NOAA Technical Report OTES- 8

Characterization Tests of Datawell HIPPY 120C Vessel Motion Sensor

Rockville, Md.
May 1982

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Ocean Technology and Engineering Services

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Donald L. Pryor
Engineering Development Office

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U. S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

Ocean Technology and Engineering Services
M. E. Ringenbach, Director

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CHARACTERIZATION TESTS OF DATAWELL HIPPY 120C VESSEL MOTION SENSOR

Donald Pryor
Engineering Development Office
Office of Ocean Technology and Engineering Services
National Oceanic and Atmospheric Administration
Rockville, MD

ABSTRACT. This report describes the results of a series of tests conducted to characterize the performance of a vessel motion sensor - the HIPPY 120C. The HIPPY 120C was designed to measure heave, roll, and pitch motions so that errors caused by these motions can be removed from hydrographic data. The series of tests include lab tests, van tests, and field tests. Laboratory tests were conducted to examine the response to ideal, well-controlled motions. The effects of horizontal accelerations were examined by testing the device mounted in a van. Field tests were run to examine the performance in a realistic operating environment. The test results showed that the HIPPY is capable of meeting the error budgets proposed for NOS' automated survey system. With the exception of physical size and low frequency response, the device appears to meet all NOS requirements which have been proposed for this type of device.

1. INTRODUCTION

The HIPPY 120C is an instrument manufactured by the Datawell Corporation which was designed to measure the heave, roll, and pitch of a ship so that hydrographic data can be corrected. Ship motion is a major error source in modern surveys. The standard technique now used is to manually examine survey records and "average" the effects of motion. This is time consuming and presents the possibility of mistakenly ignoring features which should be charted. The HIPPY 120C offers the potential of automatically and accurately removing these errors. It could also be used to improve the performance of other shipboard systems such as current profiling systems or precise positioning systems.

2. REQUIREMENTS

Hydrographic data gathered by NOS is required to meet the standards of the International Hydrographic Bureau. A proposed Accuracy Standard for NOS Hydrographic Systems (Appendix A) sets error bounds for the various components of an automated sonar so as to support the international standard on system accuracy. The 90 percent confidence interval for depth in feet is required to be ±1.1 + .01d where d is the depth. The standard deviation of depth due to heave error is allowed to be 0.30 feet and that due to pointing error is allowed to be 0.003d. This heave error budget results directly in a requirement on the motion sensor. The roll and pitch accuracies required depend on the geometry of the sounding system. For a conventional single beam sounder, angular errors of 0.3 degrees would be acceptable. In shallow water, correction for pointing angle can be ignored entirely. The development of swath sounding systems such as the Bathymetric Swath Survey System (BS^3) imposes much stricter requirements. Roll errors must be less than 0.1 degrees in order to gather acceptable data from the outer beams. A motion sensing instrument is a necessity in a swath system since there is no means for manual scanning and correction.

The vessel motions which are to be measured are caused by waves. Ocean waves typically have periods ranging from one to 20 seconds. The vessel motions caused by the waves are doppler shifted by the ship's velocity and can have very long periods. Hopkins and Adamo (1980) discussed this effect in detail. A goal for the vessel motion sensor is to be able to measure accurately motions with periods as long as 60 seconds. Then only a small set of wave and operating conditions would create motions which could not be compensated. For instance, at typical survey speeds of ten knots moving with waves of three to four seconds period would create this "surfing" condition. If the low frequency performance of the motion sensor is limited, then a wider range of conditions would cause motions that could not be accurately measured.

3. DESCRIPTION

Datawell's HIPPY 120C uses a long period pendulum as a vertical reference. The pendulum period of 120 seconds is achieved by forming the pendulum as a platform suspended in fluid in which it is nearly neutrally buoyant. Without the buoyancy effect a pendulum length of 3600 meters would be required in order to achieve this natural frequency. The platform supports an accelerometer whose outputs are processed to deliver the heave estimate. In addition, the platform supports a pair of crossed coils. These coils sense magnetic fields generated at different frequencies by a pair of crossed coils fixed to the case of the instrument. One coil generates a field parallel to the pitch axis and the second generates a field parallel to the roll axis. One pickup coil senses a component of the generated field proportional to the pitch angle and the second pickup coil senses a component proportional to the roll angle. Datawell's manual (Appendix B) provides a more complete description of the principles of operation.

The vertical acceleration as well as the roll and pitch signals are processed by a Texas Instruments 9900 microprocessor. The microprocessor doubly integrates the vertical acceleration to estimate heave. It is necessary to eliminate signals below 60 seconds period (the second harmonic of the pendulum natural frequency) since the accelerometer will sense motions at these frequencies which are in fact caused by horizontal accelerations exciting the pendulum. Any linear network which rejects low frequency signals will also phase shift signals nearly a decade above the cutoff frequency. The phase shifts produce a large difference between the estimated heave and the actual heave. It is necessary to compromise between phase and amplitude variations in order to maintain a tolerable vector error to the lowest possible frequency. The Datawell design is specified to have a vector error of less than 3.5 percent down to a period of 16 seconds. Since this is well short of the desired 60 seconds, it is necessary to resort to other techniques. A second parallel channel subjects the vertical acceleration to filtering which is not realizable in real time. The output of this channel is accurate at a time 77.2 seconds after the actual motion and it is accurate down to periods of 30 seconds. Datawell refers to the real-time processing as the version A filter and the delayed processing as the version C filter and the instrument is referred to as the HIPPY 120C in this report to indicate that the delayed processing is included. The microprocessor outputs can be easily programmed to deliver the information to the user's system in a wide variety of formats. The instruction manual for the HIPPY 120C contains complete instructions.

The HIPPY 120C is physically a fairly large device. It stands 33 inches tall and is 26 inches in diameter. It weighs 260 pounds.

4. DEVELOPMENT

The HIPPY 120C was developed specifically in response to the needs of the BS^3. It is an evolution of techniques devised by Datawell and used very successfully in the Waverider wave measurement buoys. The first tests of this concept of vessel motion sensing were conducted in June of 1976. In these tests, two separate sensors were used. One was a production pitch-roll sensor and the second was a prototype heave sensor. All processing was done off-line by Louis C. Adamo, Inc. These tests were encouraging and provided the design information necessary to construct an integrated prototype. This unit was provided on loan to NOS and interfaced with the BS^3 system aboard the DAVIDSON. Production versions included minor changes in the sensor and a completely redesigned microprocessor. The first three production units were delivered in January, 1980. Two of these belong to NOS and the third belongs to the Army Corps of Engineers. All three of these first units were involved in the tests described in this report.

5. LABORATORY TESTS

Laboratory tests were the first phase of the characterization tests. Both static and dynamic tests were conducted under well controlled situations.

A. Dynamic Tests

Dynamic tests consisted of measurements of the frequency responses of roll, pitch, and heave.

These tests were conducted at the Wave Buoy Test Facility (WBTF) at the NOAA Engineering Support Office. The instrument under test is attached to a beam which carries it around a vertical circle. Drive for the beam is supplied by a motor through a variable speed transmission. A second HIPPY was used as a counterweight so that the load on the motor was nearly constant. The circular radius (peak-to-peak heave) was 2.009 meters. During these tests, data was taken at rotational rates whose periods ranged from 4.2 seconds to 83.9 seconds per revolution. An even wider range of periods can be obtained with the WBTF by making more changes of drive sprockets.

The vertical attitude of the HIPPY was controlled through a chain and eccentric gear arrangement so as to either maintain its axis vertical or to provide a tilting motion with respect to the vertical. Peak amplitudes of 0, 4, 8, 12, 18, and 24 degrees could be selected. This tilt should be related to the rotation of the beam by:

$$\phi = A \sin \theta$$

where:

ϕ = tilt of HIPPY

A = preset peak amplitude

θ = inclination of beam from vertical

By rotating the HIPPY on its mounting frame, it was possible to produce roll or pitch or combination motions in synchronism with the heave motion.

Instrumentation was connected to the HIPPY as shown in Figure 1. Analog outputs recorded on the strip charts were the primary means of monitoring. Digital outputs recorded on the terminal were the secondary means of monitoring. The HIPPY was programmed to transmit all six available outputs (roll, pitch, heave, acceleration, delayed heave, and error) in decimal format with a one centimeter per bit resolution of heave and 0.1 degrees resolution of angles. Transmission was at 300 baud at intervals of 1.35 seconds.

The procedure used in these tests was to first align the HIPPY in rotation so that either roll or pitch or combined motion was produced. For pitch, this was done by plumbing from the v-notches in the base of the HIPPY. The HIPPY then was rotated until the v-notch at the rear tracked the v-notch at the front. A similar procedure was followed to adjust for roll using marks scribed on the base at 90 degrees from the v-notches. The next step was to shim the HIPPY so that the vertical axis was parallel to the plane of rotation (vertical). This was done with a level to within 0.1 degrees. The resolver was then set to coincide with the inclination of the beam. Finally, a set of static measurements were made with the level on the top of the HIPPY at various beam inclinations for comparison to the selected tilt.

The conditions under which tests were run are listed in Table 1 together with the results.

The observed frequency response of delayed heave is plotted in Figure 2. It is in excellent agreement with the response function supplied by Datawell (Figure 3). There appears to be no difference in response between the two units tested. Plotted values were determined from the peaks of the recorded outputs. The delay of the output signal with respect to the actual motion was determined to be within one second of the 77.20 seconds specified by Datawell. Estimation of the peak and instrumentation limitations made it difficult to determine the exact delay with any greater accuracy. Datawell specifies the delay to be accurate to within less than 20 milliseconds.

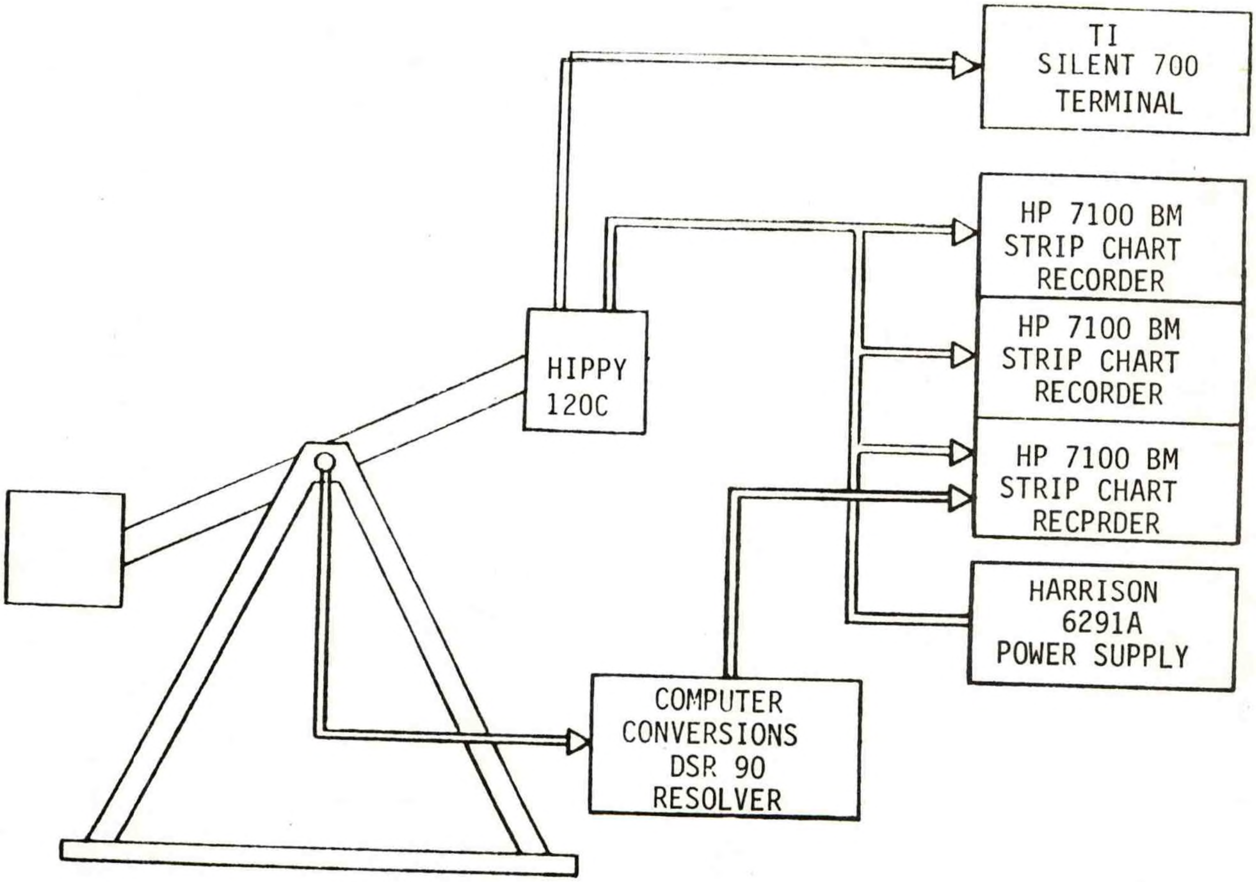


Figure 1. Wave Buoy Test Facility Instrumentation

DATE	UNIT	SETUP	RECORD I	RECORD II	PERIOD SEC	ANALOG HEAVE		DIGITAL HEAVE		ERROR		ROLL	PITCH	FREQ (H_Z)
						A	φ	A	77.2 + ΔSEC	A	77.2 + ΔSEC			
3/6	19004	0° PITCH	ANALOG/DIG. HEAVE	X	42.62	2.625	----	0.169	----					0.2350
NOTE:	NO DIGITAL RECORD		"	"	26.89	5.615	----	1.006	----					0.0372
				"	14.87	0.986	----	0.986						0.0672
3/12	19004	12° PITCH	PITCH/ROLL	"	40.81							1.00°	23.20°	0.0245
		"	PITCH/ROLL	"	29.46							"	"	0.0339
		"	PITCH/ROLL	"	14.95							"	23.30°	0.0669
		"	PITCH/ROLL	"	8.11							"	23.30°	0.1233
		"	PITCH/ROLL	"	4.22							1.20°	23.70°	0.2370
3/28	19004	12° PITCH												
3/31	19004	12° PITCH	ANALOG HEAVE VS. RESOLVER	PITCH/ROLL	40.8	2.867	120.0°					0.66°	23.10°	0.0245
		"		"	33.51	4.659	77.4°					"	"	0.0298
		"		"	32.30	5.097	66.9°					"	"	0.0310
		"		"	31.20	5.416	60.0°					"	"	0.0321
		"		"	28.54	5.814	30.3°					"	"	0.0350
		"		"	26.32	5.256	0.0°					"	"	0.0380
		"		"	20.93	1.573	-48.2°					"	"	0.0478
		"		"	10.26	0.966	0.0°					0.69°	"	0.0975
		"		"	6.28	0.976	0.0°					0.76°	"	0.1592
4/1	19004	0° PITCH	DIGITAL HEAVE VS. ERROR	PITCH/ROLL	37.49			0.438	----	0.936	8.6	0.66°	0.30°	0.0267
		"	"	"	33.32			0.767	----	0.796	8.6	"	"	0.0300
		"	"	"	31.26			0.906	----	0.657	7.4	"	"	0.0320
		"	"	"	29.49			0.996	----	0.442	8.2	"	"	0.0339
		"	"	"	27.66			1.035	----	0.269	8.2	"	"	0.0362
		"	"	"	26.12			1.015	----	0.110	7.8	"	"	0.0333
		"	"	"	23.86			0.996	----	0.030	----	"	"	0.0419
		"	"	"	20.32			1.005	----	0.022	-3.0	"	"	0.0492
		"	"	"	13.97			"	----	0.005	----	"	"	0.0716
		"	"	"	10.30			"	----	0.006	----	0.69°	"	0.0971
		"	"	"	7.86			0.996	----	0.005	----	0.73°	"	0.1272
		"	ERROR VS. RESOLVER	"	35.57					0.916	9.0	0.66°	"	0.0281
			"	"	40.61					0.946	6.6	"	"	0.0246

Table 1. WBTF Tests

DATE	UNIT	SETUP	RECORD I	RECORD II	PERIOD SEC	ANALOG HEAVE		DIGITAL HEAVE		ERROR		ROLL	PITCH	FREQ (H_Z)
						A	ϕ	A	77.2 + ΔSEC	A	77.2 + ΔSEC			
4/1	19004	0° PITCH	ERROR VS. RESOLVER	X	43.50					0.866	9.0			0.0230
		"	"	"	26.08					0.115	7.8			0.0383
		"	"	"	20.70					0.038	0.2			0.0483
		"	DIGITAL HEAVE VS. RESOLVER	"	10.38			0.986	-0.2					0.0963
		"	"	"	20.39			0.986	-0.2					0.0490
		"	"	"	26.40			"	-0.2					0.0379
		"	"	"	31.20			0.906	-0.2					0.0321
		"	"	"	37.40			0.428	+0.2					0.0267
4/3	19004	0° PITCH	ERR. + DIG. HEAVE VS. RESOLVER	----	83.88			0.000	----	0.064	9.0	0.69°	0.30°	0.0119
NOTE: SMALL SPROCKET		"	"	PITCH/ROLL	58.19			0.030	----	0.380	9.0	"	"	0.0172
		"	DIGITAL HEAVE VS. RESOLVER	"	46.43			0.128	0.0	----	----	"	"	0.0215
5/22	19004	8° ROLL	ROLL VS. RESOLVER	X	49.84							15.46°		0.0201
		"	"	"	29.00							"		0.0345
		"	"	"	19.72							"		0.0507
		"	"	"	14.36							15.40°		0.0696
		"	"	"	10.99							15.46°		0.0910
		"	"	"	8.56							15.40°		0.1168
		"	"	"	59.77							"		0.0167
5/23	19004	24° ROLL	ROLL VS. RESOLVER	X	51.00							44.92°		0.0196
		"	"	"	29.18							"		0.0343
		"	"	"	19.71							"		0.0507
		"	"	"	14.38							"		0.0695
		"	"	"	11.01							"		0.0908
		"	"	"	8.60							"		0.1163
		"	"	"	6.77							45.16°		0.1477
		"	"	"	59.57							45.04°		0.0168
5/27	19006	24° PITCH	PITCH VS. RESOLVER	X	22.38								45.29°	0.0447
		"	"	"	12.70								"	0.0787
5/28	19006	24° PITCH	PITCH VS. RESOLVER	DIGITAL HEAVE VS. RESOLVER	51.60			0.015	----				45.16°	0.0194
		"	"	"	28.25			1.015	0.0				45.29°	0.0354
		"	"	"	19.64			1.000	0.0				"	0.0509
		"	"	"	14.52			0.986	0.0				"	0.0689

Table 1 (cont). WBTF Tests

DATE	UNIT	SETUP	RECORD I	RECORD II	PERIOD SEC	ANALOG HEAVE		DIGITAL HEAVE		ERROR		ROLL	PITCH	FREQ (H_Z)
						A	ϕ	A	77.2 + ΔSEC	A	77.2 + ΔSEC			
5/28	19006	24° PITCH	DIG. PITCH VS. RESOLVER	HEAVE VS. RESOLVER	11.04			0.990	----				45.29°	0.0906
		"	"	"	8.63			0.976	0.0				45.41°	0.1159
		"	"	"	6.70			0.990	0.0				45.29°	0.1493
		"	"	"	7.67			0.980	----				"	0.1304
		"	"	"	9.91			0.994	0.0				"	0.1009
		"	"	"	12.83			0.992	0.0				"	0.0779
		"	"	"	16.87			1.011	----				"	0.0593
		"	"	"	23.21			1.015	----				"	0.0431
		"	"	"	37.53			0.476	0.0				----	0.0266
		"	"	"	61.40			0.010	----				----	0.0163
		"	"	"	57.66			0.014	----				45.29°	0.0173
		"	"	"	45.00			0.085	0.0				"	0.0222
		8° PITCH	"	ANALOG HEAVE VS. RESOLVER	52.40	1.469	149.0°						15.40°	0.0191
		"	"	"	36.40	4.008	98.0°						"	0.0275
		"	"	"	26.62	6.037	30.0°						15.44°	0.0349
		"	"	"	23.49	3.436	-36.4°						"	0.0426
		"	"	"	19.78	1.162	-43.2°						"	0.0506
		"	"	"	16.99	0.861	-12.7°						"	0.0589
		"	"	"	14.4	0.939	0.0°						15.38°	0.0694
		"	"	"	11.12	0.990	"						15.40°	0.0899
		"	"	"	8.61	0.996	"						"	0.1161
		"	"	"	6.80	"	"						15.52°	0.1471
		0° PITCH	"	ERROR VS. RESOLVER	49.77					0.632	----		0.22°	0.0201
5/29	19006	0° PITCH	PITCH VS. RESOLVER	"	51.30					0.587	10.8		0.20°	0.0195
		"	"	"	28.80					0.438	8.4		"	0.0347
		"	"	"	19.39					0.020	7.2		0.23°	0.0516
		"	"	"	14.40					0	----		0.20°	0.0694
		"	"	"	11.0					"	----		0.18°	0.0909
		"	"	"	8.64					"	----		0.25°	0.1157
		"	"	"	6.80					"	----		0.30°	0.1471
		"	"	"	37.20					0.956	8.4		0.23°	0.0269
		"	"	"	45.60					0.796	8.4		0.20°	0.0219
		"	"	"	60.52					0.328	9.0		0.18°	0.0165
		"	"	"	61.20					0.314	"		"	0.0163
		"	"	"	57.60					0.309	9.6		0.20°	0.0174
		12° @ 45°	PITCH VS. ROLL	X	53.40							16.50°	16.50°	0.0187
		"	"	"	29.40							"	16.51°	0.0340
		"	"	"	19.80							"	"	0.0505
		"	"	"	14.60							"	"	0.0685
		"	"	"	11.20							"	"	0.0893
		"	"	"	8.70							"	"	0.1149
		"	"	"	6.70							16.54°	16.51°	0.1493

Table 1 (cont). WBTF Tests

DATE	UNIT	SETUP	RECORD I	RECORD II	PERIOD SEC	ANALOG HEAVE		DIGITAL HEAVE		ERROR		ROLL	PITCH	FREQ (H_Z)
						A	ϕ	A	77.2 + ΔSEC	A	77.2 + ΔSEC			
6/3	19006	12° ROLL	DIGITAL HEAVE VS. RESOLVER	X	----	----	----	----	----					----
		"	"	ANALOG HEAVE VS. RESOLVER	45.11	----	134.1	0.960	0.0					0.0222
		"	"	"	42.37	2.61	----	0.176	"					0.0236
		"	"	"	39.05	3.31	110.6	0.344	"					0.0256
		"	"	"	36.37	3.98	95.0	0.520	"					0.0275
		"	"	"	34.50	4.54	81.4	0.683	"					0.0290
		"	"	"	31.57	5.46	57.5	0.896	"					0.0317
		"	"	"	29.40	5.89	41.1	1.004	"					0.0340
		"	"	"	26.78	5.61	3.2	1.030	"					0.0373
		"	"	"	25.40	5.06	-8.5	1.012	"					0.0394
		"	"	"	23.40	3.31	-36.9	1.006	"					0.0427
		"	"	"	20.00	1.18	-44.6	1.006	"					0.0500
			ROLL VS. RESOLVER	X	50.40							23.30°		0.0198
		"	"	"	28.87							"		0.0346
		"	"	"	19.90							"		0.0503
		"	"	"	14.50							"		0.0691
		"	"	"	11.00							23.21°		0.0909
		"	"	"	8.60							23.42°		0.1168
		"	"	"	6.72							23.48°		0.1488
		"	"	"	60.95							23.26°		0.0164

Table 1 (cont). WBTF Tests

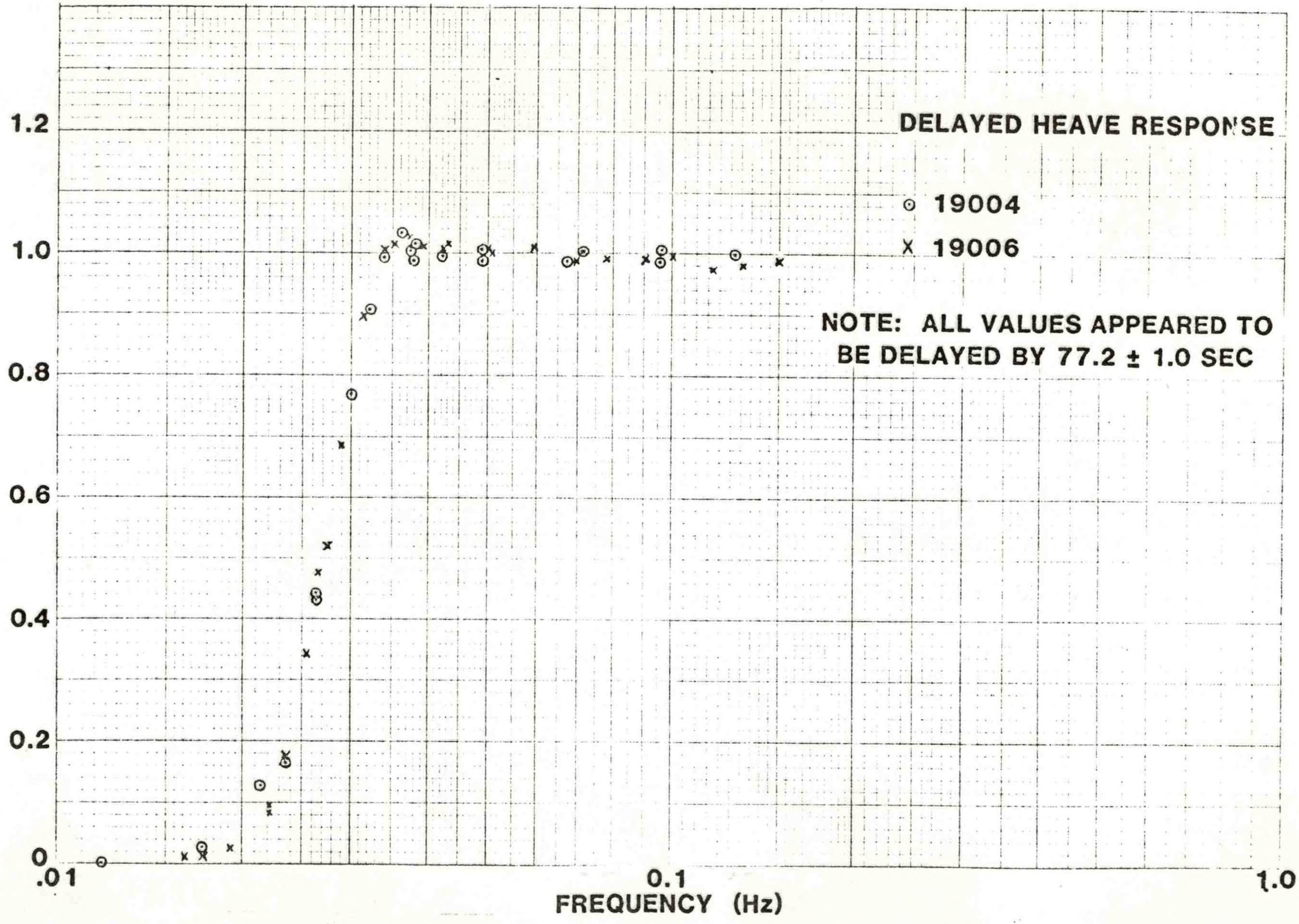


Figure 2. Delayed Heave Response

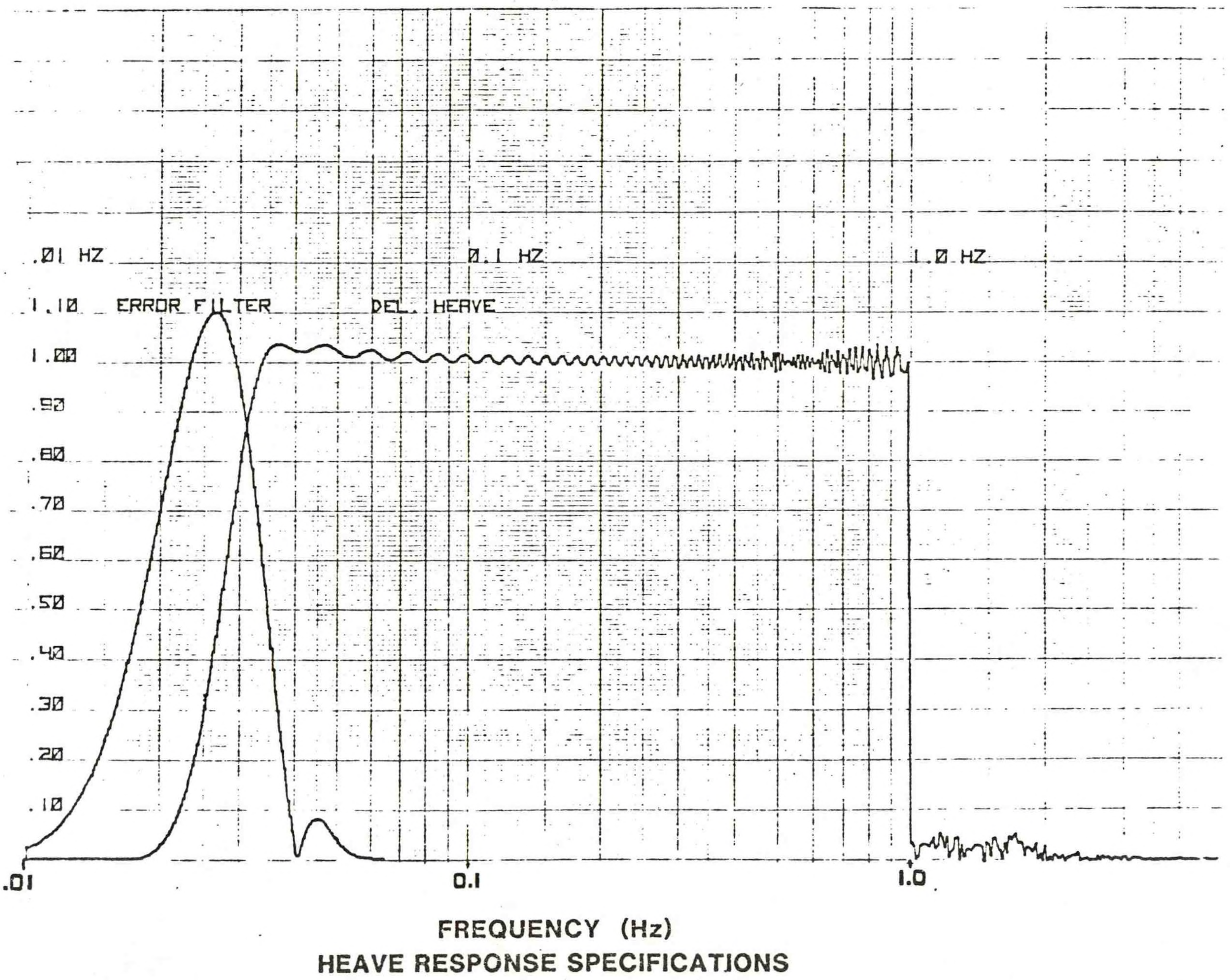


Figure 3. Heave Response Specifications

The observed frequency response of the error output is shown in Figure 4. The peak of this response is 0.95 whereas the response specified by Datawell peaks at 1.1. The shape of the response curve agrees with that supplied by Datawell. The delay between the actual motion and the error output was approximately nine seconds longer than the 77.2 seconds indicated in the Datawell manual. Gerritzen (1980) has indicated that this observation is indeed correct. The additional delay is incurred in a software anti-aliasing filter. The correct value for total delay should be 84.96 seconds plus zero to 80 milliseconds. The WBTF measurements indicated the delay was approximately 81 seconds. The response functions of the two instruments tested appear to be identical.

