N72-18150

Design Study Report

Prepared for:
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland

Design Study for Multi-Channel Tape Recorder System

Volume II

AED R-3775F
January 20, 1972
In Response to:
Contract No. NAS5-21511

RCA|Government and Commercial Systems
Astro-Electronics Division|Princeton, New Jersey

APPENDIX A

SKEW MEASUREMENT RESULTS ON IR&D TRANSPORT
D. H. SAPP TO L. BAKER, FEBRUARY 25, 1971.

Internal Correspondence RCA

To	L. Baker	Location	AED - Hightstown	Date	2/25/71
From	D. H. Sapp	Location	10-5-3	Telephone	PC-4955

Subject Skew Measurement Results on I R & D Transport.

Ref "Design Study - NASA Multi-Channel Tape Recorder (AED Prop #101150-A)", D. H. Sapp, February 17, 1971.

The referenced memo gave the results of the skew experimental tests performed on an existing model of the ERTS transport. Further skew tests conducted under our I R & D Program on another transport with a double capstan drive has yielded data with much less skew. The skew measurements were made with the same seven track head used in the first tests, but the center track (track 4) was repaired to obtain an exact center track. The same procedure described in the referenced memo was also used for the later skew tests. A 100 KHz tone was recorded on five tracks simultaneously. Playback was in the same direction as the recording. The skew was measured using phase detectors where the center channel was the 100 KHz reference. Figure 1 shows some of the pertinent skew measurement results. The following table compares the two test results:

	ERTS Transport Model	I R & D Transport
Max edge to edge skew	160 microinches	40 microinches
Max edge to center skew	100 microinches	30 microinches
Max non-linearity relative to straight line from edge to center of tape	10 microinches	3 microinches

With a bit packing density of 18.75 kbpi for the proposed recorder, the bit length would be 53.3 microinches. Thus, all the channels would be within ±0.6 of a bit of the center channel due to the dynamic skew alone. Preliminary static skew tests conducted by playing back a day after the recording was made have indicated that the edge channel can move as much as 80 microinches referenced to the center channel. Further static skew tests must be conducted in order to determine the cause of this static skew as it may be the test equipment or test procedure rather than the transport or tape.

The most prominent dynamic skew rate of 51 Hz was due to the capstan drive. Tests were conducted both with and without the flywheel to determine the effect of the flywheel. Without the flywheel, some low frequency skew ($\precsim$3.5 Hz) was also present.

Figure 2 shows three worst case dynamic skew samples. Sample 1 was the worst dynamic skew measured. Table 1 lists the skew and deviation from linear skew for these three skew samples. Although the percent non-linearity is high, the actual deviation from a linear skew is low for an edge to center track.

Further skew tests which will be conducted are:

1) Controlled static skew tests.

2) Both static and dynamic skew measurements under varying temperature conditions.

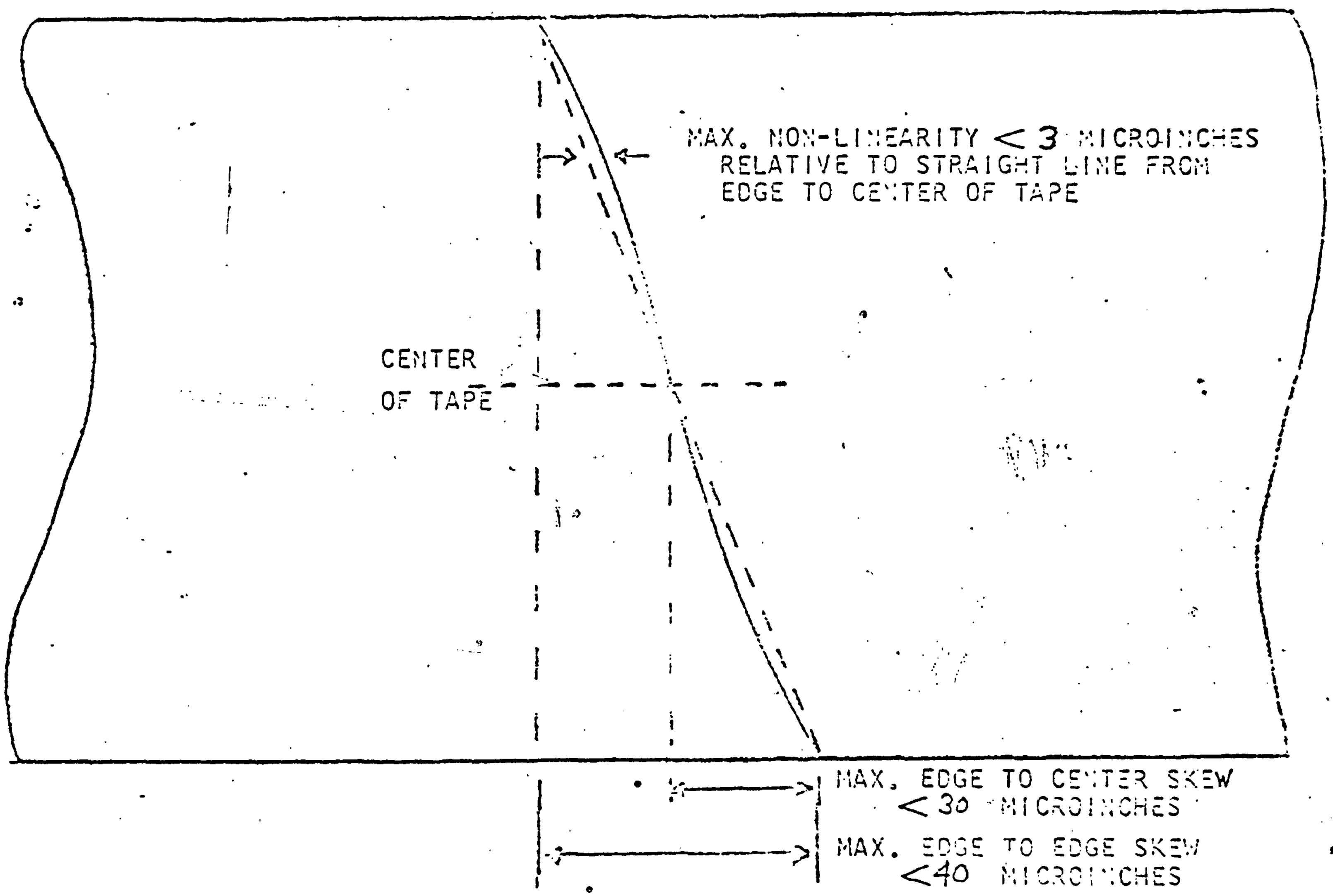
D. H. Sapp

D. H. Sapp
Recording Equipment

DHS:bj

xc: O. E. Bessette - 10-5
S. P. Clurman - 10-5
F. D. Kell - 10-5
C. R. Thompson - 10-5
R. Millor - AED
R. Treadwell - AED

Figure 1 SKEW MEASUREMENT RESULTS (IRED TRANSPORT)



NOTE: THE MOST PROMINENT SKEW RATE WAS ≈ 51 HZ

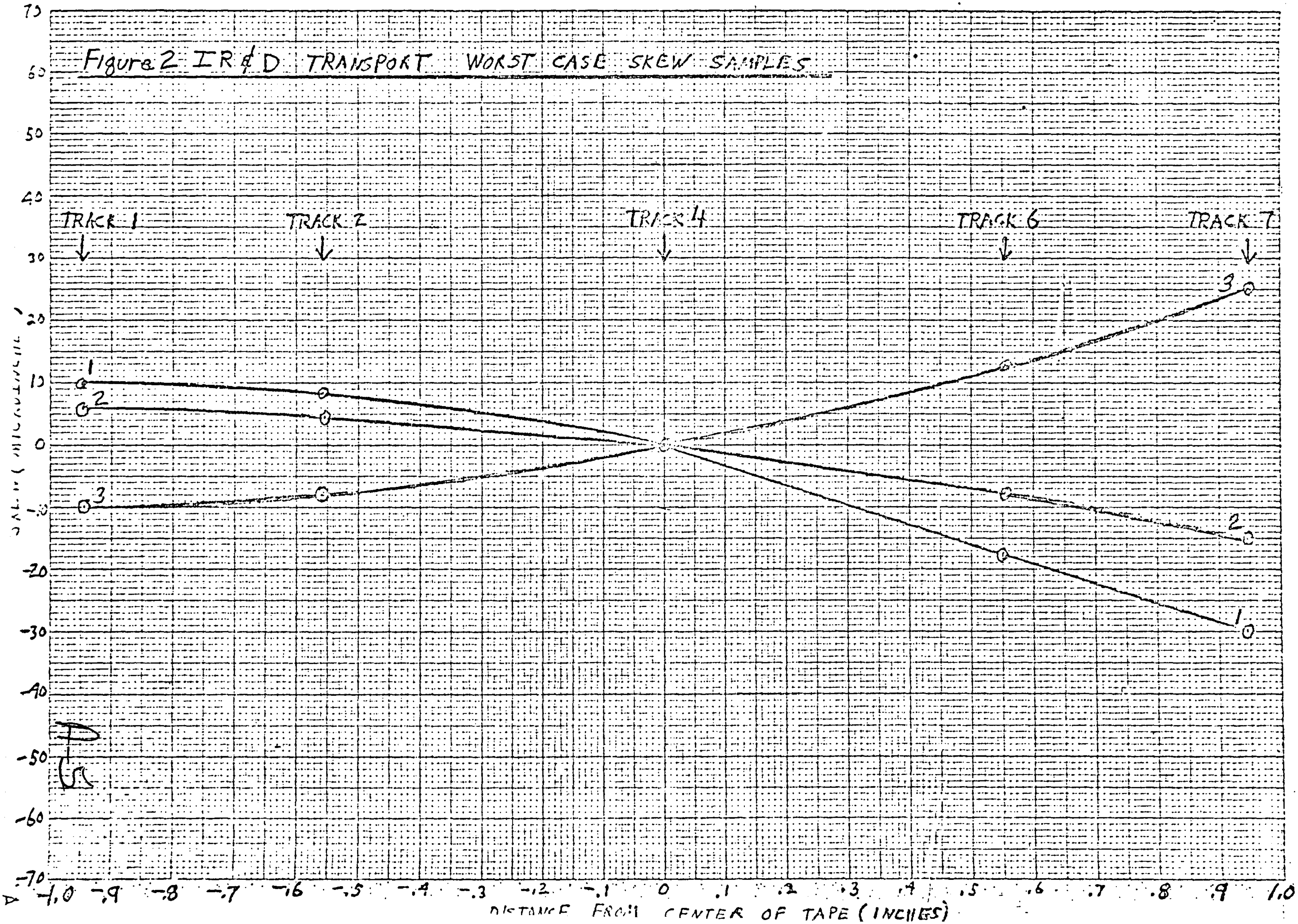


Figure 2 IR&D TRANSPORT WORST CASE SKEW SAMPLES
TRACK 1
TRACK 2
TRACK 4
TRACK 6
TRACK 7
1
2
3
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-1.0
-.9
-.8
-.7
-.6
-.5
-.4
-.3
-.2
-.1
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
DISTANCE FROM CENTER OF TAPE (INCHES)

TABLE 1 WORST CASE DEVIATION FROM LINEAR STRAIGHT LINE

	Sample 1			Sample 2			Sample 3		
	(µ") Skew	(µ inches) Deviation	% Non-Linearity	(µ") Skew	(µ inches) Deviation	% Non-Linearity	(µ") Skew	(µ inches) Deviation	% Non-Linearity
Edge to Edge Line (Track 1 to Track 7)	40	10	25%	21	5	23.8%	-35	8	28.6%
Edge to Center Line (Track 1 to Center)	10	2.5	25%	6	1.5	25%	-10	2.5	25%
(Track 7 to Center)	-30	0	0%	-15	2	13.3%	25	2.5	10%
Best Fit Straight Line Across Tape	—	5	12.5%	—	2	9.5%	—	3.5	10%

APPENDIX B

ANGULAR MOMENTUM STUDIES, TABULATION OF COMPUTER RESULTS.

Co-rotating reels

```
LOGIN
AL/COM-C     JOB 15       LINE 12   11-MAY-71   14:24
TYPE COMPANY PROJECT NAME
RC44ED,A054F63013,DAMANDA

              DIMENSION C(10),G(5)
              C(1)=0
              C(2)=.1
              C(3)=.2
              C(4)=.3
              C(5)=.4
              C(6)=.5
              C(7)=1.
              DO 50 J=1,7
              YK=0
   10         XN=1.2
              DO 30 I=1,5
   20         A=C(J)*(XN**2.+1.)/(2.*(XN-1.))
              B=(XN**2.-1.)*((1.-YK)**2.)/2.
              D=((XN**2.-1.)*(1.-YK)+1.)**.5
              E=(XN**2.-1.)*(YK**2.)/2.
              F=((XN**2.-1.)*YK+1.)**.5
              G(I)=(A+B+1.-YK)/D+(A+E+YK)/F
              XN=XN+.2
   30         CONTINUE
              WRITE (6,40) C(J),YK,G
   40         FORMAT (2F10.2,5F10.4)
              YK=YK+.05
              IF(1.-YK) 50,10,10
   50         CONTINUE
              STOP
              END
*E

EXIT
^C

.EXECUTE MOM.FOR
COMPILING: MOM.FOR
LOADING.

CORE 3.
START 000317
```

Co-rotating reels

XN

C	XK	1.2	1.4	1.6	1.8	2.0
0.00	0.00	1.0167	1.0571	1.1125	1.1778	1.2500
0.00	0.05	1.0145	1.0503	1.0999	1.1597	1.2242
0.00	0.10	1.0126	1.0441	1.0882	1.1411	1.2004
0.00	0.15	1.0108	1.0384	1.0777	1.1252	1.1789
0.00	0.20	1.0093	1.0335	1.0684	1.1112	1.1600
0.00	0.25	1.0080	1.0292	1.0604	1.0992	1.1439
0.00	0.30	1.0069	1.0257	1.0539	1.0892	1.1306
0.00	0.35	1.0060	1.0229	1.0486	1.0815	1.1200
0.00	0.40	1.0054	[illegible]	1.0448	1.0759	1.1125
0.00	0.45	1.0051	1.0197	1.0426	1.0725	1.1083
[illegible]	[illegible]	[illegible]	[illegible]	1.0417	1.0714	[illegible]

[illegible]	0.55	[illegible]	[illegible]	[illegible]	1.0705	[illegible]
0.00	0.60	1.0054	[illegible]	1.0448	1.0759	1.1100
0.00	0.65	1.0068	1.0280	1.0476	1.0815	1.1208
0.00	0.70	1.0080	1.0257	1.0530	1.0892	1.1320
0.00	0.75	1.0090	1.0302	1.0604	1.0999	1.1439
0.00	0.80	1.0103	1.0335	1.0684	1.1112	1.1602
0.00	0.85	1.0120	1.0384	1.0777	1.1252	1.1759
0.00	0.90	1.0126	1.0441	1.0882	1.1411	1.2204
0.00	0.95	1.0145	1.0503	1.0999	1.1557	1.2242
0.00	1.00	1.0167	1.0571	1.1125	1.1778	1.2500
0.10	0.00	2.1350	1.6914	1.5946	1.5900	1.6250
0.10	0.05	2.1302	1.6793	1.5739	1.5599	1.5848
0.10	0.10	2.1259	1.6685	1.5555	1.5332	1.5496
0.10	0.15	2.1220	1.6589	1.5393	1.5100	1.5192
0.10	0.20	2.1187	1.6506	1.5252	1.4900	1.4933
0.10	0.25	2.1159	1.6435	1.5134	1.4732	1.4716
0.10	0.30	2.1136	1.6378	1.5037	1.4595	1.4540
0.10	0.35	2.1118	1.6333	1.4962	1.4490	1.4404
0.10	0.40	2.1105	1.6301	1.4909	1.4414	1.4307
0.10	0.45	2.1097	1.6282	1.4876	1.4369	1.4249
0.10	0.50	2.1095	1.6275	1.4866	1.4354	1.4230
0.10	0.55	2.1097	1.6282	1.4876	1.4369	1.4249
0.10	0.60	2.1105	1.6301	1.4909	1.4414	1.4307
0.10	0.65	2.1118	1.6333	1.4962	1.4490	1.4404
0.10	0.70	2.1136	1.6378	1.5037	1.4595	1.4540
0.10	0.75	2.1159	1.6435	1.5134	1.4732	1.4716
0.10	0.80	2.1187	1.6506	1.5252	1.4900	1.4933
0.10	0.85	2.1220	1.6589	1.5393	1.5100	1.5192
0.10	0.90	2.1259	1.6685	1.5555	1.5332	1.5496
0.10	0.95	2.1302	1.6793	1.5739	1.5599	1.5848
0.10	1.00	2.1350	1.6914	1.5946	1.5900	1.6250
0.20	0.00	3.2533	2.3257	2.0767	2.0000	2.0000
0.20	0.05	3.2458	2.3084	2.0480	1.9610	1.9453
0.20	0.10	3.2392	2.2929	2.0227	1.9254	1.8989
0.20	0.15	3.2333	2.2794	2.0008	1.8948	1.8595
0.20	0.20	3.2281	2.2678	1.9821	1.8688	1.8265
0.20	0.25	3.2238	2.2580	1.9664	1.8473	1.7992
0.20	0.30	3.2203	2.2500	1.9537	1.8299	1.7773
0.20	0.35	3.2175	2.2438	1.9439	1.8165	1.7605
0.20	0.40	3.2156	2.2394	1.9369	1.8070	1.7487
0.20	0.45	3.2144	2.2367	1.9327	1.8013	1.7416
0.20	0.50	3.2140	2.2358	1.9313	1.7994	1.7393
0.20	0.55	3.2144	2.2367	1.9327	1.8013	1.7416
0.20	0.60	3.2156	2.2394	1.9369	1.8070	1.7487
0.20	0.65	3.2175	2.2438	1.9439	1.8165	1.7605
0.20	0.70	3.2203	2.2500	1.9537	1.8299	1.7773
0.20	0.75	3.2238	2.2580	1.9664	1.8473	1.7992
0.20	0.80	3.2281	2.2678	1.9821	1.8688	1.8265
0.20	0.85	3.2333	2.2794	2.0008	1.8948	1.8595
0.20	0.90	3.2392	2.2929	2.0227	1.9254	1.8989
0.20	0.95	3.2458	2.3084	2.0480	1.9610	1.9453
0.20	1.00	3.2533	2.3257	2.0767	2.0000	2.0000
0.30	0.00	4.3717	2.9600	2.5558	2.4144	2.3750
0.30	0.05	4.3615	2.9374	2.5220	2.3621	2.3059
0.30	0.10	4.3524	2.9174	2.4907	2.3175	2.2491
0.30	0.15	4.3445	2.8999	2.4624	2.2795	2.1998
0.30	0.20	4.3376	2.8849	2.4392	2.2475	2.1597
0.30	0.25	4.3317	2.8724	2.4194	2.2213	2.1269
0.30	0.30	4.3270	2.8621	2.4037	2.2002	2.1007
0.30	0.35	4.3233	2.8542	2.3915	2.1840	2.0807
0.30	0.40	4.3207	2.8486	2.3829	2.1725	2.0666
0.30	0.45	4.3191	2.8453	2.3777	2.1657	2.0583
0.30	0.50	4.3186	2.8441	2.3760	2.1634	2.0555
0.30	0.55	4.3191	2.8453	2.3777	2.1657	2.0583
0.30	0.60	4.3207	2.8486	2.3829	2.1725	2.0666
[illegible]	[illegible]	4.3233	2.8542	2.3915	2.1840	2.0807

[illegible]	[illegible]	[illegible]	[illegible]	2.4[illegible]37	2.2[illegible]	2.1[illegible]7
0.30	0.75	4.3317	2.8724	2.4194	2.2213	2.1269
0.30	0.80	4.3376	2.8840	2.4390	2.2476	2.1597
0.30	0.85	4.3445	2.8999	2.4624	2.2795	2.1998
0.30	0.90	4.3524	2.9174	2.4898	2.3175	2.2481
0.30	0.95	4.3615	2.9374	2.5208	2.3621	2.3058
0.30	1.00	4.3717	2.9500	2.5577	2.4144	2.3750
0.40	0.00	5.4900	3.5943	3.0400	2.8267	2.7500
0.40	0.05	5.4778	3.5664	2.9960	2.7633	2.6664
0.40	0.10	5.4657	3.5419	2.9573	2.7096	2.5973
0.40	0.15	5.4557	3.5204	2.9240	2.6643	2.5401
0.40	0.20	5.4470	3.5021	2.8958	2.6265	2.4909
0.40	0.25	5.4397	3.4868	2.8725	2.5954	2.4545
0.40	0.30	5.4337	3.4743	2.8536	2.5705	2.4240
0.40	0.35	5.4290	3.4647	2.8391	2.5515	2.4009
0.40	0.40	5.4257	3.4579	2.8289	2.5381	2.3846
0.40	0.45	5.4238	3.4537	2.8228	2.5301	2.3749
0.40	0.50	5.4231	3.4524	2.8207	2.5274	2.3717
0.40	0.55	5.4238	3.4537	2.8228	2.5301	2.3749
0.40	0.60	5.4257	3.4579	2.8289	2.5381	2.3846
0.40	0.65	5.4290	3.4647	2.8391	2.5515	2.4009
0.40	0.70	5.4337	3.4743	2.8536	2.5705	2.4240
0.40	0.75	5.4397	3.4868	2.8725	2.5954	2.4545
0.40	0.80	5.4470	3.5021	2.8958	2.6265	2.4909
0.40	0.85	5.4557	3.5204	2.9240	2.6643	2.5401
0.40	0.90	5.4657	3.5419	2.9573	2.7096	2.5973
0.40	0.95	5.4778	3.5664	2.9960	2.7633	2.6664
0.40	1.00	5.4900	3.5943	3.0408	2.8267	2.7500
0.50	0.00	6.6003	4.2006	3.5229	3.2379	3.1050
0.50	0.05	6.5928	4.1954	3.4731	3.1644	3.0260
0.50	0.10	6.5790	4.1662	3.4245	3.1017	2.9466
0.50	0.15	6.5669	4.1409	3.3856	3.0491	2.8804
0.50	0.20	6.5564	4.1193	3.3527	3.0053	2.8262
0.50	0.25	6.5476	4.1012	3.3255	2.9694	2.7822
0.50	0.30	6.5404	4.0865	3.3036	2.9408	2.7474
0.50	0.35	6.5348	4.0751	3.2868	2.9190	2.7210
0.50	0.40	6.5308	4.0671	3.2749	2.9036	2.7025
0.50	0.45	6.5284	4.0623	3.2678	2.8945	2.6916
0.50	0.50	6.5276	4.0607	3.2655	2.8914	2.6879
0.50	0.55	6.5284	4.0623	3.2678	2.8945	2.6916
0.50	0.60	6.5308	4.0671	3.2749	2.9036	2.7025
0.50	0.65	6.5348	4.0751	3.2868	2.9190	2.7210
0.50	0.70	6.5404	4.0865	3.3036	2.9408	2.7474
0.50	0.75	6.5476	4.1012	3.3255	2.9694	2.7822
0.50	0.80	6.5564	4.1193	3.3527	3.0053	2.8262
0.50	0.85	6.5669	4.1409	3.3856	3.0491	2.8804
0.50	0.90	6.5790	4.1662	3.4245	3.1017	2.9466
0.50	0.95	6.5928	4.1954	3.4731	3.1644	3.0260
0.50	1.00	6.6003	4.2006	3.5229	3.2379	3.1050
1.00	0.00	12.2000	7.4200	5.9333	5.3000	5.0000
1.00	0.05	12.1711	7.3404	5.8403	5.1701	4.8296
1.00	0.10	12.1455	7.2884	5.7608	5.0623	4.6927
1.00	0.15	12.1232	7.2434	5.6935	4.9730	4.5819
1.00	0.20	12.1036	7.2051	5.6378	4.8994	4.4923
1.00	0.25	12.0872	7.1731	5.5906	4.8396	4.4205
1.00	0.30	12.0739	7.1473	5.5534	4.7923	4.3642
1.00	0.35	12.0636	7.1274	5.5250	4.7565	4.3218
1.00	0.40	12.0562	7.1133	5.5049	4.7313	4.2923
1.00	0.45	12.0518	7.1049	5.4930	4.7164	4.2748
1.00	0.50	12.0503	7.1020	5.4891	4.7115	4.2691
1.00	0.55	12.0518	7.1049	5.4930	4.7164	4.2748
1.00	0.60	12.0562	7.1133	5.5049	4.7313	4.2923
1.00	0.65	12.0636	7.1274	5.5250	4.7565	4.3218
1.00	0.70	12.0739	7.1473	5.5534	4.7923	4.3642
1.00	0.75	12.0872	7.1731	5.5906	4.8396	4.4205
1.00	0.80	12.1036	7.2051	5.6378	4.8994	4.4923
1.00	.85	12.1232	7.2434	5.6935	4.9730	4.5819
1.00	0.90	12.1455	7.2884	5.7608	5.0623	4.6927
1.00	0.95	12.1711	7.3404	5.8403	5.1701	4.8296
1.00	1.00	12.2000	7.4200	5.9333	5.3000	5.0000

```
[illegible],270
      DIMENSION C(10),G(5)
      C(1)=0
      C(2)=.95
      C(3)=1.
      C(4)=1.05
      C(5)=1.1
      C(6)=1.15
      C(7)=1.2
      DO 50 J=1,7
      XK=0
10    XN=1.2
      DO 30 I=1,5
20    A=C(J)*(XN**2.+1.)/(2.*(XN-1.))
      B=(XN**2.-1.)*((1.-XK)**2.)/2.
      D=((XN**2.-1.)*(1.-XK)+1.)**.5
      E=(XN**2.-1.)*(XK**2.)/2.
      F=((XN**2.-1.)*XK+1.)**.5
      G(I)=(A+B+1.-XK)/D-(A+E+XK)/F
      XN=XN+.2
30    CONTINUE
      WRITE (6,40) C(J),XK,G
40    FORMAT (2F10.2,5F10.4)
      XK=XK+.05
      IF(1.-XK) 50,10,10
50    CONTINUE
      STOP
      END
E
```

C = Empty reel inertia factor.

XK = tape position 1 > XK > 0

XN = reel full/empty radius ratio

G = Angular momentum factor

Angular momentum = G mSR₁

m = mass of tape

S = tape speed

R₁ = empty reel radius

```
XIT
:
```

Angular Momentum Balance

Contra-rotating reels

```
EXECUTE MOM.FOR
OMPILING:  MOM.FOR
OADING.

ORE 3.
TART 000317
```

		XN				
C	XK	1.2	1.4	1.6	1.8	2.0
0.00	0.00	1.0167	1.0571	1.1125	1.1778	1.2500
0.00	0.05	0.9145	0.9503	0.9998	1.0586	1.1240
0.00	0.10	0.8125	0.8439	0.8877	0.9401	0.9987
0.00	0.15	0.7137	0.7378	0.7763	0.8221	0.8737
0.00	0.20	0.6089	0.6319	0.6647	0.7043	0.7489
0.00	0.25	0.5073	0.5263	0.5536	0.5868	0.6242
0.00	0.30	0.4057	0.4208	0.4427	0.4693	0.4994
0.00	0.35	0.3042	0.3155	0.3319	0.3519	0.3746
0.00	0.40	0.2028	0.2103	0.2212	0.2346	0.2493
0.00	0.45	0.1014	0.1051	0.1106	0.1173	0.1249
0.00	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
0.00	0.55	-0.1014	-0.1051	-0.1106	-0.1173	-0.1249
0.00	0.60	-0.2028	-0.2103	-0.2212	-0.2346	-0.2493
0.00	0.65	-0.3042	-0.3155	-0.3319	-0.3519	-0.3746
0.00	0.70	-0.4057	-0.4208	-0.4427	-0.4693	-0.4994
0.00	0.75	-0.5073	-0.5263	-0.5536	-0.5868	-0.6242
0.00	0.80	-0.6089	-0.6319	-0.6647	-0.7043	-0.7489
0.00	0.85	-0.7137	-0.7378	-0.7763	-0.8221	-0.8737
0.00	0.90	-0.8125	-0.8439	-0.8877	-0.9401	-0.9987
0.00	0.95	-0.9145	-0.9503	-0.9998	-1.0586	-1.1240
0.00	1.00	-1.0167	-1.0571	-1.1125	-1.1778	-1.2500
0.95	0.00	0.0508	0.0529	0.0556	0.0589	0.0625
0.95	0.05	0.0487	0.0588	0.0743	0.0947	0.1197
0.95	0.10	0.0456	0.0609	0.0841	0.1142	0.1504
0.95	0.15	0.0417	0.0598	0.0869	0.1213	0.1619
0.95	0.20	0.0371	0.0563	0.0839	0.1189	0.1594

0.95	0.25	0.0318	0.0499	0.0763	0.1092	0.1463
0.95	0.30	0.0261	0.0423	0.0651	0.0934	0.1253
0.95	0.35	0.0199	0.0327	0.0512	0.0735	0.0986
0.95	0.40	0.0134	0.0224	0.0352	0.0506	0.0679
0.95	0.45	0.0068	0.0114	0.0179	0.0258	0.0346
0.95	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
0.95	0.55	-0.0068	-0.0114	-0.0179	-0.0258	-0.0346
0.95	0.60	-0.0134	-0.0224	-0.0352	-0.0506	-0.0679
0.95	0.65	-0.0199	-0.0327	-0.0512	-0.0735	-0.0986
0.95	0.70	-0.0261	-0.0423	-0.0651	-0.0934	-0.1253
0.95	0.75	-0.0318	-0.0499	-0.0763	-0.1092	-0.1463
0.95	0.80	-0.0371	-0.0562	-0.0839	-0.1189	-0.1594
0.95	0.85	-0.0417	-0.0598	-0.0869	-0.1213	-0.1619
0.95	0.90	-0.0456	-0.0639	-0.0841	-0.1142	-0.1504
0.95	0.95	-0.0437	-0.0538	-0.0743	-0.0947	-0.1197
0.95	1.00	-0.0538	-0.0529	-0.0556	-0.0539	-0.0625
1.00	0.00	0.0000	0.0000	0.0000	0.0000	0.0000
1.00	0.05	0.0031	0.0119	0.0256	0.0439	0.0668
1.00	0.10	0.0053	0.0197	0.0418	0.0707	0.1057
1.00	0.15	0.0065	0.0241	0.0506	0.0845	0.1245
1.00	0.20	0.0070	0.0256	0.0533	0.0882	0.1283
1.00	0.25	0.0068	0.0248	0.0512	0.0838	0.1211
1.00	0.30	0.0061	0.0221	0.0452	0.0736	0.1057
1.00	0.35	0.0049	0.0178	0.0364	0.0589	0.0841
1.00	0.40	0.0035	0.0125	0.0254	0.0412	0.0583
1.00	0.45	0.0018	0.0064	0.0130	0.0210	0.0298
1.00	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
1.00	0.55	-0.0018	-0.0064	-0.0130	-0.0210	-0.0298
1.00	0.60	-0.0035	-0.0125	-0.0254	-0.0412	-0.0583
1.00	0.65	-0.0049	-0.0178	-0.0364	-0.0589	-0.0841
1.00	0.70	-0.0061	-0.0221	-0.0452	-0.0736	-0.1057
1.00	0.75	-0.0068	-0.0248	-0.0512	-0.0838	-0.1211
1.00	0.80	-0.0070	-0.0256	-0.0533	-0.0882	-0.1283
1.00	0.85	-0.0065	-0.0241	-0.0506	-0.0845	-0.1245
1.00	0.90	-0.0053	-0.0197	-0.0418	-0.0707	-0.1057
1.00	0.95	-0.0031	-0.0119	-0.0256	-0.0439	-0.0668
1.00	1.00	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
1.05	0.00	-0.0528	-0.0529	-0.0556	-0.0539	-0.0625
1.05	0.05	-0.0424	-0.0351	-0.0232	-0.0068	0.0140
1.05	0.10	-0.0351	-0.0215	-0.0035	0.0273	0.0611
1.05	0.15	-0.0287	-0.0116	0.0143	0.0476	0.0870
1.05	0.20	-0.0231	-0.0047	0.0227	0.0572	0.0973
1.05	0.25	-0.0182	-0.0003	0.0261	0.0537	0.0960
1.05	0.30	-0.0139	0.0021	0.0254	0.0538	0.0862
1.05	0.35	-0.0100	0.0030	0.0216	0.0442	0.0696
1.05	0.40	-0.0065	0.0026	0.0156	0.0313	0.0488
1.05	0.45	-0.0032	0.0015	0.0082	0.0162	0.0251
1.05	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
1.05	0.55	0.0032	-0.0015	-0.0082	-0.0162	-0.0251
1.05	0.60	0.0065	-0.0026	-0.0156	-0.0313	-0.0488
1.05	0.65	0.0100	-0.0030	-0.0216	-0.0442	-0.0696
1.05	0.70	0.0139	-0.0021	-0.0254	-0.0538	-0.0862
1.05	0.75	0.0182	0.0003	-0.0261	-0.0537	-0.0960
1.05	0.80	0.0231	0.0047	-0.0227	-0.0572	-0.0973
1.05	0.85	0.0287	0.0116	-0.0143	-0.0476	-0.0870
1.05	0.90	0.0351	0.0215	0.0035	-0.0273	-0.0611
1.05	0.95	0.0424	0.0351	0.0232	0.0068	-0.0140
1.05	1.00	0.0528	0.0529	0.0556	0.0539	0.0625
1.10	0.00	-0.1317	-0.1257	-0.1112	-0.1178	-0.1250
1.10	0.05	-0.0880	-0.0820	-0.0719	-0.0575	-0.0339
1.10	0.10	-0.0754	-0.0627	-0.0423	-0.0162	0.0164
1.10	0.15	-0.0639	-0.0473	-0.0219	0.0107	0.0495
1.10	0.20	-0.0532	-0.0350	-0.0073	0.0264	0.0663
1.10	0.25	-0.0432	-0.0253	0.0010	0.0335	0.0703
1.10	0.30	-0.0339	-0.0178	0.0055	0.0340	0.0663
1.10	0.35	-0.0250	-0.0119	0.0068	0.0296	0.0551

1.10	0.40	-0.0165	-0.0073	0.0053	0.0216	0.0392
1.10	0.45	-0.0082	-0.0034	0.0033	0.0113	0.0233
1.10	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
1.10	0.55	0.0082	0.0034	-0.0033	-0.0113	-0.0233
1.10	0.60	0.0165	0.0073	-0.0058	-0.0216	-0.0392
1.10	0.65	0.0252	0.0119	-0.0063	-0.0296	-0.0551
1.10	0.70	0.0339	0.0178	-0.0055	-0.0343	-0.0663
1.10	0.75	0.0432	0.0253	-0.0010	-0.0335	-0.0733
1.10	0.80	0.0532	0.0350	0.0073	-0.0264	-0.0663
1.10	0.85	0.0639	0.0473	0.0219	-0.0107	-0.0495
1.10	0.90	0.0754	0.0627	0.0428	0.0162	-0.0154
1.10	0.95	0.0880	0.0820	0.0719	0.0575	0.0339
1.10	1.00	0.1017	0.1057	0.1112	0.1178	0.1250
1.15	0.00	-0.1525	-0.1586	-0.1669	-0.1767	-0.1375
1.15	0.05	-0.1336	-0.1289	-0.1236	-0.1083	-0.0917
1.15	0.10	-0.1158	-0.1039	-0.0851	-0.0597	-0.0282
1.15	0.15	-0.0991	-0.0829	-0.0582	-0.0262	0.0121
1.15	0.20	-0.0833	-0.0653	-0.0384	-0.0044	0.0352
1.15	0.25	-0.0683	-0.0504	-0.0242	0.0084	0.0457
1.15	0.30	-0.0539	-0.0377	-0.0144	0.0142	0.0466
1.15	0.35	-0.0400	-0.0268	-0.0079	0.0149	0.0435
1.15	0.40	-0.0264	-0.0172	-0.0040	0.0119	0.0296
1.15	0.45	-0.0132	-0.0084	-0.0016	0.0065	0.0156
1.15	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
1.15	0.55	0.0132	0.0084	0.0016	-0.0065	-0.0156
1.15	0.60	0.0264	0.0172	0.0040	-0.0119	-0.0296
1.15	0.65	0.0400	0.0268	0.0079	-0.0149	-0.0435
1.15	0.70	0.0539	0.0377	0.0144	-0.0142	-0.0466
1.15	0.75	0.0683	0.0504	0.0242	-0.0084	-0.0457
1.15	0.80	0.0833	0.0653	0.0384	0.0044	-0.0352
1.15	0.85	0.0991	0.0829	0.0582	0.0262	-0.0121
1.15	0.90	0.1158	0.1039	0.0851	0.0597	0.0282
1.15	0.95	0.1336	0.1289	0.1236	0.1083	0.0917
1.15	1.00	0.1525	0.1586	0.1669	0.1767	0.1375
1.20	0.00	-0.2333	-0.2114	-0.2225	-0.2356	-0.2530
1.20	0.05	-0.1791	-0.1758	-0.1693	-0.1590	-0.1446
1.20	0.10	-0.1562	-0.1451	-0.1273	-0.1031	-0.0729
1.20	0.15	-0.1343	-0.1186	-0.0945	-0.0631	-0.0254
1.20	0.20	-0.1134	-0.0956	-0.0690	-0.0352	0.0042
1.20	0.25	-0.0933	-0.0755	-0.0493	-0.0168	0.0205
1.20	0.30	-0.0738	-0.0577	-0.0342	-0.0056	0.0269
1.20	0.35	-0.0549	-0.0417	-0.0227	0.0003	0.0260
1.20	0.40	-0.0364	-0.0271	-0.0138	0.0022	0.0200
1.20	0.45	-0.0181	-0.0133	-0.0065	0.0017	0.0108
1.20	0.50	0.0000	0.0000	0.0000	0.0000	0.0000
1.20	0.55	0.0181	0.0133	0.0065	-0.0017	-0.0108
1.20	0.60	0.0364	0.0271	0.0138	-0.0022	-0.0200
1.20	0.65	0.0549	0.0417	0.0227	-0.0003	-0.0260
1.20	0.70	0.0738	0.0577	0.0342	0.0056	-0.0269
1.20	0.75	0.0933	0.0755	0.0493	0.0168	-0.0205
1.20	0.80	0.1134	0.0956	0.0690	0.0352	-0.0042
1.20	0.85	0.1343	0.1186	0.0945	0.0631	0.0254
1.20	0.90	0.1562	0.1451	0.1273	0.1031	0.0729
1.20	0.95	0.1791	0.1758	0.1693	0.1590	0.1446
1.20	1.00	0.2333	0.2114	0.2225	0.2356	0.2530

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APPENDIX C

LIFE OF ANDOK C GREASE

APPENDIX C

LIFE OF ANDOK C GREASE

The following documents are the correspondence between RCA and the Humble Oil Co. on the life of the lubricating grease we propose to use on the HEAO Tape Recorder. For further information, refer to "The Behavior of Lubricating Oils in Inert Gas Atmospheres," by A. Beerbower and D. F. Greene, ASLE Transactions 4, 87-96, 1961, presented to the American Society of Lubrication Engineers at the Lubrication Conference held in Boston.

March 21, 1967 M.E. #1155

D. Ettleman 99

C. A. McBurney 64
3431

Andok C Lubricating Grease -- HDRSS

Reference: Materials Engineering memo #1097, from C. A. McBurney to D. Ettleman/R. Miller, re: Andok C Anti-Friction bearing grease

Attached you will find a letter from Mr. K. A. Dunphy of Humble Oil and Refining Co. which outlines our request to him for life expectance of the lubrication life of this material in HDRSS. This letter confirms information submitted in the above mentioned memo.

Attached also is a copy of an article from Humble Oil on some of the parameters surrounding the use of lubricating greases such as Andok C.

C. A. McBurney
Materials Engineering

CAM/glb

cc: L. Caplan
R. Miller
S. L. Rhodeside

Esso

HUMBLE OIL & REFINING COMPANY

PELHAM, NEW YORK 10803

MARKETING DEPARTMENT
NORTHEASTERN ESSO REGION
W. M. PITCHER
INDUSTRIAL BUSINESS MANAGER

HUTCHINSON RIVER PARKWAY

February 20, 1967

Radio Corporation of America
Astro Electronics Division
Hightstown, New Jersey

Attention of Mr. C. A. McBurney

Gentlemen:

This letter will serve to confirm our recent telephone conversations regarding the use of ANDOK C in space vehicle components. Our ANDOK greases are formulated to provide outstanding service in anti-friction bearing applications subjected to most severe conditions. They have been used by bearing manufacturers for many years as the factory fill grease in sealed-for-life bearings. Further, many of our customers allow anti-friction bearings to operate in excess of five years without relubrication.

The two factors which most greatly effect lubrication life of a grease in a bearing are oxidation and evaporation of the base oil. Since the bearings in question will be operated in a nitrogen-helium atmosphere, oxidation will be no problem at all. In a closed system, evaporation should cause no major difficulties, since the process will reach steady state conditions long before the lubrication performance of the grease is impaired. Under the conditions which you outlined, ANDOK C should have indefinite lubrication life.

For your information and reference, we are enclosing a data sheet on our ANDOK line of greases, and a paper by A. Beerbower and D.F. Greene, of Esso Research & Engineering Company, entitled, "The Behavior of Lubricating Oils in Inert Gas Atmospheres".

We hope that this information is helpful; should you have any additional questions, please feel free to call upon us.

Very truly yours,

SALES ENGINEERING

K. A. Dunphy

ajt

HUMBLE OIL & REFINING COMPANY
PELHAM, NEW YORK 10803

MARKETING DEPARTMENT
NORTHEASTERN REGION
MARKETING TECHNICAL SERVICES

HUTCHINSON RIVER PARKWAY

December 29, 1967

Mr. S. Halpern
Radio Corporation of America
Astro Electronics Division
Box 800
Princeton, New Jersey 08054

Dear Mr. Halpern:

This letter will serve to confirm your recent conversation with A. Beerbower of Esso Research & Engineering Company concerning the use of ANDOK C in space vehicle tape recorder components.

Under the conditions outlined in K. A. Dunphy's correspondence of February 20, 1967 to C. A. McBurney, the lubrication life of ANDOK C was considered to be indefinite. But since we understand you are interested in the performance of this grease under another set of circumstances, we are pleased to let you know ANDOK C will serve your lubrication requirements in the following environment with no difficulty:

- atmospheric pressure of 17 psig
- atmospheric composition consisting of 72% nitrogen, 18% oxygen, and 10% helium
- temperature of 75°C
- 30% relative humidity
- negligible load between moving parts

In fact, since our ANDOK greases have been formulated to provide outstanding service in bearing applications considerably more severe than the conditions described above, you may look forward to a lubrication life in excess of four years, which we understand is the minimum length of time you desire to operate your equipment without relubrication.

We hope that this information is helpful; however, should you have any additional questions, please feel free to get in touch with us.

Very truly yours,

F. D. Marusi

F. D. Marusi

ajt

APPENDIX D

CIRCUIT ANALOGS OF MECHANICAL SYSTEMS, BASED UPON DIMENSIONAL ANALYSIS.

APPENDIX D

CIRCUIT ANALOGS OF MECHANICAL SYSTEMS
(BASED UPON DIMENSIONAL ANALYSIS)

I. Magnetic Model (Vs) = (NΦ) or Weber turn (flux linkage) factored.

$$V = (Vs) \cdot \frac{1}{s} \equiv (Vs) \cdot \frac{rad}{s}, \quad \text{Voltage} \equiv \text{Velocity x (Vs)}$$

$$A = \frac{W}{V} = \frac{J}{(Vs)} = \frac{Nm}{(Vs)}, \quad \text{Current} \equiv \text{Torque/(Vs)}$$

$$\Omega = \frac{V}{A} = \frac{V^2}{W} = \frac{V^2 s}{J} = (Vs)^2 \cdot \frac{1}{Js} = \frac{(Vs)^2}{Nm/1/s}, \frac{(Vs)^2}{Nm/rad/s}$$

$$\text{Resistance} \equiv \frac{(Vs)^2}{\text{Torque/Velocity}}$$

$$H = \frac{Vs}{A} = \frac{V^2 s}{W} = \frac{(Vs)^2}{J} = \frac{(Vs)^2}{Nm} \equiv \frac{(Vs)^2}{Nm/rad},$$

$$\text{Inductance} \equiv \frac{(Vs)^2}{\text{Torque/radian}}$$

$$F = \frac{As}{V} = \frac{Ws}{V^2} = \frac{J}{V^2} = \frac{Nm.s^2}{(Vs)^2} = \frac{kgm^2}{(Vs)^2}, \quad \text{Capacitance} \equiv \frac{\text{Inertia}}{(Vs)^2}$$

II. Electric Model (As) or coulomb factored

$$V = \frac{W}{A} = \frac{J}{(As)} = \frac{Nm}{(As)}, \quad \text{Voltage} \equiv \text{Torque/(As)}$$

$$A = \frac{(As)}{S} \equiv (As). \frac{rad}{S}, \quad \text{Current} \equiv \text{Velocity x (As)}$$

$$\Omega = \frac{V}{A} = \frac{W}{A^2} = \frac{J}{A^2 s} = \frac{1}{(As)^2} \cdot \frac{Nm}{1/s} \equiv \frac{Nm/rad/s}{(As)^2},$$

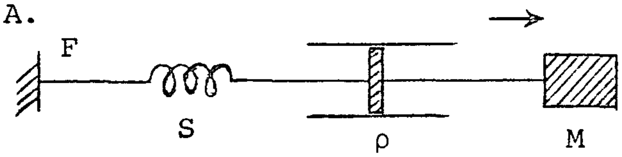
$$\text{Resistance} \equiv \frac{\text{Torque/Velocity}}{(As)^2}$$

$$H = \frac{Vs}{A} = \frac{Ws}{A^2} = \frac{J}{A^2} = \frac{Nm.s^2}{(As)^2} = \frac{kgm^2}{(As)^2}, \quad \text{Inductance} \equiv \frac{\text{Inertia}}{(As)^2}$$

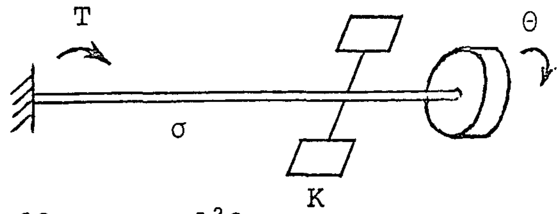
$$F = \frac{As}{V} = \frac{A^2 s}{W} = \frac{(As)^2}{J} = \frac{(As)^2}{Nm} \equiv \frac{(As)^2}{Nm/rad}, \quad \text{Capacitance} \equiv \frac{(As)^2}{\text{Torque/radian}}$$

Circuit Analogs of Mechanical Spring/Mass or Torque/Inertia Systems

A.



or

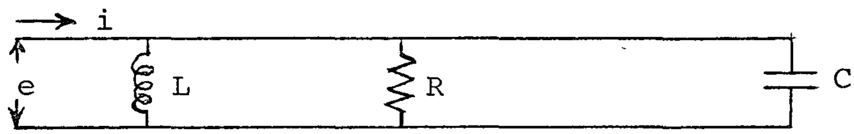


$$F = Sx + \rho \frac{dx}{dt} + M \frac{d^2x}{dt^2} \quad \text{or} \quad T = \sigma\Theta + K \frac{d\Theta}{dt} + J \frac{d^2\Theta}{dt^2}$$

alternately

$$F = S\int \dot{x}dt + \rho\dot{x} + M \frac{d\dot{x}}{dt} \quad \text{or} \quad T = \sigma\int \dot{\Theta}dt + K\dot{\Theta} + J \frac{d\dot{\Theta}}{dt}$$

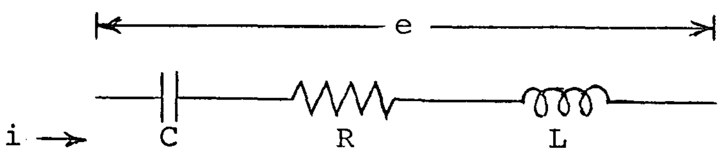
B. Magnetic Model; Velocity ≡ Voltage



$$i = \frac{1}{L}\int edt + e/R + C \frac{de}{dt}$$

equivalents F or T ≡ i, $\dot{x}$ or $\dot{\Theta}$ ≡ e, S or σ ≡ $\frac{1}{L}$, ρ or K ≡ $\frac{1}{R}$,
M or J ≡ C

C. Electric Model; Force or Torque ≡ Voltage



$$e = \frac{1}{C}\int idt + iR + L \frac{di}{dt}$$

equivalents F or T ≡ e, $\dot{x}$ or $\dot{\Theta}$ ≡ i, S or σ ≡ $\frac{1}{C}$, ρ or K ≡ R,

M or J ≡ L

APPENDIX E

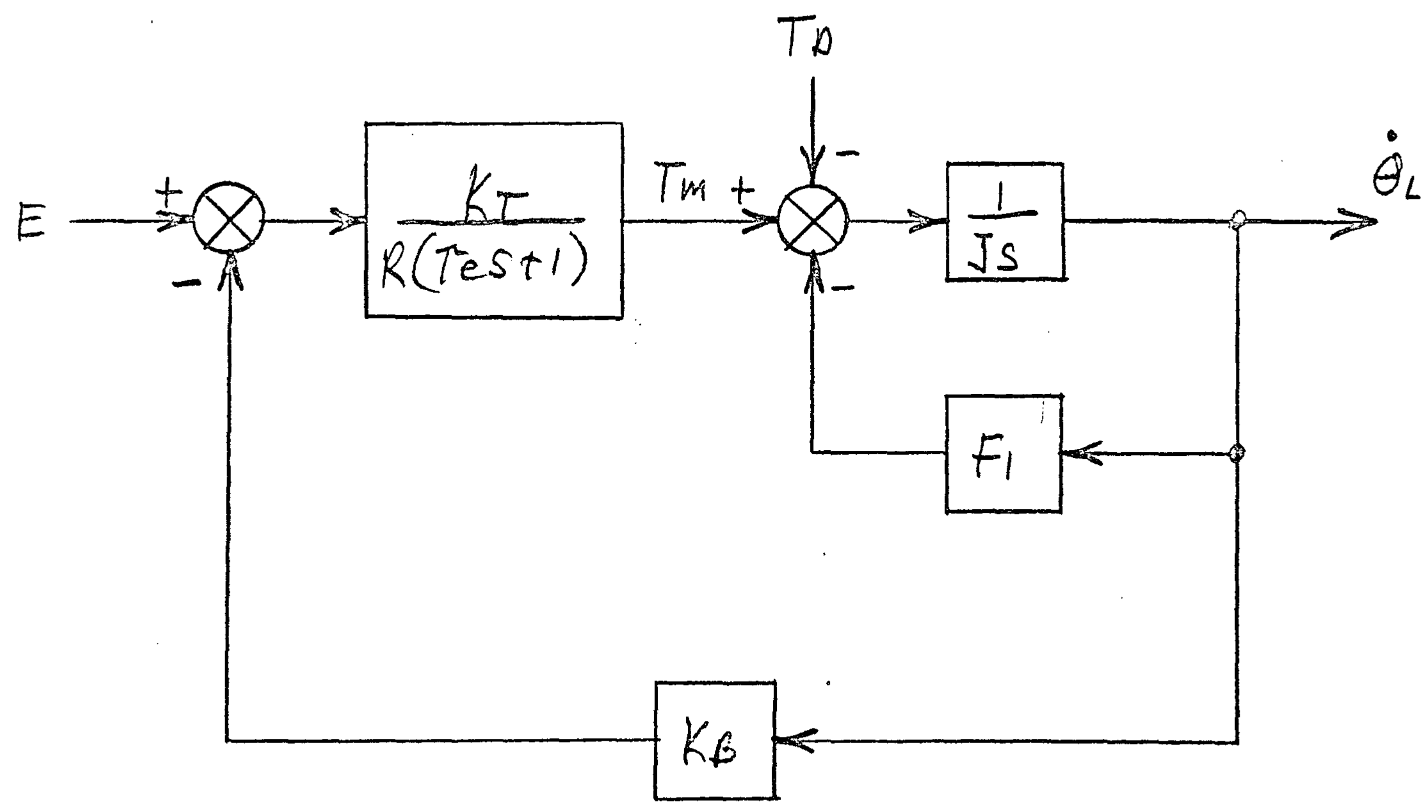
SERVO LOOP ANALYSIS, MCTR CAPSTAN-DRIVEN SYSTEM

Servo Loop Analysis

MCTR Capstan Driven System

FIG. 1

Motor Transfer Function Block Diagram



Cont.

Where:

E = Terminal Voltage (V)
K_T = Torque Constant (N·m/A)
K_B = Motor Back EMF (V/rad/sec)
τ_e = Motor Elec. Time Constant (L/R-secs)
R = Motor Winding/CKT Resistance (Ω)
T_m = Motor Torque (N·m)
T_D = Disturbance Torque (N·m)
J = System Inertia (Motor + Load) (Kg·m²)
F_1 = Motor Viscous Damping Coefficient (eddy current, windage, hysteresis losses) plus load viscous friction coefficient (N·m/rad/sec)
$\dot{\theta}_L$ = Tape Velocity at Head (rad/sec)

(all referred to idler velocity in rad/sec)

1. $$T_m = \frac{K_T}{R(\tau_e s + 1)} (E - K_B \dot{\theta}_L)$$

2. $$\dot{\theta}_L = \frac{1}{Js} (T_m - T_D - F_1 \dot{\theta}_L)$$

or

3. $$\dot{\theta}_L = \frac{T_m - T_D}{Js + F_1}$$

Solving 3. for T_M:

4. $T_M = \dot{\theta}_L(Js + F_1) + T_D$

4. → 1.:

5. $$\frac{K_T}{R(\tau_e s+1)}(E - K_B\dot{\theta}_L) = \dot{\theta}_L(Js + F_1) + T_D$$

Solving for $\dot{\theta}_L$:

$$\dot{\theta}_L = \frac{\dfrac{E \cdot K_T}{R(\tau_e s+1)} - T_D}{Js + F_1 + \dfrac{K_B K_T}{R(\tau_e s+1)}}$$

6. $$\dot{\theta}_L = \left[\frac{E \cdot K_T}{R(\tau_e s+1)} - T_D\right]\left[\left(\frac{R}{RF_1 + K_B K_T}\right) \times \frac{\tau_e s+1}{\dfrac{RJ\tau_e s^2}{RF_1 + K_B K_T} + \dfrac{(F_1\tau_e + J)Rs}{RF_1 + K_B K_T} + 1}\right]$$

If $\tau_e \ll J/F_1$

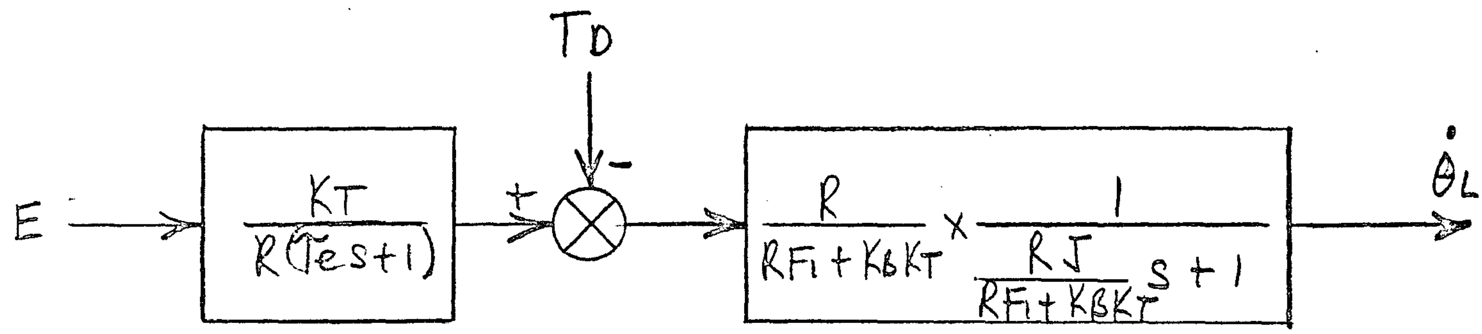
6. Reduces to:

7. $$\dot{\theta}_L = \left[\frac{E \cdot K_T}{R(\tau_e s+1)} - T_D\right]\left[\left(\frac{R}{RF_1 + K_B K_T}\right) \times \frac{1}{\left(\dfrac{RJs}{RF_1 + K_B K_T} + 1\right)}\right]$$

where $\dfrac{RJ}{RF_1 + K_B K_T} = \tau_1$, the motor mechanical time constant

A new block diagram is formed as follows:

FIG. 2



Typical constants for the Macbar motor:

$R = 9\ \Omega$

$K_T = 0.0642$ N·m/amp

$K_B = 63.5$ mv/rad/sec

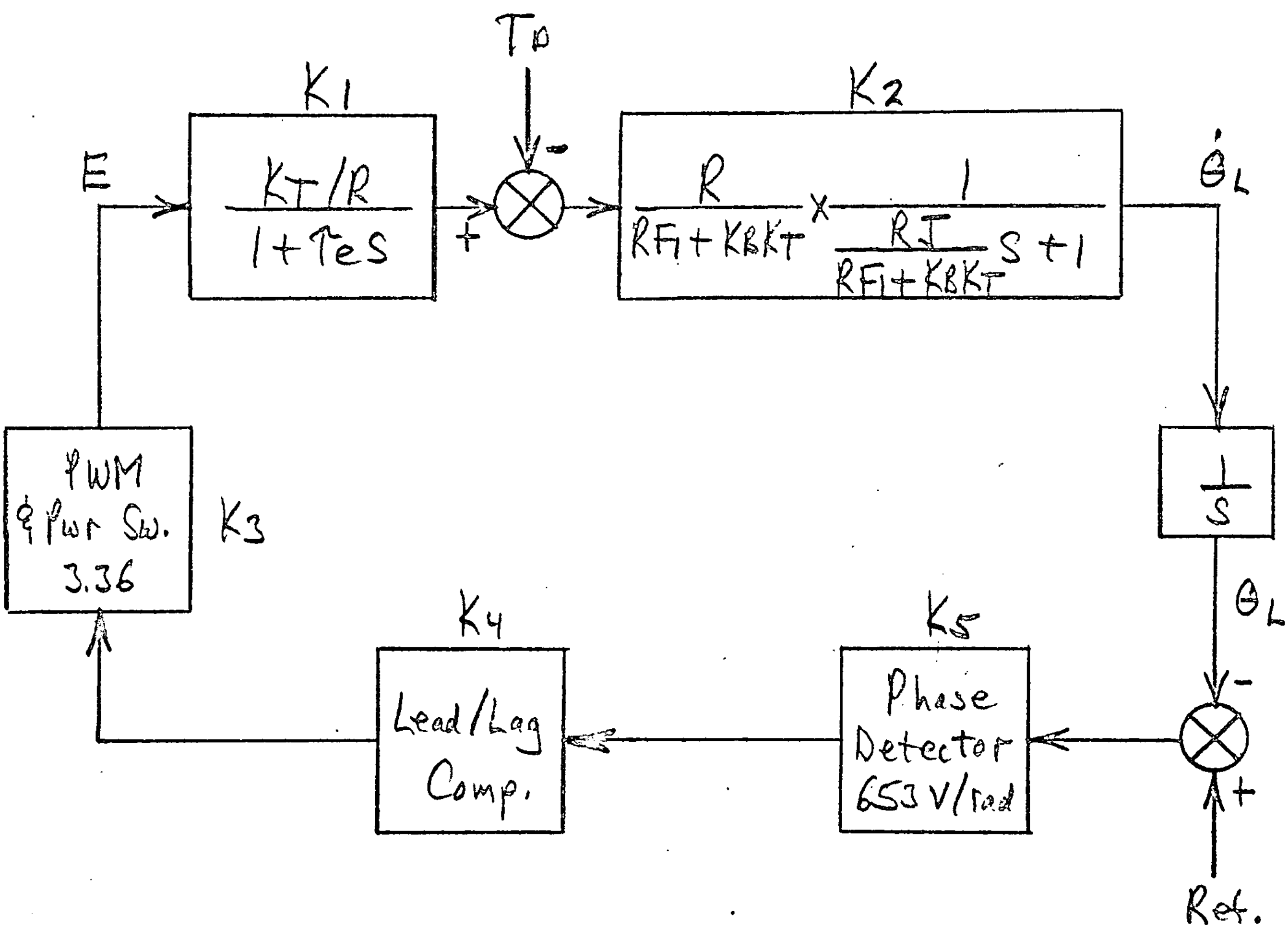
$\tau_e = 0.0004$ sec

$F_1 = 0.0005$ N·m/rad/sec

$J = 0.0015$ Kg·m^2

FIG. 3

Complete MCTR Capstan Drive Servo Loop



Open-Loop Gain:

$$G = K1 \cdot K2 \cdot K3 \cdot K4 \cdot K5 \cdot \frac{1}{S}$$

Flutter (Due to Torque Disturbance):

$$\frac{\dot{\theta}_L}{T_D} = \frac{-K_2}{1 - \frac{K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5}{S}}$$

Jitter (Due to Torque Disturbance):

$$\frac{\theta_L}{T_D} = \frac{\dot{\theta}_L}{T_D} \cdot S$$

APPENDIX F

COMPUTER RESULTS FOR SERVO LOOP ANALYSES, MCTR CAPSTAN-DRIVEN AND REEL-DRIVEN SYSTEMS

.1	-27.9	89.
.1	-27.4	89.
.1	-26.9	89.
.1	-26.4	89.
.1	-25.9	89.
.1	-25.4	89.
.1	-24.9	89.
.1	-24.4	89.
.2	-23.9	89.
.2	-23.4	89.
.2	-22.9	89.
.2	-22.4	89.
.2	-21.9	89.
.2	-21.4	89.
.2	-20.9	89.
.2	-20.4	89.
.3	-19.9	89.
.3	-19.4	88.
.3	-18.9	88.
.3	-18.4	88.
.3	-17.9	88.
.3	-17.4	88.
.4	-16.9	88.
.4	-16.4	88.
.4	-15.9	88.
.4	-15.4	88.
.4	-14.9	87.
.5	-14.4	87.
.5	-13.9	87.
.5	-13.4	87.
.6	-12.9	87.
.6	-12.4	87.
.6	-11.9	86.
.7	-11.4	86.
.7	-10.9	86.
.7	-10.4	86.
.8	-9.9	86.
.8	-9.4	85.
.9	-8.9	85.
.9	-8.4	85.
1.0	-7.9	84.
1.1	-7.4	84.
1.1	-6.9	84.
1.2	-6.4	83.
1.3	-5.9	83.
1.3	-5.4	82.
1.4	-4.9	82.
1.5	-4.4	82.
1.6	-3.9	81.
1.7	-3.5	81.
1.8	-3.0	80.
1.9	-2.5	79.
2.0	-2.0	79.
2.1	-1.5	78.
2.2	-1.0	77.
2.4	-.5	77.
2.5	-.0	76.
2.7	.5	75.
2.8	1.0	74.

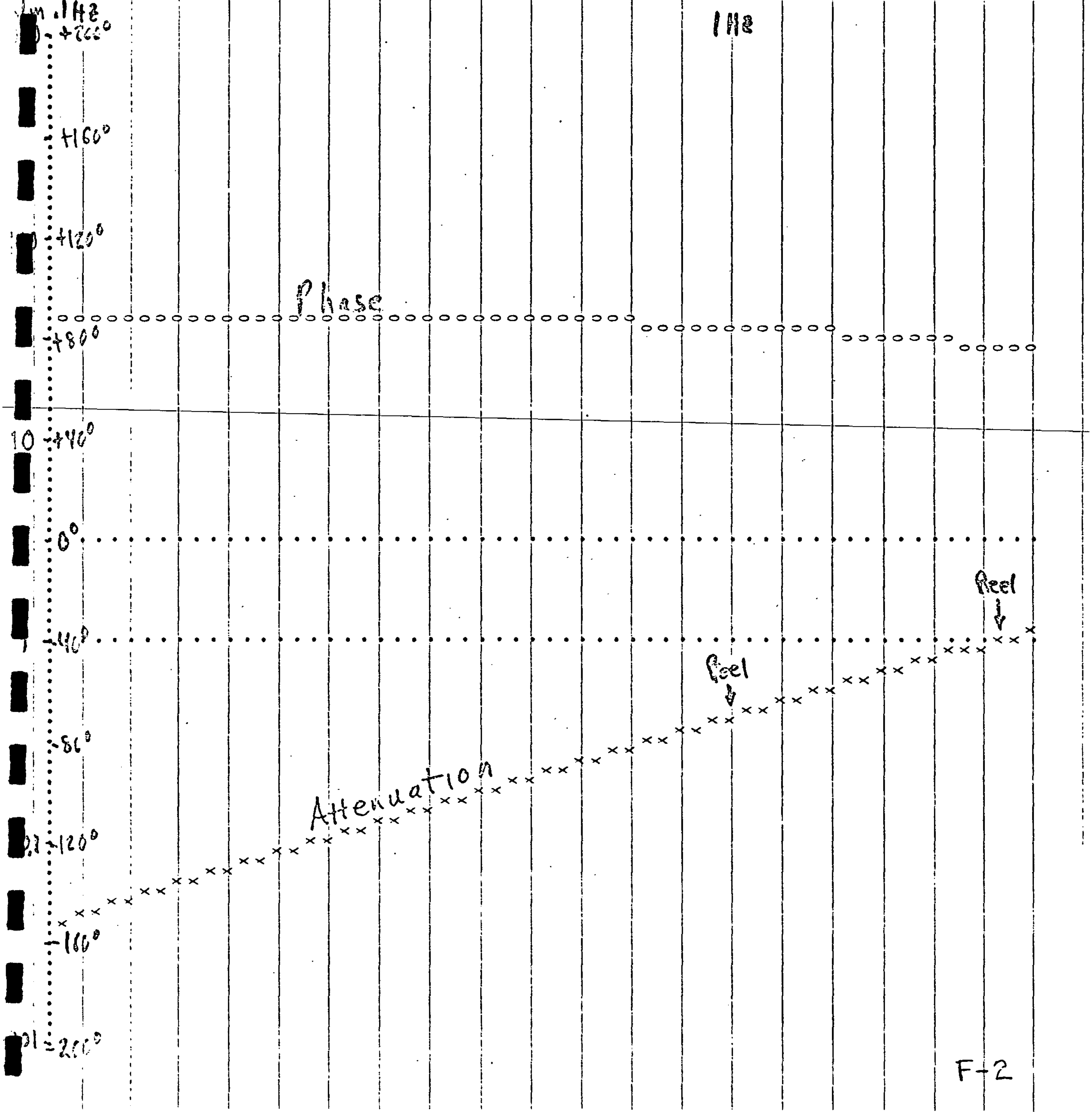
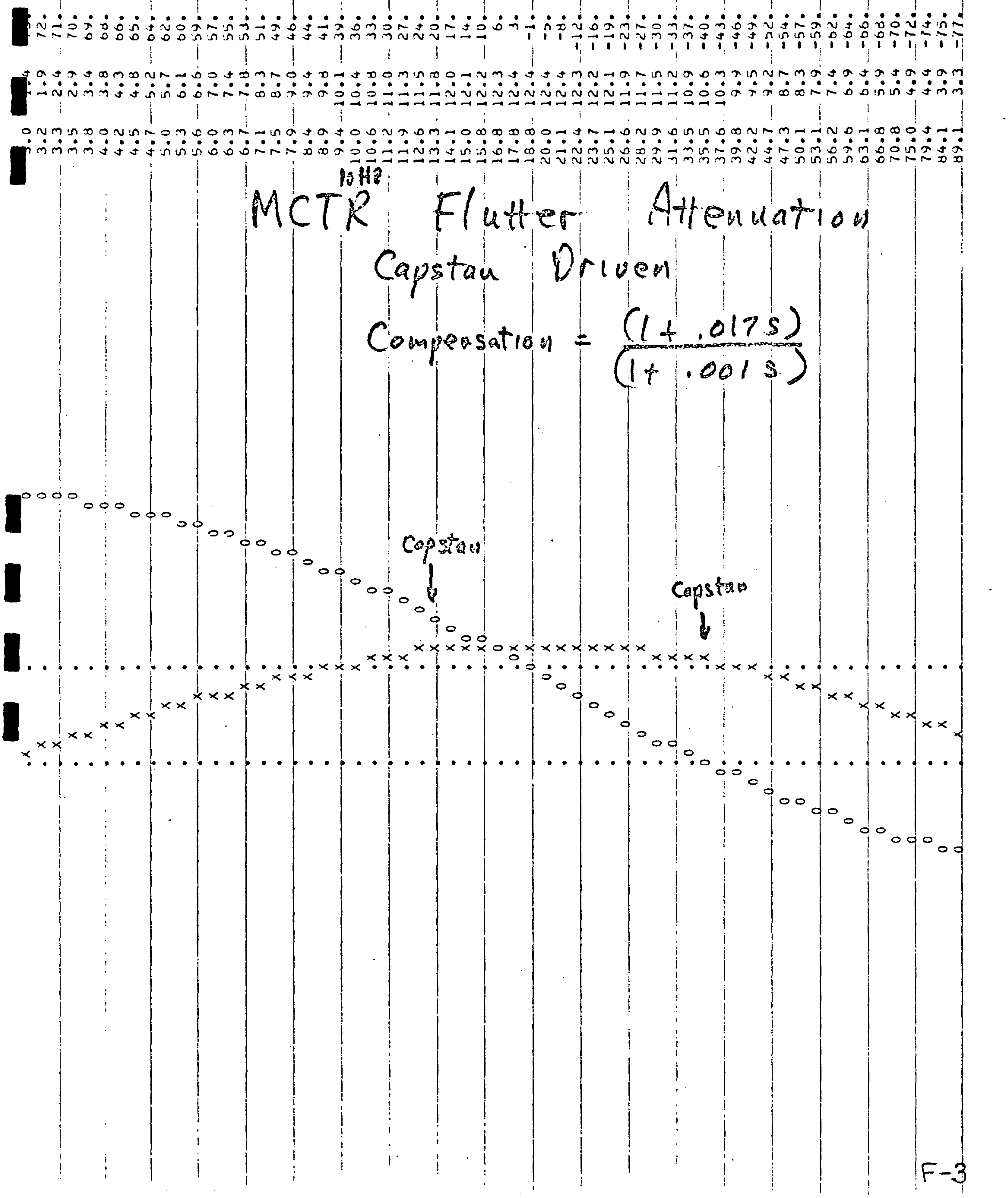
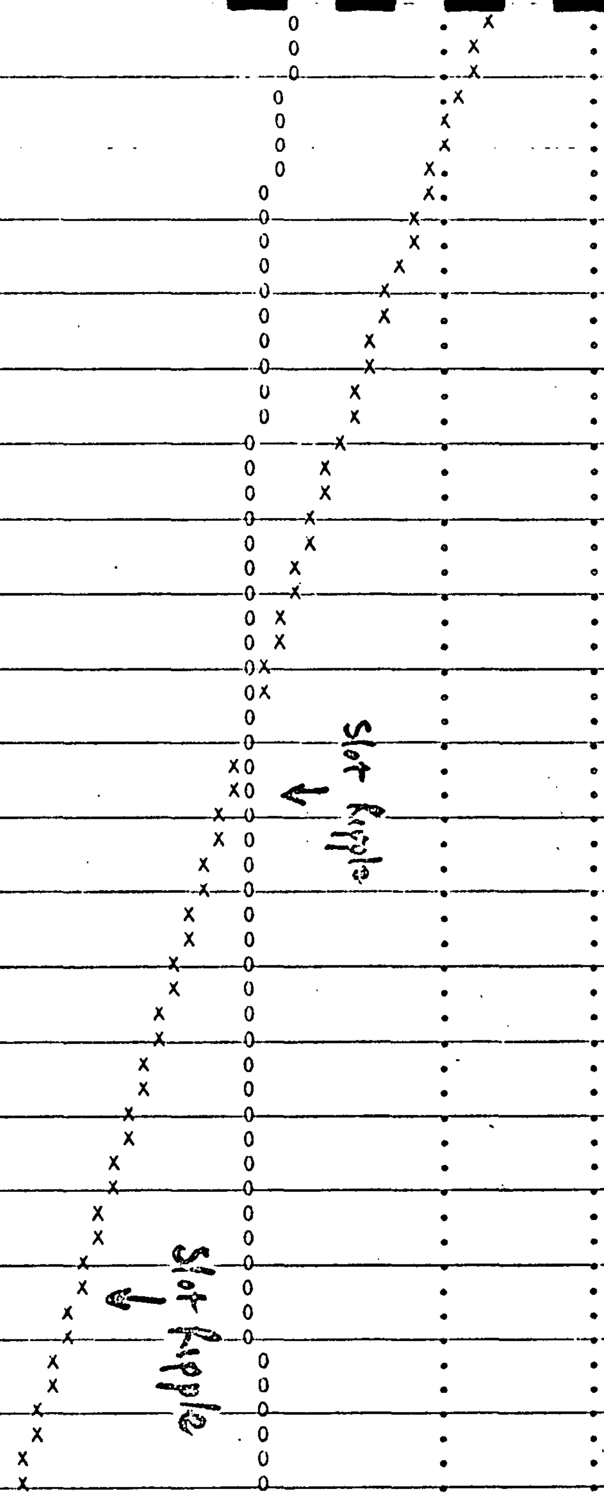


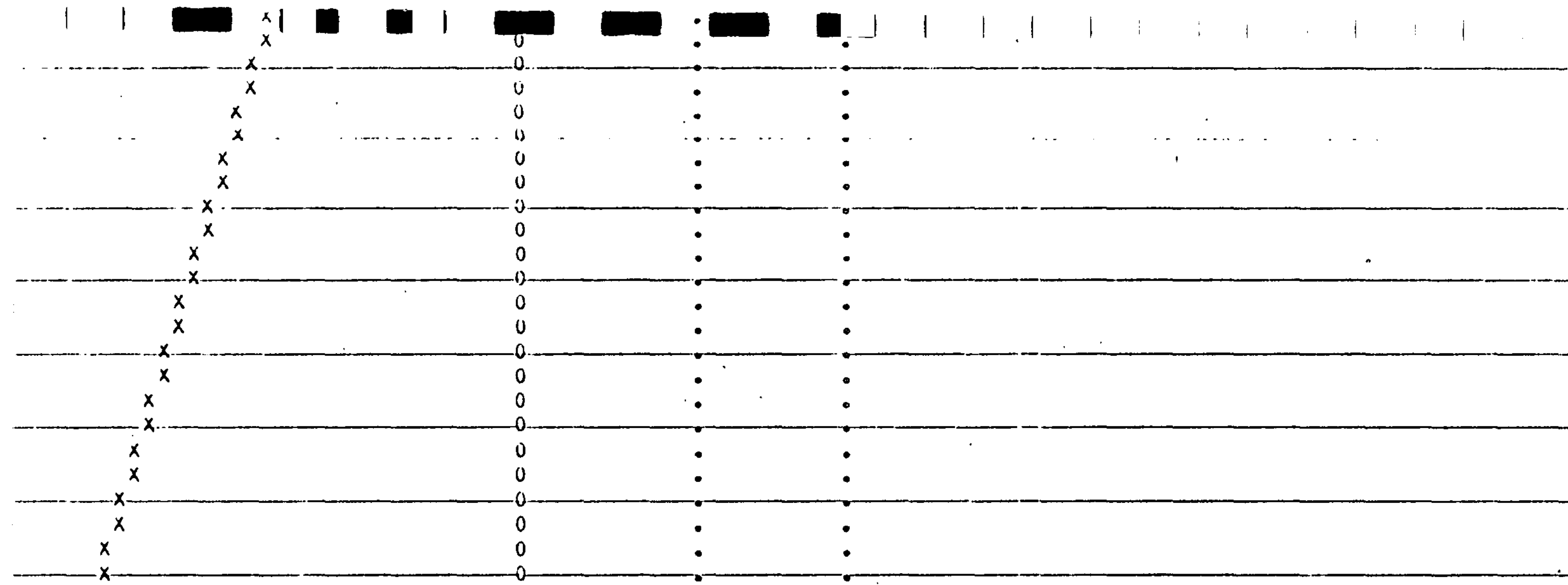
FIG. 1


MCTR 10Hz Flutter Attenuation
Capstan Driven
Compensation = (1+ .017s) / (1+ .001s)
Capstan
Capstan

[redacted]



100Hz	94.4	2.8	-78.
	100.0	2.2	-80.
	105.9	1.6	-81.
	112.2	1.1	-82.
	118.9	.5	-83.
	125.9	-.1	-84.
	133.4	-.7	-85.
	141.3	-1.3	-86.
	149.6	-1.8	-87.
	158.5	-2.4	-87.
	167.9	-3.0	-88.
	177.8	-3.6	-88.
	188.4	-4.2	-89.
	199.5	-4.7	-89.
	211.3	-5.3	-89.
	223.9	-5.9	-90.
	237.1	-6.4	-90.
	251.2	-7.0	-90.
	266.1	-7.5	-90.
	281.8	-8.1	-90.
	298.5	-8.6	-90.
	316.2	-9.2	-90.
	335.0	-9.7	-90.
	354.8	-10.2	-90.
	375.8	-10.8	-90.
	398.1	-11.3	-90.
	421.7	-11.8	-90.
	446.7	-12.3	-90.
	473.2	-12.8	-90.
	501.2	-13.4	-90.
	530.9	-13.9	-90.
	562.3	-14.4	-90.
	595.7	-14.9	-90.
	631.0	-15.4	-90.
	668.3	-15.9	-90.
	707.9	-16.4	-90.
	749.9	-16.9	-90.
	794.3	-17.4	-90.
	841.4	-17.9	-90.
	891.2	-18.4	-90.
	944.1	-18.9	-90.
1kHz	1000.0	-19.4	-90.
	1059.3	-19.9	-90.
	1122.0	-20.4	-90.
	1188.5	-20.9	-90.
	1258.9	-21.4	-90.
	1333.5	-21.9	-90.
	1412.5	-22.4	-90.
	1496.2	-22.9	-90.
	1584.9	-23.4	-90.
	1678.8	-23.9	-90.
	1778.3	-24.4	-90.
	1883.6	-24.9	-90.
	1995.3	-25.4	-90.
	2113.5	-25.9	-90.
	2238.7	-26.4	-90.
	2371.4	-26.9	-90.
	2511.9	-27.4	-90.
	2660.7	-27.9	-90.
	2818.4	-28.4	-90.



