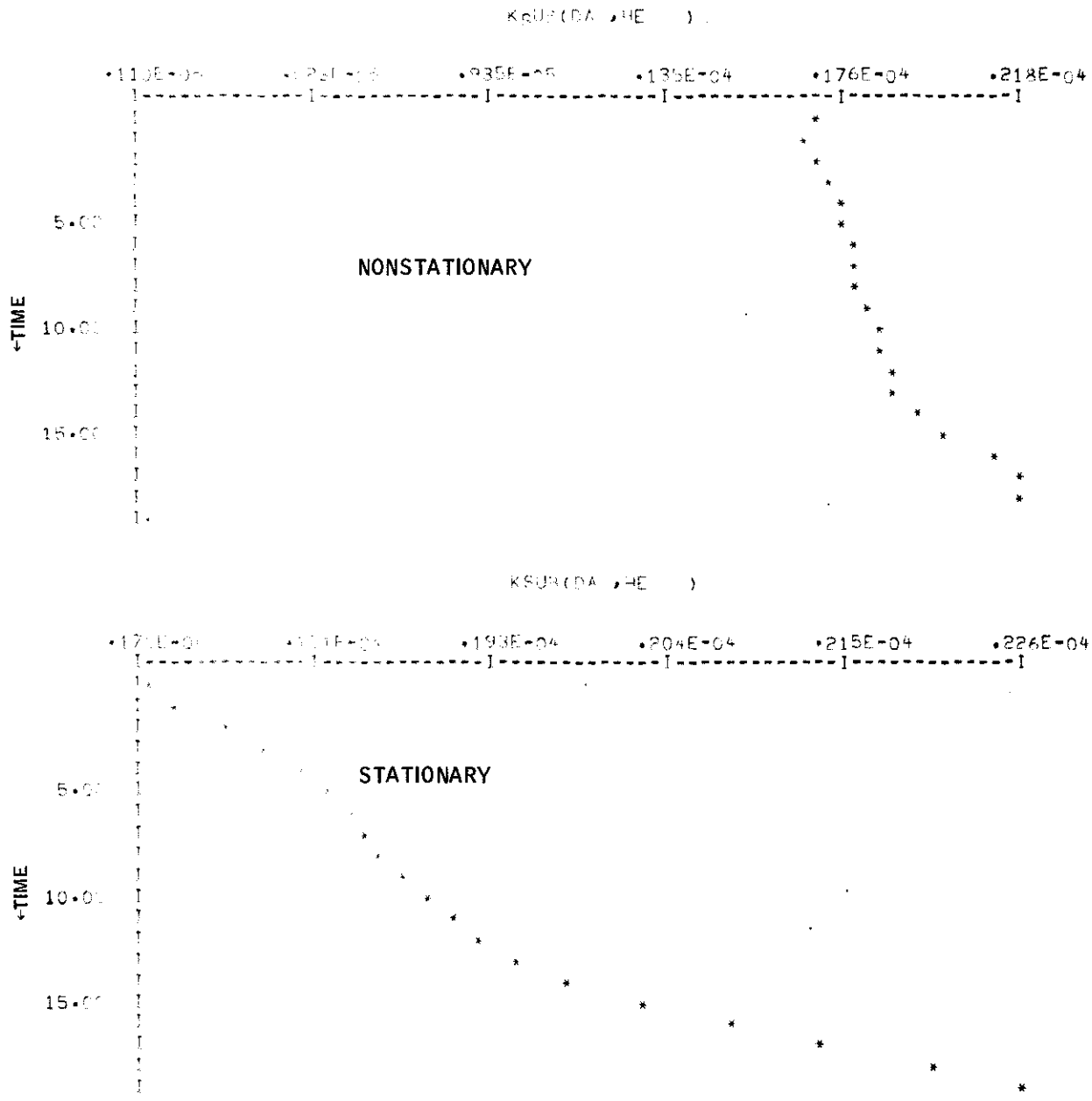


Figure 73. Optimal Controller Gain Plots (continued)

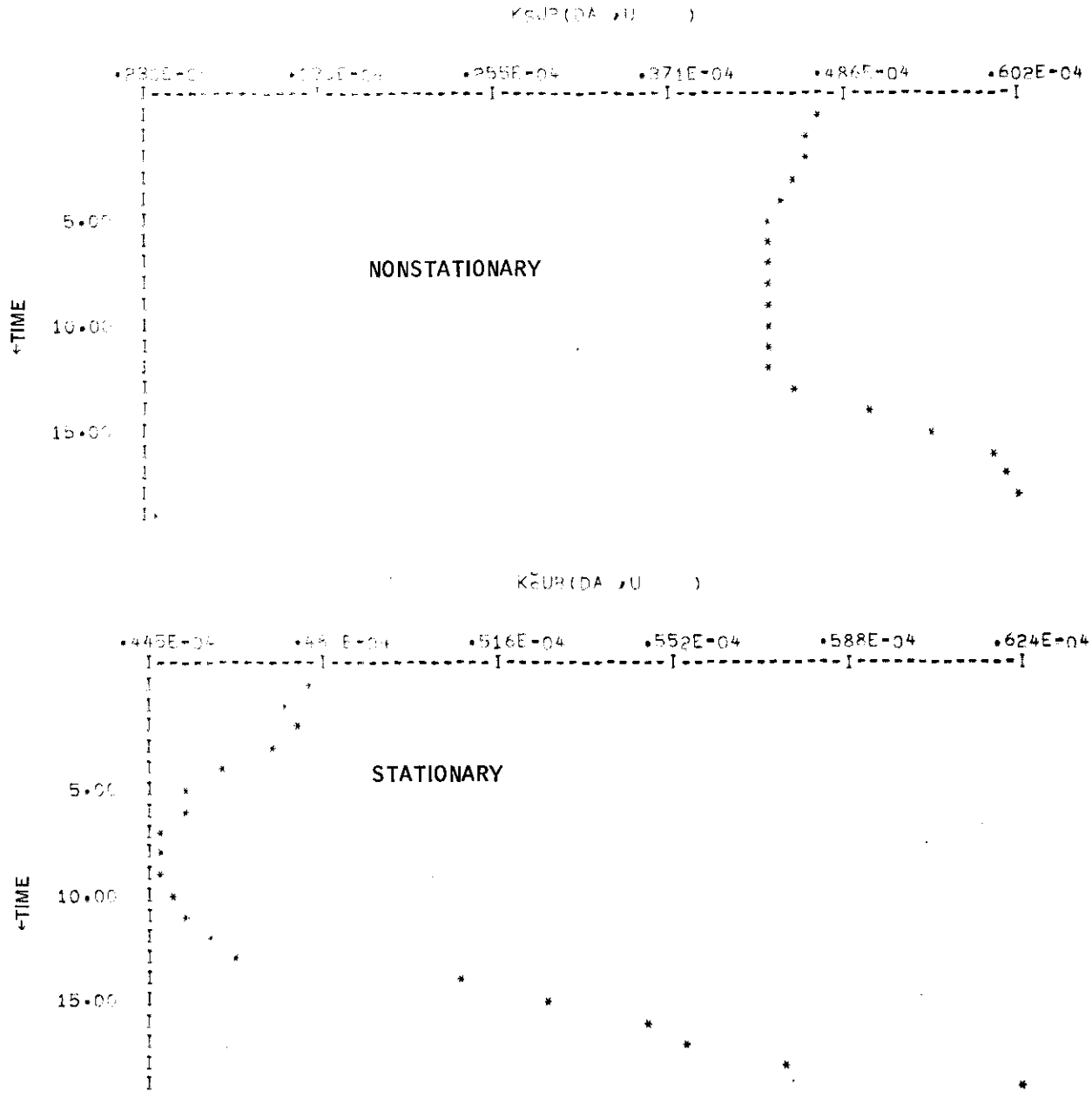


Figure 73. Optimal Controller Gain Plots (continued)

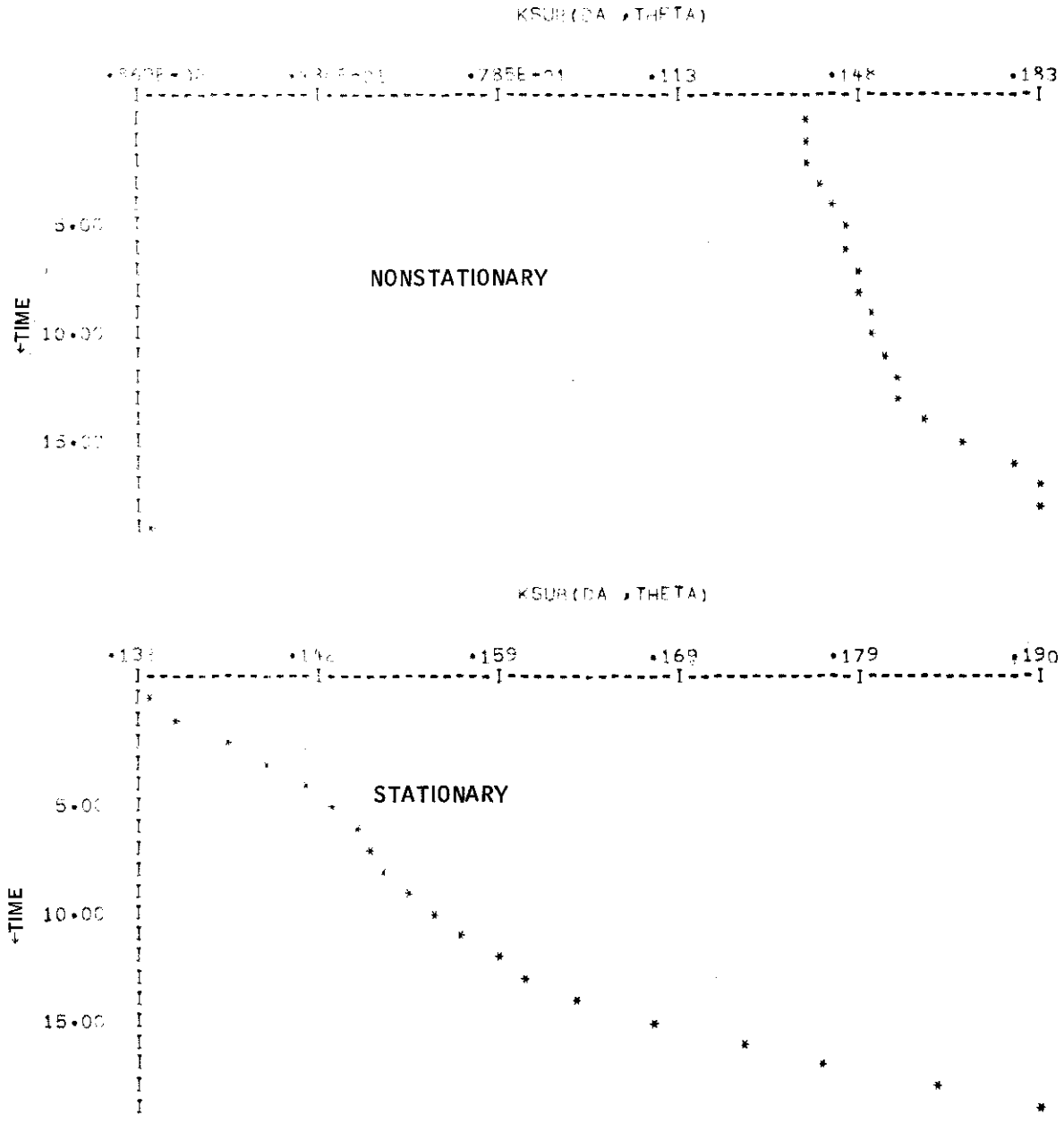


Figure 73. Optimal Controller Gain Plots (continued)

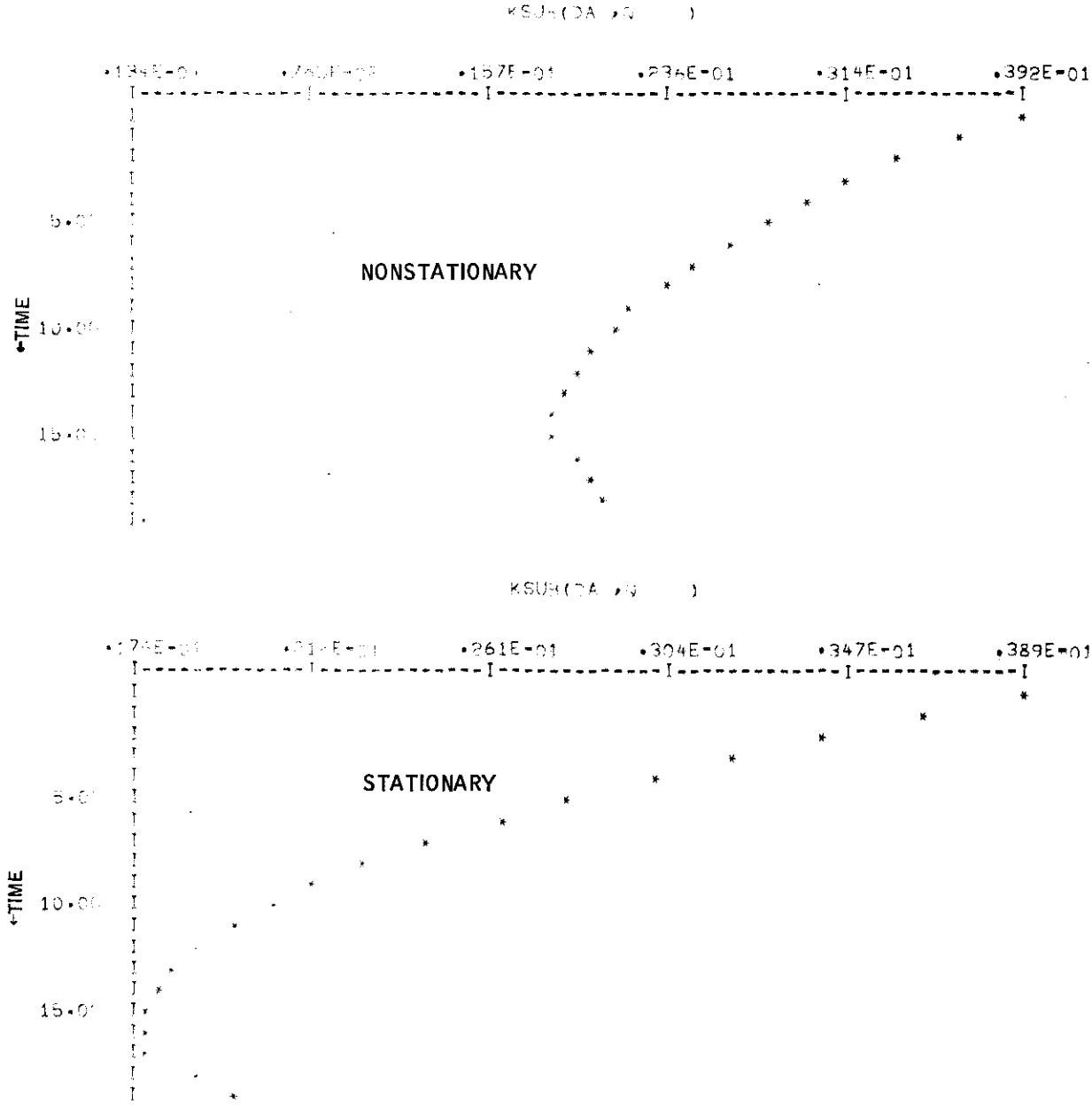


Figure 73. Optimal Controller Gain Plots (continued)

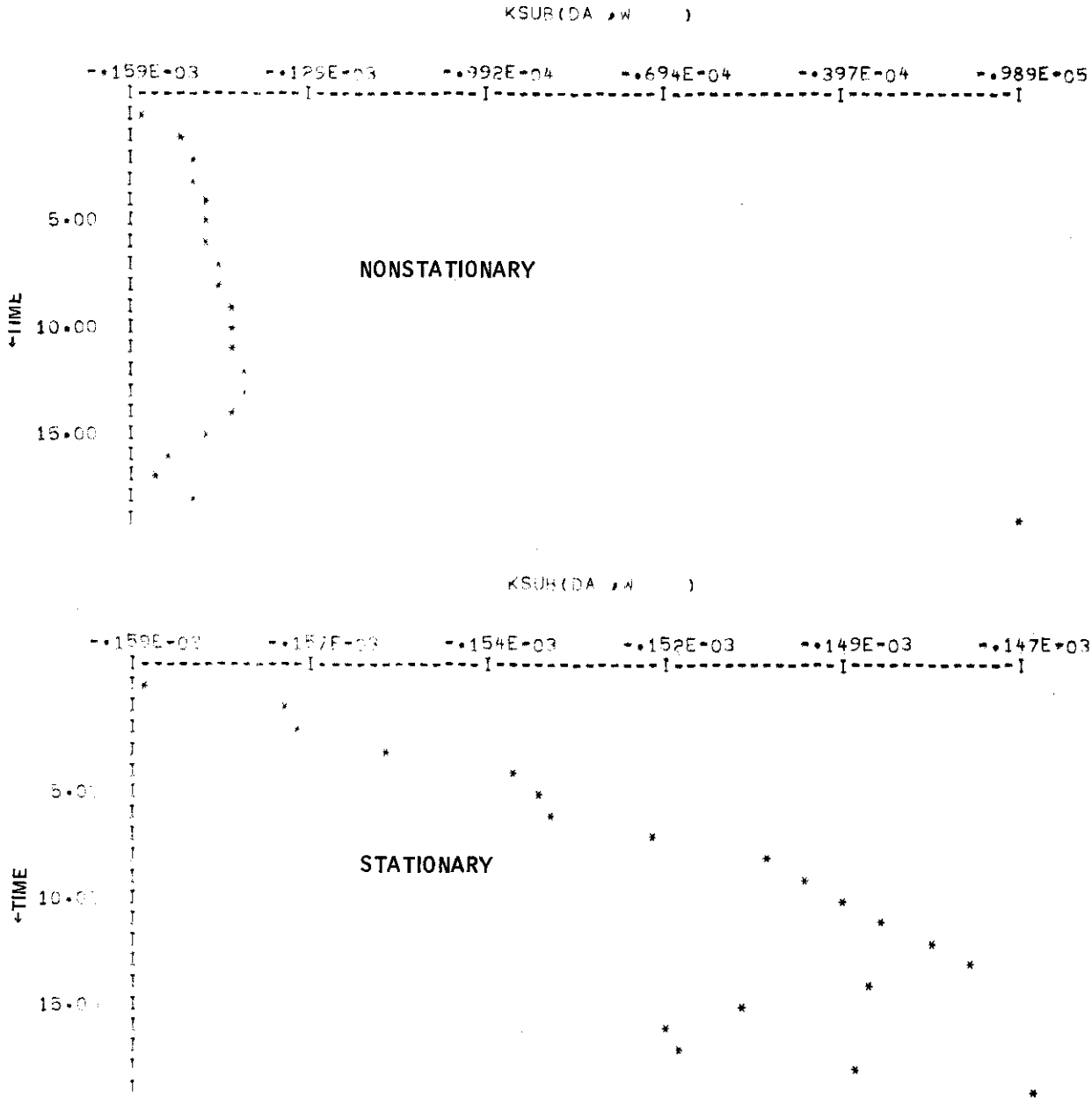


Figure 73. Optimal Controller Gain Plots (continued)

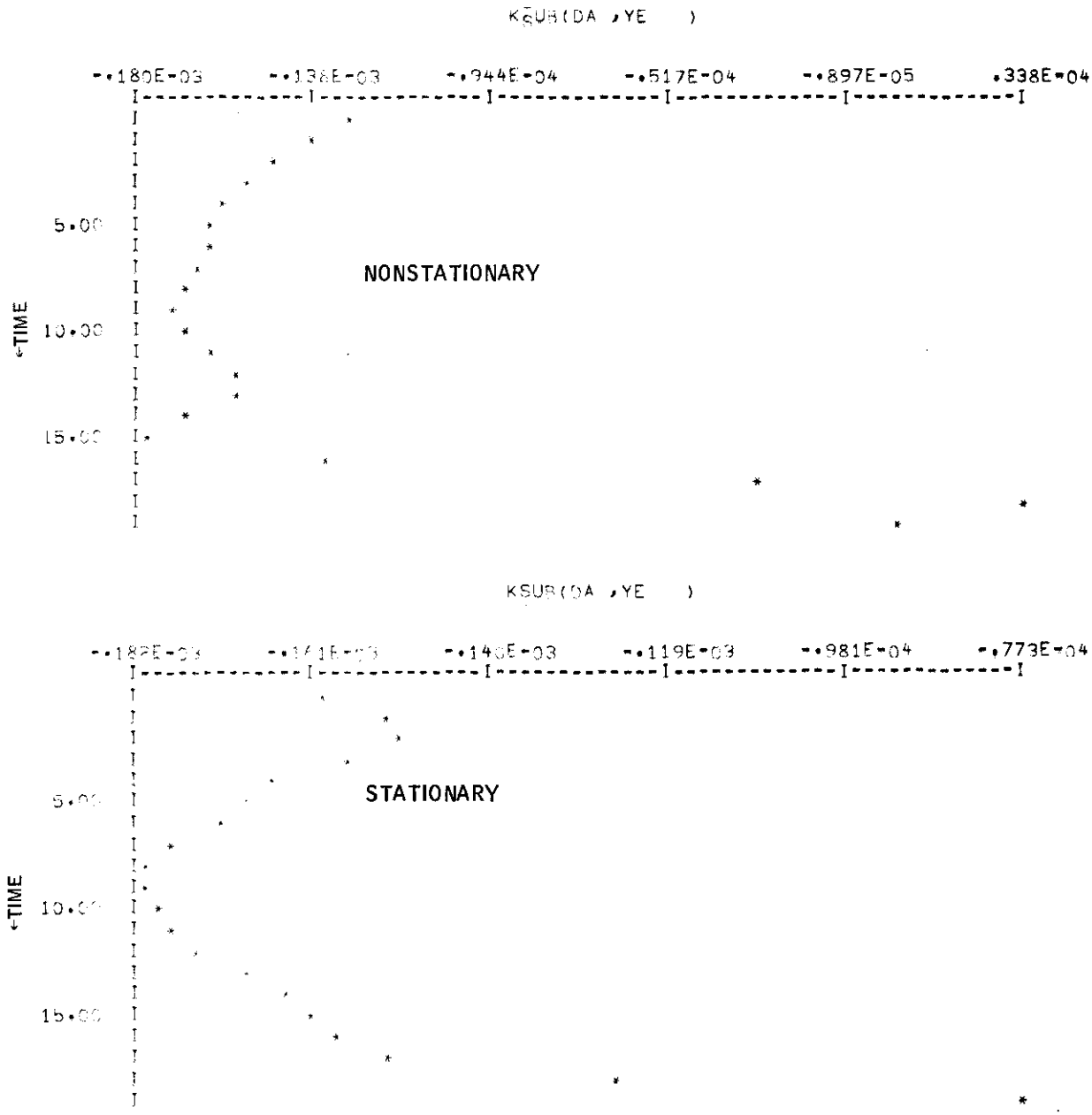


Figure 73. Optimal Controller Gain Plots (continued)

