7-1-1980

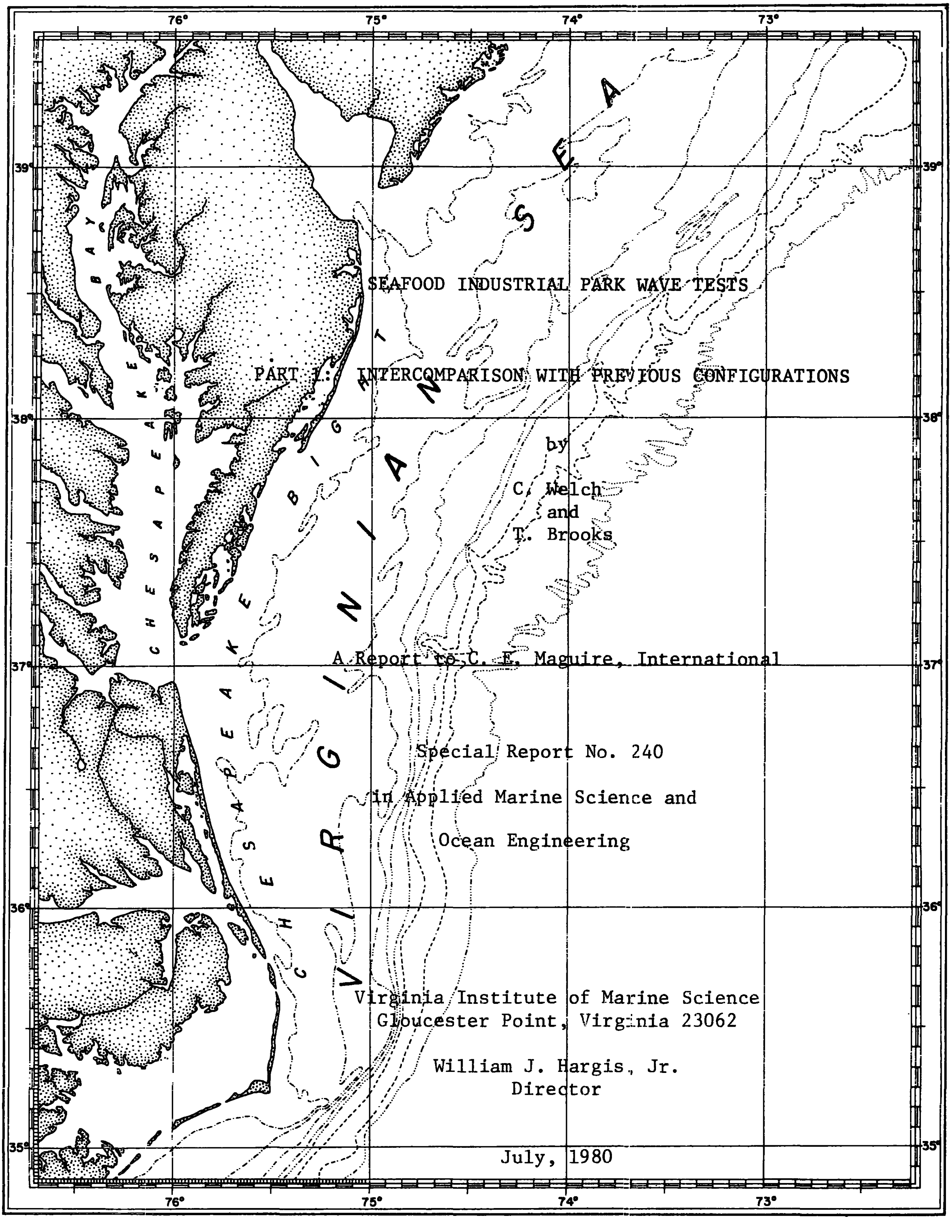
Seafood Industrial Park Wave Tests Part 1: Intercomparison with Previous Configurations

C. Welch
Virginia Institute of Marine Science

T. Brooks
Virginia Institute of Marine Science

Recommended Citation

Welch, C., & Brooks, T. (1980) Seafood Industrial Park Wave Tests Part 1: Intercomparison with Previous Configurations. Special Reports in Applied Marine Science and Ocean Engineering (SRAMSOE) No. 240. Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.21220/V5JJ17



SEAFOOD INDUSTRIAL PARK WAVE TESTS

PART I: INTERCOMPARISON WITH PREVIOUS CONFIGURATIONS

by

C. Welch
and
T. Brooks

A Report to C. E. Maguire, International

Special Report No. 240
in Applied Marine Science and
Ocean Engineering

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

William J. Hargis, Jr.
Director

July, 1980

SEAFOOD INDUSTRIAL PARK WAVE TESTS

PART 1: INTERCOMPARISON WITH PREVIOUS CONFIGURATIONS

by

C. Welch
and
T. Brooks

A Report to C. E. Maguire, International

Special Report No. 240

in Applied Marine Science and

Ocean Engineering

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

William J. Hargis, Jr.
Director

July, 1980

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors wish to acknowledge the financial support of the City of Newport News through the C. E. Maguire Company. The efforts of D. Harbit and J. Richards are appreciated, and close technical support was given by D. Killoy and K. Schoellner. The wave tank was the work of many people, E. P. Ruzecki and R. J. Lukens being chief architects of the generation machinery and the observation apparatus respectively. Technical support for this project was provided by W. Matthews, J. Cumbee and S. Fenstermacher. Tank operation was aided by J. Sweeney. S. Crossley did the greatest share of the typing and manuscript preparation.

LIST OF TABLES

LIST OF FIGURES

Conclusions and Recommendations

The present study in the VIMS wave tank has provided an intercomparison between the proposed Seafood Industrial Park breakwater configuration and previously tested configurations to complement the proposed I-664 crossing of Hampton Roads at the North Tunnel Island. As noted in a letter previously transmitted to C. E. Maguire via The Harwood Beebe Company (Appendix 1), the proposed Seafood Industrial Park breakwater is expected to deflect currents past the tunnel island on flood tide sufficiently well that the navigation hazard represented by the island is minimized. As also noted in the letter, the proposed breakwater will tend to prevent the sediment leaving Hampton Flats from shoaling the entrance to the enclosed harbor. Finally, the intercomparison wave experiment shows that the proposed Seafood Industrial Park breakwater will protect the present Small Boat Harbor from the effects of extreme storm waves as well as or better than the previously tested jetties.

Results from the intercomparison experiment also indicate some concerns which can be investigated with further proposed experiments. In particular, the waves which do not enter the present Small Boat Harbor seem to be reflected into the area of the Seafood Industrial Park. While this effect may be an artifact of the experimental conditions used in obtaining the intercomparison, the proposed Harbor Response Study is designed to provide more precise estimates. The tests also indicate that substantial energy will be reflected back out into Hampton Roads from the long, straight outer wall of the proposed breakwater. The reflection of this energy may be shown in further tests to be highly modified by the interconnected cylinder construction of the breakwater.

1. Introduction

As a part of the I-664 highway project, a bridge-tunnel crossing of Hampton Roads is planned between Newport News Point and the City of Suffolk (Virginia Department of Highways and Transportation, December, 1978). The north tunnel island of this crossing is proposed to be a peninsula, connected to the present tip of Newport News Point. Previous tests by VIMS in the James River Model at the Army Corps of Engineers Waterways Experiment Station (Fang, 1979) and the VIMS wave tank (Welch and Fang, 1980) have shown that a jetty complementing the tunnel island will provide adequate protection for the mouth of the Small Boat Harbor, which must be moved in conjunction with the proposed highway construction. Several configurations for this jetty have been tested in the VIMS wave tank, and a suitable configuration has been identified. This configuration has been judged to have good potential in three areas of concern:

- Expected alongshore littoral drift of sediment will be deflected from shoaling the entrance to Small Boat Harbor.
- Currents on flood tide will be deflected past the tip of the North tunnel island.
- The existing Small Boat Harbor will be well protected from waves generated by severe storms.

The proposed Seafood Industrial Park would expand the role of the protective jetty to include harbor space in addition to the three functions noted above. To this end, two preliminary configurations have already been tested for their wave transmission properties

(Welch, 1979). The tests of a third configuration, the Seafood Industrial Park (figure 1), is the subject of the present study. In particular, this report considers an intercomparison of the Seafood Industrial Park breakwater with the previously chosen jetty. This intercomparison covers the three concerns for which the previously tested configurations were evaluated.

Because intercomparison with previous work is the object of the present study, the conservative assumptions which applied to the previous work are repeated. The additional test series designed to produce an estimate of wave reductions in the harbor is deferred to a further study.

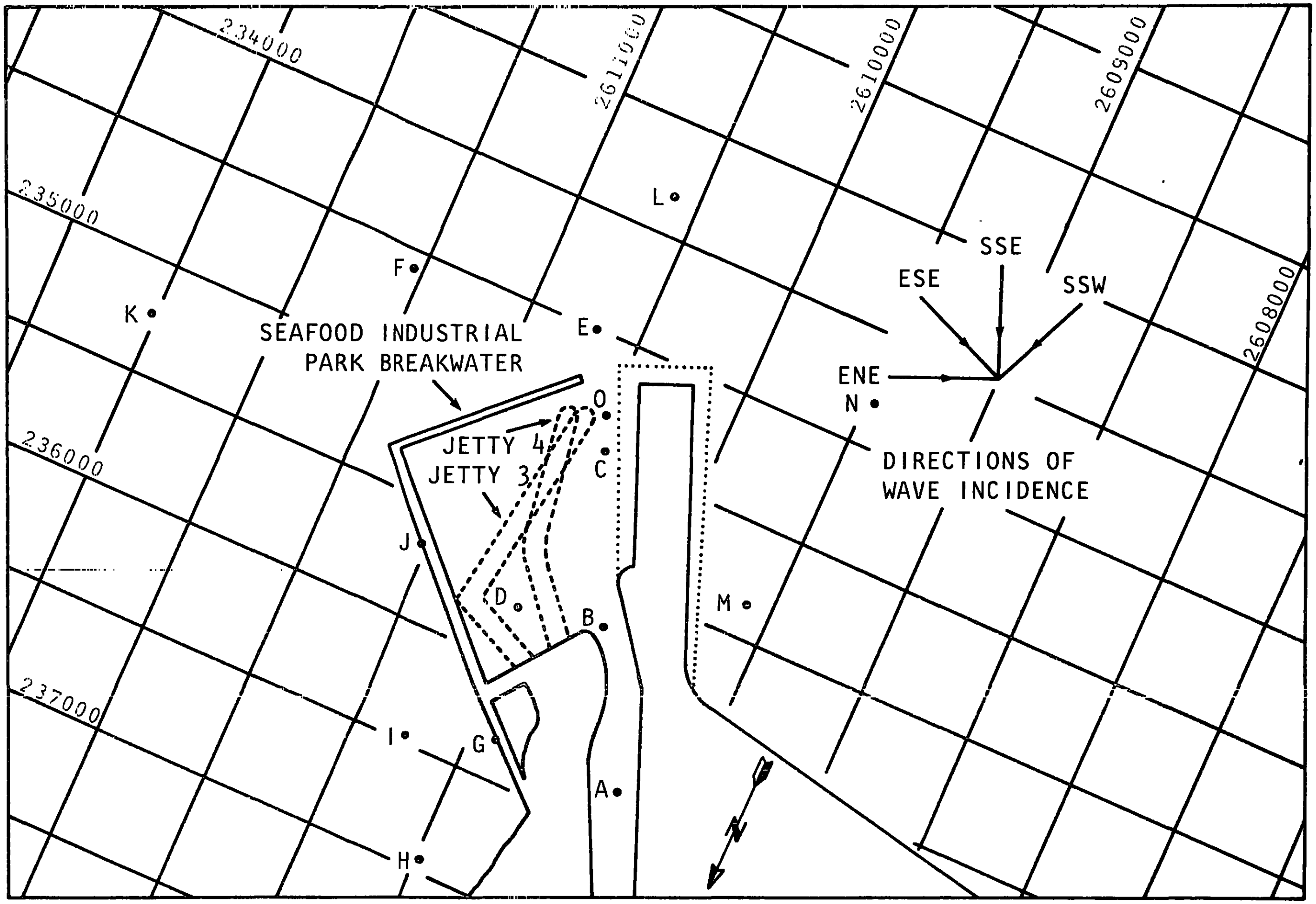


Figure 1. Location of Seafood Industrial Park breakwater. Previously tested configurations, the test stations, and wave incidence directions are indicated. Grid lines are for the Virginia coordinate system, south zone.

2. Methods and Materials

The intercomparison tests were performed in the VIMS wave tank, which has a wave generation section eight feet wide and seven feet long with a test section eight feet wide and twelve feet long. Wave absorbing material lines the perimeter of the tank. The wave generation was accomplished by a vertically plunging paddle with a 90 degree "V" cross section and a length of eight feet. The paddle was driven by an electronic signal through modified loudspeaker coils. This wave generation approach permits a great variety of waves to be generated with precise control. For this test, the generator was driven by a sinusoidal signal of frequency 5.16 Hz corresponding to a 96 ft. long wave in deep water in the prototype. The same wave characteristics were used in the previous tests. Wave heights were measured simultaneously at two locations, immediately in front of the wave generator and at one of sixteen test stations. These stations are indicated on figure 1. The measurements were made with capacitive gauges, each of which obtained 256 sequential measurements encompassing a time interval corresponding to 27 wave periods. The least count interval on the gauges in this configuration was 70 microns, the static hysterisis being about 500 microns. The heights of the waves were about 2 millimeters. These conditions correspond with those used in the previous jetty tests (Welch and Fang, 1980). The waves generated for the present tests were smaller than those previously used. These smaller waves had greatly reduced nonlinearities and hence clear spectra.

A bathymetric model of the area of Hampton Roads adjacent to the area of the tunnel island was used. With respect to the prototype, this model is scaled at 1:125 in the vertical and 1:500 in the horizontal, with a resulting 4:1 vertical distortion. The rationale for these scales is to reduce the size of the model itself as much as possible while still retaining the ability of the waves to propagate in a realistic manner through the study region. The model was the same one used in previous tests, and the rationale is presented in detail in Welch and Fang (1980). For the present test series, a breakwater corresponding to the C. E. Maguire jetty labelled Alternative I (C. E. Maguire, April 11, 1980) was fabricated for use with the bathymetric model. In section, this breakwater consists of a vertical wall towards the inside of the harbor with a 1:1.5 (prototype) slope on the outside of the breakwater. At the termination of the breakwater, a conical section (C. E. Maguire, undated) was placed with a 1:2 (prototype) slope around most of the cone. In order to obtain a direct intercomparison with the previous jetty tests, the proposed dredging of the inside of the harbor was not included in the model, but rather the present bathymetry was used.

3. Experimental Plan

The goal of the experiment, to obtain an intercomparison with previous work, was achieved by measuring the wave heights at the same places that they had been measured previously (stations A-P, Welch and Fang, 1980). In addition, two tests were performed to examine the reproducibility and accuracy of the entire system. The first of these was performed by locating the test gauge as close as possible to the monitor gauge and measuring the same train of waves near the wave generator with both gauges. The results of these measurements are indicated on the summary sheets as station "Z". The "Z" tests were performed subsequent to the station tests as each direction of the incident waves was examined. In addition, the tests for the no-jetty case (jetty 0) were repeated in the present study. The plan resulted in 17 paired measurements for each of 4 directions for each of 2 configurations yielding a total of 136 paired measurements called test runs, or 272 gauge records.

4. Data

The data from each test run consist of 256 pairs of simultaneous counter readings corresponding to the heights of waves at the monitor and test gauges at sequential 20.5 millisecond intervals. In addition, two counter readings are taken for calibration immediately preceding each test run with no waves present and with the test gauge sensing wire immersed to two depths separated by 1 centimeter. These counter readings are placed on magnetic tape along with the measurements and corresponding header information entered via a keyboard. The information is then analyzed on the VIMS IBM 370-115 computer to yield the wave records, presented as departures from a mean value, Fourier amplitude spectra of the records, and cumulative variance (as a percentage of the total variance) plotted as a function of frequency. The program package used for this calculation is called WAVECAL, and a listing of the programs is given in Appendix 2. The output from WAVECAL is used for all subsequent analysis and interpretation. An example from the current tests is given in Appendix 3. A static calibration was performed for both gauges following the test runs.