The real time heave frequency response data are plotted in Figure 5. The amplitude function is in agreement with the response described in Datawell's manual. No phase response is given in Datawell's manual. The error vector (that is, the amplitude of the output heave minus true heave) is specified to be less than 3.5 percent, between 0.067 Hz, and 1.0 Hz. For sinusoidal motions, the rms error is given by:

$$E = \frac{(1 - R\cos\phi)}{\sqrt{2}} + \frac{R\sin\phi}{\sqrt{2}}$$

where:

R = amplitude response

ϕ = phase function

The data indicates that the rms error was up to sevent percent in the 0.067 Hz to 1.0 Hz frequency range. The data also shows some difference between the two units tested. Within the 0.067 Hz to 1.0 Hz working frequency range, serial number 19006 shows small error except at the low frequency end. Serial number 19004 shows a constant error due to low amplitude response throughout the working frequency range. The behavior below the working frequency range changes dramatically. The amplitude response rises to a peak of 6 times the actual heave with motions of about 30 seconds period. This is in general agreement with the specifications and is a consequence of controlling the phase response in the working frequency range.

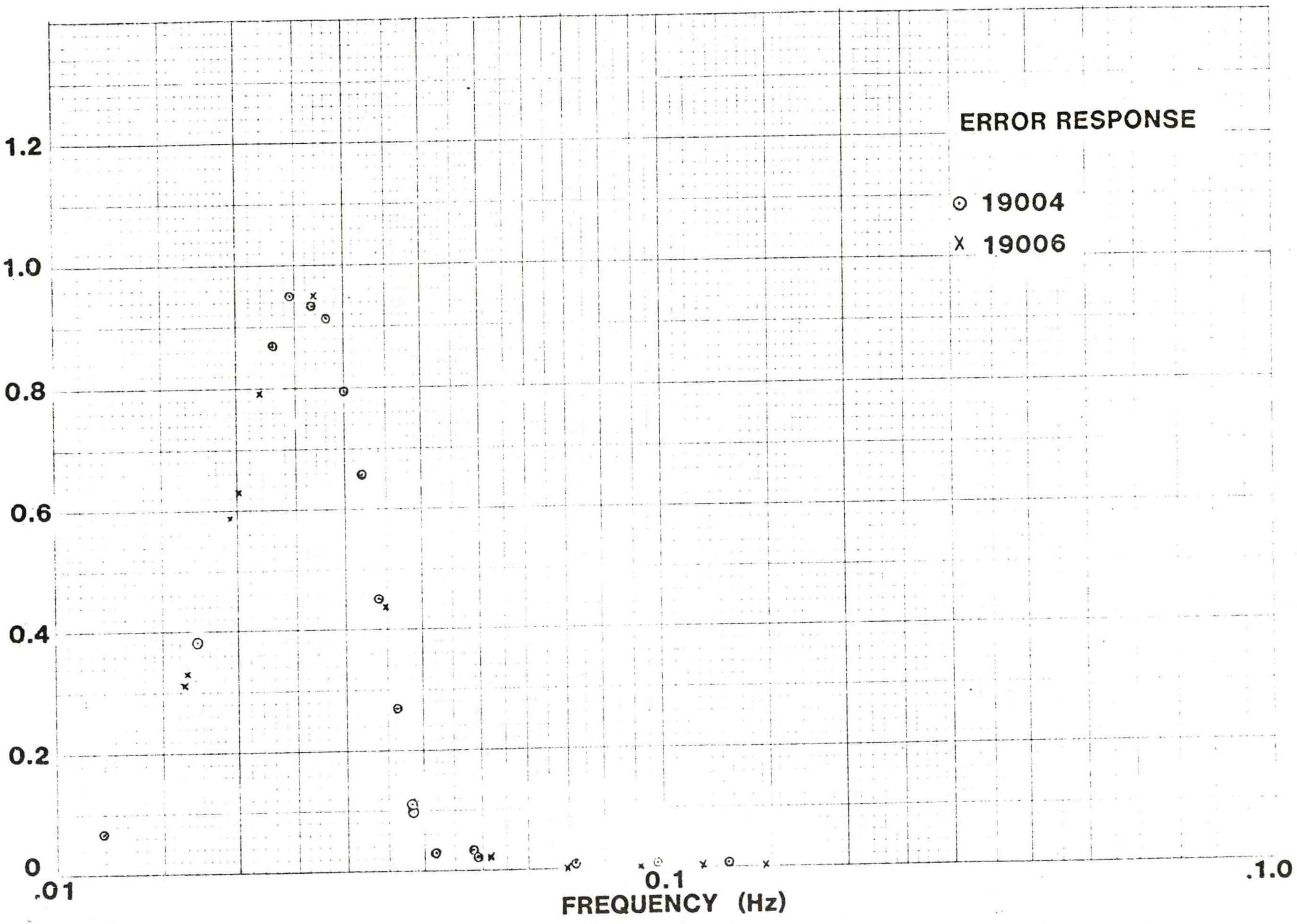


Figure 4. Error Response

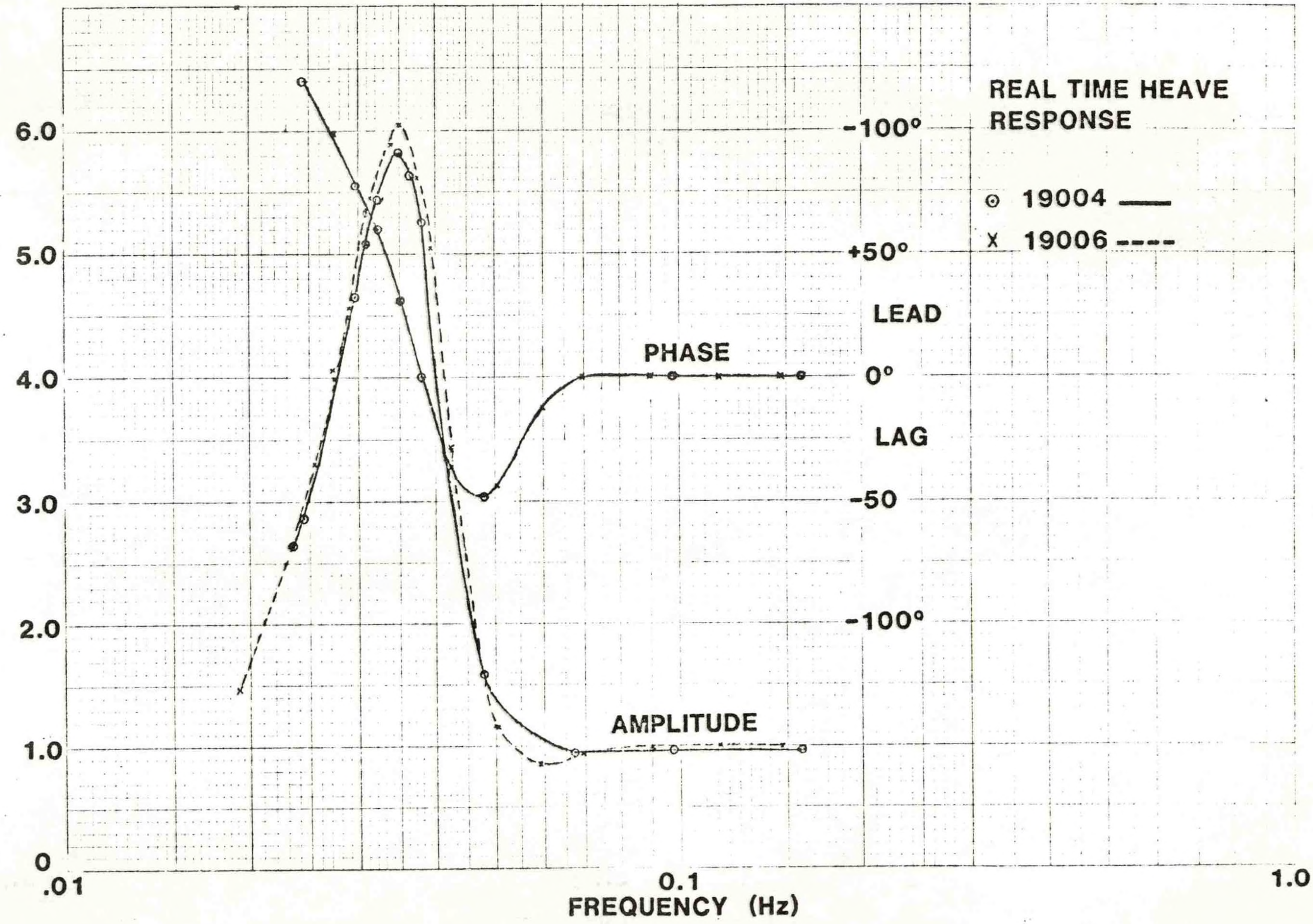


Figure 5. Real Time Heave Response

The roll and pitch outputs agreed with level measurements of static tilt within 0.1 degrees. In dynamic tests, the peak outputs agreed with the static measurements within one or two percent accuracy limitations of the test equipment except at the highest frequencies measured. At these short periods, the motion appeared to increase in amplitude by from 0.2 to 0.5 degrees peak-to-peak. This is likely to be a real increase in motion due to inertial effects on the mounting frame. The static measurements deviated from the programmed tilt by several degrees as shown in Figure 6. Considerable effort was devoted to tuning the linkage to make the actual tilt conform more closely. The differences were reduced but the relationship to the recorded resolver indication of beam angle was never close enough to be useful in judging the accuracy of the HIPPY. The tests did show that the HIPPY reported the same values statically as dynamically and that these values were correct within the test accuracy. Furthermore, any variation in roll and pitch response versus frequency was less than two percent.

Heave, roll, and pitch waveforms appeared to be sinusoidal once steady state was achieved. One exception was some high frequency motion superimposed on the roll and pitch signals when testing near periods of 20 seconds. This was found to be due to a resonance vibration of the mounting frame. The other distortion was the quantization in ten millivolts steps of all the analog outputs.

B. Static Tests

Static tests were designed to check the zero offset of the roll and pitch outputs. Static measurements made at the Wave Buoy Test Facility covered much of the range of the roll and pitch outputs but were limited in accuracy to one or two tenths of a degree. Separate tests checked only the zero tilt outputs but were done within accuarcy of 0.01 degrees or better.

The HIPPY was installed on a leveling table. Prior to installation, the mounting surface was adjusted to level within 0.005 degrees with a Master Precision Level (Starett No. 199). Once installed, the HIPPY could be rotated azimuthally. The outputs were monitored at several different points of rotation. Sufficient time was allowed for all transient effects to

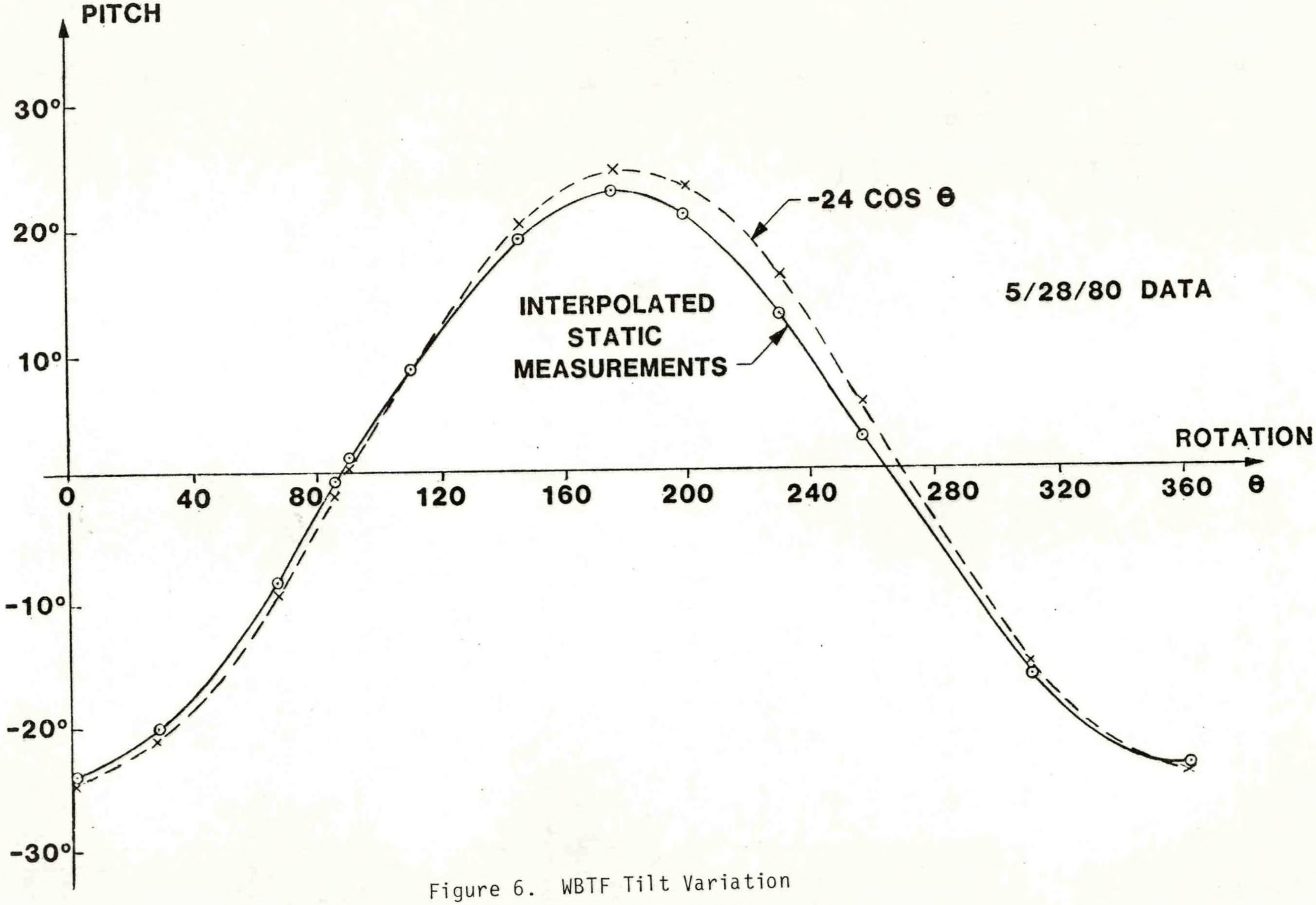


Figure 6. WBTF Tilt Variation

stabilize. Two units were tested in this way. In neither case did the digital outputs ever exceed 0.1 degrees. The analog outputs were generally within 20 millivolts (or two quantization steps) of zero.

The Datawell specifications allow the zero offset of roll and pitch to be up to 0.5 degrees over the temperature range of zero degrees to 35 degrees C. The zero stability with time over one year is specified only to be within one degree. Tests performed on the production instruments show no problems with zero offset. As tested, the units are within 0.1 degrees.

6. FIELD TESTS

A. Van Tests

Van tests were designed to subject the HIPPY to horizontal accelerations. Such accelerations, particularly those resulting from ship manuevers, could be a major error source in normal operation with the HIPPY. The van offered a greater degree of control than would be possible aboard ship. Some of the van manuevers were more extreme than ship manuevers would be. By relating the outputs to predictions based on physical principles, it was hoped to extrapolate results from the van test to realistic conditions which might be encountered aboard ship.

Horizontal accelerations affect the HIPPY output because they disturb the pendulum. Much of the following analyses follows Rademakers (1979, 1980). The equation of motion for a pendulum subjected to horizontal acceleration is:

$$\frac{d^2\theta}{dt^2} + F_s \frac{d\theta}{dt} + \omega_o{}^2 \sin\theta = -\omega_o{}^2 \frac{A_x}{g}$$

where:

θ = angle of pendulum from vertical
F_s = damping coefficient
$\omega_o = \frac{2\pi}{T_o}$ = natural frequency of pendulum
A_x = horizontal acceleration
g = gravitational acceleration

This can be written as a transfer function by linearizing about small θ and using Laplace operator notation:

$$\frac{\theta}{A_x} = \frac{-\omega_o^2/g}{s^2 + Fs + \omega_o^2}$$

For a steady state (zero frequency), horizontal acceleration:

$$\theta = \frac{A_x}{g} \sim \frac{A_x}{10} \text{ where } A_x \text{ is in meters/sec}^2.$$

A sudden change in velocity will approximate an impluse of acceleration. The response will be a damped sinusoid which for near critical damping will have a peak of:

$$\theta = \frac{\omega_o \ \Delta V}{g} \sim \frac{\Delta V}{180}$$

where ΔV is in meters/second assuming $T_o = 120$ seconds. A sudden change in displacement will produce:

$$\theta = \frac{\omega_o^2 \ \Delta S}{g} \sim \frac{\Delta S}{3600} \text{ where } \Delta S \text{ is in meters.}$$

(Note that 3600 meters is the equivalent length of the pendulum.)

The pendulum angle caused by horizontal accelerations is indistinguishable from inclination due to roll or pitch and thus these outputs show directly the disturbance to the pendulum.

When the pendulum is displaced from the vertical, a false acceleration is sensed. This is due to two effects. First, the component of gravity measured is reduced and, second, a component of the horizontal acceleration is picked up while some of the actual vertical acceleration is lost. If the vertical acceleration is small this false acceleration is approximately:

$$A_f \sim A_x \sin\theta + g\,(1 - \cos\phi) \sim A_x\,\theta + \frac{1}{2}\,g\,\theta^2$$

The heave output produced by this false acceleration depends on the transfer function of the filter used to compute heave. According to information supplied by Datawell, a step function of 1 m/sec^2 at the input to the analog filter will produce a heave output with a peak of about 75 meters. The same input applied to the digital filter will result in a peak heave signal of about four meters.

In the case of a rapid turn around such as at the end of a survey line, these relationships indicate:

$$A_f \sim A_x\,\theta + \frac{1}{2}\,g\,\theta^2 = -\,\omega_o\,\Delta V\,\left(\frac{\omega_o\,\Delta V}{g}\right) + \frac{1}{2}\,g\,\left(\frac{\omega_o\,\Delta V}{g}\right)^2$$

$$A_f \sim \frac{1}{2}\,\frac{\omega_o^{\,2}\,\Delta V^2}{g} = \frac{\Delta V^2}{7200}$$

For a turn around $\Delta V = 2v$ where v is the ship speed. This impulse applied to the analog filter will produce a false output of $4v^2$ centimeters where v is in meters/sec. The false output of the digital filter will be $0.22v^2$ centimeters. These are the Datawell specifications for "turn around false output".

The van tests sought to produce data to compare to this physical model. Tests were run at two abandoned airstrips. These were large enough to perform the desired manuevers and were very close to being flat so that outputs due to the horizontal accelerations should be dominant. Table 2 lists the tests conducted.

The first set of tests subjected the HIPPY to sudden displacement. The van was accelerated sharply from a stop to a speed of about 30 miles per hour then sharply deccelerated to a stop so as to cover a total of 1000 feet. The procedure took about 33 seconds to complete. Figure 7 is a copy of a strip chart record of one such test. A sudden displacement of 1000 feet should produce a pendulum angle of:

$$\Theta = \frac{\Delta S}{3600} = \left(\frac{1000/3.28}{3600}\right) = 0.0847 \text{ radians} = 4.85^{0}$$

The disturbance should be registered as pitch and the sign should be negative since the effect would be to appear to raise the "bow" or the front of the van. The chart shows the pitch swings negatively by about two degrees. The discrepency between predicted 4.85 degrees and observed two degrees might be explained by the fact that 33 seconds is not short by comparison to the 120 seconds natural frequency. The effect of a less-than-sudden displacement is approximated by:

$$\theta = \frac{\Delta S}{3600} \frac{\sin \omega_0 T}{3600} \quad \text{where T is the duration of the displacement}$$

For this case this would predict a pitch of 2.77 degrees. After stopping the observed period of oscillation in the pitch signal was 145 seconds. Since:

$$T_0 = 2\pi \left(\frac{L}{G}\right)^{1/2}$$

this implies the equivalent pendulum length, L, was 5326 meters instead of 3600 as used in the previous calculations. If this were so, the predicted pendulum angle for a sudden displacement of 1000 feet would be 3.28 degrees.

	RIVERDALE			BELTSVILLE
UNIT S/N	0-30 mph-0 1000 ft.	0-30 mph-0 +180° turn 1000 ft	10,-10 1000 ft forward & reverse	 200 ft diameter
19004	8/20 #1-4 #11:0-25-0 with fast acceleration	8/20 #5-6	8/20 #7-8	8/21 #1 4 turns 10 mph #2 " " 5 mph #3 " " 15 mph #4 " " 10 mph
19006	8/19 #1-4	8/19 #5-6 #9: 0-25-0 + 180°	8/19 #7-8	8/19 #12 4 turns 5 mph #13 " " 10 mph #14 " " 15 mph #15 " " 15 mph
19007	4/11 #1-2 4/3 #3-5 40 paces ~ 120 ft			4/7 #1 6 turns 7 mph

TABLE 2: VAN TESTS

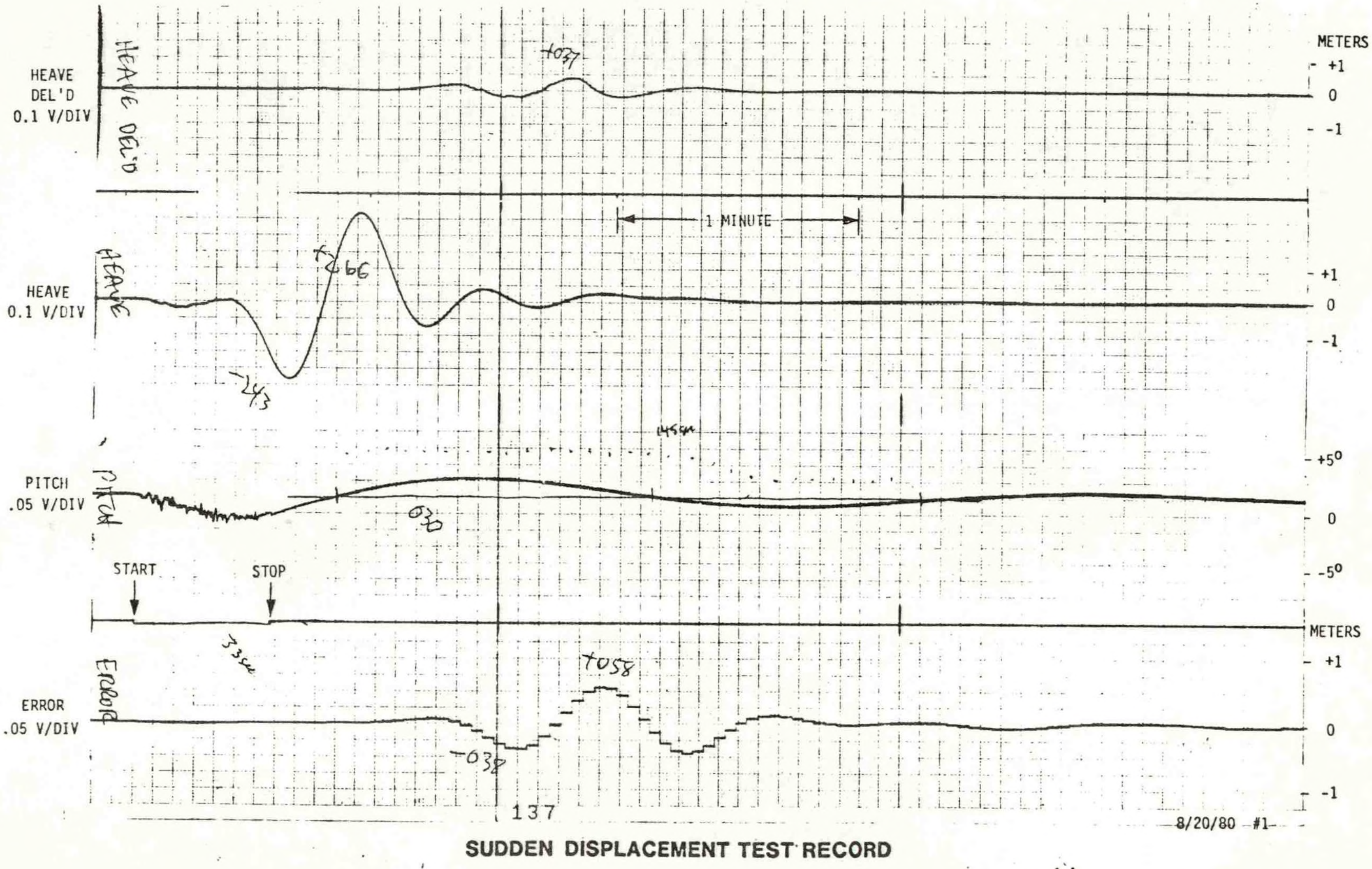


Figure 7.--Sudden Displacement Test Record

Considering the duration of the displacement, the predicted pendulum angle would be 1.87 degrees. The amplitudes of successive peaks of the pitch oscillation were six, three, two, and 1.5 degrees. This implies a damping factor of 0.015 or a damping ratio of 0.175 which is underdamped.

The heave output from this sudden displacement test should be due to a false acceleration of:

$$A_f = A_x \theta + \frac{1}{2} g \theta^2$$

For $\theta = 2$ degrees, the second term is .006 m/sec^2. Assuming uniform acceleration over ten seconds from zero to 30 miles per hour and $\theta = 2$ degrees, the first term becomes 0.047 m/sec and is dominant. The chart shows a time history consistent with being caused by the acceleration and deceleration rather than a change in gravitational acceleration. If the acceleration is assumed to be an impulse the response of the analog heave should be 3.51 meters. A response of 2.66 meters was observed. The digital heave would be expected to show 0.19 meters but actually showed 0.37 meters. Again, the less than sudden nature of the displacement has yielded an actual output slightly different from the predicted case of a sudden step.

A second series of tests repeated the sudden displacement tests but included a 180 degrees turn immediately before the final stop. Figure 8 is a copy of a strip chart record of one of these runs. As expected, the record is very similar to that produced in the first series of tests. The major difference is that the oscillation in pitch after the stop is reversed in sign by the 180 degrees turn. The oscillation is almost entirely damped out before it returns to the pitch plane. What has happened here is that the pendulum has been disturbed by the sudden displacement producing a "platform offset". The 180 degrees turn puts a twist on the suspension of the pendulum. As the suspension untwists, the "platform offset" moves from the pitch to the roll output and finally back to the pitch output. The unwinding appears to take more than nine minutes.

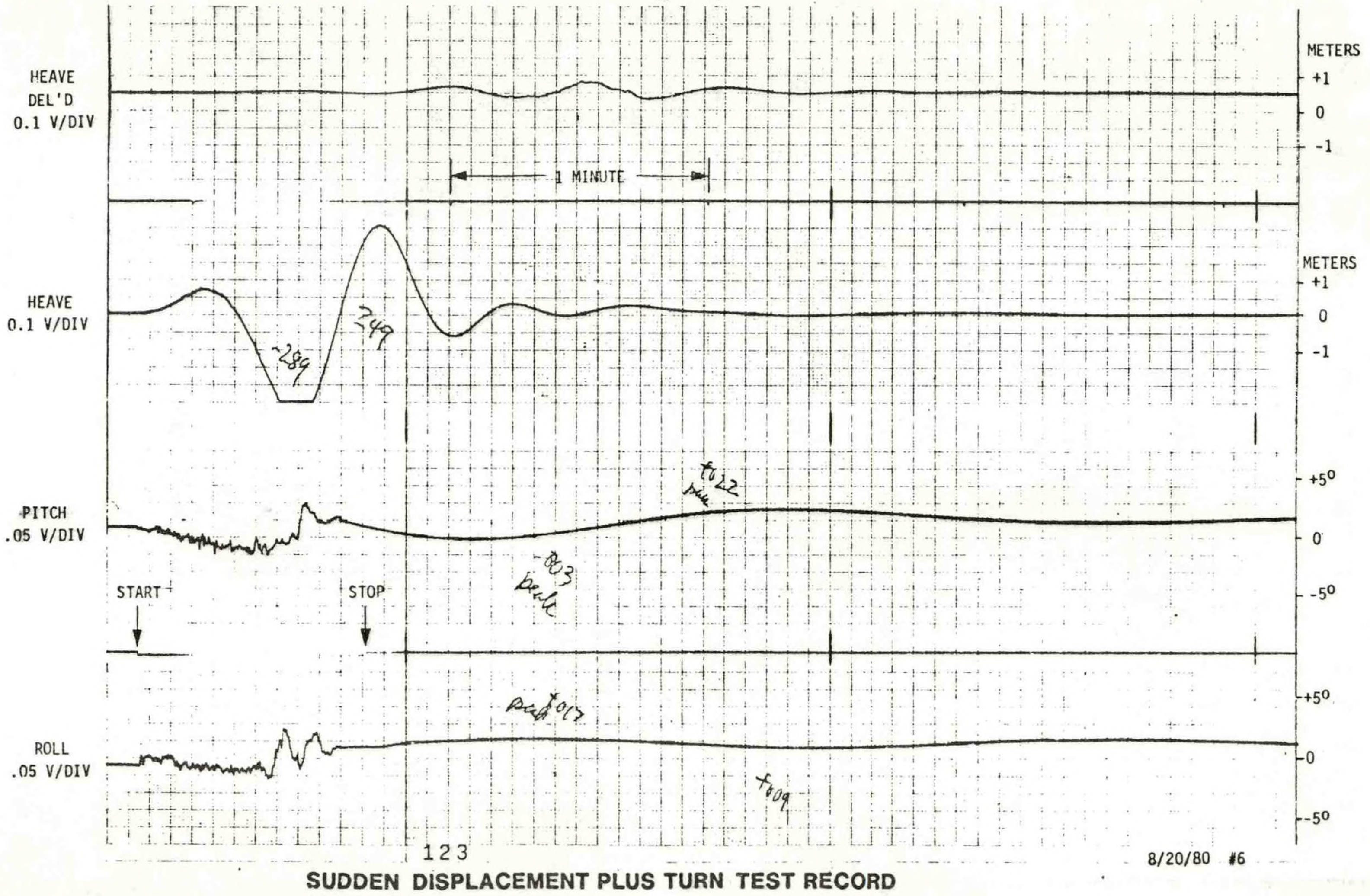


Figure 8. Sudden Displacment Plus Turn Test Record

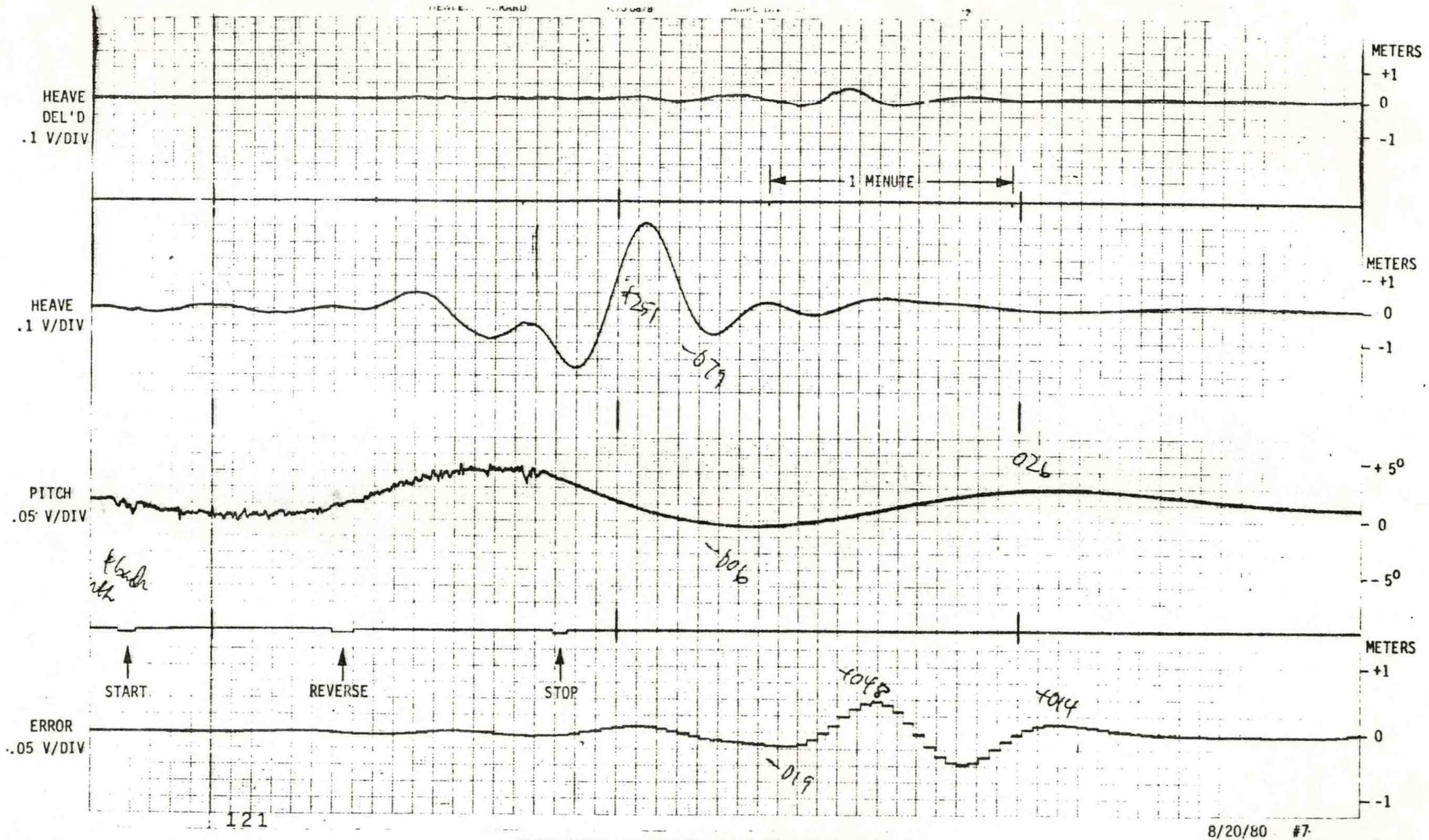
A third series of tests were designed to determine the effect of a sudden change in velocity. The van was accelerated from a stop to ten miles per hour. It was stopped after a distance of 1000 feet and immediately put into reverse and backed up the same distance and stopped. A strip chart record of one such run is shown in Figure 9. The predicted pitch output is:

$$\theta = \frac{\Delta V}{180} = \frac{9.1\ \text{m/sec}}{180} = 0.51\ \text{radians} = 2.9^{0}$$

The record shows a deviation of just about 2.9 degrees from the initial position in pitch. In reality, however, the situation is complicated by the transients of initial start up and final stopping. The time between these events is too short to separate them neatly. The available space at the air strip did not permit a longer time between the initial start-up and final stopping. The period of oscillation after the test was again observed to be about 145 seconds.

