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FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER ATL--ETC F/6 1 /7
PRECISION L-BAND DME TESTS.(U)

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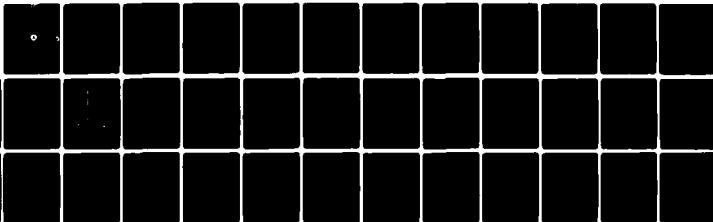
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FAA-RD-80-74

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Report No. FAA-RD-80-74
FAA-CT-80-25

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PRECISION L-BAND DME TESTS

Harold Postel

FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER

Atlantic City, N. J. 08405



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INTERIM REPORT

AUGUST 1980

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Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D. C. 20590

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16. Abstract This phase of the project was performed under Technical Program Document (TPD) 04-109, subprogram 075-725-210. The report covers the findings on system accuracy and stability of the L-Band Precision Distance Measuring Equipment (PDME). The results showed differences in bias under varying conditions of approaches, orbits, radials, and river runs. The 24-hour overall stability of the system was recorded. Further testing should be performed with simulators that have the desired accuracy required for testing a PDME system so that a baseline can be established.					
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JOB

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol When You Know Multiply by To Find Symbol

LENGTH

in	inches	2.5	cm	centimeters
ft	feet	30	m	meters
yd	yards	0.9	m	meters
mi	miles	1.6	km	kilometers

AREA

sq in	square inches	6.5	cm ²	square centimeters
sq ft	square feet	9.0	m ²	square meters
sq yd	square yards	0.8	m ²	square meters
sq mi	square miles	2.6	km ²	square kilometers
acres	acres	0.4	ha	hectares

MASS (weight)

oz	ounces	28	g	grams
lb	pounds	0.45	kg	kilograms
	short tons (2000 lb)	0.9	t	tonnes

VOLUME

cup	cup	0.24	l	liters
pt	pints	0.47	l	liters
qt	quarts	0.95	l	liters
gal	gallons	3.8	l	liters
cu ft	cubic feet	0.03	m ³	cubic meters
yd ³	cubic yards	0.76	m ³	cubic meters

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	°C	Celsius temperature
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Approximate Conversions from Metric Measures

Symbol When You Know Multiply by To Find Symbol

LENGTH

mm	millimeters	0.04	inches
cm	centimeters	0.4	inches
m	meters	3.3	feet
km	kilometers	0.6	miles

AREA

sq cm	square centimeters	0.15	sq in
sq m	square meters	1.2	sq yd
ha	hectares (10,000 m ²)	2.5	acres

MASS (weight)

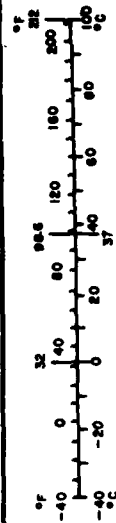
g	grams	0.035	oz
kg	kilograms	2.2	lb
t	tonnes (1000 kg)	1.1	short tons

VOLUME

ml	milliliters	0.03	fl oz
l	liters	1.06	qt
m ³	cubic meters	35	cu yd
m ³	cubic meters	1.3	cu yd

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	°F	Fahrenheit temperature
----	---------------------	-------------------	----	------------------------



* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SD Catalog No. C1310286.

PREFACE

The author wishes to acknowledge Mr. Ron Polillo of the Range Programming and Analysis Branch, ACT-750, who was responsible for the programming which generated the flight plots in this report.

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PURPOSE

The purpose of this project was to determine the system accuracy of L-Band Precision Distance Measuring Equipment (PDME) utilizing a modified Aerocom model 5351A DME ground transponder.

BACKGROUND

The Federal Aviation Administration (FAA) Technical Center, in coordination with the Systems Research and Development Service (SRDS), tested a C-band DME for range measurement accuracy in accordance with Radio Technical Commission for Aeronautics (RTCA) specifications prepared by the Special Committee, SC-117. Previous testing in 1974 at the Technical Center and Crows Landing, California, showed that an L-band DME would be simpler and more economical to implement (related final report, Contract No. WI-74-1245-1, "Experimentation for Use of L-Band DME with the Microwave Landing System," April 1974).

These 1974 tests resulted in the selection of a $\cos/\cos^2$ shaped pulse for Microwave Landing System (MLS)/(L-Band) DME. The Bendix Avionics Division, in coordination with Aerocom, modified a standard model 5351 DME ground transponder to operate specifically as a DME system applicable to MLS/DME. The design also provides the necessary stability and an overall accuracy of 100 feet (2 sigma), which was incorporated into the specification, when used with the Bendix airborne MLS/DME interrogator. The Aerocom DME is one of several ground transponders undergoing accuracy tests.

DESCRIPTION OF EQUIPMENT

The Aerocom 5351A DME was modified for MLS/DME operation and redesigned to

provide a first pulse output of a $\cos/\cos^2$ wave shape and a second pulse of a $\cos^2$ wave shape. The first pulse provides a fast rise time on the start of the pulse and a $\cos^2$ shape for the rest of the pulse. Designers increased the ground receiver band width from 0.35 megahertz (MHz) to 3.5 MHz to pass the higher frequencies of the $\cos/\cos^2$ wave shape transmitted for the airborne interrogator.

To optimize the DME accuracy of the ground transponder, the reply delay is automatically maintained by the system signal generator as a source pulse, thus automatically maintaining system reply delay. In the normal configuration, an identification keyer is provided. The keyer was not utilized during this test.

TECHNICAL APPROACH

To determine the accuracy of an L-Band PDME several tests were conducted. Three primary areas were tested:

1. Static Tests. These tests were conducted utilizing a mobile van with an adjustable antenna mast. The van collected data at specially surveyed test points (TP) to determine accuracy at various antenna heights and distances from the PDME.
2. Stability Tests. To determine the overall accuracy of the PDME system over a period of time, a calculator programmed to take a specified number of samples was used. An error mean and error standard deviation was obtained from the results.
3. Flight Tests. Test flights consisting of orbits, radials, and approaches were made to determine the system accuracies under varying flight conditions. Tracking to obtain absolute accuracy was performed by use of a Sylvania mobile laser tracker.

TEST CONFIGURATION

Van instrumentation (shown in figure 1) was used to collect static data at all TP's (see figure 2). DME information for accuracy was collected at several surveyed TP's located on taxiway "B" parallel to runway 13/31.

The programmed Hewlett Packard 9830 calculator (figure 1) was used to collect samples of size 200 DME range error data at each of nine antenna heights at each test point shown in figure 2. The mean and standard deviation of each sample were then calculated.

Technicians positioned the adjustable antenna tower, mounted on the rear of the test van, over the surveyed test points. The antenna height varied from 45 to 5 feet in 5-foot increments. A calibrated meter with a light-emitting diode (LED) readout attached to the antenna mast measured the exact height above each test point.

The airborne interrogator, a Bendix MLS/DME precision interrogator system, is designed to function as a navigational aid while en route, and to provide precise MLS/DME range upon arrival at the airport. From 0 to 5 nautical miles (nmi), which is the range of the MLS/DME precision mode, system accuracies are specified to be ± 50 feet (2 sigma). Beyond 5 nmi, during normal mode operation, accuracies are ± 0.1 nmi or 0.2 percent of the indicated range.

Because accurate airborne interrogator test equipment was not available, a TS-101C tactical air navigation aid (TACAN) simulator was utilized to operationally check the airborne interrogator.

The video output of the Bendix airborne receiver was monitored visually to note any unusual occurrences during the test, such as susceptibility to multipath and erroneous range indication.

STABILITY TESTS

Tests were made to determine if any significant changes in stability occurred over a period of time that would adversely affect the transmittal of distance information. A block diagram of the test setup utilized is shown in figure 3. A 9830 Hewlett Packard calculator programmed to accept 1,000 samples of DME information during each 2-minute period produced, from the samples, an error mean and error standard deviation.

Using table 1, a series of four tests were made with the three receivers. In the series, technicians adjusted the signal input to the interrogator receiver in upward steps at approximately -45 decibels above 1 milliwatt (dBm), -60 dBm, -65 dBm, and -77 dBm. To reach the desired signal level for each receiver, testers read the automatic gain control (AGC) voltage meter, while adjusting the attenuator, until the desired level was reached, as interpreted from figure 4. The plots shown in figure 4 were obtained by injecting a signal from the TS-101C simulator and recording the corresponding AGC voltage. The plots were utilized in formulating the data shown in table 1.

FLIGHT TESTS

The airborne instrumentation package (figure 5), which consists of a Kennedy 7-track recorder, real-time clock interface, and a Bendix MLS/DME airborne interrogator was installed on a Convair 580 for flight test data collection. The instruments collected data during orbits, approaches, "river runs," and selected radials at the Washington National Airport, Washington, D.C. At the airport, a Sylvania mobile laser tracking system recorded data on the aircraft position to an accuracy of ± 1 foot for 0-5 nmi, ± 2 feet for 5-10 nmi, and ± 5 feet for 10 to 25 nmi.

TABLE 1. INTERROGATOR TESTS

Test	Interrogator Serial No.	Distance to Transponder (ft)	Sample Pilot Readout nmi (ft)	Mean Error (ft)	Standard Deviation (ft)	AGC Volts	Interrogator Input	
							dBm	Mode
1	109	9700	1.60 (9730)	31.96	7.58	1.31	-46	Precision
	104	9700	1.61 (9767)	66.59	11.38	0.38	-45	
	103	9700	1.61 (9761)	62.13	22.66	1.11	-46	
2	109	9700	1.60 (9718)	18.90	15.48	1.85	-62	Precision
	104	9700	1.62 (9791)	88.89	18.33	0.88	-63	
	103	9700	1.59 (9712)	9.57	17.11	1.52	-58	
3	109	9700	1.60 (9721)	20.94	14.60	1.81	-65	Normal
	104	9700	1.61 (9774)	74.25	19.93	1.07	-65	
	103	9700	1.61 (9756)	57.75	19.32	1.71	-68	
4	109	9700	1.60 (9718)	17.86	36.26	2.17	-77	Normal
	104	9700	1.62 (9812)	112.07	40.95	1.36	-76	
	103	9700	1.61 (9791)	90.07	50.13	1.99	-78	

STATIC TEST RESULTS

Static test results include laboratory tests made in building 301 and those made at test points on the airport. Figure 6 shows sample plots of static accuracy data recorded at the surveyed test points TP-90 and TP-108 (shown in figure 2). Based on reflectometer measurements, a total of 186 feet was subtracted from the error data to correct for the 125-foot length of cable between the receiver and the antenna. The results of which show an average mean error of ± 50 feet and a standard error deviation of ± 5 feet for all pole heights and test points.

No range errors due to reflections or other abnormalities were observed during this test. The signal strength ranged from -36 dBm at test point 90 at an antenna height of 15 feet, to a low of -85 dBm at test point 108 with the antenna at 10 feet above the surveyed test point. Figure 7 is a plot of the signal strength versus the pole height of the antenna to the test van antenna, at various heights and at two different test points, TP-90 and TP-116. A signal level of -36 dBm would be representative of the MLS/DME interrogator in the precision mode.

Three interrogator receivers were tested to determine if significant changes in the system accuracy occurred between them. A change of ± 50 feet is considered significant. Table 1 is a comparison of the readouts a pilot would see and the calculated error means and standard deviations. The data in the table shows that a variation of 79 feet in mean error of system accuracy did occur between different interrogators while in the precision mode, and 95 feet in the normal mode. This variation was obtained by subtracting the high mean error and low mean error in both the precision and normal modes. Receiver sensitivity in the MLS precision and

normal modes is -60 dBm and -80 dBm, respectively.

FLIGHT TEST RESULTS

Test results for each type flight are tabulated in table 2. Where appropriate, path following range error statistics are calculated for both 0 to 5 and 5 to 10 nmi for each flight type. In addition, summary range error standard deviation is calculated for each flight type. No determination could be made as to the cause of shifts in bias from approximately 200 feet on March 28, 1979, to approximately 10 feet on July 9, 1979. Although there were variations in bias, the overall system accuracy of the collected DME data, with all bias removed, was as shown in table 3. The error values were calculated by using all data of each type of flight. Bendix engineers investigated the significant decrease in error means in the July data, but could not find the cause. Manufacturer's equipment specifications set processing accuracy of ± 35 feet bias (-10 to -50 dBm) and ± 30 feet for noise (standard deviation). The length of cable in the aircraft was not deducted from the calculations.

Figure 8 shows sample plots of data collected during the Washington National Airport test flights. Scatter plots, figure 9, show individual point plots of filtered data with bias removed (zero means) of all runs of each type flight.

To determine system accuracy, MLS/DME precision equipment design required that data be separated into two bins; 0 to 5 nmi and 5 to 10 nmi. The first bin contains precision mode data, while the second bin contains nonprecision mode data. Histogram plots required bin data to be grouped. In this instance, 0.5 nmi increments were selected. Plotted by flight type and bin range, histograms of figure 10 show error distribution with zero means. The summary standard

TABLE 2. FLIGHT TEST DATA TABULATION OF RANGE ERROR

Type of Flight	Flight Date	0 - 5 nmi			5 - 10 nmi		
		Mean $\bar{X}$	Standard Deviation	No. of Data Pt. n	Mean $\bar{X}$	Standard Deviation	No. of Data Pt. n
Approaches	3/28/79	189.595	6.686	278	258.925	68.285	123
	3/28/79	186.987	6.742	275	219.906	39.754	200
	3/28/79	191.361	14.438	470	201.825	79.193	172
	4/30/79	295.853	12.485	441	277.529	62.895	373
	4/30/79	289.325	19.746	282	261.340	101.883	466
	7/9/79	15.516	8.972	982	9.060	16.503	512
	7/9/79	10.385	5.349	157	15.571	14.072	104
Orbits	5/1/79	--	--	--	316.406	36.103	479
	5/1/79	--	--	--	148.310	16.015	449
	7/3/79	--	--	--	40.211	49.068	137
	10/25/79	--	--	--	57.905	49.612	1248
Radials	3/28/79	173.332	2.762	134	182.104	19.580	94
	4/30/79	276.710	7.832	69	278.803	9.729	197
	4/30/79	270.639	2.510	82	264.119	19.047	135
	7/3/79	128.322	2.501	41	133.456	9.041	165
	7/3/79	129.384	4.551	200	132.526	17.234	560
River Runs	3/28/79	186.089	4.395	483	200.888	40.919	325
	4/30/79	293.577	6.098	258	285.399	11.301	278
	7/3/79	61.239	1.520	73	53.008	11.439	121
	7/9/79	21.551	8.902	193	-4.398	25.269	68
	7/10/79	73.297	8.978	1110	55.839	43.979	205
All Approaches	--	--	9.129	2885	--	42.649	1950
All Orbits	--	--	--	--	--	41.714	2313
All Radials	--	--	2.935	526	--	12.031	1151
All River Runs	--	--	3.776	2117	--	18.255	997

TABLE 3. FLIGHT TEST DATA SUMMARY

<u>Type of Flight</u>	Range Error	Range Error
	Std Deviation (ft) <u>0 to 5 nmi</u>	Std Deviation (ft) <u>5 to 10 nmi</u>
Approaches	±9	±42
Orbits	No Data	±42
Radials	±3	±12
River Runs	±4	±18

deviations of table 2 relate to these plots. These are normal distributions. Identification keyer effect was not determined on DME transponder accuracy.

