NASA CR-147394

(NASA-CR-147394) THE 3-AXIS DYNAMIC MOTION SIMULATOR (DMS) SYSTEM Final Report (Contraves Goerz Corp., Pittsburgh, Pa.) 175 p HC $6.75 CSCL 14B

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Contraves
Goerz
Corporation

301 Alpha Drive, Pittsburgh, Pa. 15238

The American Subsidiary of Contraves AG,
Oerlikon-Bührle Holding

FINAL REPORT

FOR THE

3-AXIS DYNAMIC MOTION SIMULATOR (DMS)

SYSTEM

R-3599

The American Subsidiary of Contraves AG, Oerlikon-Bührle Holding

FINAL REPORT

FOR THE

3-AXIS DYNAMIC MOTION SIMULATOR (DMS)

SYSTEM

(Customer Order No. NAS9-14185)

R-3599

K-00997

November 22, 1975

Prepared for:

NASA LBJ Space Center
Houston, Texas

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1.0 INTRODUCTION

This document is the final report covering NASA Contract No. NAS 9-14185, issued by NASA LBJ Space Center in Houston, Texas.

The scope of the contract was to design, construct, deliver, install, and test one (1) three-axis dynamic motion simulator (DMS), consisting of one (1) three-degree of freedom test table, one (1) control electronics system, and documentation, as required in the data requirements list (DRL), which is a part of the NASA specification.

The DMS system was designed, built, assembled, and tested by the Contraves-Goerz Corporation located in Pittsburgh, Pennsylvania.

2.0 SIGNIFICANT CONCTRACTUAL EVENTS

The contract NAS9-14185 was issued to the Fecker Systems Division of Owens-Illinois, Inc., Pittsburgh, Pennsylvania by NASA LBJ Space Center, Houston, Texas, on June 24, 1974. It then was executed on July 1, 1974.

During the course of the contract, (in November 1974) Fecker Systems Division was acquired by Contraves-Goerz Corporation, Pittsburgh, Pennsylvania. Contraves-Goerz Corporation continued the contractual obligation and shipped, installed, and performed the final checkout at NASA JSC Houston, Texas.

2.1 DETAILED EVENTS

Engineering and design efforts were started immediately on receipt of the contract, followed by fabrication of the hardware.

Assembly and preliminary testing were done in Pittsburgh, Pennsylvania. Shipment of the complete system occured on July 31, 1975.

Installation at the site in Houston, Texas was done in the week of August 4, 1975, followed by electrical systems checkout and training which was performed during the two-week period from August 11 through August 22, 1975.

Final acceptance testing at NASA JSC, Houston, Texas, was performed during the period of September 29 through October 9, 1975.

3.0 ACCOMPLISHED SCHEDULE

3.1 SCHEDULE REQUIREMENTS

The contractual schedule requirements are listed below:

A. Equipment

Contraves-Goerz shall deliver the three axis DMS within twelve (12) months after date of receipt of a signed copy of this contract.

B. Installation and Checkout

Contraves-Goerz shall supervise the installation and checkout of the three axis DMS immediately upon delivery and complete the installation and checkout within fifteen (15) days after delivery of the DMS.

C. Final Acceptance Tests

Final acceptance testing shall be performed at JSC. They shall be completed within a continuous two-week period as soon as possible, but no later than 45 days after installation and checkout. Contraves-Goerz shall allow forty-five (45) days from completion of installation for the Government representative to make final acceptance.

D. Documentation

Contraves-Goerz shall deliver all documentation, in accordance with the Data Requirements List (DRL), which is an attachment to the Statement of Work.

3.2 BARCHART OF ACCOMPLISHED SCHEDULE

Figures 1 and 2 show the accomplished schedules during the contract period. They also show pertient dates for various special events, such as design reviews, critical design reviews, etc.

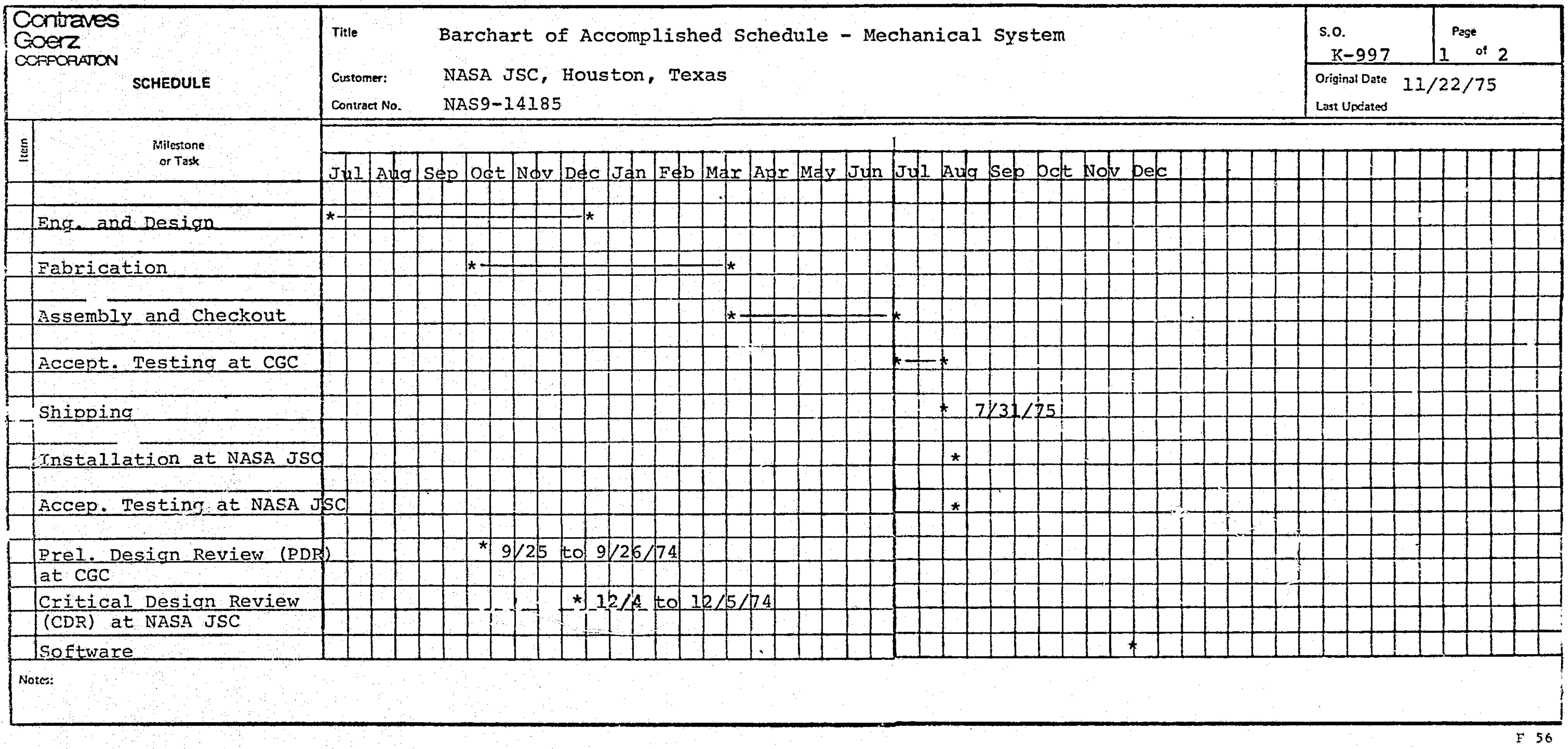


Figure 1. Barchart of Accomplished Schedule
Mechanical System

Contraves Goerz Corporation

SCHEDULE

Title: Barchart of Accomplished Schedule - Electrical System

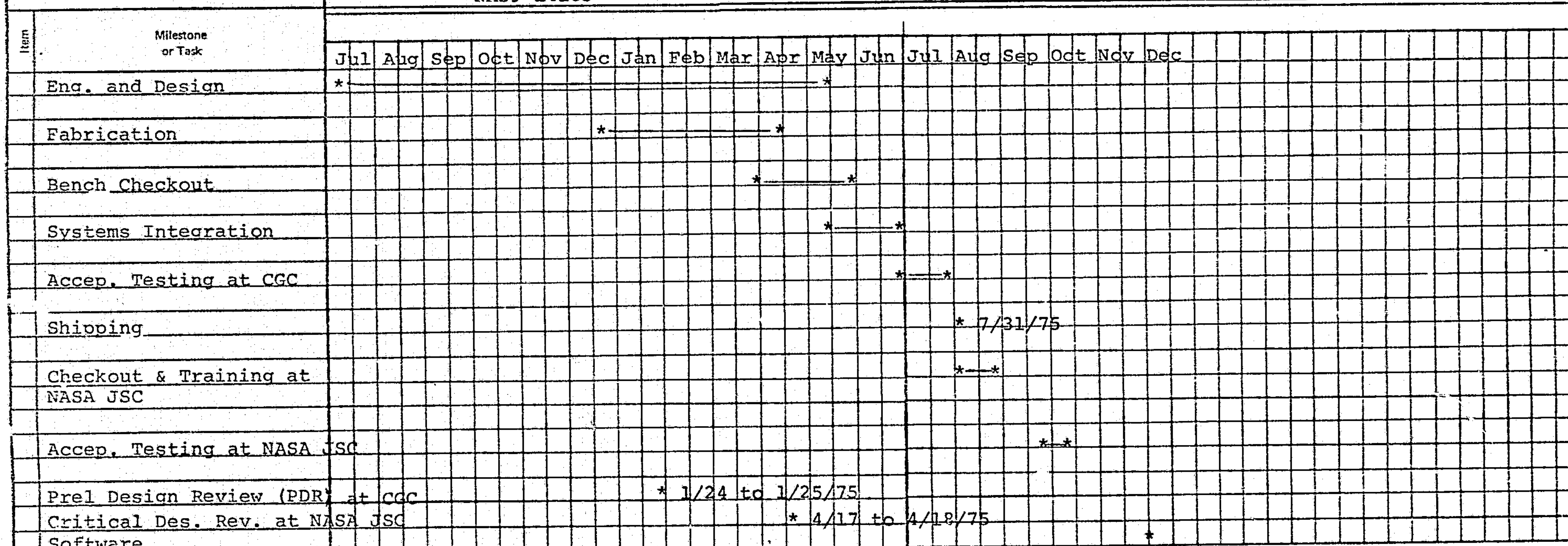
Customer: NASA JSC, Houston, Texas

Contract No. NAS9-14185

S.O. K-997

Original Date 11/22/75

Last Updated



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3.3 COMMENTS CONCERNING ACCOMPLISHED SCHEDULE

The contract required a delivery of twelve (12) months for the equipment. A total of thirteen (13) months were required to design, build, and checkout the equipment.

Major problems causing a delay in delivery occured during the design phase. Frequent computer breakdowns during the structural analysis of the mechanical system caused some delay in releasing manufacturing information. In addition, the procurement of large cast structures required longer lead-times than normal, because of a work overload in the pattern-making industry. Otherwise, most of the subcontractor and vendor items were received as scheduled in the PERT-chart submitted during the precontract phase.

4.0 LIST OF DOCUMENTATION PROVIDED UNDER THIS CONTRACT

The documentation provided to NASA JSC, during and at the end of the contract NAS9-14185 is itemized below.

4.1 MONTHLY TECHNICAL PROGRESS REPORTS

A total of twelve (12) progress reports were submitted under this contract. Progress report No. 1 was issued on August 12, 1975 and progress report No. 12 on July 18, 1975. The reports are numbered F(3)-997-023-022-2496-1 through -12.

4.2 PHASE/MILESTONE CHART

A phase/milestone chart in the form of a PERT chart was prepared and updated monthly and submitted as part of the Technical Progress Reports (refer to Section 4.1).

4.3 ACCEPTANCE TEST PLAN

An acceptance test plan, document number TP-3512, was submitted to NASA JSC for review.

4.4 DESIGN ANALYSIS REPORT

Two (2) design analysis reports (one mechanical and one electrical) were prepared and submitted at the critical design review (CDR) meetings, held at NASA JSC, Houston, Texas. The file number for the mechanical design report is F(7)-997-023-022-2539, and for the electrical design report is TR-3513.

4.5 MANUALS

4.5.1 MAINTENANCE AND OPERATION MANUALS

A maintenance and operation manual was prepared by Contraves-Goerz Corporation. The final issue is being submitted with this report. The file number is IM-3557.

4.5.2 VENDOR MANUALS

Vendor manuals for the following equipment are provided under this contract:

A) Rockland Synthesizer Model 5100

B) Exact Oscillator Model 605

C) Exact Oscillator Model 337

D) Compunetics CIE Electronics Model 4490

4.6 DESIGN DOCUMENTATION

4.6.1 DESIGN DOCUMENTATION, PRELIMINARY

Certain preliminary design documentation (drawings), was submitted at the mechanical and electrical critical design review meetings, held at NASA JSC in Houston, Texas.

4.6.2 DESIGN DOCUMENTATION, FINAL

Tables 1a and 1b list the final and updated drawings and parts lists which are supplied under this contract. Mechanical and electrical drawings are listed separately.

TABLE 1a

ITEMIZED DRAWING LIST

(MECHANICAL)

ITEM	LEVEL	DWG.NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
1		700-0075	1	3-Axis Dynamic Motion Simulator	A	PL only Sheets 1, 2	B					
2		267-0500	1	Three-Axis Dynamic Motion Simulator-General Arrangement	D	1 thru 7	B	D	1,2,3,4	E		
3		267-0501		Three-Axis Motion Simulator-Middle Axis Assembly	D	1 thru 7	B	C	1,2,3	E		
4		267-0502		Three-Axis Dynamic Motion Simulator-Inner Axis Assembly	D	1 thru 8	B	C	1,2,3	E		
5		500,399	1	2-Passage Rotary Joint		1	B		1	D		
6		267-0508	1	Cable Wrapper Assembly		1,2	B		1	E		
7		212-0105	2	Lock Assembly	B	1	B		1	C		
8		267-1337	1	Package Mt'g. Platform					1,2	E		
9		267-1338	1	Machining Assy Platform					1,2	E		

TABLE 1b

ITEMIZED DRAWING LIST

(ELECTRICAL)

LEVEL	DWG.NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
0	701053		Block Diagram		None			None	E		Block Diagram
0	700-007		Top Assembly								1
1	267-0500		Table Wiring						E		5,6,7,8
2	005-5143	3	Rotor Amps		1	B		1			
3	3A8-A	1	Rotor Amp P/C Board			C		6	C		1
1 2	701018 see shts 2 to 6		Console Assy		1,2,3,4,5	E		1	E		2,3,4
1	700890		Extender (top edge conn)		1	C		1			same
1	700067	2	60 Pin Extender		1	C		1			
1	155-0092		Extender Card Assembly		N/A	C		N/A			

TABLE 1b (cont)
ITEMIZED DRAWING LIST
(ELECTRICAL)

ITEM	LEVEL	DWG. NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
14	2	700805	2	Ind. Fbk. Cable		1			none	B		1
15	2	701029		Interconnect Cable		1			none	C		1
16	2	701030		"		1			none	C		1
17	2	701031		"		1			none	C		1
18	2	701032		"		1			none	C		1
19	2	701034		"		1			none	E		1
20	2	701036		Servo Error Cables		1			none	B		1
21	2	701012		Logic & Display Supply		1,2	E		1	E		2
22	2	701013		Power Supply		1,2	E		1	E		2
23	2	712-0007	1	Inner Axis Dual Power Amp		1,2,3,4,5,6	E		1	E		2
24	3	007-0153	1	DC Preamp		1,2	D		1			same
25	3	007-0154	1	DC Preamp		1,2	D		1			same
26	2	712-0007	2	Middle & Outer Axis Dual Pwr Amp		1,2,3,4,5,6	E		1	E		2
27	3	007-0155	1	DC Preamp		1,2	D		1			same
28	3	007-0156	1	DC Preamp		1,2	D		1			same

TABLE 1b (cont)

ITEMIZED DRAWING LIST

(ELECTRICAL)

ITEM	LEVEL	DWG.NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
29	2	700198	6	Display Panel		1	D		1			none
30	3	3M7	8	4 Digit Display Board		1	C		1	C		5
31	2	700198	2	Display Panel		1	D		1			none
32	3	3M7	2	Display Board		1	C		1	C		5
33	2	700198	5	Display Panel		1	D		1			none
34	3	3M7	3	Display Board		1	C		1	C		5
35	2	701017		Console Control Panel		1,2,3	E		1	E		2
36	3	701070		Torquer Delay Card		1	C		1			same
37	2	701005		R/O Chassis		1,2,3	E		1	E		2,3
38	3	700375		BCD R/O Tray		1,2	E		1	E		2,3
39	3	700899	2	Zero Crossing Detector		1,[illegible],3	C		2	C		4
40	3	700899	5	"		"	"		"	"		5
41	3	700036	9	8.6 MHz VCO Card		1,2,3,4,5,6	C		6	C		7
42	4	700035	2	VCO Subassy		1	B		1,6	B		2
	3	700036	8			1,2,3,4,5,6	C		6	C		7
	4	700035	1			1	B		1,6	B		2

TABLE 1b (cont)

ITEMIZED DRAWING LIST

(ELECTRICAL)

ITEM	LEVEL	DWG.NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
43	3	701037		Timing Tray		1,2	E		1			same
44	3	700034	1	Phase & Amp Det. Card		1,2,3,4	C		1	C		2
45	3	700032	1	Phase & Amp Control Card		1,2,3	C		1	C		2
46	3	700043	1	Ind. Stator Amp		1,2,3,4,5	C		1,6,7,10	D		10
47	3	701006		Absolute Pulse Gen		1	E		1			same
48	2	701009		Cmd Chassis		1,2	E		1	E		2
49	3	701010		Posn Cmd Tray		1,2	E		1			same
50	3	700899	6	Dual Zero Crossing Det		1,2,3	C		1	C		8
51	3	700075	6	Coarse/Fine Switch Card		1,2,3,4	C		1	C		2,6 (usage chart)
52	3	701011		C/F Posn Output Card		1,2	C		1	C		2
53	2	701014		Station Control chassis		1,2,3	E		1	E		2,3
54	3	701035		Direct Rate R/O Tray		1,2	E		1			same
55	3	701007		Interface to CIE		1	E		1,2			same
56	3	700256	3	Manual Control Tray		1,2	E		1	E		2
57	3	700079		Incr. Pulse Gen		1,2	E		1			same

TABLE 1b (cont)

ITEMIZED DRAWING LIST

(ELECTRICAL)

ITEM	LEVEL	DWG.NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
58	2	701047		3 Axis Servo Chassis		1,2,3	E		1	E		2,3,4,5
59	3	701016	1	Rate Trip Card		1,2	C		1			same
60		"	2	"			C		1			
61		"	3	"			C		1			
62	3	701044		Zero Posn & Mode Sync Card		1	D		1			same
63	3	701045		Posn Drift Summation Card		1	D					
64	3	701088	1	Acceleration Comparator		1,2,3	C		1			
65		"	2	"		"	C		1			
66		"	3	"		"	C		1			
67	3	701038		Accel Storage Buffer		1	D		1			same
68	3	701040		~~Dia~~ D/A Switch & Sample & Hold		1,2	D		1			same
69	3	701050		Mode Switching & Tach Buffer		1	D		1			same
70	3	701039		Acceleration Comparator		1,2	D		1			same
71	3	701051		Earth Rate Sign Switch		1	D		1			same
72	3	701042	1	Servo Summing Amp Card		1,2,3	D		1			same
73		"	2	"			D		2			same
74		"	3	"			D		3			same
75		"	4	"			D		4			same

TABLE 1b (cont)

ITEMIZED DRAWING LIST

(ELECTRICAL)

ITEM	LEVEL	DWG.NO.	DASH NO.	TITLE	REV.	PARTS LIST SHEETS	SIZE	REV.	ASSEMBLY SHEETS	SIZE	REV.	SCH. SHTS.
76	3	701015		Acceleration Limit Card		1	C		1			same
77	3	701043		Rate Osc. Amp Card		1	D		1			same
78	3	701041		Coarse Drift Det. Card		1,2	D		1			same
79	3	701079		Low Rate Clamp Enable		1	D		1			same
80	0	N/A		Family Tree		N/A			N/A			N/A

5.0 TEST RESULTS

5.1 PRELIMINARY TEST RESULTS

Preliminary results of tests performed at the Contraves-Goerz plant in Pittsburgh, Pennsylvania were submitted previously (in September 1975) under document number TP-3512A.

5.2 FINAL TEST RESULTS

Final results of the tests performed at the installation site at NASA JSC in Houston, Texas, are submitted as a separate item per the Data Requirement List (DRL) and are included in this final report as Appendix A.

6.0 RECOMMENDATIONS

6.1 SLIP RINGS ON OUTER AXIS

The use of slip rings instead of a cable wrapper on the outer axis would improve the system with regard to an unlimited rotation angle in both the clockwise and counter-clockwise directions. However, the noise level and cross talk problems may increase somewhat.

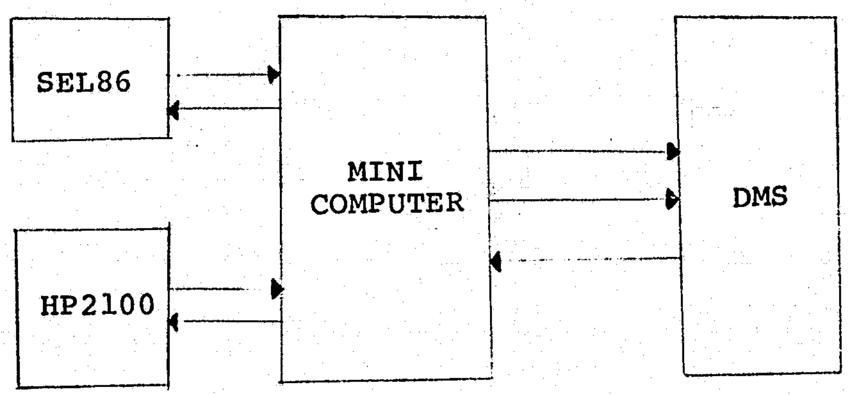
6.2 COMPUTER INTERFACE EQUIPMENT

6.2.1 GENERAL

In any new design of similar equipment, a different approach to the interface should be considered.

The suggested approach would be to use a mini-computer to perform the function of the CIE interface. In this scheme the minicomputer would be used to process all data which would be used external to the system. This means that all number conversions would be accomplished via the mini-computer. Other functions such as precision acceleration to a rate and precision rate to a position could be handled by software. Also variable position bias could be calculated by the mini-computer to allow the user access to adjust the zero of the readout and command. Also, the rate readout could be calculated by the mini-computer to determine the rate by a 100-point best straight line fit to position giving better confidence in the measured rate.

The I/O required for the SEL-86 and an HP2100 could be via I/O slots in the mini-computer or may be by DMA access to the memory for a faster data transfer rate. The block diagram of the system would be as shown below.



Modification of the present hardware is discussed in Section 6.2.2 and 6.2.3.

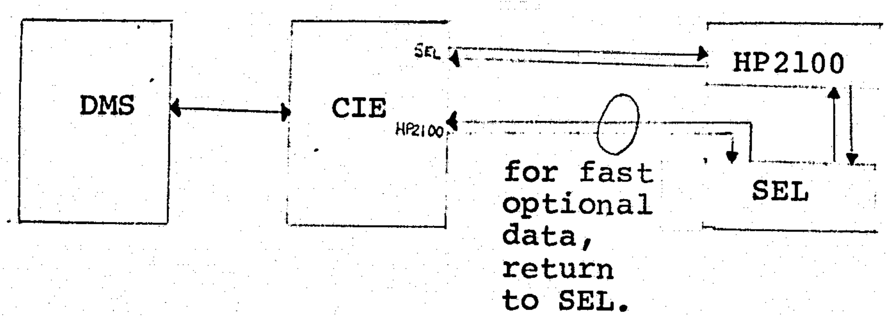
6.2.2 ADD DEDICATED HP2100 TO PRESENT SYSTEM USING CIE

The addition of a dedicated HP2100 to the system would allow higher order functions to be executed using a HP2100 as the system controller. One specific function would be a profiled rate to a position. This would be done by using the HP2100 to change rates on a time base interrupt and use the axis position readout as a feedback element. In this manner, controlled accelerations and decelerations could be accomplished with the computer determining when to begin deceleration so that the axis will smoothly stop at the final position. A simplified flow diagram is shown in Figure 1. This does not show any sub-routine required for converting the calculated position to a number less than 360.0 degrees.

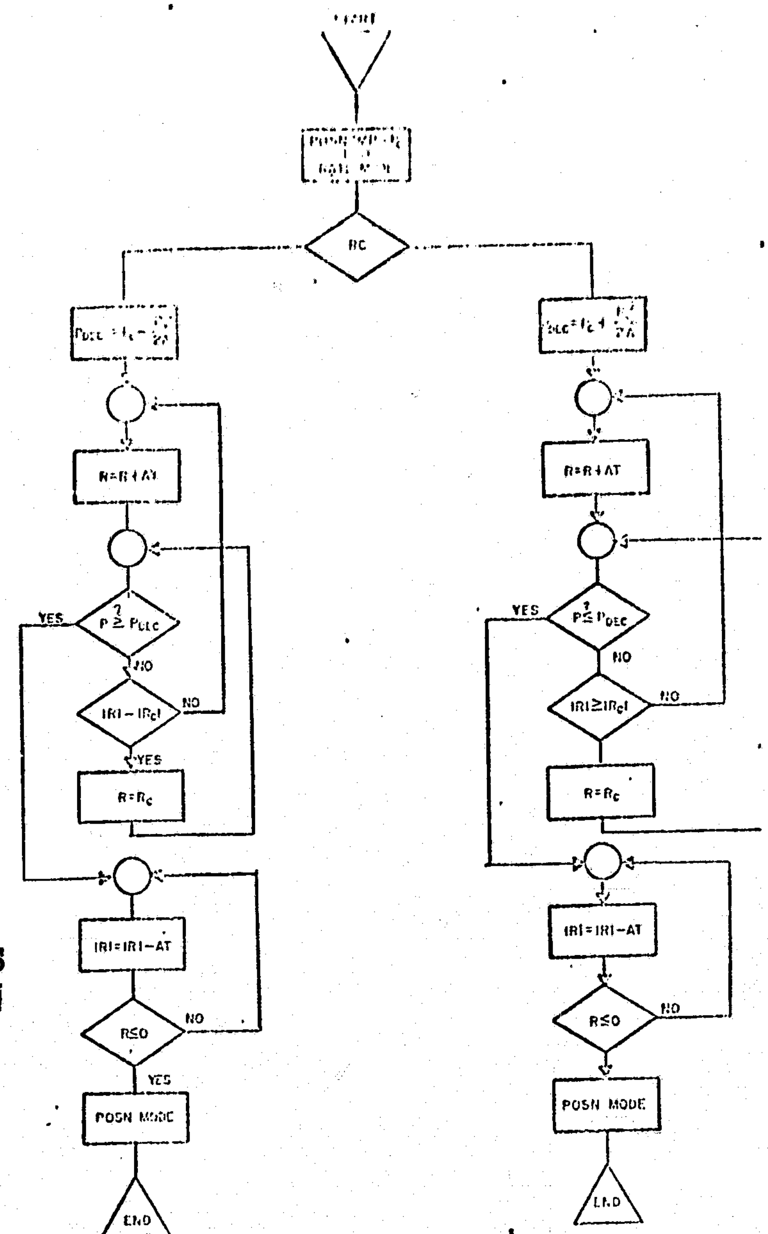
As another option, the HP2100 could be used to bias any command or readout position to allow arbitrary zero position of the axis. Another possibility is to allow the HP2100 to do the special formatting required and, thus, minimize the SEL programming requirement.

6.2.2.2.1 IMPLEMENTATION

To implement the dedicated HP2100, the following format could be used.



The HP2100 is connected to the SEL input because the HP2100 would be commanding and reading data from the CIE. The SEL connection to the CIE could be used for fast data reading only. Any commanding would be done via the HP2100. The SEL connection to the CIE could be eliminated by receiving its data from the HP2100. This would be slower. To read data via the HP2100, the SEL could interrupt the HP2100.



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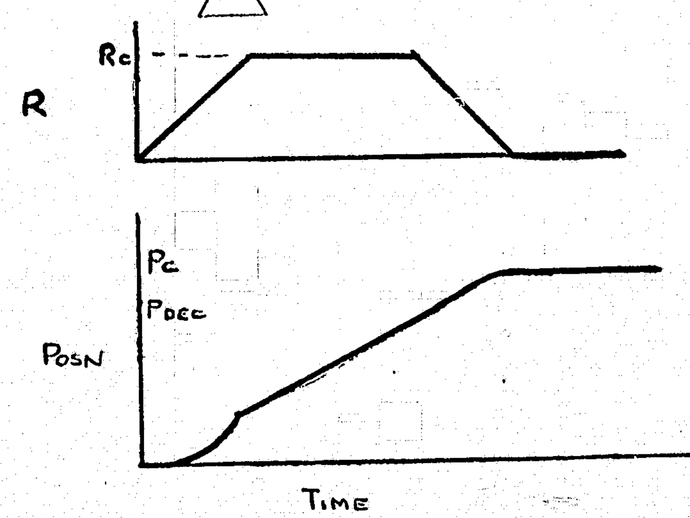


R = Present Rate

P = Present Position

P_{dec} = Position to Begin Deceleration

A = Acceleration

T = Interrupt Time

R_c = Commanded Rate

P_c = Commanded Final Position

Figure 1. Flow Diagram of Controlled Rate and Acceleration to Position

When the data had been read by the HP2100 via the CIE, the SEL could either wait for the HP2100 to I/O the data, or a DMA channel may be used. SEL data reading via the HP2100 would reduce the I/O requirements of the SEL.

6.2.3 MODIFY PRESENT EQUIPMENT TO ELIMINATE CIE

6.2.3.1 GENERAL

If it is desired to interface the HP2100 computer directly to the system without the use of the CIE chassis, it may be done via the standard bus matrix with the exception of the following functions. The rate data to the Rockland synthesizers, the acceleration command, the acceleration readout, the Earth rate correction, the angular oscillation frequency, and the status are not available to the bus. What is available is the modes, position command, position readout, and rate readout (Section 6.2.3.3). Separate I/O slots would be required for all the functions indicated by "-" in the bus address column.

This is equivalent to three (3), 16-bit input channels and thirteen (13), 16-bit output channels in addition to one input and two output required for bus interface. A standard HP2100 has 10 I/O slots so an I/O extender or special interface logic would be required for bus interface. A single ended computer interface logic tray would be required. This tray is made by Contraves-Goerz and is described in Section 7 of the instruction manual, IM-3557.

The attached bus matrix block diagram (Figure 2) shows how the system would be interconnected if the bus matrix were extended to cover the other functions not now encoded.

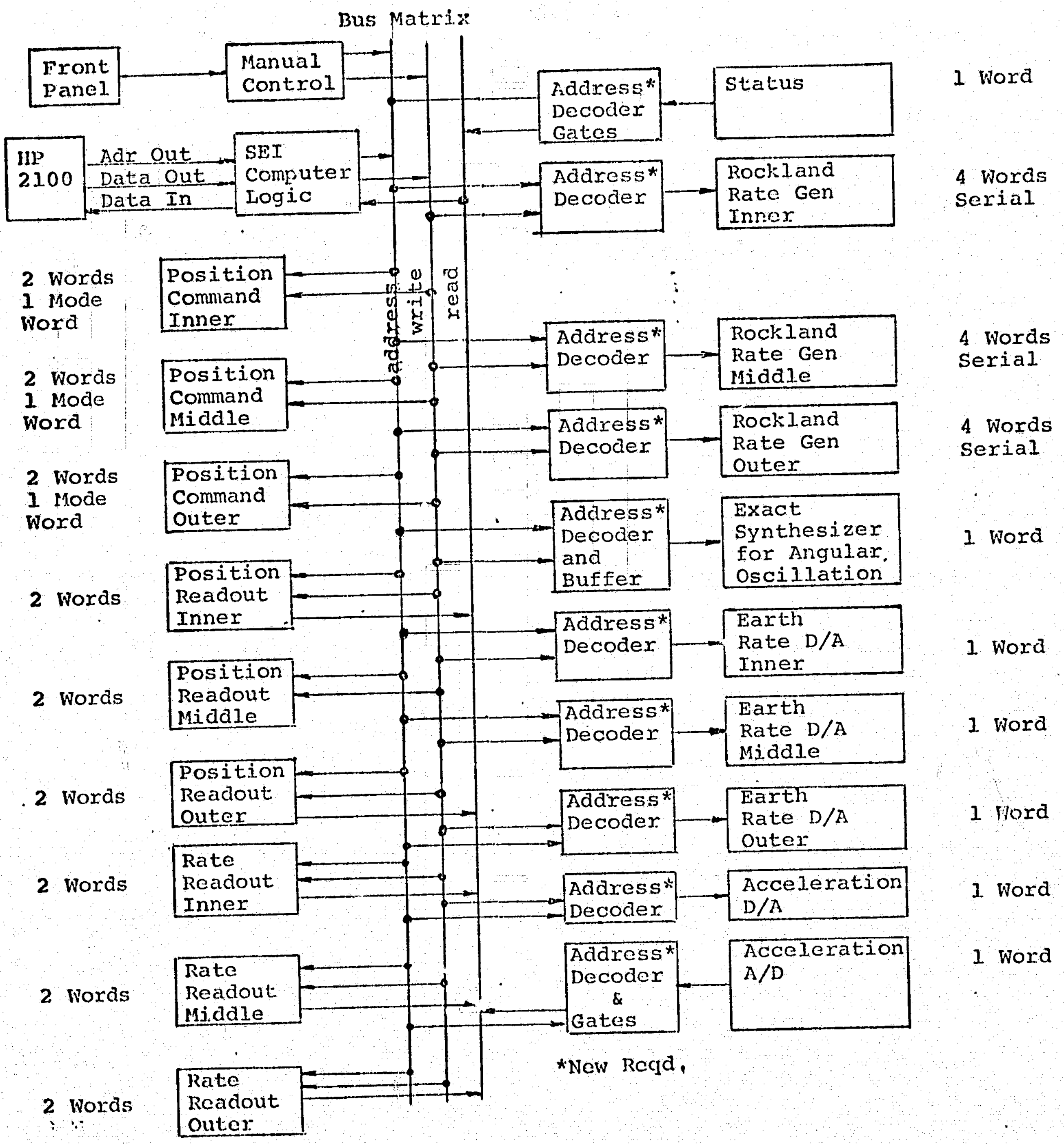


Figure 2. Bus Matrix Block Diagram

Probably the best way to extend the bus would be to create another identical bus driven from the standard bus matrix. This would change all the functions not available on the bus now from position true logic to the ground true logic required for the bus. Also, this tray could contain the multiplexer functions and the address decoding which would allow the addition of a single chassis containing the modification bus extension logic. All existing cables would then be plugged into this chassis. Using this method, the CIE electronics would be disconnected and a dedicated HP2100 would be used for the system. To interface the SEL to the system, it would be connected via the HP2100 and optical isolators would have to be made compatible to the HP2100-SEL interface. With this scheme the HP2100 would accomplish any formatting changes such as data packing and unpacking and binary to BCD, BCD to binary conversions. The actual data transfer to the SEL could occur via an interrupt to an HP2100 I/O slot or could be via a DMA channel in the HP2100 with the HP2100 manipulating the SEL data before it is used. The use of a dedicated HP2100 allows possible programmed functions to the DMS such as positioning at a rate and/or controlled acceleration via rate profile generation. In this scheme, the HP2100 would monitor the actual position and modify the commanded position or rate as a function of the actual position or time.