The last series of tests in the van were designed to examine the effects of centripetal forces in the horizontal plane. If centripetal effects are large, then the performance of the HIPPY might be very sensitive to its location relative to the center of motion of the ship on which it is installed. If not, there might be some greater latitude to install it in a more convenient location.

Centripetal forces in the vertical plane were encountered in the tests at the WBTF. The effect was not large. The outputs were essentially as expected for pure heave, roll, and pitch motions. Tests in the van involved motions in the horizontal plane at a larger distance from the center of motion. A 200 foot diameter circle was laid out on nearly flat ground. Figure 10 is a record of the response when four complete turns were made around this circle at approximately 15 mph. (Note that Datawell cautions against anymore than six revolutions in two minutes for fear of damaging the platform suspension). Prior to running this test, static measurements were made by stopping at four points of the circle. These showed a slight slope to the area which caused the roll output to change form +0.3 degrees at the start to



FOREWARD/REVERSE TEST RECORD

Figure 9. Foreward/Reverse Test Record

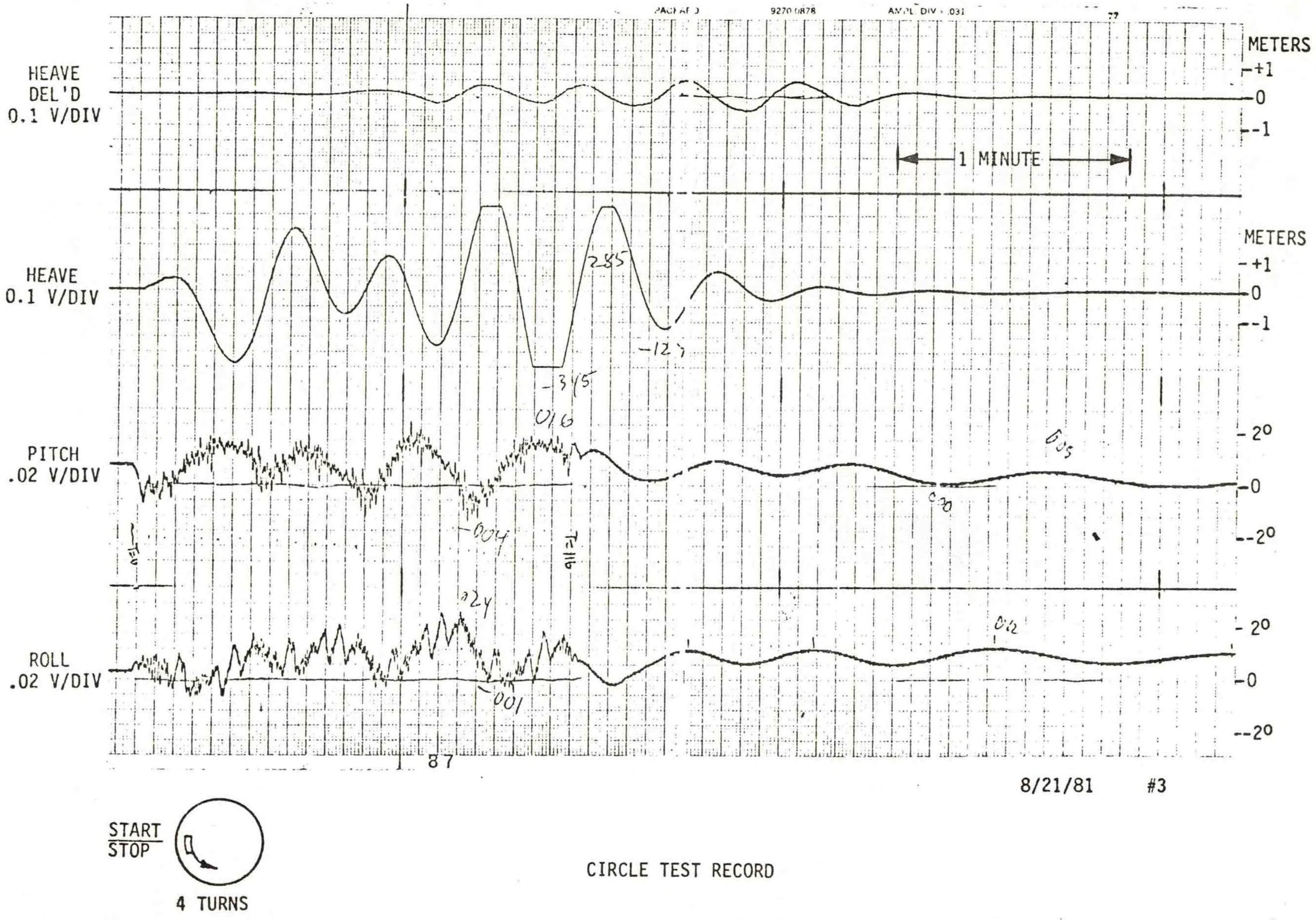


Figure 10. Circle Test Record

-0.3 degrees across the circle. The pitch varied in a similar way with a phase shift of roughly 90 degrees. This is the major cause of the pitch signal recorded in Figure 10. The roll signal is less distinct. It is biased positively by centripetal force on the van which causes it to tilt. The terrain effect is still present but it is obscured by "noise" which is not as effectively removed by the vehicle suspension as in the pitch direction. These seem to explain the major observed features of the roll and pitch outputs. They are real effects and involve no false accelerations. The heave outputs, however, show that false accelerations were generated. The form of the false accelerations is most easily understood by resolving the circular motion into two periodic components perpendicular and out of phase with each other. These displacements have a period of about 29 seconds and thus are only partly stabilized by the pendulum. The resulting platform offset causes periodic false accelerations and the heave outputs reflect this. The magnitude of the platform offset must be approximately the same as in the previous tests discussed judging from the first peaks of the heave outputs. Without precise instrumentation on the van a quantitative explanation of the outputs is not possbile.

B. Ship Tests

Ship tests were the final stage of the effort to characterize the performance of the HIPPY as a motion sensing device for use in correcting hydrographic data. These tests provided an opportunity to observe the performance of the HIPPY in a realistic operating environment. Of particular interest were questions of how sea conditions, heading, speed, and ship manuevers would affect its operation.

The approach was to select an area with a flat sea floor and conduct the tests under moderate to large wave conditions. The deviation of corrected soundings from the expected flat profile could then be interpreted as a measure of performance of the HIPPY. Repeatability of corrected depth profiles over preset courses provided an alternative means of assessing the results. Both measures are of course corrupted by actual bottom irregularities and depth sounder inaccuracies. Consequently these tests provide only an upper bound on the errors produced by the HIPPY. With moderate to large vessel motion this upper bound can more correctly be interpreted as actual errors.

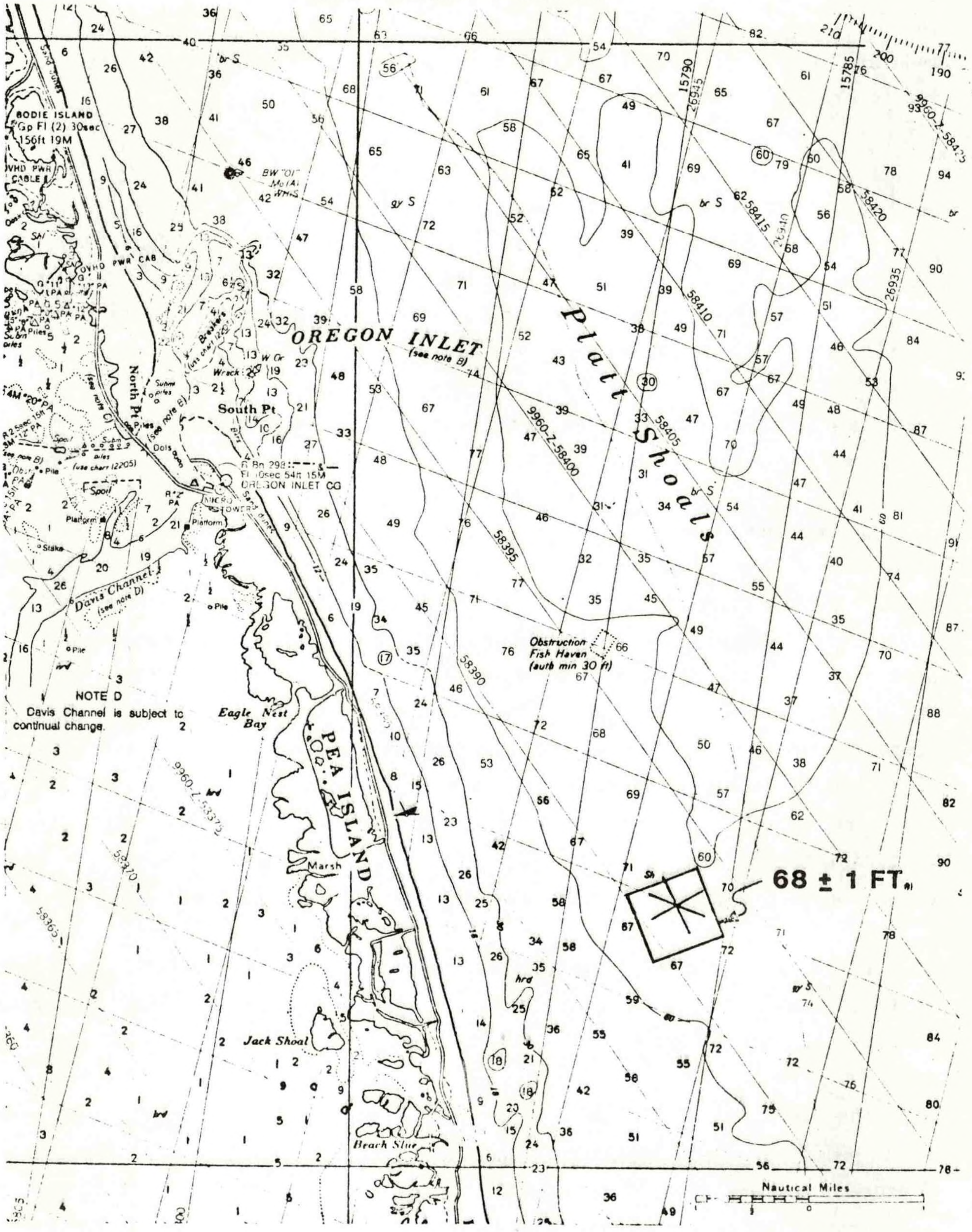
The site selected for these tests was just south of Oregon Inlet off Cape Hatteras, North Carolina. The location is plotted on the nautical chart in Figure 11. The area was last surveyed by NOS in July and August of 1970 (NOS hydrographic survey no. 9137). Inspection of the smooth sheet produced by this survey shows that the variation in depth over the one square mile site is not more than plus or minus one foot. The average depth at mean low water is 68 feet. Figure 12 is a copy of the depth sounder record made over the test site on 13 November 1980 when seas were unusually calm. This record shows few deviations exceeding one foot.

Courses over the test site were marked with a set of 6 buoys as shown in Figure 13. The buoys marked the beginning and end of one half mile long runs. The location of the buoys was chosen so that the orientation of one course would be with or against the waves, a second course would experience beam seas, and the third a combination. The buoys were set in position using LORAN coordinates. The buoys were anchored with railroad wheels. A short scope mooring was used to reduce the movement of the buoys. The buoys were 28 inches in diameter and each carried a 5 foot mast with a flashing light and day mark flag. Despite the effort to make the buoys recognizable, the destination buoy was, at times, not visible at the start of runs. In those cases a magnetic course was steered until the buoy was spotted.

The HIPPY field tests were conducted aboard the M/V LAIDLY. This is a 55 foot vessel with a 14 foot beam. It is equipped with a Ross Automated Hydrographic Survey System.

The HIPPY was installed near the center of motion of the LAIDLY as shown in Figure 14. This location is nearly directly over the Ross transducer. Measurements were made of the exact alignment for use in the depth correction algorithm. The center of the transducer was 15.5 inches forward of the center of the HIPPY sensor and the face of the transducer element was 25.4 inches below the HIPPY sensor. (This includes 11.4 inches which is the distance of the HIPPY sensor above its base according to information supplied by

NOS CHART #12204



TEST SITE

Figure 11. Test Site

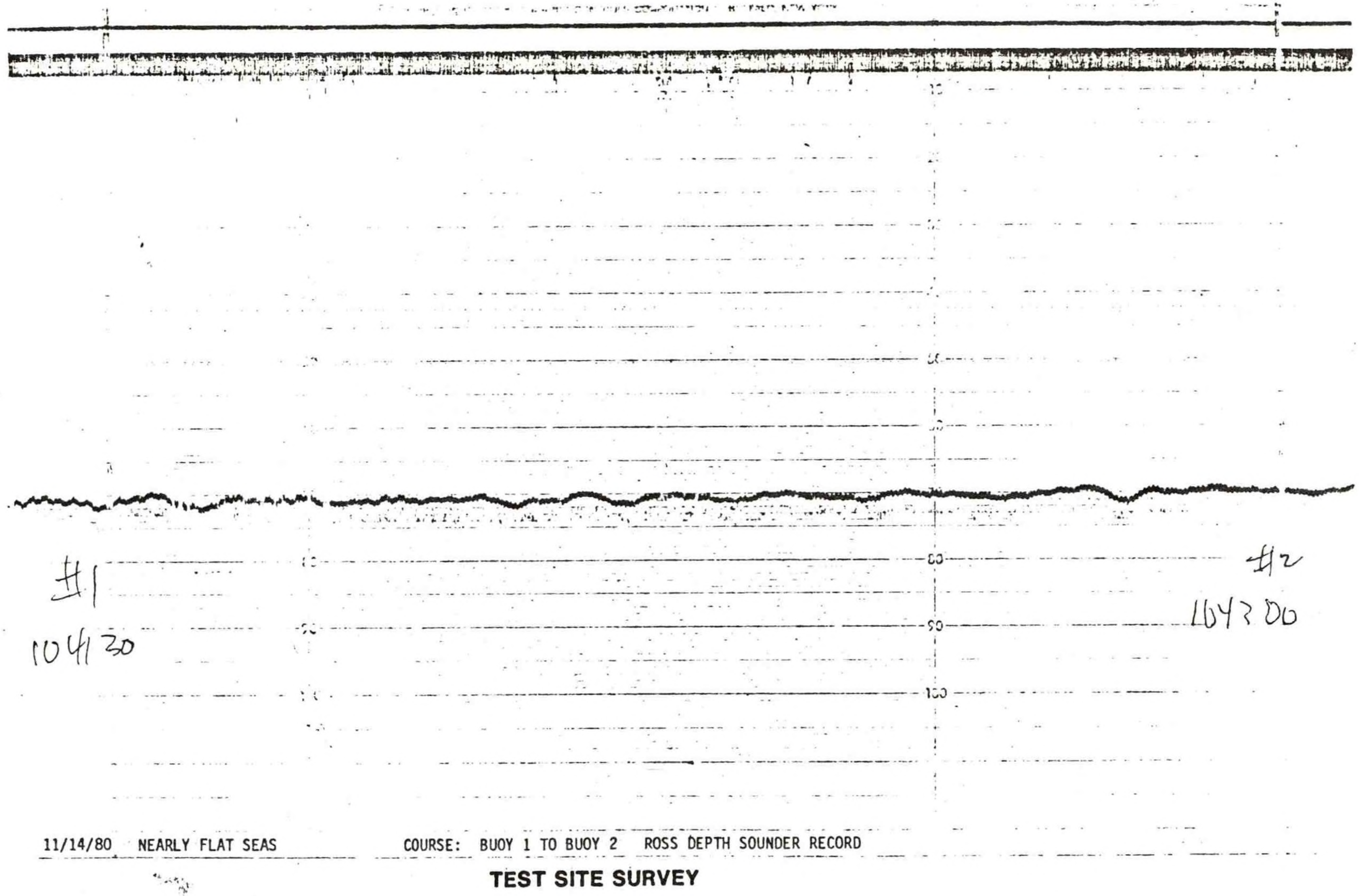


Figure 12. Test Site Survey

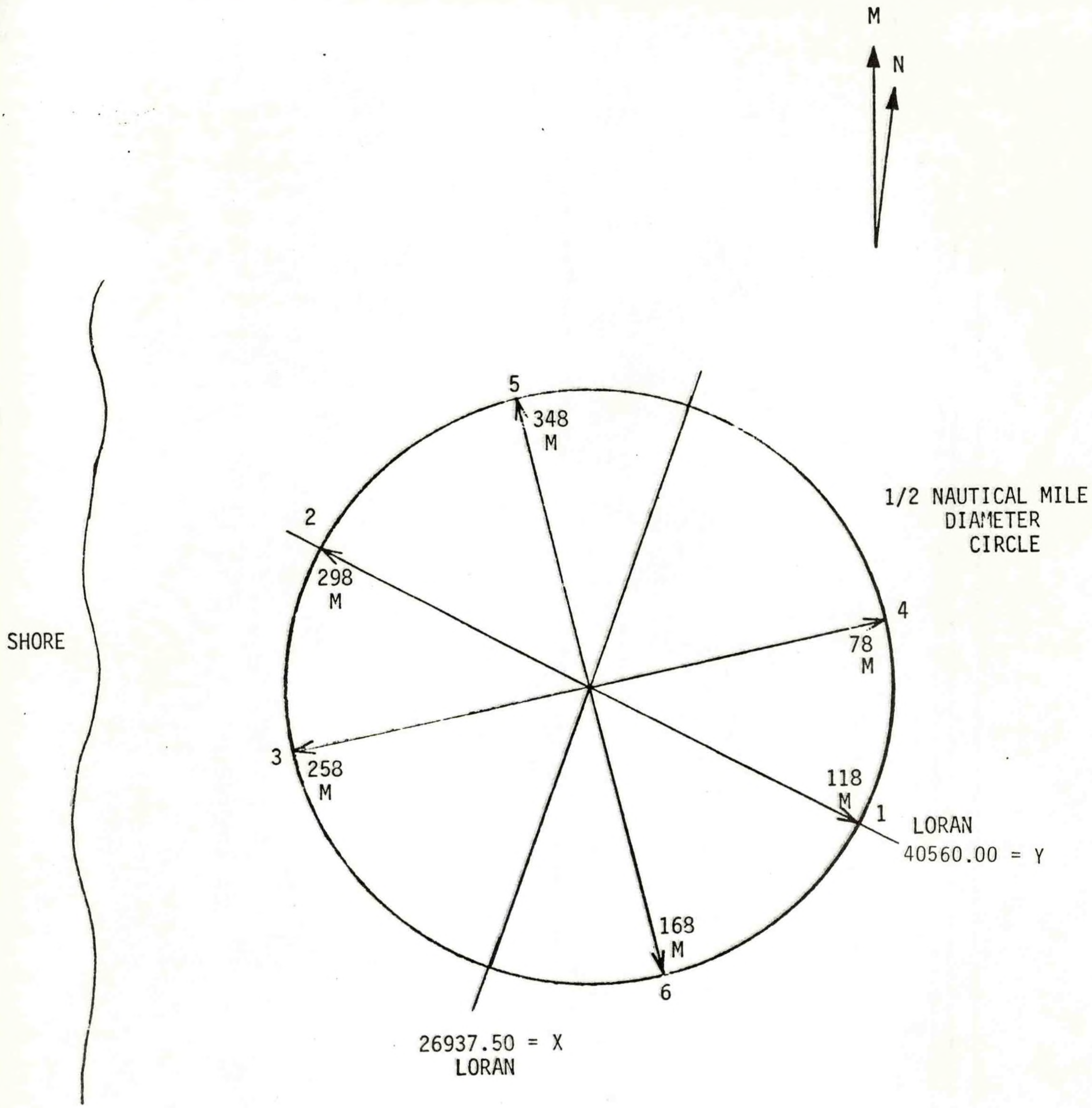


Figure 13. Buoy Locations

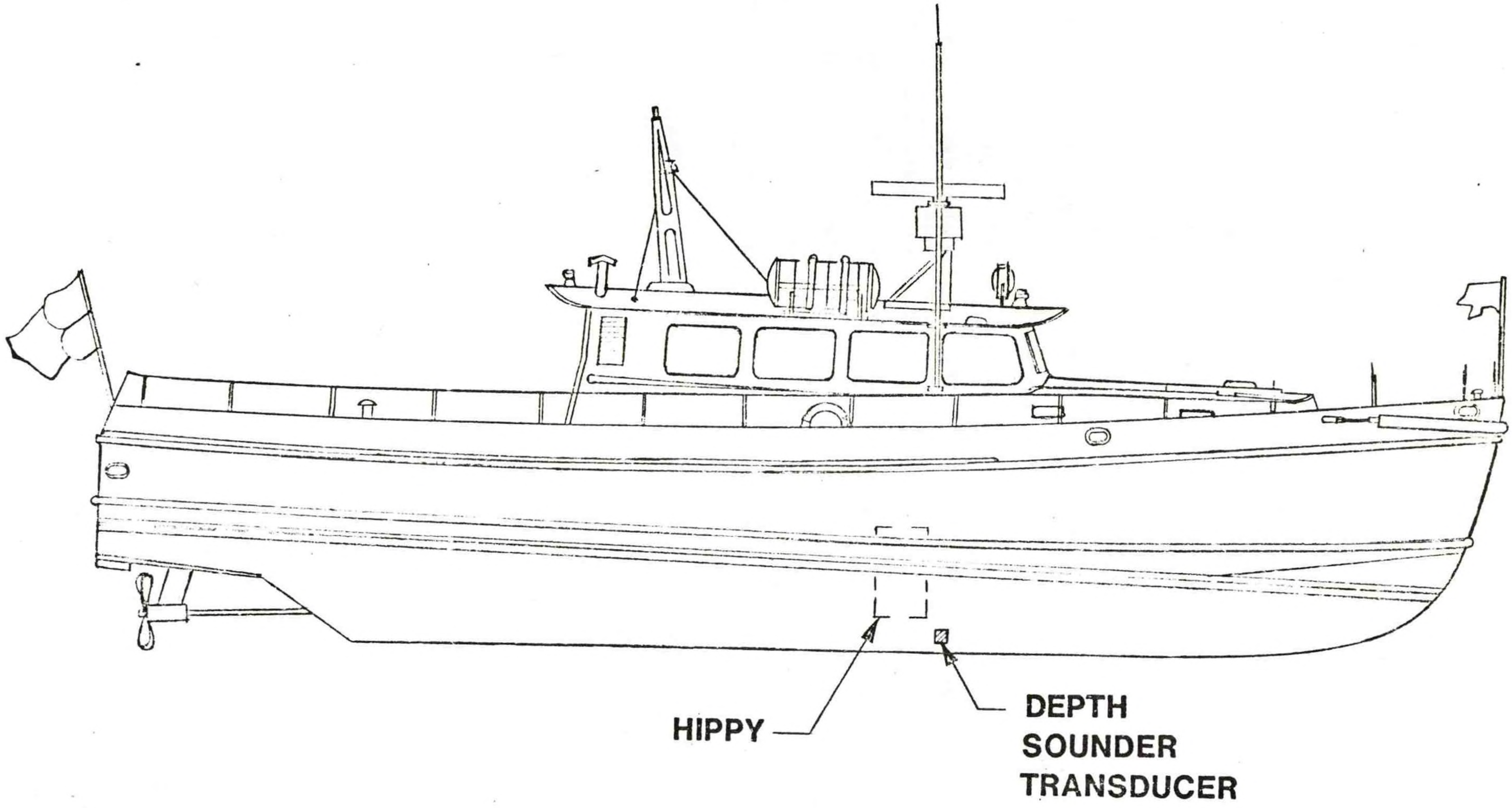


Figure 14. LAIDLY Installation

Datawell). The pointing angle of the transducer with respect to the HIPPY base plate was 2.2 degrees to port. The relative pitch pointing angle was zero. The Ross transducer used in this test had a 7.5 degrees beamwidth.

The data acquisition equipment used in the HIPPY field tests is shown in Figure 15. Logging was controlled by a Hewlett Packard 9825T calculator. Timing was controlled by the Ross depth sounder. Soundings were at a rate of 6 per second. Upon receipt of a new sounding, the calculator would log it and interrogate the HIPPY, then log its response (roll, pitch, analog heave, acceleration, digital heave, and error). The data was passed from the calculator to a Columbia 300B tape recorder for storage. A complete description of this data acquisition system and the programs used is given in Appendix C. After preliminary tests, an additional function was incorporated to ensure that data was gathered at a uniform rate. A circuit was installed in the Ross system to cause the calculator to log data if more than 100 milliseconds elapsed after an acoustic transmit pulse without registering a new sounding. This prevented missed soundings from upsetting the time shifting required to use the digital or delayed heave for sounding correction.

Post processing of data was also done on the 9825T calculator. One program, COPIER, read the data from the Columbia 300B tapes, aligned the delayed heave with the real time information, and rerecorded it on the 9825T cassette. Other programs, described in Appendix D, applied the depth correction algorithm, computed some statistical measures, and plotted the data. The correction algorithm was:

$$D_C = D_R \cos \gamma - H_T$$

where:

D_C = corrected depth

D_R = depth measured by Ross system

γ = pointing angle

and H_T = heave at transducer

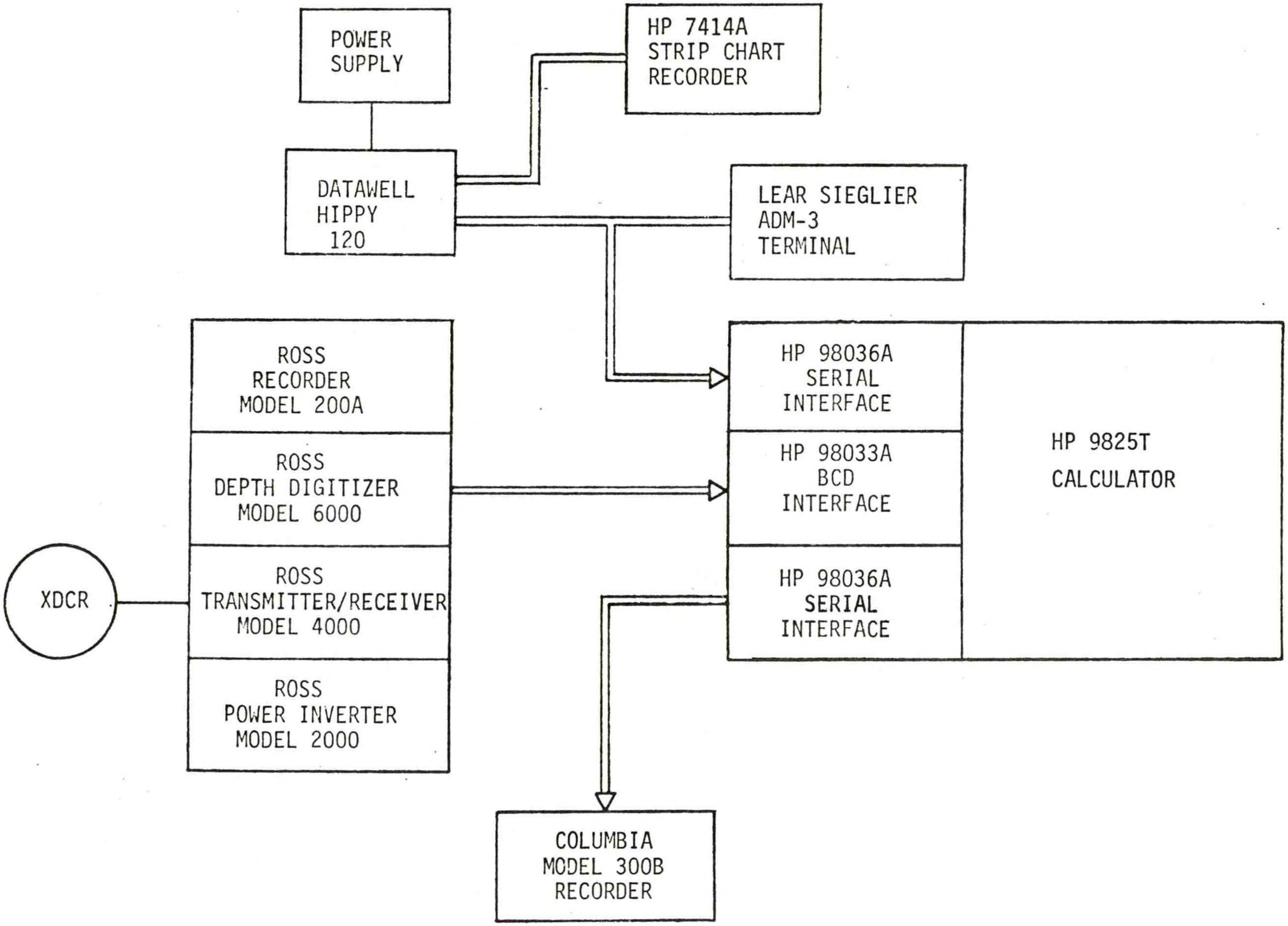


Figure 15. Data Acquisition Equipment

$$\sin^2 \gamma = \sin^2 R + \sin^2 P$$

where:

R = roll angle = $R_H + R_T$

R_H = HIPPY roll angle

R_T = transducer roll angle relative to HIPPY base plate

and P = pitch angle = $P_H + P_T$

P_H = HIPPY pitch angle

P_T = transducer pitch angle relative to HIPPY base plate

$$H_T = H_H + X \sin P_H + Y \sin R_H + Z\ (1 - \cos \gamma_H)$$

where:

H_H = heave at HIPPY

X = HIPPY offset from transducer along centerline

Y = HIPPY offset from transducer athwartship

Z = HIPPY offset from transducer truckward

and $\sin^2 \gamma_H = (\sin^2 R_H + \sin^2 P_H)$

No corrections were routinely made for tide, sound velocity, or vessel settlement and squat.