STABILITY TEST RESULTS

The data shown in figure 11 were calculated from data collected in the MLS laboratory in building 301. The 9830 Hewlett Packard calculator was programmed to accept 1,000 samples of DME information each 2-minute period for approximately 20 hours, and then produced a mean and standard deviation. Five of the means were averaged to produce a mean of the differences and a standard deviation. The plot shown in figure 12 is a result of these calculations. The results show a high degree of stability over the test period. The standard deviation of the group was 27.47 feet. No erroneous distance measurements were recorded due to reflections or any other abnormalities during the test.

CONCLUSIONS

Based on these tests, it was concluded that:

1. The data collected during static and flight tests provided an adequate data base for measuring system accuracy.

2. Static test measurements of mean error for the system exceeded 100 feet with a 1-sigma standard deviation of as much as ±50 feet.

3. The flight test data showed mean errors from 10 feet to more than 200 feet, with standard deviation of as much as 20 feet. However, if mean errors were removed, the standard deviation for one sigma error, 0 to 5 nmi, would be ±3 feet during radials and ±9 feet during approaches.

4. The static data showed variations of as much as 79 feet when the airborne interrogator was in the precision mode.

RECOMMENDATIONS

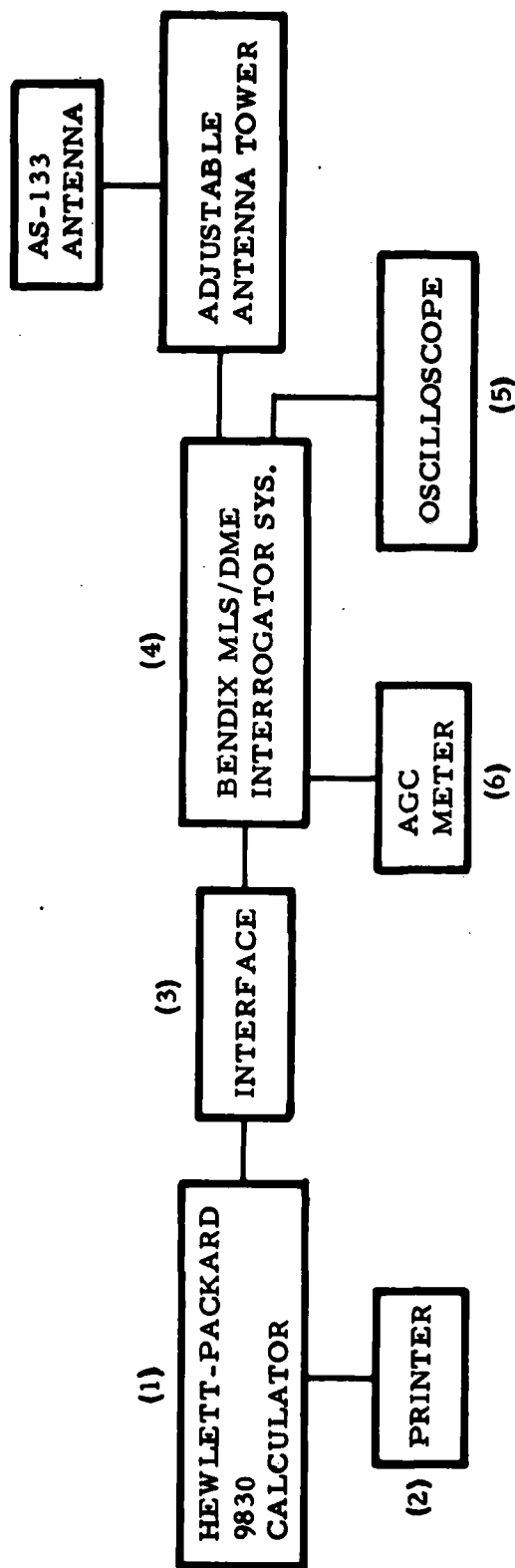
1. Further testing be conducted to determine the effects on system accuracy during ident times.

2. Testing be continued to determine the reasons for shifts in bias.

3. Action be initiated to obtain or modify existing simulators to perform as a test set for Precision Distance Measuring Equipment (PDME).

This project was accomplished under Technical Program Document (TPD) 04-309,

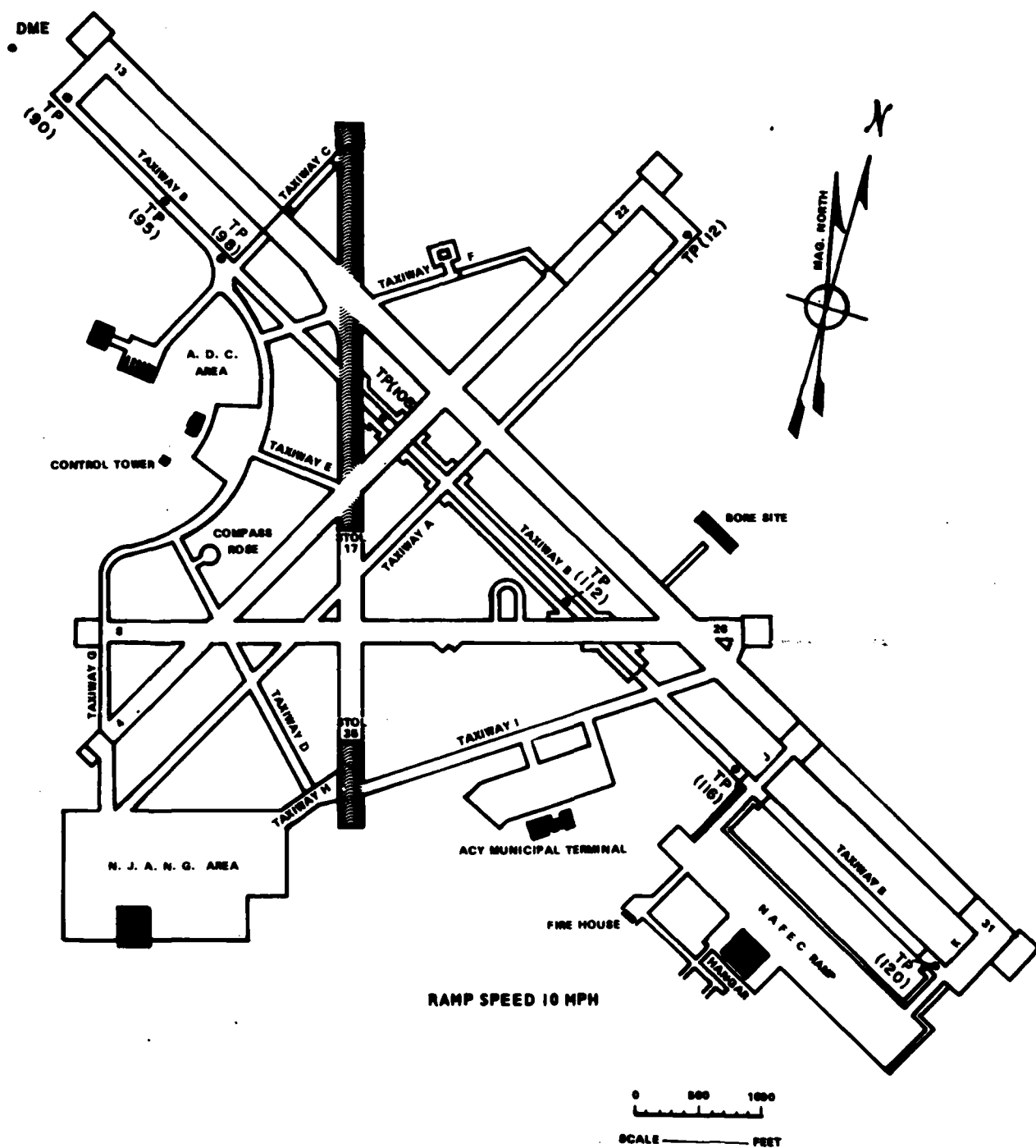
subprogram 075-725-810. For further information, contact Harold Postel, ACT-100B.1, or Edward M. Sawtelle, Federal Aviation Administration (FAA) Technical Center Program Manager, ACT-100B.1, telephone FTS 8-346-3913, commercial (609) 641-8200, extension 3913.



1. HEWLETT-PACKARD 9830 CALCULATOR
2. HEWLETT-PACKARD 9866 PRINTER
3. LABORATORY INTERFACE
4. MLS/DME PRECISION INTERROGATOR SYSTEM
5. HEWLETT-PACKARD 1741 OSCILLOSCOPE
6. HEWLETT-PACKARD 5328 COUNTER

80-25-1

FIGURE 1. TEST VAN INSTRUMENTATION

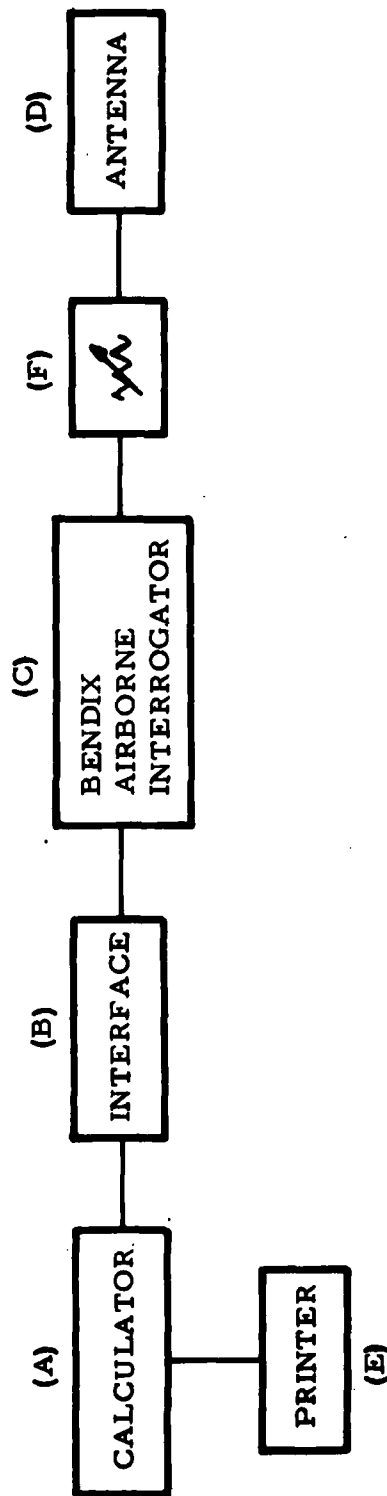


NAFEC/ATLANTIC CITY AIRPORT, ATLANTIC CITY, NEW JERSEY

NA FORM 5320-1 (6-69)

80-25-2

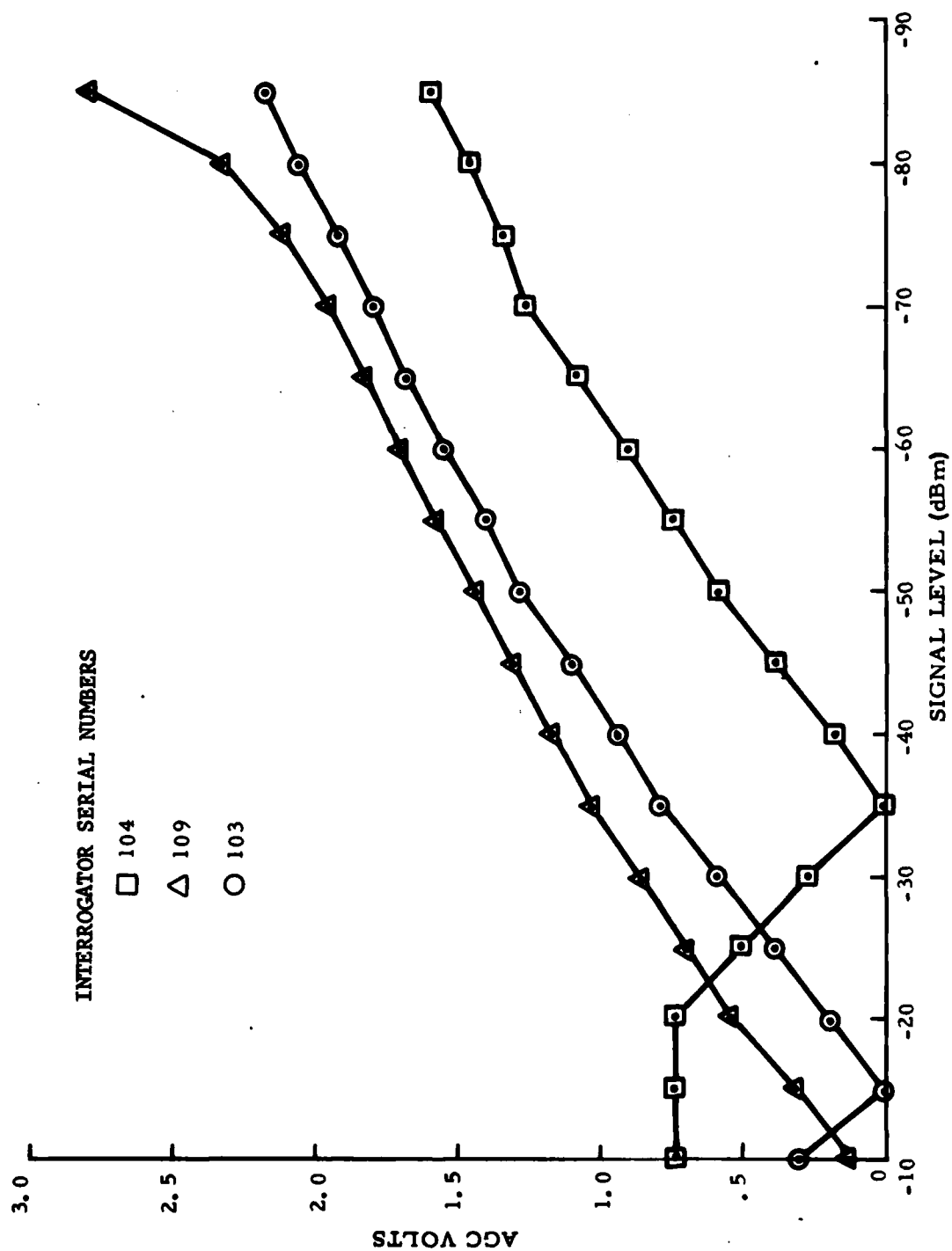
FIGURE 2. TAXIWAY TEST POINTS



- A. HEWLETT-PACKARD 9830 DESKTOP COMPUTER
- B. LOCALLY FABRICATED INTERFACE ANALOG TO DIGITAL CONVERSION
- C. MLS/DME PRECISION SYSTEM, 2041118-1101
- D. HORN ANTENNA L-BAND
- E. HEWLETT-PACKARD THERMAL PRINTER
- F. VARIABLE ATTENUATOR