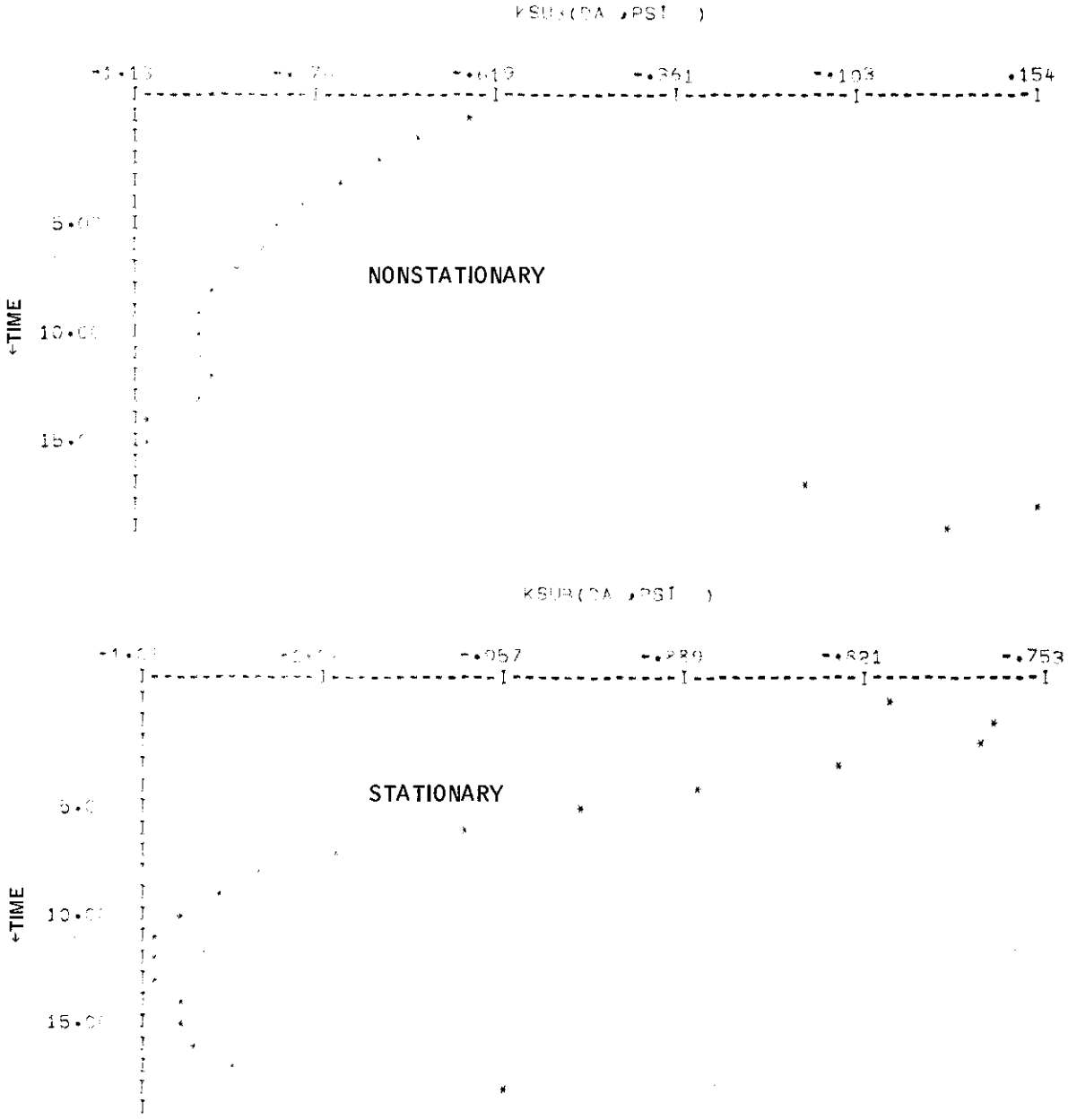


Figure 73. Optimal Controller Gain Plots (continued)

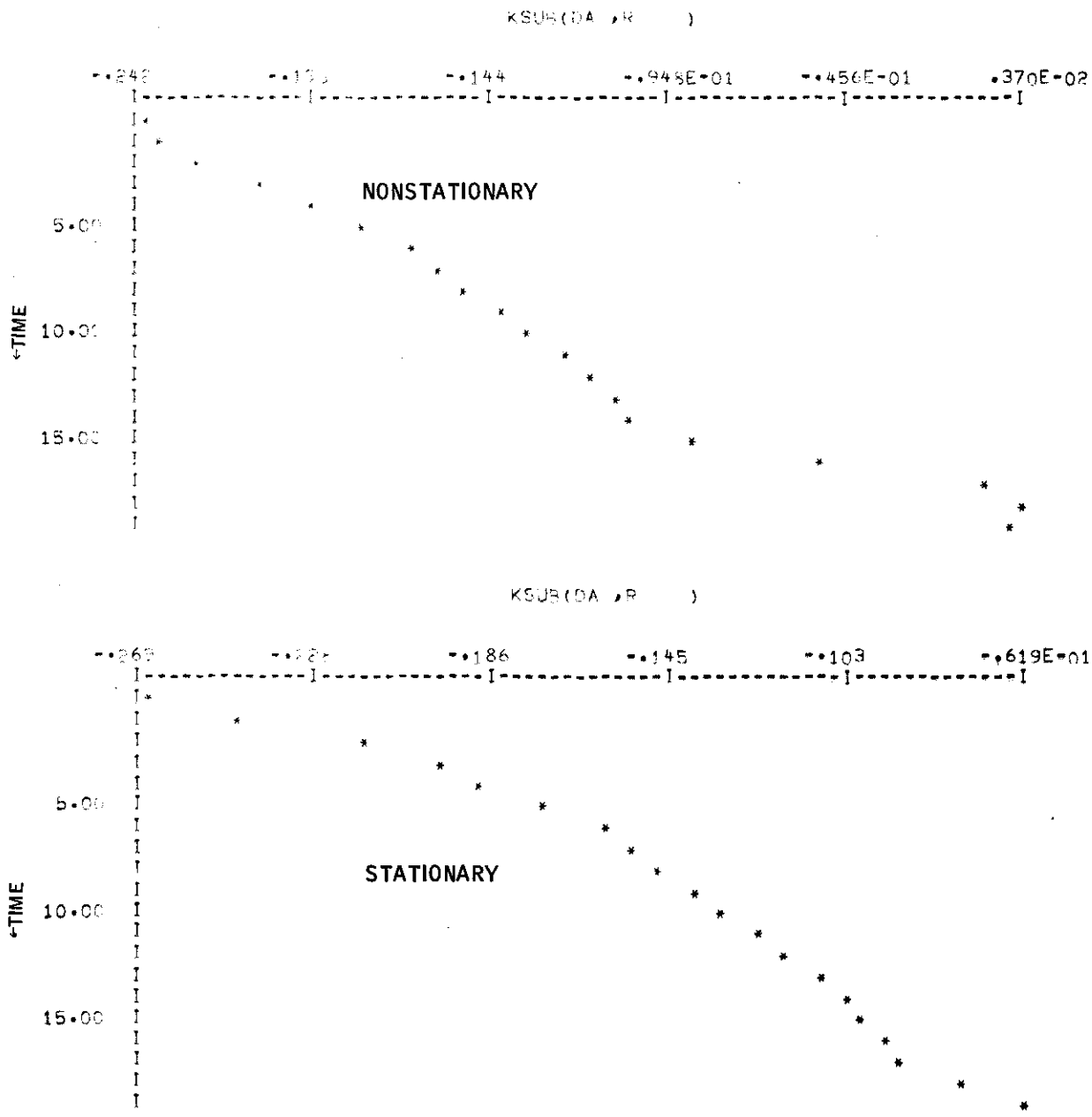


Figure 73. Optimal Controller Gain Plots (continued)

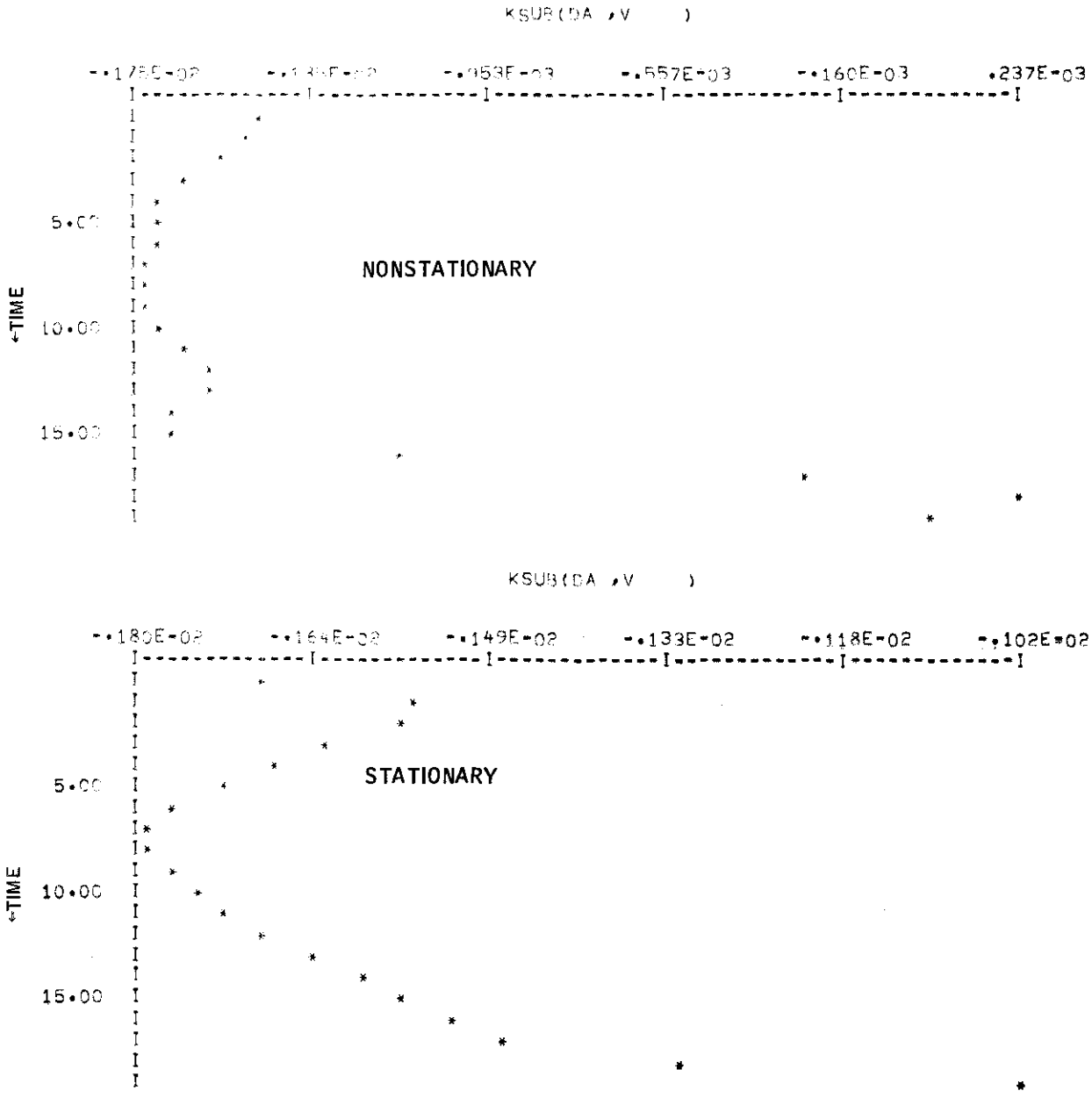


Figure 73. Optimal Controller Gain Plots (continued)

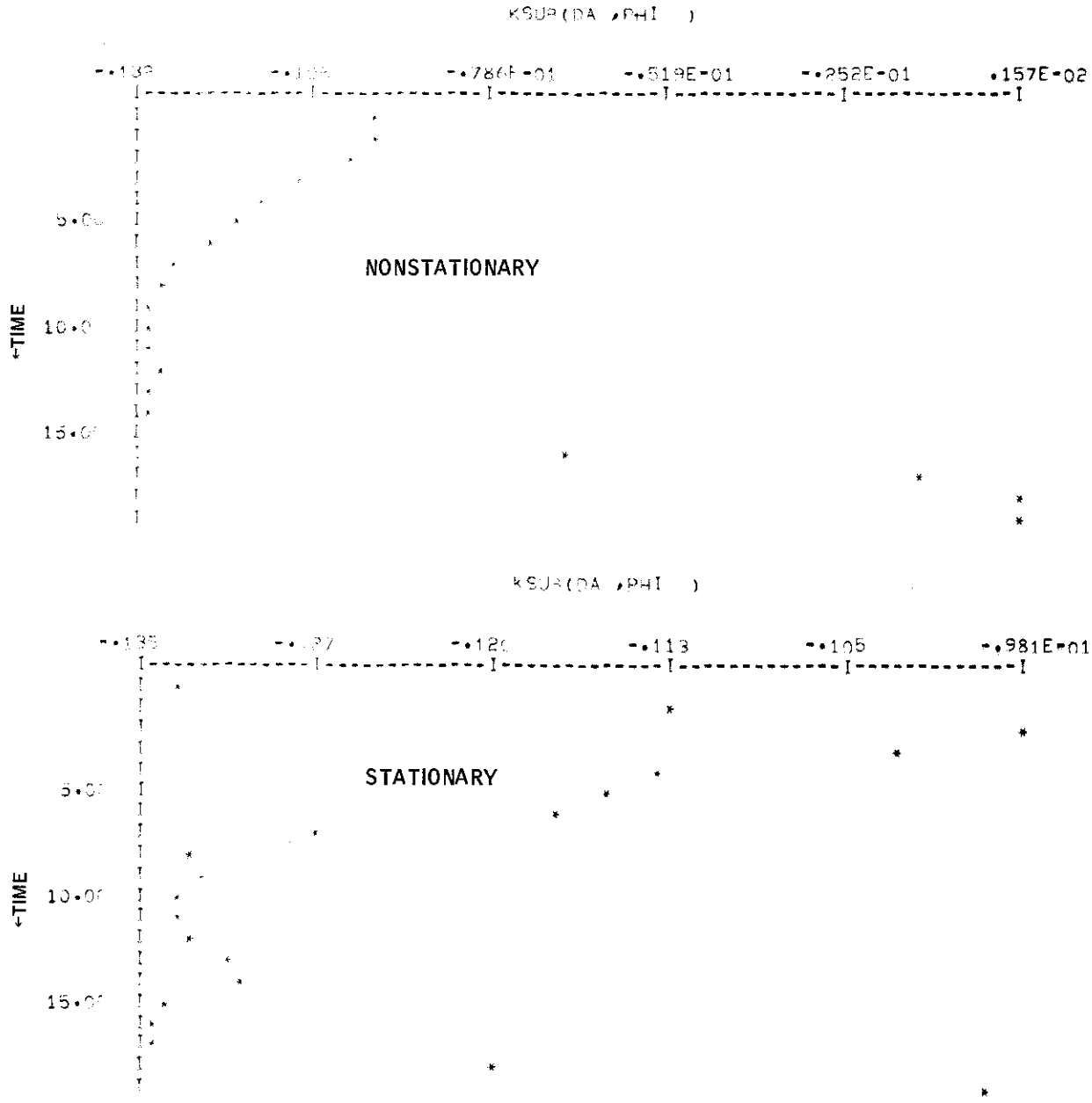


Figure 73. Optimal Controller Gain Plots (continued)

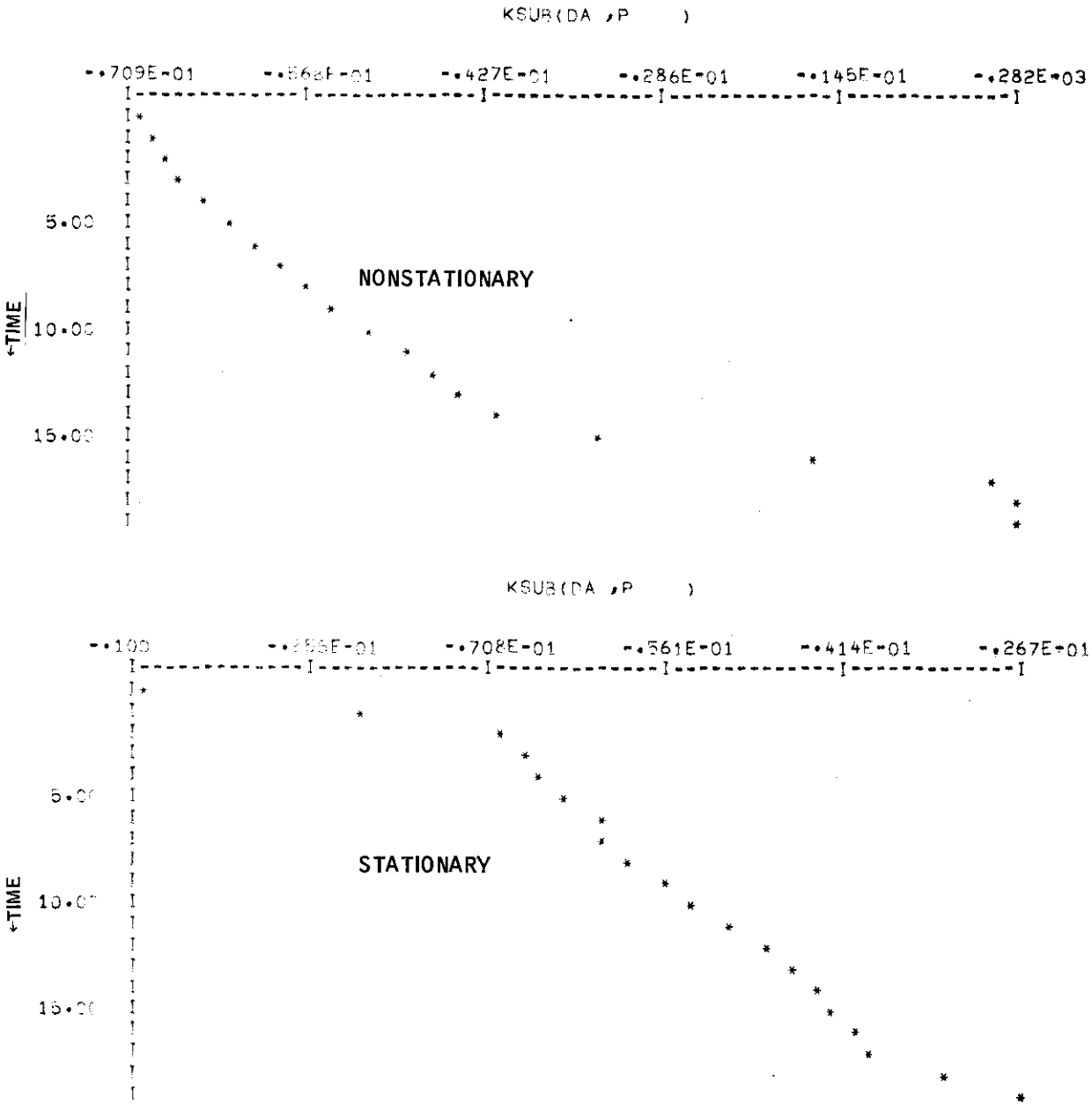


Figure 73. Optimal Controller Gain Plots (continued)

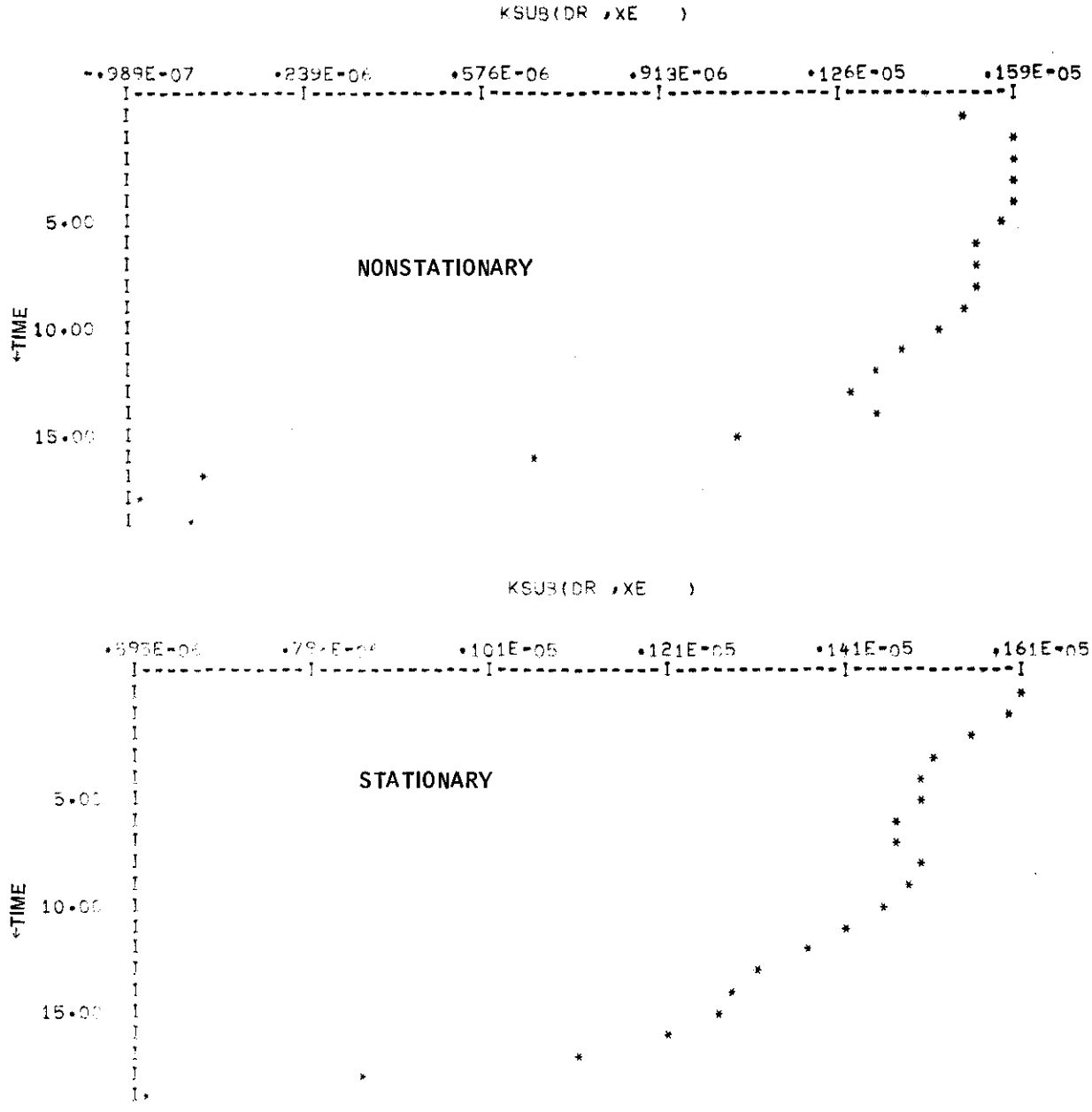


Figure 73. Optimal Controller Gain Plots (continued)