A total of 16 runs were conducted. These are listed in Table 3. Type A runs were intended to examine the steady state performance of the HIPPY. The LAIDLY was put on a steady course approximately two minutes before reaching the start buoy to allow any turn transients to settle out. These runs ended at the destination buoy. Type B runs were designed to examine the transient performance of the HIPPY. As before, the run began with the LAIDLY on a steady course before the first buoy. Instead of stopping at the destination buoy, however, a 180 degrees turn was made just beyond this buoy and the course between buoys was retraced. This type run ended at the start buoy. Runs were conducted at speeds ranging from five to 14 knots. Most of the data

Date: 11/23/80
Weather: Cloudy
Wind NE 6 mph

RUN	COURSE	TYPE	SPEED	START TIME	TIME BETWEEN BUOYS	CART#	TRACK	FILE
1	5-6	A	10	1309	----	3	1	1
2	6-5	A	10	1320	2:55	3	1	2
3	5-6	A	10	1330	2:40	3	1	3
4	6-5-6	B	10	1336	6:21	4	1	1
5	6-5	A	5	1347	----	4	2	1
6	5-6	A	5	1347	5:15	4	3	1
7	6-5	A	14	1410	2:10	4	4	1
8	5-6	A	14	1416	2:05	4	4	2
9	6-5-6	B	14	1428	6:05	5	1	1
10	1-2	A	10	1440	3:04	5	2	1
11	2-1	A	10	1451	2:50	5	2	2
12	1-2-1	B	14	1500	6:05	5	3	1
13	4-3	A	10	1511	3:05	5	4	1
14	3-4	A	10	1519	3:02	5	4	2
15	4-3-4	B	14	1528	5:50	6	1	1
16	3-4	A	14	1544	----	6	2	1

TABLE 3: SHIP TESTS

were gathered between buoys five and six but some runs were completed between each of the other sets of buoys. A stopwatch was used to measure the actual transit time between buoys.

All of the runs were conducted during a three hour period on 23 November 1980. A waverider buoy 20 miles north of the test site in the same water depth showed waves growing from a significant height of 1.4 meters with periods of 13.5 seconds an hour before the tests to a significant height of 1.8 meters with periods of 14 seconds two hours after the tests. Testing which had been planned for other days was cancelled because of wave conditions which made it impossible to leave Oregon Inlet or schedule conflicts.

The data taken in the first minute of run two is plotted in Figure 16. This is typical of all the runs between buoys five and six Seas were more or less abeam though the long period made the roll comfortably small. Peak-to-peak heave is approximately five feet and peak-to-peak roll is about eight degrees. The first portion of the record shows lower frequency motion than the latter. During this time, there is a difference between analog and digital or delayed heave of about one foot. The error output is essentially zero throughout. The Ross depth shows peak-to-peak variations of about five feet. The gap in the middle of this record is caused by missed soundings. When the Ross depth is corrected with the analog or real-time heave, an obvious low frequency residual remains. The peak-to-peak variations are reduced to two or three feet. The root-mean-square deviation from a constant depth is reduced from the 1.04 feet seen on the raw Ross depth to 0.56 feet. When corrected with the delayed heave, the peak-to-peak variation is less than one foot and the rms variation is reduced to 0.15 feet or 1.8 inches. There is an optical illusion that some low frequency component remains but comparison with a straight edge shows that the deviations are random. Note that the mean depth of the corrected soundings is slightly less than the mean depth of the raw soundings. This is because non-zero pointing angles will bias the average of the raw soundings deeper than the actual depth.

The runs between buoys five and six provided the best opportunity to assess the accuracy of the correction since these runs were generally parallel

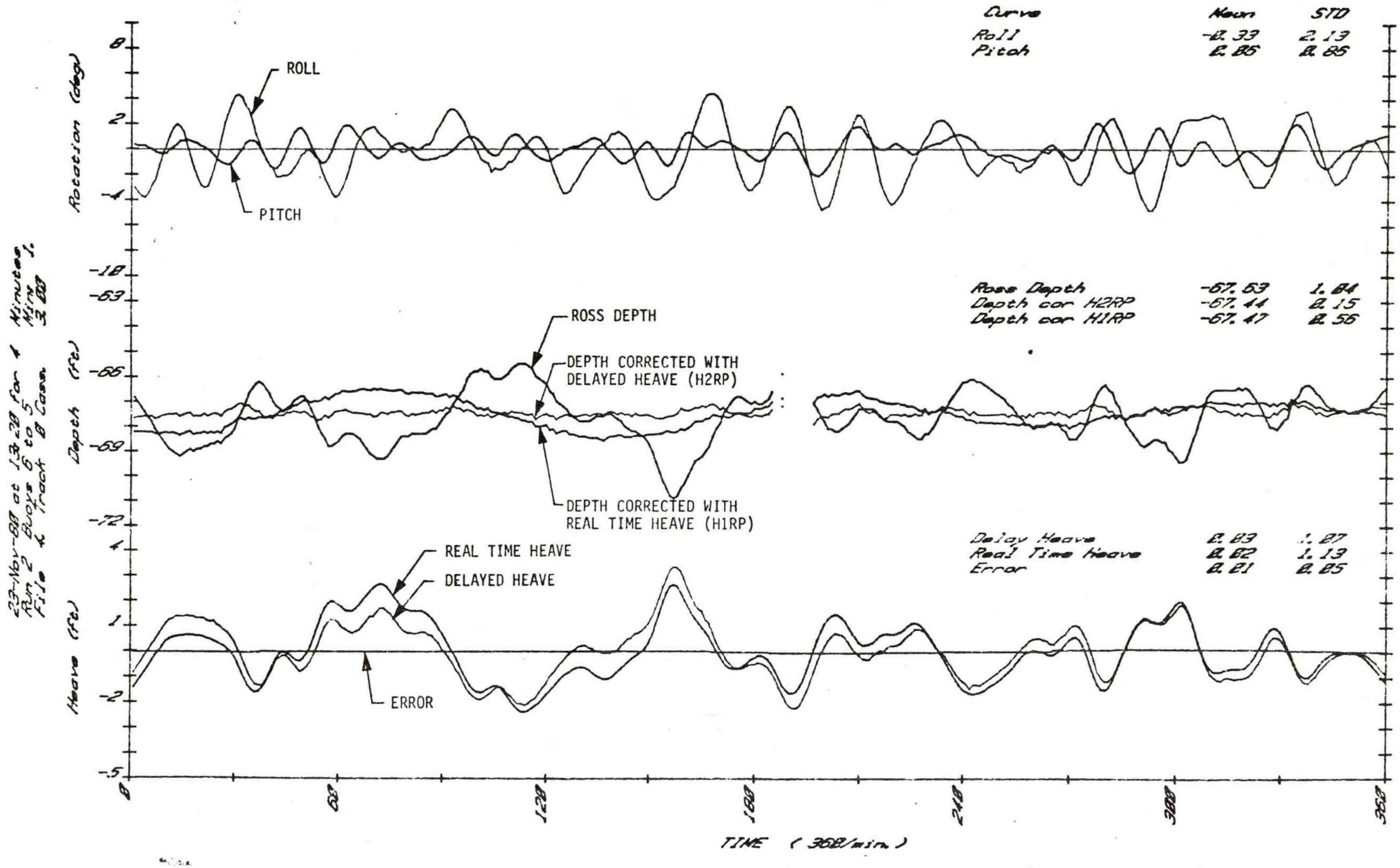


Figure 16. Typical Test Data - Run 2, Minute 1

to the beach. Data from other runs were influenced by a slight slope running into and away from the shore. This showed up as a small change in mean depth from one minute interval to the next. The standard deviation for these intervals was increased by the change in mean depth. Table 4 lists minute by minute statistics for the runs between buoys five and six. If the intervals in which the changes in mean depth are greater than 0.33 feet are discarded, the average standard deviation is 0.18 feet or 2.2 inches.

The mean delayed heave corrected depths for the first 2000 feet of each run between buoys five and six were corrected for tide using data recorded at the CERC pier at Duck, North Carolina, about 35 miles north of the test site. These data are listed in Table 5. The average of the mean depths on the runs at five and ten knots was 67.28 feet. The deviation from this overall average was less than 0.09 feet. The runs at 14 knots averaged 67.69 feet. The difference is presumably due to settlement and squat.

The repeatability of course profiles is demonstrated in Figure 17. This shows data from runs two, five, and seven each of which started at buoy six and headed toward buoy five. The curves are plotted to a distance of 3600 feet from buoy six which is past the end of the intended course at buoy five (a distance of 0.5 mile or 2640 feet). The three runs show very repeatable profiles of a ridge or rise just beyond buoy five. Considering the fact that distance was converted from stopwatch time measurements and there was no precise navigation, the consistency of these profiles is remarkable. The small spikes and gaps in the profiles are due to missed soundings.

The presence of this ridge complicated the interpretation of runs designed to investigate the performance of the HIPPY after a turn around. The turns took approximately 55 seconds. The turning circle was about 400 feet in diameter. The resulting platform offset should be:

$$\theta = \frac{\Delta V}{180} = 3.3^{0} \text{ at 10 knots}$$

RUN	MINUTE	MEAN DEPTH (FT)	CHANGE IN DEPTH (FT)	STANDARD DEVIATION (FT)
2	1	67.44	0.00	0.15
	2	67.22	0.22	0.19
	3	66.96	0.26	0.21
	4	66.32	0.64	*
3	1	67.13	0.00	0.14
	2	67.36	0.23	0.12
	3	67.56	0.20	0.13
4	1	67.33	0.00	0.19
	2	67.05	0.28	0.20
	3	66.04	0.99	*
	4	66.83	0.79	*
	5	67.27	0.44	*
	6	67.45	0.18	0.15
	7	67.53	0.08	0.20
	8	67.72	0.19	0.25
5	1	67.30	0.00	0.18
	2	67.25	0.05	0.19
	3	67.04	0.21	0.16
	4	66.82	0.78	*
	5	65.49	1.33	0.01
	6	66.90	1.41	*
	7	65.03	1.87	*
6	1	66.74	0.00	0.12
	2	67.01	0.27	0.13
	3	67.17	0.16	0.12
	4	67.32	0.15	0.14
	5	67.38	0.06	0.17
	6	67.42	0.04	0.16
	7	67.63	0.21	0.14
7	1	67.81	0.00	0.23
	2	67.61	0.20	0.20
	3	66.82	0.79	*

TABLE 4: CORRECTED DEPTH STATISTICS
1 MINUTE INTERVALS

RUN	MINUTE	MEAN DEPTH (FT)	CHANGE IN DEPTH (FT)	STANDARD DEVIATION (FT)
8	1	67.34	0.00	0.18
	2	67.64	0.30	0.31
	3	67.45	0.19	0.25
9	1	67.65	0.00	0.21
	2	67.33	0.32	0.18
	3	65.85	1.48	*
	4	67.18	1.33	*
	5	67.88	0.70	*
	6	67.43	0.45	*
	average of standard deviations without those where the mean depth changed by greater than .33 feet			0.18

* denotes standard deviation deleted from average due to excess change in mean depth

Table 4 (cont). Corrected Depth Statistics
1 Minute Intervals

RUN#	COURSE BUOYS	SPEED (KNOTS)	CORRECTED DEPTH (WITH* TIDE CORRECTION) (FT)	DEVIATION FROM MEAN (FT)
2	6-5	10	67.30	+0.03
4a	6-5	10	67.25	-0.02
5	6-5	5	67.27	0.00
MEAN			67.27	
7	6-5	14	67.95	+0.08
9a	6-5	14	67.78	-0.09
MEAN			67.87	
3	5-6	10	67.25	-0.03
4b	5-6	10	67.37	+0.09
6	5-6	5	67.21	-0.07
MEAN			67.28	
8	5-6	14	67.40	-0.11
9b	5-6	14	67.62	+0.11
			67.51	

* = RELATIVE TO 13:20 (RUN 2)

TABLE 5: RUN MEAN DEPTHS AND DEVIATIONS

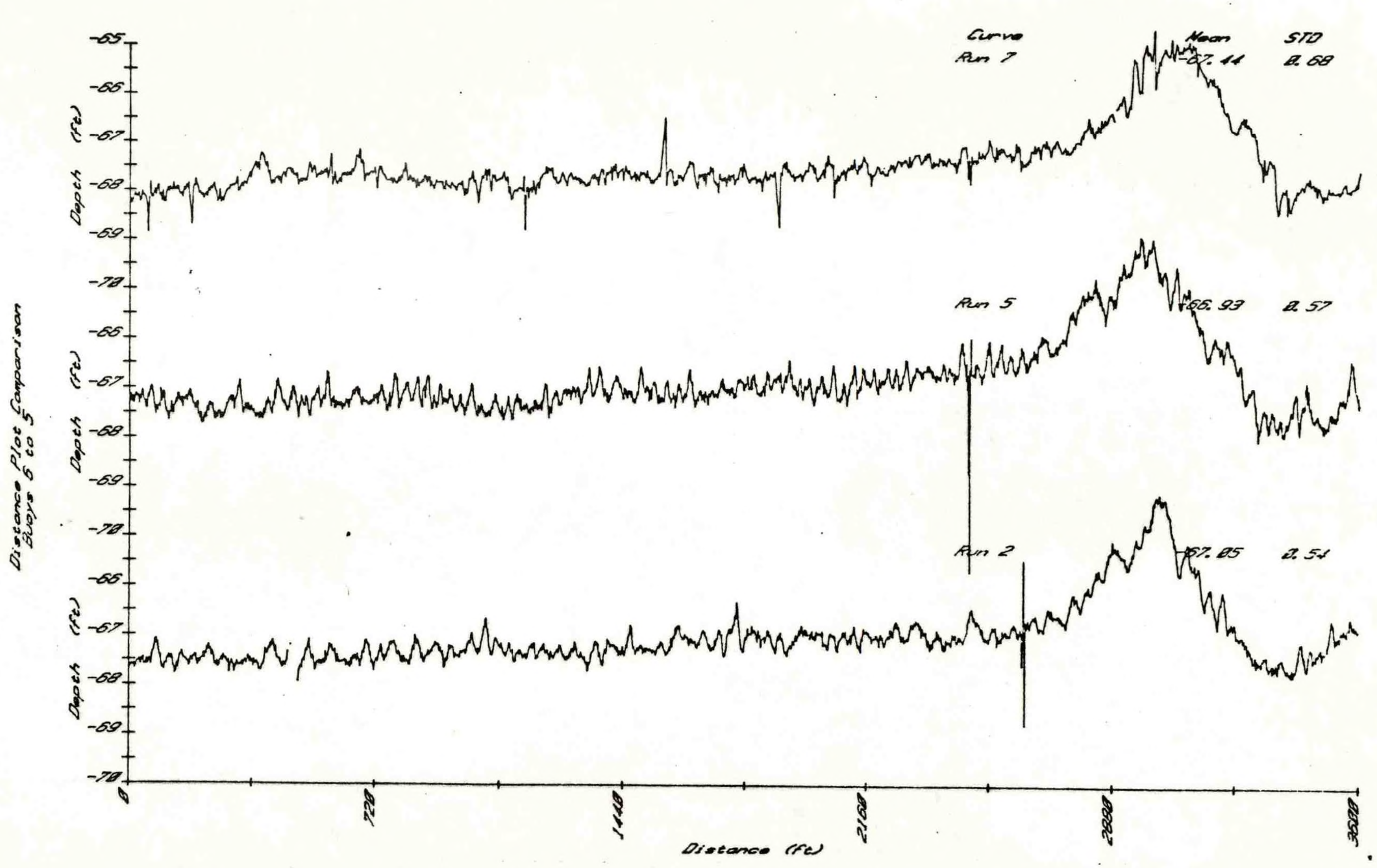


Figure 17.--Course Profiles

Since the depth sounder output will be corrected by an angle which is in error by this amount the depth error should be:

$$D_E = D_A \left(\frac{1}{\cos\theta} - 1\right) = .0016\ D_A$$

where:

D_E = depth error
D_A = actual depth

In this case, this amounts to 0.11 feet. In addition, there will be a heave error caused by false accelerations. The turn around false output should be $0.22v^2$ centimeters. At 10 knots, this amounts to 5.90 centimeters or 0.22 feet. In reality, both of these effects would be reduced because of the fact that a 55 second turn is not "sudden" by comparison with the 120 second period of the pendulum. An error of 0.3 feet would have been barely noticeable in these tests. The fact that the turn occurred on the skirt of a rise, however, obscurred such a small change. Turn effects on two other type B runs on other courses were also contaminated with bottom variations and the slope mentioned previously.

Depth correction with the analog or real time heave was inadequate. On the runs between buoys five and six, residual errors were greater than one foot and the rms variation was 0.56 feet. The situation was considerably worse in other cases. Figure 18 is a plot of data from run 15 from buoy four to three. This course was toward the beach and, as expected, the period of the motion is much longer than between buoys five and six. The predominant period appears to be about 25 seconds. The digital heave shows peak-to-peak excursions of eight to ten feet. The analog heave is off scale and is out of phase with the actual motion. This case clearly shows that in some instances correction with the analog heave output is worse than no correction at all. Even at this low frequency the digital heave still provides a good correction to the soundings. The rms variation of the corrected soundings is

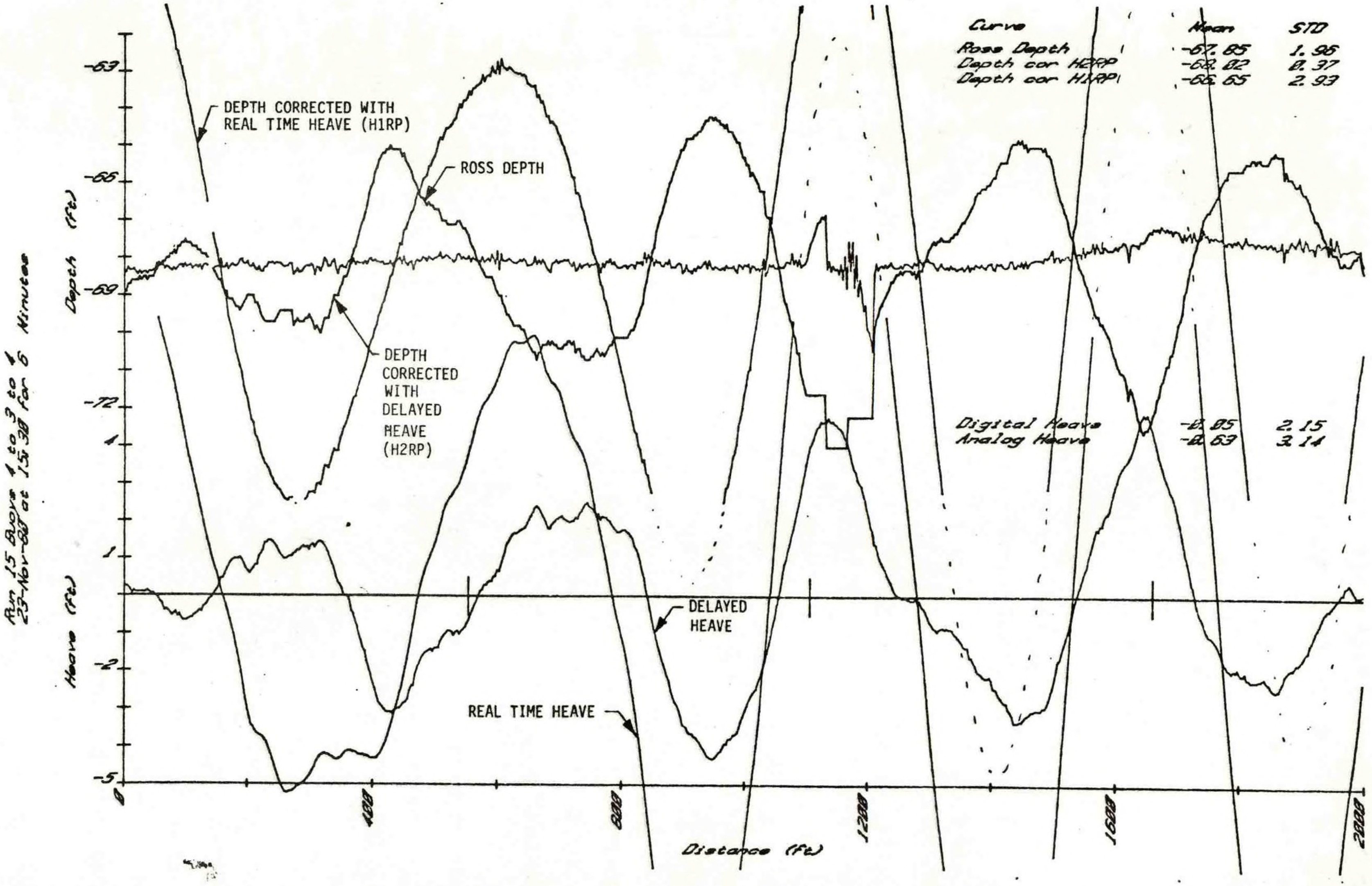


Figure 18. Long Period Test Data - Run 15

overstated at 0.37 feet due to the glitch in the middle of the record caused by missed soundings. In addition there is a slight slope away from the beach. There is no evidence that the rms variation due to HIPPY errors is any greater on this run than on the runs between buoys five and six. The "error" output had peaks of just under one foot but the corrected depth shows no evidence of residual low frequency deviations.

These field tests were generally insensitive to roll or pitch errors because only a single vertical beam echo sounder was used and the peak roll or pitch angles were less than 10 degrees. It was observed that the roll signal occasionally exhibited some high frequency noise of about two degrees peak-to-peak. Figure 19 is a record of one such burst from the first minute of run 15. This phenomena was observed both on the digital output of the HIPPY and on the strip chart record of the analog output. Thus it must be generated internally in the HIPPY. It did not seem to be associated with any particular combination of motions. It is possible that is the result of some high frequency resonance in the foundation of the HIPPY as installed on the LAIDLY.

7. CONCLUSIONS

A comprehensive set of tests were completed to characterize the performance of Datawell's HIPPY 120C in correcting hydrographic data for vessel motion. These include static and dynamic laboratory tests as well as tests in a van and aboard ship. The tests showed the characteristics to be essentially as the manufacturer specified. The real time heave output is accurate down to a period of 16 seconds. Another output delayed by 77.2 seconds is accurate down to periods of 30 seconds. Minor discrepencies between the test results and the manufacturer's specifications included the delay and amplitude of the error output and slight deviations from the stated accuracy of the analog or real time heave output. The van tests showed results which were in reasonable agreement with theoretical predictions of the error caused by horizontal accelerations. Tests aboard ship showed that an upper bound on the error in depth correction is of the order of 0.2 feet. These tests were insensitive to roll and pitch errors so that the result may not apply to surveys in deep water. Laboratory tests indicated that the roll and pitch accuracy was within the specified 0.1 degrees. The field tests also

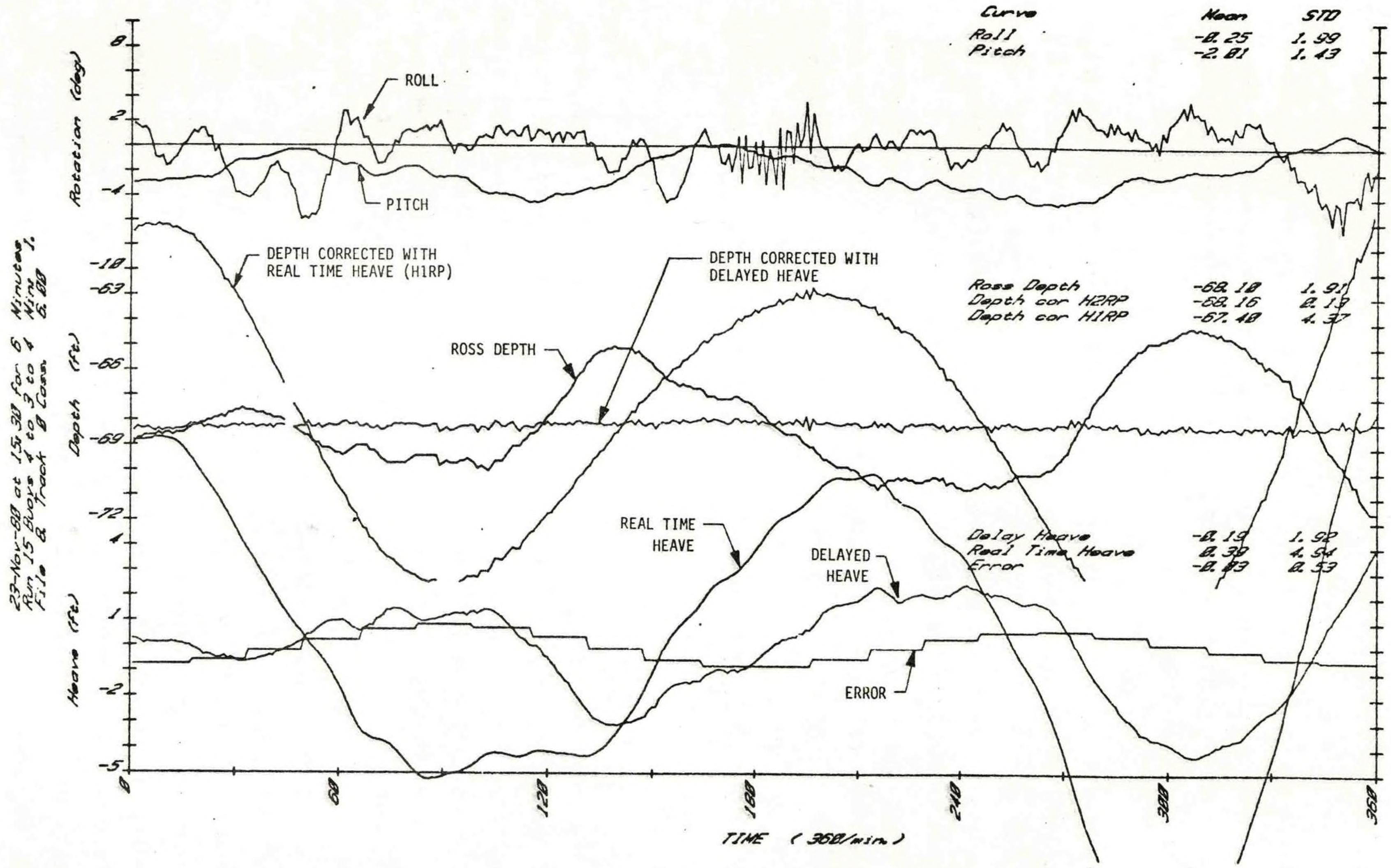


Figure 19. Roll Noise Burst -
Run 15, Minute 1

showed that the analog or real time heave output is generally not sufficiently accurate to meet hydrographic standards and in some cases may be worse than no correction at all. The delayed heave was adequate under all conditions tested. Transient effects caused by turns were not a major problem. The physical size of the HIPPY limits its applicability to larger hydrographic survey ships. A smaller device is required for the survey launches. No malfunctions were observed in any of the three units tested. For the survey ships, the HIPPY 120C appears to be an entirely adequate instrument for motion correction of hydrographic data.

ACKNOWLEDGEMENTS

This work is the product of the efforts of a number of people. Dick Ribe of ESO assisted with tests at the WBTF. Randy Hinzman assisted with several phases and did much of the field test data processing. Donny Sharp prepared the buoys for the field test. John Ericcson and Jerry Firtag operated the LAIDLY. Dave Dillon of EG&G developed the data acquisition codes. Mr. P. Gerritzen and Mr. P. Rademakers of Datawell were most helpful in reviewing the problems and results.

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Hopkins, R.D. and Adamo, Louis C. (1980): Heave-Roll-Pitch Correction for Hydrographic and Multibeam Survey Systems, *Proceedings of the NOS Hydrographic Survey Conference*, 7-11 January 1980.

