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HELICOPTER REMOTE WIND SENSOR (HRWS) GROUND TEST

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Ground tests of the Helicopter Remote Wind Sensor (HRWS) were run at Biggs Optical Range (BOR) to determine the suitability of the HRWS for measuring low-level cross winds for surface-launched weapons ballistics. The HRWS accurately measured winds under a variety of atmospheric turbulence conditions. Average absolute differences (with respect to the BOR) were 0.6 m/s for point measurement, 0.8 m/s for the near field, and 1.3 m/s for a 500-m path.

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INTRODUCTION

Ground tests of the Helicopter Remote Wind Sensor (HRWS) were performed at Biggs Optical Range (BOR) for the purpose of demonstrating the potential application of the HRWS as a low level cross wind measurement device for surface-launched weapons ballistics. The test objectives were designed to attempt measurement of winds under a variety of atmospheric turbulence conditions, shown in Table 1, and were conducted 25 Apr 1978 through 28 Apr 1978. Results of the tests are presented in the sequel as comparisons of cross wind computed from HRWS data and cross wind measured by BOR, using the Analog Wind Adder (AWA) and Laser Crosswind Sensor (LCS) for the 500 meter range.

For a description of BOR, refer to Appendix A; for a description of HRWS, see the Helicopter Remote Wind Sensor System Description report.

TEST SETUP AND GEOMETRY

HRWS was not designed for surface measurements of wind, so it was necessary to manipulate its orientation and apply the point-pair wind computation method (see Wind Computation Method) so that BOR comparable data could be generated. It should be noted that in the test set-up, winds derived from HRWS output are the results of space measurements while the BOR AWA winds are the results of point measurements. One-minute averages of wind are used in comparisons to obtain statistically valid values.

The sensor was elevated approximately 11 degrees to give a point-pair separation of approximately 29 degrees in the horizontal plane (Figure 1). Due to uncertainties in actual orientation caused by motion of the van, the point-pair used for wind computation was selected so that the plane of measurement was slightly above the horizon, with an elevation of approximately 0.5 degrees. This choice was made to avoid measurements too close to or on the ground.

Position of the sensor was approximately 24 meters behind the first anemometer station and offset from the array line by 6 meters with the cone axis in a vertical plane parallel to the array line.

WIND COMPUTATION METHOD

Winds measured along two non-collinear rectors in a plane are sufficient to deduce wind along two orthogonal vectors in that plane (Figure 1). Thus any pair of sample points from a circular scan of the sensor can be used to deduce wind in the plane defined by those points. However, the points should be separated by at least 15 degrees because of measurement noise:

$$w_x = \frac{v_1 + v_2}{2\cos\gamma/2} \quad \text{, range wind}$$

$$w_y = \frac{v_1 - v_2}{2\sin\gamma/2} \quad \text{, cross wind.}$$

Both range and cross wind can be computed; however, for the ground test, the cross wind component was the principle datum to be compared to the BOR output. In the BOR array only the first station was instrumented for range wind. Since the van and other equipment generally interfered with the range component of wind, comparison of range wind was not done for anemometer # 1.

DATA ANALYSIS

Analog tapes from the 8 tests were run through a digitizing process and the resulting raw data were stored on disks. Data reduction computer programs developed for the HRWS flight tests were modified to handle the ground test formats. Reduced data were then treated by a computer program designed to compute cross wind from the selected point-pair.

Large variations in the results, i.e., sudden changes in computed cross wind led to additional examination of the reduced data. This examination revealed the occurance of false doppler tracking by the HRWS. This false tracking appears to be localized to a given portion of the circular scan, somewhere in the vicinity of 72° ± 10° with respect to the vertical. Depending on the relative strength of false doppler and wind doppler, the measured doppler signal for one point of the selected pair would be compromised, resulting in computation of an erroneous cross wind value. It is hypothesized that false doppler is caused by degradation of part of the HRWS optics.

An interactive computer program was designed for manual editing of the data to remove erroneous measurements. Thus valid wind data were recovered for analysis.

For comparison to BOR data, the HRWS cross wind data were condensed to one minute averages for a range corresponding to the first anemometer station and for all ranges exceeding 24 meters. Table 2 summarizes all data, while Table 3 contains the results of comparisons as absolute differences. Three types of comparisons have been made: at single range, HRWS vs. anemometer #1; for the 500 meter path, HRWS vs. the BOR AWA output; and, for the 500 meter path, HRWS vs. the LCS.

The absolute differences show best agreement at single range (Figure 2) since the space difference between the point-pair is small and no integrated path is involved in the comparison. For the 500 meter path, there is generally a bias between HRWS and AWA or LCS. This bias might be due to the fact that the HRWS optical weighing function for far field measurements is not known. The greatest differences occurred in Test 4; it should be noted that both HRWS and LCS showed large biases with respect to AWA.

CONCLUSIONS

The HRWS, operated as a low level cross wind sensor can accurately measure winds under a variety of atmospheric turbulence conditions, with average absolute differences with respect to BOR of 0.6 m/s for point measurement, 0.8 m/s for the near field and 1.3 m/s for a 500 meter path. The maximum absolute differences found were 1.7, 2.0 and 3.3 m/s. If an optical weighting function for HRWS can be found, it is believed that far field average winds can be accurately determined. The accuracy of measurements at a range less than 100 meters is very good, which should be expected, since the HRWS was designed for that region. However, when the HRWS was not operating as designed, optical problems were compounded by the frequency tracking method used in the sensor electronics.