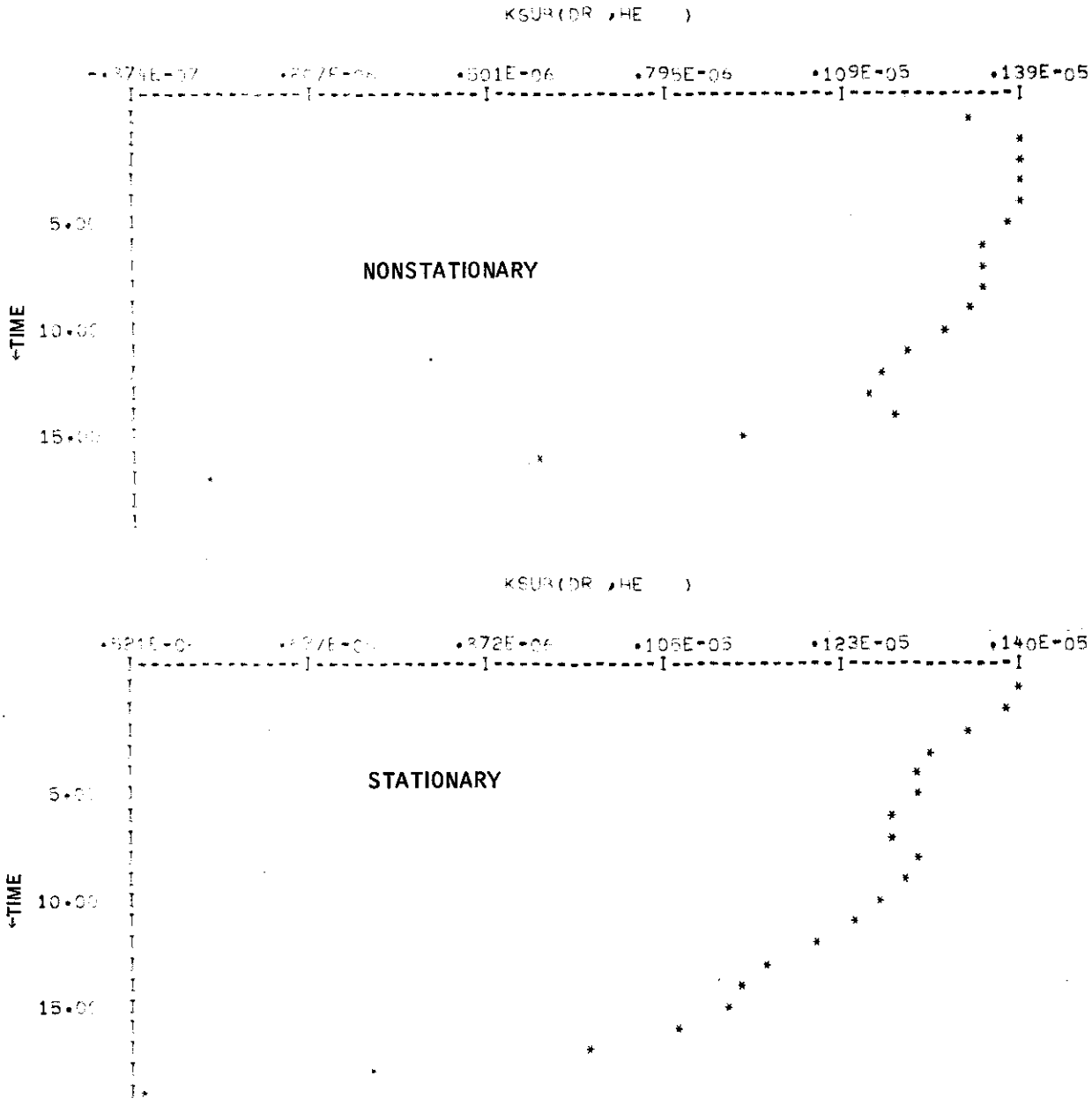


Figure 73. Optimal Controller Gain Plots (continued)

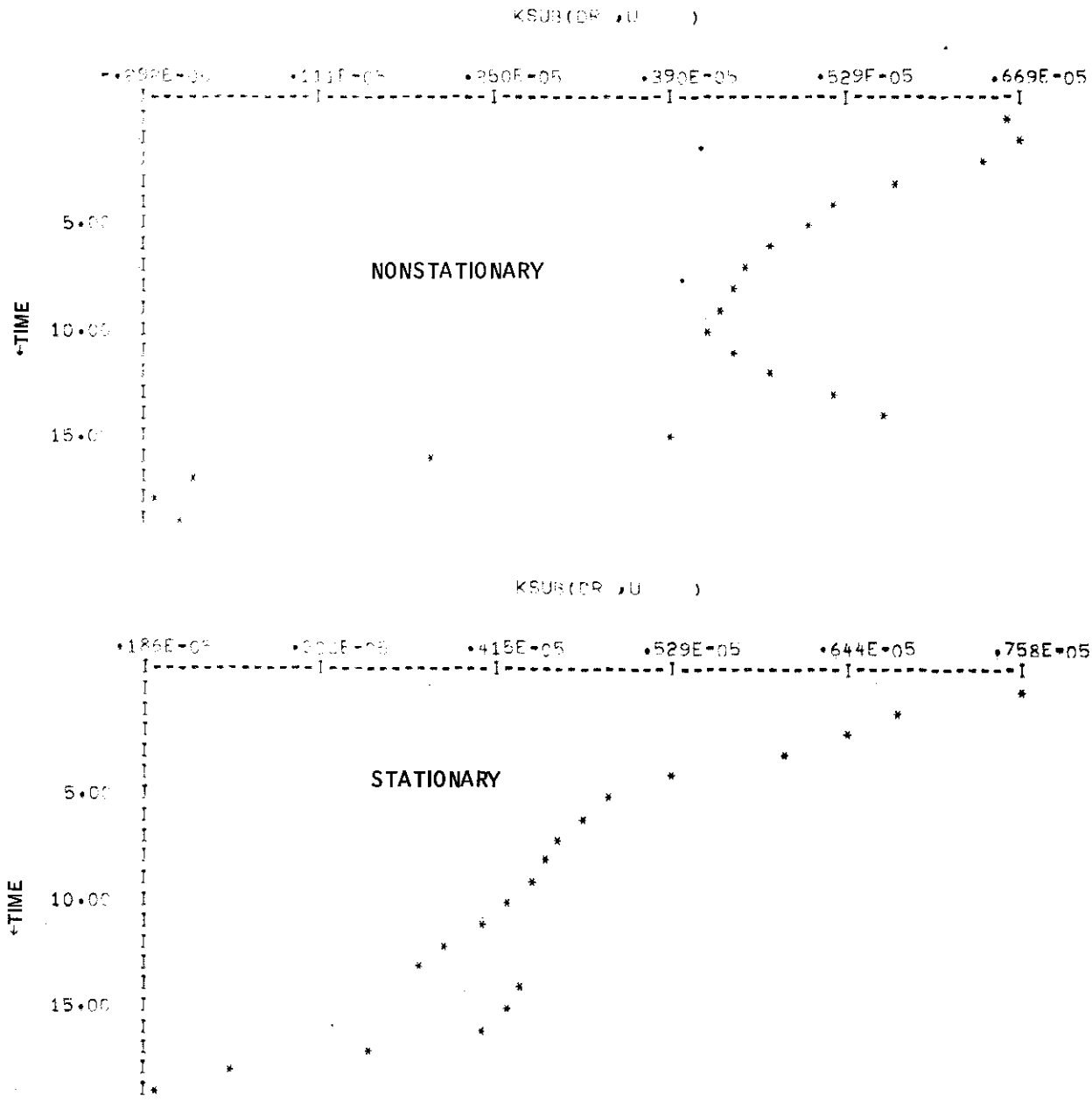


Figure 73. Optimal Controller Gain Plots (continued)

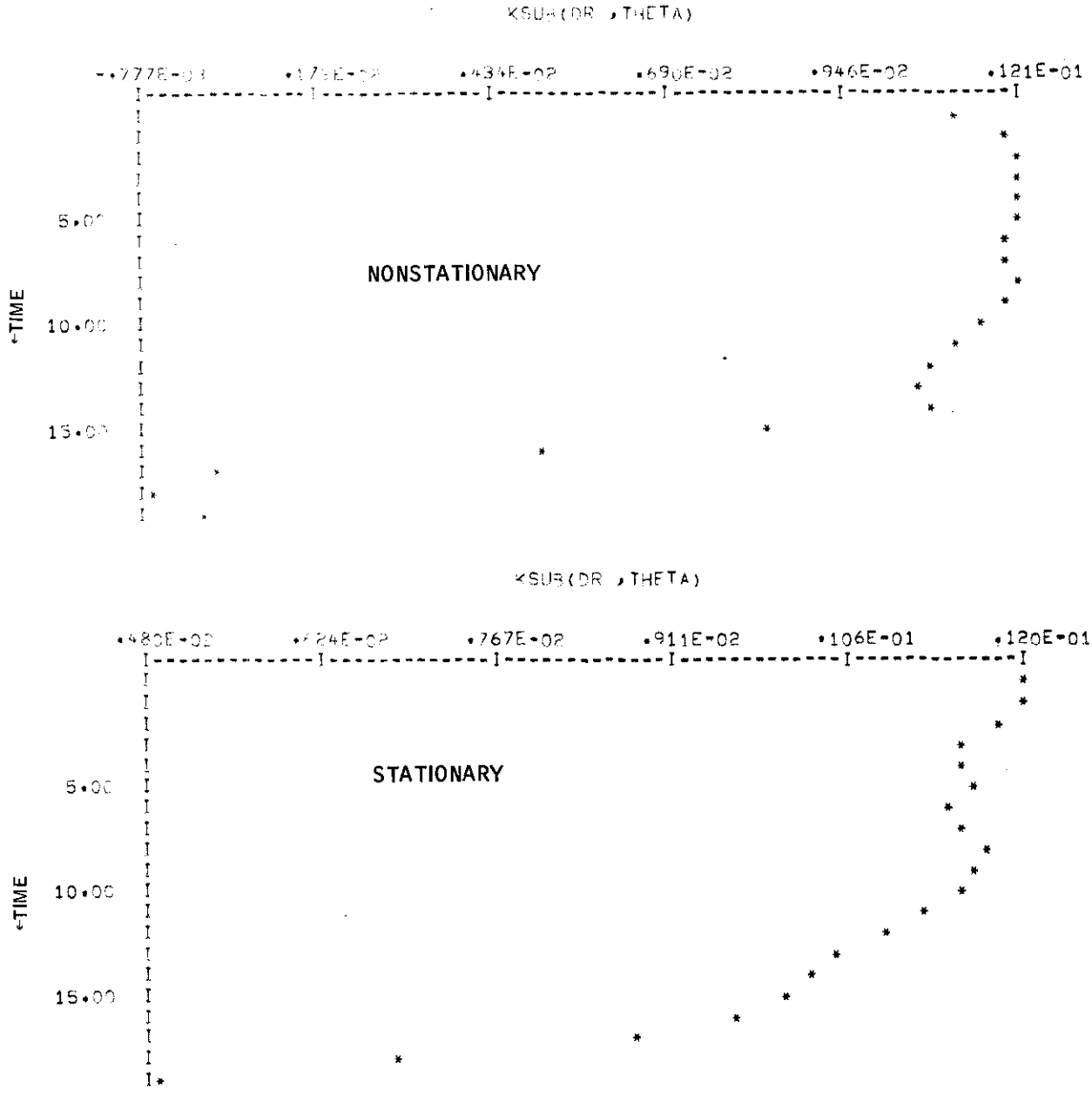


Figure 73. Optimal Controller Gain Plots (continued)

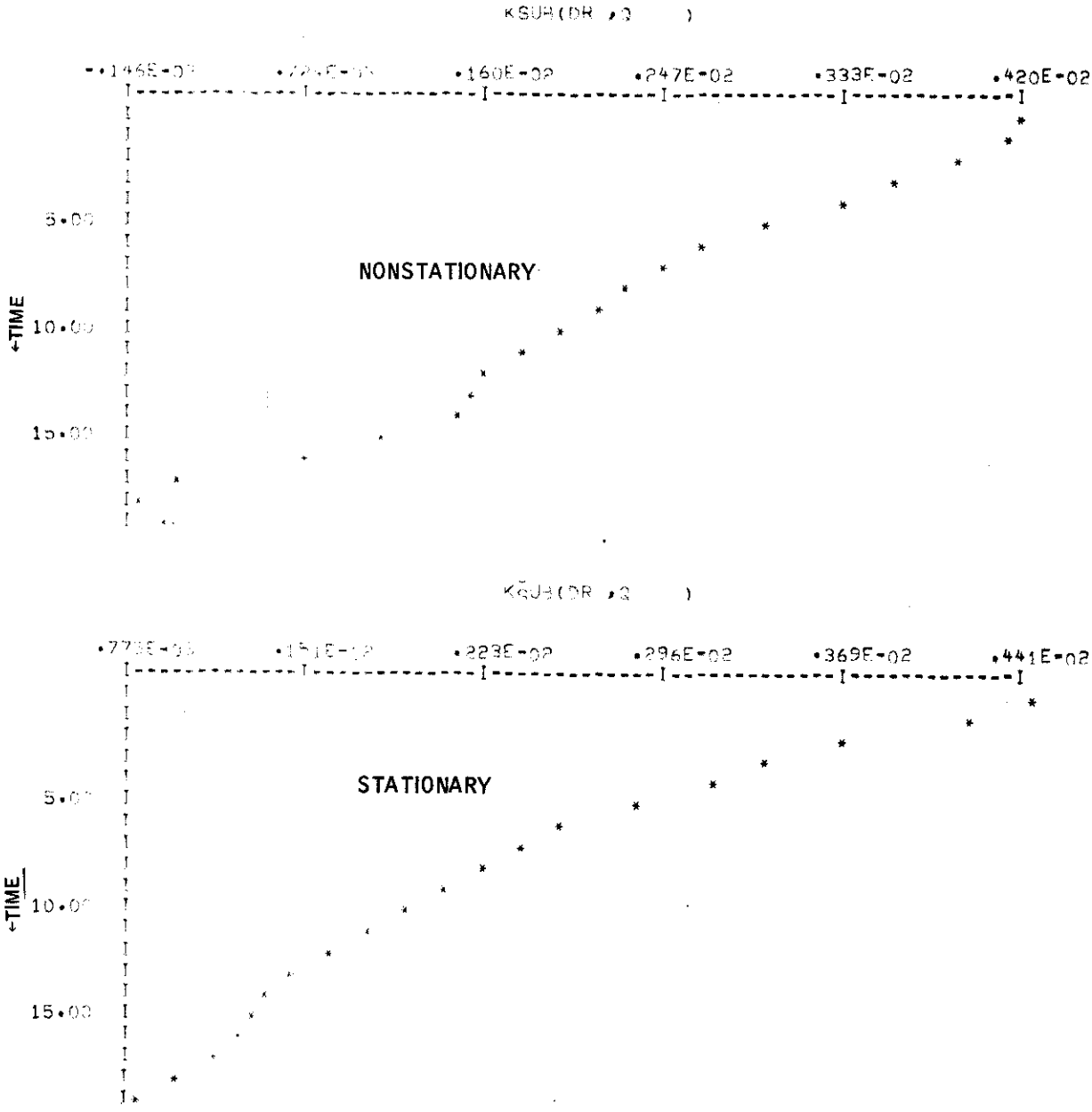


Figure 73. Optimal Controller Gain Plots (continued)

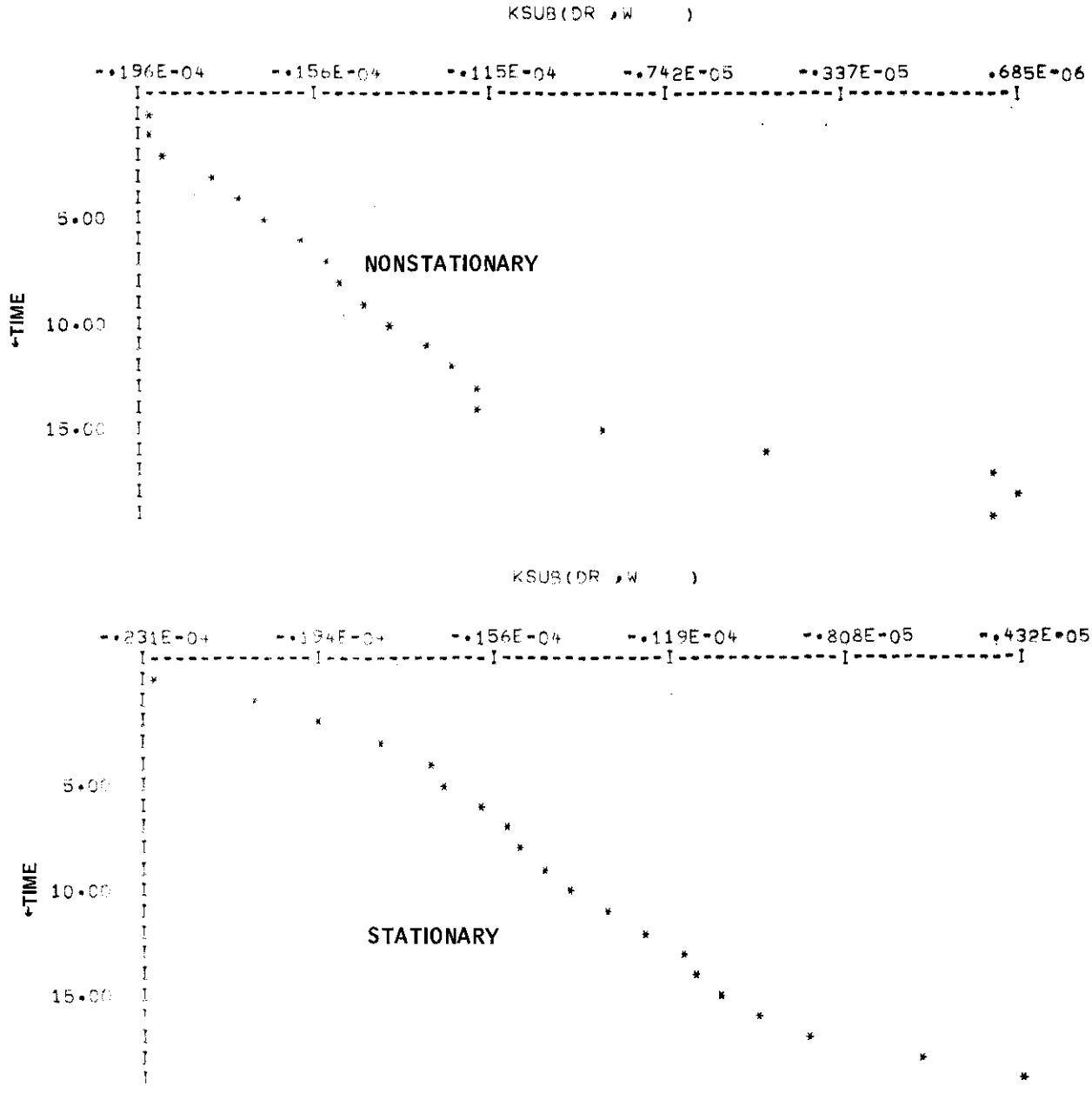


Figure 73. Optimal Controller Gain Plots (continued)

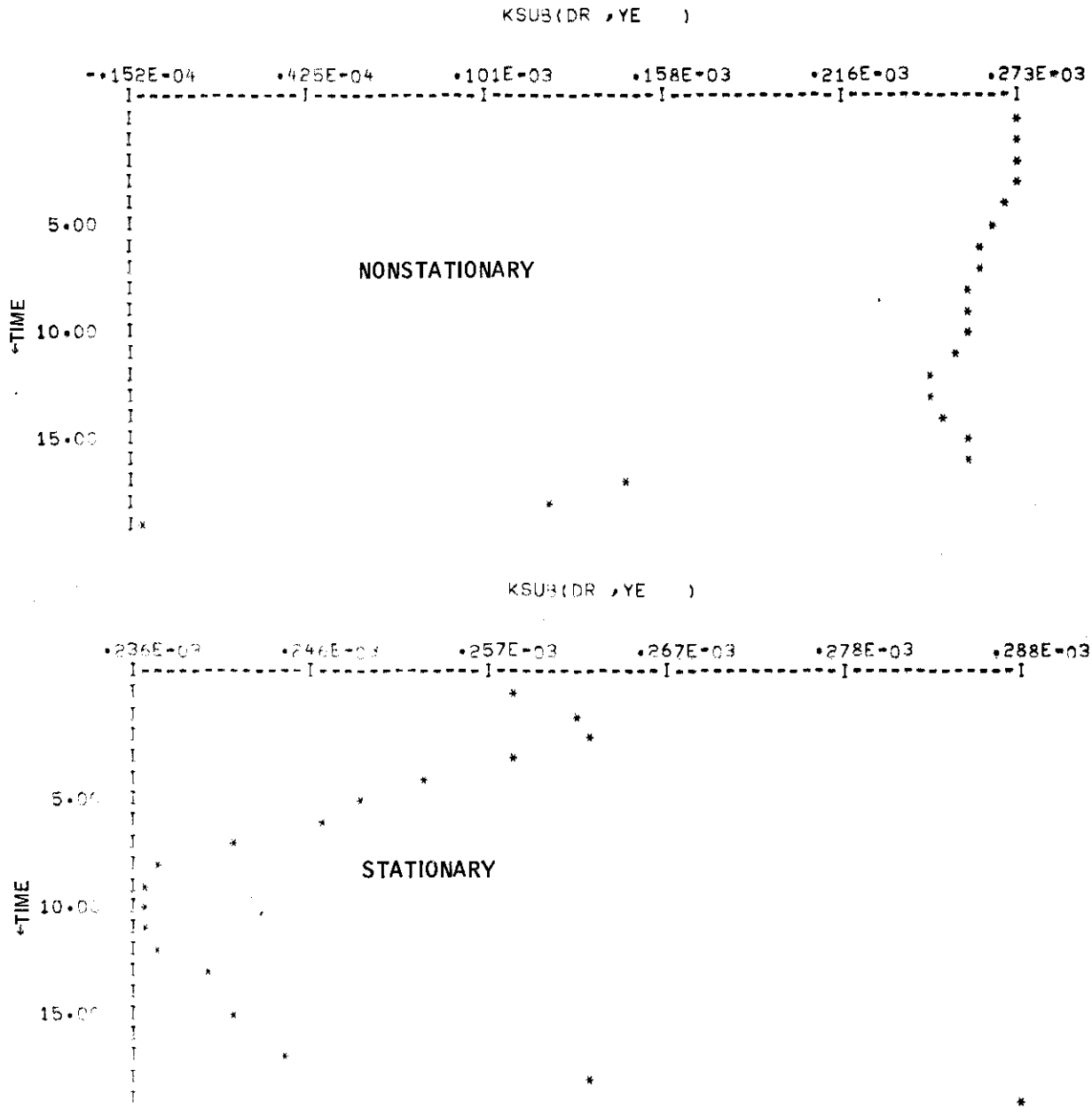


Figure 73. Optimal Controller Gain Plots (continued)