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APPENDIX A

VERTICAL ERROR SOURCES - AUTOMATED SONAR

(d = depth)

Error Source	Feet	Meters	Fathoms
Depth Measurement (timed)	±.30 + .003 d	±.10 + .003 d	±.12 + .003
Heave Error	±.30	±.12	±.12
Pointing Error (roll and pitch)	± .003 d	± .003 d	± .003
Tidal Zone (variation)	±.12 + .003 d	±.06 + .003 d	±.06 + .003
(rounding)	±.06 +	±.06	±.06
Velocity Measurement	.002 d	.002 d	.002
Zone variation	.002 d	.002 d	.002
Rounding	±.06	±.06	±.06
Draft Measurement	±.12	±.06	±.06
Time variation	±.30	±.12	±.12
Settlement & Squat			
Measurement	±.12	±.06	±.06
Variation	±.30	±.12	±.12
TRA Rounding	±.06	±.06	±.06
Tidal Datum	±.18	±.06	±.03

With the assumption that all the above errors are independent, the law of propagation of variance yields:

Standard Deviation of a Single Depth Measurement

Feet	Meters	Fathoms
±.67 + .006 d	±.28 + .006 d	±.28 + .006 d

90 Percent Confidence Interval for Single Depth

Feet	Meters	Fathoms
+1.1 + .01 d	±.5 + .01 d	±.5 + .01 d

FROM MEMORANDUM C72/6842 9674.0 SUBJECT: RAYTHEON DSF-600 FATHOMETER TESTS

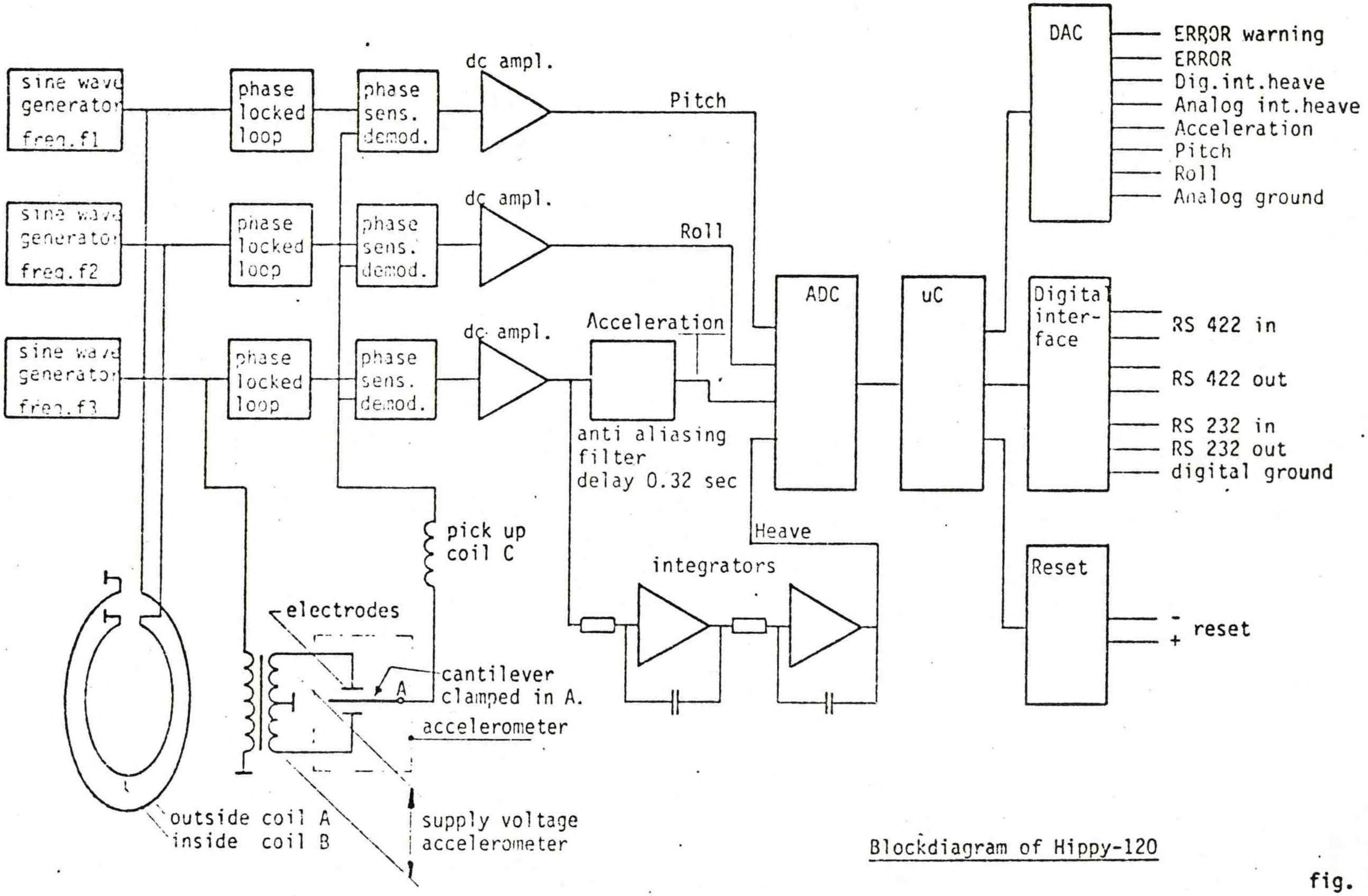
APPENDIX B

Preliminary
Manual
Hippy 120 sensor
with digital filter

19003

Contents

Specifications for digital communications to Host (computer device :



Blockdiagram of Hippy-120

fig. 1

Introduction

The Hippy measures pitch, roll and vertical acceleration.
The vertical reference is a gravity stabilised platform with a natural period time of 120 seconds that carries the accelerometer and the pitch/roll pick-up coil.
Heave is obtained by integrating the acceleration twice.
Horizontal accelerations (course and speed changes) cause very low frequency disturbances of the platform attitude, leading to false acceleration outputs and cross sensitivity. In order to minimise the resulting false heave output high pass filtering is used.
(The remaining false heave is proportional to the square of the speed change and in the following specification characterised as "turn around false output", that is the output caused by a speed reversal or sudden 180^0 course change).
For integration and filtering two separate processes are built in:
a) Analog processing with negligible time delay.
b) Digital processing with 77.2 seconds delay.
The latter process offers a lower cut off frequency, better performance when manoeuvring and when heave is present at frequencies below the cut off frequency of the digital filter ("surfriding" of the ship).
A third process provides an estimate of the heave movement in a frequency range below the digital integrator's cut off.
The output is available for display on a small recorder.
Also a "go-no go" signal is derived that can be used to trigger an alarm.
Pitch, roll, analog heave, digital heave and the low frequency ("error") heave are presented as analog outputs with fixed scales and up date cycles.
The same outputs are also presented in ASCII format at two (RS422 and RS232 compatible) digital input/output ports.
As the preferred site for the instrument is in the ship's center of gravity, which may be a dirty and inaccessible place there are no controls.
Initiation and self-test at power-up is automatic, digital outputs are presented on command from the ship's ("host") computer. The specification for the digital communication lists the choices that the host system can make. The Hippy detects the signalling speed of the host system and, unless it is told to do else, transmits at the same speed.
When no digital output line from the ship's system is connected to Hippy's digital input ports, the Hippy senses this and "defaults" to the autonomous mode and sends the digital information at a fixed rate and format.

The latter formats are listed in the specification, but must be chosen before ordering.

Supply is from any d.c. source between 10 and 30 volts.

Supply lines, analog outputs and digital in/out ports are all isolated from the case and from each other and have separate ground connections.

Principle of operation

Acceleration measurement:

The deflection of the tip of a cantilever is a measure for the acceleration. (Vertical acceleration since the accelerometer is mounted on a gravity stabilised platform).

As the cantilever is placed in an electric field, the potential of the cantilever is a measure for this deflection.

Pitch roll measurement:

An alternating magnetic field H_1 is generated parallel to pitch axis and another field H_2 at different frequency parallel to roll axis (by means of coils A and B, fixed to housing and perpendicular to each other).

A pick up coil C, mounted on the stabilised platform (horizontal plane) measures the vertical components of H_1 and H_2 (fig. 2 and 3).

The induced voltage in coil C is amplified, phase sensitive demodulated and amplified again. The pich up coil C is placed in series with the output of the accelerometer. See block diagram fig. 1.

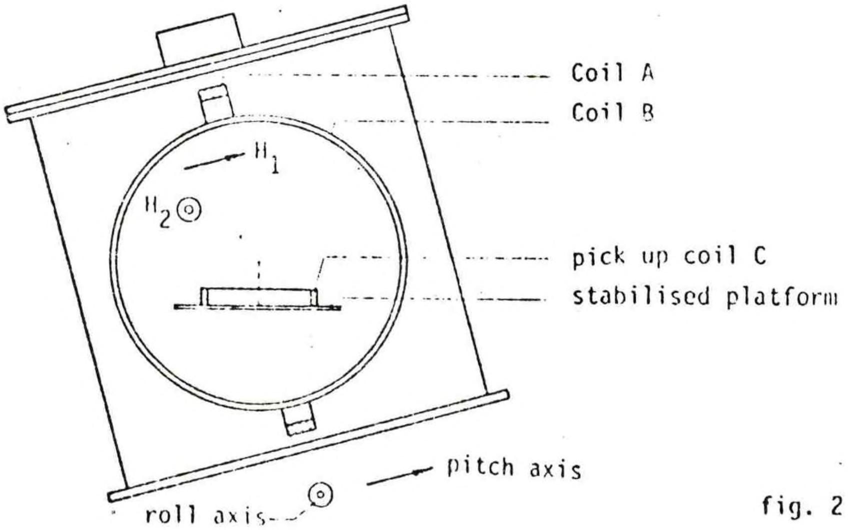


fig. 2

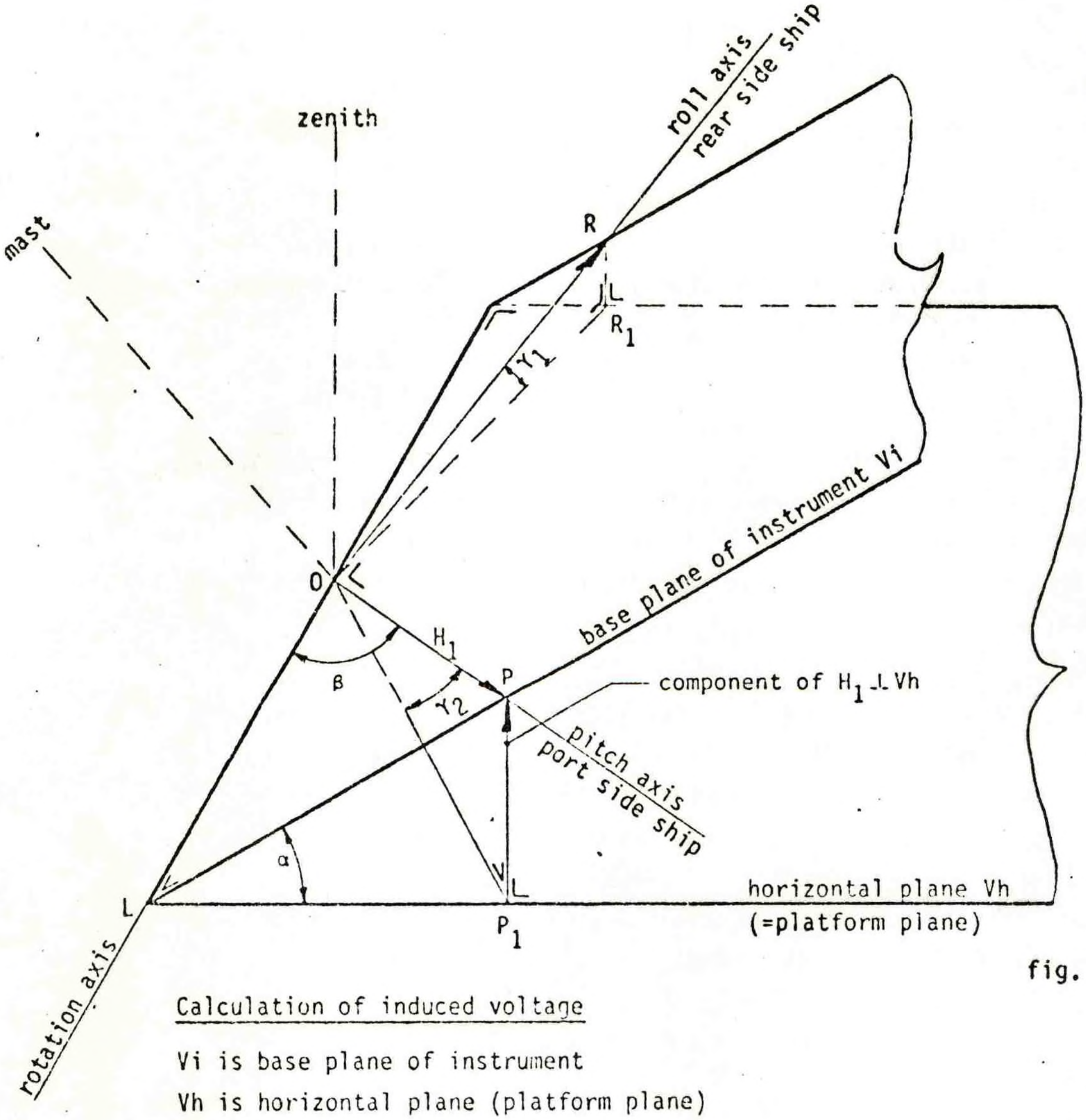


fig. 3

Calculation of induced voltage

Vi is base plane of instrument

Vh is horizontal plane (platform plane)

OL intersection of both planes

angle between both planes is α

Be H_1 = OP the magnetic field vector generated parallel to the pitch axis.

OP_1 the projection of OP on horizontal plane.

Component of H_1 perpendicular to Vh = PP_1

So induced voltage in pick up coil on platform plane = e_i ;

$e_i = PP_1/OP = \sin\angle POP_1$ (roll output)

also is $PP_1/OP = PP_1/PL \, . \, PL/OP = \sin\alpha\sin\beta$

$$\boxed{\begin{array}{l}\text{So roll output } r = \sin\angle POP_1 = \sin\alpha\sin\beta \\ \text{Also pitch output } p = \sin\angle ROR_1 = \sin\alpha\cos\beta\end{array}}$$

for scale factor see specs page 7

α = angle between instrument plane and horizontal plane

β = angle between pitch axis and rotation axis

$\angle POP_1$ = angle between pitch axis and horizontal plane

$\angle ROR_1$ = angle between roll axis and horizontal plane

High pass filter for heave measurement

The heave is obtained by integrating the acceleration twice.
Temporary offset of the platform caused by horizontal acceleration (varying ship speed) leads to false acceleration outputs; in order to minimise the resulting false heave outputs a high pass filter is used.
The remaining false output caused by a 180° reversal of ship's direction is given in the specifications under "turn around false output".
This output is proportional to the square of the ship's speed.
Two outputs are available.

1° Analog heave

Analog integrator delivers a heave output without time delay in the frequency range of 0.066 - 1 Hz (no phase shift in this frequency range).

2° Digitally integrated heave

Integration by means of digital techniques delivers a heave output in the frequency range of 0.033 Hz - 1 Hz. Cut off is extremely sharp (see fig. 5). (Delay of this output is 77.20 sec (equal for all frequency components)).

With the processor and the window used, containing (954+1) samples, the sampling frequency is 6.25 Hz.
Assuming vibration of the sensor of 0.03 inch (MIL-STD-202B, Method 201A), combined with an anti-aliasing filter with cut-off frequency of 1.6 Hz attenuating 30 dB/octave, the sampling frequency cannot be chosen much below 6 Hz.
A basic sampling period of 10 msec is chosen. For each filter sample 16 samples are averaged.
The delay is a fixed time given by 477 times the sampling period + 0.32 sec filter delay + 0.48 sec interpolation delay + 0.08 sec sample integration delay.

Error signal (Heave)

Because of "surfing", heave components below 0.033 Hz may be present, outside range of digital integrator.
A separate digital integrator delivers heave in the frequency range of 0.033 Hz - 0.016 Hz (error signal).
This signal may be contaminated by "false acceleration outputs" (second harmonic of platform natural frequency) and frequencies in working range (see error filter fig. 5). It serves as an indication if surfing occurred and is recorded on a small recorder.
The delay of the error signal is the same as that of the digital integrated heave, about 77 sec.

Connections

See fig. 6

Position of pitch and roll axis

Pitch and roll axis are indicated by V formed cuttings in the rim of the bottom flange.
Mount the instrument with small hole through bottom flange in the direction of the bow of the ship (see drawing Hippy-001).

Outputs

Analog

Roll	$10 \sin\gamma_2$ V (-10 - +10 V)
Pitch	$10 \sin\gamma_1$ V (-10 - +10 V)
Analog integrated heave	1,0 V/m (-10m- +10 m)
Acceleration	1,0 V/m/sec^2 (-10m/sec^2- +10m/sec^2)
Digitally integrated heave	1,0 V/m (-10m - +10m)
Error (low frequency heave)	1,0 V/m (-10m - +10m)
Error recorder span	5 m (-2.5-0-2.5 m)

All these outputs are obtained from D.A. convertors.

Resolutions for all outputs	11 bits for full scale 10 mV steps
Update cyclus: Roll, Pitch, An. Heave, Acceleration	10 msec
D. Heave	160 msec
Error heave	2.72 sec

Digital

All data ASCII formatted upon request via RS232 and RS422 compatible duplex channels without handshaking; Baud rate 110 - 38400 Baud.
Reset input for reinitiation of communication routines.

An Error magnitude comparator output is available.

Comparator level	arbitrary (standard ± 20 cm)
Output level	T.T.L. compatible (open collector)
polarity	Low when error is too large

Influence of platform offset

Platform offset is directly shown by the pitch and roll outputs if the ship is accurately trimmed (horizontal base plane of Hippy).
Platform offset results further in an accelerometer output for horizontal accelerations (cross sensitivity) proportional to the offset.

Amount of platform offset

Under the specifications maximum initial and longterm offset are given (zero offset and stability of pitch roll).

A temporary offset $\Delta\alpha$ is caused by horizontal acceleration.

For sinusoïdal accelerations and period times $T >> 120$ sec. is

$\Delta\alpha = a/g$ (radian) a = peak value of horizontal acceleration (m/sec^2).

For period times $T = << 120$ sec is

$\Delta\alpha = \Delta s/3600$ (radian) Δs = peak value of horizontal displacement (m).

For sudden changes in ship speed (Δv m/sec) is

$\Delta\alpha = \Delta v/180$ (radian)

Platform orientation

The pitch roll measurement is independent of the platform orientation as the platform with pick up coil is symetrical for rotation around a vertical axis (see fig. 2)

This is not quite true if the platform has an unbalance leading to an offset from horizontal.

This unbalance may lead to a pitch error or roll error depending of the orientation of the unbalance.

When a ship rotates, the platform will keep its original orientation; it takes the platform about 15 minutes to follow the ship.

Hence, if the ship rotates 90°, an original error in pitch output will temporarily cause a roll output error till the torque in the suspension has disappeared and the platform has followed the ship to its new orientation.

Transportation

" DO NOT ROLL OR SPIN "

Rolling or spinning the Hippy when it is being hoisted may damage the accelerometer beyond repair.

The Hippy should not make more than six revolutions in two minutes.

Spinning may also lead to an entangled suspension of the stabilised platform which causes in most cases excessive platform tilt.

Specifications:

General

Platform natural period time : 120 sec.

Temperature range : 0 - 35°C.

Storage temperature range : -5 - +40°C.
If an instrument is exposed to low temperatures for a sufficiently long time to reduce the fluid temperature in the instrument below -5°C, the fluid will be permanently altered.
This will result in a reduced natural period time of the instrument's platform.

Supply : Junction box terminal no. 1 positive.
Junction box terminal no. 2 negative.
10 - 30 V dc, 5 W
input capacitance 2200 μF.
Max. permissible voltage between output, battery and chassis 350 V dc.
Supply unit is protected against reverse polarity by a series diode.

Size/weight : See drawing Hippy-001

Housing : Material 10 mm aluminium ALMg3
Junction box is dripproof.

Vibration max. : < 16 Hz; 1 mm peak, > 16 Hz; 1 g peak.

Humidity : The housing is checked to be watertight with a pressure of 0.5 atmosphere.
To prevent initially a large relative humidity within the can, two one-pound bags of silicagel are inserted in the can.
The capacity is sufficient to maintain a low relative humidity within the can for several years even if environment has a constant relative humidity of 100%.

All outputs are short circuit protected.

Pitch roll

Scale pitch : $10 \sin\gamma$ V (analog)

(γ is angle between roll axis and horizontal plane sign) : positive if rear side ship is lifted.

Scale roll : $10 \sin\delta$ V (analog)

(δ is angle between pitch axis and horizontal plane sign) : positive if port side is lifted.

Output range : -10 ÷ +10 V

Linearity error : < 0.05° up to 5°
< 0.15° up to 30°
< 1° up to 60°

Zero offset : Within temperature range < 0.5°

Zero stability : With time over one year < 1°
After quick rotation around vertical < 1°

Noise : Below 0.05°

Loading resistance : min. 5 kΩ

Acceleration

Scale : 1 V/m/sec^2 (analog)

Sign : Positive during upward acceleration

Output range : -10 ÷ +10 V

Accuracy within temperature range) : < 1.5%

Change in accuracy during 1 year : < 1%

Zero offset : < 1 m/sec^2

Bandwidth : Fifth order filter;
cut off frequency 1.6 Hz

Time delay in pass band : 0.32 sec.

Loading resistance : min. 5 kΩ

Heave

Analog heave

Frequency range (3.5% error vector) : 0.067 Hz - 1.0 Hz (fig. 5 curve "Analog filter")

Error vector is amplitude of output heave minus true heave.

Scale accuracy (within temperature range) : < 1.5%

Change in accuracy during 1 year : < 1%

Zero offset : < 5 cm

Noise : < 3 cm, peak-peak
Sign : Positive going for upward motion
Scale : 1.0 V/m
Maximum output : ± 10 V
Turn around false output : 4 cm/(m/sec = shipspeed)^2
This false output decreases with time constant of 60 sec.
Loading resistance : min. 500Ω

Digital heave

Frequency range (3%) : 0.033 Hz - 0.5 Hz (1.0 Hz, 13%) (fig. 5 curve "Digital filter")
Output range : -10 V - +10 V
Scale : 1 V/m (analog)
Scale accuracy (within temperature range) : < 2%
Change in accuracy during 1 year : < 1%
Integration phase error : Zero
Sampling period : 0.160 sec
Delay : 77.20 sec
Turn around false output : 0.24 cm/(m/sec = shipspeed)^2
Loading resistance : min. 5 kΩ

Error Heave

Frequency range : 0.016 Hz - 0.033 Hz (see fig. 5 curve "Error Filter")
Range : -10 V - +10 V
Scale : approx. 1 V/m
Sampling period : 2.72 sec
Delay : ≈ 77 sec
Loading resistance : min. 5 kΩ

Simple System Check (Analog heave)

Connect a recorder with a sensitivity of approximately 2V to the heave output. The recorder will show a straight line.
Have two men lift the Hippy several times within 10 seconds to a height of about 0.5 m, and lower it without bouncing.
If it bounces the acceleration will be outside the linear range of the accelerometer (10 m/sec^2).
When the recorder shows about 0.5 m displacement, the system is working.

Calibration

Heave

To calibrate the heave meter it is necessary to give the instrument a precisely known vertical "input" motion.

To avoid the complex problem of relating the time history of input and output to a specification given in terms of phase, amplitude and frequency this test motion should be single frequency.

A low-cost set up that meets this requirement is suspending the Hippy from springs, e.g. "extenders" that can be bought in a sports shop.

The low mechanical losses of the resulting mass-spring resonant system allow one to maintain a constant-amplitude oscillation with little physical effort.

Also peak acceleration is limited and known.

The period time T is related to the (static) extension lenght L by:

$$T = 2\pi \sqrt{(L/g)}$$

where g is the acceleration of gravity.

As $\sqrt{g}$ is very close to $\pi = 3.14$ a good approximation is

$$T = 2 \sqrt{L} \text{ or the inverse: } L = 0.25\ T^2$$

So, to obtain a period time of 2 seconds the springs should be chosen so that the extension by the weight of the Hippy is 0.25x4 = 1 metre.

It will be clear that the longest period time that can be attained is limited by the height that is available for the set up.

The acceleration is directly visible, as it is proportional to the spring extension.

In the example for T = 2 sec the static extension is 1 metre, and that is the extension caused by the 1 g of gravity.

Thus a 60 cm peak-to-peak motion is a dynamic extension of 30 cm amplitude; that is 30% of 1 g.

When testing the output of the digital filter it should be kept in mind that:

1) The output appears with a delay of 77 seconds.
2) The amplitude transfer characteristic has a ripple (plus and minus 3%) with a length, in terms of frequency of 0.006 Hz.

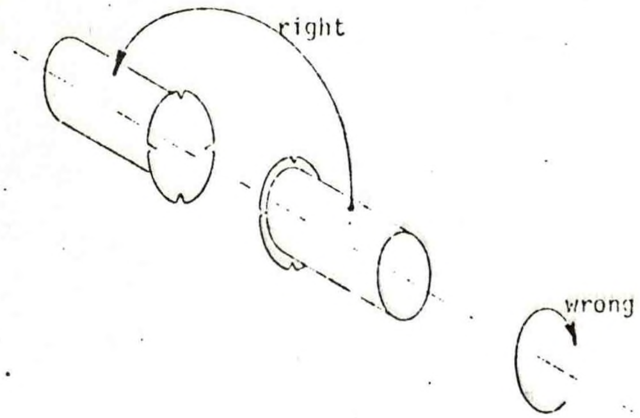
In order to calibrate accurately it is recommended to calibrate at a few closely spaced frequencies, changing the tuning of the mass-spring system by adding some weight.

System check and calibration pitch and roll

scale	Measure pitch output at pitch angle of + 90^0 and again at pitch angle of - 90^0 (check with plummet if roll axis is vertical within 5^0) The difference of the obtained values has to be : 20 V ± 0.2 V The same applies for the roll output at roll angles of + and - 90^0 (pitch axis vertical).
zero offset	Zero offset is equal to measured output if instrument is placed on horizontal plane. Base plane and top plane are parallel within 0.1 degree. So zero offset can be measured within 0.1 degree with horizontal top plane (to be checked with water level).

DO NOT ROLL INSTRUMENT

Rotate via upright position



Specifications of Hippy 120 for digital communications to Host (computer) device

General: Besides digitally processed data all analog sensor outputs will be digitally presented by Hippy in a serial format upon request from the user. There is a choice of:

1) Roll
2) Pitch
3) Analog integrated Heave (A.H.)
4) Acceleration
5) Digitally integrated Heave (D.H.) and a
6) Digitally processed error Heave output (E)

All channels are basically processed with 12 bits resolution.

Electrical output levels:

1) RS 422 - compatible receive and transmit lines on junction bar
recommended for all Baud rates and long distance between Hippy and Host and or noisy envoironments.

2) RS 232 - compatible receive and transmit lines on junction bar
Has limited use at high Baud rates and is not recommended for long distance and in noisy envoironments.

Inside the junction box a female EIA connector is installed to use an ASCII data terminal for service purposes (checking Hippy without the need for a computer). This connection can be used ONLY IF no output from other devices is connected to the RS 232 input terminal on the bar.

pin 1 - AA (Protective ground)
pin 2 - BA (Transmitted Data)
pin 3 - BB (Received Data)
pin 7 - AB (Signal ground)
pin 8 - CF (+12 V)

On junction bar are also present connections:
for RS 232 use: -12 V +12 V and ground
for RS 422 use: + 5 V and ground

NOTE To use the RS 232 connections (plug or terminals) the RS 422 input must be connected to a terminal or with jumpers: input A to digital ground, input B to +5 V (RS 422).

Reset

The reset input is floating.

Required level: min 3 V; max. 12 V; minimum current drive capability 1 mA.

Minimum pulse duration: 10 msec.

Input/Output character format:

Serial ASCII 1 start bit; 7 data bits; 1 parity bit; 2 stop bits for all Baud rates.

When Hippy sends data : Parity is allways even.

When Hippy receives data : The parity bit will be ignored by Hippy but should be present.

Message appearance: A contiguous block of ASCII characters. (Due to interrupts there can be a gap of ≈ 1 character for the highest Baud rate).

Message delay: Depending of message format and message length; between 0.4-3 msec after complete control character is received.

Baud rates: Hippy determines automatically the Baud rate closest to

110
150
300
600
1200
2400
4800
9600
19200
38400 Baud,

from the start bit duration of the first character received after Hippy has cleared a Break.

Output Modes:

1) Normal
   - a) Non modified: output in compressed format and resolution in 0.5 cm/bit
   - b) Modified : output for all commands according to programmed format and resolution

2) Autonomous

Normal modes:

General:

In the normal mode, output from Hippy is obtained by sending a control character. There is a choise of 12 fixed messages. One special message for "0" can be programmed by the user.
After sending an "M" (modify), Hippy can be programmed.
When receiving the first edge of the start bit, Hippy starts the A.D. conversions and an interpolation routine for the Digitally Integrated Heave.

The message presentation formats:

1) Compressed format: Any channel is in 12 bits two's complement and will be formatted in two ASCII characters. Channels will not be separated.

$A_1B_1A_2B_2A_3B_3$......(S E) CR LF
A_n: MSB byte
B_n: LSB byte
S : Space character
E : Echo of command character
CR
LF: Termination characters.

Space and Echo can be deleted (see programming) to have the shortest message.

Bit pattern per data channel: 2 characters:

bit 1: startbit	bit 11: startbit
2: D 6	12: D 0 (LSB)
3: D 7	13: D 1
4: D 8	14: D 2
5: D 9	15: D 3
6: D10	16: D 4
7: D11 (MSB)	17: D 5
8: 1	18: 1
9: Parity bit	19: Parity bit
10: Stopbit	20: Stopbit
(10a)Stopbit	(20a)Stopbit

There are no separation characters between the channel characters.

2) Hexadecimal format: 12 bit two's complement formatted in 3 parts of 4 bits. MSB's first. Channels are separated by spaces.

$H_2H_1H_0S$ $H_2H_1H_0S$ ....(S E) CR LF

H_n: Hexadecimal character 0-9 and A-F

S : Space character

E : Echo of command character

CR

LF: Termination characters.

Bit pattern per data channel: 3 characters + space:

MSB's		LSB's	Space
bit 1: startbit	11: startbit	21: startbit	31: startbit
2: D 8	12: D 4	22: D 0 (LSB)	32: 0
3: D 9	13: D 5	23: D 1	33: 0
4: D10	14: D 6	24: D 2	34: 0
5: D11 (MSB)	15: D 7	25: D 3	35: 0
6: 1) 0	16: 1) 0	26: 1) 0	36: 0
7: 1 or 0	17: 1 or 0	27: 1 or 0	37: 1
8: 0) 1	18: 0) 1	28: 0) 1	38: 0
9: Parity bit	19: Parity bit	29: Parity bit	39: Parity bit
10: Stopbit	20: Stopbit	30: Stopbit	40: Stopbit
(10a)Stopbit	(20a)Stopbit	(30a)Stopbit	(40a)Stopbit

3) Decimal format: The basic 12 bits are converted to signed decimal presentation in 3 digits. MSD first. Channels are separated by spaces.

T $D_2D_1D_0$S T $D_2D_1D_0$S.......(S E) CR LF

T : Sign - (> 2D) for negative

Space (> 20) for positive

D_n: Digit (0-9)

S : Space character

E : Echo of command character

CR

LF: Termination characters.

Bit pattern per data channel: sign + 3 digits + space:

Sign - or Spc	MSD:		LSD	Space
bit 1: startbit	11: startbit	21: startbit	31: startbit	41: startbit
2: 1 0	12: B 0	22: B 0	32: B 0	42: 0
3: 0 0	13: B 1	23: B 1	33: B 1	43: 0
4: 1 0	14: B 2	24: B 2	34: B 2	44: 0
5: 1 or 0	15: B 3	25: B 3	35: B 3	45: 0
6: 0 0	16: 1	26: 1	36: 1	46: 0
7: 1 1	17: 1	27: 1	37: 1	47: 1
8: 0 0	18: 0	28: 0	38: 0	48: 0
9: Parity bit	19: Parity bit	29: Parity bit	39: Parity bit	49: Parity bit
10: Stopbit	20: Stopbit	30: Stopbit	40: Stopbit	50: Stopbit
(10a)Stopbit	(20a)Stopbit	(30a)Stopbit	(40a)Stopbit	(50a)Stopbit

D 0 - D 11 Data bit of output word.

B 0 - B 3 BCD representation of Digits.

(10a, 20a etc) 2nd Stopbit all rates.

Administration message: A string of ASCII characters reflecting the modification of Hippy communication routines, between double quotes, preceeded and terminated by CR-LF characters.

So: CR LF "(M) 1 N 2 N 3 N 4 N (N..)5 N 6 N (N) 7 S"CR LF

N specifies the status of each phase as programmed.