6.2.3.2 CHANGES REQUIRED

A) Data Changes

1) Data format would be BCD.

2) One 16-bit word per address transferred.

3) Two 16-bit I/O slots would be required (one for address, one for data in and out transfers).

B) Functional Changes

1) Only one remote local switch controls all axes.

2) Rate generators (Rockland) would have to be rewired to accept multiple word input.

3) Rate and acceleration thumbwheels would have to be wired to be entered on the bus in proper format.

4) All address decoding would have to be generated.

5) Bus requested data ready would have to be made for the acceleration readout.

6) All data to the non-bus compatible functions would have to be made ground true.

7) Interface tray for bus to computer would have to be added to prevent manual and remote access at the same time.

8) Rate sign storage must be implemented.

9) Address must be assigned for the undefined functions.

10) Zero reference pulse would have to be changed to an interrupt function.

6.2.3.3 PRESENT DATA FUNCTIONS

INCOMING DATA (FSDMS TO DMS I/O TO CIE CONTROL)

CATEGORY	DATA RANGE	TYPE	PARALLEL WIDTH (BITS)	Bus	Adr.
AXIS 1 (INNER)					
Position	000.0000 to 359.9999	BCD	Integer	10	10
			Fraction	16	11
Rate	±180.000	BCD	Integer	9	30
			Sign	1	30
			Fraction	12	31
Zero Reference				1	*
AXIS 2 (OUTER)					
Position	000.000 to 359.9999	BCD	Integer	10	14
			Fraction	16	15
Rate	±60.000	BCD	Integer	7	34
			Sign	1	34
			Fraction	12	34
Zero Reference				1	*
AXIS 3 (MIDDLE)					
Position	000.000 to 359.999	BCD	Integer	10	12
			Fraction	16	13
Rate	±120.000	BCD	Integer	9	32
			Sign	1	32
			Fraction	12	33
Zero Reference				1	*
Acceleration	±40.00	BCD	Integer	7	-
			Sign	1	-
			Fraction	8	-
FSDMS STATUS		BIN		16	-

*Available via interrupt with a modification to position readout tray.

OUTGOING DATA (CIE CONTROL TO DMS I/O TO FSDMS)

CATEGORY	DATA RANGE	TYPE	PARALLEL WIDTH (BITS)		Bus Adr.
AXIS 1 (INNER)					
Position	000.0000 to 359.9999	BCD	Integer Fraction	10 16	10 11
Rate	±180.0000	BCD	Integer Sign Fraction	9 1 12	- - -
Earth Rate Correction	0000 to 9999	BCD	Integer	16	-
Acceleration	0000 to 9999	BCD	Integer	16	-
AXIS 2 (OUTER)					
Position	000.0000 to 359.9999	BCD	Integer Fraction	10 16	14 15
Rate	±60.000	BCD	Integer Sign Fraction	7 1 12	- - -
Earth Rate Correction	0000 to 9999	BCD	Integer	16	-
Acceleration	000 to 9999	BCD	Integer	16	-
AXIS 3 (MIDDLE)					
Position	000.0000 to 359.9999	BCD	Integer Fraction	10 16	12 13
Rate	±120.000	BCD	Integer Sign Fraction	9 1 12	- - -
Earth Rate Correction	0000 to 9999	BCD	Integer	16	-
Acceleration	±40.00	BCD	Integer Sign Fraction	7 8 8	- - -

CATEGORY	DATA RANGE	TYPE	PARALLEL WIDTH (BITS)		Bus Adr.
ANGULAR					
Integer	000 to 999	BCD	Integer	12	-
Range	6 Ranges	BIN	Integer	4	-
CIE STATUS (Modes)		BIN		16	01,03,05**

**Separated into three words on bus.
- Not connected to bus.

6.3 ADDITION OF A POSITION INDEX MODE

6.3.1 GENERAL

This is an option often used to generate positioning at a rate. This tray takes position increment pulses from the rate generator and accumulates them forming an accumulated change in position. If an index command of 45.0000 degrees is commanded and index mode is selected, the position increment pulses (from the rate generator with the frequency of these pulses forming the rate) will be gated through into the position command tray until 450000 pulses have been accumulated. At this time no more pulses are allowed through. This method of positioning forms a rate step from 0 to the set rate and return to zero at the beginning and ending of the interval. This means only the rates which allow the axis to stop within less than 0.5 degree position movements may be used. The actual maximum rate which the position index will work is dependent on the acceleration capability of each axis. Normally, this is around 15 degrees per second or less. Using the equations below.

$$P = \tfrac{1}{2}\alpha t^2 , \quad \frac{2P}{\alpha} = t^2 , \quad R = \alpha t$$

$$\text{if } P = 0.5 \qquad \sqrt{\frac{1}{\alpha}} = t$$

$$R = \frac{\alpha}{\sqrt{\alpha}} = \sqrt{\alpha}$$

So maximum rate for any axis equals $\sqrt{\text{acceleration limit}}$

For low rates (multiple Earth rates) this is a satisfactory method of getting from one position to the next at precision rates.

Two other functions are available with the position index options; a variable dwell time at position. With this option, automated index testing is available. The axis will rate to the first position and dwell at the position for a preset time interval. When the time interval has expired the axis will index (move the preset position delta) and wait again. A cycle complete counter is available to halt the indexing after a preset number of cycles are complete. A flow diagram of the function is presented in Figure 3 and the specifications for the function are presented in Table 3.

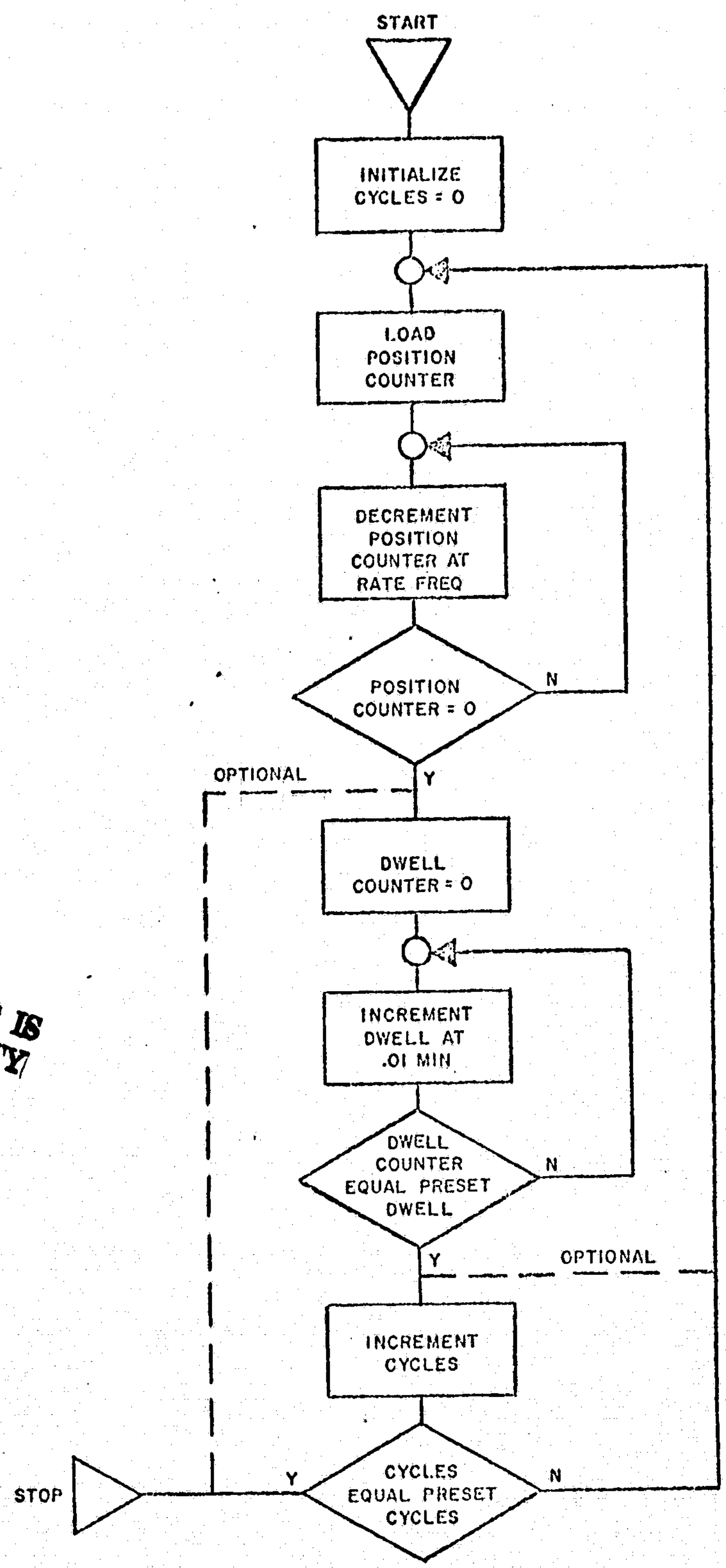


Figure 3. Position Index Flow Diagram

TABLE 3

POSITION INDEX GENERATOR SPECIFICATIONS

Range -------------------	000.0000 degree to 999.9999 degrees
Resolution -------------	0.0001 degree
Maximum Index Frequency--	1 MHz
Dwell Resolution * -----	0.01 min.
Dwell Range* -----------	00.00 to 99.99 degrees
Cycles Range* ----------	00 to 99 degrees
Position Data Input -----	BCD via the Standard Bus Matrix
Dwell and Cycles* ------	Manual thumbwheel

*Optional functions not required.

6.3.2 ADDITION TO PRESENT SYSTEM

To add this option to the present system would require the addition of a chassis and modification to the enter switches on the Station Control chassis. Access to the position index mode would be manual only since no compatible data slots are available through the CIE interface. The position index tray would be located between the rate generator and the command chassis rate input. An additional mode buffer would be required to store the position index mode.

6.4 COMPUTER ACCESS TO SYSTEM TEST FUNCTION

6.4.1 GENERAL

The system test is designed as a manual check of the integrity of the command and readout logic. It is used simultaneously on all three axes and simulates axis motion with the torquer off. It is not intended that switching between normal and system test be accomplished during the use of the DMS for axis motion. Since the axis servo is dependent on the data in the command trays, any modification of this data will cause an axis motion unless the axis torquers are off. Keeping the system test function at manual operation minimizes the possibility of the computer reading system test data instead of actual axis position. The procedure for adding computer control of system test to the present system is described in Section 6.4.2.

6.4.2 MODIFY PRESENT EQUIPMENT

This is the suggested method for adding computer control of the system test mode. It uses the acceleration axis 1 word from the CIE chassis. This word was not used in the original system. The change requires the addition of the circuitry shown on interface tray to the CIE schematic (drawing 701007). This must be wire wrapped in the tray which is in the Station Control chassis. I/O is done by 14-pin headers plugged in the tray. The test switches in the readout chassis require rewiring and adding a connector to the rear of the readout chassis (drawing 701005). Also required are assembly of two cables for bringing signals from the CIE to the interface and bringing the switches in the Readout chassis to the Station Control chassis.

6.4.2.1 DATA FORMAT

Data for the remote test are sent to address 34 octal which has been defined as acceleration word for Axis 1 in the CIE documents.

DATA				FUNCTION
LSB+3	LSB+2	LSB+1	LSB	
0	0	0	0	Normal Readout
0	0	1	1	System Test
0	1	0	1	Readout Test, 0
1	0	0	1	Readout Test, 90

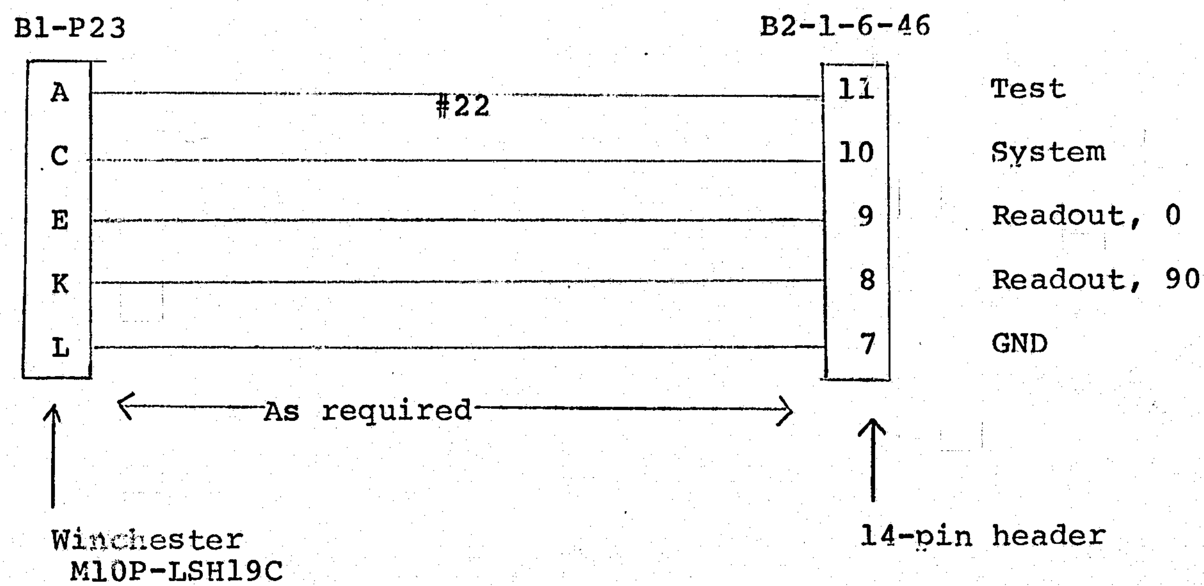
Other bit arrangements are not allowable.

Remote system test is available only when all axes remote/local switches are in remote.

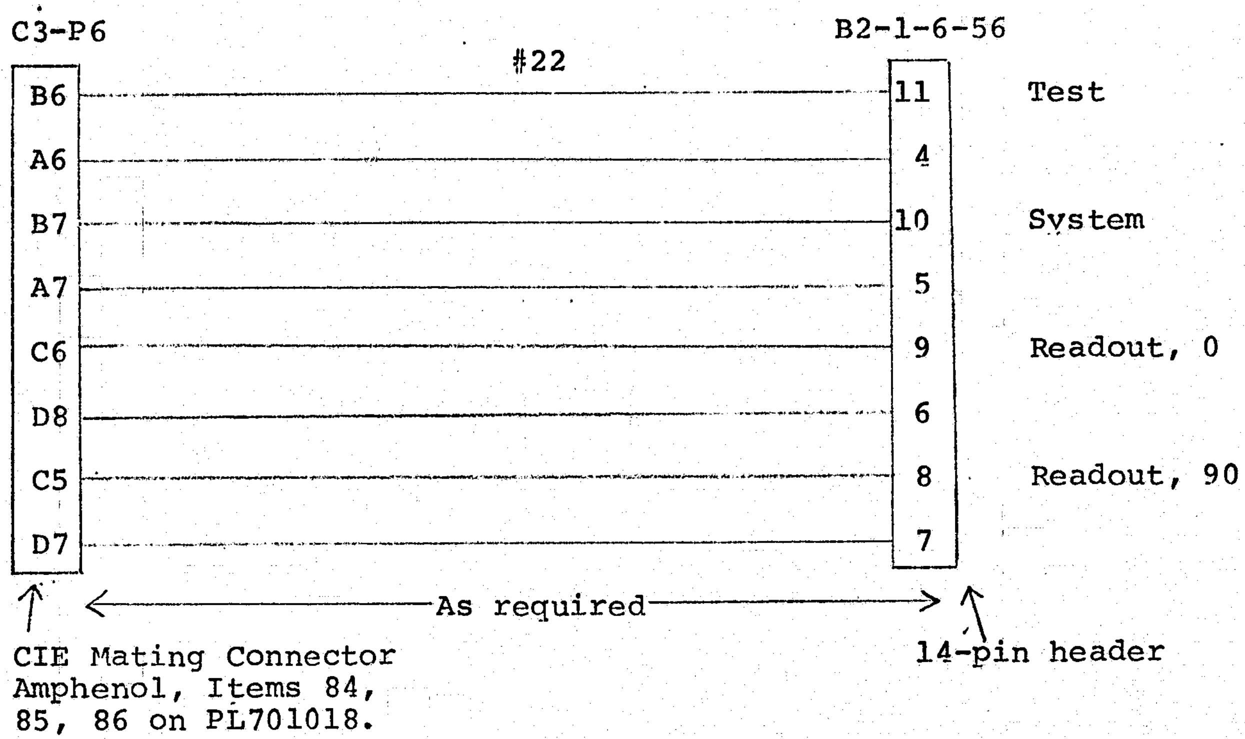
6.4.2.2 PARTS REQUIRED

QTY	NBR	ITEM	MFG
1	SN 74158	Integrated Circuit	TI or EQ
1	$M10S-L_RN$	Connector J-23	Winchester
1.	M10P-LSH19C	Connector B1-P23	Winchester
AR		22 Avg Wire	
		Connector supplied with system, Items 84-86 on PL701018.	Amphenol
2		14-pin headers similar to Augat 614-CG1.	

6.4.2.3 CABLE BETWEEN READOUT CHASSIS AND STATION CONTROL



6.4.2.4 CABLE CIE TO STATION CONTROL



LSB	=	test
LSB+1	=	system test
LSB+2	=	readout test, 0
LSB+3	=	readout test, 90

To activate test set Bit 1 and only 1 of Bits 2, 3, or 4.
For Axis 1 acceleration adr = 11100 = 34_B.

APPENDIX A

TEST PLAN FOR A THREE-AXIS

DYNAMIC MOTION SIMULATOR

MODEL 267-0050

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contraves Goerz

TEST PLAN FOR A THREE AXIS DYNAMIC MOTION SIMULATOR

TP-3512B

NOTE

This plan contains FINAL Acceptance Test Data taken at the NASA JSC Installation site in Houston, Texas.

The American Subsidiary of Contraves AG, Oerlikon-Bührle Holding

TEST PLAN FOR A THREE AXIS

DYNAMIC MOTION SIMULATOR

MODEL 267-0500

FINAL ACCEPTANCE TEST DATA

TP-3512B

December 1, 1975

Prepared for:

NASA/LYNDON B. JOHNSON SPACE CENTER

1.0 INTRODUCTION

This acceptance test plan is divided into two sections, Mechanical Tests and Electrical Tests. Most mechanical tests were performed during assembly and the electrical tests after assembly.

Several manufacturing processes and tolerances have been specified for the production of the hardware. These manufacturing tolerances and processes are indicated on the manufacturing drawings and required in-process quality control checks and reports. These checks are not included in this test procedure.

Also, installation information for the Dynamic Motion Simulator (DMS) such as leveling and azimuth (north) alignment of the outer axis and axis alignment are not contained in this test plan. These tasks appear in the "Installation" section of the maintenance and operation manual for the DMS System.

All electrical tests were repeated at the NASA JSC installation site. At the discretion of the NASA JSC technical monitor no mechanical tests were repeated except for axis wobble (Item 3.3.1). Data sheets and procedures for the tests not completed are included without any data. The data from the in-plant acceptance test have been delivered to the technical monitor.

Data from the clamp orientation sensitivity portion of the test (Item 3.8b) are not included. This test was rewritten with agreement from the technical monitor and the data were to be taken by JSC personnel.

The outer axis position mode did not meet the rate sensitivity test at NASA JSC. Since this test was passed when performed at the Contraves-Goerz facility, the problem appears to be an unbalance of the inner and middle gimbals. Per our telecon agreement, NASA will fine balance the system and rerun the orientation sensitivity tests in accordance with Paragraph 3.8b. The data may then be recorded by NASA.

2.0 FOUNDATION AND ENVIRONMENTAL CONDITIONS

The test table was mounted on a seismic block for all of the test procedures contained herein. All theodolites, autocollimators, and mirrors were mounted on the same seismic block.

The DMS (table and control system) was tested and operated within the specified tolerances and accuracies when exposed to a laboratory environment of 72 degrees F ±5 degrees F and at a relative humidity of up to 50 percent.

3.0 MECHANICAL TESTS

3.1 SCHEDULING OF TESTS

All the tests were scheduled and performed at the discretion of the mechanical assembly department.

3.2 IN-PROCESS TESTS

The following tests are In-Process Tests, i.e., they were performed during the mechanical assembly of the Dynamic Motion Simulator (DMS). In-Process Tests are advised where testing becomes much more difficult after the incorporation of all the components and wiring is completed, or where the outcome of the final testing must be predictable.

These testa were performed under supervision of a government inspector. Two (2) tests--the intersection of the three axes and the non-orthogonality of consecutive axes tests--were performed during mechanical assembly. The axes wobble tests were performed as In-Process and were repeated as "Final Tests" after complete assembly of the DMS. The "brake stiffness" tests were repeated but these tests appear under Section 4.0 Electrical Test Plan using the electronic controls for the tests.

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IN-PROCESS
TEST PLAN

CUSTOMER: NASA/Houston
SALES ORDER: 997
INSTRUMENT:

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.1	Intersection of all three (3) axes.	All 3 axes must intersect within a sphere of 0.020 inch radius (=0.040 inch diameter).	Install a crosshair reticle to the inner axis platform at the intersection of the three (3) axes. Perform test per STP-M-2267		

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IN-PROCESS
TEST PLAN

CUSTOMER: NASA/Houston
SALES ORDER: 997
INSTRUMENT:

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.3.1 (Table I)	Non-orthogonality of consecutive axes.	The nonorthogonality of two consecutive axes must not exceed ±2.0 arc seconds.	Load inner axis platform with dummy packages having a total wt. of 250 lbs. Using the optical cube at the axes intersection perform tests per STP-M-213		Inner axis to Middle axis = ________ i Middle axis to Outer axis = ________ i

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IN-PROCESS

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SALES ORDER: K00997
INSTRUMENT:

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.3.1 (Table I)	Axis Wobble (Inner Axis) (Middle Axis) (Outer Axis)	Axis Wobble must not exceed ±2.0 arc seconds	Load Inner Axis Platform with dummy packages having a total weight of 250 lbs. Using optical cube at axes intersection, check wobble per STP-M-201A. Inner & Middle Axes: Check wobble with axis horizontal and at ±45 degree attitudes; also Inner axis in a vertical position, and middle gimbal orthogonal to outer gimbal.		See data plots attached. Highest wobble reading = ____ arc

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IN-PROCESS

TEST PLAN

CUSTOMER: NASA/Houston
SALES ORDER: 997
INSTRUMENT: ______

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.8b	Brakes (in-process test of stiffness to meet rate and acceleration sensitivity)	Stiffness requirements (calculated) Inner Axis ≥ 2.6 ftlbs/sec Middle Axis ≥ 8 ftlbs/sec Outer Axis ≥ 8 ftlbs/sec	Measure the angular rotation with the optical cube at the axes intersection and an autocollimator under the following torques on the axes: Inner Axis 13 ft-lbs Middle Axis 40 ft-lbs. Outer Axis 40 ft-lbs Calculate rotational stiffness.		Measured Stiffness: I.A. ______ ft- M.A. ______ ft- O.A. ______ ft-

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3.3 FINAL TESTS

The following section contains the final tests, i.e., they were performed after complete assembly and wiring of the DMS.

These tests can be repeated as often as required without any disassembly of the DMS.

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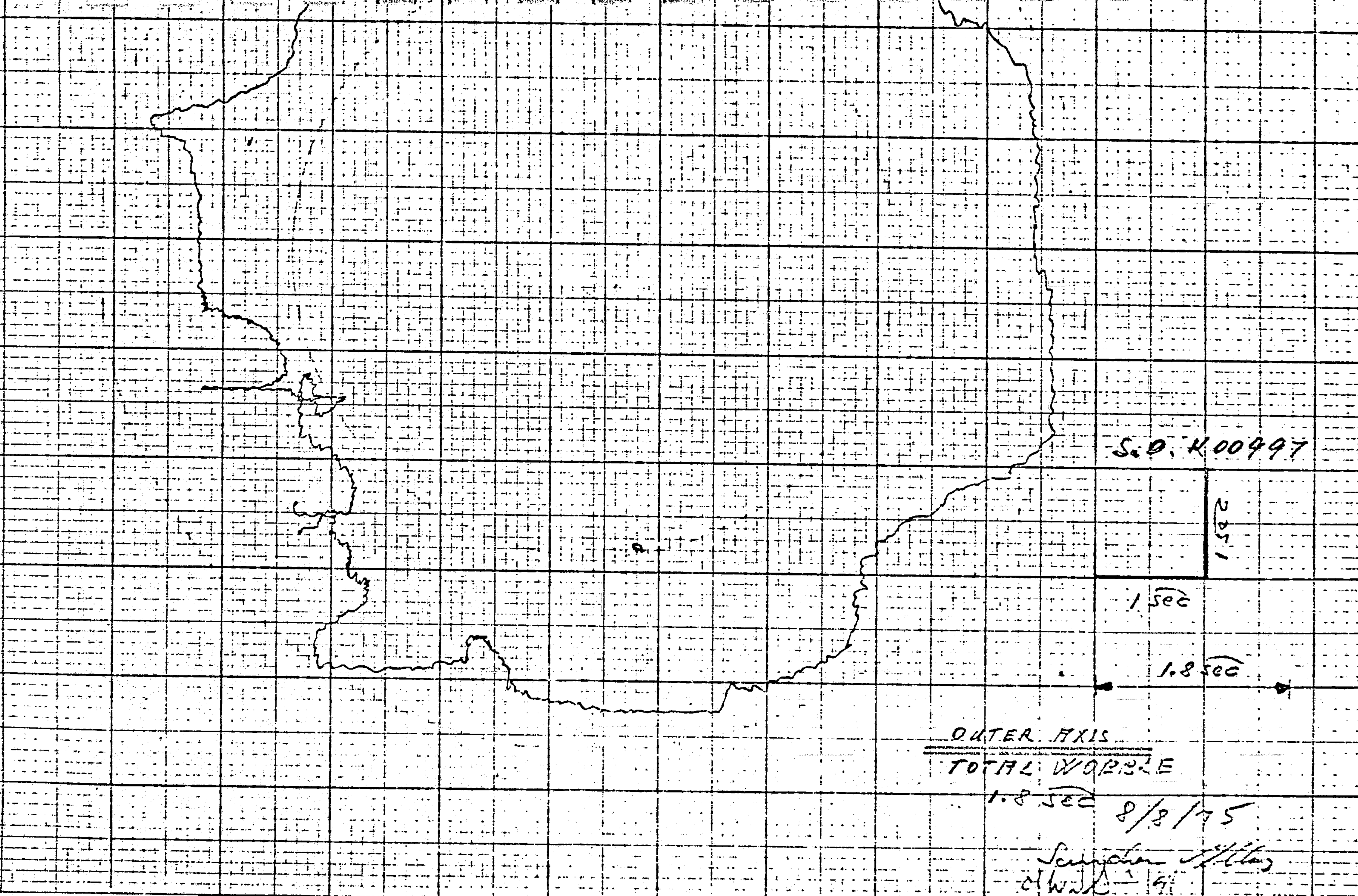
TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.3.1 (Table I)	Axis Wobble (Inner Axis) (Middle Axis) (Outer Axis)	Axis Wobble must not exceed ±2.0 arc seconds	Load Inner Axis Platform with dummy packages having a total weight of 250 lbs. Using optical cube at axes intersection, check wobble per STP-M-201A. Inner & Middle Axes: Check wobble with axis horizontal and at ±45 degree attitudes; also inner axis in a vertical position and middle gimbal orthogonal to outer gimbal.	At final acceptance testing use position loop to statically hold gimbal, and use rate loop to drive gimbal under test. Rate shall be 1 deg/sec for one (1) test each axis and 10 deg/sec for remaining tests.	See data plots attached. Highest wobble reading: = ±0.55 arc s (Inner Axis) = ±0.38 arcsec (Middle Axis) = ±0.90 arcsec (Outer Axis) – See three (3) Data Plots attached. –

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE __ OF __
8/8/75	Sandor Illes			


S.O. KL06997
INNER AXIS.
TOTAL WOBBLE 1.1 sec
8/8/75
1 sec
1.1 sec


1. sec
NO LOAD
.1 sec
S.O. K00997
~~INNER END~~
MIDDLE AXIS
.75 sec
TOTAL WOBBLE
.75 sec
8/7/75


S.O. K00997
1 sec
1.8 sec
OUTER AXIS
TOTAL WOBBLE
1.8 sec
8/8/75

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.3.4	Frictional Torques	The frictional torque of each axis was determined and specified in the design analysis report and shall be verified by testing. No tolerance is specified, but it is desired that the measured values do not exceed 130% of the calculated values. Calculated Friction Torque: Inner Axis: 3.4 ft-lbs Middle Axis: 7.8 ft ft-lbs Outer Axis: 13.2 ft-lbs	Completely assemble each axis. Measure friction torques per STP-M-2268	Measure friction torques in a horizontal and vertical attitude of the Inner and Middle gimbals.	I.A. ______ ft-l M.A. ______ ft-l O.A. ______ ft-l

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INSTRUMENT:

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.3.1 (Table I)	Rotational Freedom	Inner and Middle axis: infinite, CW & CCW.	Visual	Mount dummy loads (IMUS) to Inner axis loadplate (refer to para. 3.4.1.c.2, Exhibit B of NASA Spec.). Rotate Inner and Middle axis through ±2 revolutions.	Rotation angle (revolutions): Inner Axis: = ±______ re Middle Axis: = ±______ re
		Outer Axis: ±540° minimum. Zero (0) position is vertical middle axis with the read-out components at the bottom.	Visual with position readout of outer axis. Record actual angle at each end-stop and calculate total angular travel.		

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INSTRUMENT:

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.6.1	Azimuth Range	±1 degree	Check length of the six (6) slots for holddown bolts in base (arranged at a 58.75" radius). Length must be 3 3/4" minimum.		

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INSTRUMENT:

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.7	Counter-balance	The table shall contain provisions for a simple means to offset a minimum of 10 ft-lbs unbalance caused by mis-centering of the test article.	All 3 axes establish unbalance of 10 ft-lbs. Try to balance each axis with the counter weights furnished with the DMS. Balancing must be achieved within the friction torque of each axis. Record the rate after balancing for each axis Rate must be zero (0) if balancing is perfect.		Measured Rate after balancin Inner Axis: R_I= _____ deg/ Middle Axis: R_M= _____ deg/ Outer Axis: R_O= _____ deg/

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SALES ORDER: 997
INSTRUMENT: ____

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.4.2.1	Fluidic Lines & Swivel Joints	a) Pressure line, return line and 3 swivel joints: Check for leaks at 60 PSIG operating pressure with air and water at the following rates: I.A. Rate: 180 deg/sec. M.A. Rate: 120 deg/sec O.A. Oscillate at 15 Hz at peak amplitude. Perform static test at 150 PSIG for 1 hour. b) Measure pressure drop between inlet port and outlet port when operated with water at a maximum flow rate of 2 GPM. Pressure drop must not exceed 10 PSI. (Inlet & outlet line 5 PSI each.)	STP-M-2269		Leak test with air: I.A. ____ (V M.A. ____ (V O.A. ____ (V Leak test with water: I.A. ____ (V M.A. ____ (V O.A. ____ (V Pressure drop a given rates measured: I.A. ____ PS M.A. ____ PS O.A. ____ PS

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
		Rates to be the same as under (a); also measure at zero (0) rate.			

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.2	Table (DMS) Height	The height of the table (DMS) as installed in its maximum height configuration shall not exceed 10.5 ft (=126 inches). Height includes the mounting base and leveling wedges.	Position the middle axis vertical with the readout side up. With a tape measure check the height from the floor to the end of the slipring assembly.		

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE ___ OF ___

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.10	Net weight of Simulator Assembly	The weight of the table (DMS), excluding the control electronics, shall not exceed 15,000 lbs.	Check the wt. with one or two forklifts which are equipped with load gauges.		

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE ___ OF ___

TEST EQUIPMENT:

1 Tooling Mirror
1 Automatic Autocollimator, Kollmorgen K-342
1 X-Y Plotter - HP No. 7006AM or equivalent

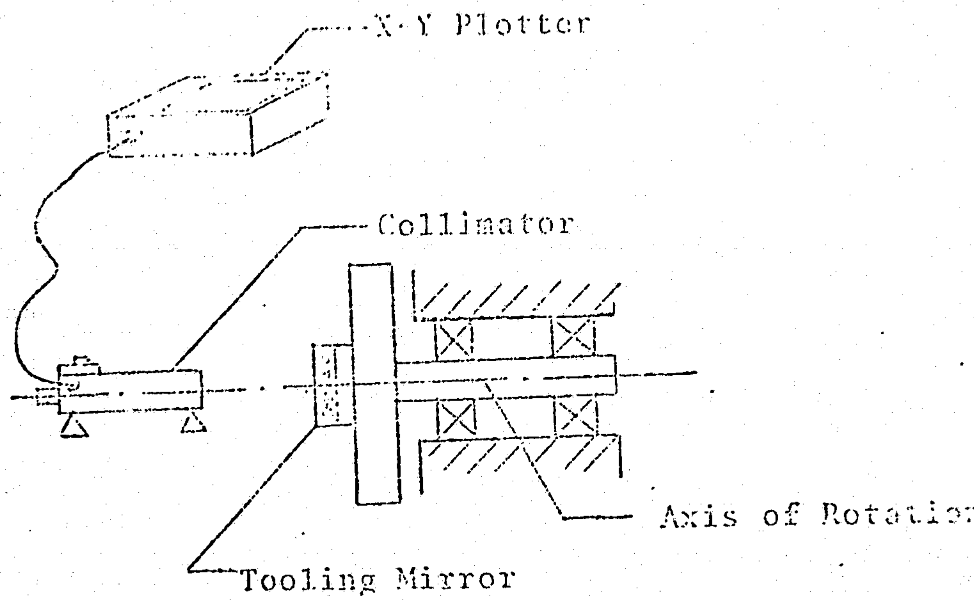


FIGURE 1

PROCEDURE:

1. Make test setup as shown in Figure 1.

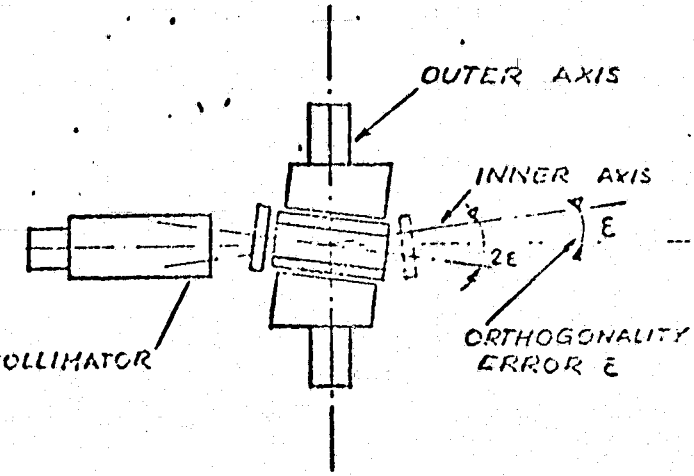
2. Establish autocollimation through 360 degrees of shaft rotation.