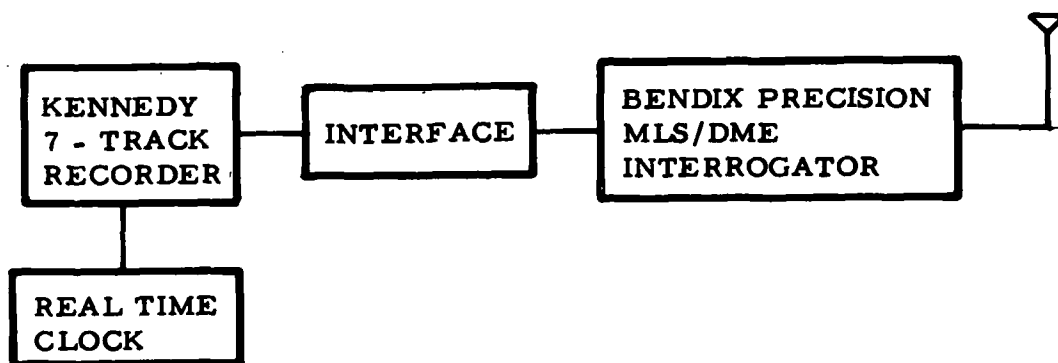
80-25-4

FIGURE 3. STABILITY TEST INSTRUMENTATION



80-25-3

FIGURE 4. SIGNAL LEVEL VERSUS AGC VOLTAGE



80-25-7

FIGURE 5. AIRBORNE INSTRUMENTATION PACKAGE

MLS PRECISION L-BAND DME (AEROCOM)

SURVEY POINT# 108
 X = 4681.745 Y = -293.161
 BENDIX INTERROGATOR S/N 114
 DATE 7-17-78
 Z = -19.658

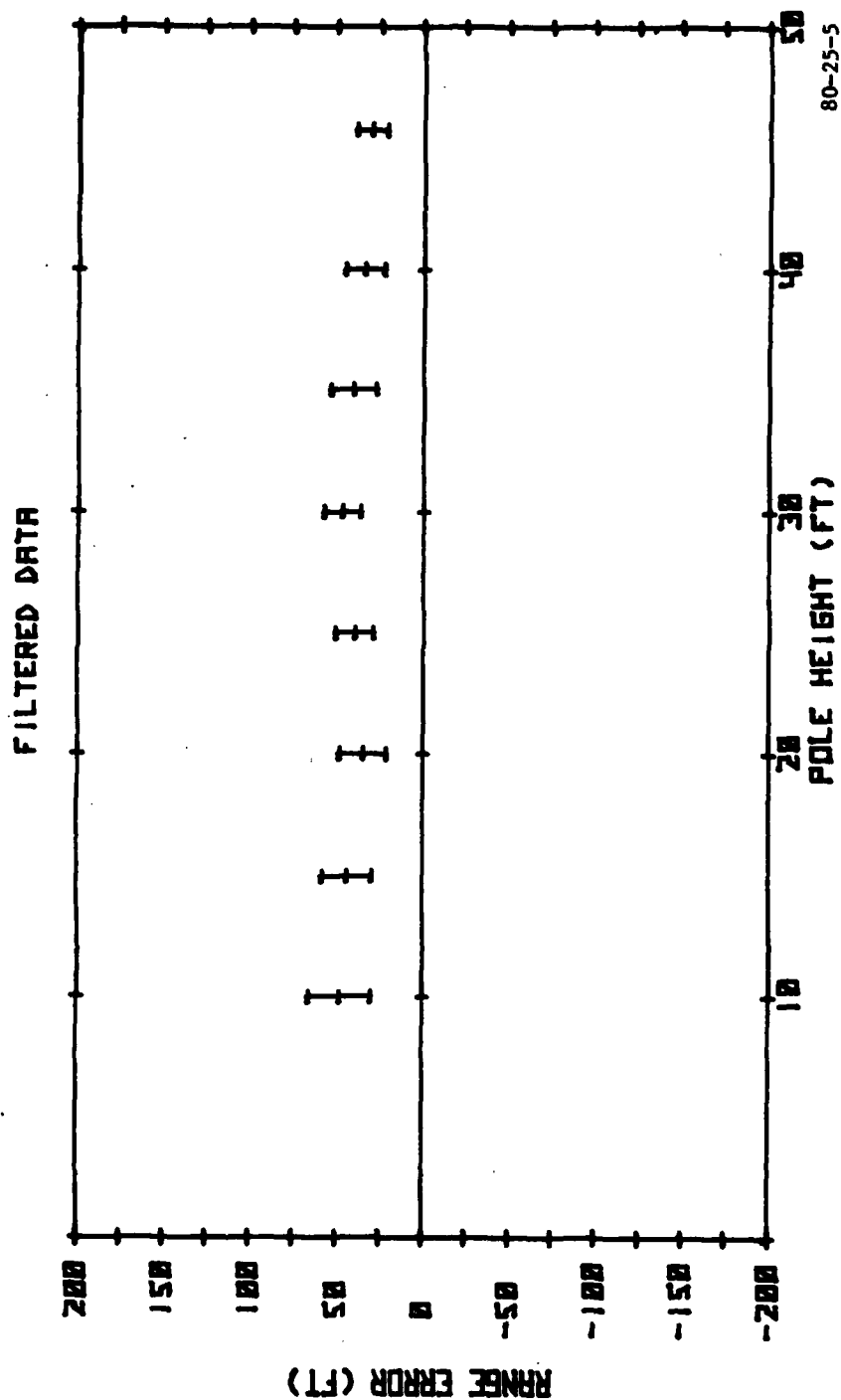


FIGURE 6. VAN DATA PLOTS (SHEET 1 OF 2)

MLS PRECISION L-BAND DME (AEROCOM)

SURVEY POINT# 90 DATE 7-12-78
 X= 1001.745 Y= -293.161
 BENDIX INTERROGATOR S/N 114

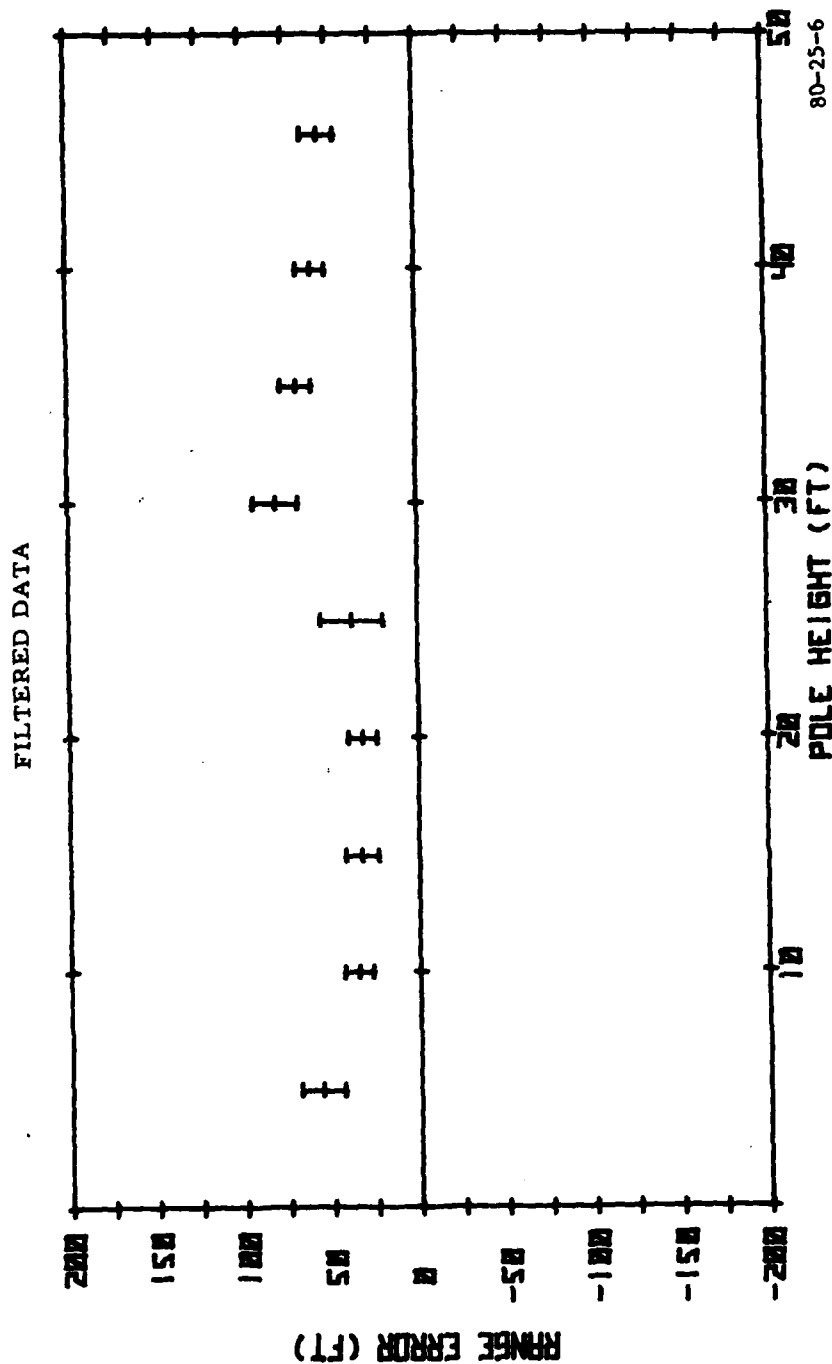
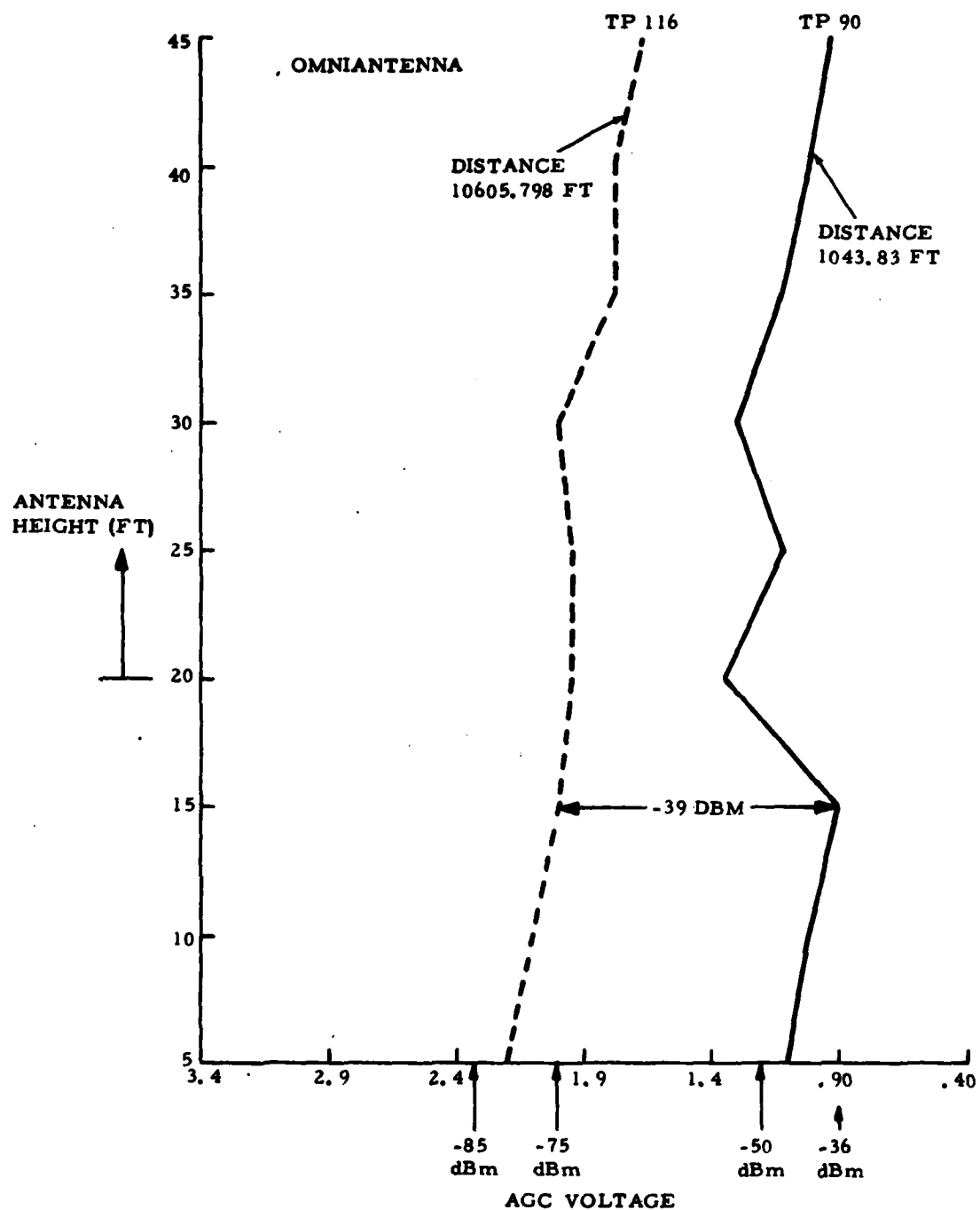