[illegible]52.[illegible]	[illegible].4	[illegible]
3349.6	-29.9	-90.
3548.1	-30.4	-90.
3758.4	-30.9	-90.
3981.1	-31.4	-90.
4217.0	-31.9	-90.
4466.8	-32.4	-90.
4731.5	-32.9	-90.
5011.9	-33.4	-90.
5308.8	-33.9	-90.
5623.4	-34.4	-90.
5956.6	-34.9	-90.
6309.6	-35.4	-90.
6683.4	-35.9	-90.
7079.4	-36.4	-90.
7498.9	-36.9	-90.
7943.3	-37.4	-90.
8413.9	-37.9	-90.
8912.5	-38.4	-90.
9440.6	-38.9	-90.
******	-39.4	-90.
******	-39.9	-90.
******	-40.4	-90.

F-5

[illegible] CARDS OUT PAGES 9

```
[redacted] ST[redacted]E U[redacted](BL[redacted] NA[redacted]ENG[redacted]

         0001    *CODE    000475
         0000    *DATA    000246
         0002    *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

         0003    NWDU$
         0004    NIO1$
         0005    NIO2$
         0006    COV$
         0007    CABS
         0010    ALOG10
         0011    ATAN2
         0012    NEXP6$
         0013    NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001   000014 117G       0001   000025 125G       0001   000033 133G       0001   000426 157G       0000   000031 20F
     0001   000043 40L        0000   000033 50F        0000 C 000002 A          0000 C 000004 B          0000 I 000012 BLANK
     0000 C 000006 C          0000 R 000025 DB         0000 I 000013 DOT        0000 C 000010 FCT        0000 I 000015 FI
     0000 R 000024 HERTZ      0000 I 000022 I          0000 I 000023 I$         0000 I 000027 J          0000 I 000030 K
     0000 I 000101 LINE       0000 I 000020 M          0000 I 000021 N          0000 R 000016 P          0000 R 000026 PHASE
     0000 R 000017 Q          0000 C 000000 S          0000 I 000014 X

   00000  *DIAGNOSTIC*  THE NAME D APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
   00000  *DIAGNOSTIC*  THE NAME E APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
   00000  *DIAGNOSTIC*  THE NAME Q2F2 APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
   00000  *DIAGNOSTIC*  THE NAME Q3 APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
   00000  *DIAGNOSTIC*  THE NAME FI APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
   00100       1*    C      CLOSED LOOP RESPONSE
   00100       2*    C      TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
   00100       3*    C      CAPSTAN DRIVE - MID REEL
   00101       4*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
   00103       5*           INTEGER BLANK,DOT,X,FI
   00104       6*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
   00111       7*           DIMENSION LINE(101)
   00111       8*    C      P IS DB PER CHARACTER SPACE
   00112       9*           P=1.
   00112      10*    C      Q IS DEGREES PER CHARACTER SPACE
   00113      11*           Q=4.
   00113      12*    C      M IS DB ZERO LOCATION
   00114      13*           M=41
   00114      14*    C      N IS PHASE ZERO LOCATION
   00115      15*           N=51
   00116      16*           DO 10 I=1,101
   00121      17*        10 LINE(I)=DOT

F-6
   00123      18*           WRITE (6,20) LINE
   00131      19*        20 FORMAT (1H1,101A1)
   00132      20*           DO 30 I=1,101
   00135      21*        30 LINE(I)=BLANK
   00137      22*           LINE(M)=DOT
```

```
00141     24*          HERTZ=.1
00142     25*       40 S=CMPLX(0.,6.283*HERTZ)
00143     26*          A=1.06E3*(.001*S+1.)*(.0004*S+1.)
00144     27*          B=S*(.001*S+1.)*(.0004*S+1.)*(1.58*S+1.)
00145     28*          C=1.655E4*(.017*S+1.)
00146     29*          FCT=A*S/(C+B)
00147     30*          DB=20.*ALOG10(CABS(FCT))
00150     31*          PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00151     32*          I=DB/P+FLOAT(M)+0.5
00152     33*          LINE(I)=X
00153     34*          J=PHASE/Q+FLOAT(N)+0.5
00154     35*          LINE(J)=FI
00155     36*          WRITE(6,50) LINE,HERTZ,DB,PHASE
00166     37*       50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00167     38*          LINE(I)=BLANK
00170     39*          LINE(J)=BLANK
00171     40*          LINE(M)=DOT
00172     41*          LINE(N)=DOT
00172     42*    C     K IS NUMBER OF STEPS PER DECADE
00173     43*          K=40
00174     44*          HERTZ=HERTZ*10.**(1./FLOAT(K))
00175     45*          IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00200     46*       60 STOP
00201     47*          END

          END OF UCC 1108 FORTRAN V COMPILATION.     5 *DIAGNOSTIC* MESSAGE(S)

14:57:26     @ XQT ATTEN
UCC ALLOCATOR......VERSION 1/7      03 MAY 71
```

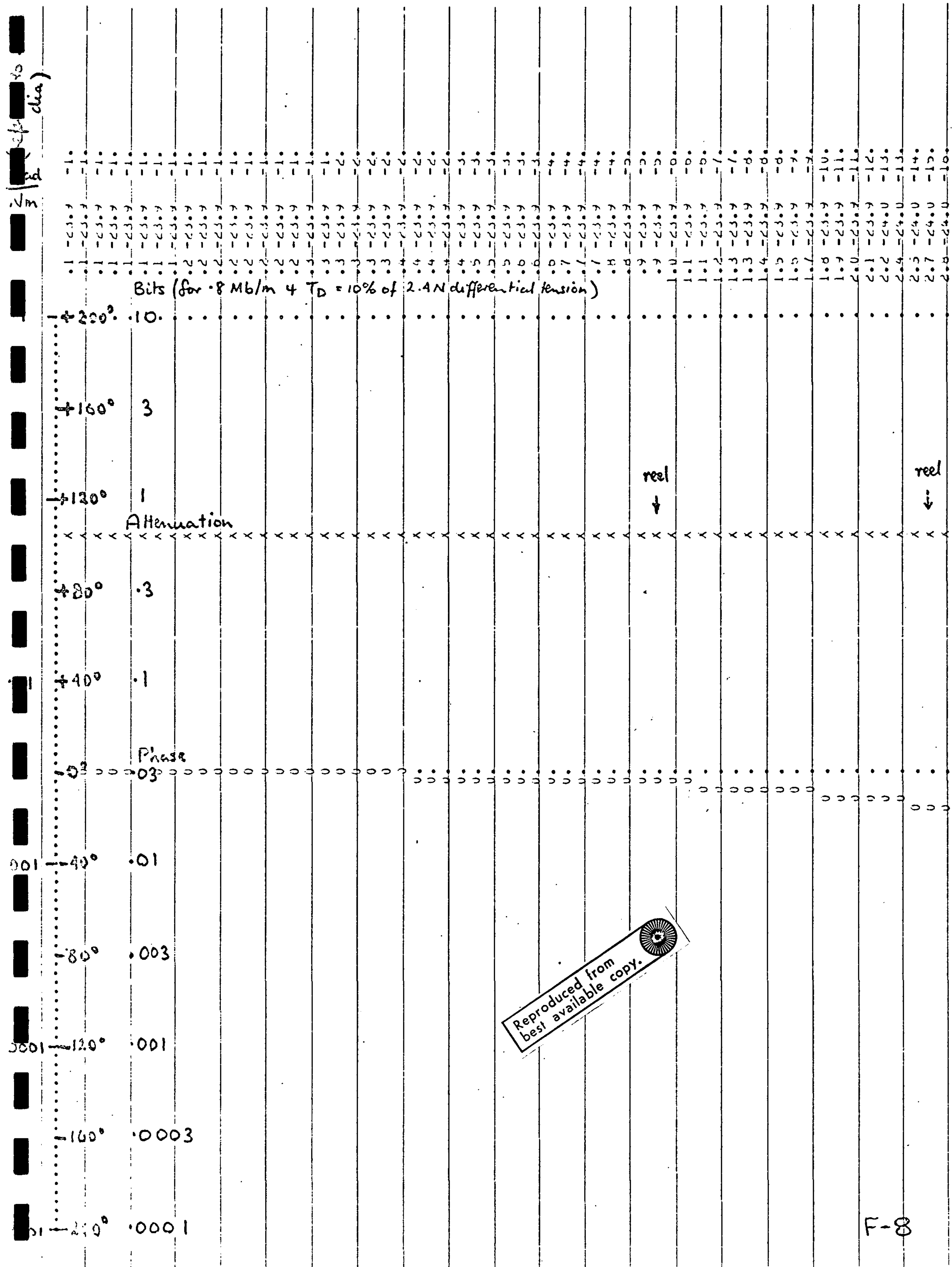
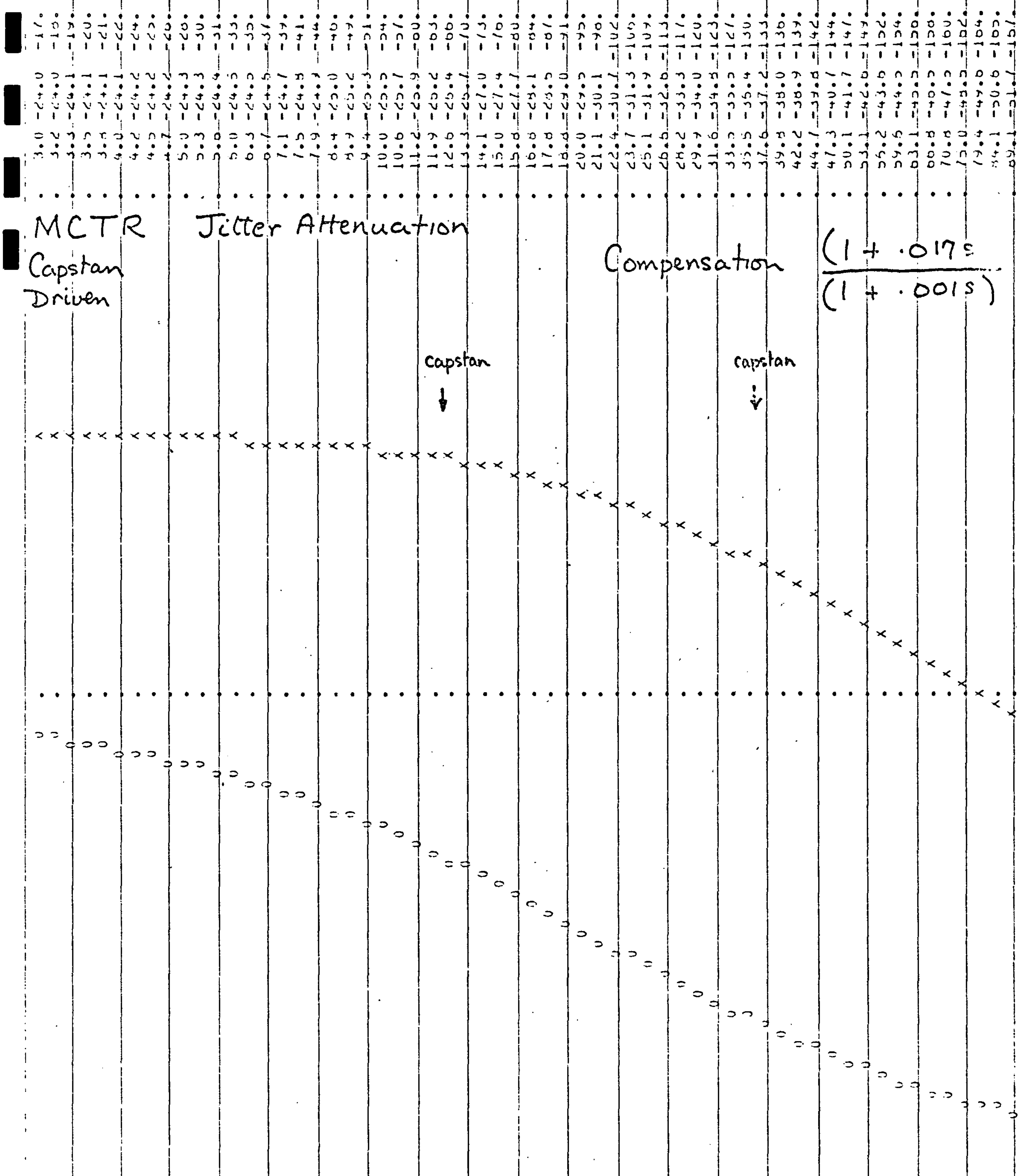
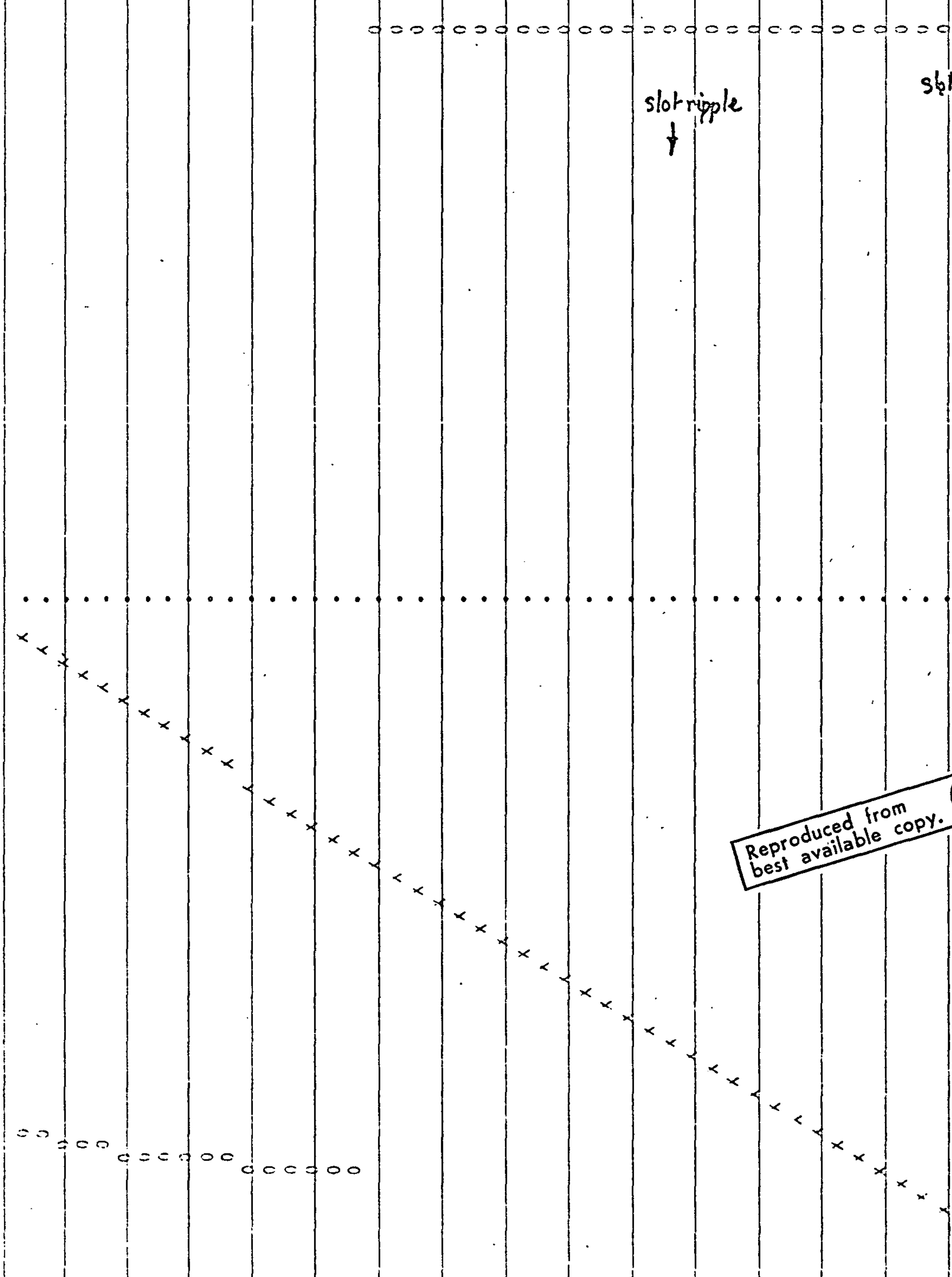

Bits (for ·8 Mb/m 4 T_D = 10% of 2.4N differential tension)
+200° ·10·
+160° 3
+120° 1
Attenuation
reel
reel
+80° ·3
+40° ·1
Phase
0° ·03
-40° ·01
-80° ·003
-120° ·001
-160° ·0003
-200° ·0001

FIG. 2


MCTR Jitter Attenuation
Capstan Driven
Compensation
$\frac{(1 + .017s)}{(1 + .001s)}$
capstan
capstan

94.4	-52.7	-168.
100.0	-53.8	-170.
105.9	-54.8	-171.
112.2	-55.9	-172.
118.9	-57.0	-173.
125.9	-58.1	-174.
133.4	-59.1	-175.
141.3	-60.2	-176.
149.6	-61.3	-177.
158.5	-62.4	-177.
167.9	-63.5	-178.
177.8	-64.5	-178.
188.4	-65.6	-179.
199.5	-66.7	-179.
211.3	-67.8	-179.
223.9	-68.8	-180.
237.1	-69.9	-180.
251.2	-70.9	180.
266.1	-72.0	180.
281.8	-73.0	180.
298.5	-74.1	180.
316.2	-75.1	180.
335.0	-76.2	180.
354.8	-77.2	180.
375.8	-78.2	180.
398.1	-79.2	180.
421.7	-80.3	180.
446.7	-81.3	180.
473.2	-82.3	180.
501.2	-83.3	180.
530.9	-84.3	180.
562.3	-85.3	180.
595.7	-86.3	180.
631.0	-87.4	180.
668.3	-88.4	180.
707.9	-89.4	180.
749.9	-90.4	180.
794.3	-91.4	180.
841.4	-92.4	180.
891.2	-93.4	180.
944.1	-94.4	180.
1000.0	-95.4	180.
1059.3	-96.4	180.
1122.0	-97.4	180.
1188.5	-98.4	180.
1258.9	-99.4	180.
1333.5	-100.4	180.



15mm dia capstan
2.4 N differential tension

Torque at 10% of differential tension

$\cdot 1 \times 2.4 \times \frac{15}{2} \times 10^{-3} = 1.8 \times 10^{-3}$ Nm

1 rad → $7.5 \times 10^{-3} \times \cdot 8 \times 10^{6}$ bits $= 6 \times 10^{3}$ bits

1 rad/Nm → $6 \times 10^{3} \times 1.8 \times 10^{-3} = 10.8$ bits

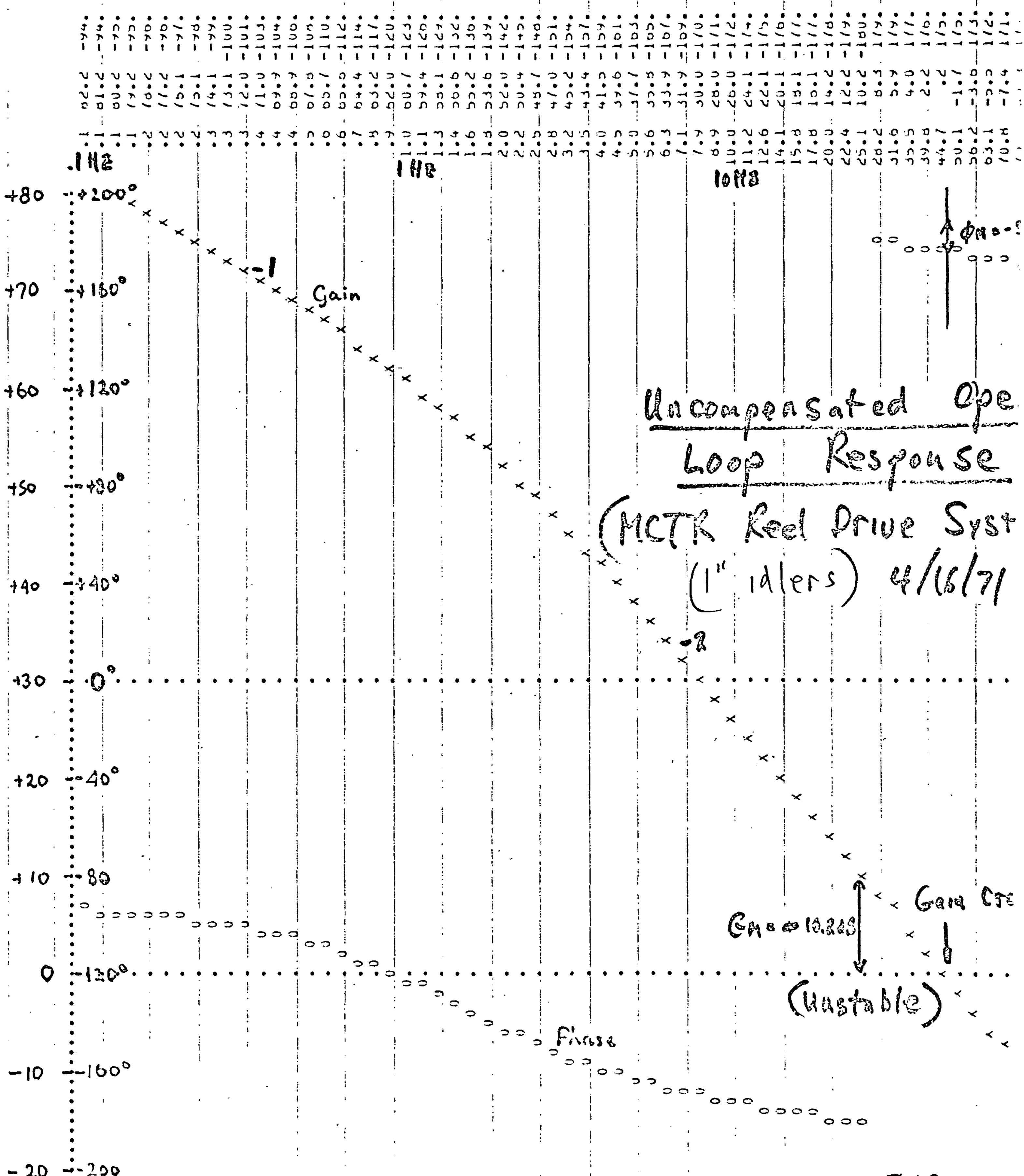
	Rec	PB	
	·575	1.72	m/s
Reel	·92	2.76	99mm rad
Capstan	12.2	36.4	7.5mm rad
Slot	585.	1750	48 slots

```
1424232    VS FOR ATTENUATION                                      IF9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 23 APR 71 AT 14:32:32

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

     0001    *CODE    000457
     0000    *DATA    000245
     0002    *BLANK   000000

EXTERNAL REFERENCES (BLOCK, NAME)

     0003    NWDU$
     0004    NIO1$
     0005    NIO2$
     0006    CONV$
     0007    CAB$
     0010    ALOG10
     0011    ATAN2
     0012    NERR2$
     0013    NSTOP$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001   000014 117G     0001   000025 125G     0001   000033 133G     0001   000410 157G     0000   000031 20F
0001   000043 40L      0000   000033 50F      0000 C 000002 A        0000 C 000004 B        0000 I 000012 BLANK
0000 C 000005 C        0000 R 000025 DB       0000 I 000013 DOT      0000 C 000010 FCT      0000 I 000015 FI
0000 R 000024 HERTZ    0000 I 000022 I        0000 I 000023 IS       0000 I 000027 J        0000 I 000030 K
0000 I 000101 LINE     0000 I 000020 M        0000 I 000021 N        0000 R 000016 P        0000 R 000026 PHASE
0000 R 000017 Q        0000 C 000000 S        0000 I 000014 X

00000  *DIAGNOSTIC*  THE NAME D APPEARS IN A DIMENSION OR TYPE STATEMENT BUT IS NEVER REFERENCED.
00100     1*   C     JITTER VS TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
00100     2*   C     CLOSED LOOP RESPONSE
00101     3*         COMPLEX S,A,B,C,D,FCT
00103     4*         INTEGER BLANK,DOT,X,FI
00104     5*         DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
00111     6*         DIMENSION LINE(101)
00111     7*   C     P IS DB PER CHARACTER SPACE
00112     8*         P=1.
00112     9*   C     Q IS DEGREES PER CHARACTER SPACE
00113    10*         Q=4.
00113    11*   C     M IS DB ZERO LOCATION
00114    12*         M=101
00114    13*   C     N IS PHASE ZERO LOCATION
00115    14*         N=51
00115    15*         DO 10 I=1,101
00121    16*      10 LINE(I)=DOT
00123    17*         WRITE (6,20) LINE
00131    18*      20 FORMAT (1H1,101A1)
00132    19*         DO 30 I=1,101
00135    20*      30 LINE(I)=BLANK
00137    21*         LINE(M)=DOT
```

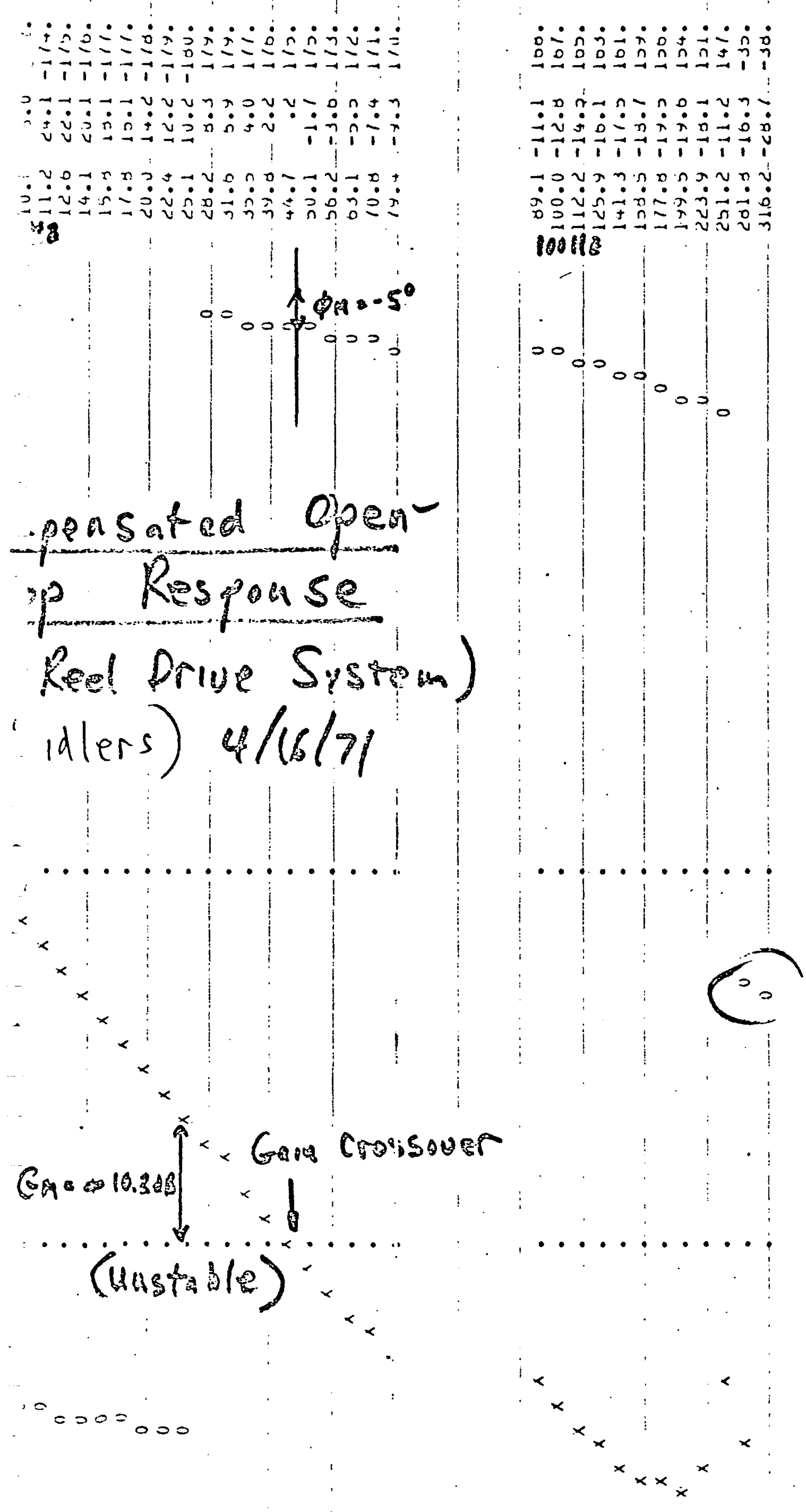
```
      LINE(M)=DOT
      HERTZ=.1
   40 S=CMPLX(0.,6.283*HERTZ)
      A=1.06E3*(.001*S+1.)*(.0004*S+1.)
      B=S*(.001*S+1.)*(.0004*S+1.)*(1.58*S+1.)
      C=1.655E4*(.017*S+1.)
      FCT=A/(C+B)  --> * S
      DB=20.*ALOG10(CABS(FCT))
      PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
      I=DB/P+FLOAT(M)+0.5
      LINE(I)=X
      J=PHASE/Q+FLOAT(N)+0.5
      LINE(J)=FI
      WRITE(6,50) LINE,HERTZ,DB,PHASE
   50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
      LINE(I)=BLANK
      LINE(J)=BLANK
      LINE(M)=DOT
      LINE(N)=DOT
C     K IS NUMBER OF STEPS PER DECADE
      K=40
      HERTZ=HERTZ*10.**(1./FLOAT(K))
      IF ((FLOAT(M)-1.)*P+DB) 60,60,40
   60 STOP
      END

END OF UCC 1108 FORTRAN V COMPILATION.      1 *DIAGNOSTIC* MESSAGE(S)
```

FOLDOUT FRAME 1

FIG. 3



FOLDOUT FRAME 2



...pensated Open-
...p Response
Reel Drive System)
...idlers) 4/16/71

```
16:13:40     WB FOR GAIN.GAIN
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 16 APR 71 AT 16:13:40

  MAIN PROGRAM

  STORAGE USED (BLOCK, NAME, LENGTH)

      0001   *CODE    001167
      0000   *DATA    000316
      0002   *BLANK   000000

  EXTERNAL REFERENCES (BLOCK, NAME)

      0003   NWDU$
      0004   NI01$
      0005   NI02$
      0006   COV$
      0007   CABS
      0010   ALOG10
      0011   ATAN2
      0012   NEXP6$
      0013   NSTOP$

  STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

  0001   000014 117G      0001   000025 125G      0001   000033 133G      0001   001120 161G      0000   000035 20F
  0001   000043 40L       0000   000037 50F       0000 C 000002 A         0000 C 000004 B         0000 I 000016 BLANK
  0000 C 000006 C         0000 C 000010 D         0000 R 000031 DB        0000 I 000017 DOT       0000 C 000012 E
  0000 C 000014 FCT       0000 I 000021 FI        0000 R 000030 HERTZ     0000 I 000026 I         0000 I 000027 I$
  0000 I 000033 J         0000 I 000034 K         0000 I 000151 LINE      0000 I 000024 M         0000 I 000025 N
  0000 R 000022 P         0000 R 000032 PHASE     0000 R 000023 Q         0000 C 000000 S         0000 I 000020 X

00100      1*    C     GAIN AND PHASE PLOT
00100      2*    C     OPEN LOOP RESPONSE
00101      3*          COMPLEX S,A,B,C,D,E,FCT
00103      4*          INTEGER BLANK,DOT,X,FI
00104      5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
00111      6*          DIMENSION LINE(101)
00111      7*    C     P IS DB PER CHARACTER SPACE
00112      8*          P=1.
00112      9*    C     Q IS DEGREES PER CHARACTER SPACE
00113     10*          Q=4.
00113     11*    C     M IS DB ZERO LOCATION
00114     12*          M=21
00114     13*    C     N IS PHASE ZERO LOCATION
00115     14*          N=51
00115     15*          DO 10 I=1,101
00121     16*       10 LINE(I)=DOT
00123     17*          WRITE (6,20) LINE
00131     18*       20 FORMAT (1H1,101A1)
00132     19*          DO 30 I=1,101
00135     20*       30 LINE(I)=BLANK
                       LINE(M)=DOT
```

F-15

```
      HERTZ=.1
   40 S=CMPLX(0.,6.283*HERTZ)
      A=1.+48.9E-6*S**2+603.E-12*S**4+160.E-18*S**6+10.09E-24*S**8
      B=26.2*S*(1.02+25.2E-6*S**2+12.39E-12*S**4+1.23E-18*S**6)
      C=187.E3*(1.+2.43E-5*S**2+1.24E-11*S**4+1.23E-18*S**6)
      D=187.E3*S*(9.3E-7+2.26E-17*S**2+6.15E-18*S**4+4.17E-28*S**6)
      E=187.E3*(1.+24.25E-6*S**2+3.3E-12*S**4)
      FCT=(11.4/(1.+.0004*S+(.0014+2.6E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
      DB=20.*ALOG10(CABS(FCT))
      PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
      I=DB/P+FLOAT(M)+0.5
      LINE(I)=X
      J=PHASE/Q+FLOAT(N)+0.5
      LINE(J)=FI
      WRITE(6,50) LINE,HERTZ,DB,PHASE
   50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
      LINE(I)=BLANK
      LINE(J)=BLANK
      LINE(M)=DOT
      LINE(N)=DOT
C     K IS NUMBER OF STEPS PER DECADE
      K=20
      HERTZ=HERTZ*10.**(1./FLOAT(K))
      IF ((FLOAT(M)-1.)*P+DB) 60,60,40
   60 STOP
      END
```

END OF UCC 1108 FORTRAN V COMPILATION.   0 *DIAGNOSTIC* MESSAGE(S)

$$A = 1 + 48.9\cdot10^{-6}S^2 + 603\cdot10^{-12}S^4 + 160\cdot10^{-18}S^6 + 10.09\cdot10^{-24}S^8$$

$$B = 26.2\,S\,(1.02 + 25.2\cdot10^{-6}S^2 + 12.39\cdot10^{-12}S^4 + 1.23\cdot10^{-18}S^6)$$

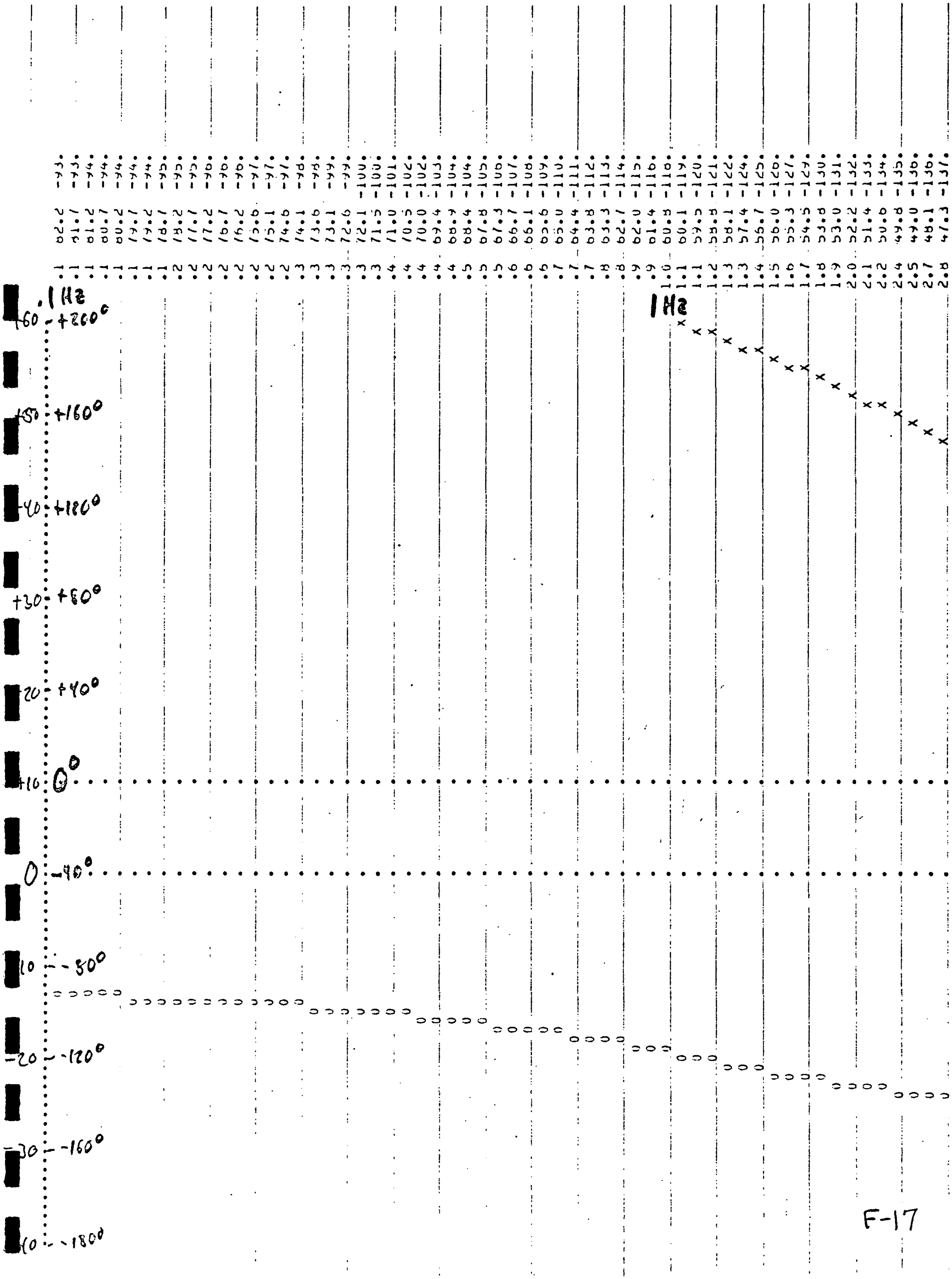
$$C = 187\cdot10^3\,(1 + 2.43\cdot10^{-5}S^2 + 1.24\cdot10^{-11}S^4 + 1.23\cdot10^{-18}S^6)$$

$$D = 187\cdot10^3 S\,(9.3\cdot10^{-7}S + 2.26\cdot10^{-17}S^2 + 6.15\cdot10^{-18}S^4 + 4.17\cdot10^{-28}S^6)$$

$$E = 187\cdot10^3\,(1 + 24.25\cdot10^{-6}S^2 + 3.3\cdot10^{-12}S^4)$$

$$FCT = \frac{11.4}{1 + .0004S + (.0014 + 2.6\cdot10^{-7}S)\dfrac{(C+D)}{(A+B)}} \times \frac{E}{S(A+B)}$$

$(11.4 = .00917\cdot370\cdot3.36)$


.1 Hz
1 Hz
+60 +200°
+50 +160°
+30 +80°
+20 +40°
+10 0°
0 -40°
-20 -120°
-30 -160°

FOLDOUT FRAME 1

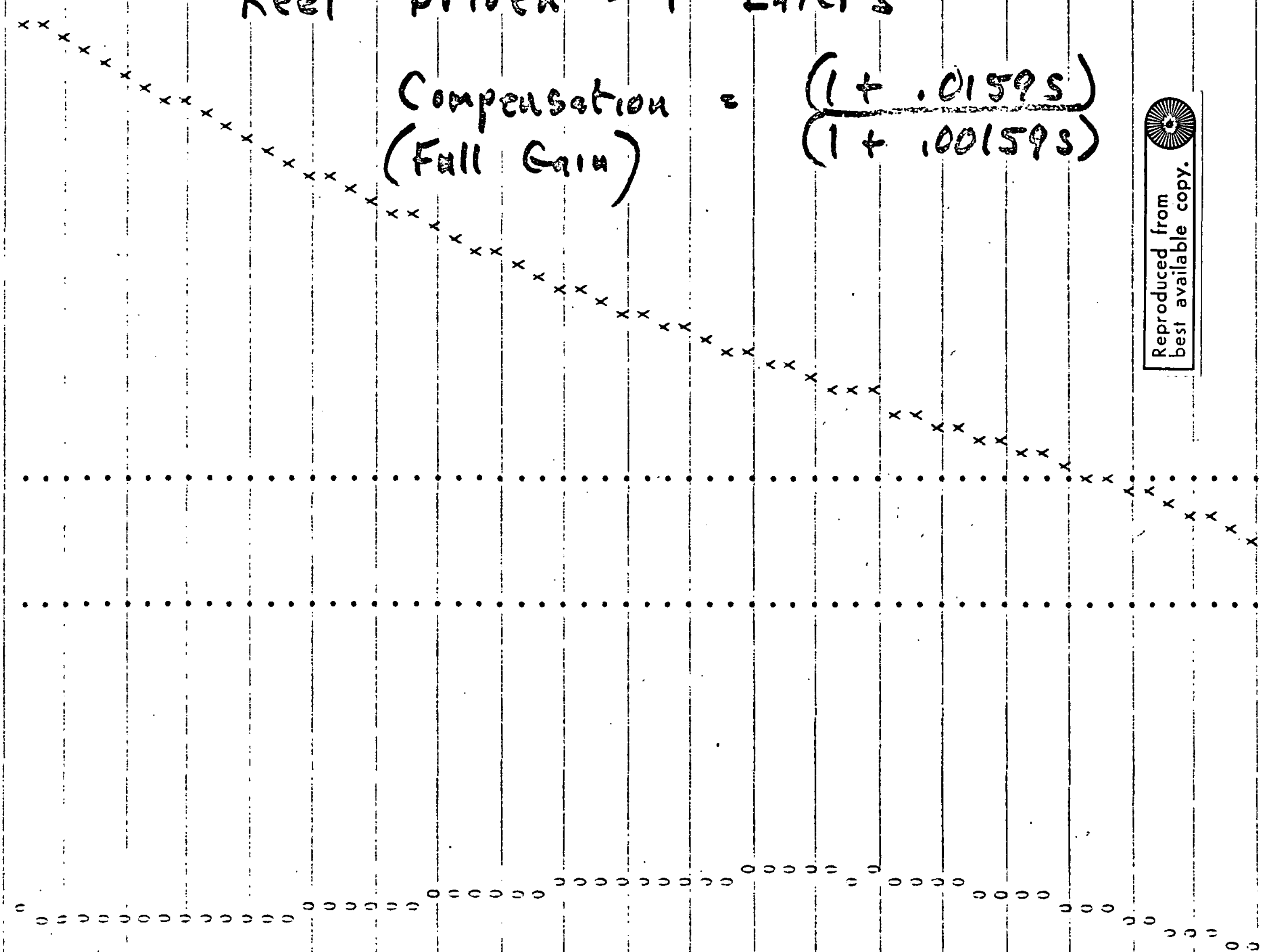
FIG. 4

3.0	46.4	-138.
3.2	45.6	-138.
3.3	44.7	-139.
3.5	43.9	-139.
3.8	43.0	-139.
4.0	42.1	-140.
4.2	41.3	-140.
4.5	40.4	-140.
4.7	39.5	-140.
5.0	38.7	-140.
5.3	37.8	-139.
5.6	37.0	-139.
6.0	36.1	-139.
6.3	35.3	-138.
6.7	34.5	-138.
7.1	33.7	-137.
7.5	32.9	-137.
7.9	32.1	-136.
8.4	31.3	-135.
8.9	30.5	-135.
9.4	29.7	-134.
10.0	29.0	-133.
10.6	28.3	-132.
11.2	27.5	-132.
11.9	26.8	-131.
12.6	26.1	-130.
13.3	25.4	-130.
14.1	24.8	-129.
15.0	24.1	-128.
15.8	23.5	-128.
16.8	22.8	-127.
17.8	22.2	-127.
18.8	21.6	-127.
20.0	21.0	-126.
21.1	20.4	-126.
22.4	19.8	-126.
23.7	19.2	-126.
25.1	18.6	-126.
26.6	18.0	-126.
28.2	17.4	-126.
29.9	17.0	-126.
31.6	15.9	-126.
33.5	15.1	-128.
35.5	14.9	-128.
37.6	14.3	-129.
39.8	13.9	-129.
42.2	13.2	-130.
44.7	12.7	-131.
47.3	12.1	-132.
50.1	11.5	-133.
53.1	10.9	-135.
56.2	10.3	-136.
59.6	9.7	-137.
63.1	9.1	-139.
66.8	8.5	-141.
70.8	7.9	-142.
75.0	7.3	-144.
79.4	6.7	-146.
84.1	6.1	-148.
89.1	5.4	-150.

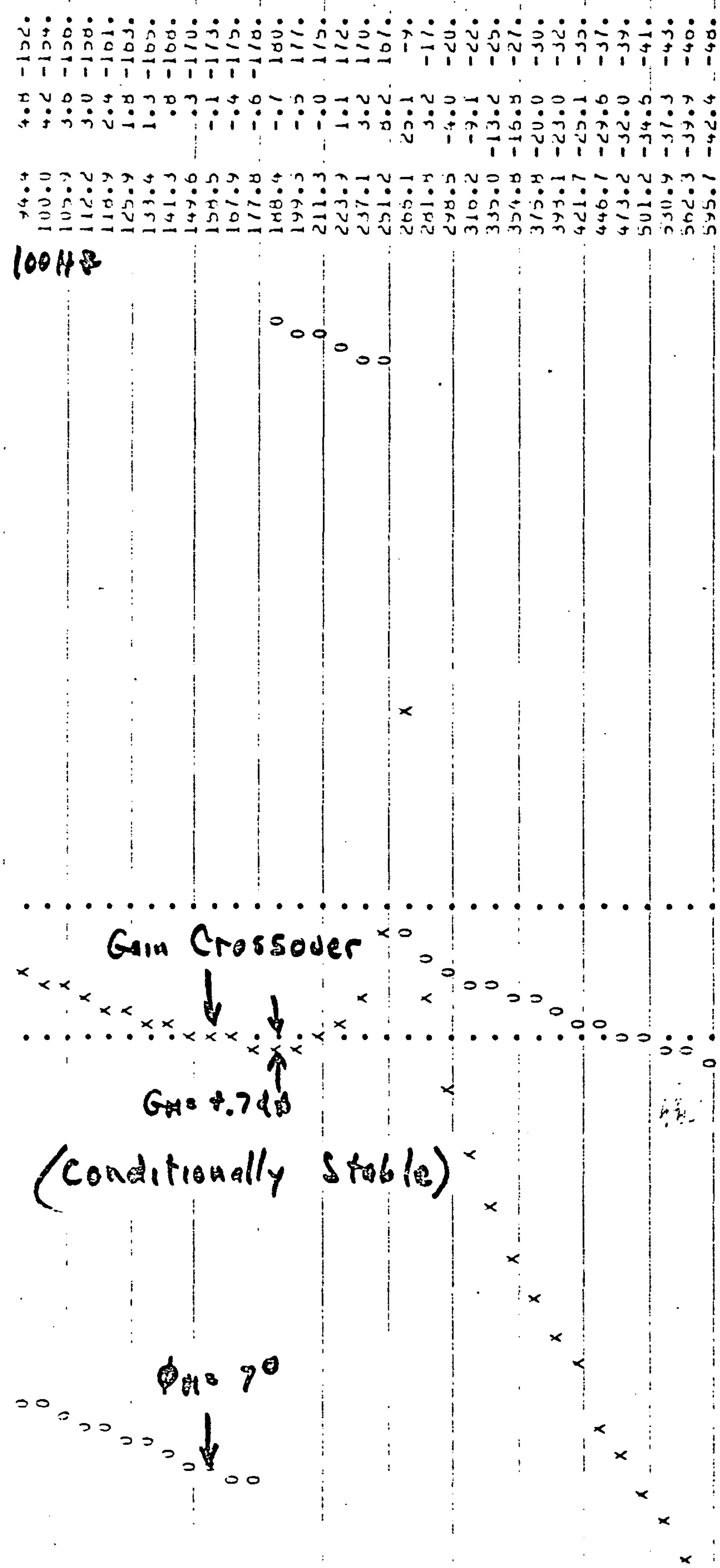
10Hz

MCTR Open Loop Gain
Reel Driven - 1" Idlers

Compensation (Full Gain) = $\frac{(1 + .0159s)}{(1 + .00159s)}$



FOLDOUT FRAME 2



```
15:51:24     DB FOR GAIN.GAIN
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 21 APR 71 AT 15:51:24

     MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001    *CODE    001257
          0000    *DATA    000324
          0002    *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003    NWDU$
          0004    NIO1$
          0005    NIO2$
          0006    COV$
          0007    CABS
          0010    ALOG10
          0011    ATAN2
          0012    NEXP6$
          0013    NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001   000014 117G      0001   000025 125G      0001   000033 133G      0001   001210 162G      0000   000037 20F
     0001   000043 40L       0000   000041 50F       0000 C 000002 A         0000 C 000004 B         0000 I 000020 BLANK
     0000 C 000006 C         0000 C 000010 D         0000 R 000033 DB        0000 I 000021 DOT       0000 C 000012 E
     0000 C 000014 FCT       0000 C 000016 FCTCOM    0000 I 000023 FI        0000 R 000032 HERTZ     0000 I 000030 I
     0000 I 000031 I$        0000 I 000035 J         0000 I 000036 K         0000 I 000157 LINE      0000 I 000026 M
     0000 I 000027 N         0000 R 000024 P         0000 R 000034 PHASE     0000 R 000025 Q         0000 C 000000 S
     0000 I 000022 X

   00100      1*    C      GAIN AND PHASE PLOT
   00100      2*    C      OPEN LOOP RESPONSE
   00101      3*           COMPLEX S,A,B,C,D,E,FCT,FCTCOM
   00103      4*           INTEGER BLANK,DOT,X,FI
   00104      5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
   00111      6*           DIMENSION LINE(101)
   00111      7*    C      P IS DB PER CHARACTER SPACE
   00112      8*           P=1.
   00112      9*    C      Q IS DEGREES PER CHARACTER SPACE
   00113     10*           Q=4.
   00113     11*    C      M IS DB ZERO LOCATION
   00114     12*           M=41
   00114     13*    C      N IS PHASE ZERO LOCATION
   00115     14*           N=51
   00116     15*           DO 10 I=1,101
   00121     16*        10 LINE(I)=DOT
   00123     17*           WRITE (6,20) LINE
   00131     18*        20 FORMAT (1H1,101A1)
   00132     19*           DO 30 I=1,101
   00135     20*        30 LINE(I)=BLANK
   00137     21*           LINE(M)=DOT
```

```
00140            LINE(N)=DOT
00141            HERTZ=.1 .
00142         40 S=CMPLX(0.,6.283*HERTZ)
00143            A=1.+44.9E-5*S**2+603.E-12*S**4+160.E-18*S**6+10.09E-24*S**8
00144            B=26.2*S*(1.02+25.2E-6*S**2+12.39E-12*S**4+1.23E-18*S**6)
00145            C=187.E3*(1.+2.43E-5*S**2+1.24E-11*S**4+1.23E-18*S**6)
00146            D=187.E3*S*(9.3E-7+2.26E-17*S**2+6.15E-18*S**4+4.17E-28*S**6)
00147            E=187.E3*(1.+24.25E-6*S**2+3.3E-12*S**4)
00150            FCT=(11.4/(1.+.0004*S+(.0014+2.6E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
00151            FCTCOM=FCT*((1.+.0159*S)/(1.+.00159*S))
00152            DB=20.*ALOG10(CABS(FCTCOM))
00153            PHASE=57.29*ATAN2(AIMAG(FCTCOM),REAL(FCTCOM))
00154            I=DB/P+FLOAT(M)+0.5
00155            LINE(I)=X
00156            J=PHASE/Q+FLOAT(N)+0.5
00157            LINE(J)=FI
00160            WRITE(6,50) LINE,HERTZ,DB,PHASE
00171         50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00172            LINE(I)=BLANK
00173            LINE(J)=BLANK
00174            LINE(M)=DOT
00175            LINE(N)=DOT
00175      C     K IS NUMBER OF STEPS PER DECADE
00176            K=40
00177            HERTZ=HERTZ*10.**(1./FLOAT(K))
00200            IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00203         60 STOP
00204            END

END OF UCC 1108 FORTRAN V COMPILATION.       0 *DIAGNOSTIC* MESSAGE(S)
```

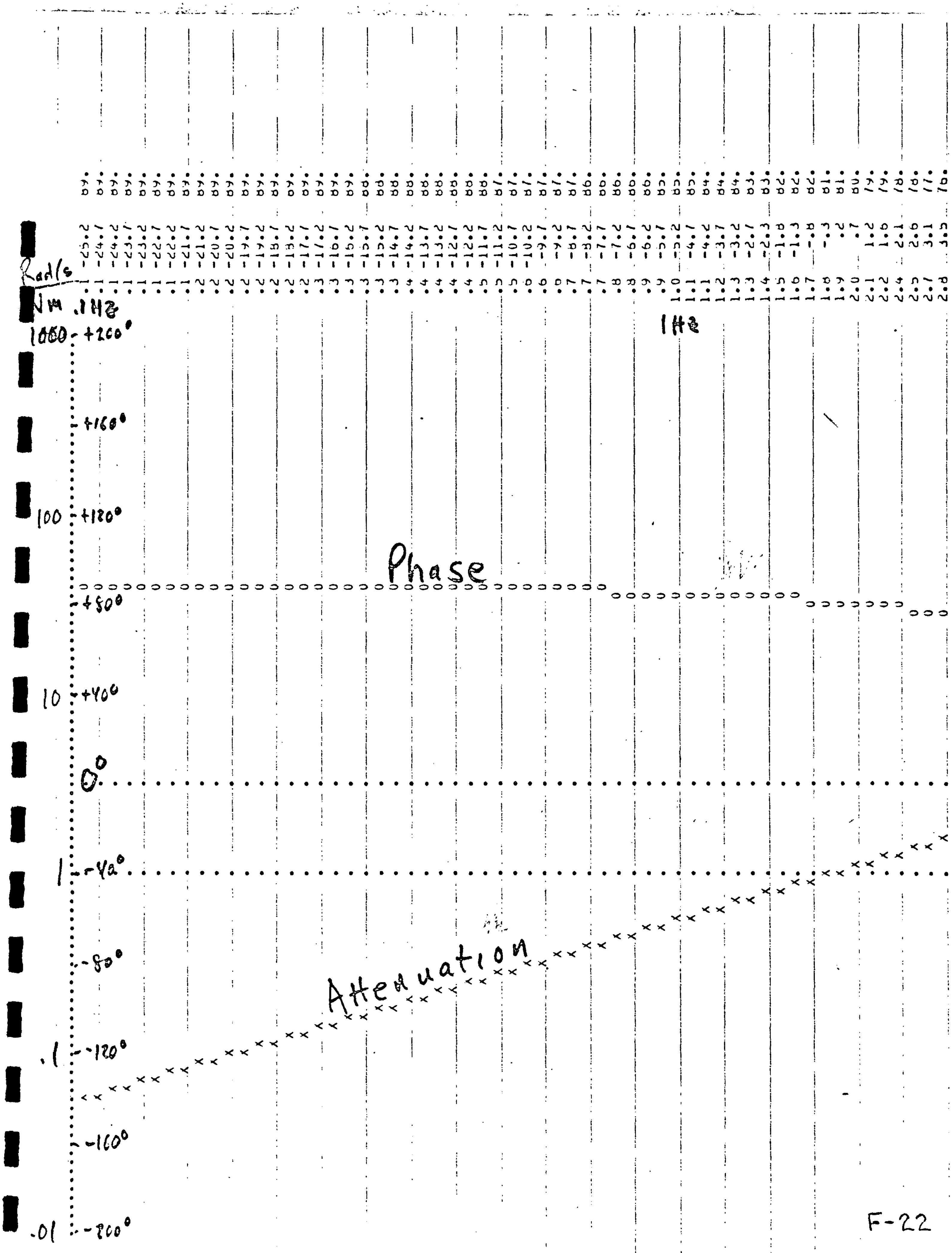

Rad/s
Nm .1Hz
1Hz
1000 +200°
+160°
100 +120°
Phase
+80°
10 +40°
0°
1 -40°
-80°
Attenuation
.1 -120°
-160°
.01 -200°

FIG. 5

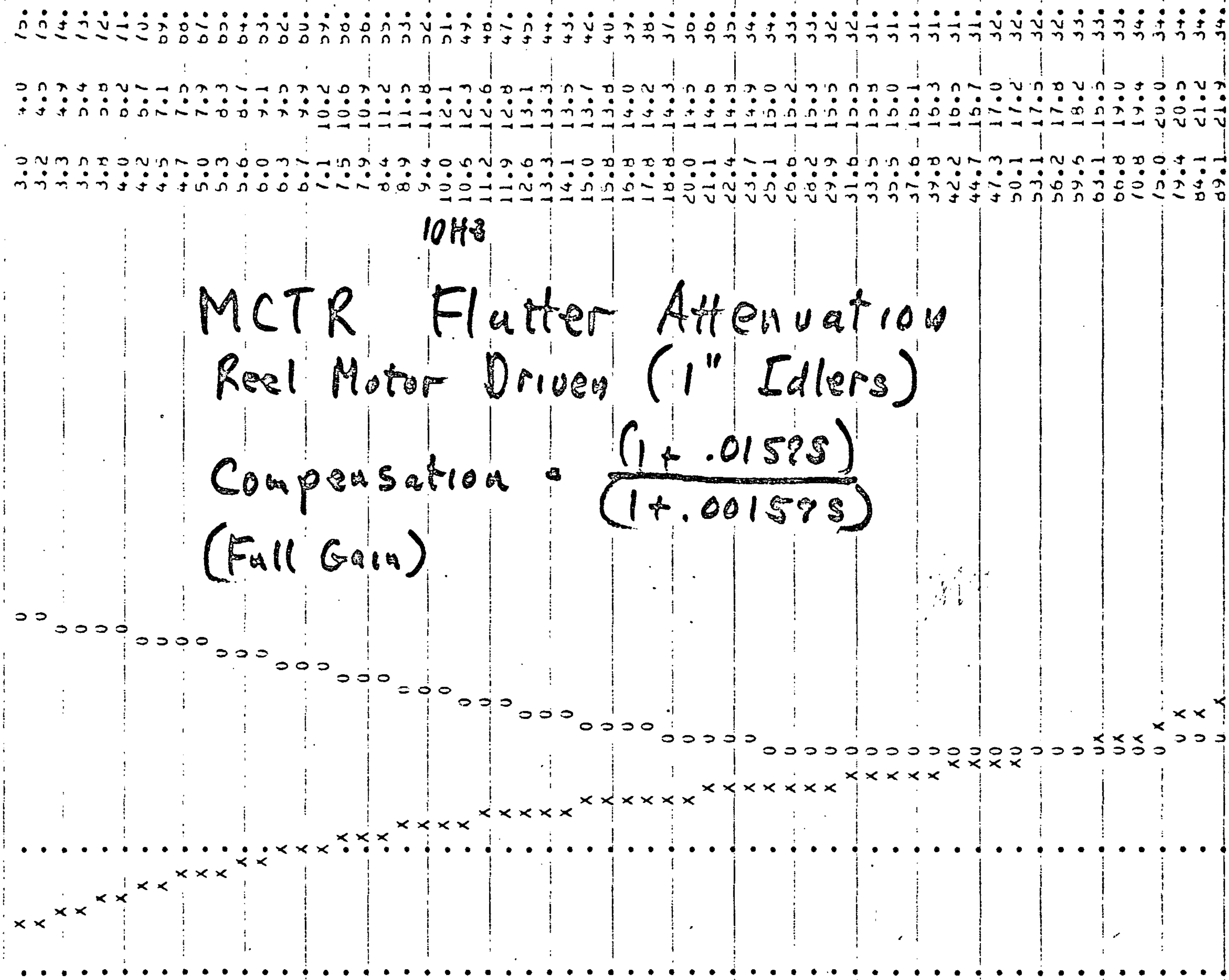
10H3

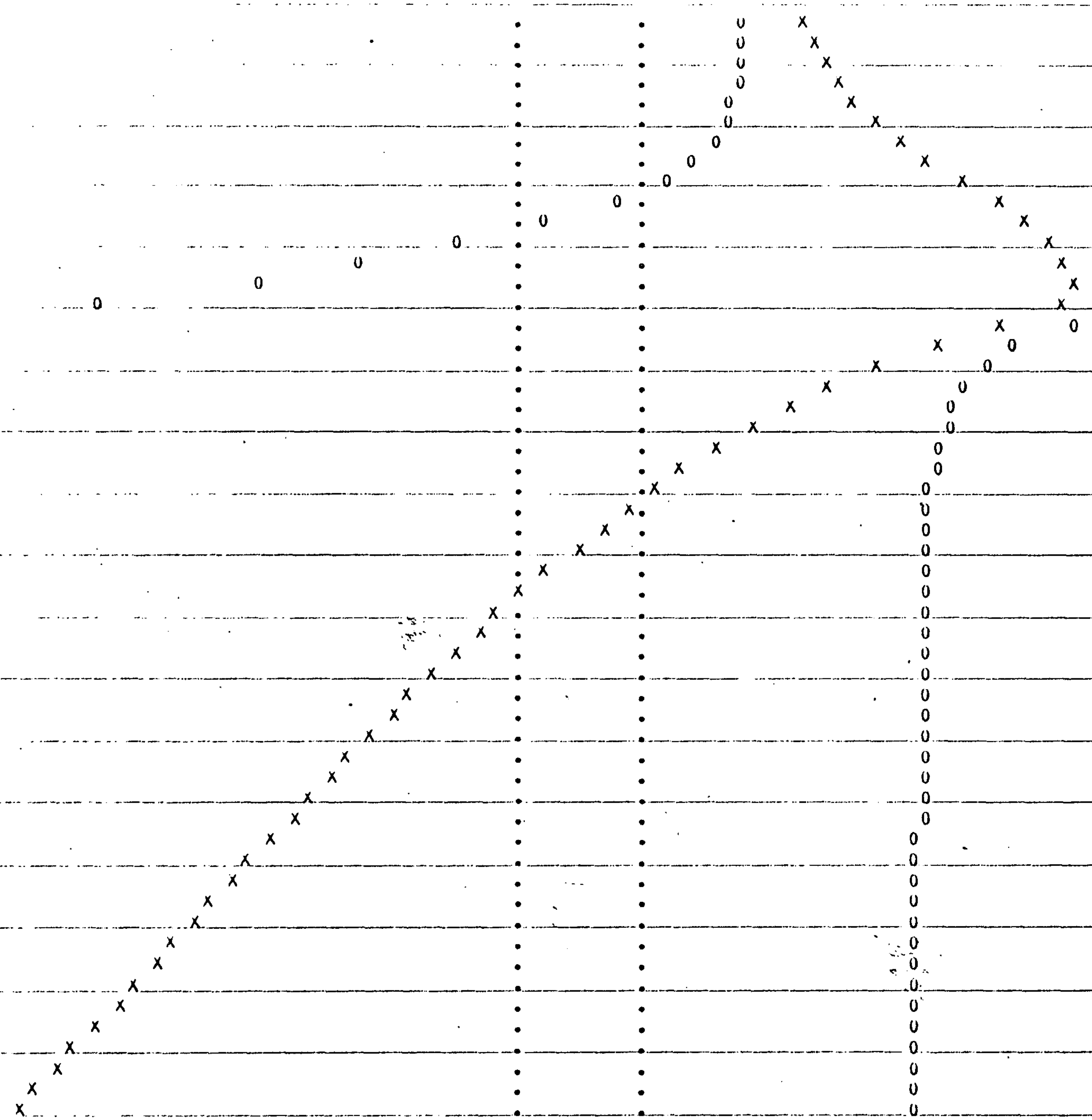
MCTR Flutter Attenuation

Reel Motor Driven (1" Idlers)

Compensation = $\frac{(1+.0159S)}{(1+.00159S)}$

(Full Gain)





94.4	22.8	34.
100.0	23.7	34.
105.9	24.8	33.
112.2	25.0	32.
118.9	27.4	30.
125.9	29.1	27.
133.4	31.0	23.
141.3	33.2	16.
149.6	35.8	6.
158.5	38.6	-9.
167.9	41.2	-33.
177.8	42.8	-61.
188.4	43.8	-91.
199.5	45.0	-126.
211.3	44.2	-177.
223.9	39.1	141.
237.1	33.6	121.
251.2	29.0	111.
266.1	25.0	105.
281.8	21.6	101.
298.5	18.6	98.
316.2	15.8	96.
335.0	13.2	95.
354.8	10.9	94.
375.8	8.6	93.
398.1	6.6	92.
421.7	3.4	92.
446.7	1.7	91.
473.2	.1	91.
501.2	-1.6	91.
530.9	-3.4	91.
562.3	-5.2	90.
595.7	-6.9	90.
631.0	-8.6	90.
668.3	-10.3	90.
707.9	-12.0	90.
749.9	-13.6	90.
794.3	-15.2	90.
841.4	-16.9	90.
891.2	-18.5	90.
944.1	-20.0	90.
1000.0	-21.6	90.
1059.3	-23.2	90.
1122.0	-24.8	90.
1188.5	-26.3	90.
1258.9	-27.9	90.
1333.5	-29.4	90.
1412.5	-30.9	90.
1496.2	-32.5	90.
1584.9	-34.0	90.
1678.8	-35.5	90.
1778.3	-37.1	90.
1883.6	-38.6	90.
1995.3	-40.1	90.