3. On the graph from the X-Y plotter, draw the smallest circle inscribing the wobble graph. Draw the largest circle possible circumscribing the wobble graph.

4. The radial difference is the total range of the random wobble.

Instrument: ______________
Unit: ________ Shop Order: ________
Customer: ______________

Specification Requirement: ________



Task
Determine the perpendicularity error between two intersecting gimbal axes.

Test Setup
Set up an autocollimator or theodolite with an autocollimating eyepiece with a resolution of 0.2 arc seconds minimum, such that autocollimation can be established with the mirror placed on the center of the inner axis. Mount an adjustable double surface mirror on the inner axis and align it perpendicular to the axis of rotation. Two tooling mirrors are to be used if the shaft does not have a central perforation.

Test Procedure
Establish autocollimation and measure and record the shaft direction in the coordinate parallel to the outer axis. Rotate the inner axis about itself 180°. Measure and record the shaft direction. Rotate the inner axis about the outer axis 180° and measure and record the shaft direction as above. Rotate the inner axis about itself 180° and measure the shaft direction. Repeat each measurement 3 times.

Data Reduction
Average the readings of the first two sets of measurements. Average the readings of the second two sets of measurements. The angular difference between the two averages equals 2 times the orthogonality error ε.

ANGULAR POSITION OF THE INNER AXIS			
Outer Axis at 0°		Outer Axis at 180°	
Inner Axis At Start Pos.		Inner Axis At Start Pos.	
Inner Axis 180° From Start Pos.		Inner Axis 180° From Start Pos.	
Avg 1. Set		Avg 2. Set	
Diff. Between Averages = 2ε =			

ANGULAR POSITION OF THE INNER AXIS			
Outer Axis at 0°		Outer Axis at 180°	
Inner Axis At Start Pos.		Inner Axis At Start Pos.	
Inner Axis 180° From Start Pos.		Inner Axis 180° From Start Pos.	
Avg 1. Set		Avg 2. Set	
Diff. Between Averages = 2ε =			

Average Orthogonality Error ε = ______ Arc Sec

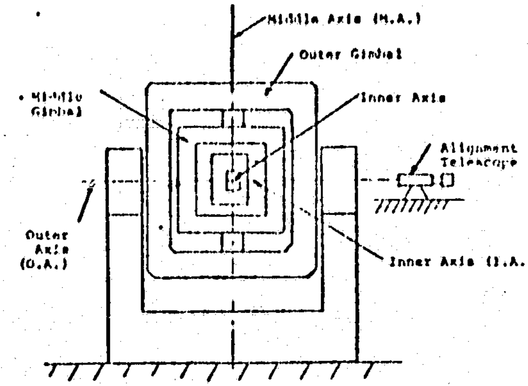
Date	Tested By	Witnessed (Goerz)	Witnessed (Customer)	PAGE 1 OF 1

INSTRUMENT: ______________________

SHOP ORDER: ______________________

CUSTOMER: ______________________

SPECIFICATION: ______________________



TASK

To determine the sphere of intersection deviation of the axes.

TEST SETUP

Position gimbals and axes as shown above. Mount reticle on inner gimbal. Set up alignment scope to view reticle through outer axis. Rotate inner axis and align reticle to the inner axis.

TEST PROCEDURE

1) Rotate middle axis 180 degrees and record azimuth displacement (=2A) of reticle. Rotate middle axis back to original position.

2) Rotate outer axis 180 degrees and record displacement in azimuth and elevation (=2 A_2 and $2e_2$) of the reticle. Rotate azimuth axis back to original position. NOTE: Observe positive or negative (+ or -) movements for azimuth readings.

3) Calculate maximum intersection deviation D as indicated below.

AXIS DISPLACEMENT (Inch) (ALIGNMENT SCOPE READINGS)	ACTUAL AXIS SEPARATION (Inch) (1/2 ALIGNMENT SCOPE READING)
I.A. - M.A., $2A_1$ = ______	A_1 = ______
I.A. - O.A., $2A_2$ = ______	A_2 = ______
$2e_2$ = ______	e_2 = ______
M.A. - O.A., $2A = 2A_1 - 2A$ = ______	$A = A_1 - A_2$ = ______
= ______	= ______

Calculate the maximum intersection D (diameter of sphere) as follows:

$$D = \sqrt{A^2 + A_1^2 + e_2^2} = \sqrt{(\quad)^2 + (\quad)^2 + (\quad)^2} = \underline{\qquad}$$

(D must be $\leq$ 0.040 inch)

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE 1 OF 1

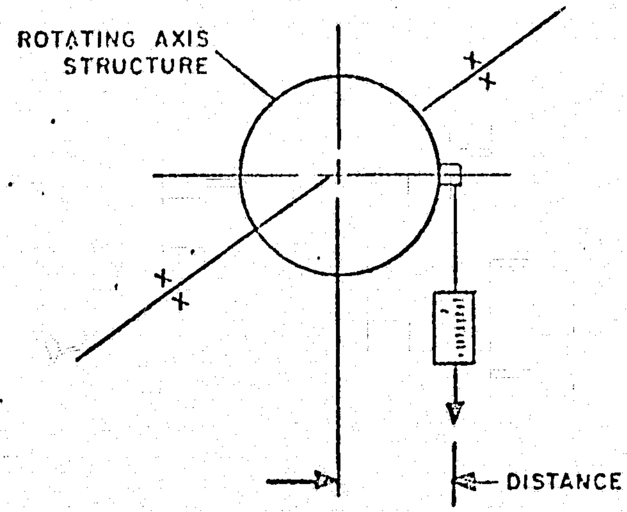
INSTRUMENT ______

UNIT ______

S.O/SERIES NO. ______

CUSTOMER ______

REQUIREMENTS ______



TASK

To determine the amount of friction in the axis assembly including bearings, electrical sliprings, fludic rotary joints, tachometer, Inductosyn, etc.

SET-UP AND PROCEDURE

Attach a spring scale to a covenient location of the rotating axis structure. Pull on spring scale and record force applied to scale at break away point. Repeat for 4 Clockwise and 4 Counterclockwise measurements.

FORCE		x DISTANCE		=		ft-lbs
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	

DATE	TESTED BY	WITNESSED BY: GOERZ	WITNESSED BY: CUSTOMER	PAGE 1 OF 2

DATA REDUCTION

1) Find the arithmetic mean of the torques:

2) The torque values should be within 1.3 times the mean value.

Inner Axis: Mean Value = ____________ ft-lbs

Middle Axis: Mean Value = ____________ ft-lbs

Outer Axis: Mean Value = ____________ ft-lbs

3) The measured mean torque values should be within the following units:

Inner Axis: 1.3 x 3.4 = 4.4 ft-lbs

Middle Axis: 1.3 x 7.8 = 10.2 ft-lbs

Outer Axis: 1.3 x 13.2 = 17.2 ft-lbs

INSTRUMENT

UNIT

S.O./SERIES NO.

CUSTOMER

REQUIREMENTS

TASK:

Check rotary joints for leaks.

SET-UP PROCEDURE:

Joint assembled to table.

1. Pressurize ports with specified pressures. With outlets plugged rotate table at 3 radians per second and check for leaks at time interval noted.

RESULTS:

TEST 1

	PORT "A"			PORT "B"		
Air Pressure	Initial 60 PSIG	at 5 min	at 10 min	Initial 60 PSIG	at 5 min	at 10 mi

TEST 2

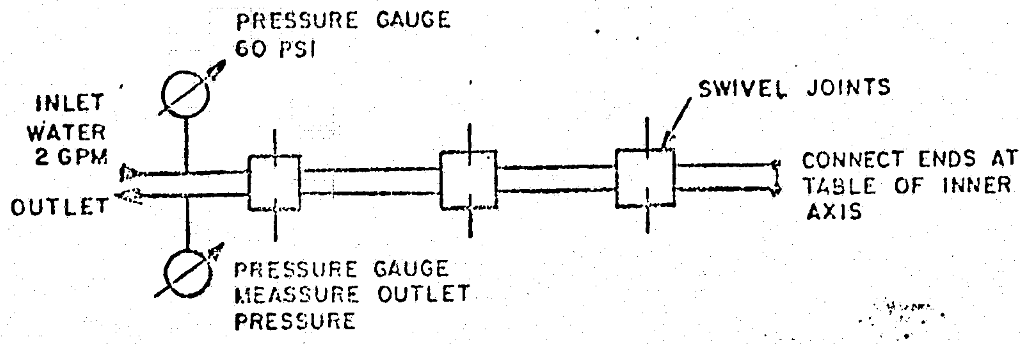
	PORT "A"			PORT "B"		
Water Pressure	Initial 60 PSIG	at 5 min	at 10 min	Initial 60 PSIG	at 5 min	at 10

TEST 3 State Pressure Test

Ports A & B proof test at 150 PSIG (No rotation).

DATE	TESTED BY:	WITNESSED BY: GOERZ	WITNESSED BY: CUSTOMER	PAGE 1 OF

TEST 4 Check pressure drop between inlet and outlet port



Pressure drop: ____________________ psig
($\leq$10 psig)

DATE	TESTED BY:	WITNESSES BY: GOERZ	WITNESSED BY: CUSTOMER	PAGE 2 OF 2

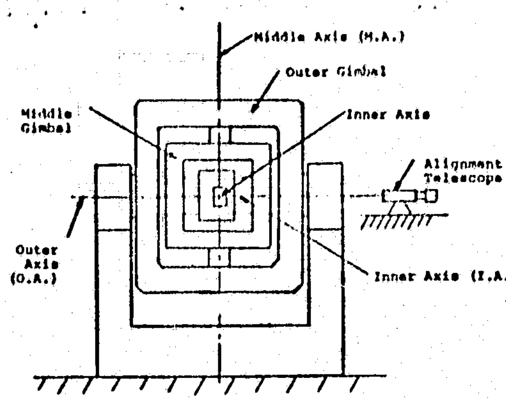
CONTRAVES-GOERZ CORPORATION	TEST SPECIFICATION INTERSECTION OF AXIS	STP-M-2267

INSTRUMENT: ______________________

SHOP ORDER: ______________________

CUSTOMER: ______________________

SPECIFICATION: ______________________



TASK

To determine the sphere of intersection deviation of the axes.

TEST SETUP

Position gimbals and axes as shown above. Mount reticle on inner gimbal. Set up alignment scope to view reticle through outer axis. Rotate inner axis and align reticle to the inner axis.

TEST PROCEDURE

1) Rotate middle axis 180 degrees and record azimuth displacement (=2A) of reticle. Rotate middle axis back to original position.

2) Rotate outer axis 180 degrees and record displacement in azimuth and elevation (=2 A_2 and $2e_2$) of the reticle. Rotate azimuth axis back to original position. NOTE: Observe positive or negative (+ or -) movements for azimuth readings.

3) Calculate maximum intersection deviation D as indicated below.

AXIS DISPLACEMENT (Inch) (ALIGNMENT SCOPE READINGS)	ACTUAL AXIS SEPARATION (Inch) (1/2 ALIGNMENT SCOPE READING)
I.A. - M.A., $2A_1$ = ______	A_1 = ______
I.A. - O.A., $2A_2$ = ______	A_2 = ______
$2e_2$ = ______	e_2 = ______
M.A. - O.A., 2A = $2A_1$-2A = ______	A = A_1 - A_2 = ______
= ______	= ______

Calculate the maximum intersection D (diameter of sphere) as follows:

$$D = \sqrt{A^2 + A_1^2 + e_2^2} = \sqrt{(\quad)^2 + (\quad)^2 + (\quad)^2} = \_\_\_\_\_\_$$

(D must be $\leq$ 0.040 inch)

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE 1 OF 1

SP 1183A

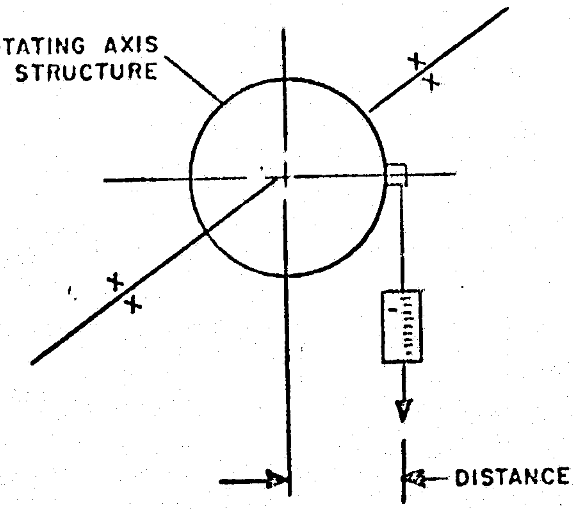
INSTRUMENT ____________

UNIT ____________

S.O/SERIES NO. ____________

CUSTOMER ____________

REQUIREMENTS ____________



TASK

To determine the amount of friction in the axis assembly including bearings, electrical sliprings, fludic rotary joints, tachometer, Inductosyn, etc.

SET-UP AND PROCEDURE

Attach a spring scale to a covenient location of the rotating axis structure. Pull on spring scale and record force applied to scale at break away point. Repeat for 4 Clockwise and 4 Counterclockwise measurements.

FORCE		x DISTANCE		=		
	______		______	=	______	ft-lbs
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	
	______		______	=	______	

DATE	TESTED BY	WITNESSED BY: GOERZ	WITNESSED BY: CUSTOMER	PAGE 1 OF 2

DATA REDUCTION

1) Find the arithmetic mean of the torques:

2) The torque values should be within 1.3 times the mean value.

Inner Axis:	Mean Value = ____________	ft-lbs
Middle Axis:	Mean Value = ____________	ft-lbs
Outer Axis:	Mean Value = ____________	ft-lbs

3) The measured mean torque values should be within the following units:

Inner Axis: 1.3 x 3.4 = 4.4 ft-lbs

Middle Axis: 1.3 x 7.8 = 10.2 ft-lbs

Outer Axis: 1.3 x 13.2 = 17.2 ft-lbs

TESTED BY	WITNESSED BY GOERZ	WITNESSED BY CUSTOMER	PAGE 2 OF 2

INSTRUMENT

UNIT

S.O./SERIES NO.

CUSTOMER

REQUIREMENTS

TASK:

Check rotary joints for leaks.

SET-UP PROCEDURE:

Joint assembled to table.

1. Pressurize ports with specified pressures. With outlets plugged rotate table at 3 radians per second and check for leaks at time interval noted.

RESULTS:

TEST 1

	PORT "A"			PORT "B"		
Air Pressure	Initial 60 PSIG	at 5 min	at 10 min	Initi[illegible] 60 PSIG	at 5 min	at 10 min

TEST 2

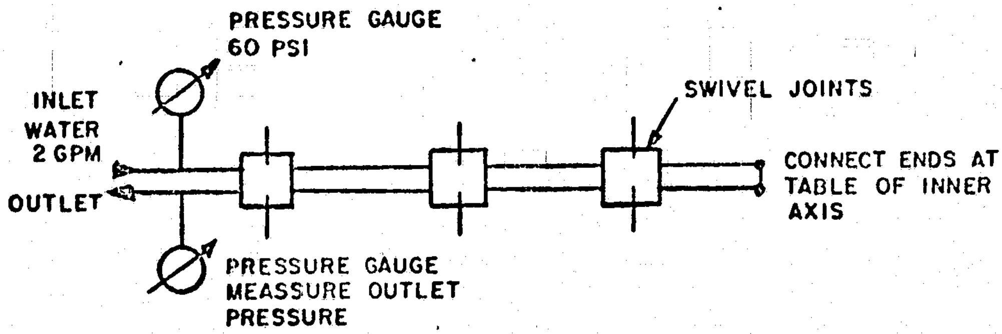
	PORT "A"			PORT "B"		
Water Pressure	Initial 60 PSIG	at 5 min	at 10 min	Initial 60 PSIG	at 5 min	at 10 min

TEST 3 State Pressure Test

Ports A & B proof test at 150 PSIG (No rotation).

DATE	TESTED BY:	WITNESSED BY: GOERZ	WITNESSED BY: CUSTOMER	PAGE 1 OF 2

TEST 4 Check pressure drop between inlet and outlet port



Pressure drop: ____________________ psig
($\leq$10 psig)

4.0 ELECTRICAL TEST PLAN

This section of the Acceptance Test Plan includes the electrical tests.

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CUSTOMER: NASA/Houston
SALES ORDER: K00997
INSTRUMENT:

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.4.3.3	Sliprings				
3.4.3.3.1	Test Article Power	18 conductors, 5 amp twisted shielded with each shield carried through	By design	Pins A-f of J114 to J104, 16 cond. at 10 amp, 240 V, 2 cond at 5 amp, 150 V.	OK
3.4.3.3.2	Signal to Inner Gimbal				
a		48 cond.@ 2 amp with shield common carried through	By design	Pins A-c of J110 to J100 Pins A-c of J111 to J101	OK
b		48 cond.@ 2 amp 1 pair per shield	By design	Pins A-s of J112 to J102 Pins A-s of J113 to J103	OK
3.4.3.3.3	Signal to Middle Gimbal	8 cond.@ 2 amp	By design	1-8 shield on 9 to TB5 from J110 d-n	OK
3.4.3.4	Signal to Outer Gimbal	8 cond.@ 2 amp	By design	1-8 shield 9 to TB6 from J111 d-n	OK

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE 1 OF

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CUSTOMER: ______
SALES ORDER: ______
INSTRUMENT: ______

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.4.3.3.4	Slipring Noise	Signal circuits 30,100 miliohms per circuit.	STP-E-212 J110 R-S J111 N-P J112 G-H L-M J113 d-e J114 g-h d-e G-M	Use strip chart recorder. Check 2 rings in service using 1 amp DC. Rate both axes at maximum rate CW and at 6 deg/sec CCW. Noise should be less than 60 mv or 200 mv depending on ring selection. Ten rings will be checked at acceptance. Data will be available on all rings. Demonstrate no noise pickup with an axis oscillating.	J110 R-S No Noise - less than 10 mv J111 [illegible] 10 mv No [illegible] Ten [illegible] [illegible] m.25.
3.4.3.5	Slipring Voltage Ratings	Min. of 6 power sliprings with 210 VAC rating. Others at 150 VAC.	By design	8 pairs J114 A-C to J104 10 amp at 240 VAC Demonstrate 210 VAC, 5 amp for 10 minutes on each pair.	OK

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DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE
2/7/7		[illegible]	[illegible]	2 OF ___

CONTRAVES-GOERZ, CORP.
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CONTRAVES AG. OERLIKON-BÜHRLE HOLDING

CUSTOMER:
SALES ORDER:
INSTRUMENT:

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.1	Electrical Power	3 phase, 4 wire, 120/208, 60 Hz less than 40 amps	By design	3 phase, 4 wire, 120/208, 60 Hz less than 10 amp per phase.	Blue 6.5 - 8 A, Red 8.5A, WH 3.75 - 6 A
			Measure	Rate oscillate all axes in phase peak 1 Hz peak acceleration. Monitor phase current.	
4.2.2	Monitor Req				
a.	Digital Output		To computer		
b.	Display	Position Rate Acceleration	By design	1 display for each function and axis.	OK
c.	Analog Voltages	Proportional to Rate	By design	Buffered tach, buffered Inductosyn position, and position error. Take 20 points equally spaced over the range of each output. Use rate mode for tach output data. Use position mode for position calibration. Lock brake and index manually using the readout display as the reference	

FUNCTION	RANGE
Analog Posn.	±0.5 deg
Posn Error	±0.5 deg
Buffered tach	±200 ^{o}/sec

Take position outputs at 32.75 -33.75 and 250.75 to 251.75 deg.

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE OF
9/25		[illegible]	[illegible]	

TABLE III

ANALOG SCALE FACTORS

		POSITION ERROR		INDUCTOSYN POSITION		RATE		AXIS
CONNECTOR	HI LO	A9-J7	D E	A9-J7	A B	B3-J7	A B	INNER
SCALE FACTOR		13.4 mv/arc sec		13.1 mv/arc sec		.051 v/~~rad~~ deg/sec		
CONNECTOR	HI LO	A9-J8	D E	A9-J8	A B	B3-J7	E F	MIDDLE
SCALE FACTOR		13.0 mv/arc sec		13.2 mv/arc sec		.0494 v/~~rad~~ deg/sec		
CONNECTOR	HI LO	A9-J9	D E	A9-J9	A B	B3-J7	J K	OUTER
SCALE FACTOR		12.8 mv/arc sec		13.0 mv/arc sec		.050 v/~~rad~~ deg/sec		

Eli Mislove

Analog Scale Factor Test 7/27

	Pos Error	Analog Pos Output	Pos Error	Analog Pos Output	Pos Error	Analog Pos Output		Pos Error	Analog Out	Pos Error	Analog Out	Pos Error	Analog Out
	INNER		Middle		Outer			250.	33.		Middle	250.	Outer
0.250	9.4	11.8	11.7	11.9	11.5	11.7	.75	-1.3M	-11.7	-36M	-11.8	32M	-11.5
.225	8.9	10.7	10.6	10.8	10.4	10.5							
.200	7.5	9.5	9.4	9.6	9.2	9.3	.85	3.7	-7.0	4.7	-7.1	4.6	-6.9
.175	6.5	8.3	8.2	8.4	8.1	8.2							
.150	5.6	7.1	7.0	7.2	6.9	7.0	.95	7.5	-2.4	9.4	-2.4	9.2	-2.3
.125	4.7	5.9	5.8	6.0	5.8	5.8							
.100	3.7	4.7	4.7	4.8	4.6	4.7	.105	6.9	2.4	9.4	2.4	9.2	2.3
.075	2.8	3.5	3.5	3.6	3.5	3.5							
.050	1.9	2.4	2.3	2.4	2.3	2.3	.15	2.1	7.1	4.7	7.2	4.6	7.0
.025	.9	1.2	1.1	1.2	1.2	1.2							
0.000	-.02	.0	-.03	-.02	.03	-.018	.25	-2.8	11.8	35M	11.9	29M	11.7
.975	-1.2	-1.2	-1.2	-1.2	-1.1	-1.2							
.950	-2.4	-2.4	-2.4	-2.4	-2.3	-2.3	.35	-6.5	7.2	-4.7	7.3	-4.6	7.1
.925	-3.7	-3.5	-3.6	-3.6	-3.4	-3.5							
.900	-4.8	-4.7	-4.7	-4.7	-4.5	-4.6	.45	-10.3	2.5	-9.4	2.5	-9.2	2.5
.825	-6.1	-5.9	-5.9	-5.9	-5.7	-5.8							
.850	-7.3	-7.0	-7.1	-7.1	-6.8	-6.9	.55	-9.7	-2.2	-9.4	-2.2	-9.1	-2.2
.825	-8.5	-8.2	-8.2	-8.3	-8.0	-8.1							
.800	-9.7	-9.4	-9.4	-9.5	-9.1	-9.2	.65	-4.9	-7.0	-4.7	-7.0	-4.5	-6.8
.775	-10.9	-10.6	-10.6	-10.6	-10.2	-10.4							
.750	-12.1	-11.7	-11.7	-11.8	11.4	-11.5	.75	-12M	-11.7	-30M	-11.8	31M	-11.5
		13.1M			12.8	13.0							
	13.1M		13.0	13.2									

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C.G.

Measured Inch Output 11/29

	INNER 51 mV/in	MIDDLE 47.1 mV	OUTER 50 mV/	
180	9.2 V	8.9	1.5	30
160	8.1	8.0	1.0	20
140	7.1	7.0	0.5	10
120	6.1	6.0	0.195	4
100	5.1	5.0	0.146	3
80	4.1	4.0	0.097	2
60	3.1	3.0	0.047	1
40	2.0	2.0	.002	0
20	1.0	1.0	− 0.051	−1
0	.01	.00	− 0.101	−2
−20	− 1.0	−1.0	− 0.150	−3
−40	− 2.0	−2.0	− 0.199	−4
−60	− 3.0	−3.0	− 0.5	−10
−80	− 4.1	−4.0	− 1.0	−20
−100	− 5.1	−5.0	− 1.5	−30
−120	− 6.1	−6.0		
−140	− 2.1	−7.0		
−160	− 8.1	−8.0		
−180	− 9.2	−8.9		

[illegible] C. G.

CONTRAVES-GOERZ, CORP.
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CUSTOMER: ____________
SALES ORDER: ____________
INSTRUMENT: ____________

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.8 b	Clamps	Range 0 to 360 deg	By design		Accuracy Arc Sec
	Repeatability	±1.0 arc second	✓	Servo the axis in position mode for each orientation shown in Tab. 1. Monitor fine position error on strip chart. Apply brakes and note axis movement per fine error scale factor. Repeat 4 times. Accuracy is the peak movement from servo to brake on final position.	I 1.33-2.7 p-p M .49-1.05 p-p O 1.98-4.13 p-p
	Accuracy	5.0 arc sec (WRT pre-application of brakes)		Repeatability is the largest peak to peak final position in any orientation. (Peak to peak over 5 positions.)	Repeatability Arc Sec I .18-.54 p-p M .32-.50 p-p O 0-.67 p-p
	Orientation Sensitivity	1 arc sec	To be completed by NASA at JSC. See Introduction	In orientations 1 and 2, table 1C with monitored axis clamped, rotate outer axis through 360 degrees in 45-degree steps. Record the position of the axis being monitored. The orientation sensitivity is the peak to peak measured position over the full rotation of the outer axis.	

DATE	TESTED BY	WITNESSED (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE ___ OF ___

TABLE I

STATIC CLAMP TEST

	AXIS POSITION			MONITOR	A		B		C		D		E			
	I	M	O	*	S	C	S	C	S	C	S	C	S	C		
1	0	0	0	Inner	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]	0	[illegible]	[illegible]	[illegible]
2	0	0	90	Inner	0	-2.34	0	-2.16	0	-2.34	0	-[illegible]	0	-[illegible]	[illegible]	-2.[illegible]
3	225	0	0	Inner	0	1.14	0	1.14	0	.76	0	1.33	0	1.[illegible]	[illegible]	1.33
4	0	0	0	Middle	0	1.48	0	1.32	0	1.32	0	1.32	0	1.[illegible]	.32	1.48
5	0	0	90	Middle	0	1.46	0	1.81	0	1.81	0	1.81	0	1.[illegible]	.50	1.95
6	0	225	0	Middle	0	.49	0	.33	0	.33	0	.76	0	[illegible]	.33	.49
7	0	0	0	Outer	0	4.[illegible]	0	3.79	0	3.79	0	3.79	0	3.[illegible]	.67	4.15
8	0	0	90	Outer	0	2.31	0	2.14	0	1.98	0	1.9[illegible]	0	1.81	.50	2.31
9	0	90	90	Outer	0	1.9[illegible]	0	1.98	0	1.98	0	1.98	0	1.9[illegible]	[illegible]	1.98

ARC SECONDS

APPLY BRAKES WHILE OTHER AXIS IS IN MOTION

1	0	-	0	Inner	.76	1.33	60 deg/sec
2	0	90	-	Inner		1.52	30 deg/sec
3	-	0	0	Middle		1.8	60 deg/sec
4	0	0	-	Middle		2.34	30 deg/sec
5	-	-	0	Outer		4.32	60 deg/sec
6	-	-	0	Outer		—	120 deg/sec

-Axis In Motion

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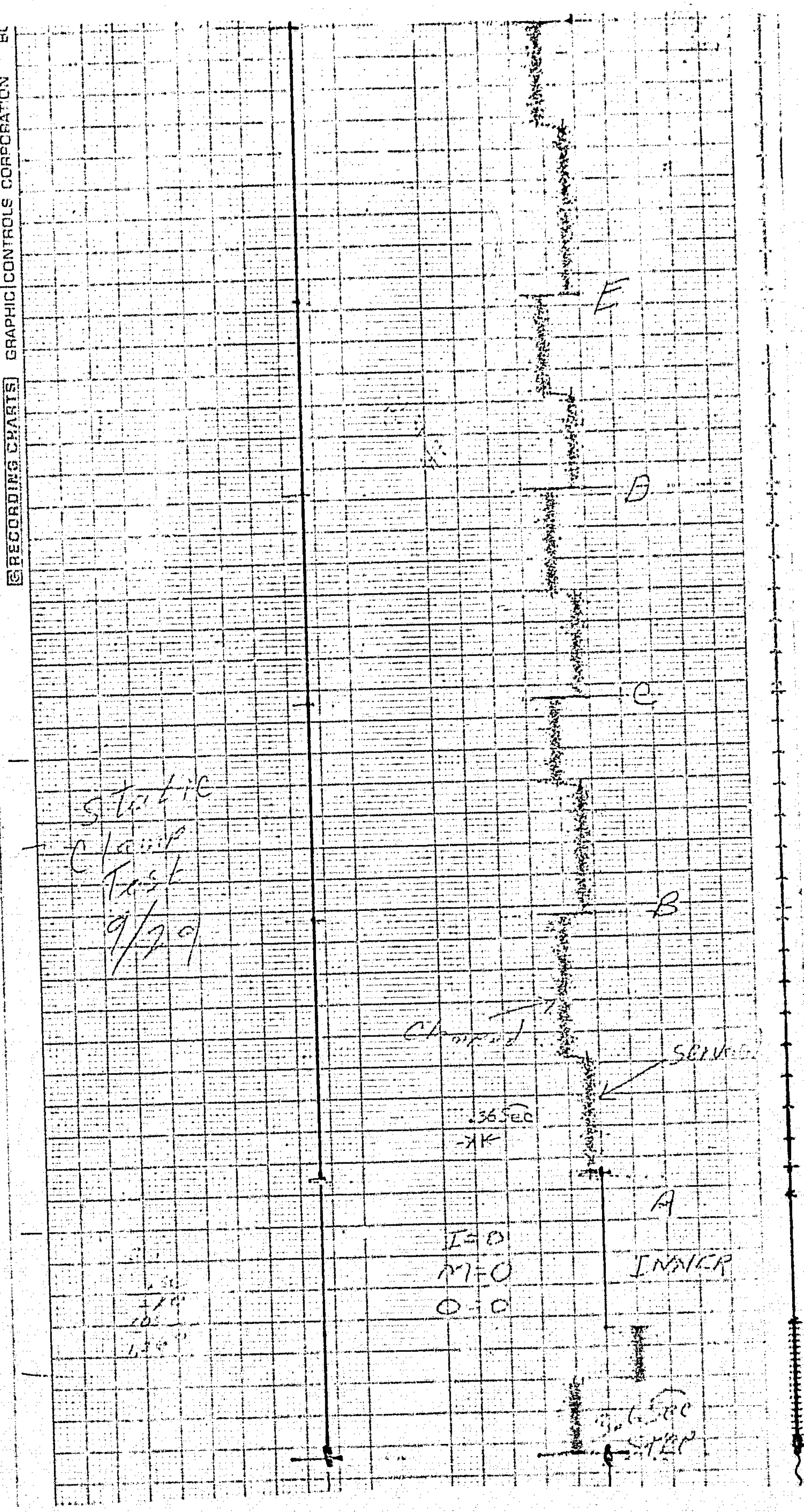
INNER	HI	J7-D	LO	J7-E	I_{SF} =	mv/arc sec	
MIDDLE	HI	J8-D	LO	J8-E	M_{SF} =	mv/arc sec	S = Servoed
OUTER	HI	J9-D	LO	J9-E	O_{SF} =	mv/arc sec	C = Clamp On

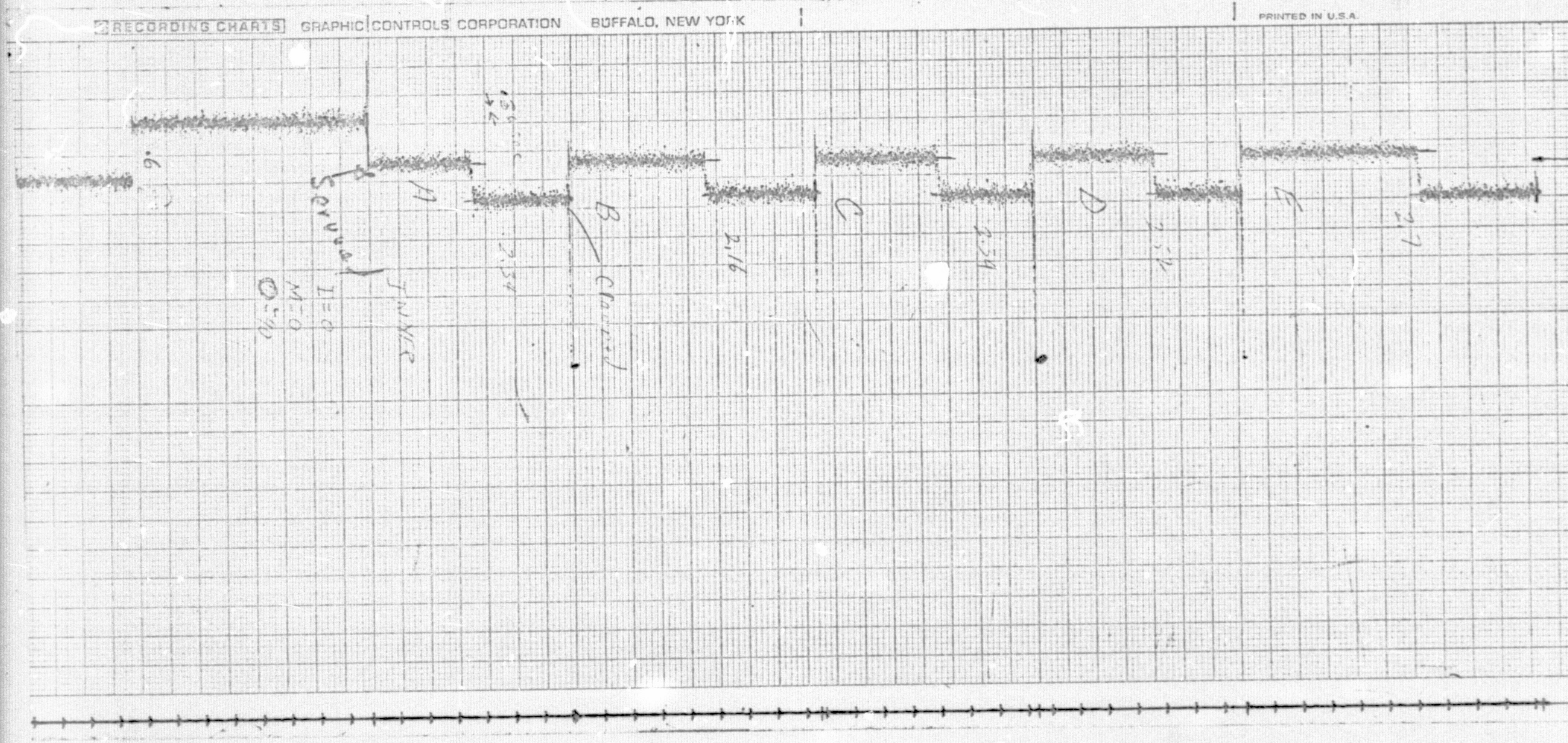
Accuracy = largest peak difference (S - C) of Col A-E.
Repeatability = largest peak difference of (Min C to Max C) **Col A-E.**