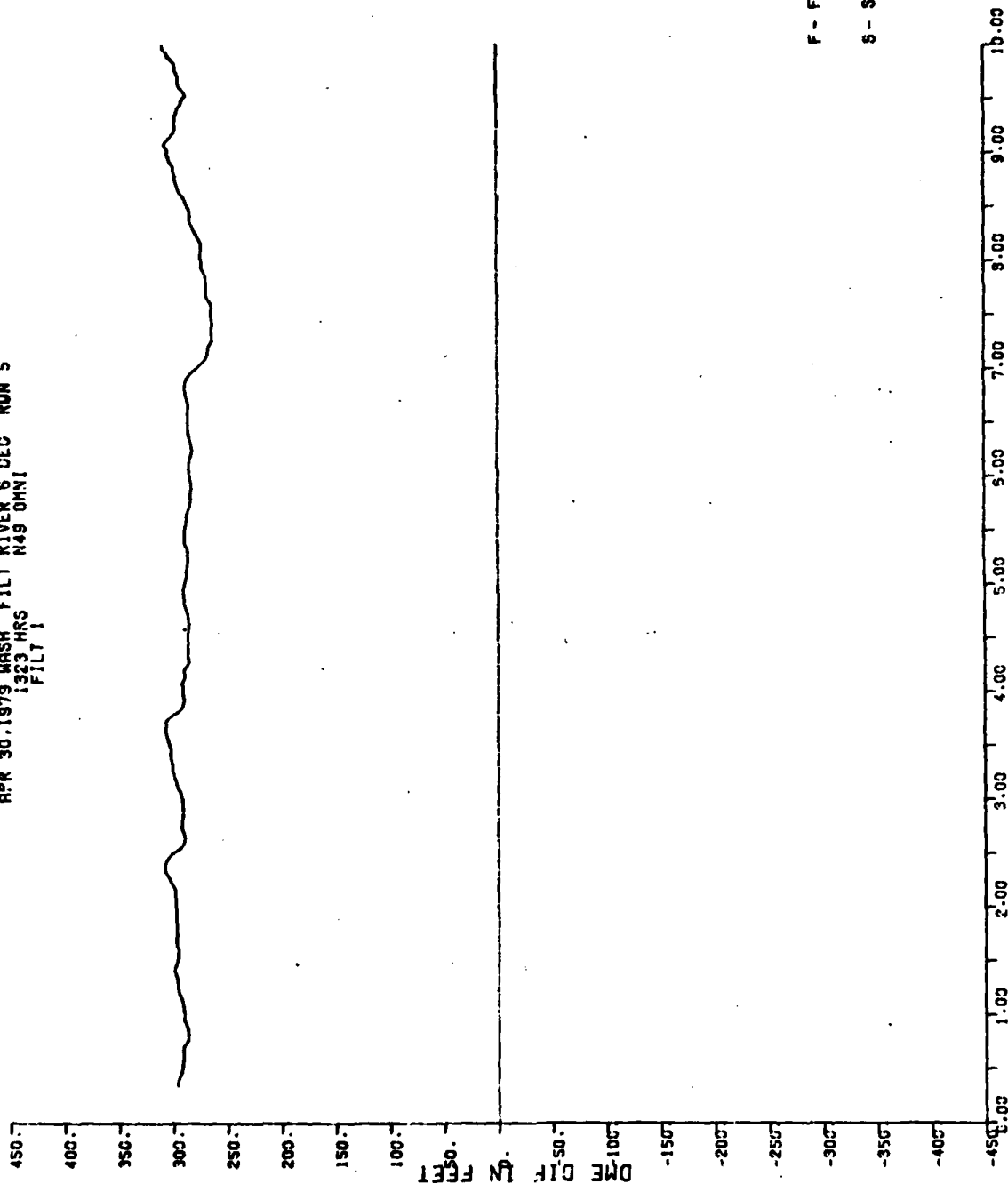
FIGURE 6. VAN DATA PLOTS (SHEET 2 OF 2)



80-25-8

FIGURE 7. PLOT OF ANTENNA HEIGHT VERSUS SIGNAL STRENGTH, BENDIX INTERROGATOR SN-104

APR 30.1979 WASH FILT RIVER 6 DEC RUN 5
 1923 HRS N49 OMNI
 FILT 1

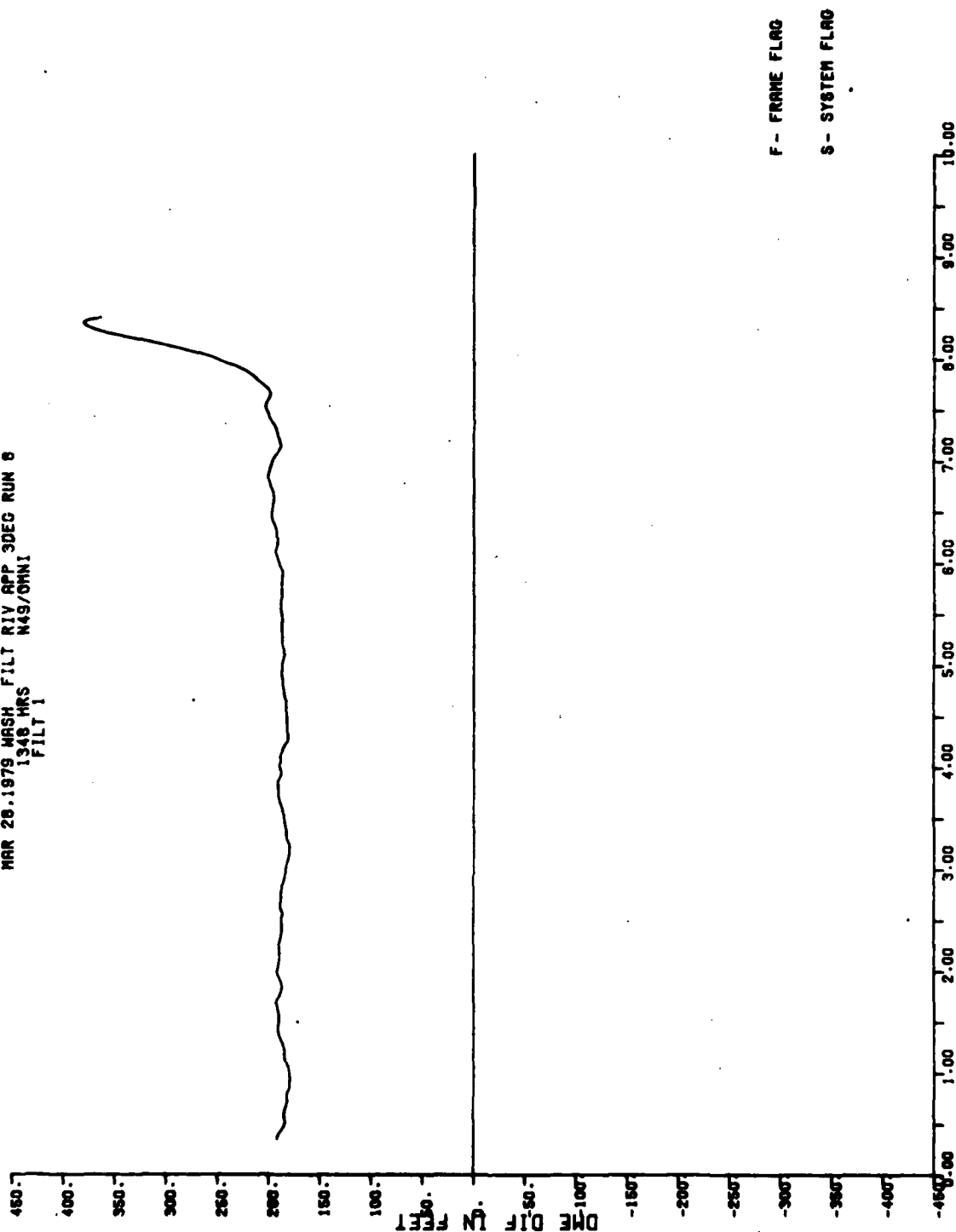


NM FROM AZ PHASE CENTER

FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 1 OF 4)

80-25-9

MAR 28.1979 WASH FILT RIV APP 3DEC RUN 8
 1348 HRS N49/OMNI
 FILT 1

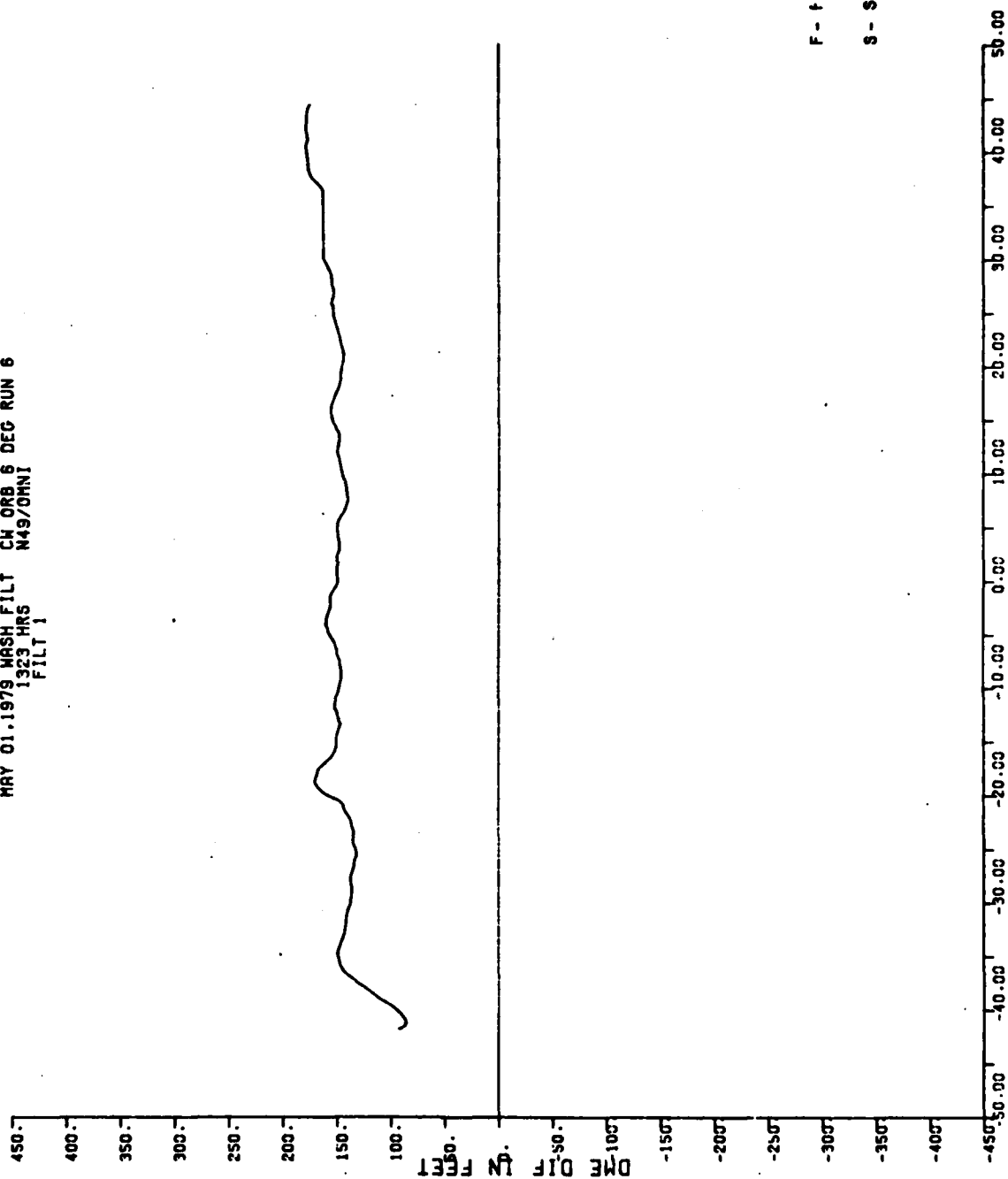


NM FROM AZ PHASE CENTER

80-25-10

FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 2 OF 4)

MAY 01.1979 WASH FILT CW ORB 6 DEG RUN 6
 1323 HRS N49/0HNI
 FILT 1



F - FRAME FLAG

S - SYSTEM FLAG

AZ TRACKER IN DEGREES
 FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 3 OF 4)

80-25-11

JUL 09, 1979 WASH. FILT 30R APP 3 DC RUN 3
 1342 HRS N49/00N1
 FILT 1

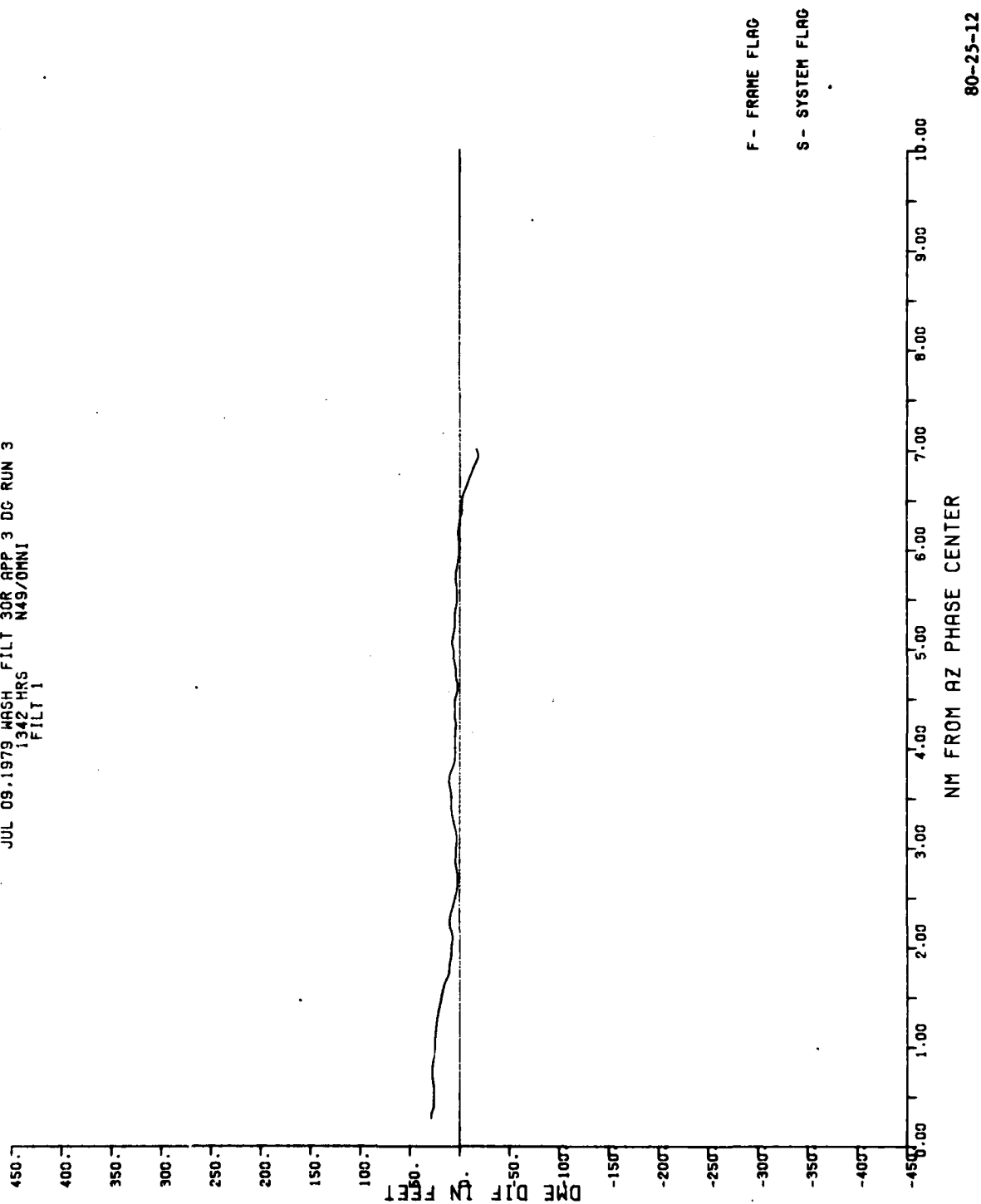


FIGURE 8. PLOTS OF FLIGHT DATA (SHEET 4 OF 4)

WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - APPROACH RUNS
 RANGE BIN - (0.0 - 5.0)

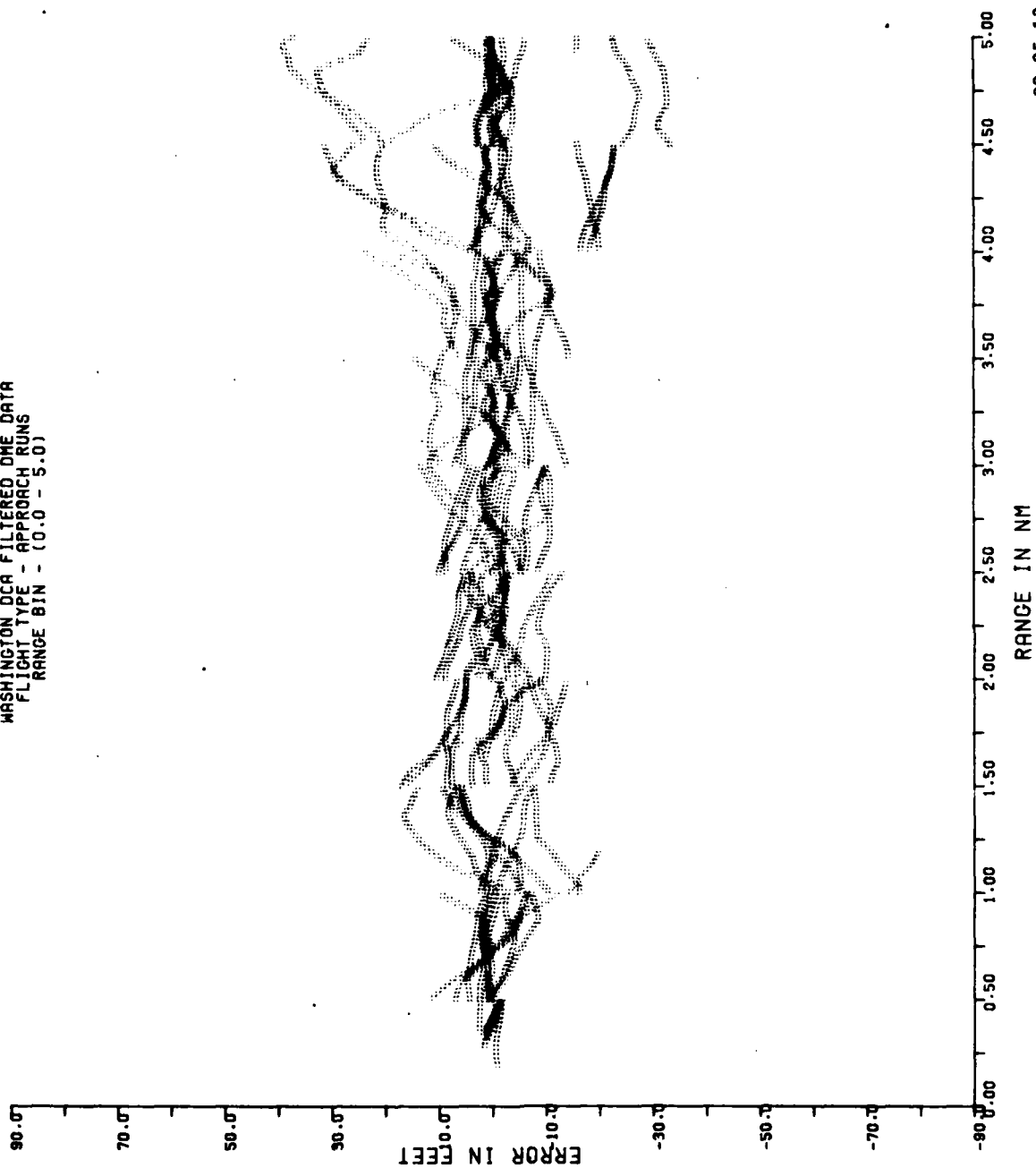


FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 1 OF 6)

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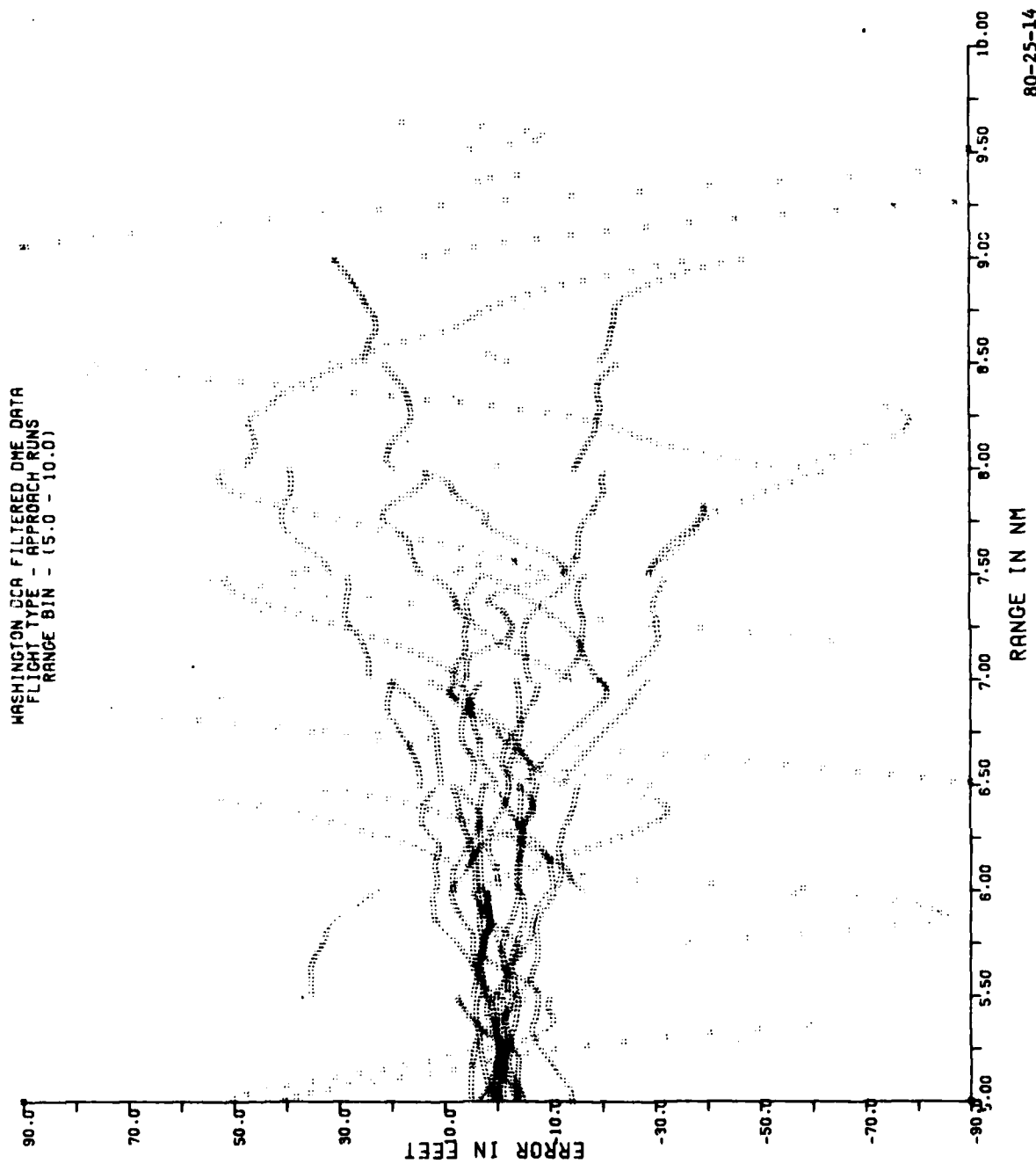
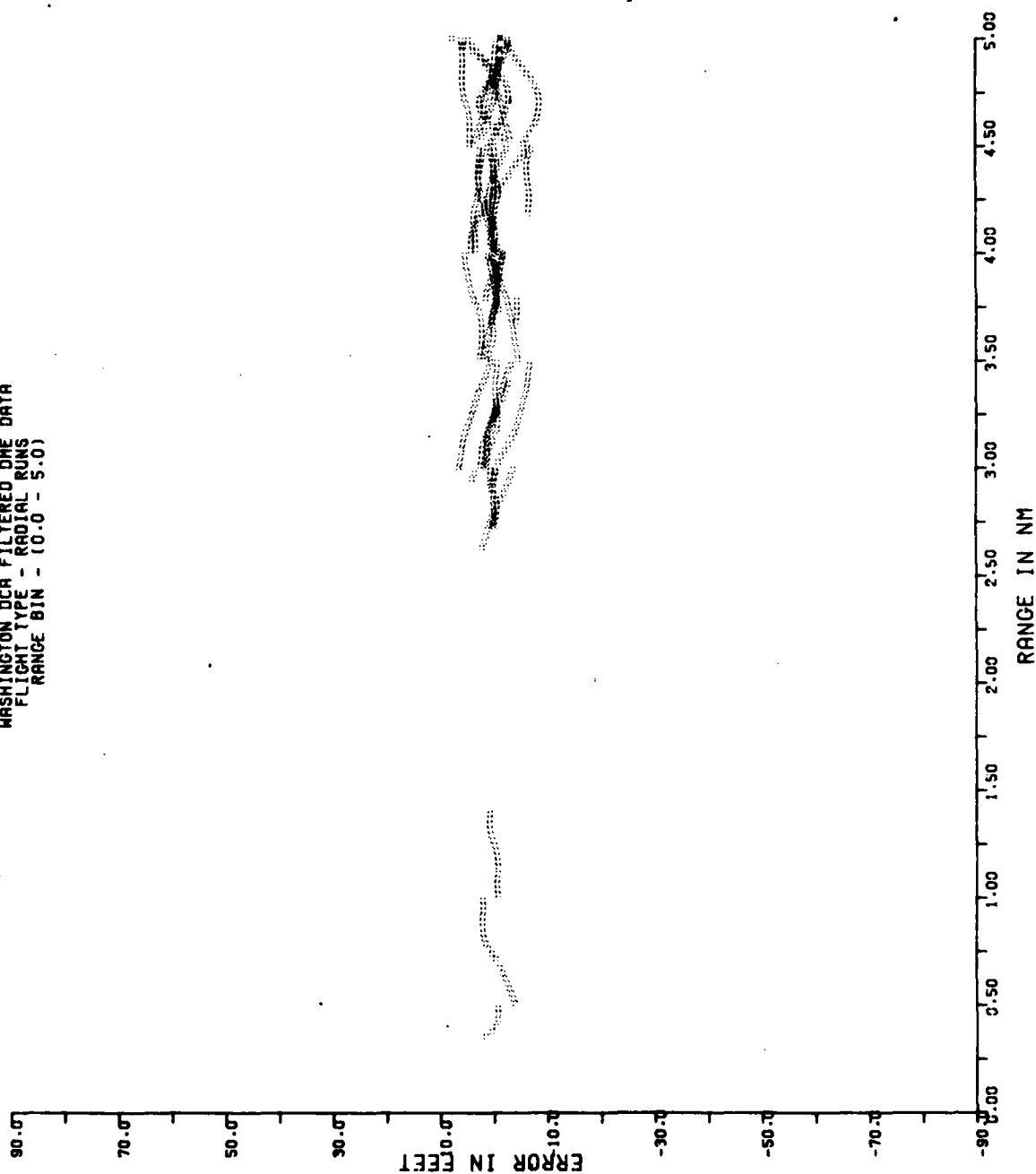


FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 2 OF 6)

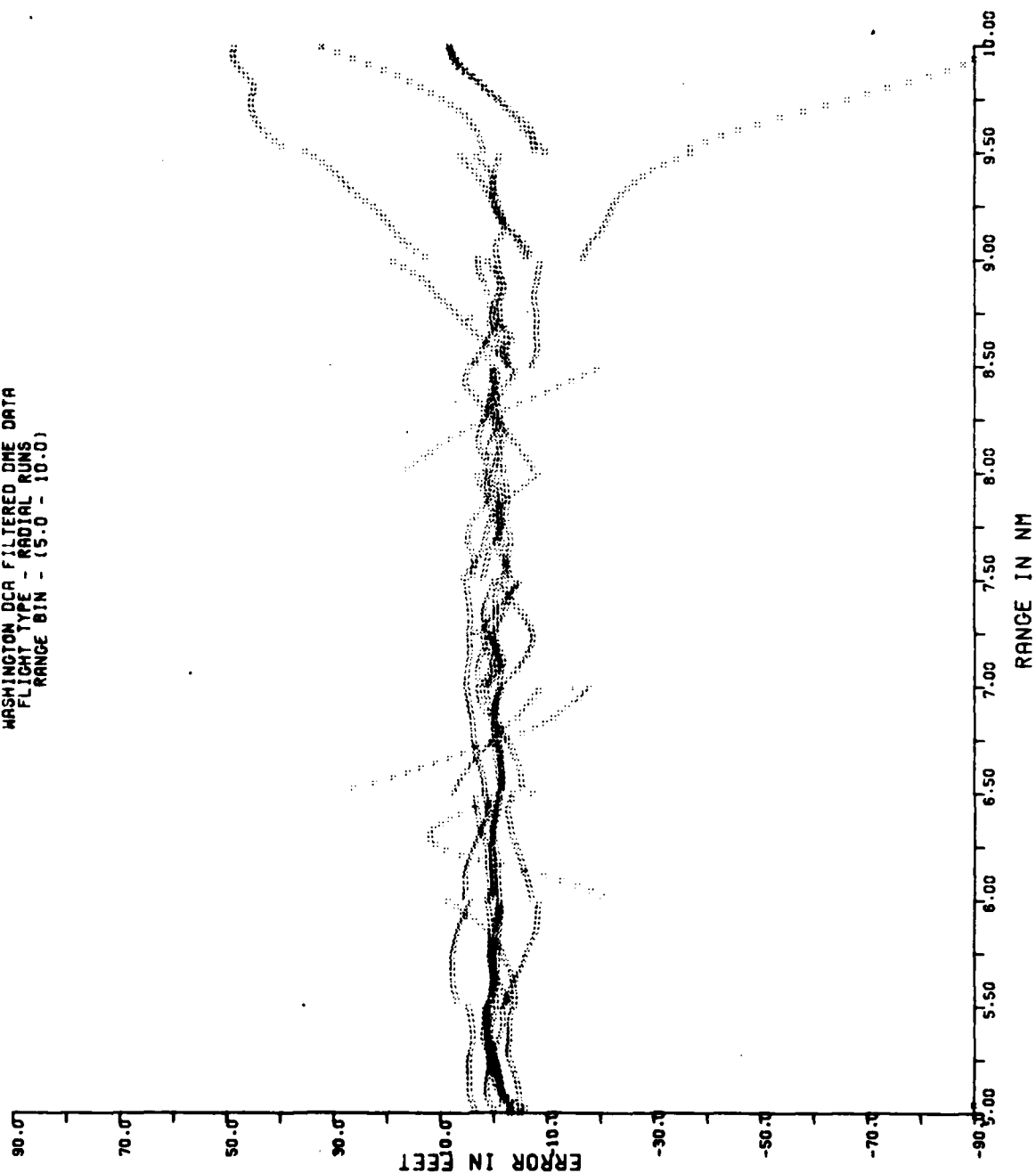
WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - RADIAL RUNS
 RANGE BIN - (0.0 - 5.0)