Table 1

Ground Test Schedule

TEST NUMBER	DATE	TIME	ATMOSPHERIC CONDITION	DATA TIME USED (MIN)
1	4-25	9:56:11-10:04:11	high wind, high turb	6
2	4-25	10:37:10-10:47:11	high wind, high turb	7
3	4-25	15:23:48-15:31:45	low wind, mod/light turb	0
4	4-25	17:58:41-18:09:00	mod wind, low turb	4
5	4-25	19:03:43-19:13:44	low wind, low turb	5
6	4-26	11:11:30-11:21:33	2-4, high turb	3
7	4-27	05:07:47-05:18:13	low wind, low turb	0
8	4-27	07:30:00-07:40:15	mod wind, low/mod turb	0
9	4-28	12:40:10-13:41:53	dusty	1

GROUND TEST DATA SUMMARY

TEST NUMBER	ELAPSED TIME AVERAGES (min)	SINGLE RANGE (m/s) HRWS FIXED RANGE	BOR SINGLE POINT	500 M PATH (m/s) HRWS AUTO RANGE	BOR AWA	LCS
1	0-1	4.1	4.7	N/A	4.5	4.2
	1-2	3.5	4.8	N/A	4.9	4.6
	2-3	-	5.4	N/A	5.0	4.8
	3-4	-	4.7	N/A	4.6	4.6
	4-5	-	4.2	N/A	4.1	4.0
	5-6	4.0	4.1	N/A	3.5	3.3
	6-7	3.8	3.5	N/A	3.4	3.2
	7-8	4.2	3.3	N/A	3.2	3.1
2	0-1	5.9	5.6	6.0	5.2	5.0
	1-2	4.4	4.6	4.9	4.3	4.1
	2-3	4.8	4.6	4.9	4.3	4.1
	3-4	5.0	4.5	5.4	4.7	4.7
	4-5	4.0	2.3	4.5	3.4	3.5
	5-6	4.1	5.5	4.5	4.8	4.5
	6-7	4.6	5.3	5.0	5.2	5.0
3	-0-	-		-	-	-
4	0-1	4.2	3.4	5.1	3.5	2.0
	1-2	4.1	3.4	5.3	3.3	2.0
	2-3	3.4	3.4	4.7	3.5	1.7
	3-4	3.7	2.9	4.8	3.2	1.7
5	0-1	3.3	2.6	4.1	2.7	2.6
	1-2	2.7	2.4	3.2	2.9	2.7
	2-3	-	2.4	-	2.9	2.7
	3-4	-	2.3	-	2.8	2.6
	4-5	-	2.9	-	2.9	2.6
	5-6	2.6	3.1	3.1	2.8	2.4
	7-7	3.0	3.5	3.4	2.7	2.3
	7-8	3.5	2.7	4.0	2.7	2.5
6	0-1	3.1	3.2	3.1	3.4	3.1
	1-2	2.8	2.3	2.7	2.8	2.7
	2-3	2.6	1.6	2.7	2.1	2.0
7	-0-	-	-	-	-	-
8	-0-	-	-	-	-	-
9	-0-	-	-	-	-	-

N/A : Data not required as Test objective
 - : Data considered invalid

Table 2

CROSSWIND ABSOLUTE DIFFERENCES (m/s)

HRWS vs BOR

TEST NUMBER		SINGLE RANGE HRWS/ANEMOMETER	HRWS/AWA	500 M PATH HRWS/LCS	AWA/LCS
1	MIN	0.1			0.0
	MAX	1.3	N/A	N/A	0.3
	AVG	0.6			0.2
	MIN	0.2	0.2	0.0	0.0
	MAX	1.7	1.1	1.0	0.3
	AVG	0.7	0.6	0.6	0.2
3	MIN	N/A	N/A	N/A	N/A
	MAX	N/A	N/A	N/A	N/A
	AVG	N/A	N/A	N/A	N/A
4	MIN	0.0	1.2	3.0	1.3
	MAX	0.8	2.0	3.3	1.8
	AVG	0.6	1.6	3.1	1.5
5	MIN	0.3	0.3	.5	0.1
	MAX	0.8	1.4	1.5	0.4
	AVG	0.6	0.8	1.1	0.3
6	MIN	0.1	0.1	0.0	0.1
	MAX	1.0	0.6	0.7	0.3
	AVG	0.5	0.3	0.2	0.2
7	MIN	N/A	N/A	N/A	N/A
	MAX	N/A	N/A	N/A	N/A
	AVG	N/A	N/A	N/A	N/A
8	MIN	N/A	N/A	N/A	N/A
	MAX	N/A	N/A	N/A	N/A
	AVG	N/A	N/A	N/A	N/A
9	N/A				
ALL TEST	MIN	0.0	0.1	0.0	0.0
	MAX	1.7	2.0	3.3	1.8
	AVG	0.6	0.8	1.3	0.5