TABLE Ic

Orientation Sensitivity

				Outer Axis									
	I	M	Monitored Axis	0	45	90	135	180	225	270	315	360	P-P
1	0	0	Inner										
2	0	0	Middle										


RECORDING CHARTS
GRAPHIC CONTROLS CORPORATION
E
D
C
B
A
Static
Clamp
Test
9/29
Clamped
SENSED
.365ec
I=0
M=0
O=0
INNER
STEP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GRAPHIC CONTROLS CORPORATION
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A
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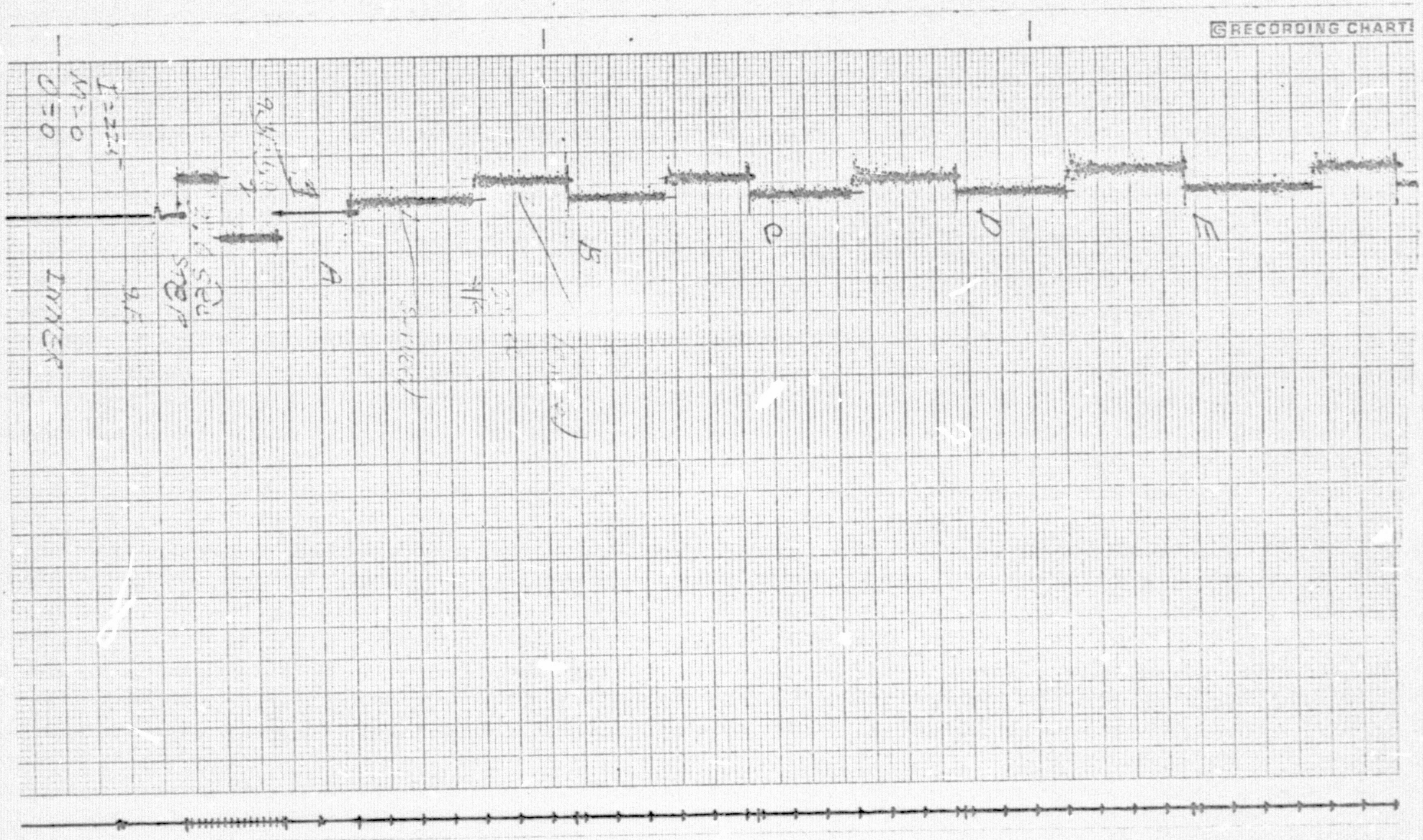
RECORDING CHART
A
B
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RDING CHARTS
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
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I=0
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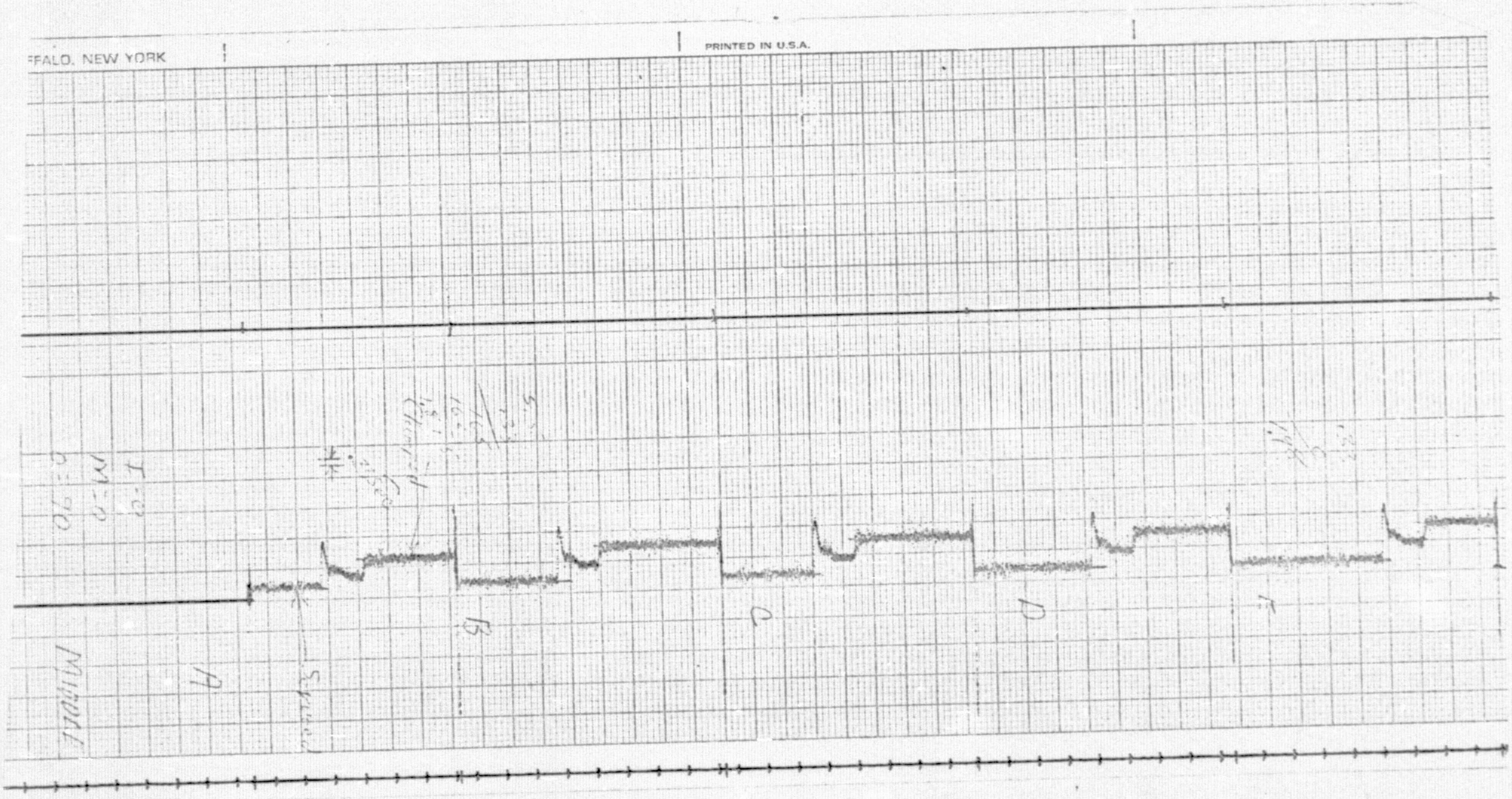
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A
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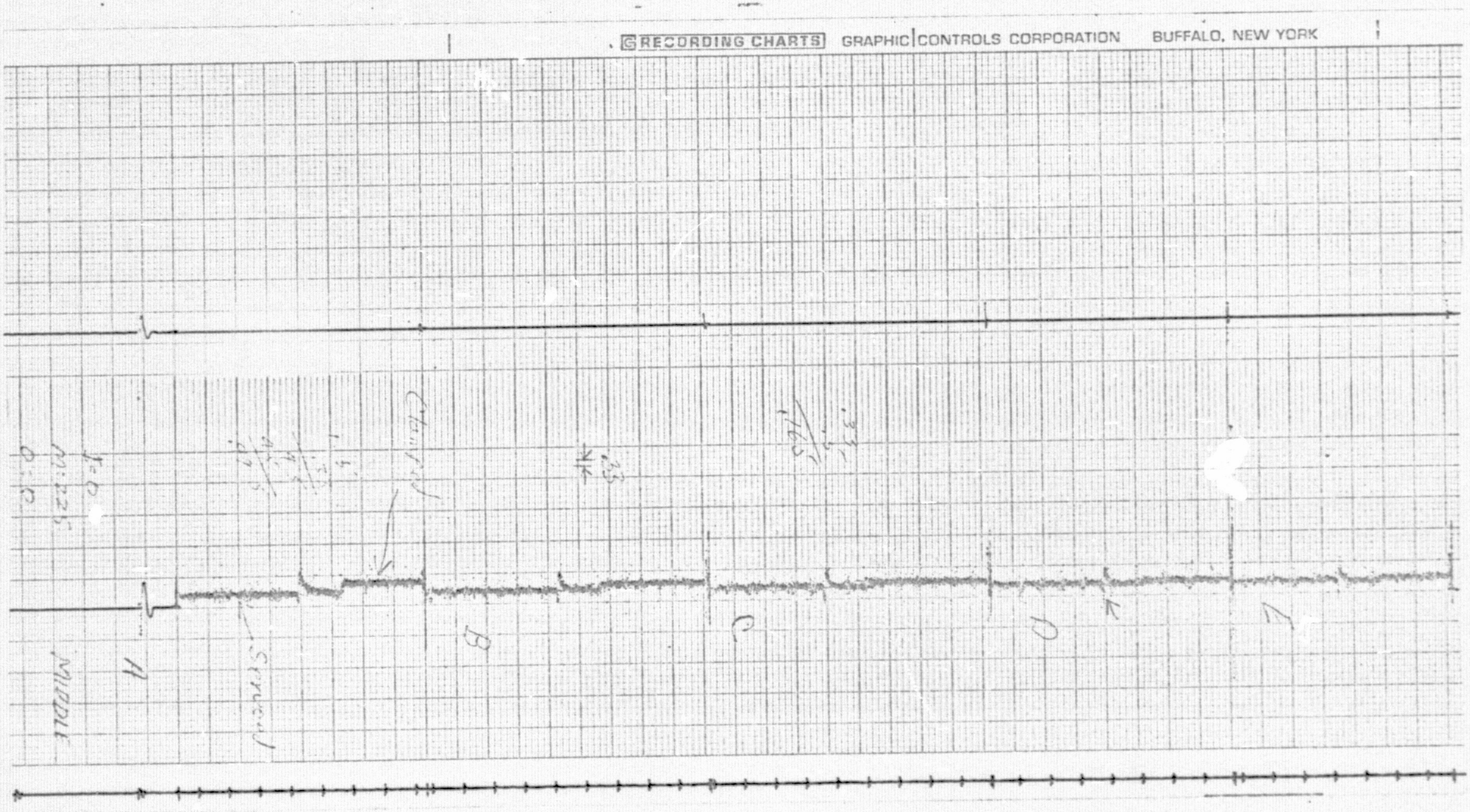
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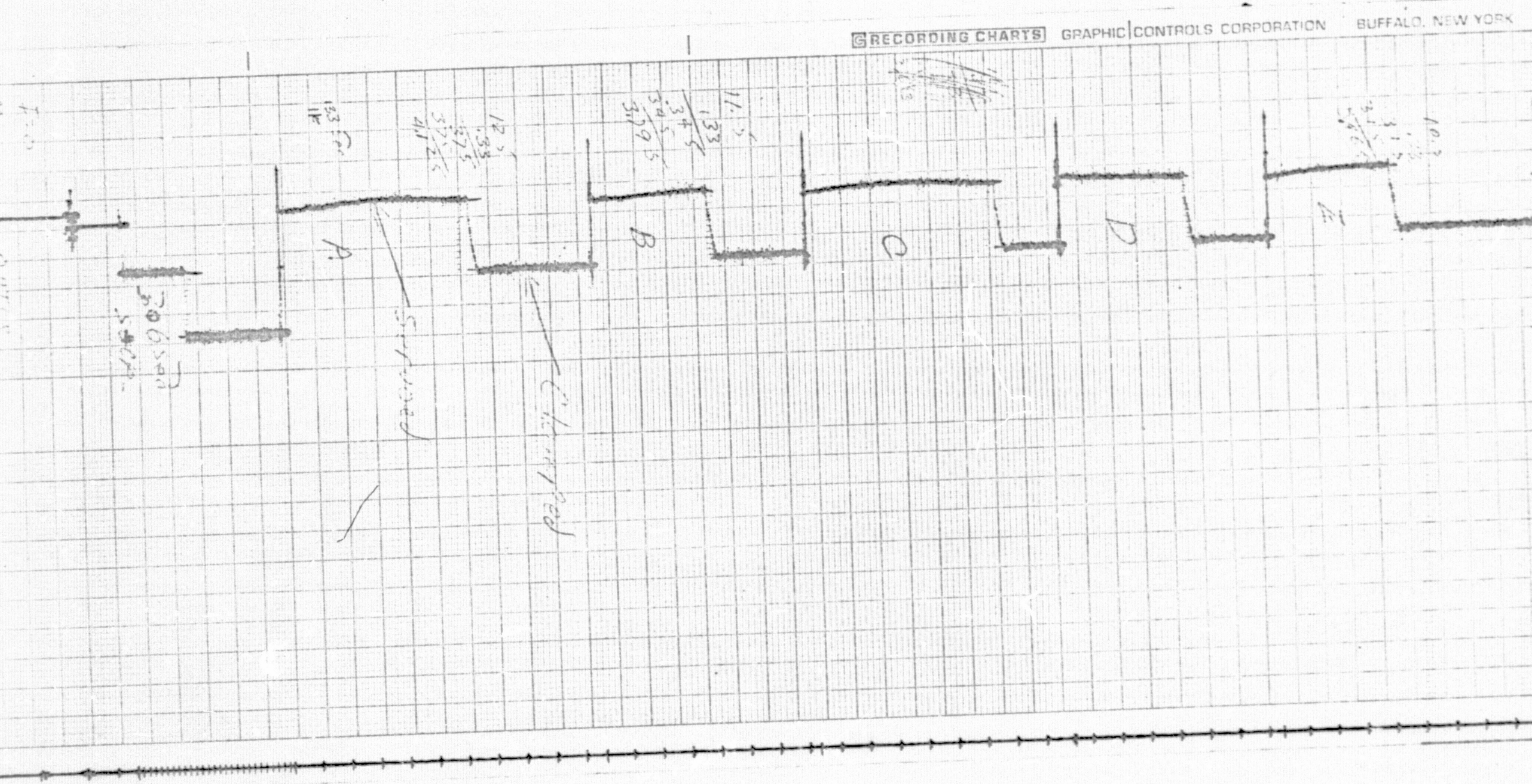
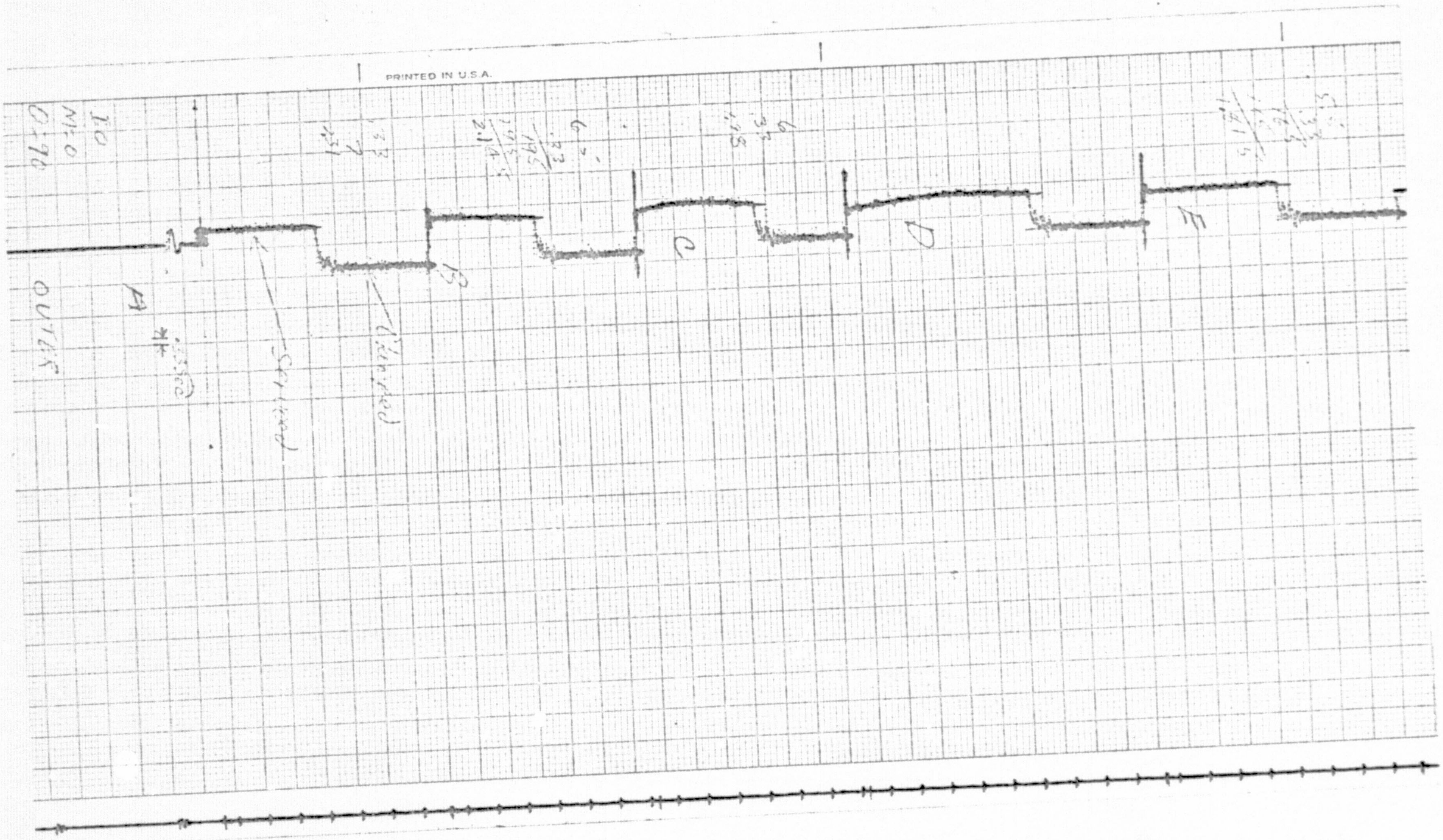
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
A
B
C
D
MIDDLE


RECORDING CHARTS
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
A
B
C
D
E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ADING CHARTS
GRAPHIC CONTROLS CORPORATION
BUFFALO, NEW YORK
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A
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STOP
INNER
INNER
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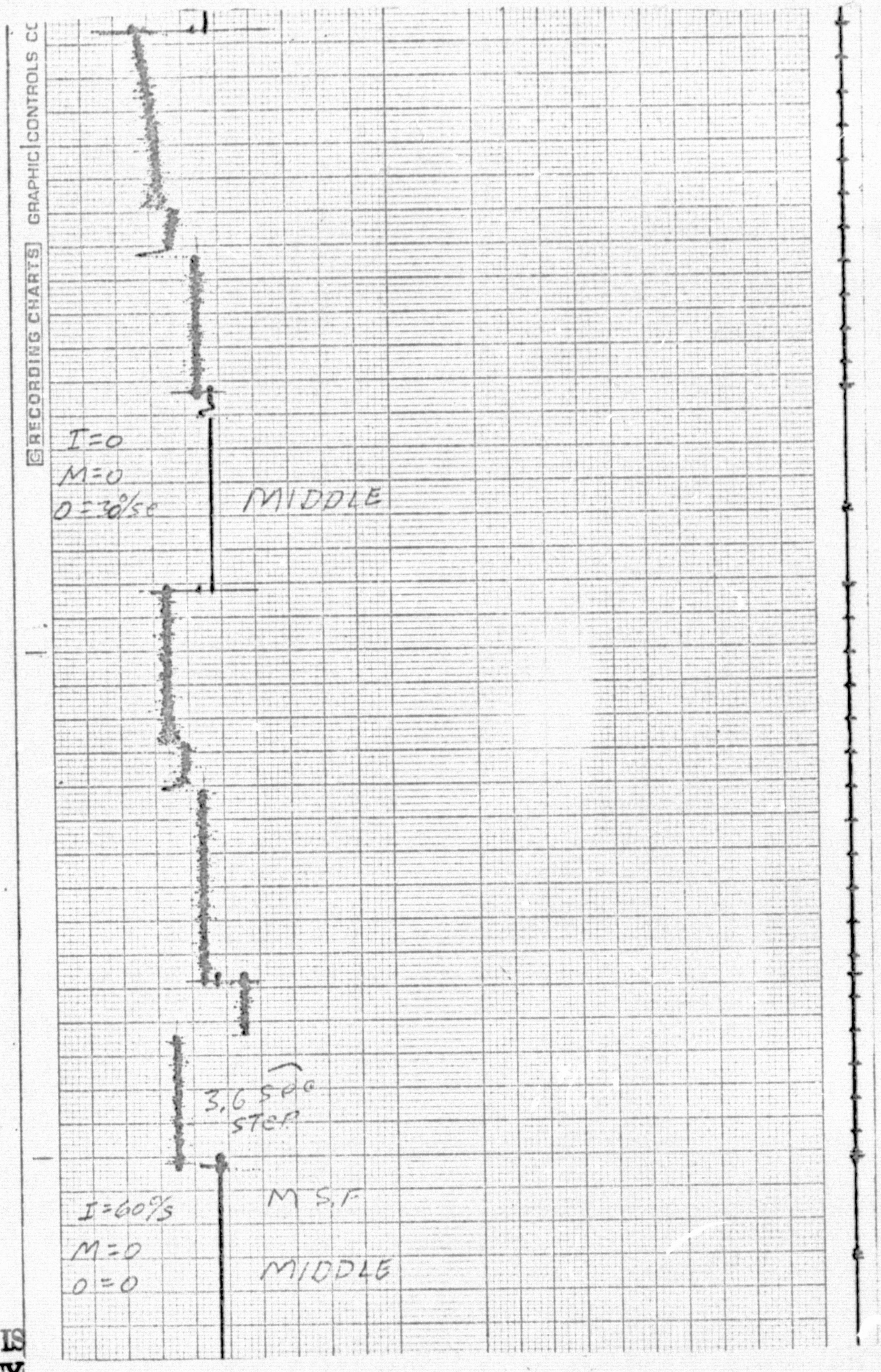
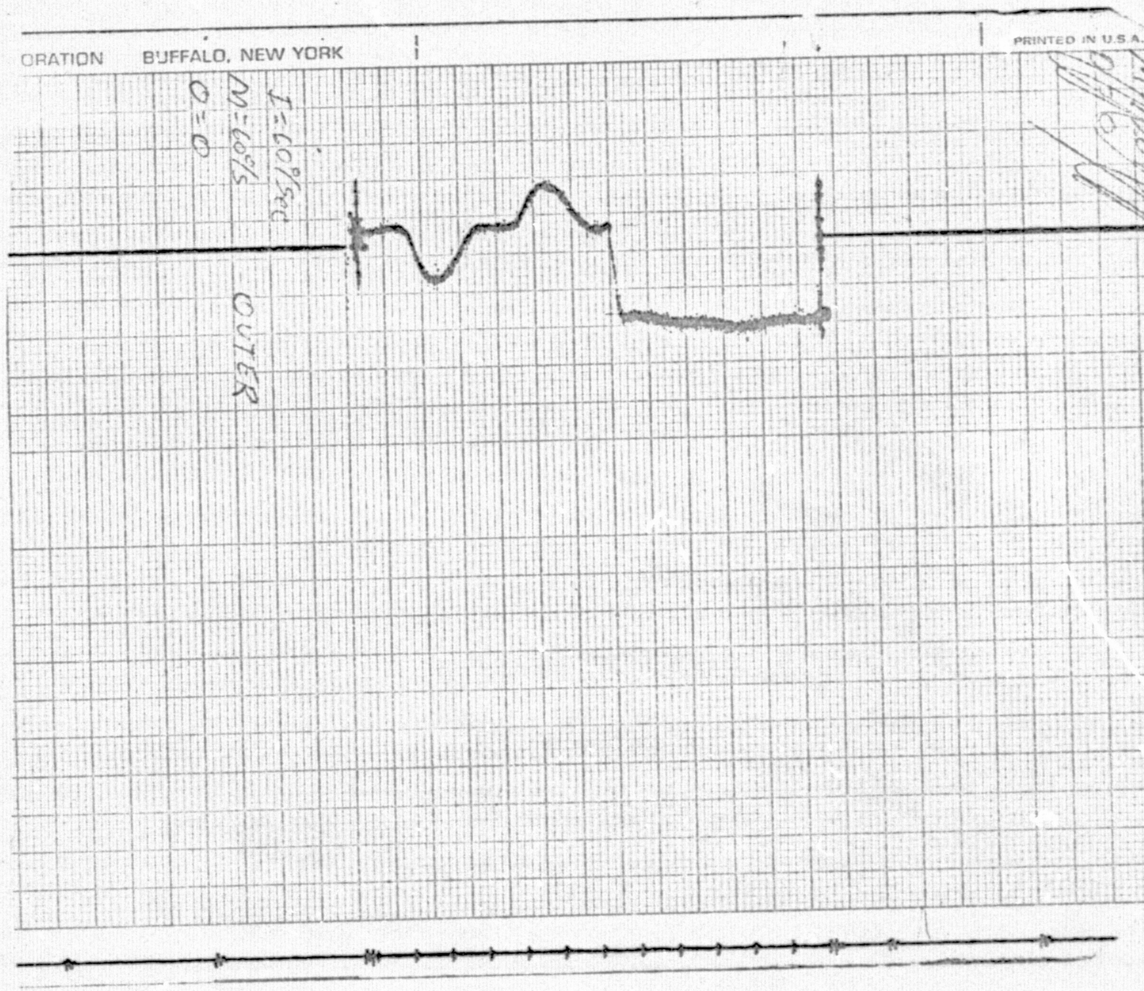

GRAPHIC CONTROLS CO
RECORDING CHARTS
I=0
M=0
O=30%sec
MIDDLE
3.6 sec
STEP
I=60%s
M=0
O=0
M S.F
MIDDLE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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
3.8 b	Clamp Rate Sensitivity	5 arc sec/rad/sec for rates on other axis.	STP-E-2260	1. Use dual channel strip chart. Monitor test axis position error and moving axis buffered tach. 2. On all axis in rate mode: 180 deg/sec = Inner 120 deg/sec = Middle 60 deg/sec = Outer 3. 57 deg/sec^2 = Inner 34 deg/sec^2 = Middle 14 deg/sec^2 = Outer 4. Full load balanced. 5. For axis orientations refer to Table II chart attached.	
	Acceleration Sensitivity	5 arc $sec/rad/sec^2$ for acceleration on other axis (axes).			

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Accel + Rate Error [illegible] Rate [illegible] RP

	Spec Limit MIN	Spec Limit MAX	Measured RP MIN	Measured RP MAX	Spec MIN	Spec MAX	Measured RP MIN	Measured RP MAX	[illegible]
Inner	4.4	20.9	<.72	1.44	2.6	17.5	<.72	.72	[illegible]
Middle	4.4	23.9		.65	2.6	17.5	<.65	.65	[illegible]
Outer	11.0	23.9	<.65	1.35	17.5	17.5	<.65	.6	[illegible]

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		[illegible]		

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
.8 b	Clamp Rate Sensitivity	5 arc sec/rad/sec for rates on other axis.	STP-E-2260	1. Use dual channel strip chart. Monitor test axis position error and moving axis buffered tach. 2. On all axis in rate mode: 180 deg/sec = Inner 120 deg/sec = Middle 60 deg/sec = Outer 3. 57 deg/sec^2 = Inner 34 deg/sec^2 = Middle 14 deg/sec^2 = Outer 4. Full load balanced. 5. For axis orientations refer to Table II chart attached.	
	Acceleration Sensitivity	5 arc sec/rad/sec^2 for acceleration on other axis (axes).			

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Accel + Rate Sens [illegible]

Inner	4.4	22.7	<.72	[illegible]	2.6	17.5	<.72	.72	[illegible]
Middle	4.4	23.7		[illegible]	[illegible]	17.5	<.65	.65	[illegible]
Outer	21.0	23.9	<.65	1.3[illegible]	17.5	17.5	[illegible]	[illegible]	[illegible]

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TABLE II

DYNAMIC CLAMP TEST

Apply brakes before axis is moving.

	AXIS ORIENTATION			POSN * MONITOR	RATE** MONITOR	BRAKES
	INNER	MIDDLE	OUTER			
1	0.0	--	0.0	OUTER	MIDDLE	INNER & OUTER
2	--	0.0	0.0	OUTER	INNER	MIDDLE & OUTER
3	--	90.0	0.0	OUTER	INNER	MIDDLE & OUTER
4	0.0	0.0	--	MIDDLE	OUTER	INNER & MIDDLE
5	--	0.0	0.0	MIDDLE	INNER	OUTER & MIDDLE
6	--	0.0	90.0	MIDDLE	INNER	OUTER & MIDDLE
7	0.0	--	0.0	INNER	MIDDLE	INNER & OUTER
8	45.0	--	90.0	INNER	MIDDLE	INNER & OUTER
9	0.0	90.0	--	INNER	OUTER	INNER & MIDDLE
10	45.0	--	90.0	OUTER	MIDDLE	INNER & OUTER

		HI	LO
*	Inner	J7-D	J7-E
	Middle	J8-D	J8-E
	Outer	J9-D	J9-E
**	Inner	J7-A	J7-B
	Middle	J7-E	J7-F
	Outer	J7-J	J7-K

orie	Accel [illegible]	Rate	[illegible]	Accel
1	.65 sec	.65 sec	200%/sec	40.0
[illegible]	<.65 sec	<.65 sec	200%/sec	74.0 %/sec
[illegible]	1.35 sec	.65 sec	200%/sec	[illegible]
[illegible]	.[illegible] sec	<.65 sec	50%/sec	21.1%/sec
[illegible]	.65 sec	.65 sec	200%/sec	[illegible]
[illegible]	.65 sec	<.65 sec	200%/sec	[illegible]
7	<.72 sec	.[illegible] sec	200%/sec	40.0 [illegible]
8	1.44 sec	<.72 sec	200%/sec	40 %/sec
9	.[illegible]	.[illegible] sec	60%/sec	21
10	[illegible]	.65 [illegible]	200%/sec	40 %/sec

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SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.2.3	Mode Control	Position, rate Angular Acceleration, Angular Oscillation and Remote	By design	Position Mode, Rate Mode, Rate Oscillation Mode and Angular Acceleration (middle axis only) under manual control. All of the above under Remote Control. Each is on a per axis basis.	

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TEST PLAN

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SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II	Position Command Mode	Range and Resolution	~~By design~~	Command 0.0001 degree change watch readout change.	P-P
		Transducer ±0.5 arc sec	By Vendor Data	Accuracy: Inner	0.6 | 1.8 arc s
		Accuracy ±1 arc sec	STP-E-2254	Accuracy: Middle	1.3 | 1.7 arc s
				Accuracy: Outer	[illegible] | 1.3 arc s
				Record readout and position command at each position. Do fine accuracy at 47 degrees and 292 degrees. Also record the analog position output and the incremental readout during this test	
			STP-E-2237A	Coarse Accuracy. Do only 45 degree stops.	