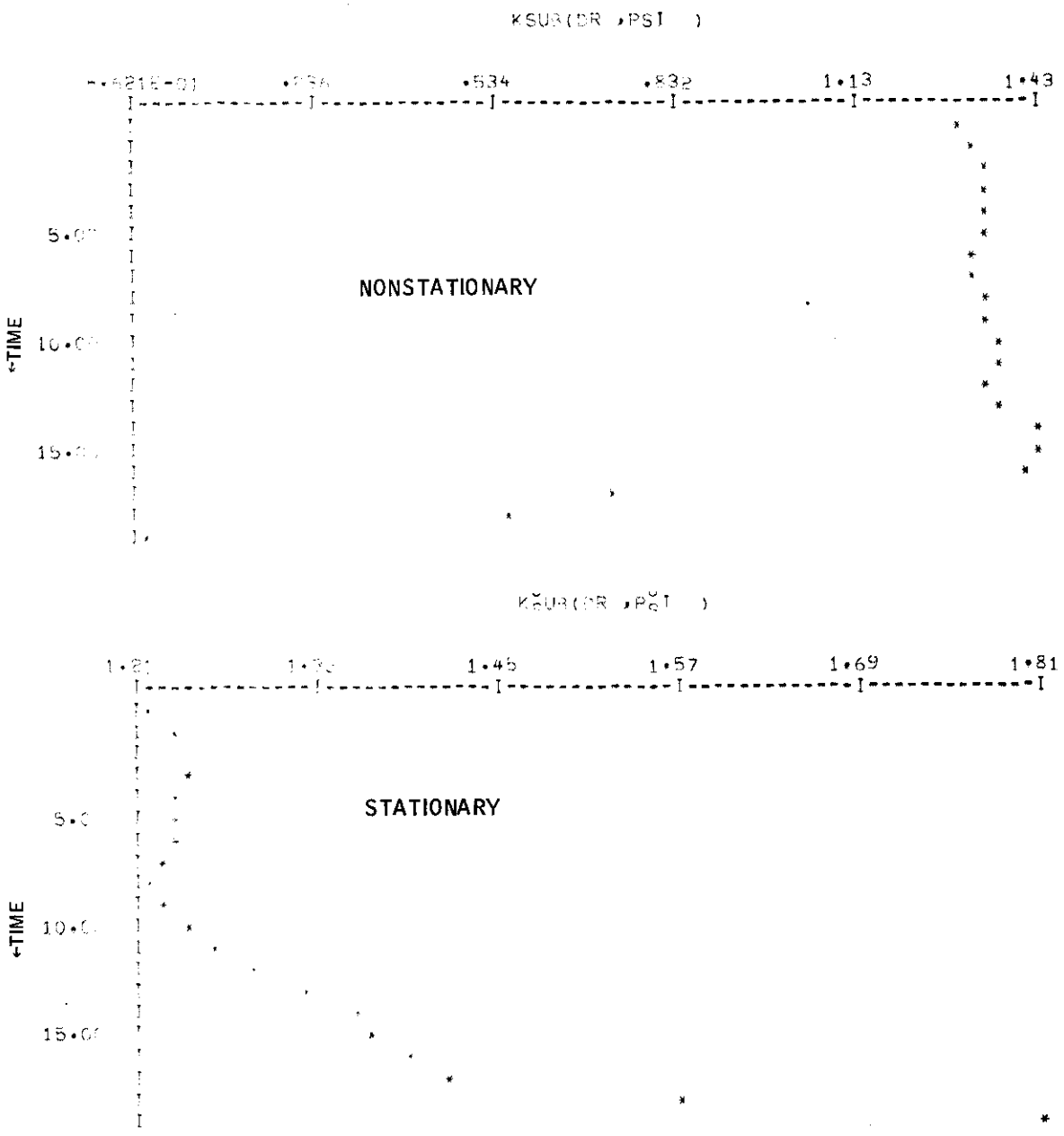


Figure 73. Optimal Controller Gain Plots (continued)

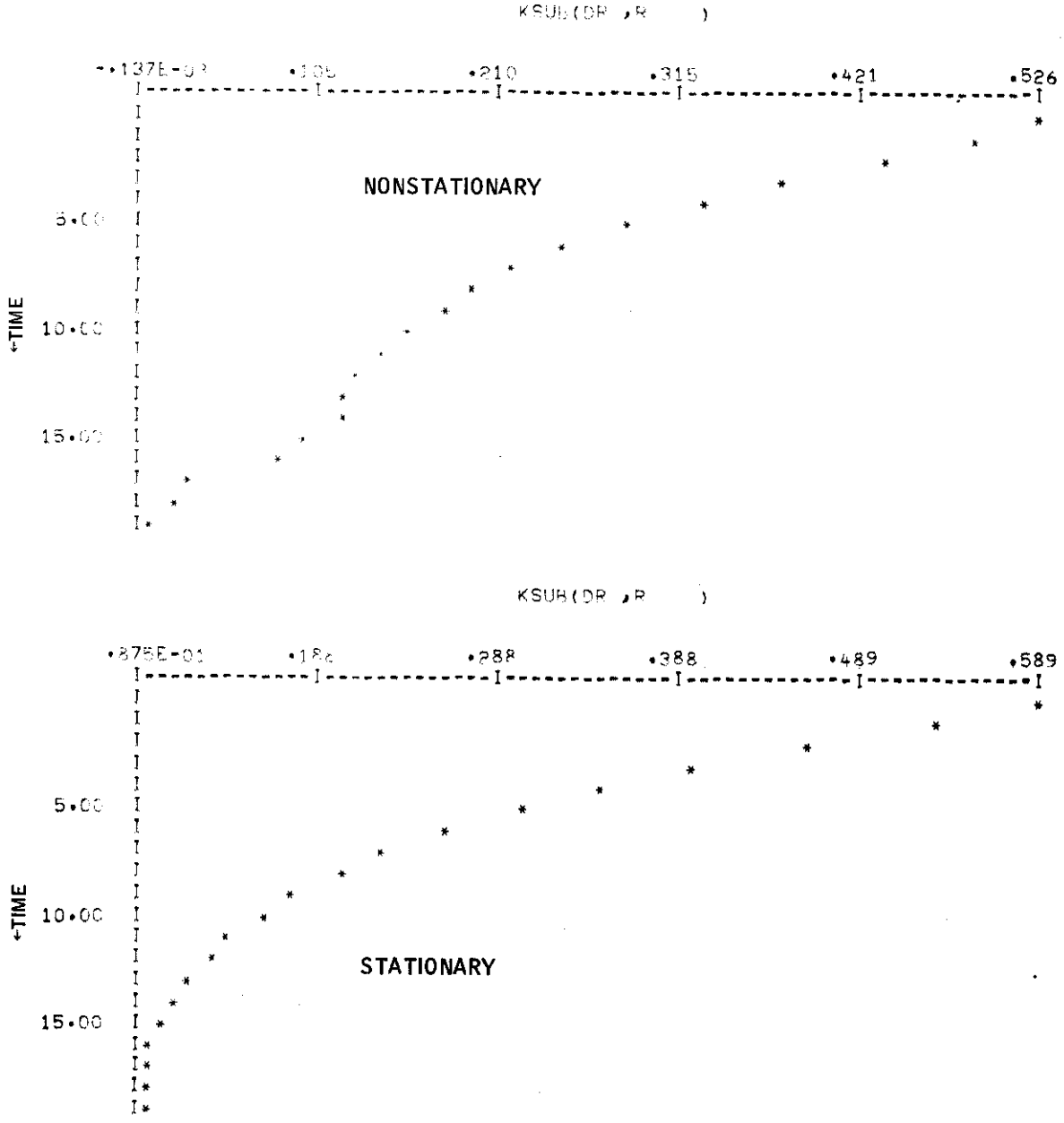


Figure 73. Optimal Controller Gain Plots (continued)

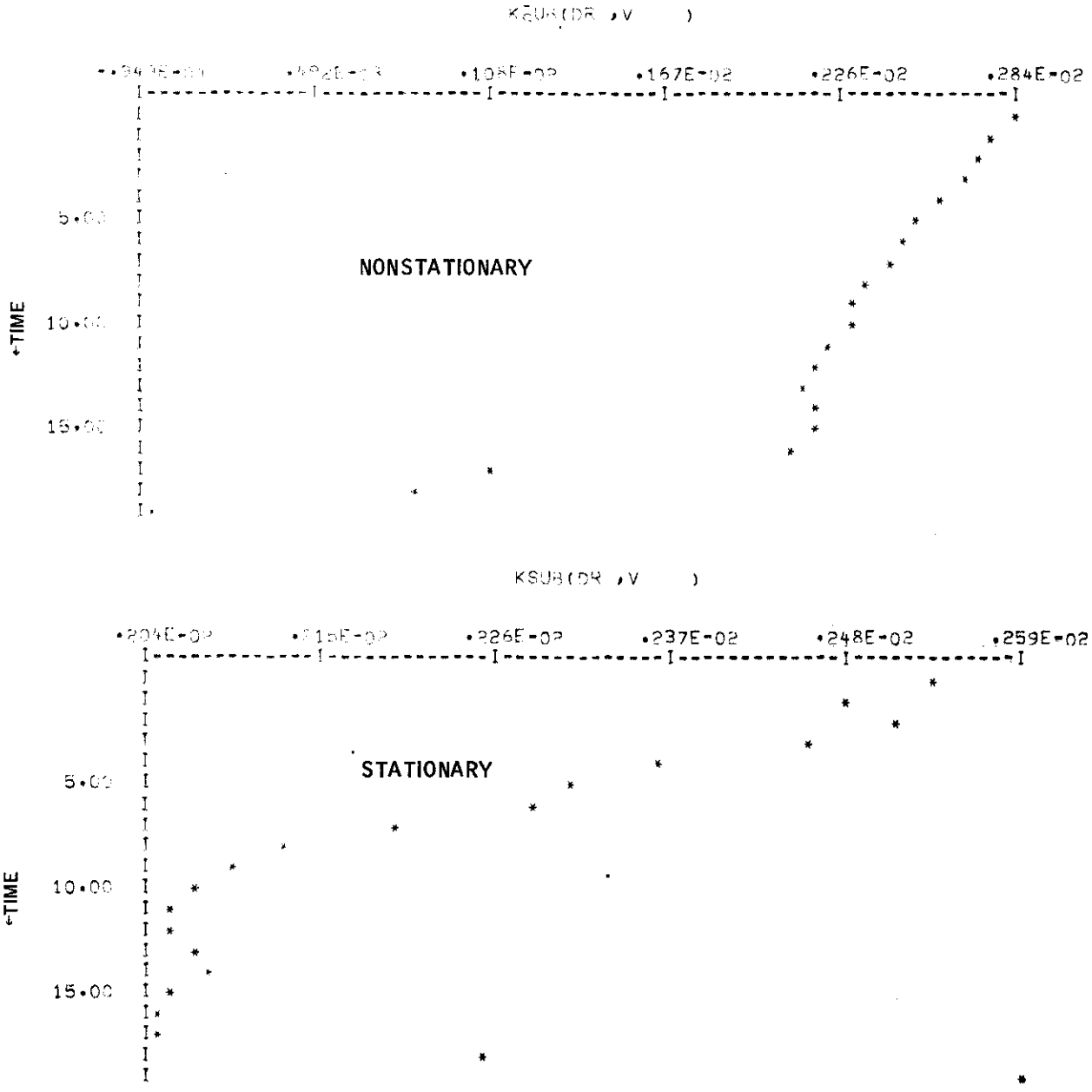


Figure 73. Optimal Controller Gain Plots (continued)

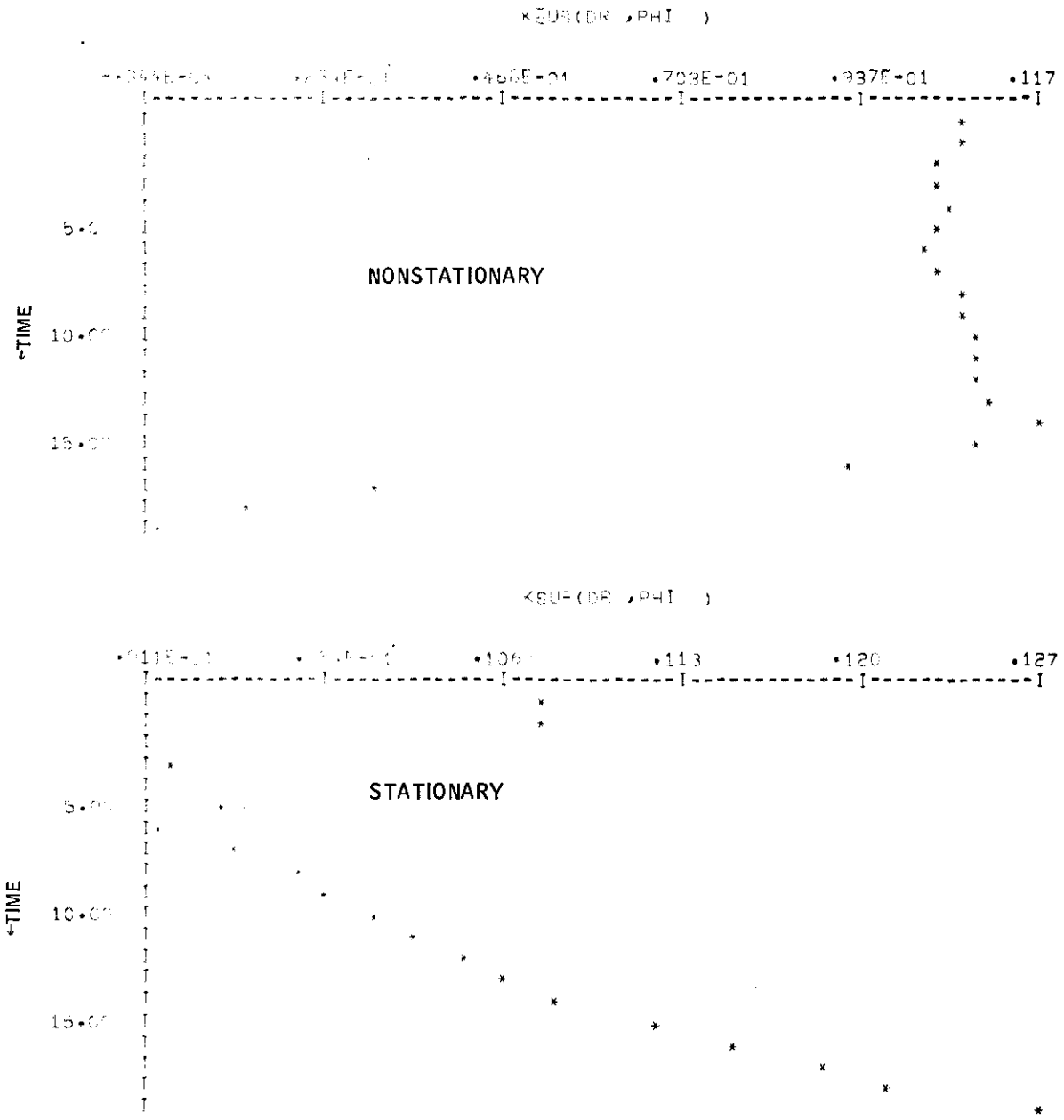


Figure 73. Optimal Controller Gain Plots (continued)

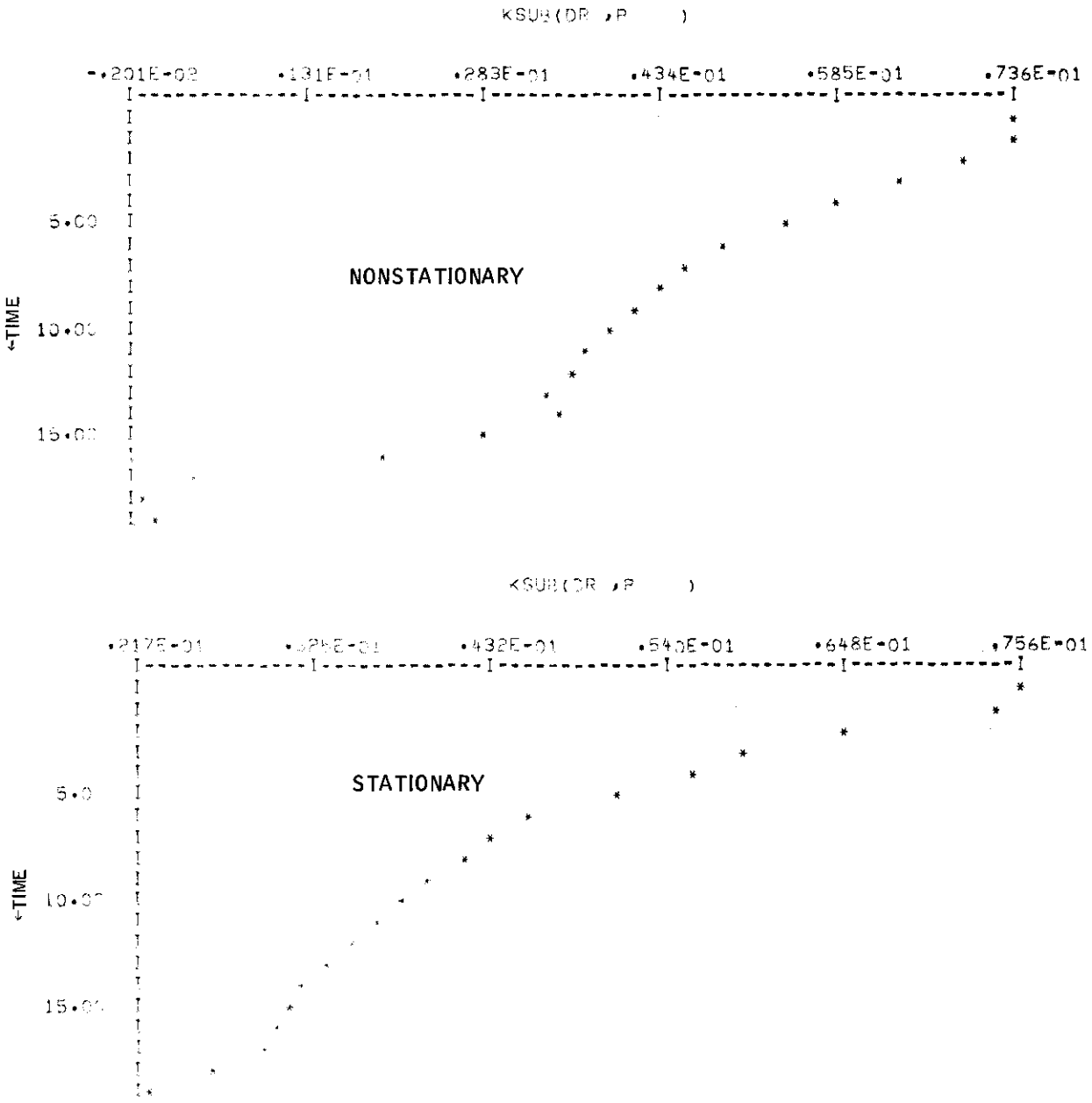


Figure 73. Optimal Controller Gain Plots (continued)

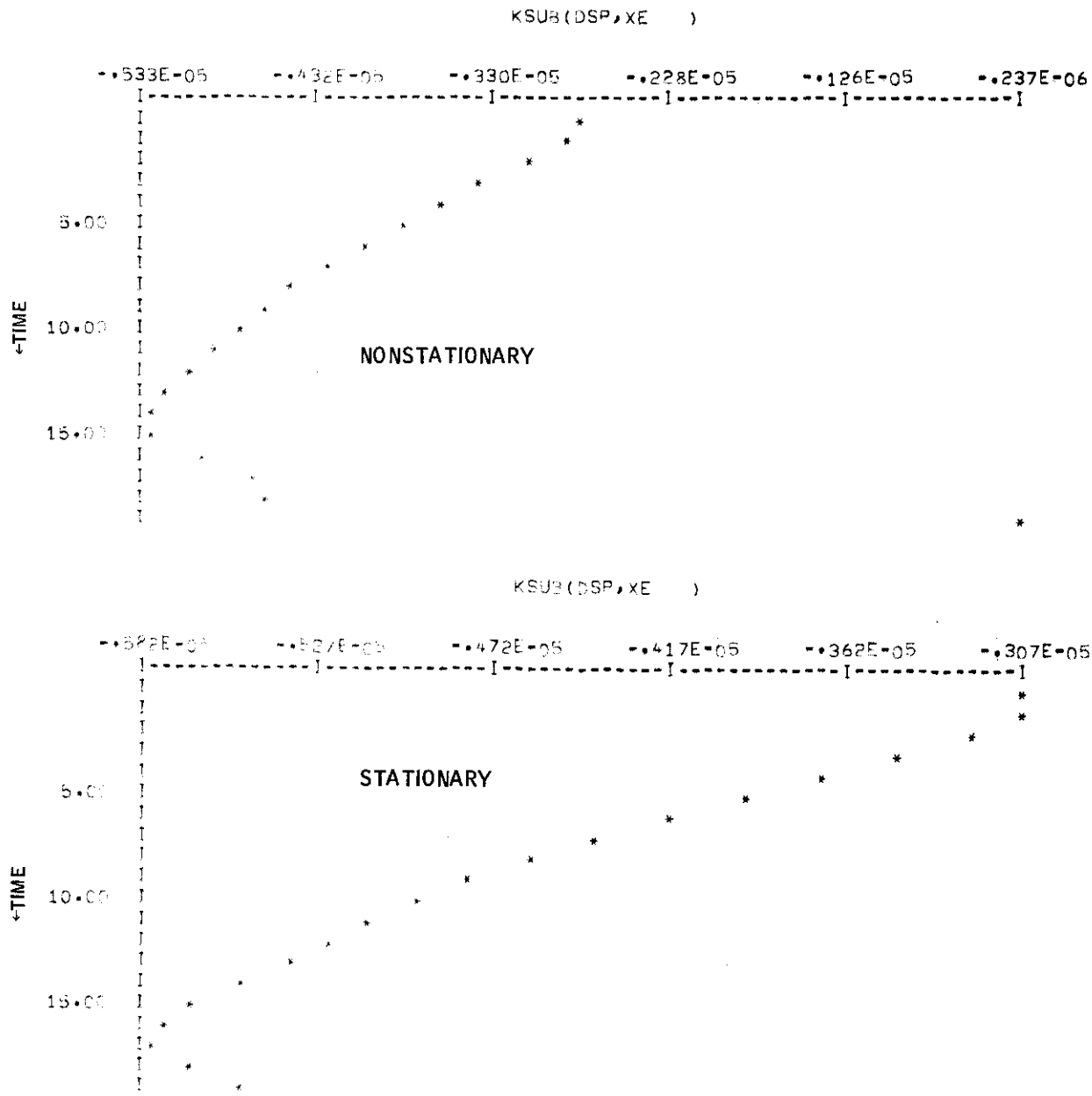


Figure 73. Optimal Controller Gain Plots (continued)