Table 3

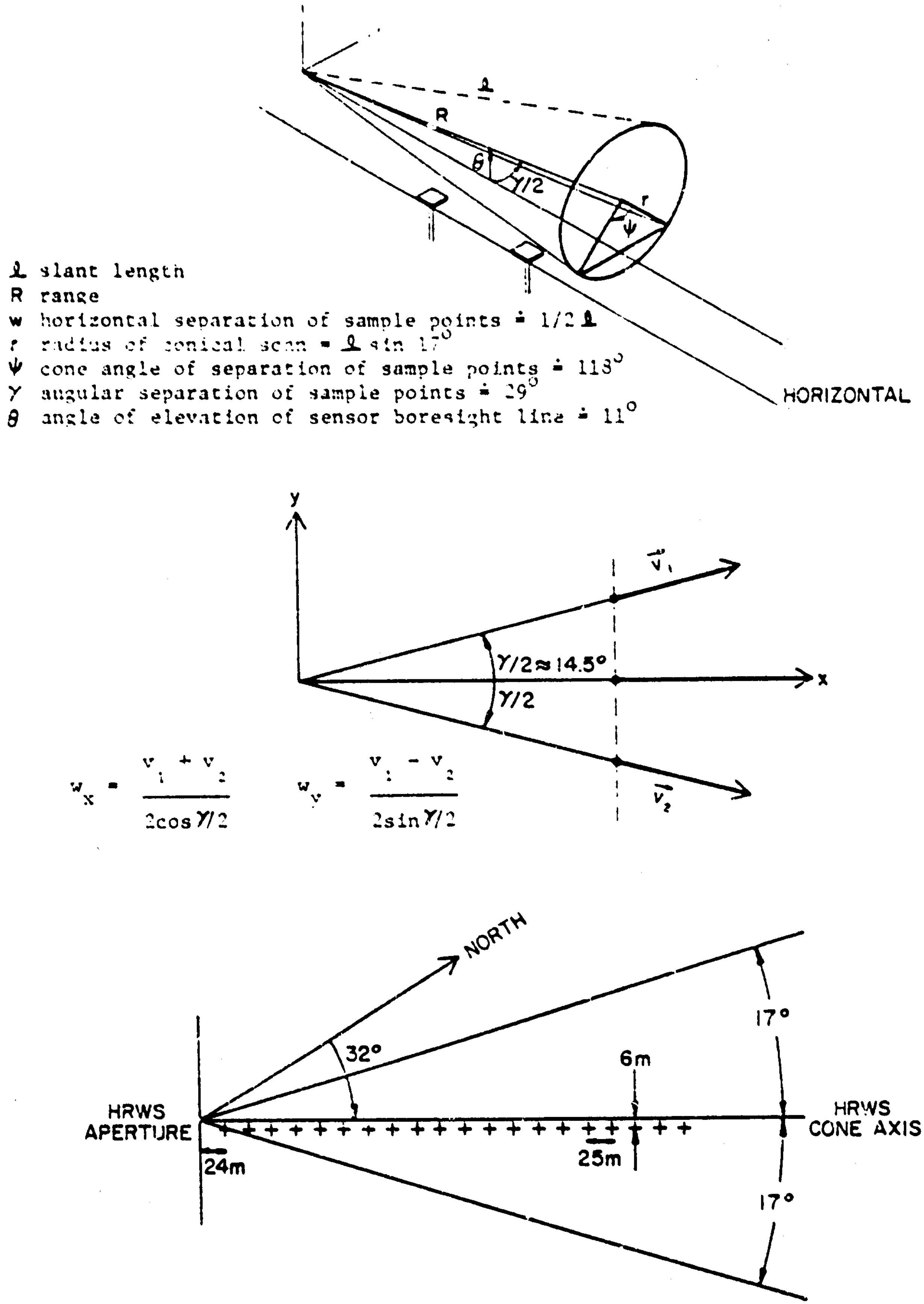

Figure 1: Geometric Layout of HRWS on BOR & Anemometer Array and Axis of Laser Crosswind Sensor