The data consist of about 1300 pages of computer printout from storage on portions of two magnetic tapes as well as the static calibration notes. A subset of the total data analyzed is of particular interest for the evaluation of wave response. For the Seafood Industrial Park phase 1 tests, these data summaries are included as tables 1 and 2. Table 1 corresponds to the proposed breakwater being present, while table 2 is a baseline with no breakwater. In these

Table 1. Seafood Industrial Park Breakwater Data Summary

Test Run	Dir/Sta	A_{Mon}	A_{Test}	Code	Bad Point Mon/Test	Ratio	Cal(Test) $x10^6$ cm/sec	Status	Comments
001	ENE/A	0.265	0.011	4,4	1/0	0.041	0.503		
002	ENE/B	0.297	0.005	4,4	1/0	0.016	0.527		
003	ENE/C	0.260	0.034	4,4	2/0	0.130	0.520		
004	ENE/D	0.269	0.922	1,4	0/16	3.430	0.463	0	Noise on 2
005	ENE/E	0.254	1.085	4,0	21/0	4.265	0.502	0	
006	ENE/F	0.276	0.775	4,0	1/0	2.814	0.518		
007	ENE/G	0.267	0.626	4,0	3/0	2.346	0.794	0 -	
008	ENE/H	0.231	0.150	4,1	5/0	0.649	0.717	0 -	
009	ENE/I	0.211	1.401	4,4	2/10	6.645	0.462	0	Noise on 2
010	ENE/J	0.203	0.108	4,1	1/0	0.533	0.536		
011	ENE/K	0.220	0.701	4,0	8/0	3.183	0.477	0	
012	ENE/L	0.181	0.845	4,1	17/0	4.674	0.455	0	∞
013	ENE/M	0.180	1.156	4,4	15/33	6.419	0.520	0	Noise on 2, bad run
014	ENE/M	0.450	0.054	4,4	26/0	0.120	0.512	0 +	
015	ENE/N	0.315	0.249	4,1	17/0	0.790	0.443	0	
016	ENE/O	0.368	0.026	1,4	0/1	0.070	0.515		
017	ENE/P	0.315	0.010	4,4	4/1	0.032	0.516	0	
018	ENE/Z	0.333	0.546	4,0	13/0	1.638	0.477	0	
019	ESE/A	0.262	0.068	4,4	1/1	0.261	0.519		
020	ESE/B	0.483	0.010	4,4	2/1	0.020	0.523		Noise on 1, bad run
021	ESE/B	0.292	0.013	4,4	1/0	0.043	0.503		Grounded scope lead
022	ESE/C	0.256	0.338	1,0	0/0	1.321	0.509		
023	ESE/D	0.411	0.592	4,0	1/0	1.441	0.491		
024	ESE/E	0.223	0.618	4,0	1/0	2.774	0.480		
025	ESE/F	0.187	0.832	4,0	0/0	4.452	0.489	+	Good "Test", "Dirty" Monitor
026	ESE/G	0.152	0.514	4,4	2/3	3.375	0.456	0	Bad run
027	ESE/G	0.285	0.783	1,0	0/0	2.750	0.462		
028	ESE/H	0.233	0.358	1,4	0/24	1.536	0.584	0 -	Noise on 2
029	ESE/I	0.002	0.002	4,4	0/0	0.896	0.438		Bad run

Table 1 (Cont'd)

Test Run	Dir/Sta	A_{Mon}	A_{Test}	Code	Bad Point Mon/Test	Ratio	Cal(Test) $\times 10^6$ cm/sec	Status	Comments
030	ESE/I	0.224	0.291	1,0	0/0	1.296	0.479		
031	ESE/J	0.219	0.103	1,1	0/0	0.468	0.513		
032	ESE/K	0.181	0.741	1,0	0/0	4.091	0.528		
033	ESE/L	0.338	0.783	4,1	1/0	2.313	0.507		
034	ESE/M	0.287	0.136	1,1	0/0	0.475	0.511		
035	ESE/N	0.229	0.605	1,1	0/0	2.650	0.499		"Probe in reflection from skimmer"
036	ESE/O	0.171	0.155	4,1	1/0	0.903	0.504		
037	ESE/P	0.323	0.017	4,4	1/0	0.054	0.515		Bad run
038	ESE/P	0.209	0.097	4,1	1/0	0.466	0.511		
039	ESE/Z	0.294	0.239	4,1	1/0	0.812	0.498		
040	SSE/A	0.335	0.025	4,4	1/0	0.075	0.506		
041	SSE/B	0.298	0.021	4,4	2/0	0.069	0.502		
042	SSE/C	0.309	0.468	4,1	1/0	1.517	0.511		
043	SSE/D	0.297	0.269	1,1	0/0	0.904	0.477		
044	SSE/E	0.341	0.920	1,0	0/0	2.693	0.506		
045	SSE/F	0.281	0.963	4,0	1/0	3.432	0.493		
046	SSE/G	0.225	5.228	1,4	0/79	23.197	0.451	0	Noise on 2
047	SSE/H	0.359	0.449	1,0	0/0	1.251	0.602	-	
048	SSE/I	0.351	0.108	1,0	0/0	0.308	0.465		
049	SSE/J	0.387	0.254	1,1	0/0	0.656	0.480		
050	SSE/K	0.374	0.537	1,0	0/0	1.436	0.473		
051	SSE/L	0.507	0.822	1,0	0/0	1.622	0.476		
052	SSE/M	0.445	0.497	1,1	0/0	1.116	0.499		
053	SSE/N	0.455	0.954	1,0	0/0	2.097	0.478		
054	SSE/O	0.445	0.892	1,0	0/0	2.007	0.518		
055	SSE/P	0.448	0.603	1,1	0/0	1.347	0.492		
056	SSE/Z	0.341	0.399	1,1	0/0	1.168	0.499		

Table 1 (Cont'd)

Test Run	Dir/Sta	A_{Mon}	A_{Test}	Code	Bad Point Mon/Test	Ratio	Cal(Test) $\times 10^6$ cm/sec	Status	Comments
057	SSW/A	0.344	0.031	1,4	0/0	0.091	0.501		
058	SSW/B	0.473	0.062	1,4	0/0	0.131	0.500	+	
059	SSW/C	0.654	0.457	1,1	0/1	0.699	0.517		
059	SSW/D	0.766	0.204	1,0	1/0	0.266	0.460		Actually #60
061	SSW/E	0.744	0.354	0,1	0/0	0.476	0.530		
062	SSW/F	0.755	0.318	0,1	0/0	0.421	0.501		
063	SSW/G	0.736	0.030	0,1	0/0	0.041	0.450		
064	SSW/H	0.785	0.010	4,4	3/0	0.013	0.654	0 -	
065	SSW/I	0.024	0.001	4,4	1/0	0.033	0.469		Bad run
066	SSW/I	0.748	0.027	0,4	0/0	0.036	0.462		
067	SSW/J	0.015	0.002	4,4	2/0	0.118	0.552	-	Bad run
068	SSW/J	0.764	0.610	1,0	2/0	0.798	0.520		
069	SSW/K	0.709	0.218	1,1	0/0	0.308	0.498		
070	SSW/L	0.752	0.817	4,0	5/0	1.086	0.506	0	
071	SSW/M	0.778	0.933	4,0	5/0	1.198	0.494	0	Bad run
072	SSW/M	0.628	1.036	0,0	0/0	1.649	0.507		Actually "N"
073	SSW/M	0.570	6.114	4,4	4/45	10.731	0.471	0 +	Noise on 2
074	SSW/O	0.703	0.196	1,1	0/0	0.279	0.529		
075	SSW/P	0.747	0.209	1,4	0/2	0.280	0.494		
076	SSW/Z	0.221	0.455	4,4	0/2	2.063	0.529	+	

Table 2. Baseline Data Summary, No Jetty Present

Test Run	Dir/Sta	A_{Mon}	A_{Test}	Code	Bad Point Mon/Test	Ratio	Cal(Test) $x10^6$cm/sec	Status	Comments
077	SSW/A	1.140	0.047	0,4	0/2	0.041	0.574		
078	SSW/B	1.289	0.090	0,4	0/1	0.070	0.484		
079	SSW/C	1.245	0.247	0,4	0/6	0.199	0.500	0	
080	SSW/D	0.006	0.019	4,4	0/2	3.093	0.443		Bad run
081	SSW/D	1.413	0.178	0,4	0/1	0.126	0.448		
082	SSW/E	1.174	0.821	0,1	0/1	0.699	0.500		
083	SSW/F	1.391	0.474	0,4	0/1	0.341	0.473		
084	SSW/G	1.109	0.068	0,4	0/1	0.061	0.418		
085	SSW/H	1.065	0.144	0,4	0/3	0.135	0.101	0 -	
086	SSW/I	0.991	0.119	0,4	0/5	0.120	0.443	0	
087	SSW/J	1.150	2.431	0,4	0/2	2.114	0.491		
088	SSW/K	1.025	0.320	0,4	0/1	0.312	0.472		
089	SSW/L	1.150	0.920	0,4	0/1	0.800	0.480		
090	SSW/M	1.145	1.384	0,4	0/1	1.208	0.474		
091	SSW/N	1.154	0.815	1,4	1/2	0.706	0.477		
092	SSW/O	1.141	7.920	0,4	0/all	6.943	0.475	0	Noise on 2
093	SSW/P	1.295	0.072	0,4	0/7	0.056	0.469	0	
094	SSW/Z	0.788	0.988	1,4	0/10	1.254	0.512	0	
095	SSE/A	0.659	0.120	1,4	0/2	0.182	0.483		
096	SSE/B	0.472	0.355	1,4	0/4	0.752	0.487	0	
097	SSE/C	0.522	0.433	1,1	0/2	0.830	0.498		
098	SSE/D	0.508	0.608	1,1	0/1	1.198	0.449		
099	SSE/E	0.471	0.811	1,4	0/4	1.721	0.673	0 -	
100	SSE/F	0.509	0.600	1,1	0/5	1.179	0.485	0	
101	SSE/G	0.531	0.448	1,0	0/0	0.843	0.301	-	
102	SSE/H	0.704	2.031	1,4	0/3	2.884	0.111	0 -	Noise on 2
103	SSE/I	0.717	0.467	1,0	0/0	0.651	0.448		
104	SSE/J	0.643	0.553	1,4	0/2	0.860	0.510		
105	SSE/K	0.677	0.435	1,1	0/0	0.642	0.478		
106	SSE/L	0.660	0.697	0,4	0/7	1.056	0.490	0	

Table 2 (Cont'd)

Test Run	Dir/Sta	A_{Mon}	A_{Test}	Code	Bad Point Mon/Test	Ratio	Cal(Test) x10^6cm/sec	Status	Comments
107	SSE/M	0.689	0.860	1,1	0/4	1.247	0.488	0	
108	SSE/N	0.717	1.062	0,1	0/2	1.480	0.481		
109	SSE/O	0.753	0.657	1,4	0/2	0.873	0.489		
110	SSE/P	0.728	0.833	0,1	0/2	1.144	0.484		
111	SSE/Z	0.672	0.707	1,4	0/5	1.051	0.480	0	
112	ESE/A	0.736	0.694	0,1	0/4	0.942	0.492	0	
113	ESE/B	0.572	2.341	1,4	0/27	4.096	0.493	0	Noise on 2
114	ESE/C	0.665	1.012	1,4	0/4	1.522	0.500	0	
115	ESE/D	0.665	0.585	1,1	0/1	0.880	0.449		
116	ESE/E	0.731	1.039	0,4	0/3	1.423	0.484	0	
117	ESE/F	0.666	0.843	1,0	0/0	1.267	0.492		
118	ESE/G	0.667	1.027	0,4	0/6	1.540	0.419	0	Noise on 2
119	ESE/H	0.646	0.278	0,4	0/2	0.431	0.871	-	
120	ESE/I	0.674	0.443	1,1	0/1	0.657	0.448		
121	ESE/J	0.639	1.445	0,0	0/0	2.263	0.490		
122	ESE/K	0.545	0.710	1,4	0/8	1.303	0.467	0	Noise on 2
123	ESE/L	0.572	0.854	1,0	0/0	1.492	0.481		
130	ESE/M	0.525	0.171	1,4	0/6	0.327	0.523	0	
131	ESE/N	0.537	0.650	1,4	0/9	1.211	0.484	0	
132	ESE/O	0.567	1.535	1,0	0/1	2.707	0.497		
133	ESE/P	0.531	1.397	1,0	0/1	2.630	0.478		
134	ESE/Z	0.545	0.667	1,4	0/6	1.224	0.491	0	
135	ENE/A	0.595	0.173	0,4	0/3	0.290	0.483	0	
136	ENE/B	0.948	0.353	0,4	0/2	0.372	0.483		
137	ENE/C	0.801	0.971	1,0	0/3	1.213	0.500	0	
138	ENE/D	0.443	0.415	0,0	0/1	0.938	0.438		
139	ENE/E	0.478	0.356	0,4	0/4	0.744	0.502	0	
140	ENE/F	0.476	0.928	1,4	0/2	1.949	0.507		
141	ENE/G	0.380	0.437	1,1	0/2	1.150	0.425		

Table 2 (Cont'd)

Test Run	Dir/Sta	A_{Mon}	A_{Test}	Code	Bad Point Mon/Test	Ratio	Cal(Test) x10^6cm/sec	Status	Comments
142	ENE/H	0.405	1.284	1,1	0/1	3.172	0.929	-	
143	ENE/I	0.465	0.730	1,1	0/1	1.569	0.436		
144	ENE/J	0.426	0.892	1,1	0/1	2.093	0.504		
145	ENE/K	0.552	0.480	0,4	0/7	0.871	0.465	0	
146	ENE/L	0.514	0.795	0,1	0/5	1.547	0.517	0	
147	ENE/M	0.421	0.088	1,4	0/6	0.209	0.478	0	
148	ENE/N	0.592	1.433	0,4	0/35	2.421	0.492	0	Noise on 2
150	ENE/O	0.564	0.310	0,4	0/3	0.549	0.493	0	
151	ENE/P	0.825	0.516	1,1	0/2	0.626	0.490		
152	ENE/Z	0.483	0.845	0,1	0/3	1.748	0.489	0	

tables, the test run number is a sequential number assigned at the time of measurement and serves as a master indexing number. The direction (Dir) is that of the incident waves, while the station (Sta) refers to the location of the measurement, as given in figure 1. A_{Mon} and A_{Test} are the amplitudes of the monitor and test waves at the generation frequency as calculated from the Fourier analysis of the wave records. The spectrum code is a qualitative measure of the spectrums displayed on the analysis printout. The codes are represented by single hexadecimal digits in an ordered pair corresponding to the monitor and test records respectively. The hexadecimal digits are the sums of base codes 0,1,2,4 and 8. A code of 0 corresponds to a measured spectrum with more than 95% of the total variance occurring at the driving frequency, the best condition. A code of 1 indicates that more than 5% of the variance is located in the second and higher harmonics of the driving frequency. If the waves tend to form groups, as indicated by broad spectra, a code of 2 is assigned to the spectrum. A code of 4 is assigned if the variance associated with the wave frequency and its overtones accounts for less than 80 percent of the total, an indication of a very small signal or the presence of noise. A code of 8 is assigned if a broad, low frequency noise characteristic is observed. During this study, the electronic measuring circuits were subject to episodes of noise which produced false counter readings. These points, when present, lower the signal-to-noise ratio for the amplitude estimates. The points are easily detected on the time series presentation of the waves. The bad point count represents the number of points (out of 256 counter readings) which are visually seen to be affected by the noise. The ratio column is the ratio of A_{Test} to A_{Mon}. This number best indicates the effect of the jetty under test on incoming waves. Under ideal test conditions, the height of a wave within the harbor at a given point is estimated by the model to be this ratio multiplied by the height of a wave incident on the modeled region in the prototype. Finally, the gauge constant (Cal) is the calibration constant of the test gauge associated with the run as determined by the associated calibration.

With the exception of the bad point counts, the data tables and their interpretation are the same as those given in Appendix X.1 of Welch and Fang (1980).

5. Analysis

The data are subject to several tests to verify that conclusions are based on the tested experimental conditions rather than chance happenings or the misinterpretation of values whose source is instrumental error or chance occurrences. These tests can be loosely grouped into quality control checks and intercomparisons. Quality control checks are used to locate erroneous data points so that corresponding runs can be eliminated. Intercomparisons establish the precision which can be associated with the results.

The first quality control check is a count of the number of bad points within each test run. These counts are tabulated by gauge and test series (with and without breakwater) in table 3. The large majority of test runs had fewer than two bad points in the gauge records. A review of the distribution of bad points as well as consideration of degradation of the data caused by bad points suggests that a limit of two bad points be placed on the data as a quality acceptance limit.

Table 3. Distribution of Bad Points from the Wave Gauges during Seafood Industrial Park Tests

Breakwater	Gauge	Number of Bad Points Within a Single Run											
		0	1	2	3	4	5	6	7	8	9	10	>10
Yes	Monitor	37	18	7	2	2	3	0	0	1	0	0	6
		49	72	82	84	87	91	91	92	92	92	92	100
Yes	Test	62	5	2	1	0	0	0	0	0	0	1	5
		81	88	91	92	92	92	92	92	92	92	93	100
No	Monitor	68	1	0	0	0	0	0	0	0	0	0	0
		98	100										100
No	Test	10	17	14	7	6	3	3	3	1	1	1	3
		14	39	59	70	78	82	87	91	93	94	96	100

NOTE: Numbers shown are counts of runs with the indicated number of bad points. Cumulative percentages of total runs are shown below each count.

With this limit, only two of the test run records associated with the critical directions of incidence are eliminated, and neither of these is in the Small Boat Harbor channel, where most of the interest lies. Data eliminated because of too many bad points are noted with a "0" in the status column of tables 1 and 2.

The test gauge calibration results in a gauge constant, which is applied to the counter data to convert the readings to height measurements. During the course of a day's operation, the gauge constant measurements accumulate, and histograms of these values are shown in figures 2a and 2b. For each day of operation during the study, the distribution of gauge constants shows a characteristic bimodal distribution with the static calibration value near the minimum between the modes. In addition to the central bimodal distribution, outliers occur with values far from the bulk of the points. For the purpose of quality control, the outliers can be taken as signs of potential instrument malfunction and the corresponding data eliminated from further consideration. In the present study, tests with gauge constants outside of the range .41 - .54 x 10^6 cm-sec^{-1} can be eliminated from consideration. In addition, the resulting span results in an estimate of gauge accuracy of 15%, bearing in mind that the calibration measurements are over a range of 1 cm. The resulting limits remove a maximum of 12 test run records, shown on tables 1 and 2 as "-" in the status column. Of these 12, 10 are located at stations G and H, where the shallowness of the water can prohibit proper gauge operation. Of the other two, one is already eliminated, and the other test run was repeated because of suspected malfunctions detected during the test sequence.

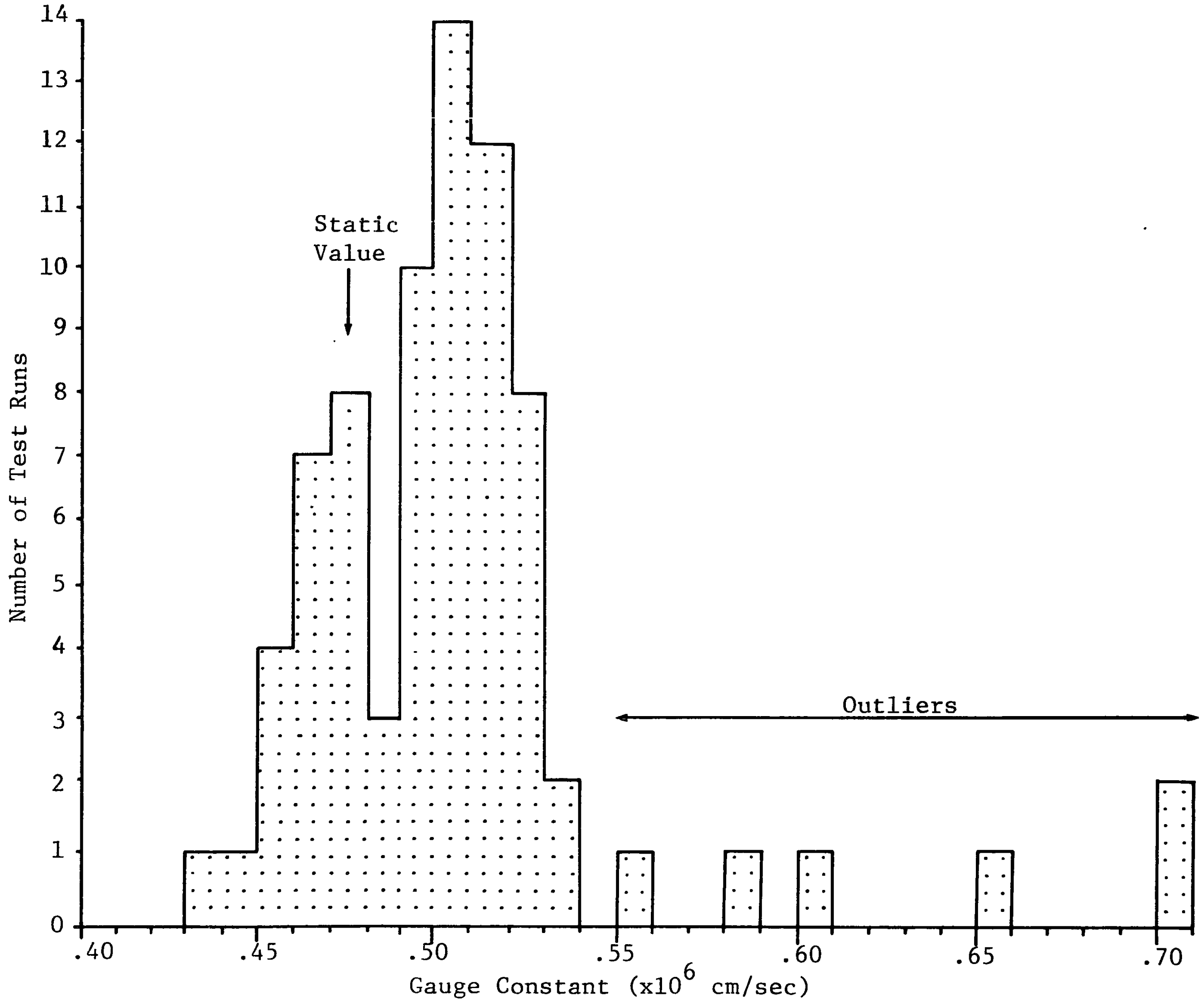


Figure 2a. Histogram of gauge constants measured during the Seafood Industrial Park intercomparison tests. Breakwater in place.