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		[illegible signature]	[illegible signature]	

Position Accuracy

	A	B	C	D	E	F	G	H	I
[illegible]	[illegible]	[illegible]	111.0006	156.1[illegible]1	201.2509	[illegible]	[illegible]	336.[illegible]	[illegible]
T3 [illegible]	[illegible] 37.5"	36.0	36.1	35.4	36.4	37.4	37.7	36.1	37.[illegible]
[illegible]	0	- 1.5	- 1.4	- 2.1	- 1.1	- .1	+ .2	1.4	2.2 [illegible]
[illegible]	2[illegible]	[illegible]	111.0006	156.1312	201.2510	2[illegible]85	291.5028	336.6[illegible]	

	A	B	C	D	E	F	G	H	I
OMNO [illegible]	111.0025	156.1281	201.[illegible]1	246.3806	291.5039	336.6[illegible]	21.7550	[illegible].8823	111.00[illegible]
T3 Readout	2[illegible]	26.5	27.1	26.8	26.6	26.9	26.0	25.8	
[illegible]	0	- .7	+ .1	- .2	- .4	- .1	- 1.0	-1.2	1.[illegible]
Readout	111.0026	1[illegible]6.12[illegible]	201.2532	246.3157	291.5035	336.6310	21.7550	66.8[illegible]	

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Position accuracy

SET 1	A	B	C	D	E	F	G	H	
CMND Ang	180.0	22[illegible]	270.2506	315.3811	0.5009	45.6284	90.7525	135.8798	180.0
T3 Reading	0°0'8.2"	8.3"	9.7	8.9	9.3	8.9	[illegible]		
Norm	0	+.6"	+1.5	+.7	+1.1	+.7	[illegible]		
Readout	180.0000	225.1256	270.2506	315.3811	0.5009	45.6284	90.7525	135.8798	
	2.5	2.7	2.8	3.3	2.3	2.1	2.0	2.1	
	0	+.2	+.3	+.8	-.2	-.4	-.5	-.4	1.3 RP

SET 2	A	B	C	D	E	F	G	H	
	270.0	315.1256	0.2506	45.3811	90.5009	135.6284	180.7525	225.8798	270.0
T3 Read	0°0'2.7"	4.0"	4.1	2.4"	4.0"	3.8	3.8	4.01	
Norm	0	+1.3	+1.4	-.3	+1.3	+1.1	+1.1	+1.4	1.7 RP
Readout	270.0000	315.1256	0.2506	45.3811	90.5009	135.[illegible]	180.7525	225.8798	270.0[illegible]

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INNER Axis

Position Accuracy

Set 1	A	B	C	D	E	F	G	H	A'
Cmnd Ang	0.02	45.1456	90.2706	135.4011	180.5209	225.6484	270.7725	315.8998	0.02
T.S. Reading	56.5	56.3	56.5	56.4	56.0"	56.4	56.6	56.4	
Norm	0	-.2	0	-.1	-.5	-.1	+.1	-.1	.6 P
Readout	000.0200	45.1456	90.2706	135.4010	180.5209	225.6484	270.7725	315.8978	

Set 2									
Cmnd Ang	90.02	135.1456	180.2706	225.4011	270.5209	315.6484	0.7725	45.8998	90.02
T.S. Reading	37.1"	35.3"	35.5"	36.0"	35.5	35.6	36.0	35.6	
Norm	0	-1.8	-1.6	-1.1	-1.6	-1.5	-1.1	-1.5	1.8 P
Readout	090.0200	135.1456	180.2706	225.4011	270.5209	315.6484	0.7725	45.8997	

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
Table II (cont.)		Repeatability ≤1 arc second ≤ 1 sec ≤ .24 sec Ok		Use strip chart monitoring analog position output on each axis. Command axis at analog voltage. Command axis off ±.1 deg and ±90.0 deg and return to zero. Record analog voltage after axis has settled. Convert using scale factors. Repeat the test 5 times at angles of 0.0000 degree and 135.2738 degrees.	≤ .24 sec All Axis

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
Table II (Cont)	Position Command	Rate Sensitivity Acceleration Sensitivity 3 arc sec/rad/sec^2 .05 sec/°/sec .05 sec/°/sec	STP-E-2260	1) Use dual channel strip chart monitor test axis position error and moving axis buffered tach. (Table IV) 2) Rate ~~180~~ 600 deg/sec, Inner ~~120~~ 600 deg/sec, Middle 30 deg/sec, Outer on all axes in rate mode. 3) Acceleration Limits 57 deg/sec, Inner 34 deg/sec, Middle 14 deg/sec, Outer 4) Full Load 5) Orientation per attached chart.	See attached sheet

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Position Command & Rate Acceleration Sensitivity

	Rate °/sec	Accel °/sec²	Rate Sens.		Rate °/sec
1	200°/sec	40 = 7 [illegible]	.25	*S	5.1
2	200°/sec	79	2.62		<.62
3	200°/sec	79	1.5		1.5
4	60°/sec	21.1	<.65		<.65
5	200°/sec	79	<.65		<.65
6	200°/sec	79	<.65		<.65
7	200°/sec	40	.6		.6
8	200°/sec	40	1.2		2.4
9	60°/sec	21.1	2.1		2.9
10	200°/sec	40	1.6		1.6

Limit for 200°/sec = 10 deg

60°/sec = 3 deg

(1) AT 100°/sec - Inner approx is 7.5 deg

* This point out of spec Data to Be run due to axis imbalance see Introduction for Details

TABLE IV
POSITION COMMAND, RATE AND ACCELERATION SENSIVITY

Position axis then set others in motion.

	POSITION			AXIS MODE			POSITION MONITOR	RATE MONITOR
	Inner	Middle	Outer	I	M	O		
1	0.0	---	0.0	P	R	P	O	M
2	---	0.0	0.0	R	P	P	O	I
3	---	90.0	0.0	R	P	P	O	I
4	0.0	0.0	~~0.0~~	P	P	R	M	O
5	---	0.0	0.0	R	P	P	M	I
6	---	0.0	90.0	R	P	P	M	I
7	0.0	---	0.0	P	R	P	I	M
8	45.0	---	90.0	P	R	P	I	M
9	0.0	90.0	---	P	P	R	I	O
10	45.0	---	90.0	P	R	P	I	M

Position axis when others in motion.

	POSITIONS				
	I	M	O	MONITOR	RATE %
1	90-0	---	0	Inner	60
2	270-0	---	0	Inner	60
3	90-0	90	-	Inner	30
4	270-0	90	-	Inner	30
5	---	90-0	0	Middle	60
6	---	270-0	0	Middle	60
7	0	90-0	-	Middle	30
8	0	270-0	-	Middle	30
9	---	---	90-0	Outer	60
10	---	---	270-0	Outer	60
11	---	---	90-0	Outer	120
12	---	---	270-0	Outer	120

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II CONT	RATE MODE	Resolution	By design	0.001 deg/sec	
		Range	By design	0-199 deg/sec inner and middle Outer 0-79 deg/sec	
		Instability ±0.1% over 1 sec		Use Direct Readout Display. Take 4 readings as in attached Rate Chart	
		Accuracy .1% or .001°/sec whichever is greater.		Take each axis independently with the two axes not being tested in position mode.	
		Repeatability .01°/sec		Accuracy is peak deviation from command value. Instability is deviation from the average rate.	
				Repeatability is the average rate difference from set to set.	

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RATE MODE

Initial Position	I	M	O
SET I	0.0	0.0	0.0

Rate deg/sec	Inner	Middle	Outer	Spec	deg/sec
+000.100	+000.1000	+.1002	+.1002		
+000.100	+000.1001	+.0997	+.0999	.100	±0.001
+000.100	+000.1000		+.1001		
+000.100	+000.0999		+.0999		
+000.100	+000.1000		+.1000		
1.000					
+001.000	+.999	+1.0003	+1.0003	1.000	±0.001
+001.000	+1.000 +.999		+0.9997		
+001.000	+1.000	+0.9997			
+001.000	+1.000				
10.000					
+010.000	+10.000 +9.999	+10.000	+10.000	10.000	±0.01
+010.000	+10.000	+9.999	+9.999		
+010.000	+9.999				
+010.000	+10.000				
Maximum	+180.000		60±.0005	60.000	±0.06
Maximum	+179.999	120±.0005		120.0	±0.12
Maximum	+180.000			180.0	±0.18
Maximum	+179.999				
Maximum	+180.000				

Initial Position	I	M	O
Set 2	0.0	0.0	0.0

-000.100	-.1±.0003	-.1±.0004	.1+.0001 -.0002	.100	±.0.001
-000.100			.1±.0003		
-000.100					
-000.100					
-000.100					
-001.000	1.0±.0008	1.±.0003	1±.0006	1.000	±0.001
-001.000					
-001.000					
-001.000					
-001.000					
-010.000	10±0.001	10±.001	10±.0006	10.000	±0.01
-010.000					
-010.000					
-010.000					
-010.000					
Maximum	180±0.011	120±.0010	60±.006		
Maximum					
Maximum			60±.06		
Maximum					
Maximum					

RATE MODE

	I	M	O
Initial Position Set 3	0.0	0.0	0.0

Rate deg/sec	Inner	Middle	Outer	Spec	Deg/sec
+000.100				.100	±0.001
+000.100					
+000.100					
+000.100					
+000.100					
+001.000				1.000	±0.001
+001.000					
+001.000					
+001.000					
+C01.000					
+010.000				10.000	±0.01
+010.000					
+010.000					
+010.000					
+010.000					
Maximum					
Maximum					
Maximum					
Maximum					
Maximum					

	I	M	O
Initial Position Set 4	0.0	0.0	0.0

-000.100				.100	±0.001
-000.100					
-000.100					
-000.100					
-000.100					
-001.000				1.000	±0.001
-001.000					
-001.000					
-001.000					
-001.000					
-010.000				10.000	±0.01
-010.000					
-010.000					
-010.000					
-010.000					
Maximum					
Maximum					
Maximum					
Maximum					
Maximum					

RATE MODE

Initial Position I 90.0 M 0 O 90.0

Set 5

Rate deg/sec	Inner	Middle	Outer	Spec	deg/sec
+000.100	+.1±.0003	+.1±.0003	+.1±,0003		
+000.100				.100	±.001
+000.100					
+000.100					
+000.100					
+001.000	+1.0±,0006	+1.0±,0004	+1.0±,0004		
+001.000				1.000	±.001
+001.000					
+001.000					
+001.000					
+010.000					
+010.000	+10.0±.0007	+10±.0006	+10±.0006	10.000	±.01
+010.000					
+010.000					
+010.000					
Maximum					
Maximum					
Maximum	+180±,0005	+120±,0017	+60±.005		
Maximum					
Maximum					

Initial Position I 90.0 M 90.0 O 90.0

Set 6

Rate deg/sec	Inner	Middle	Outer	Spec	deg/sec
-000.100					
-000.100	-0,1±.0003	-0.1±.0003	-0.1±,0003	.100	±001
-000.100					
-000.100					
-000.100					
-001.000					
-001.000	-1.0±,0005	-1,0±,0003	-1.0±,0006	1.000	±.001
-001.000					
-001.000					
-001.000					
-010.000					
-010.000				10.000	±.01
-010.000	-10±,0005	-10±.0009	-10±.0005		
-010.000					
-010.000					
Maximum	-180±.0007	-120±.0008	-60±.00	100.000	±.1
Maximum					
Maximum					
Maximum					
Maximum					

Initial Position	I	M	O
	0.0	0.0	0.0

Set 7

Rate deg/sec	Inner	Middle	Outer	Spec	deg/sec
Maximum					
- Maximum					
Maximum					
Maximum					
Maximum					

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)	Angular Acceleration Mode (Middle Axis)	Resolution Range	By design By design	.01 deg/sec^2 .01-39.99 deg/sec^2 Demonstrate range and resolution by readout.	OK
		Accuracy $\pm.01 = \pm.57\ deg/sec^2$ Repeatability $\pm.005 = \pm.29\ deg/sec^2$ Instability $\pm.005$ rad/sec = .29 deg/sec^2	STP-E-2256	Do STP with I = 0.0 and O = 0.0 Middle initial position at 0. Repeat test at +15 deg/sec^2 only for the following: 1. Inner = 0, Outer = 90 12.6 2. Outer oscillating at 1 Hz. 3. Inner oscilating at 1HZ 4. Outer = 0, Inner rating at +180 deg/sec. 12.6 At + 15 deg/sec^2, Outer = 0, Inner = 0, monitor acceleration error. Check with scale factor for instability.	Peak rate 7°/sec Peak rate 10°/sec See STP For Data

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SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)	Acceleration Limit	Resolution .05 rad/ sec^2 = 2.9 deg/sec^2	By design	1 deg/sec^2	
		Range I 0-±1 rad/sec^2 M 0-±6 rad/sec^2 O 0-±.25 rad/sec^2	By design	0-69 deg/sec^2 58°/sec^2 0-39 deg/sec^2 36 0-19 deg/sec^2	
	ORIGINAL PAGE IS OF POOR QUALITY	Repeatability .05 rad/sec^2 3°/sec	STP-E-2257	Do STP, 2 times and record the difference as repeatability.	I ______ °/sec M ______ °/sec O ______ °/sec
				Do acceleration limit calibration Acceleration Mode On, Middle Axis set. Acceleration limit at 30 deg/sec^2. Record acceleration readout. Set acceleration limit at 29 deg/sec^2. Record acceleration rate. Difference between the two is resolution. Setting Accel +30 => 15 −30 => 16 − 14	See Sheets

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Inner Axis Acceleration
Limit Calibration

Set Threshold Switch	Acc. 0 to +Rate °/sec²	+Rate to 0 °/sec²	0 to -Rate °/sec²	-Rate to 0 °/sec²
30	4	38.7	7.6	37.5
40	12.2	44.9	13.9	43.7
50	18.7	55	20.8	55
60	27.6	66.5	31.4	66.5
70	36.4	72.5	40	72.5
80	40.4	76	44.4	77.5
90	50	89	51.5	88.4
99	58	94.5	59.3	91

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GOERZ OPTICAL COMPANY
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Middle Axis Acceleration
Limit Calibration

Set Thumbwheel Switch	Acc. 0 to +Rate °/Sec²	+Rate to 0 °/Sec²	0 to -Rate °/Sec²	-Rate to 0 °/Sec²
20	7.4	20	8	20
30	15.4	26.6	15.4	26.6
40	22.9	34.9	22.1	34.8
50	30.2	41	30.2	42.2
59	34.8	48.5	36.3	50

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Outer Axis Acceleration
Limit

10	6.65	12.8	7.05	12.8
15	7	15.2	7.95	15.8
20	9.1	19.1	9	15.4
25	14.6	23.1	13.1	22.1

Middle Acceleration Limiting

Set 1

TW Setting	Meas. [illegible]	ΔT [illegible]	A.C.	ΔT	A.C.
20	± 80 °/sec	10 sec	8 °/sec²	4 sec	20 °/sec²
30	± 80	5	15.4	3	26.8
40	± 80	3.6	22.1	2.3	33.9
50	± 80	2.65	30.2	1.85	41.0
59	± 80	2.2	36.3	1.65	48.5

Set 2

20	± 80	9.55	8.35	4.6	17.4
30	± 80	[illegible]	15.25	2.85	28.1
40	± 80	3.55	22.5 °/s²	2.4	33.3
50	± 80	2.65	30.2	1.9	42.1
59	± 80	2.2	36.3	1.6	50 °/s²

INNER Acceleration limiting

Set 1

30	± 60	9.4	6.4 %	1.5	40
40	± 80	5.8	13.8 %	1.7	47.0
50	± 80	3.65	21.9	1.45	55.
60	± 80	2.75	29.05	1.25	59.3
70	± 80	2.15	37.2	1.1	72.5
80	± 80	1.77	45.2	1.02	78.5
90	± 80	1.55	51.5	.9	89
99	± 80	1.38	58	.85	94.5 °/s²

Set 2

30	± 60	6.25	9.6	1.55	38.7 °/s²
40	± 80	5.75	13.9	1.83	53.7 °/s²
50	± 80	3.85	20.8	1.45	55.
60	± 80	2.55	31.4 °/s	1.2	66.5
70	± 80	2	40 %	1.1	72.5
80	± 80	1.8	44.4	1.03	72.5
90	± 80	1.55	51.5	.9	89
99	± 80	1.38	58	.85	94.5 %

TW Setting	Micro Rate	ΔT Meas°	ACC	ΔT Meas	ACC
OUTER Axis Acceleration Limiting					
Set 1					
10	±20	2.85	7.05	1.55	12.8
15	±10	5.05	7.95	2.53	15.8
20	±10	4.45	9	2.2	16.9
25	±10	3.05	13.1	1.9	22.1
29					
Set 2					
10	±20	2.7	7.4	1.65	12.1
15	±40	5.15	7.75	2.6	15.4
20	±40	4.3	9.3	2.3	17.4
25	±40	2.85	14.05%	1.75	22.8
29					

CONTRAVES-GOERZ, CORP.
SUBSIDIARY
CONTRAVES AG, OERLIKON-BÜHRLE HOLDING

CUSTOMER: ____
SALES ORDER: ____
INSTRUMENT: ____

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)	Angular Rate Oscillation	Range I .005 to 75Hz M .005 to 40 Hz O .005 to 15 Hz 3 digit resolution	Exact 605 Specs	1800 times the frequency of oscillation for slaved mode. Command Axis Oscillation OSC Range / Minimum / Maximum 100-999K / 55.5 Hz / 555 Hz 10-99.9K / 5.55 Hz / 55.5 1-9.99 K / .55 Hz / 5.55 .1-.999K / .055 / .55 10-99 Hz / .0055 / .055	
		Accuracy ±1% of setting ±LSB of range above 10.0 mHz ±2% of setting ±LSB of range below 9.99 mHz	"	±1% of setting ±1 digit over above ranges. Use Hf clock gated by reference output of each axis. Record period in seconds, per Table V. Do second set 1 hour later.	
		Stability ≤.5 Hz	"	.2% for 24 Hrs. or .15 Hz at 75 Hz.	

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DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE 9 OF ___

TABLE V

OSCILLATION SOURCE ACCURACY

REFERENCE FREQUENCY	OSCILLATION FREQUENCY	SPEC PERIOD	SEC	INNER 1st	INNER 2nd	MIDDLE 1st	MIDDLE 2nd	OUTER 1st	OUTER 2nd
135 KHz	75	0.0133	±.000013						
45 KHz	25	0.04	±.00004						
4.5 KHz	2.5	0.4	±.0004						
450 Hz	0.25	4.0	±.004						
45 Hz	0.025	40.0	±.04						

Covered by certificate of Compliance

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CUSTOMER: ____________
SALES ORDER: ____________
INSTRUMENT: ____________

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)	Angular Rate Oscillation Continued	Phase Adjustment Resolution ≤ ±1 deg Accuracy ±1 deg	Exact 337	±.2 deg ±.2 deg	
			Demonstrate	Oscillate inner axis and middle axis around 0.0. Position command. Oscillate at 10 Hz. Monitor zero reference pulses for middle and inner axis on oscilloscope. Determine that the time relationship changes for phase shifts of 45 degrees and 90 degrees to a resolution of 1 degree.	

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE 10 OF ___

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CUSTOMER: ____________
SALES ORDER: ____________
INSTRUMENT: ____________

TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
Table II (cont)	Frequency Response	I ±3db 0 to 75 Hz M ±3db 0 to 400Hz O ±3db 0 to 15 Hz	STP-E-272 For method only.	Plot amplitude and phase. Position 0, 0, 0, 0, 0, 90. Other axis in position mode. Test axis in rate oscillation mode. For Rate oscillation Loop use external Input Jack for noise source inputs and Buffered tach as the feedback. For Position Loop Connect as shown.	See attached Frequency Response Data

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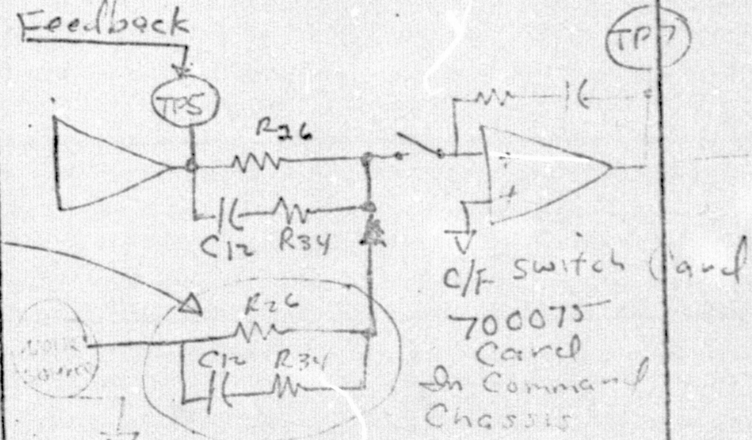
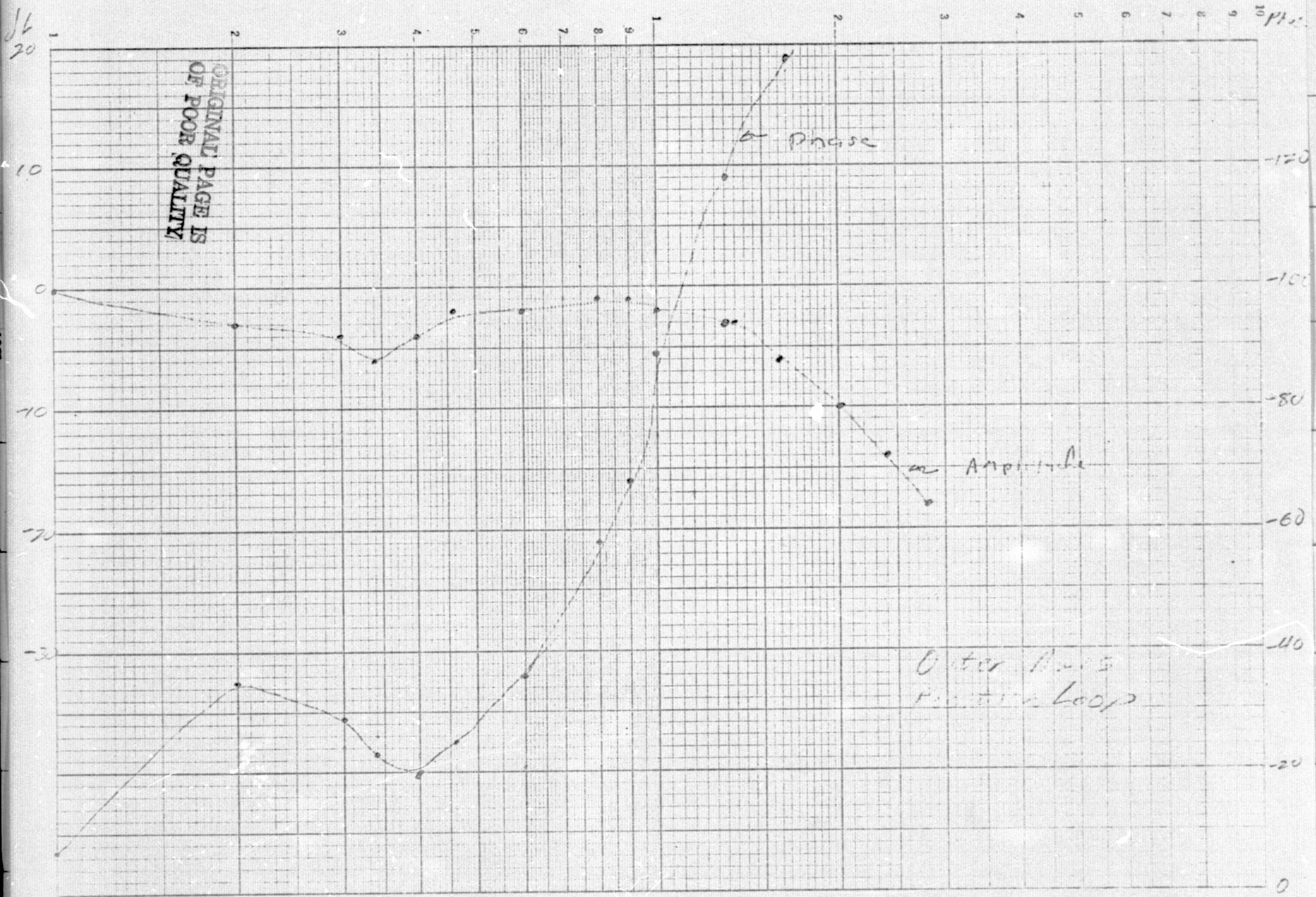
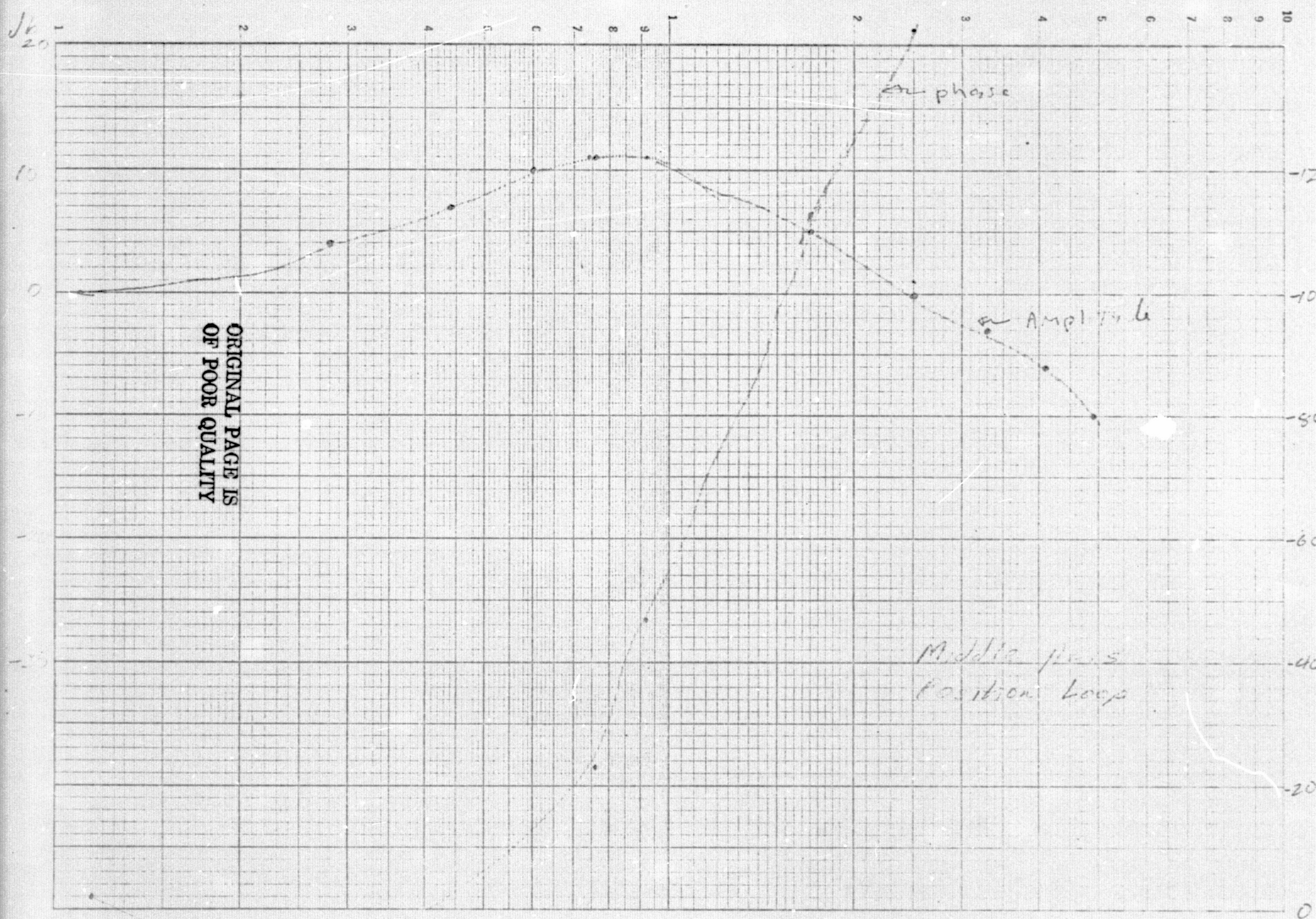


make this network the same as the network on the Card.

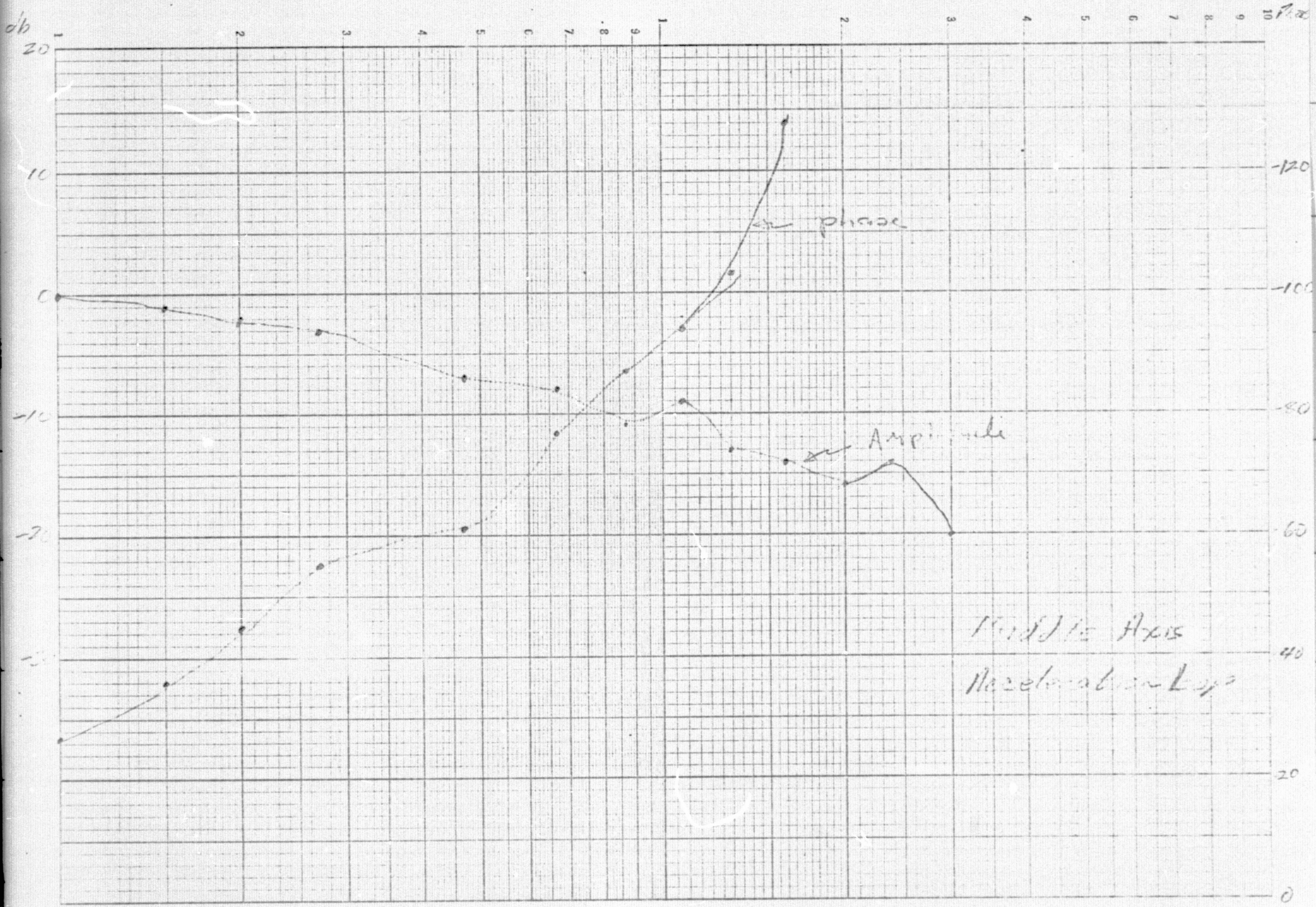
DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE ___ OF ___