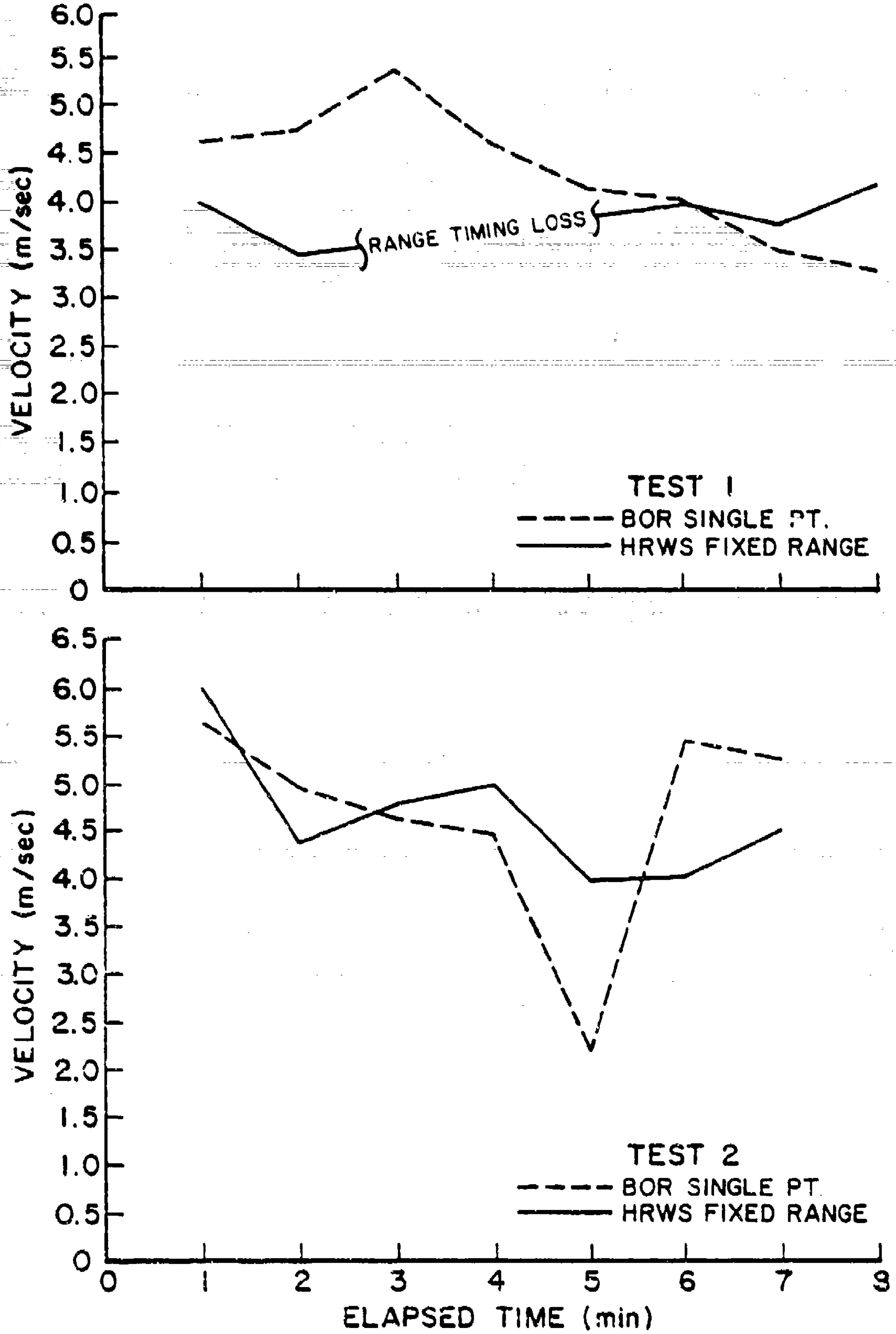

Figure 2: Comparison of BOR and HRWS.
High wind.

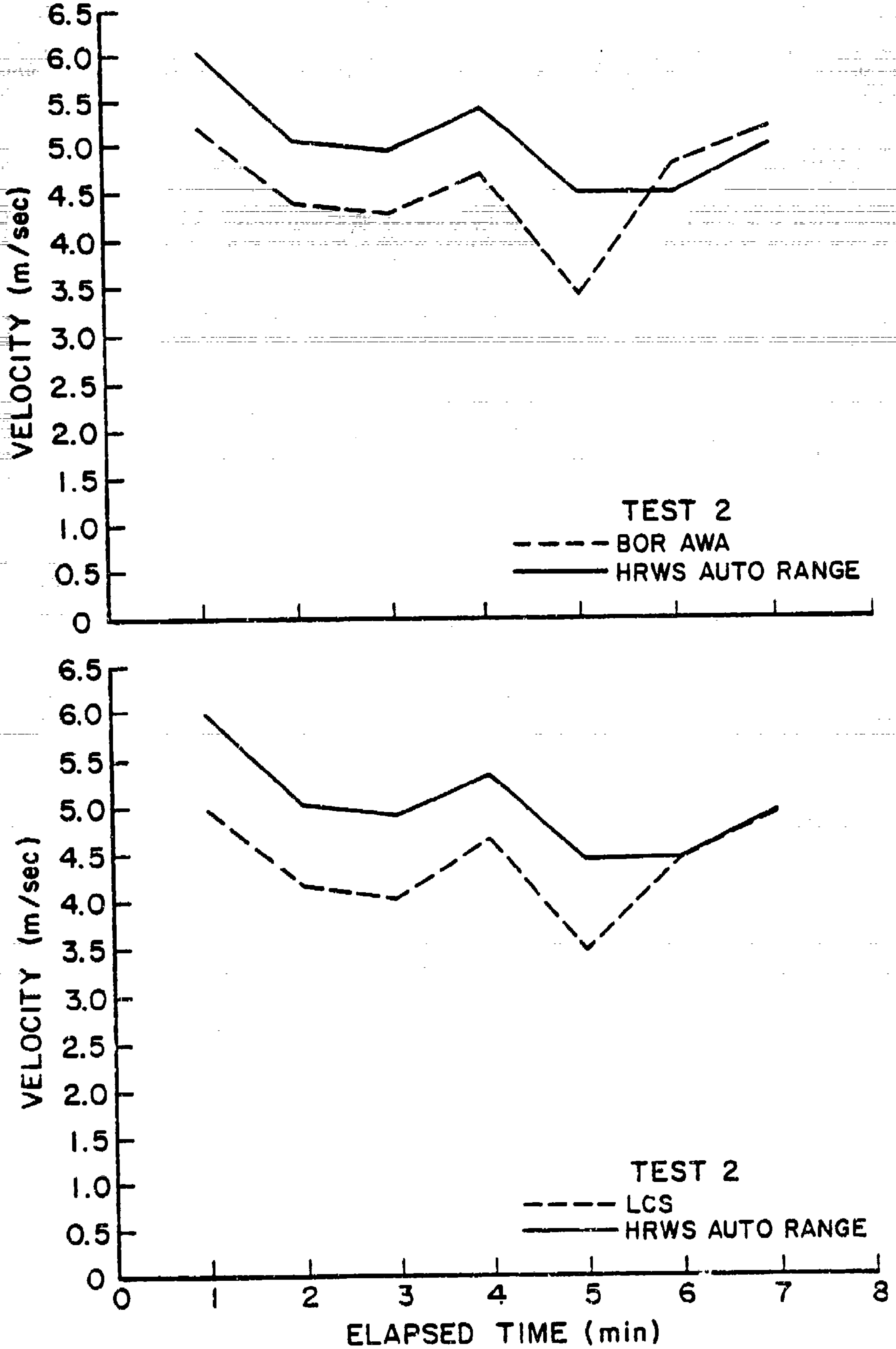

Figure 2 (con'd)