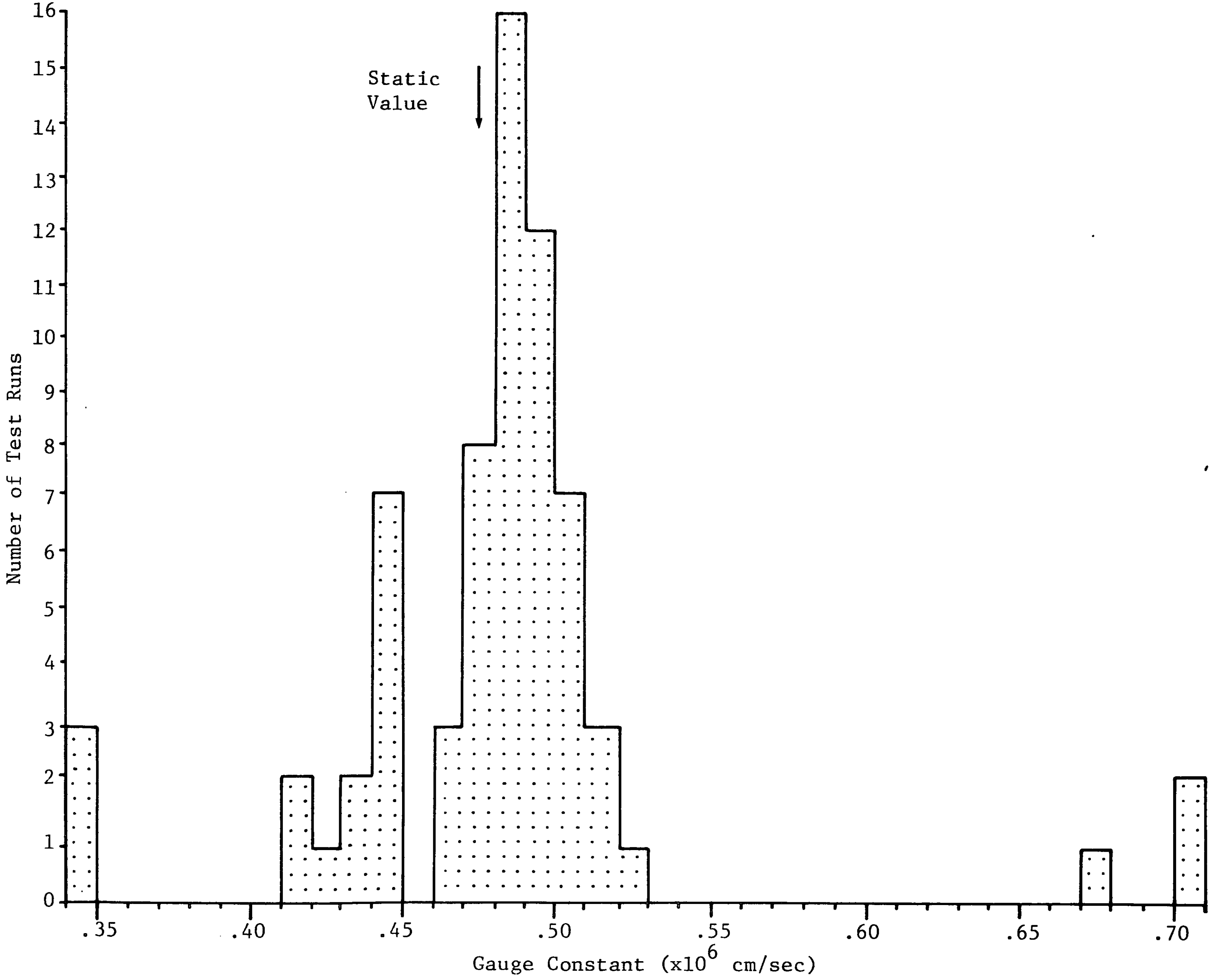


Figure 2b. Histogram of gauge constants measured during the Seafood Industrial Park intercomparison tests. No breakwater in place.

The remaining data can be considered to be unaffected by noise and to have been successfully tested for correct operation at the operating range endpoints immediately prior to each test run. A further quality control examination is introduced later.

The gauge intercomparison runs fared relatively poorly in the quality control eliminations, five of the eight data sets being eliminated. Of the data sets not eliminated, two runs (test runs 39,56) show estimated amplitudes measured by gauges at close proximity to be identical within 20% at the 200-300 micron level. The third (test run 76) indicates a 100% difference between the readings. While a 20% accuracy at the 300 micron level is consistent with the least count increment at that level, the larger error in test 76 is cause for concern. A review of the time plot for that test shows that a number of the wave cycles measured by the monitor gauge have several slope reversals during a wave period. The test gauge which was within two inches of the monitor gauge shows no similar slope reversals. The spectrum for the monitor gauge also shows that less than 80% of the total variance is associated with the line spectrum of the generated wave with its overtones. This characteristic is caused by a low signal-to-noise ratio, usually associated with the signals generated by very small waves. In this instance, the character of the spectrum is associated with a high noise level, and crosstalk between the gauges is suspected. With the discrepancy in character between the gauge data, the 100% variation in readings of the same wave can be interpreted as a gross measurement error. The result is that 6 of the 8 test run records from the intercomparison test are eliminated because of measurement quality. The result, that the gauges have a comparability of about 20% at the 300 micron level, must be considered tentative in view of the high data attrition rate.

The passage of the apparently bad measurement through the quality control screen indicates that the screen is not quite fine enough. A further quality control screen was applied to the data to find measurements for which: no bad points were evident on the time plot, less than 80% of the variance was found in lines, and the measured amplitude of the wave was 50 microns or greater. Data eliminated by this screen are noted with a "+" in the status column of tables 1 and 2. In addition to the intercomparison measurement, this screen eliminated two other test run records, tests 25 and 58. The rationale for this screen is that at levels of 50 microns or greater, the extra variance is most easily interpreted as wideband noise. If bad points are not evident in the time series, the noise must be represented by a large number of smaller deviations, which implies that a substantial portion of the record is bad.

A further test of the system is obtained by repeating the "no jetty" test to examine the repeatability of the entire system after a period of about one year during which the system was idle. The resulting intercomparison data, after being screened for quality control, is shown for repeated measurements as amplitude ratios from the new tests versus amplitude ratios from the old tests on log-log paper (figure 3). A census of the spread of data shows that 71% agree within a factor of 2, 82% agree within a factor of 3 and all but one outlier agree within a factor of 4. This distribution provides a conservative estimate of the present reproducibility of the entire measurement and wave

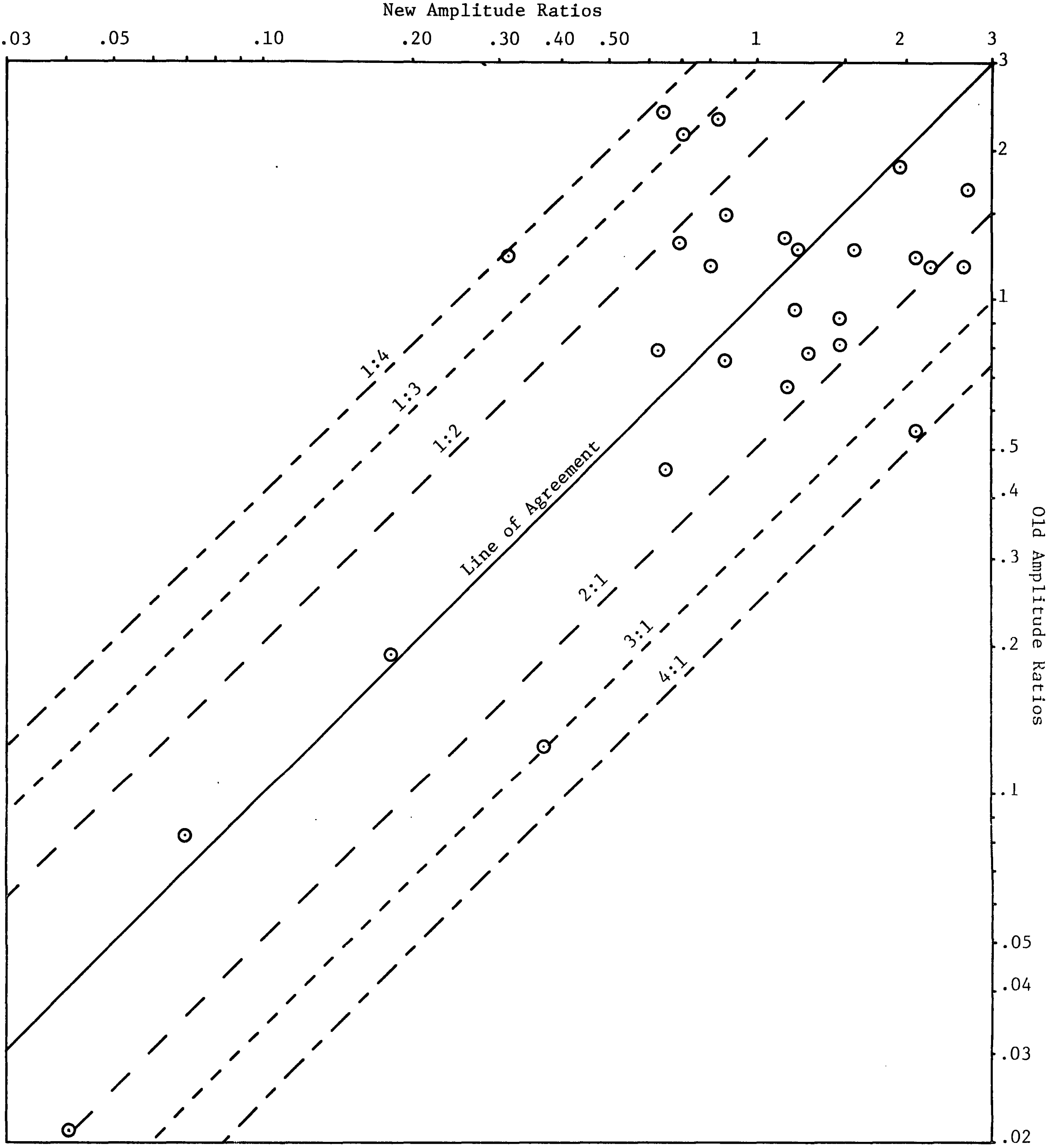


Figure 3. Intercomparison of replicate measurements between base configurations of present and previous tests.

generation process. This reproducibility is also much lower than the tentative value for the gauge accuracy. This suggests that in addition to the model changes, factors such as wave reflection, generation instabilities and variable propagation damping are affecting the observations.

6. Interpretation

The interpretation is facilitated by plotting amplitude ratios on a line running along the axis of the channel from the present Small Boat Harbor entrance to the proposed Seafood Industrial Park entrance (figures 4a-d). The angular variation of the amplitude ratios at the same stations is also useful (figures 5a,b). For the sake of comparison, the no-jetty case and the analogous data for the jetties considered good in Welch and Fang (1980) are included with the Seafood Industrial Park plots. In both figures, the vertical axis, used for the ratio, is logarithmic, and the error bars corresponding to the intercomparison of the no-jetty cases are included for reference.

The clearest advantage of the Seafood Industrial Park configuration over the previously tested configurations is found at station B, the mouth of the present Small Boat Harbor. This advantage is best seen in figure 5a, station B. A plausible reason for this improvement is that the waves which would be deflected into the mouth of the Small Boat Harbor in the jetty-only configurations are reflected back out into the Seafood Industrial Park portion of the enclosed harbor.

A question arises when comparing the waves at station A with those at station B. If the wave energy passing B is the only source for wave energy at A and, in addition, if the channel widens between B and A, so that the waves must disperse to fill the wider channel, it would seem that the waves at A should be smaller than the ones at B, not larger as shown by the data. One possibility for the observed results is that the inner part of Small Boat Harbor is subject to

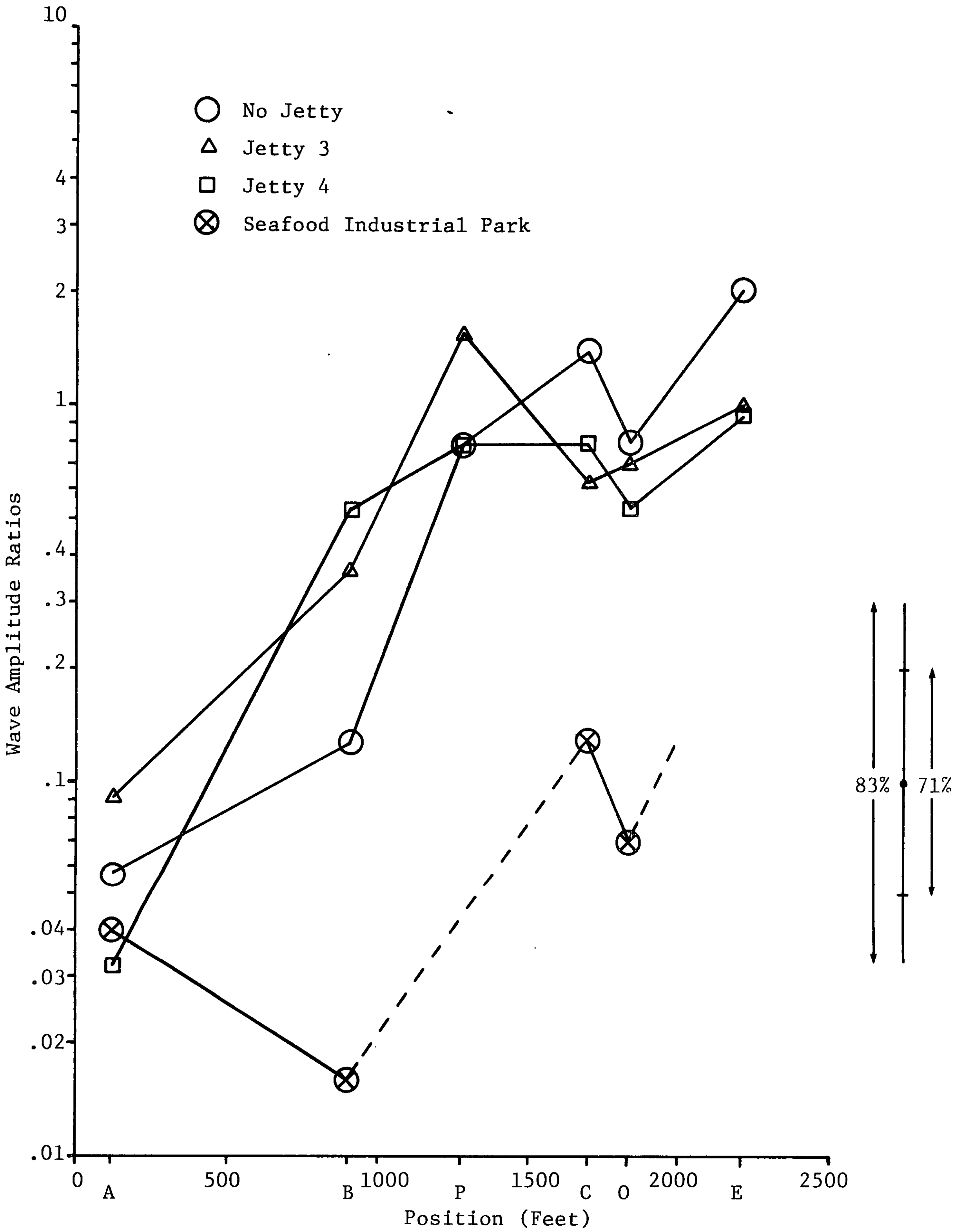


Figure 4a. Intercomparison results of the Seafood Industrial Park breakwater with previously tested configurations. Wave amplitude ratios are shown as a function of position along the Small Boat Harbor channel for waves incident from ENE. Error bars shown are based on the repeatability tests.