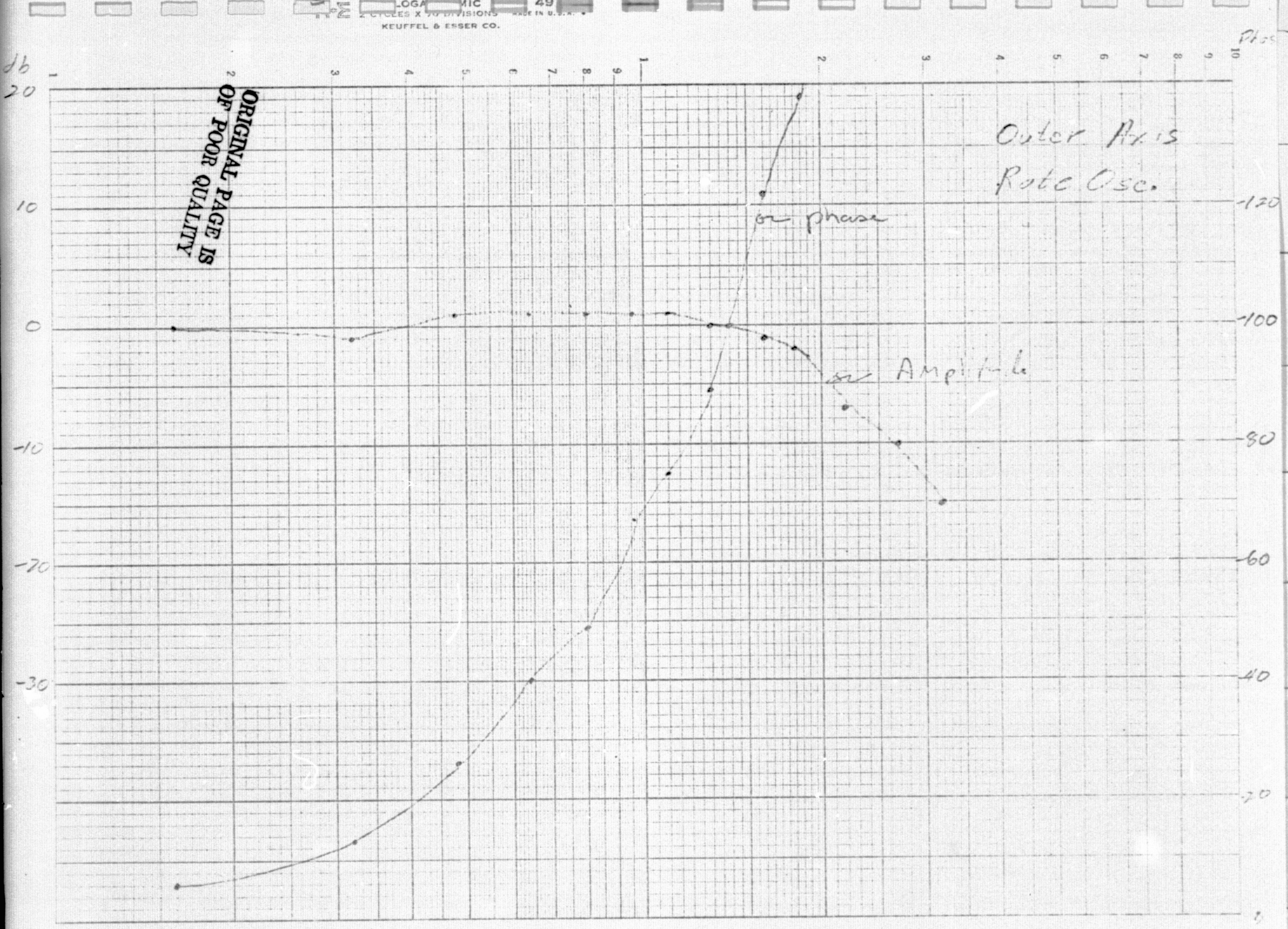

Phase
Amplitude
-120
-100
-80
-60
-40
-20
0
10
0
-10
-20
-30
Loop

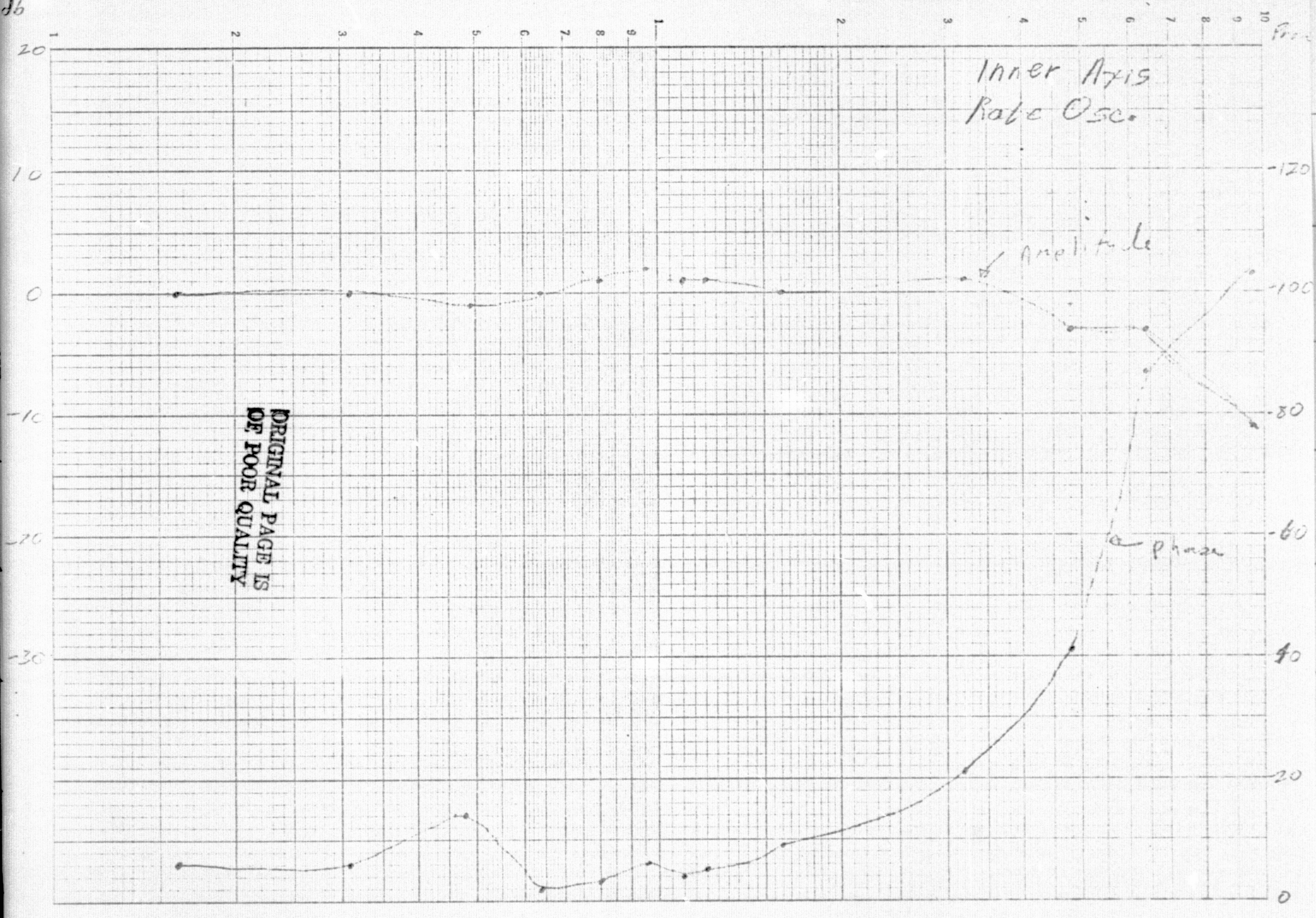

db
phase
Amplitude
Middle press
Position Loop
1
2
3
4
5
6
7
8
9
10
20
10
0
-10
-120
-100
-80
-60
-40
-20
0


db
phase
AMplitude

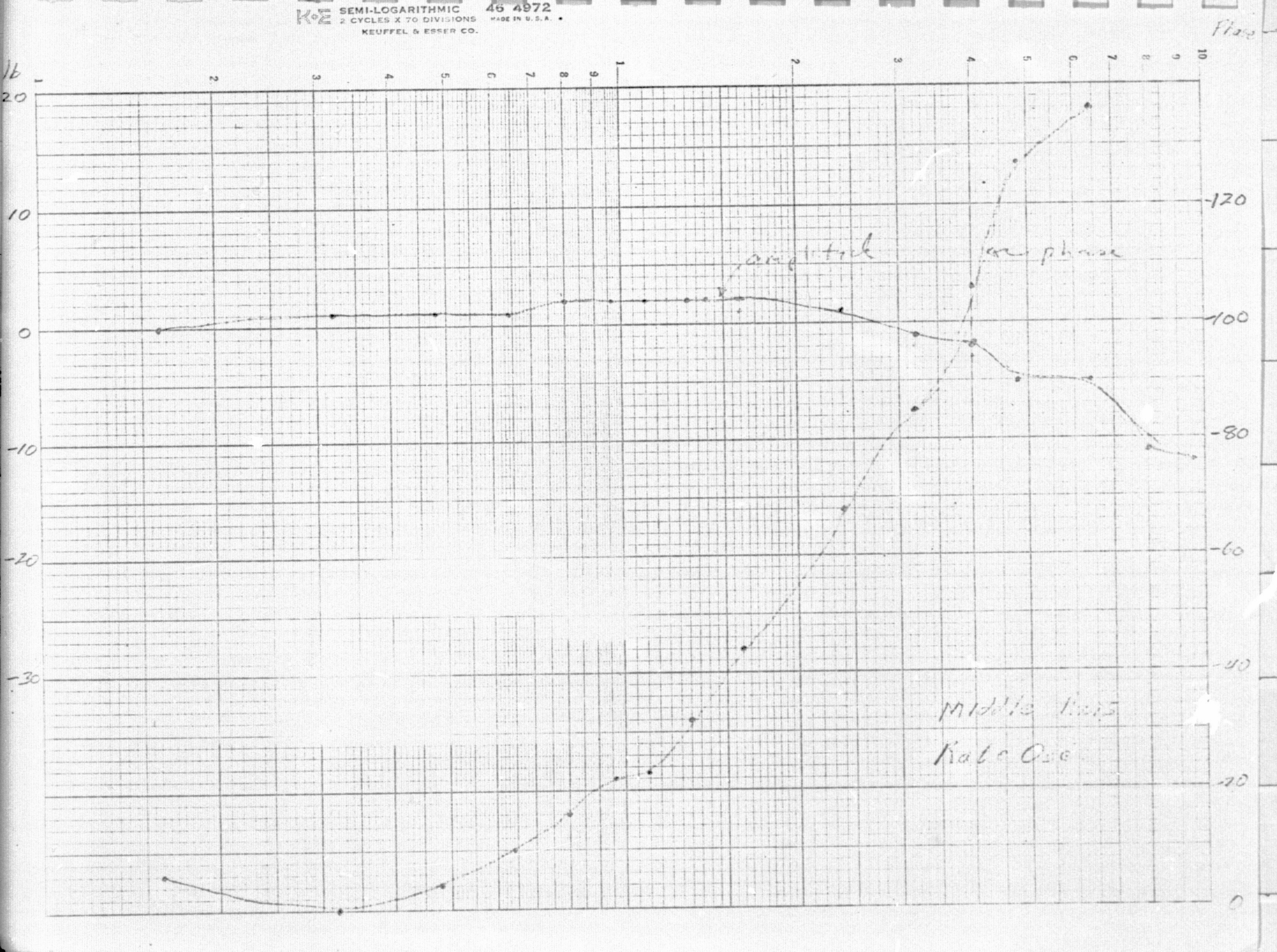
LOGARITHMIC 49
2 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.




KEUFFEL & ESSER CO.
ORIGINAL PAGE IS OF POOR QUALITY
Outer Axis
Rate Osc.
phase
Amplitude
db
20
10
0
-10
-20
-30
-120
-100
-80
-60
-40
-20



db
Inner Axis
Rate Osc.
Amplitude
phase
20
10
0
-10
-20
-30
-120
-100
-80
-60
40
20
0


K+E SEMI-LOGARITHMIC 46 4972
2 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.
db
20
10
0
-10
-20
-30
120
100
80
60
40
20
0
amplitude
phase

INNER AXIS position loop
10-9-75
$f_{max} = 100$ Hz
$\Delta F = \frac{100}{256} = .39$ Hz

B7512
RA
J 3
TPS
TLS
D 1
D 3
RA
J 8
D 1
TP
TL
M 8

← add to dB reading

SF	41		dB 7	Phase 151	dB	← Phase (deg)			.1.2		
(	0)		-10400		-1625	-63	-1726	2371	-1246	3733	
(	4)	1.6	-1433	-2412	-1343	2113	-1351	2144	-1293	1373	2.8"
(	8)		-1119	1984	-1210	1357	-1843	2046	-1023	1678	4.4
(	12)		-1333	1533	-836	999	-832	836	-378	1433	6
(	16)		-889	929	-752	302	-901	-632	-851	-295	7.6
(	20)		-633	-683	-779	-1230	-684	-999	-789	-922	9.2
(	24)		-713	-1491	-682	-2344	-647	-2113	-631	-2119	10.8
(	28)		-635	-2938	-610	-2334	-594	-3349	-651	-3210	
(	32)		-523	-3391	-627	-3573	-638	-4147	-622	-4477	
(	36)		-626	-4591	-618	-5872	-691	-5146	-671	-5145	
(	40)	16	-653	-5139	-325	-5111	-619	-5991	-613	-6153	17.2
(	44)		-711	-6774	-673	-6134	-631	-6778	-734	-6777	18.8
(	48)		-671	-7117	-723	-7559	-719	-7333	-635	-8274	
(	52)		-753	-3593	-777	-8333	-778	-8873	-748	-8121	
(	56)		-731	-9195	-793	-8364	-745	-9316	-883	-9263	23.6
(	60)		-851	-11326	-749	-9733	-836	-10066	-893	-9191	
(	64)		-829	-9776	-821	-9631	-937	-10334	-848	-10530	
(	68)		-923	-10333	-922	-10943	-954	-11430	-999	-11325	28.4
(	72)		-992	-11164	-1033	-11783	-1017	-12253	-1023	-11365	
(	76)		-1311	-12333	-1311	-12533	-1113	-12536	-1033	-12542	
(	80)	32	-1062	-12462	-1133	-12536	-1094	-13428	-1225	-13763	33.2
(	84)		-1134	-13335	-1255	-13351	-1167	-13533	-1133	-12957	
(	88)		-1214	-13546	-1296	-14161	-1312	-13214	-1213	-14462	
(	92)		-1266	-13930	-1355	-14322	-1293	-14822	-1432	-14339	38
(	96)		-1314	-14124	-1313	-14229	-1361	-15727	-1337	-15239	
(	100)		-1473	-15352	-1494	-16352	-1431	-15463	-1537	-15754	
(	104)		-1521	-15762	-1393	-15633	-1517	-16463	-1564	-16639	42.8
(	108)		-1423	-16655	-1593	-15693	-1530	-16713	-1652	-16534	
(	112)		-1632	-16639	-1633	-16672	-1720	-16433	-1774	-16934	
(	116)		-1761	-16932	-1723	-16435	-1648	-17231	-1813	-15833	
(	120)	48	-1659	-17536	-1749	-16312	-1945	17724	-1833	17763	47.7
(	124)		-1753	-16941	-1775	17712	-1747	-16611	-1937	17329	
(	128)		-1833	17597	-1936	17334	-1832	-17336	-1962	17354	
(	132)		-1939	-17332	-2275	-17216	-2215	17591	-2021	-17913	54
(	136)		-2337	17596	-1995	-17773	-2154	17596	-1838	17333	
(	140)		-1938	-17332	-2137	16924	-2122	17450	-2250	-17237	
(	144)		-2152	16613	-2040	16553	-2150	17733	-2225	16911	
(	148)		-2137	16142	-2193	16228	-2333	16793	-2341	16130	
(	152)		-2315	16427	-2194	16136	-2236	16113	-2516	17463	
(	156)		-2463	15597	-2334	16282	-2364	17357	-2453	16231	
(	160)	64	-2335	17037	-2395	13679	-2679	15342	-2415	17419	
(	164)		-2632	15461	-2352	16157	-2734	16597	-2513	16029	
(	168)		-2634	15072	-2735	15306	-2496	14668	-2723	14156	
(	172)		-2317	14561	-3474	12370	-3577	17995	-2653	16097	
(	176)		-2979	-17148	-2245	13643	-3036	-16969	-2623	16837	
(	180)		-3934	13691	-3343	14135	-3135	15838	-2851	17137	
(	184)		-2843	13344	-3333	-16913	-3332	14214	-3271	13963	
(	188)		-2355	-16813	-2994	15752	-3118	16935	-3732	11535	
(	192)		-2806	17495	-3354	17999	-4352	11669	-3166	16449	
(	196)		-2335	15657	-3333	16159	-3533	-15520	-3597	17225	
(	200)	80	-3934	17731	-3223	-16475	-3337	-14353	-3194	16923	
(	204)		-2393	-17479	-3863	16476	-3129	-15937	-3398	-12533	
(	208)		-3301	-14633	-3146	-14312	-2713	-12633	-2465	-16633	
(	212)		-2643	-15173	-2763	15776	-2926	17544	-2979	-17331	
(	216)		-2342	-13240	-2544	-17316	-2384	16567	-2273	16543	
(	220)		-2471	16333	-2546	115[illegible]	-2586	13151	-2849	17742	
(	224)		-2663	16156	-2430	145[illegible]	-2313	14135	-2723	-13315	
(	228)		-2556	-17826	-2419	13[illegible]	-2336	16730	-2479	9611	
(	232)		-4124	3	-2901	16[illegible]	-4766	17999	-2534	16774	
(	236)		-2579	13336	-2638	143[illegible]1	-2594	13821	-2634	12576	
(	240)	96	-3356	12372	-3265	-17664	-2925	12381	-3929	-16437	
(	244)		-2737	15396	-2673	17999	-3155	-16293	-3363	10394	
(	248)		-2513	3561	-3193	-13530	-3933	11656	-3349	15625	
(	252)		-4236	-12365	-2393	-14397	-3166	2975	-3219	17542	
(	256)		-3110	0							

RA

J Ø

TP

D 1

TLØ

W Ø Ø 128

SF 6Ø 7 15

(	Ø)	-1ØØØØ	Ø	-4339	313	-33Ø1	3262	-3534	-1Ø9	1.2
(	4)	-3633	514Ø	-3371	2619	-3139	3518	-3193	2Ø63	2.8
(	8)	-3Ø25	3Ø73	-311Ø	3Ø95	-2331	1452	-2845	832	4.4
(	12)	-2579	1221	-2523	1355	-2563	555	-2511	1Ø48	6
(	16)	-2495	-1Ø45	-2474	-1844	-232Ø	-25Ø3	-2394	-2394	7.6
(	2Ø)	-2389	-2713	-2393	-3473	-2351	-3886	-2411	-4749	9.2
(	24)	-2419	-6Ø87	-2369	-6421	-2432	-6369	-2448	-7254	10.8
(	28)	-2419	-6887	-2547	-7667	-2661	-7849	-2651	-8294	
(	32)	-263Ø	-8599	-27Ø5	-8795	-2659	-9236	-2837	-9576	
(	36)	-28Ø9	-9944	-2839	-1ØØ4Ø	-2844	-1Ø458	-2846	-1Ø52Ø	
(	4Ø)	-29Ø1	-1Ø425	-2936	-1Ø826	-3Ø3Ø	-11297	-2983	-11392	17.2
(	44)	-3Ø44	-11267	-3Ø61	-118ØØ	-3155	-123Ø4	-3Ø91	-11481	
(	48)	-3193	-12345	-3152	-125Ø7	-31Ø8	-13522	-3246	-126Ø3	
(	52)	-314Ø	-12749	-3256	-12387	-3287	-137Ø3	-3266	-142Ø3	
(	56)	-3343	-13274	-3338	-13Ø92	-3412	-1377Ø	-3455	-13199	
(	6Ø)	-3417	-13663	-3332	-1411Ø	-3463	-13971	-3478	-1422Ø	25.2
(	64)	-3484	-14471	-3544	-14679	-3493	-14541	-36Ø9	-14685	
(	68)	-3622	-15162	-36Ø8	-15128	-36Ø5	-14822	-3624	-1527Ø	
(	72)	-3663	-15694	-3716	-15396	-3781	-15592	-3791	-15612	
(	76)	-3694	-15133	-3686	-15956	-3741	-1598Ø	-366Ø	-158Ø3	
(	8Ø)	-3795	-16189	-3849	-16143	-3772	-15965	-3793	-16722	33.2
(	84)	-38Ø5	-16338	-383Ø	-16544	-3872	-16515	-3849	-17577	
(	88)	-3859	-167ØØ	-3911	-16834	-3899	-17Ø84	-3957	-16915	
(	92)	-396Ø	-17173	-3922	-17378	-3915	-17Ø34	-4ØØ7	-17288	
(	96)	-4Ø38	-17782	-4Ø56	-17459	-4114	-16925	-4Ø28	-17791	
(	1ØØ)	-4Ø47	-17492	-4125	-17324	-414Ø	17999	-4113	-17745	41.2
(	1Ø4)	-4137	16995	-41Ø2	17267	-4Ø92	-17523	-4146	1742Ø	
(	1Ø8)	-4132	17288	-4267	17Ø39	-42Ø5	17329	-4242	17514	
(	112)	-4221	17428	-4215	17176	-4284	16954	-4321	16462	
(	116)	-4358	16734	-4328	17Ø53	-4347	16564	-431Ø	16868	
(	12Ø)	-4318	16773	-4515	16241	-457Ø	172Ø9	-4461	16595	49.2
(	124)	-4382	16552	-44Ø2	16196	-44Ø2	15945	-4453	16637	
(	128)	-4489	15546							

MIDDLE AXIS Position Loop
Fmax = 100
$\Delta\delta = \frac{100}{256}$
(only first 128 printed points)

RA

J 0

D 1

J 0

J 0

D 1

TP

TL

Outer Axis Position Loop

Fmax = 50 Hz

ΔF = 50/256

Δf = .2

first 150 points Printed

W 0 0 150

SF	40	7	11						
(	0)	-10000	0	-2001	-214	-1746	-671	-1844	-1646
(	4)	-2086	-2353	-2029	-730	-2520	-5804	-2297	-796
(	8)	-2682	-1971	-2491	-1778	-2283	-3482	-2469	-1796
(	12)	-2516	-737	-2481	-2343	-2413	380	-2356	-1890
(	16)	-2342	-1789	-2609	-1344	-2397	-1015	-2459	-1590
(	20)	-2361	-1923	-2220	-2450	-2304	-2701	-2170	-1464
(	24)	-2359	-1693	-2370	-1543	-2277	-2003	-2270	-2997
(	28)	-2159	-3253	-2170	-3219	-2161	-3694	-2226	-3070
(	32)	-2272	-3264	-2215	-3799	-2202	-4621	-2212	-4592
(	36)	-2179	-4751	-2157	-4539	-2156	-4396	-2137	-4904
(	40)	-2084	-5803	-2129	-6244	-2051	-6482	-2055	-6353
(	44)	-2131	-6758	-2110	-6324	-2096	-7716	-2101	-7459
(	48)	-2209	-7382	-2122	-8152	-2197	-8961	-2159	-9027
(	52)	-2132	-9308	-2129	-9057	-2152	-9358	-2187	-9750
(	56)	-2163	-10175	-2234	-9820	-2196	-10173	-2294	-10245
(	60)	-2262	-10552	-2299	-10436	-2300	-11033	-2297	-11209
(	64)	-2304	-11414	-2349	-11786	-2355	-11985	-2410	-12050
(	68)	-2479	-12113	-2443	-12334	-2478	-12657	-2468	-12725
(	72)	-2542	-13112	-2504	-13046	-2511	-13416	-2519	-13152
(	76)	-2555	-13399	-2615	-13512	-2613	-13484	-2612	-14095
(	80)	-2636	-13772	-2703	-13837	-2752	-13944	-2756	-14100
(	84)	-2732	-14571	-2769	-14480	-2787	-15109	-2818	-14913
(	88)	-2869	-14909	-2797	-15468	-2848	-15036	-2891	-15078
(	92)	-2925	-15204	-2916	-15511	-2873	-15354	-2949	-15308
(	96)	-2939	-15612	-2975	-16040	-3010	-15676	-3021	-16290
(	100)	-3025	-16028	-3035	-16198	-2889	-15833	-3056	-16350
(	104)	-3094	-16664	-3038	-16410	-3085	-16431	-3140	-16470
(	108)	-3213	-16956	-3120	-16613	-3205	-16470	-3245	-16958
(	112)	-3227	-17317	-3240	-17084	-3273	-17148	-3318	-17333
(	116)	-3213	-17175	-3270	-17629	-3287	-17026	-3257	-16748
(	120)	-3423	17924	-3362	-17874	-3348	17937	-3444	-17643
(	124)	-3412	-17510	-3406	17999	-3356	17536	-3447	17344
(	128)	-3474	-17742	-3433	17742	-3440	-17592	-3434	17349
(	132)	-3586	17339	-3552	17579	-3503	17999	-3522	17480
(	136)	-3540	17890	-3563	17666	-3555	-17591	-3624	17999
(	140)	-3750	17258	-3578	16952	-3769	17759	-3615	17543
(	144)	-3716	16632	-3745	17012	-3739	16829	-3672	17037
(	148)	-3797	16596	-3756	16931	-3758	17739		

Handwritten values beside the right edge of the table (top to bottom, with the row they sit beside):

Row	Note
SF	.6
0)	.6
4)	1.4
20)	4.6 4.0
40)	8.6
48)	9.6
60)	12.6
80)	16.8
100)	20.8
120)	[illegible]
140)	28.6

MIDDLE AXIS Accelerometer loop

10-8-75 Fmax = 25 Hz

ΔF = 25/256

ΔF = .1

RA

J 0

D 1

RA

J 0

D 1

TP

TL

M 0 0 256

SF	20	7	7						.3
(	0)	-10033	0	-1700	-17863	-1691	17333	-1674	17130
(	4)	-1739	16929	-1719	16539	-1763	16236	-1761	15933 .7
(	8)	-1319	16112	-1835	15619	-1736	15323/	-1796	15346
(	12)	-1335	14751	-1876	14843	-1899	14563	-1357	14430 1.5
(	16)	-1395	14149	-1923	14036	-1936	13773	-1996	13773
(	20)	-1993	13565	-2027	13377	-2079	13429	-2047	13161
(	24)	-2029	12927	-2079	13173	-2095	12734	-2145	12519 2.7
(	28)	-2162	12497	-2156	12303	-2209	12482	-2221	12077
(	32)	-2263	12127	-2295	12127	-2237	12121	-2314	12064
(	36)	-2336	12514	-2362	11672	-2253	11905	-2302	11054
(	40)	-2309	12355	-2263	12011	-2249	11065	-2329	11071
(	44)	-2463	10753	-2339	11533	-2419	10952	-2431	11030 4.7
(	48)	-2443	11074	-2437	12341	-2472	11696	-2531	10511
(	52)	-2531	11047	-2472	11695	-2524	10779	-2466	11120
(	56)	-2663	11276	-2543	10277	-2634	10894	-2592	11147
(	60)	-2595	10522	-2613	10756	-2531	10507	-2652	10717
(	64)	-2606	9533	-2653	10067	-2633	11134	-2624	10376 6.7
(	68)	-2663	10959	-2715	10367	-2676	10097	-2634	10159
(	72)	-2633	10345	-2620	9152	-2323	10526	-2356	9426
(	76)	-2643	10001	-2776	10073	-2774	9012	-2739	10173
(	80)	-2317	7651	-2731	10739	-2702	9633	-2796	10057
(	84)	-2770	8045	-2765	8946	-2659	9932	-2791	9220 8.7
(	88)	-2394	10453	-2734	9097	-2931	9773	-2359	9190
(	92)	-2655	9647	-2975	9361	-2836	9454	-2645	9736
(	96)	-3075	9727	-3035	8344	-2025	8709	-2394	9633
(	100)	-2313	8377	-3029	8796	-2877	8528	-2398	9371
(	104)	-2751	10194	-2733	9075	-2794	9320	-2744	8659 10.7
(	108)	-2353	7773	-2963	9341	-3346	9343	-3016	6949
(	112)	-2983	8149	-2814	8365	-3196	9332	-2724	6160
(	116)	-2848	7744	-3413	12114	-3016	7281	-2333	7132
(	120)	-2713	7764	-3147	5720	-2469	5379	-2724	8529
(	124)	-3221	10414	-3132	9903	-2945	7295	-3102	7677 12.7
(	128)	-2314	5694	-2939	6403	-2833	7057	-2519	6651
(	132)	-2936	6622	-3043	6215	-2834	6954	-3189	6332
(	136)	-2991	7837	-2775	6693	-3353	6063	-3628	7039
(	140)	-3288	7573	-3359	6719	-3032	7353	-3033	7204
(	144)	-2382	5613	-3024	6211	-2933	5354	-2964	5645 14.7
(	148)	-3096	5742	-3137	6329	-3919	6537	-3012	6366
(	152)	-2934	6280	-3133	5359	-2954	5669	-2976	4332
(	156)	-2918	5377	-3357	7132	-3023	5376	-2933	4645
(	160)	-3318	5345	-3117	5066	-3174	6363	-3031	5156
(	164)	-3233	4251	-3277	5347	-3337	5172	-3237	5222 16.7
(	168)	-3193	5230	-3699	6231	-2954	5572	-3301	4325
(	172)	-3091	4593	-3222	4231	-3397	3460	-3465	3958
(	176)	-3213	4305	-3133	5377	-3367	3556	-3131	3323
(	180)	-3117	3422	-3269	3561	-3167	4475	-3226	3713
(	184)	-3153	3492	-3252	3713	-3284	2983	-3337	3503 18.7
(	188)	-2999	3372	-3195	3046	-3232	1896	-3332	3293
(	192)	-3436	2694	-4063	3659	-3391	2120	-3232	2736
(	196)	-3219	3043	-3373	2397	-3725	3236	-3238	2941
(	200)	-3203	1773	-3401	1995	-3516	2339	-3351	2720
(	204)	-3512	3632	-3334	1333	-3454	339	-3437	2747 20.7
(	208)	-3619	-751	-3657	1390	-3472	3376	-3373	1686
(	212)	-3276	3113	-3363	2130	-3635	3853	-3527	2294
(	216)	-3532	1545	-3343	2572	-3523	325	-3530	1533
(	220)	-3473	623	-3559	2308	-3473	352	-3326	1274
(	224)	-3574	-343	-3426	1679	-4206	1666	-3663	-225 22.7
(	228)	-4033	1732	-4494	1735	-3320	-3233	-3644	4674
(	232)	-3333	1934	-3638	2655	-4114	959	-4025	6567
(	236)	-3633	1697	-3956	-1131	-3675	-1359	-4125	1794
(	240)	-3597	3515	-4115	-1423	-3362	142	-3733	1792
(	244)	-4023	1532	-3611	-1129	-4193	11462	-3413	407 24.7
(	248)	-3332	-3049	-3779	-1139	-3734	-731	-4479	-5987
(	252)	-4656	3363	-4314	-3524	-4518	5534	-3833	-3459
(	256)	-3124	0						

TP

TL

D 1

D 8

D 1

D

INNER AXIS
OSC MODE
fmax = 100 Hz
ΔF = 100/256
10-7-75

.4 HZ

Closed Loop

-70.48
-111.24°

W Ø 1 256 0.4 .8 1.2 463.2

SF	Ø	7	15						
(	1)	[illegible]	-111[illegible]	-2729	-16743	-2661	17669	-2555	17395
(	5)	-2633	-17931	-2566	17337	-2662	-17395	-2571	17397 3.2
(	9)	-2637	17391	-2530	17026	-2634	17331	-2651	16673 4.8
(	13)	-2541	17797	-2562	17935	-2521	17617	-2533	17387 6.4
(	17)	-2596	17166	-2396	17947	-2562	-17959	-2497	17673 8
(	21)	-2513	17672	-2616	17461	-2584	17615	-2429	-17333 7.6
(	25)	-2576	17973	-2527	17441	-2533	17672	-2534	17551 11.2
(	29)	-2491	17549	-2513	17722	-2535	-17937	-2584	17349 12.8
(	33)	-2533	17603	-2457	17710	-2542	17911	-2432	17515 14.4
(	37)	-2425	17992	-2543	17179	-2515	17921	-2562	17279 16
(	41)	-2433	17323	-2573	16957	-2566	17137	-2523	16631
(	45)	-2426	-17991	-2547	17534	-2454	17132	-2395	16969
(	49)	-2459	17169	-2475	17243	-2269	17333	-2435	17193
(	53)	-2523	16935	-2471	16907	-2493	16523	-2454	17267
(	57)	-2480	16124	-2447	16462	-2473	15892	-2327	15933
(	61)	-2319	16263	-2433	17152	-2477	16632	-2437	16793
(	65)	-2448	16335	-2463	16105	-2424	17173	-2465	16397
(	69)	-2432	16033	-2433	16637	-2384	15894	-2533	16353
(	73)	-2422	16394	-2431	16115	-2333	16243	-2421	16135
(	77)	-2452	16532	-2367	16033	-2417	16139	-2411	15949 .32
(	81)	-2414	15973	-2359	15693	-2314	16705	-2396	15397
(	85)	-2372	15734	-2353	15736	-2431	16283	-2316	16353
(	89)	-2383	15530	-2313	15667	-2333	15796	-2412	15332
(	93)	-2417	14911	-2347	15375	-2335	14896	-2335	15353
(	97)	-2339	15351	-2343	15063	-2356	15314	-2317	15205
(	101)	-2419	14573	-2317	14732	-2297	14495	-2339	14932
(	105)	-2236	15262	-2275	14770	-2221	13934	-2332	14271
(	109)	-2397	15013	-2283	14536	-2323	14716	-2376	14471
(	113)	-2312	14171	-2314	13038	-2359	14563	-2247	13793
(	117)	-2248	14791	-2386	13929	-2336	13722	-2276	13371 48
(	121)	-2311	13363	-2254	13452	-2233	13533	-2264	13313
(	125)	-2350	13670	-2245	12378	-2253	13109	-2307	12587
(	129)	-2226	12746	-2319	12724	-2212	12556	-2372	12531
(	133)	-2332	13077	-2353	13150	-2233	13065	-2236	12333
(	137)	-2264	12615	-2240	12735	-2293	12406	-2175	12435
(	141)	-2243	12392	-2229	12463	-2139	13439	-2236	12363
(	145)	-2166	11705	-2223	11535	-2204	11336	-2215	11395
(	149)	-2341	11134	-2248	10924	-2239	11231	-2036	10699
(	153)	-1966	13036	-2123	15069	-2195	10461	-2256	10273
(	157)	-2443	12131	-2247	9571	-2248	9554	-2251	9333 64
(	161)	-2273	9554	-2247	9290	-2393	9311	-2347	8412
(	165)	-2485	9372	-2329	8532	-2304	8379	-2338	8663
(	169)	-2533	7373	-2427	8027	-2414	7283	-2523	7333
(	173)	-2563	8027	-2562	7349	-2511	7534	-2612	7261
(	177)	-2532	6914	-2620	7211	-2257	7221	-2665	7231
(	181)	-2772	6472	-2747	6217	-2373	6673	-2343	6304
(	185)	-2901	6529	-2971	6726	-3033	6212	-3049	5266
(	189)	-3236	5364	-3136	6493	-3495	5607	-3555	7399
(	193)	-3623	7543	-3550	7391	-3727	6134	-3473	3373
(	197)	-3736	10497	-3293	11562	-3222	10790	-3534	-17273 80
(	201)	-3533	12361	-3527	12449	-3313	12077	-2858	13332
(	205)	-2537	14362	-3251	12359	-2951	10657	-2594	12946
(	209)	-2363	11324	-2334	12983	-2767	10731	-2579	12674
(	213)	-2624	10792	-3109	10933	-2728	7591	-3036	12052
(	217)	-3036	10939	-2335	11783	-2430	12533	-2633	11137
(	221)	-2461	11936	-2672	9644	-2465	8963	-2543	6533
(	225)	-3344	9413	-2331	6147	-3430	9135	-3129	14629
(	229)	-2457	11971	-2449	7567	-3250	9800	-2562	8641
(	233)	-2935	5934	-3359	5060	-3161	3107	-3472	4332
(	237)	-3131	7582	-3463	4963	-3147	7490	-3663	7732
(	241)	-4501	3025	-4136	-7220	-4625	-13590	-5373	-3693
(	245)	-3436	-16033	-3792	8305	-4523	13361	-4413	-9521
(	249)	-4095	5170	-2635	11315	-4136	10345	-3404	-17031
(	253)	-4369	12095	-4216	-12097	-3250	-16493	-3494	0