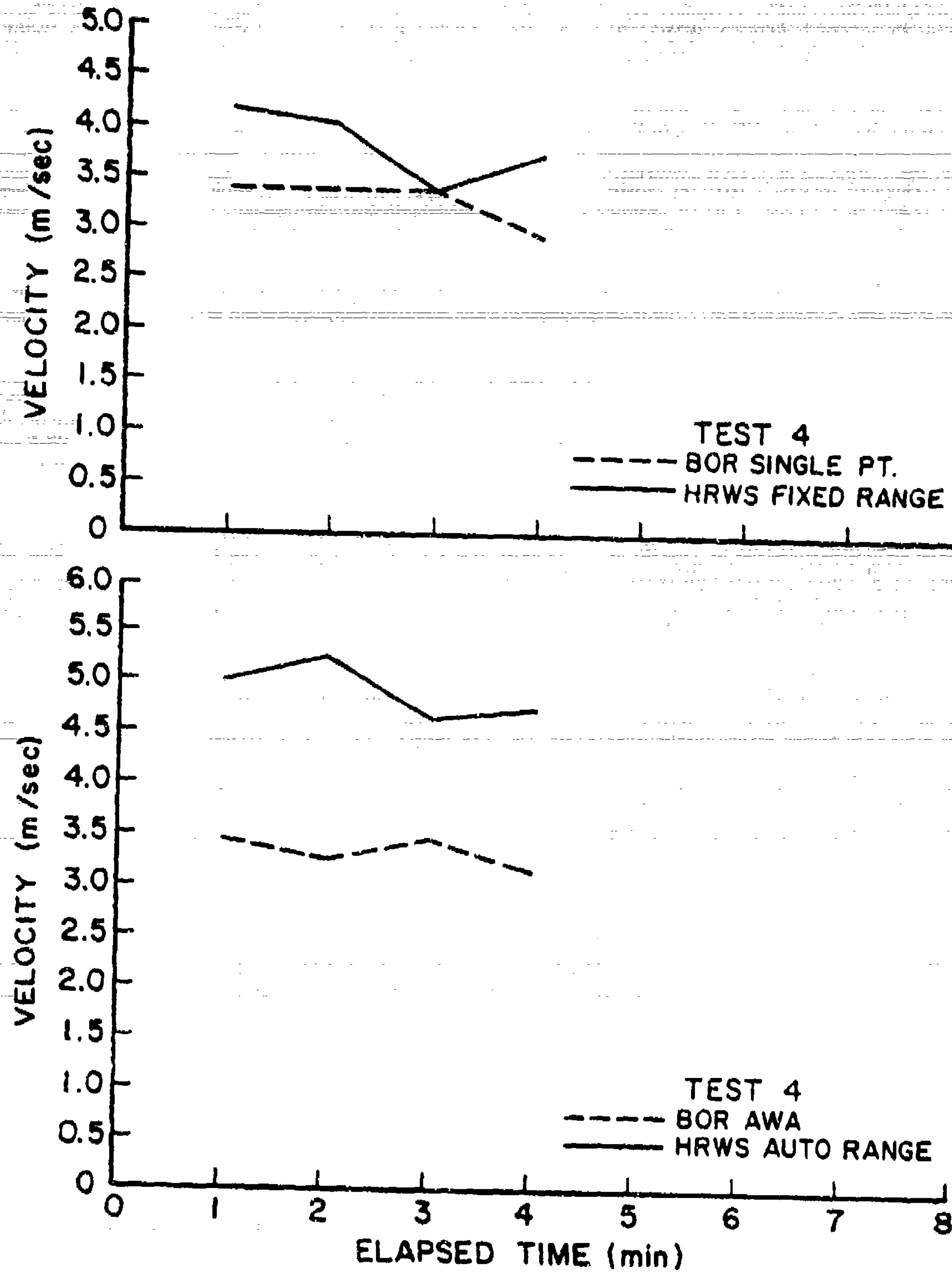

Figure 3. Comparison of BOR and HRWS.
Medium and low wind.