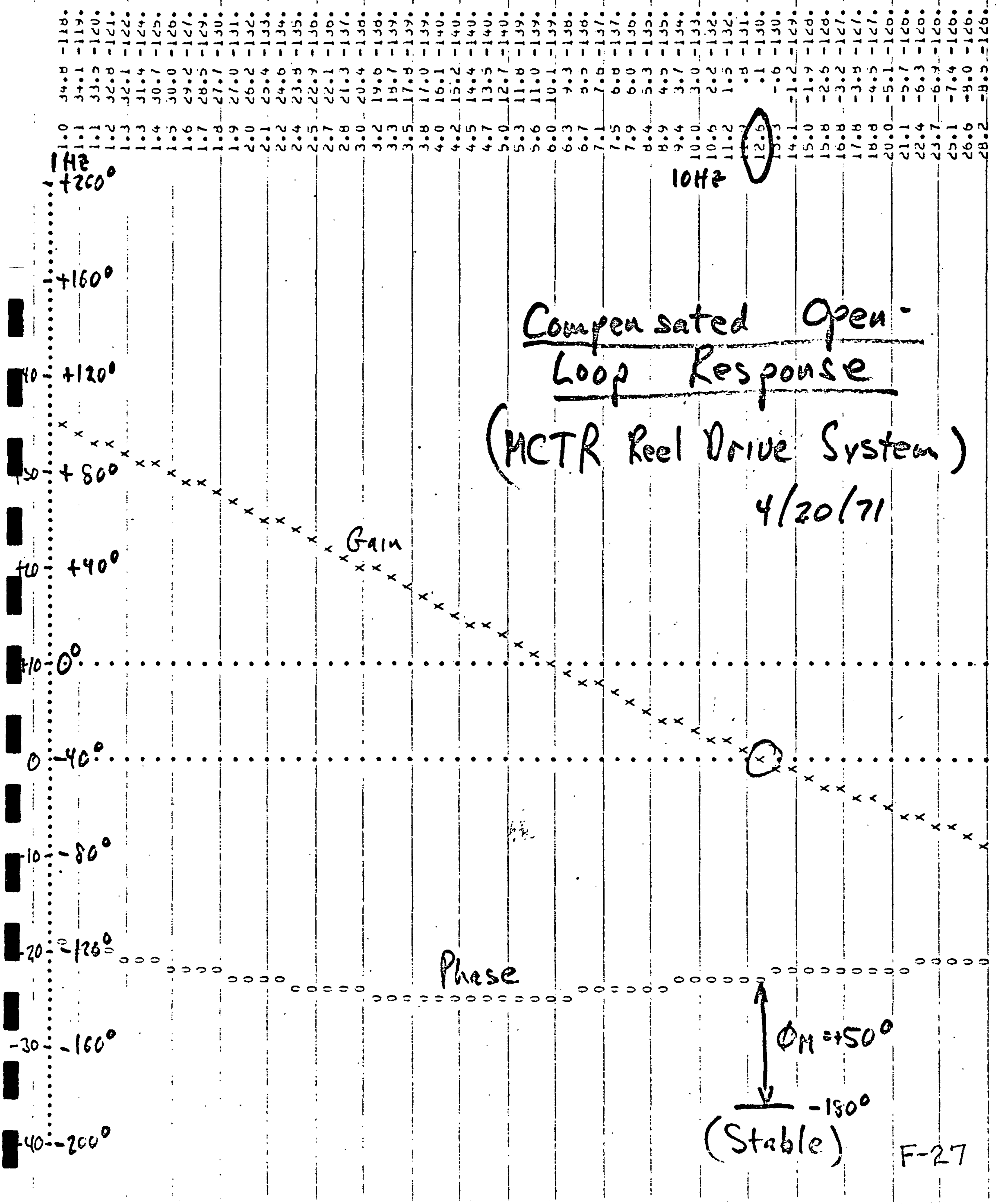
100Hz

1KHz

```
15:36:14     DB FOR ATTEN.ATTEN                                          1F9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 21 APR 71 AT 15:36:14

   MAIN PROGRAM

      STORAGE USED (BLOCK, NAME, LENGTH)

          0001    *CODE    001315
          0000    *DATA    000332
          0002    *BLANK   000000

      EXTERNAL REFERENCES (BLOCK, NAME)

          0003    NWDU$
          0004    NI01$
          0005    NI02$
          0006    CDV$
          0007    CABS
          0010    ALOG10
          0011    ATAN2
          0012    NEXP6$
          0013    NSTOP$

      STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

      0001   000014 117G     0001   000025 125G     0001   000033 133G     0001   001246 164G     0000   000043 20F
      0001   000043 40L      0000   000045 50F      0000 C 000002 A        0000 C 000004 B        0000 I 000024 BLANK
      0000 C 000005 C        0000 C 000010 D        0000 R 000037 DB       0000 I 000025 DOT      0000 C 000012 E
      0000 C 000014 FCT      0000 I 000027 FI       0000 C 000022 F1       0000 R 000036 HERTZ    0000 I 000034 I
      0000 I 000035 I$       0000 I 000041 J        0000 I 000042 K        0000 I 000165 LINE     0000 I 000032 M
      0000 I 000033 N        0000 R 000030 P        0000 R 000040 PHASE    0000 R 000031 Q        0000 C 000016 Q2F2
      0000 C 000020 Q3       0000 C 000000 S        0000 I 000026 X

  00100      1*    C      TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
  00100      2*    C      CLOSED LOOP RESPONSE
  00101      3*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
  00103      4*           INTEGER BLANK,DOT,X,FI
  00104      5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
  00111      6*           DIMENSION LINE(101)
  00111      7*    C      P IS DB PER CHARACTER SPACE
  00112      8*           P=1.
  00112      9*    C      Q IS DEGREES PER CHARACTER SPACE
  00113     10*           Q=4.
  00113     11*    C      M IS DB ZERO LOCATION
  00114     12*           M=41
  00114     13*    C      N IS PHASE ZERO LOCATION
  00115     14*           N=51
  00115     15*           DO 10 I=1,101
  00121     16*        10 LINE(I)=DOT
  00123     17*           WRITE (6,20) LINE
  00131     18*        20 FORMAT (1H1,101A1)
  00132     19*           DO 30 I=1,101
  00135     20*        30 LINE(I)=BLANK
  00137     21*           LINE(M)=DOT
```

```
00140            LINE(N)=DOT
00141            HERTZ=.1
00142         40 S=CMPLX(0.,6.283*HERTZ)
00143            A=1.+48.9E-6*S**2+603.E-12*S**4+160.E-18*S**6+10.09E-24*S**8
00144            B=26.2*S*(1.02+25.2E-6*S**2+12.39E-12*S**4+1.23E-18*S**6)
00145            C=187.E3*(1.+2.43E-5*S**2+1.24E-11*S**4+1.23E-18*S**6)
00146            D=187.E3*S*(9.3E-7+2.26E-17*S**2+6.15E-18*S**4+4.17E-28*S**6)
00147            E=187.E3*(1.+24.25E-6*S**2+3.3E-12*S**4)
00150            F1=(C+D)/(A+B)
00151            U3=(1+.0159*S)/(1+.00159*S)
00152            U2F2=((1+.0004*S)/(1+.0004*S+(.0014+2.6E-7*S)*F1))*(E/(A+B))
00153            FCT=(U2F2)/(1+(U2F2*U3*11.4)/(S*(1+.0004*S)))
00154            DB=20.*ALOG10(CABS(FCT))
00155            PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156            I=DB/P+FLOAT(M)+0.5
00157            LINE(I)=X
00160            J=PHASE/Q+FLOAT(N)+0.5
00161            LINE(J)=FI
00162            WRITE(5,50) LINE,HERTZ,DB,PHASE
00173         50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174            LINE(I)=BLANK
00175            LINE(J)=BLANK
00176            LINE(M)=DOT
00177            LINE(N)=DOT
00177      C     K IS NUMBER OF STEPS PER DECADE
00200            K=40
00201            HERTZ=HERTZ*10.**(1./FLOAT(K))
00202            IF ((FLOAT(M)-1.)*P+DB) 60,50,40
00205         60 STOP
00206            END

     END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```

FIG. 6


1 Hz
10 Hz
Compensated Open-Loop Response
(MCTR Reel Drive System)
4/20/71
Gain
Phase
ϕ_M = +50°
-180°
(Stable)
+200°
+160°
+120°
+80°
+40°
0°
-40°
-80°
-120°
-160°
-200°
40
30
20
10
0
-10
-20
-30
-40

29.9	-9.0	-126.
31.6	-9.1	-126.
33.5	-10.9	-128.
35.5	-11.2	-128.
37.6	-11.7	-129.
39.8	-12.2	-129.
42.2	-12.8	-130.
44.7	-13.4	-131.
47.3	-13.9	-132.
50.1	-14.5	-133.
53.1	-15.1	-135.
56.2	-15.7	-136.
59.6	-16.3	-137.
63.1	-16.9	-139.
66.8	-17.5	-141.
70.8	-18.1	-142.
75.0	-18.7	-144.
79.4	-19.3	-146.
84.1	-20.0	-148.
89.1	-20.6	-150.
94.4	-21.2	-152.
100.0	-21.8	-154.
105.9	-22.4	-156.
112.2	-23.0	-158.
118.9	-23.6	-161.
125.9	-24.2	-163.
133.4	-24.8	-165.
141.3	-25.3	-168.
149.6	-25.7	-170.
158.5	-26.1	-173.
167.9	-25.5	-175.
177.8	-26.7	-178.
188.4	-25.7	180.
199.5	-26.5	177.
211.3	-25.0	175.
223.9	-24.9	172.
237.1	-22.8	170.
251.2	-17.8	167.
266.1	-.9	-9.
281.8	-22.8	-17.
298.5	-30.1	-20.
316.2	-35.1	-22.
335.0	-39.2	-25.
354.8	-42.8	-27.

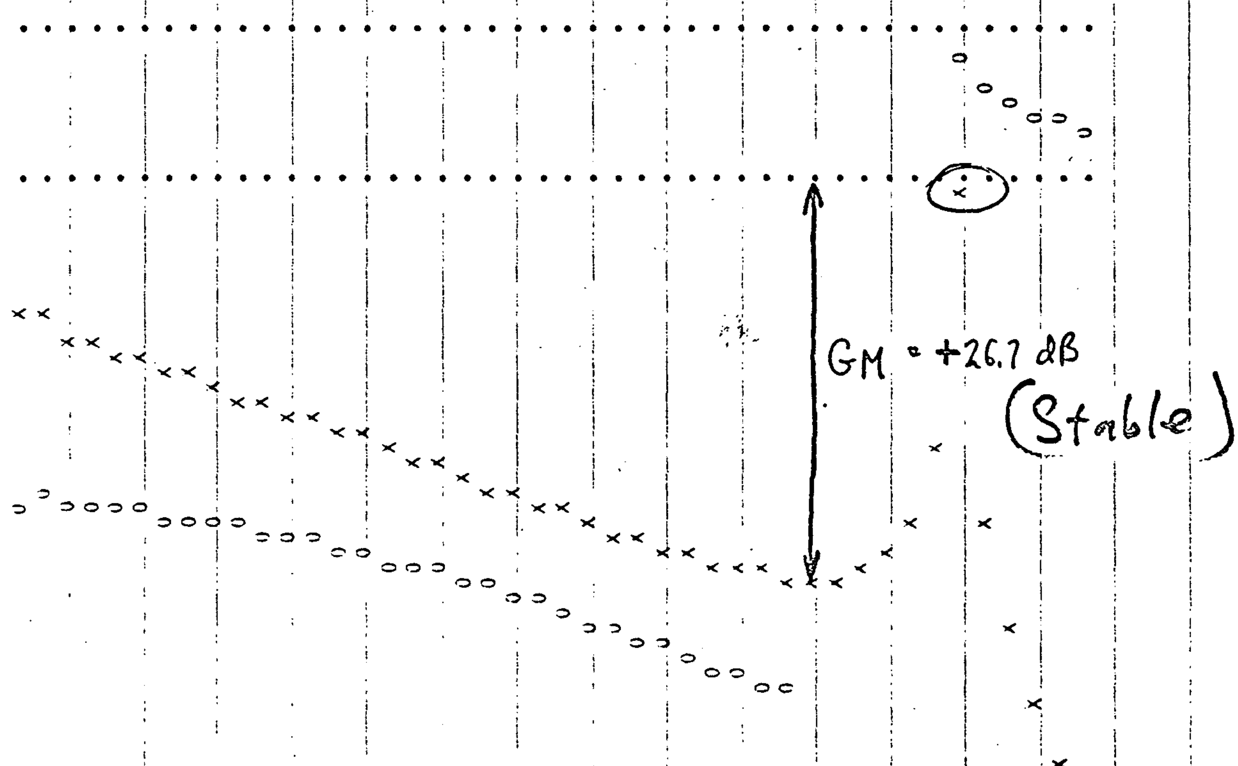
100HZ

10HZ

$$\text{Comp.} = 0.05\,\frac{(1+.0159\,S)}{(1+.00159\,S)}$$

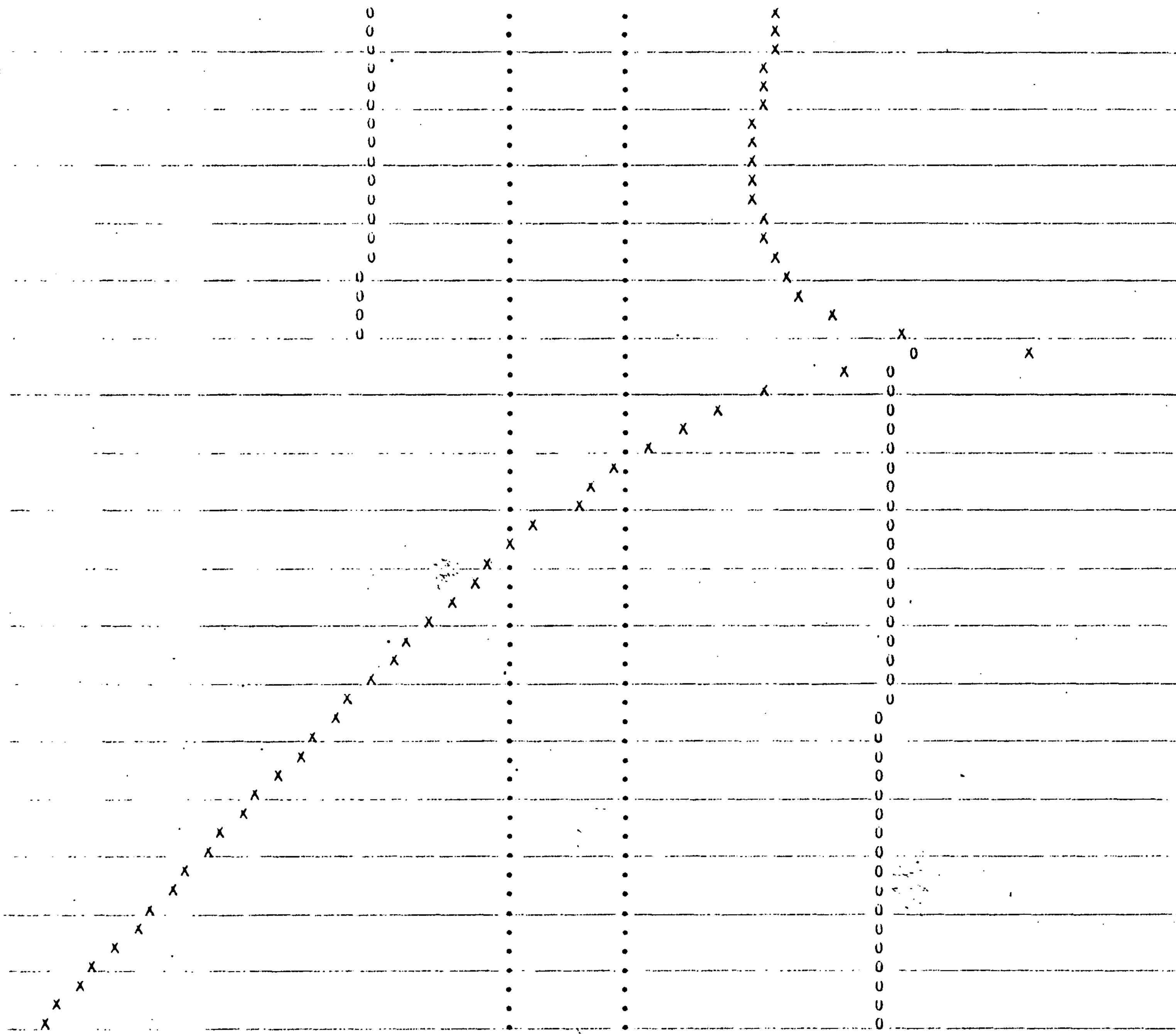
100HZ

[1" Dia Idlers]



```
13:29:23     GB FOR GAIN.GAIN
UCC 1108 FORTRAN V  :  LEVEL    3.2A
THIS COMPILATION WAS DONE ON 20 APR 71 AT 13:29:23

    MAIN PROGRAM

    STORAGE USED (BLOCK, NAME, LENGTH)

        0001    *CODE    001274
        0000    *DATA    000325
        0002    *BLANK   000000

    EXTERNAL REFERENCES (BLOCK, NAME)

        0003    NWDU$
        0004    NI01$
        0005    NI02$
        0006    COV$
        0007    CABS
        0010    ALOG10
        0011    ATAN2
        0012    NEXP6$
        0013    NSTOP$

    STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000014 1176     0001    000025 1256     0001    000033 133G     0001    001225 162G     0000    000037 20F
    0001    000043 40L      0000    000041 50F      0000 C 000002 A        0000 C 000004 B        0000 I 000020 BLANK
    0000 C 000005 C        0000 C 000010 D        0000 R 000033 DB       0000 I 000021 DOT      0000 C 000012 E
    0000 C 000014 FCI      0000 C 000016 FCTCOM   0000 I 000023 FI       0000 R 000032 HERTZ    0000 I 000030 I
    0000 I 000031 I$       0000 I 000035 J        0000 I 000036 K        0000 I 000160 LINE     0000 I 000026 M
    0000 I 000027 N        0000 R 000024 P        0000 R 000034 PHASE    0000 R 000025 Q        0000 C 000000 S
    0000 I 000022 X

 00100      1*    C     GAIN AND PHASE PLOT
 00100      2*    C     OPEN LOOP RESPONSE
 00101      3*          COMPLEX S,A,B,C,D,E,FCI,FCTCOM
 00103      4*          INTEGER BLANK,DOT,X,FI
 00104      5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
 00111      6*          DIMENSION LINE(101)
 00111      7*    C     P IS DB PER CHARACTER SPACE
 00112      8*          P=1.
 00112      9*    C     Q IS DEGREES PER CHARACTER SPACE
 00113     10*          Q=4.
 00113     11*    C     M IS DB ZERO LOCATION
 00114     12*          M=41
 00114     13*    C     N IS PHASE ZERO LOCATION
 00115     14*          N=51
 00116     15*          DO 10 I=1,101
 00121     16*       10 LINE(I)=DOT
 00123     17*          WRITE (6,20) LINE
 00131     18*       20 FORMAT (1H1,101A1)
 00132     19*          DO 30 I=1,101
 00135     20*       30 LINE(I)=BLANK
 00137     21*          LINE(M)=DOT
```

```
      LINE(N)=DOT
      HERTZ=1.
   40 S=CMPLX(0.,6.283*HERTZ)
      A=1.+43.9E-6*S**2+503.E-12*S**4+160.E-18*S**6+10.09E-24*S**8
      B=26.2*S*(1.02+25.2E-6*S**2+12.39E-12*S**4+1.23E-18*S**6)
      C=187.E3*(1.+2.43E-5*S**2+1.24E-11*S**4+1.23E-18*S**6)
      D=187.E3*S*(9.3E-7+2.26E-17*S**2+6.15E-18*S**4+4.17E-28*S**6)
      E=187.E3*(1.+24.25E-6*S**2+3.3E-12*S**4)
      FCT=(11.4/(1.+.0004*S+(.0014+2.6E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
      FCTCOM=FCT*((1.+.0159*S)/(1.+.00159*S))*.05
      DB=20.*ALOG10(CABS(FCTCOM))
      PHASE=57.29*ATAN2(AIMAG(FCTCOM),REAL(FCTCOM))
      I=DB/P+FLOAT(M)+0.5
      LINE(I)=X
      J=PHASE/Q+FLOAT(N)+0.5
      LINE(J)=FI
      WRITE(6,50) LINE,HERTZ,DB,PHASE
   50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
      LINE(I)=BLANK
      LINE(J)=BLANK
      LINE(M)=DOT
      LINE(N)=DOT
C     K IS NUMBER OF STEPS PER DECADE
      K=40
      HERTZ=HERTZ*10.**(1./FLOAT(K))
      IF ((FLOAT(M)-1.)*P+DB) 60,60,40
   60 STOP
      END

END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```



100Hz	94.4	23.3	-87.
	100.0	22.9	-87.
	105.9	22.6	-87.
	112.2	22.2	-88.
	118.9	21.9	-88.
	125.9	21.7	-88.
	133.4	21.5	-89.
	141.3	21.3	-89.
	149.6	21.2	-89.
	158.5	21.2	-89.
	167.9	21.3	-89.
	177.8	21.6	-90.
	188.4	22.0	-90.
	199.5	22.7	-90.
	211.3	23.7	-90.
	223.9	25.4	-90.
	237.1	28.2	-91.
	251.2	34.3	-92.
	266.1	45.1	100.
	281.8	28.7	92.
	298.5	22.4	91.
	316.2	18.2	91.
	335.0	14.8	91.
	354.8	11.9	90.
	375.8	9.3	90.
	398.1	7.1	90.
	421.7	5.7	90.
	446.7	2.0	90.
	473.2	.3	90.
	501.2	-1.5	90.
	530.9	-3.3	90.
	562.3	-5.1	90.
	595.7	-6.9	90.
	631.0	-8.6	90.
	668.3	-10.3	90.
	707.9	-12.0	90.
	749.9	-13.6	90.
	794.3	-15.2	90.
	841.4	-15.9	90.
	891.2	-18.5	90.
	944.1	-20.0	90.
1KHz	1000.0	-21.6	90.
	1059.3	-23.2	90.
	1122.0	-24.8	90.
	1188.5	-26.3	90.
	1258.9	-27.9	90.
	1333.5	-29.4	90.
	1412.5	-30.9	90.
	1496.2	-32.5	90.
	1584.9	-34.0	90.
	1678.8	-35.5	90.
	1778.3	-37.1	90.
	1883.6	-38.6	90.
	1995.3	-40.1	90.

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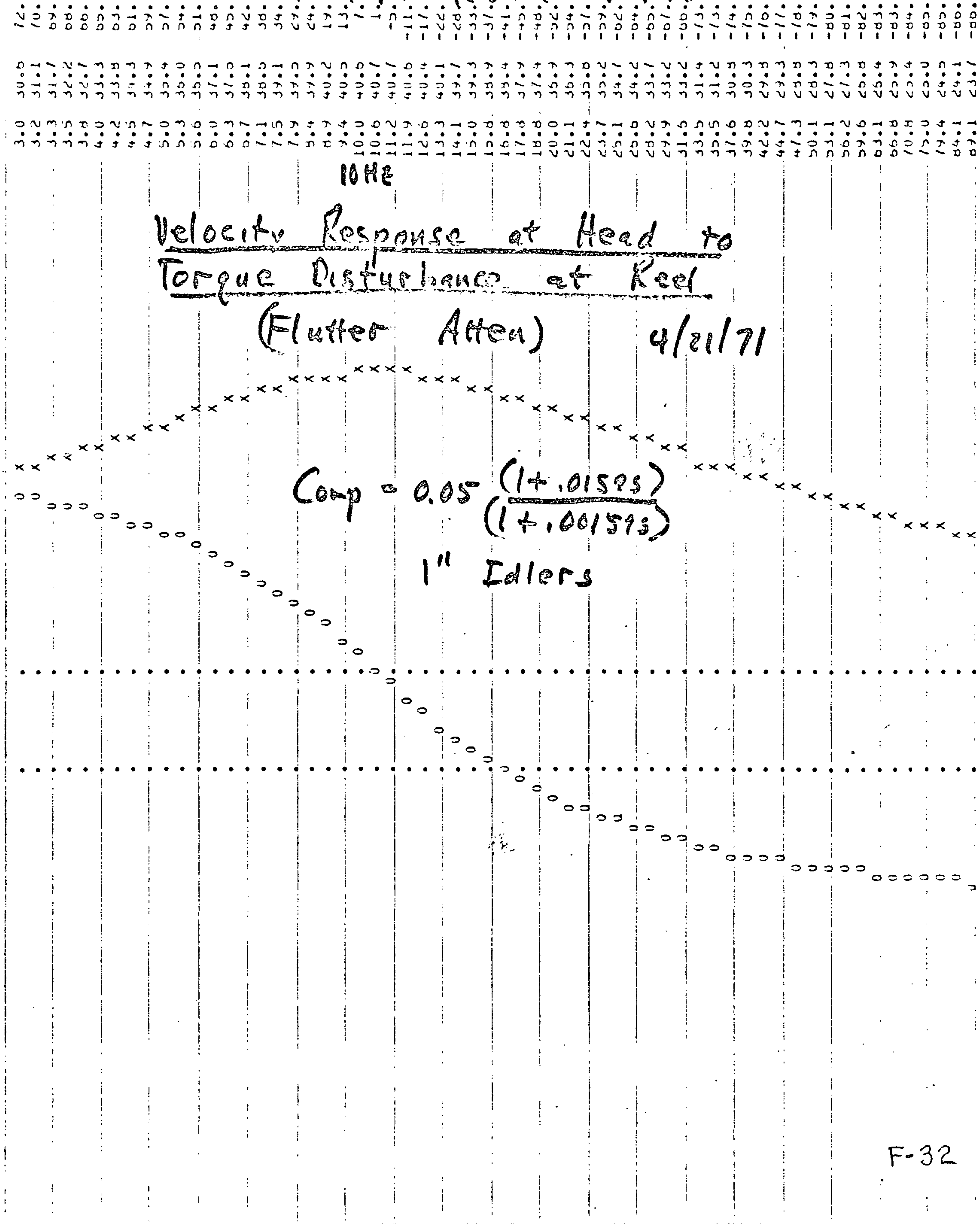
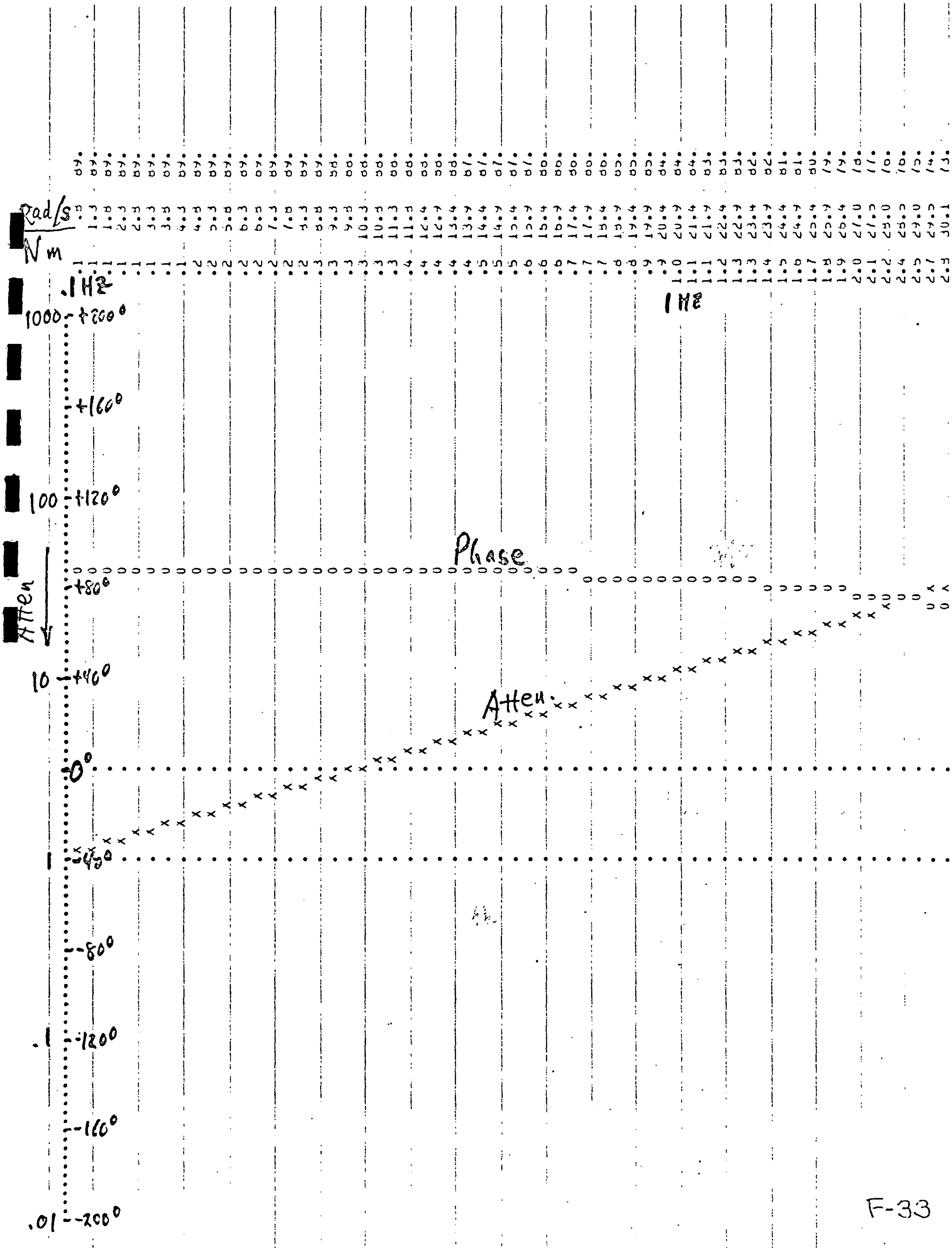
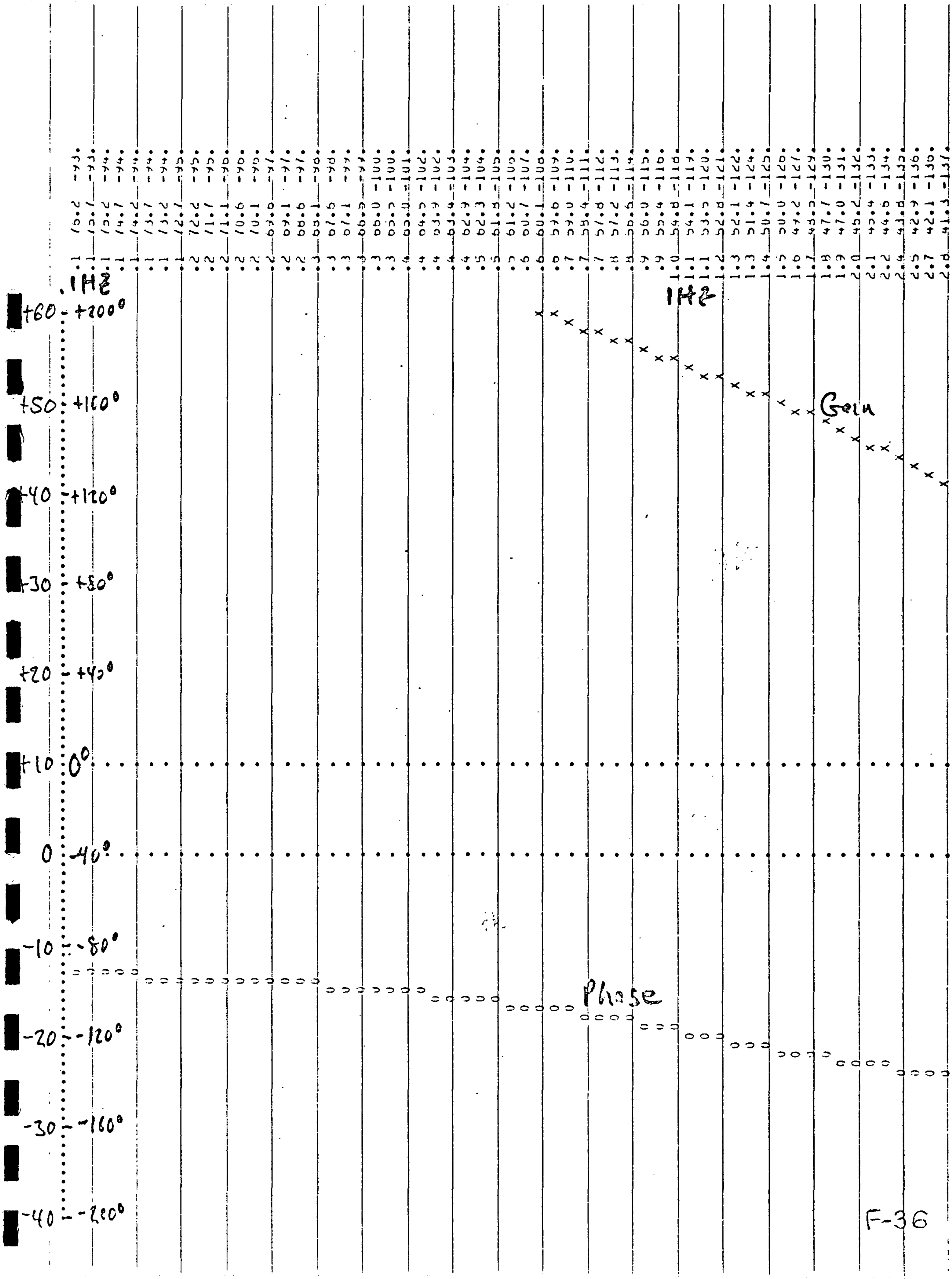
FIG. 7
MCTR Reel Drive




Rad/s
N m
.1 Hz
1 Hz
1000 - +200°
+160°
100 - +120°
+80°
10 - +40°
0°
1 - -40°
-80°
.1 - -120°
-160°
.01 - -200°
Phase
Atten.
Atten

```
13:21:34     @B FOR ATTEN,ATTEN                                         1F9002
UCC 1108 FORTRAN V  :  LEVEL    3.2A
THIS COMPILATION WAS DONE ON 21 APR 71 AT 13:21:34

     MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001     *CODE    001332
          0000     *DATA    000334
          0002     *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003     NWDU$
          0004     NI01$
          0005     NI02$
          0006     CDV$
          0007     CABS
          0010     ALOG10
          0011     ATAN2
          0012     NEXP6$
          0013     NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001     000014 117G      0001     000025 125G      0001     000033 133G      0001     001263 164G      0000     000043 20F
     0001     000043 40L       0000     000045 50F       0000 C 000002 A          0000 C 000004 B          0000 I 000024 BLANK
     0000 C 000005 C           0000 C 000010 D          0000 R 000037 DB         0000 I 000025 DOT        0000 C 000012 E
     0000 C 000014 FCT         0000 I 000027 FI         0000 C 000022 F1         0000 R 000036 HERTZ      0000 I 000034 I
     0000 I 000035 I$          0000 I 000041 J          0000 I 000042 K          0000 I 000167 LINE       0000 I 000032 M
     0000 I 000033 N           0000 R 000030 P          0000 R 000040 PHASE      0000 R 000031 Q          0000 C 000015 Q2F2
     0000 C 000020 Q3          0000 C 000000 S          0000 I 000025 X

   00100      1*    C      TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
   00100      2*    C      CLOSED LOOP RESPONSE
   00101      3*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
   00103      4*           INTEGER BLANK,DOT,X,FI
   00104      5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
   00111      6*           DIMENSION LINE(101)
   00111      7*    C      P IS DB PER CHARACTER SPACE
   00112      8*           P=1.
   00112      9*    C      Q IS DEGREES PER CHARACTER SPACE
   00113     10*           Q=4.
   00113     11*    C      M IS DB ZERO LOCATION
   00114     12*           M=41
   00114     13*    C      N IS PHASE ZERO LOCATION
   00115     14*           N=51
   00116     15*           DO 10 I=1,101
   00121     16*        10 LINE(I)=DOT
   00123     17*           WRITE (6,20) LINE
   00131     18*        20 FORMAT (1H1,101A1)
   00132     19*           DO 30 I=1,101
   00135     20*        30 LINE(I)=BLANK
   00137     21*           LINE(M)=DOT
```

```
00140          LINE(I)=DOT
00141          HERTZ=.1
00142       40 S=CMPLX(0.,6.283*HERTZ)
00143          A=1.+48.9E-6*S**2+603.E-12*S**4+160.E-18*S**6+10.09E-24*S**8
00144          B=25.2*S*(1.02+25.2E-6*S**2+12.39E-12*S**4+1.23E-18*S**6)
00145          C=187.E3*(1.+2.43E-5*S**2+1.24E-11*S**4+1.23E-18*S**6)
00146          D=187.E3*S*(9.3E-7+2.26E-17*S**2+6.15E-18*S**4+4.17E-28*S**6)
00147          E=187.E3*(1.+24.25E-6*S**2+3.3E-12*S**4)
00150          F1=(C+D)/(A+B)
00151          Q3=.05*(1+.0159*S)/(1+.00159*S)
00152          Q2F2=((1+.0004*S)/(1+.0004*S+(.0014+2.6E-7*S)*F1))*(E/(A+B))
00153          FCT=(Q2F2)/(1+(Q2F2*Q3*11.4)/(S*(1+.0004*S)))
00154          DB=20.*ALOG10(CABS(FCT))
00155          PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00155          I=DB/P+FLOAT(M)+0.5
00157          LINE(I)=X
00160          J=PHASE/W+FLOAT(N)+0.5
00161          LINE(J)=FI
00162          WRITE(6,50) LINE,HERTZ,DB,PHASE
00173       50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174          LINE(I)=BLANK
00175          LINE(J)=BLANK
00176          LINE(M)=DOT
00177          LINE(N)=DOT
00177    C     K IS NUMBER OF STEPS PER DECADE
00200          K=40
00201          HERTZ=HERTZ*10.**(1./FLOAT(K))
00202          IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205       60 STOP
00206          END

  END OF UCC 1108 FORTRAN V COMPILATION.     0 *DIAGNOSTIC* MESSAGE(S)
```



1HZ
+60 +200°
+50 +160°
+40 +120°
+30 +80°
+20 +40°
+10 0°
0 -40°
-10 -80°
-20 -120°
-30 -160°
-40 -200°
1HZ
Gain
Phase

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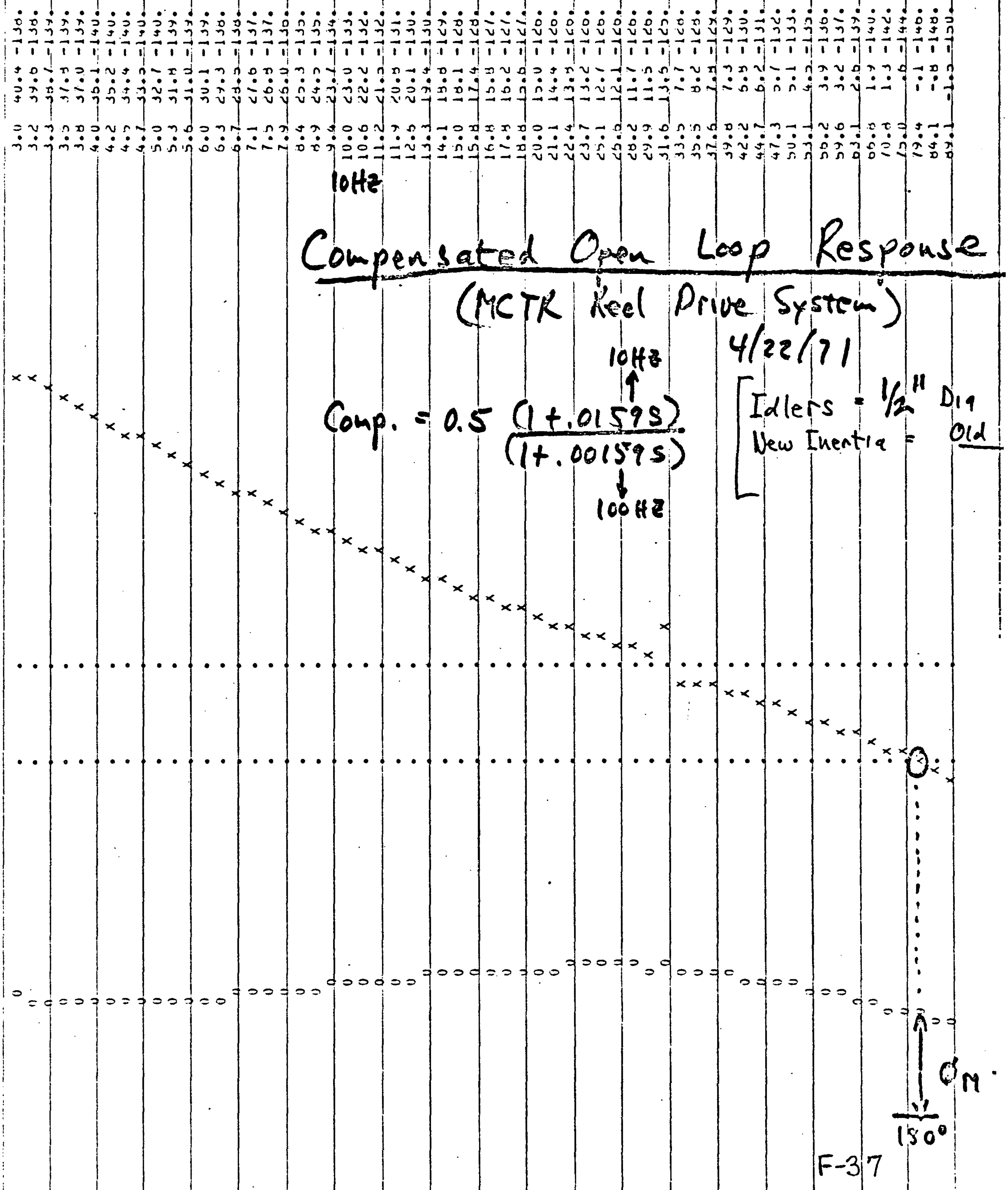
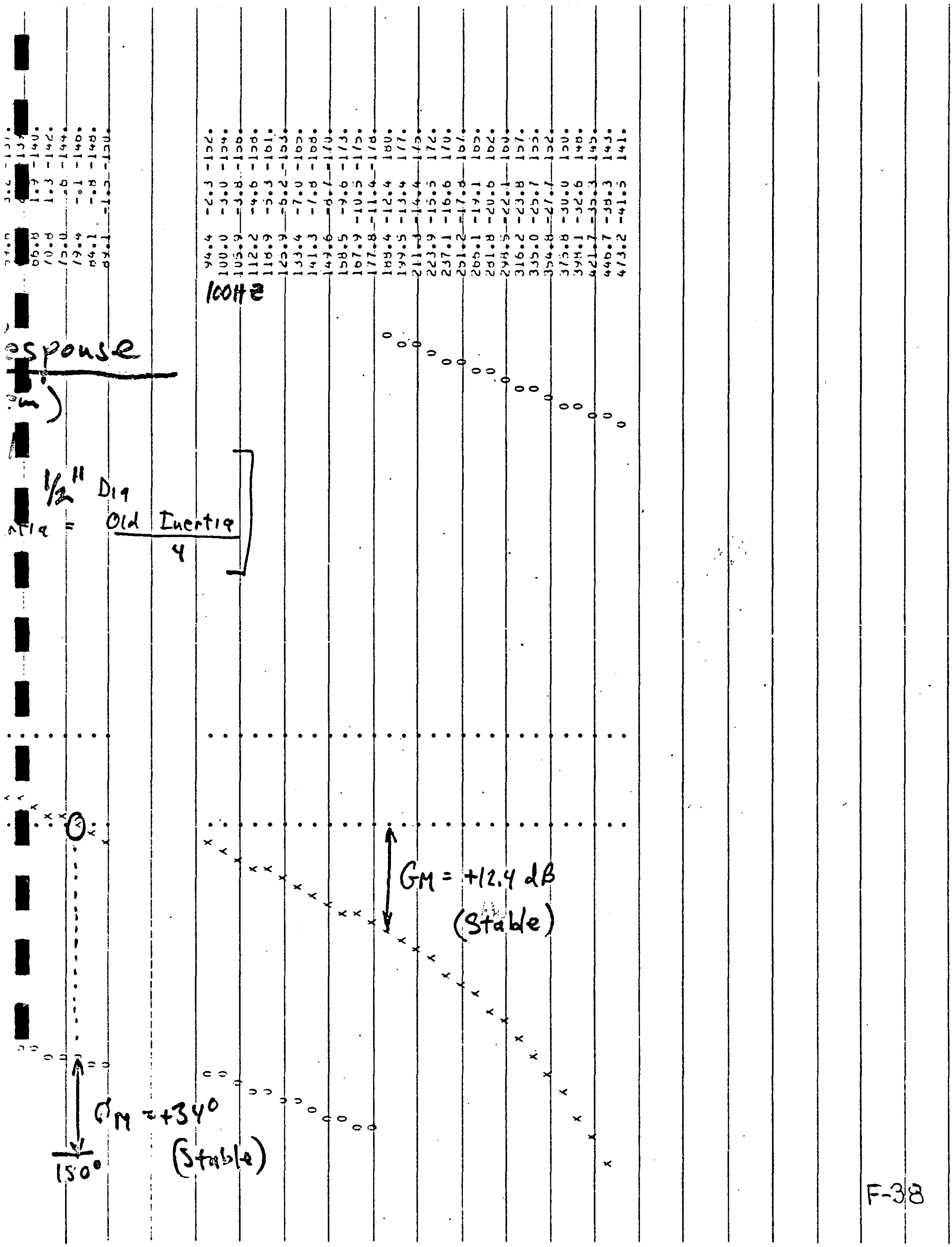
FIG. 8


10HZ
Compensated Open Loop Response
(MCTR Reel Drive System)
4/22/71
Comp. = 0.5 (1+.0159S) / (1+.00159S)
10HZ
100HZ
Idlers = 1/2" Dia
New Inertia = Old
ϕ_M
180°



100Hz
esponse
1/2" Dia
Old Inertia / 4
GM = +12.4 dB
(Stable)
ΦM = +34°
(Stable)
150°

```
13:50:29     #B FOR GAIN.GAIN
UCC 1108 FORTRAN V  :  LEVEL  3.2A
THIS COMPILATION WAS DONE ON 22 APR 71 AT 13:50:29

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

        0001    *CODE    001274
        0000    *DATA    000326
        0002    *BLANK   000000

EXTERNAL REFERENCES (BLOCK, NAME)

        0003    NWDU$
        0004    NI01$
        0005    NI02$
        0006    CDV$
        0007    CABS
        0010    ALOG10
        0011    ATAN2
        0012    NEXP6$
        0013    NSTOP$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001   000014 117G      0001   000025 125G      0001   000033 133G      0001   001225 162G      0000   000037 20F
0001   000043 40L       0000   000041 50F       0000 C 000002 A         0000 C 000004 B         0000 I 000020 BLANK
0000 C 000006 C         0000 C 000010 D         0000 R 000033 DB        0000 I 000021 DOT       0000 C 000012 E
0000 C 000014 FCT       0000 C 000016 FCTCOM    0000 I 000023 FI        0000 R 000032 HERTZ     0000 I 000030 I
0000 I 000031 I$        0000 I 000035 J         0000 I 000036 K         0000 I 000161 LINE      0000 I 000026 M
0000 I 000027 N         0000 R 000024 P         0000 R 000034 PHASE     0000 R 000025 Q         0000 C 000000 S
0000 I 000022 X

 00100      1*    C     GAIN AND PHASE PLOT
 00100      2*    C     OPEN LOOP RESPONSE
 00101      3*          COMPLEX S,A,B,C,D,E,ECI,ECICOM
 00103      4*          INTEGER BLANK,DOT,X,FI
 00104      5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
 00111      6*          DIMENSION LINE(101)
 00111      7*    C     P IS DB PER CHARACTER SPACE
 00112      8*          P=1.
 00112      9*    C     Q IS DEGREES PER CHARACTER SPACE
 00113     10*          Q=4.
 00113     11*    C     M IS DB ZERO LOCATION
 00114     12*          M=41
 00114     13*    C     N IS PHASE ZERO LOCATION
 00115     14*          N=51
 00116     15*          DO 10 I=1,101
 00121     16*       10 LINE(I)=DOT
 00123     17*          WRITE (6,20) LINE
 00131     18*       20 FORMAT (1H1,101A1)
 00132     19*          DO 30 I=1,101
 00135     20*       30 LINE(I)=BLANK
 00137     21*          LINE(M)=DOT
```

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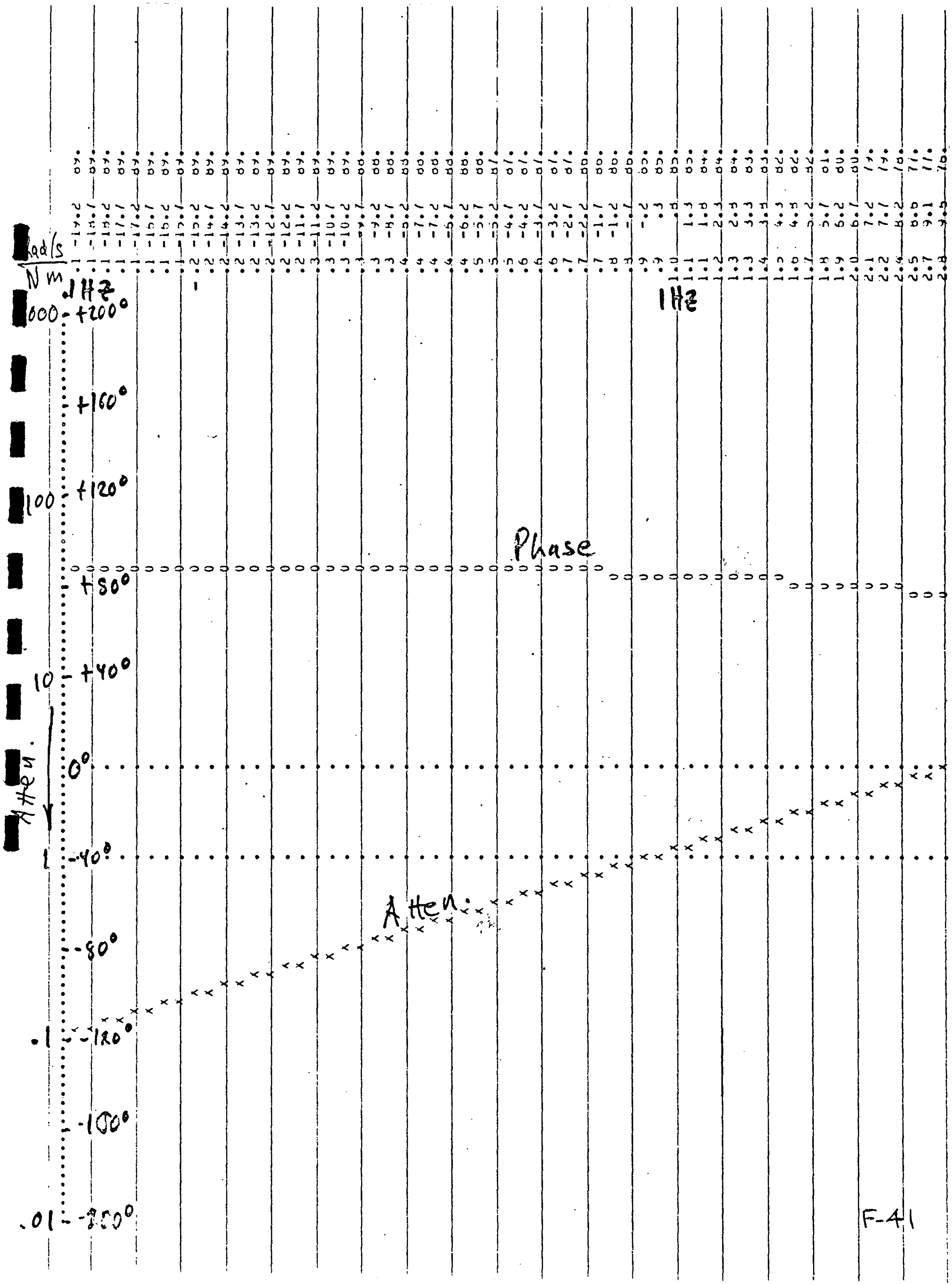
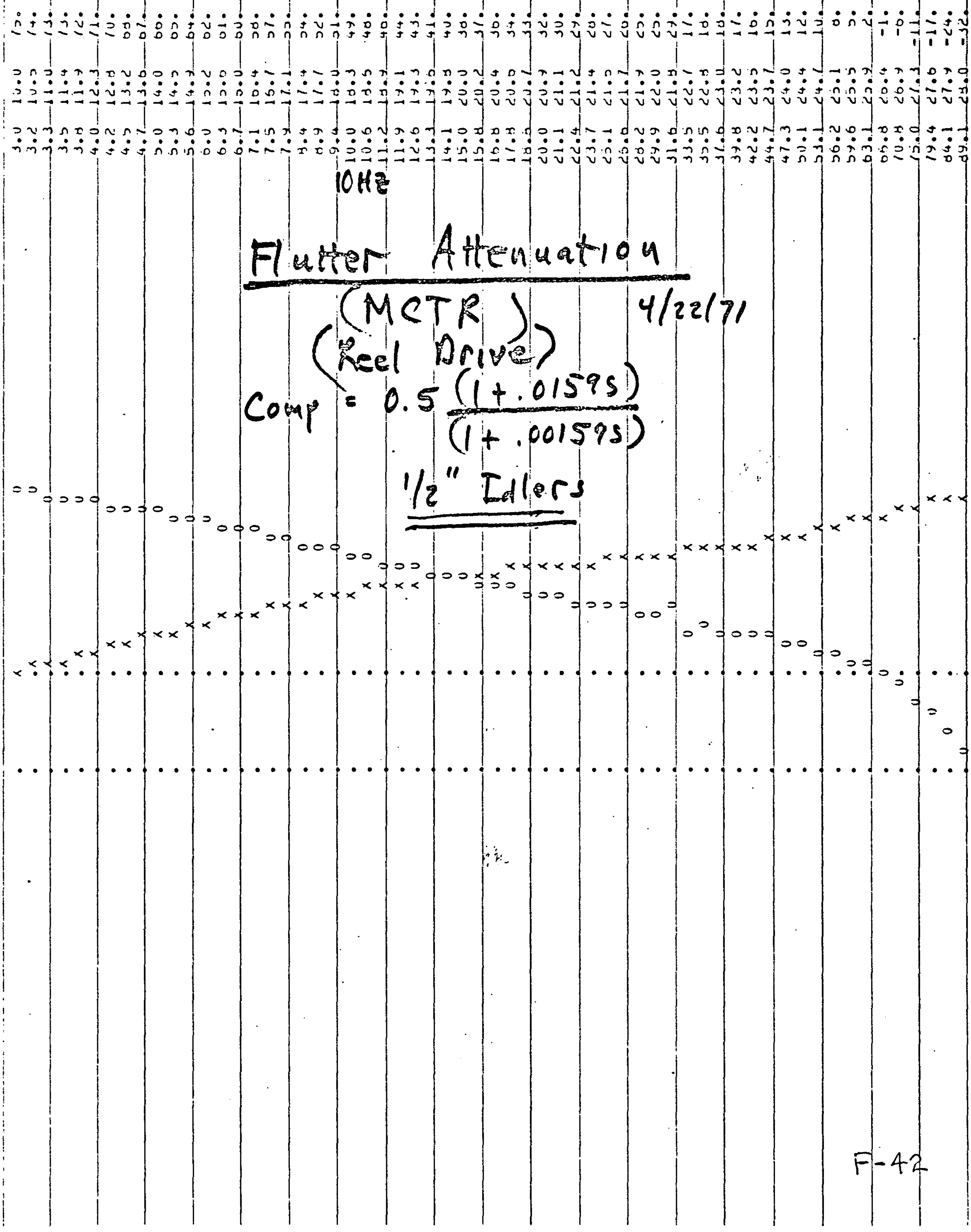
```
00140     22*           LINE(M)=DOT
00141     23*           HERTZ=.1
00142     24*       40  S=CMPLX(0.,6.283*HERTZ)
00143     25*           A=1.+48.9E-6*S**2+603.E-12*S**4+4.E-17*S**6+6.3E-25*S**8
00144     26*           B=26.2*S*(1.02+25.2E-6*S**2+3.1E-12*S**4+7.7E-19*S**6)
00145     27*           C=187.E3*(1.+2.43E-5*S**2+3.1E-12*S**4+7.7E-20*S**6)
00146     28*           D=187.E3*S*(9.3E-7+2.26E-17*S**2+1.54E-19*S**4+2.6E-29*S**6)
00147     29*           E=187.E3*(1.+24.25E-6*S**2+8.3E-13*S**4)
00150     30*           FCT=(11.47/(1.+.0004*S+(.0014+2.6E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
00151     31*           FCTCOM=FCT*((1.+.0159*S)/(1.+.00159*S))*.5
00152     32*           DB=20.*ALOG10(CABS(FCTCOM))
00153     33*           PHASE=57.29*ATAN2(AIMAG(FCTCOM),REAL(FCTCOM))
00154     34*           I=DB/P+FLOAT(M)+0.5
00155     35*           LINE(I)=X
00156     36*           J=PHASE/Q+FLOAT(N)+0.5
00157     37*           LINE(J)=FI
00160     38*           WRITE(6,50) LINE,HERTZ,DB,PHASE
00171     39*       50  FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00172     40*           LINE(I)=BLANK
00173     41*           LINE(J)=BLANK
00174     42*           LINE(M)=DOT
00175     43*           LINE(N)=DOT
00175     44*     C     K IS NUMBER OF STEPS PER DECADE
00176     45*           K=40
00177     46*           HERTZ=HERTZ*10.**(1./FLOAT(K))
00200     47*           IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00203     48*       60  STOP
00204     49*           END

        END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```



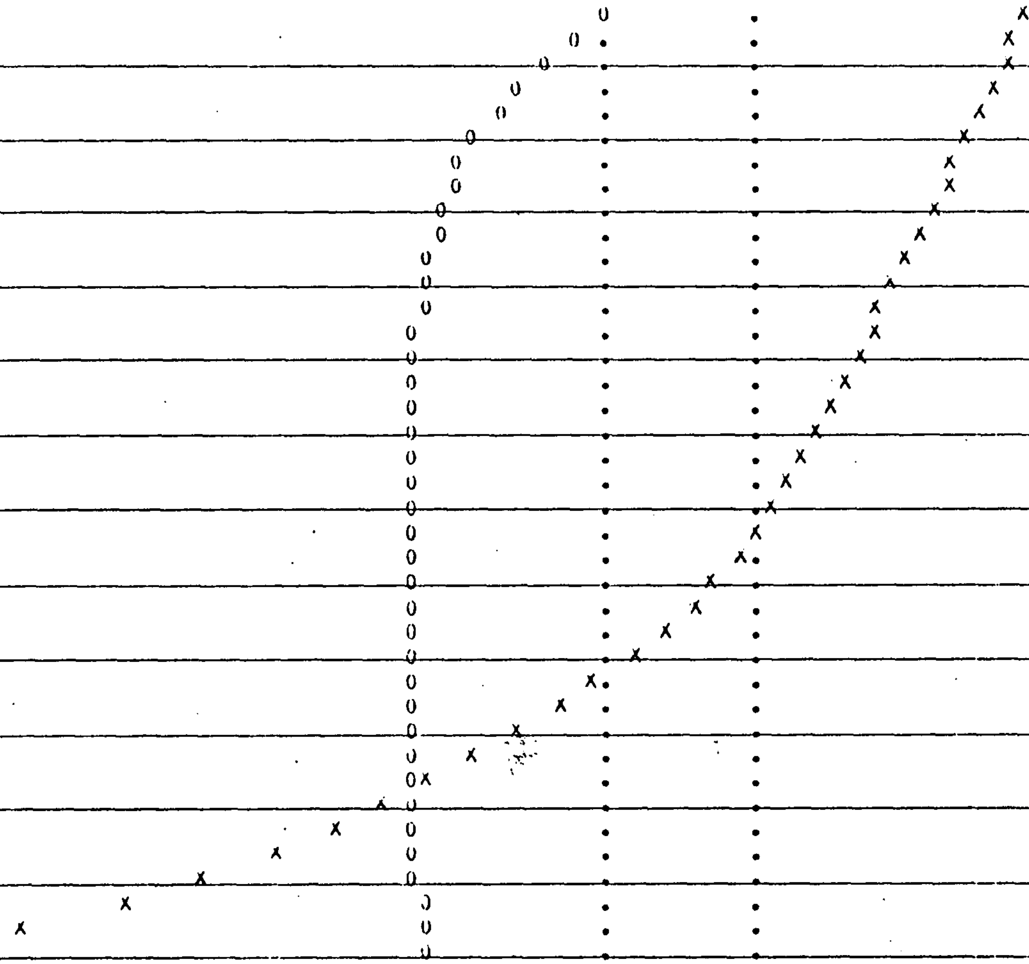
Rad/s
Nm
1Hz
1000
+200°
+160°
100
+120°
Phase
+80°
10
+40°
Atten.
0°
1
-40°
Atten.
-80°
.1
-120°
-160°
.01
-200°

FIG. 9


10Hz
Flutter Attenuation
(MCTR)
(Reel Drive)
4/22/71
Comp = 0.5 (1+.0159s) / (1+.00159s)
1/2" Idlers

100Hz

94.4	27.8	-41.
100.0	27.5	-49.
105.9	26.9	-57.
112.2	26.2	-63.
118.9	25.3	-69.
125.9	24.4	-74.
133.4	23.5	-78.
141.3	22.6	-81.
149.6	21.7	-84.
158.5	20.8	-86.
167.9	19.9	-87.
177.8	19.1	-89.
188.4	18.3	-90.
199.5	17.5	-90.
211.3	16.7	-91.
223.9	15.9	-91.
237.1	15.1	-92.
251.2	14.2	-92.
266.1	13.3	-92.
281.8	12.4	-92.
298.5	11.3	-92.
316.2	10.1	-91.
335.0	8.8	-91.
354.8	7.3	-91.
375.8	5.6	-91.
398.1	3.7	-91.
421.7	1.7	-91.
446.7	-.6	-90.
473.2	-3.1	-90.
501.2	-5.7	-90.
530.9	-8.6	-90.
562.3	-11.6	-90.
595.7	-14.9	-90.
631.0	-18.4	-90.
668.3	-22.2	-90.
707.9	-26.5	-90.
749.9	-31.7	-90.
794.3	-38.5	-90.
841.4	-51.9	-90.



```
15:15:02    DB FOR ATTEN.ATTEN                                   1F9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 22 APR 71 AT 16:15:02

     MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001    *CODE    001332
          0000    *DATA    000334
          0002    *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003    NWDU$
          0004    NI01$
          0005    NI02$
          0006    CMS$
          0007    CABS
          0010    ALOG10
          0011    ATAN2
          0012    NEXP6$
          0013    NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001    000014 117G     0001    000025 125G     0001    000033 133G     0001    001263 164G     0000    000043 20F
     0001    000043 40L      0000    000045 50F      0000 C 000002 A         0000 C 000004 B         0000 I 000024 BLANK
     0000 C 000005 C         0000 C 000010 D         0000 R 000037 DB        0000 I 000025 DOT       0000 C 000012 E
     0000 C 000014 FCT       0000 I 000027 FI        0000 C 000022 F1        0000 R 000036 HERTZ     0000 I 000034 I
     0000 I 000035 I$        0000 I 000041 J         0000 I 000042 K         0000 I 000167 LINE      0000 I 000032 M
     0000 I 000033 N         0000 R 000030 P         0000 R 000040 PHASE     0000 R 000031 Q         0000 C 000015 Q2F2
     0000 C 000020 Q3        0000 C 000000 S         0000 I 000026 X

   00100      1*    C      TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
   00100      2*    C      CLOSED LOOP RESPONSE
   00101      3*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
   00103      4*           INTEGER BLANK,DOT,X,FI
   00104      5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
   00111      6*           DIMENSION LINE(101)
   00111      7*    C      P IS DB PER CHARACTER SPACE
   00112      8*           P=1.
   00112      9*    C      Q IS DEGREES PER CHARACTER SPACE
   00113     10*           Q=4.
   00113     11*    C      M IS DB ZERO LOCATION
   00114     12*           M=41
   00114     13*    C      N IS PHASE ZERO LOCATION
   00115     14*           N=51
   00115     15*           DO 10 I=1,101
   00121     16*        10 LINE(I)=DOT
   00123     17*           WRITE (6,20) LINE
   00131     18*        20 FORMAT (1H1,101A1)
   00132     19*           DO 30 I=1,101
   00135     20*        30 LINE(I)=BLANK
   00137     21*           LINE(M)=DOT
```

```
00140        LINE(N)=DOT
00141        HERTZ=.1
00142     40 S=CMPLX(0.,6.283*HERTZ)
00143        A=1.+43.9E-6*S**2+603.E-12*S**4+4.E-17*S**6+6.3E-25*S**8
00144        B=25.2*S*(1.02+25.2E-6*S**2+3.1E-12*S**4+7.7E-19*S**6)
00145        C=187.E3*(1.+2.43E-5*S**2+3.1E-12*S**4+7.7E-20*S**6)
00146        D=187.E3*S*(9.3E-7+2.26E-17*S**2+1.54E-19*S**4+2.6E-29*S**6)
00147        E=187.E3*(1.+24.25E-6*S**2+8.3E-13*S**4)
00150        F1=(C+D)/(A+B)
00151        Q3= .5*(1+.0159*S)/(1+.00159*S)
00152        Q2F2=((1+.0004*S)/(1+.0004*S+(.0014+2.6E-7*S)*F1))*(E/(A+B))
00153        FCT=(Q2F2)/(1+(Q2F2*Q3*11.4)/(S*(1+.0004*S)))
00154        DB=20.*ALOG10(CABS(FCT))
00155        PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156        I=DB/P+FLOAT(M)+0.5
00157        LINE(I)=X
00160        J=PHASE/Q+FLOAT(N)+0.5
00161        LINE(J)=FI
00162        WRITE(6,50) LINE,HERTZ,DB,PHASE
00173     50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174        LINE(I)=BLANK
00175        LINE(J)=BLANK
00176        LINE(M)=DOT
00177        LINE(N)=DOT
00177  C     K IS NUMBER OF STEPS PER DECADE
00200        K=40
00201        HERTZ=HERTZ*10.**(1./FLOAT(K))
00202        IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205     60 STOP
00205        END
```

END OF UCC 1108 FORTRAN V COMPILATION.   0 *DIAGNOSTIC* MESSAGE(S)

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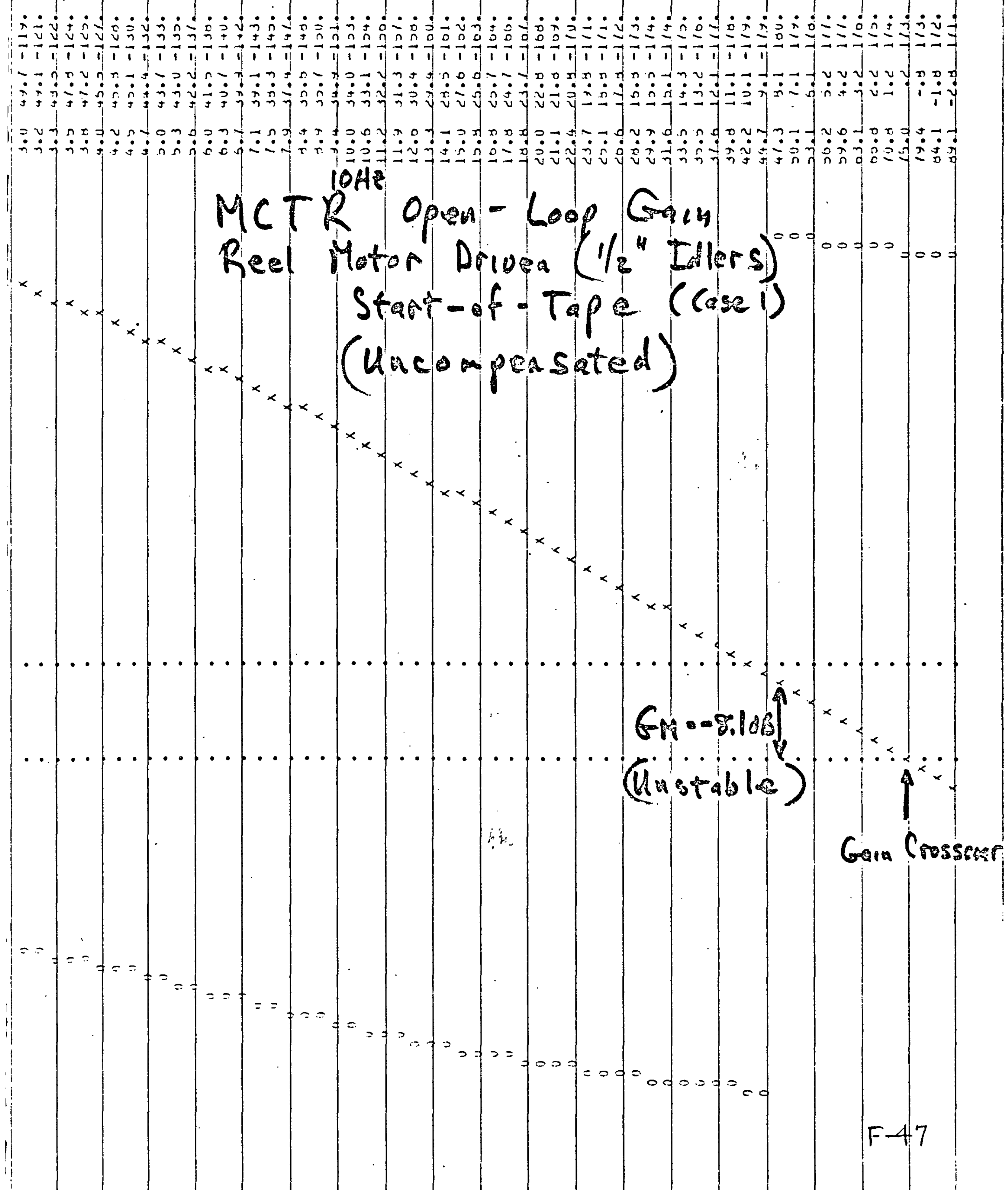
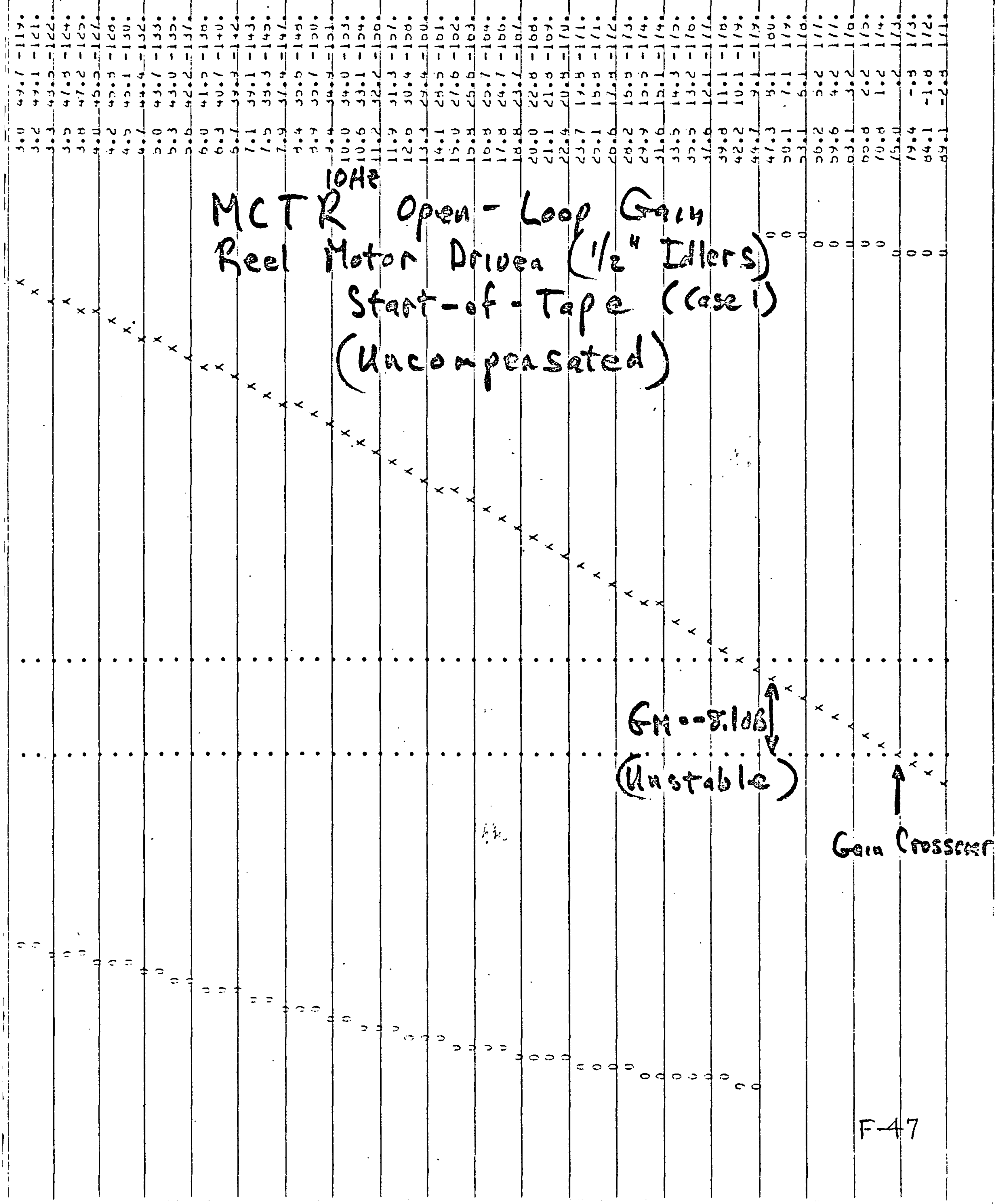
PRECEDING PAGE [redacted] NOT FILMED
MISSING

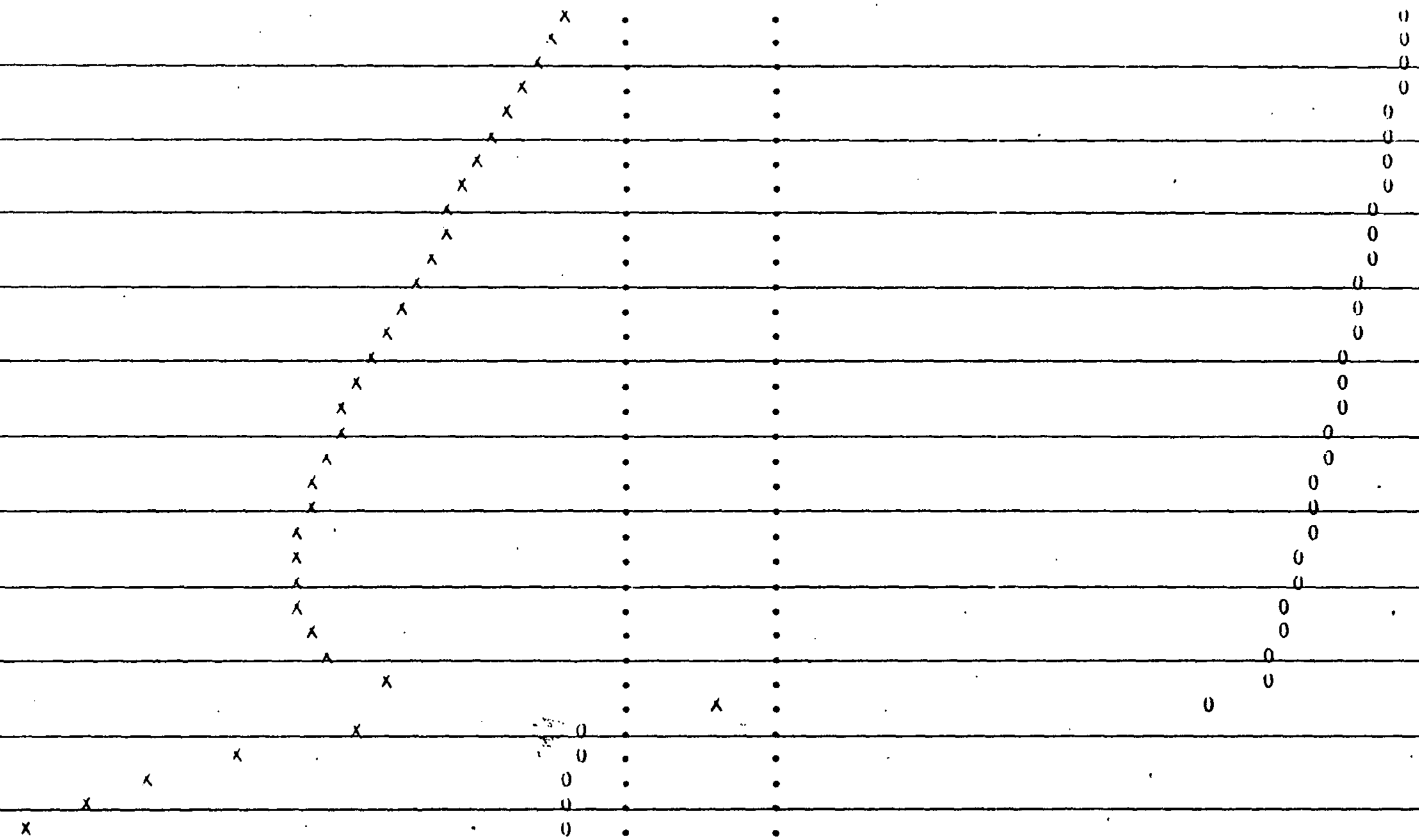
FIG. 10



PRECEDING PAGE [redacted] NOT FILMED
MISSING

FIG. 10





100Hz

94.4	-3.8	170.
100.0	-4.7	169.
105.9	-5.7	168.
112.2	-5.7	167.
118.9	-7.7	166.
125.9	-8.7	165.
133.4	-9.6	164.
141.3	-10.5	162.
149.6	-11.5	161.
158.5	-12.5	160.
167.9	-13.4	159.
177.8	-14.4	157.
188.4	-15.3	156.
199.5	-16.2	155.
211.3	-17.0	153.
223.9	-17.9	152.
237.1	-18.7	150.
251.2	-19.5	149.
266.1	-20.2	147.
281.8	-20.9	145.
298.5	-21.5	144.
316.2	-21.9	142.
335.0	-22.3	140.
354.8	-22.4	139.
375.8	-22.1	137.
398.1	-21.4	135.
421.7	-19.7	133.
446.7	-15.7	131.
473.2	6.4	116.
501.2	-18.2	-50.
530.9	-26.3	-52.
562.3	-31.8	-54.
595.7	-36.2	-56.
631.0	-40.1	-57.

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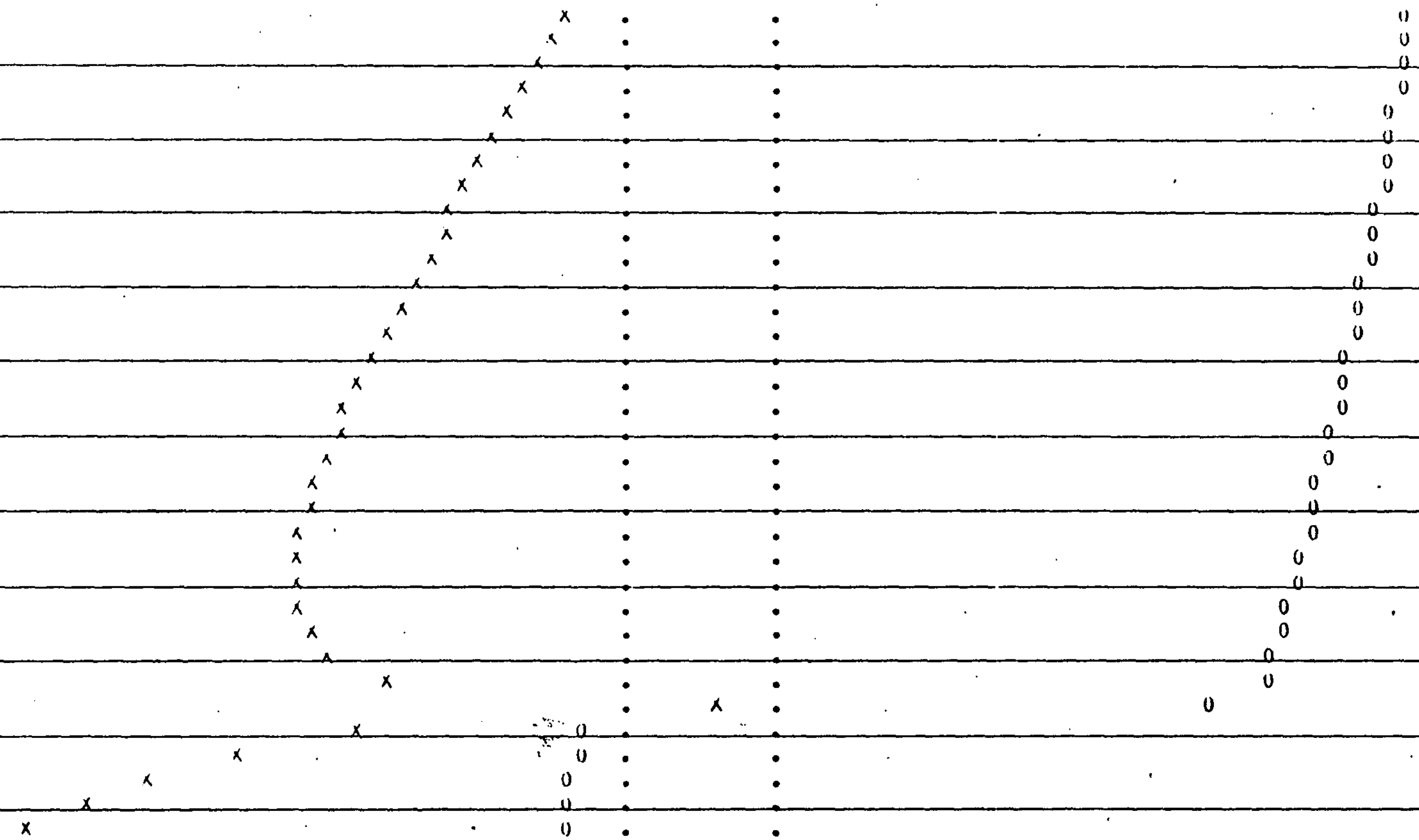

100Hz

94.4	-3.8	170.
100.0	-4.7	169.
105.9	-5.7	168.
112.2	-6.7	167.
118.9	-7.7	166.
125.9	-8.7	165.
133.4	-9.6	164.
141.3	-10.5	162.
149.6	-11.5	161.
158.5	-12.5	160.
167.9	-13.4	159.
177.8	-14.4	157.
188.4	-15.3	156.
199.5	-16.2	155.
211.3	-17.0	153.
223.9	-17.9	152.
237.1	-18.7	150.
251.2	-19.5	149.
266.1	-20.2	147.
281.8	-20.9	145.
298.5	-21.5	144.
316.2	-21.9	142.
335.0	-22.3	140.
354.8	-22.4	139.
375.8	-22.1	137.
398.1	-21.4	135.
421.7	-19.7	133.
446.7	-15.7	131.
473.2	6.4	116.
501.2	-18.2	-50.
530.9	-26.3	-52.
562.3	-31.8	-54.
595.7	-36.2	-56.
631.0	-40.1	-57.

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```
10:07:31      ... ...                                IF9002
UCC 1108 F... ... : LEVEL    3.2A
THIS COMPILATION WAS DONE ON ... AT 10:07:31

MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001   *CODE    001145
          0000   *DATA    000312
          0002   *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003   ...
          0004   ...
          0005   ...
          0006   CAVS
          0007   CAMS
          0010   ALOG10
          0011   ATAN2
          0012   NEXP6$
          0013   NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001   000061 117G     0001   000025 125G     0001   000033 133G     0001   001076 161G     0000   000035 20F
     0001   000043 30L      0000   000037 50F      0000 C 000002 A       0000 C 000004 B       0000 I 000015 BLANK
     0000 C 000006 C       0000 C 000010 D       0000 R 000031 DB      0000 I 000017 DOT     0000 C 000012 E
     0000 C 000001 FCT     0000 I 000021 FI      0000 R 000030 HERTZ   0000 I 000026 I       0000 I 000027 I$
     0000 I 000033 J       0000 I 000034 K       0000 I 000145 LINE    0000 I 000024 M       0000 I 000025 N
     0000 R 000022 P       0000 R 000032 PHASE   0000 R 000023 Q       0000 C 000000 S       0000 I 000020 X

  00100       1*    C     OPEN LOOP RESPONSE
  00100       2*    C     GAIN AND PHASE PLOT
  00101       3*          COMPLEX S,A,B,C,D,E,FCT
  00103       4*          INTEGER BLANK,DOT,X,FI
  00104       5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
  00111       6*          DIMENSION LINE(101)
  00111       7*    C     P IS DB PER CHARACTER SPACE
  00112       8*          P=1.
  00112       9*    C     Q IS DEGREES PER CHARACTER SPACE
  00113      10*          Q=4.
  00113      11*    C     M IS DB ZERO LOCATION
  00114      12*          M=41
  00114      13*    C     N IS PHASE ZERO LOCATION
  00115      14*          N=61
  00116      15*          DO 10 I=1,101
  00121      16*       10 LINE(I)=DOT
  00123      17*          WRITE (6,20) LINE
  00131      18*       20 FORMAT (1H1,101A1)
  00132      19*          DO 30 I=1,101
  00135      20*       30 LINE(I)=BLANK
  00137      21*          LINE(M)=DOT
  00140      22*          LINE(N)=DOT
```