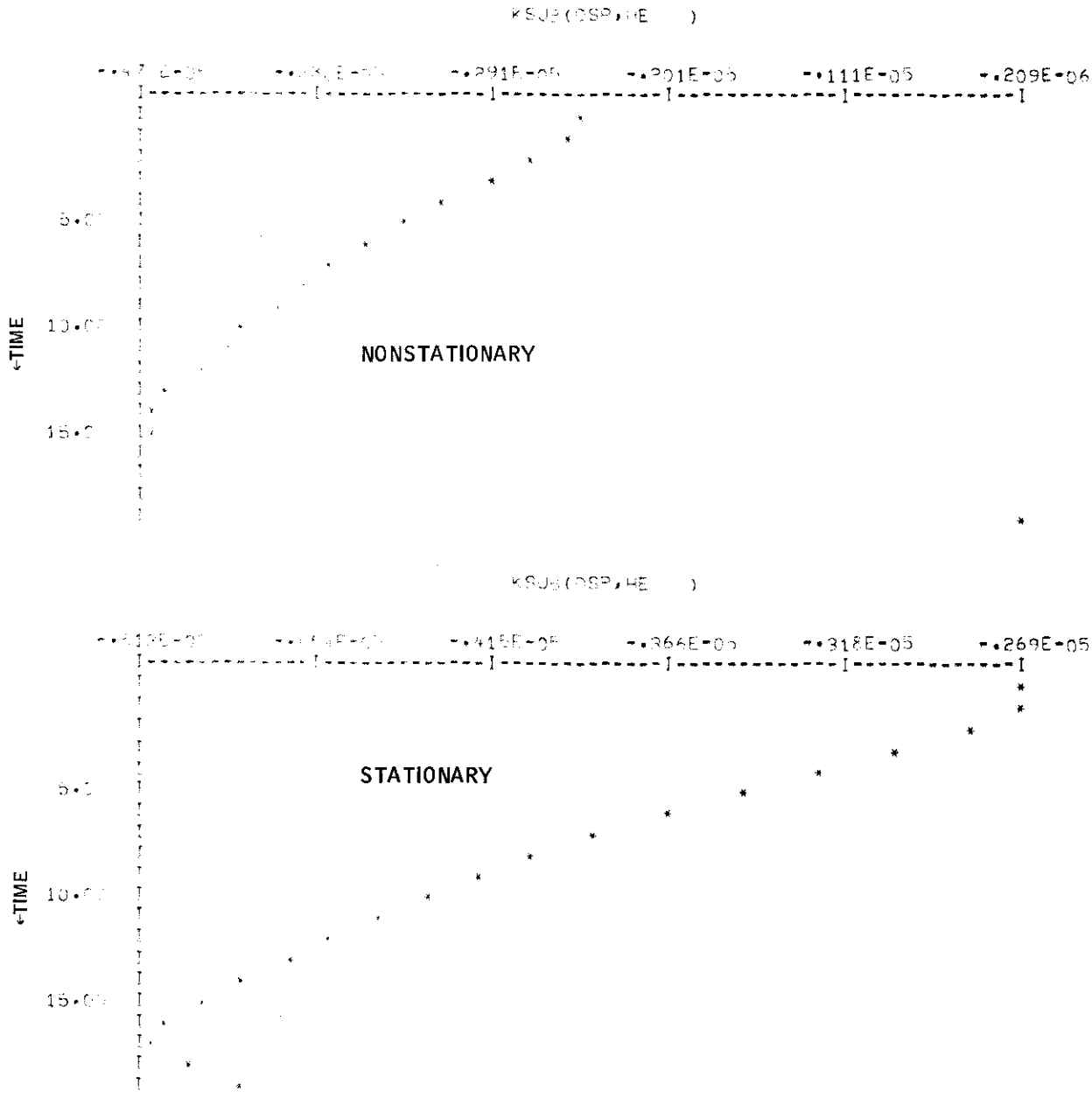


Figure 73. Optimal Controller Gain Plots (continued)

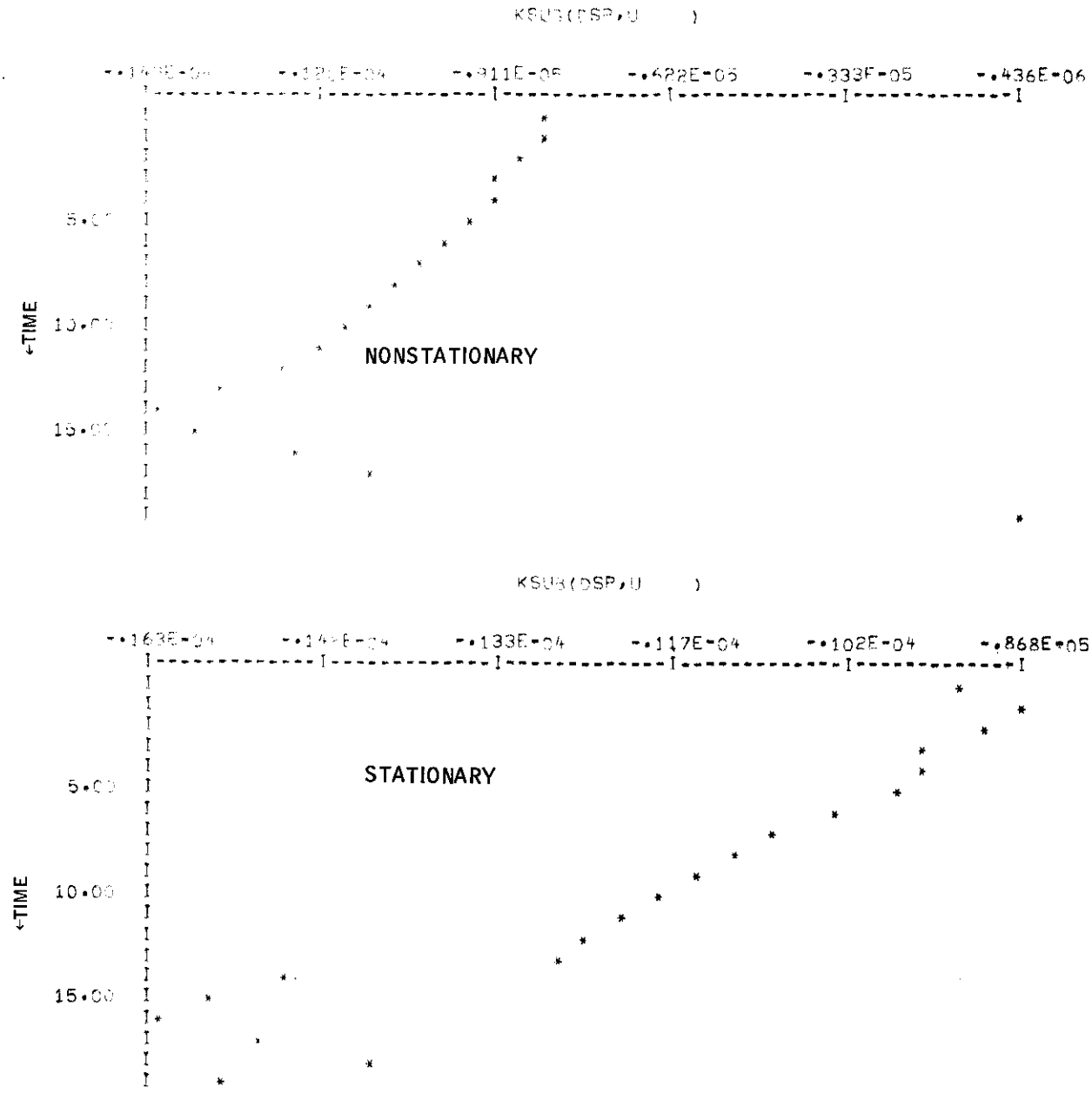


Figure 73. Optimal Controller Gain Plots (continued)

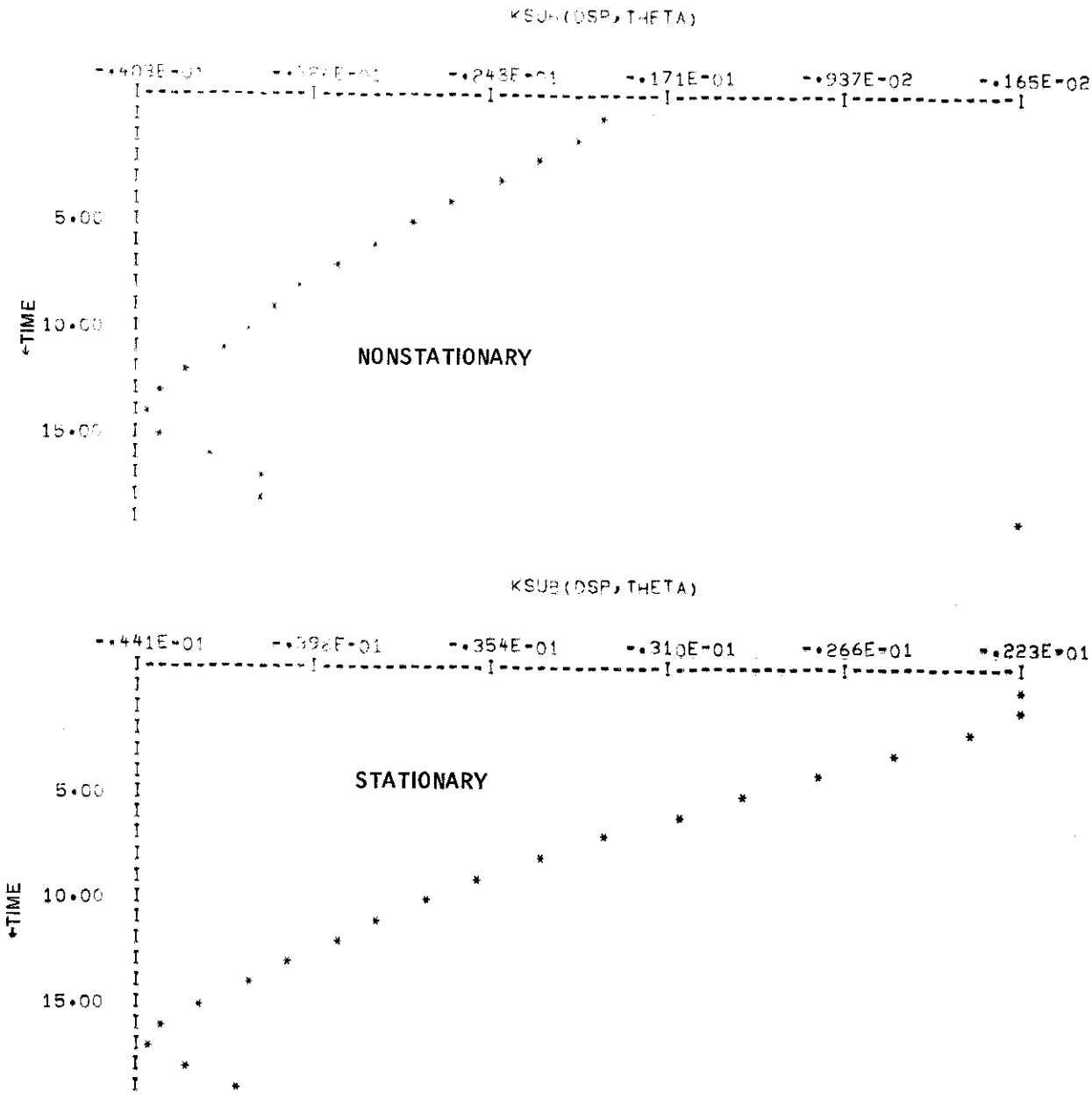


Figure 73. Optimal Controller Gain Plots (continued)

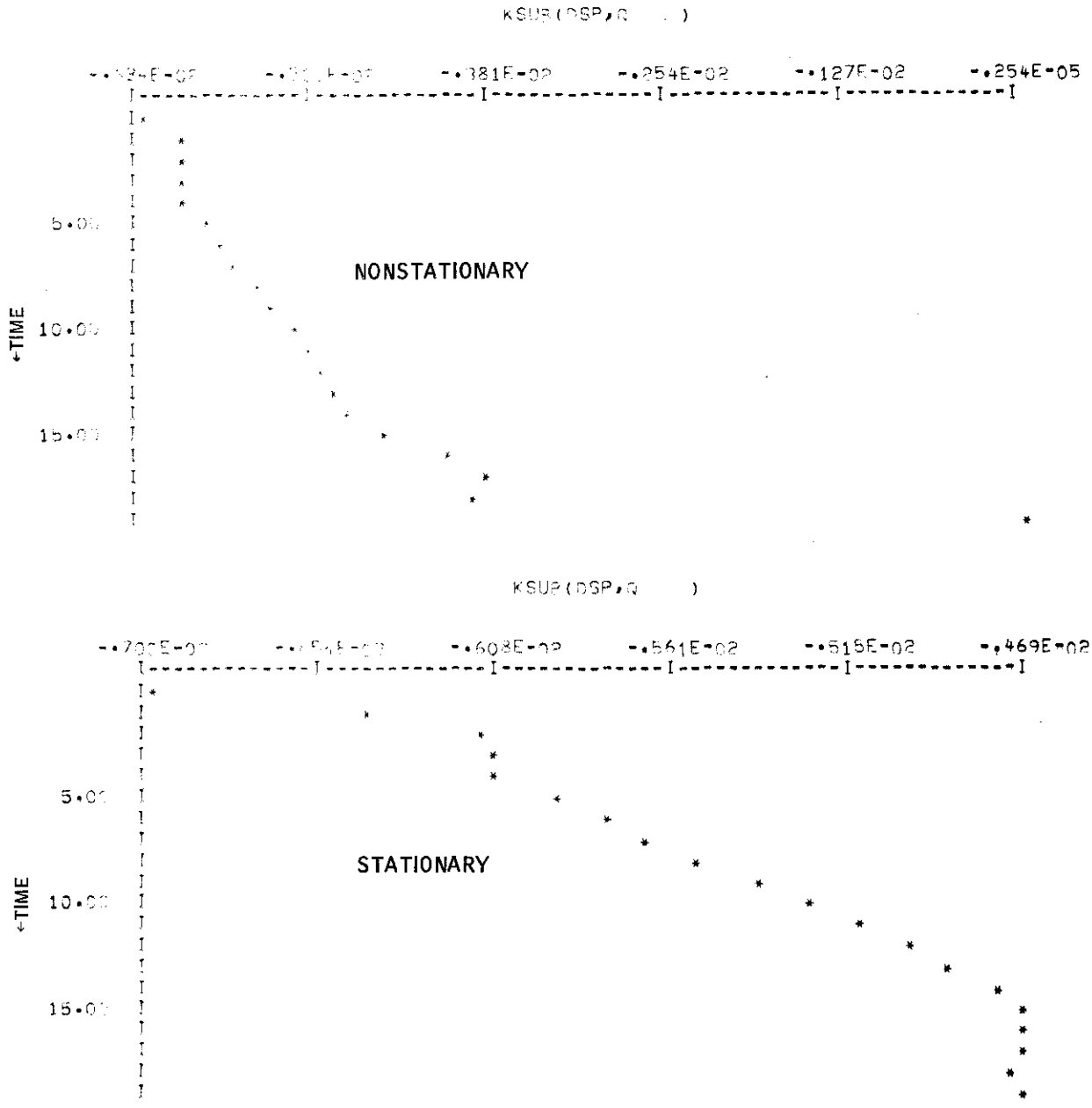


Figure 73. Optimal Controller Gain Plots (continued)

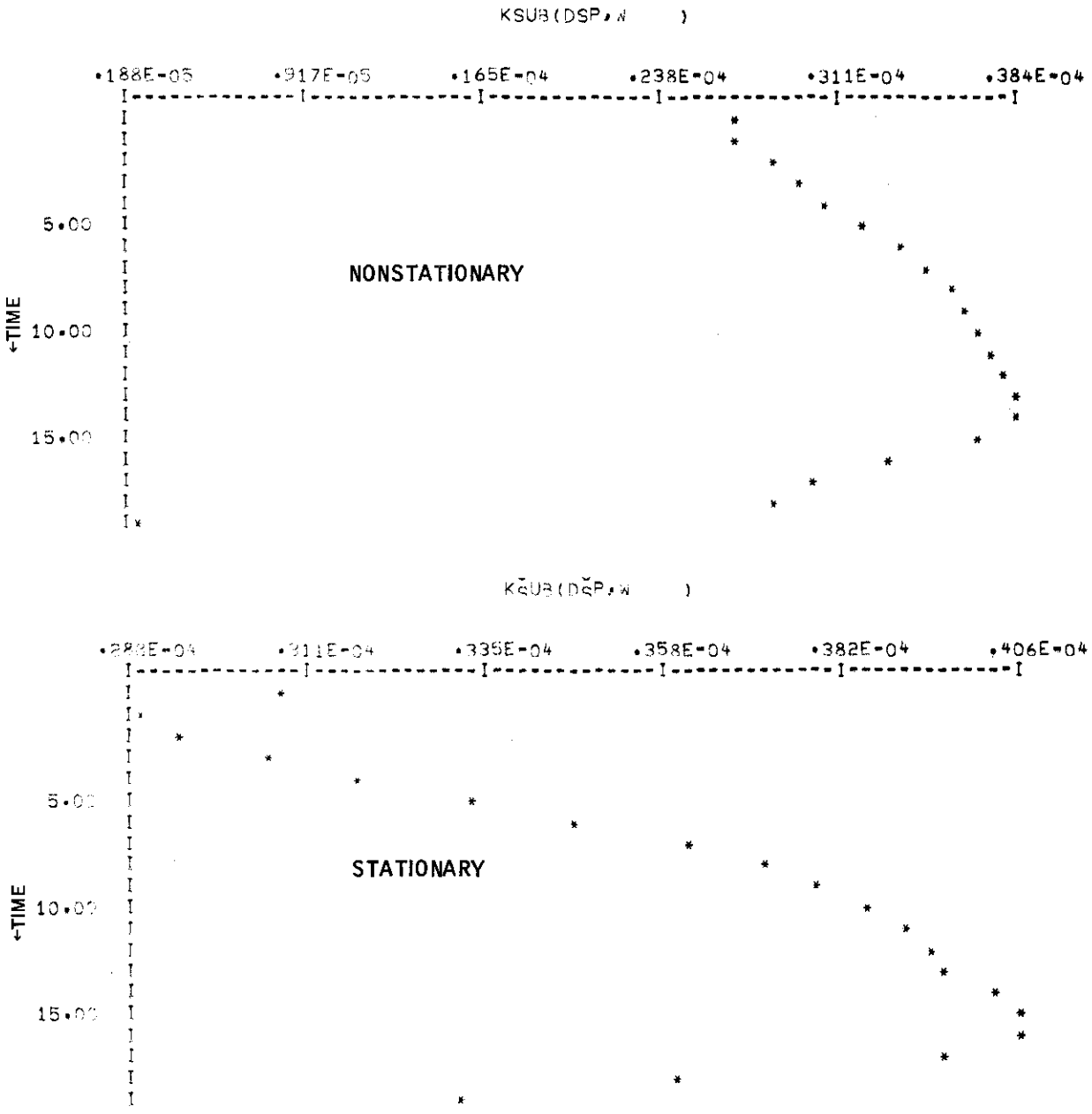


Figure 73. Optimal Controller Gain Plots (continued)

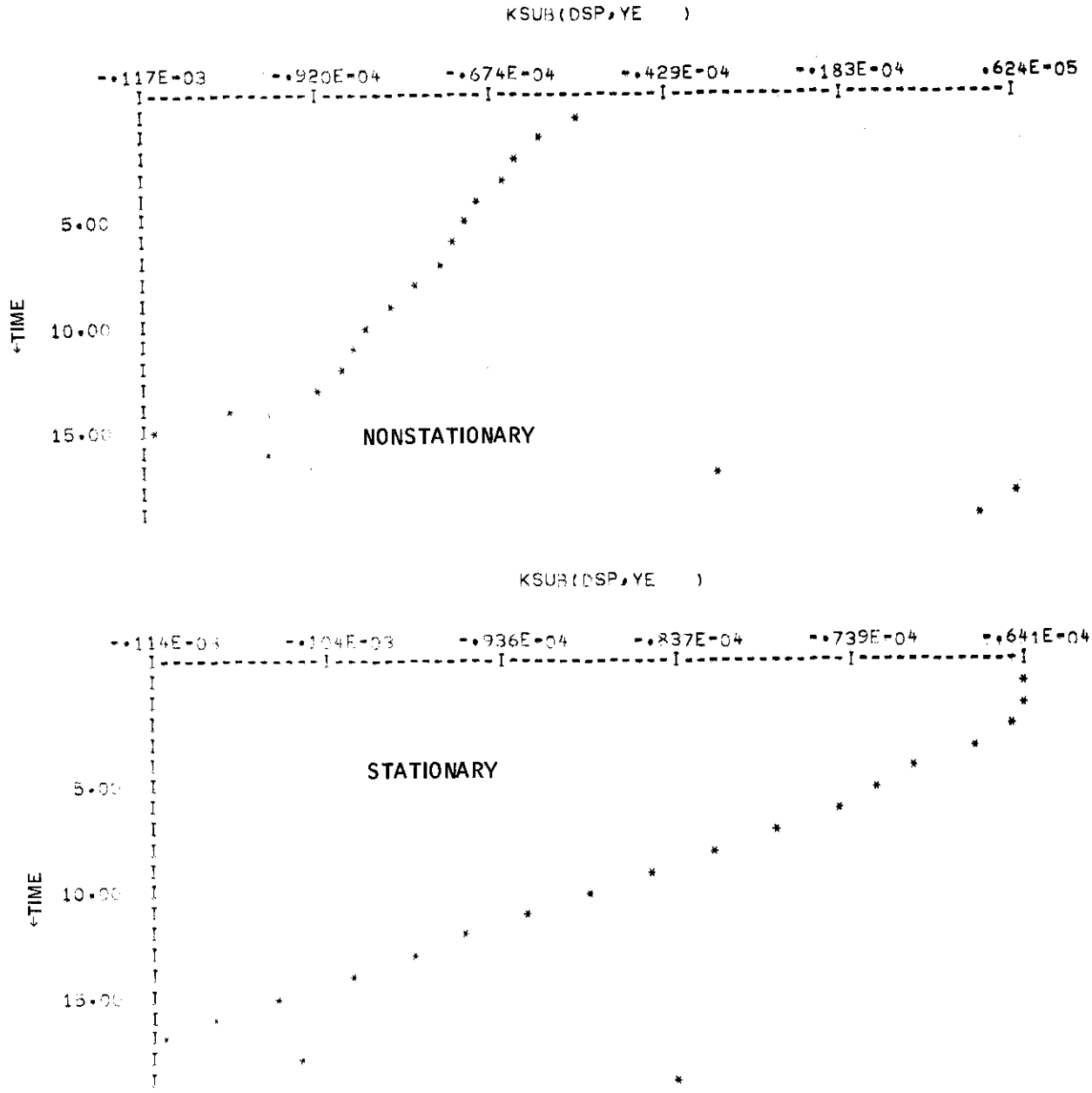


Figure 73. Optimal Controller Gain Plots (continued)