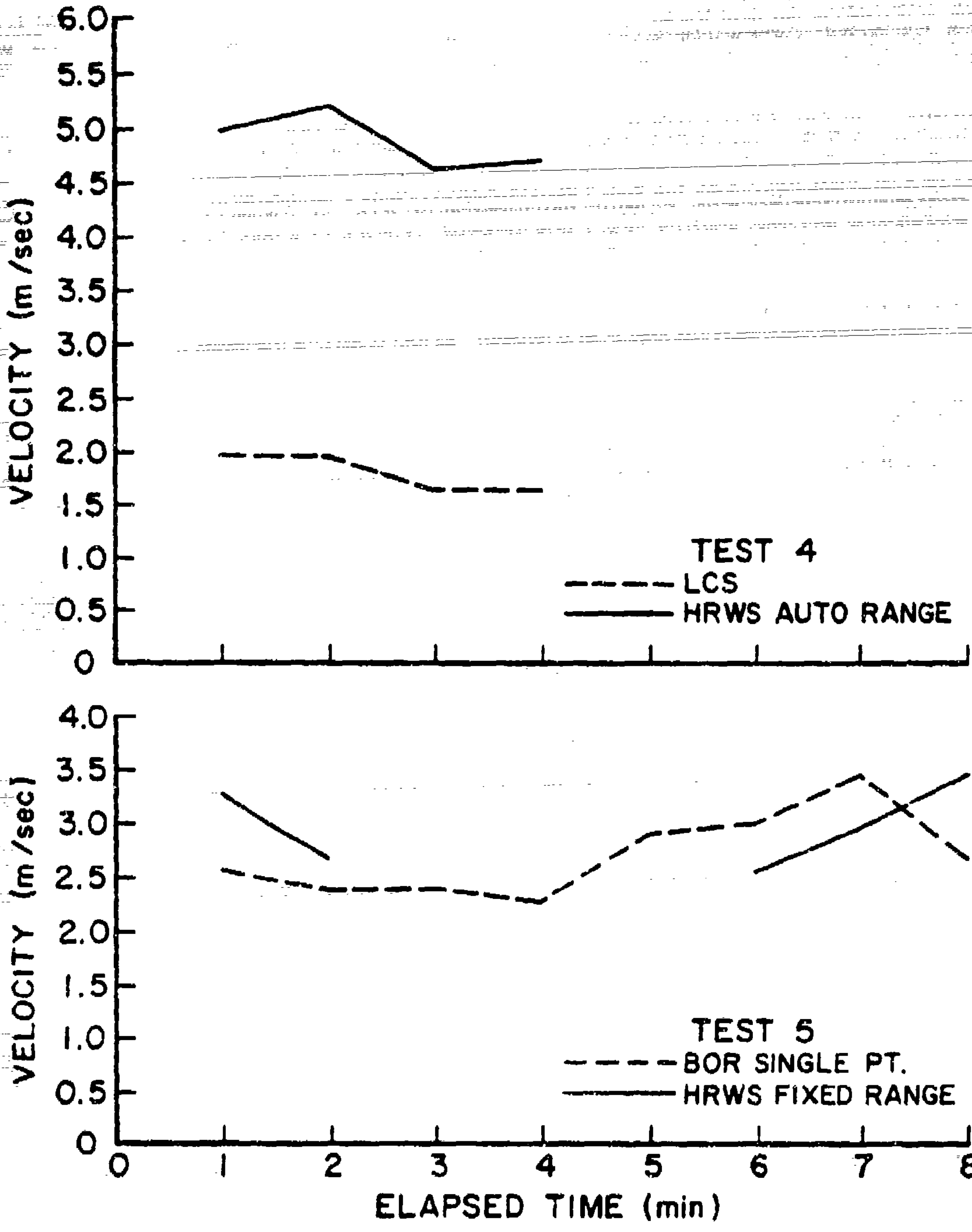

Figure 3 (con'd)