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```
00141   23*        HERTZ=.1
00142   24*     40 S=CMPLX(0.,6.283*HERTZ)
00143   25*        A=1.+40.25E-6*S**2+333.2E-12*S**4+24.94E-18*S**6+.337E-24*S**8
00144   26*        B=1.35*S*(1.+25.25E-6*S**2+3.55E-12*S**4+.0814E-18*S**6)
00145   27*        C=187.53*(1.+25.3E-6*S**2+3.60E-12*S**4+.0816E-18*S**6)
00146   28*        D=187.53*S*(1.017E-6+26.68E-12*S**2+1.736E-18*S**4+.0277E-24*S**6)
00147   29*        E=187.53*(1.+26.25E-6*S**2+.7322E-12*S**4)
00150   30*        FCT=(17.17(1.+.0994*S+(.0026+3.9E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
00151   31*        DB=20.*ALOG10(CABS(FCT))
00152   32*        PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00153   33*        I=DB/P+FLOAT(M)+0.5
00154   34*        LINE(I)=X
00155   35*        J=PHASE/Q+FLOAT(N)+0.5
00156   36*        LINE(J)=PI
00157   37*        WRITE(6,50) LINE,HERTZ,DB,PHASE
00170   38*     50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00171   39*        LINE(I)=BLANK
00172   40*        LINE(J)=BLANK
00173   41*        LINE(M)=DOT
00174   42*        LINE(N)=DOT
00174   43*   C    K IS NUMBER OF STEPS PER DECADE
00175   44*        K=40
00176   45*        HERTZ=HERTZ*10.**(1./FLOAT(K))
00177   46*        IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00202   47*     60 STOP
00203   48*        END

     END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```

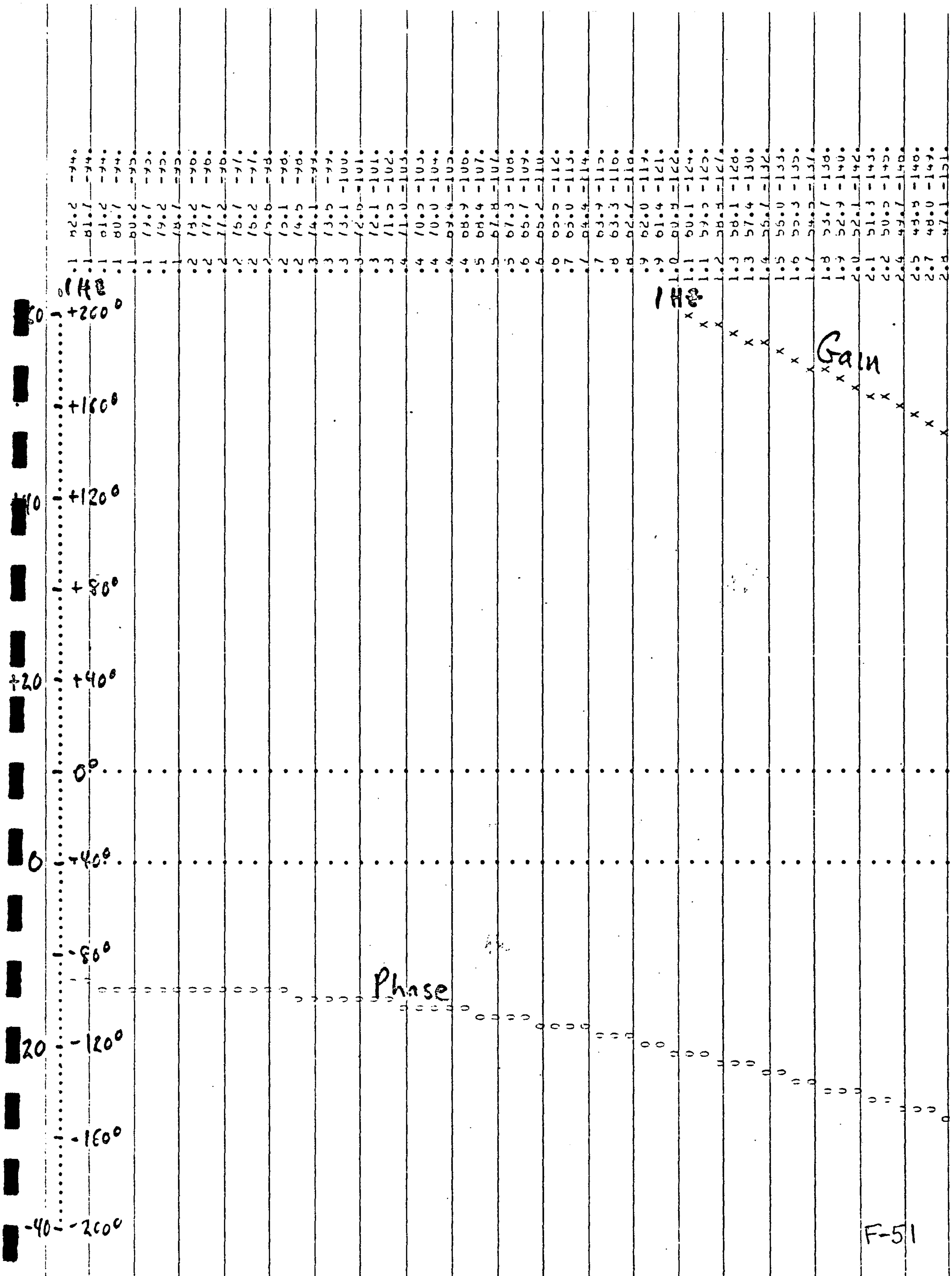
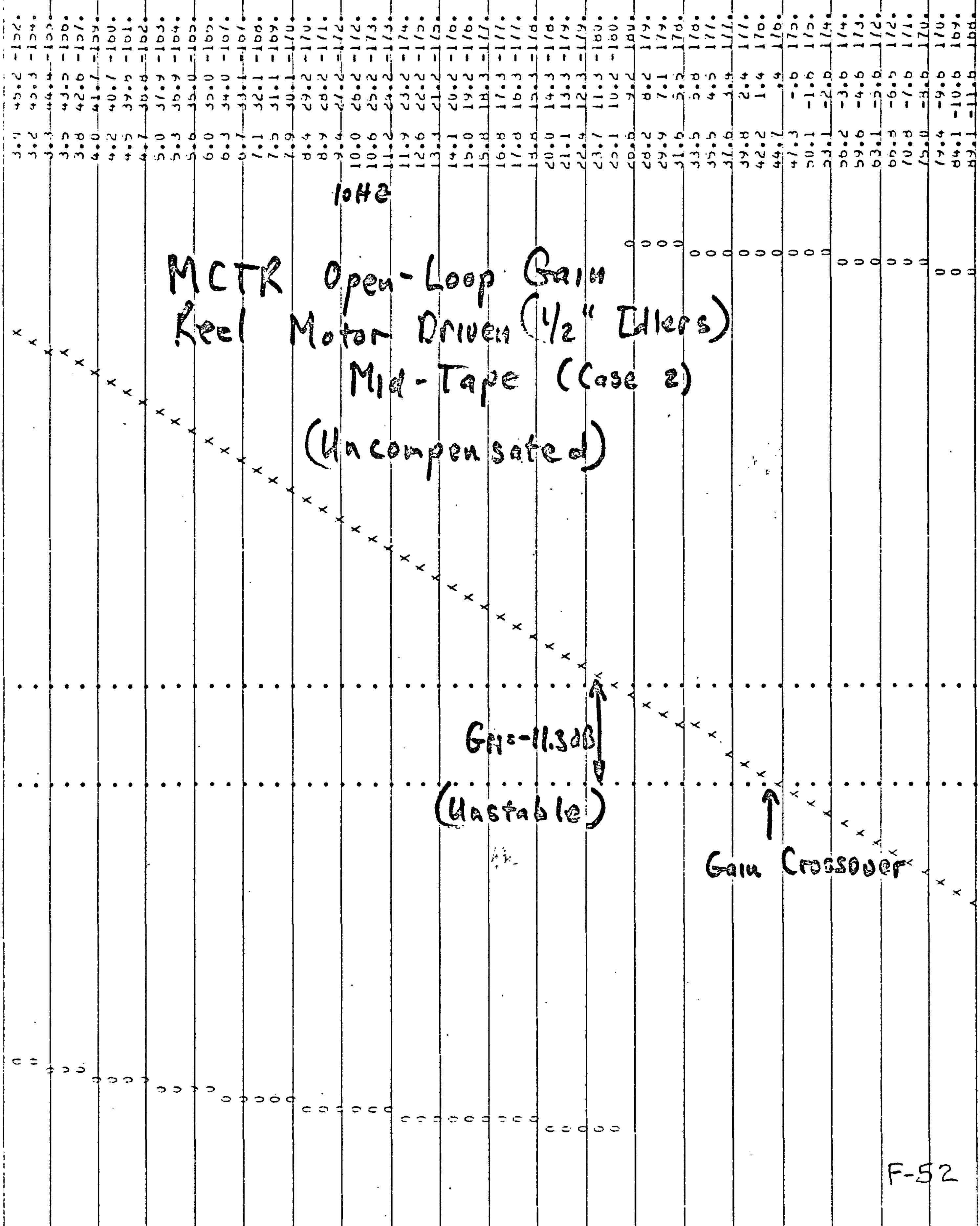
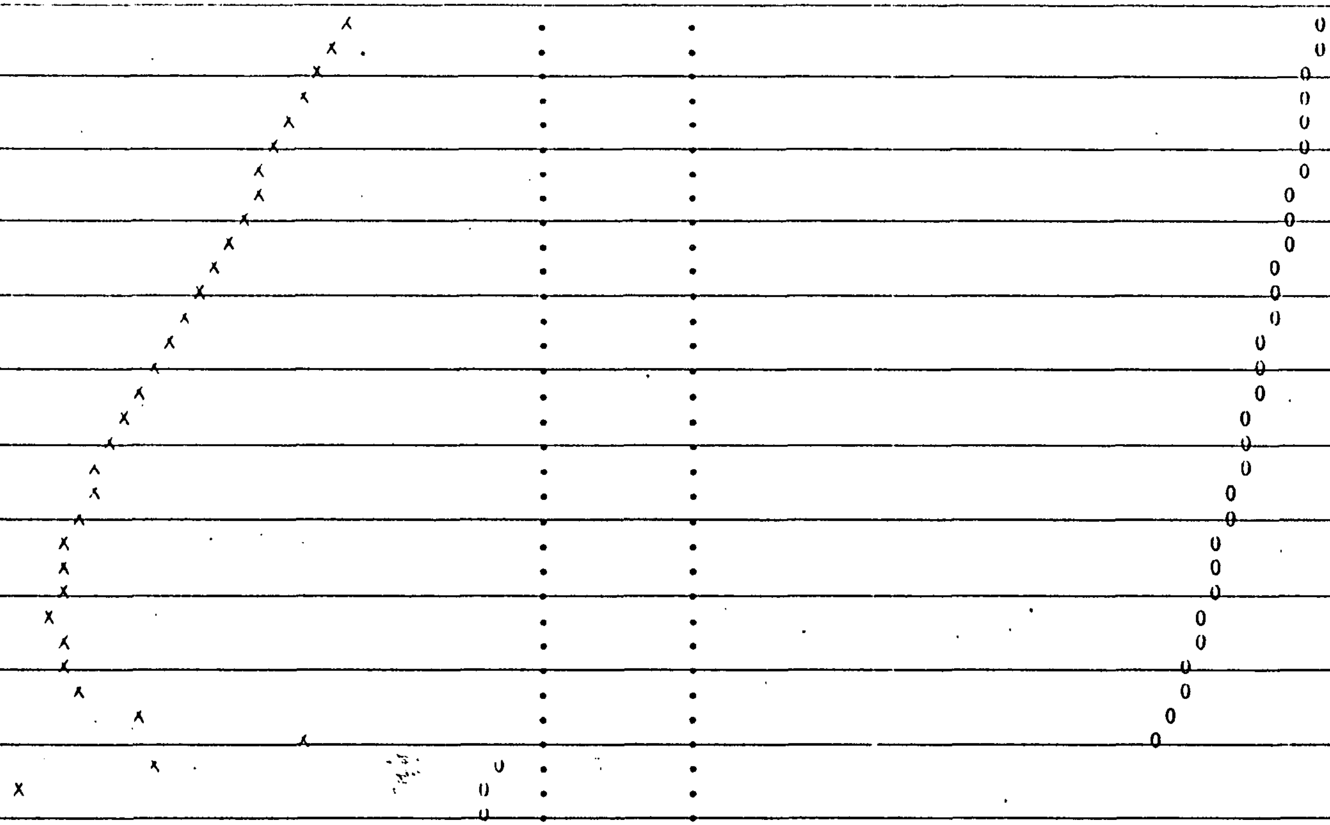

1 Hz
Gain
Phase
+200°
+160°
+120°
+80°
+40°
0°
-40°
-80°
-120°
-160°
-200°
+20
0
20
-40

FIG. 11


10HZ
MCTR Open-Loop Gain
Reel Motor Driven (1/2" Idlers)
Mid-Tape (Case 2)
(Uncompensated)
GH=-11.3dB
(Unstable)
Gain Crossover



100 HZ

94.4	-12.6	168.
100.0	-13.6	167.
105.9	-14.5	166.
112.2	-15.6	165.
118.9	-16.5	164.
125.9	-17.5	163.
133.4	-18.5	162.
141.3	-19.5	161.
149.6	-20.5	160.
158.5	-21.4	159.
167.9	-22.4	158.
177.8	-23.3	156.
188.4	-24.3	155.
199.5	-25.2	154.
211.3	-26.1	152.
223.9	-27.0	151.
237.1	-27.9	149.
251.2	-28.7	148.
266.1	-29.5	146.
281.8	-30.3	145.
298.5	-31.0	143.
316.2	-31.6	142.
335.0	-32.1	140.
354.8	-32.4	138.
375.8	-32.6	137.
398.1	-32.5	135.
421.7	-31.9	133.
446.7	-30.5	131.
473.2	-27.3	129.
501.2	-15.1	125.
530.9	-25.7	-52.
562.3	-35.2	-54.
595.7	-41.1	-56.

```
15:12:57     DB FOR ATTEN.ATTEN                                        1F9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 27 APR 71 AT 16:13:00

   MAIN PROGRAM

   STORAGE USED (BLOCK, NAME, LENGTH)

        0001    *CODE    001130
        0000    *DATA    000312
        0002    *BLANK   000000

   EXTERNAL REFERENCES (BLOCK, NAME)

        0003    NOUO$
        0004    NIOI$
        0005    NIO2$
        0006    NOV$
        0007    CABS
        0010    ALOG10
        0011    ATAN2
        0012    NEXP6$
        0013    NSTOP$

   STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

   0001     000014 117G       0001     000025 125G       0001     000033 133G       0001     001061 161G       0000     000035 20F
   0001     000043 30L        0000     000037 50F        0000 C 000002 A           0000 C 000004 B           0000 I 000015 BLANK
   0000 C 000005 C            0000 C 000010 D           0000 R 000031 DB          0000 I 000017 DOT         0000 C 000012 E
   0000 C 000014 FCT          0000 I 000021 FI          0000 R 000030 HERTZ       0000 I 000026 I           0000 I 000027 I$
   0000 I 000033 J            0000 I 000034 K           0000 I 000145 LINE        0000 I 000024 M           0000 I 000025 N
   0000 R 000022 P            0000 R 000032 PHASE       0000 R 000023 Q           0000 C 000000 S           0000 I 000020 X

 00100      1*   C      OPEN LOOP RESPONSE
 00100      2*   C      GAIN AND PHASE PLOT
 00101      3*          COMPLEX S,A,B,C,D,E,FCT
 00103      4*          INTEGER BLANK,DOT,X,FI
 00104      5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
 00111      6*          DIMENSION LINE(101)
 00111      7*   C      P IS DB PER CHARACTER SPACE
 00112      8*          P=1.
 00112      9*   C      Q IS DEGREES PER CHARACTER SPACE
 00113     10*          Q=4.
 00113     11*   C      M IS DB ZERO LOCATION
 00114     12*          M=41
 00114     13*   C      N IS PHASE ZERO LOCATION
 00115     14*          N=51
 00116     15*          DO 10 I=1,101
 00121     16*       10 LINE(I)=DOT
 00123     17*          WRITE (5,20) LINE
 00131     18*       20 FORMAT (1H1,101A1)
 00132     19*          DO 30 I=1,101
 00135     20*       30 LINE(I)=BLANK
 00137     21*          LINE(M)=DOT
 00140     22*          LINE(N)=DOT
```

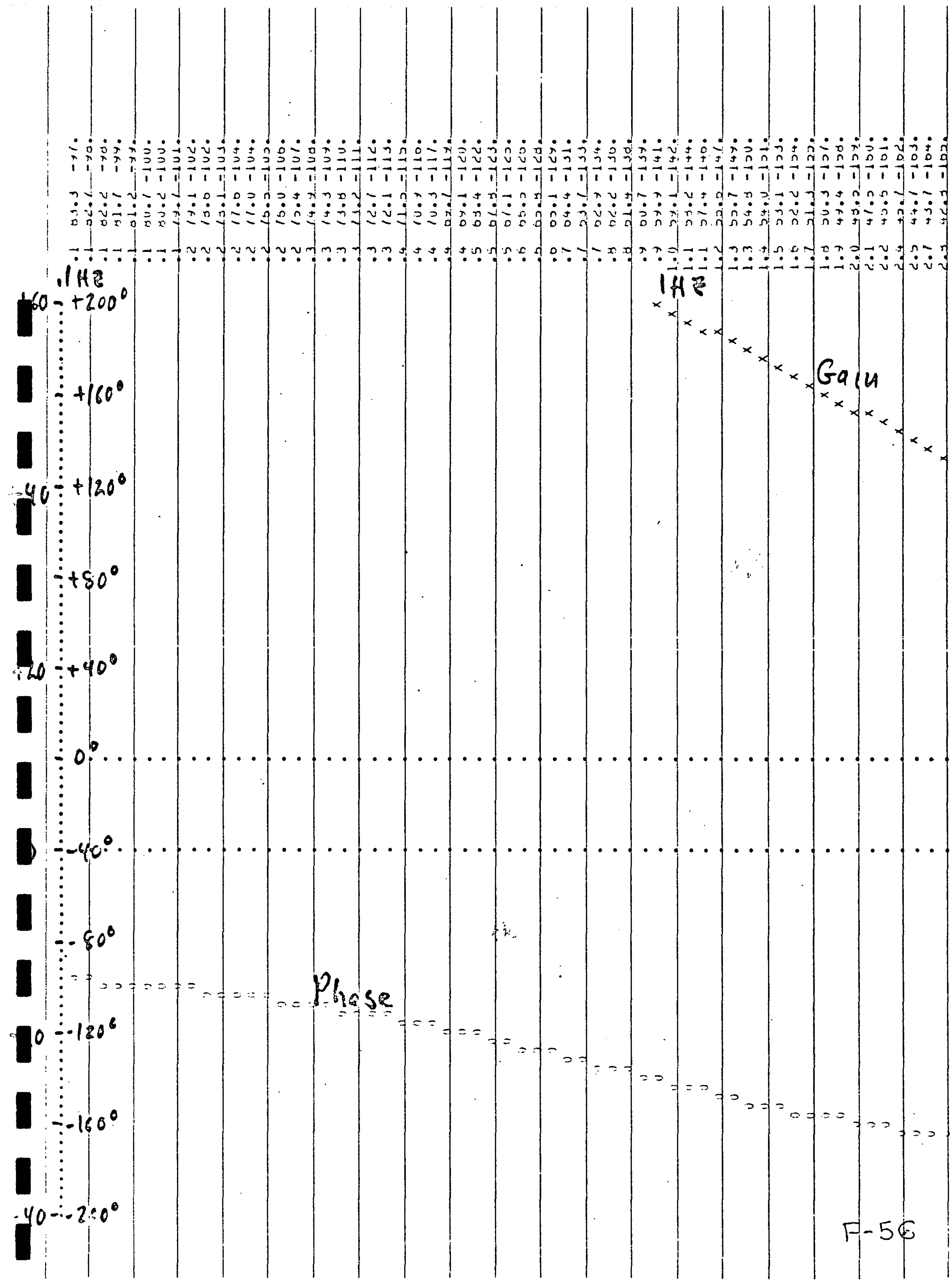
```
      HERTZ=.1
   40 S=CMPLX(0.,6.283*HERTZ)
      A=1.+43.5E-6*S**2+.31.3E-12*S**4+41.88E-18*S**6+.742E-24*S**8
      B=26.1E*S*(1.+24.32E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
      C=187.E3*(1.+24.3E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
      D=187.E3*S*(40.92E-6+30.07E-12*S**2+1.600E-18*S**4+.0283E-24*S**6)
      E=187.E3*(1.+24.32E-6*S**2+.8615E-12*S**4)
      FCT=(11.4/(1.+.0004*S+(.0014+2.6E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
      DB=20.*ALOG10(CABS(FCT))
      PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
      I=DB/P+FLOAT(M)+0.5
      LINE(I)=X
      J=PHASE/Q+FLOAT(N)+0.5
      LINE(J)=PI
      WRITE(6,50) LINE,HERTZ,DB,PHASE
   50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
      LINE(I)=BLANK
      LINE(J)=BLANK
      LINE(M)=OUT
      LINE(N)=OUT
C     K IS NUMBER OF STEPS PER DECADE
      K=40
      HERTZ=HERTZ*10.**(1./FLOAT(K))
      IF ((FLOAT(4)-1.)*P+DB) 60,60,40
   60 STOP
      END
```

END OF UCC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC* MESSAGE(S)

Case 2

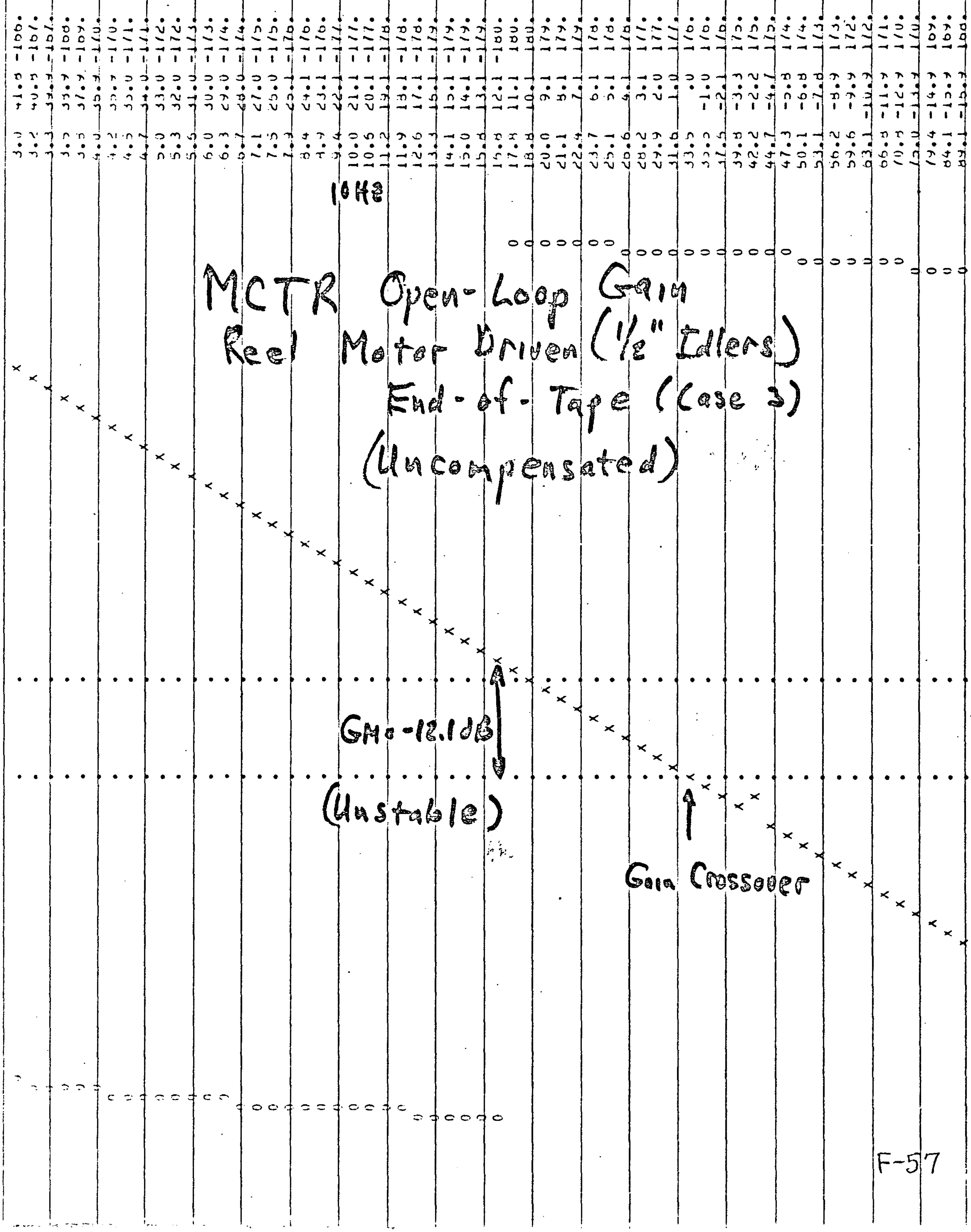
Uncompensated

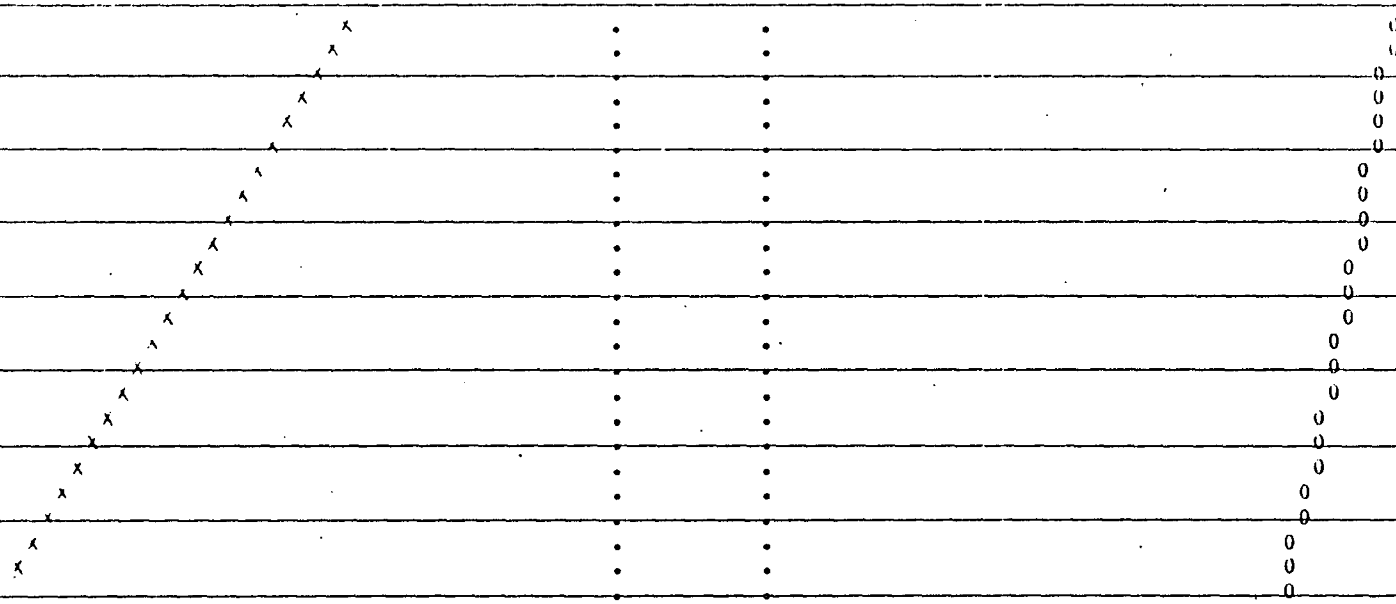
11.3 dB 23.7 Hz



.1HZ
1HZ
+200°
+160°
+120°
+80°
+40°
0°
-40°
-80°
-120°
-160°
Gain
Phase

FIG. 12


10 Hz
MCTR Open-Loop Gain
Reel Motor Driven (1/2" Idlers)
End-of-Tape (Case 3)
(Uncompensated)
GM = -12.1dB
(Unstable)
Gain Crossover



100 HE

94.4	-17.9	167.
100.0	-18.9	166.
105.9	-19.3	165.
112.2	-21.0	165.
118.9	-22.0	164.
125.9	-23.0	163.
133.4	-24.0	162.
141.3	-25.0	161.
149.5	-25.0	160.
158.5	-27.0	158.
167.9	-28.0	157.
177.3	-29.0	156.
188.4	-30.0	155.
199.5	-31.0	154.
211.3	-32.0	152.
223.9	-33.0	151.
237.1	-34.0	149.
251.2	-35.0	148.
265.1	-35.0	146.
281.8	-37.0	145.
298.5	-37.9	143.
316.2	-38.8	142.
335.0	-39.7	140.
354.8	-40.6	138.

```
10:45:34    -1 - OR ATTENUATION                                   1F9002
DOC 1104 FORTRAN V : LEVEL  3.2A
THIS COMPILATION WAS DONE ON 24 APR 71 AT 10:06:45

MAIN PROGRAM

  STORAGE USED (BLOCK, NAME, LENGTH)

      0001   *CODE    001120
      0000   *DATA    000312
      0002   *BLANK   000000

  EXTERNAL REFERENCES (BLOCK, NAME)

      0003   NIOU$
      0004   NIO1$
      0005   NIO2$
      0006   CDV$
      0007   CABS
      0010   ALOG10
      0011   ATAN2
      0012   NEXP6$
      0013   NSTOP$

  STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

  0001     000014 117G     0001     000025 125G     0001     000033 133G     0001     001051 161G     0000     000035 20F
  0001     000043 40L      0000     000037 30F      0000 C 000002 A         0000 C 000004 B         0000 I 000015 BLANK
  0000 C 000006 C          0000 C 000010 D         0000 R 000031 DB        0000 I 000017 DOT       0000 C 000012 E
  0000 C 000014 FCT        0000 I 000021 FI        0000 R 000030 HERTZ     0000 I 000026 I         0000 I 000027 I$
  0000 I 000033 J          0000 I 000034 K         0000 I 000145 LINE      0000 I 000024 M         0000 I 000025 N
  0000 R 000022 P          0000 R 000032 PHASE     0000 R 000023 Q         0000 C 000000 S         0000 I 000020 X

 00100      1*   C      OPEN LOOP RESPONSE
 00100      2*   C      GAIN AND PHASE PLOT
 00101      3*          COMPLEX S,A,B,C,D,E,FCT
 00103      4*          INTEGER BLANK,DOT,X,FI
 00104      5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
 00111      6*          DIMENSION LINE(101)
 00111      7*   C      P IS DB PER CHARACTER SPACE
 00112      8*          P=1.
 00112      9*   C      Q IS DEGREES PER CHARACTER SPACE
 00113     10*          Q=4.
 00113     11*   C      M IS DB ZERO LOCATION
 00114     12*          M=41
 00114     13*   C      N IS PHASE ZERO LOCATION
 00115     14*          N=51
 00116     15*          DO 10 I=1,101
 00121     16*       10 LINE(I)=DOT
 00123     17*          WRITE (6,20) LINE
 00131     18*       20 FORMAT (1H1,101A1)
 00132     19*          DO 30 I=1,101
 00135     20*       30 LINE(I)=BLANK
 00137     21*          LINE(M)=DOT
 00140     22*          LINE(N)=DOT
```

```
00141    23*         HERTZ=.1
00142    24*      40 S=CMPLX(0.,6.283*HERTZ)
00143    25*         A=1.+4.35E-6*S**2+3.3.2E-12*S**4+24.93E-18*S**6+.337E-24*S**8
00144    26*         B=35.71*S*(1.+14.60E-6*S**2+1.35E-12*S**4+.0302E-18*S**6)
00145    27*         C=187.3*(1.+14.6E-6*S**2+1.36E-12*S**4+.0303E-18*S**6)
00146    28*         D=187.3*S*(0.578E-6+3.300E-12*S**2+0.644E-18*S**4+.0103E-24*S**5)
00147    29*         E=187.3*(1.+14.60E-6*S**2+.5429E-12*S**4)
00150    30*         FCT=(7.25/(1.+.0004*S+(.0010+2.1E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
00151    31*         DB=20.*ALOG10(CABS(FCT))
00152    32*         PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00153    33*         I=DB/P+FLOAT(M)+0.5
00154    34*         LINE(I)=X
00155    35*         J=PHASE/Q+FLOAT(N)+0.5
00156    36*         LINE(J)=PI
00157    37*         WRITE(6,50) LINE,HERTZ,DB,PHASE
00170    38*      50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00171    39*         LINE(I)=BLANK
00172    40*         LINE(J)=BLANK
00173    41*         LINE(M)=DOT
00174    42*         LINE(N)=DOT
00174    43*    C    K IS NUMBER OF STEPS PER DECADE
00175    44*         K=40
00176    45*         HERTZ=HERTZ*10.**(1./FLOAT(K))
00177    46*         IF ((FLOAT(M)-1.)**2+DB) 60,60,40
00202    47*      60 STOP
00203    48*         END

   END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```

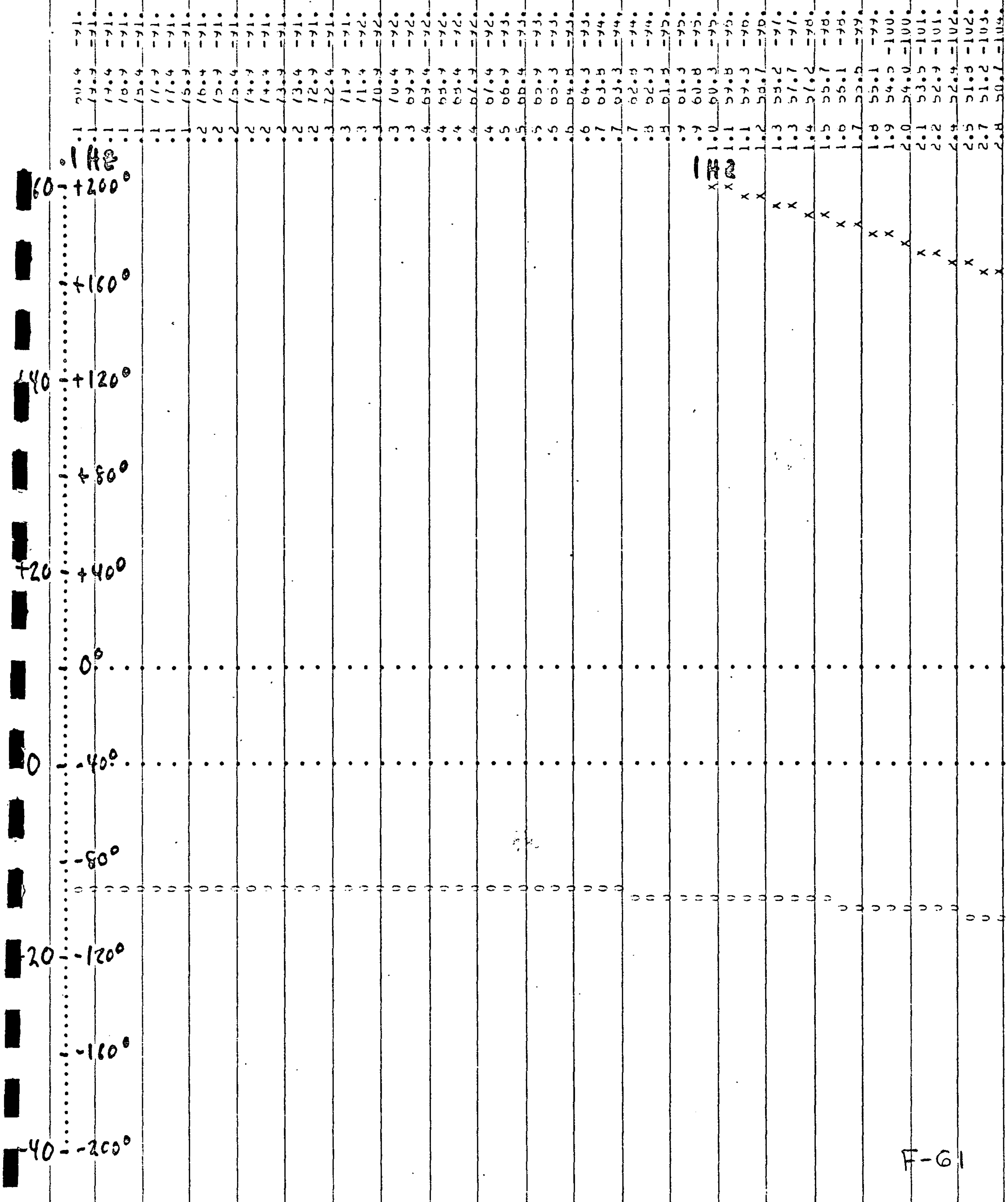
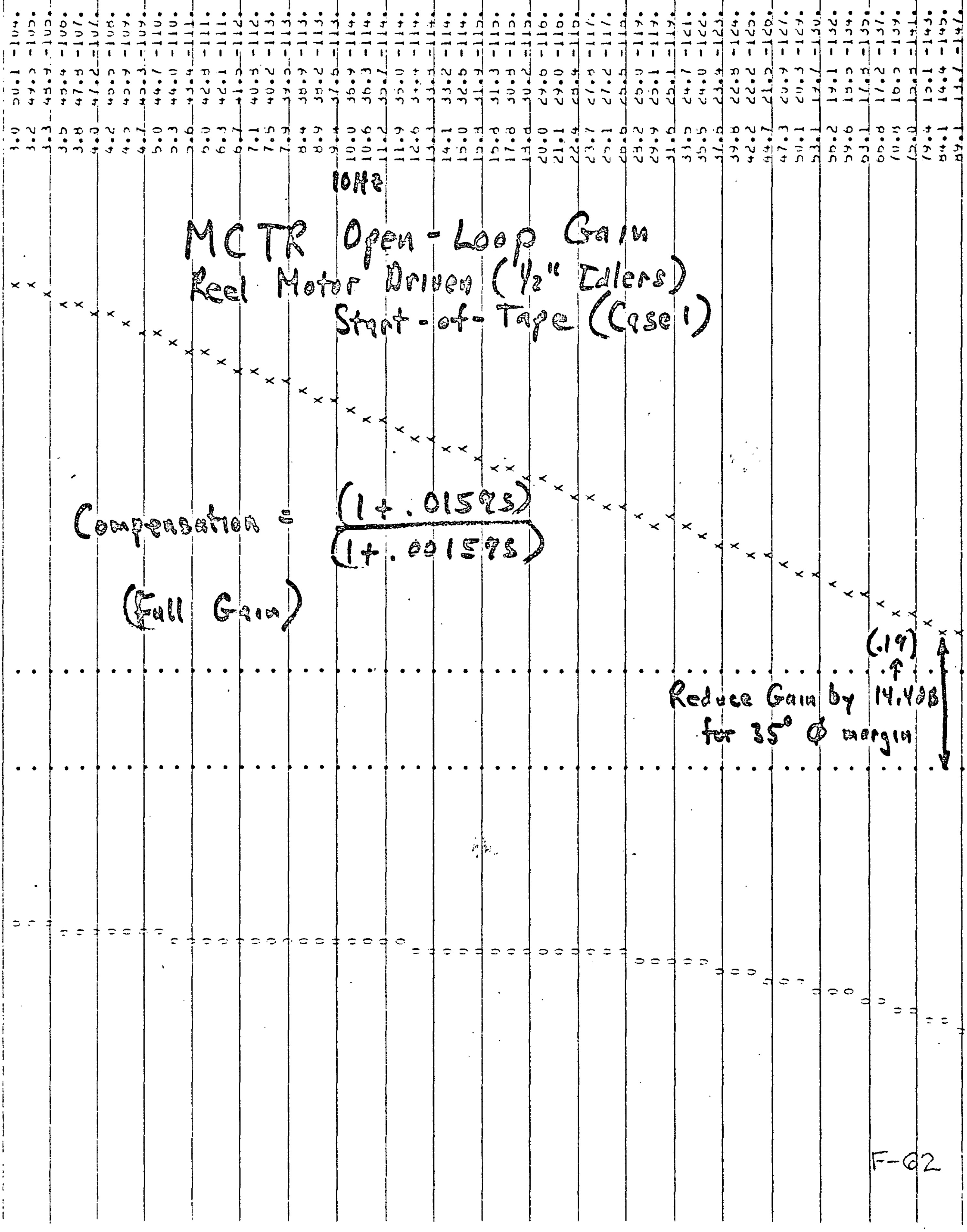
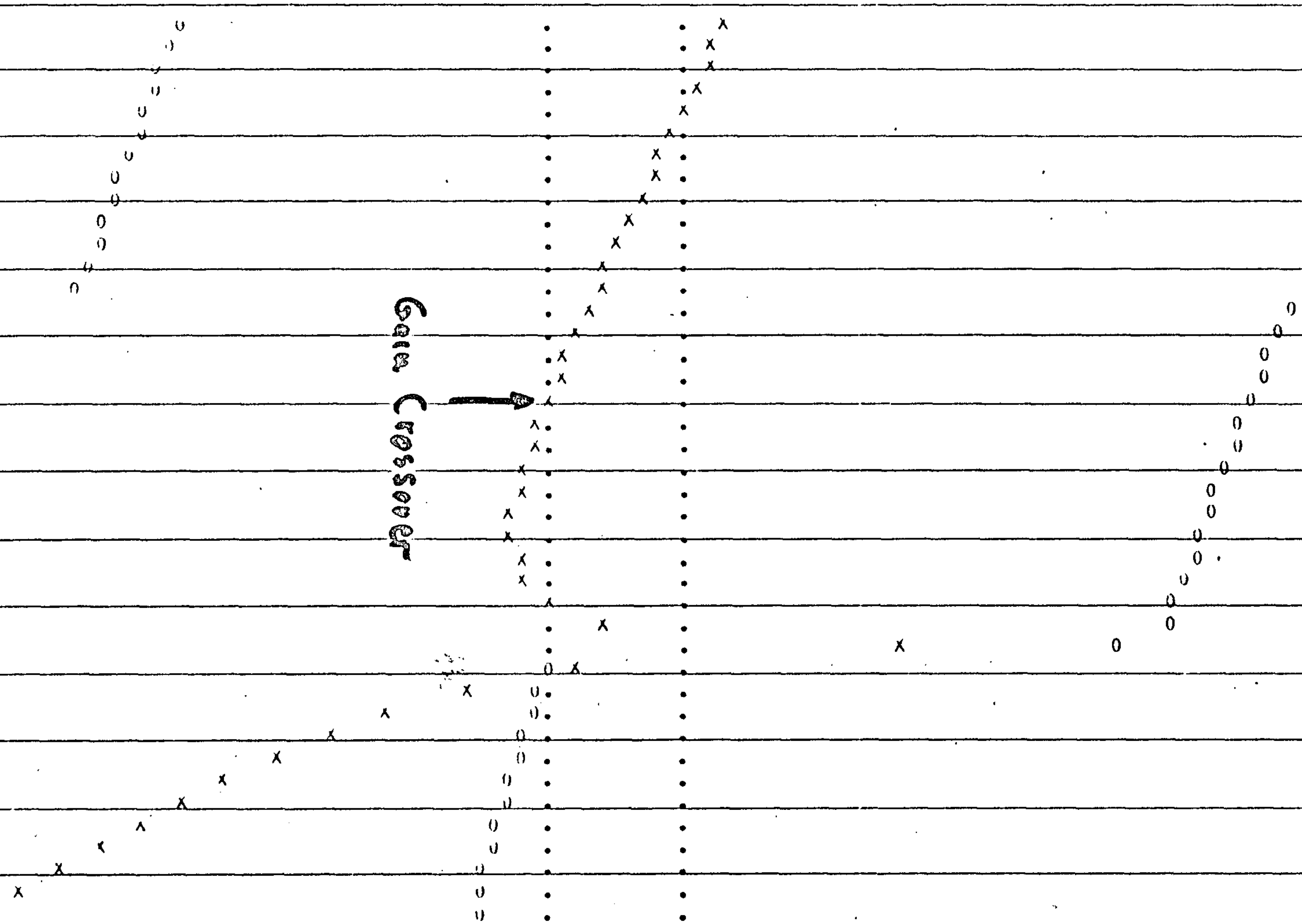

.1 Hz
1 Hz
60 +200°
+160°
40 +120°
+80°
+20 +40°
0°
0 -40°
-80°
-20 -120°
-160°
-40 -200°

FIG. 13



10Hz
MCTR Open-Loop Gain
Reel Motor Driven (½" Idlers)
Start-of-Tape (Case 1)
Compensation = (1 + .0159S) / (1 + .00159S)
(Full Gain)
(.19)
Reduce Gain by 14.4dB
for 35° Ø margin



100 Hz

94.4	13.0	-150.
100.0	12.3	-152.
105.9	11.5	-154.
112.2	10.8	-155.
118.9	10.0	-159.
125.9	9.2	-161.
133.4	8.5	-164.
141.3	7.7	-166.
149.6	6.9	-169.
158.5	6.1	-171.
167.9	5.3	-174.
177.8	4.5	-176.
188.4	3.7	-179.
199.5	2.9	178.
211.3	2.1	176.
223.9	1.3	173.
237.1	.5	171.
251.2	-.1	168.
266.1	-.8	165.
281.8	-1.4	163.
298.5	-1.9	160.
316.2	-2.3	158.
335.0	-2.6	155.
354.8	-2.7	153.
375.8	-2.4	150.
398.1	-1.7	148.
421.7	.1	145.
446.7	4.1	143.
473.2	26.2	127.
501.2	1.7	-40.
530.9	-5.5	-43.
562.3	-11.9	-45.
595.7	-15.3	-47.
631.0	-20.2	-49.
668.3	-23.7	-51.
707.9	-27.0	-53.
749.9	-30.1	-55.
794.3	-33.2	-57.
841.4	-36.1	-58.
891.2	-39.1	-60.
944.1	-44.0	-62.

```
10:04:19      PH FOR ATTENUATION                                              1F9002
DOC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 24 APR 71 AT 10:04:19

    MAIN PROGRAM

    STORAGE USED (BLOCK, NAME, LENGTH)

          0001    *CODE    001235
          0000    *DATA    000320
          0002    *BLANK   000000

    EXTERNAL REFERENCES (BLOCK, NAME)

          0003    NWDU$
          0004    NI01$
          0005    NI02$
          0006    CONV$
          0007    CABS
          0010    ALOG10
          0011    ATAN2
          0012    NEXP6$
          0013    NSTOP$

    STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001    000014 1176      0001    000025 1256      0001    000033 133G      0001    001166 162G      0000    000037 20F
    0001    000043 40L       0000    000041 50F       0000 C 000002 A         0000 C 000004 B         0000 I 000020 BLANK
    0000 C 000006 C          0000 C 000010 D          0000 R 000033 DB        0000 I 000021 DOT       0000 C 000012 E
    0000 C 000014 FCT        0000 C 000016 FCICOM     0000 I 000023 FI        0000 R 000032 HERTZ     0000 I 000030 I
    0000 I 000031 IS         0000 I 000035 J          0000 I 000036 K         0000 I 000151 LINE      0000 I 000026 M
    0000 I 000027 N          0000 R 000024 P          0000 R 000034 PHASE     0000 R 000025 Q         0000 C 000000 S
    0000 I 000022 X

  00100      1*     C      OPEN LOOP RESPONSE
  00100      2*     C      GAIN AND PHASE PLOT
  00101      3*            COMPLEX S,A,B,C,D,E,FCT,FCICOM
  00103      4*            INTEGER BLANK,DOT,X,FI
  00104      5*            DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
  00111      6*            DIMENSION LINE(101)
  00111      7*     C      P IS DB PER CHARACTER SPACE
  00112      8*            P=1.
  00112      9*     C      Q IS DEGREES PER CHARACTER SPACE
  00113     10*            Q=4.
  00113     11*     C      M IS DB ZERO LOCATION
  00114     12*            M=41
  00114     13*     C      N IS PHASE ZERO LOCATION
  00115     14*            N=51
  00116     15*            DO 10 I=1,101
  00121     16*         10 LINE(I)=DOT
  00123     17*            WRITE (6,20) LINE
  00131     18*         20 FORMAT (1H1,101A1)
  00132     19*            DO 30 I=1,101
  00135     20*         30 LINE(I)=BLANK
  00137     21*            LINE(M)=DOT
```

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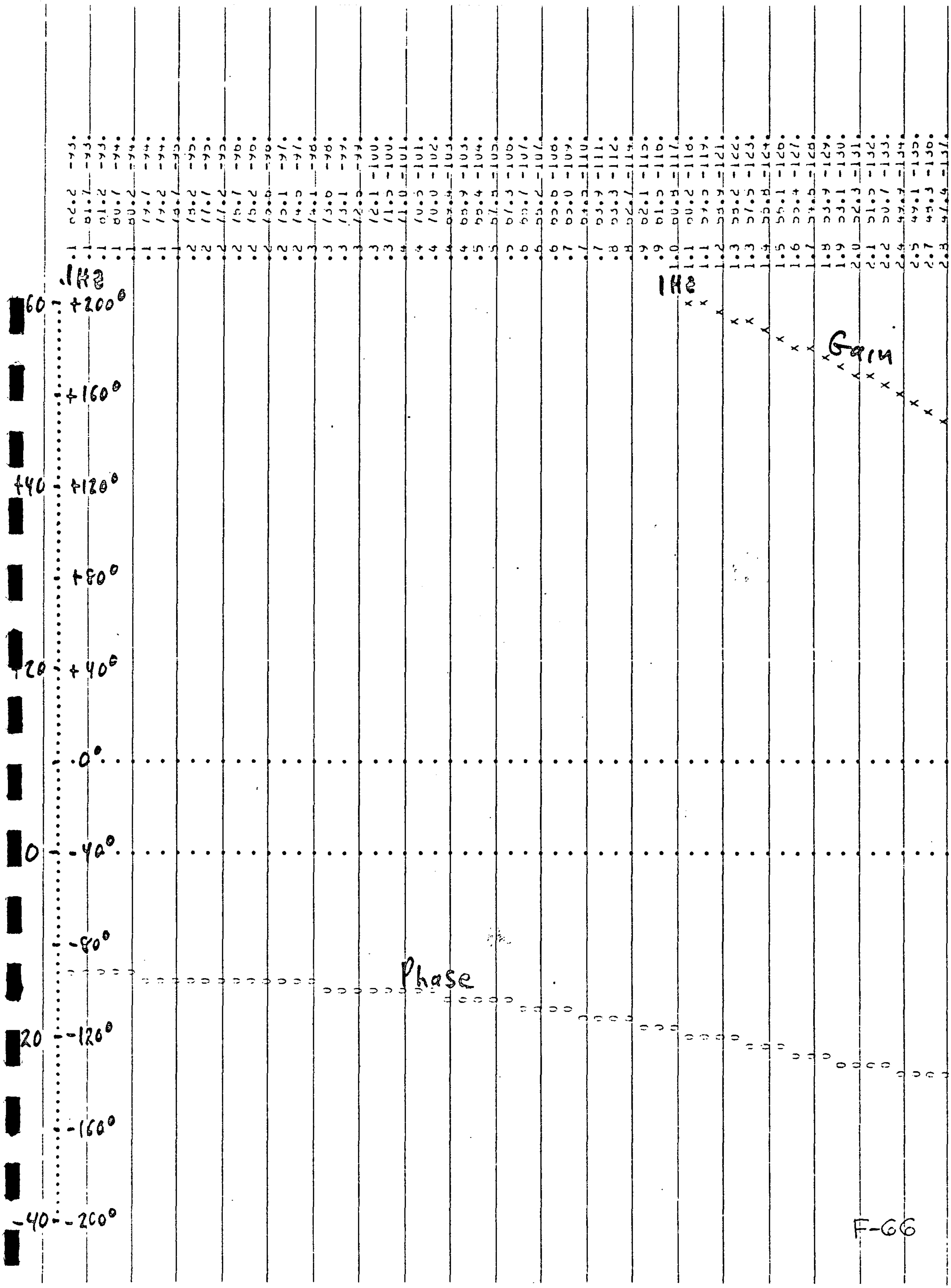
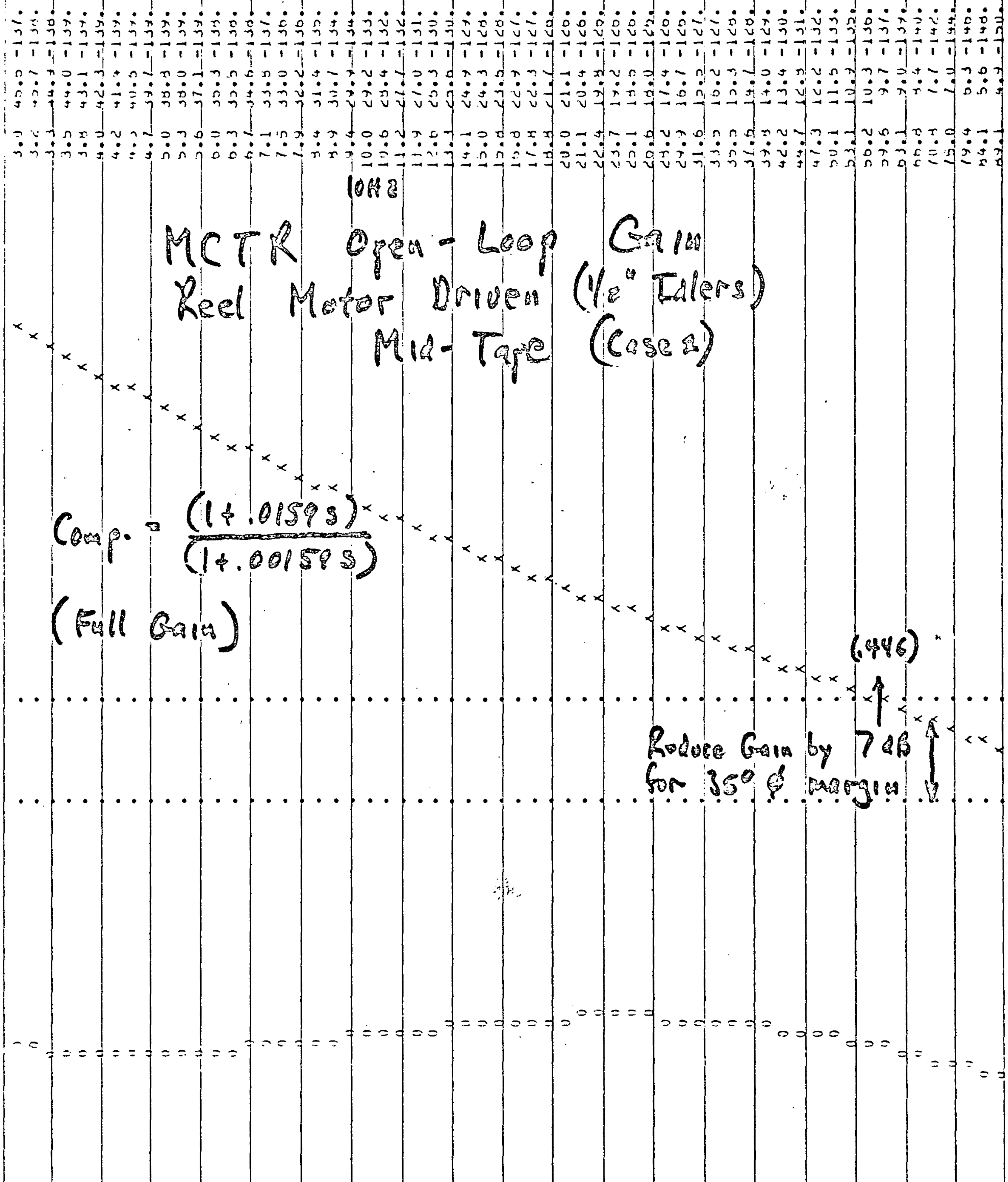
```
00140    LINE(N)=DOT
00141    HERTZ=.1
00142 40 S=CMPLX(0.,6.2831853*HERTZ)
00143    A=1.+10.75E-6*S**2+333.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
00144    B=14.35*S*(1.+25.25E-6*S**2+3.66E-12*S**4+.0814E-18*S**6)
00145    C=147.23*(1.+25.36E-6*S**2+4.66E-12*S**4+.0815E-18*S**6)
00146    D=147.23*S*(1.017E-6+26.58E-12*S**2+1.736E-18*S**4+.0277E-24*S**6)
00147    E=147.23*(1.+25.25E-6*S**2+.7322E-12*S**4)
00150    FCT=(17.1/(1.+.0004*S+(.0026+3.9E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
00151    FCTCOM=FCT*((1.+.0159*S)/(1.+.00159*S))
00152    DB=20.*ALOG10(CABS(FCTCOM))
00153    PHASE=57.29*ATAN2(AIMAG(FCTCOM),REAL(FCTCOM))
00154    I=DB/P+FLOAT(M)+0.5
00155    LINE(I)=X
00156    J=PHASE/P+FLOAT(N)+0.5
00157    LINE(J)=PI
00160    WRITE(6,50) LINE,HERTZ,DB,PHASE
00171 50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00172    LINE(I)=BLANK
00173    LINE(J)=BLANK
00174    LINE(M)=DOT
00175    LINE(N)=DOT
00175 C  K IS NUMBER OF STEPS PER DECADE
00175    K=40
00177    HERTZ=HERTZ*10.**(1./FLOAT(K))
00200    IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00203 60 STOP
00204    END

END OF UCC 1108 FORTRAN V COMPILATION.     0 *DIAGNOSTIC* MESSAGE(S)
```

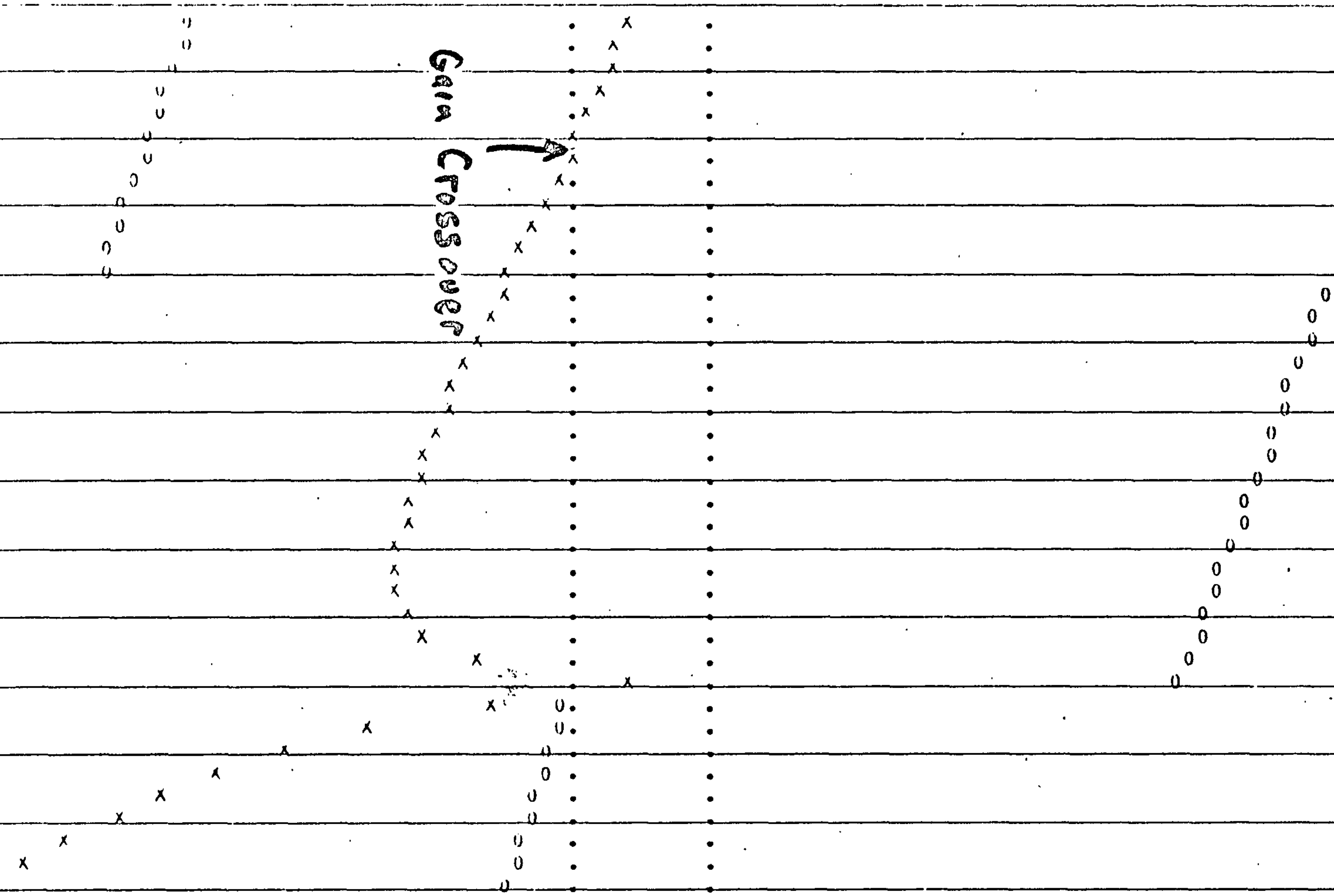


.1Hz
1Hz
Gain
Phase
+60
+40
+20
0
-20
-40
+200°
+160°
+120°
+80°
+40°
0°
-40°
-80°
-120°
-160°
-200°

FIG. 14



10HZ
MCTR Open-Loop Gain
Reel Motor Driven (1/2" Idlers)
Mid-Tape (Case 2)
Comp. = (1+.01593S)/(1+.00159S)
(Full Gain)
(.446)
Reduce Gain by 7 dB for 35° φ margin



100 HB

94.4	4.2	-152.
100.0	3.4	-154.
105.9	2.7	-156.
112.2	1.9	-158.
118.9	1.2	-161.
125.9	.4	-163.
133.4	-.4	-165.
141.3	-1.2	-168.
149.6	-2.0	-170.
158.5	-2.9	-173.
167.9	-3.7	-175.
177.8	-4.5	-178.
188.4	-5.3	180.
199.5	-6.2	177.
211.3	-7.0	175.
223.9	-7.8	172.
237.1	-8.6	170.
251.2	-9.3	167.
266.1	-10.1	165.
281.8	-10.8	162.
298.5	-11.4	160.
316.2	-12.0	157.
335.0	-12.4	155.
354.8	-12.8	152.
375.8	-12.9	150.
398.1	-12.8	148.
421.7	-12.1	145.
446.7	-10.7	143.
473.2	-7.5	140.
501.2	3.7	135.
530.9	-5.9	-42.
562.3	-15.3	-45.
595.7	-21.2	-47.
631.0	-25.8	-49.
668.3	-29.8	-51.
707.9	-33.4	-53.
749.9	-36.7	-55.
794.3	-39.9	-57.
841.4	-44.1	-59.

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```
15:25:36     DB FOR ATTEN,ATTEN                                  1F9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 27 APR 71 AT 16:25:36

     MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001    *CODE     001220
          0000    *DATA     000320
          0002    *BLANK    000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003    NWDU$
          0004    NIO1$
          0005    NIO2$
          0006    SQRT
          0007    CABS
          0010    ALOG10
          0011    ATAN2
          0012    NEXP6$
          0013    NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001   000014 117G      0001   000025 125G      0001   000033 133G      0001   001151 162G      0000   000037 20F
     0001   000043 40L       0000   000041 50F       0000 C 000002 A         0000 C 000004 B         0000 I 000020 BLANK
     0000 C 000006 C         0000 C 000010 D         0000 R 000033 DB        0000 I 000021 DOT       0000 C 000012 E
     0000 C 000014 FCT       0000 C 000016 FCTCOM    0000 I 000023 FI        0000 R 000032 HERTZ     0000 I 000030 I
     0000 I 000031 IS        0000 I 000035 J         0000 I 000036 K         0000 I 000153 LINE      0000 I 000026 M
     0000 I 000027 N         0000 R 000024 P         0000 R 000034 PHASE     0000 R 000025 Q         0000 C 000000 S
     0000 I 000022 X

  00100      1*    C     OPEN LOOP RESPONSE
  00100      2*    C     GAIN AND PHASE PLOT
  00101      3*          COMPLEX S,A,B,C,D,E,FCT,FCTCOM
  00103      4*          INTEGER BLANK,DOT,X,FI
  00104      5*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
  00111      6*          DIMENSION LINE(101)
  00111      7*    C     P IS DB PER CHARACTER SPACE
  00112      8*          P=1.
  00112      9*    C     Q IS DEGREES PER CHARACTER SPACE
  00113     10*          Q=4.
  00113     11*    C     M IS DB ZERO LOCATION
  00114     12*          M=41
  00114     13*    C     N IS PHASE ZERO LOCATION
  00115     14*          N=51
 I00115     15*          DO 10 I=1,101
  00121     16*       10 LINE(I)=DOT
 600123     17*          WRITE (6,20) LINE
 600131     18*       20 FORMAT (1H1,101A1)
  00132     19*          DO 30 I=1,101
  00135     20*       30 LINE(I)=BLANK
  00137     21*          LINE(M)=DOT
```

```
00140            LINE(M)=DOT
00141            HERTZ=1.
00142         40 S=CMPLX(0.,6.2832*HERTZ)
00143            A=1.+45.54E-6*S**2+391.3E-12*S**4+41.88E-18*S**6+.742E-24*S**8
00144            B=26.18*S*(1.+24.32E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
00145            C=187.23*(1.+24.3E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
00146            D=187.23*S*(0.929E-6+30.07E-12*S**2+1.600E-18*S**4+.0283E-24*S**6)
00147            E=187.23*(1.+24.32E-6*S**2+.8615E-12*S**4)
00150            FCT=(1./(1.+.0004*S+(.0014+2.6E-7*S)*(C+D)/(A+B)))*(E/(S*(A+B)))
00151            FCTCOM=FCT*((1.+.0159*S)/(1.+.00159*S))
00152            DB=20.*ALOG10(CABS(FCTCOM))
00153            PHASE=57.29*ATAN2(AIMAG(FCTCOM),REAL(FCTCOM))
00154            I=DB/P+FLOAT(M)+0.5
00155            LINE(I)=X
00156            J=PHASE/Q+FLOAT(N)+0.5
00157            LINE(J)=PI
00160            WRITE(6,50) LINE,HERTZ,DB,PHASE
00171         50 FORMAT(1H ,101A1,1F5.1,1F6.1,1F6.0)
00172            LINE(I)=BLANK
00173            LINE(J)=BLANK
00174            LINE(M)=DOT
00175            LINE(N)=DOT
00175      C     K IS NUMBER OF STEPS PER DECADE
00176            K=40
00177            HERTZ=HERTZ*10.**(1./FLOAT(K))
00200            IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00203         60 STOP
00204            END

     END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)
```


Case 2 Compensated

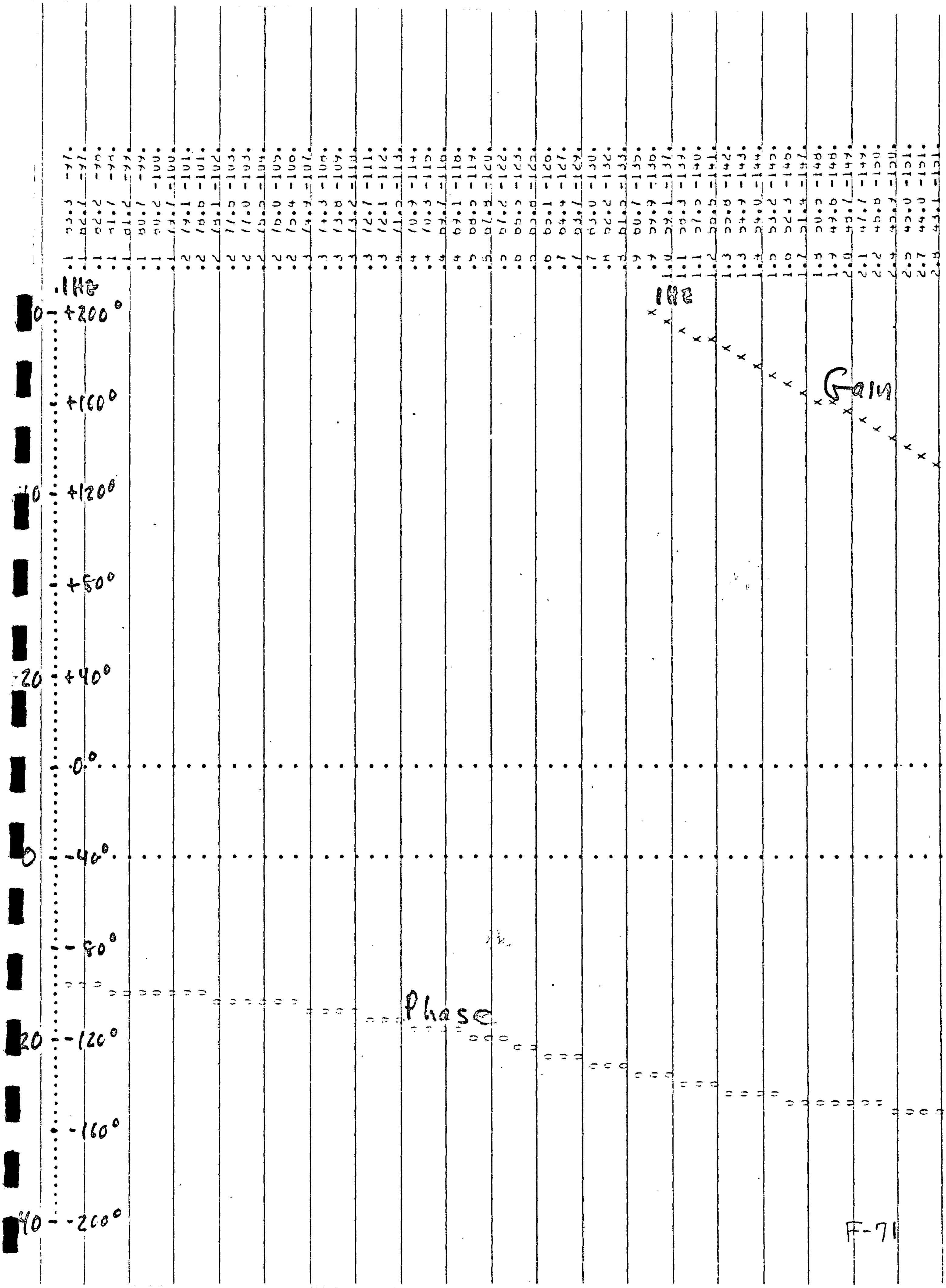
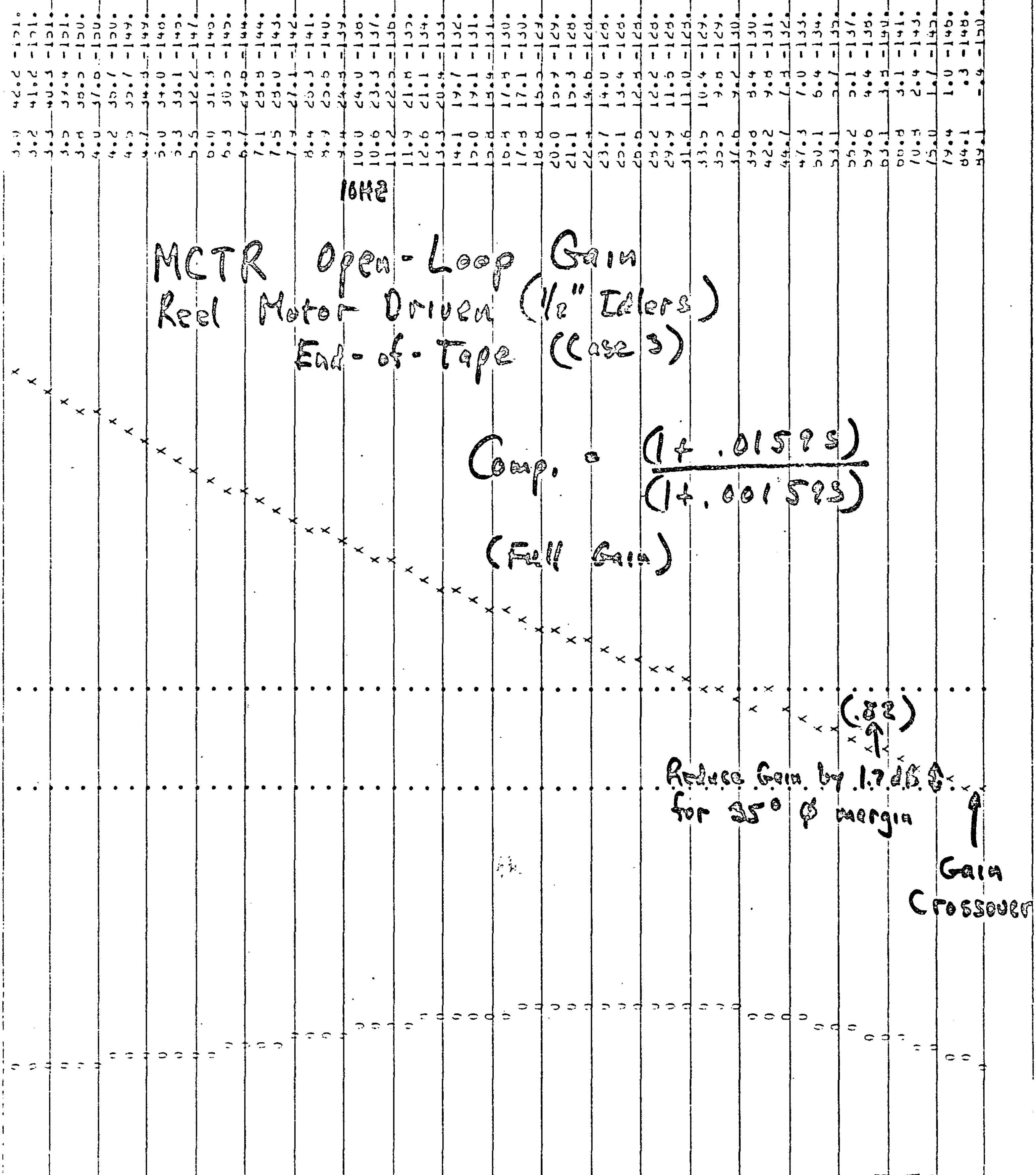