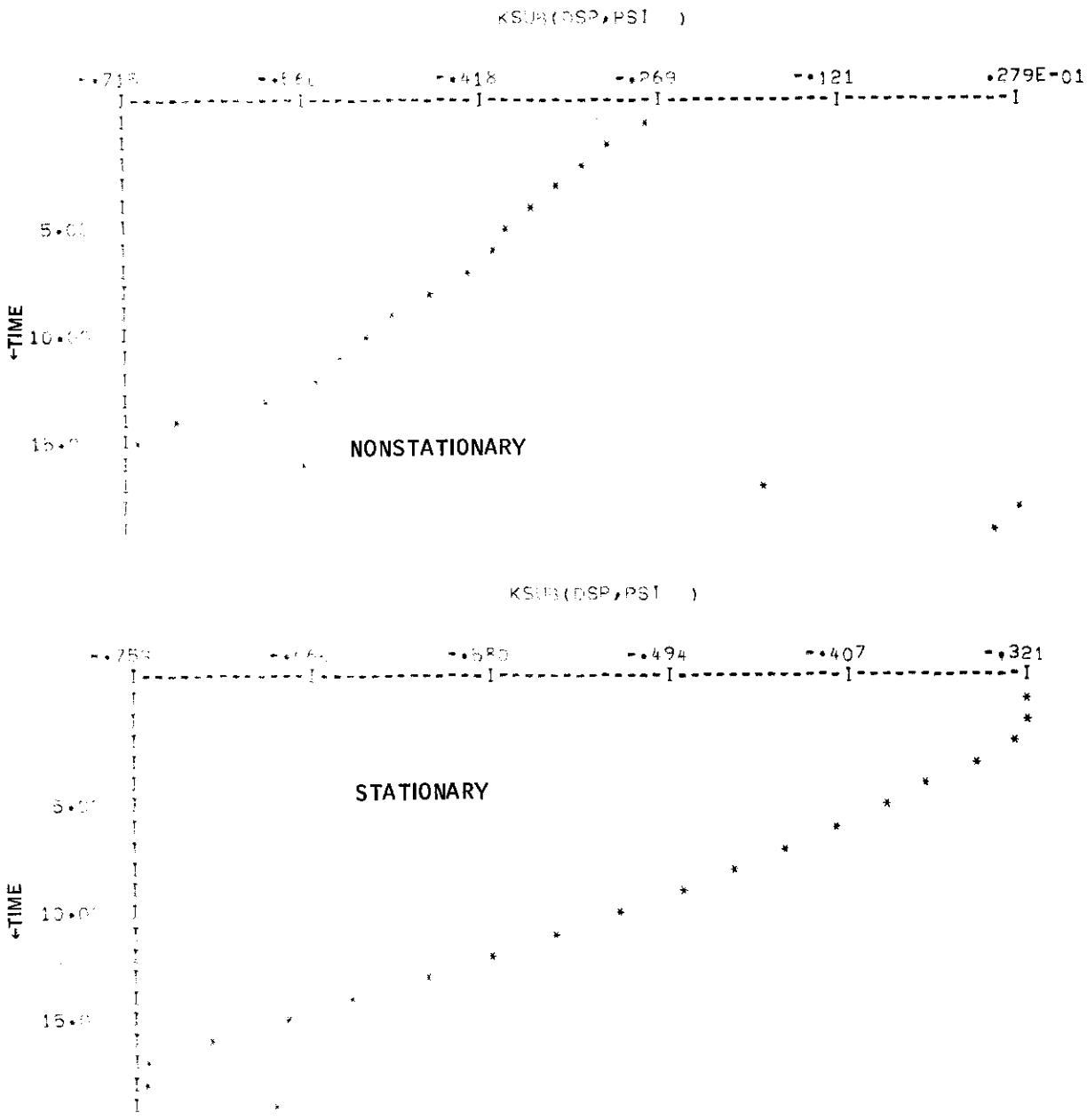


Figure 73. Optimal Controller Gain Plots (continued)

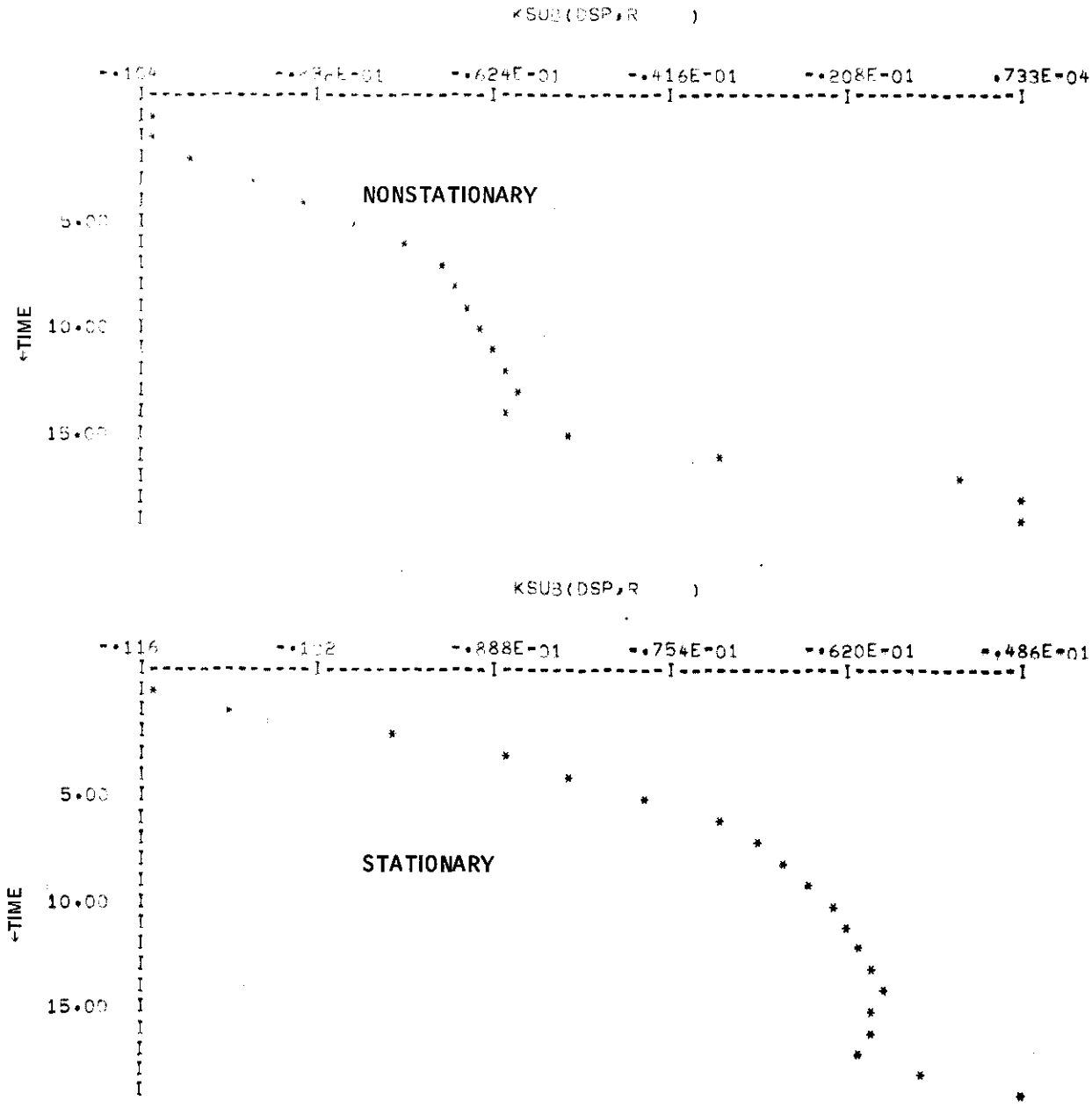


Figure 73. Optimal Controller Gain Plots (continued)

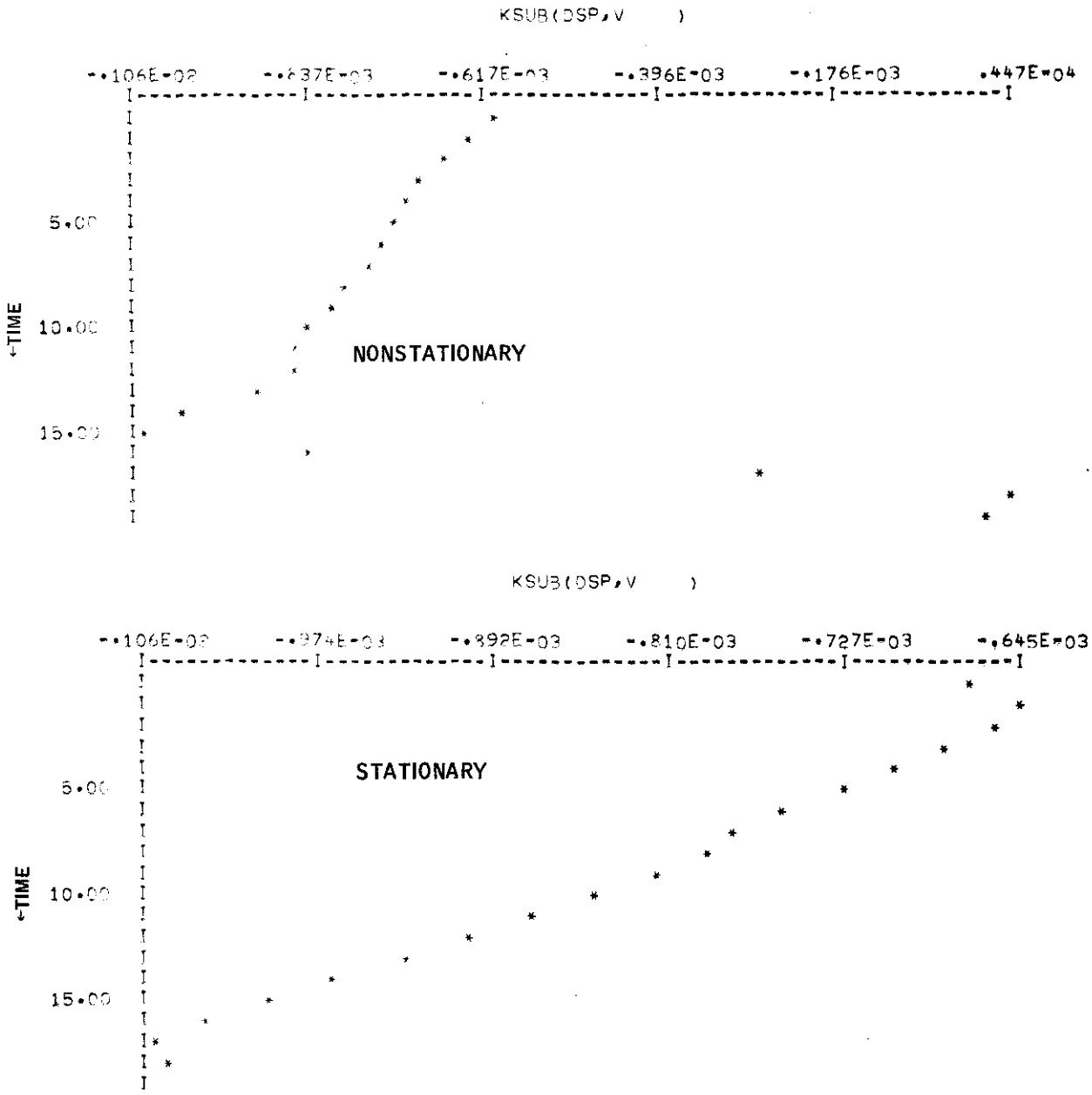


Figure 73. Optimal Controller Gain Plots (continued)

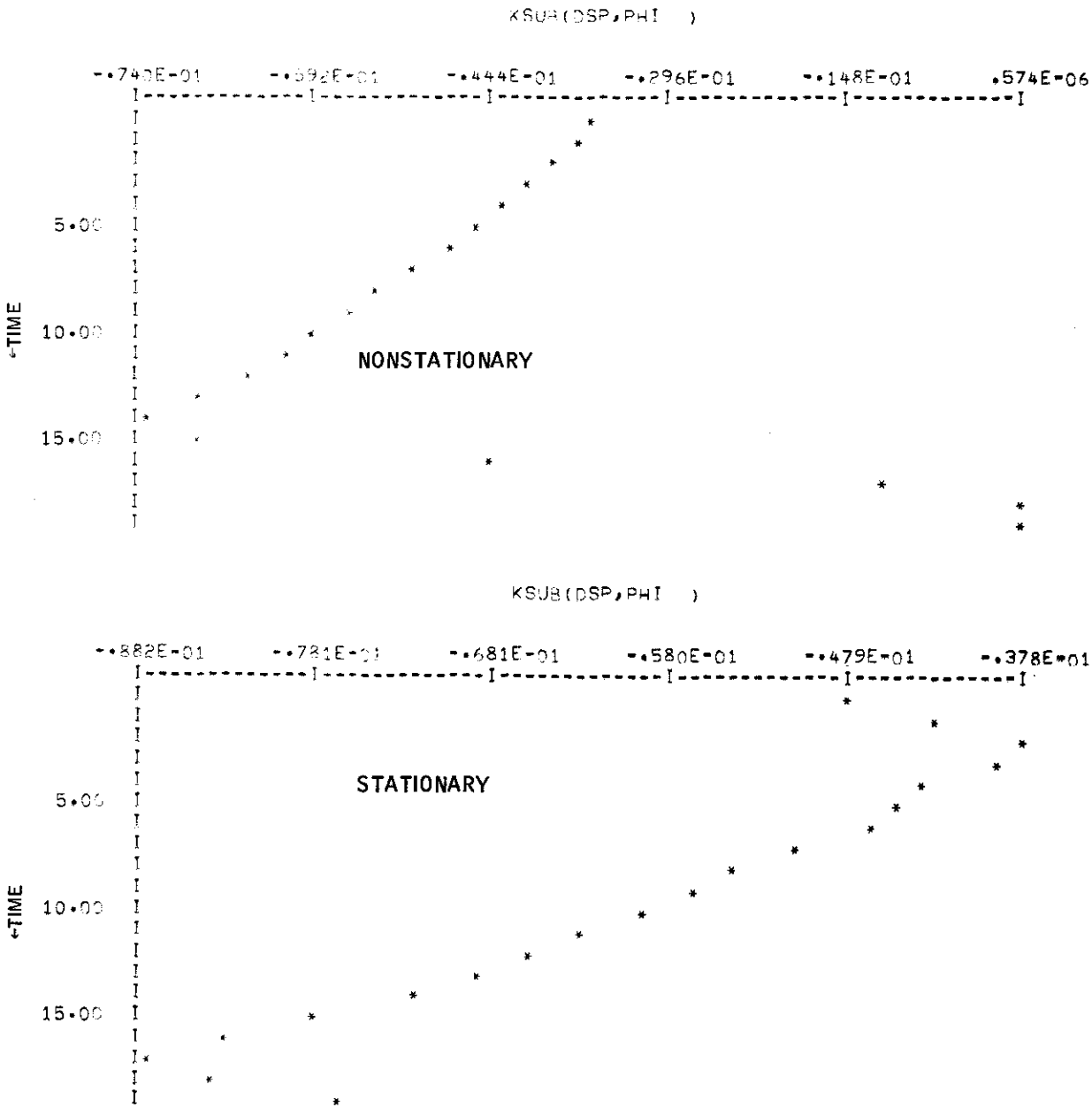


Figure 73. Optimal Controller Gain Plots (continued)

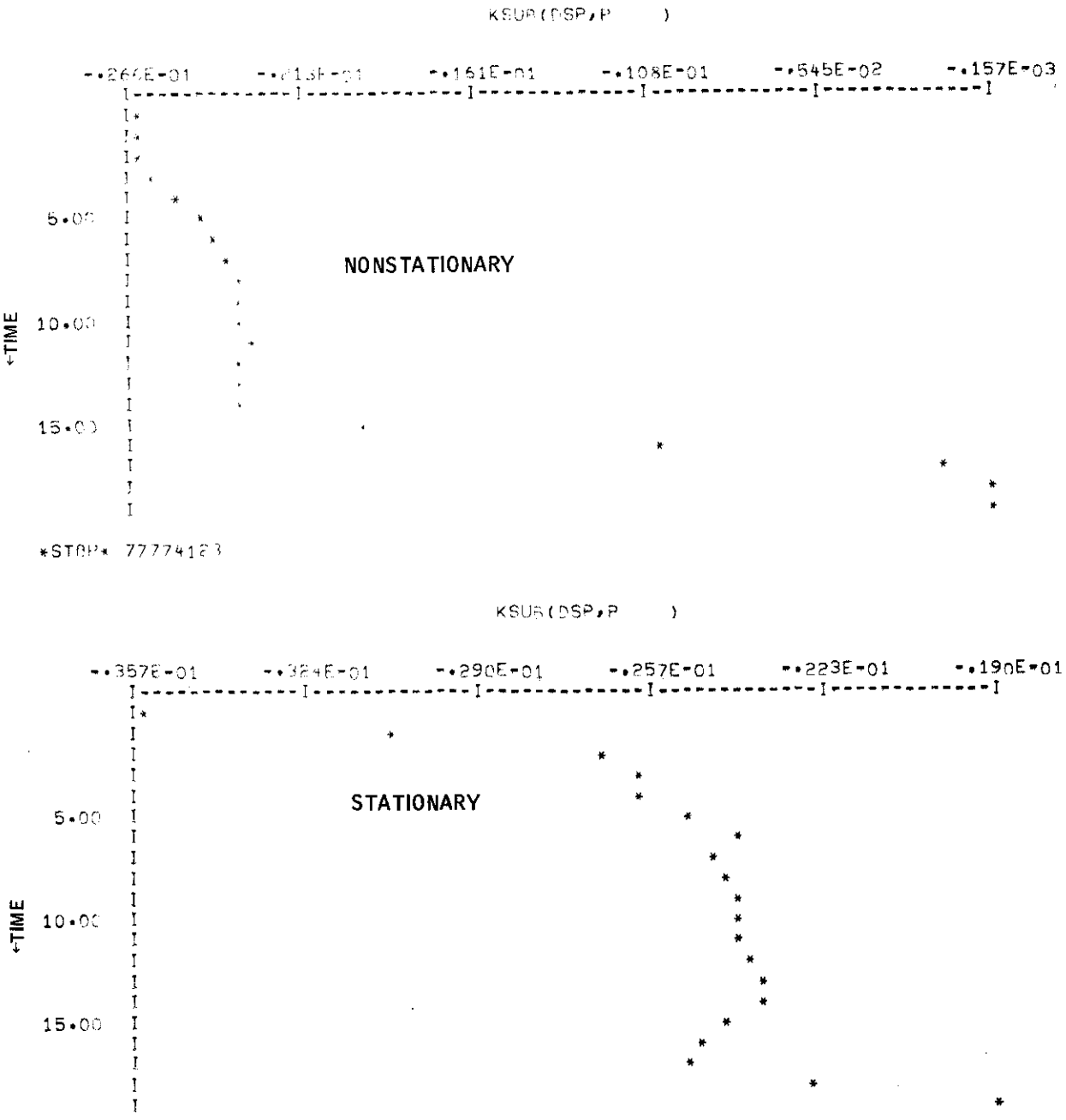


Figure 73. Optimal Controller Gain Plots (concluded)

STATIONARY, FREE AND NONSTATIONARY SPECTRUMS

The stationary and nonstationary controllers were compared with respect to the frozen-point closed-loop eigenvalues of the aircraft transition matrices.

Figure 74 shows the program for finding the eigenvalue spectrum of the aircraft at the frozen-time points. The spectrums corresponding to the aircraft with fixed-gain controller, airframe only, and with the time varying controller are shown at each data point in Figure 75. Note increased dampings and the stabilization of the position and attitude states.

```
@FORTRAN LS,G
      1:       DIMENSION F(17,17),G1(17,4),G2(17,3),H(21,17),D(21,4),Q(21,21)
      2:       DIMENSION AK(4,18)
      3:       DO 10 L=1,2
      4:       READ(4)((F(I,J),J=1,17),I=1,17)
      5:       READ(4)((G1(I,J),J=1,4),I=1,17)
      6:       READ(4)((G2(I,J),J=1,3),I=1,17)
      7:       READ(4)((H(I,J),J=1,17),I=1,21)
      8:       READ(4)((D(I,J),J=1,4),I=1,21)
      9:       READ(4)((Q(I,J),J=1,21),I=1,21)
     10:       LL=21-L
     11:       DO 20 M=1,LL
     12:    20 READ(2)((AK(I,J),J=1,18),I=1,4)
     13:       REWIND 2
     14:       DO 11 I=1,17
     15:       DO 11 J=1,17
     16:       DO 11 K=1,4
     17:    11 F(I,J)=F(I,J)+G1(I,K)*AK(K,J)
     18:       TIME=L-1
     19:       WRITE(9,30)TIME
     20:    30 FORMAT(1H1/7X,59H CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS=
     21:      1100000. AT F8.3,4HSEC./)
     22:       CALL ROOT(F,17)
     23:    10 CONTINUE
     24:       END


      1:       SUBROUTINE ROOT(A,NX)
      2:       DIMENSION A(NX,NX),RR(80)
      3:       LWR=9
      4:       CALL HESSEN(NX,A,NX)
      5:       CALL ORCALL(NX,A,RR,MM,NX)
      6:       WRITE(LWR,900)
      7:   900 FORMAT(///74H           REAL                    IMAG                    DAMP
      8:      1ING              FREQ/)
      9:       MN=MM/2
     10:       DO 901 K=1,MN
     11:       I=2*K-1
     12:       II=2*K
     13:       IF(RR(II).EQ.0.) GOTO 903
     14:       FREQ=SQRT(RR(I)*RR(I)+RR(II)*RR(II))
     15:       DAMP=ABS(RR(I))/FREQ
     16:       WRITE(LWR,904)RR(I),RR(II),DAMP,FREQ
     17:   904 FORMAT(4E20.8)
     18:       GOTO 901
     19:   903 WRITE(LWR,802)RR(I),RR(II)
     20:   901 CONTINUE
     21:   802 FORMAT(2E20.8)
     22:       RETURN
     23:       END
```

Figure 74. Eigenvalue Spectrum Program Listing

CLOSED LOOP ROOTS AT .000SEC.

REAL	IMAG
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.14683385E-02	.67066482E-02
-.82580376E-01	.00000000E 00
-.13639452E 00	.00000000E 00
-.16674493E 00	.00000000E 00
-.12167729E 00	.13906176E 00
-.12796527E 01	.00000000E 00
-.74473323E-01	.14958737E 01
-.53333156E 00	.12644271E 01

ROOTS OF A/C FRAME AT .000SEC.

REAL	IMAG
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.34426327E-01	.00000000E 00
-.63233281E-01	.00000000E 00
-.12796926E 01	.00000000E 00
-.68212634E-01	.14958388E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.33400319E-02	.00000000E 00
-.27407776E-01	.81259815E-01
-.50473045E 00	.12410152E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT .000SEC.