S 6 LSB's of this ASCII character is the contents of the spike counter for quality check of the comminication receive lines.

M if present, means output status is modified.

Starting up (see flow chart fig. 4).
After power up Hippy performs a selftest and initiation routine, which runs for about 30 seconds.
During this routine all analog outputs show a ramp from +10 V to -10 V (all 2048 codes are sent sequentially to the digital to analog output converters). This ramp takes about 15 seconds if the Analog to Digital converter works properly, if not the ramp takes about 30 seconds.
At the digital outputs Hippy sends a break except for the time that the communication circuitry is tested.
The communication test shows a string of 60 U's (>55) at a rate of 300 Baud terminated with a CR-LF.
If the result of the selftest is good system initiation follows about one second after the CR-LF.
The clearance of a 160 msec break during initiation marks the end of the start-up routine.
If the test result is not good the test is retried one more time.
If the result is again false the break after communication test is not cleared.

The delayed digitally integrated heave and error heave are not valid until about 160 seconds after power-up. During this time spaces are sent instead of data for these channels.

Reset: Activating the reset input restarts the initiation routine.
The reset is quasi edge triggered so its status, once detected, is disregarded until the reset has been removed.
The filter routines continue during this reset operation.

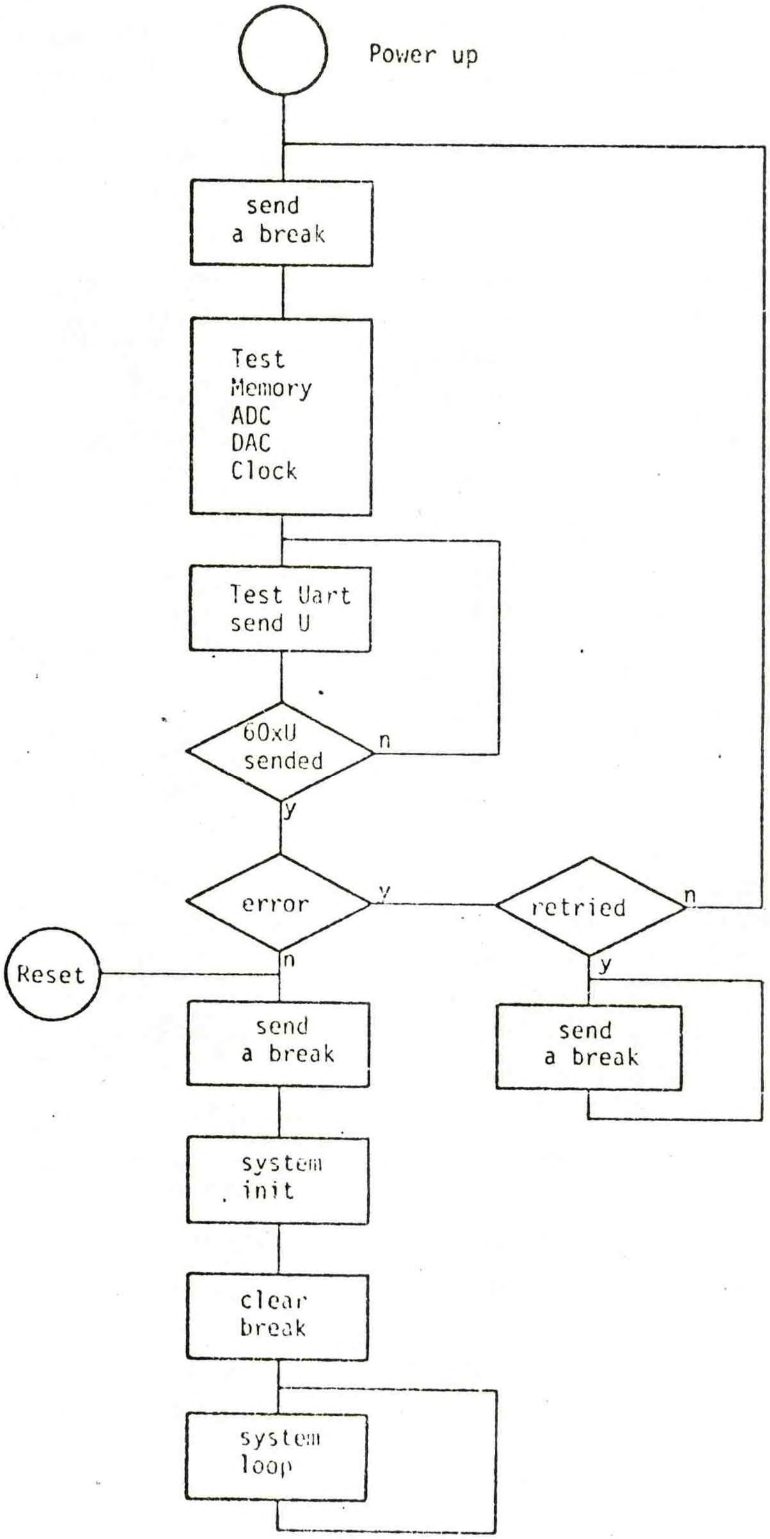


Figure 4.--Test flow chart

Autonomous operation

At the end of the initiation sequence Hippy checks if a break is present. When no control lines at the RS422 input are present a break will be read.

If "break" is detected during initiation Hippy goes to the autonomous operation mode.

Autonomous mode:

In this mode the Hippy is self-repeating without external request.

The fixed message that will be send must be specified in the same way as for the Normal modified mode before order.

The standard message is, when not specified by the user:

Baud rate : 1200 Baud
Repetition interval time : 160 msec
Delay Digital Integrated Heave: 77.20 seconds
Presentation : Compressed
Resolution : 0.5 cm/bit and 0.0005/bit for R and P.
Channel sequence : R(oll); P(itch); (Analog H(eave); A(celeration); D(ig. Heave); E(rror).

Once in this mode the status of the RS422 control input is disregarded until the reset line is activated to restart the initiation routine.

Controlled operation

When at the end of the initiation routine a "no break" condition is detected at both input ports, Hippy waits for control. If one wishes to use the RS232 connections for control, the "no break" condition must be forced by installing jumpers from RS422 input A to digital ground and from RS422 input B to +5 V (RS422).

The first legal character coming in is used to measure the Baud rate. (At the high Baud rates this may miss the first time and two characters may be needed).

When the Baud rate is detected the Hippy answers with the administration message that gives in which output mode it is working; after power-up it allways is the normal mode.

After receiving this message control characters can be sent one-at-a-time (make sure that the host does no send leading spaces or quotes!) and will be answered with the required message.

Control characters for this purpose are:

A (> 41): Roll, Pitch (sin) (Real time) 0.0005/bit
C (> 43): Roll, Pitch (arcsin) (Real time) 0.1°/bit
E (> 45): Analog integrated Heave (Real time) 0.5 cm/bit
G (> 47): Acceleration (Real time) $0.5\ cm^{-2}$/bit
I (> 49): Digitally integrated Heave (77.20 sec delayed) 0.5 cm/bit
K (> 4B): Error signal (~ 77 sec delayed) 0.5 cm/bit

Note that the delayed outputs are valid for a moment in time 77.20 sec ago. All others are valid, for a moment within 1 msec after the leading edge of the control word.

Q (> 51): Short message (real time data)
Roll, Pitch and Analog Heave resolution 0.5 cm/bit
S (> 53): Long message
Roll, Pitch, Analog Heave, Acceleration, Digital I Heave,
Error resolution 0.5 cm/bit
U (> 55): Short message as Q resolution: 0.25 inch/bit
W (> 57): Long message as S resolution: 0.25 inch/bit
Y (> 59): Short message as Q resolution: 1/32 ft/bit
[(> 5B): Long message as S resolution: 1/32 ft/bit

Special control characters are:

] (> 5D): Restores sin values for Roll and Pitch in short and long messages.
Deletes echoing of the control character at the end of a message.
Hippy sends CR-LF in Return.
- (> 5F): Restores sin values for Roll and Pitch in short and long messages.
Restores echoing of the control character at the end of a message.
Hippy sends CR-LF in Return.

Note 1 An A or C command before short or long message commands will modify the value of Roll and Pitch outputs for short and long messages (sin or arcsin) when in normal non modified mode.

Note 2 U, W, Y and I are invalid when Hippy is in normal modified mode.

Note 3 All given resolutions are valid for the normal non modified mode and the normal modified mode, except for decimal presentation. See bit resolution.

Modified outputs

In the normal mode the output format is "compressed".

The output format is changed by sending modification instructions; one character at a time; without leading or terminating characters.
Each character is answered by one or more characters from Hippy.
The next character must not be sent until at least 3 msec after the complete answer is received.

1) Send: M (> 4D)
   Answer: M
2) Send format character:
   C all data in compressed format
   H all data in hexa decimal format
   D all data in decimal format
   Space = default ≡ C
   Answer: M1 and the format character and a 2.
3) Send resolution character:
   Not for Roll and Pitch

For C or H message format:	For D message format:
C 0.5 cm/bit	C 1 cm/bit
I 0.25 inch/bit	I 0.5 inch/bit
Q 1/32 ft/bit	Q 1/16 ft/bit
F 1/40 ft/bit	F 1/20 ft/bit

   Space = default ≡ C.
   Answer: resolution character and a 3.
4) Send Pitch/roll scale character:

A arcsin	output 0.05°
S sin	output 0.0005/bit

   Space = default ≡ S
   Answer: Scale character and 4.
   What follows is the specification for the answer to the special "O" command. This programming sequence must be completed, even if the "O" command will not be used.

5) Message lay-out exclusive for "0" command:

R	Roll
P	Pitch
H	Analog Heave
A	Acceleration
D	Digital delayed Heave
E	Error signal

In any combination and number.
When first character is:
space = default ≡ standard (R, P, H, A, D, E)
otherwise space: terminates message if number is less than 6.

Each character is answered by returning the same character, but after the sixt one or a terminating space, the answer is terminated with a 5. If the first character sent was a space the answer is: RPHADE5.

6) Select Baud rate exclusive for "0" command:

@	110 B	E	2400
A	150	F	4800
B	300	G	9600
C	600	H	19200
D	1200	I	38400

Space = default ≡ Transmit Baud rate equal to Baud rate of control character.

Answer: Baud rate character and a 6.

7) Auto repeat interval select, exclusive for "0" command:

HH (x 10 msec) two Hex characters.
Selecting an interval of 10 - 2550 msec. *
Space = default ≡ NO AUTO REPEAT.
Auto repeat is started anytime by sending an "0" command.
Auto repeat can be interrupted when Break is released after Hippy has detected a received break signal (> 10 msec).

The first Hex character (if sent) is answered by returning that character, the second or the space terminates the programming and Hippy returns the complete new administration message.

* Note that the interval must be sufficiently long to transmit the message at the working Baud rate.

The "0" command

The "0" command can be used for two purposes:

1) Transmission of a message as specified by the procedure above every time an "0" is received.
2) Semi-autonomous transmission.
   If an Auto-repeat rate is specified output will continue to appear at that rate until a break longer than 10 msec is received. In this mode all commands are illegal and will be ignored or regarded as a break.

The output generated upon an "0" command will be at the specified Baud rate, without disturbing the rate for the normal commands.

Display of Hippy communication status:

An - (> 2D) character following an "M" will display the status without modifying.

Restoration of normal non modified mode:

Issue "M" command followed by an "!" character.
Hippy sends administration message in Return.

Identification:

A "space" (> 20) character following an "M" will display the identifier, software release and status

example:
Datawell : Hippy 120
Release : 00-00
MODE : 1C2C3S4RPHADE5 6 7

When Hippy is in Normal Modified Mode, Commands U, W, Y and [are invalid.
Data sampling delay (request delay) from 1st edge of start bit: ≈ 0.5msec.

Mixed use of RS 422 and RS 323 ports:

The input ports are "ored" into Hippy, so input from two devices can be handled provided that they do not occur at the same time.
The output from Hippy appears simultanuously at the RS422 and RS323 outputs.
For instance: An RS323 ASCII terminal could be used at the RS323 port to specify a message to be sent at a fixed interval and (different from the ASCII terminal) Baud rate to a (recording) device connected to the RS422 port. Once the "0" command is transmitted the terminal can be switched off.

Mixed Baud rates

If more than one device communicates with Hippy at different Baud rates the best way to change rates is to send a break of at least 160 msec followed by a valid command.

Hippy will then answer with the administration message at the new Baud rate, except at the highest rate where it may need more than one character to find the rate.

Generally, if the Baud rate is changed without giving a break the rate will be found after reception of two or three valid commands but this is not always safe.

Anyway, the output from Hippy of an administration message is an unambiguous sign that the rate has been determined correct.

Invalid characters.

Only characters that have an isolated start bit will be recognised.

Other characters are echoed, but if more than one invalid character is received within one second the program concludes that the rate may have changed, sends a break and tries to determine the rate.

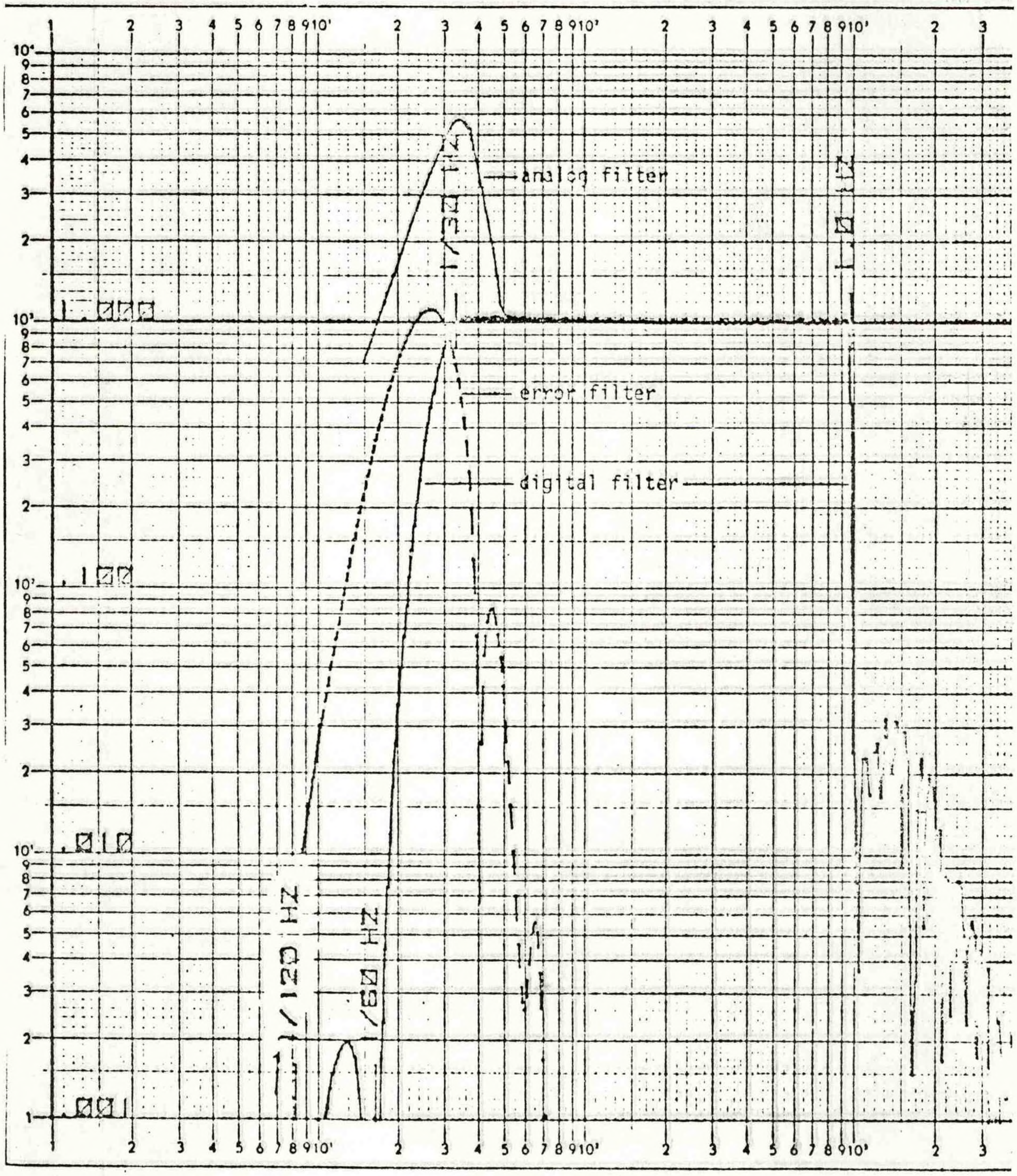
The rate is determined from the start bit. So a next invalid character will result in a wrong rate.

Warning signal from Hippy:

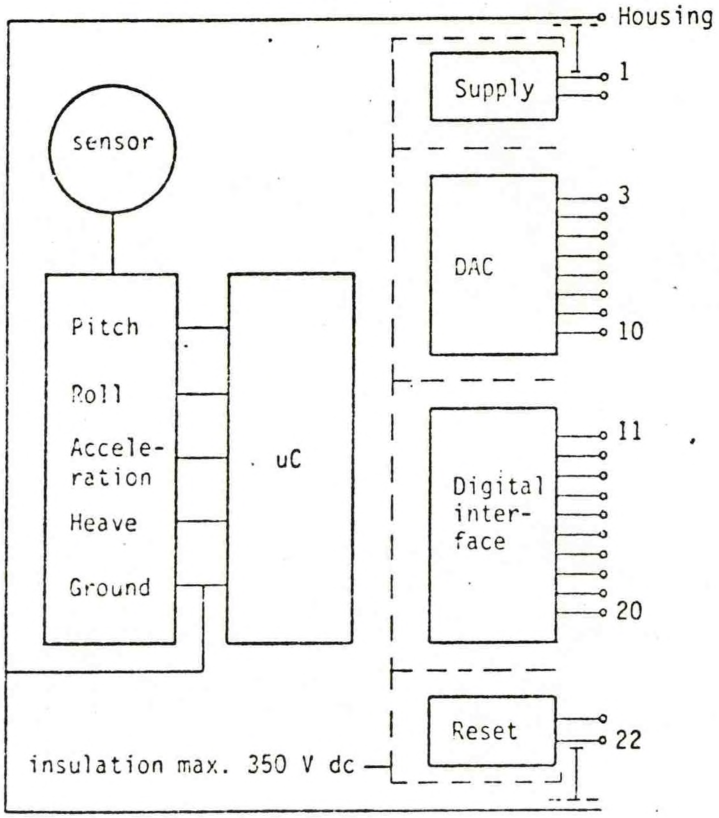
The Hippy sends a break signal for > 160 msec in case of:

1) Returning a break from the Host. Hippy will clear the break signal ≈ 160 msec after Host has cleared its break signal.
2) Host has send a control character within 3 msec after termination of last message character.
3) More than 1 invalid command within ≈ 1 sec is received.
4) Noisy communication lines that would disturb housekeeping within Hippy.
5) Determination of Baud rate failed e.g. input Baud rate < 110 Baud or > 38400 Baud.
6) After Power Up when selfcheck and initiation are running.
7) Activating the Reset line.

   After sending a break to Hippy, the output routine has to be initiated again. i.e. Baud rate has to be fixed, the modified status will remain unchanged.



Heave transfer Hippy-120 fig.5

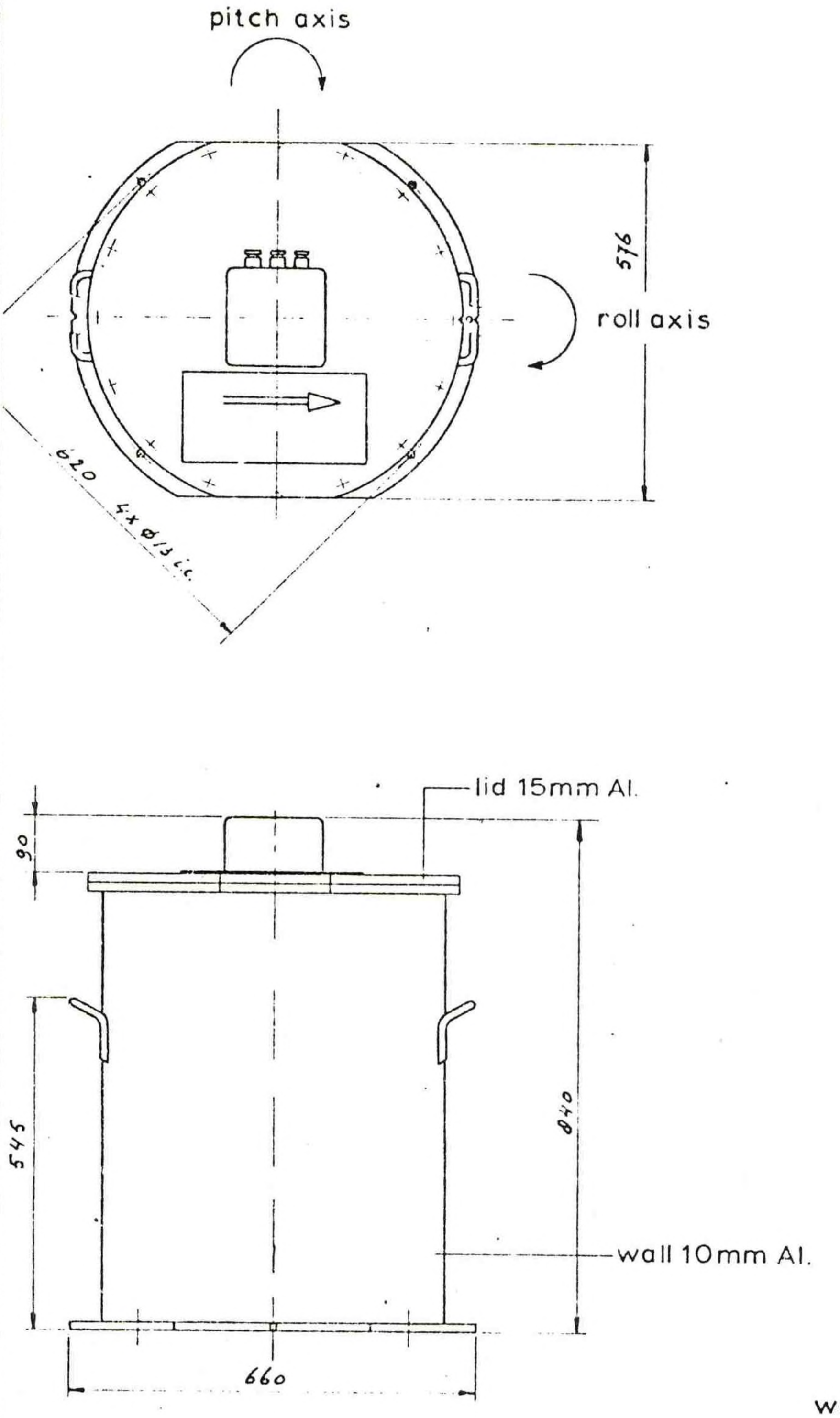


1	+ SUPPLY 10-30 V dc	12	RS 422 INPUT A
2	-	13	RS 422 INPUT B
3	ERROR WARNING	14	DIGITAL GROUND
4	ERROR	15	RS 422 OUTPUT A
5	HEAVE (DEL'D)	16	RS 422 OUTPUT B
6	HEAVE	17	+ 12 V (RS 232)
7	ACCELERATION	18	RS 232 INPUT
8	PITCH	19	- 12 V (RS 232)
9	ROLL	20	RS 232 OUTPUT
10	ANALOG GROUND	21	+ RESET
11	+ 5 V (RS 422)	22	-

Connections of HIPPY 120 sec. - version C

fig.6

List of drawings and documentation



weight 120 kg

25-9-'79	
1-11-'78	

HIPPY 120
HEAVE/PITCH-ROLL SENSOR

Datawell bv Haarlem

1:10			
	2-2-'78	HIPPY -001	

APPENDIX C

EGGLOG

LOGGING BATHYMETRIC DATA CORRELATED WITH SHIP MOTION MEASUREMENTS

DAVID B. DILLON

E G & G

OCTOBER 1980

TECHNICAL MEMORANDUM E930-0001

CONTENTS

EGGLOG: Logging Bathymetric Data Correlated with Ship Motion

By David B. Dillon and Andrew Gerber

EG & G October, 1980

Section 1. Introduction

Bathymetric measurements are made at sea by timing an acoustic pulse as it travels from the survey ship to the sea floor and echoes back to the ship. In shallow water, the time is significantly affected by the motion on the ship in the seaway. Roll and pitch increase the slant range; heave moves the ship further from the bottom.

This report describes a procedure to correlate each measurement of depth with corresponding measurements of ship motion, as well as a particular system of hardware and software to implement the concept. Reference 1 is the report of a preliminary study that led to the selection of this concept.

Section 2. Equipment

2.1 Depth Sensor

Depth measurements are made by a Ross Laboratories, Inc. Automated Hydrographic Survey System. The Ross fathometer presents depth as a 16-bit parallel word in BCD format. The value is updated six times per second when the fathometer is set for its shallowest depth range. (References 2-4)

The fathometer provides the basic timing mechanism for the EGGLOG system. As soon as each depth reading is presented by the fathometer, the LOGGER program accepts it and immediately requests a corresponding readout of the six HIPPY measurands. These values are extrapolated to the time of the request from its most recent measurements.

2.2 Ship Motion Sensor

The Hippy 120 Ship Motion Sensor is made by Datawell bv, Laboratory for Instrumentation, The Netherlands. The Hippy is controlled by a microprocessor. It presents its data in ASCII serial form at a transmission rate and format selected by the user. The measurements are repeated every 160 millisecond, but the instrument will respond to any request for data with a value extrapolated from its most recent readings. Reference 5 gives further details.

2.3 Control Computer

Control of the data sampling and recording process is maintained by a Hewlett-Packard 9825-T desktop calculator. The calculator receives the data streams from the Ross and Hippy sensors, merges them and controls the operation of a digital magnetic tape data recorder. (References 6-10)

2.4 Data Recorder

The depth and ship motion data are recorded in ASCII serial form on a Columbia Data Products, Inc. model 300-B digital magnetic tape recorder. This recorder uses a standard 3M format data cartridge. Each cartridge has four tracks of data; each track holds up to 16 minutes of data (TC-2000). Reference 11 describes its operation in detail.

2.5 Data Monitor

A Lear-Siegler ADM-3 video data terminal displays the ASCII data stream as received by the data recorder in real time. The data stream is too rapid for practical use of individual values. However, the monitor is the best indication that the data are being recorded, and values in any channel can be qualitatively evaluated for plausibility. The users guide is Reference 12.

2.6 Interfaces

Interfaces are electronic circuits that mediate the transfer of data between the calculator and the ship motion sensor, the fathometer, or the recorder. The HP-98036A Serial I/O interface accepts the ASCII from the HIPPY, using the option 001 male cable plug to match the female socket in the HIPPY connector box (Reference 13).

Another HP-98036A interface is used with the Columbia 300-B recorder. The standard female cable socket mates with the male plug on the CPU/MODEM cable of the 300-B. (An option 001 interface can be used with the 300-B recorder, but several changes in connections must be made. See Appendix A.)

An HP-98033A BCD interface is used to accept the depth data from the fathometer (Reference 14). The cable from this interface does not have a connector on the end of its fifty wires. The EGGLOG connector box provides screw terminals for the interface wires, with electronic connection to a standard 50-pin connector. A switch allows the user to connect a test signal in place of the data signal. Any four digit number can be set using thumbwheel switches on the connector box. The box allows the interface to be used with other instruments simply by assembling a patch cable from the standard connector to the new interface output connector(s).

Section 3. Approach

3.1 Sampling Sequence

The HP-9825-T calculator provides overall control of the sensors and recorder, with the fathometer ping rate providing the overall sample sweep frequency. When a data run is started, the calculator requests a depth reading from the Ross; this is granted whenever a valid new depth has been obtained from an echo sounding pulse. The calculator immediately requests a sweep of ship motion data from the Hippy. This is supplied by that instrument by extrapolating from its most recent values.

The Hippy sweep and Ross depth are accumulated in a 36-character ASCII string. Three sweeps (0.5 seconds of data) are sent to the data recorder in a single string of 108 characters. The recorder pads this string to 128 characters with blanks and records them on the tape cartridge. One hundred twenty such data blocks represent a 1-minute data sample.

After accumulating each data sweep (36 characters), the calculator requests another depth reading and waits for the Ross fathometer to reply. This is repeated 120 times for each minute of the total sample duration, plus an additional 77.5 seconds. The latter provides for the 77.2 second delay that the Hippy processor imposes on the output of its digitally integrated heave data.

3.2 Post Processing

A post-processing program is provided that copies the data from the Columbia 300-B recorder onto smaller cassettes used by the HP9825 calculator directly. The data are recorded on the HP cassette in files holding one minute each. As the data are copied, the heave data are shifted by 77.2 seconds, so that no further processing is required by users' of the HP cassette data. This also reduces the instrumentation required to use the data after the sea trial to the HP 9825 calculator alone. The post-processor program can also be used to display the cassette data on the calculator, or to print character by character "maps" of the records on 300-B cartridges or HP cassettes.

3.3 Archive Control

The first record of each file on a 300-B cartridge holds archive data describing the data sample recorded in that file. The 126-character archive record consists of 9 fields, along with an identifying label for each field. Figure 3-1 is a "map" of the 300-B archive record:

Field	Position	Content
File	6-7	Sample file position on track of cartridge
Track	15	Cartridge track (1, 2, 3, or 4) of file
Cartridge	23-25	300-B cartridge number (1 - 999)
Run	31-35	Sea trial run number (1-5 letters, digits, or symbols).

Run Name	37-57	Sea trial run description (1-20 letters)
Trial Name	68-88	Sea trial description (1-20 letters)
Trial Date	93-101	Date of run (Form: 04-Jul-76 = Bicentennial of the United States)
Run Time	106-110	Start time for sample run (17:30 = 5:30 pm)
Duration	116-117	Sample length in minutes.

When a cartridge is copied to an HP cassette, the archive record for the cartridge is broken into 4 parts. Each part is recorded on the cassette as one line of a five line cassette archive. The first line of the cassette archive identifies the cassette file. Lines 2, 3, 4, and 5 hold the cartridge archive. Since a separate cassette file is created for each minute of data on a cartridge file, the five line archive is placed at the start of each cassette file. The sample minute contained in that cassette file is added to the second line.

The origin of any cassette file may be traced through its archive record to the cartridge, track, and file that provided the raw data,and on back to the date, time, run, and trial that gathered the raw data.

Cassette Line	Field Name	Character Position	Field Content
1	File	6-8	Cassette file number (0-10)
	Track	16-17	Cassette track number (0, 1)
	Cass.	26,31	Cassette number (1-99999)
2	Cartridge	1-26	Cartridge file, track, and number
	Minute	32-34	Minute within sample duration
3	Sample Run	1-34	Run number and name
4	Trial Name	1-34	Trial name and date
5	Sample Time	1-34	Sample start time and duration

Figures 3-2 through 3-6 illustrate these archive record maps.

3.4 Data Formatting

Both the HIPPY and the Ross present their measured values calibrated in engineering units. These values are recorded as character strings. The fathometer times the LOGGER program to collect six sample sweeps per second. These are recorded at half-second intervals, so each data record on a 300-B cartridge holds three data sweeps. The first data sweep on a record has the following format:

Character Position	Field Content	Units
1-4	Ship Roll	Degrees
6-9	Pitch	Degrees
11-14	Heave	Centimeters
16-19	Analog Heave	Centimeters
21-24	Digital Heave	Centimeters
26-29	Heave Error	Centimeters
31-34	Water Depth	Tenths of a Foot

The second and third samples have the same format, but begin in character positions 37 and 73, respectively. Figure 3-7 is a map of a 300-B data record.