.1Hz
+200°
+160°
+120°
+80°
+40°
0°
-40°
-80°
-120°
-160°
-200°
1Hz
Gain
Phase

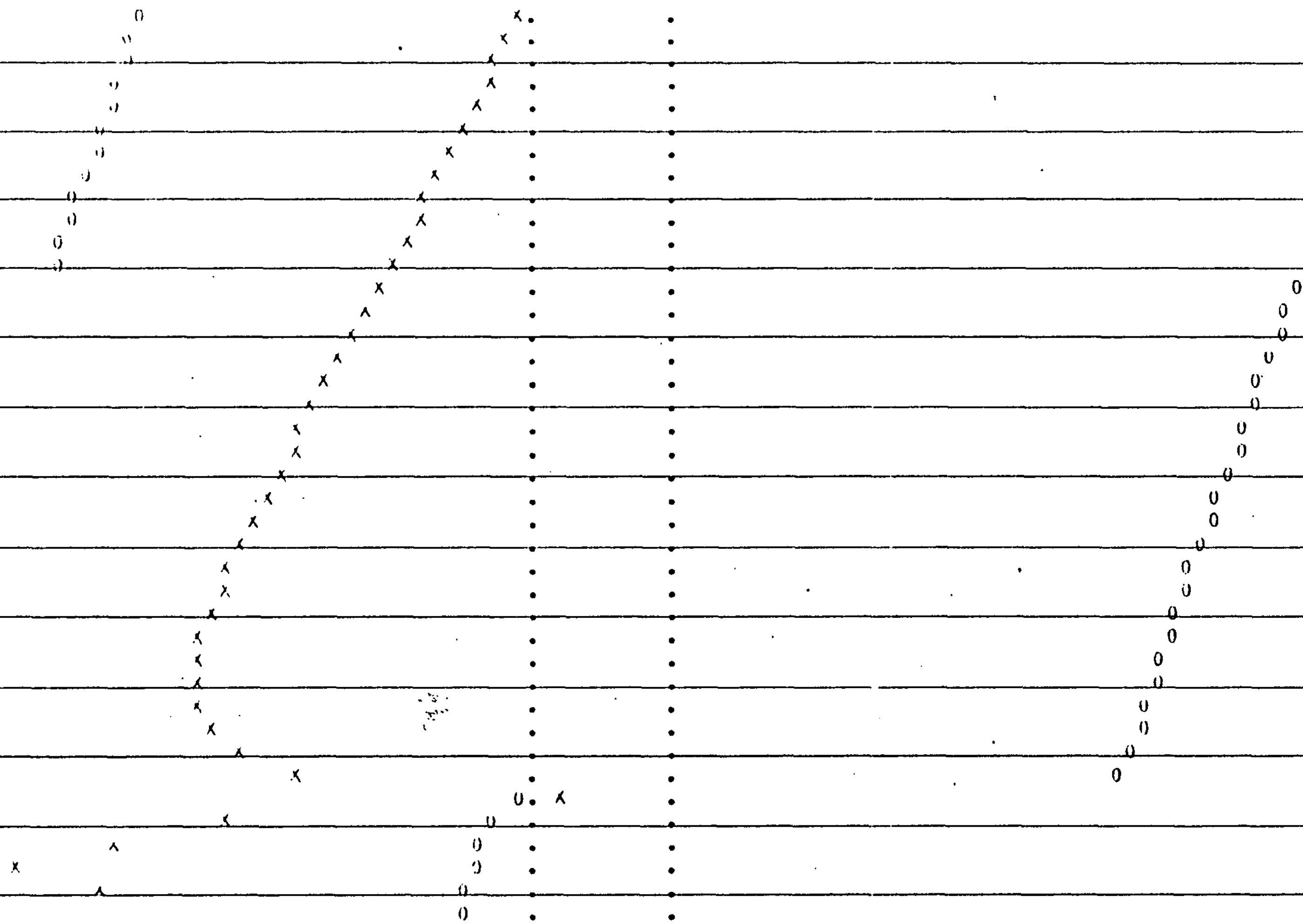
FIG. 15



10HZ
MCTR Open-Loop Gain
Reel Motor Driven (1/2" Idlers)
End-of-Tape (Case 3)
Comp. = (1+.0159S)/(1+.00159S)
(Full Gain)
(.82)
Reduce Gain by 1.7dB
for 35° ϕ margin
Gain
Crossover

100Hz

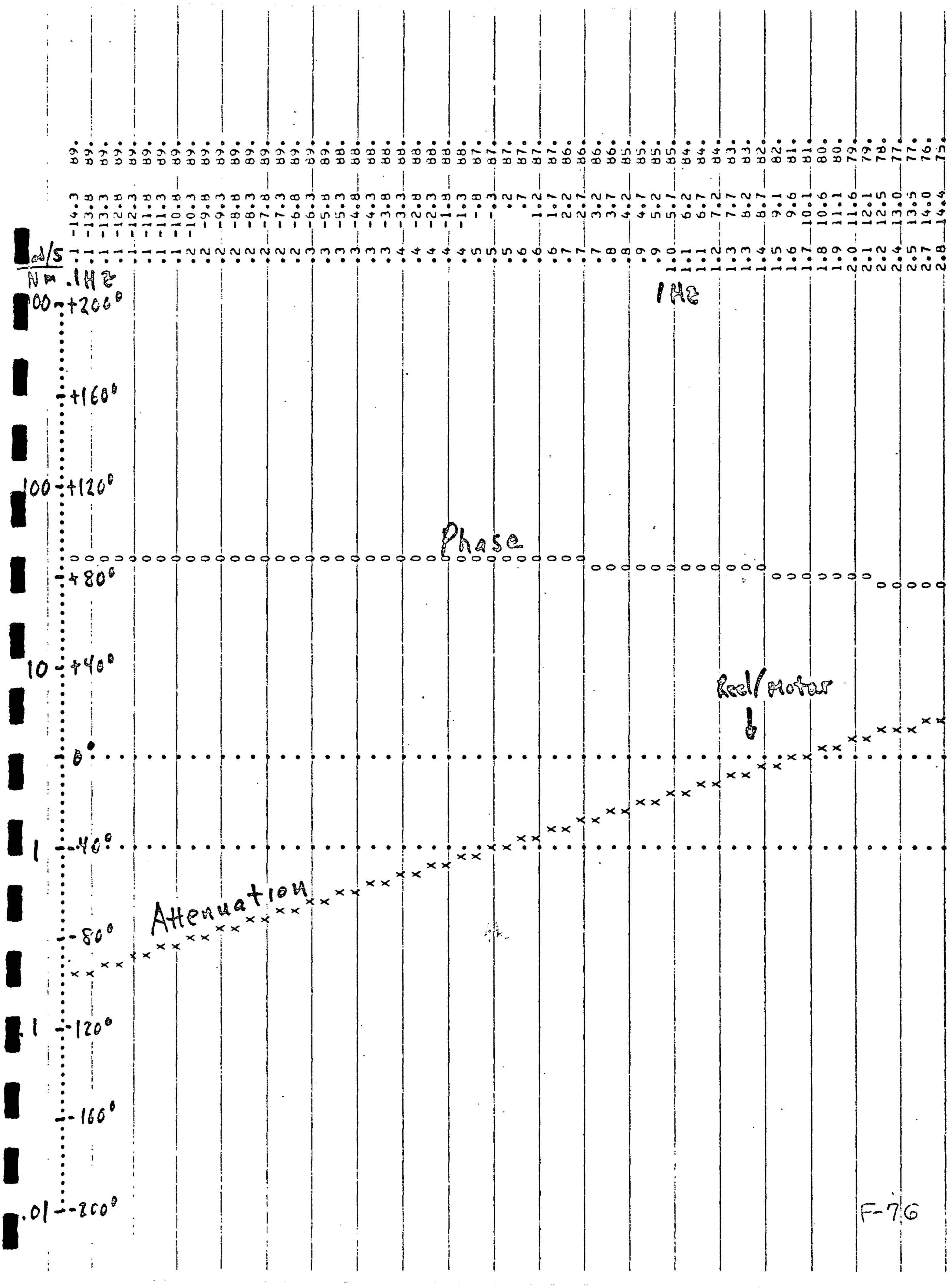
94.4	-1.2	-152.
100.0	-1.9	-154.
105.9	-2.7	-157.
112.2	-3.5	-159.
118.9	-4.3	-161.
125.9	-5.1	-163.
133.4	-5.9	-166.
141.3	-6.7	-168.
149.6	-7.6	-170.
158.5	-8.5	-173.
167.9	-9.3	-175.
177.8	-10.2	-178.
188.4	-11.1	180.
199.5	-12.0	177.
211.3	-12.9	175.
223.9	-13.8	172.
237.1	-14.7	170.
251.2	-15.6	167.
266.1	-16.5	165.
281.8	-17.5	162.
298.5	-18.4	160.
316.2	-19.2	157.
335.0	-20.1	155.
354.8	-20.9	152.
375.8	-21.7	150.
398.1	-22.4	148.
421.7	-23.0	145.
446.7	-23.5	143.
473.2	-23.9	141.
501.2	-24.0	138.
530.9	-23.8	136.
562.3	-23.1	134.
595.7	-21.3	132.
631.0	-15.8	130.
668.3	2.4	-43.
707.9	-22.2	-53.
749.9	-30.1	-55.
794.3	-35.9	-57.
841.4	-38.8	-58.
891.2	-41.1	-60.



```
10:03:38     FOR ATTEMPTS                                  1F9002
UCC 1108 FORTRAN V  : LEVEL   3.2A
THIS COMPILATION WAS DONE ON 21 APR 71 AT 10:03:39

     MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001   *CODE    001210
          0000   *DATA    000320
          0002   *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003   NDOU$
          0004   NIO1$
          0005   NIO2$
          0006   LIV$
          0007   CABS
          0010   ALOG10
          0011   ATAN2
          0012   EXP6$
          0013   NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001   000014 117G     0001   000025 125G     0001   000033 133G     0001   001141 162G     0000   000037 20F
     0001   000143 30L      0000   000041 50F      0000 C 000002 A        0000 C 000004 B        0000 I 000020 BLANK
     0000 C 000006 C        0000 C 000010 D        0000 R 000033 DB       0000 I 000021 DOT      0000 C 000012 E
     0000 C 000014 FCT      0000 C 000016 FCTCOM   0000 I 000023 FI       0000 R 000032 HERTZ    0000 I 000030 I
     0000 I 000031 I3       0000 I 000035 J        0000 I 000036 K        0000 I 000153 LINE     0000 I 000026 M
     0000 I 000027 N        0000 R 000024 P        0000 R 000034 PHASE    0000 R 000025 Q        0000 C 000000 S
     0000 I 000022 X

   00100      1*    C      OPEN LOOP RESPONSE
   00100      2*    C      GAIN AND PHASE PLOT
   00101      3*           COMPLEX S,A,B,C,D,E,FCT,FCTCOM
   00103      4*           INTEGER BLANK,DOT,X,FI
   00104      5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
   00111      6*           DIMENSION LINE(101)
   00111      7*    C      P IS DB PER CHARACTER SPACE
   00112      8*           P=1.
   00112      9*    C      Q IS DEGREES PER CHARACTER SPACE
   00113     10*           Q=4.
   00113     11*    C      M IS DB ZERO LOCATION
   00114     12*           M=41
   00114     13*    C      N IS PHASE ZERO LOCATION
   00115     14*           N=51
   00115     15*           DO 10 I=1,101
   00121     16*        10 LINE(I)=DOT
   00123     17*           WRITE (6,20) LINE
   00131     18*        20 FORMAT (1H1,101A1)
   00132     19*           DO 30 I=1,101
   00135     20*        30 LINE(I)=BLANK
   00137     21*           LINE(M)=DOT
```

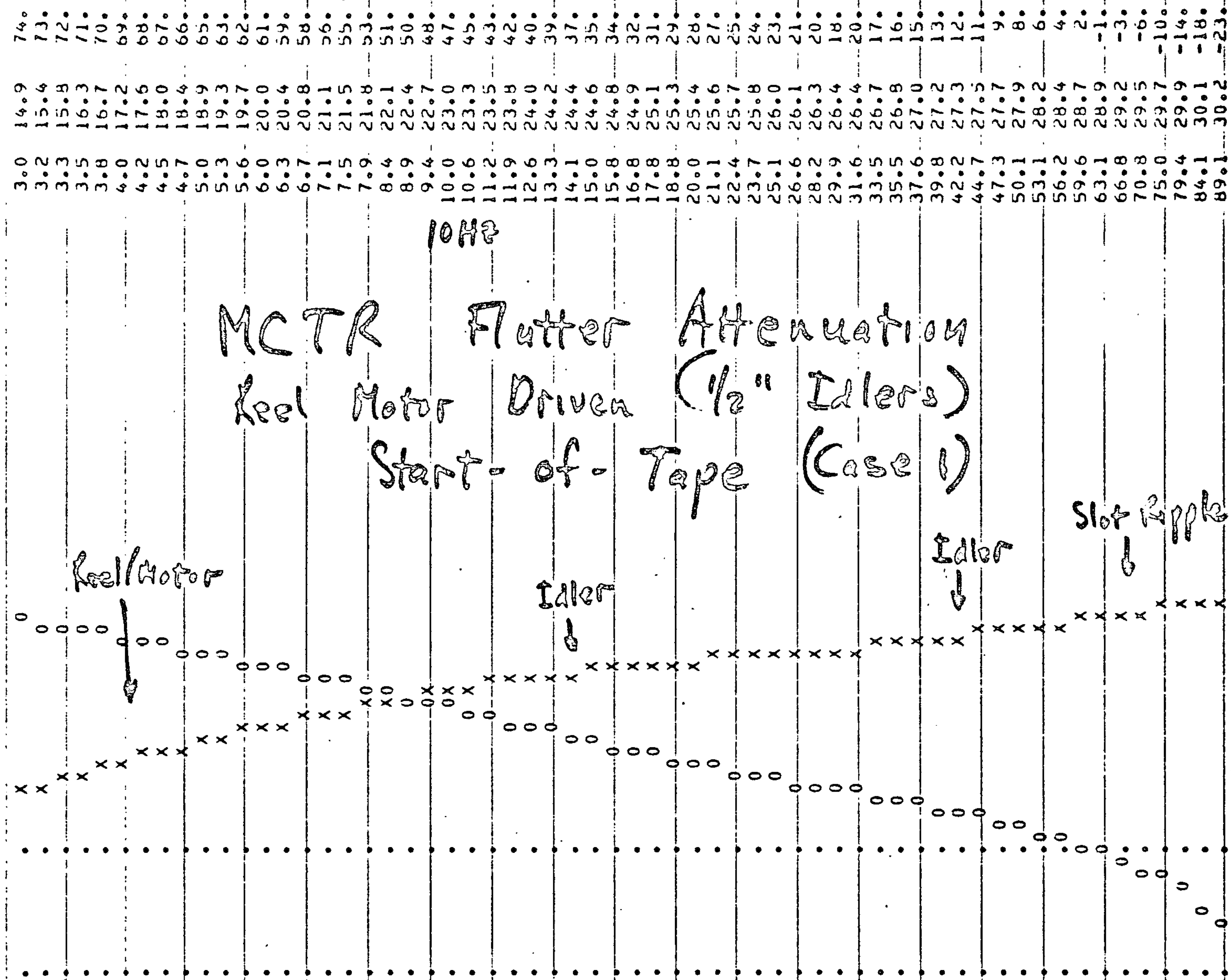
```
      LINE(N)=DOT
      HERTZ=.1
   40 S=CMPLX(0.,6.2832*HERTZ)
      A=1.+40.39E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
      B=38.71*S*(1.+14.60E-6*S**2+1.36E-12*S**4+.0302E-18*S**6)
      C=147.63*(1.+14.6E-6*S**2+1.36E-12*S**4+.0303E-18*S**6)
      D=137.53*S*(0.679E-6+9.900E-12*S**2+0.644E-18*S**4+.0103E-24*S**6)
      E=147.63*(1.+14.50E-6*S**2+.5429E-12*S**4)
      FCT=(9.26/(1.+.0034*S+1.0010+2.1E-7*S))*(C+D)/(A+B)))*(E/(S*(A+B)))
      FCTCOM=FCT*((1.+.0159*S)/(1.+.00159*S))
      DB=20.*ALOG10(CABS(FCTCOM))
      PHASE=57.29*ATAN2(AIMAG(FCTCOM),REAL(FCTCOM))
      I=DB/P+FLOAT(M)+0.5
      LINE(I)=X
      J=PHASE/Q+FLOAT(N)+0.5
      LINE(J)=FI
      WRITE(6,50) LINE,HERTZ,DB,PHASE
   50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
      LINE(I)=BLANK
      LINE(J)=BLANK
      LINE(M)=DOT
      LINE(N)=DOT
C     K IS NUMBER OF STEPS PER DECADE
      K=40
      HERTZ=HERTZ*10.**(1./FLOAT(K))
      IF ((FLOAT(M)-1.)*P+DB) 60,60,40
   60 STOP
      END
```

END OF UCC 1108 FORTRAN V COMPILATION.   0 *DIAGNOSTIC* MESSAGE(S)

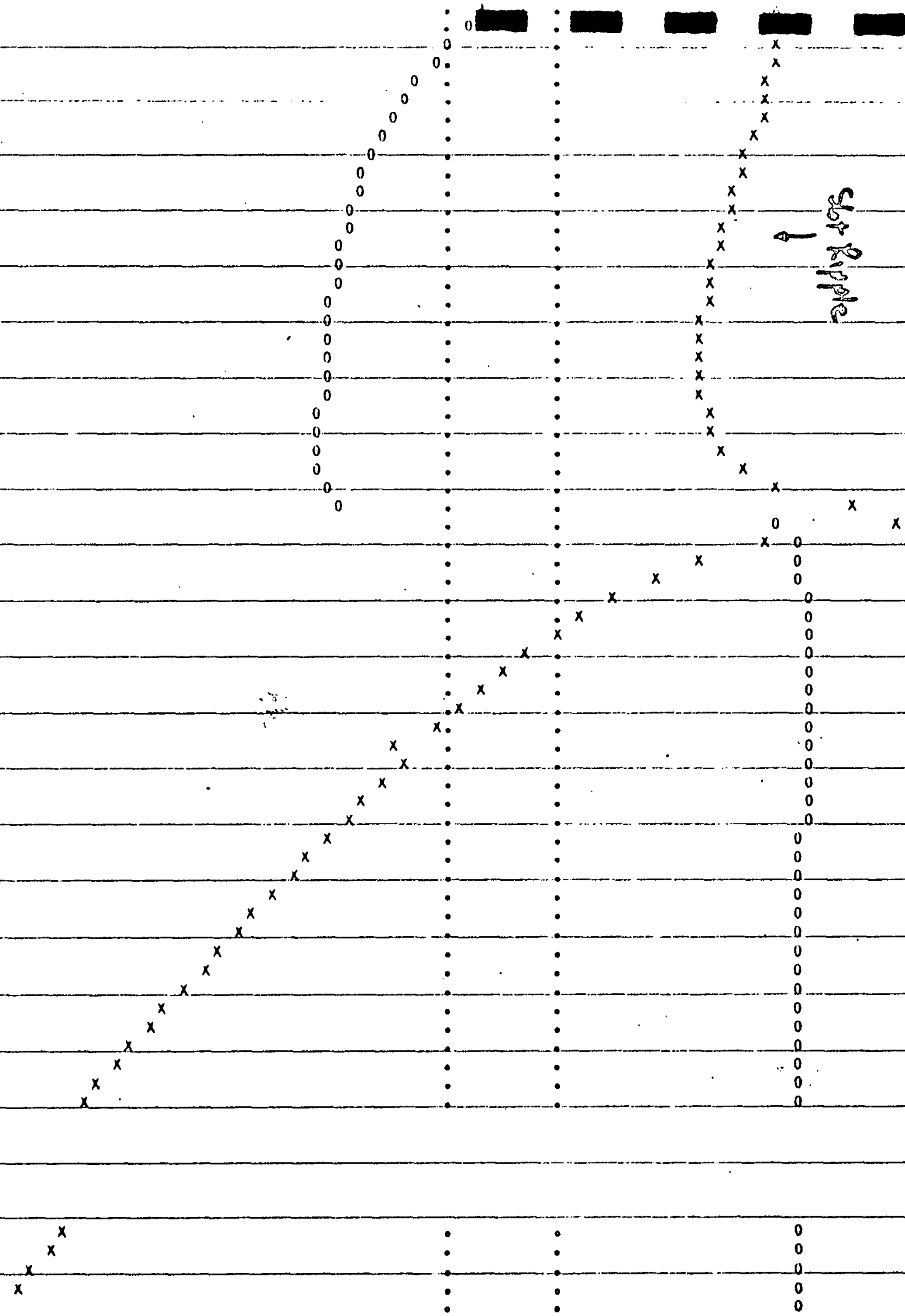


rad/s
Nm .1Hz
1000 +200°
+160°
100 +120°
+80°
10 +40°
0°
1 -40°
-80°
.1 -120°
-160°
.01 -200°
Phase
1Hz
Reel/motor
Attenuation

FIG. 16



$$\text{Comp.} = \frac{.19\,(1 + .0159S)}{(1 + .00159S)}$$



10[illegible]	30.[illegible]	[illegible]
105.9	30.1	-39.
112.2	29.8	-45.
118.9	29.5	-50.
125.9	29.0	-55.
133.4	28.5	-60.
141.3	28.0	-64.
149.6	27.4	-67.
158.5	26.8	-70.
167.9	26.3	-73.
177.8	25.7	-75.
188.4	25.2	-77.
199.5	24.7	-79.
211.3	24.2	-80.
223.9	23.8	-82.
237.1	23.5	-83.
251.2	23.2	-84.
266.1	23.1	-84.
281.8	23.0	-85.
298.5	23.0	-85.
316.2	23.2	-86.
335.0	23.6	-86.
354.8	24.2	-86.
375.8	25.3	-86.
398.1	27.0	-86.
421.7	30.1	-85.
446.7	37.2	-82.
473.2	41.0	80.
501.2	28.6	88.
530.9	22.7	89.
562.3	18.6	90.
595.7	15.3	90.
631.0	12.4	90.
668.3	9.8	90.
707.9	7.4	90.
749.9	5.2	90.
794.3	3.1	90.
841.4	1.0	90.
891.2	-1.0	90.
944.1	-3.0	90.
1000.0	-3.8	90.
1059.3	-5.9	90.
1122.0	-7.7	90.
1188.5	-9.4	90.
1258.9	-11.1	90.
1333.5	-12.8	90.
1412.5	-14.4	90.
1496.2	-16.1	90.
1584.9	-17.7	90.
1678.8	-19.3	90.
1778.3	-20.9	90.
1883.6	-22.4	90.
1995.3	-24.0	90.
2113.5	-25.6	90.
2238.7	-27.1	90.
2371.4	-28.6	90.
2511.9	-30.2	90.
2660.7	-31.7	90.
2818.4	-33.3	90.
2985.4	-34.8	90.
3162.3	-36.3	90.
3349.6	-37.8	90.
3548.1	-39.4	90.
3758.4	-40.9	90.

```
S[redacted]AGE [redacted] (BL[redacted] NA[redacted]LEN[redacted]

0001     *CODE    001310
0000     *DATA    000332
0002     *BLANK   000000


EXTERNAL REFERENCES (BLOCK, NAME)

0003   NWDU$
0004   NIO1$
0005   NIO2$
0006   CDV$
0007   CABS
0010   ALOG10
0011   ATAN2
0012   NEXP6$
0013   NSTOP$


STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001   000014 117G     0001   000025 125G     0001   000033 133G     0001   001241 164G     0000   000043 20F
0001   000043 40L      0000   000045 50F      0000 C 000002 A        0000 C 000004 B        0000 I 000024 BLANK
0000 C 000006 C        0000 C 000010 D        0000 R 000037 DB       0000 I 000025 DOT      0000 C 000012 E
0000 C 000014 FCT      0000 I 000027 FI       0000 C 000022 F1       0000 R 000036 HERTZ    0000 I 000034 I
0000 I 000035 I$       0000 I 000041 J        0000 I 000042 K        0000 I 000165 LINE     0000 I 000032 M
0000 I 000033 N        0000 R 000030 P        0000 R 000040 PHASE    0000 R 000031 Q        0000 C 000016 Q2F2
0000 C 000020 Q3       0000 C 000000 S        0000 I 000026 X

00100      1*    C      CLOSED LOOP RESPONSE
00100      2*    C      TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
00100      3*    C      CASE 1 - EMPTY REEL
00101      4*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
00103      5*           INTEGER BLANK,DOT,X,FI
00104      6*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
00111      7*           DIMENSION LINE(101)
00111      8*    C      P IS DB PER CHARACTER SPACE
00112      9*           P=1.
00112     10*    C      Q IS DEGREES PER CHARACTER SPACE
00113     11*           Q=4.
00113     12*    C      M IS DB ZERO LOCATION
00114     13*           M=41
00114     14*    C      N IS PHASE ZERO LOCATION
00115     15*           N=51
00116     16*           DO 10 I=1,101
00121     17*        10 LINE(I)=DOT
00123     18*           WRITE (6,20) LINE
00131     19*        20 FORMAT (1H1,101A1)
00132     20*           DO 30 I=1,101
00135     21*        30 LINE(I)=BLANK
```

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```
00137     22*           LINE(M)=DOT
00140     23*           LINE(N)=DOT
00141     24*           HERTZ=.1
00142     25*        40 S=CMPLX(0.,6.283*HERTZ)
00143     26*           A=1.+40.85E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
```

```
00140    23*        LI... )=U0
00141    24*        HERTZ=.1
00142    25*     40 S=CMPLX(0.,6.283*HERTZ)
00143    26*        A=1.+40.85E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
00144    27*        B=14.36*S*(1.+26.25E-6*S**2+3.66E-12*S**4+.0814E-18*S**6)
00145    28*        C=187.E3*(1.+26.3E-6*S**2+3.66E-12*S**4+.0816E-18*S**6)
00146    29*        D=187.E3*S*(1.017E-6+26.68E-12*S**2+1.736E-18*S**4+.0277E-24*S**6)
00147    30*        E=187.E3*(1.+26.25E-6*S**2+.7322E-12*S**4)
00150    31*        FI=(C+D)/(A+B)
00151    32*        Q3=.190*(1+.0159*S)/(1+.00159*S)
00152    33*        Q2F2=((1+.0004*S)/(1+.0004*S+(.0026+3.9E-7*S)*FI))*(E/(A+B))
00153    34*        FCT=(Q2F2)/(1+(Q2F2*Q3*17.1)/(S*(1+.0004)))
00154    35*        DB=20.*ALOG10(CABS(FCT))
00155    36*        PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156    37*        I=DB/P+FLOAT(M)+0.5
00157    38*        LINE(I)=X
00160    39*        J=PHASE/Q+FLOAT(N)+0.5
00161    40*        LINE(J)=FI
00162    41*        WRITE(6,50) LINE,HERTZ,DB,PHASE
00173    42*     50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174    43*        LINE(I)=BLANK
00175    44*        LINE(J)=BLANK
00176    45*        LINE(M)=DOT
00177    46*        LINE(N)=DOT
00177    47*   C    K IS NUMBER OF STEPS PER DECADE
00200    48*        K=40
00201    49*        HERTZ=HERTZ*10.**(1./FLOAT(K))
00202    50*        IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205    51*     60 STOP
00206    52*        END

END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)

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UCC ALLOCATOR......VERSION 1/7      03 MAY 71
```

FIG. 17

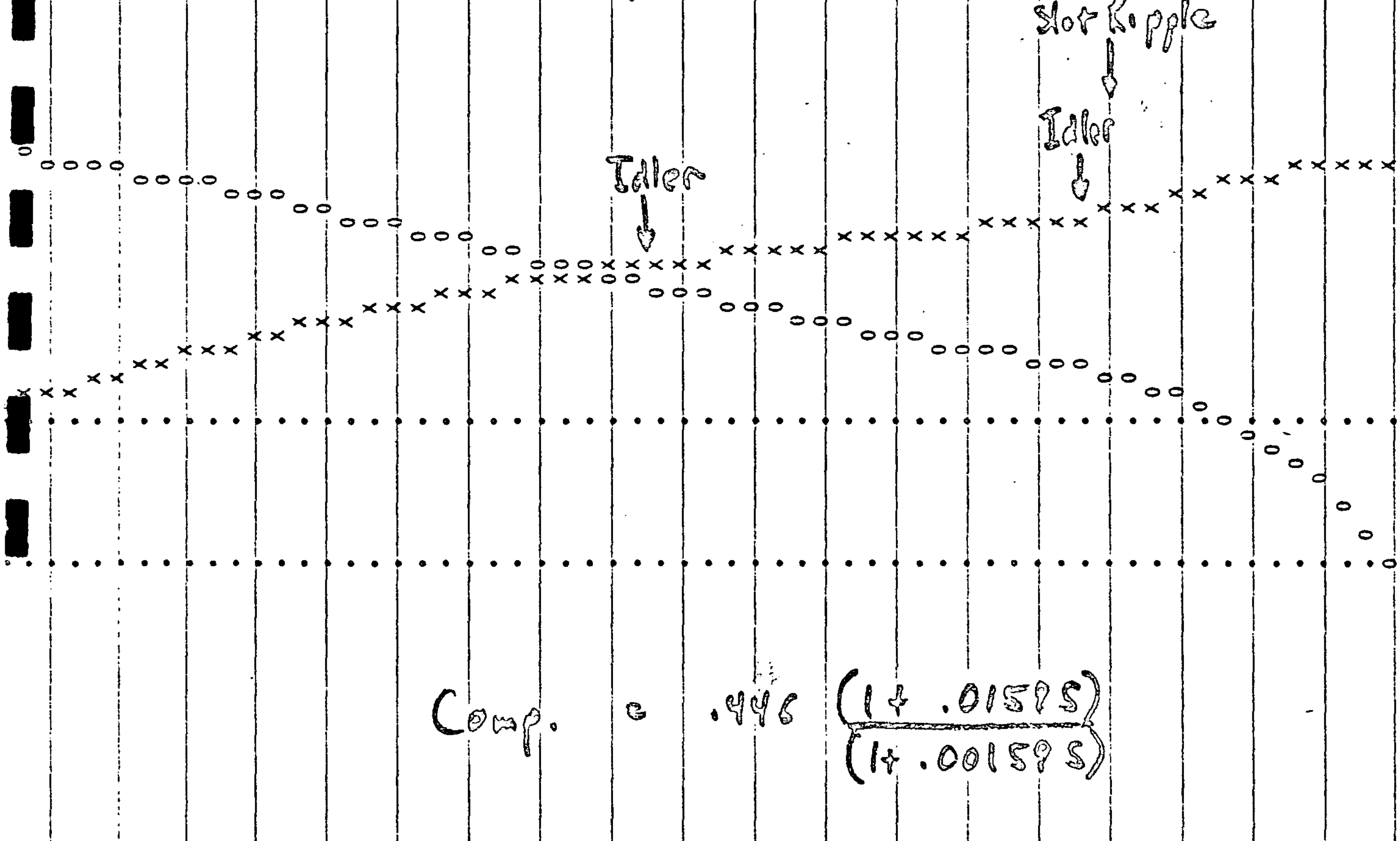
3.[illegible]	[illegible]	[illegible]
3.3	12.0	73.
3.5	12.4	72.
3.8	12.9	72.
4.0	13.3	71.
4.2	13.8	69.
4.5	14.2	68.
4.7	14.6	67.
5.0	15.0	66.
5.3	15.5	65.
5.6	15.9	63.
6.0	16.3	62.
6.3	16.6	61.
6.7	17.0	59.
7.1	17.4	58.
7.5	17.7	56.
7.9	18.1	55.
8.4	18.4	53.
8.9	18.7	52.
9.4	19.0	50.
10.0	19.3	49.
10.6	19.6	47.
11.2	19.9	46.
11.9	20.1	44.
12.6	20.4	42.
13.3	20.6	41.
14.1	20.8	39.
15.0	21.1	38.
15.8	21.3	36.
16.8	21.5	35.
17.8	21.6	33.
18.8	21.8	32.
20.0	22.0	30.
21.1	22.2	29.
22.4	22.3	28.
23.7	22.5	27.
25.1	22.7	25.
26.6	22.8	24.
28.2	23.0	23.
29.9	23.2	21.
31.6	23.5	18.
33.5	23.5	21.
35.5	23.8	19.
37.6	24.0	17.
39.8	24.2	16.
42.2	24.5	14.
44.7	24.9	13.
47.3	25.1	11.
50.1	25.4	9.
53.1	25.8	7.
56.2	26.1	4.
59.6	26.5	1.
63.1	26.9	-2.
66.8	27.3	-6.
70.8	27.7	-11.
75.0	28.0	-17.
79.4	28.3	-23.
84.1	28.4	-30.
89.1	28.3	-38.

10Hz

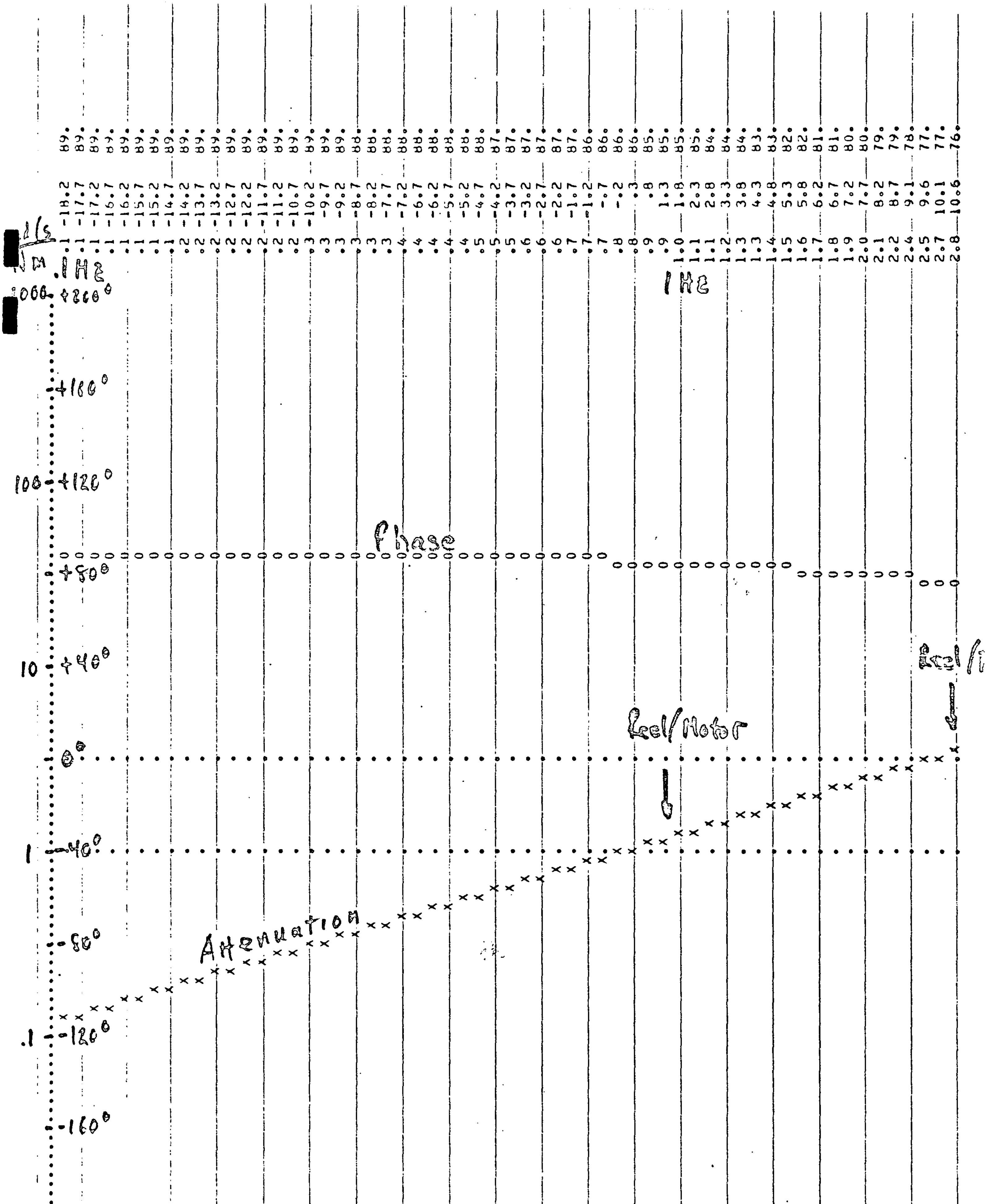
MCTR Flutter Attenuation

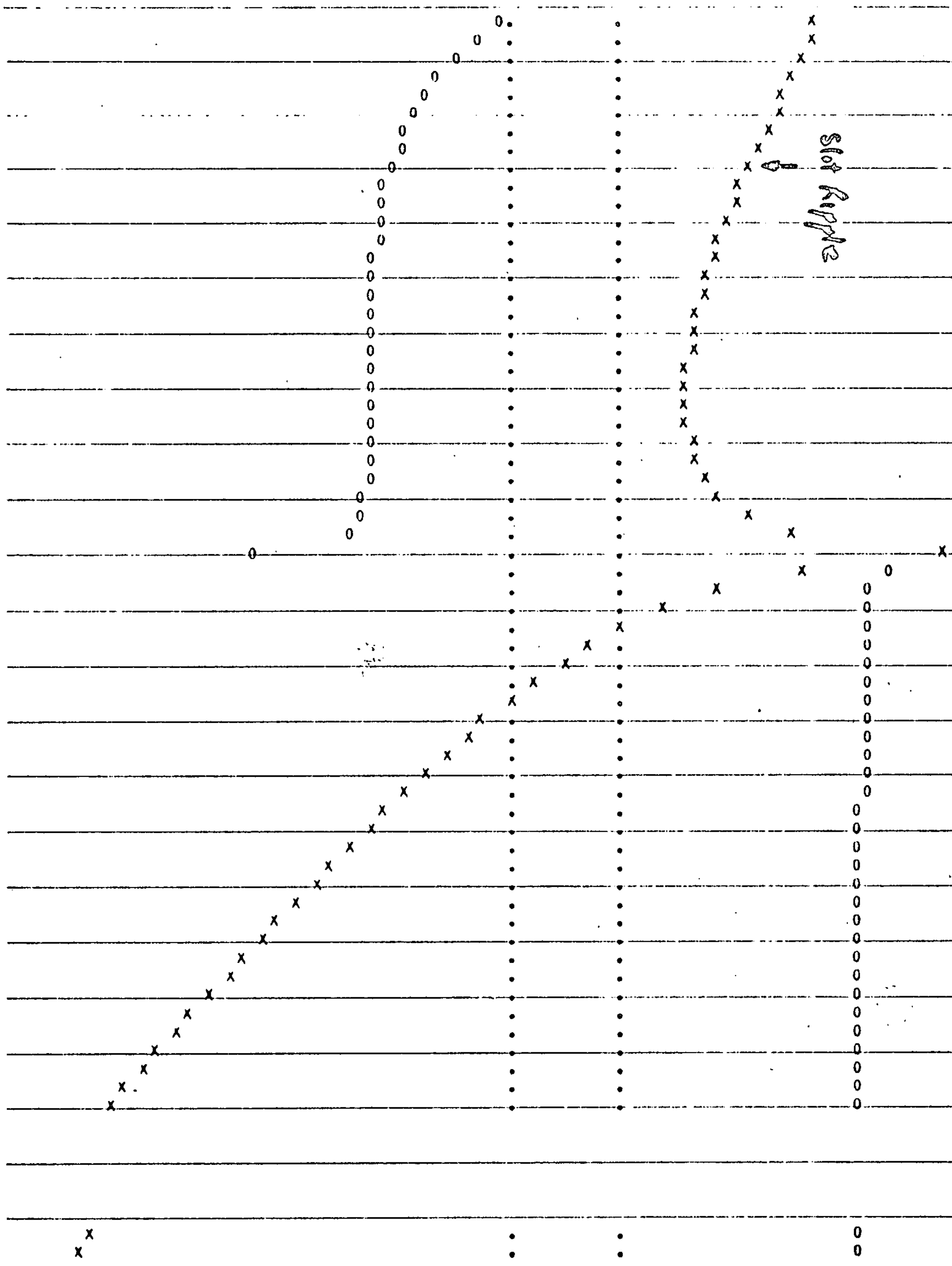
Reel Motor Driven (1/2" Idlers)

Mid-Tape (Case 2)



$$\text{Comp.} = .446 \frac{(1 + .0159 S)}{(1 + .00159 S)}$$


Phase
Attenuation
Reel/Motor
1 Hz
.1 Hz
+80°
+40°
0°
-40°
-80°
-120°
-160°
-200°
+120°
+160°
+200°
1000
100
10
1
.1
.01



100 Hz	94.4	28.0	-46.
	100.0	27.6	-53.
	105.9	25.9	-60.
	112.2	26.2	-66.
	118.9	25.4	-71.
	125.9	24.6	-76.
	133.4	23.7	-79.
	141.3	22.9	-82.
	149.6	22.1	-84.
	158.5	21.4	-86.
	167.9	20.6	-88.
	177.8	20.0	-89.
	188.4	19.3	-90.
	199.5	18.8	-90.
	211.3	18.2	-91.
	223.9	17.8	-91.
	237.1	17.3	-92.
	251.2	17.0	-92.
	266.1	16.7	-92.
	281.8	16.5	-92.
	298.5	16.3	-93.
	316.2	16.3	-93.
	335.0	16.4	-93.
	354.8	16.7	-93.
	375.8	17.3	-93.
	398.1	18.1	-94.
	421.7	19.5	-94.
	446.7	21.8	-95.
	473.2	25.1	-99.
	501.2	39.9	-136.
	530.9	26.6	99.
	562.3	18.9	94.
	595.7	14.1	92.
	631.0	10.5	91.
	668.3	7.4	91.
	707.9	4.7	91.
	749.9	2.2	90.
	794.3	-.1	90.
	841.4	-3.3	90.
	891.2	-4.0	90.
	944.1	-6.0	90.
1 KHz	1000.0	-7.9	90.
	1059.3	-9.7	90.
	1122.0	-11.5	90.
	1188.5	-13.3	90.
	1258.9	-15.0	90.
	1333.5	-16.7	90.
	1412.5	-18.3	90.
	1496.2	-20.0	90.
	1584.9	-21.6	90.
	1678.8	-23.2	90.
	1778.3	-24.8	90.
	1883.6	-26.4	90.
	1995.3	-28.0	90.
	2113.5	-29.5	90.
	2238.7	-31.1	90.
	2371.4	-32.6	90.
	2511.9	-34.2	90.
	2660.7	-35.7	90.
	2818.4	-37.3	90.
	2985.4	-38.8	90.
	3162.3	-40.3	90.

```
STORAGE USED (BLOCK, NAME, LENGTH)

      0001    *CODE    001273
      0000    *DATA    000326
      0002    *BLANK   000000


EXTERNAL REFERENCES (BLOCK, NAME)

      0003    NWDU$
      0004    NIO1$
      0005    NIO2$
      0006    COV$
      0007    CABS
      0010    ALOG10
      0011    ATAN2
      0012    NEXP6$
      0013    NSTOP$


STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

 0001   000014 117G    0001   000025 125G    0001   000033 133G    0001   001224 164G    0000   000043 20F
 0001   000043 40L     0000   000045 50F     0000 C 000002 A       0000 C 000004 B       0000 I 000024 BLANK
 0000 C 000006 C       0000 C 000010 D       0000 R 000037 DB      0000 I 000025 DOT     0000 C 000012 E
 0000 C 000014 FCT     0000 I 000027 FI      0000 C 000022 F1      0000 R 000036 HERTZ   0000 I 000034 I
 0000 I 000035 I$      0000 I 000041 J       0000 I 000042 K       0000 I 000161 LINE    0000 I 000032 M
 0000 I 000033 N       0000 R 000030 P       0000 R 000040 PHASE   0000 R 000031 Q       0000 C 000016 Q2F2
 0000 C 000020 Q3      0000 C 000000 S       0000 I 000026 X

00100      1*   C      CLOSED LOOP RESPONSE
00100      2*   C      TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
00100      3*   C      CASE 2 - MID REEL
00101      4*          COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
00103      5*          INTEGER BLANK,DOT,X,FI
00104      6*          DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
00111      7*          DIMENSION LINE(101)
00111      8*   C      P IS DB PER CHARACTER SPACE
00112      9*          P=1.
00112     10*   C      Q IS DEGREES PER CHARACTER SPACE
00113     11*          Q=4.
00113     12*   C      M IS DB ZERO LOCATION
00114     13*          M=41
00114     14*   C      N IS PHASE ZERO LOCATION
00115     15*          N=51
00116     16*          DO 10 I=1,101
00121     17*       10 LINE(I)=DOT
00123     18*          WRITE (6,20) LINE
00131     19*       20 FORMAT (1H1,101A1)
00132     20*          DO 30 I=1,101
00135     21*       30 LINE(I)=BLANK


00137     22*          LINE(M)=DOT
00140     23*          LINE(N)=DOT
00141     24*          HERTZ=.1
00142     25*       40 S=CMPLX(0.,6.283*HERTZ)
                       [illegible]5**2+591.3E-12*S**4+41.88E-18*S**6+.742E-24*S**8
```

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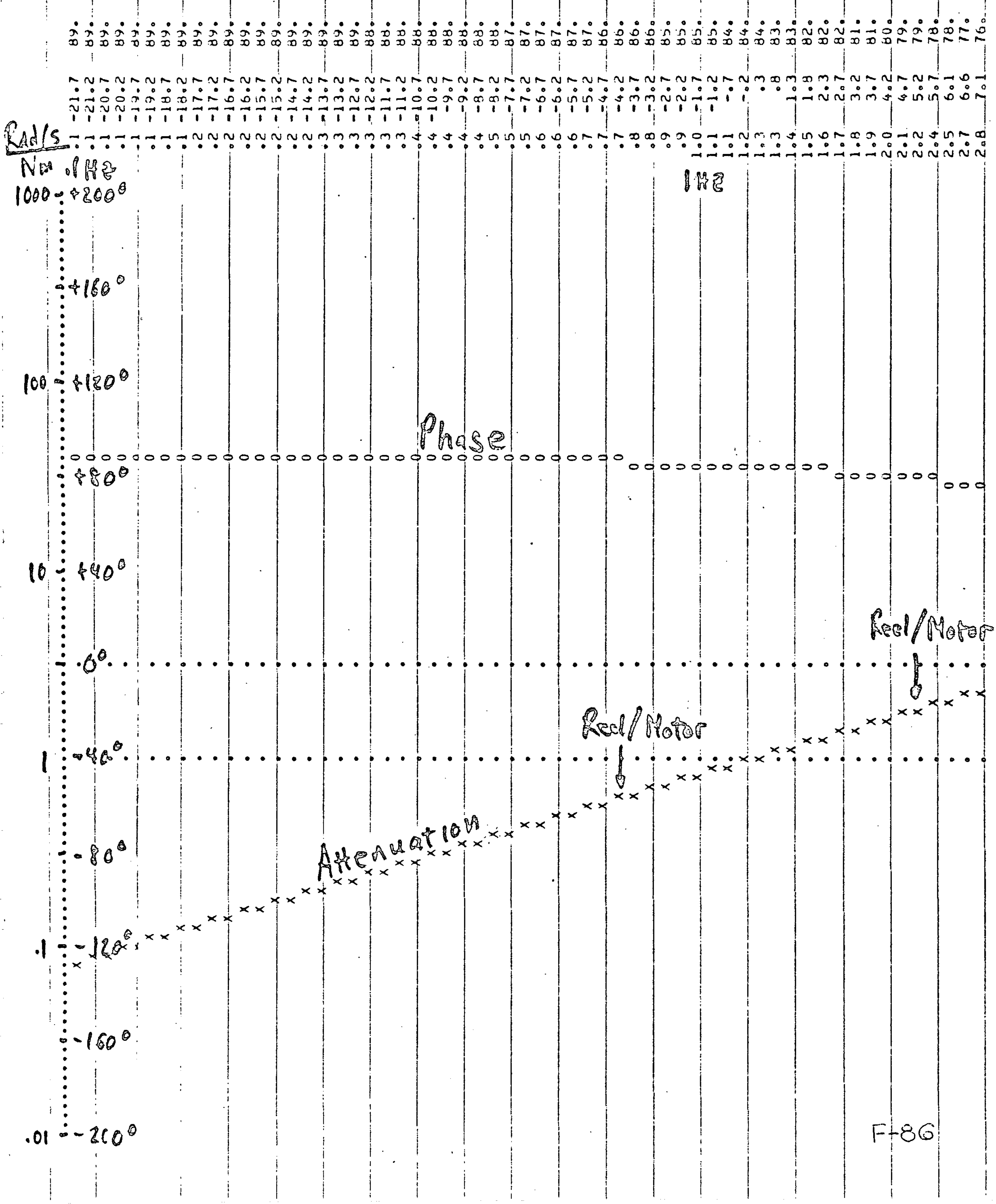
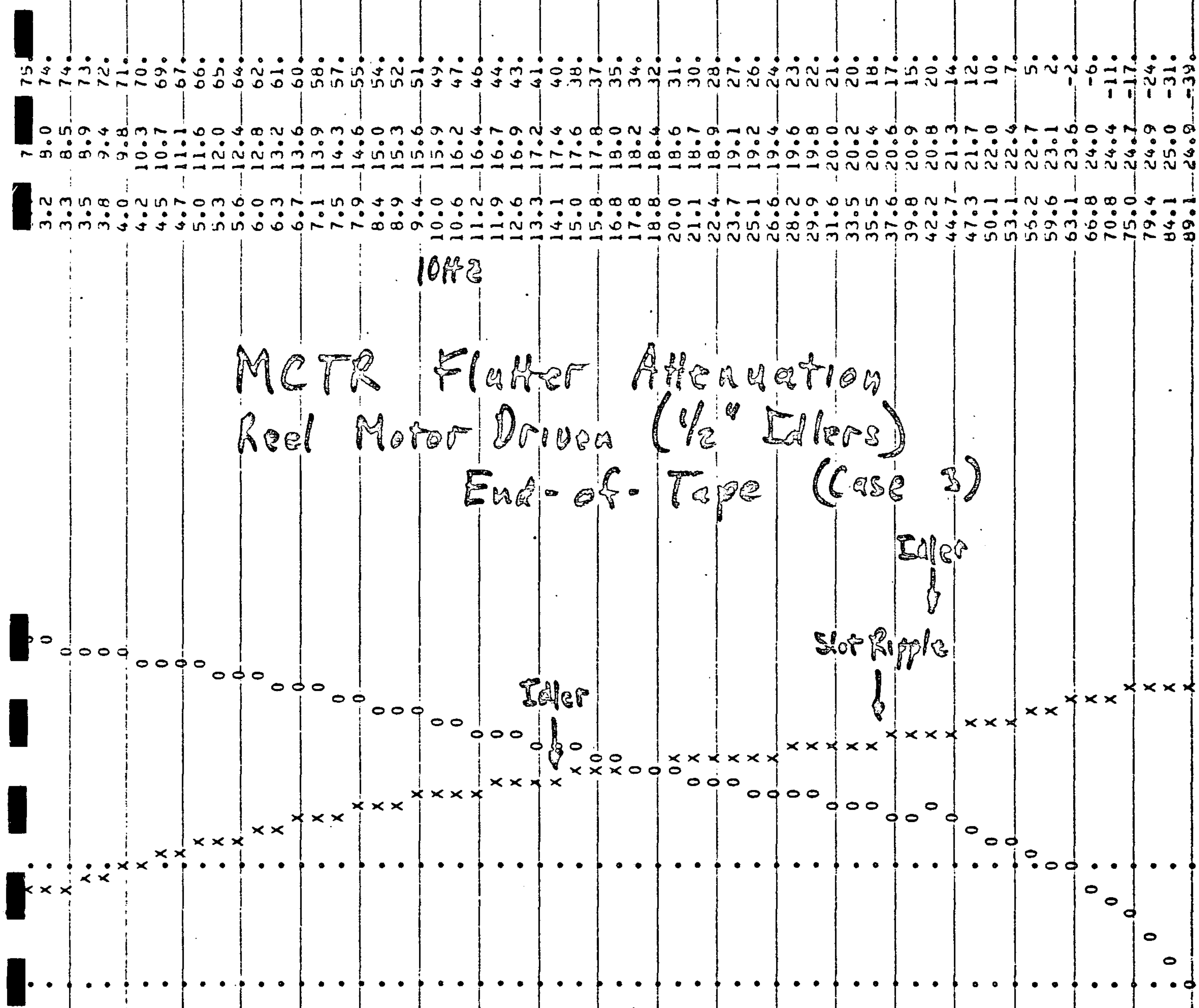
```
013.              L        )=0
00140             LINE(N)=DOT
00141             HERTZ=.1
00142          40 S=CMPLX(0.,6.283*HERTZ)
00143             A=1.+48.64E-6*S**2+591.3E-12*S**4+41.88E-18*S**6+.742E-24*S**8
00144             B=26.18*S*(1.+24.32E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
00145             C=187.E3*(1.+24.3E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
00146             D=187.E3*S*(0.929E-6+30.07E-12*S**2+1.600E-18*S**4+.0283E-24*S**6)
00147             E=187.E3*(1.+24.32E-6*S**2+.8615E-12*S**4)
00150             FI=(C+D)/(A+B)
00151             Q3=.446*(1+.0159*S)/(1+.00159*S)
00152             Q2F2=((1+.0004*S)/(1+.0004*S+(.0014+2.6E-7*S)*FI))*(E/(A+B))
00153             FCT=(Q2F2)/(1+(Q2F2*Q3*11.4)/(S*(1+.0004*S)))
00154             DB=20.*ALOG10(CABS(FCT))
00155             PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156             I=DB/P+FLOAT(M)+0.5
00157             LINE(I)=X
00160             J=PHASE/Q+FLOAT(N)+0.5
00161             LINE(J)=FI
00162             WRITE(6,50) LINE,HERTZ,DB,PHASE
00173          50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174             LINE(I)=BLANK
00175             LINE(J)=BLANK
00176             LINE(M)=DOT
00177             LINE(N)=DOT
00177       C     K IS NUMBER OF STEPS PER DECADE
00200             K=40
00201             HERTZ=HERTZ*10.**(1./FLOAT(K))
00202             IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205          60 STOP
00206             END

END OF UCC 1108 FORTRAN V COMPILATION.     0 *DIAGNOSTIC* MESSAGE(S)

14:36:35    @ XQT ATTEN
UCC ALLOCATOR......VERSION 1/7      03 MAY 71
```

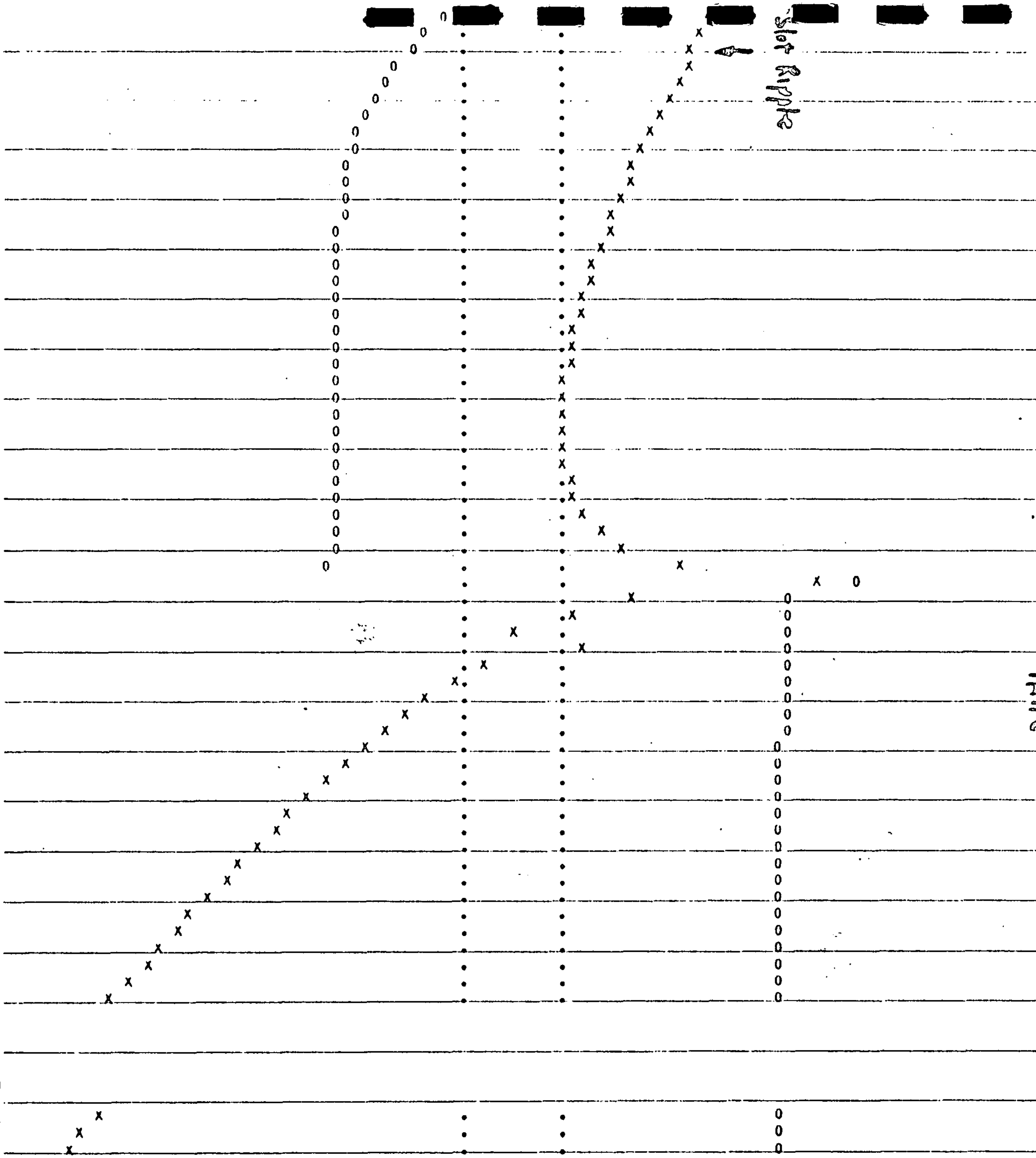


Rad/s
Nm
Hz
1000
+200°
+160°
100
+120°
Phase
+80°
10
+40°
0°
1
-40°
-80°
.1
-120°
-160°
.01
-200°
1 Hz
Attenuation
Reel/Motor
Reel/Motor

FIG. 18



$$\text{Comp.} = .881 \frac{(1+.0159S)}{(1+.00159S)}$$



[redacted].4	[redacted]	-4[redacted]
100.0	24.1	-55.
105.9	23.4	-61.
112.2	22.6	-67.
118.9	21.7	-72.
125.9	20.9	-77.
133.4	20.0	-80.
141.3	19.1	-83.
149.6	18.3	-85.
158.5	17.4	-87.
167.9	16.7	-88.
177.8	15.9	-89.
188.4	15.2	-90.
199.5	14.6	-91.
211.3	13.9	-91.
223.9	13.4	-91.
237.1	12.8	-92.
251.2	12.3	-92.
266.1	11.8	-92.
281.8	11.4	-92.
298.5	11.0	-92.
316.2	10.7	-92.
335.0	10.4	-92.
354.8	10.2	-92.
375.8	10.1	-92.
398.1	10.0	-92.
421.7	10.1	-92.
446.7	10.3	-92.
473.2	10.6	-92.
501.2	11.2	-92.
530.9	12.2	-92.
562.3	13.8	-93.
595.7	16.5	-94.
631.0	22.1	-96.
668.3	35.7	121.
707.9	17.4	93.
749.9	10.5	91.
794.3	4.7	91.
841.4	11.7	91.
891.2	2.3	90.
944.1	-.9	90.
1000.0	-3.6	90.
1059.3	-5.9	90.
1122.0	-8.1	90.
1188.5	-10.1	90.
1258.9	-12.1	90.
1333.5	-14.0	90.
1412.5	-15.8	90.
1496.2	-17.6	90.
1584.9	-19.4	90.
1678.8	-21.1	90.
1778.3	-22.7	90.
1883.6	-24.4	90.
1995.3	-26.0	90.
2113.5	-27.7	90.
2238.7	-29.3	90.
2371.4	-30.9	90.
2511.9	-32.5	90.
2660.7	-34.0	90.
2818.4	-35.6	90.
2985.4	-37.2	90.
3162.3	-38.7	90.
3349.6	-40.3	90.

1KHZ

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```
[redacted] ST[redacted]E U[redacted]BL[redacted] NA[redacted]ENG[redacted]

      0001    *CODE    001263
      0000    *DATA    000326
      0002    *BLANK   000000


  EXTERNAL REFERENCES (BLOCK, NAME)

      0003    NWDU$
      0004    NIO1$
      0005    NIO2$
      0006    CDV$
      0007    CABS
      0010    ALOG10
      0011    ATAN2
      0012    QEXP6$
      0013    NSTOP$


  STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

  0001   000014 117G    0001   000025 125G    0001   000033 133G    0001   001214 164G    0000   000043 20F
  0001   000043 40L     0000   000045 50F     0000 C 000002 A       0000 C 000004 B       0000 I 000024 BLANK
  0000 C 000006 C       0000 C 000010 D       0000 R 000037 DB      0000 I 000025 DOT     0000 C 000012 E
  0000 C 000014 FCT     0000 I 000027 FI      0000 C 000022 F1      0000 R 000036 HERTZ   0000 I 000034 I
  0000 I 000035 IS      0000 I 000041 J       0000 I 000042 K       0000 I 000161 LINE    0000 I 000032 M
  0000 I 000033 N       0000 R 000030 P       0000 R 000040 PHASE   0000 R 000031 Q       0000 C 000016 Q2F2
  0000 C 000020 Q3      0000 C 000000 S       0000 I 000026 X

 00100      1*    C       CLOSED LOOP RESPONSE
 00100      2*    C       TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
 00100      3*    C       CASE 3 - FULL REEL
 00101      4*            COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
 00103      5*            INTEGER BLANK,DOT,X,FI
 00104      6*            DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
 00111      7*            DIMENSION LINE(101)
 00111      8*    C       P IS DB PER CHARACTER SPACE
 00112      9*            P=1.
 00112     10*    C       Q IS DEGREES PER CHARACTER SPACE
 00113     11*            Q=4.
 00113     12*    C       M IS DB ZERO LOCATION
 00114     13*            M=41
 00114     14*    C       N IS PHASE ZERO LOCATION
 00115     15*            N=51
 00116     16*            DO 10 I=1,101
 00121     17*         10 LINE(I)=DOT
 00123     18*            WRITE (6,20) LINE
 00131     19*         20 FORMAT (1H1,101A1)
 00132     20*            DO 30 I=1,101
 00135     21*         30 LINE(I)=BLANK


 00137     22*            LINE(M)=DOT
 00140     23*            LINE(N)=DOT
 00141     24*            HERTZ=.1
 00142     25*         40 S=CMPLX(0.,6.283*HERTZ)
 00143     26*            A=1.+40.85E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
```

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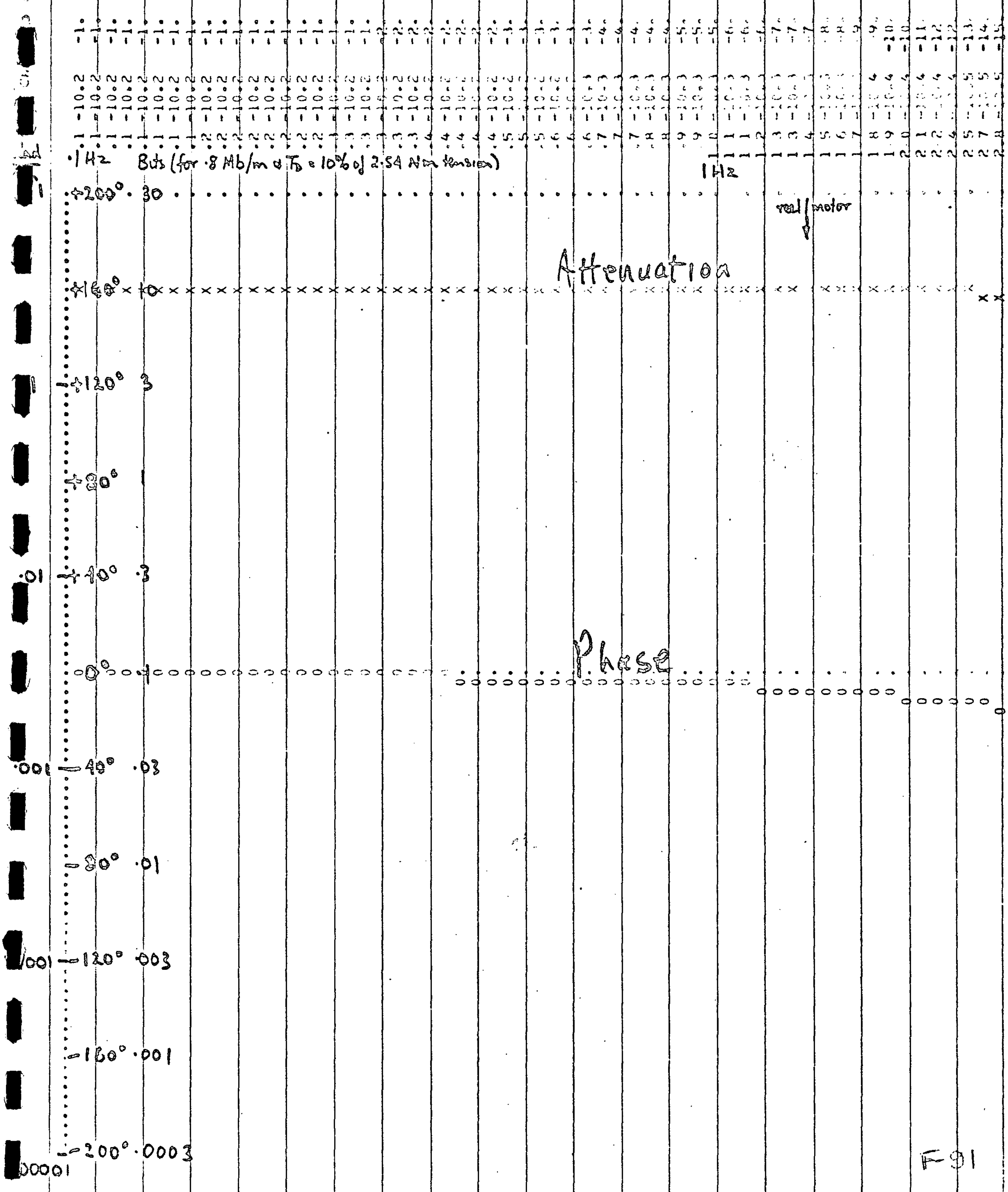
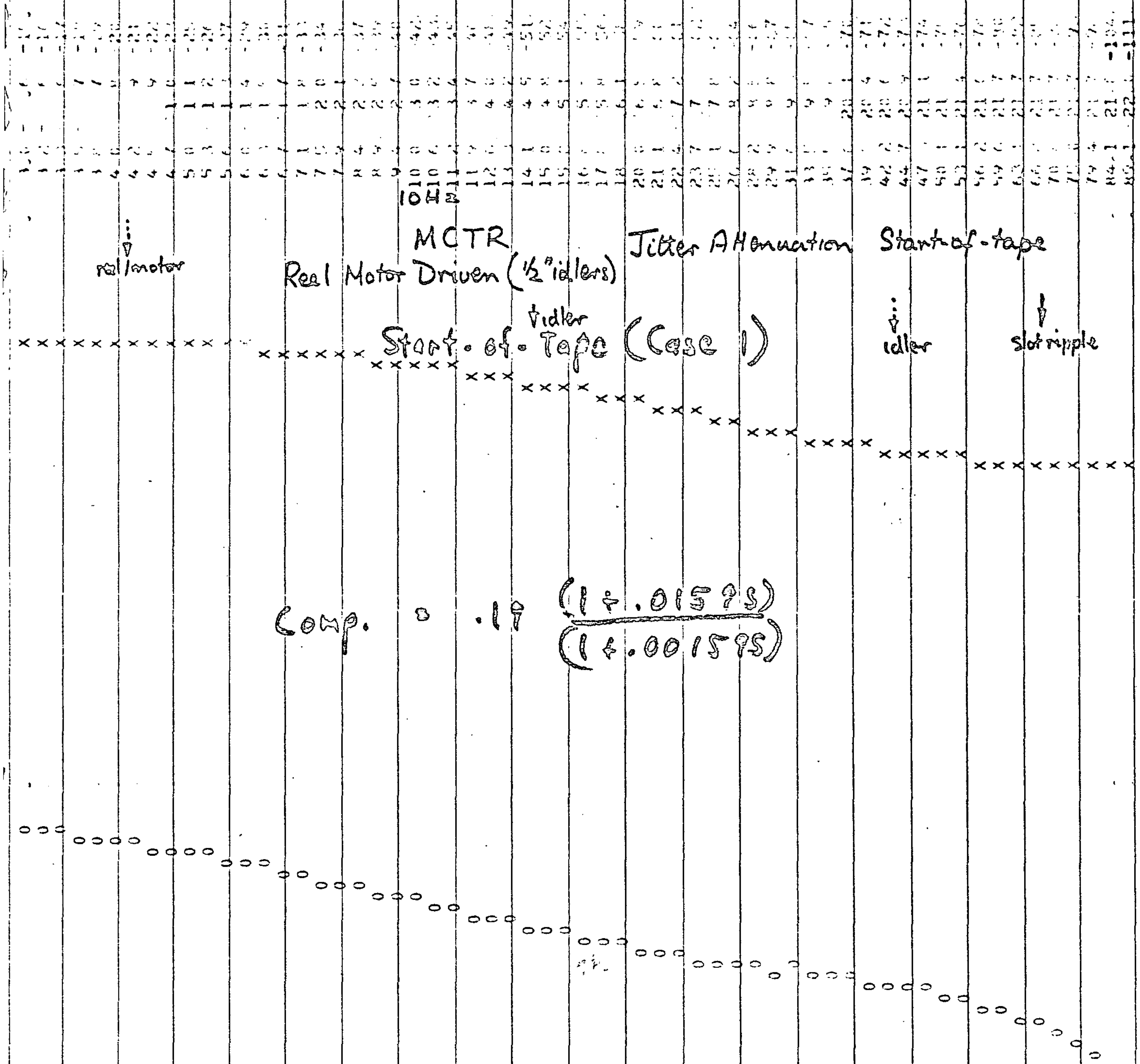
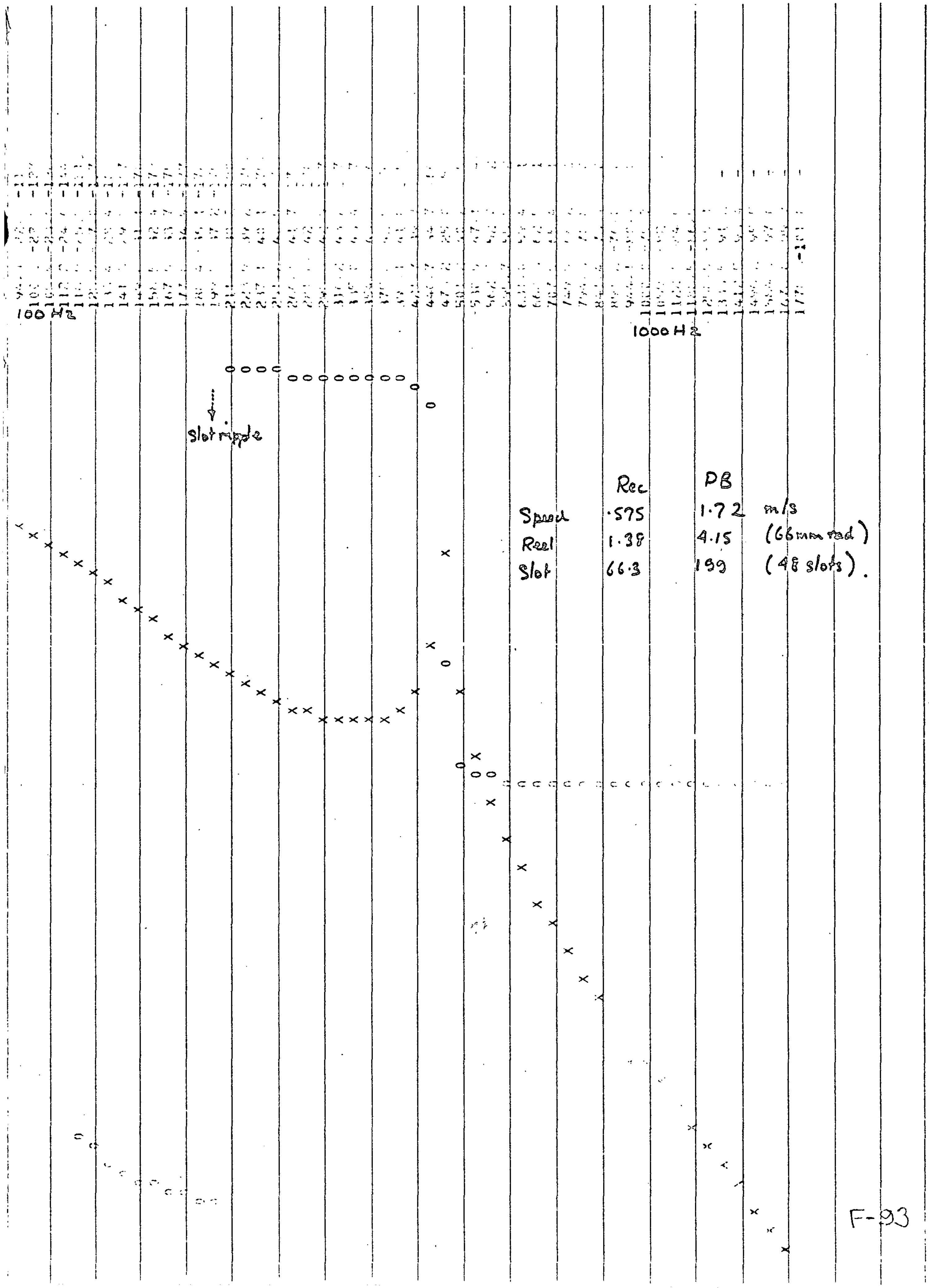
```
[redacted]137 [redacted]   [redacted]   LI[redacted]=DO[redacted]
00140          LINE(N)=DOT
00141          HERTZ=.1
00142       40 S=CMPLX(0.,6.283*HERTZ)
00143          A=1.+40.85E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
00144          B=38.71*S*(1.+14.60E-6*S**2+1.36E-12*S**4+.0302E-18*S**6)
00145          C=187.E3*(1.+14.6E-6*S**2+1.36E-12*S**4+.0303E-18*S**6)
00146          D=187.E3*S*(0.678E-6+9.900E-12*S**2+0.644E-18*S**4+.0103E-24*S**6)
00147          E=187.E3*(1.+14.60E-6*S**2+.5429E-12*S**4)
00150          F1=(C+D)/(A+B)
00151          Q3=.821*(1+.0159*S)/(1+.00159*S)
00152          Q2F2=((1+.0004*S)/(1+.0004*S+(.0010+2.1E-7*S)*F1))*(E/(A+B))
00153          FCT=(Q2F2)/(1+(Q2F2*Q3*9.26)/(S*(1+.0004*S)))
00154          DB=20.*ALOG10(CABS(FCT))
00155          PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156          I=DB/P+FLOAT(M)+0.5
00157          LINE(I)=X
00160          J=PHASE/Q+FLOAT(N)+0.5
00161          LINE(J)=FI
00162          WRITE(6,50) LINE,HERTZ,DB,PHASE
00173       50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174          LINE(I)=BLANK
00175          LINE(J)=BLANK
00176          LINE(M)=DOT
00177          LINE(N)=DOT
00177     C    K IS NUMBER OF STEPS PER DECADE
00200          K=40
00201          HERTZ=HERTZ*10.**(1./FLOAT(K))
00202          IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205       60 STOP
00206          END

     END OF UCC 1108 FORTRAN V COMPILATION.      0 *DIAGNOSTIC* MESSAGE(S)

14:33:48    @ XQT ATTEN
UCC ALLOCATOR......VERSION 1/7      03 MAY 71
```