80-25-15

FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 3 OF 6)

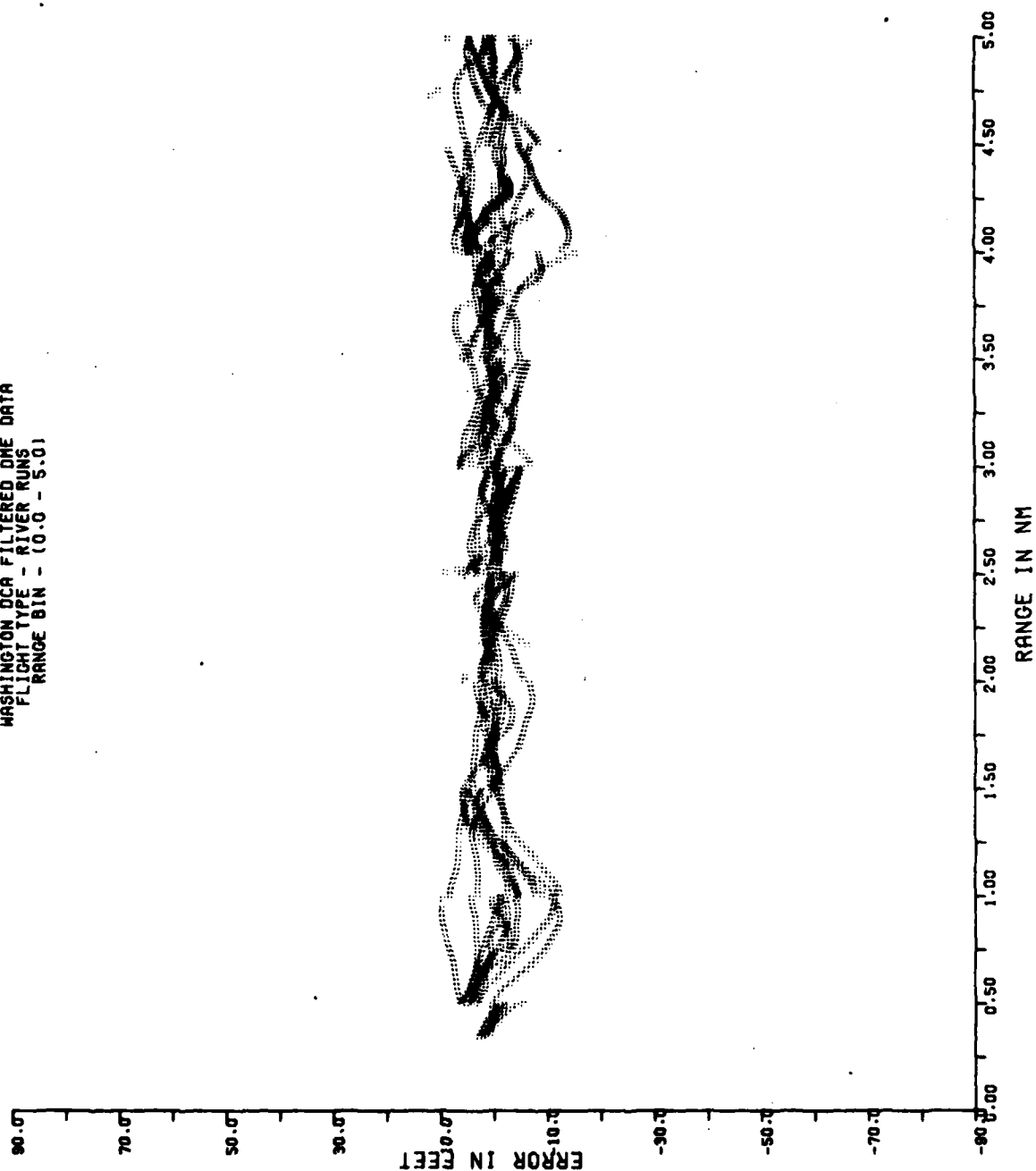
WASHINGTON DCA FILTERED DME DATA
 FLICAT TYPE - RADIAL RUNS
 RANGE BIN - (5.0 - 10.0)



80-25-16

FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 4 OF 6)

WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - RIVER RUNS
 RANGE BIN - (0.0 - 5.0)



80-25-17

FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 5 OF 6)

WASHINGTON DCA FILTERED DME DATA
FLIGHT TYPE - RIVER RUNS
RANGE BIN - (5.0 - 10.0)

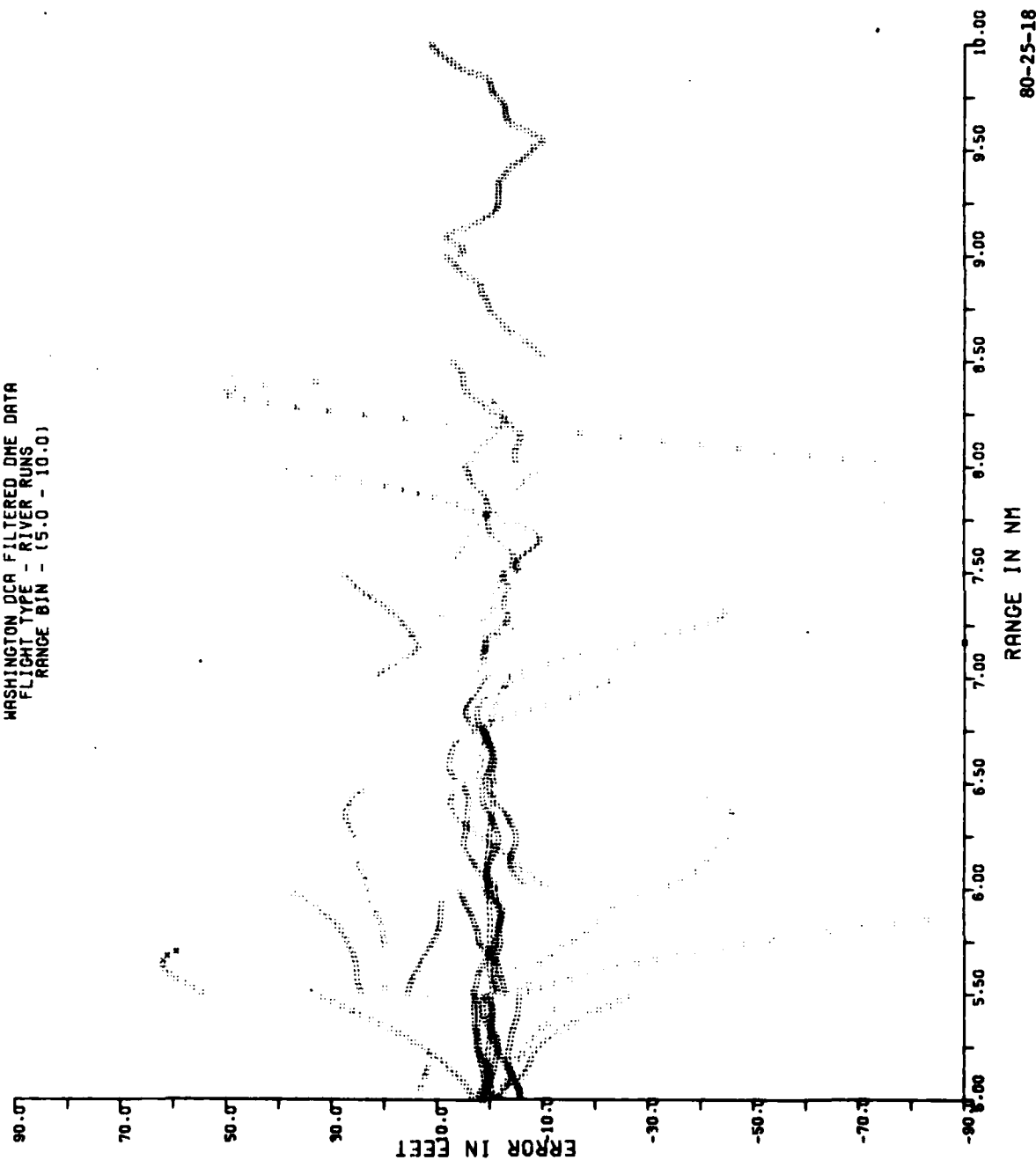
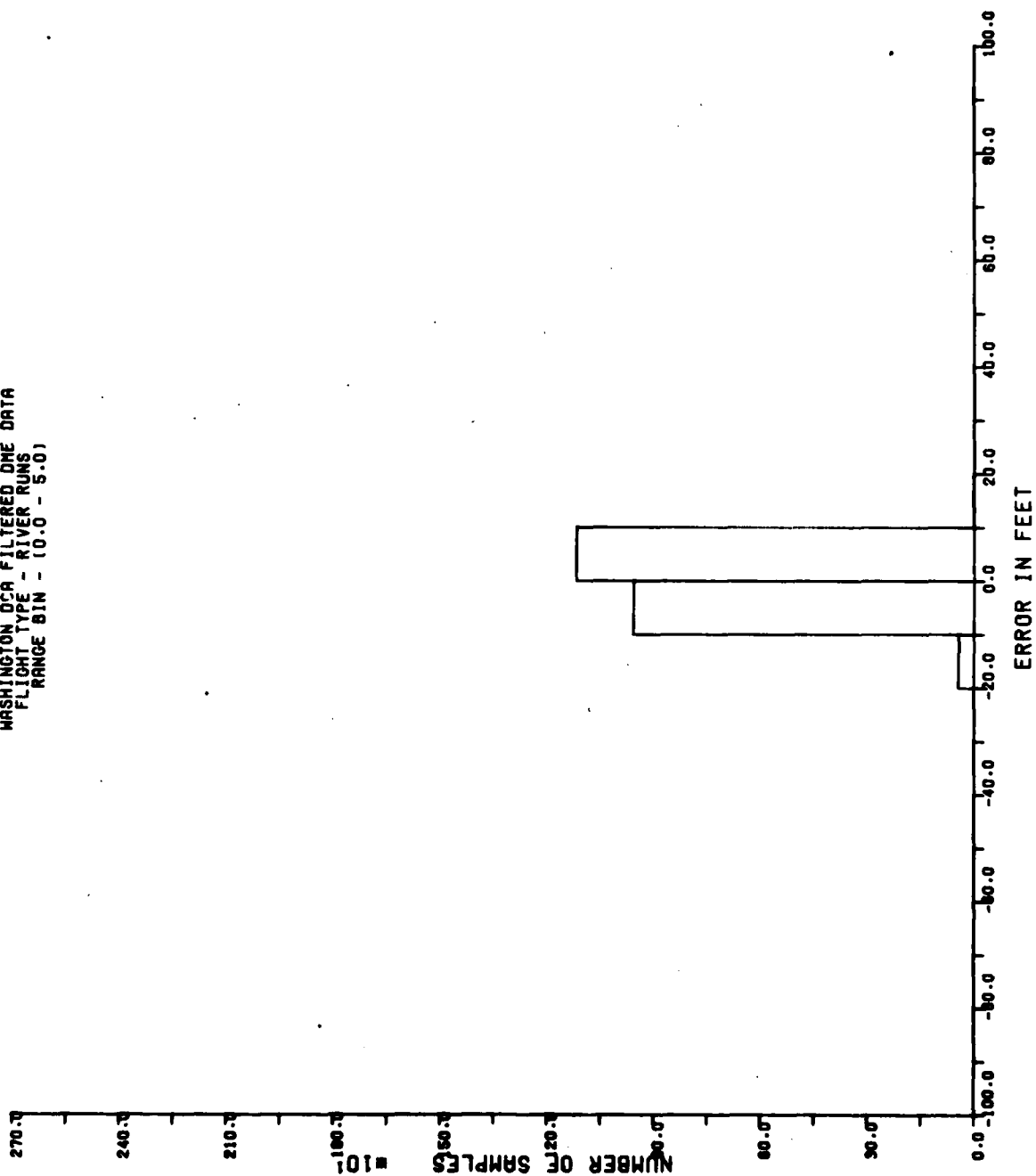


FIGURE 9. PLOTS OF FLIGHT SCATTER DATA (SHEET 6 OF 6)

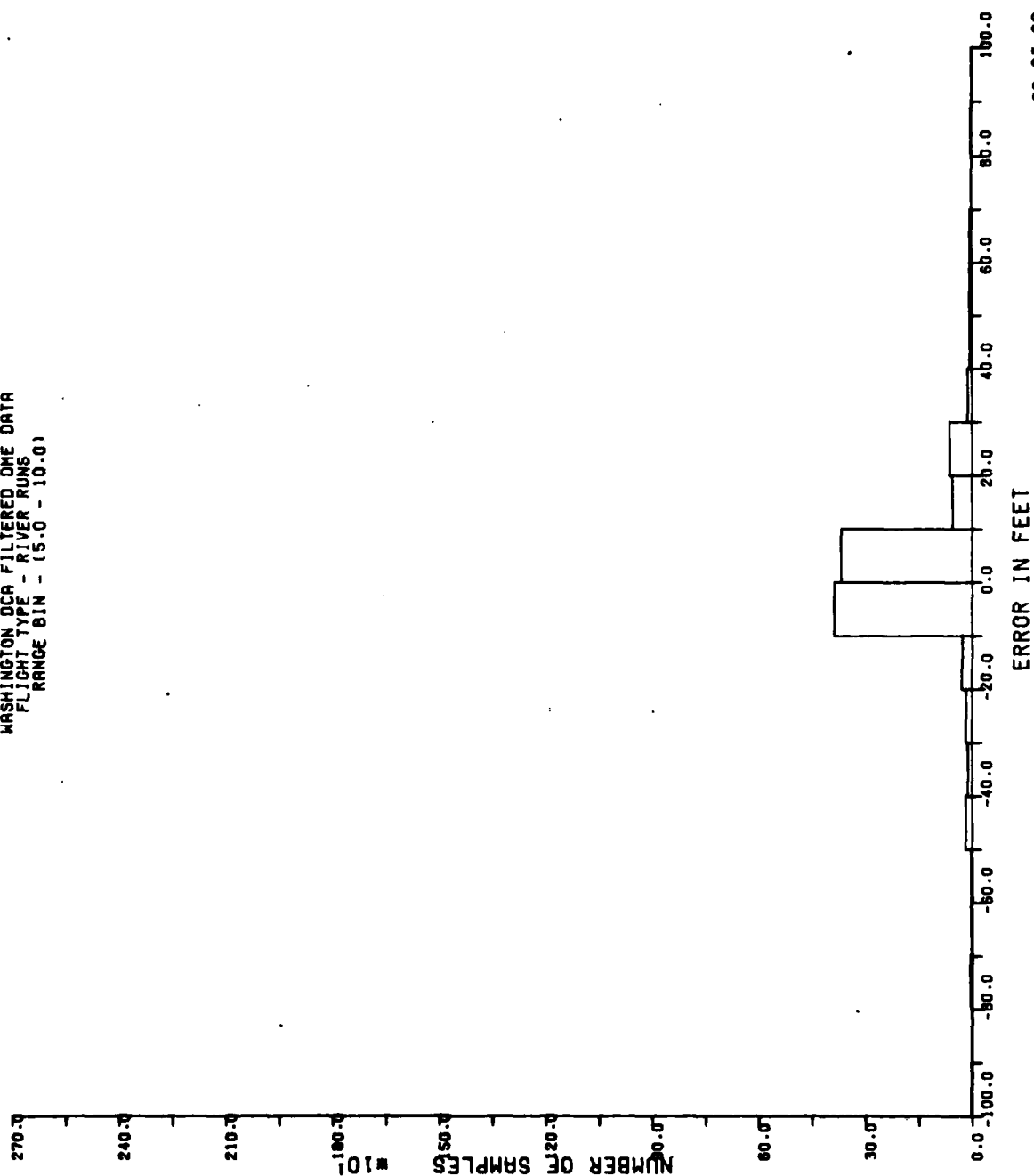
WASHINGTON DCA FILTERED ONE DATA
 FLIGHT TYPE - RIVER RUNS
 RANGE BIN - (0.0 - 5.0)