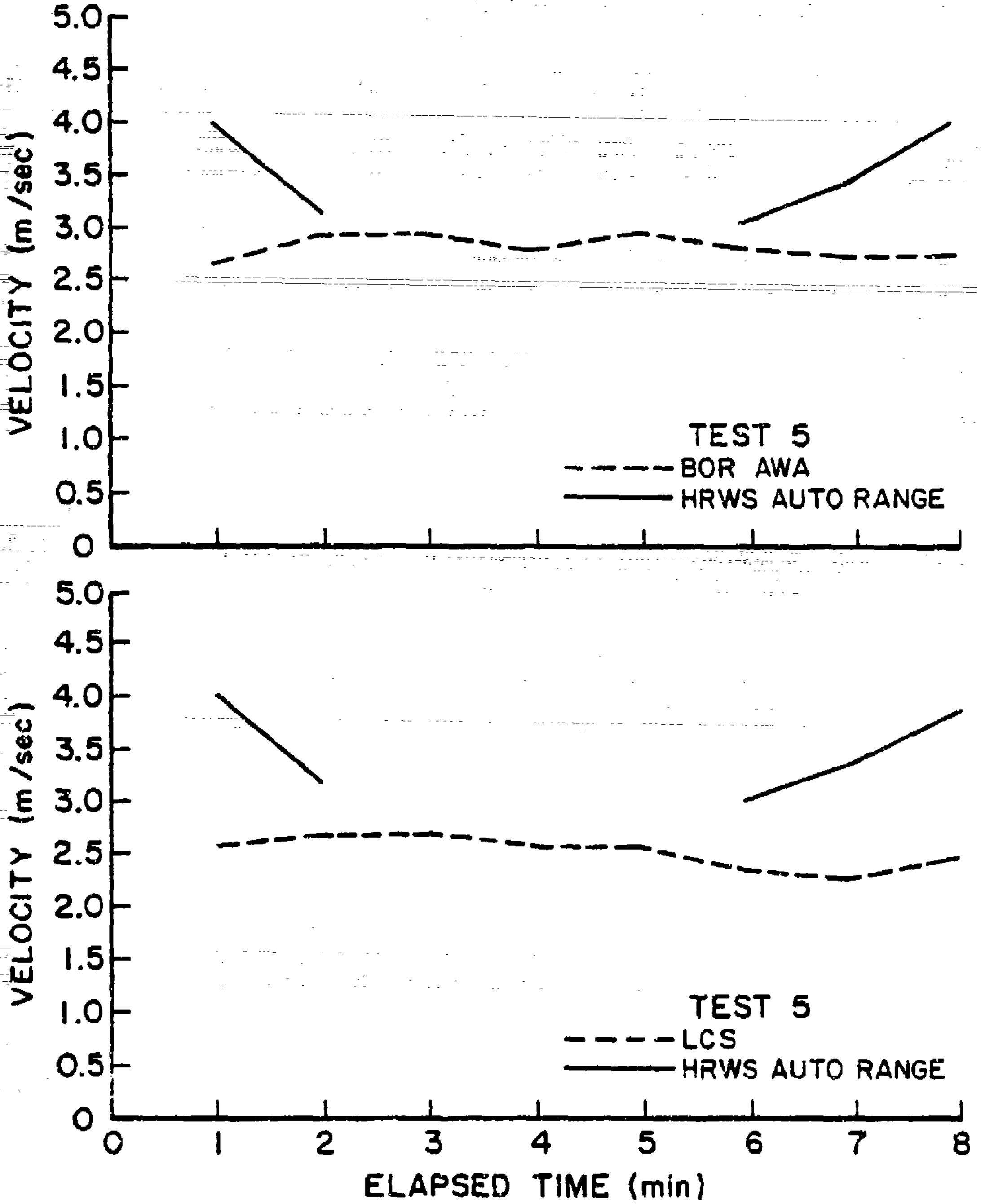

Figure 3 (con'd)

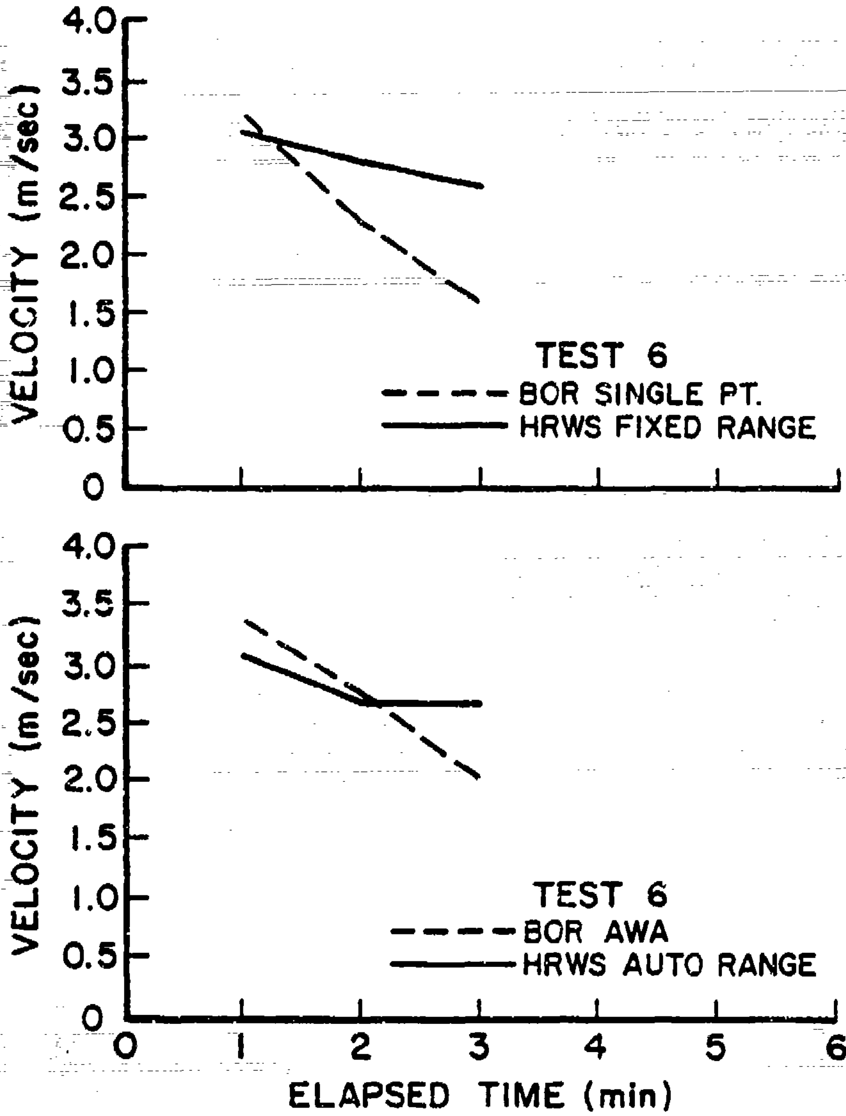

Figure 3 (con'd)