·1Hz
Bits (for ·8 Mb/m & T_D = 10% of 2.54 N·m tension)
1Hz
reel/motor
Attenuation
Phase
+200° 30
+160° 10
+120° 3
+80° 1
·01 +40° ·3
0° 1
·001 −40° ·03
−80° ·01
·0001 −120° ·003
−160° ·001
·00001 −200° ·0003

FIG. 19


10Hz
MCTR
reel motor
Reel Motor Driven (½" idlers)
Jitter Attenuation
Start-of-tape
idler
Start-of-Tape (Case 1)
idler
slot ripple
Comp. = .19 (1+.0159s)/(1+.00159s)


100 Hz
1000 Hz
slot ripple
Rec PB
Speed ·575 1·72 m/s
Reel 1·38 4.15 (66mm rad)
Slot 66·3 199 (48 slots).

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```
14:54:31    @B FOR ATTEN.ATTEN                                                    1F9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 28 APR 71 AT 14:54:31

    MAIN PROGRAM

    STORAGE USED (BLOCK, NAME, LENGTH)

          0001    $CODE    001325
          0000    $DATA    000330
          0002    BLANK    000000

    EXTERNAL REFERENCES (BLOCK, NAME)

          0003    [illegible]
          0004    [illegible]
          0005    [illegible]
          0006    [illegible]
          0007    [illegible]
          0010    ALOG10
          0011    [illegible]
          0012    [illegible]
          0013    [illegible]

    STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

    0001     000014 117.     0001     000025 125G     0001     000033 133G     0001     001256 164G     0000     000043 20F
    0001     000043 50L      0000     000045 50F      0000 C 000002 A         0000 C 000004 B         0000 I 000024 BLANK
    0000 C 000006 C          0000 C 000010 D         0000 R 000037 DB        0000 I 000025 DOT       0000 C 000012 E
    0000 C 000014 FCT        0000 I 000027 FI        0000 C 000022 F1        0000 R 000036 HERTZ     0000 I 000034 I
    0000 I 000035 [illegible] 0000 I 000041 J        0000 I 000042 K         0000 I 000163 LINE      0000 I 000032 M
    0000 I 000033 N          0000 R 000030 P         0000 R 000040 PHASE     0000 R 000031 Q         0000 C 000016 Q2F2
    0000 C 000020 [illegible] 0000 C 000000 S        0000 I 000026 X

 00100       1*    C      CLOSED LOOP RESPONSE
 00100       2*    C      JITTER VS TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
 00101       3*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
 00103       4*           INTEGER BLANK,DOT,X,FI
 00104       5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
 00111       6*           DIMENSION LINE(101)
 00111       7*    C      P IS DB PER CHARACTER SPACE
 00112       8*           P=1.
 00112       9*    C      Q IS DEGREES PER CHARACTER SPACE
 00113      10*           Q=4.
 00113      11*    C      M IS DB ZERO LOCATION
 00114      12*           M=11
 00114      13*    C      N IS PHASE ZERO LOCATION
 00115      14*           N=51
 00116      15*           DO 10 I=1,101
 00121      16*        10 LINE(I)=DOT
 00123      17*           WRITE (6,20) LINE
 00131      18*        20 FORMAT (1H1,101A1)
 00132      19*           DO 30 I=1,101
 00135      20*        30 LINE(I)=BLANK
 00137      21*           LINE(M)=DOT
```

Case1, Start of Tape.

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```
00140             LINE(N)=DOT
00141             HERTZ=.1
00142          40 S=CMPLX(0.,6.283*HERTZ)
00143             A=1.+40.85E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
00144             B=1.+.36*S*(1.+26.25E-6*S**2+3.66E-12*S**4+.0814E-18*S**6)
00145             C=1.+7.E3*(1.+26.3E-6*S**2+3.66E-12*S**4+.0816E-18*S**6)
00146             D=1.+7.E3*S*(1.017E-5+26.68E-12*S**2+1.736E-18*S**4+.0277E-24*S**6)
00147             E=1.+7.E3*(1.+26.25E-6*S**2+.7322E-12*S**4)
00150             F1=(C+D)/(A+B)
00151             Q3=.190*(1+.0159*S)/(1+.00159*S)
00152             Q2F2=((1+.0004*S)/(1+.0004*S+(.0026+3.9E-7*S)*F1))*(E/(A+B))
00153             FCT=(Q2F2)/(S*(1+(Q2F2*Q3*17.1)/(S*(1+.0004*S))))
00154             DB=20.*ALOG10(CABS(FCT))
00155             PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156             I=DB/Z+FLOAT(M)+0.5
00157             LINE(I)=X
00160             J=PHASE/Q+FLOAT(N)+0.5
00161             LINE(J)=FI
00162             WRITE(6,50) LINE,HERTZ,DB,PHASE
00173          50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174             LINE(I)=BLANK
00175             LINE(J)=BLANK
00176             LINE(M)=DOT
00177             LINE(N)=DOT
00177     C       K IS NUMBER OF STEPS PER DECADE
00200             K=40
00201             HERTZ=HERTZ*10.**(1./FLOAT(K))
00202             IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205          60 STOP
00206             END

      END OF UCC 1108 FORTRAN V COMPILATION.     0 *DIAGNOSTIC* MESSAGE(S)
```

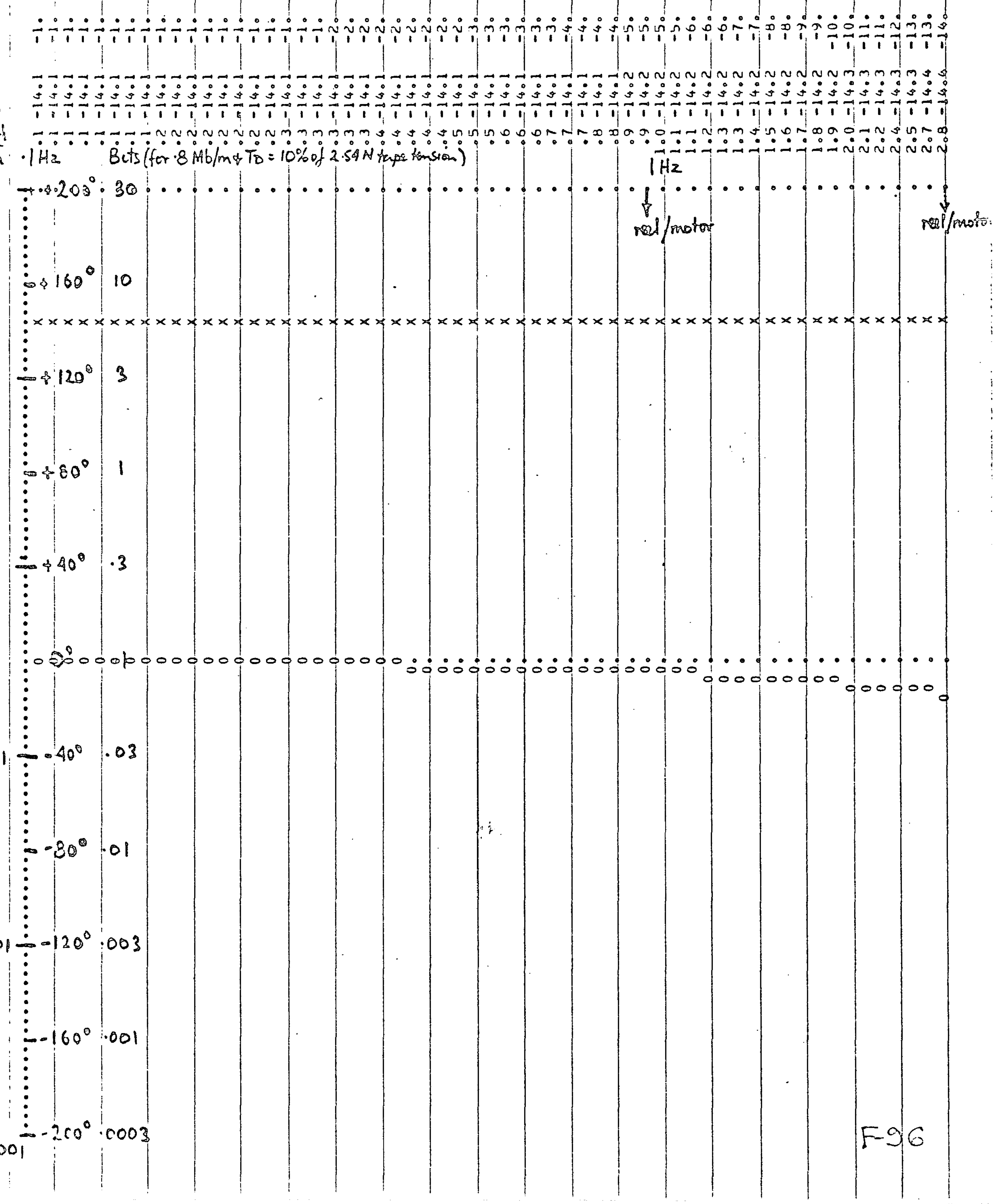
·1Hz
Bcts (for ·8 Mb/m & TD = 10% of 2.54N tape tension)
1Hz
reel/motor
reel/motor
+200° 30
+160° 10
+120° 3
+80° 1
+40° ·3
0° ·1
-40° ·03
-80° ·01
-120° ·003
-160° ·001
-200° ·0003

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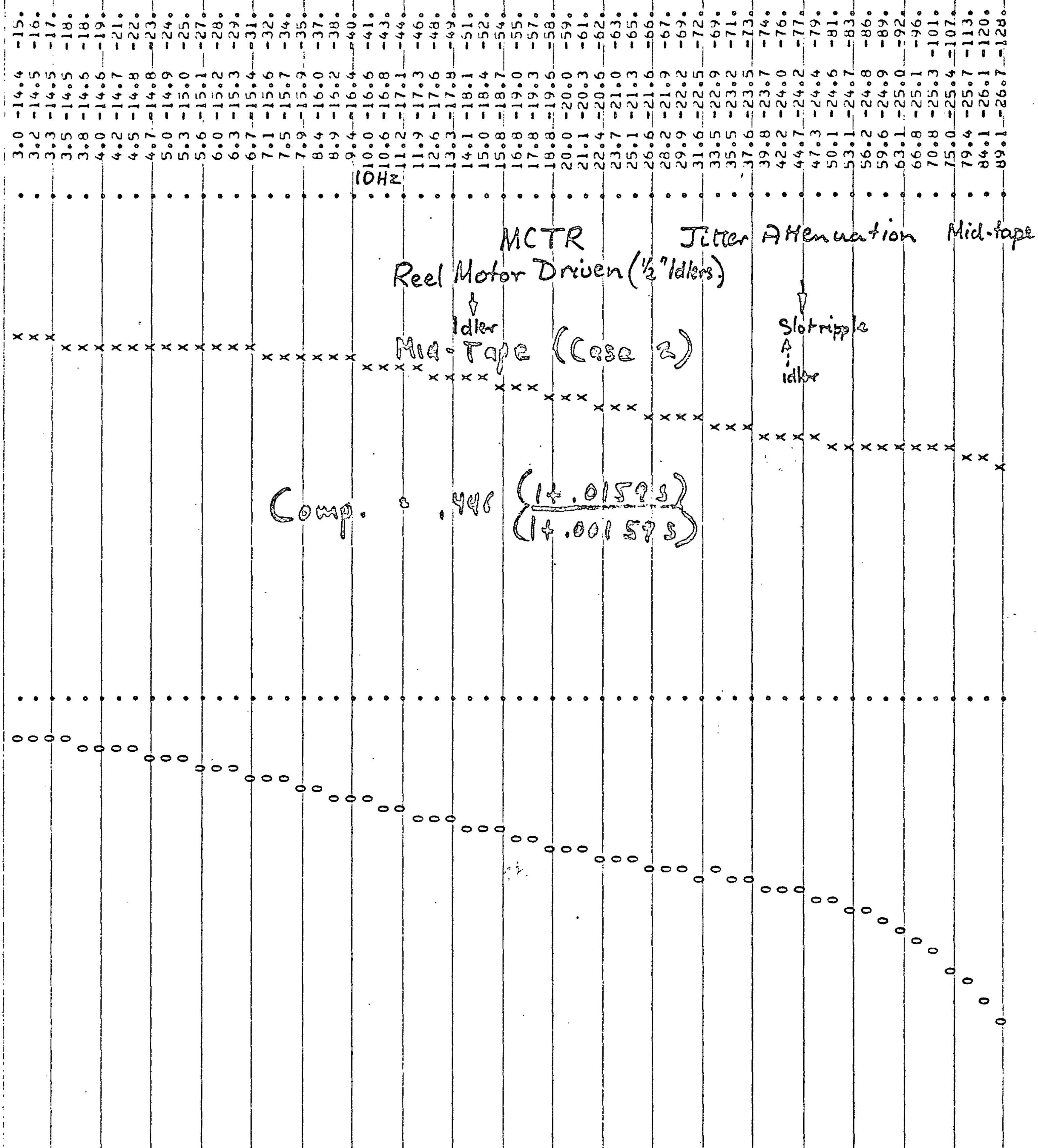
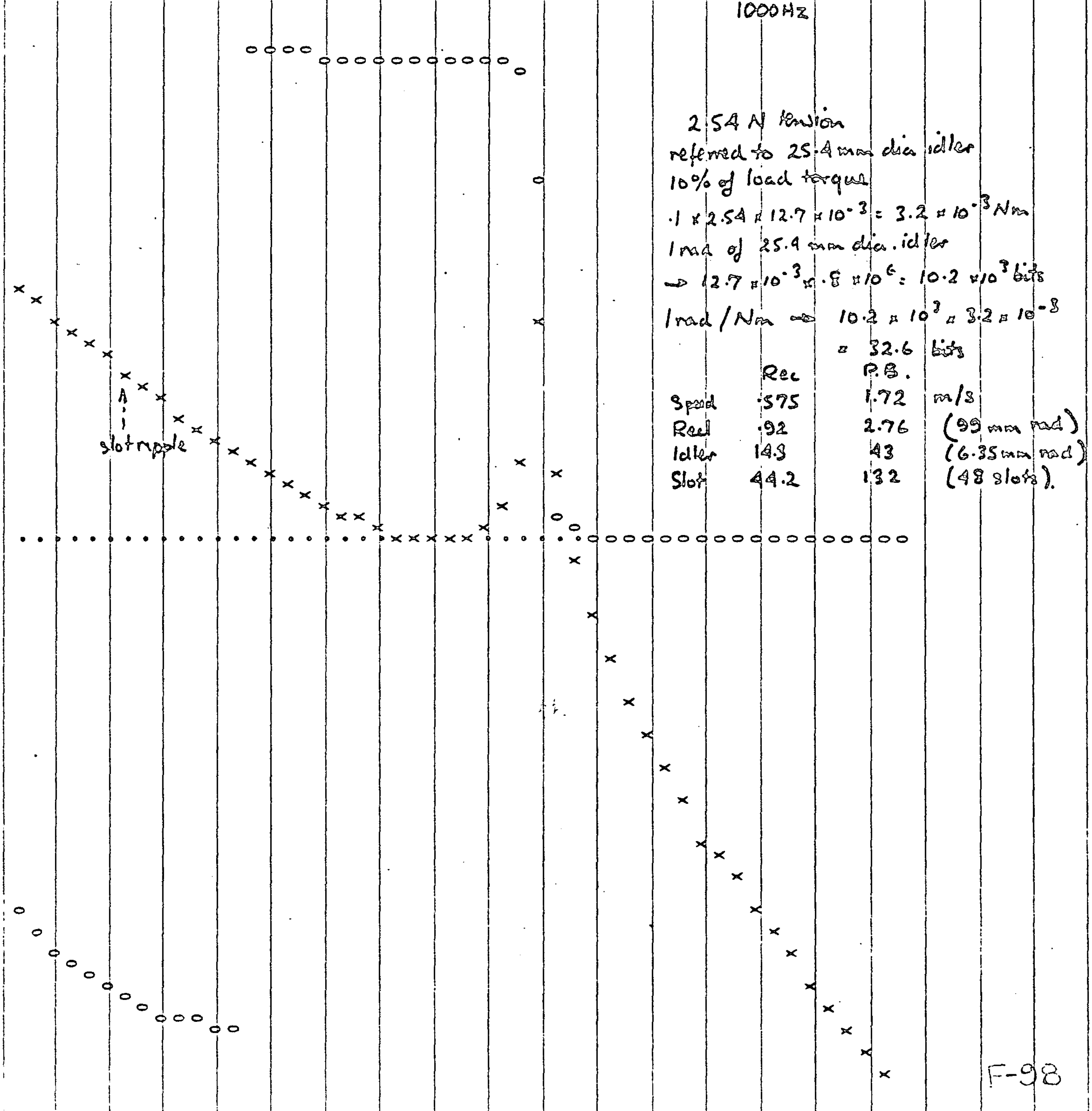
FIG. 20


3.0 -14.4 -15.
3.2 -14.5 -16.
3.3 -14.5 -17.
3.5 -14.5 -18.
3.8 -14.6 -18.
4.0 -14.6 -19.
4.2 -14.7 -21.
4.5 -14.8 -22.
4.7 -14.8 -23.
5.0 -14.9 -24.
5.3 -15.0 -25.
5.6 -15.1 -27.
6.0 -15.2 -28.
6.3 -15.3 -29.
6.7 -15.4 -31.
7.1 -15.6 -32.
7.5 -15.7 -34.
7.9 -15.9 -35.
8.4 -16.0 -37.
8.9 -16.2 -38.
9.4 -16.4 -40.
10.0 -16.6 -41.
10.6 -16.8 -43.
11.2 -17.1 -44.
11.9 -17.3 -46.
12.6 -17.6 -48.
13.3 -17.8 -49.
14.1 -18.1 -51.
15.0 -18.4 -52.
15.8 -18.7 -54.
16.8 -19.0 -55.
17.8 -19.3 -57.
18.8 -19.6 -58.
20.0 -20.0 -59.
21.1 -20.3 -61.
22.4 -20.6 -62.
23.7 -21.0 -63.
25.1 -21.3 -65.
26.6 -21.6 -66.
28.2 -21.9 -67.
29.9 -22.2 -69.
31.6 -22.5 -72.
33.5 -22.9 -69.
35.5 -23.2 -71.
37.6 -23.5 -73.
39.8 -23.7 -74.
42.2 -24.0 -76.
44.7 -24.2 -77.
47.3 -24.4 -79.
50.1 -24.6 -81.
53.1 -24.7 -83.
56.2 -24.8 -86.
59.6 -24.9 -89.
63.1 -25.0 -92.
66.8 -25.1 -96.
70.8 -25.3 -101.
75.0 -25.4 -107.
79.4 -25.7 -113.
84.1 -26.1 -120.
89.1 -26.7 -128.
10Hz
MCTR Jitter Attenuation Mid-tape
Reel Motor Driven (½" Idlers)
Idler
Mid-Tape (Case 2)
Slotripple
idler
Comp. = .446 (1+.0159 s) / (1+.00159 s)

94.4	-27.4	-136.
100.0	-28.4	-143.
105.9	-29.5	-150.
112.2	-30.7	-156.
118.9	-32.1	-161.
125.9	-33.4	-166.
133.4	-34.7	-169.
141.3	-36.0	-172.
149.6	-37.3	-174.
158.5	-38.6	-176.
167.9	-39.8	-178.
177.8	-41.0	-179.
188.4	-42.1	-180.
199.5	-43.2	180.
211.3	-44.2	179.
223.9	-45.2	179.
237.1	-46.1	178.
251.2	-47.0	178.
266.1	-47.8	178.
281.8	-48.5	178.
298.5	-49.1	177.
316.2	-49.6	177.
335.0	-50.0	177.
354.8	-50.2	177.
375.8	-50.2	177.
398.1	-49.8	176.
421.7	-49.0	176.
446.7	-47.2	175.
473.2	-43.3	171.
501.2	-30.0	134.
530.9	-43.9	9.
562.3	-52.0	4.
595.7	-57.3	2.
631.0	-61.5	1.
668.3	-65.1	1.
707.9	-68.3	1.
749.9	-71.2	0.
794.3	-74.0	0.
841.4	-77.0	0.
891.2	-79.0	0.
944.1	-81.5	0.
1000.0	-83.9	0.
1059.3	-86.2	0.
1122.0	-88.5	0.
1188.5	-90.7	-0.
1258.9	-93.0	-0.
1333.5	-95.1	-0.
1412.5	-97.3	-0.
1496.2	-99.4	-0.
1584.9	-101.6	-0.



```
15:09:38    @3 FOR ATTEN,ATTEN                                          1F9002
UCC 1108 FORTRAN V  :  LEVEL    3.2A
THIS COMPILATION WAS DONE ON 28-APR-71 AT 15:09:38

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

        0001    *CODE    001310
        0000    *DATA    000326
        0002    *BLANK   000000

EXTERNAL REFERENCES (BLOCK, NAME)

        0003    NWDU$
        0004    NIO1$
        0005    NIO2$
        0006    CDV$
        0007    CABS
        0010    ALOG10
        0011    ATAN2
        0012    NEXP6$
        0013    NSTOP$

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001    000014 117G    0001    000025 125G    0001    000033 133G    0001    001241 164G    0000    000043 20F
0001    000043 40L     0000    000045 50F     0000 C 000002 A       0000 C 000004 B       0000 I 000024 BLANK
0000 C 000006 C        0000 C 000010 D        0000 R 000037 DB      0000 I 000025 DOT     0000 C 000012 E
0000 C 000014 FCT      0000 I 000027 FI       0000 C 000022 F1      0000 R 000036 HERTZ   0000 I 000034 I
0000 I 000035 I$       0000 I 000041 J        0000 I 000042 K       0000 I 000161 LINE    0000 I 000032 M
0000 I 000033 N        0000 R 000030 P        0000 R 000040 PHASE   0000 R 000031 Q       0000 C 000016 Q2F2
0000 C 000020 Q3       0000 C 000000 S        0000 I 000026 X

00100      1*   C     CLOSED LOOP RESPONSE
00100      2*   C     JITTER VS TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
00101      3*         COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
00103      4*         INTEGER BLANK,DOT,X,FI
00104      5*         DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
00111      6*         DIMENSION LINE(101)
00111      7*   C     P IS DB PER CHARACTER SPACE
00112      8*         P=1.
00112      9*   C     Q IS DEGREES PER CHARACTER SPACE
00113     10*         Q=4.
00113     11*   C     M IS DB ZERO LOCATION
00114     12*         M=101
00114     13*   C     N IS PHASE ZERO LOCATION
00115     14*         N=51
00116     15*         DO 10 I=1,101
00121     16*      10 LINE(I)=DOT
00123     17*         WRITE (6,20) LINE
00131     18*      20 FORMAT (1H1,101A1)
00132     19*         DO 30 I=1,101
00135     20*      30 LINE(I)=BLANK
00137     21*         LINE(M)=DOT
```

Case 2, Midtape

```
      LINE(N)=DOT
      HERTZ=.1
   40 S=CMPLX(0.,6.283*HERTZ)
      A=1.+48.64E-6*S**2+591.3E-12*S**4+41.88E-18*S**6+.742E-24*S**8
      B=26.18*S*(1.+24.32E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
      C=187.E3*(1.+24.3E-6*S**2+3.22E-12*S**4+.0836E-18*S**6)
      D=187.E3*S*(0.929E-6+30.07E-12*S**2+1.600E-18*S**4+.0283E-24*S**6)
      E=187.E3*(1.+24.32E-6*S**2+.8615E-12*S**4)
      F1=(C+D)/(A+B)
      Q3=.446*(1+.0159*S)/(1+.00159*S)
      Q2F2=((1+.0004*S)/(1+.0004*S+(.0014+2.6E-7*S)*F1))*(E/(A+B))
      FCT=(Q2F2)/(S*(1+(Q2F2*Q3*11.4)/(S*(1+.0004*S))))
      DB=20.*ALOG10(CABS(FCT))
      PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
      I=DB/P+FLOAT(M)+0.5
      LINE(I)=X
      J=PHASE/Q+FLOAT(N)+0.5
      LINE(J)=FI
      WRITE(6,50) LINE,HERTZ,DB,PHASE
   50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
      LINE(I)=BLANK
      LINE(J)=BLANK
      LINE(M)=DOT
      LINE(N)=DOT
C     K IS NUMBER OF STEPS PER DECADE
      K=40
      HERTZ=HERTZ*10.**(1./FLOAT(K))
      IF ((FLOAT(M)-1.)*P+DB) 60,60,40
   60 STOP
      END
```

END OF UCC 1108 FORTRAN V COMPILATION.   0 *DIAGNOSTIC* MESSAGE(S)

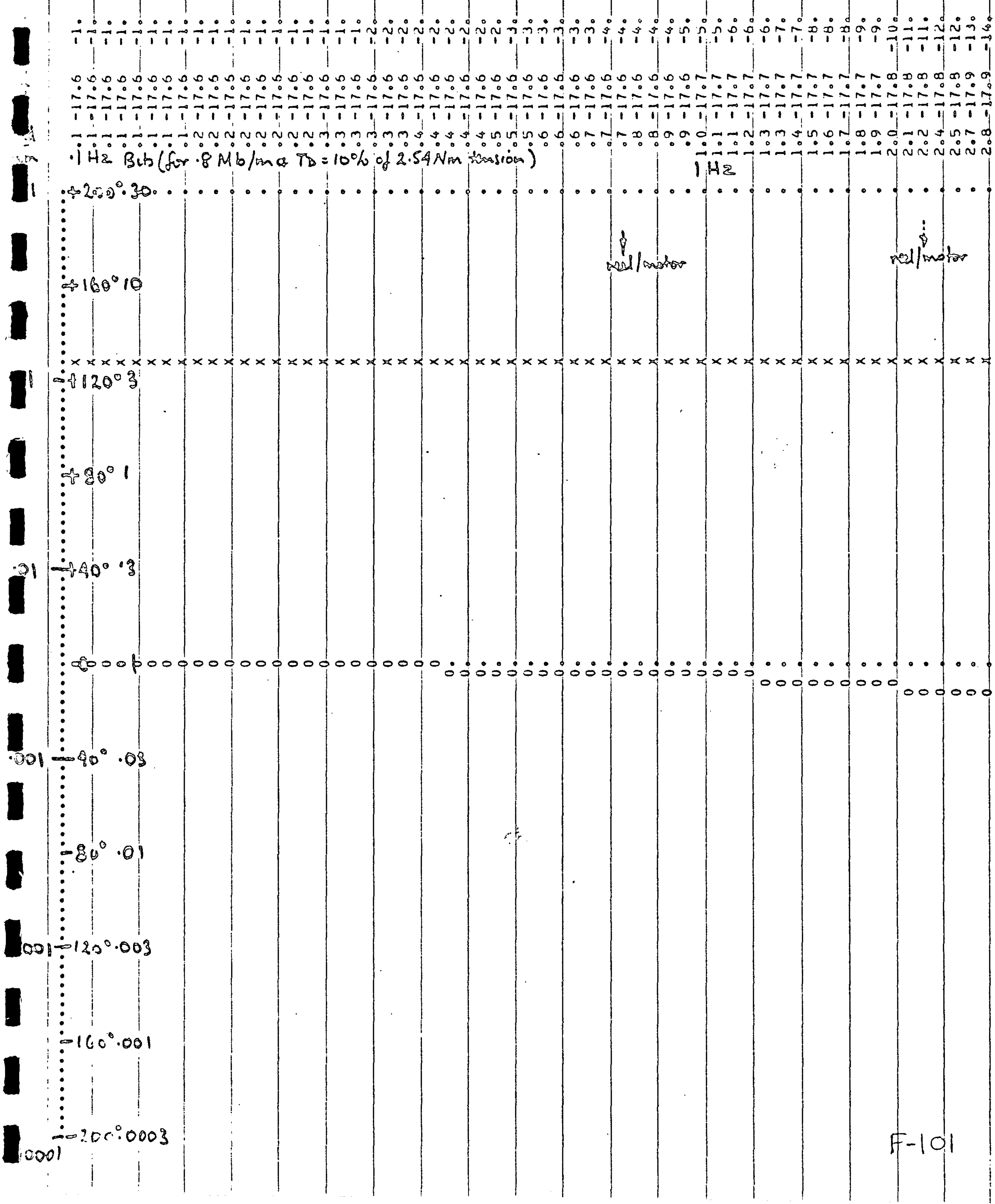
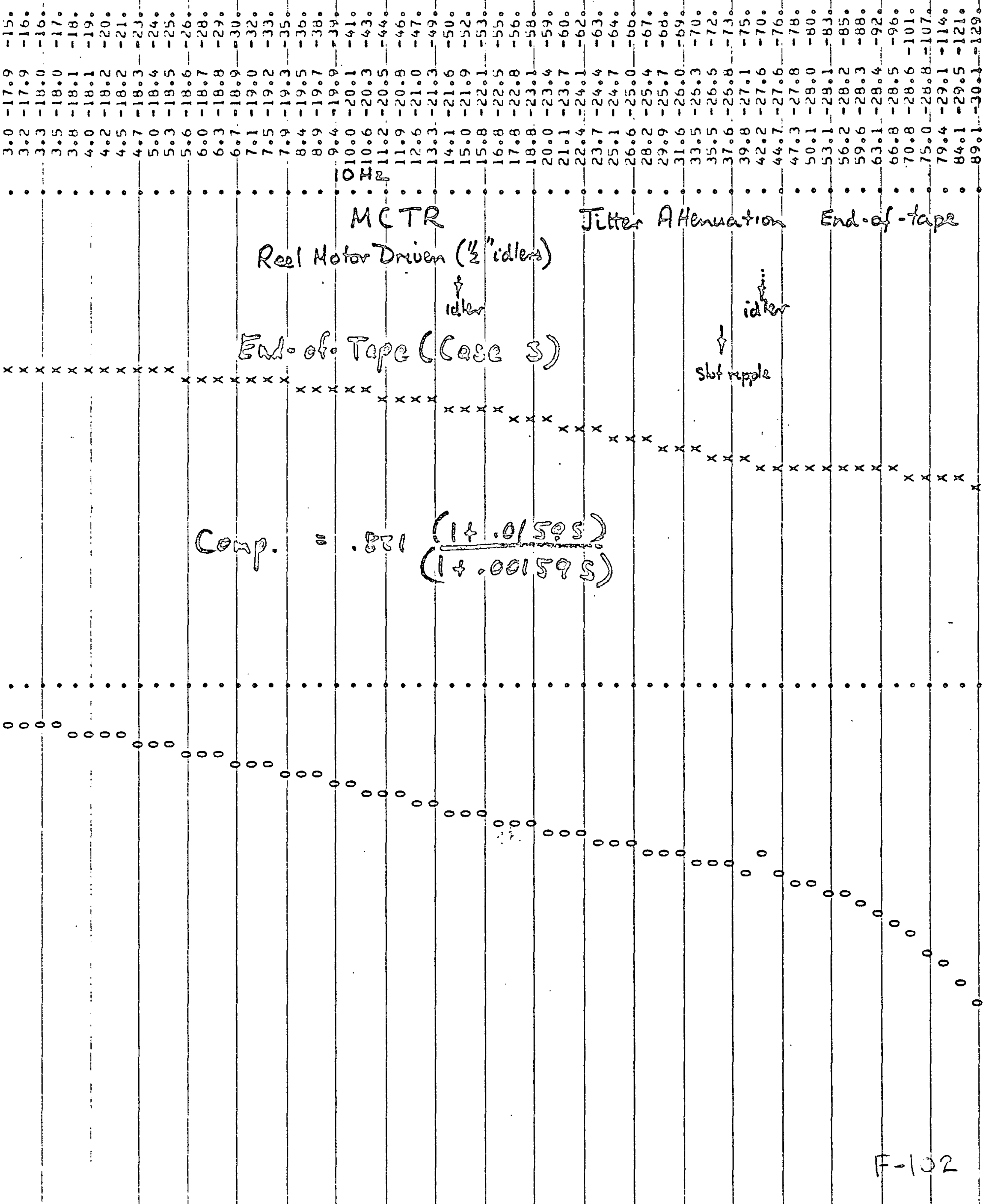
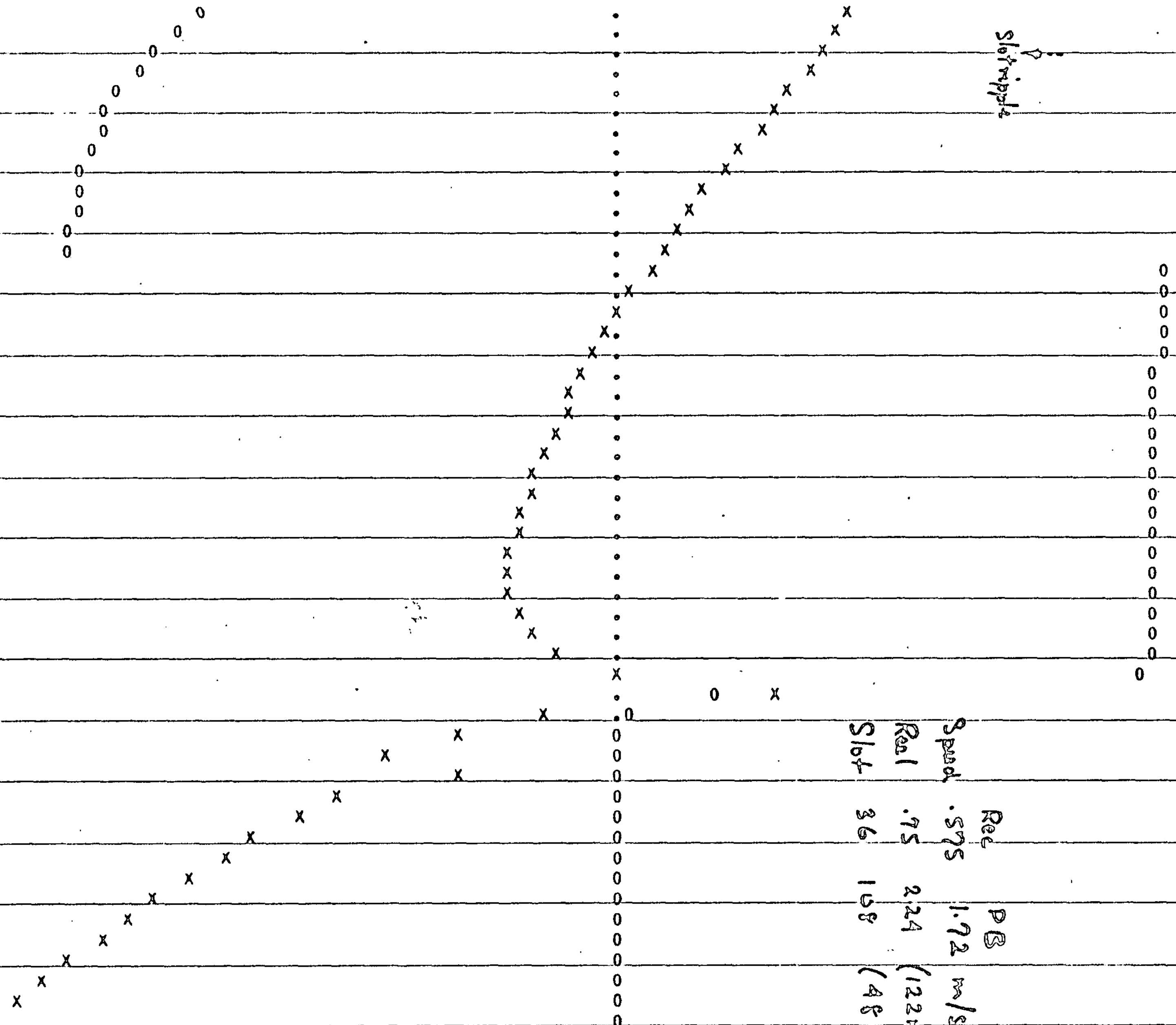

.1 Hz Bib (for .8 Mb/ma TD = 10% of 2.54 Nm tension)
1 Hz
reel/motor
reel/motor
+200° 30
+160° 10
+120° 3
+80° 1
+40° .3
-40° .03
-80° .01
-120° .003
-160° .001
-200° .0003
.01
.001
.0001

FIG. 21


10Hz
MCTR
Jitter Attenuation End-of-tape
Reel Motor Driven (½" idlers)
idler
idler
End-of-Tape (Case 3)
Slot ripple
Comp. = .821 (1+.01595)/(1+.001595)



94.4	-30.9	-137.
100.0	-31.9	-144.
105.9	-33.1	-151.
112.2	-34.4	-157.
118.9	-35.7	-162.
125.9	-37.1	-166.
133.4	-38.5	-170.
141.3	-39.9	-173.
149.6	-41.2	-175.
158.5	-42.5	-177.
167.9	-43.8	-178.
177.8	-45.0	-179.
188.4	-46.2	-180.
199.5	-47.4	179.
211.3	-48.5	179.
223.9	-49.6	179.
237.1	-50.7	178.
251.2	-51.7	178.
266.1	-52.6	178.
281.8	-53.6	178.
298.5	-54.4	178.
316.2	-55.3	178.
335.0	-56.1	178.
354.8	-56.8	178.
375.8	-57.4	178.
398.1	-58.0	178.
421.7	-58.4	178.
446.7	-58.7	178.
473.2	-58.8	178.
501.2	-58.7	178.
530.9	-58.2	178.
562.3	-57.2	177.
595.7	-55.0	176.
631.0	-49.9	174.
668.3	-36.7	31.
707.9	-55.6	3.
749.9	-62.9	1.
794.3	-69.2	1.
841.4	-62.8	1.
891.2	-72.6	0.
944.1	-76.4	0.
1000.0	-79.5	0.
1059.3	-82.4	0.
1122.0	-85.1	0.
1188.5	-87.6	-0.
1258.9	-90.1	-0.
1333.5	-92.5	-0.
1412.5	-94.8	-0.
1496.2	-97.1	-0.
1584.9	-99.3	-0.
1678.8	-101.5	-0.

100 Hz

1000 Hz

	Rec	PB	
Speed	.575	1.72	m/s
Reel	.75	2.24	(122 mm rad)
Slot	36	108	(48 slots).

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```
14:54:38    @B FOR ATTEN,ATTEN                                                    1F9002
UCC 1108 FORTRAN V  :  LEVEL   3.2A
THIS COMPILATION WAS DONE ON 28-APR-71 AT 14:54:39

     MAIN PROGRAM

     STORAGE USED (BLOCK, NAME, LENGTH)

          0001    *CODE    001300
          0000    *DATA    000326
          0002    *BLANK   000000

     EXTERNAL REFERENCES (BLOCK, NAME)

          0003    NWDU$
          0004    NIO1$
          0005    NIO2$
          0006    CDV$
          0007    CABS
          0010    ALOG10
          0011    ATAN2
          0012    NEXP6$
          0013    NSTOP$

     STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

     0001    000014 117G      0001    000025 125G      0001    000033 133G      0001    001231 164G      0000    000043 20F
     0001    000043 40L       0000    000045 50F       0000 C 000002 A          0000 C 000004 B          0000 I 000024 BLANK
     0000 C 000006 C          0000 C 000010 D          0000 R 000037 DB         0000 I 000025 DOT        0000 C 000012 E
     0000 C 000014 FCT        0000 I 000027 FI         0000 C 000022 F1         0000 R 000036 HERTZ      0000 I 000034 I
     0000 I 000035 I$         0000 I 000041 J          0000 I 000042 K          0000 I 000161 LINE       0000 I 000032 M
     0000 I 000033 N          0000 R 000030 P          0000 R 000040 PHASE      0000 R 000031 Q          0000 C 000016 Q2F2
     0000 C 000020 Q3         0000 C 000000 S          0000 I 000026 X

  00100      1*    C      CLOSED LOOP RESPONSE
  00100      2*    C      JITTER VS TORQUE DISTURBANCE ATTENUATION AND PHASE PLOT
  00101      3*           COMPLEX S,A,B,C,D,E,FCT,Q2F2,Q3,F1
  00103      4*           INTEGER BLANK,DOT,X,FI
  00104      5*           DATA BLANK/' '/,DOT/'.'/,X/'X'/,FI/'0'/
  00111      6*           DIMENSION LINE(101)
  00111      7*    C      P IS DB PER CHARACTER SPACE
  00112      8*           P=1.
  00112      9*    C      Q IS DEGREES PER CHARACTER SPACE
  00113     10*           Q=4.
  00113     11*    C      M IS DB ZERO LOCATION
  00114     12*           M=101
  00114     13*    C      N IS PHASE ZERO LOCATION
  00115     14*           N=51
  00116     15*           DO 10 I=1,101
  00121     16*        10 LINE(I)=DOT
  00123     17*           WRITE (6,20) LINE
  00131     18*        20 FORMAT (1H1,101A1)
  00132     19*           DO 30 I=1,101
  00135     20*        30 LINE(I)=BLANK
  00137     21*           LINE(M)=DOT
```

Case 3, End of tape

F-104

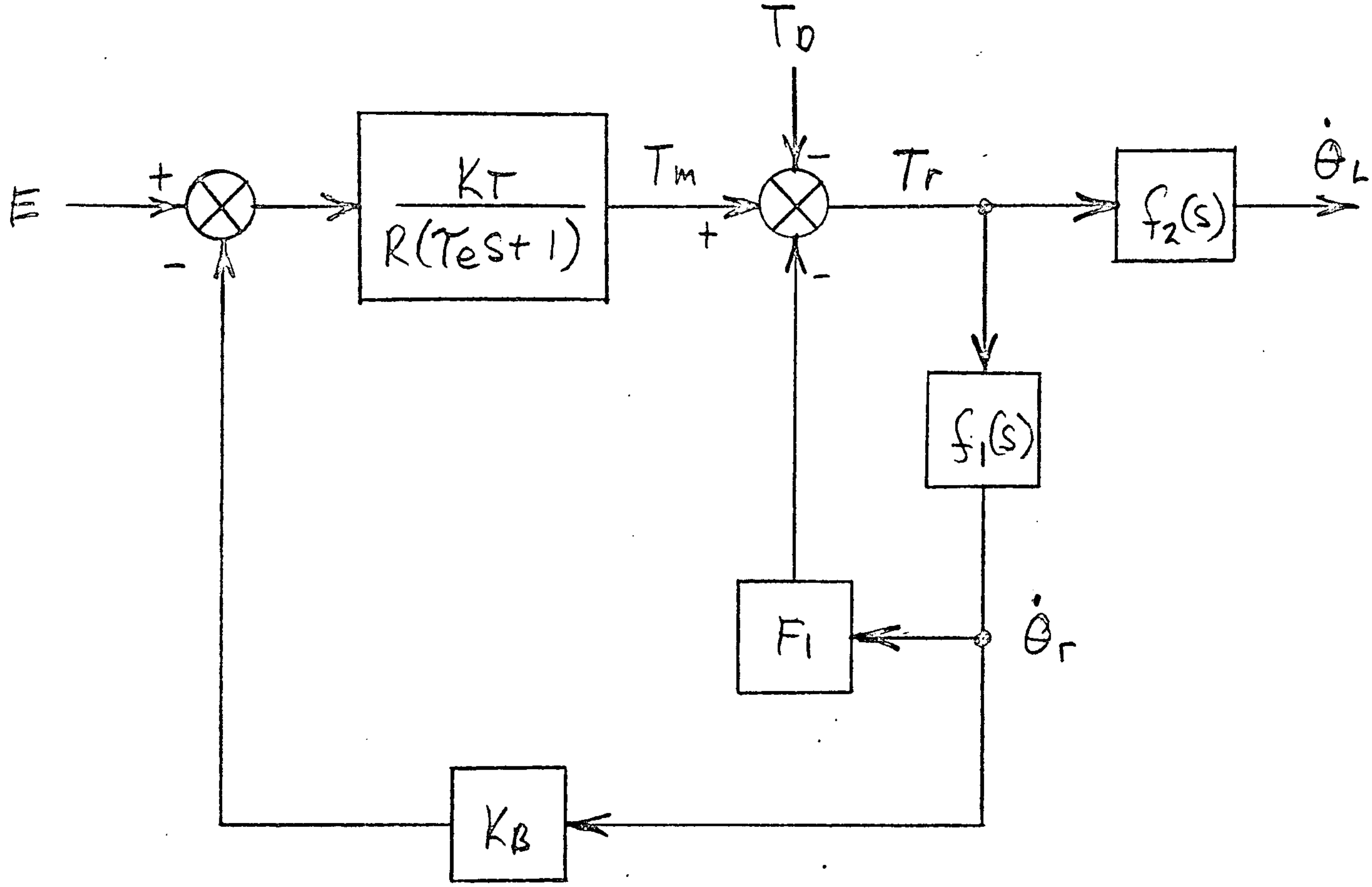
```
00140   22*         LINE(N)=DOT
00141   23*         HERTZ=.1
00142   24*      40 S=CMPLX(0.,6.283*HERTZ)
00143   25*         A=1.+40.85E-6*S**2+383.2E-12*S**4+24.93E-18*S**6+.397E-24*S**8
00144   26*         B=38.71*S*(1.+14.60E-6*S**2+1.36E-12*S**4+.0302E-18*S**6)
00145   27*         C=187.E3*(1.+14.6E-6*S**2+1.36E-12*S**4+.0303E-18*S**6)
00146   28*         D=187.E3*S*(0.678E-6+9.900E-12*S**2+0.644E-18*S**4+.0103E-24*S**6)
00147   29*         E=187.E3*(1.+14.60E-6*S**2+.5429E-12*S**4)
00150   30*         F1=(C+D)/(A+B)
00151   31*         Q3=.821*(1+.0159*S)/(1+.00159*S)
00152   32*         Q2F2=((1+.0004*S)/(1+.0004*S+(.0010+2.1E-7*S)*F1))*(E/(A+B))
00153   33*         FCT=(Q2F2)/(S*(1+(Q2F2*Q3*9.26)/(S*(1+.0004*S))))
00154   34*         DB=20.*ALOG10(CABS(FCT))
00155   35*         PHASE=57.29*ATAN2(AIMAG(FCT),REAL(FCT))
00156   36*         I=DB/P+FLOAT(M)+0.5
00157   37*         LINE(I)=X
00160   38*         J=PHASE/Q+FLOAT(N)+0.5
00161   39*         LINE(J)=FI
00162   40*         WRITE(6,50) LINE,HERTZ,DB,PHASE
00173   41*      50 FORMAT(1H ,101A1,1F6.1,1F6.1,1F6.0)
00174   42*         LINE(I)=BLANK
00175   43*         LINE(J)=BLANK
00176   44*         LINE(M)=DOT
00177   45*         LINE(N)=DOT
00177   46*   C     K IS NUMBER OF STEPS PER DECADE
00200   47*         K=40
00201   48*         HERTZ=HERTZ*10.**(1./FLOAT(K))
00202   49*         IF ((FLOAT(M)-1.)*P+DB) 60,60,40
00205   50*      60 STOP
00206   51*         END

     END OF UCC 1108 FORTRAN V COMPILATION.     0 *DIAGNOSTIC* MESSAGE(S)
```

APPENDIX G

SERVO LOOP ANALYSIS, MCTR REEL-DRIVEN SYSTEM.

Servo Loop Analysis
MCTR Reel Driven System
Motor Transfer Function Block Diagram
FIG. 1



Where: E = Terminal Voltage (V)

K_T = Torque Constant (N·m/A)

K_B = Motor Back EMF (V/rad/s)

Cont.

T_e = Motor Elec. Time Constant (L/R-secs)
R = Motor Winding/CKt Resistance (Ω)
T_m = Motor Torque (N·m)
T_D = Disturbance Torque (N·m)
T_r = Net Reel Torque (N·m)
F_1 = Motor Viscous Damping (N·m / rad/sec)
$f_1(s)$ = Torque-to-Reel Velocity Transfer Function
$\dot{\theta}_r$ = Reel Velocity (rad/sec)
$f_2(s)$ = Torque-to-Tape Velocity at Head Transfer Function
$\dot{\theta}_L$ = Tape Velocity at Head (rad/sec)

(all referred to idler velocity in rad/sec)

1. $$T_m = \frac{K_T}{R(T_e s+1)}(E - K_B \dot{\theta}_r)$$

2. $$T_r = T_m - T_D - F_1 \dot{\theta}_r$$

3. $$\dot{\theta}_r = f_1(s) T_r$$

4. $$\dot{\theta}_L = f_2(s) T_r$$

3. → 1. :

5. $$T_m = \frac{K_T}{R(T_e s+1)}(E - K_B f_1(s) T_r)$$

Cont.

3. → 2. & solving for T_m:

6. $T_m = T_D + T_r[1 + F_1 f_1(s)]$

5. → 6.:

7. $\frac{K_T}{R(T_e s+1)}[E - K_B f_1(s) T_r] = T_D + T_r[1 + F_1 f_1(s)]$

Solving for T_r:

8. $$T_r = \frac{\frac{K_T E}{R(T_e s+1)} - T_D}{1 + \left[F_1 + \frac{K_T K_B}{R(T_e s+1)}\right] f_1(s)}$$

A new block diagram is formed as follows:

FIG. 2

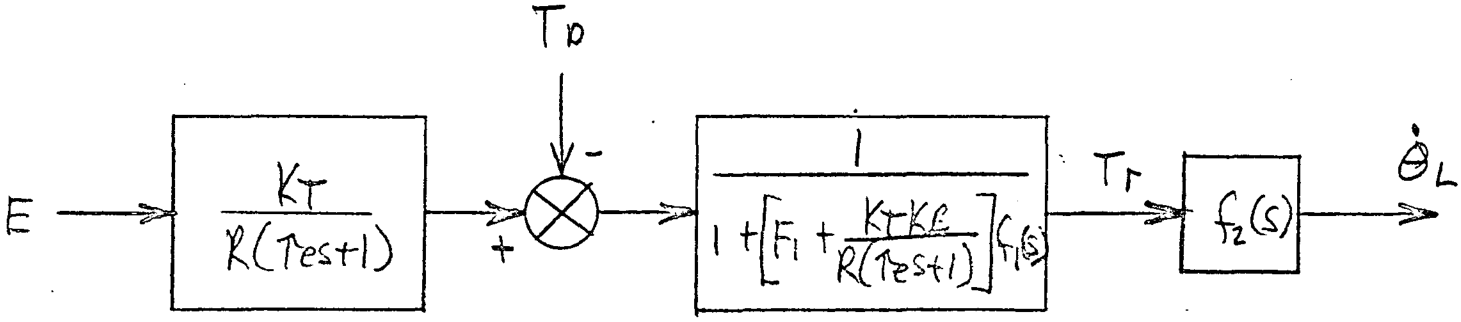
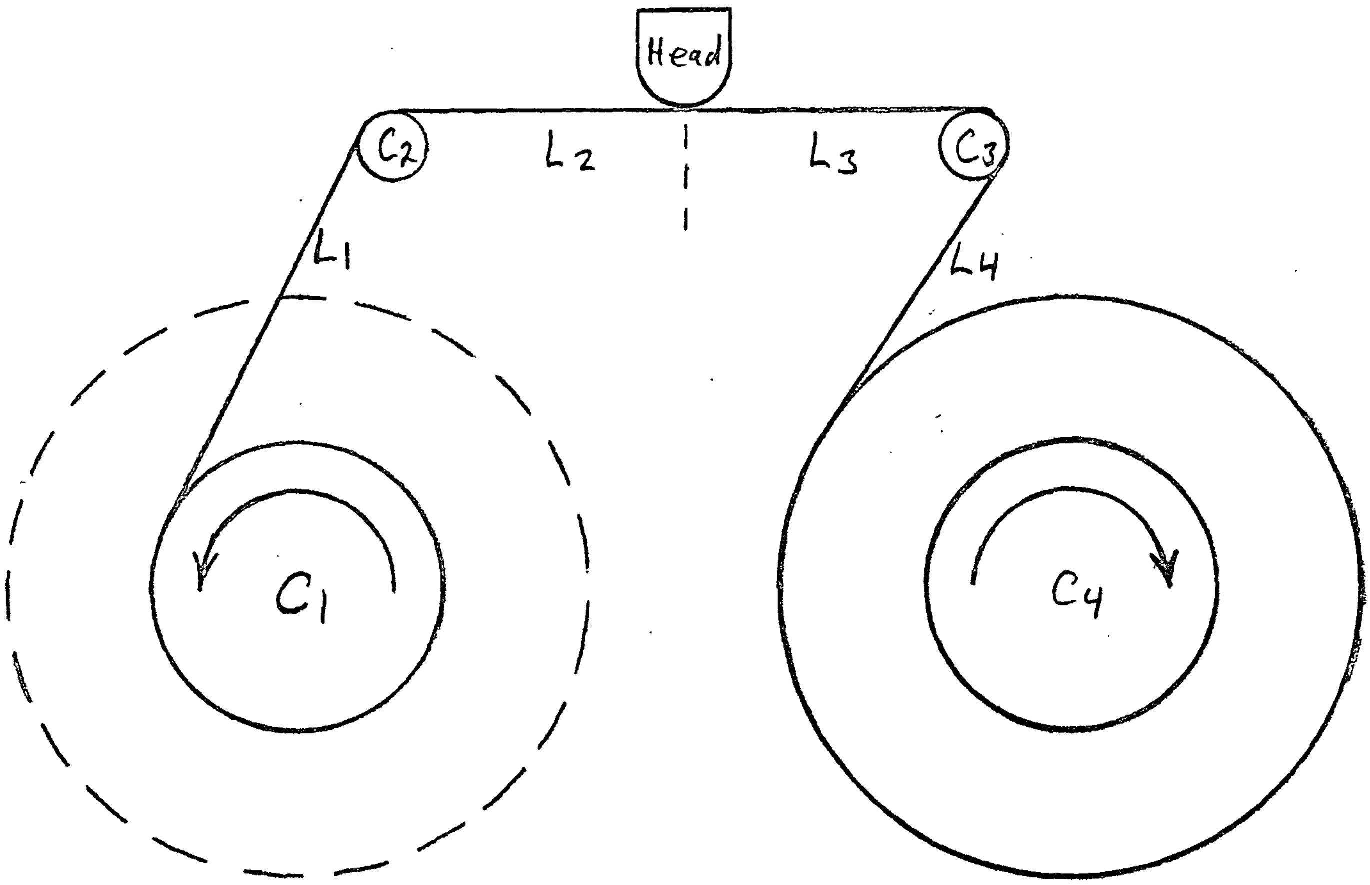
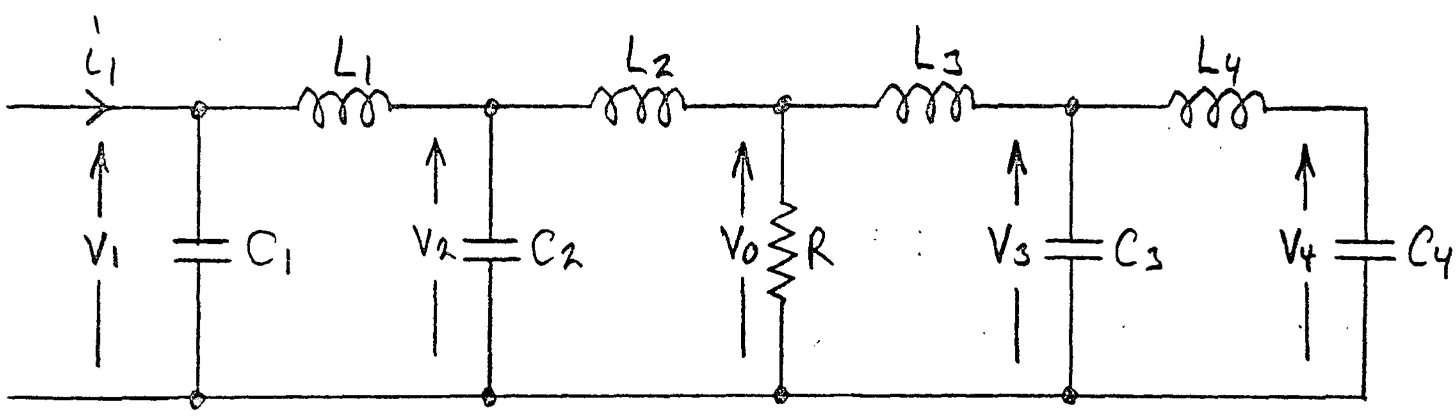


FIG. 3

MCTR Reel Drive System



Electrical Analog



The following expressions are derived for $f_1(s)$ ė $f_2(s)$:

$$f_1(s) = \frac{V_1}{i_1} = \frac{R\left[1 + \frac{(L_1+L_2)s}{R} + (L_2+L_4)C_4 s^2 + \frac{(L_1L_2+L_1L_4+L_2L_4+L_2^2)C_4 s^3}{R} + (L_1L_4+L_2L_4+L_1L_2)C_2C_4 s^4 + \frac{(2L_1L_2L_4+L_1L_2^2+L_2^2L_4)C_2C_4 s^5}{R} + L_1L_2L_4C_2^2C_4 s^6 + \frac{L_1L_2^2L_4C_2^2C_4 s^7}{R}\right]}{\left\{\begin{array}{l} 1 + C_1Rs + \left[C_1(L_1+L_2) + C_4(L_2+L_4)\right]s^2 \\ + (L_2+L_4)C_1C_4Rs^3 + (L_1L_4+L_1L_2+L_2L_4+L_2^2)C_1C_4s^4 \\ + (L_1L_2+L_1L_4+L_2L_4)C_1C_2C_4Rs^5 \\ + (2L_1L_2L_4+L_1L_2^2+L_2^2L_4)C_1C_2C_4s^6 \\ + L_1L_2L_4C_1C_2^2C_4Rs^7 + L_1L_2^2L_4C_1C_2^2C_4s^8 \end{array}\right\}}$$

$$f_2(s) = \frac{V_o}{i_1} = \frac{\left[1 + (L_2+L_4)C_4 s^2 + L_2 L_4 C_2 C_4 s^4\right]}{\left\{\begin{array}{l} 1 + C_1 R s + \left[C_1(L_1+L_2) + C_4(L_2+L_4)\right] s^2 \\ + (L_2+L_4) C_1 C_4 R s^3 + (L_1 L_4 + L_1 L_2 + L_2 L_4 + L_2^2) C_1 C_4 s^4 \\ + (L_1 L_2 + L_1 L_4 + L_2 L_4) C_1 C_2 C_4 R s^5 \\ + (2 L_1 L_2 L_4 + L_1 L_2^2 + L_2^2 L_4) C_1 C_2 C_4 s^6 \\ + L_1 L_2 L_4 C_1 C_2^2 C_4 R s^7 + L_1 L_2^2 L_4 C_1 C_2^2 C_4 s^8 \end{array}\right\}}$$

Assuming that:

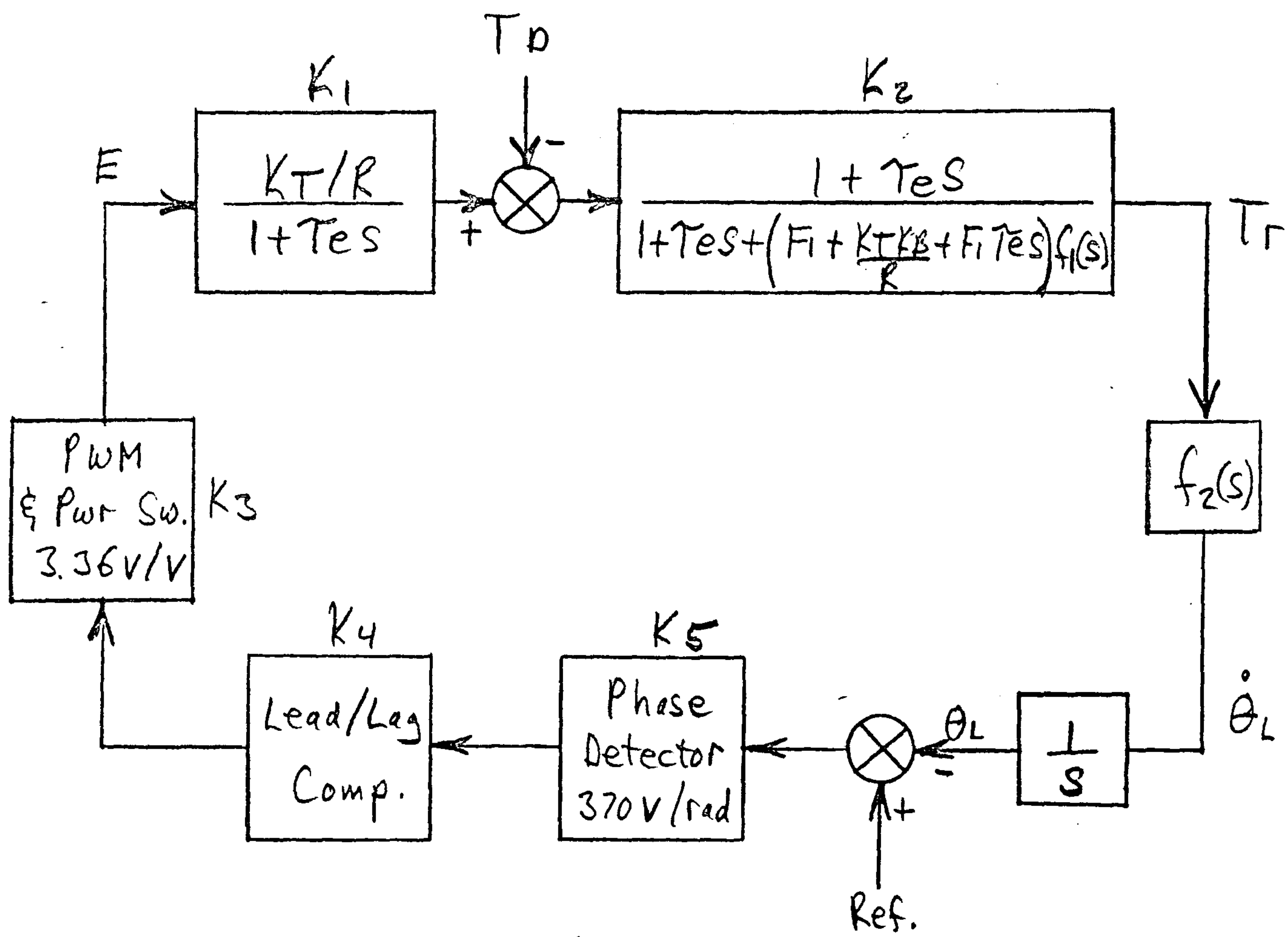
$C_2 = C_3$
$C_1 >> C_2$
$C_4 >> C_2$
$L_2 = L_3$

Where:

		Start-of-Tape	Mid-Tape	End-of-Tape
R	=	$187 \cdot 10^3 \Omega$	$187 \cdot 10^3 \Omega$	$187 \cdot 10^3 \Omega$
C_1	=	76.8 µf	140 µf	207 µf
(Idler Dia.: 1/2"/1") C_2	=	.88/3.37 µf	.88/3.37 µf	.88/3.37 µf
C_4	=	207 µf	140 µf	76.8 µf
L_1	=	126.7 mh	110.3 mh	63.4 mh
L_2	=	63.4 mh	63.4 mh	63.4 mh
L_4	=	63.4 mh	110.3 mh	126.7 mh

FIG. 4

Complete MCTR Reel Drive Servo Loop



AED 561 6/69

$$f_1(s) = \frac{\dot{\theta}_r}{T_r} = \frac{V_1}{i_1}$$

$$f_2(s) = \frac{\dot{\theta}_L}{T_r} = \frac{V_0}{i_1}$$

Open-Loop Gain:

$$G = K_1 \cdot K_2 \cdot K_3 \cdot K_4 \cdot K_5 \cdot \frac{1}{s} \cdot f_2(s)$$

Flutter (Due to Torque Disturbance):

$$\frac{\dot{\theta}_L}{T_D} = \frac{-K_2 \cdot f_2(s)}{1 - \frac{K_2 \cdot f_2(s) \cdot K_1 \cdot K_3 \cdot K_4 \cdot K_5}{s}}$$

Jitter (Due to Torque Disturbance):

$$\frac{\theta_L}{T_D} = \frac{\dot{\theta}_L}{T_D} \cdot s$$

APPENDIX H

COMPUTER READOUT FOR UNEQUALIZED RECORDER

```
FORTRAN IV PROGRAM DELAY  (LINK-EDITED AS DELAY ) STARTED --- 05/18/71

    44 225.00000
    0.46742  -3.30298

     0      0.00000      0.00000      0.00000      0.00000      0.00000

     0      0.00000      0.00000      0.00000      0.00000      0.00000

FL1,FLN NUM AND DENOM OF THE FILTERS

 9999.00000   1.00000
    0.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
    1.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  1
    0.00058 -32.33028

   22.00000   1.00000
    1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
    1.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  2
    0.00000 -56.53169

   75.00000   1.00000
    1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
    1.000  2.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
  2
    0.00000 -74.30933

    1.50000   1.00000
    1.000  1.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000
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  1
    0.00000 -74.30933

   23.00000   1.00000
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  1
    0.00000 -74.30933