When a 300-B file is copied onto an HP cassette, it is divided into several files, each containing one minute of the overall sample: 360 sweeps at six Hz. The three sweeps on a 300-B record are copied into three separate records on the cassette. Each record has 34 characters and duplicates the format of the first 34 characters in Figure 3-7.

Section 4. Setting Up

4.1 HIPPY Ship Motion Sensor

The HIPPY 120 sensor is a cylinder about 2 feet in diameter and 2.75 feet tall that stands upright on the ship's deck. An electrical connection box is on the top end. Open the box and connect terminal 11 to terminal 13 with a short jumper wire. Then connect terminals 12 and 14.

Set the Baud rate of the HP-98036A-Option 001 Serial Interface to 9600. Do this by turning the selector recessed in the side of the interface to position 1 using a small screwdriver. Set the Select Code of the interface to 11 by turning the selector on the top edge of the interface. Turn the HP-9825 calculator off, and plug the body of the interface into any of the slots recessed into the back of the calculator. Plug the interface cable into the RS-232 socket in the HIPPY connection box. (Imagine the box as a clock face. There are two sockets, one at "11 O'clock", and one at "1 O'clock". The RS-232 socket is at "11 O'clock". There are three cable penetrations at 5, 6, and 7 O'clock.)

Connect the ground lead of a DC power supply to terminal 2 in the connector box. The power supply must be able to supply at least 2 amperes at between 10 and 30 volts. Connect the positive lead from the power supply to terminal 1 in the box.

Turn on the power supply when all these connections have been made, at least several minutes before the first data sample is to be started.

4.2 ROSS Precision Fathometer

Use the multi-colored ribbon jumper cable to connect the Ross fathometer to the EGGLOG connector box attached to the HP-98033A BCD Parallel Interface. Plug the interface into any of the slots recessed into the back of the HP-9825 calculator.

The EGGLOG connector box has two toggle switches. When a sample is to be gathered, turn the power switch ON. The data selector toggle may be set either to TEST or OPERATE. The TEST setting ignores the Ross depth readings; it supplies the four digit number shown on the thumbwheel dial whenever a data request is received from the calculator. OPERATE is the normal setting for logging depth data. Whenever a data request arrives from the calculator, the next depth measured by the Ross is returned to the calculator.

The four thumbwheels are used to set the value that will be returned to the calculator when the selector is in the TEST position.

4.3 Columbia 300-B Recorder

Set the Baud rate of the Standard Option HP-98033A Serial Interface to 9600 by turning the selector recessed in the side of the interface to position 1. Set Select Code 10 on the top edge of the interface. Turn the calculator off and plug the interface into any remaining slot in the back of the calculator.

The internal switches on the interface should be at the factory settings shown in Reference 13, Chapter 2.

Connect the socket on the end of the interface cable to the (male) plug on the end of the MOD/CPU cable from the Columbia 300-B recorder.

Set both thumbwheels on the back panel of the recorder to position 6 (9600 Baud). Snap all three toggle switches on the back of the recorder to the right (HALF duplex; Transparent data recording OFF; Error checking OFF).

To use the recorder with either EGGLOG program, turn the power toggle switch on the front panel of the recorder ON. Wait a second until only the STOP lamp on the front panel is lit, then press the white ONLINE and BLOCK buttons to light the corresponding lamps. These buttons are "flip-flops" that alternately light and extinguish their respective lamps. Make sure that both ONLINE and BLOCK lamps are lit.

Select the desired recording track to 1, 2, 3, or 4 by setting the TRACK thumbwheel on the front panel. Be sure the thumbwheel is not set to 5, 6, 7, 8, 9, or 0.

Insert a data cartridge in the slot along the top of the front panel. Hold the cartridge with the metal base plate on the bottom and firmly press it into the slot until it engages. When the cartridge is properly inserted only 7/8-inch will protrude from the slot.

The data cartridge has a write-protect key on the lower right corner of the top surface. To permit data to record on the cartridge, the key must be turned to cover the hole in the front edge of the cartridge. When all four tracks of a cartridge have been filled with data, turn the key to open a small recess in the front edge. This will allow the recorder only to read data from the cartridge, but not to write new data over the present recording.

4.4 Monitor

The ADM-3A interactive display terminal comes with a patch cable that has male connectors on each end. Two female sockets are mounted at the back of the monitor at the junction between the molded cover and the base. Plug the patch cable into the main I/O port. This is the socket nearest the power cord penetration.

Plug the other end of the patch cable into the TERMINAL socket on the back panel of the Columbia 300-B recorder.

There are two sets of front panel switches on the ADM-3A to the left of the keyboard. The cover for these switches may be screwed down. Open the cover and set them as follows:

Top Front Panel Switch Settings

Switch	ON	OFF	Name	Function
6		down	Bit 8	Set bit 8 to 1
5		down	Parity	Inhibit parity test

4	down		Stop	Use 1 stop bit
3		down	Data	Use 8 data bits
2	down		Parity	Set ODD parity (ignored, since switch 5 inhibits either parity)
1	down		Lowercase	Enable lowercase letter display

Lower Front Panel Switch Settings

Switch	ON	OFF	Name	Function
7		down	Auto NL	Inhibits foldover display of lines longer than 80 characters
6	down		RS-232	Set RS-232 communications
5	down		Duplex	Set half duplex transmission
4		down	19600	Select Baud rate
3	down		9600	Use 9600 Baud Rate
2		down	4800	Do not use any other
1		down	2400	baud rate
7		down	1800	
6		down	1200	
5		down	600	
4		down	300	
3		down	150	
2		down	110	
1		down	75	

By removing the screws underneath the front corners of the keyboard, the cover may be tilted up to reveal the main printed circuit board of the ADM-3A. At the back of this board, are two more multiple switches:

Left Circuit Board Switch Panel Settings

Switch	ON	OFF	Name	Function
6		down	ADV	Cursor control (either setting is valid with EGGLOG programs)
5		down	U/L DISP	Enable lowercase display
4	down		Keyboard	Disable keyboard lock
3		down	Screen	Enable screen clearing by control-Z character
2		down	60 Hz	Select 60 Hz AC power
1		down	24 Line	Select 24 line display

Only the settings of left switches 2 and 4 are mandatory.

Right Circuit Board Switch Panel Settings

Switch	ON	OFF	Name	Function
7		down	Cursor	Cursor control (use either)
6	down		LOCAL	Select LOCAL operation
5		down	103	Reject 103 operation
4		down	202	Reject 202 operation
3		down		Ignored in LOCAL
2		down		Ignored in LOCAL
1		down		Ignored in LOCAL

Allow a minute for the ADM-3A TV display tube to warm up before transmitting data to or from the recorder. The contrast of the letters is controleled by the knob at the upper right corner of the keyboard. Appendix B is a program for the HP-9825 that verifies the correct set-up of the recorder and monitor through the interface to the calculator. User entries are requested alternately from the calculator keyboard and the monitor keyboard. When you press CONTINUE on the calculator, whatever you have typed will appear on the tv screen. Then type an answer on the monitor keyboard and press RETURN and LINE-FEED. Whatever you typed should be printed by the calculator.

4.5 Power

The calculator, recorder, monitor, Ross connector box, and presumably, HIPPY power supply all require 110-120 volt, 60 Hz regulated AC power with grounded receptacles. As usual on shipboard, precautions against ground loops may be needed.

Section 5. Logging Data

To gather data and record it on the 300-B recorder, connect the equipment as described in Section 4. Then turn on the HIPPY power supply, HP-9825 calculator, Ross fathometer, EGGLOG/Ross connector box, 300-B recorder, and ADM-3A tv monitor. Load the EGGLOG program LOGGER into memory from the program cassette, and press RUN on the calculator keyboard. The monitor keyboard is not used during data logging. This message will appear in the LED strip display on the calculator:

```
Skip Header (y/n)
```

If you type an n and press CONTINUE, a summary of Section 4 will be listed on the printer (about 50 lines). If you enter y, this information will be skipped.

The calculator will beep whenever a user input is required. The next entry request is in the form:

```
Trial Name (1-20 Char.)
```

Enter any phrase that identifies the overall trial. A name will also be requested later for each sample collected during the trial. If you enter more than 21 characters, the message "Entry Too Long" will be printed, and a new trial name requested.

At the next beep, the LED display will show:

```
Trial Date (DD-Mon-YY)
```

Enter the date of the trial recording session. DD, of course, represents the digits for the day of the month; Mon is the month abbreviation; and YY represents the digits for the decade and year. 04-Jul-76, for example is the Bicentennial of the United States. If you enter more than 9 characters, a new date will be requested.

When the date has been accepted, the printer will show:

```
Continue when
HIPPY on and
ready . .
```

and the LED will request:

```
HIPPY ready?
```

Be sure the HIPPY has completed its warm-up sequence before you press CONTINUE without entering any characters.

A sequence of HIPPY modification characters will be printed and sent to the HIPPY, then the printer will show:

```
Turn 300-B    ON
Push 300-B  STOP
Set ONLINE    ON
Set  BLOCK    ON
```

Mount new 300-B
Cartridge
Then the LED will display:

300-B Cartridge No.?

Enter a number from 1 thru 999 that is unique to the 300-B cartridge that you have inserted into the recorder slot. Values less than 1 or greater than 999 will be rejected and a new value sought.

The next entry will be prompted by:

Set and enter TRACK (1-4)

Set the 300-B track number using the thumbwheel on the front panel of the 300-B. Enter the track that you have set. Only 1, 2, 3 or 4 will be accepted by the calculator.

The calculator will beep when the next message is displayed:

File Position (1-99)

Enter a 1 to locate the file at the start of the track. It will overprint any data previously recorded there. Enter a 2 to skip the first file, a 3 to skip two files, and so on. The LOGGER program does not check for pre-existing files, nor does it check for sufficient tape on a track to hold a sample. A track will hold a 16 minute sample plus the 77.5 second heave delay in one sample. Each sample of N minutes has an extra 77.5 seconds recorded. If you wish to record several short samples on a single track, be sure the total recording time does not exceed 17 minutes, 17.5 seconds. If you exceed this limit, the tape will spool completely off the hub of the cartridge, ruining the sample and requiring dis-assembly of the cartridge to repair it. (These limits apply to a TC-2000 cartridge. The smaller TC-1200 cartridge holds less.)

The 300-B will begin to rewind the cartridge and the LED will prompt:

Continue when REWIND over

Wait for the 300-B transport to stop, then press CONTINUE.

If the file position is more than 1, the 300-B will begin to skip forward over files, one at a time. For each file skipped, the LED will show:

Continue when FORWARD over

Wait for the transport to stop, then press CONTINUE.

When all the files have been skipped, then printer will display the following explanation of the run options available:

```
Enter:
1-5 Char. Run No
q QUIT Session
f Reset FILE No.
t New TRACK
c New CARTRIDGE
h This HELP list
Run No. may mix
up to 5 digits,
letters and
symbols.
```

Then the LED will give the abbreviated prompt:

```
Run (1-5 Ch. q f t c h=HELP)
```

If you want to stop the LOGGER program, enter a q.
If you want to change the 300-B file number, enter an f.
If you want to change the 300-B track setting, enter a t.
If you want to use a new 300-B cartridge, enter a c.
If you enter an h, the printer will repeat the above list.

Ordinarily, you will enter a run number for the sample you want to record on the 300-B recorder. Run numbers will usually consist of 1 thru 5 digits, but sometimes you may want to use letters to distinguish variations, like runs 1 and 1-A. Do not use the letters q, f, t, c, or h as the first character in a run number: the calculator will perform the alternate option corresponding to the letter. If you enter more than 5 characters, a new run number will be requested.

When a valid run number has been entered, the LED will request:

```
Run Title (1-20 Char.)
```

Enter a title phrase that identifies this sample as distinct from other samples in the trial. If you enter more than 21 characters, a new title will be requested.

The next input is prompted by:

```
Duration (Minutes)
```

Enter the sample length in minutes. Remember, a track will only hold a 16 minute sample. If you have already used part of a track, it will hold less. The duration you enter DOES NOT include the 77.5 second heave delay. The calculator will extend your entry by that much. You must allow for the longer actual sample in considering whether the sample will fit on the track. It is probably best to always start with a fresh track and restrict the duration to 16 minutes or less. Cartridges are cheaper than lost data or extended ship time. The program accomodates short samples for laboratory checkout procedures.

After the sample duration has been entered, the LED will request the approximate sample start time in hours (HH) and minutes (MM):

Run Time (HH:MM):

Enter the start time as indicated. Then the LED will display:

Start Sample

The actual gathering of the sample will commence a moment after you press CONTINUE in response to this prompt. The calculator will beep when it has gathered the 77.5 second heave delay, then beep once for each minute of the sample duration. The recorder should be "jumping" in bursts each half second, and the data should be streaming across the tv monitor. If it is not, press STOP on the calculator keyboard and diagnose the problem.

When the entire sample has been logged, an end of file mark will be made on the cartridge track, and the LED will request another run number or other option with the abbreviated prompt:

Run (1-5 Ch. q f t c h=HELP)

that appeared before. You may gather another sample as described above, or enter one of the other options. To stop the program, enter a q, and press CONTINUE. Then turn all the equipment off.

Figure 5-1 shows the strip printer output for an example session. Appendix C is an annotated listing of the LOGGER program.

Section 6. Copying Data

A postprocessing program is included in the EGGLOG system. A listing of COPIER is annotated in Appendix D. The primary purpose of this program is to copy the data from the Columbia 300-B digital recorder cartridges to cassettes used with the HP-9825 calculator. This reduces the amount of equipment needed to use the data after the trial is complete. During the copy process, however, the 77.2 second heave delay is corrected by shifting the HIPPY heave and error values by 463 data sweeps. (At a 6 Hz sweep rate, the compensation is 463/6 = 77.2 seconds.)

The HP-9825 cassette recorder cannot record a file line by line. The contents of the entire file must be accumulated in memory and recorded in a single operation. In order to make the cassette files independent of the memory size in a particular calculator and for other reasons of convenience, the files that EGGLOG creates on HP cassettes each store one minute of data. A sample of 16 minutes duration stored in a single file on a 300-B cartridge is divided into 16 files on the HP cassette. One track on an HP cassette holds 10 of these one-minute files. So one track of a 300-B cartridge nearly fills both tracks of the HP cassette. This suggests that cassettes be numbered in the form "crt0t", where "crt" represents the 3 digit 300-B cartridge number, and "0t" is the 300-B track number (01, 02, 03, or 04).

The COPIER program copies 300-B cartridge files into HP cassette files. In addition, HP cassette files may be reviewed on the LED display. Each of the five lines of the archive header is displayed for five seconds. Then the 360 data sweeps are reviewed at a rate of ten per second, giving a kind of motion picture scan of the data.

COPIER offers two other options. One prints a map of the archive and first data record of a 300-B file on the strip printer (Figures 3-1 and 3-7). The other prints a similar series of maps of the five line archive and first three data lines of an HP cassette file (Figures 3-2 through 3-6).

To use the COPIER program, load it into memory from the EGGLOG program archive. If you plan to copy 300-B files or map their record format, connect the Columbia 300-B recorder and Lear-Siegler ADM-3A tv monitor (optional) to an HP-9825 calculator. HP cassette files may be displayed or mapped with the HP-9825 calculator alone. (See Section 4.)

When these preparations are complete, press RUN on the calculator keyboard. The strip printer will output an introduction and the list of options available:

```
Enter To
0 QUIT program
1 COPY Tape from
  300-B to HP
2 LIST Cassette
  in LED display
3 MAP 300-B file
```

```
  header & first
  data line on
  strip printer
4 MAP HP file:
  five header
  lines and 3
  data lines.
5 HELP with this
  option list
```

The LED display prompts for the option with the abbreviation:

```
Opt. (0=QUIT 1 2 3 4 or 5=HELP)
```

As the printer message indicates, enter a zero and press CONTINUE if you want to stop the program. If you enter a 1, the program will prompt you through the steps used to copy a 300-B data file onto a series of HP cassette one-minute files. Options 3 and 4 produce printed "maps" of the header and data records in 300-B and HP cassette files respectively. If you enter a 5, the printer explanation above will be repeated.

6.1 Copy Option

If you select option 1, the printer will respond by typing:

```
Insert 300-B
cartridge
Set ONLINE     ON
Set  BLOCK     ON
Set  TRACK    1-4
Enter File No.
when 300-B ready
```

Then the LED prompt will appear:

```
300-B File No. (0=QUIT)
```

Select the cartridge that you want to copy from and insert it into the slot in the front panel of the 300-B recorder. Dial the track number of the file to be copied into the thumbwheel on the 300-B front panel. Be sure to use only a 1, 2, 3, or 4. Of course, be sure the recorder power is turned on, with the ONLINE and BLOCK lamps lit as instructed above. Then enter the position number of the file to be copied on the calculator keyboard and press RETURN.

The 300-B recorder should immediately respond by rewinding. If it does not, press STOP and diagnose the problem. Otherwise, note the LED warning:

```
Continue when REWIND over
```

Press CONTINUE when the recorder stops. If the file number that you entered exceeds 1, a second warning will be displayed:

Continue when FORWARD over

Wait until the recorder stops, then press CONTINUE. This will be repeated for each file that must be skipped over. Finally, the header record for the file will be read and the run number and sample duration displayed on the printer.

Once the 300-B cartridge is in place and ready, the calculator will proceed to set up the HP cassette. The printer will list:

Insert an HP
tape cassette

and the LED will display:

HP Tape No. (1-99999 0=QUIT)

Insert a cartridge into the slot to the left of the HP keyboard. One method for numbering cassettes has been suggested in the previous sub-section. Another method would be to number cassettes by the sample run number recorded on them. This assumes that a different cassette would be used for every sample run. This is acceptable, since a 16 minute sample nearly fills the two tracks on a cassette.

The calculator will scan the cassette and print a directory of the files already marked on track 0. Then it will position the cassette ready to mark a new file. Later, when a sample is ready to record, it will mark the file, using track 1 if necessary, or even requesting a new cassette.

A sub-option is available in the COPY option. You may verify that each minute of data has been successfully recorded by requesting that the file be displayed. After each one-minute file is written on the HP cassette, it will be immediately re-read back into the calculator memory. The five archive header lines will be displayed on the LED strip for 5 seconds each, followed by the first 5 data lines at .1 second each. This sub-option will be explained briefly on the strip printer, and a selection requested by:

Display (0=No 1=Yes 2=HELP)

If you enter a zero, none of the one-minute cassette files will be re-scanned and displayed. If you enter a 1, each file will be re-scanned and displayed. If you enter a 2, the HELP message will be printed as follows:

5 file header
lines and 5 data
lines may be

```
shown on the LED
strip display.
Enter: To:
0 Display OFF
1 Display  ON
2 This HELP list
```

When you have selected a display sub-option, the calculator will begin to read the 300-B file, starting with the 77.2 second heave delay, followed by one minute bursts. After each minute is read, the heave delay will be corrected. Then the calculator will try to mark the new one-minute file on the HP cassette. If there is not enough space on track 0 of the cassette, the calculator will scan track 1. If track 1 is full, a new cassette will be requested using the same prompting messages as described above.

When a file has been marked, the archive header and data lines will be written on the cassette file. If you have accepted the display sub-option, the header and data lines will be read back from the cassette file and displayed as described above. Finally, the printer will acknowledge completion of the file by cassette number, track number, file number, and minute. These steps will be repeated for each minute of the 300-B file. The printer will acknowledge when the 300-B file is completely copied. Then the LED display will return to the OPTION prompt:

```
Opt. (0=QUIT 1 2 3 4 5=HELP)
```

option. A five minute sample from a 300-B cartridge was copied into five one-minute files on an HP cassette. Track 0 of the cassette was already filled with 10 one-minute files from another 300-B track. Track 1 also had nine small files from another source, as well as five EGGLOG data files. The new files were therefore copied into positions 15 through 19 on track 1 of the cassette.

6.2 The LIST Option

The LIST option displays a one-minute file recorded on an HP-9825 cassette using the LED strip. The display takes about a minute, showing each archive header record for 5 seconds, and scanning the 360 data records in 36 seconds.

If you enter a 2 in response to the option prompt, the printer will instruct:

```
Insert an HP
Tape Cassette to
display on LED
```

The track, file, and number of data records to display will be requested on the LED in order:

```
Track (0,1)
```

File (0-9)

Lines (1-360)

Then the LED display will ask:

HP cassette ready?

When you press CONTINUE, the calculator will search the cassette for the track and file that you have requested. If it cannot find that file number on the track named, or if the file exists, but is of the wrong type or size for a one-minute data file, the printer will note "Wrong File No." and the calculator will begin he LIST option over again.

Once an appropriate file has been located, the display will take place. The LIST option ends by returning to the OPTION prompt:

Opt. (0=QUIT 1 2 3 4 5=HELP)

which has been described above.

6.3 The 300-B MAP Option

If you enter a 3 in response to the OPTION prompt, the calculator will commence the 300-B MAP option. The option begins in exactly the same way that the COPY option starts (see Section 6.1), requesting that the recorder be connected, a 300-B cartridge inserted, the track set, and a file number specified. As in the COPY option, the calculator then rewinds the 300-B cartridge and skips forward to the desired file.

When the file is found on the 300-B cartridge in the recorder, the archive header record is read. Each letter in the record is printed, along with its character position in the record. Figure 3-1 is a sample.

When the header record has been mapped, the first data record is read from the recorder. It is printed on the strip printer in the same way (Figure 3-2). Finally, the calculator returns to the OPTION prompt.

6.4 The Cassette MAP Option

Option 4 begins in the same form as the LIST option: You will be instructed to insert an HP cassette, and to specify the track, file, and number of lines to map. When you indicate that the cassette is ready, a search will be made for the file. When it is found, each of the five archive header records will be mapped on the strip printer. Then maps will be printed for each of the data records that you have requested.

These maps are shorter than the 300-B maps: 34 characters each.

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12. Lear Siegler, Inc., ADM-3A Interactive Display Terminal: Operators Manual

13. Hewlett-Packard 98036A Serial I/O Interface Installation and Service Manual

14. Hewlett-Packard 98033A BCD Interface Installation and Service Manual

Appendix A

Alternate Connections for The Columbia 300-B Recorder

The EGGLOG system can be used with an HP-98036A Option 001 interface to connect the calculator with the Columbia 300-B recorder in place of the standard interface. Several changes of procedure are required. If the recorder is used with an option 001 interface, the ONLINE lamp must be OFF, contradicting a prompting message that occurs several times in the LOGGER and COPIER programs.

When the ONLINE lamp is off, only the TERMINAL socket on the back panel of the recorder is active. The option 001 cable may be plugged there. If this is done, the system will function, but there is no way to use the tv monitor.

In order to use the tv monitor with an option 001 interface, plug the interface cable into the main I/O port of the ADM-3A monitor (Near the power cable pass-through). Patch the extension port of the monitor to the TERMINAL socket on the back of the 300-B recorder.

APPENDIX B

TALKBACK: Check Out HP-98036A RS-232 Interface Operation

```
 0: dim H$[80]                    HP keyboard input buffer
 1: dim T$[20]                    TV prompt message
 2: dim L$[80]                    TV keyboard input buffer
 3: "Type Here (q=Quit)" -> T$    TV prompt message
 4: prt "    TALKBACK"            Introduction
 5: prt "98036A Checker"
 6: prt "Connect 98036A"
 7: prt "to termial"
 8: prt "Set mutual BAUD"
 9: ent "Select Code:", S         Input Select Code
10: ent "Mode Number:", M         78 for ADM-3A with 300-B
11: ent "USART Control", U        Use 37
12: wsm S, M, U                   Turn Interface on
13: "next": enp "Type Here (q=Quit)", H$
14: wrt S, H$                     Send entry to TV display
15: if H$="q"; stp                End of session
16: wrt S, T$                     Prompt for reply
17: red S, L$                     Accept TV keyboard reply
18: prt L$                        Acknowledge reply
19: if L$="q"; stp                End session from TV
20: gto "next"                    Say some more
```

APPENDIX C

The LOGGER Program

```
 0: prt "HIPPY/ROSS DATA"                      Begin documentary heading
 1: prt "      LOGGER"
 2: prt "David B. Dillon"
 3: prt "      EG&G"
 4: prt "September, 1980"
 5: dim T$[35]                                 HIPPY decimal data string
 6: dim H$[11]                                 HIPPY modify characters
 7: dim I$[30]                                 User input string
 8: dim L$[128]                                Recorder file header
 9: for I = 1 to 128                           Fill file header
10: " " -> L$[I]                               with spaces
11: next I
12: "File "         -> L$[1,5]                 Fill header field names
13: " Track "       -> L$[8,14]
14: " Cart. "       -> L$[16,22]
15: " Run "         -> L$[26,30]
16: " in Trial:"    -> L$[58,67]
17: " on "          -> L$[89,92]
18: " at "          -> L$[102,105]
19: " for "         -> L$[111,115]
20: " Minutes"      -> L$[118,125]
21: wsm 10,78,37                               Start RS-232 to recorder
22: wsm 11,254,37                              Start RS-232 to HIPPY
23: fixd 0                                     Set integer math
24: beep
25: enp "Skip Header (y/n)", I$[1,30]
26: if I$[1,1] = "y"; gto "TRIAL"              Skip wiring message
27: prt ""
28: prt "+ Connections +"                      Instrumentation set up
29: prt "HIPPY:"                               HIPPY to HP9825
30: prt "98036A - Opt.001"                     RS-232 Interface
31: prt "Select Code    11"
32: prt "Baud Rate   9600"
33: prt ""
34: prt "ROSS:"                                ROSS to HP9825
35: prt "98033A  BCD Port"                     BCD Parallel Interface
36: prt "with EG&G adap-"
37: prt "ter connector"
38: prt "Select Code    13"
39: prt "Power          ON"
40: prt "TEST or OPERATE"
41: prt ""
42: prt "RECORDER:"                            Digital Tape to HP9825
43: prt "Columbia - 300-B"
44: prt "98036A: Standard"                     RS-232 Interface
45: prt "Select Code - 10"
```

```
46: prt "Input:  CPU/MOD."           Cable to cable
47: prt "Block Mode:   ON"           Use 128 chars. per record
48: prt "Line Mode:    ON"           Control thru CPU/MOD. cable
49: prt "Baud Rate - 9600"
50: prt "300-B Back Panel"           Fixed switch settings
51: prt "Duplex:     HALF"
52: prt "Transparent: OFF"
53: prt "Error Check: OFF"
54: prt "Both Rotaries: 6"
55: prt ""
56: prt "TV Data Monitor:"           Real time data display
57: prt "Lear-Siegler"
58: prt "ADM-3 Set-Up"
59: prt "Bit 8:         1"           Front Panel switches
60: prt "Parity:      INH"
61: prt "Stop Bits:     1"
62: prt "Data Bits:     8"
63: prt "Parity:      ODD"
64: prt "Lowercase ENABLE"
65: prt ""
66: prt "Autolinefeed OFF"
67: prt "RS-232        ON"
68: prt "Duplex:     HALF"
69: prt "Baud Rate   9600"
70: prt ""
71: prt "Normal Monitor"             As read by recorder
72: prt "Patch ADM-3 Main"
73: prt "I/O to 300-B"
74: prt "TERMINAL PORT"
75: prt ""
76: "TRIAL": Beep                    Begin next trial
77: enp "Trial Name (1-20 Char.)", I$[1,30]
78: 22 -> A;gsb "PARSE"              Verify
79: if A = 0; gto "TRIAL"            Entry too long
80: I$[1,21] -> L$[68,88]            Fill file header
81: prt "Trial Name:"
82: prt I$[1,21]
83: "DATE": beep
84: enp "Trial Date (DD-Mon-YY):", I$[1,30]
85: 10 -> A; gsb "PARSE"             Verify date
86: if A = 0; gto "DATE"
87: I$[1,9] -> L$[93,101]            Date to file header
88: prt "Date ", I$[1,9]
89: prt ""
90: prt "Continue when"              Wait for HIPPY to warm up
91: prt "HIPPY on and "
92: prt "ready . ."
93: beep
94: ent "HIPPY Ready?", A
95: "MMMMD A   S" -> H$              HIPPY Modify characters
```

```
 96: for I = 1 to 11                          Modify HIPPY format
 97: wtb 11, H$[I,I]
 98: prt H$[I,I]
 99: Wait 1500                                Wait for HIPPY response
100: next I                                   Allow for 300 Baud
101: rdb (11) -> A                            remove last character
102: prt ""
103: prt "Turn 300-B    ON"
104: prt "Push 300-B  STOP"
105: prt "Set ONLINE    ON"
106: prt "Set  BLOCK    ON"
107: "TAPE": prt ""
108: prt "Mount new 300-B"
109: prt "Cartridge"
110: beep
111: enp "300-B Cartridge No.?", I$[1,30]
112: val(I$) -> C                             Assign cartridge number
113: if C < 1; gto "BCART"                    Verify
114: if C < 1000; gto "GCART"
115: "BCART": prt ""                          Invalid Cartridge number
116: prt "Use 1-999 Carts."
117: gto "TAPE"
118: "GCART": 4 -> A                          Parse valid cartridge
119: gsb "PARSE"
120: if A = 0; gto "TAPE"
121: I$[1,3] -> L$[23,25]                     Cartridge to file header
122: prt ""
123: prt "Cartridge", C
124: "TRACK": beep
125: enp "Set and enter TRACK (1-4)", I$[1,30]
126: val(I$) -> T                             Assign Track Number
127: if T < 1; gto "BTRK"                     Verify
128: if T < 5; gto "GTRK"
129: "BTRK": prt ""                           Invalid Track number
130: prt "Enter 1 2 3 or 4"
131: gto "TRACK"
132: "GTRK": 2 -> A                           Parse valid Track
133: gsb "PARSE"
134: if A = 0; gto "TRACK"
135: I$[1,1] -> L$[15,15]
136: prt "Track", T
137: "FILE": beep
138: enp "File Position (1-99)", I$[1,30]
139: val(I$) -> F                             Assign File Position
140: if F < 1; gto "BFIL"                     Verify
141: if F < 100; gto "GFIL"
142: "BFIL": prt ""                           Invalid file position
143: prt "Use 1 thru 99"
144: gto "FILE"
145: "GFIL": 3 -> A                           Parse valid file no.
```

```
146: gsb "PARSE"
147: if A = 0; gto "FILE"
148: I$[1,2] -> L$[6,7]                  File position to header
149: prt "File", F
150: wtb 10,26
151: beep
152: ent "Continue when REWIND over", A
153: for I = 2 to F                      Locate file position
154: wtb 10, 11                          Control-K skips 1 file
155: beep
156: ent "Continue when FORWARD over", A
157: next I
158: "HELP": prt ""
159: prt "Enter:"
160: prt "1-5 Char. Run No"              Prompt for run options
161: prt "q QUIT Session"
162: prt "f Reset FILE No."
163: prt "t New TRACK"
164: prt "c New CARTRIDGE"
165: prt "h This HELP list"
166: prt "Run No. may mix"
167: prt "up to 5 digits,"
168: prt "letters and"
169: prt "symbols."
170: "RUN": beep
171: enp "Run (1-5 Ch. q f t c h=HELP)", I$[1,30]
172: if I$[1,1] = "q"; stp
173: if I$[1,1] = "f"; gto "FILE"
174: if I$[1,1] = "t"; gto "TRACK"
175: if I$[1,1] = "c"; gto "CART"
176: if I$[1,1] = "h"; gto "HELP"
177: 6 -> A; gsb "PARSE"
178: if A = 0; gto "RUN"
179: I$[1,5] -> L$[31,35]                 Run No. to file header
180: prt "Run No.      ", I$[1,5]
181: "NAME": beep
182: enp "Run Title (1-20 Char.):", I$[1,30]
183: 22 -> A; gsb "PARSE"                 Validate run title
184: if A = 0; gto "NAME"
185: I$[1,21] -> L$[37,57]                Title to file header
186: prt "Name:"
187: prt I$[1,21]
188: "MINS": beep                         Run Duration
189: enp "Duration (Minutes)", I$[1,30]
190: val(I$) -> N                         Convert to numeric
191: if N < 0; gto "BMIN"                 Invalid duration
192: if N < 17; gto "GMIN"
193: "BMIN": prt""                        Invalid duration prompt
194: prt "Use 1 - 16 Mins."
195: gto "MINS"
```

```
196: "GMIN": 3 -> A                            Parse valid duration
197: gsb "PARSE"
198: if A = 0; gto "MINS"
199: I$[1,2] -> L$[116,117]                   Run duration to file head
200: prt "Duration",N
201: "TIME": beep                             Note run start time
202: enp "Run Time (HH:MM):", I$[1,30]
203: 6 -> A; gsb "PARSE"                      Validate time
204: if A = 0; gto "TIME"
205: I$[1,5] -> L$[106,110]                   Start time to file header
206: prt "Time      ", I$[1,5]
207: "BEGIN": beep                            Trigger sample start
208: ent "Start Sample", A
209: fmt 1,c30,fz4.0,x,x,z                    Set format for 1 data sweep
210: wtb 10, 18                               Control-R sets 300-B WRITE
211: wait 100                                 Delay for 300-B to respond
212: wtb 10, L$[1,126], 10, 13                Record file header
213: 155 -> Z                                 155/2=77.5 sec extra sample
214: gsb "COPY"                               For digital heave offset
215: 120 -> Z                                 120/2=60 sec normal sample
216: for M = 1 to N                           Loop over run duration
217: gsb "COPY"                               Record 1 minute
218: next M
219: wtb 10, 28                               Control-\ marks end of file
220: F + 1 -> F                               Set next file number
221: prt "Next File:", F
222: gto "RUN"                                Run complete: start another
223: "COPY": for S = 1 to Z                   Record Z half-second lines
224: for K = 1 to 3                           3 data sweeps/tape record
225: red 13, D, A                             Trigger sweep on ROSS depth
226: wtb 11, "S"                              Request HIPPY sweep
227: red 11, T$                               Collect HIPPY sweep
228: wrt 10.1, T$[1,30], D                    Record the sweep
229: next K
230: wtb 10, 10, 13                           LF/CR end file line
231: next S                                   Start another line
232: beep                                     Mark 1 minute
233: ret                                      Start another minute
234: "PARSE": for I = A to 30                 Scan unused part of line
235: if I$[I,I] #" "; gto "BAD"
236: next I                                   Look for non-blanks
237: ret
238: "BAD": 0 -> A                            Set error flag
239: prt "Entry Too Long"
240: ret
```