ORIGINAL PAGE IS
OF POOR QUALITY

-97
-90
-110

RA

J Ø

TPØ

D 1

TLØ

W Ø 1 256

SF	Ø	7	15				0		
(1)	-2426	-17348	-2562	17423	-2515	17391	-2594	17482	1.6
(5)	-2695	17236	-2612	17375	-2552	-17959	-2588	17974	3.2
(9)	-2563	-17643	-2439	17710	-2583	17552	-2523	17625	4.8
(13)	-2519	17669	-2502	17215	-2475	17859	-2526	17885	6.4
(17)	-2525	16815	-2443	17127	-2434	16432	-2441	16433	8
(21)	-2366	15933	-2443	16185	-2373	16545	-2419	15739	9.6
(25)	-2372	15632	-2447	15817	-2436	15560	-2400	15703	11.2
(29)	-2357	15263	-2403	15463	-2394	14318	-2422	14776	12.8
(33)	-2398	14628	-2372	14566	-2416	14512	-2377	14184	14.4
(37)	-2398	14132	-2333	14875	-2444	14976	-2411	13617	
(41)	-2413	13163	-2337	13465	-2428	13249	-2397	13318	16
(45)	-2414	12931	-2421	13072	-2452	12563	-2417	13019	
(49)	-2424	12328	-2452	12332	-2437	12133	-2427	12233	
(53)	-2453	12126	-2474	11937	-2446	11580	-2465	11537	
(57)	-2473	11295	-2498	11065	-2535	11234	-2453	11166	
(61)	-2531	10663	-2512	11004	-2541	10762	-2566	10713	
(65)	-2520	10304	-2534	10682	-2555	10777	-2612	9982	
(69)	-2527	10135	-2584	9637	-2548	9919	-2605	9395	
(73)	-2594	9333	-2665	9838	-2563	9391	-2603	9236	
(77)	-2679	9333	-2674	9175	-2691	9033	-2711	9533	
(81)	-2631	9339	-2696	8339	-2637	8436	-2632	8734	32
(85)	-2732	8435	-2784	8551	-2813	8617	-2692	8333	
(89)	-2798	8077	-2762	7983	-2776	7398	-2762	7852	
(93)	-2779	7542	-2771	7447	-2868	6998	-2893	7390	
(97)	-2887	8318	-2810	7233	-2853	6754	-2826	7433	
(101)	-2943	7599	-3032	7633	-2814	7143	-3052	7353	
(105)	-2933	6473	-2939	7004	-2944	6403	-2834	7362	
(109)	-2947	6191	-3039	5937	-2934	6223	-2952	6335	
(113)	-2945	6443	-2946	6134	-3034	5819	-2961	6164	
(117)	-2981	6094	-3038	5647	-3356	6032	-3050	5324	
(121)	-2973	5464	-2980	5891	-3097	5465	-3224	5300	48
(125)	-3030	5547	-3085	5341	-3255	5533	-3135	4795	
(129)	-3102	5530	-3163	4595	-3066	4940	-3211	4853	
(133)	-3253	4432	-3183	5694	-3266	5155	-3353	4636	
(137)	-3193	4227	-3312	4529	-3434	5237	-3402	3942	
(141)	-3336	5066	-3422	3994	-3365	4066	-3303	4561	
(145)	-3393	3346	-3557	5291	-3415	5724	-3637	5027	
(149)	-3561	4275	-3566	5772	-3373	4198	-3446	7439	
(153)	-3439	8356	-2354	3798	-3097	6702	-3321	6038	
(157)	-3162	6792	-3139	7542	-3130	5292	-3022	5094	
(161)	-3041	4503	-3027	4790	-3100	4581	-3033	4453	64
(165)	-3060	4392	-3116	3171	-3168	3633	-3177	3264	
(169)	-3125	3331	-3155	3735	-3162	3602	-3116	2672	
(173)	-3232	2300	-3280	2913	-3243	3313	-3165	3224	
(177)	-3393	2607	-3139	2809	-3315	3259	-3177	3222	
(181)	-3255	3066	-3494	2379	-3333	2630	-3271	2236	
(185)	-3194	2937	-3201	2365	-3294	1740	-3339	2769	
(189)	-3345	2340	-3534	3578	-3530	1654	-3445	711	
(193)	-3541	833	-3415	2364	-3535	2452	-3465	1392	
(197)	-3406	2523	-3476	2669	-3433	1146	-3342	2307	
(201)	-3561	1310	-3476	1449	-3445	90	-3747	-607	80
(205)	-3982	3447	-3392	1453	-3642	928	-3592	1235	
(209)	-3442	1159	-3314	1919	-3499	1343	-3487	437	
(213)	-3494	1737	-3636	-225	-3632	253	-3633	1500	
(217)	-3503	1323	-3792	1568	-3472	-236	-3463	1762	
(221)	-3685	3624	-3429	-857	-3691	438	-3634	650	
(225)	-3725	1136	-3474	1539	-3503	238	-3763	1373	
(229)	-3501	633	-3413	0	-3753	932	-3303	-336	
(233)	-3552	-1121	-3691	-2135	-3365	-1348	-3710	-961	
(237)	-3834	348	-3515	0	-3313	1329	-3793	2292	
(241)	-3674	-2352	-3730	-4996	-3998	711	-3810	-335	76
(245)	-3674	247	-3980	-1701	-3614	-744	-3534	-1310	
(249)	-3387	-1737	-3646	-306	-3913	-409	-3765	1841	
(253)	-3632	0	-4011	1624	-3733	-795	-3872	0	

ORIGINAL PAGE IS
OF POOR QUALITY

RA

J 0

D 1

D 0

TP

TL

Outer Axis
Rate Osc
Mode

" 0 1 25
" 0 1 30

SF -20	7	15							
(1)	-680	-17479	-739	-17953	-653	16881	-729	17358	1.6
(5)	-701	17132	-628	16516	-592	16783	-821	16738	3.2
(9)	-635	16037	-603	15977	-650	15392	-593	15414	4.8
(13)	-557	14807	-557	15233	-545	14126	-659	14097	6.4
(17)	-566	13616	-510	13790	-570	13522	-579	13165	8
(21)	-730	12256	-548	12551	-539	11781	-604	11348	9.6
(25)	-533	11003	-607	10373	-564	10721	-602	10523	11.2
(29)	-638	10004	-633	9761	-690	8691	-633	9177	12.8
(33)	-671	8149	-630	7766	-692	7231	-713	7330	14.4
(37)	-677	7048	-730	6132	-693	5973	-845	5344	16
(41)	-899	5583	-344	4832	-891	5033	-937	4263	17.6
(45)	-1091	4500	-1015.	4663	-1003	3390	-1034	3623	
(49)	-1067	3323	-1037	3171	-1106	2666	-1291	2779	
(53)	-1200	3485	-1134	2163	-1218	1297	-1413	2001	22.4
(57)	-1409	2306	-1364	1968	-1324	1656	-1370	1032	
(61)	-1461	1242	-1462	1117	-1515	975	-1657	1733	
(65)	-1621	190	-1612	772	-1629	416	-1716	853	27.2
(69)	-1680	-475	-1783	-136	-1893	1272	-1861	-737	
(73)	-1907	-881	-2092	-1063	-1932	-947	-2058	-1786	
(77)	-2175	-1202	-2723	860	-2172	-2110	-2239	-1639	32

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)	Angular Oscillation Continued	Null point drift ≤ .5 arc sec per min.		Oscillate each axis separately at 15 Hz with a rate amplitude of .2°/sec for 1 hour. Begin with amplitude at zero and record position readout angle. Increase amplitude to .2°/sec and let oscillate for 1 hour. Decrease the amplitude to zero and record position readout angle. The difference between initial and final should be <3 arc sec or .0009 degree. Record $P_I - P_f$	I 1.8 arcsec M 1.1 O .72

	P_I	P_f
I	000.0003	359.9998
M	000.0001	359.9998
O	359.9999	359.9997

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)		Rate Perturbation through zero rate I .15 deg/sec M .12 deg/sec O .085 deg/sec None observable		Connect buffered tach output to strip charts. Rate oscillate at .01 Hz and .1 deg/sec rate amplitude. Determine perturbation from straight line. Use tach scale factor to convert the perturbation to deg/sec. Also monitor analog position output during this test. Theory all wrong! Ok	I ________ % M ________ % O ________ %

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TEST PLAN

SPEC PAPAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II	Single Amplitude at Bandwidth	I = .9 arc sec at 75 Hz. M = 1.9 arc sec at 40 Hz. O = 5.8 arc sec at 15 Hz	See test parameter	a) Use analog position outputs. b) Rate oscillate each axis at the bandwidth and increase the input rate amplitude until the required peak amplitude is achieved. This amplitude is found using spec amplitude and the SF from Table III. Record this amplitude. V_I -------mv c) Increase input setting until output appears to saturate. Record this amplitude.	mv | arc/sec V_I ____ V_M ____ V_O ____ V_I ____ V_M ____ V_O ____

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE II (Cont.)	Acceleration Capability	I = 1 rad/sec^2 = 57.3 deg/sec^2 M = .6 rad/sec^2 = 34.4 deg/sec^2 O = .25 rad/sec^2 = 14.3 deg/sec^2	STP-E-2257	Use buffered tach output Fully loaded. Inner = 0, Middle = 0, Outer = 0	
				Max acceleration. deg/sec^2	A_I ______
				Do STP with acceleration limits set at maximum.	A_M ______
				Determine acceleration for each axis	A_O ______
					
			AI	94.5 58	
			AM	50 36.3	
			AO	22.8 14.05	

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		[illegible]		14 OF ___

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE III	Position Readout	Resolution .0001	By design		
		Accuracy ±1 arc sec TR-3011	STP-E-2254	See position command test. Data was taken with position command test.	
	Rate Readout	Resolution .001 deg/sec	By design	.0001 deg/sec	
		Accuracy .001 deg/sec	Calculated in design report	.001 deg/sec	
				In system test rate mode, oscillate other axis and determine the effect on the rate readout.	
		Range 0-180.000 deg/sec	By design	0-199.9999 deg/sec	

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
TABLE III	Acceleration Readout	Resolution 0.1 deg/sec^2	By design	4-digit DA converter	
		Accuracy 0.1 deg/sec^2	Calculated from vendor certification	Demonstrate 0.1 deg/sec step in in system test mode.	
	Analog Rate Output			See Analog Scale factors determined earlier. (Table III)	
	Analog Position Outputs				
4.3.2	Mode Change	Response to mode change ≤2 msec	By design		

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.2.4	Servo Loop	Gain margin 12 db Phåse margin 45 degrees Rate OSC Mode		Plot closed loop response on a Nichol's chart to obtain gain and phase margin. See frequency response in rate oscillation mode. 1 hr max rates middle and inner axis with outer oscillating at 15 Hz max rate.	
		Harmonic Distortion <5% third Harmonic	STP-E-2251	Measure distortion of rate oscillation source (S) and of buffered tach feedback (F) while oscillating at 5 Hz and .2°/sec Amplitude. Look at residual on scope and estimate the third harmonic content (E). E(F-S) = third harmonic distortion	________ %
		Posn Rate, and	STP-E-272	Do frequency response with OFF MODE (Zero Rate) and plot the data on a Nichols chart to obtain gain and phase margin.	
		Acceleration Mode	STP-E-272	Do frequency response in Acceleration mode on middle axis. Set acceleration command to zero. Oscillate inner at a frequency above the outer axis oscillation bandwidth. Outer axis maintains position as observed on analog position output within acceleration to rate sensitivity spec.	

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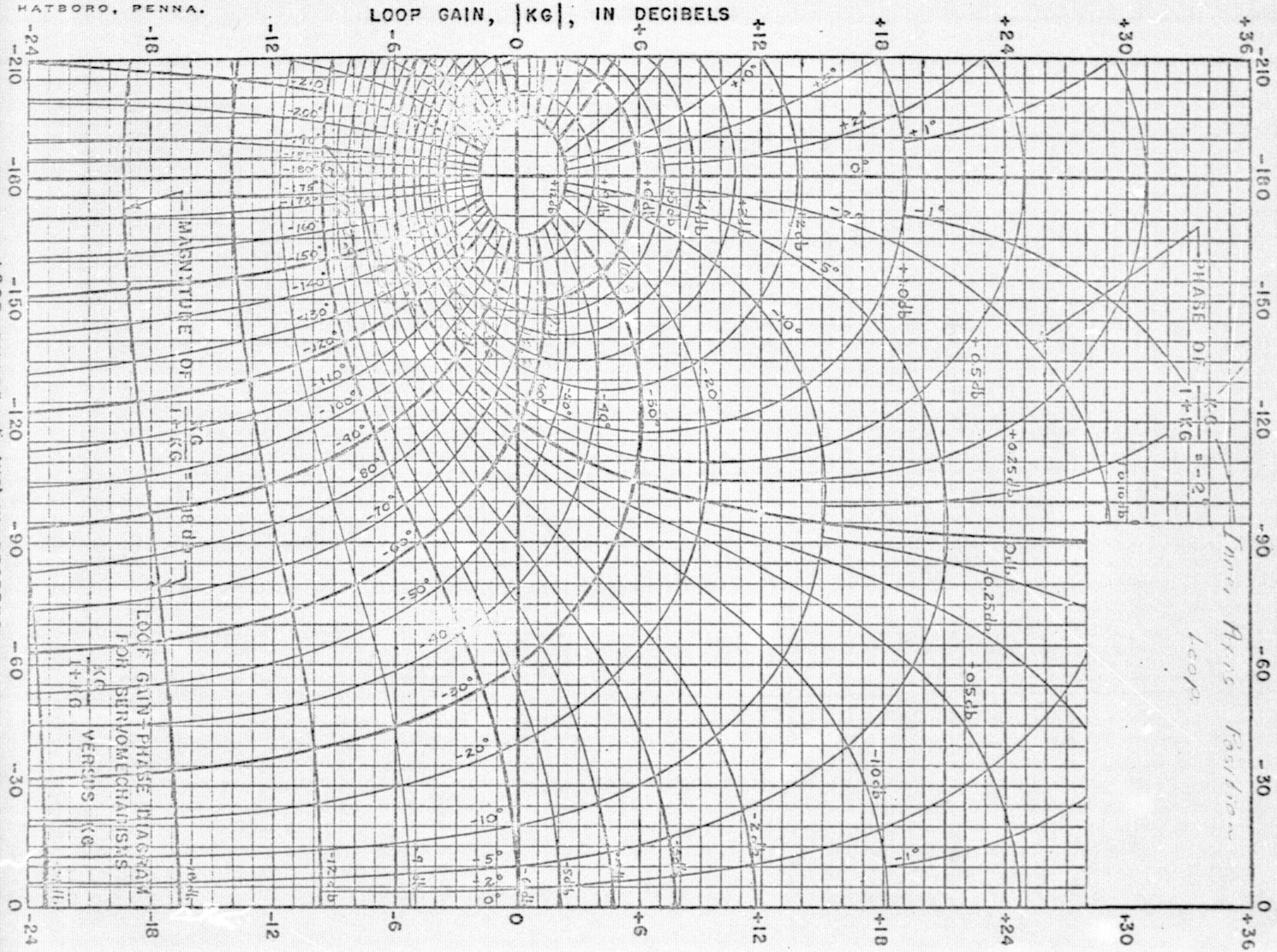

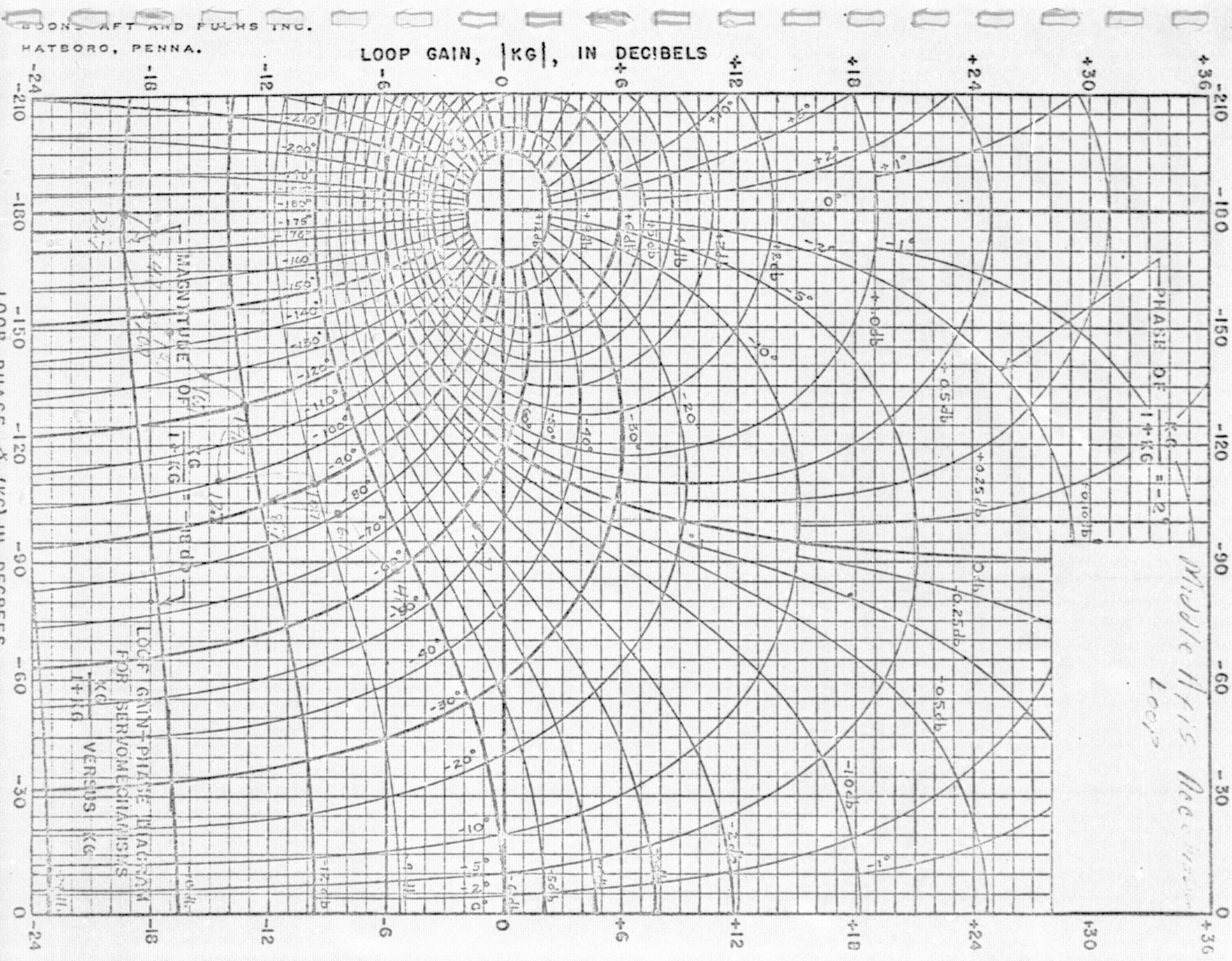
HATBORO, PENNA.
LOOP GAIN, |KG|, IN DECIBELS
LOOP PHASE, ∠ (KG), IN DEGREES
MAGNITUDE OF KG/(1+KG)
PHASE OF KG/(1+KG) = -2°
LOOP GAIN-PHASE DIAGRAM FOR SERVOMECHANISMS
KG/(1+KG) VERSUS KG

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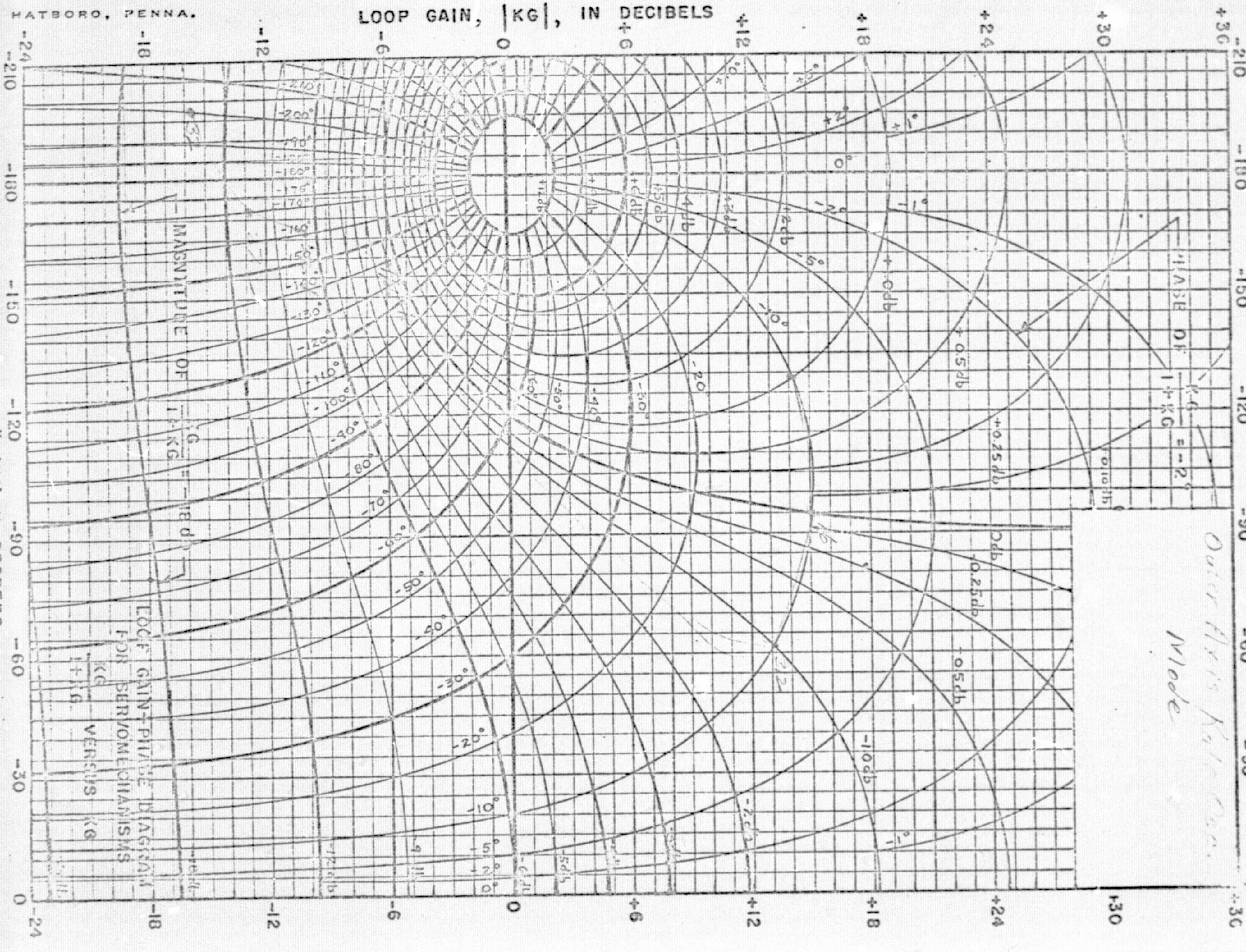

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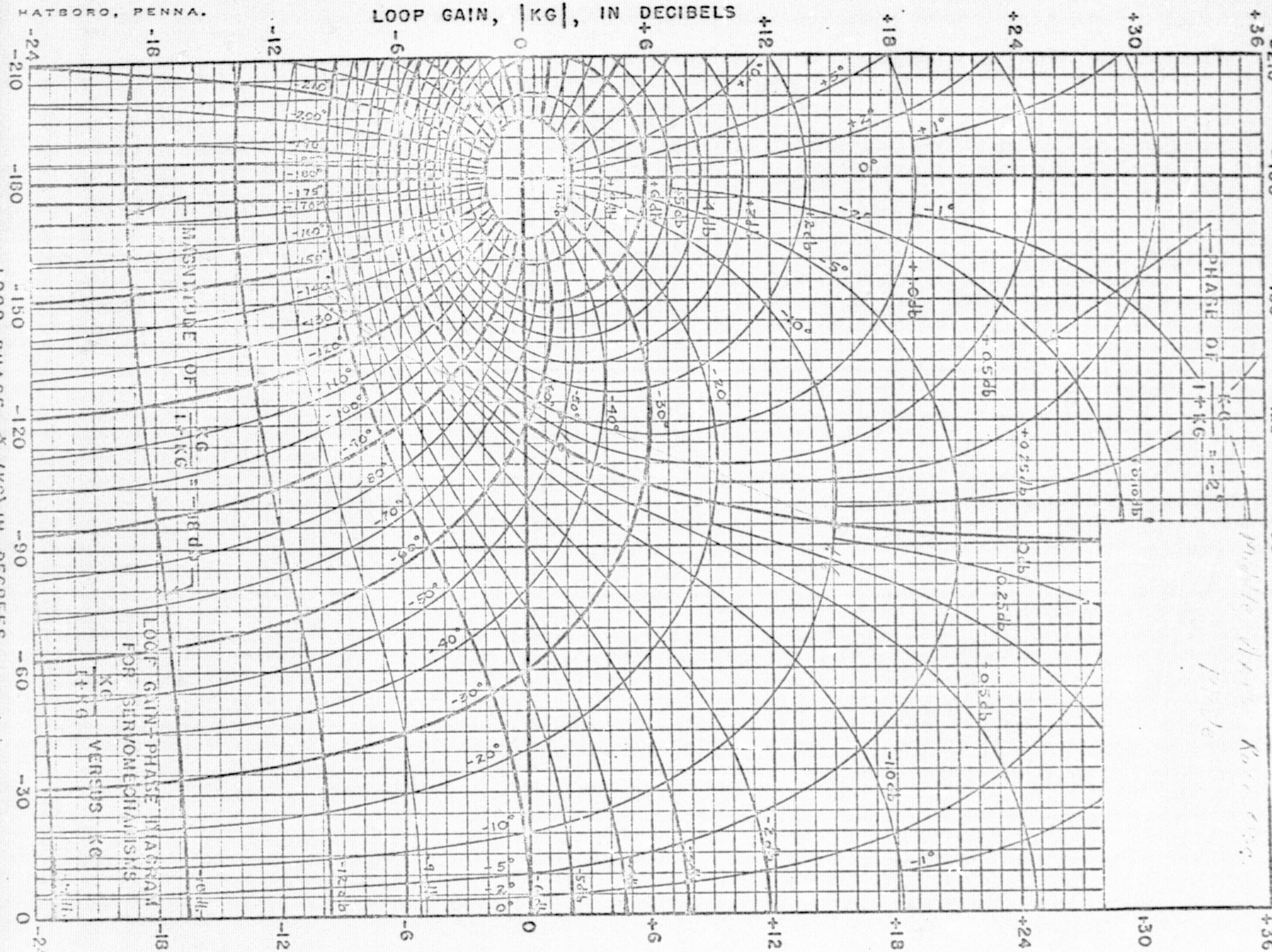

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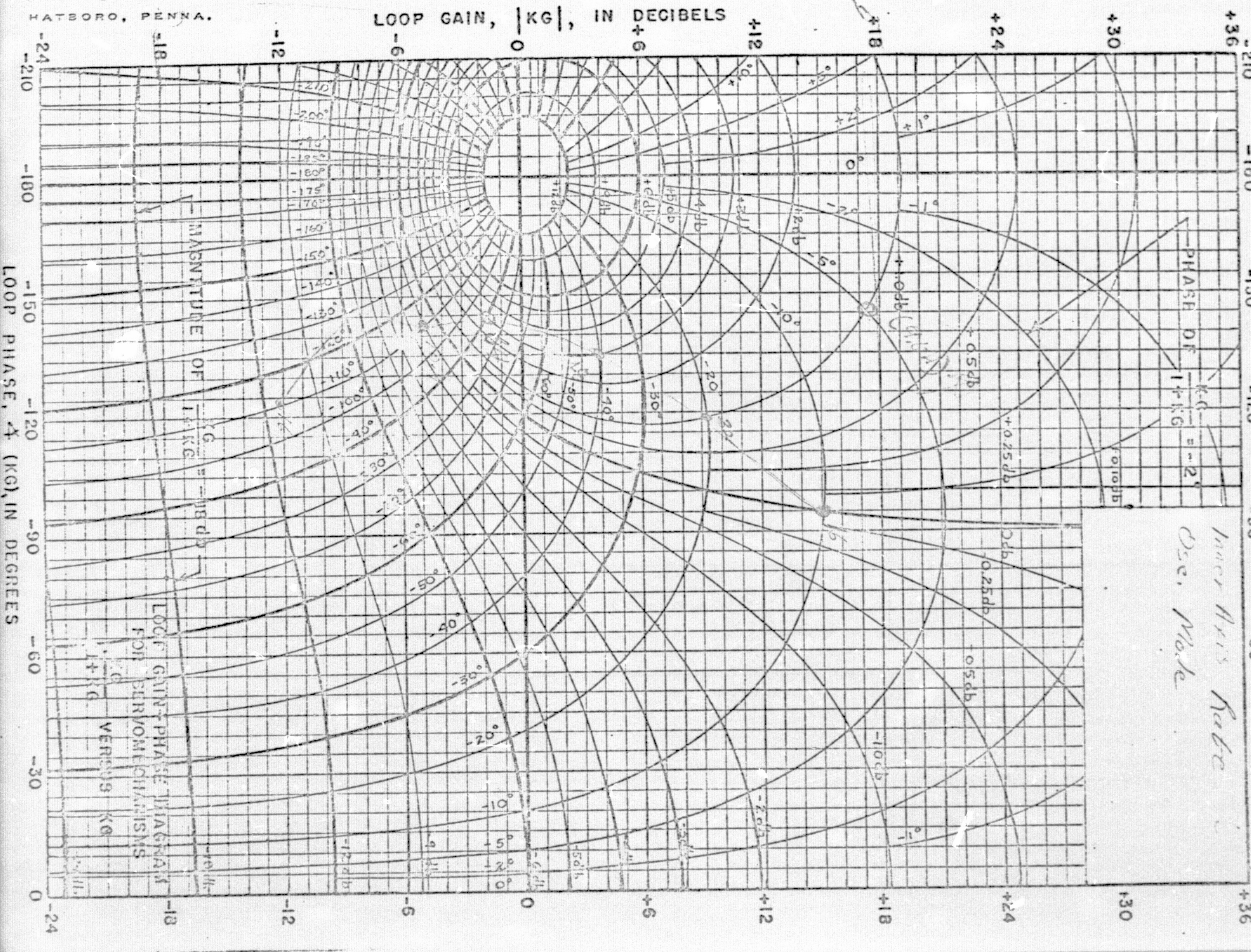

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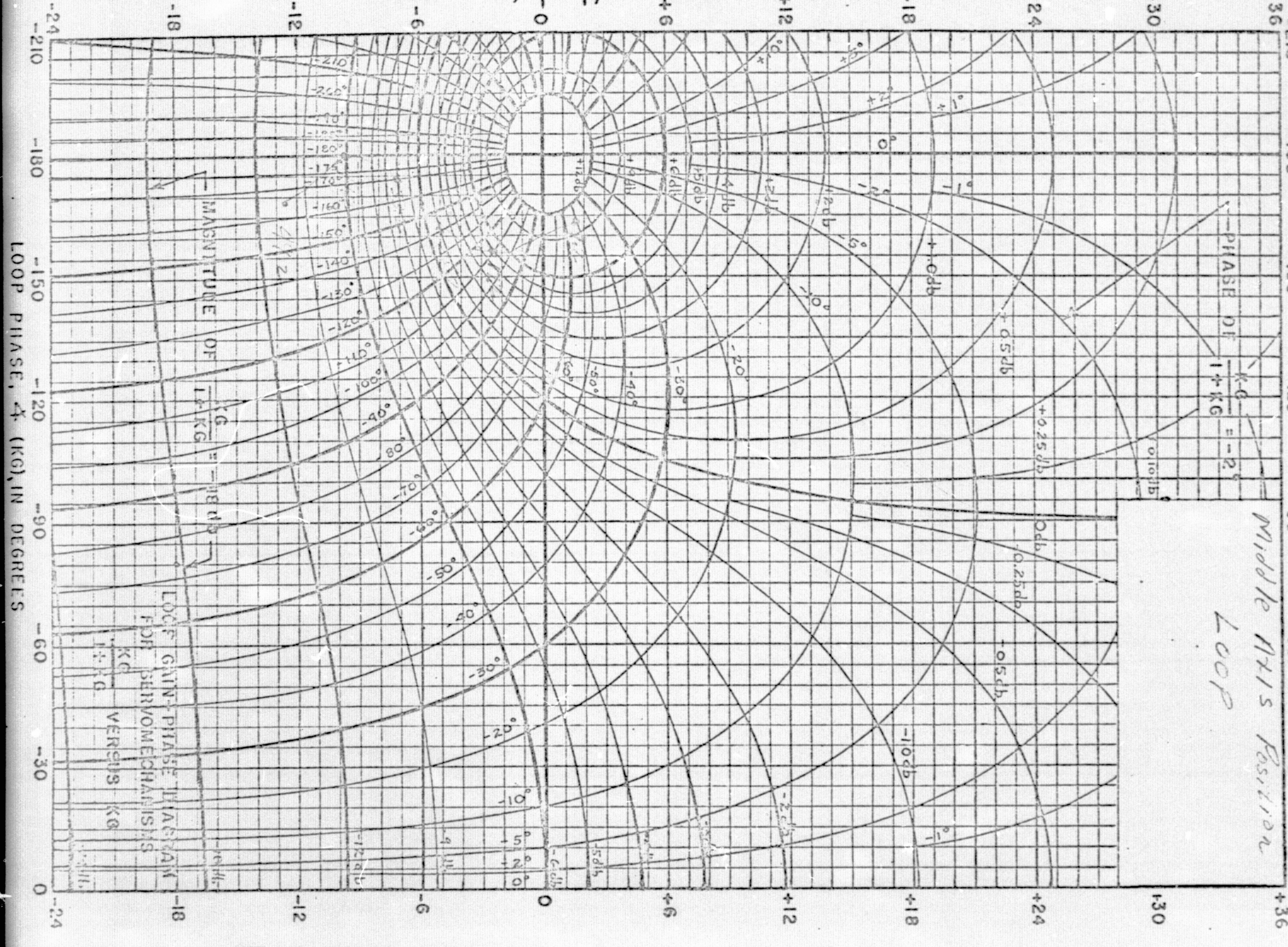
LOOP GAIN, |KG|, IN DECIBELS



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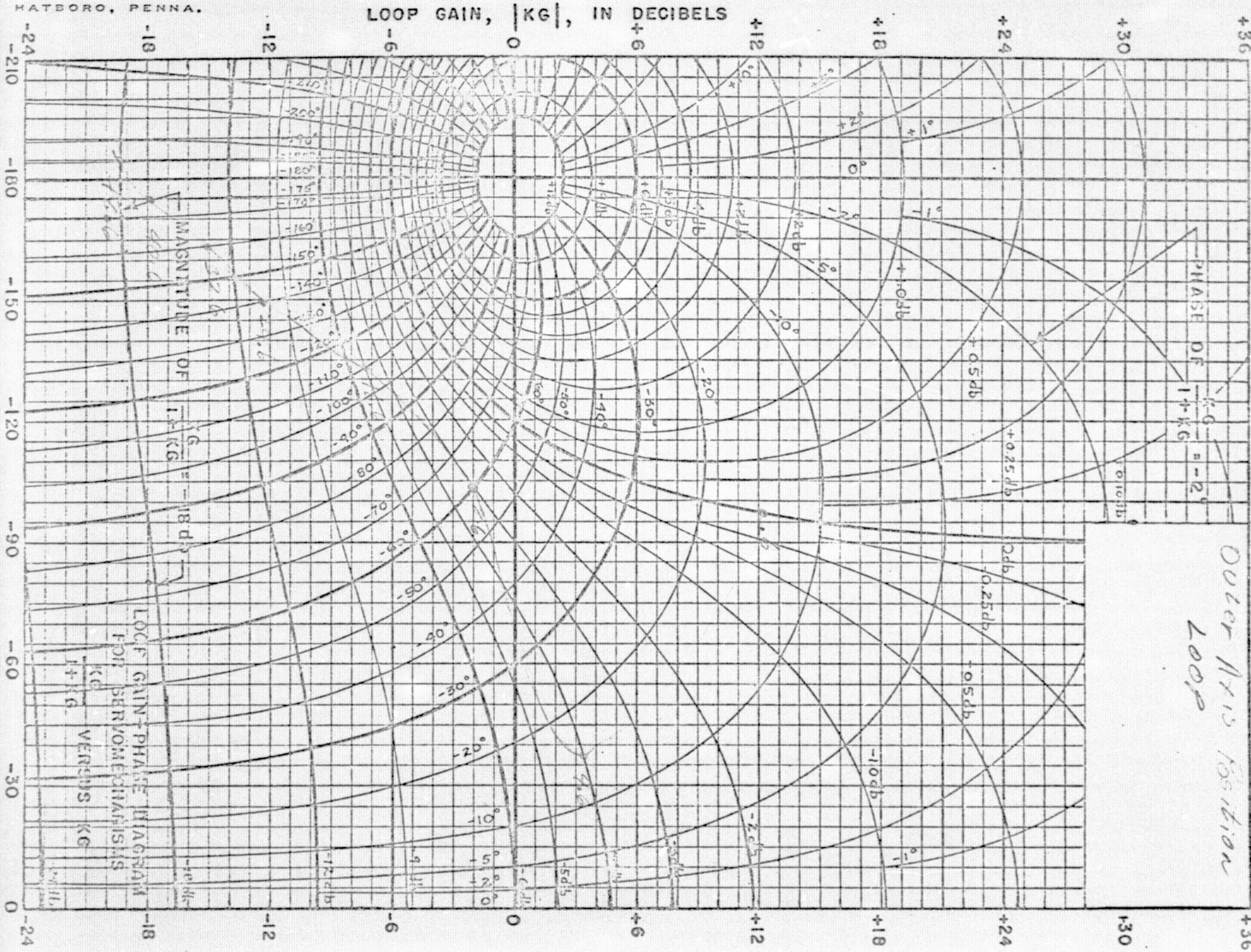

Third Harmonic Distortion test

RA

J 0

D 1 0 50

" 1 10 30

SF	-6	12	53						
(	10)	3121	0	3	0	1	0	1	0
(	14)	1	0	0	0	0	0	1	0
(	18)	0	0	0	0	2	0	1	2
(	22)	0	0	0	0	0	0	1	0
(	26)	0	0	6	0	0	0	1	2
(	30)	1	0						

5Hz

5Hz .03%

Outer 5Hz 2°/sec

5Hz/[illegible]

MIDDLE 5Hz 2°/sec 10-8-75

All 3 Axis Oscillating

RA

J 0

D 1 0 50

W 1 0

V 1 10 30

SF	-6	12	53						
(	10)	3173	3	3	0	1	0	1	0
(	14)	1	0	0	0	0	0	0	0
(	18)	0	0	0	0	0	0	0	0
(	22)	0	0	0	0	0	0	0	0
(	26)	0	0	0	0	0	0	0	0
(	30)	3	0						

5Hz

5Hz

RA

D 1

.09%

INNER 5Hz 2°/sec 10-8-75

All three Axis Osc.