   18.00000   1.00000
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  1
    0.00000 -74.30933
```
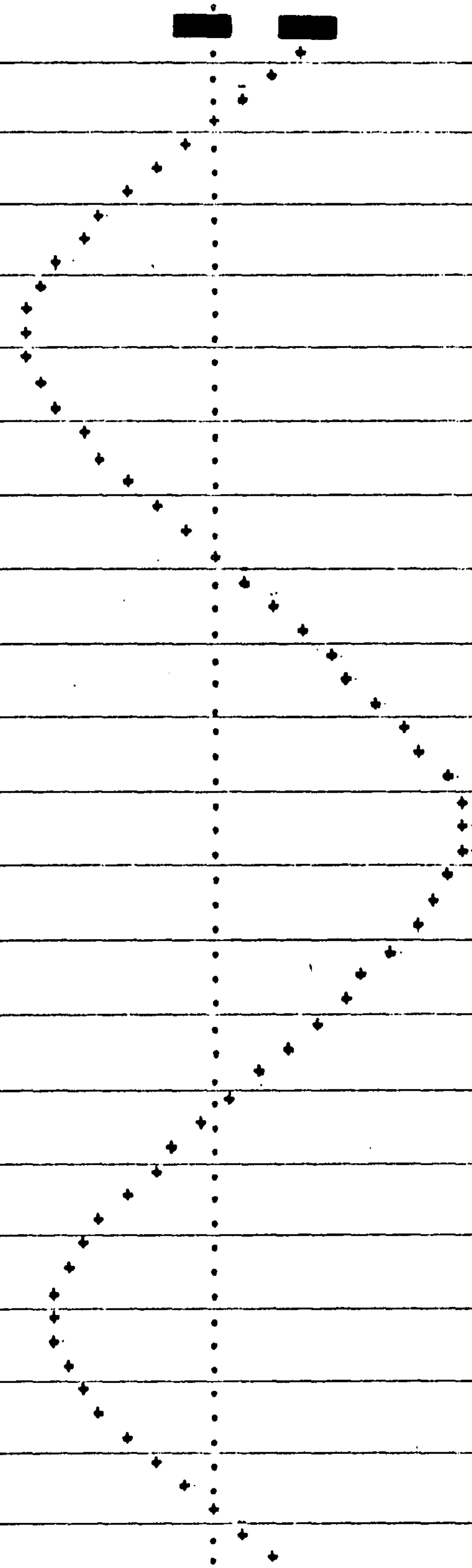

REF. TIME= 9.504 AFTER 5 +GOING CROSSINGS

BIT	AREA 100%,BIT TYPE 9	% ZERO CROSSING ERROR(FROM REF.)
		0.35%
1	0.000	
		-0.07%
		0.47%
2	0.000	
		-0.30%
		0.73%
3	0.000	
		-0.73%
		1.50%
4	0.000	
		-1.80%
		3.15%
		-4.23%
5	0.000	
		8.03%
		-10.63%
6	0.000	
7	0.000	
		-14.45%
8	0.000	
		0.17%
9	-0.000	
		14.62%
10	0.000	
11	0.000	
		10.83%
		-7.56%
12	0.000	
		4.49%
		-2.94%
13	0.000	
		2.11%
		-1.16%
14	0.000	
		0.99%
		-0.48%
15	0.000	
		0.58%
		-0.13%
16	0.000	
		0.34%
		-0.08%
17	0.000	
		0.36%



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16.65	-4.45E-05
16.70	-6.24E-05
16.75	-7.95E-05
16.80	-9.55E-05
16.85	-1.10E-04
16.90	-1.22E-04
16.95	-1.30E-04
17.00	-1.33E-04
17.05	-1.31E-04
17.10	-1.24E-04
17.15	-1.12E-04
17.20	-9.79E-05
17.25	-8.17E-05
17.30	-6.44E-05
17.35	-4.62E-05
17.40	-2.72E-05
17.45	-7.41E-06
17.50	1.30E-05
17.55	3.34E-05
17.60	5.34E-05
17.65	7.27E-05
17.70	9.11E-05
17.75	1.09E-04
17.80	1.25E-04
17.85	1.40E-04
17.90	1.53E-04
17.95	1.62E-04
18.00	1.65E-04
18.05	1.64E-04
18.10	1.57E-04
18.15	1.46E-04
18.20	1.33E-04
18.25	1.17E-04
18.30	1.01E-04
18.35	8.32E-05
18.40	6.49E-05
18.45	4.59E-05
18.50	2.63E-05
18.55	6.65E-06
18.60	-1.26E-05
18.65	-3.10E-05
18.70	-4.86E-05
18.75	-6.53E-05
18.80	-8.11E-05
18.85	-9.52E-05
18.90	-1.07E-04
18.95	-1.15E-04
19.00	-1.17E-04
19.05	-1.15E-04
19.10	-1.07E-04
19.15	-9.53E-05
19.20	-8.05E-05
19.25	-6.38E-05
19.30	-4.61E-05
19.35	-2.75E-05
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19.50	3.32E-05
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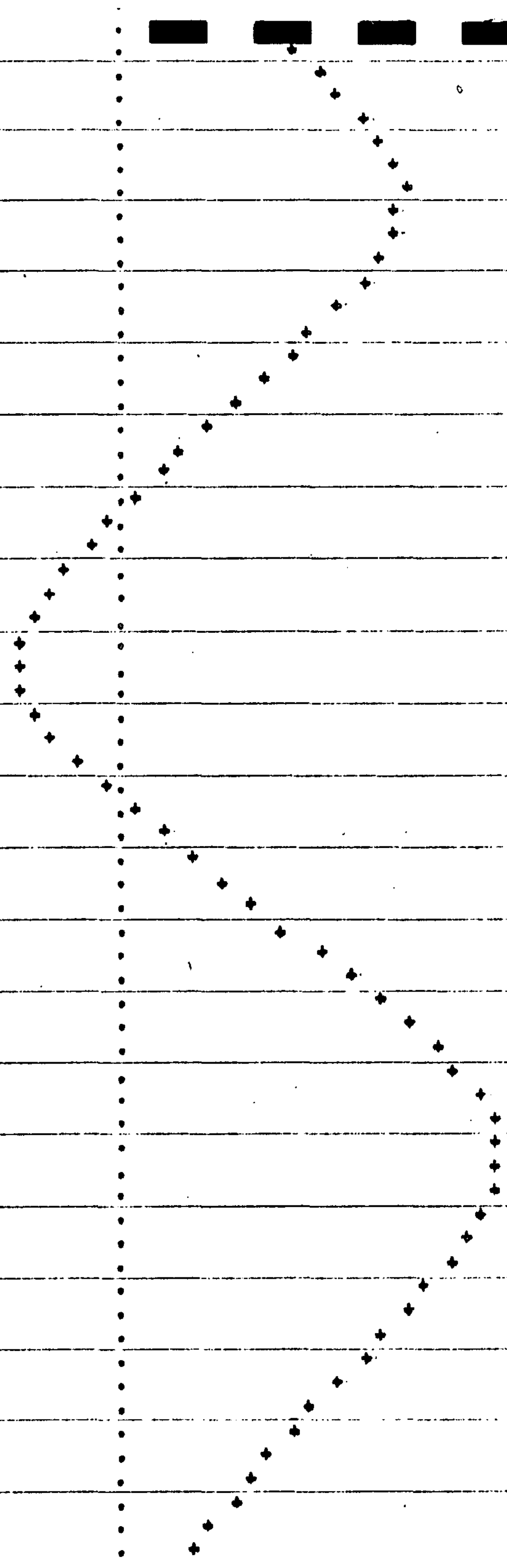

[redacted]	
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20.00	1.92E-04
20.05	1.91E-04
20.10	1.85E-04
20.15	1.75E-04
20.20	1.62E-04
20.25	1.47E-04
20.30	1.31E-04
20.35	1.14E-04
20.40	9.68E-05
20.45	7.85E-05
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20.80	-4.24E-05
20.85	-5.56E-05
20.90	-6.62E-05
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21.00	-7.47E-05
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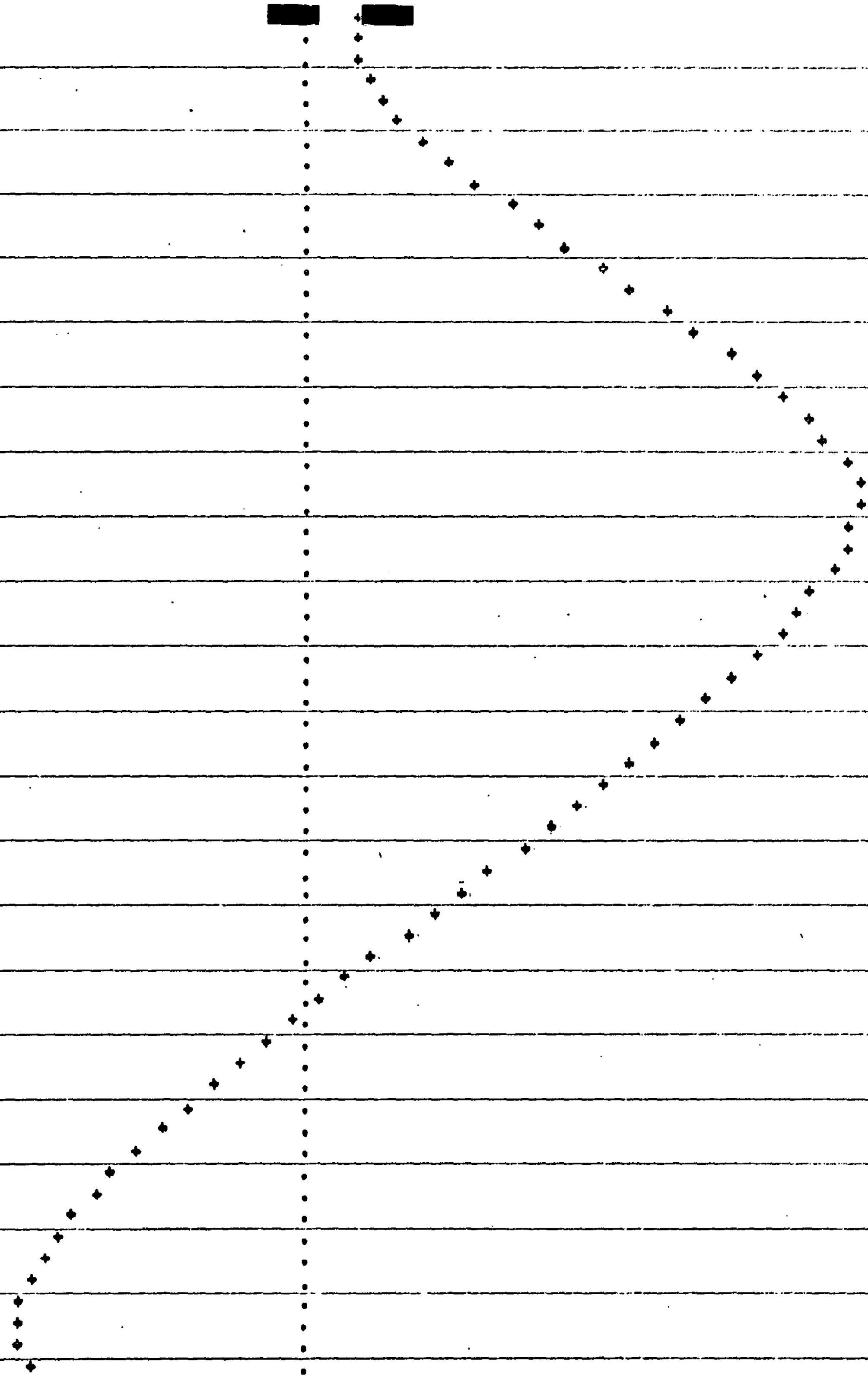
21.10	-6.24E-05
21.15	-4.94E-05
21.20	-3.35E-05
21.25	-1.57E-05
21.30	3.17E-06
21.35	2.30E-05
21.40	4.37E-05
21.45	6.53E-05
21.50	8.74E-05
21.55	1.10E-04
21.60	1.32E-04
21.65	1.53E-04
21.70	1.73E-04
21.75	1.93E-04
21.80	2.12E-04
21.85	2.29E-04
21.90	2.43E-04
21.95	2.54E-04
22.00	2.61E-04
22.05	2.61E-04
22.10	2.57E-04
22.15	2.49E-04
22.20	2.38E-04
22.25	2.25E-04
22.30	2.11E-04
22.35	1.96E-04
22.40	1.81E-04
22.45	1.64E-04
22.50	1.48E-04
22.55	1.31E-04
22.60	1.15E-04
22.65	9.96E-05
22.70	8.52E-05
22.75	7.17E-05
22.80	5.93E-05
22.85	4.86E-05



22[redacted]	3.[redacted]05
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23.10	5.44E-05
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23.25	1.09E-04
23.30	1.31E-04
23.35	1.53E-04
23.40	1.76E-04
23.45	2.01E-04
23.50	2.26E-04
23.55	2.51E-04
23.60	2.75E-04
23.65	2.99E-04
23.70	3.22E-04
23.75	3.44E-04
23.80	3.65E-04
23.85	3.84E-04
23.90	4.01E-04
23.95	4.14E-04
24.00	4.22E-04
24.05	4.24E-04
24.10	4.22E-04
24.15	4.14E-04
24.20	4.04E-04
24.25	3.92E-04
24.30	3.78E-04
24.35	3.62E-04
24.40	3.46E-04
24.45	3.28E-04
24.50	3.09E-04
24.55	2.89E-04
24.60	2.69E-04
24.65	2.48E-04
24.70	2.27E-04
24.75	2.06E-04
24.80	1.84E-04
24.85	1.61E-04
24.90	1.39E-04
24.95	1.17E-04
25.00	9.47E-05
25.05	7.26E-05
25.10	5.05E-05
25.15	2.84E-05
25.20	6.54E-06
25.25	-1.50E-05
25.30	-3.60E-05
25.35	-5.65E-05
25.40	-7.65E-05
25.45	-9.60E-05
25.50	-1.15E-04
25.55	-1.33E-04
25.60	-1.50E-04
25.65	-1.66E-04
25.70	-1.80E-04
25.75	-1.93E-04
25.80	-2.04E-04
25.85	-2.13E-04
25.90	-2.20E-04
25.95	-2.22E-04
26.00	-2.19E-04
26.05	-2.11E-04
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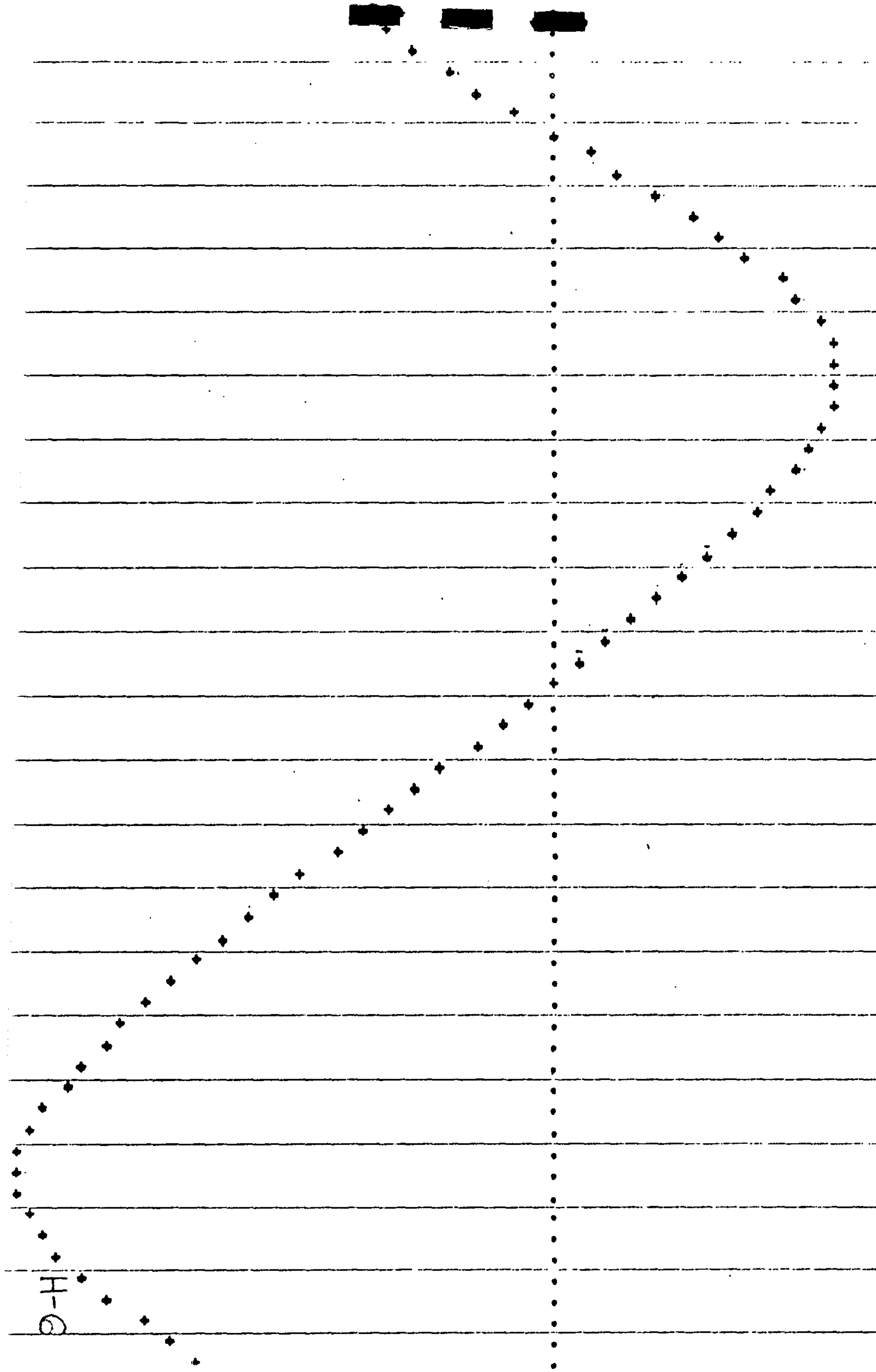

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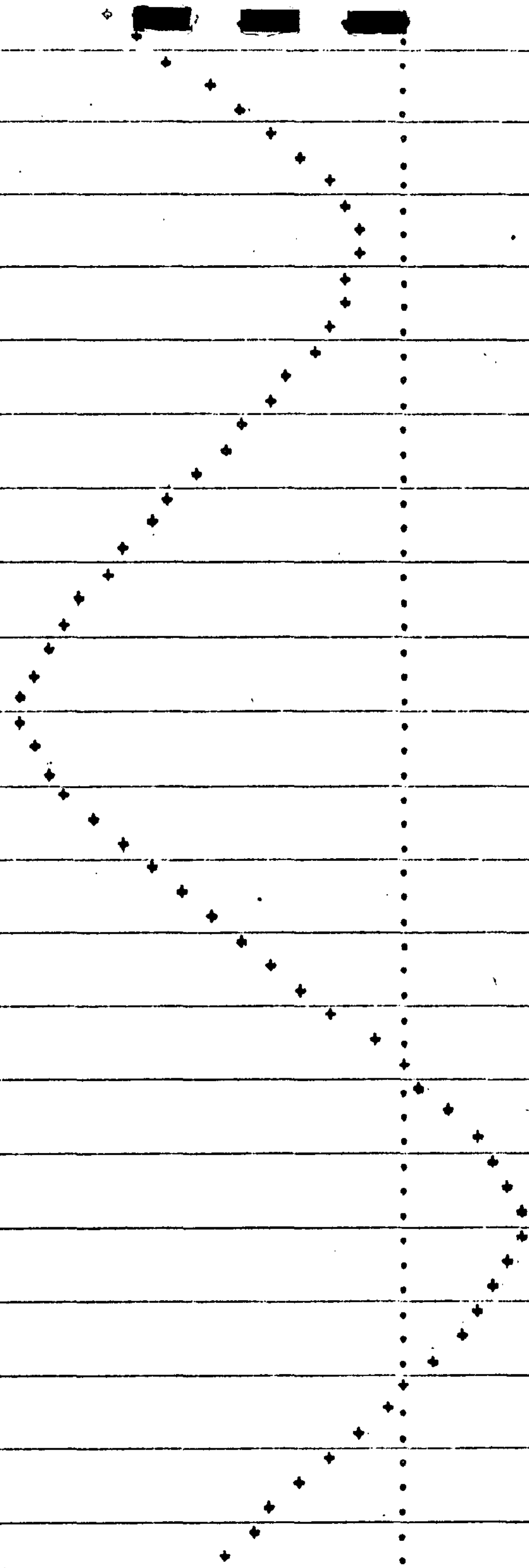

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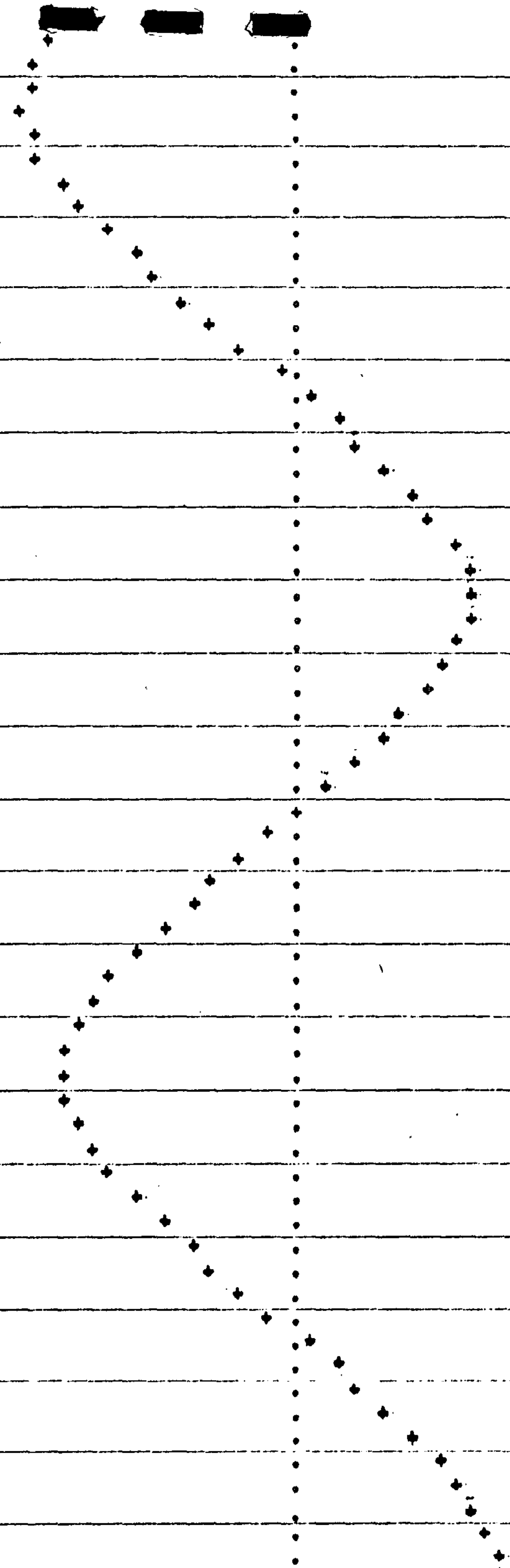

APPENDIX I

COMPUTER READOUT FOR RECORDER WITH ZERO-CROSSING EQUALIZER

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    0       0.00000      0.00000      0.00000      0.00000      0.00000

FL1,FLN NUM AND DENUM OF THE FILTERS

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                                     -0.01%
                                     -0.61%
  2     0.000
                                     -0.02%
                                     -0.61%
  3     0.000
                                     -0.04%
                                     -0.62%
  4     0.000
                                     -0.00%
                                     -0.65%
  5     0.000
                                      0.04%
                                     -0.76%
  6     0.000
                                      0.24%
                                     -1.10%
  7     0.000
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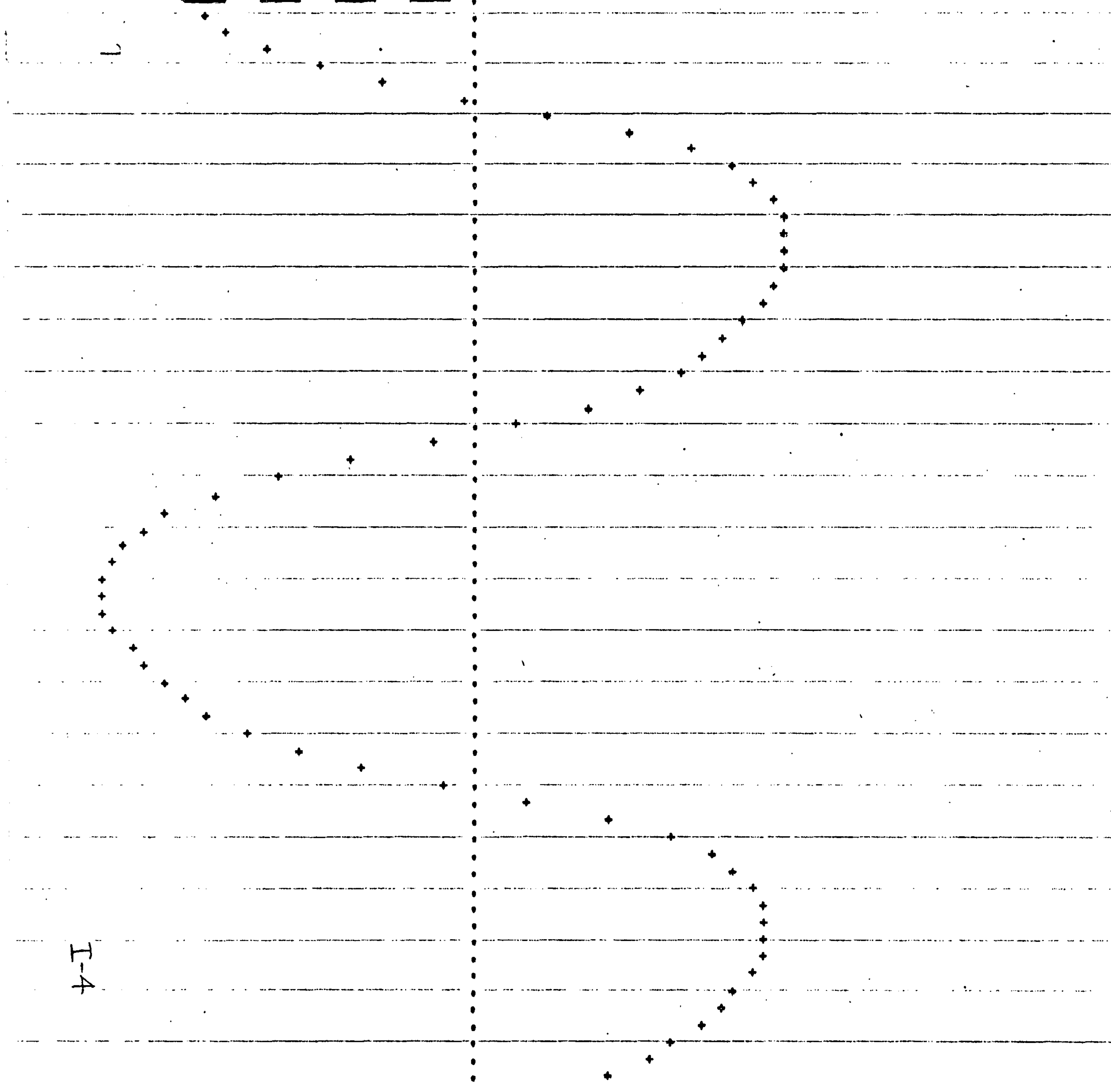

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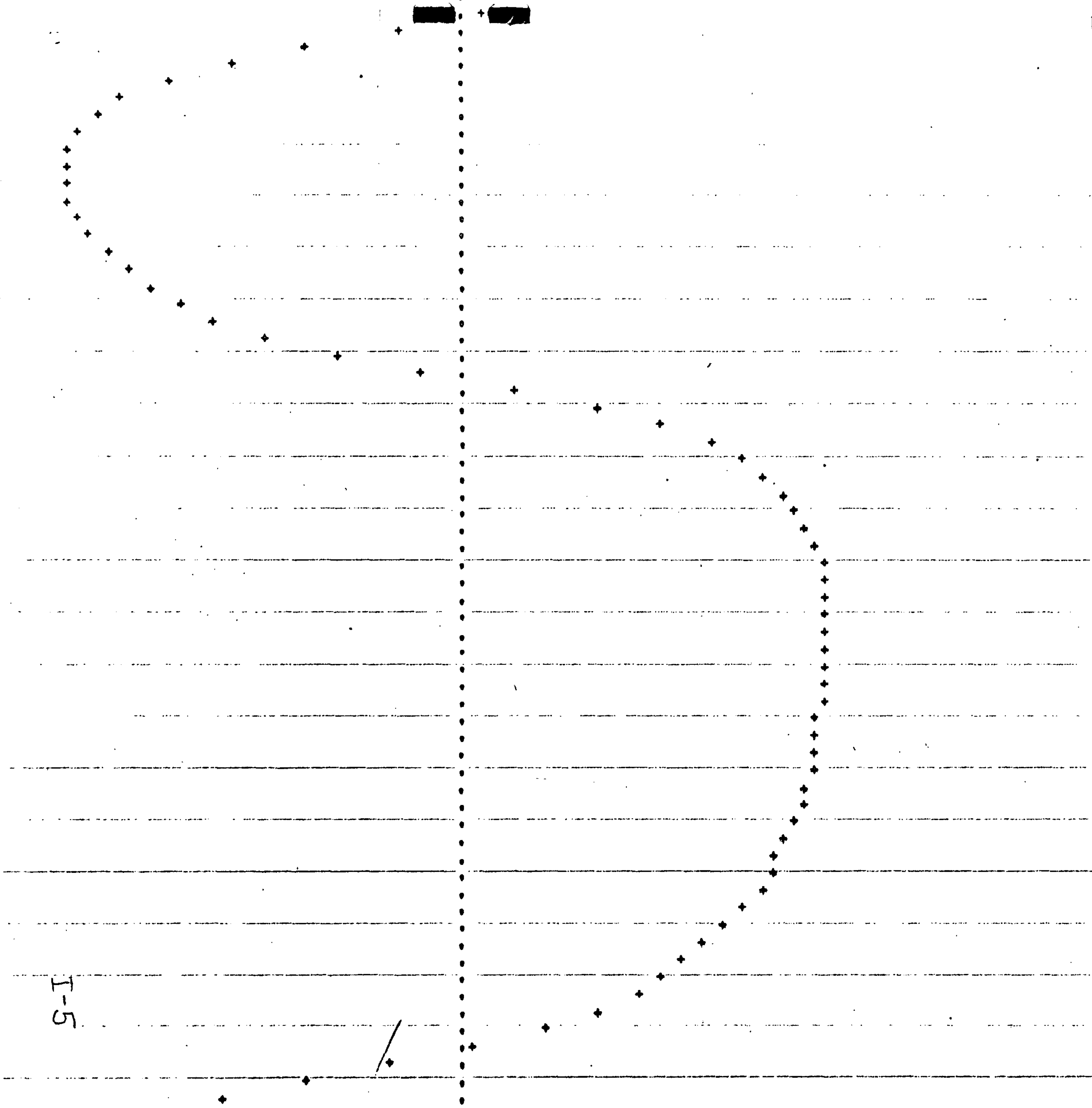

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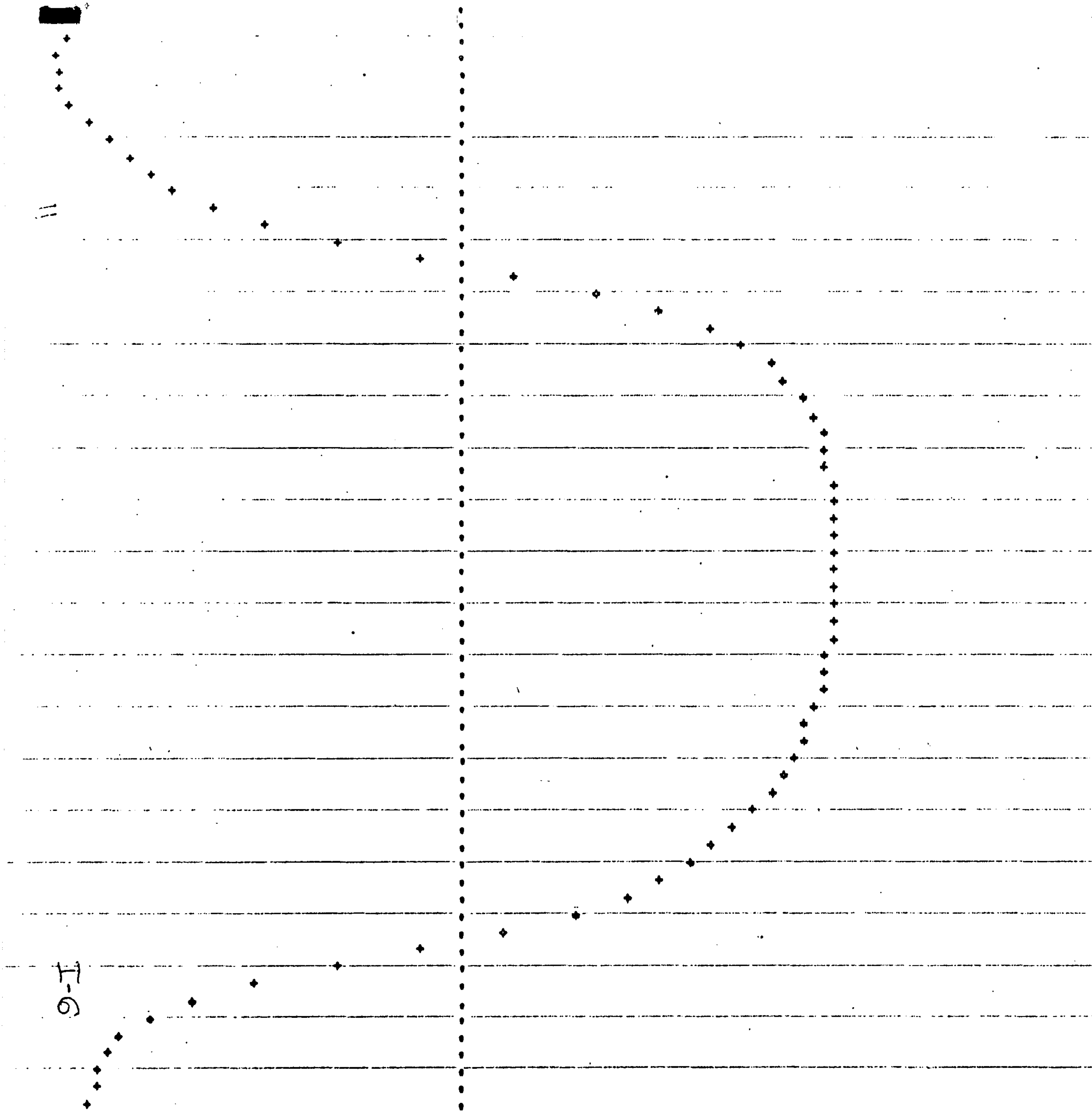

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I-6

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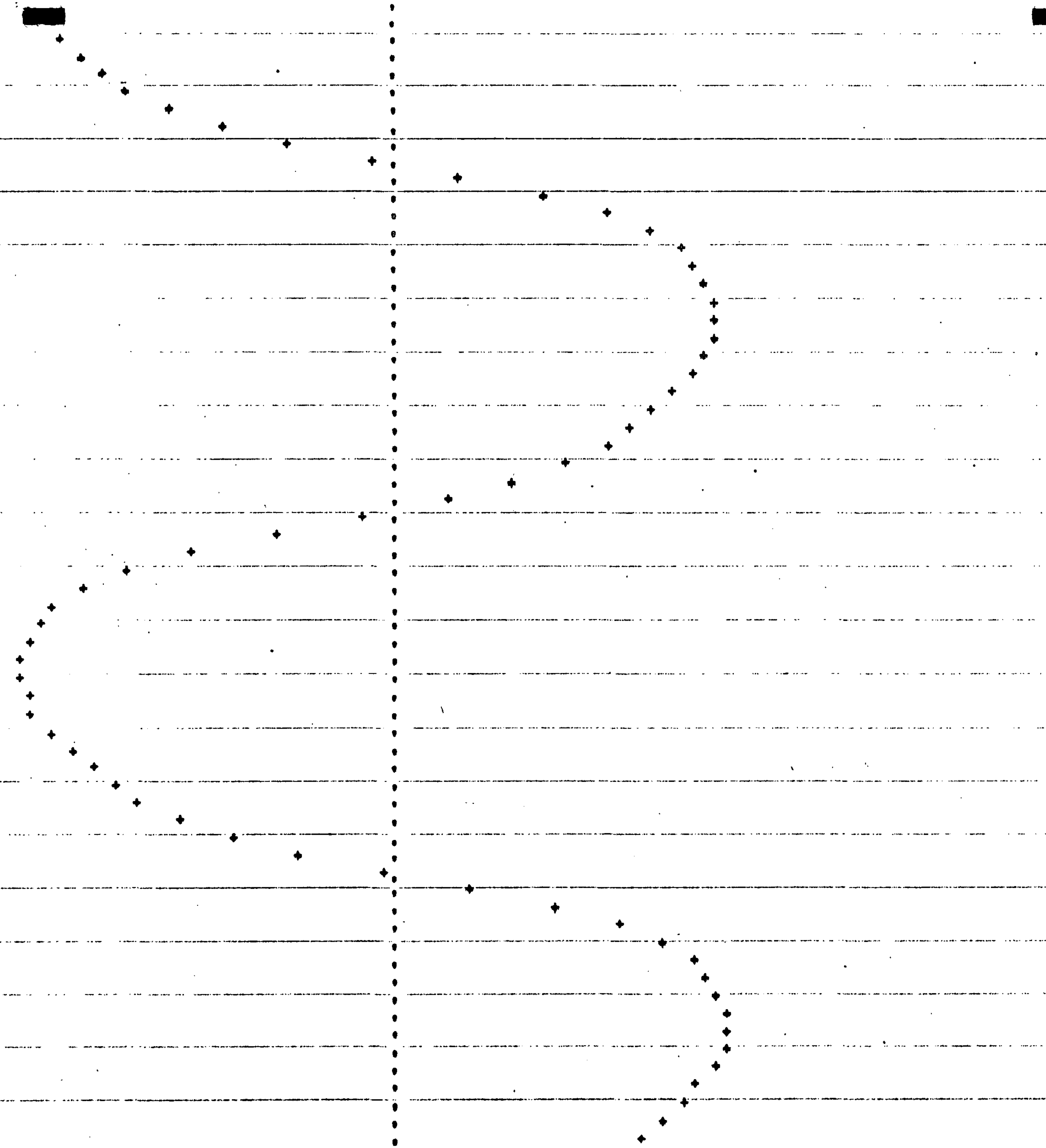

12

I-7

APPENDIX J

DESIGN STUDY - NASA MULTI-CHANNEL TAPE RECORDER,
C. R. THOMPSON TO L. BAKER, NOVEMBER 20, 1970.

Internal Correspondence RCA

To	L. Baker	Location	RCA AED Hightstown	Date	11/20/70
From	C. R. Thompson	Location	10-5-3	Telephone	PC-5327

Subject Design Study - NASA Multi-Channel Tape Recorder (AED Prop. #101150-A).

In anticipation of the receipt of formal authorization to proceed with the GCS portion of the design study, Attachment 1 delineates our anticipated action regarding tradeoff studies to be undertaken for the two-inch co-planar tape transport.

Stan Clurman (SPC) and Ollie Bessette (OEB) will participate actively in the study and will conduct flutter and skew tests on an existing model of the ERTS transport. A tentative schedule for performance is included in Attachment 2.

In our kickoff meeting (12 November 1970) we agreed that the two-inch tape transport now under construction for the ERTS Program would be used as a base-line for our studies. The Feasibility Model and the Engineering Model are now in operation in our laboratories and all attendees of the kickoff meeting are cordially invited to Camden for a demonstration.

With regard to Attachment 1, we have categorized each characteristic for which a specification and narrative was requested in the Preliminary Statement of Work. In most cases, we will endeavor to make positive statements (PS) about existing hardware or existing techniques. In some cases, a Tradeoff Study (TS) will be provided from information currently available in our files. In other cases, New Data (ND) will be observed in our laboratory or derived from laboratory observations and a narrative will be provided. We currently plan to postpone (PN) preparation of information for the last four items until a more convenient time.

I look forward to a successful study program, a superb report submission to NASA and all of the follow on business for RCA.

C R Thompson

C. R. Thompson, Manager
Recording Equipment Projects

CRT:bj

xc: J. Graebner - AED
R. Miller - AED
R. Treadwell - AED

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ATTACHMENT 1

Paragraph No.	Characteristic	Category	Responsibility
3.2.5.1	Vibration, Shock, Acceleration	PS	SPC
3.2.5.2	Temperature	PS	SPC
3.2.5.3	Humidity	PS	SPC
3.2.5.4	Reliability - MTBF	TS	OEB
3.2.5.5	Size	PS	SPC
3.2.5.6	Weight	PS	SPC
3.2.5.7	Volume	PS	SPC
3.2.5.8	Tape Speed	TS	SPC
3.2.5.9	Record/Reproducer Speed Ratio	TS	SPC
3.2.5.10	Wow and Flutter	ND	OEB/SPC
3.2.5.11	Tape Edge-to-Edge Dynamic Skew	ND	OEB/SPC
3.2.5.11.1	Percent Linearity	ND	OEB/SPC
3.2.5.11.2	Shape of the Linearity Curve	ND	OEB/SPC
3.2.5.11.3	Skew Spectra	ND	OEB/SPC
3.2.5.11.4	Variation/Dynamic Skew Parameters	PS	OEB/SPC
3.2.5.12	Tape Capacity (maximum)	TS	OEB
3.2.5.13	Record Time (maximum)	PS	OEB
3.2.5.14	Reproduce Time (maximum)	PS	OEB
3.2.5.15	Magnetic Head Stacks	PS	OEB
3.2.5.16	Number of Tracks	TS	OEB
3.2.5.17	Start-Up Time	PS	SPC
3.2.5.18	Reverse Time	PS	SPC
3.2.5.19	Power Requirements	PS	SPC
3.2.5.20	Power Drain (maximum)	PS	SPC

Attachment 1 (continued.......)

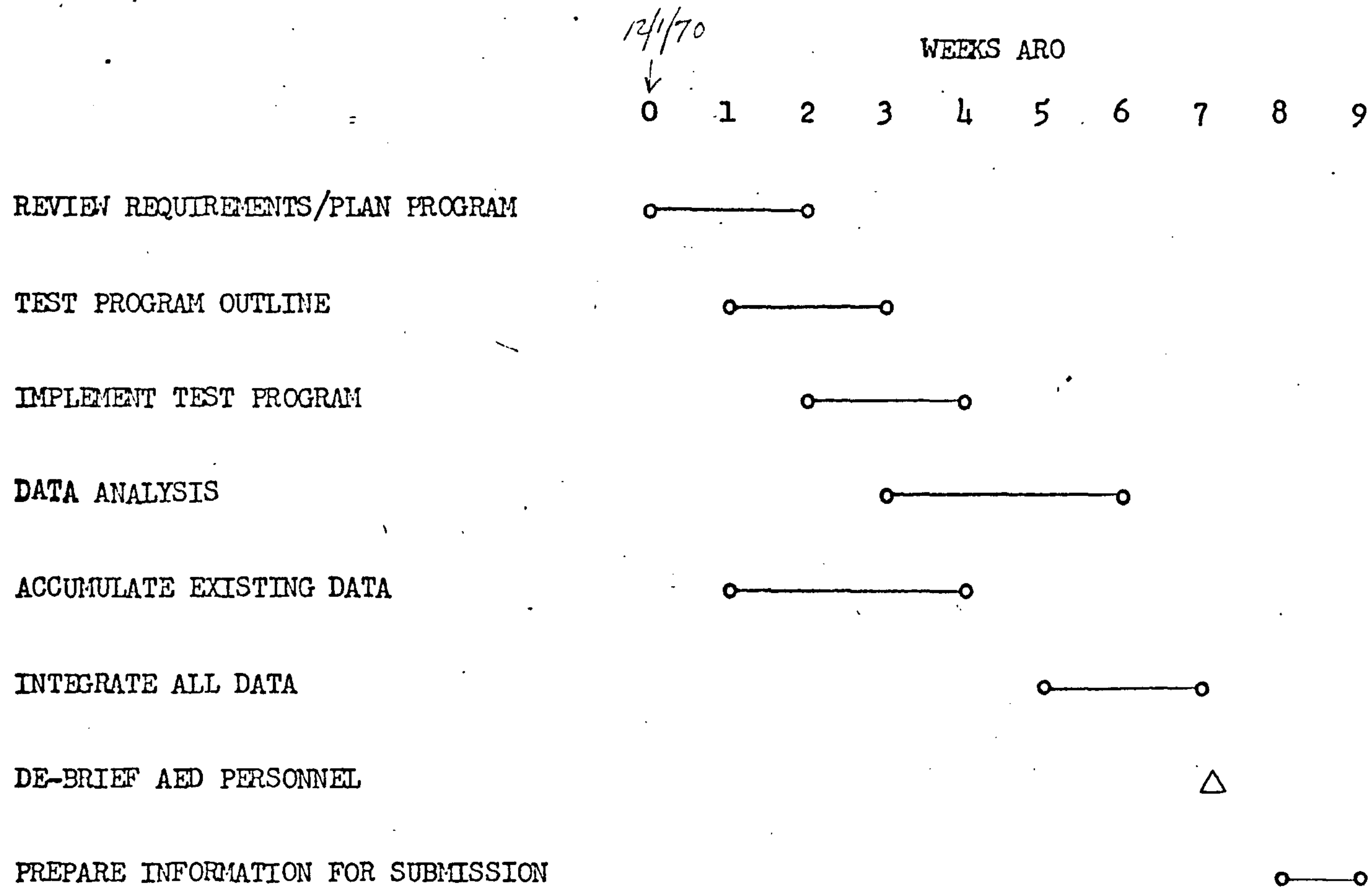
Paragraph No.	Characteristic	Category	Responsibility
3.2.5.21	Control Logic	PS	FLP
3.2.5.22	Record/Reproduce Electronics	PS	OEB
3.2.5.23	Record/Reproduce Ratio	PS	OEB
3.2.5.24	Input Impedance	PS	OEB
3.2.5.25	Signal Input Level	PS	OEB
3.2.5.26	Output Impedance	PS	OEB
3.2.5.27	Record Frequency Change	PS	OEB
3.2.5.28	Reproduce Frequency Response	PS	OEB
3.2.5.29	Signal Output Level	PS	OEB
3.2.5.30	System Noise Level	PS	OEB
3.2.5.31	Max Distortion	PS	OEB
3.2.5.32	Reference Oscillator	PS	OEB
3.2.5.33	Rise and Fall Time	PS	OEB
3.2.5.34	Overshoot and Undershoot	PS	OEB
3.2.5.35	Amplitude Linearity	PS	OEB
3.2.5.36	Tape Drive and Speeds	PS	SPC
3.2.5.37	Tape Start - Stop Distance	PS	SPC
3.2.5.38	End-of-Tape Sensing	PS	SPC
3.2.5.39	Tape Motion Sensor	PS	SPC
3.2.5.40	Speed Accuracy - Long Term	PS	OEB
3.2.5.41	Static Skew	PS	OEB
3.2.5.43	Packing Density	TS	OEB
3.2.5.44	Data Quality	TS	OEB
3.2.5.46	Track Width and Spacing	PS	OEB
3.2.5.47	Tape Length, Width, Thickness	PS	SPC
3.2.5.48	Erasure Method	PS	OEB

Attachment 1 (continued.......)

Paragraph No.	Characteristic	Category	Responsibility
3.2.5.49	Drift	PS	SPC
3.2.5.50	Type of Drive Motor	PS	SPC
3.2.5.51	Type of Braking	PS	SPC
3.2.5.42	Interface Connectors	PN	---
3.2.5.45	FM Spectrum/or Data Rate	PN	---
3.2.5.52	Type of Equalization & Characteristics -	PN	---
3.2.5.53	Phase Response	PN	---
3.2.5.54	Amplitude Response	PN	---
3.2.5.55	Harmonic Distortion	PN	---

DESIGN STUDY SCHEDULE

TWO-INCH CO-PLANAR TRANSPORT



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ATTACHMENT 2

APPENDIX K

DESIGN STUDY - NASA MULTI-CHANNEL TAPE RECORDER, D. H. SAPP TO L. BAKER, FEBRUARY 17, 1971.

Internal Correspondence

RCA

To L. Baker ✓ Location AED Hightstown Date February 17, 1971

From D.H. Sapp Location Camden 10-5-3 Telephone 4955

Subject <u>Design Study - NASA Multi-Channel Tape Recorder (AED Prop.#101150-A)</u>

The attached report summarizes the conclusion of the design study for the NASA multi-channel tape recorders. The two-inch tape transport now under construction for the ERTS program has been used as a baseline for the studies. Flutter and skew experimental tests were performed on an existing model of the ERTS transport. The flutter and skew conclusions have been based on these tests. However, flutter skew tests conducted under our IR&D program on another transport with a double capstan drive has yielded preliminary data with approximately one-half the skew of the previous tests.

D. H. Sapp

D.H. Sapp
Recording Equipment

/njp

xc: S.P. Clurman
O.E. Bessette
C.R. Thompson
F.D. Kell
R. Treadwell - AED
R. Miller - AED

1. General

The two-inch tape transport now under construction for the ERTS program has been used as a baseline for the studies. The ERTS recorder would be modified to provide multi-track longitudinal scan capability. The ERTS recorder was designed for long life, high reliability, minimum power consumption and minimum weight. The recorder is divided into two discrete packages; one a hermetically sealed unit containing the tape transport and the other a housing which accommodates most of the electronics. The present ERTS recorder uses a transverse scan with a head-to-tape speed of 2000 ips. It has a tape load of 2,000 feet of 2-inch magnetic tape with a record or playback time of 33 minutes for a record or playback tape speed of 12 ips. A 4:1 speedup is used to obtain a 48 ips rewind tape speed. The head gap size is 40 microinches to obtain a limiting resolution of 50 MHz. The track width is 7.0 mils and track spacing is 9.6 mils. The modified ERTS recorder which would provide 100 longitudinal channels would use the same 2,000 foot tape load as the present ERTS recorder, but would increase its record tape speed to 13.33 ips with a record time of 30 minutes. A playback/record tape speed ratio of 4:1 would provide a 53.33 ips playback tape speed and a playback time of 7.5 minutes. Each of the 100 channels will have the capability of recording 250 Kbps of delay modulation digital data and playback back at a data rate of 1 Mbps. The bit packing density would be 18,750 bpi.

The tape transport tape reeling system tape tension is always maintained through a Negator-differential mechanism. The mechanism is arranged with the two Negators fully wound at the start of the transport cycle so that they may supply the necessary differential drive to the take-up sides of the reeling system. At center of tape, the Negators reach a minimum energy state and then are rewound as the direction of the differential turns reverses.

II Detailed Specification Parameters

The important parameters for the multi-track recorder are given below. The paragraph numbers used are those of the AED statement of work.

3.2.5.1 Vibration, Shock, Acceleration

3.2.5.2 Temperature

The transport shall meet the requirements prescribed in the Nimbus D Environmental Specification, dated September 22, 1967.

3.2.5.5 Size

The external dimensions of the transport enclosure shall be: 17.1" length, 13.76" width, and 6.75" height. This envelope includes any expansion in a vacuum environment.

3.2.5.6 Weight

The weight of the complete transport assembly shall be 39 pounds. This does not include the cables and connectors to the external system, or the weight of signal processing electronics.

3.2.5.8 Tape Speed

The record tape speed shall be 13-1/3 ips. The playback tape speed shall be 53-1/3 ips.

3.2.5.9 Playback/Record Speed Ratio

The playback/record tape speed ratio shall be 4 to 1.

3.2.5.10 Wow and Flutter

All discrete wow and flutter components shall be less than 0.2 percent rms. The cumulative wow and flutter for frequencies up to 20 kHz shall be less than 0.4 percent rms.

3.2.5.11 Dynamic Skew

3.2.5.11.1 Percent Linearity

The two-inch width tape edge-to-edge dynamic skew linearity shall be less than 25 percent.

3.2.5.11.2 Shape of the Dynamic Skew Curve

The tape edge-to-edge dynamic skew shall be within 25 microinches of a straight line connecting the edge skew points.

3.2.5.11.3 Maximum Dynamic Skew

The tape edge-to-edge dynamic skew shall be less than 200 microinches.

3.2.5.12 Tape Capacity

The two-inch width tape shall be 2,000 feet or greater.

3.2.5.13 Record Time

The record time shall be 30 minutes or greater.

3.2.5.14 Reproduce Time

The reproduce time shall be one-quarter the record time or 7.5 minutes or greater.

3.2.5.15 Magnetic Head Stacks

A single record/playback magnetic head stack shall be used for both recording and playback of the 100 tracks.

3.2.5.16 Number of Tracks

The number of tracks shall be 100.

3.2.5.17 Start-Up Time

Start-up times are based upon acceleration to synchronous speed of the transport inertia, which includes a momentum-compensation flywheel. It also includes a setting time for transients to die down and tape speed to be stabilized. The start-up time in the record mode shall be 1 second. The start-up time in the playback mode shall be 2.5 seconds.

3.2.5.18 Reverse Time

The total reverse time includes time for full deceleration and acceleration, plus stabilizing time. The reversal time at low speed shall be 1.5 seconds. The reversal time at high speed shall be 4.0 seconds.

3.2.5.19 Power Requirements

The power requirements shall not exceed those listed for each operational mode in the Power Budget, Table 3.2.5.19-1.

3.2.5.36 Tape Drive

The tape shall be driven by a urethane coated capstan, around which it is wrapped with a wrap angle of 190°. The capstan, in turn, shall be driven by the capstan motor through a single mylar belt.

3.2.5.38 End-of-Tape Sensing

EOT sensing shall be done by a primary microswitch, with a secondary microswitch as a backup feature. The primary switch shall be activated by the reel follower arm which is moving towards minimum reel diameter. The secondary switch shall be activated by the reel follower arm which is moving toward maximum reel diameter. The secondary switch shall be set to operate after the primary switch by a tape length increment of 15 feet.

3.2.5.41 Static Skew

The static skew shall not exceed the dynamic skew specified in para. 3.2.5.11.

3.2.5.43 Packing Density.

Each data track shall be capable of digital bit packing densities of 18,750 bpi when delay modulation is used. With this packing density a 250 Kbps data rate can be recorded and played back at a 1.0 Mbps data rate.

3.2.5.46 Track Width and Spacing

Each of the 100 heads shall have a track width of 12 mils and spacing between tracks of 8 mils. Each head shall have a gap of 35 microinches.

3.2.5.47 Tape Length, Width, Thickness

The magnetic tape shall 2,000 feet in length, 2 inches in width, and 1.2 mils thick.

TABLE 3.2.5.19-1 POWER BUDGET FOR MTR TRANSPORT