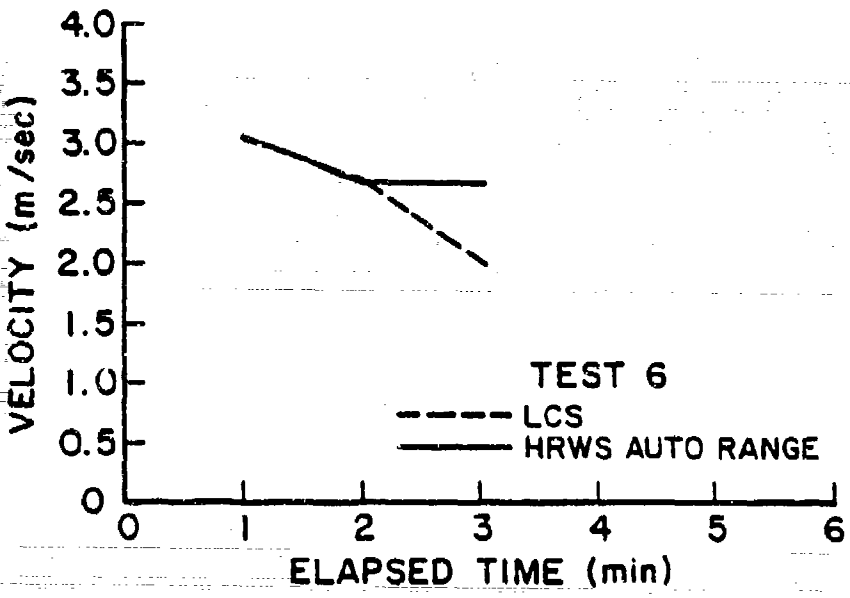

Figure 3 (con'd)

Appendix A

B.O.R. DESCRIPTION

1. Biggs Optical Range (BOR) is designed as a 2Km extended crosswind array divided into two sections, 500 meters and 1500 meters. Positioned along the length of the array are research type anemometers (GILL U-V-W) oriented perpendicular to the length of the path. The array path orientation is approximately 032-212 degrees. For the first 500 meters the anemometers are separated at 25 meter intervals and for the remaining 1500 meters at 100 meter intervals. Usually, wind data along this 2Km path is collected from individual anemometers and processed through an analogue wind adder (AWA). This procedure separates the 2Km path into four consecutive paths of 500 meters each. The collection of anemometers within this sector is summed to give an average wind profile and finally, the four sectors are summed to give an overall profile. Each sector plus the overall profile can be recorder and displayed in real time. This same procedure can be used within the 500 meter path when a shorter path is desired. Positioned at each end of the 2Km path and at 500 meters are three elevated platforms on which equipment, such as, laser anemometers can be operated. Sufficient power is provided at each platform position to operate necessary recording equipment.

2. In addition to cross winds measurement of and collection of data on the following parameters are available if desired.

a.) Temperature at two elevations 1.5m and 6.0m.

b.) Pressure

c.) Dew Point

d.) Soil Temperature

e.) At for thermal turbulence and for resolving C_T^2 (This is point measurement)

f.) Three dimensional winds at two elevations, 1.5m and 6.0m.

g.) Integrated wind measurement of cross wind over the 500 meter path with a laser anemometer (LCS). Turbulence measurement from this instrument is a direct output.

Appendix B

OPERATION BREAKWIND GROUND TEST
TELEMETRY COMPUTER FORMAT

From the HRWS telemetry computer format, the output is modified to include IRIG "B" time from the time code reader. The word 0 and 1 of the HRWS data frame are left the same and 5 words are added for IRIG "B" timing. The hours 40 and 20 min timing bits are left out of IRIG timing from the normal FM/FM telemetry computer format to give a data frame as follows:

Word No.	BIT POSITIONS															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	MSB						LSB									
0				Range											**	*
	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	F_6	F_5	F_4	F_3	0	"0"	1	1
1				VCO												
	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	F_2	F_1	F_0	V	0	"0"	0	0
2			BLANK							MINUTES						
									10	8	4	2	0	0	0	0
3									MIN	SEC						
									1	40	20	10				
4										SEC						
									8	4	2	1				
5										MSEC	X 10^2					
									8	4	2	1				
6										MSEC	X 10					
									8	4	2	1				
7										MSEC						
									8	4	2	1				

* Subcommutator sync "on" only at word 0.

** Main frame sync "on" only at word 0.

BINARY TO WIND VELOCITY CONVERSION

Channel	Frequency	Velocity Along Beam	Longitudinal Velocity	Transverse Velocity
F-9	6.4×10^6 Hz	34 m/sec 63Kts	35 m/sec 66 Kts	116 m/sec 215 Kts
F-8	3.2×10^6	17 m/sec 31 Kts	18 m/sec 33 Kts	59 m/sec 108 Kts
F-7	1.6×10^6	8.5 m/sec 16 Kts	8.9 m/sec 16 Kts	29 m/sec 54 Kts
F-6	8.0×10^5	4.2 m/sec 7.9 Kts	4.4 m/sec 8.2 Kts	14 m/sec 27 Kts
F-5	4.0×10^5	2.1 m/sec 3.9 Kts	2.2 m/sec 4.1 Kts	7.3 m/sec 13 Kts
F-4	2.0×10^5	1.1 m/sec 2.0 Kts	1.1 m/sec 2.1 Kts	3.6 m/sec 6.7 Kts
F-3	1.0×10^5	.53 m/sec .98 Kts	.55 m/sec 1.0 Kts	1.8 m/sec 3.4 Kts
F-2	6.0×10^4	.26 m/sec .49 Kts	.28 m/sec .51 Kts	.91 m/sec 1.7 Kts
F-1	2.5×10^4	.13 m/sec .25 Kts	.14 m/sec .26 Kts	.45 m/sec .84 Kts
F-0	1.25×10^4	.066 m/sec .12 Kts	.069 m/sec .13 Kts	.23 m/sec .42 Kts

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