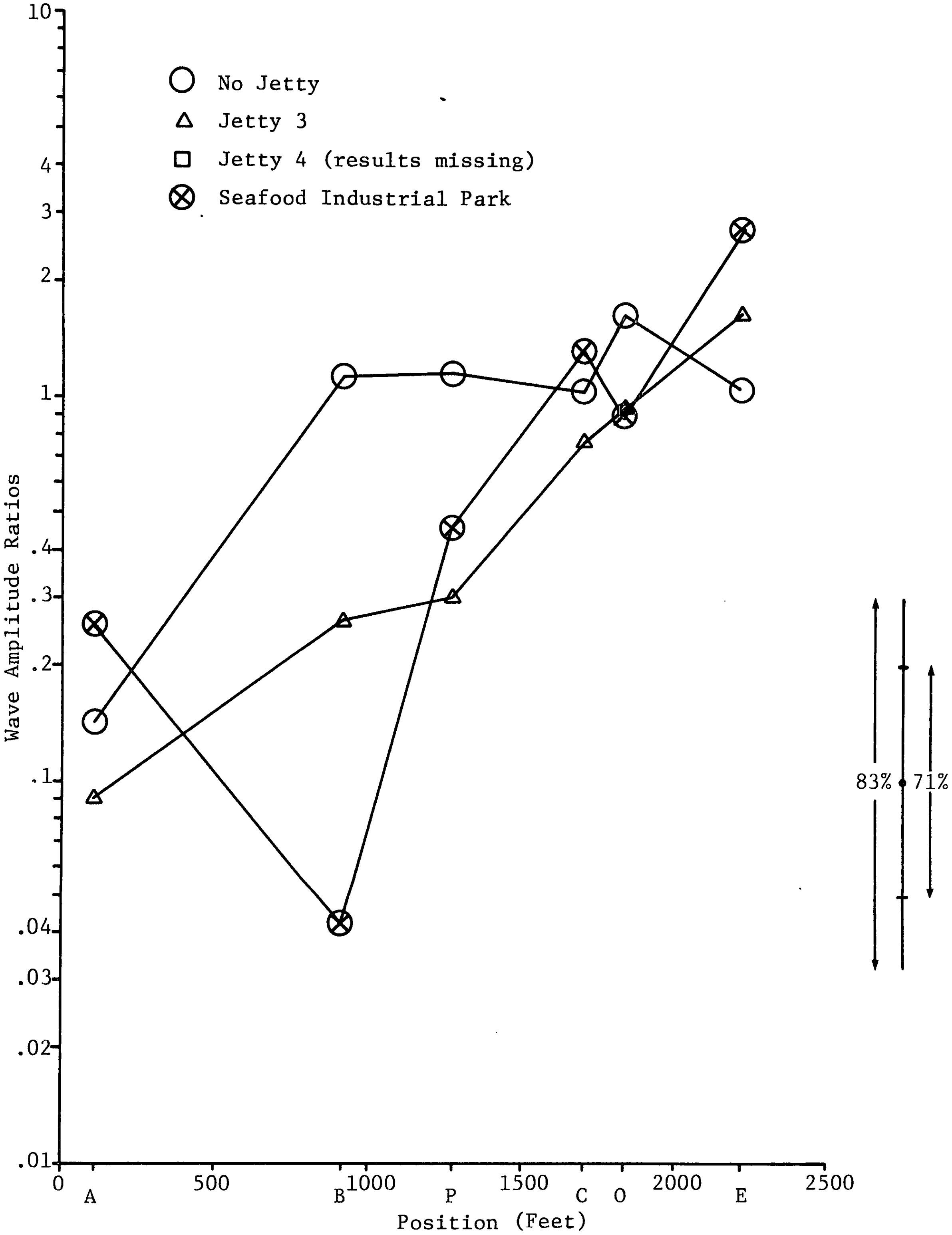


Figure 4b. Intercomparison results of the Seafood Industrial Park breakwater with previously tested configurations. Wave amplitude ratios are shown as a function of position along the Small Boat Harbor channel for waves incident from ESE direction. Error bars shown are based on the repeatability tests.

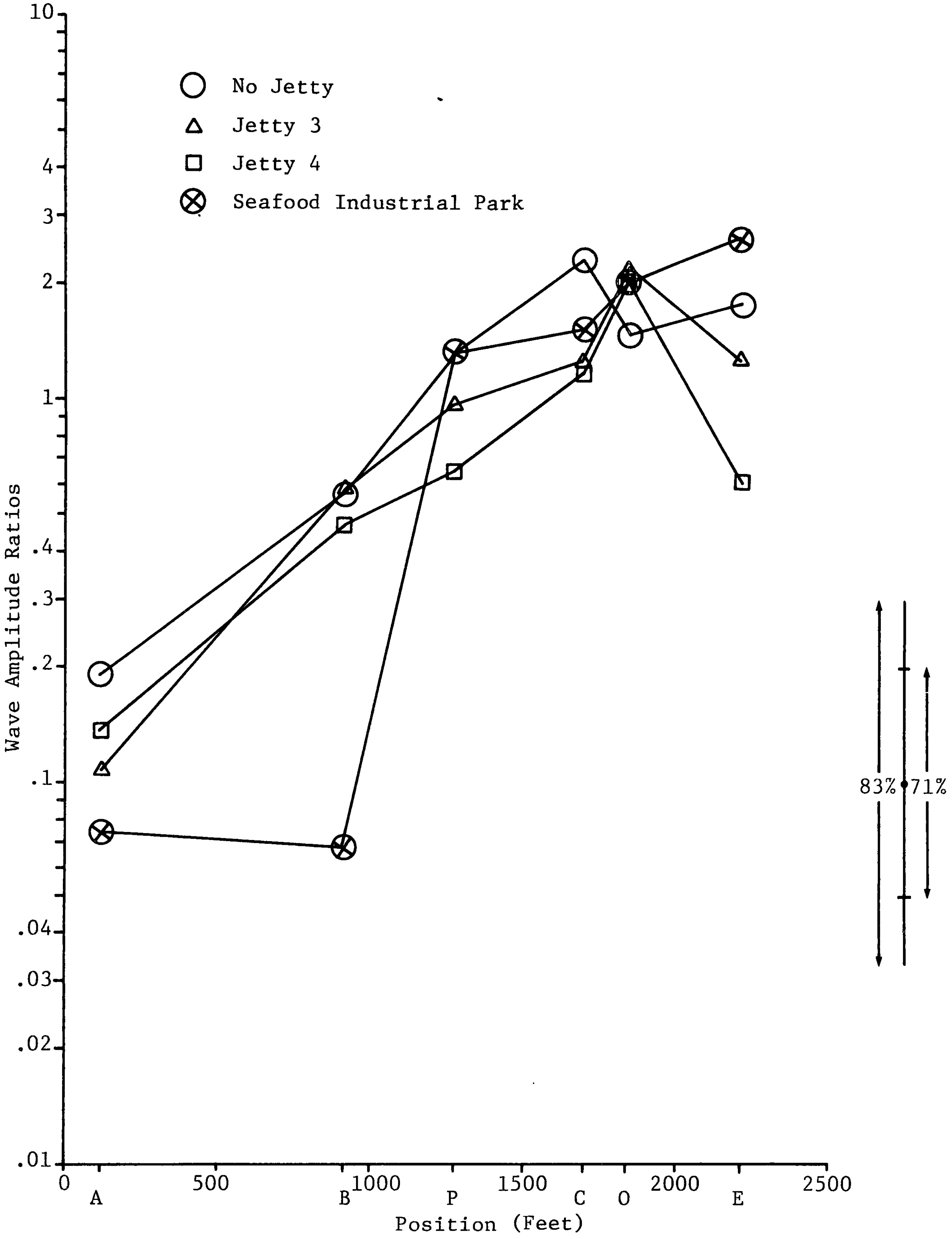


Figure 4c. Intercomparison results of the Seafood Industrial Park breakwater with previously tested configurations. Wave amplitude ratios are shown as a function of position along the Small Boat Harbor channel for waves incident from SSE direction. Error bars shown are based on the repeatability tests.

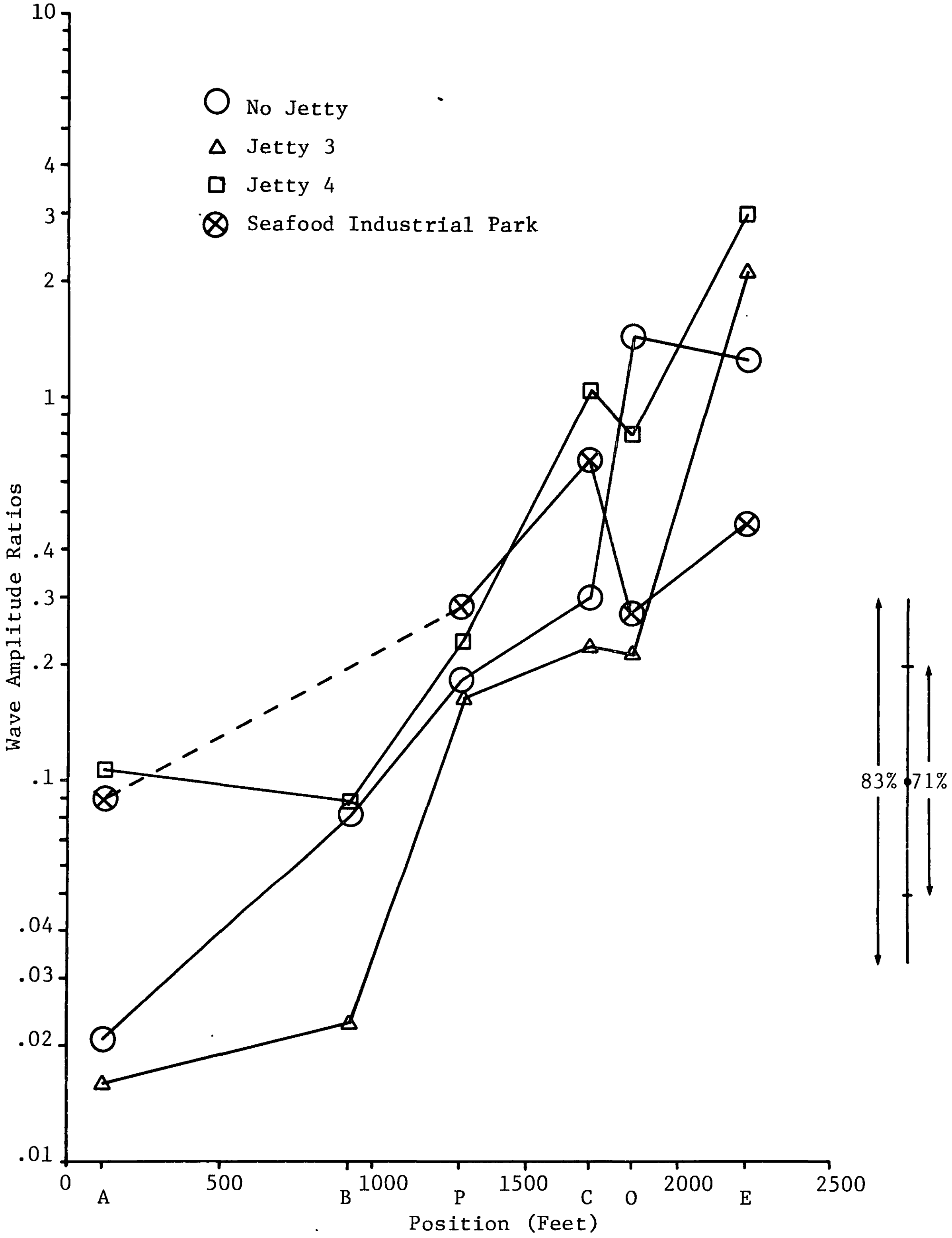


Figure 4d. Intercomparison results of the Seafood Industrial Park breakwater with previously tested configurations. Wave amplitude ratios are shown as a function of position along the Small Boat Harbor channel for waves incident from SSW direction. Error bars shown are based on the repeatability tests.

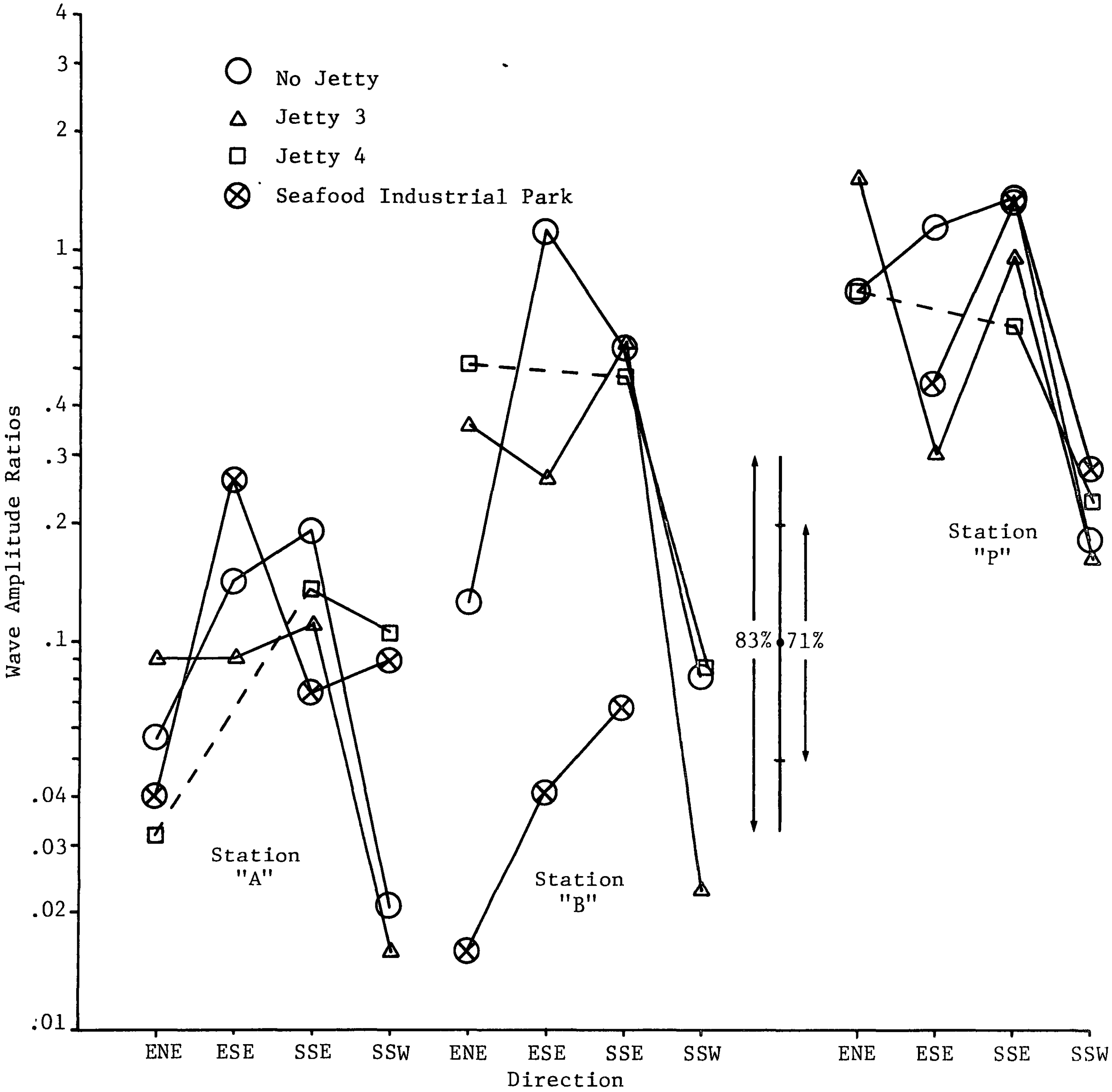


Figure 5a. Intercomparison results of the Seafood Industrial Park breakwater with previously tested configurations. Wave amplitude ratios are shown as a function of direction for stations A, B, and P along the Small Boat Harbor channel. Station positions are shown in figure 1.

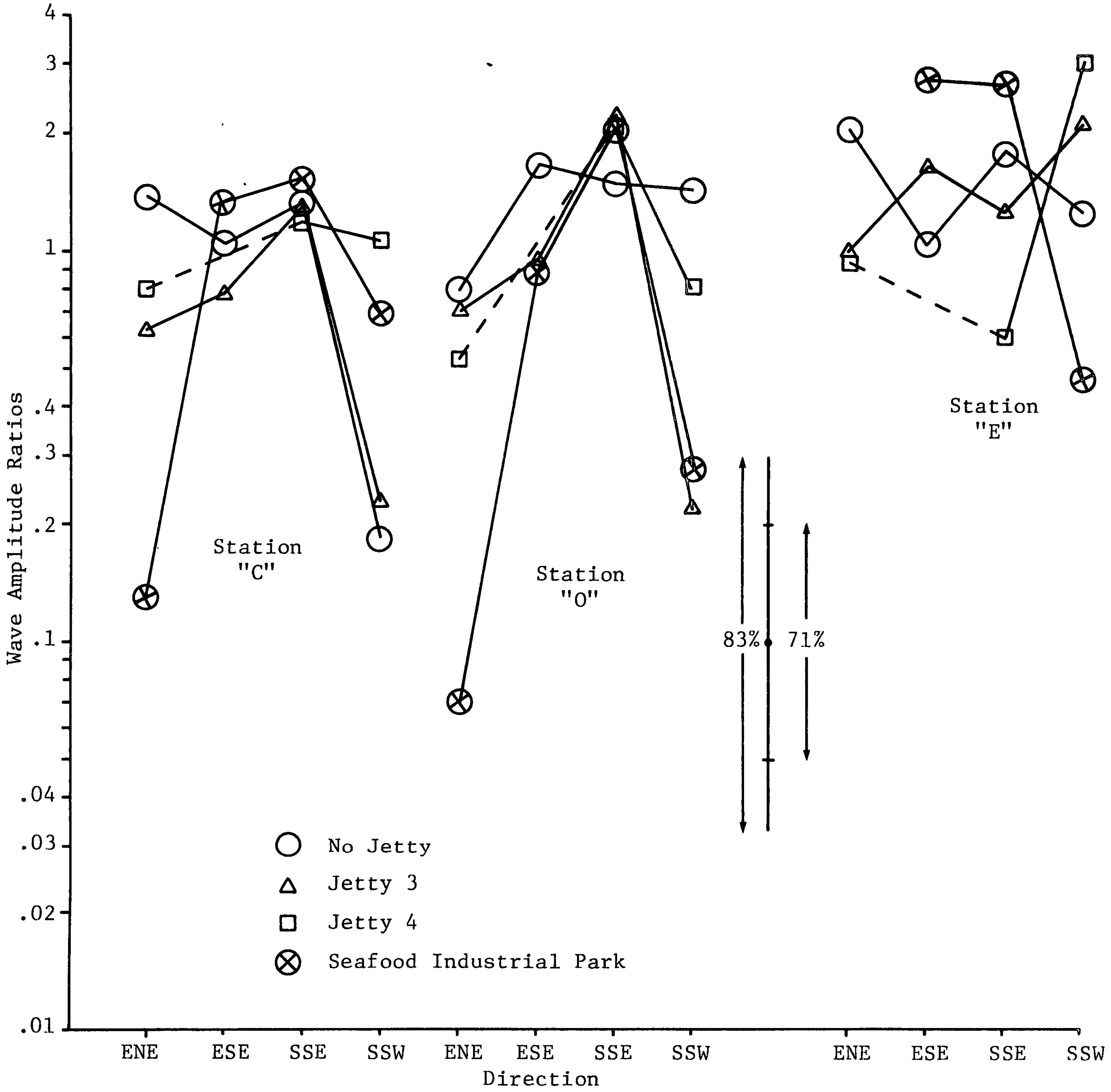


Figure 5b. Intercomparison results of the Seafood Industrial Park breakwater with previously tested configurations. Wave amplitude ratios are shown as a function of direction for stations C, O, and E along the Small Boat Harbor channel. Station positions are shown in figure 1.

transverse oscillations in resonance with the generated waves. Another possibility is that the waves appearing at station A are due to wave energy entering the model from the open end of the Small Boat Harbor after being partly reflected by the tank's wave absorbers, an experimental artifact. Whatever the reason, indications are that the proposed Seafood Industrial Park breakwater will provide excellent protection from impinging waves in the present Small Boat Harbor. Harbor resonance remains a possibility, and proposed tests are designed specifically to determine the modes, frequencies and "Q" of harbor resonances as well as the possible oscillation between the new and present harbors.