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FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 1 OF 7)

WASHINGTON OCA FILTERED DME DATA
 FLIGHT TYPE - RIVER RUNS
 RANGE BIN - (5.0 - 10.0)



80-25-20

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 2 OF 7)

WASHINGTON DCA FILTERED ONE DATA
 FLIGHT TYPE - RADIAL RUNS
 RANGE BIN - (5.0 - 10.0)

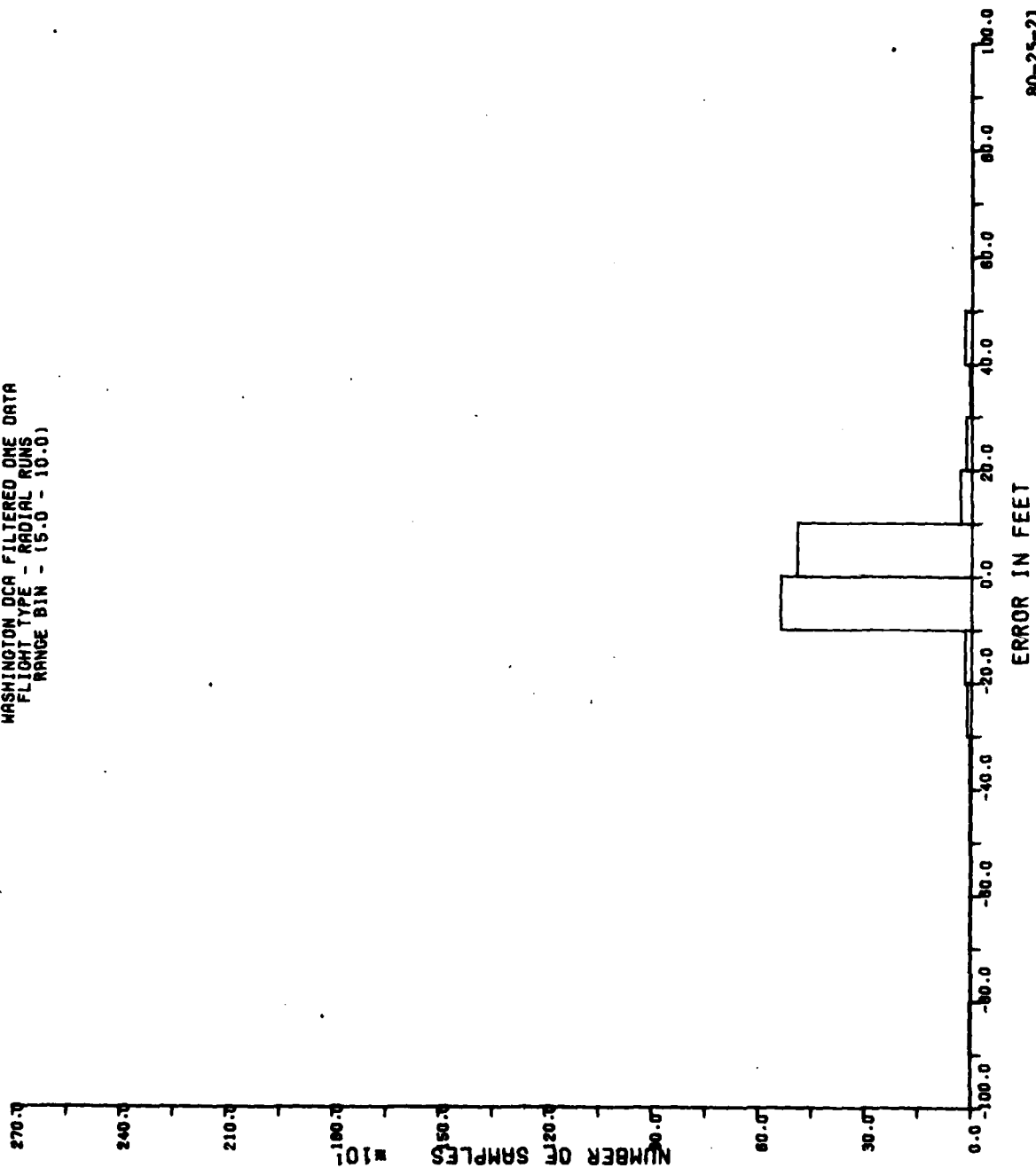
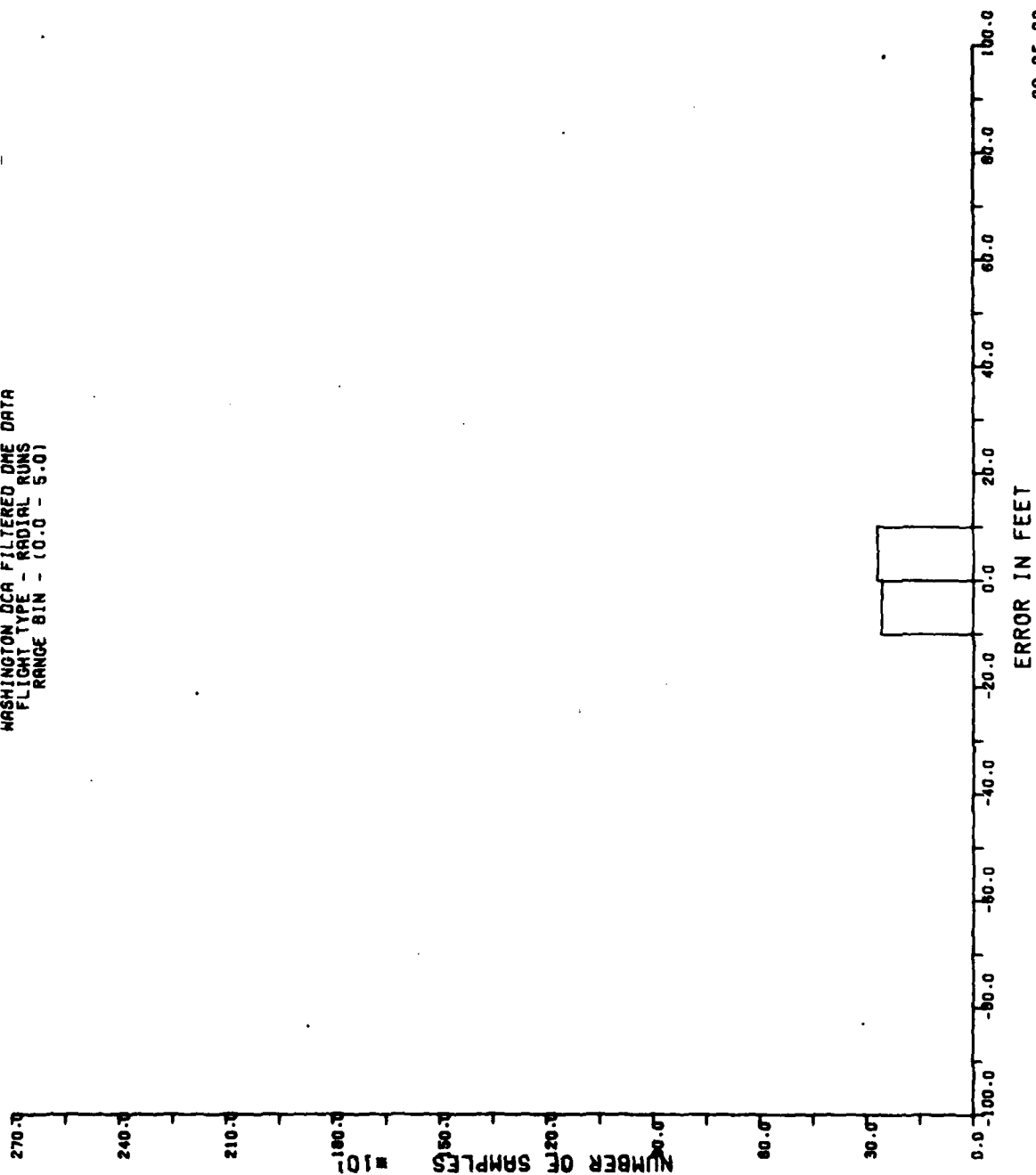


FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 3 OF 7)

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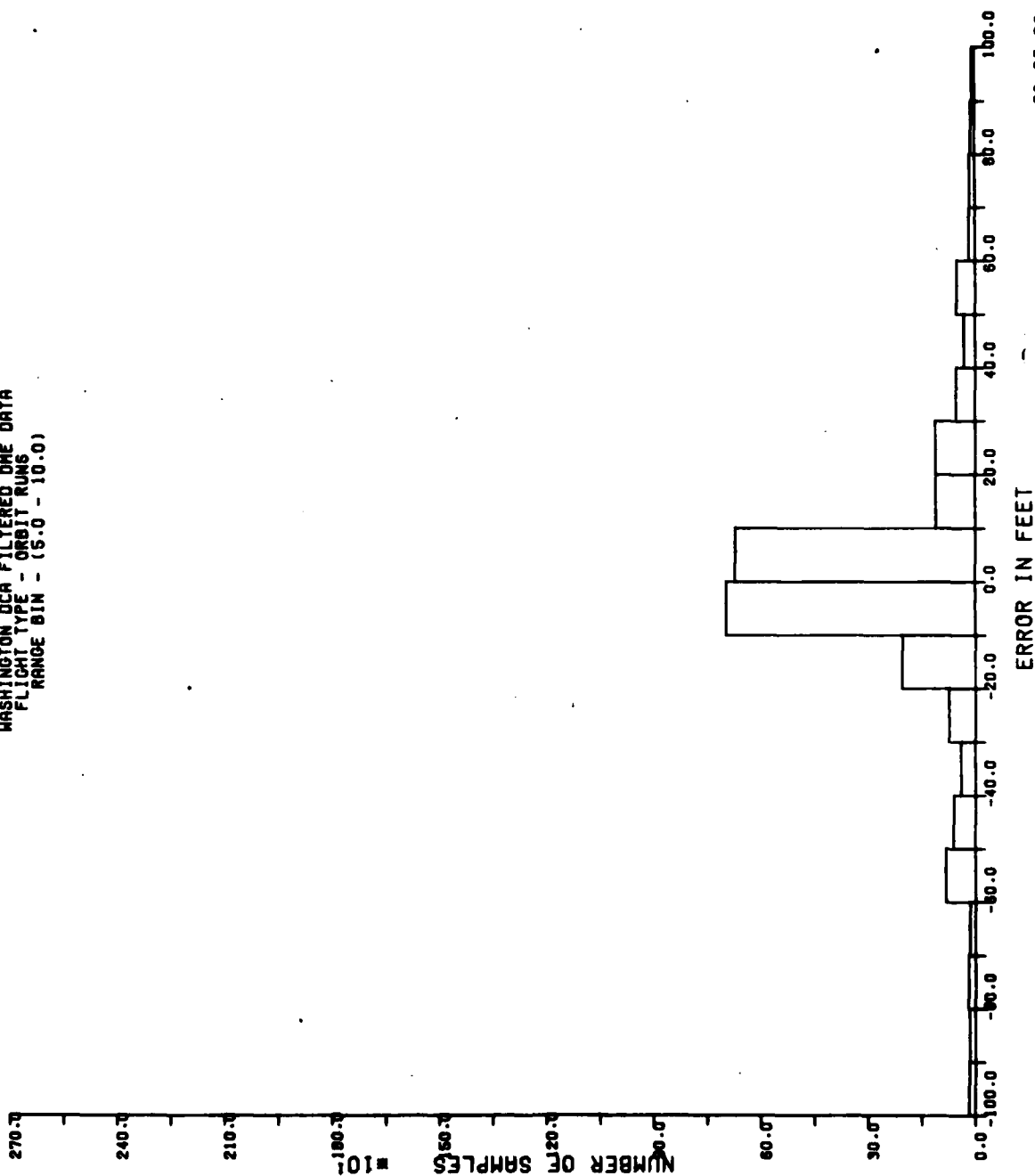
WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - RADIAL RUNS
 RANGE BIN - (0.0 - 5.0)



80-25-22

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 4 OF 7)

WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - ORBIT RUNS
 RANGE BIN - (5.0 - 10.0)



80-25-23

FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 5 OF 7)

WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - APPROACH RUNS
 RANGE BIN - (0.0 - 5.0)