RA

J 0

V 1 10 30

SF	-6	12	53						
(	10)	2375	0	3	0	1	0	1	0
(	14)	1	0	0	0	0	0	0	0
(	18)	0	0	0	0	2	0	0	0
(	22)	0	0	0	0	0	0	0	0
(	26)	0	0	3	0	0	0	0	0
(	30)	5	0						

.19% 3rd harmonic

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.2.4	Servo Loop (Cont.)	Acceleration will be within 5% of command value within 50 msec (Middle only)		Connect strip chart to the accelerometer output. Enter 20 deg/sec command. Select acceleration mode. Record time when the acceleration is within 5% of the final value.	2 ______ msec
4.2.4	PP3	Max Rate Switching Test		Command max rate + switch to max rate - on each axis. (Watch outer axis.)	OK
4.2.4	Null Point Drift	Adjustment Control	By design	By design null point drift is an adoptive control	OK

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.2.5	Earth Rate Compensation	Accuracy 0.15 deg/hr or consistent with resolution. Range and accuracy of each mode.		The earth rate compensation is computer generated by calculating position changes on a fixed time base. If the position accuracy test has passed the earth rate compensation is dependent on the computer.	

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.2.7	Zero Reference Pulse	Repeatability ±1.0 arc sec (rev. to rev.) Static Accuracy ±1.0 arc second		Determine that zero reference pulse occurs within .0002 degree of zero by monitoring the analog position output on a strip chart and the 000.0000 degree output before the pulse shaper on another channel. Rat at .0001 deg/sec through zero, two different revolutions. Repeat 5 times. Convert the voltage at the transistion time to arc sec using the scale factor taken earlier on page . $(V_1 - V_2)$ (SF) = Repeatability SF $\left(\frac{V_1 + V_2}{2}\right)$ = Static Accuracy Mathmatical Description of Acceleration of Velocity Spec.	 ____ arc se ____ arc se

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
4.2.7	Zero Reference Pulse (Cont.)	Rate Error $\leqslant$ 1.0 sec/rad/sec Acceleration Error $\leqslant$ 2.0 sec/rad/sec	By design	Compatible with position readout. Sampling Error: Sampling time = $.416 \times 10^{-6}$ sec at 100 deg/sec $100 \times .416 \times 10^{-6} = .4 \times 10^{-4}$ deg = .00004 deg or ≈ .08 arc sec/rad/sec	
4.2.8 b				Demonstration of 3 different frequencies.	
4.2.8 c		External Oscillation Inputs	By design	Show external oscillation inputs.	
4.2.8 e		Isolation	By design	Multimeter check for ground isolation.	
5.4		Flux ~~Devity~~ Density	By design based on test data on S.O. 226		

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
5.6.1	Rate Limiting (Trip)	Resolution 0.05 rad/sec	By design	1°/sec on all axes.	
		Range .1 - 3 rad/sec I .1 - 2 rad/sec M .1 - 1 rad/sec O	By design	1 - 199°/sec Inner 1 - 199°/sec Middle 1 - 79°/sec Outer	
		Accuracy ±.1 rad/sec		Set rate trip to the value shown in the chart. Enter the rate below the final rate and step up the step size indicated. Record rate trip.	
		Repeatability ±.1 rad/sec		Repeatability may be calculated from items 1, 2, 6, 7, 9, 10, 14, 15, 17, 18, 22, and 23.	

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE ___ OF ___

RATE TRIP

	Axis	Rate Trip Setting °/sec	Initial Rate °/sec	Step Size °/sec	Command Rate at Which Rate Trip Occurs	Accuracy Spec °/sec
1	Inner	180	+170	+1	+182.0	180 ±5.7
2		180	+170	+1	+182	180 ±5.7
3		180	-170	-1	-182	180 ±5.7
4		60	+50	+1	+61	60 ±5.7
5		60	-50	-1	-61	60 ±5.7
6		5	+3	+.5	+6.0	5 ±5.7
7		5	+3	+.5	+6.0	5 ±5.7
8		5	-3	-.5	-6.0	5 ±5.7
9	Middle	120	+110	+1	+124	120 ±5.7
10		120	+110	+1	[illegible]	120 ±5.7
11		120	-110	-1	-124	120 ±5.7
12		60	+50	+1	+63	60 ±5.7
13		60	-50	-1	-63	60 ±5.7
14		5	+3	+.5	+6.0	5 ±5.7
15		5	+3	+.5	+6.0	5 ±5.7
16		5	-3	-.5	-5.5	5 ±5.7
17	Outer	~~60~~	~~+50~~	~~+1~~		~~60 ±5.7~~
18		~~60~~	~~+50~~	~~+1~~		~~60 ±5.7~~
19		~~60~~	~~-50~~	~~-1~~		~~60 ±5.7~~
20		30	+20	+1	+31	30 ±5.7
21		30	-20	-1	-31	30 ±5.7
22		5	+3	+.5	+5.5	5 ±5.7
23		5	+3	+.5	+5.5	5 ±5.7
24		5	-3	~~+~~-.5	-5.5	5 ±5.7

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TEST PLAN

SPEC PARAGRAPH	ITEM	SPECIFICATION	METHOD OF VERIFICATION	TEST PARAMETER	RESULTS
5.6.1.2	Rotational Limits		Demonstrate	Rate into CW and CCW stops at 57 deg/sec	
5.6.1.4	Loss of Control			Dynamic Braking Incorporated Demonstrate dynamic braking from a rate.	

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE ___ OF ___

EQUIPMENT:

A. Oscillator 1 - 1000 Hz, continuously variable

B. Dual Channel Oscilloscope with horizontal sweep channel

PURPOSE:

This procedure is specifically designed to verify linear system gains and time constants as they effect small signal frequency response (the frequency response of the system when all of its elements are operating within their linear range).

USE:

When using this procedure, amplitude levels and frequency ranges as well as specification points should be specified.

PROCEDURE:

(1) Connect the test equipment to the system under test as defined by the functional diagram. (Note, if a frequency response analyzer is used for this test, the scope should still be connected in order to monitor wave shapes).

(2) With the system ON in the STOP mode, adjust the amplitude of the oscillator to a value as high as possible which does not saturate either the power amplifier or any preamplifier stage over the frequency range of 1 - 1000 Hz (see note 1).

(3) Obtain the frequency response data for all the frequencies in Table I as well as at a sufficient number of other frequencies to clearly define all large gain or phase changes. At each frequency perform the following measurements:

a) Monitor the tachometer output and input a constant rate command of either polarity, such that the tachometer voltage does not swing through zero volts.

b) Monitor power amplifier output voltage; confirm that it is not saturated and record its peak to peak amplitude.

c) Monitor tach output voltage and record its peak to peak amplitude as well as its relative phase shift with respect to the input voltage.

To obtain a phase measurement using the HP-202A oscillator, adjust the reference output until the lissajous pattern indicates a straight line sloping from left to right. Perform correction as required to account for $0^{o}/360^{o}$ transitions.

d) Scan the frequency range from 200 to 2000 Hz for any resonances. Take data sufficient to define the height and width of all resonant peaks.

DATE	TESTED BY	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE 1 OF 5

4). At the completion of the frequency response gathering stage, perform the calculations required by the data sheet and plot:

a) F (cps) vrs. 20 log (Rate Measured/Rate Command)

b) F (cps) vrs. $\angle$(Rate Measured/Rate Command)

on four decade semilog paper. Examine the plot to assure that sufficient data points were run to clearly define the resultant curve. Run additional points as required.

5) Calculation & Plotting

a) Output Ratio - Note that the output ratio to be plotted is a normalized function; that is, the ratio at all frequencies is to be divided by the ratio calculated at f = 1 cps

b) Phase Shift - Typically the phase shift between input and output will be approximately -180° at low frequencies and increase negatively as the frequency is increased.

c) Ratio to Decibel conversion. The conversion from gain ratio to decibels can be easily accomplished by the use of figure I. The normalized gain ratio should be found on the X axis and the corresponding decibel value read off the Y axis.

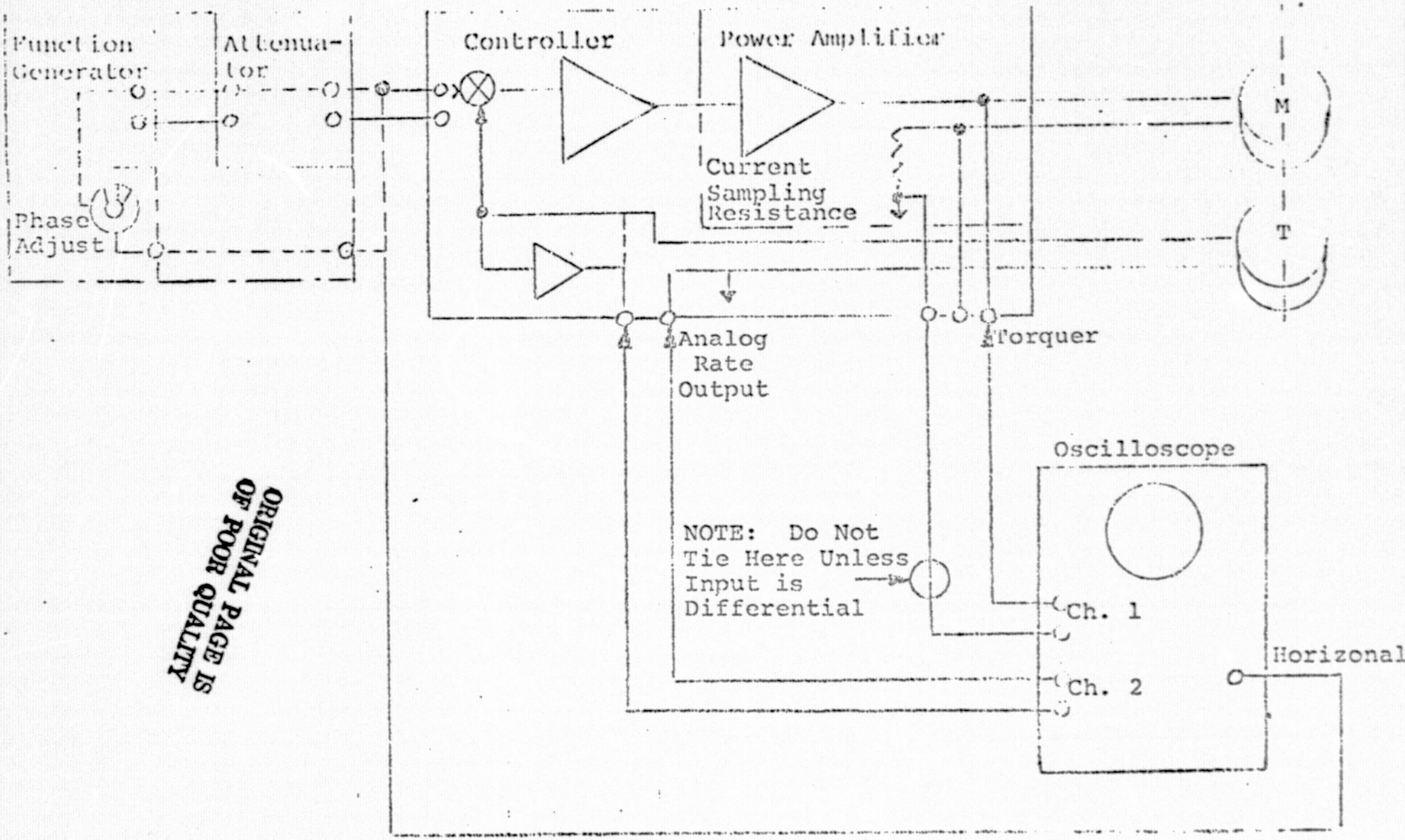
NOTE I:

The amplitude at which this test is run is fairly critical if useable results are to be obtained. Too high a level results in saturation, too low a level causes the inherent system noise level to obscure the gain/phase characteristics of the loop under test.

For convenience in data reduction, it is desirable to run the test at a constant input amplitude. For the reasons above it may not be possible. A rule of thumb is that the input is high enough so the output is driven to at least 10X its inherent noise level. At certain frequencies, this level cannot be achieved due to saturation or gain loss due to linear bandwidth limitations, the input level must be lowered or raised to obtain a useful measurement.

Amplitude adjustment may be required particularly when scanning for mechanical resonances.

Power bandwidth (ability of the system to produce a specific level of acceleration at specific frequencies) is tested in another test procedure.



FUNCTIONAL DIAGRAM SMALL SIGNAL FREQUENCY RESPONSE TESTS

TESTED BY

WITNESSED BY

WITNESSED BY (CUSTOMER)

INCORPORATED

GOERZ OPTICAL COMPANY INCORPORATED	SERVO FREQUENCY RESPONSE	STP-E-272A

FRE-QUENCY (HZ)	W_D LOOP INPUT (P-P VOLTS	TORQUER OUTPUT VOLTAGE (P-P VOLTS)	W_m TACH OUTPUT (P-P VOLTS)	W_m/W_D OUTPUT TO INPUT RATIO	*W_m/W_D=1 @f=1 Normal-ized . RATIO	GAIN (DB)	PHASE SHIFT
1					1	0 DB	
2							
5							
7							
10							
20							
30							
40							
50							
70							
100							
150							
200							

*Normalized Ratio = Output to Input Ratio/Output to Input Ratio at f = 1

DATA SHEET - FREQUENCY RESPONSE TEST

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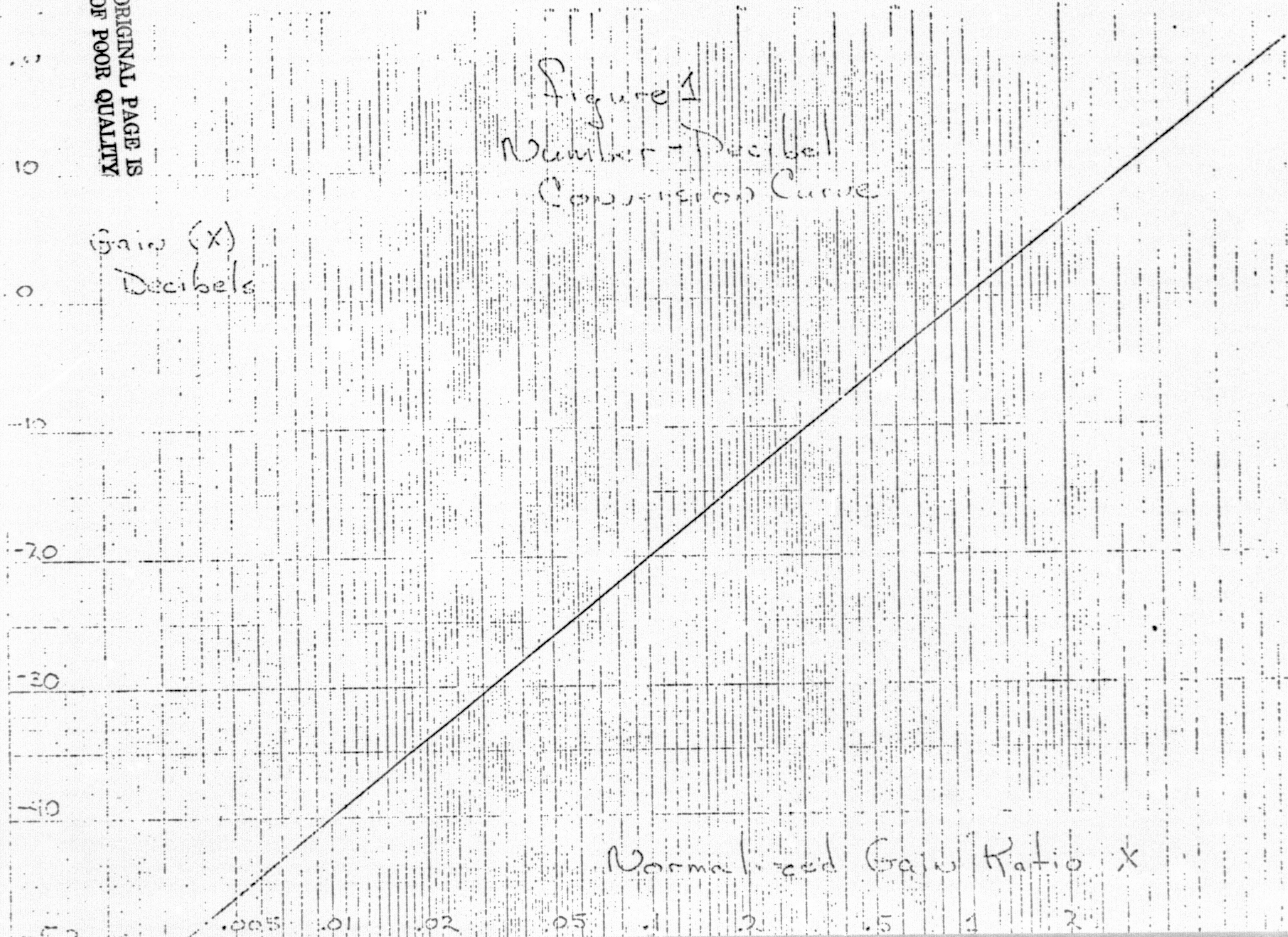
Figure 1
Number-Decibel
Conversion Curve
Gain (X)
Decibels
10
0
-10
-20
-30
-40
-50
Normalized Gain Ratio X
.005
.01
.02
.05
.1
.2
.5
1
2

CONTRAVES-GOERZ CORPORATION	INDUCTOSYN FINE POSITION ERROR TEST	STP-E-2254

INSTRUMENT: ____________________

SHOP ORDER: ____________________

CUSTOMER: ____________________

AXES: ____________________

SPECIFICATION: ____________________

____

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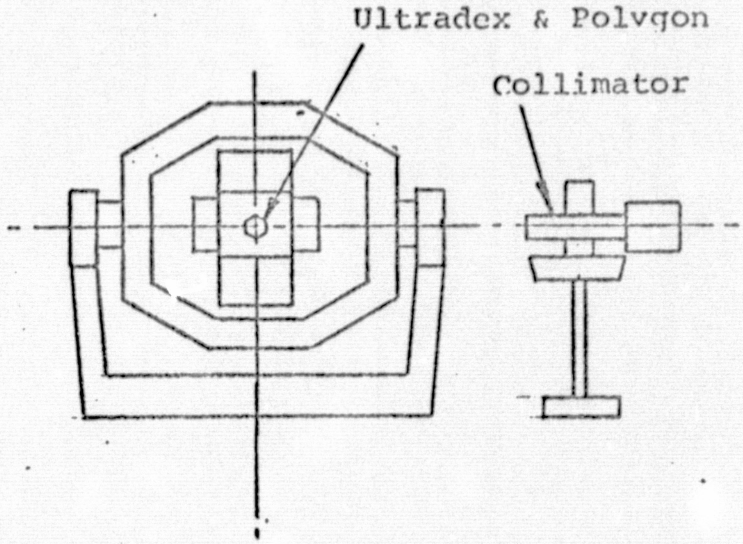

TEST EQUIPMENT:

1) Collimator with 0.1 arc second resolution.

2) Ultradex with 1 degree resolution and an eight-sided calibrated irregular polygon.

PROCEDURE:

Set up test equipment as shown above. Command axis to position indicated using the position command system.

POSITION COMMAND NOMINAL*		ULTRADEX POSITION (45° STEPS)	R/O DISPLAY	COLLIMATOR	ΔPOSITION R/O CMD
.0000	0	______	______	______	______
.1250	45	______	______	______	______
.2500	90	______	______	______	______
.3700	135	______	______	______	______
.5000	180	______	______	______	______
.6250	225	______	______	______	______
.7500	270	______	______	______	______
.8750	315	______	______	______	______
1.0000		______	______	______	______

*Actual positions determined from polygon calibration data.

$$\text{Mean} = \frac{1}{n}\sum_{i=1}^{n} e_i$$

ΔP = Position - Mean

$$e_{RMS} = \frac{1}{n}\sqrt{\sum_{i=1}^{n} \Delta_i^2}$$ = ____________ arc seconds

P-P error = Collimator Max. - Collimator Min. = ____________ arc seconds.

DATE	TESTED BY:	WITNESSED BY CUSTOMER	WITNESSED BY GOERZ	1 PAGE 1 OF

INSTRUMENT: ____________________

SHOP ORDER: ____________________

CUSTOMER: ____________________

AXIS: ____________________

SPECIFICATION: ____________________

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TEST EQUIPMENT

1) Time Interval Counter H-P Model 523C or equivalent.
2) Two channel Strip Chart Recorder HP Model 7700 or equivalent.

PROCEDURE

Connect the first channel of the strip chart recorder to the accelerometer. Connect the second channel to the buffered tach output. Obtain tach scale factor by running axis at 100°/sec in the digital mode and record the tach output.

Set acceleration command to the command in Table 1. Run for amount of time called for in Table 1. Record the accelerometer output and the tach. Record the data on Table 1.

For accelerations of 15°/sec^2 and less the Time Interval Counter can also be connected to the once per revolution zero pulse. A time measurement can be made of successive zero pulses when accelerating through 360°. Above 15 deg/sec^2, use 1 degree pulses. Those may be predivided using a prescaler if available.

ACC. COMD	TIME SEC	ACC. R/O DISPLAY	ACCELEROMETER RIPPLE		ACCELERATION		COUNTER ≤15°/SEC²	TIME SPEC SEC
			MEASURED	SPEC.	CALC (A)	SPEC°/SEC²		
+34.38	3	+34.78		.025V	34.5°/sec²	34.38±.57		
+30.00	3	+30.36		.025V	29.6°/sec²	30.00±.57		
+20.00	5	+20.25		.025V	19.5°/sec²	20.00±.57		
+15.00	7	+15.19		.025V	14.6°/sec²	15.00±.57		6.72 $^{+.14}_{-.12}$
+10.00	9	+10.13		.025V	9.75°/sec²	10.00±.57		8.49 $^{+.25}_{-.24}$
+ 5.00	13	+ 5.07		.025V	4.94°/sec²	05.00±.57		12.00 $^{+.74}_{-.64}$
+ 1.00	28	+ 1.02		.025V	1.05°/sec²	01.00±.57		26.83 $^{+14.9}_{-5.4}$

RESULTS

ACC. COMD	SEC TIME INTVL ΔT	°/SEC INITIAL TACH (R_1)	°/SEC FINAL TACH (R_f)	°/SEC² CALC ACCEL (A)
+34.38	2.32 Sec	10°/sec	90°/Sec	34.5°/sec²
+30.00	2.7 Sec	10°/sec	90°/sec	29.6°/sec²
+20.00	4.1 Sec	10°/sec	90°/sec	19.50°/sec²
+15.00	5.4 Sec	10°/sec	90°/sec	14.6°/sec²
+10.00	8.2 Sec	10°/sec	90°/sec	9.75°/sec²
+ 5.00	16.2 Sec	10°/sec	90°/sec	4.94°/sec²
+ 1.00	19 Sec	15°/sec	30°/sec	1.05°/sec²

$$A = \frac{R_f - R_1}{\Delta T}$$

ANGULAR ACCELERATION TEST

STP-E-2256

INSTRUMENT: ______________________

SHOP ORDER: ______________________

CUSTOMER: ______________________

AXIS: ______________________

SPECIFICATION: ______________________

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TEST EQUIPMENT

1) Two channel Strip Chart Recorder HP Model 7700 or equivalent.
2) Function Generator, Exact, Models 605 + 337 or equivalent.

PROCEDURE

Connect strip chart recorder to buffered tach output.

Setup Function Generator for a large amplitude low frequency square wave output. Put axis in Rate Oscillation Mode.

Record tach output on strip chart recorder and calculate acceleration from recorder plot.

SP 11836A

CONTRAVES-GOERZ CORPORATION	ACCELERATION LIMITING TEST	STP-E-2257

LIMIT deg/sec	RATE AMPLITUDE	MEASURED RATE °/sec	ΔT (spec) CAL. sec	ΔT MEAS	ERROR
3 Inner	TW Setting 99.	80	≈ 26.7		
10 Inner	99.	80	≈ 8.0		
60 Inner	99.	80	≈ 1.3		
3 Middle	99.	80	≈ 26.7		
10 Middle	99.	80	≈ 8.0		
34 Middle	99.	80	≈ 1.3		
3 Outer	50.	40	≈ 13.3		
10 Outer	50.	40	≈ 4.0		
14 Outer	50.	40	≈ 2.86		

5
10
25
OUTER

20
40
89

DATE	TESTED BY:	WITNESSED BY (GOERZ)	WITNESSED BY (CUSTOMER)	PAGE OF

PURPOSE

This test is to determine the position sensitivity of one axis to rate and acceleration applied to another axis. It may be done with the test axis servoed to determine the servoed sensitivity or with the brakes applied to determine brake sensitivity. To determine the sensitivities a method for controlling rate and acceleration must be available.

TEST PARAMETER DEFINITION

1. Define the method of monitoring the position movement and the rate monitoring points.
2. Define the rate of the moving axis and the mode in which this is to be accomplished.
3. Define the acceleration limit setting, if available.
4. Specify the axis loading requirements.
5. Specify the orientation of any other nonmoving axis.

TEST EQUIPMENT

Monitoring equipment (two channel strip chart or oscilloscope)

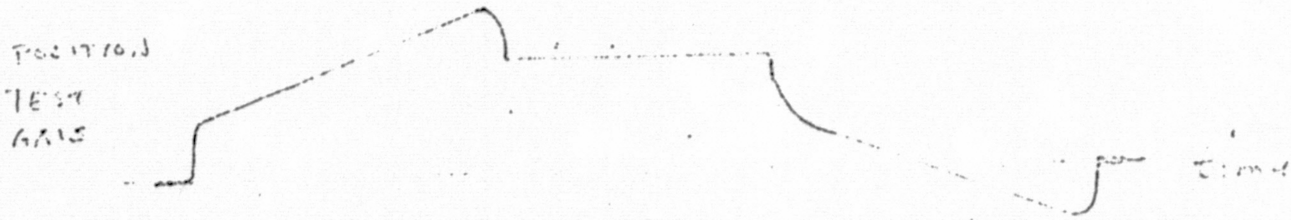
TEST PROCEDURE

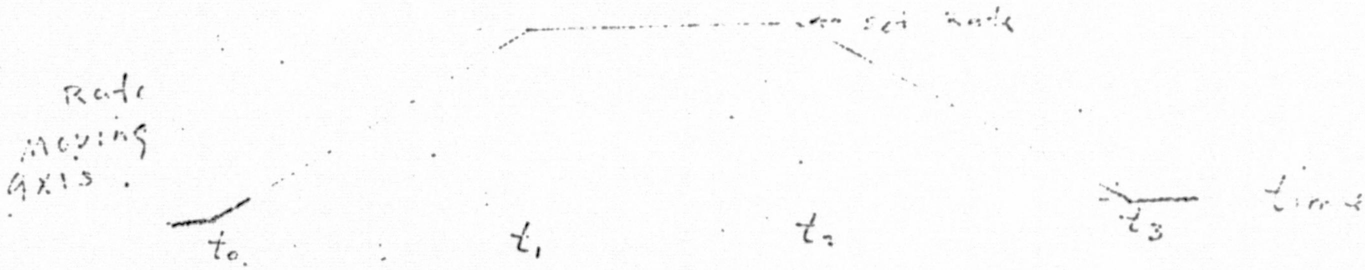
1. Prior to performing the actual test the following steps should be performed:
   a. Determine the required position and rate monitoring points by referring to the applicable FTS.
   b. Ensure that the required rate from the FTS will not exceed any rotational limits or rate limits of the equipment.
   c. Set the acceleration limit, if available, as defined in the FTS.
   d. Attach the specified test load as described in the FTS.

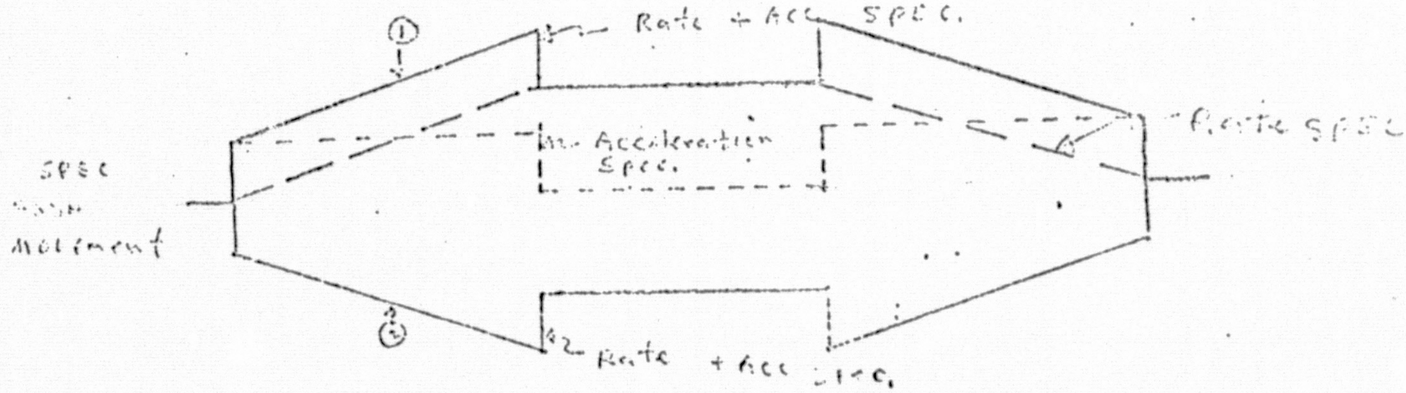
2. Attach the monitoring equipment to the position and rate test points depending on the axis and orientation being tested. Rate monitoring may require differential input.
3. Determine the scale factors of the position and rate of test points.
4. Set each axis at its test orientation.
5. Do a step rate command as specified in the FTS. Record the position movement of the test axis and the rate of rotating axis. When the required rate has been reached, command zero rate to stop the axis.
6. Label each recording with the appropriate orientation, scale factors, time base, and axis.
7. Repeat Steps 1 through 6 for each axis orientation required in the FTS.

RESULTS

1. The data recorded should be plots of test axis position and moving axis rate vs. time. They should be as shown below.







2. In zones t_0 through t_1 and t_2 through t_3 both acceleration and rate are being applied. Maximum Specification value must be determined at each point by determining the rate at these points and acceleration at these points. Because the rate and acceleration specification is a magnitude, position error may occur anywhere between curve 1 and 2.

ACCURACY CONSIDERATIONS ON THE RESULTS

The amplitude measuring instrument and the point monitored directly affect the accuracy of the results. If an oscilloscope or a strip chart is used, the accuracy should be better than 5% of the full scale measurement.

The acceleration is calculated for a rate and a time interval; the rate is assumed constant over the time interval. The maximum acceleration is determined from the plotted data, thus the accuracy of the acceleration is dependent on the accuracy of the measurements.