In the Seafood Industrial Park part of the channel, the data generally show the present tests to be comparable to the previous configurations. For waves from the ENE, the direction from which the highest waves are expected, the Seafood Industrial Park breakwater reduces amplitudes substantially more than the previously tested jetties. In the ESE and SSE directions, however, the Seafood Industrial Park configuration shows systematically larger wave amplitudes within the harbor enclosed by the breakwater than the previously tested configurations. Because this amplitude is, in general, larger than that of the incident wave, an understanding of possible causes for the larger measured ratios is of interest. As a first consideration, the differences between cases all fall within the 71% level of the distribution of the repeatability experiment, and we examine the possibility that the difference is a chance occurrence. Subsequent to editing of the 9 comparisons of readings at the three stations

(P, C, and O) in the outer harbor with waves from the ESE and SSE directions, 7 show the Seafood Industrial Park amplitude to be higher than the amplitudes associated with previous jetties tested. Under the assumption that a higher amplitude is as likely as a lower amplitude (the no-difference hypothesis), the chance for 7 or more of the comparisons to be higher is 46/512 or 9%. Thus, there is a 9% chance that the apparent difference is simply random chance. This leaves a 91% chance that the difference is real. One possible explanation for the difference is that the waves which are reflected away from the existing Small Boat Harbor are found in the main channel stations. If this is so, it is highly plausible that such reflection would be much less in the actual harbor than in the model because of the 4:1 vertical distortion employed in the model. The distorted beach adjacent to the mouth of Small Boat Harbor reflects more of the incident waves than is expected in the prototype. If this explanation is correct, the amplitude ratios in the outer channel measured in the proposed harbor response tests will be much smaller than they are in the intercomparison test. Pending the results of the harbor response tests, the measured high amplitudes within the Seafood Industrial Park portion of the proposed harbor are a cause for concern.

Outside the mouth of the harbor, at station E, the tests indicate that the waves are much larger than they are next to the wave maker. This growth of the waves is partly due to the local topography, which refracts the waves towards the harbor mouth in addition to causing the waves to become shorter and steeper. An additional factor, associated with the Seafood Industrial Park breakwater, was evident from casual observations of the model operation as well as from the measurements. The straight outer wall of the model breakwater reflects a substantial portion of the incident wave energy back out into Hampton Roads as a defined beam. At certain places this reflected beam will cause the amplitude of the waves to be much larger than the incident wave alone. The gauge location at station E may be in one of these places where the amplitude is substantially increased. While the fact of reflection was well represented in the model, the precise pattern of reflection may be altered by the proposed construction of the wall, which consists of a series of interconnected cylinders. The details of this effect are the subject of a further proposed study.

References

C. E. Maguire, Inc., "Proposed jetty and berthing plan, Newport News Seafood Industrial Park," 2 sheets, April 11, 1980.

C. E. Maguire, Inc., "Conditions at end of breakwater-cylindrical pile scheme," undated.

Fang, C. S., Principal Investigator," James River Hydraulic Model study with respect to the proposed third bridge-tunnel causeway in Hampton Roads," VIMS Special Report in Applied Marine Science and Ocean Engineering No. 212, February, 1979.

Virginia Department of Highways and Transportation, Design Study Report for Route 664, Cities of Suffolk and Newport News, December, 1978.

Welch, Christopher S., Wave tests of proposed modifications to Small Boat Harbor, Newport News, Virginia, A Report to the City of Newport News, October 1979.

Welch, C. S. and C. S. Fang, "Wave tank study of Newport News Point for I-664", a supplement to VIMS Special Report in Applied Marine Science and Ocean Engineering No. 212, February 1980.

COMMONWEALTH of VIRGINIA
Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

June 12, 1980

Mr. James B. Richards, Jr.
The Harwood Beebe Company
27[illegible] [illegible]ham Road
Richmond, Virginia 23229

[illegible]

This letter is to transmit to you our preliminary findings from our intercomparison tests of the jetty plan (C. E. Maguire Newport News Seafood Industrial Park, alternate I, preliminary plan of April 11, 1980) as modified by our later discussion. Detailed findings will be submitted in a report in about one week.

These preliminary findings are answers to three questions:

1) Does the proposed plan deflect currents sufficiently past the proposed I-664 bridge tunnel island as discussed in Welch and Fang (February, 1980, p5)?

2) Does the proposed plan prevent the accumulation of sediment from Hampton Flats in the entrance channel to Small Boat Harbor as discussed in Byrne et al. (February, 1979)?

3) Does the proposed plan protect the present Small Boat Harbor from the action of waves due to extreme storms as studied in Welch and Fang (1980)?

For questions 1 and 2, Welch and Fang (February, 1980) conclude that a jetty extending more than 1000 feet from shore will satisfy these conditions. As the proposed Seafood Industrial Park breakwater extends 1200 feet from the present Newport News Point, the first two questions are answered affirmatively.

For question 3, an intercomparison test has been performed in the VIMS Wave Tank. In this test, the Seafood Industrial Park breakwater has been subjected to the level 2 tests performed on the previously tested jetty configurations in Welch and Fang (February, 1980). The results for the three inner stations (see attached map, Figure VI-3 in (Welch and Fang, ibid) "A", "B" and "P", are plotted in the enclosed figure with [illegible] to the previously tested configurations. The results show the behavior of the Seafood Industrial Park breakwater to be comparable to previously tested jettys.

In particular, the Seafood Industrial Park breakwater provides excellent protection from SSE and ESE wave incidence at point B, the entrance to Small Boat Harbor. In view of the low waves at "B", the higher measured amplitudes at "A" from ENE and ESE directions are difficult to interpret. They may be due to the artificial effect of waves entering the Small Boat Harbor in the model through the open back, which may have been insufficiently closed.

The high waves at "P" may be an artifact introduced by the modeling assumption of a 4:1 vertical distortion used to obtain a precise intercomparison with previous tests. A better estimate of harbor response will be obtained during the next phase of testing, which will use a larger harbor and a dredged bottom.

These results show that the proposed breakwater for the Seafood Industrial Park will satisfy the concerns expressed in the three questions.

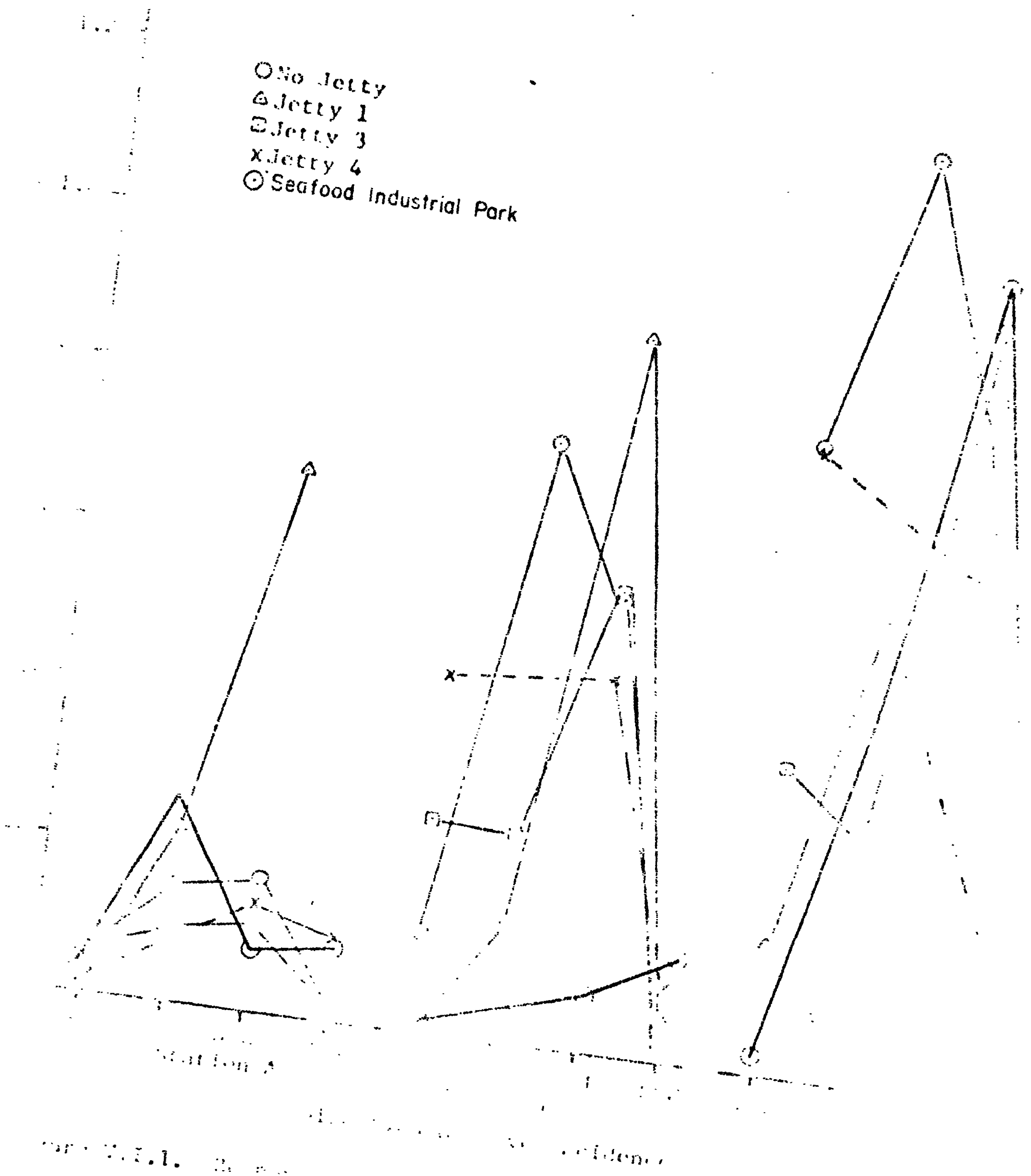
If you need additional information prior to the report for phase 1, please let me know.

Yours truly,

Christopher S. Welch

Christopher S. Welch, Ph.D.
Associate Marine Scientist
Dept. of Physical Oceanography
and Hydraulics

CSW:smc
Enclosures
Copy to: Mr. Douglas Harbit



[illegible] 3.3.1. [illegible]
at [illegible] [illegible] four jetty [illegible]
[illegible] and [illegible]

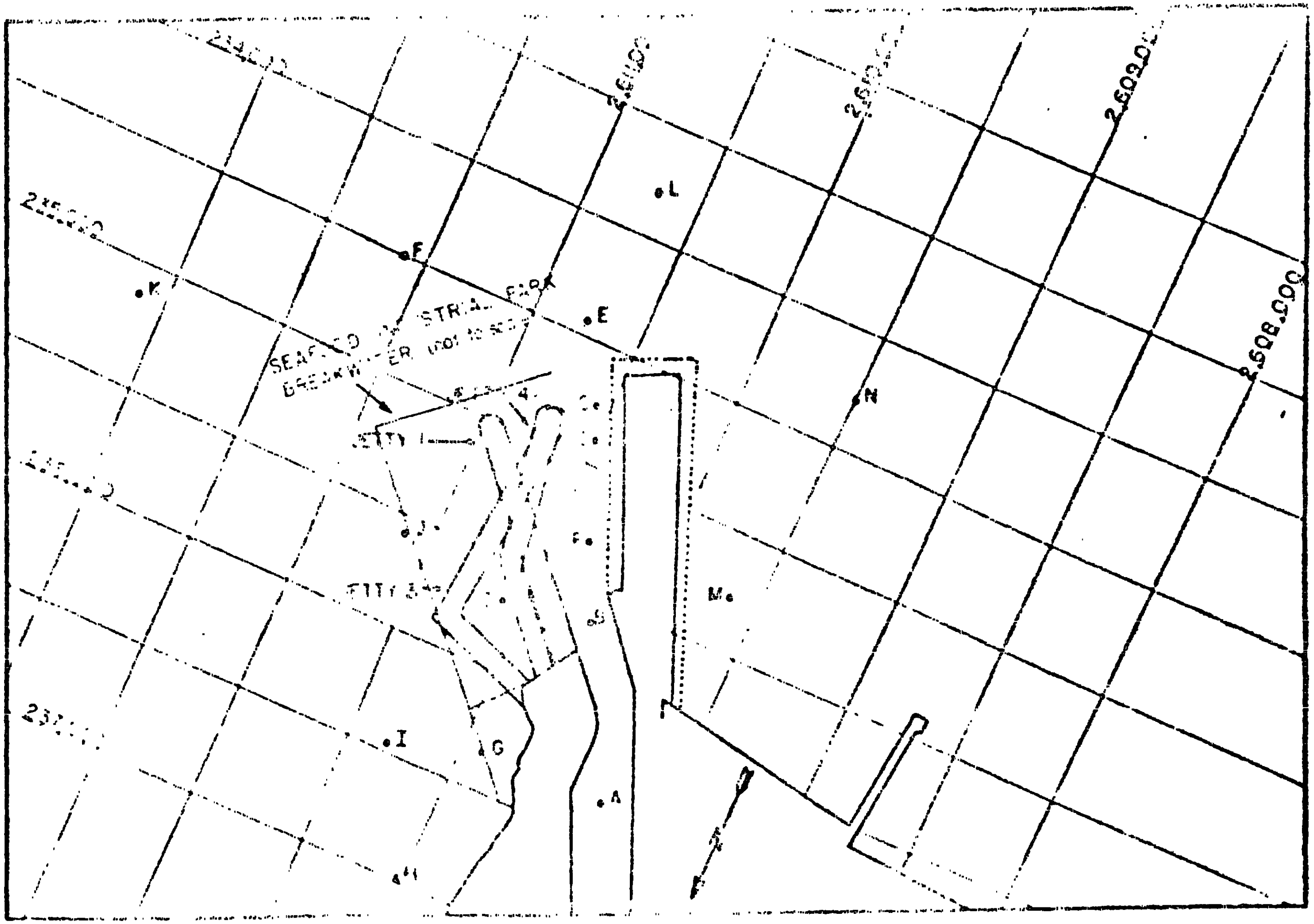


Figure VI.3. [illegible] and measurement stations

References

Welch, C. S. and C. S. Fang. 1980. Wave Tank Study of Newport News Point for I-664. A Report to the Virginia Department of Highways and Transportation. A Supplement to Special Report in Applied Marine Science and Ocean Engineering No. 212, February.

Byrne, R. J. 1979. Geological Effect Study, Part Two in James River Hydraulic Model Study with Respect to the Proposed Third Bridge-Tunnel Causeway in Hampton Roads. Virginia Institute of Marine Science, Special Report in Applied Marine Science and Ocean Engineering No. 212, February.