REAL	IMAG	DAMPING	FREQ
-.34426327E-01	.00000000E 00		
-.34426327E-01	.00000000E 00		
-.34426327E-01	.00000000E 00		
-.34426327E-01	.00000000E 00		
-.34426327E-01	.00000000E 00		
-.15625444E-02	.64446099E-02	.23563091E 00	.66313216E-02
-.80197431E-01	.00000000E 00		
-.91842136E-01	.00000000E 00		
-.28593329E 00	.47494569E 00	.51577230E 00	.55437311E 00
-.89096372E 00	.00000000E 00		
-.12685772E 01	.00000000E 00		
-.26621978E 00	.14821498E 01	.17609304E 00	.15117735E 01
-.12807923E 01	.19213996E 01	.55986581E 00	.21982094E 01

Figure 75. Eigenvalue Spectrums

CLOSED LOOP ROOTS AT 1.000SEC.

REAL	IMAG
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.40861953E-02	.67246887E-02
-.89032666E-01	.00000000E 00
-.12568193E 00	.00000000E 00
-.20841872E 00	.00000000E 00
-.12530873E 00	.13516527E 00
-.13718116E 01	.00000000E 00
-.89358141E-01	.16192289E 01
-.55857163E 00	.13045287E 01

ROOTS OF A/C FRAME AT 1.000SEC.

REAL	IMAG
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.37788856E-01	.00000000E 00
-.62719468E-01	.00000000E 00
-.13719553E 01	.00000000E 00
-.85002979E-01	.16192409E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.36663012E-02	.00000000E 00
-.26928097E-01	.78043273E-01
-.52881299E 00	.12784632E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 1.000SEC.

REAL	IMAG	DAMPING	FREQ
-.37788856E-01	.00000000E 00		
-.37788856E-01	.00000000E 00		
-.37788856E-01	.00000000E 00		
-.37788856E-01	.00000000E 00		
-.37788856E-01	.00000000E 00		
-.40637551E-02	.67732923E-02	.51447525E 00	.78988350E-02
-.85314930E-01	.00000000E 00		
-.97556155E-01	.00000000E 00		
-.34166722E 00	.48195680E 00	.57833420E 00	.59077817E 00
-.97278326E 00	.00000000E 00		
-.13490308E 01	.00000000E 00		
-.26062988E 00	.16160821E 01	.15921546E 00	.16369634E 01
-.12772858E 01	.18878297E 01	.56037693E 00	.22793333E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 2.000SEC.

REAL	IMAG
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.50678403E-02	.70569783E-02
-.94475366E-01	.00000000E 00
-.12715564E 00	.00000000E 00
-.22680410E 00	.00000000E 00
-.11591753E 00	.12864415E 00
-.14527789E 01	.00000000E 00
-.10786765E 00	.17175086E 01
-.61546902E 00	.14502170E 01

ROOTS OF A/C FRAME AT 2.000SEC.

REAL	IMAG
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.41303573E-01	.00000000E 00
-.54077351E-01	.00000000E 00
-.14529390E 01	.00000000E 00
-.10418060E 00	.17174806E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.36025698E-02	.00000000E 00
-.26014455E-01	.77513507E-01
-.58928694E 00	.14258967E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 2.000SEC.

REAL	IMAG	DAMPING	FREQ
-.41303573E-01	.00000000E 00		
-.41303573E-01	.00000000E 00		
-.41303573E-01	.00000000E 00		
-.41303573E-01	.00000000E 00		
-.41303573E-01	.00000000E 00		
-.50770382E-02	.71754625E-02	.57759825E 00	.87899992E-02
-.93715691E-01	.00000000E 00		
-.10185261E 00	.00000000E 00		
-.37540357E 00	.41150108E 00	.67396598E 00	.55701413E 00
-.11337419E 01	.00000000E 00		
-.13971649E 01	.00000000E 00		
-.26661383E 00	.17267477E 01	.15259409E 00	.17472094E 01
-.13122891E 01	.20292489E 01	.54301345E 00	.24165665E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 3.000SEC.

REAL	IMAG
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.51945629E-02	.75658567E-02
-.98180156E-01	.00000000E 00
-.12641717E 00	.00000000E 00
-.11189052E 00	.12872929E 00
-.25172744E 00	.00000000E 00
-.15399110E 01	.00000000E 00
-.12135063E 00	.18082812E 01
-.65623655E 00	.15409240E 01

ROOTS OF A/C FRAME AT 3.000SEC.

REAL	IMAG
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.45020312E-01	.00000000E 00
-.48360[illegible]6E-01	.00000000E 00
-.15400058E 01	.00000000E 00
-.11808564E 00	.18082149E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.35488833E-02	.00000000E 00
-.25410536E-01	.75416394E-01
-.63213491E 00	.15161505E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 3.000SEC.

REAL	IMAG	DAMPING	FREQ
-.45020312E-01	.00000000E 00		
-.45020312E-01	.00000000E 00		
-.45020312E-01	.00000000E 00		
-.45020312E-01	.00000000E 00		
-.45020312E-01	.00000000E 00		
-.51934417E-02	.76577186E-02	.56128921E 00	.92527018E-02
-.99283313E-01	.00000000E 00		
-.10566262E 00	.00000000E 00		
-.37034292E 00	.39520062E 00	.68378618E 00	.54160633E 00
-.12597039E 01	.00000000E 00		
-.14882921E 01	.00000000E 00		
-.27993624E 00	.18197058E 01	.15204737E 00	.18411121E 01
-.13476972E 01	.21328769E 01	.53416781E 00	.25229846E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 4.000SEC.

REAL	IMAG
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.59374256E-02	.77363343E-02
-.10179632E 00	.00000000E 00
-.12561655E 00	.00000000E 00
-.11263865E 00	.13121616E 00
-.27779386E 00	.00000000E 00
-.16300932E 01	.00000000E 00
-.13362364E 00	.19033602E 01
-.69691777E 00	.16310865E 01

ROOTS OF A/C FRAME AT 4.000SEC.

REAL	IMAG
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.48979674E-01	.00000000E 00
-.46753165E-01	.00000000E 00
-.16301294E 01	.00000000E 00
-.13051101E 00	.19032812E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.41578161E-02	.00000000E 00
-.24858019E-01	.68452741E-01
-.67430886E 00	.16059047E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS= 10000. AT 4.000SEC.

REAL	IMAG	DAMPING	FREQ
-.48979674E-01	.00000000E 00		
-.48979674E-01	.00000000E 00		
-.48979674E-01	.00000000E 00		
-.48979674E-01	.00000000E 00		
-.48979674E-01	.00000000E 00		
-.59425897E-02	.77912096E-02	.60645831E 00	.97988428E-02
-.10197766E 00	.00000000E 00		
-.10946464E 00	.00000000E 00		
-.35680459E 00	.41564113E 00	.65136028E 00	.54778377E 00
-.13934538E 01	.00000000E 00		
-.15983650E 01	.00000000E 00		
-.28993026E 00	.19130685E 01	.14984145E 00	.19349136E 01
-.13711490E 01	.22368401E 01	.52261262E 00	.26236432E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 5.000SEC.

REAL	IMAG
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.69193312E-02	.77980359E-02
-.10489058E 00	.00000000E 00
-.12926164E 00	.00000000E 00
-.10993213E 00	.13064649E 00
-.28244596E 00	.00000000E 00
-.17024360E 01	.00000000E 00
-.14705144E 00	.19977164E 01
-.73728107E 00	.17691357E 01

ROOTS OF A/C FRAME AT 5.000SEC.

REAL	IMAG
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.53215289E-01	.00000000E 00
-.42935093E-01	.00000000E 00
-.17024360E 01	.00000000E 00
-.14432117E 00	.19976264E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.50200480E-02	.00000000E 00
-.24402902E-01	.62871699E-01
-.71699280E 00	.17460709E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 5.000SEC.

REAL	IMAG	DAMPING	FREQ
-.53215289E-01	.00000000E 00		
-.53215289E-01	.00000000E 00		
-.53215289E-01	.00000000E 00		
-.53215289E-01	.00000000E 00		
-.53215289E-01	.00000000E 00		
-.69311697E-02	.78343210E-02	.66261726E 00	.10460291E-01
-.10708879E 00	.00000000E 00		
-.11352291E 00	.00000000E 00		
-.35394474E 00	.39987513E 00	.66184586E 00	.53342291E 00
-.15036257E 01	.00000000E 00		
-.16729755E 01	.00000000E 00		
-.29282224E 00	.20086167E 01	.14425816E 00	.20298487E 01
-.13925174E 01	.23664376E 01	.50715413E 00	.27457479E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 6.000SEC.

REAL	IMAG
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.81490700E-02	.76839214E-02
-.10666535E 00	.00000000E 00
-.13433839E 00	.00000000E 00
-.10541366E 00	.12812794E 00
-.28441735E 00	.00000000E 00
-.17713904E 01	.00000000E 00
-.16087315E 00	.20892493E 01
-.77788548E 00	.19087338E 01

ROOTS OF A/C FRAME AT 6.000SEC.

REAL	IMAG
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.57777648E-01	.00000000E 00
-.38572154E-01	.00000000E 00
-.17713700E 01	.00000000E 00
-.15843871E 00	.20891454E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.44494036E-02	.00000000E 00
-.24849471E-01	.62088128E-01
-.75963851E 00	.18874615E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCAP) FOR CONTROL WEIGHTS= 10000. AT 6.000SEC.

REAL	IMAG	DAMPING	FREQ
-.57777648E-01	.00000000E 00		
-.57777648E-01	.00000000E 00		
-.57777648E-01	.00000000E 00		
-.57777648E-01	.00000000E 00		
-.57777648E-01	.00000000E 00		
-.81645285E-02	.77166486E-02	.72675960E 00	.11234153E-01
-.11391941E 00	.00000000E 00		
-.11753436E 00	.00000000E 00		
-.34832385E 00	.36696992E 00	.68843963E 00	.50596048E 00
-.16089352E 01	.00000000E 00		
-.17392323E 01	.00000000E 00		
-.29420185E 00	.21009492E 01	.13867973E 00	.21214481E 01
-.14131454E 01	.24991454E 01	.49221166E 00	.28710116E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 7.000SEC.

REAL	IMAG
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.92767990E-02	.96775134E-02
-.10923990E 00	.00000000E 00
-.13930526E 00	.00000000E 00
-.10714446E 00	.13069426E 00
-.28736076E 00	.00000000E 00
-.18468328E 01	.00000000E 00
-.17375634E 00	.21863935E 01
-.82084606E 00	.20496591E 01

ROOTS OF A/C FRAME AT 7.000SEC.

REAL	IMAG
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.62729204E-01	.00000000E 00
-.37762579E-01	.00000000E 00
-.18467901E 01	.00000000E 00
-.17165702E 00	.21862941E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.53338050E-02	.00000000E 00
-.24663779E-01	.62297038E-01
-.80438667E 00	.20298076E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 7.000SEC.

REAL	IMAG	DAMPING	FREQ
-.62729204E-01	.00000000E 00		
-.62729204E-01	.00000000E 00		
-.62729204E-01	.00000000E 00		
-.62729204E-01	.00000000E 00		
-.62729204E-01	.00000000E 00		
-.92926717E-02	.97125908E-02	.69131461E 00	.13442030E-01
-.11570699E 00	.00000000E 00		
-.12139570E 00	.00000000E 00		
-.34374175E 00	.38472662E 00	.66627009E 00	.51591953E 00
-.17143349E 01	.00000000E 00		
-.18260975E 01	.00000000E 00		
-.29747635E 00	.21946484E 01	.13431797E 00	.22147175E 01
-.14373302E 01	.26353883E 01	.47881251E 00	.30018643E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 8.000SEC.

REAL	IMAG
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.10338856E-01	.95497069E-02
-.11250372E 00	.00000000E 00
-.14371573E 00	.00000000E 00
-.10352207E 00	.13394400E 00
-.29188873E 00	.00000000E 00
-.19241516E 01	.00000000E 00
-.18696494E 00	.22872930E 01
-.86453506E 00	.21900195E 01

ROOTS OF A/C FRAME AT 8.000SEC.

REAL	IMAG
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.68129636E-01	.00000000E 00
-.37626650E-01	.00000000E 00
-.19241016E 01	.00000000E 00
-.18527422E 00	.22872106E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.49052220E-02	.00000000E 00
-.25234531E-01	.60527342E-01
-.84963510E 00	.21713360E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 8.000SEC.

REAL	IMAG	DAMPING	FREQ
-.68129636E-01	.00000000E 00		
-.68129636E-01	.00000000E 00		
-.68129636E-01	.00000000E 00		
-.68129636E-01	.00000000E 00		
-.68129636E-01	.00000000E 00		
-.11741138E 00	.00000000E 00		
-.10359168E-01	.95760273E-02	.73431859E 00	.14107185E-01
-.12527470E 00	.00000000E 00		
-.35137143E 00	.46211710E 00	.65799424E 00	.53400377E 00
-.12171533E 01	.00000000E 00		
-.19087186E 01	.00000000E 00		
-.29549131E 00	.22930715E 01	.12780589E 00	.23120320E 01
-.14623360E 01	.27721894E 01	.46658345E 00	.31342690E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 9.000SEC.

REAL	IMAG
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.11345441E-01	.93522413E-02
-.11458667E 00	.00000000E 00
-.14823075E 00	.00000000E 00
-.10811350E 00	.13375242E 00
-.29647097E 00	.00000000E 00
-.19986799E 01	.00000000E 00
-.20121833E 00	.23858560E 01
-.90806470E 00	.23288213E 01

ROOTS OF A/C FRAME AT 9.000SEC.

REAL	IMAG
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.74052534E-01	.00000000E 00
-.35859670E-01	.00000000E 00
-.19986311E 01	.00000000E 00
-.19987026E 00	.23857857E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.41436901E-02	.00000000E 00
-.26011962E-01	.59652955E-01
-.89446803E 00	.23110756E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS= 10000. AT 9.000SEC.

REAL	IMAG	DAMPING	FREQ
-.74052534E-01	.00000000E 00		
-.74052534E-01	.00000000E 00		
-.74052534E-01	.00000000E 00		
-.74052534E-01	.00000000E 00		
-.74052534E-01	.00000000E 00		
-.12132282E 00	.00000000E 00		
-.11369601E-01	.93719015E-02	.77164039E 00	.14734326E-01
-.12909728E 00	.00000000E 00		
-.35436129E 00	.39228285E 00	.67032927E 00	.52863765E 00
-.19157517E 01	.00000000E 00		
-.19826305E 01	.00000000E 00		
-.29357601E 00	.23914240E 01	.12184729E 00	.24093766E 01
-.14894886E 01	.29089873E 01	.45575940E 00	.32681468E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 10.000SEC.

REAL	IMAG
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.12326535E-01	.90602543E-02
-.11637335E 00	.00000000E 00
-.15245017E 00	.00000000E 00
-.10709529E 00	.13372003E 00
-.30162815E 00	.00000000E 00
-.20725934E 01	.00000000E 00
-.21542376E 00	.24829351E 01
-.95154632E 00	.24654478E 01

ROOTS OF A/C FRAME AT 10.000SEC.

REAL	IMAG
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.80599608E-01	.00000000E 00
-.34549007E-01	.00000000E 00
-.20725472E 01	.00000000E 00
-.21437125E 00	.24828768E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.31135475E-02	.00000000E 00
-.26977336E-01	.58693416E-01
-.93903298E 00	.24484503E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS= 10000. AT 10.000SEC.

REAL	IMAG	DAMPING	FREQ
-.80599608E-01	.00000000E 00		
-.80599608E-01	.00000000E 00		
-.80599608E-01	.00000000E 00		
-.80599608E-01	.00000000E 00		
-.80599608E-01	.00000000E 00		
-.12416346E 00	.00000000E 00		
-.12353161E-01	.90737312E-02	.80594594E 00	.15327530E-01
-.13277337E 00	.00000000E 00		
-.35090011E 00	.38807613E 00	.67068587E 00	.52319592E 00
-.20096831E 01	.00000000E 00		
-.20585844E 01	.00000000E 00		
-.29368672E 00	.24872614E 01	.11726174E 00	.25045401E 01
-.15193398E 01	.30450529E 01	.44646430E 00	.34030487E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 11.000SEC.

REAL	IMAG
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.13319379E-01	.86369998E-02
-.11776668E 00	.00000000E 00
-.15642227E 00	.00000000E 00
-.10574194E 00	.13325862E 00
-.30730079E 00	.00000000E 00
-.21456099E 01	.00000000E 00
-.22984320E 00	.25786803E 01
-.99514316E 00	.25993729E 01

ROOTS OF A/C FRAME AT 11.000SEC.

REAL	IMAG
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.87899924E-01	.00000000E 00
-.33222586E-01	.00000000E 00
-.21455689E 01	.00000000E 00
-.22903651E 00	.25786333E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.19351583E-02	.00000000E 00
-.28064726E-01	.57740295E-01
-.98352330E 00	.25829597E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 11.000SEC.

REAL	IMAG	DAMPING	FREQ
-.87899924E-01	.00000000E 00		
-.87899924E-01	.00000000E 00		
-.87899924E-01	.00000000E 00		
-.87899924E-01	.00000000E 00		
-.87899924E-01	.00000000E 00		
-.12705767E 00	.00000000E 00		
-.13348190E-01	.86441027E-02	.83936822E 00	.15902663E-01
-.13632334E 00	.00000000E 00		
-.34553267E 00	.37843630E 00	.67427348E 00	.51245181E 00
-.29994414E 01	.00000000E 00		
-.21328338E 01	.00000000E 00		
-.29462114E 00	.25827121E 01	.11333927E 00	.25994622E 01
-.15521788E 01	.31797965E 01	.43866527E 00	.35384128E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 12.000SEC.

REAL	IMAG
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.14323167E-01	.80518103E-02
-.11860929E 00	.00000000E 00
-.16012730E 00	.00000000E 00
-.10389675E 00	.13218568E 00
-.31351359E 00	.00000000E 00
-.22174925E 01	.00000000E 00
-.24450225E 00	.26726459E 01
-.10387788E 01	.27300764E 01

ROOTS OF A/C FRAME AT 12.000SEC.

REAL	IMAG
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.96120967E-01	.00000000E 00
-.31784913E-01	.00000000E 00
-.22174589E 01	.00000000E 00
-.24389434E 00	.26726084E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
-.53637959E-03	.00000000E 00
-.29306102E-01	.56854793E-01
-.10278800E 01	.27141031E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 12.000SEC.

REAL	IMAG	DAMPING	FREQ
-.96120967E-01	.00000000E 00		
-.96120967E-01	.00000000E 00		
-.96120967E-01	.00000000E 00		
-.96120967E-01	.00000000E 00		
-.96120967E-01	.00000000E 00		
-.13020481E 00	.00000000E 00		
-.14358707E-01	.80481804E-02	.87231677E 00	.16460427E-01
-.13969288E 00	.00000000E 00		
-.34138011E 00	.36053547E 00	.68755377E 00	.49651405E 00
-.21854184E 01	.00000000E 00		
-.22050853E 01	.00000000E 00		
-.29756071E 00	.26759446E 01	.11051721E 00	.26924379E 01
-.15881716E 01	.33126865E 01	.43230672E 00	.36737149E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 13.000SEC.

REAL	IMAG
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.11891895E 00	.00000000E 00
-.15325779E-01	.72746311E-02
-.16380918E 00	.00000000E 00
-.10172583E 00	.13063358E 00
-.31983665E 00	.00000000E 00
-.22883285E 01	.00000000E 00
-.25935417E 00	.27647899E 01
-.10824044E 01	.28570984E 01

ROOTS OF A/C FRAME AT 13.000SEC.

REAL	IMAG
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.10548581E 00	.00000000E 00
-.30314556E-01	.00000000E 00
-.22883036E 01	.00000000E 00
-.25890225E 00	.27647600E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.12578740E-02	.00000000E 00
-.30784191E-01	.56950289E-01
-.10720722E 01	.28414365E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS= 10000. AT 13.000SEC.

REAL	IMAG	DAMPING	FREQ
-.10548581E 00	.00000000E 00		
-.10548581E 00	.00000000E 00		
-.10548581E 00	.00000000E 00		
-.10548581E 00	.00000000E 00		
-.10548581E 00	.00000000E 00		
-.13407781E 00	.00000000E 00		
-.15410025E-01	.72127007E-02	.90570157E 00	.17014463E-01
-.14258882E 00	.00000000E 00		
-.34120253E 00	.34554812E 00	.70261832E 00	.48561577E 00
-.22732145E 01	.34993913E-02	.99999882E 00	.22732172E 01
-.30147380E 00	.27677271E 01	.10828421E 00	.27840976E 01
-.16223632E 01	.34445518E 01	.42609754E 00	.38074926E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 14.000SEC.

REAL	IMAG
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11913469E 00	.00000000E 00
-.16066598E-01	.68593704E-02
-.17466957E 00	.00000000E 00
-.10016289E 00	.12948108E 00
-.30936584E 00	.00000000E 00
-.23585095E 01	.00000000E 00
-.27421557E 00	.28551234E 01
-.11177303E 01	.25896244E 01

ROOTS OF A/C FRAME AT 14.000SEC.

REAL	IMAG
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.11629597E 00	.00000000E 00
-.29290763E-01	.00000000E 00
-.23584939E 01	.00000000E 00
-.27388365E 00	.28550999E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.65796416E-02	.00000000E 00
-.34014924E-01	.73562121E-01
-.11079004E 01	.29746403E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 14.000SEC.

REAL	IMAG	DAMPING	FREQ
-.11629597E 00	.00000000E 00		
-.11629597E 00	.00000000E 00		
-.11629597E 00	.00000000E 00		
-.11629597E 00	.00000000E 00		
-.11629597E 00	.00000000E 00		
-.13667733E 00	.00000000E 00		
-.16156204E-01	.68322141E-02	.92103072E 00	.17541439E-01
-.14621078E 00	.00000000E 00		
-.34120828E 00	.34896352E 00	.69911872E 00	.48805704E 00
-.23293597E 01	.00000000E 00		
-.23430494E 01	.00000000E 00		
-.31168997E 00	.28576852E 01	.10842774E 00	.28746331E 01
-.16576280E 01	.35716658E 01	.42097645E 00	.39375789E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 15.000SEC.

REAL	IMAG
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12052835E 00	.00000000E 00
-.17138985E-01	.53846842E-02
-.17760603E 00	.00000000E 00
-.10094971E 00	.13058097E 00
-.31870704E 00	.00000000E 00
-.24289820E 01	.00000000E 00
-.28862808E 00	.29444595E 01
-.11299112E 01	.30305789E 01

ROOTS OF A/C FRAME AT 15.000SEC.

REAL	IMAG
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.12895388E 00	.00000000E 00
-.29529046E-01	.00000000E 00
-.24289739E 01	.00000000E 00
-.28839595E 00	.29444425E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.80866172E-02	.00000000E 00
-.35387972E-01	.74918278E-01
-.11199753E 01	.30151240E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS. 10000. AT 15.000SEC.