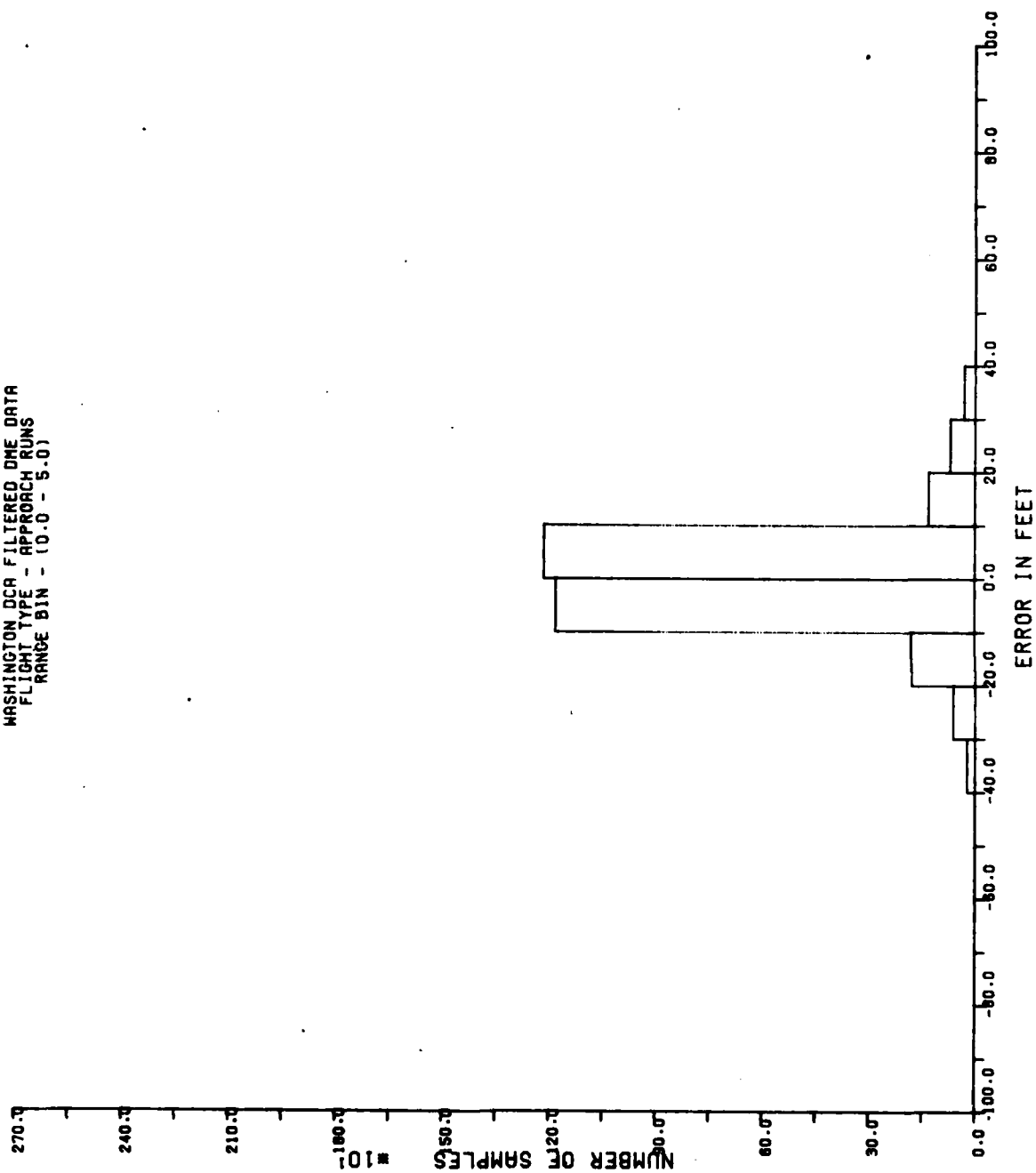


FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 6 OF 7)

80-25-24

WASHINGTON DCA FILTERED DME DATA
 FLIGHT TYPE - APPROACH RUNS
 RANGE BIN - (5.0 - 10.0)

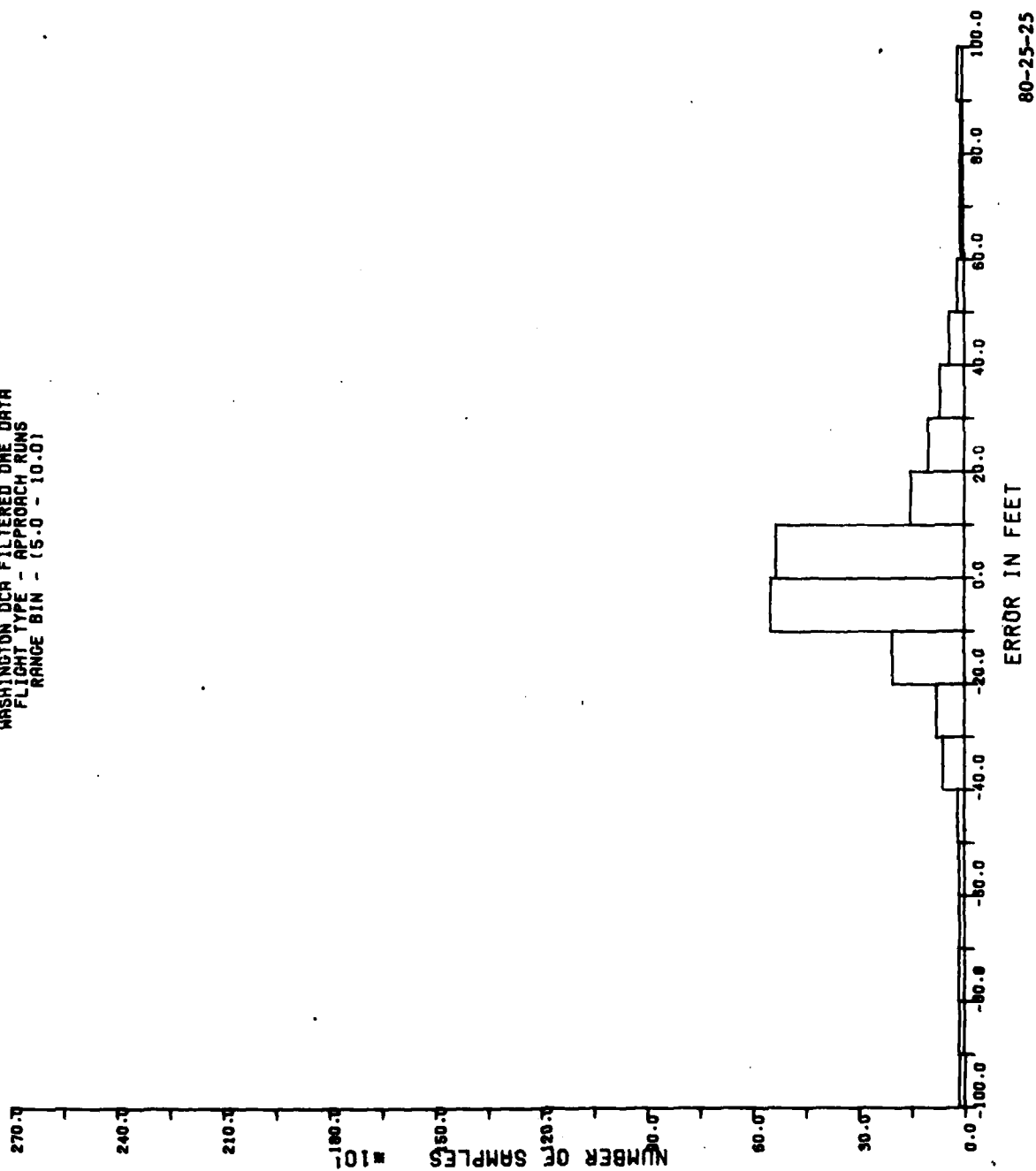


FIGURE 10. HISTOGRAM OF FLIGHTS (SHEET 7 OF 7)

PRECISION DME STABILITY TEST
 DATE OF TEST 11/15/78
 TYPE - AEROCOM
 RANGE - 9559.823700

		MEAN OF DIFF	STAND DEU
SAMPLE	1	501.20627730	27.92836452
SAMPLE	2	494.60206840	24.85668795
SAMPLE	3	495.14230240	23.19867858
SAMPLE	4	506.99103020	23.89018329
SAMPLE	5	512.02309740	24.92077967
SAMPLE	6	505.49779900	25.24851504
SAMPLE	7	503.18511200	26.29222476
SAMPLE	8	506.58433710	24.74976879
SAMPLE	9	513.35243730	24.42382688
SAMPLE	10	517.19477570	24.57177260
SAMPLE	11	517.33439600	24.45273650
SAMPLE	12	487.70549730	22.30204055
SAMPLE	13	488.50135400	21.95294419
SAMPLE	14	508.87681410	24.46335831
SAMPLE	15	507.37344300	24.77697925
SAMPLE	16	508.28394970	24.59330076
SAMPLE	17	515.30092170	24.69526240
SAMPLE	18	520.12053740	25.24528277
SAMPLE	19	519.37332190	25.26297976
SAMPLE	20	517.58932860	25.78321388
SAMPLE	21	509.86023150	24.67546919
SAMPLE	22	514.97313930	24.97225600
SAMPLE	23	512.71500250	24.86640650
SAMPLE	24	511.73173530	26.50628594
SAMPLE	25	512.52084110	24.78753633
SAMPLE	26	512.02916750	26.84336095
SAMPLE	27	513.12177560	25.63448206
SAMPLE	28	510.20208390	26.98326100
SAMPLE	29	511.93204670	23.92634901

80-25-26

FIGURE 11. SAMPLE DATA OF DME STABILITY TESTS (SHEET 1 OF 3)

SAMPLE	30	512.34480980	24.58438920
SAMPLE	31	513.12784560	24.34384536
SAMPLE	32	515.08953950	27.12437281
SAMPLE	33	516.64847170	27.93334699
SAMPLE	34	519.08971920	26.17876458
SAMPLE	35	488.83552570	22.32311458
SAMPLE	36	489.31505920	22.41132255
SAMPLE	37	488.93871650	22.23469707
SAMPLE	38	488.96587590	22.23889692
SAMPLE	39	469.41218000	22.24609115
SAMPLE	40	488.68984460	22.33118676
SAMPLE	41	483.55023360	22.32561580
SAMPLE	42	487.99785950	22.21556408
SAMPLE	43	484.33155230	22.25667706
SAMPLE	44	481.96423480	22.22214379
SAMPLE	45	479.49823510	21.86664589
SAMPLE	46	478.82602160	21.89425871
SAMPLE	47	478.23115720	21.75203664
SAMPLE	48	477.91551480	21.75063889
SAMPLE	49	476.99893800	21.81935602
SAMPLE	50	478.41325850	22.00943839
SAMPLE	51	500.17436970	24.81739184
SAMPLE	52	488.39289320	22.87955238
SAMPLE	53	479.22057450	21.94547219
SAMPLE	54	481.32881000	22.83249680
SAMPLE	55	464.59863430	22.46022927
SAMPLE	56	485.35131990	22.19211396
SAMPLE	57	484.79287580	22.12852579
SAMPLE	58	486.17077600	22.23153310
SAMPLE	59	486.05544510	22.19840125
SAMPLE	60	486.46213810	22.24408293
SAMPLE	61	486.06151510	22.24785997
SAMPLE	62	485.52735120	22.21284204
SAMPLE	63	485.27240930	22.15172042
SAMPLE	64	484.86875050	22.18714144

80-25-27

FIGURE 11. SAMPLE DATA OF DME STABILITY TESTS (SHEET 2 OF 3)

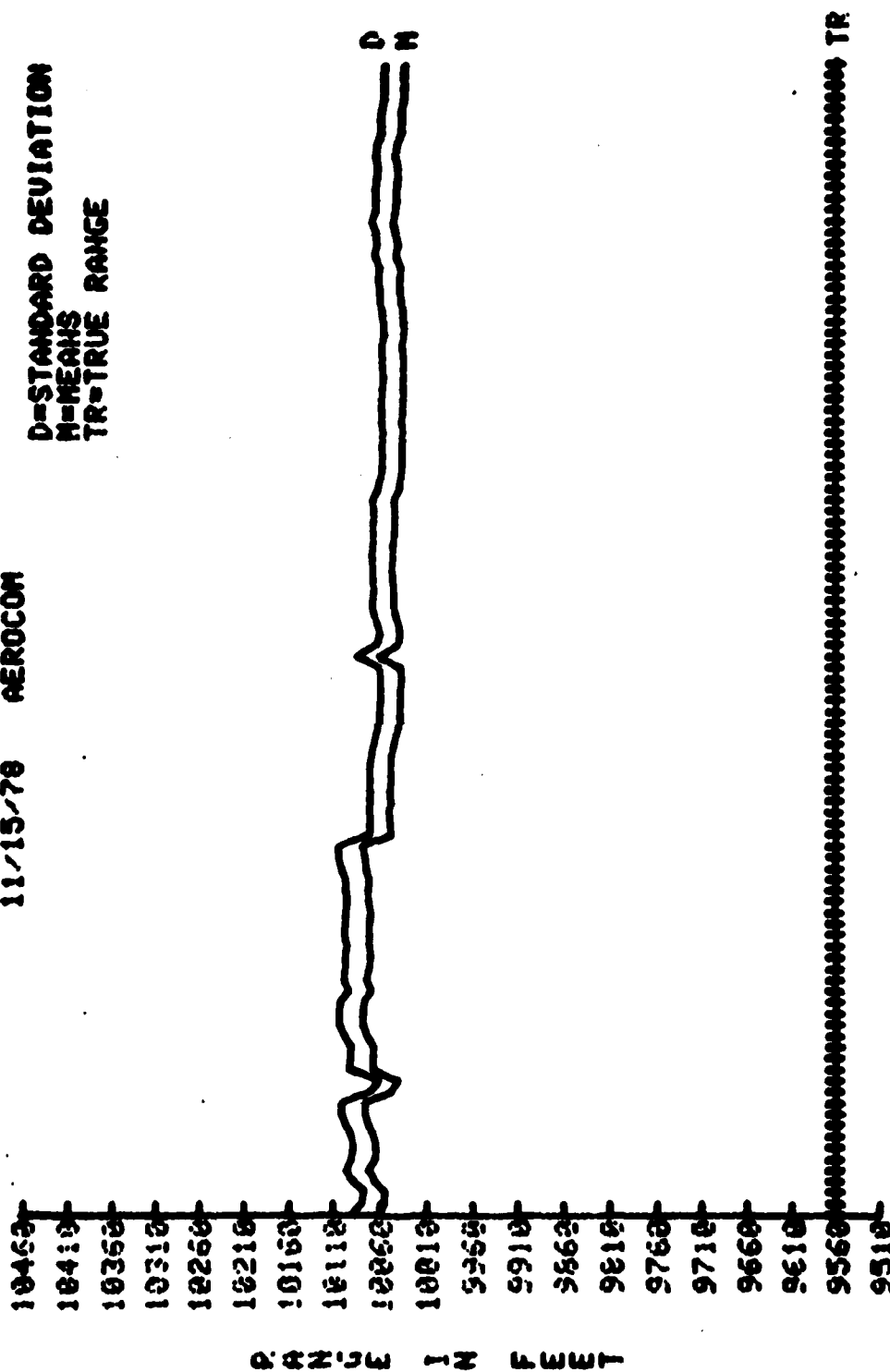
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FIGURE 11. SAMPLE DATA OF DME STABILITY TESTS (SHEET 3 OF 3)

PRECISION ONE STABILITY TEST
11/15/78 AEROCON

D=STANDARD DEVIATION
M=MEANS
TR=TRUE RANGE



104 SAMPLES

80-25-30

FIGURE 12. PLOT OF DATA, STABILITY TESTS