Appendix 2

```
C     PROGRAM WAVECAL
C     VERSION CSW 2.2
C     READS WAVE DATA FROM TAPE VIA FT03, AND PROVIDES
C     DISPLAYS AND ANALYSES OF VIMS WAVE TANK DATA
      REAL GCON(2),DATA(2,256),PROP(2),CUP(2),CON(2),MEAN(2),
     1RANGE(2,2),AMP(2,128),PERVAR(2,128),ABSIS(4,2),ORD(2),PTAB(4,256),
     2RATIO(2,128)
      LOGICAL CHAN(4)
      LOGICAL*1 COMENT(64)
      INTEGER KUP(2),KDN(2)
      INTEGER*2 IDATA(4,256),ICAL(64)
C     READ THE TAPE RECORD
      IN=3
      CALL OPSYS('FILEOPT',IN,4086)
    5 CALL TAPGET(IN,COMENT,ICAL,IDATA)
C     GET ADDITIONAL INFORMATION
      CALL INFO(COMENT,SM)
      IF(SM.EQ.0.)STOP
      IF(SM.LT.0)GO TO 5
C     SET SPECIAL VALUES
      KUP(1)=156.
      KDN(1)=65.
      CALL CALIB(ICAL,SM,PROP,CUP,CON)
      CALL XFORM(IDATA,DATA,MEAN,RANGE,CUP,CON,PROP)
 1000 FORMAT(1H )
      WRITE(6,1000)
      WRITE(6,1003)
      WRITE(6,1004)(COMENT(K1),K1=1,64)
      WRITE(6,1000)
      WRITE(6,1000)
 1003 FORMAT('1ANALYSIS FOR THE RECORD WITH HEADER:')
 1004 FORMAT(1H ,64A1)
 1013 FORMAT(' SAMPLE TIME (MILLISECONDS):',F7.2)
      WRITE(6,1000)
      WRITE(6,1013)SM
 1010 FORMAT(' GAUGE CONSTANTS (CM/SEC) - CHAN 1-4:')
 1011 FORMAT(1H ,4G13.5)
      WRITE(6,1000)
      WRITE(6,1010)
      DO 15 I=1,2
   15 GCON(I)=1000.*PROP(I)/SM
      WRITE(6,1011)(GCON(I),I=1,2)
      CALL CRUNCH(DATA,1,AMP,PERVAR,RATIO)
 1005 FORMAT(' DATA SAMPLES (MILLIMETERS)')
      DO 20 I=1,2
      CHAN(I)=.TRUE.
      CHAN(I+2)=.FALSE.
      DELT=RANGE(I,2)-RANGE(I,1)
      ABSIS(I,1)=-5.
      ABSIS(I,2)=5.
      IF(DELT.LT.20.) GO TO 20
      ABSIS(I,1)=-DELT/2.
      ABSIS(I,2)=DELT/2.
   20 CONTINUE
      TIM=SM/1000.
      ORD(1) 0.
      ORD(2)=TIM
      WRITE (6,1000)
```

```
      WRITE (6,1000)
      WRITE (6,1005)
      DO 21 I=1,4
      DO 21 J=1,256
   21 PTAB(I,J)=0
      DO 22 J=1,256
      DO 22 I=1,2
   22 PTAB(I,J)=DATA(I,J)
      CALL PLOT(PTAB,256,ABSIS,ORD,0,CHAN)
C     PLOT AMPLITUDE SPECTRA AND CUMULATIVE PERCENT VARIANCE
      DO 30 I=1,4
      CHAN(I)=.TRUE.
      ABSIS(I,1)=0.
      ABSIS(I,2)=2.
   30 CONTINUE
      ABSIS(3,2)=100.
      ABSIS(4,2)=100.
      DO 40 I=1,2
      DO 40 J=1,128
      PTAB(I+2,J)=PERVAR(I,J)
      PTAB(I,J)=AMP(I,J)
   40 CONTINUE
      ORD(2)=1./(256.*TIM)
 1006 FORMAT(' AMPLITUDE SPECTRA (1,2) AND CUMULATIVE VARIANCE (4,8)')
 1014 FORMAT (' WITH UNITS OF MILLIMETERS (1,2) AND PERCENT (4,8)')
      WRITE(6,1000)
      WRITE(6,1006)
      WRITE(6,1007)
      WRITE(6,1000)
      CALL PLOT(PTAB,128,ABSIS,ORD,0,CHAN)
C     PRINT LIST OF AMPLITUDES, CUMULATIVE VARIANCES, AND RATIO
 1007 FORMAT(1H ,2('COMP FREQ AMPLITUDE 1  AMPLITUDE 2  CUM VAR 1  CUM V
     *AR 2  RATIO    '))
 1008 FORMAT(1H ,2(I4,1X,F5.2,F8.3,F13.3,2F11.3,F9.3))
      WRITE(6,1000)
      WRITE(6,1000)
      WRITE(6,1007)
      WRITE(6,1000)
      DO 50 I=1,64
      FC=ORD(2)*(I-1)
      I64=I+64
      F64=ORD(2)*(I64-1)
      WRITE(6,1008)I,FC,AMP(1,I),AMP(2,I),PERVAR(1,I),PERVAR(2,I),
     *RATIO(1,I),I64,F64,AMP(1,I64),AMP(2,I64),PERVAR(1,I64),
     *PERVAR(2,I64),RATIO(2,I64)
   50 CONTINUE
      WRITE(6,1000)
      WRITE(6,1005)
      WRITE(6,1010)
 1010 FORMAT(1H ,4('    TIME     MONITOR      TEST    '))
      TDEL=64.*TIM
      TDEL2=128.*TIM
      TDEL3=192.*TIM
      DO 60 I=1,64
      TIME=TIM*(I-1)
      T64=TIME+TDEL
      T128=TIME+TDEL2
      T192=TIME+TDEL3
```

```
      I64=I+64
      I128=I+128
      I192=I+192
      WRITE (6,1015)TNOW,(DATA(J,I),J=1,2),T64,(DATA(J,I64),J=1,2),
     1T128,(DATA(J,I128),J=1,2),T192,(DATA(J,I192),J=1,2)
 1015 FORMAT(12F10.3)
   60 CONTINUE
 1009 FORMAT(1H ,'END OF ANALYSIS FOR RECORD WITH HEADER:')
      WRITE(6,1009)
      WRITE(6,1004)(COMENT(I),I=1,64)
      DO 51 I=1,10
   51 WRITE(6,1000)
      GOTO 5
      END
```

```
      SUBROUTINE CRUNCH(DATA,STAND,AMP,PERVAR,RATIO)
C     VERSION CSW 2.1
      REAL DATA(2,256),AMP(2,128),PERVAR(2,128),TVAR(128), RATIO(2,1
      COMPLEX CTMP(256)
      INTEGER STAND
C     COMPUTE SPECTRUMS, CHANNEL BY CHANNEL
      DO 100 I=1,2
      DO 10 J=1,256
      CTMP(J)=CMPLX(DATA(I,J),0.)
   10 CONTINUE
      CALL FORK(256,CTMP,-1)
      VARSUM=0.
      DO 20 J=1,128
      AMPIJ=CABS(CTMP(J))/8.
      AMP(I,J)=AMPIJ
      IF(J.EQ.1)AMPIJ=.5*AMPIJ
      TVARJ=AMPIJ*AMPIJ
      VARSUM=VARSUM+TVARJ
      TVAR(J)=VARSUM
   20 CONTINUE
      DO 30 J=1,128
      PERVAR(I,J)=0.
      IF(VARSUM.EQ.0.)GO TO 30
      PERVAR(I,J)=100.*TVAR(J)/VARSUM
   30 CONTINUE
  100 CONTINUE
C     CALCULATE RATIOS OF AMPLITUDES TO STANDARD
      DO 110 I=1,2
      DO 110 J=1,128
      IF(AMP(STAND,J).EQ.0.)GO TO 120
      RATIO(I,J)=AMP(I,J)/AMP(STAND,J)
      GO TO 110
  120 RATIO(I,J)=0.
  110 CONTINUE
      RETURN
      END
```

```
V 360N-FO-479 3-8            XFORM                   DATE    06/06/80      TIME     16.5
      SUBROUTINE XFORM(IDATA,DATA,MEAN,RANGE,CUP,CDN,PROP)
C     VERSION CSW 2.1
C     TRANSFORMS A SET OF COUNTER DATA, WITH OVERFLOWS, FROM THE VIMS
C    1WAVE TANK TO A SET OF ZERO MEAN RELATIVE HEIGHT DATA WITH MEAN
C    1AND RANGES REPORTED SEPARATELY.  THE HEIGHT DATA HAVE UNITS OF
C     MILLIMETERS.
      INTEGER*2 IDATA(4,256)
      REAL DATA(2,256),MEAN(2),RANGE(2,2),PROP(2),CUP(2),TEMP(256),
     1CDN(2)
C     THIS IS THE MASTER LOOP, TO TREAT CHANNELS ONE AT A TIME
      DO 100 I=1,2
      IF(PROP(I).EQ.0.)GO TO 100
C     CONVERT ABSOLUTE COUNT DATA TO HEIGHTS
      I2=2*I
      I21=I2-1
      DO 20 J=1,256
      CIJ=IDATA(I2,J)+256*IDATA(I21,J)
      TEMP(J)=10.*PROP(I)/CIJ
   20 CONTINUE
C     DETERMINE RANGE AND AVERAGE OF DATA
      BOT=TEMP(1)
      SUM=BOT
      TOP=BOT
      DO 40 J=2,256
      TRY=TEMP(J)
      IF(TRY.GT.TOP)TOP=TRY
      IF(TRY.LT.BOT)BOT=TRY
      SUM=SUM+TRY
   40 CONTINUE
      AVE=SUM/256.
      MEAN(I)=AVE
      RANGE(I,1)=TOP
      RANGE(I,2)=BOT
      DO 80 J=1,256
      DATA(I,J)=TEMP(J)-AVE
   80 CONTINUE
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INFO(COMENT,SAMPM)
C     VERSION CSW 2.1
C     REQUESTS ADDITIONAL INFORMATION FOR THE OPERATION OF WAVE DATA
C     ANALYSIS PROGRAMS.
C     ROUTINE AUTOMATICALLY RETURNS A SAMPLE TIME OF 20.5 MILLISECONDS
      LOGICAL*1 COMENT(64)
      REAL SAMPM
      SAMPM=20.5
      RETURN
      END
```

```
      SUBROUTINE CALIB(ICAL,SAMPM,PROP,CUP,CDN)
      VERSION CSW 2.1
      DETERMINES VALUES FOR CALIBRATION CONSTANTS FROM
      A SET OF WAVE TANK DATA
      VERSION 2.1 PROCESSES 2 GAUGES,ASSUMING COUNTERS
      3 AND 4 CONTAIN OVERFLOWS FROM CHANNELS 2 AND 8 RESPECTIVELY
      CALIBRATION CONSTANTS PASSED IN PROP HAVE UNITS OF CM/SEC*
      (SAMPLE TIME)
      INTEGER*2 ICAL(64)
      REAL CUP(2),CDN(2),PROP(2)
      GET CALIBRATION COUNT AVERAGES OVER 7 SAMPLES
      DO 20 I=2,2
      IUPI=0
      IDNI=0
      DO 19 J=1,7
      INDEX=2*I+4*J
      IUPI=IUPI+ICAL(INDEX)+256*ICAL(INDEX-1)
      IDNI=IDNI+ICAL(INDEX+32)+256* ICAL(INDEX+31)
   19 CONTINUE
      CUP(I)=IUPI/7.
      CDN(I)=IDNI/7.
   20 CONTINUE
      COMPUTE CALIBRATION CONSTANTS AND CHECK FOR CONSISTENCY
      DO 30 I=2,2
      PROP(I)=0.
      CTD=CDN(I)
      CTU=CUP(I)
      DEN=(1./CTD)-(1./CTU)
      PROP(I)=1./DEN
   30 CONTINUE
      PROP(1)=2508000*SAMPM/1000.
      RETURN
      END
```

```
      SUBROUTINE TAPGET(INNUM,COMENT,ICAL,IDATA)                        00000
C     READS DISK FILE OF TAPE PRODUCED BY WAVE TANK SYSTEM              00000
C     IN FORMAT 'A' AND PLACES COMMENT AND DATA IN APPROPRIATE          00000
C     ARRAYS.  CALLS SUBROUTINE TRASEB.                                 00000
      INTEGER*2 ICAL(64),IDATA(4,256),A(1158),JCAL(64),JDATA(4,256)     00000
      LOGICAL*1 B(128),COMENT(64)                                       00000
      EQUIVALENCE (A(1),B(1)),(JDATA(1,1),A(129)),(JCAL(1),A(65))       00000
      READ(INNUM,1000) A
1000  FORMAT(10 (100 A2),158 A2)
      DO 10 I=1,64                                                      00000
   10 COMENT(I)=B(2*I)                                                  00000
      CALL TRASEB(COMENT,COMENT,64,IER)                                 00000
      DO 20 I=1,64                                                      00000
   20 ICAL(I)=JCAL(I)                                                   00000
      DO 30 I=1,256                                                     00000
       DO 30 J=1,4                                                      00000
   30 IDATA(J,I)=JDATA(J,I)                                             00000
      RETURN                                                            00000
       END                                                              00000
```

```
      SUBROUTINE TRASEB(A,B,N,IER)
      TRANSLATES ASCII CHARACTERS TO EBCDIC EQUIVALENTS
      CALLS FORCE SUBROUTINE 'CBYTE'
      LOGICAL*1 A(1),B(1),TABLE(2,64),CBYTE
      DATA TABLE/Z41,'A',Z42,'B',Z43,'C',Z44,'D',Z45,'E',
     1Z46,'F',Z47,'G',Z48,'H',Z49,'I',Z4A,'J',Z4B,'K',Z4C,'L',
     2Z4D,'M',Z4E,'N',Z4F,'O',Z50,'P',Z51,'Q',Z52,'R',Z53,'S',
     3Z54,'T',Z55,'U',Z56,'V',Z57,'W',Z58,'X',Z59,'Y',Z5A,'Z',
     4Z30,'0',Z31,'1',Z32,'2',Z33,'3',Z34,'4',Z35,'5',Z36,'6',
     5Z37,'7',Z38,'8',Z39,'9',Z2B,'+',Z2D,'-',Z2F,'/',Z3D,'=',
     6Z2E,'.',Z29,')',Z2A,'*',Z27,1H',Z28,'(',Z20,' '/
      IER=0
      DO 10 I=1,N
      DO 8 J=1,46
      J1=J
      IF (CBYTE(A(I),TABLE(1,J))) GOTO 9
    8 CONTINUE
      IER=IER+1
      GO TO 10
    9 B(I)=TABLE(2,J1)
   10 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PLOT (DATA,LENGTH,ABSIS,ORD,ORD1,CHAN)
      INTEGER LENGTH,ORD1
      REAL DATA(4,LENGTH),ABSIS(4,2),ORD(2),ABS(11)
      INTEGER*2 CHAR(101),CSET(15),NUL,NP,NA,NCH,VAL(101)
      INTEGER*2 NL
      LOGICAL CHAN(4),FLGEND
      DATA NUL/' '/,CSET/'1','2','3','4','5','6','7','8',
     1'9','A','B','C','D','E','F'/,NP/'+'/,NA/'*'/,
     2NL/'|'/
C     FIRST SET UP ABSCISSAE AXES
      WRITE (6,1000)
      DO 10 I=1,4
      IF(.NOT.CHAN(I))GO TO 10
 1000 FORMAT(1H )
 1001 FORMAT(1H ,16X,'  C H A N N E L   N O.  ',I3)
 1002 FORMAT(1H ,13X,11(G9.3,1X))
 1003 FORMAT(1H ,15X,'*',10('----+----*'))
      WRITE(6,1000)
      WRITE(6,1001)I
      ALO=ABSIS(I,1)
      DEL=(ABSIS(I,2)-ALO)/10.
      DO 5 J=1,11
    5 ABS(J)=ALO+(J-1)*DEL
      WRITE(6,1002)(ABS(J),J=1,11)
      WRITE(6,1003)
   10 CONTINUE
 1004 FORMAT(1H ,3X,G10.4,2X,101A1)
 1005 FORMAT(1H ,15X,101A1)
C     NOW PLOT THE DATA
      FLGEND=.FALSE.
      DO 100 J=1,LENGTH
      DO 20 I=1,101
      VAL(I)=0
   20 CHAR(I)=NUL
C     FILL DATA BUFFER
      DO 21 I=1,4
      IF(.NOT.CHAN(I))GO TO 21
      ALO=ABSIS(I,1)
      DEL=ABSIS(I,2)-ALO
      IV=((DATA(I,J)-ALO)/DEL*100)+1.5
      IF(IV.LT.1)IV=1
      IF(IV.GT.101)IV=101
      VAL(IV)=VAL(IV)+2**(I-1)
   21 CONTINUE
      SET CHARACTER BUFFER
      DO 25 I=1,101
      IC=VAL(I)
      IF(IC.NE.0)CHAR(I)=CSET(IC)
   25 CONTINUE
      NCH=NL
      IF(J.EQ.(J/5)*5)NCH=NP
      IF(J.EQ.(J/10)*10)NCH=NA
      IF(VAL(1).EQ.0)CHAR(1)=NCH
      IF(VAL(101).EQ.0)CHAR(101)=NCH
C     PLOT LINE
      IF((J/5)*5.EQ.J)GO TO 30
      WRITE(6,1005)(CHAR(I),I=1,101)
      GO TO 100
```

```
80  CONTINUE                                                          00001
    AA=ORD(1)+(J-1)*ORD(2)                                            00001
    WRITE(6,1004)AA,(CHAR(I),I=1,101)                                 00001
90  CONTINUE                                                          00001
    WRITE(6,1003)                                                     00001
    RETURN                                                            00001
    END                                                               00001
```

```
RUN ADCN-FP-479 3-8            FORK                 DATE    06/06/80      TI              16.56

      SUBROUTINE FORK(LX,CX,SIGNI)                                                      00001
C     ADAPTED FROM CLAERBOUT (1976) FUNDAMENTALS OF GEOPHYSICAL                         00001
C     DATA PROCESSING                                                                   00001
      COMPLEX CX(LX),CARG,CW,CTEMP                                                      00001
      J=1                                                                               00001
      SC=SQRT(1./LX)                                                                    00001
      DO 30 I=1,LX                                                                      00001
      IF(I.GT.J) GO TO 10                                                               00001
      CTEMP=CX(J)*SC                                                                    00001
      CX(J)=CX(I)*SC                                                                    00001
      CX(I)=CTEMP                                                                       00001
   10 M=LX/2                                                                            00001
      IF(J.LE.M) GO TO 30                                                               00001
      J=J-M                                                                             00001
      M=M/2
      IF(M.GE.1)GO TO 20
   30 J=J+M
      L=1
   40 ISTEP=2*L
      DO 50 M=1,L
      CARG=CMPLX(0.,3.14159264*(M-1)/L)
      CW=CEXP(CARG)
      DO 50 I=M,LX,ISTEP
      CTEMP=CW*CX(I+L)
      CX(I+L)=CX(I)-CTEMP
   50 CX(I)=CX(I)+CTEMP
      L=ISTEP
      IF(L.LT.LX) GO TO 40
      RETURN
      END
```

APPENDIX 3

Annotated Results of Analysis of a Single Record from the VIMS Wave Tank

Notes:

1) The header line is entered before each test run. The format is:

   Tnnn aaa S jj tttt ddmmmyy iiiiii VIMS Wave Tank

   where: a. nnn is the sequential test number

   b. aaa is the incident wave direction

   c. S is the station letter, referring to figure 1

   d. jj is the jetty configuration code

   e. tttt is local time of day

   f. ddmmmyy is the date (e.g. 30 MAY 80)

   g. iiiiii is the identifier of the magnetic tape

2) The time axis is labeled every 5 samples in seconds from a start, one sampling interval before the first sample.

3) Where two or more points occupy the same print position, their sum is printed.

4) This line is a bug, and should be ignored.

5) Channels 1 and 2 have units of millimeters, while 3 and 4 are dimensionless. Channel 1 is the spectrum for the monitor gauge with channel 3 being its cumulative variance. Channels 2 and 4 are analagous for the test gauge.

6) Frequency scale is linear in Hertz (sec^{-1}).

7) These are the spectrum peaks for the two signals.

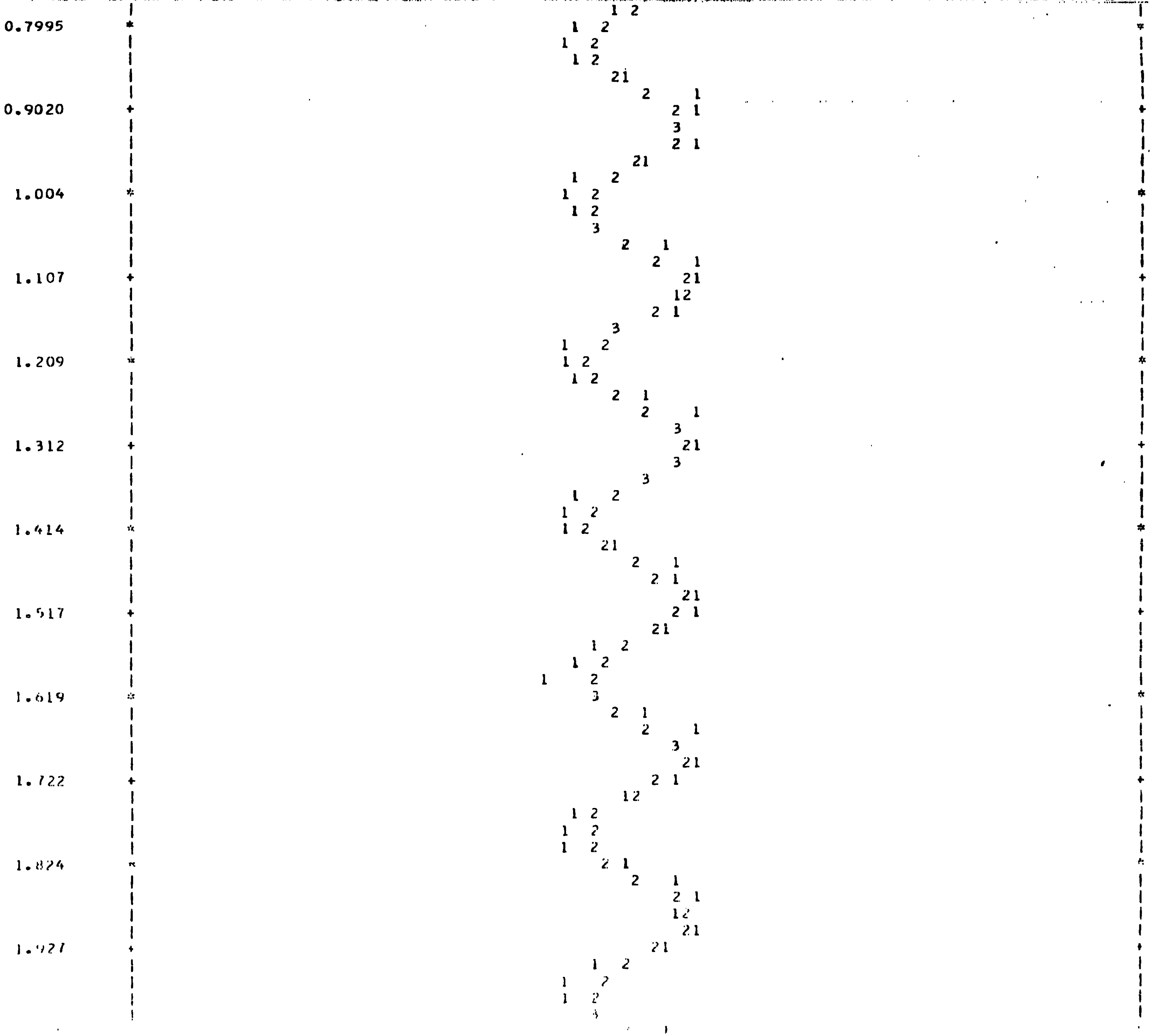
8) Second and third harmonic of the driving frequency.