	Record		Playback		Fast Forward or Rewind	
	½ sec. Start	Run	2 sec. Start	Run	2 sec. Start	Run
Capstan Motor Watts	16.0	8.0	92.0	15.0	92.0	15.0
Record Heads (100 Chan.) Watts	-	7.5	-	-	-	-
P.B. Preamp (100 Chan.) Watts	-	-	-	10.0		
Control Circuits Watts	2.0	2.0	2.0	2.0	2.0	2.0
Erase Head Watts	-	1.0	-	-	-	-
Total Watts	18.0	18.5	94.0	27.0	94.0	17.0

3.2.5.48 Erasure Method

The erasure method shall be ac erasure.

3.2.5.50 Drive Motor

The capstan motor shall be a 2-phase, 4-pole hysteresis motor. The shaft speed shall be 31.25 rps in the low speed mode and 125 rps in the high speed mode. In the low speed mode, it shall be started and run on the same windings, and its pull-out torque shall be 1.7 in-oz. In the high speed mode, it shall be brought to synchronous speed on a start winding, and then switched to a run winding, at which point its pull-out torque shall be also 1.7 in-oz.

3.2.5.51 Braking

Braking shall be accomplished by another winding within the motor which is energized with dc voltage. The brake winding shall be wound in a 2-pole configuration, so as to avoid any transformer coupling with the high speed and low speed windings.

III. Design Study Conclusions

1. Tape Speeds

The tape speed will be 13-1/3 ips in the record mode and 53-1/3 ips in the playback, rewind, and fast-forward modes. The record speed was selected on the basis of 2,000 feet of usable tape, as a realistic parameter, and a recording time of 30 minutes. A speed-up ratio of four-to-one has been selected for simplicity in electrical switching of speeds, and to obtain reasonably efficient usage of a single motor at either speed.

2. Head Configuration

Recording and playback will be done with the same head in order to avoid the effects of gap scatter on inter-track time displacement error. The head stack will contain 100 heads. Each head will have a track width of .012", and a gap of 35 microinches.

3. Crosstalk

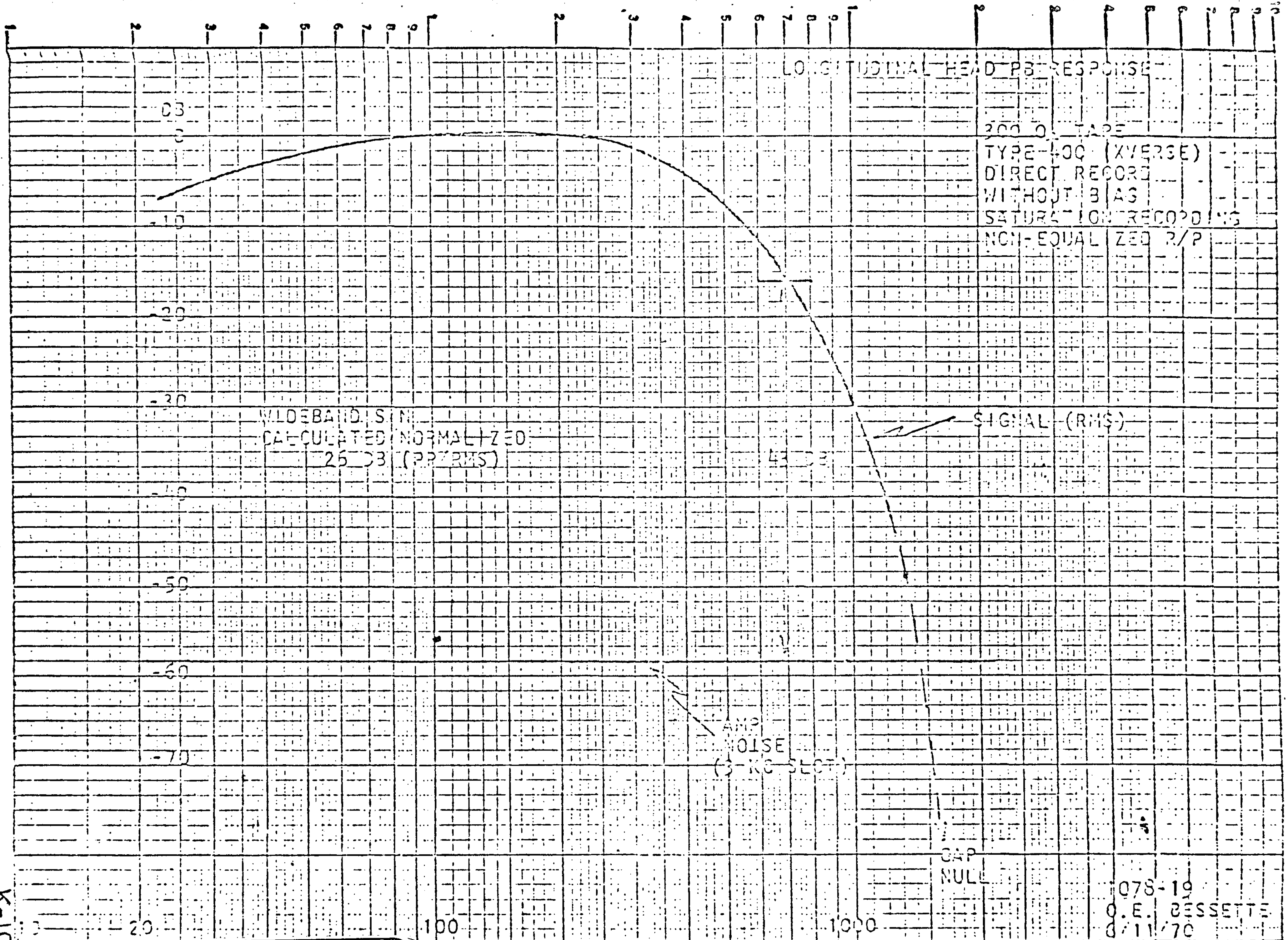
Experimental tests were conducted on several heads to determine the amount of crosstalk. Based on these experimental indications, the crosstalk between any two channels in a 100 track head should be less than 35 dB.

4. Bit Packing Density

In order to measure crosstalk, bit packing density, and skew, a head was constructed with 7 tracks. Three of the tracks were centered at 22 mils pitch for crosstalk measurements, and four tracks were spaced equally about the center for skew linearity and skew variation measurements. This head design allowed resolution of 60 microinch wavelength information. Using delay modulation, a frequency spectrum of 0.5 to 0.7 times the bit rate is required. For the 60 microinch resolution and a 1 Mbps data rate a tape speed of 30 to 42 ips would be required. This corresponds to a bit packing density of 23.8 to 33.3 Kpbi at these tape speeds. The recorder proposed in Section II of this report uses a bit packing density of 18.75 Kbpi at 53-1/3 ips tape speed.

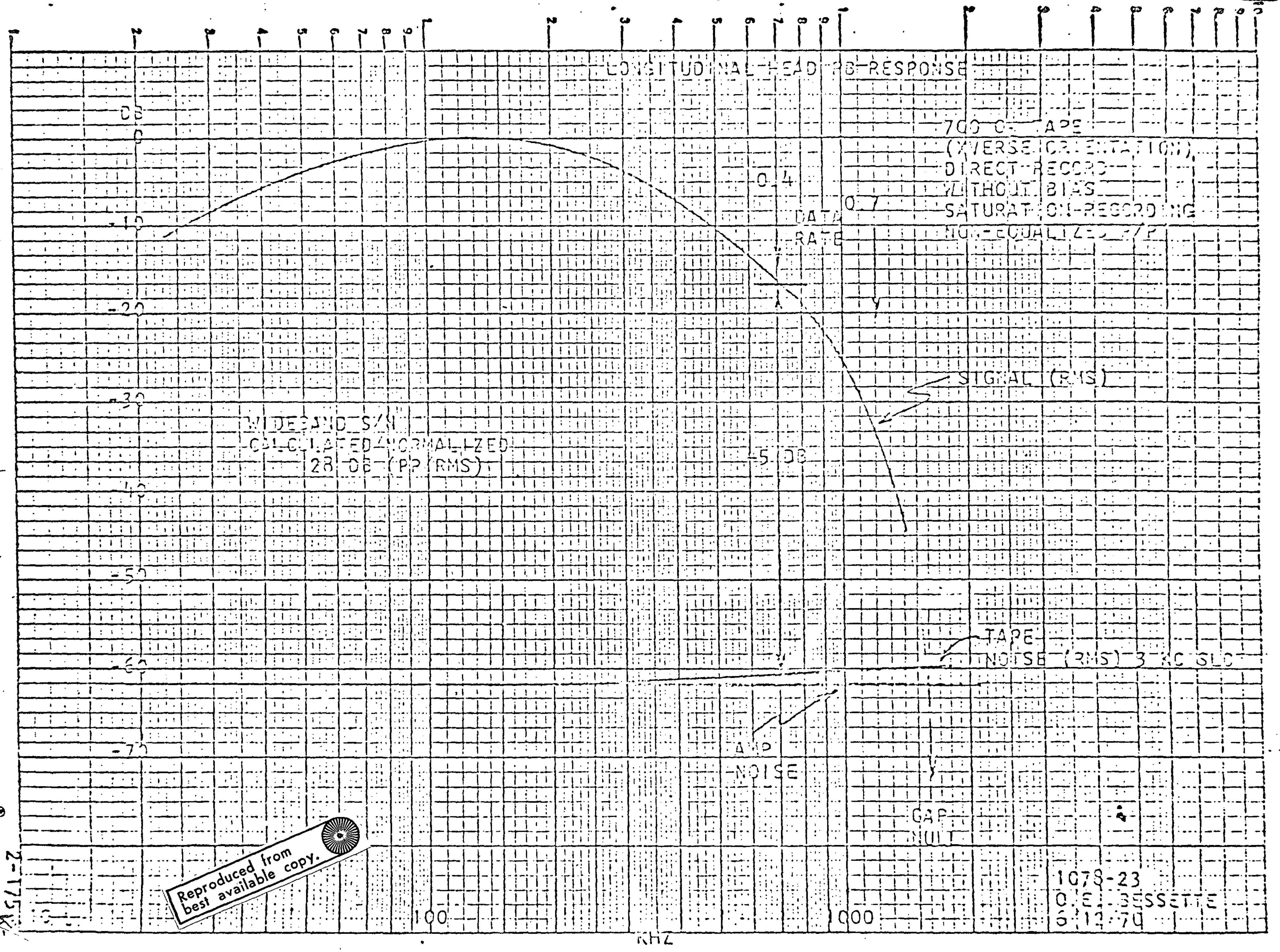
Tests were made at frequencies from 20 kHz to 1.2 MHz at 30 and 60 ips, to evaluate the performance of this head. The TR70 transport was used since the tape speed was readily available with the converted dc capstan. At both speeds, successful record playback transfer was made at wavelength approaching the gap length of 35 microinches. Response data of the fabricated head at 60 ips indicated that it was nearly adequate to handle 1 Mbps data (500 to 700 kHz response required). It was also calculated that the head was not optimum and could be improved.

Refer to Figures 4-1 and 4-2 for response data. Tests were made on standard video tape which is magnetically oriented on the "transverse" direction. This means that the "easy" axis of magnetization is "across" the tape and the "hard" axis is "along" the tape "longitudinally". This



LONGITUDINAL HEAD PB RESPONSE
300 O. TAPE
TYPE 400 (XVERSE)
DIRECT RECORD
WITHOUT BIAS
SATURATION RECORDING
NON-EQUALIZED R/P
DB
0
-10
-20
-30
-40
-50
-60
-70
WIDEBAND S/N
CALCULATED NORMALIZED
26 DB (PP/RMS)
43 DB
SIGNAL (RMS)
AMP
NOISE
(3 KC SLOT)
GAP
NULL
1078-19
O.E. BESSETTE
8/11/70
10
20
100
1000
KHZ

FIGURE 4-1


LONGITUDINAL HEAD PB RESPONSE
700 C. TAPE
(XVERSE ORIENTATION)
DIRECT RECORD
WITHOUT BIAS
SATURATION RECORDING
NON-EQUALIZED P/P
DB
0
-10
-20
-30
-40
-50
-60
-70
0.4
0.7
DATA RATE
SIGNAL (RMS)
WIDEBAND S/N
CALCULATED NORMALIZED
28 DB (PP/RMS)
-5 DB
TAPE
NOISE (RMS) 3 KC SLC
AMP NOISE
GAP NULL
100
1000
KHZ
1078-23
O. E. BESSETTE
6-13-70

difference corresponds to a relative loss in signal output during playback of about 3 dB for type 400 tape and presumably about the same for the 700 Oersted tape. For further information on orientation and retentivity refer to reference*.

The significant results of these tests show that the signal-to-noise requirements for delay mod can be met with this head. Based on the sine wave response data and the slot noise readings, a wideband signal-to-noise (pp/rms) of 28 dB was calcualted for the 700 oersted tape, and 26 dB for the standard (310 O_e) tape. 26 dB has been previously calculated to be approximately the minimum S/N requirements (21 dB +5 dB discounts). Transporting this data (26 dB using standard tape) to a system utilizing properly oriented tape (+3 to +6 dB), indicates that such a system is feasible and 18.75 Kbpi is achievable.

The primary result of the high energy tape test was a 4 dB increase in playback signal level. This corresponded (in our test) to a 4 dB improvement in signal-to-noise (S/N) over the 20 kHz to 200 kHz portion of the band and about 2 dB S/N improvement at the upper end of the band (1 MHz) where we were reading tape noise. A second result of the high energy tape tests is the definite improvement in performance at the short wavelength. This improvement is somewhat masked by the inability of the head gap to adequately resolve wavelength in this area (40-70 microinches).

5. <u>Flutter and Wow</u>

Flutter and wow measurements were performed on an existing model of the ERTS transport utilizing a two phase 250 Hz sine wave capstan motor. The discrete flutter components were measured withaa one-tenth octave GR1564A frequency analyzer. The cumulative measurements were conducted with a Krohn-Hite 330-M bandpass filter and HP3400A rms voltmeter. A 100 kHz tone was recorded on the tape and then

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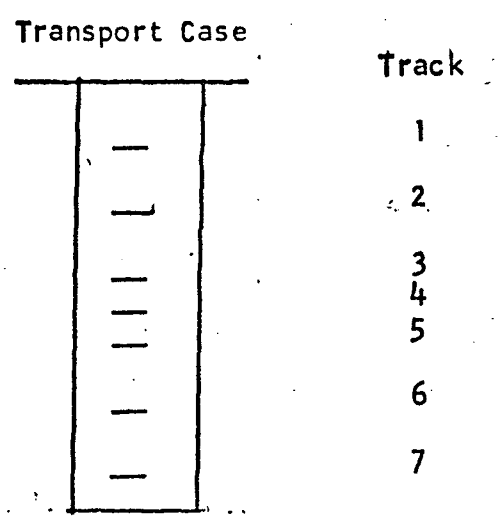
*IEEE Transaction on Magnetics, Vol. Mag. -5, No. 4, P. 821

played back in the same direction as the recording. A GR1142A frequency discriminator was used to obtain the flutter frequencies. Figure 5-1 is a plot of the discrete flutter components. The largest discrete flutter components was 0.08% at 250 Hz, the motor drive frequency. Figure 5-2 is a plot of the cumulative flutter. It measured less than 0.2% flutter for frequencies up through 20 kHz.

6. Skew

Skew measurements were made with the 7 track head described in paragraph 1114 of this report and an existing model of the ERTS transport utilizing a two phase 250 Hz sine wave capstan motor. Further skew tests now being conducted under our IR&D program on another transport with a double capstan drive have yielded preliminary data with approximately one-half of the skew of the previous tests.

Tests for measuring skew were performed on the 5 heads which were equally spaced across the 2 inch tape. Measurements were made of outer tracks vs center track and "half way out" track vs center track.



A 100 kHz tone was recorded on the five tracks simultaneously. Playback was in the same direction as the recording. The skew was measured using phase detectors where the center channel was

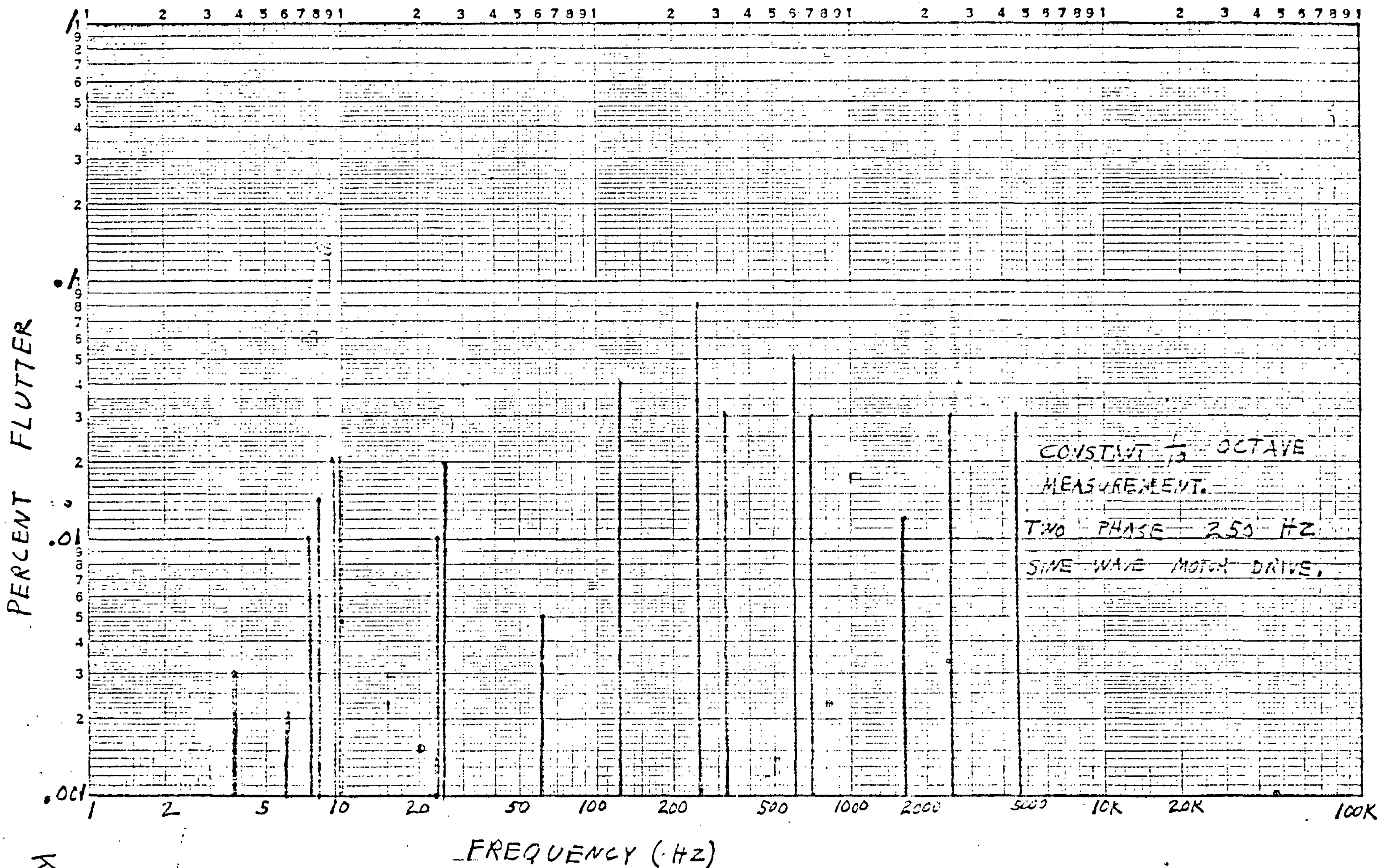


Figure 5-1 DISCRETE FLUTTER COMPONENT MEASUREMENTS ON AT-70 TRANSPORT

1/20/71 DHS

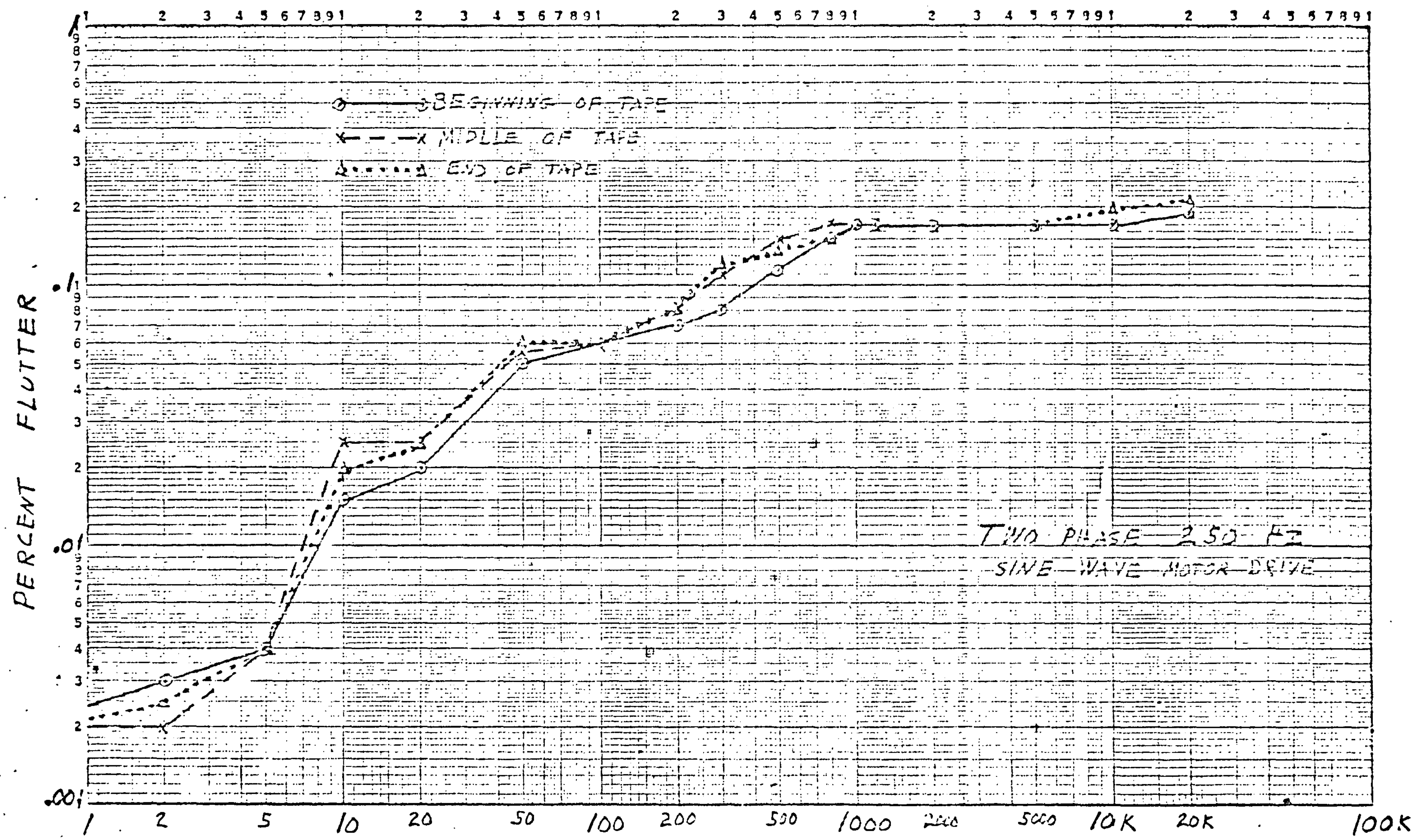
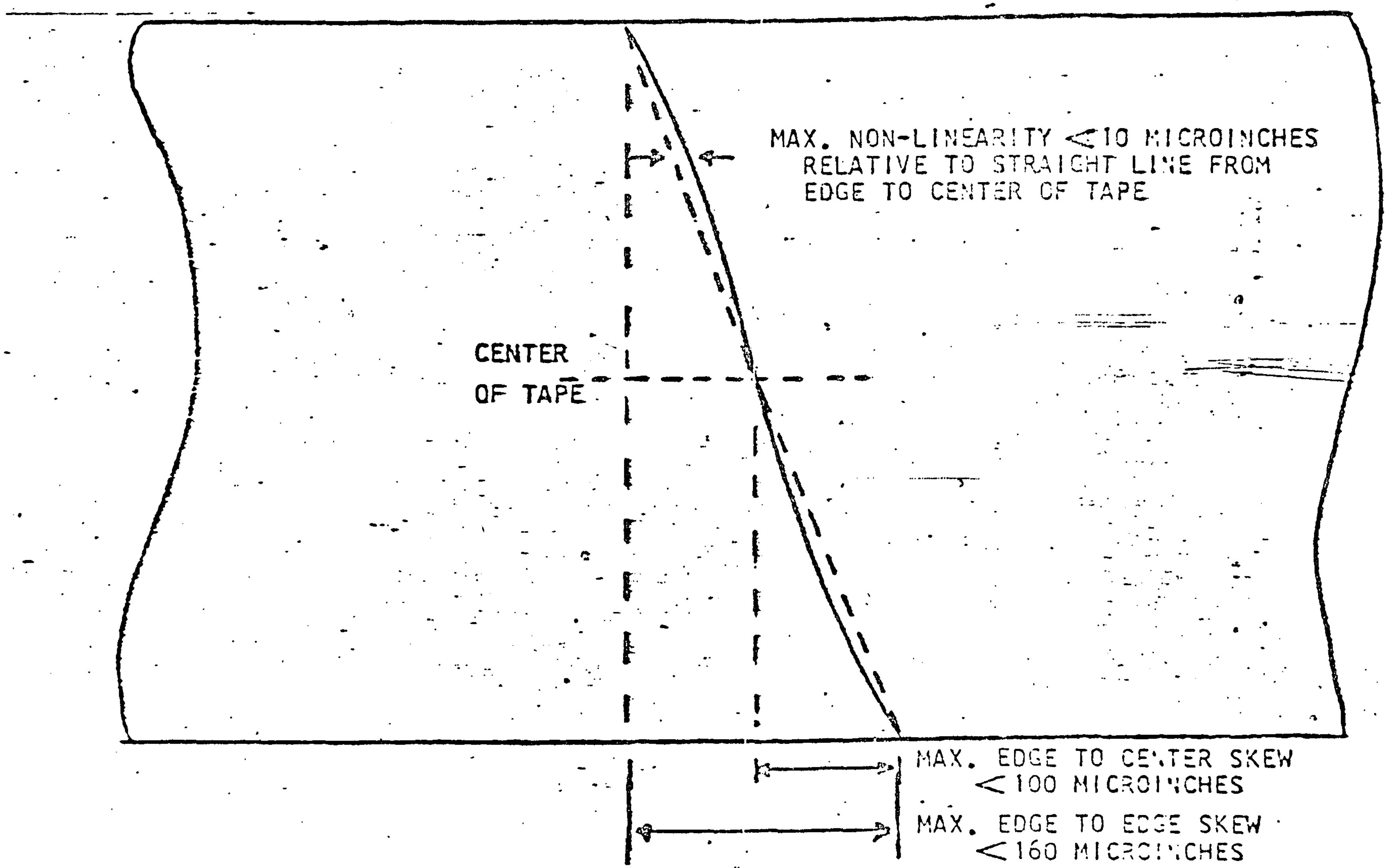


Figure 5-2 CUMULATIVE FLUTTER MEASUREMENTS ON AT-70 TRANSPORT

1/20/71 D-the 100 kHz reference. Thus the output of the four phase detectors was the phase or timing difference between the center channel and the other four channels. A Visicorder 1108 was used to simultaneously record the outputs of the four phase detectors. Two recording/playback runs were made with the visicorder turned on for 5 seconds every one minute of playback time. The visicorder charts were examined to determine the worst case dynamic skew and worst case deviation from a linear dynamic skew. Figure 6-1 shows some of the skew measurement results. The skew samples which had the worst skew or deviation from linear skew are given in Table 6-1. In this table, track 2 refers to the edge channel next to the transport case. Figure 6-2 shows how the maximum skew of track 1 during each 5 second period taken every minute varied with the length of time the tape played back. The worst skew was 100 microinches near the end of tape. Figure 6-3 shows four skew samples all taken within a 60 ms period. It shows both linear dynamic skew and non-linear dynamic skew. Due to an open lead on the head for track 4 (which has since been repaired), track 3 was used instead of track 4 to represent the center channel. Track 3 is only 22 mils from the center track 4. Figure 6-4 shows four fairly linear skew samples obtained from run #2. Figure 6-5 shows the worst case skew samples obtained in each 5 second period the visicorder ran. The numbers and letters (BOT 1, 2, 3, 4, 5 and EOT) refer to the time in minutes from the beginning of the tape when the 5 second period was recorded by the visicorder.

Fig. 6-1 SKEW MEASUREMENT RESULTS

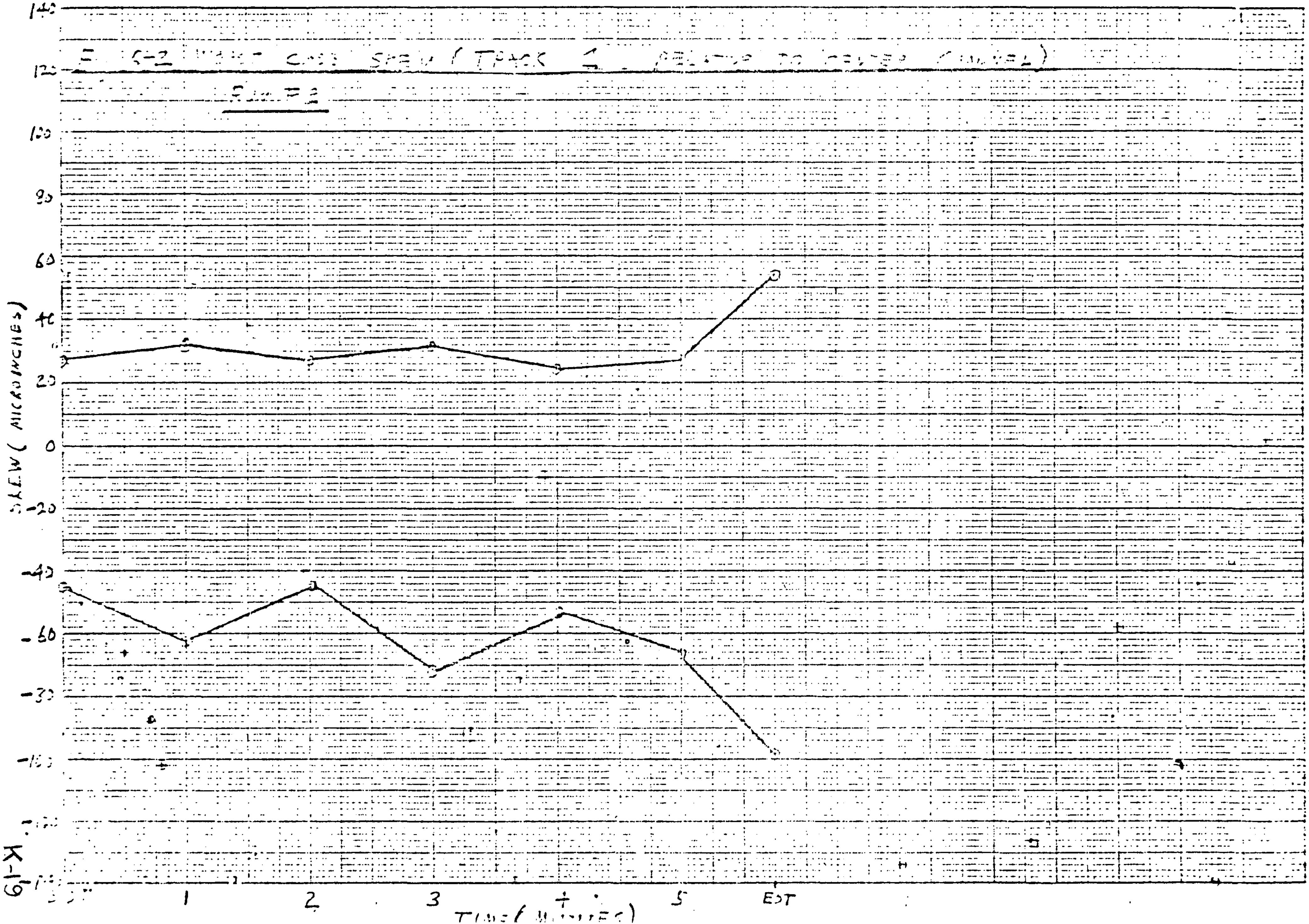


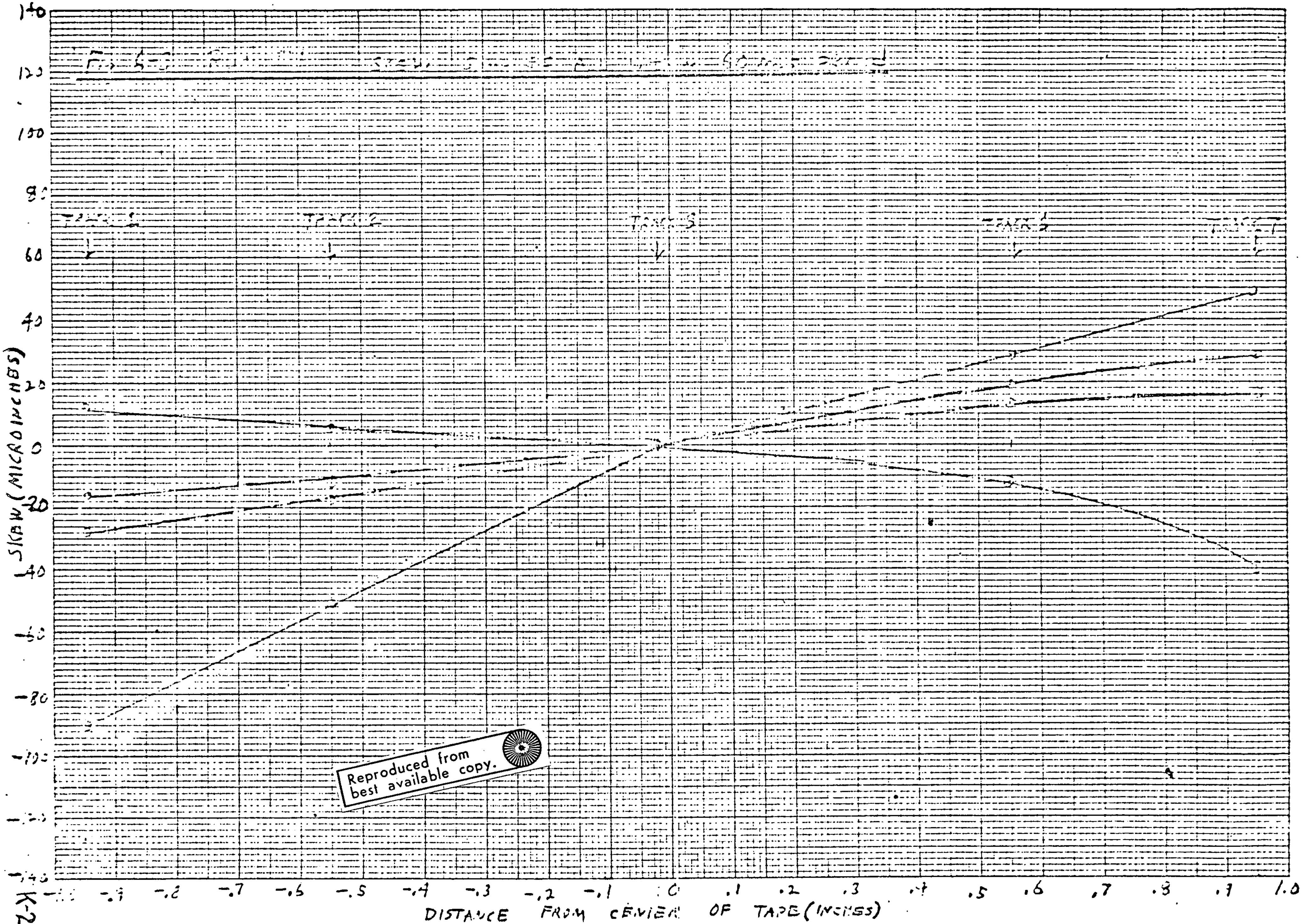
NOTE: THE MOST PROMINENT SKEW RATE WAS ≈ 25 HZ CAUSED BY TAPE ROLLER GUIDE ROTATION.

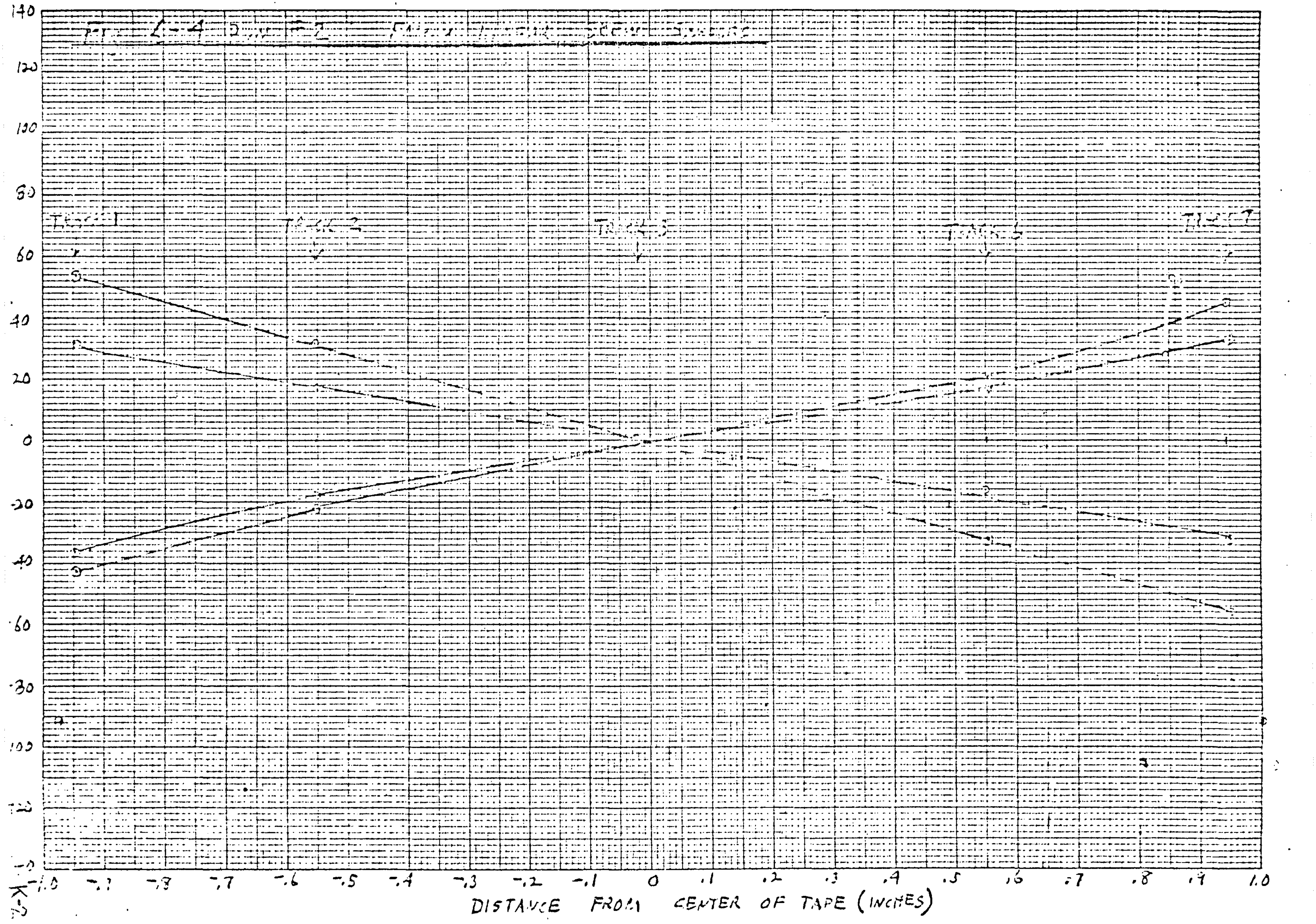
Table 6-1 Worst Case Deviation from Linear Straight Line

	Run #1		Run #2		
Deviation (Micro Inches)	Sample #1	#2	#1	#2	#3
Edge to Edge Line (Track 1 to track 7)	-22	-13	-7	-18	-21
Edge to Center Line (Track 1 to Center)	0	0	+2	-3	0
(Track 7 to Center)	0	-10	-6	0	+7
Best Fit Straight Line Across Tape	±10	±10	+±3	±11	±13
% Linearity					
Edge to Edge Line (Track 1 to track 7)	15.8%	25%	7.7%	18.1%	13.4%
Edge to Center Line (Track 1 to Center)	0%	0%	4.7%	4.4%	0%
(Track 7 to Center)	0%	25%	12.5%	0%	12.0%
Best Fit Straight Line Across Tape	7.2%	19.3%	3.3%	11.0%	8.3%

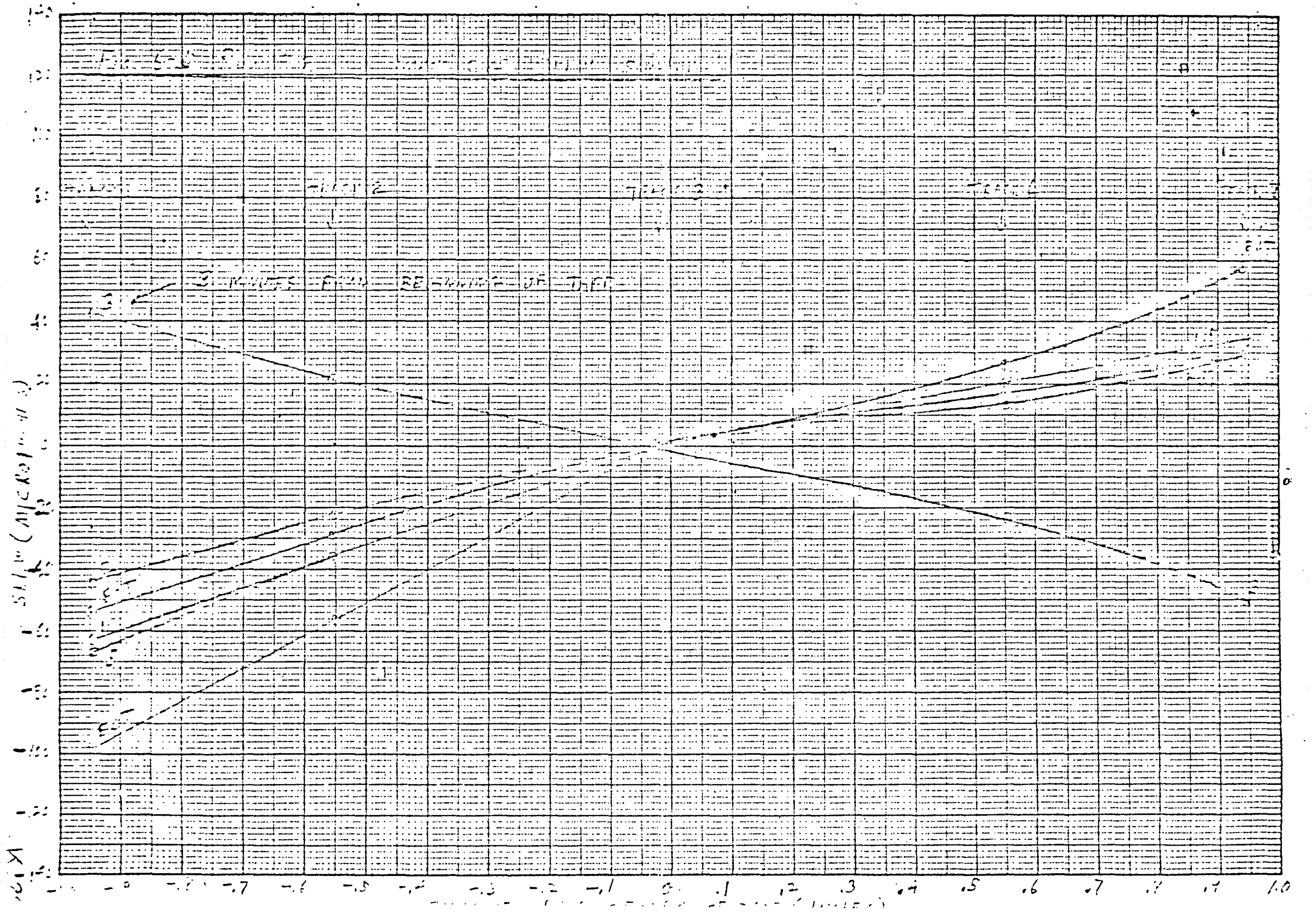
[redacted]
KEUFFEL & ESSER CO.




SKEW (MICROINCHES)
DISTANCE FROM CENTER OF TAPE (INCHES)
140
120
100
60
40
20
0
-20
-40
-80
-.5
-.4
-.3
-.2
-.1
0
.1
.2
.3
.5
.6
.7
.8
1.0


TRACK 1
TRACK 2
TRACK 3
TRACK 5
TRACK 7
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-1.0
-.9
-.8
-.7
-.6
-.5
-.4
-.3
-.2
-.1
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
DISTANCE FROM CENTER OF TAPE (INCHES)
K-2

[redacted] K+E [redacted] 10 X 10 TO THE ½ IN [redacted] 35 [redacted]
KEUFFEL & ESSER CO. MADE IN U.S.A.



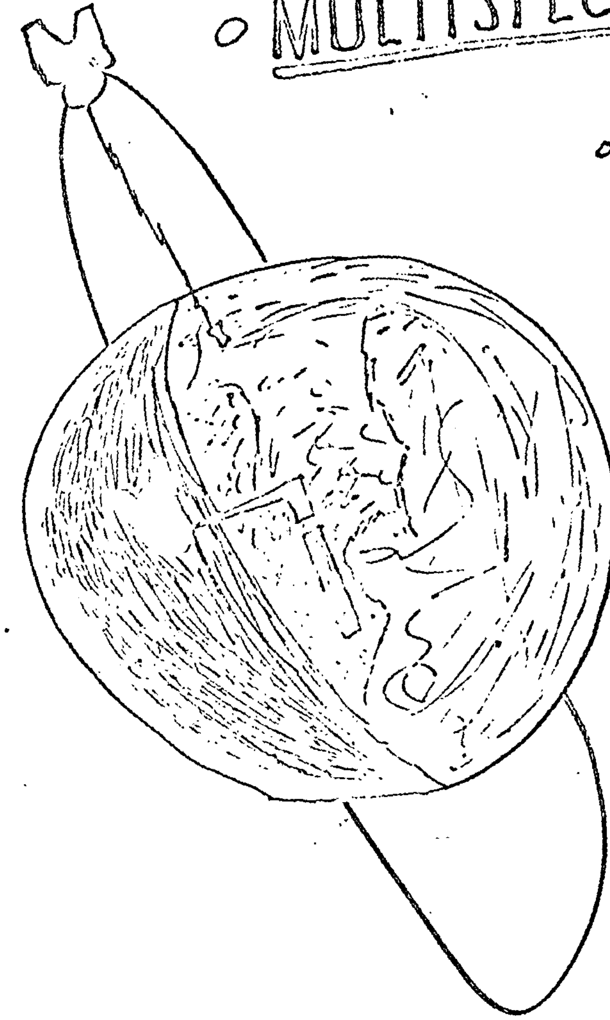
APPENDIX L

DESIGN REVIEW MATERIAL PRESENTED AT
GSFC ON MARCH 19, 1971.

MULTI-CHANNEL TAPE RECORDER SYSTEM STUDY

MCTR STUDY REVIEW

- INTRODUCTION
- OPTIMIZATION A/L-DIGITAL
- DIGITAL SYSTEM
  - TAPE TRANSPORT
  - RECORD PROCESSING
  - PLAYBACK PROCESSING
- HARDWARE PARAMETERS
- LINK CONSIDERATIONS
- GROUND STATION



- **MULTISPECTRAL SCANNER**
  - **RECORD**, 30 MIN./ORBIT
  - **PLAYBACK** TO CDA 10 MIN./ORBIT
  - LONGITUDINAL RECORDING
  - **LONG** LIFE.

MCTR TECHNOLOGY

SIGNAL PROCESSING

DIGITAL LOGIC
WIDE BAND MODULATORS
REC/PB CKTS. EQUALIZERS

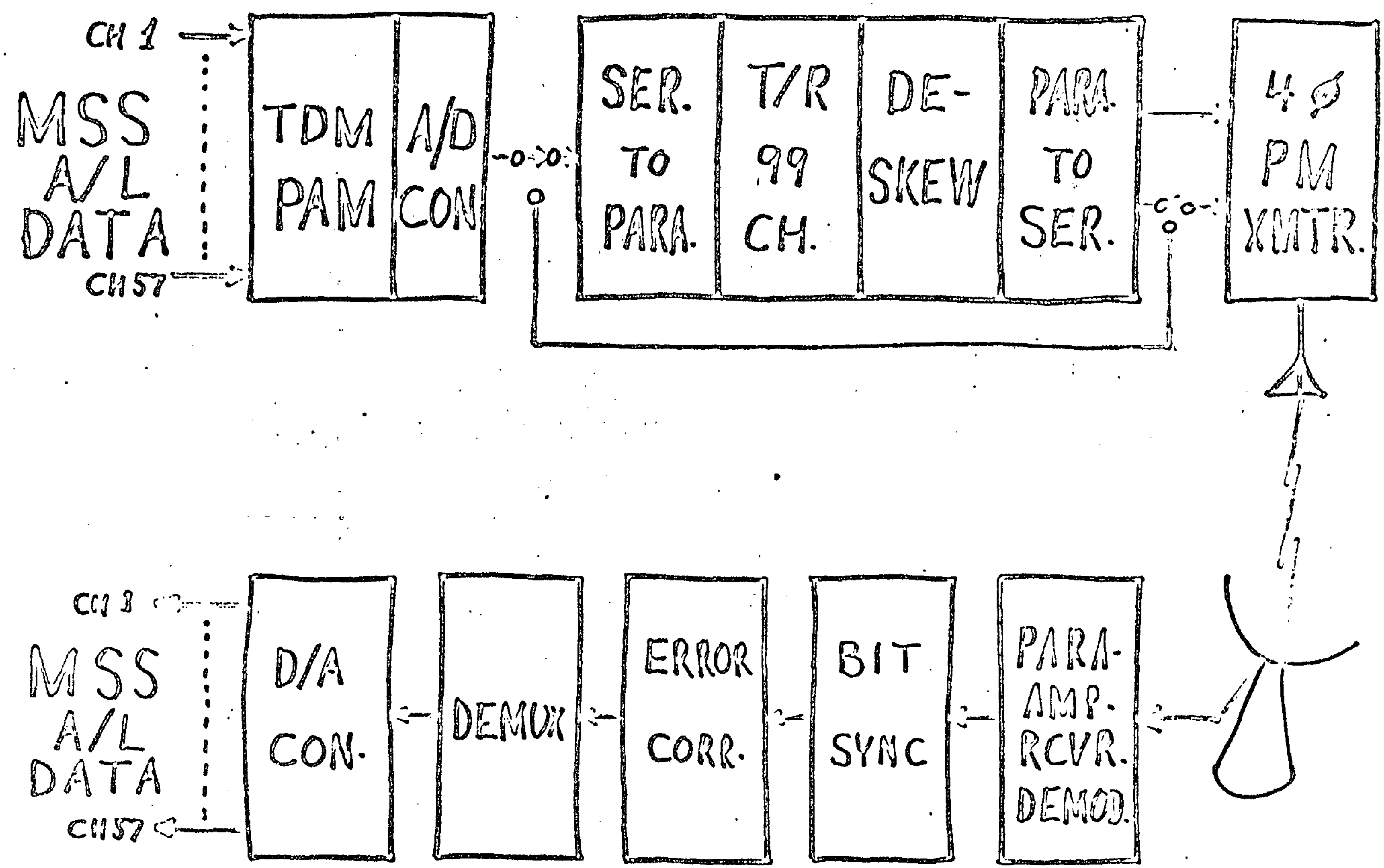
TAPE RECORDERS

DC DRIVE -DIGITAL SERVO
COPLANAR TAPE DECKS
MECHANISMS
TAPE/HEAD IITRI & RCA

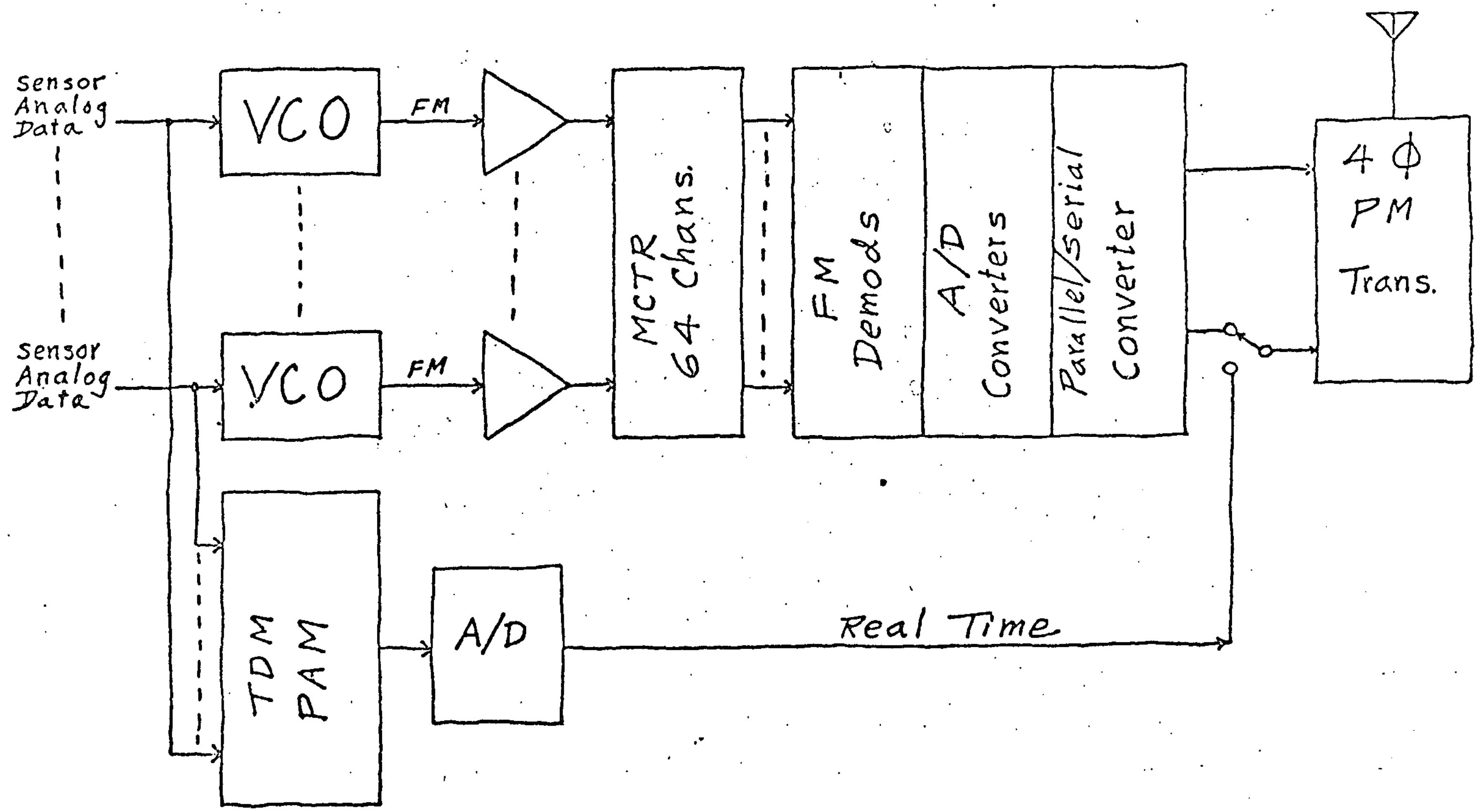
SYSTEM BASELINES

- 26 CH. MSS - DC to 60 KHZ
  - 1" COAXIAL TAPE RECORDER
  - 2" COPLANAR TAPE RECORDER
  - ANALOG / DIGITAL
- 64 CH. MSS - DC to 60 KHZ
  - 2" COPLANAR TAPE RECORDER
  - ANALOG / DIGITAL
- 57 CH. MSS - 54 DC to 40 KHZ, 3 DC to 13 KHZ
  - 2" COPLANAR TAPE RECORDER
  - DIGITAL - SERIAL CAPABILITY

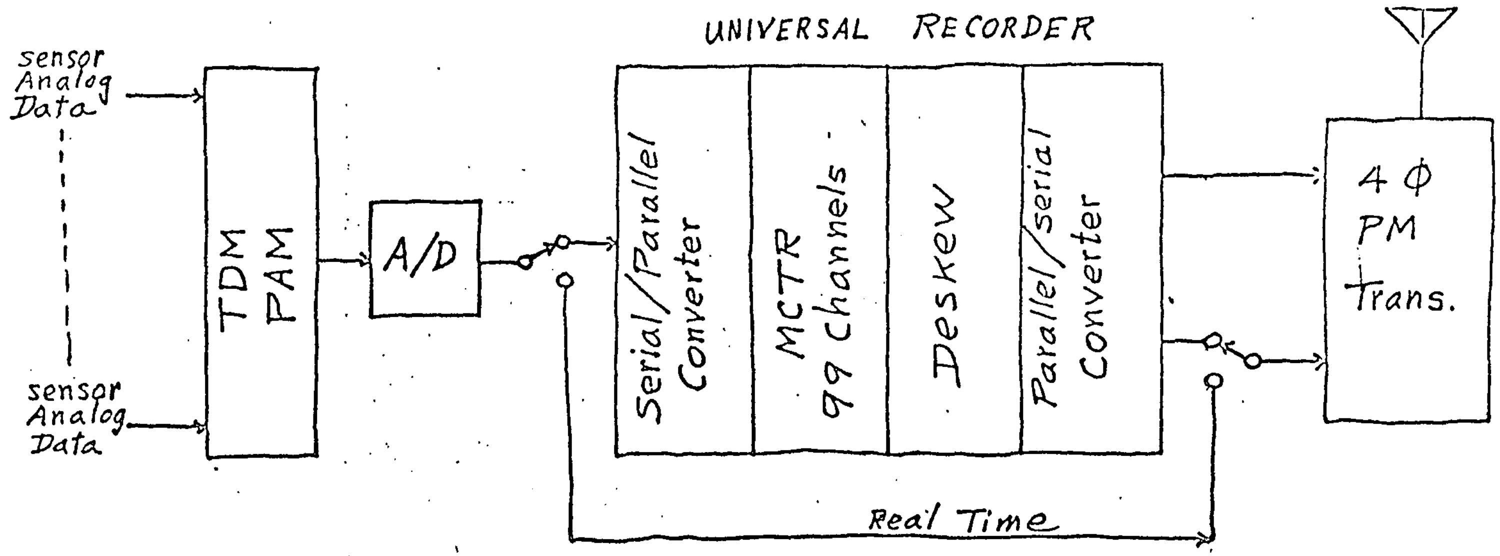
MCTR S/C & GND SYSTEM



ANALOG


Sensor Analog Data
Sensor Analog Data
VCO
VCO
FM
FM
MCTR 64 Chans.
FM Demods
A/D Converters
Parallel/serial Converter
4 Φ PM Trans.
TDM PAM
A/D
Real Time

DIGITAL


UNIVERSAL RECORDER
sensor Analog Data
sensor Analog Data
TDM PAM
A/D
Serial/Parallel Converter
MCTR 99 Channels
Deskew
Parallel/serial Converter
4 Φ PM Trans.
Real Time

ANALOG VS DIGITAL

	ANALOG	DIGITAL	
ACCURACY	STORAGE SYST. LIMITS TO 1%	STORAGE SYST. DOES NOT LIMIT ACC'Y	⊗
TBE	NOT FULLY CORRECTABLE. NON-LINEAR SKEW	NO TBE	

	ANALOG	DIGITAL	
STORED DOWN LINK	MULTIPLE A/D'S & PAR./SER. CONV.	PAR./SER. CONV.	✓
REAL TIME DOWN LINK	SAME TDM-A/D AS FOR DIGITAL	TDM-A/D USED FOR BOTH STORED & REAL TIME	✓
LOSS OF A RECORD CHANNEL	NOT EASILY CORRECTABLE	ERROR CORRECTION RECOVERS LOST CHANNEL	✓
TAPE DROPOUTS	NOT CORRECTED	NON-OVERLAPPING DROPOUTS AND MOST RANDOM ERRORS CORRECTED	✓
FLEXIBILITY	INFLEXIBLE WITH DIFFERENT SENSORS	UNIVERSAL STORAGE SYSTEM FOR FUTURE MISSIONS	⊗
IMPLEMENTATION	ANALOG & DIGITAL	ALL DIGITAL	✓

	ANALOG		DIGITAL		
TRACKS	64	✓	99		
TAPE	1930 FT., 13 IPS	✓	3400 FT., 22.6 IPS		

DIGITAL APPROACH OFFERS
BEST PERFORMANCE,
RELIABILITY, AND ORDERLY
GROWTH TO THE FUTURE

DIGITAL STORAGE SYSTEM

30 Minutes Recording. Capacity 8×10^{10} bits

Record at 22.6 ips. Playback 68 ips for 10 minutes

Input Data Rate 39.9 Mb/s. Output 133 Mb/s

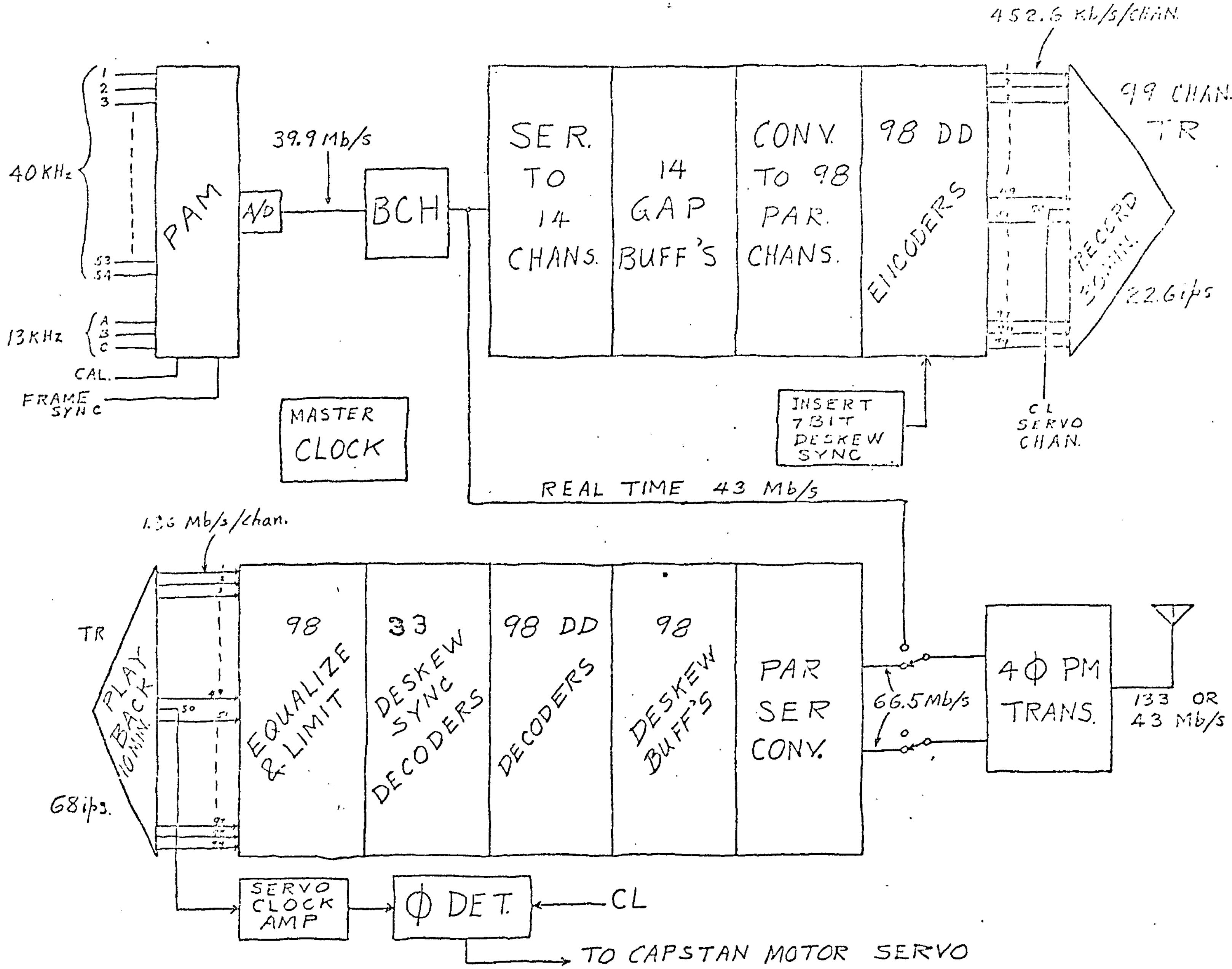
Packing Density 20 kb/s. With DD Encoding

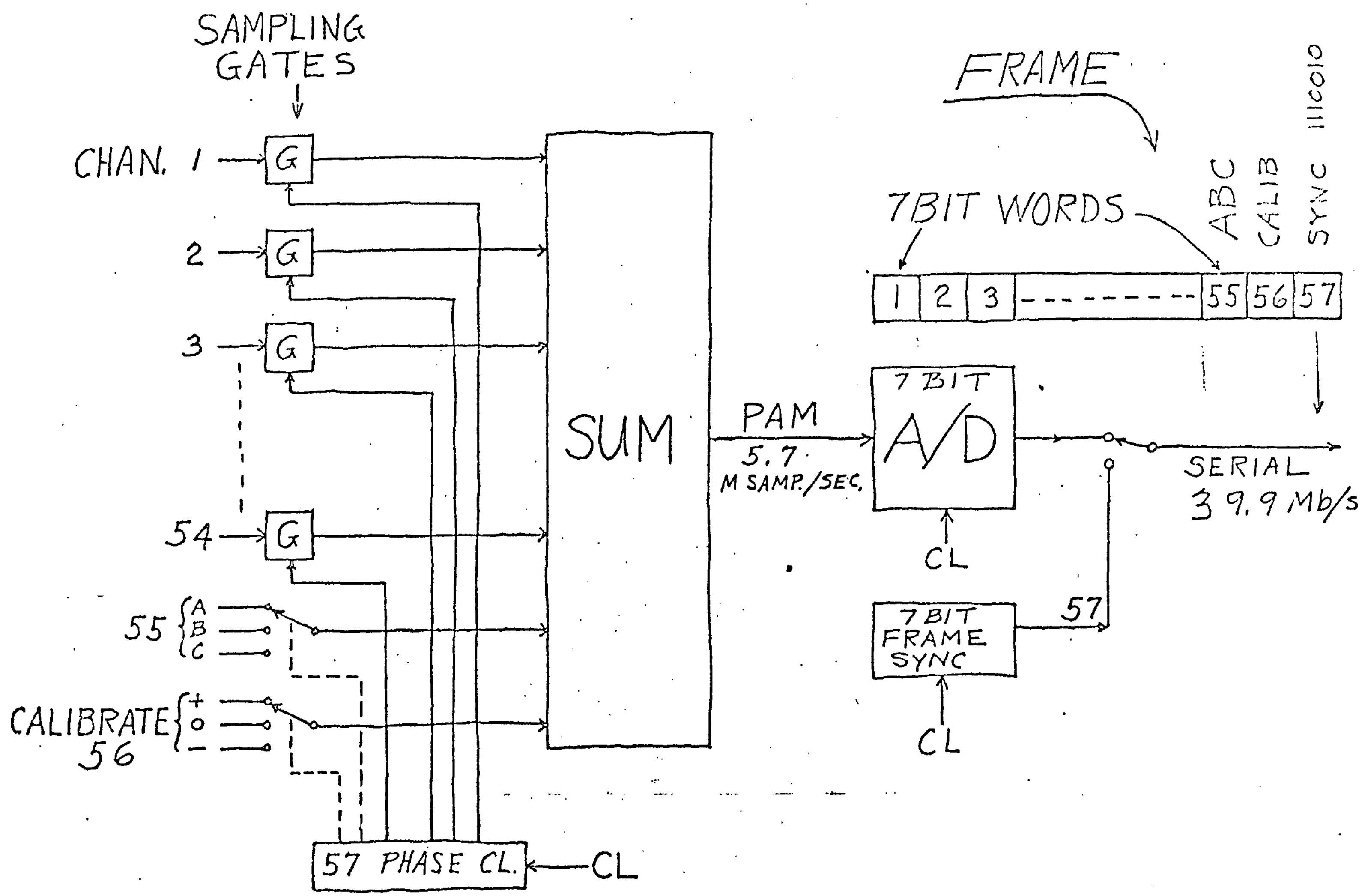
2 Inch Tape. 98 Data Tracks + One Servo Track

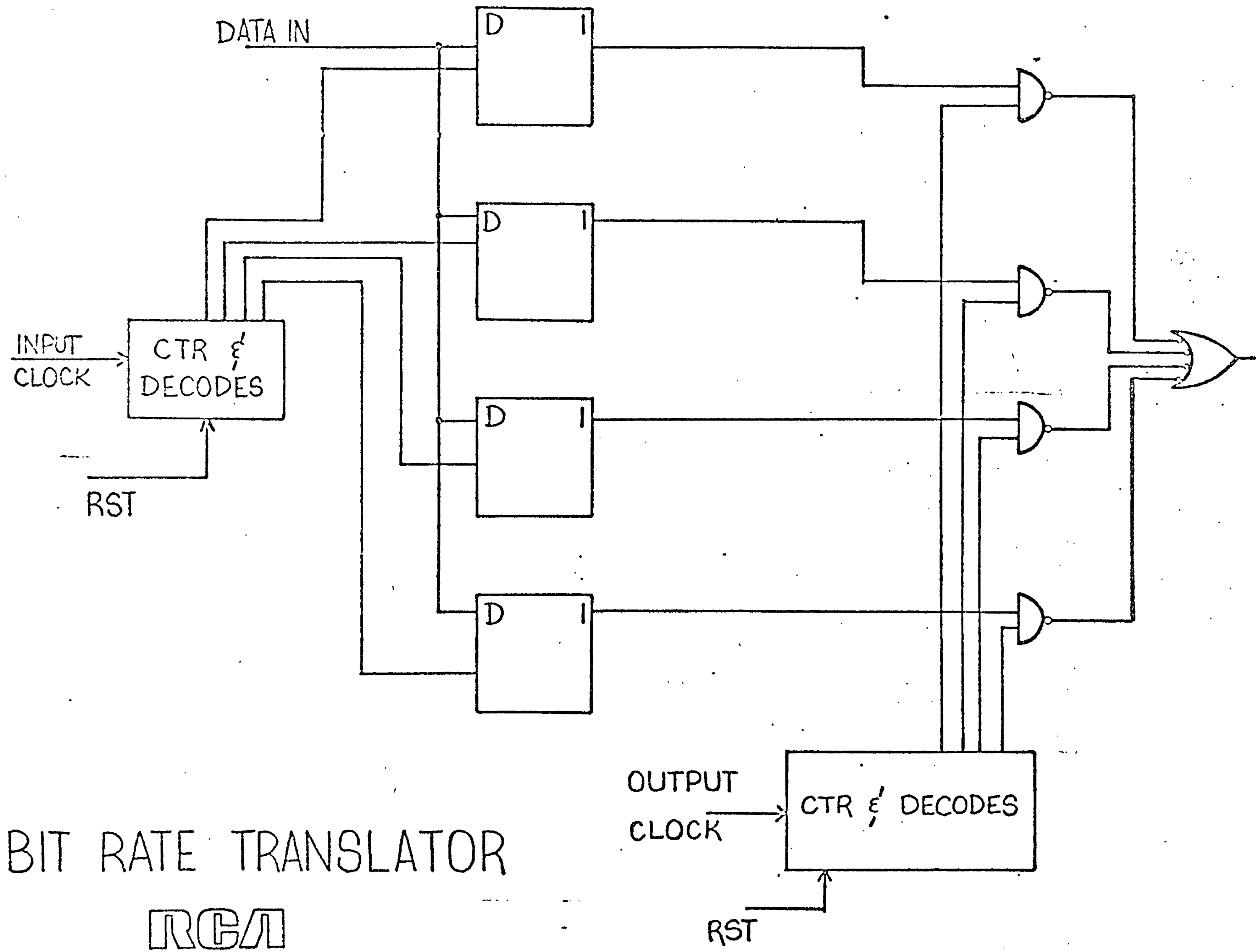
No Time Base Error

Correction of Non-Overlapping Tape Dropouts

Housekeeping Overhead $133/3 \times 39.9 = 1.11$


PAM
A/D
40 KHz
1
2
3
53
54
13 KHz
A
B
C
CAL.
FRAME SYNC
39.9 Mb/s
BCH
MASTER CLOCK
SER. TO 14 CHANS.
14 GAP BUFF'S
CONV. TO 98 PAR. CHANS.
98 DD ENCODERS
INSERT 7 BIT DESKEW SYNC
452.6 Kb/s/CHAN.
99 CHAN. TR
RECORD 30 MIN.
22.6 ips
CL SERVO CHAN.
REAL TIME 43 Mb/s
1.36 Mb/s/chan.
TR
PLAY BACK 10 MIN.
68 ips.
98 EQUALIZE & LIMIT
33 DESKEW SYNC DECODERS
98 DD DECODERS
98 DESKEW BUFF'S
PAR SER CONV.
66.5 Mb/s
4Φ PM TRANS.
133 OR 43 Mb/s
SERVO CLOCK AMP
Φ DET.
CL
TO CAPSTAN MOTOR SERVO

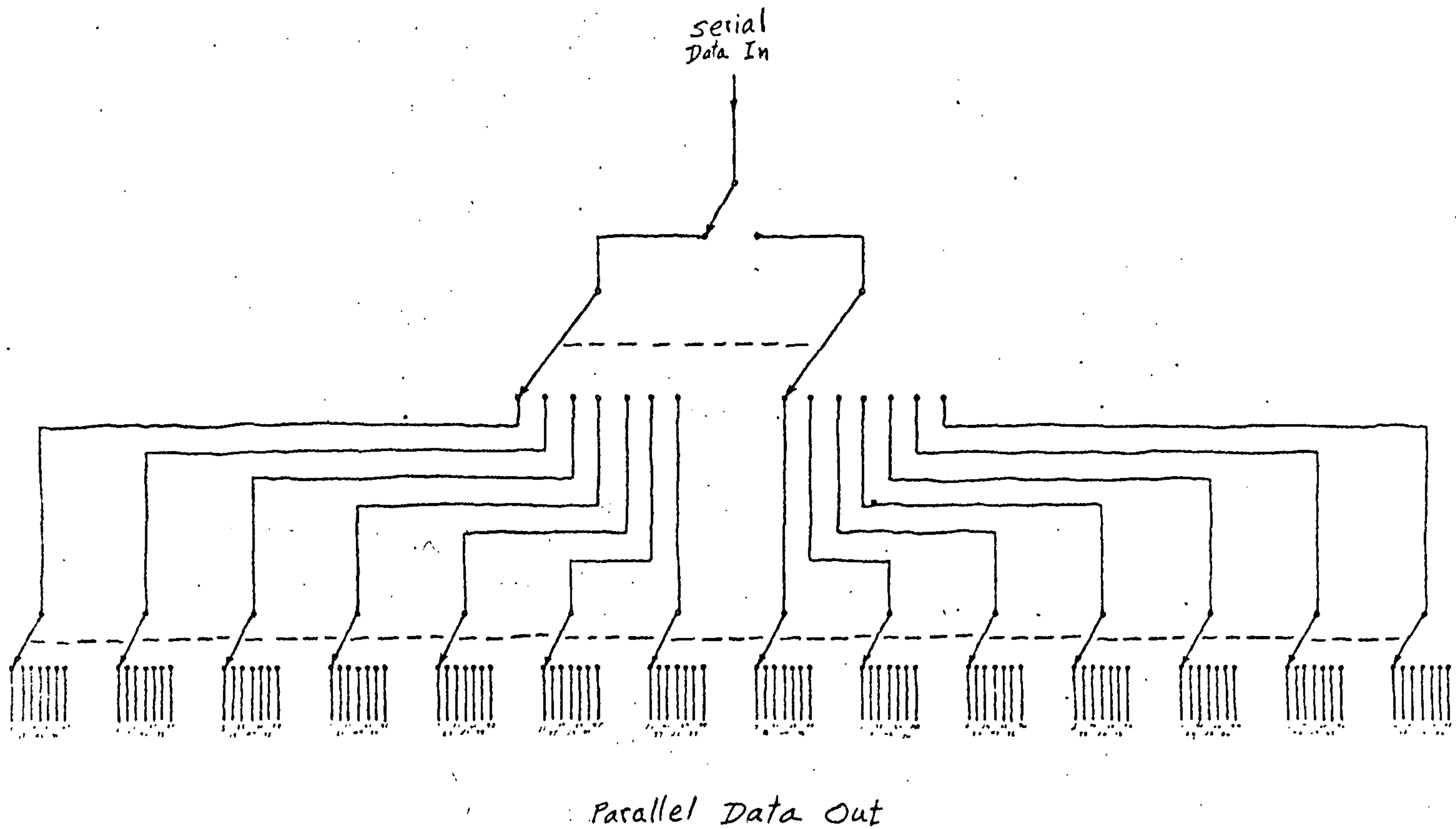

SAMPLING GATES
CHAN. 1
2
3
54
55 {A B C
CALIBRATE {+ o −
56
G
SUM
57 PHASE CL.
CL
PAM
5.7 M SAMP./SEC.
7 BIT A/D
CL
7 BIT FRAME SYNC
CL
57
SERIAL
39.9 Mb/s
FRAME
7BIT WORDS
1 2 3 55 56 57
ABC
CALIB
SYNC 1110010

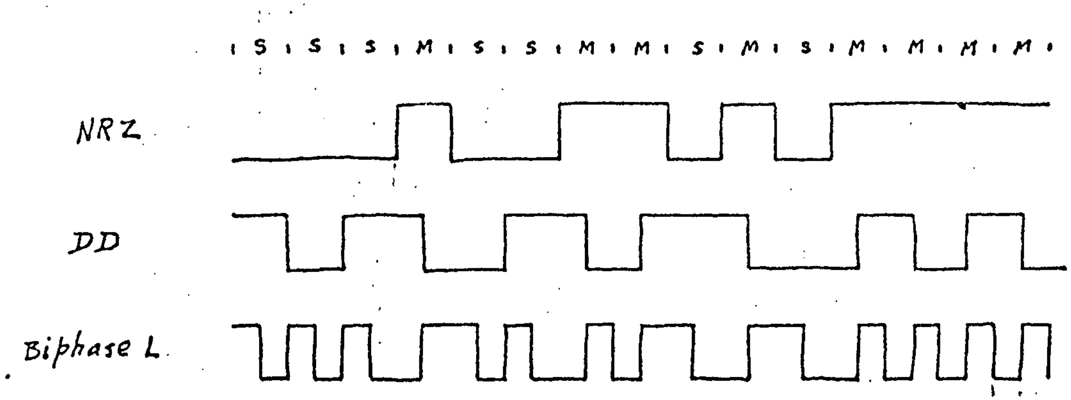


BIT RATE TRANSLATOR

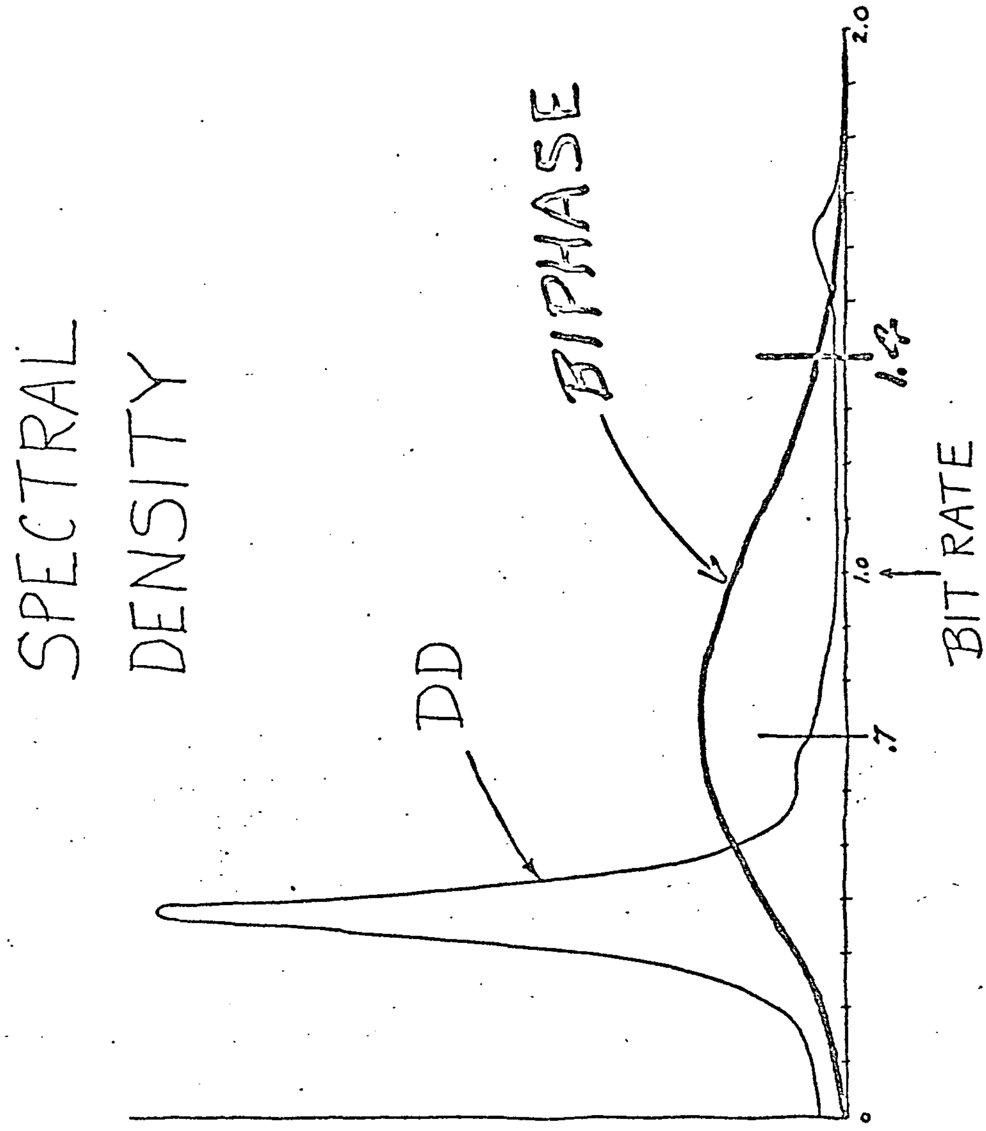
RCA

SERIAL / PARALLEL CONVERTER

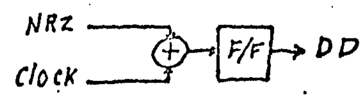




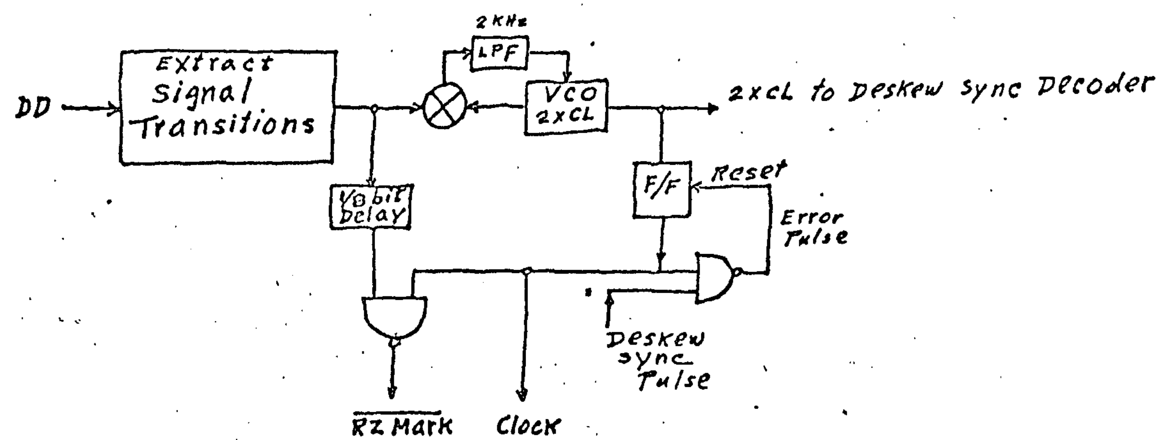
CODING WAVEFORMS


SPECTRAL
DENSITY
DD
BIPHASE
BIT RATE
0
.7
1.0
2.0

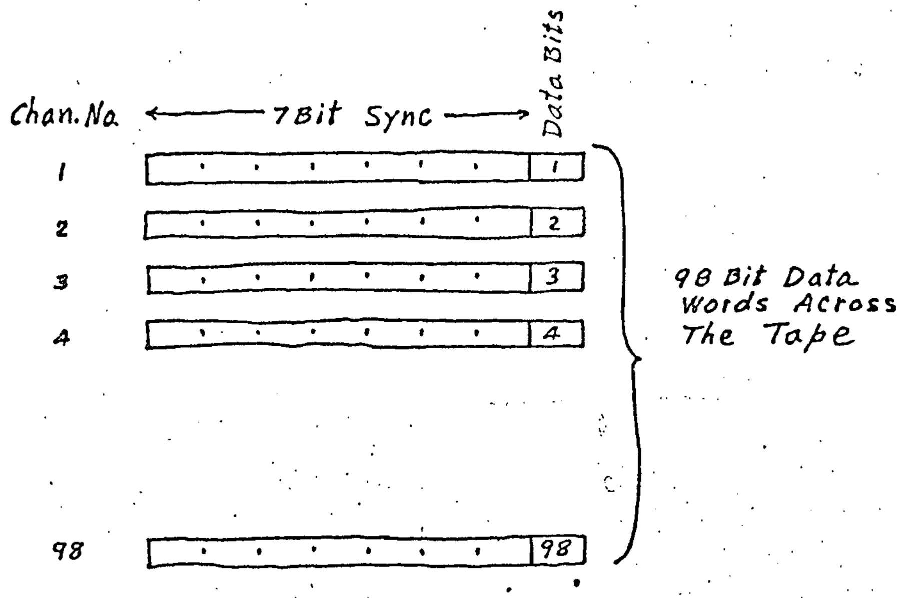
DD Encoder



DD Decoder

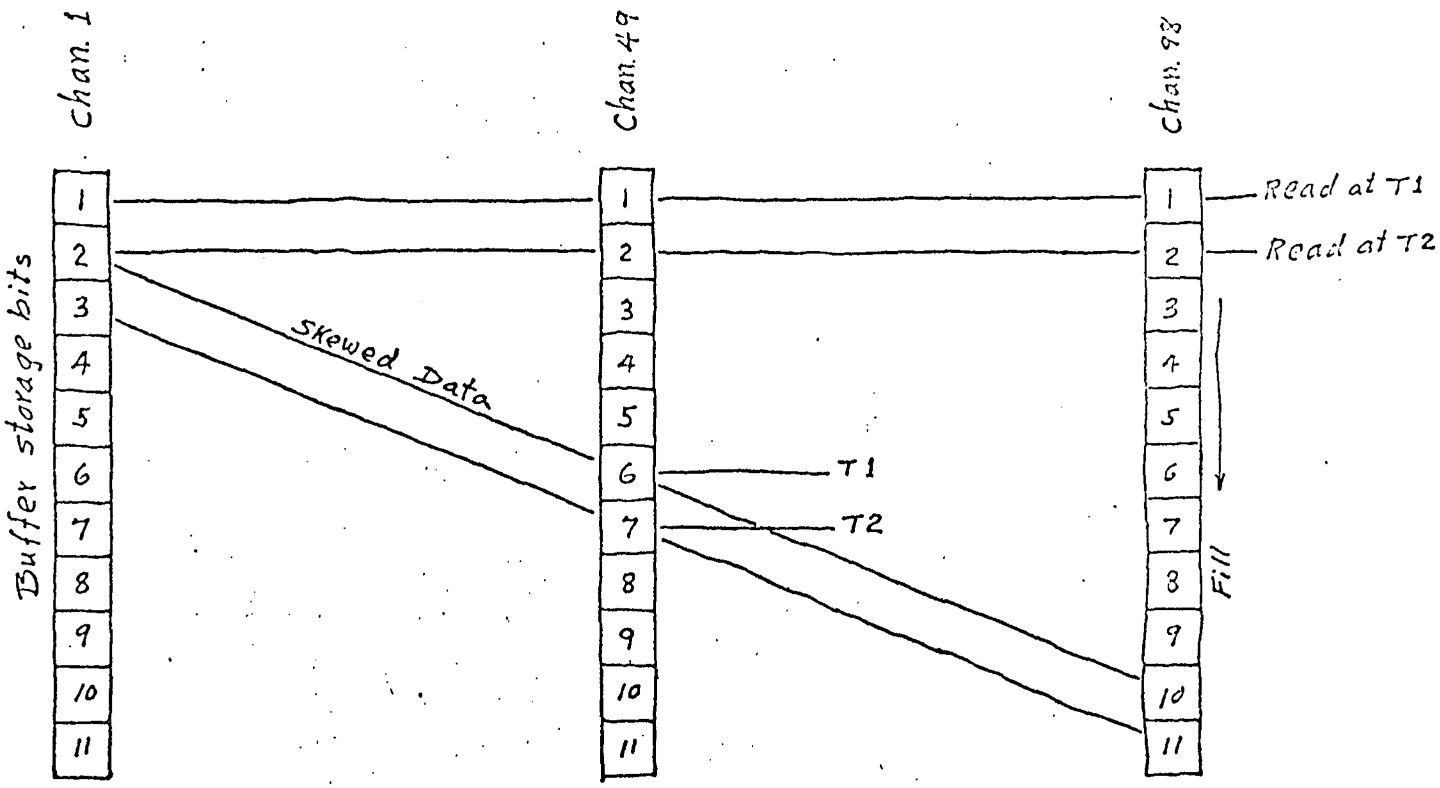


ERROR CORRECTION



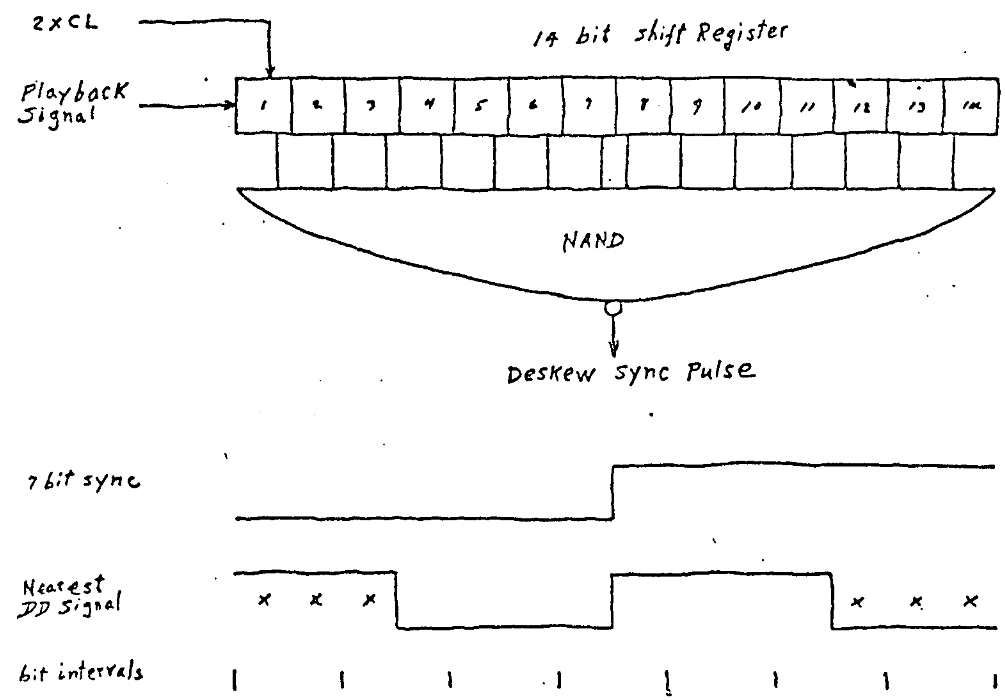
Loss of one channel causes one bit error in a 98 bit word.

P_e BEFORE	P_e AFTER
10^{-4}	2×10^{-7}
10^{-5}	2×10^{-9}
10^{-6}	2×10^{-11}



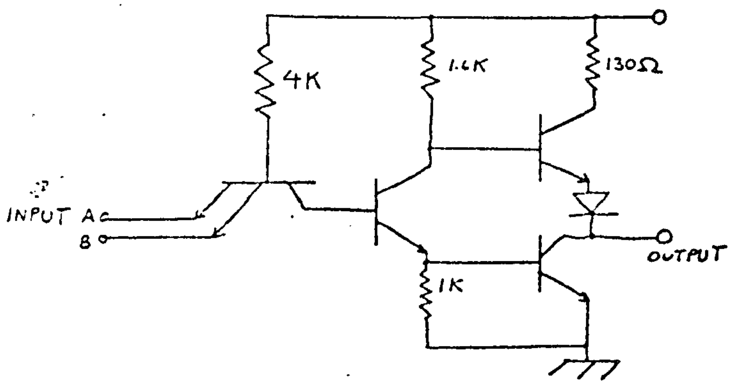
DESKEW BUFFERS

DESKEW SYNC DECODER

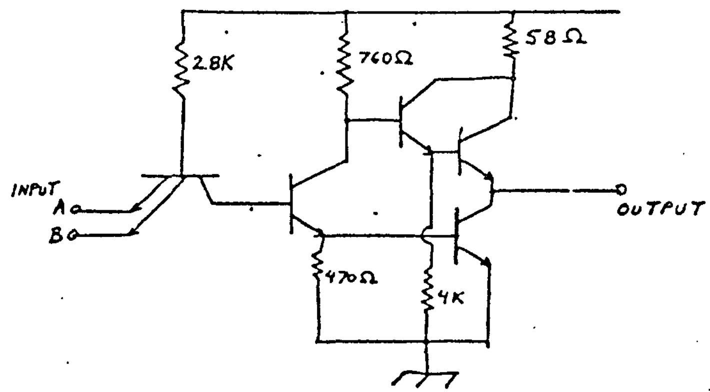


INTEGRATED CIRCUIT TYPES PROPOSED

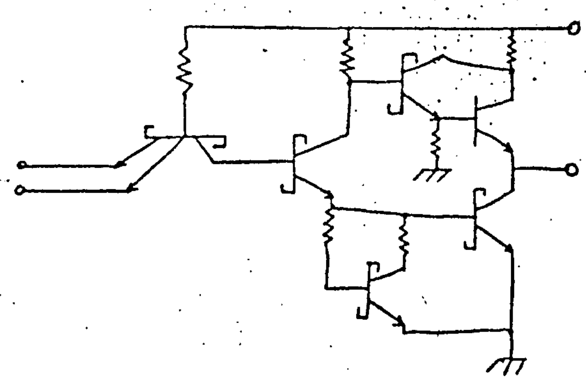
TTL-STANDARD

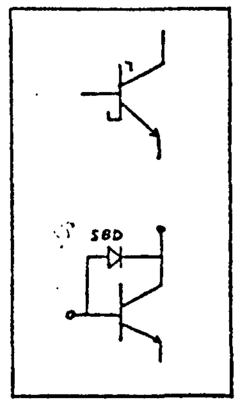


TTL-HIGH SPEED



TTL-SHOTTKY





RCA

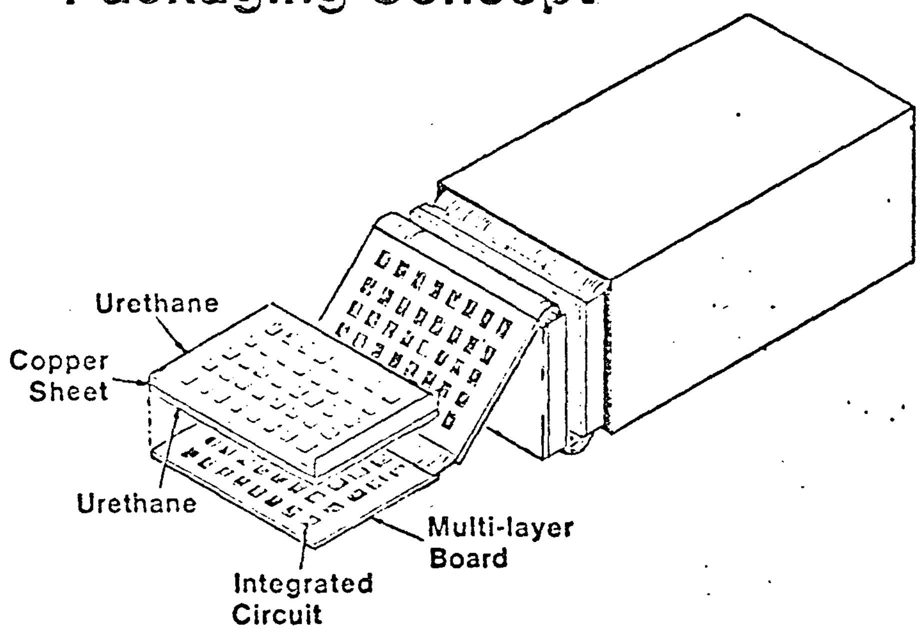
PARAMETER COMPARISON OF PROPOSED LOGIC DEVICES

PARAMETER	TTL-STANDARD				TTL-HIGH				TTL-SHOTTKY			
	Min	Typ	Max	Cond	Min	Typ	Max	Cond	Min	Typ	Max	Cond
t_{PLH} (ns)		11	22	$C_L = 15pf$ $R_L = 400\Omega$		9	13	$C_L = 25pf$ $R_L = 200\Omega$	2	3	4.5	$C_L = 15pf$ $R_L = 280\Omega$
t_{PHL} (ns)		7	15			6.5	10		2	3	5	
f_{CLOCK} (MHz)	15		20		25	30			80	100		
I_{SINK} (Ma)	16			$V_{OH} = .4v$		20		$V_{OH} = .4v$		20		$V_{OH} = .5v$
POWER DISS (MW)		10		50% D.C.		22		50% D.C.		19		50% D.C.

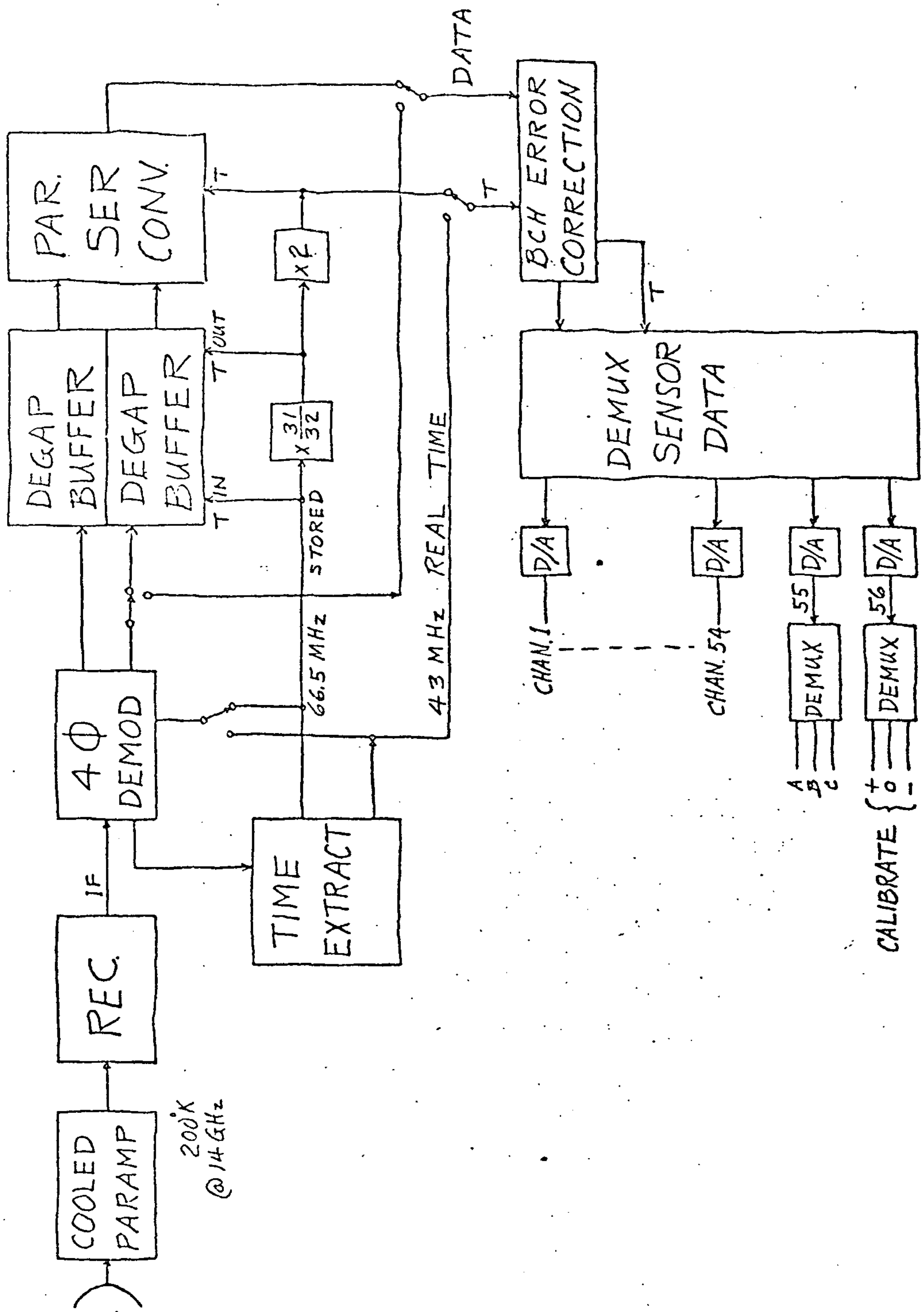
MTR FUNCTION/PACKAGE/POWER MATRIX

	FUNCTION	PACKAGE CT	PWR DISS. (W)
RECORD MODE	BCH ENCODER & DATA BUFFERING	31	4.3
	SERIAL TO 14-CHANNEL CONV	20	2.5
	FOURTEEN GAPPING BUFFERS	699	47.9
	14 TO 98 CHANNEL CONVERTER	47	11.0
	98 DD ENCODERS	152	5.8
	RECORD SUB TOTAL	949	71.5
PLAYBACK MODE	PHASE LOCK LOOPS	165	10.0
	DD DECODERS & DESKEW DET	558	19.0
	DIVIDED BY SIXTEEN COUNTERS	196	32.3
	DESKEW BUFFER STORE	755	7.0
	HIGH SPEED MUX COUNTER	8	1.2
	PARALLEL TO SERIAL CONV	817	52.5
	PLAYBACK SUB TOTAL	2,499	122.0
	SYSTEM TOTAL	3,448	71.5 122.0

MCTR - Electronics Packaging Concept



RCA


COOLED PARAMP
200°K @14GHz
REC
IF
4Φ DEMOD
TIME EXTRACT
66.5 MHz
STORED
43 MHz
REAL TIME
DEGAP BUFFER
DEGAP BUFFER
T IN
T OUT
x 31/32
x 2
PAR. SER CONV.
T
DATA
BCH ERROR CORRECTION
DEMUX SENSOR DATA
D/A
D/A
D/A
D/A
CHAN. 1
CHAN. 54
55
56
DEMUX
DEMUX
A
B
C
CALIBRATE
+
0
-

MCTR LINK SPECIFICATION

STORED MODE	REAL TIME MODE
INFORMATION RATE: 133 Mb/s.	43 Mb/s.
4 PHASE TRANSMITTER	BI-PHASE $\pm 90^\circ$
KEYING RATE: 66.5 M BAUD	43 M BAUD
$C/N_o = 93.2$ dB, $P_e = 10^{-6}$	$C/N_o = 87.9$ dB, $P_e = 10^{-6}$
SYSTEM $T = 200^\circ K$	$200^\circ K$ AT 14 GHz
REQ'D REC. POWER: −112.4 dBW	−117.7 dBW

ADD REQUIRED LINK MARGIN