REAL	IMAG	DAMPING	FREQ
-.12895388E 00	.00000000E 00		
-.12895388E 00	.00000000E 00		
-.12895388E 00	.00000000E 00		
-.12895388E 00	.00000000E 00		
-.12895388E 00	.00000000E 00		
-.17231417E-01	.53310516E-02	.95532475E 00	.18037235E-01
-.13440488E 00	.00000000E 00		
-.14930670E 00	.00000000E 00		
-.28788486E 00	.41577788E 00	.56926163E 00	.50571626E 00
-.24174946E 01	.00000000E 00		
-.23797384E 01	.00000000E 00		
-.31266040E 00	.29474693E 01	.10548575E 00	.29640061E 01
-.16836432E 01	.36237387E 01	.42135693E 00	.39957648E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 16.000SEC.

REAL	IMAG
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.12129803E 00	.00000000E 00
-.18258970E-01	.26080859E-02
-.17795458E 00	.00000000E 00
-.10074550E 00	.13067272E 00
-.33986916E 00	.00000000E 00
-.24979127E 01	.00000000E 00
-.30331021E 00	.30314124E 01
-.11438075E 01	.30339960E 01

ROOTS OF A/C FRAME AT 16.000SEC.

REAL	IMAG
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.14401335E 00	.00000000E 00
-.29300704E-01	.00000000E 00
-.24979133E 01	.00000000E 00
-.30315117E 00	.30313998E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.97435384E-02	.00000000E 00
-.36795601E-01	.76088451E-01
-.11334830E 01	.30171835E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 16.000SEC.

REAL	IMAG	DAMPING	FREQ
-.14401335E 00	.00000000E 00		
-.14401335E 00	.00000000E 00		
-.14401335E 00	.00000000E 00		
-.14401335E 00	.00000000E 00		
-.14401335E 00	.00000000E 00		
-.18336182E-01	.25156367E-02	.99071954E 00	.18507944E-01
-.13157695E 00	.00000000E 00		
-.15233181E 00	.00000000E 00		
-.16876302E 00	.43033582E 00	.36510417E 00	.46224622E 00
-.24485515E 01	.00000000E 00		
-.24909169E 01	.00000000E 00		
-.33655290E 00	.30305913E 01	.11037339E 00	.30492214E 01
-.17237086E 01	.36537001E 01	.42669057E 00	.40399265E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 17.000SEC.

REAL	IMAG
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.15224533E-01	.00000000E 00
-.12159080E 00	.00000000E 00
-.23605352E-01	.00000000E 00
-.17274199E 00	.00000000E 00
-.99987016E-01	.13014100E 00
-.38852799E 00	.00000000E 00
-.25653333E 01	.00000000E 00
-.31814451E 00	.31157462E 01
-.11604762E 01	.29674307E 01

ROOTS OF A/C FRAME AT 17.000SEC.

REAL	IMAG
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.16227730E 00	.00000000E 00
-.28816086E-01	.00000000E 00
-.25653432E 01	.00000000E 00
-.31803484E 00	.31157362E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.99572047E-02	.00000000E 00
-.37404211E-01	.66807448E-01
-.11492450E 01	.29472003E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS. 10000. AT 17.000SEC.

REAL	IMAG	DAMPING	FREQ
-.16227730E 00	.00000000E 00		
-.16227730E 00	.00000000E 00		
-.16227730E 00	.00000000E 00		
-.16227730E 00	.00000000E 00		
-.16227730E 00	.00000000E 00		
-.15225979E-01	.00000000E 00		
-.23687355E-01	.00000000E 00		
-.12102234E 00	.00000000E 00		
-.15516423E 00	.00000000E 00		
-.17789783E-01	.29126781E 00	.60963461E-01	.29181058E 00
-.25581793E 01	.73054720E-03	.99999996E 00	.25581794E 01
-.32482608E 00	.31171785E 01	.10364396E 00	.31340571E 01
-.17870675E 01	.36459363E 01	.44012620E 00	.40603524E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 18.000SEC.

REAL	IMAG
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.13157572E-01	.00000000E 00
-.11643363E 00	.00000000E 00
-.28735118E-01	.00000000E 00
-.16706014E 00	.00000000E 00
-.92525592E-01	.12219950E 00
-.49701780E 00	.00000000E 00
-.26302584E 01	.00000000E 00
-.33293445E 00	.31941979E 01
-.11712372E 01	.27090477E 01

ROOTS OF A/C FRAME AT 18.000SEC.

REAL	IMAG
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.18495925E 00	.00000000E 00
-.24992565E-01	.00000000E 00
-.26302856E 01	.00000000E 00
-.33284319E 00	.31941872E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.14010949E-01	.00000000E 00
-.39961415E-01	.61095963E-01
-.11579601E 01	.26773337E 01
.00000000E 00	.00000000E 00

CLOSED LOOP ROOTS (DISCOP) FOR CONTROL WEIGHTS= 10000. AT 18.000SEC.

REAL	IMAG	DAMPING	FREQ
-.18495925E 00	.00000000E 00		
-.18495925E 00	.00000000E 00		
-.18495925E 00	.00000000E 00		
-.18495925E 00	.00000000E 00		
-.18495925E 00	.00000000E 00		
-.13118301E-01	.00000000E 00		
-.70741767E-01	.00000000E 00		
-.28967359E-01	.00000000E 00		
-.13233640E-01	.11931860E 00	.11023419E 00	.12005023E 00
-.15576273E 00	.00000000E 00		
-.26265942E 01	.00000000E 00		
-.28504241E 01	.00000000E 00		
-.35456275E 00	.31924006E 01	.11038588E 00	.32120299E 01
-.17864391E 01	.34614207E 01	.45862252E 00	.38952276E 01

Figure 75. Eigenvalue Spectrums (continued)

CLOSED LOOP ROOTS AT 19.000SEC.

REAL	IMAG
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.12489183E-01	.00000000E 00
-.10757573E 00	.00000000E 00
-.31413622E-01	.00000000E 00
-.83672578E-01	.11134600E 00
-.16834691E 00	.00000000E 00
-.60881226E 00	.00000000E 00
-.26920363E 01	.00000000E 00
-.34608825E 00	.32641284E 01
-.11876837E 01	.24749644E 01

ROOTS OF A/C FRAME AT 19.000SEC.

REAL	IMAG
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.21274249E 00	.00000000E 00
-.20869598E-01	.00000000E 00
-.26920899E 01	.00000000E 00
-.34599882E 00	.32641168E 01
.00000000E 00	.00000000E 00
.00000000E 00	.00000000E 00
.62213290E-02	.00000000E 00
-.35483514E-01	.91807263E-01
-.11737563E 01	.24259966E 01
.00000000E 00	.00000000E 00

STOP 77774123

CLOSED LOOP ROOTS (DISCRP) FOR CONTROL WEIGHTS= 10000. AT 19.000SEC.

REAL	IMAG	DAMPING	FREQ
-.21274249E 00	.00000000E 00		
-.21274249E 00	.00000000E 00		
-.21274249E 00	.00000000E 00		
-.21274249E 00	.00000000E 00		
-.21274249E 00	.00000000E 00		
-.11829071E-01	.00000000E 00		
-.35941624E-01	.00000000E 00		
-.53089722E-01	.50283319E-01	.72603603E 00	.73122710E-01
.87698404E-01	.00000000E 00		
-.13296335E 00	.00000000E 00		
.85429444E 00	.00000000E 00		
-.26936350E 01	.00000000E 00		
-.34970008E 00	.32618574E 01	.10659803E 00	.32805493E 01
-.15539923E 01	.26583809E 01	.50466316E 00	.30792663E 01

Figure 75. Eigenvalue Spectrums (concluded)

SECTION VIII

VARIANCE CONTRIBUTION AND CRITICAL PARAMETER IDENTIFICATION

The variance contribution matrix as developed in Section VIII of Volume I, is used to show how to identify the important contributors to the weapon delivery performance.

This identification is facilitated if the starting value of the covariance matrix is diagonal. In this case, the impact covariance matrix can be written in terms of the components.

$$X = \sigma_1^2 (\phi_1 \phi_1') + \sigma_2^2 (\phi_2 \phi_2') + \cdots + \sigma_n^2 (\phi_n \phi_n')$$

where ϕ_i $i = 1, \cdots n$ are the column vectors of the transition (sensitivity) matrix ϕ as shown in Table XI. For the release error variances shown in Table XII, the components of the nominal impact variances are given in Table XIII, together with the impact variances. By inspection of Table XIII the following identifications are made:

The important contributors to the down-range error variance σ_{xe}^2 are:

- The longitudinal velocity states, u, v and the pitch attitude θ.

The important contributors to the cross-range error variance σ_{ye}^2 are:

- The side velocity component v and the yaw angle ψ.

Therefore, for the weapon delivery, the most critical states requiring tight control are u, v, w, θ, and ψ for weapons stationed near the cg of the aircraft.

These conclusions are based on the weapon dynamics only. For the aircraft-plus-weapon combination, one starts out with a diagonal aircraft initial covariance matrix and develops the total transition matrix from dive to impace given by

$$\phi = \phi_b H_+ \phi_a$$

where

ϕ_a = aircraft transition matrix at release

H_+ = discrete transition matrix at release

ϕ_b = weapon transition matrix at impact

The columns of this matrix together with the initial error variances determine the main contributors.

It is interesting to note that, by properly correlating the errors, a reduction in impact variances is possible. It is conjectured that the optimal weapon delivery controller which controls the evolution of the error covariance matrix essentially does that. Inspection of Figure 70 shows that the contribution of the release cross-covariance term $E\{u\,\theta\}$ to the downrange impact variance is negative.

A program listing for computing the contributions of diagonal variances is given in Figure 76. Figure 77 shows the outputs of this program. For each state impact variance, the first row shows the initial release variances, the second row shows the multipliers (sensitivity coefficients), the third row shows the variance components, and the fourth row shows the sum of the components.

Table XI. Sensitivity Matrix ϕ of a Weapon

	x_e	h_e	u	θ	q	w	y_e	ψ	r	v
x_e	1.0	$.32\times10^{-5}$	$.29\times10^{2}$	$.98\times10^{7}$	$.41\times10^{1}$	$.21\times10^{2}$	0	0	0	0
h_e	0	.996	$.21\times10^{2}$	$.14\times10^{8}$	$.68\times10^{2}$	$.31\times10^{2}$	0	0	0	0
u	0	$.5\times10^{-6}$	.82	$.19\times10^{5}$	.503	$.45\times10^{-1}$	0	0	0	0
θ	0	0	$.6\times10^{-7}$	.60	$.11\times10^{-5}$	$.13\times10^{-5}$	0	0	0	0
q	0	0	$.37\times10^{-9}$	.79	$.19\times10^{-6}$	$.20\times10^{-8}$	0	0	0	0
w	0	0	$.14\times10^{-9}$	.13	$.31\times10^{-3}$	$.93\times10^{-8}$	0	0	0	0
y_e	0	0	0	0	0	0	2.0	$.14\times10^{8}$	$.35\times10^{2}$	$.50\times10^{2}$
ψ	0	0	0	0	0	0		1.0	$.24\times10^{-5}$	$.36\times10^{-5}$
r	0	0	0	0	0	0	0	0	$.19\times10^{-6}$	$.80\times10^{-11}$
v	0	0	0	0	0	0	0	0	$.25\times10^{-3}$	$.15\times10^{-6}$

Table XII. Release Error Variances

σ^2_{xe}	σ^2_{he}	σ^2_u	σ^2_θ	σ^2_q	σ^2_w	σ^2_{ye}	σ^2_ψ	σ^2_r	σ^2_v
100	100	100	10^{-6}	10^{-6}	25	100	10^{-4}	10^{-4}	25

Table XIII. Components of Nominal Impact Variances

	x_e	h_e	u	θ	q	w	y_e	ψ	r	v
$\sigma^2_{xe} = .36189 \times 10^4$	100 +	$.32 \times 10^{-3}$ +	$.29 \times 10^4$ +	$.98 \times 10^1$ +	$.41 \times 10^{-5}$ +	$.52 \times 10^3$ +	0 +	0 +	0 +	0
$\sigma^2_{ne} = .2970 \times 10^4$	0 +	$.996 \times 10^2$ +	$.207 \times 10^4$ +	$.14 \times 10^2$ +	$.68 \times 10^{-4}$ +	$.77 \times 10^3$ +	0 +	0 +	0 +	0
$\sigma^2_u = .833 \times 10^2$	0 +	.5 +	$.82 \times 10^2$ +	$.18 \times 10^{-1}$ +	$.51 \times 10^6$ +	$.11 \times 10^1$ +	0 +	0 +	0 +	0
$\sigma^2_\theta = .39 \times 10^{-4}$	0 +	0 +	$.6 \times 10^{-5}$ +	$.6 \times 10^{-6}$ +	0 +	$.32 \times 10^{-4}$ +	0 +	0 +	0 +	0
$\sigma^2_q = .88 \times 10^{-7}$	0 +	0 +	$.37 \times 10^{-7}$ +	$.79 \times 10^{-9}$ +	0 +	$.51 \times 10^{-7}$ +	0 +	0 +	0 +	0
$\sigma^2_w = .38 \times 10^{-6}$	0 +	0 +	$.14 \times 10^{-7}$ +	$.13 \times 10^{-6}$ +	0 +	$.23 \times 10^{-6}$ +	0 +	0 +	0 +	0
$\sigma^2_{ye} = .27 \times 10^4$	0 +	0 +	0 +	0 +	0 +	0 +	100 +	$.14 \times 10^4$ +	0 +	$.12 \times 10^4$
$\sigma^2_\psi = .19 \times 10^{-3}$	0 +	0 +	0 +	0 +	0 +	0 +	0 +	$.1 \times 10^{-3}$ +	0 +	$.9 \times 10^{-4}$
$\sigma^2_r = .22 \times 10^{-9}$	0 +	0 +	0 +	0 +	0 +	0 +	0 +	0 +	$.19 \times 10^{-10}$ +	$.2 \times 10^{-9}$
$\sigma^2_v = .39 \times 10^{-5}$	0 +	0 +	0 +	0 +	0 +	+	0 +	0 +	$.25 \times 10^{-7}$ +	$.38 \times 10^{-5}$

```
ΔFØRTRAN LS,GØ                                                              A=00
      DIMENSIØN PHI(20,20),PSI(10,10),XR(10),PSIXR(10,11),IH(10),SIG(3),
     1CEP(2)
    1 FØRMAT(8E10.4)
      READ(2)PHI
      READ(5,1)XR
      DØ 10 I=1,10
      DØ 10 J=1,10
   10 PSI(I,J)=PHI(I,J)*PHI(I,J)
      DØ 11 I=1,10
      DØ 11 J=1,10
   11 PSIXR(I,J)=PSI(I,J)*XR(J)
      DØ 12 I=1,10
      PSIXR(I,11)=0.
      DØ 12 J=1,1C
   12 PSIXR(I,11)=PSIXR(I,11)+PSIXR(I,J)
      READ(5,2)IH
    2 FØRMAT(10A4)
      DØ 20 I=1,10
      WRITE(9,30)IH(I)
   30 FØRMAT(1H1/7X,A4)
      WRITE(9,31)
   31 FØRMAT(/115H      XE          HE              U            THETA
     1Q         W         YE          PSI             R                   V//)
      WRITE(9,32)(PSI(I,J),J=1,10)
   32 FØRMAT(10E12.5)
      WRITE(9,33)
   33 FØRMAT(//)
      WRITE(9,32)(XR(J),J=1,10)
      WRITE(9,33)
      WRITE(9,32)(PSIXR(I,J),J=1,10)
      WRITE(9,33)
      WRITE(9,34)PSIXR(I,11)
   34 FØRMAT(6H SUM =E12.5)
   20 CØNTINUE
      SIG(1)=SQRT(PSIXR(1,11))
      SIG(2)=SQRT(PSIXR(7,11))
      SIG(3)=SQRT(PSIXR(2,11))
      CALL CEPC(SIG,CEP)
 2030 FØRMAT(////7X,16H CEP HØRIZØNTAL=E15.8,14H CEP VERTICAL=E15.8/)
      WRITE(9 ,2030)CEP(1),CEP(2)
      END
```

Figure 76. Variance Contribution Program Listing

XE

XE	HE	U	THETA	Q	W	YE	PSI	R	V
•10000E 01	•32865E-05	•29863E 02	•98855E 07	•41849E 01	•20908E 02	•00000E 00	•52039E-11	•15509E-16	•18952E-16
•10000E 03	•10000E 03	•10000E 03	•10000E-05	•10000E-05	•25000E 02	•10000E 03	•10000E-03	•10000E-03	•25000E 02
•10000E 03	•32865E-03	•29863E 04	•98855E 01	•41849E-05	•52270E 03	•00000E 00	•52039E-15	•15509E-20	•47381E-15

SUM = .36189E 04

HE

XE	HE	U	THETA	Q	W	YE	PSI	R	V
•00000E 00	•99629E 00	•20780E 02	•14032E 08	•68179E 02	•31139E 02	•00000E 00	•00000E 00	•00000E 00	•00000E 00
•10000E 03	•10000E 03	•10000E 03	•10000E-05	•10000E-05	•25000E 02	•10000E 03	•10000E-03	•10000E-03	•25000E 02
•00000E 00	•99629E 02	•20780E 04	•14032E 02	•68179E-04	•77849E 03	•00000E 00	•00000E 00	•00000E 00	•00000E 00

SUM = .29702E 04

U

XE	HE	U	THETA	Q	W	YE	PSI	R	V
•00000E 00	•54897E-06	•82203E 00	•18895E 05	•50336E 00	•45637E-01	•00000E 00	•00000E 00	•00000E 00	•00000E 00
•10000E 03	•10000E 03	•10000E 03	•10000E-05	•10000E-05	•25000E 02	•10000E 03	•10000E-03	•10000E-03	•25000E 02
•00000E 00	•54897E-04	•82203E 02	•18895E-01	•50336E-06	•11409E 01	•00000E 00	•00000E 00	•00000E 00	•00000E 00

SUM = .83363E 02

Figure 77. Variance Contribution Program Outputs

THETA

XE	HE	U	THETA	Q	W	YE	PSI	R	V
.00000E 00	.51653E-14	.62963E-07	.60319E 00	.11230E-05	.13050E-05	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.10000E 03	.10000E 03	.10000E 03	.10000E-05	.10000E-05	.25000E 02	.10000E 03	.10000E-03	.10000E-03	.25000E 02
.00000E 00	.51653E-12	.62963E-05	.60319E-06	.11230E-11	.32625E-04	.00000E 00	.00000E 00	.00000E 00	.00000E 00

SUM = .39524E-04

Q

XE	HE	U	THETA	Q	W	YE	PSI	R	V
.00000E 00	.40369E-15	.37068E-09	.79635E-03	.19038E-06	.20427E-08	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.10000E 03	.10000E 03	.10000E 03	.10000E-05	.10000E-05	.25000E 02	.10000E 03	.10000E-03	.10000E-03	.25000E 02
.00000E 00	.40369E-13	.37068E-07	.79635E-09	.19038E-12	.51067E-07	.00000E 00	.00000E 00	.00000E 00	.00000E 00

SUM = .88931E-07

W

XE	HE	U	THETA	Q	W	YE	PSI	R	V
.00000E 00	.21308E-12	.14845E-09	.13162E 00	.30946E-03	.93874E-08	.00000E 00	.00000E 00	.00000E 00	.00000E 00
.10000E 03	.10000E 03	.10000E 03	.10000E-05	.10000E-05	.25000E 02	.10000E 03	.10000E-03	.10000E-03	.25000E 02
.00000E 00	.21308E-10	.14845E-07	.13162E-06	.30946E-09	.23469E-06	.00000E 00	.00000E 00	.00000E 00	.00000E 00

SUM = .38148E-06

Figure 77. Variance Contribution Program Outputs (continued)

YE

XE	HE	U	THETA	Q	W	YE	PSI	R	V
•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•10000E 01	•14081E 02	•35392E 02	•50931E 02
•10000E 03	•10000E 03	•10000E 03	•10000E-05	•10000E-05	•25000E 02	•10000E 03	•10000E-03	•10000E-03	•25000E 02
•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•10000E 03	•14081E 04	•35392E-02	•12733E 04

SUM = .27814E 04

PSI

XE	HE	U	THETA	Q	W	YE	PSI	R	V
•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•10000E 01	•24198E-05	•36152E-05
•10000E 03	•10000E 03	•10000E 03	•10000E-05	•10000E-05	•25000E 02	•10000E 03	•10000E-03	•10000E-03	•25000E 02
•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•10000E-03	•24198E-09	•90380E-04

SUM = .19038E-03

R

XE	HE	U	THETA	Q	W	YE	PSI	R	V
•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•19283E-06	•83969E-11
•10000E 03	•10000E 03	•10000E 03	•10000E-05	•10000E-05	•25000E 02	•10000E 03	•10000E-03	•10000E-03	•25000E 02
•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•00000E 00	•19283E-10	•20992E-09

SUM = .22921E-09

Figure 77. Variance Contribution Program Outputs (continued)

```
          V
   XE           HE           U          THETA          Q          W          YE          PSI          R          V
 .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .25036E-03   .15500E-04
 .10000E 03   .10000E 03   .10000E 03   .10000E-05   .10000E-05   .25000E 02   .10000E 03   .10000E-03   .10000E-03   .25000E 02
 .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .00000E 00   .25036E-07   .38750E-05

SUM =  .39001E-05

       CEP HORIZONTAL=  .67145803E 02 CEP VERTICAL=  .63558791E 02

*STOP* 7777412
```

Figure 77. Variance Contribution Program Outputs (concluded)

SECTION IX

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions were drawn from the demonstration example:

- The results of the stationary-nonstationary comparison analysis indicated that no appreciable difference existed between the delivery performances obtained from the fixed and the time-varying controllers. This led us to believe that the use of fixed optimal gains in the weapon delivery controller would be sufficient.

- It has been observed that the steady-state values of the performance measure for a frozen-time point linear data is considerably higher than that of the finite-time model. For this reason, the weapon delivery performance evaluation (i.e., computation of the total covariance and the CEP) should be based on the finite-time (i.e., nonstationary) model.

- An aircraft using the optimal controller with a perfect measurement system reduced the CEP 10 to 1 with respect to a free airframe.

- The contribution matrix of an iron bomb indicated that: (a) the longitudinal states, u, w, and θ were the prime contributors to the down-range impact variances, and (b) the lateral states ψ and v were the major contributors to the cross-range impact covariance.

Limitations inherent in the example included:

- Only order-of-magnitude checks were made on the time-varying data generated in the demonstration example. More elaborate checking via data transformation as explained on page 105 of Volume I is needed to validate the data prior to extensive parametric study of a given system.

- The aerodynamic data tables for the airframe used in the demonstration example are limited to a maximum Mach number of 0.8.

The primary emphasis in this study has been on the model and software development and the demonstration of their use. These have been achieved. For future work, a detailed parametric error analysis study using ADAPS is recommended.

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13. ABSTRACT

The testing and use of ADAPS is demonstrated by performing an analysis with a specified iron bomb (M117) and a representative tactical fighter-bomber aircraft (F4). The demonstration example revealed no appreciable performance difference between the time-invariant and time-varying optimal controllers for the weapon delivery process. The contribution matrix of an iron bomb indicated that the major contributors to the CEP are the velocity and the attitude-state errors at release.

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