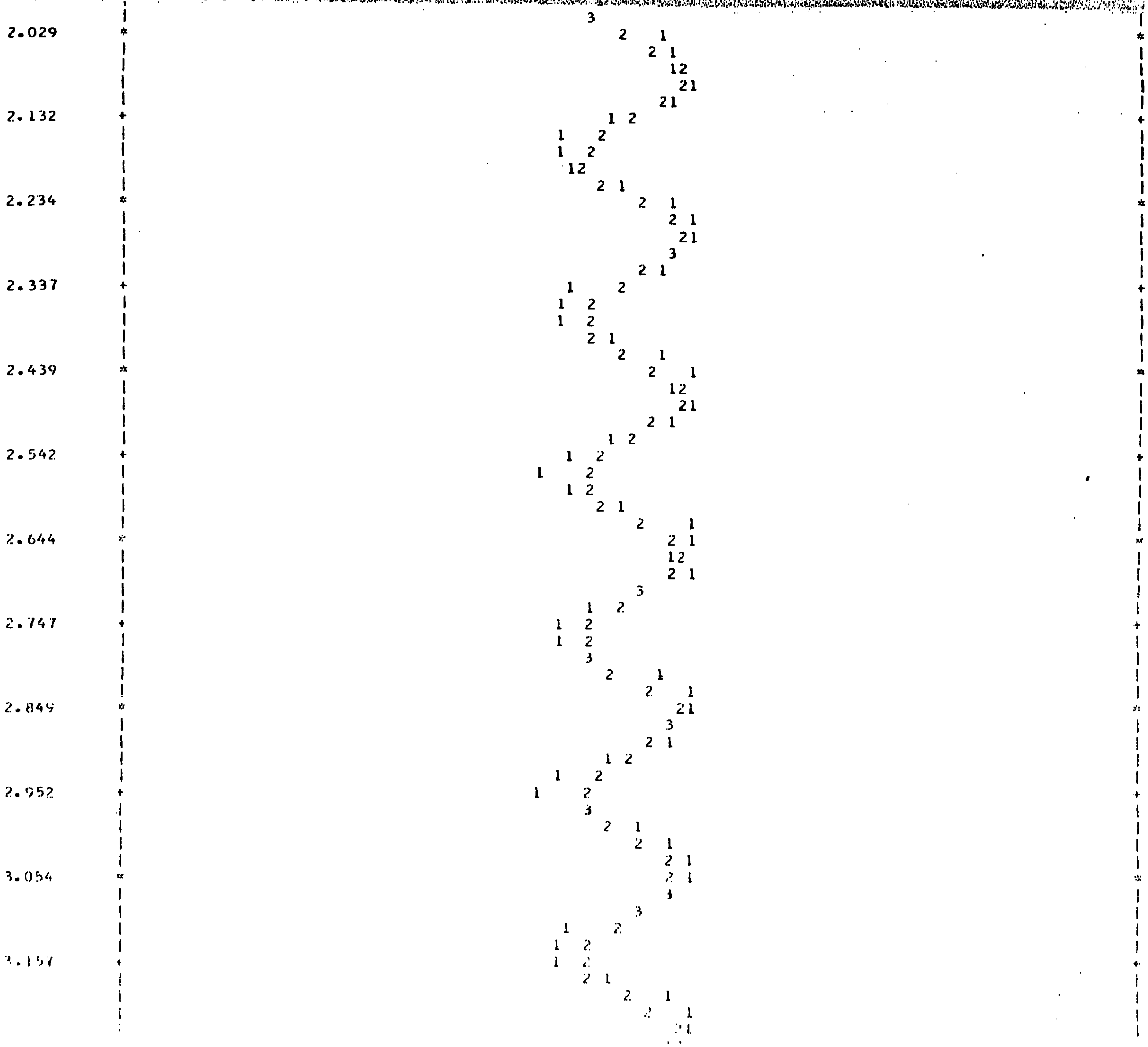
9) Listing of the amplitudes and cumulative variances.

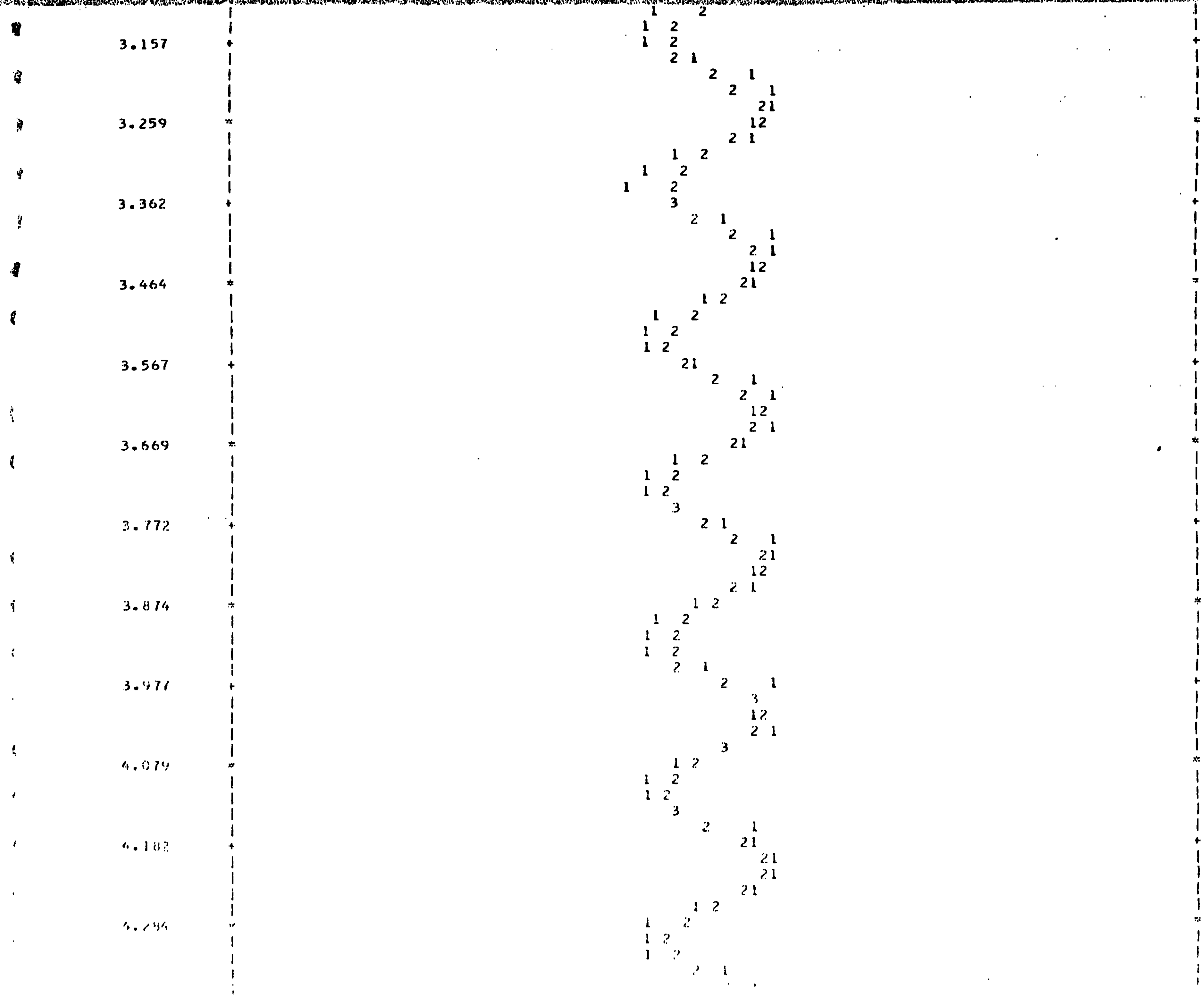
10) The 28th harmonic contains most of the information in a clean record, such as this one.

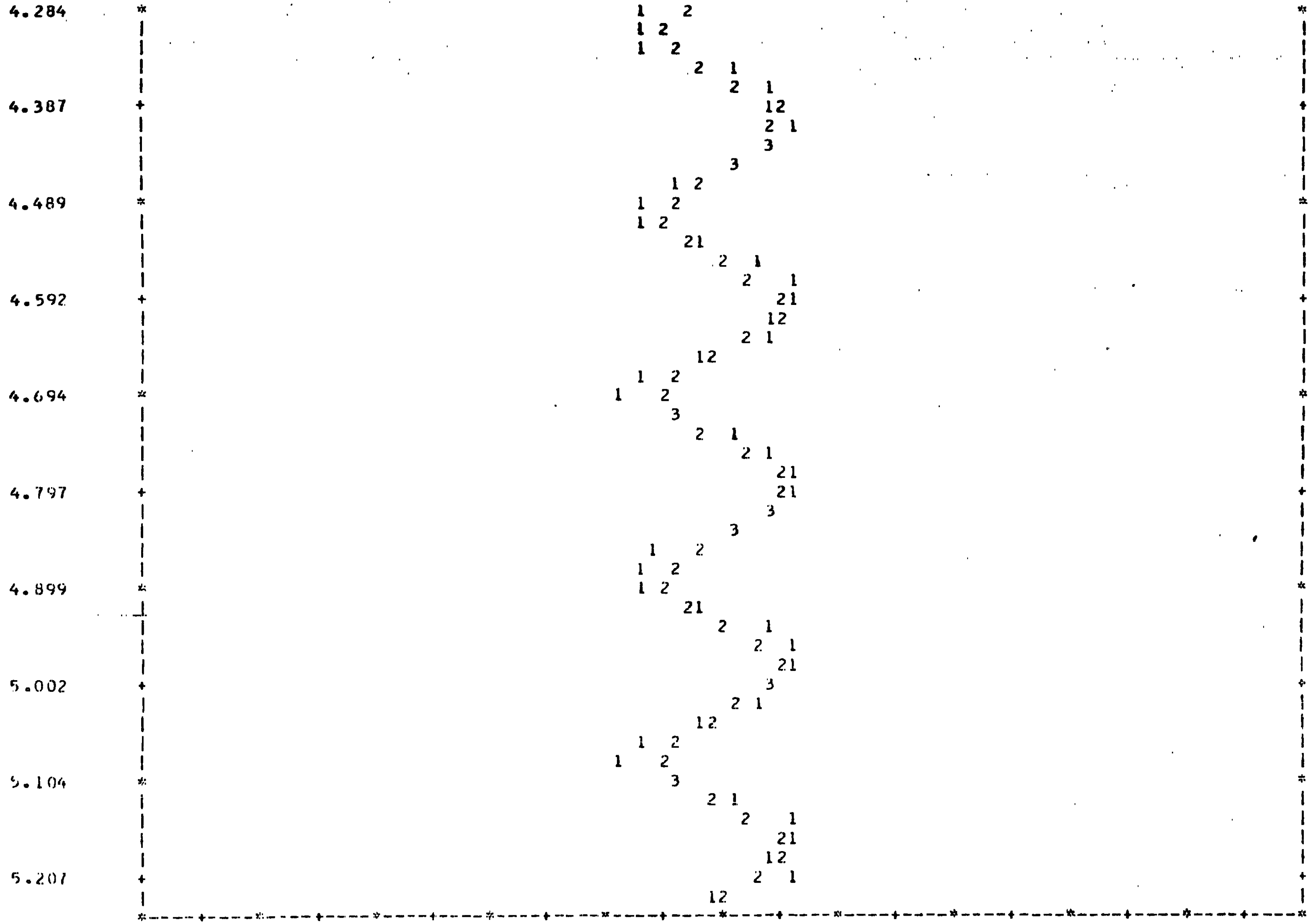
11) Listing of the data after calibration and removal of the mean value.

```
ANALYSIS FOR THE RECORD WITH HEADER:
T103 SSE I 00 1120 02JUN80 POH128 VIMS WAVE TANK  ---①


SAMPLE TIME (MILLISECONDS):  20.50

GAUGE CONSTANTS (CM/SEC) - CHAN 1-4:
  0.29080E 07  0.44827E 06


DATA SAMPLES (MILLIMETERS)


                  C H A N N E L   N O.    1
             -5.00     -4.00     -3.00     -2.00     -1.00      0.0        1.00      2.00      3.00      4.00      5.00
                *----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*

                  C H A N N E L   N O.    2
             -5.00     -4.00     -3.00     -2.00     -1.00      0.0        1.00      2.00      3.00      4.00      5.00
                *----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*
                |                                                1 2                                                |
      ②         |                                           1   2                                                   |
                |                                          1  2                                                     |
                |                                           1 2                                                     |
    0.8200E-01  +                                              21                                                   +
                |                                                 2     1                                           |
                |                                                    21                                             |
                |                                                      21                                           |
                |                                                     2 1                                           |
    0.1845      *                                                  12                                               *
                |                                               12                                                  |
                |                                          1   2                                                    |
                |                                          1  2                                                     |
                |                                             3                                                     |
    0.2870      +                                               2  1                                                +
                |                                                  2  1                                             |
                |                                                     2 1                                           |
                |                                                     2 1                                           |
                |                                                    21                                             |
    0.3895      *                                               1 2                                                 *
                |                                           1   2                                                   |
                |                                          1  2                                                     |
                |                                           1 2                                                     |
                |                                              2 1                                                  |
    0.4920      +                                                 2   1                                             +
                |                                                    2  1                                           |
                |                                                      21                                           |
                |                                                     3 --------③                                  |
                |                                                   21                                              |
    0.5945      *                                             1  2                                                  *
                |                                          1  2                                                     |
                |                                          1  2                                                     |
                |                                             3                                                     |
                |                                                2   1                                              |
    0.6970      +                                                   2   1                                           +
                |                                                     2 1                                           |
                |                                                     3                                             |
                |                                                    3                                              |
                |                                               1 2                                                 |
```


0.7995
0.9020
1.004
1.107
1.209
1.312
1.414
1.517
1.619
1.722
1.824
1.927


2.029
2.132
2.234
2.337
2.439
2.542
2.644
2.747
2.849
2.952
3.054
3.157


3.157
3.259
3.362
3.464
3.567
3.669
3.772
3.874
3.977
4.079
4.182
4.284

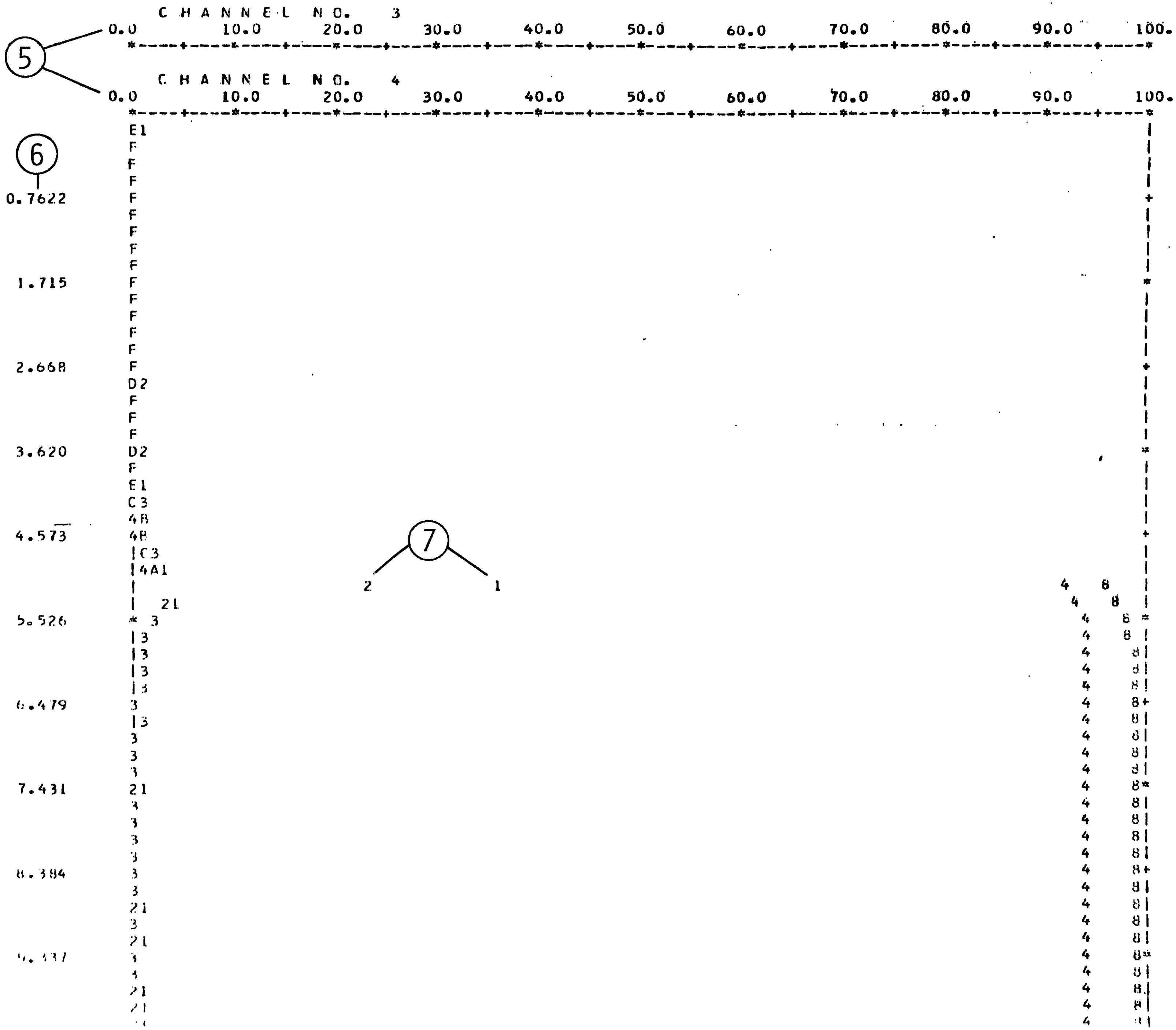


```
AMPLITUDE SPECTRA (1,2) AND CUMULATIVE VARIANCE (4,8)
COMP FREQ AMPLITUDE 1  AMPLITUDE 2  CUM VAR 1  CUM VAR 2  RATIO   COMP FREQ AMPLITUDE 1  AMPLITUDE 2  CUM VAR 1  CUM VAR 2  RATIO
```