APPENDIX D

The COPIER Program

```
 0: prt "HIPPY/ROSS DATA"      Program title and
 1: prt "      COPIER"         User Introduction
 2: prt "David B. Dillon"
 3: prt "EG&G  Oct. 1980"
 4: prt ""
 5: prt "Transfers 300-B"      Program functions
 6: prt "records to HP"
 7: prt "cassette and"
 8: prt "shifts digital"
 9: prt "heave by 463"
10: prt "records."
11: dim H$[5,34],C$[360,34]   Cassette buffers (must be first)
12: dim Z$[1]                 User single character entry
13: dim L$[128]               300-B recorder input string
14: dim A$[465,34]            77.5 second memory buffer
15: gto "Help"
16: "HELP":prt ""
17: prt "Option List"         Display user options
18: prt "Enter To"
19: prt "0 QUIT program"
20: prt "1 COPY Tape from"
21: prt "  300-B to HP"
22: prt "2 LIST Cassette"
23: prt "  in LED display"
24: prt "3 MAP 300-B file"
25: prt "  header & first"
26: prt "  data line on"
27: prt "  strip printer"
28: prt "4 MAP HP file:"
29: prt "  five header"
30: prt "  lines and 3"
31: prt "  data lines."
32: prt "5 HELP with this"
33: prt "  option list"
34: "OPTION": beep
35: ent "Opt. (0=QUIT 1 2 3 4 or 5=HELP)
36: if O=0; stp
37: if O=1; gto "CART"        Select COPY option
38: if O=2; gto "LIST"        Select LIST option
39: if O=3; gto "CART"        Select MAP 300-B option
40: if O=4; gto "LIST"        Select MAP HP option
41: "CART":prt ""
42: prt "Insert 300-B"        Begin COPY option
43: prt "cartridge."
44: prt "Set ONLINE    ON"    Set up 300-B
45: prt "Set  BLOCK    ON"
```

```
46: prt "Set  TRACK   1-4"
47: prt "Enter File No."
48: prt "when 300-B ready"
49: prt ""
50: beep
51: ent "300-B File No. (0=QUIT)", F
52: if F=0; stp
53: wsm 10, 78, 37                  Set RS-232 Interface
54: wtb 10, 26                      Control-Z: Rewind 300-B
55: beep
56: enp "Continue when REWIND over", Z$
57: for I=2 to F
58: wtb 10, 11                      Control-K: Skip 1 file
59: beep
60: enp "Continue when FORWARD over", Z$
61: next I
62: wtb 10, 17                      Control-Q requests 1 line
63: red 10, L$                      Get 300-B characters to LF
64: if O=3; gto "MAP"               Print header character by char.
65: val(L$[116,117]) -> N           Extract Run duration (minutes)
66: prt ""
67: prt "Copy Run    ", L$[31,35]
68: prt "Duration", N
69: for J = 1 to 5                  Loop over cassette header lines
70: for I = 1 to 34                 Loop over characters in line
71: " " -> H$[J,I,I]                Blank fill cassette headers
72: next I
73: next J
74: L$[1,26]   -> H$[2,1,26]        Break 300-B header into 5 lines
75: L$[26,58]  -> H$[3,1,33]
76: L$[61,89]  -> H$[4,1,29]
77: L$[93,125] -> H$[5,1,33]
78: gsb "CASS"                      Mount an HP Cassette to fill
79: "DOPT": beep
80: ent "Display (0=No 1=Yes 2=HELP)", D
81: if D=0; gto "FIRST"             Copy without display
82: if D=1; gto "FIRST"             Copy with display
83: prt ""
84: prt "5 file header"
85: prt "lines and 5 data"
86: prt "lines may be"
87: prt "shown on the LED"
88: prt "strip display."
89: prt "Enter:  To:"
90: prt "0 Display OFF"
91: prt "1 Display  ON"
92: prt "2 This HELP list"
93: gto "DOPT"
94: "FIRST": 155 -> Z               Get 155 half-sec lines from 300-B
95: 1 -> K                          Put in C$ starting at line 1
```

```
 96: gsb "Copy"                 Get lines from 300-B
 97: 120 -> Z                   Set 1 minute block size
 98: for M = 1 to N             Loop over minutes of sample
 99: for K = 1 to 360           Move 1 minute from A$ to C$
100: A$[K] -> C$[K]             A$: HP Memory Stack
101: next K                     C$: Cassette Data Buffer
102: for K = 361 to 465         Shift 17.5 sec to front of A$
103: A$[K] -> A$[K-360]
104: next K
105: 106 -> K                   Move next minute behind 17.5 sec
106: gsb "COPY"
107: for K = 1 to 360           Move Digital Heave 77.2 sec
108: A$[K+103,21,29] -> C$[K,21,29]
109: next K
110: "MARK": mrk 1, 13200, F    Mark the next cassette file
111: if F >= 0; gto "RCRD"      Test for end of track
112: T + 1 -> T                 Next track
113: if T = 1; gsb "FILE"       Find end of data on track 1
114: if T = 2; gsb "CASS"       Both tracks full: get new cassette
115: gto "MARK"                 Ready to mark file
116: "RCRD": "File " -> H$[1,5] Fill first header line
117: str(F) -> H$[1,6,8]
118: " Track " -> H$[1,9,15]
119: str(T) -> H$[1,16,17]
120: " Cass. " -> H$[1,18,25]
121: str(C) -> H$[1,26,31]
122: rcf F, H$, C$              Record header and 1 minute of data
123: 6 -> K
124: if D > 0;gsb "DISP"        Display header and first 2 seconds
125: prt ""
126: prt "HP Cassette", C
127: prt "Track", T
128: prt "File", F
129: prt "Minute", M
130: next M
131: prt ""
132: prt "Copy Complete"        End of COPY option
133: gto "OPTION"
134: "COPY": for S = 1 to Z     Get Z lines from 300-B
135: wtb 10, 17                 Control-Q: request a line
136: red 10, L$                 Accept characters to LF
137: L$[1,34] -> A$[K]          L$ brings 3 data sweeps
138: K + 1 -> K                 From 300-B file each read
139: L$[37,70] -> A$[K]
140: K + 1 -> K
141: L$[73,106] -> A$[K]
142: K + 1 -> K
143: next S
144: beep                       Block is collected
145: ret
```

```
146: "CASS": prt ""
147: prt "Insert an HP"             Get a cassette
148: prt "tape cassette"            and initialize it
149: beep
150: ent "HP Tape No.(1-99999 0=QUIT)", C
151: if C=0; stp
152: if C<0; gto "CASS"
153: if C>99999; gto "CASS"
154: 0 -> T                         Set track 0
155: "FILE":rew                     Start at beginning
156: trk T                          Set track
157: tlist                          Display contents
158: 0 -> F                         Find NULL file
159: "FIND": fdf F
160: idf F, J
161: if J = 0; ret                  NULL file found
162: F + 1 -> F                     Try next file
163: gto "FIND"
164: "LIST": prt ""
165: prt "Insert an HP"             Begin Option 2: LIST
166: prt "Tape Cassette to"         HP tape files on LED strip
167: prt "display on LED"
168: beep
169: ent "Track (0,1)", T           Select tape track
170: trk T
171: beep
172: ent "File (0-9)", F            Select file (9=track capacity)
173: beep
174: ent "Lines (1-360), K          Select lines to display
175: beep
176: ent "HP cassette ready?", Z$
177: rew
178: 0 -> U
179: "FNXT":  fdf U                 Find file
180: idf U, V, W, X, Y              Get file identity
181: if V = 0; gto "BFIL"           No such file no.
182: if U = F; gto "FTST"           Evaluate file
183: U + 1 -> U                     Try next file
184: gto "FNXT"
185: "FTST": if V≠3; gto "BFIL" File is wrong type
186: if X = 13200; gto "DISP"       Test file size
187: "BFIL": prt ""
188: prt "Wrong File No."
189: rew
190: tlist
191: rew
192: gto "LIST"
193: "DISP": ldf F, H$, C$          Get file from cassette
194: if O=4; gto "MAPHP"
195: for I = 1 to 5                 Display 5 header lines
```

```
196: dsp H$[I]
197: wait 5000                    Hold for 5 seconds
198: next I
199: for I = 1 to K               Display K data lines
200: dsp C$[I]
201: wait 100                     Hold for 0.1 sec.
202: next I
203: if O = 2; gto "OPTION"       End of Option 2
204: ret                          End of Display option of COPY
205: "MAP": prt ""
206: for K = 1 to 2               Option 3: MAP 300-B
207: prt "300-B RECORD MAP"       Header and 1 data line
208: for I = 1 to len(L$)         One character at a time along
209: prt L$[I,I], I               The strip printer
210: next I
211: prt ""
212: wtb 10, 17                   Control-Q requests another line
213: red 10,L$                    Get the data line
214: next K
215: prt ""
216: gto "OPTION"                 Option 3: MAP complete
217: "MAPHP": FXD 0               Begin Option 4
218: for J=1 to 5                 Map HP Cassette records
219: prt ""
220: prt "CASSETTE RECORD'        Five Headerlines
221: prt "       MAP"
222: prt "Archive Line", I
223: for J=1 to LEN(H$[I])        Character by
224: prt H$[I,J,J], J             Character
225: next J
226: next I
227: for I=1 to K                 Map first K data lines
228: prt ""
229: prt "Data Line      1"
230: for J=1 to LEN(C$[1])
231: prt C$[I,J,J], J
232: next J
233: prt ""
234: gto "OPTION"
```

FIGURES

300-B RECORD MAP

F	1	C	43	o	85
i	2	h	44	w	86
l	3	e	45		87
e	4	c	46		88
	5	k	47		89
2	6	o	48	o	90
	7	u	49	n	91
	8	t	50		92
T	9		51	1	93
r	10		52	3	94
a	11		53	-	95
c	12		54	O	96
k	13		55	c	97
	14		56	t	98
4	15		57	-	99
	16		58	8	100
C	17	i	59	0	101
a	18	n	60		102
r	19		61	a	103
t	20	T	62	t	104
.	21	r	63		105
	22	i	64	1	106
1	23	a	65	1	107
	24	l	66	:	108
	25	:	67	0	109
	26	D	68	9	110
R	27	i	69		111
u	28	c	70	f	112
n	29	k	71	o	113
	30		72	r	114
D	31	O	73		115
a	32	g	74	5	116
v	33	l	75		117
i	34	e	76		118
d	35	s	77	M	119
	36	b	78	i	120
F	37	y	79	n	121
i	38	'	80	u	122
n	39	s	81	t	123
a	40		82	e	124
l	41	S	83	s	125
	42	h	84		126

Figure 3-1. Columbia 300-B Header Record Format

300-B RECORD MAP

	1		37		73
0	2	0	38	0	74
0	3	0	39	0	75
1	4	1	40	2	76
	5		41		77
	6		42		78
0	7	0	43	0	79
0	8	0	44	0	80
0	9	0	45	0	81
	10		46		82
	11		47		83
0	12	0	48	0	84
0	13	0	49	0	85
0	14	0	50	0	86
	15		51		87
-	16	-	52	-	88
1	17	1	53	1	89
1	18	1	54	1	90
1	19	1	55	1	91
	20		56		92
-	21	-	57	-	93
0	22	0	58	0	94
0	23	0	59	0	95
0	24	0	60	0	96
	25		61		97
	26		62		98
0	27	0	63	0	99
0	28	0	64	0	100
0	29	0	65	0	101
	30		66		102
6	31	6	67	6	103
4	32	4	68	4	104
3	33	3	69	3	105
4	34	4	70	4	106
	35		71		107
	36		72		108

Figure 3-2. Columbia 300-B Data Record Format

```
HIPPY/ROSS DATA
    LOGGER
David B. Dillon
    EG&G
September  1980
Skip Header (y/n
)
y
Trial Name (1-20
 Char.)
Dick Oglesby's S
how
Trial Name:
Dick Oglesby's S
how
Trial Date (DD-M
on-YY):
13-Oct-80
Date
13-Oct-80

Continue when
Hippy on and
ready . .
M
M
M
M
D

A



S

Turn 300-B    ON
Push 300-B  STOP
Set ONLINE    ON
Set  BLOCK    ON

Mount new 300-B
Cartridge
300-B Cartridge
No.?
1

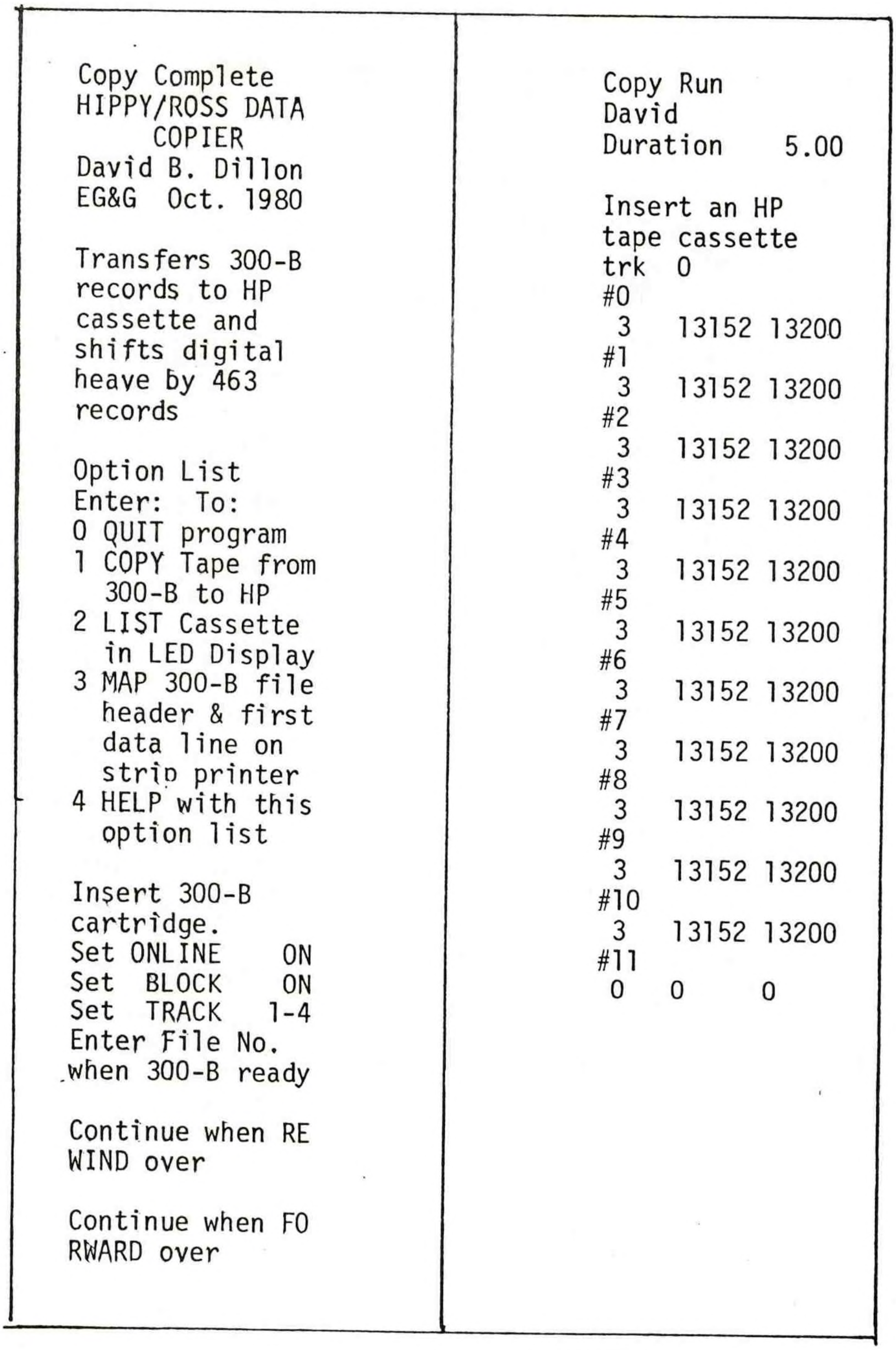
Cartridge      1
Set and enter TR
ACK (1-4)
4
```

```
Track          4
File Position (1
-99)
2
File           2

Enter:
1-5 Char. Run No.
q QUIT Session
f Reset FILE No.
t New TRACK
c New CARTRIDGE
h This HELP list
Run No. may mix
up to 5 digits,
letters, and
symbols.
Run No (1-5 Ch.
q f t c h=HELP)
David
Run No.
David
Run Title (1-20
Char.):
Final Checkout
Name:
Final Checkout

Duration (Minute
s)
5
Duration       5
Run Time (HH:MM)
:
11:09
Time
11:09
Next File:     3
Run No (1-5 Ch.
q f t c h=HELP)
q
```

Figure 5-1. Sample Data Logging Printout



```
Copy Complete
HIPPY/ROSS DATA
     COPIER
David B. Dillon
EG&G  Oct. 1980

Transfers 300-B
records to HP
cassette and
shifts digital
heave by 463
records

Option List
Enter:  To:
0 QUIT program
1 COPY Tape from
  300-B to HP
2 LIST Cassette
  in LED Display
3 MAP 300-B file
  header & first
  data line on
  strip printer
4 HELP with this
  option list

Insert 300-B
cartridge.
Set ONLINE    ON
Set  BLOCK    ON
Set  TRACK   1-4
Enter File No.
when 300-B ready

Continue when RE
WIND over

Continue when FO
RWARD over
```

```
Copy Run
David
Duration    5.00

Insert an HP
tape cassette
trk  0
#0
 3   13152 13200
#1
 3   13152 13200
#2
 3   13152 13200
#3
 3   13152 13200
#4
 3   13152 13200
#5
 3   13152 13200
#6
 3   13152 13200
#7
 3   13152 13200
#8
 3   13152 13200
#9
 3   13152 13200
#10
 3   13152 13200
#11
 0   0      0
```

Figure 6-1a. Sample Data Copying Printout

```
trk  1
#0
 2   800    800
#1
 2   800    800
#2
 2   800    800
#3
 2   800    800
#4
 2   800    800
#5
 2   800    800
#6
 2   800    800
#7
 2   800    800
#8
 2   800    800
#9
 2   800    800
#10
 3   13152 13200
#11
 3   13152 13200
#12
 3   13152 13200
#13
 3   13152 13200
#14
 3   13152 13200
#15
 0   0      0
```

```
HP Cass.  123.00
Track       1.00
File       15.00
Minute      1.00

HP Cass.  123.00
Track       1.00
File       16.00
Minute      2.00

HP Cass.  123.00
Track       1.00
File       17.00
Minute      3.00

HP Cass.  123.00
Track       1.00
File       18.00
Minute      4.00

HP Cass.  123.00
Track       1.00
File       19.00
Minute      5.00

Copy Complete
```

Figure 6-1b. Sample Data Copying Printout (Cont'd.)

APPENDIX D

```
0: "Time Plots for Hippy Data":
1: dim E$[5,34],F$[360,34],S$[5],H$[20],G$[3,34]
2: dim A[10],B[10],C[10],D[10]
3: 1.2917→X;.5833→Y;2.1183→Z;2.2→Q
4: ldk 1
5: 1180→A[1];800→A[2];13380→A[3];8025→A[4]
6: deg;fxd 0
7: 1→M;360→O
8: %
9: %
10: gto "PAGE"
11: gto "DATA"
12: gto "GRAPH"
13: gto "START"
14: gto "ROSS"
15: gto "AHEAVE"
16: gto "BHEAVE"
17: gto "ROLL"
18: gto "PITCH"
19: gto "ERROR"
20: gto "BDEPTH"
21: gto "ADEPTH"
22: "PAGE":
23: fxd 0
24: ent "How many Graphs per page?(1→10)",A[5]
25: if A[5]<1;jmp -1
26: if A[5]>10;jmp -2
27: if frc(A[5])≠0;jmp -3
28: for I=1 to A[5]
29: dsp "Enter Min value of Graph",I
30: ent "",B[I]
31: dsp "Enter Max value of Graph",I
32: ent "",C[I]
33: next I
34: 0→E;1→F
35: "SHIFT":
36: ent "Do you want Manual or Auto (m/a)",S$
37: cap(S$)→S$
38: "DATA":
39: ent "Enter New File Number (0→10)",N
40: if N>10;jmp -1
41: if N<0;jmp -2
42: if frc(N)≠0;jmp -3
43: if S$[1,1]="A";gto "LOAD"
44: ent "Enter start Position (1→360)",M
45: if M>360;jmp -1
46: if M<1;jmp -2
47: if frc(M)≠0;jmp -3
48: ent "Enter stop Position (1→360)",O
49: if O<1;jmp -1
50: if O>360;jmp -2
51: if frc(O)≠0;jmp -3
52: "LOAD":
53: ldf N,E$,F$
```

```
54: "HEADER":
55: A[1]→D[5];A[2]→D[6];A[3]→D[7];A[4]→D[8]
56: gsb "WRTSET"
57: wrt 705,G$[1]
58: E$[5,1,34]→G$[1,1,34]
59: E$[3,2,8]→G$[2,1,7]
60: "Buoys"→G$[2,8,12]
61: E$[3,15,29]→G$[2,13,27]
62: E$[2,27,34]→G$[2,27,34]
63: E$[1,1,34]→G$[3,1,34]
64: "GLBL":
65: 0→J→K
66: scl 0,100,0,100
67: lim -20,110,-20,104
68: csiz 1.2,2,1,90
69: wrt 705,"SL",tan(30)
70: pen# 1;pen
71: -8.8→J;21→K
72: for I=1 to 3
73: plt J,K,1
74: lbl G$[I,1,34]
75: J+1→J
76: next I
77: 67.3→J;101→K
78: csiz 1.2,2,1,0
79: plt J,K,1
80: lbl " Curve                    Mean       STD"
81: plt 100,100,1
82: 0→J→K
83: "AXIS":
84: (A[4]-A[2])/A[5]→A[6]
85: 0→A[7]
86: if F#1;E0→A[7]
87: scl 0,A[7],0,100
88: xax 0,A[7]/12,0,A[7],2
89: if S$[1,1]="A";plt A[7]/2-10,-9,1;lbl "TIME  ( 360/min.)"
90: for I=1 to A[5]
91: A[1]→D[5];A[2]+(I-1)A[6]→D[6];A[3]→D[7];IA[6]+A[2]→D[8]
92: gsb "WRTSET"
93: wrt 705,G$[1]
94: csiz 1.2A[5],A[5]2,1,0
95: scl 0,A[7],B[I],C[I]
96: yax 0,(C[I]-B[I])/10,B[I],C[I],3
97: yax A[7],(C[I]-B[I])/10,B[I],C[I]
98: if S$[1,1]="A";gsb "TITLE"
99: next I
100: pen
101: "GRAPH":
102: K+1→K;0→J
103: (B[K]+C[K])/2→D[2];1.5abs(C[K]-D[2])→D[3]
104: A[1]→D[5];A[2]+(K-1)A[6]→D[6];A[3]→D[7];KA[6]+A[2]→D[8]
105: gsb "WRTSET"
106: wrt 705,G$[1]
107: scl 0,A[7],B[K],C[K]
108: "START":
109: fxd 2
110: J+1→J;0→A[9]→A[10]→W
111: if S$[1,1]="A";gto "AUTO"
112: pen# ;stp
```

```
113: "ROSS":
114: pen# 1
115: for I=M to O
116: -.1val(F$[I,30,34])}V
117: FI}T
118: gsb "PLOT"
119: next I
120: "Ross Depth"}H$
121: gsb "LABLE"
122: gto "START"
123: "AHEAVE":
124: pen# 4
125: for I=M to O
126: .0328val(F$[I,11,14])}V
127: FI}T
128: gsb "PLOT"
129: next I
130: "Real Time Heave"}H$
131: gsb "LABLE"
132: gto "START"
133: "BHEAVE":
134: pen# 2
135: for I=M to O
136: .0328val(F$[I,21,24])}V
137: FI}T
138: gsb "PLOT"
139: next I
140: "Delay Heave"}H$
141: gsb "LABLE"
142: gto "START"
143: "ROLL":
144: pen# 3
145: for I=M to O
146: .1val(F$[I,1,4])}V
147: FI}T
148: gsb "PLOT"
149: next I
150: "Roll"}H$
151: gsb "LABLE"
152: gto "START"
153: "PITCH":
154: pen# 4
155: for I=M to O
156: .1val(F$[I,6,9])}V
157: FI}T
158: gsb "PLOT"
159: next I
160: "Pitch"}H$
161: gsb "LABLE"
162: if S$[1,1]="A";gsb "ZERO"
163: gto "START"
164: "ERROR":
165: pen# 3;pen
166: for I=M to O
167: .0328val(F$[I,26,29])}V
168: FI}T
169: gsb "PLOT"
170: next I
171: "Error"}H$
172: gsb "LABLE"
173: gto "START"
```

```
174: "BDEPTH":
175: pen# 2
176: 0→A[8]
177: "Depth cor H2RP"→H$
178: gto "DEPTH"
179: "ADEPTH":
180: pen# 4
181: 1→A[8]
182: "Depth cor H1RP"→H$
183: gto "DEPTH"
184: "DEPTH":
185: for I=M to O
186: if A[8]=0;.0328val(F$[I,21,24])→H
187: if A[8]=1;.0328val(F$[I,11,14])→H
188: .1val(F$[I,1,4])→R
189: .1val(F$[I,6,9])→P
190: acs(\(1-sin(P)^2-sin(R)^2))→G
191: H-Xsin(P)+Ysin(R)+Z(1-cos(G))→H
192: R+Q→R
193: acs(\(1-sin(P)^2-sin(R)^2))→G
194: -.1val(F$[I,30,34])→D[1]
195: D[1]cos(G)→D[1]
196: D[1]+H→V
197: FI→T
198: gsb "PLOT"
199: next I
200: gsb "LABLE"
201: gto "START"
202: "PLOT":
203: if abs(V-D[2])>D[3];plt T,V,1;jmp 2
204: plt T,V
205: if abs(V-D[2])<D[3];V+A[9]→A[9];V^2+A[10]→A[10];W+1→W
206: ret
207: "LABLE":
208: for I=len(H$)+1 to 20
209: " "→H$[I]
210: next I
211: A[9]/W→A[9]
212: A[10]/W→A[10]
213: \(A[10]-A[9]^2)→A[10]
214: scl 0,100,0,100
215: csiz 1.2A[5],A[5]2,1,0
216: plt 67.3,100-2JA[5],1
217: lbl H$,A[9],"    ",A[10]
218: scl 0,A[7],B[K],C[K]
219: ret
220: "AUTO":
221: if K=0;gto "DATA"
222: if K=1;if J=1;gto "BHEAVE"
223: if K=1;if J=2;gto "AHEAVE"
224: if K=1;if J=3;gto "ERROR"
225: if K=2;if J=1;gto "ROSS"
226: if K=2;if J=2;gto "BDEPTH"
227: if K=2;if J=3;gto "ADEPTH"
228: if K=3;if J=1;gto "ROLL"
229: if K=3;if J=2;gto "PITCH"
230: if K=1;if J=4;gto "GRAPH"
231: if K=2;if J=4;gto "GRAPH"
232: if K=3;if J=3;beep;gto "DATA"
```

```
233: "WRTSET":
234: fxd 0
235: "IP"→G$[1]
236: for L=5 to 8
237: len(G$[1])+1→D[9]
238: len(str(D[L]))+D[9]→D[10]
239: str(D[L])→G$[1,D[9],D[10]]
240: len(G$[1])+1→D[9]
241: ","→G$[1,D[9],D[9]]
242: next L
243: len(G$[1])→D[9]
244: ""→G$[1,D[9],D[9]]
245: ret
246: "ZERO":
247: pen# 2
248: for I=M to O+10 by 10
249: 0→V;F[I]→T
250: gsb "PLOT"
251: next I
252: pen#
253: ret
254: "TITLE":
255: if I=1;"Heave (ft)"→G$[1]
256: if I=2;"Depth  (ft)"→G$[1]
257: if I=3;"Rotation (deg)"→G$[1]
258: csiz 1,2A[5],2A[5],1,90
259: plt -15,(C[I]-B[I])/4+B[I]
260: lbl G$[1]
261: ret
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