④

```
          C H A N N E L   N O.    1
   0.0        0.200      0.400      0.600      0.800      1.00       1.20       1.40       1.60       1.80       2.00
    *----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*

          C H A N N E L   N O.    2
   0.0        0.200      0.400      0.600      0.800      1.00       1.20       1.40       1.60       1.80       2.00
    *----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*----+----*
```

⑤


CHANNEL NO. 3
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.
CHANNEL NO. 4
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.
5
6
7
2
1
0.7622
1.715
2.668
3.620
4.573
5.526
6.479
7.431
8.384
9.337
E1
D2
C3
4B
4A1
21
3
4
8

```
               21                                               4     8|
     9.337     3                                                4     8*
               3                                                4     8|
               21                                               4     8|
               21                                               4     8|
               21                                               4     8|
     10.29     +2    1 ———— ⑧                                       4  8+
               |21                                                   4  8
               21                                                    4  8
               3                                                     4  8
               3                                                     4  8
     11.24     3                                                     4  8
               3                                                     4  8
               3                                                     4  8
               3                                                     4  8
               3                                                     4  8
     12.20     21                                                     4 8
               3                                                      4 8
               21                                                     4 8
               3                                                      4 8
               21                                                     4 8
     13.15     21                                                     4 8
               21                                                     4 8
               3                                                      4 8
               21                                                     4 8
               3                                                      4 8
     14.10     3                                                      4 8
               21                                                     4 8
               3                                                      4 8
               3                                                      4 8
               21                                                     4 8
     15.05     21                                                     4 8
               3                                                      4 8
               2  1 ———— ⑧                                             48
               2 1                                                     48
               21                                                      48
     16.01     21                                                      48
               21                                                      48
               3                                                       48
               3                                                       48
               3                                                       48
     16.96     3                                                       48
               3                                                       48
               3                                                       48
               3                                                       48
               3                                                       48
     17.91     3                                                       48
               21                                                      48
               3                                                       48
               3                                                       48
               3                                                       48
     18.86     3                                                       48
               21                                                      48
               21                                                      48
               21                                                      48
               3                                                       48
     19.82     21                                                      48
               21                                                      48
               3                                                       48
               3                                                       48
               21                                                      48
```

```
          21                                                                                  48
 20.77    21                                                                                  48
          21                                                                                  48
          21                                                                                   C
          21                                                                                   C
          3                                                                                    C
 21.72    21                                                                                   C
          3                                                                                    C
          21                                                                                   C
          21                                                                                   C
          3                                                                                    C
 22.68    3                                                                                    C
          21                                                                                   C
          21                                                                                   C
          3                                                                                    C
          21                                                                                   C
 23.63    21                                                                                   C
          3                                                                                    C
          21                                                                                   C
          21                                                                                   C
          *-----+-----*-----+-----*-----+-----*-----+-----*-----+-----*-----+-----*-----+-----*-----+-----*-----+-----*-----+-----*
```

⑨

```
COMP FREQ AMPLITUDE 1  AMPLITUDE 2  CUM VAR 1  CUM VAR 2  RATIO   COMP FREQ AMPLITUDE 1  AMPLITUDE 2  CUM VAR 1  CUM VAR 2  RATIO

   1  0.0   0.016          0.002       0.012      0.001     0.151   65 12.20  0.019          0.002       97.551     99.608     0.118
   2  0.19  0.004          0.005       0.015      0.010     1.042   66 12.39  0.005          0.003       97.555     99.612     0.579
   3  0.38  0.005          0.007       0.020      0.032     1.418   67 12.58  0.014          0.007       97.592     99.634     0.499
   4  0.57  0.004          0.004       0.022      0.039     1.088   68 12.77  0.005          0.002       97.597     99.636     0.440
   5  0.76  0.001          0.003       0.023      0.042     2.503   69 12.96  0.018          0.002       97.651     99.637     0.090
   6  0.95  0.001          0.004       0.023      0.051     4.362   70 13.15  0.014          0.002       97.688     99.639     0.133
   7  1.14  0.002          0.002       0.024      0.053     0.914   71 13.34  0.014          0.003       97.723     99.644     0.248
   8  1.33  0.003          0.002       0.025      0.054     0.527   72 13.53  0.006          0.004       97.729     99.650     0.617
   9  1.52  0.005          0.005       0.030      0.064     0.939   73 13.72  0.012          0.002       97.755     99.651     0.153
  10  1.71  0.004          0.005       0.033      0.067     0.674   74 13.91  0.009          0.004       97.769     99.558     0.440
  11  1.91  0.005          0.004       0.037      0.073     0.809   75 14.10  0.003          0.001       97.771     99.659     0.403
  12  2.10  0.006          0.005       0.042      0.086     0.950   76 14.29  0.018          0.002       97.831     99.660     0.095
  13  2.29  0.006          0.004       0.050      0.092     0.570   77 14.48  0.003          0.003       97.832     99.665     1.299
  14  2.48  0.001          0.005       0.050      0.103     3.526   78 14.67  0.009          0.002       97.847     99.666     0.189
  15  2.67  0.004          0.005       0.053      0.113     1.190   79 14.86  0.014          0.003       97.882     99.669     0.183
  16  2.86  0.009          0.014       0.067      0.200     1.619   80 15.05  0.011          0.003       97.903     99.673     0.283
  17  3.05  0.010          0.006       0.084      0.217     0.626   81 15.24  0.010          0.004       97.920     99.681     0.430
  18  3.24  0.009          0.005       0.098      0.229     0.601   82 15.43  0.058          0.001       98.506     99.681     0.012
  19  3.43  0.007          0.008       0.108      0.260     1.152   83 15.62  0.032          0.001       98.686     99.682     0.033
  20  3.62  0.006          0.010       0.113      0.307     1.878   84 15.82  0.023          0.004       98.776     99.690     0.196
  21  3.81  0.005          0.007       0.117      0.329     1.478   85 16.01  0.018          0.005       98.831     99.700     0.271
  22  4.00  0.018          0.007       0.175      0.354     0.414   86 16.20  0.025          0.004       98.942     99.708     0.169
  23  4.19  0.016          0.011       0.220      0.410     0.717   87 16.39  0.005          0.006       98.947     99.724     1.064
  24  4.38  0.022          0.017       0.308      0.537     0.768   88 16.58  0.007          0.004       98.957     99.729     0.480
  25  4.57  0.021          0.017       0.387      0.655     0.784   89 16.77  0.007          0.004       98.966     99.735     0.516
  26  4.76  0.038          0.032       0.644      1.102     0.844   90 16.96  0.008          0.001       98.978     99.735     0.119
  27  4.95  0.064          0.042       1.359      1.862     0.660   91 17.15  0.006          0.004       98.983     99.743     0.770
  28  5.14  0.717          0.467      91.954     95.558     0.651   92 17.34  0.003          0.005       98.985     99.755     1.677
  29  5.34  0.088          0.066      93.317     97.455     0.755   93 17.53  0.006          0.004       98.990     99.761     0.677
  30  5.53  0.040          0.044      93.598     98.302     1.111   94 17.72  0.004          0.004       98.993     99.768     1.027
  31  5.72  0.025          0.019      93.710     98.456     0.748   95 17.91  0.007          0.003       99.002     99.772     0.419
  32  5.91  0.027          0.018      93.838     98.597     0.673   96 18.10  0.014          0.005       99.038     99.783     0.356
  33  6.10  0.018          0.016      93.896     98.710     0.891   97 18.29  0.005          0.005       99.042     99.796     1.188
  34  6.29  0.020          0.014      93.965     98.797     0.719   98 18.48  0.002          0.005       99.043     99.806     2.868
  35  6.48  0.010          0.010      93.981     98.836     1.005   99 18.67  0.009          0.003       99.056     99.810     0.376
  36  6.67  0.011          0.012      94.003     98.895     1.041  100 18.86  0.010          0.002       99.072     99.812     0.226
[illegible] [illegible] [illegible] [illegible] 94.017  98.910     0.686  101 19.05  0.021          0.002       99.151     99.814     [illegible]
```

⑩

```
 17  3.05  0.010        0.006      0.084      0.217      0.626  81 15.24  0.010        0.004   97.920   99.681   0.430
 18  3.24  0.009        0.005      0.098      0.229      0.601  82 15.43  0.058        0.001   98.506   99.681   0.012
 19  3.43  0.007        0.008      0.108      0.260      1.152  83 15.62  0.032        0.001   98.686   99.682   0.038
 20  3.62  0.006        0.010      0.113      0.307      1.878  84 15.82  0.023        0.004   98.776   99.690   0.196
 21  3.81  0.005        0.007      0.117      0.329      1.478  85 16.01  0.018        0.005   98.831   99.700   0.271
 22  4.00  0.018        0.007      0.175      0.354      0.414  86 16.20  0.025        0.004   98.942   99.708   0.169
 23  4.19  0.016        0.011      0.220      0.410      0.717  87 16.39  0.005        0.006   98.947   99.724   1.064
 24  4.38  0.022        0.017      0.308      0.537      0.768  88 16.58  0.007        0.004   98.957   99.729   0.480
 25  4.57  0.021        0.017      0.387      0.655      0.784  89 16.77  0.007        0.004   98.966   99.735   0.516
 26  4.76  0.038        0.032      0.644      1.102      0.844  90 16.96  0.008        0.001   98.978   99.735   0.119
 27  4.95  0.064        0.042      1.359      1.862      0.660  91 17.15  0.006        0.004   98.983   99.743   0.770
 28  5.14  0.717        0.467     91.954     95.558      0.651  92 17.34  0.003        0.005   98.985   99.755   1.877
 29  5.34  0.088        0.066     93.317     97.455      0.755  93 17.53  0.006        0.004   98.990   99.761   0.677
 30  5.53  0.040        0.044     93.598     98.302      1.111  94 17.72  0.004        0.004   98.993   99.768   1.027
 31  5.72  0.025        0.019     93.710     98.456      0.748  95 17.91  0.007        0.003   99.002   99.772   0.419
 32  5.91  0.027        0.018     93.838     98.597      0.673  96 18.10  0.014        0.005   99.038   99.783   0.356
 33  6.10  0.018        0.016     93.896     98.710      0.891  97 18.29  0.005        0.005   99.042   99.796   1.188
 34  6.29  0.020        0.014     93.965     98.797      0.719  98 18.48  0.002        0.005   99.043   99.806   2.868
 35  6.48  0.010        0.010     93.981     98.836      1.005  99 18.67  0.009        0.003   99.056   99.810   0.376
 36  6.67  0.011        0.012     94.003     98.895      1.041 100 18.86  0.010        0.002   99.072   99.812   0.224
 37  6.86  0.009        0.006     94.017     98.910      0.686 101 19.05  0.021        0.002   99.151   99.814   0.108
 38  7.05  0.008        0.004     94.029     98.918      0.509 102 19.25  0.020        0.003   99.223   99.819   0.155
 39  7.24  0.007        0.008     94.037     98.946      1.206 103 19.44  0.016        0.006   99.266   99.837   0.413
 40  7.43  0.014        0.009     94.072     98.978      0.610 104 19.63  0.009        0.004   99.279   99.844   0.481
 41  7.62  0.008        0.005     94.082     98.988      0.630 105 19.82  0.017        0.004   99.332   99.851   0.235
 42  7.81  0.000        0.006     94.082     99.006     12.935 106 20.01  0.011        0.005   99.352   99.863   0.504
 43  8.00  0.009        0.007     94.097     99.030      0.815 107 20.20  0.009        0.006   99.365   99.878   0.665
 44  8.19  0.003        0.004     94.099     99.037      1.341 108 20.39  0.008        0.004   99.377   99.885   0.513
 45  8.38  0.006        0.004     94.104     99.043      0.696 109 20.58  0.012        0.001   99.401   99.886   0.077
 46  8.57  0.006        0.005     94.110     99.052      0.787 110 20.77  0.018        0.004   99.461   99.893   0.227
 47  8.77  0.017        0.005     94.164     99.061      0.263 111 20.96  0.014        0.003   99.496   99.898   0.229
 48  8.96  0.008        0.009     94.175     99.098      1.148 112 21.15  0.012        0.004   99.522   99.903   0.292
 49  9.15  0.015        0.002     94.215     99.100      0.155 113 21.34  0.019        0.003   99.583   99.908   0.186
 50  9.34  0.003        0.002     94.217     99.103      0.763 114 21.53  0.006        0.001   99.590   99.908   0.128
 51  9.53  0.009        0.009     94.230     99.136      1.002 115 21.72  0.022        0.003   99.675   99.912   0.126
 52  9.72  0.010        0.005     94.249     99.147      0.499 116 21.91  0.005        0.004   99.679   99.919   0.907
 53  9.91  0.021        0.007     94.326     99.165      0.316 117 22.10  0.016        0.004   99.722   99.927   0.275
 54 10.10  0.014        0.006     94.360     99.190      0.543 118 22.29  0.010        0.001   99.741   99.928   0.116
 55 10.29  0.125        0.026     97.119     99.478      0.207 119 22.48  0.008        0.003   99.753   99.931   0.372
 56 10.48  0.036        0.013     97.345     99.547      0.355 120 22.68  0.009        0.003   99.767   99.936   0.349
 57 10.67  0.023        0.004     97.438     99.553      0.169 121 22.87  0.019        0.001   99.830   99.936   0.048
 58 10.86  0.004        0.003     97.440     99.557      0.765 122 23.06  0.011        0.003   99.852   99.939   0.227
 59 11.05  0.005        0.005     97.445     99.568      0.989 123 23.25  0.010        0.003   99.869   99.943   0.318
 60 11.24  0.006        0.004     97.451     99.577      0.719 124 23.44  0.014        0.008   99.905   99.971   0.572
 61 11.43  0.008        0.003     97.463     99.580      0.315 125 23.63  0.012        0.004   99.932   99.979   0.335
 62 11.62  0.008        0.002     97.473     99.582      0.282 126 23.82  0.004        0.005   99.935   99.990   1.166
 63 11.81  0.008        0.005     97.484     99.591      0.574 127 24.01  0.013        0.004   99.963   99.999   0.359
 64 12.00  0.002        0.006     97.485     99.606      2.692 128 24.20  0.015        0.001  100.000  100.000   0.103
```

⑪

```
DATA SAMPLES (MILLIMETERS)
    TIME       MONITOR       TEST        TIME    MONITOR      TEST       TIME    MONITOR      TEST       TIME    MONITOR      TEST
    0.0        -0.063        0.075       1.312     0.618      0.487      2.624     0.618      0.099      3.936    -0.741      -0.425
    0.020      -0.572       -0.189       1.332     0.448      0.365      2.644     0.618      0.414      3.956    -0.063      -0.355
    0.041      -0.741       -0.378       1.353     0.107      0.075      2.665     0.448      0.512      3.977     0.618       0.075
    0.061      -0.572       -0.402       1.373    -0.572     -0.189      2.685     0.618      0.414      3.997     0.448       0.414
    0.082      -0.233       -0.307       1.394    -0.741     -0.402      2.706     0.107      0.123      4.018     0.448       0.536
    0.102       0.618       -0.021       1.414    -0.741     -0.543      2.726    -0.403     -0.141      4.038     0.618       0.414
    0.123       0.448        0.292       1.435    -0.233     -0.331      2.747    -0.741     -0.378      4.059     0.107       0.123
    0.143       0.618        0.463       1.455     0.448     -0.021      2.767    -0.741     -0.449      4.079    -0.403      -0.165
    0.164       0.618        0.432       1.476     0.448      0.219      2.788    -0.403     -0.355      4.100    -0.741      -0.378
    0.184       0.107        0.219       1.496     0.618      0.512      2.808     0.277     -0.165      4.120    -0.741      -0.473
  [illegible]   0.233     [illegible]    1.517     0.618      0.438      2.829     0.618      0.244      4.141    -0.403      -0.376
```

```
  0.205  -0.233  -0.069    1.517   0.618   0.438    2.829   0.618   0.244    4.141  -0.403  -0.378
  0.225  -0.741  -0.307    1.537   0.277   0.195    2.849   0.618   0.463    4.161   0.448  -0.069
  0.246  -0.741  -0.425    1.558  -0.403  -0.141    2.870   0.448   0.438    4.182   0.448   0.268
  0.266  -0.403  -0.378    1.578  -0.572  -0.331    2.890   0.448   0.219    4.202   0.618   0.487
  0.287   0.107  -0.165    1.599  -0.910  -0.449    2.911  -0.233  -0.045    4.223   0.618   0.487
  0.307   0.448   0.123    1.619  -0.403  -0.402    2.931  -0.741  -0.284    4.243   0.448   0.268
  0.328   0.618   0.390    1.640   0.107  -0.165    2.952  -0.910  -0.425    4.264  -0.233  -0.045
  0.348   0.618   0.438    1.660   0.618   0.147    2.972  -0.403  -0.402    4.284  -0.741  -0.331
  0.369   0.448   0.292    1.681   0.448   0.438    2.993   0.107  -0.236    4.305  -0.741  -0.543
  0.389  -0.233   0.027    1.701   0.618   0.487    3.013   0.448   0.099    4.325  -0.741  -0.425
  0.410  -0.572  -0.236    1.722   0.448   0.219    3.034   0.618   0.414    4.346   0.107  -0.212
  0.430  -0.741  -0.402    1.742  -0.063   0.027    3.054   0.618   0.414    4.366   0.448   0.147
  0.451  -0.572  -0.402    1.763  -0.572  -0.355    3.075   0.448   0.414    4.387   0.448   0.463
  0.471  -0.063  -0.284    1.783  -0.741  -0.425    3.095   0.107   0.147    4.407   0.618   0.414
  0.492   0.448   0.003    1.804  -0.741  -0.425    3.116  -0.572  -0.141    4.428   0.448   0.390
  0.512   0.618   0.341    1.824  -0.063  -0.284    3.136  -0.741  -0.378    4.448   0.107   0.099
  0.533   0.618   0.487    1.845   0.448   0.027    3.157  -0.741  -0.425    4.469  -0.403  -0.189
  0.553   0.448   0.438    1.865   0.618   0.365    3.177  -0.233  -0.355    4.489  -0.741  -0.402
  0.574   0.277   0.171    1.886   0.448   0.512    3.198   0.448  -0.045    4.510  -0.741  -0.473
  0.594  -0.403  -0.117    1.906   0.618   0.463    3.218   0.618   0.219    4.530  -0.233  -0.331
  0.615  -0.741  -0.355    1.927   0.277   0.219    3.239   0.618   0.487    4.551   0.277  -0.045
  0.635  -0.741  -0.425    1.947  -0.403  -0.093    3.259   0.448   0.463    4.571   0.618   0.219
  0.656  -0.403  -0.378    1.968  -0.741  -0.331    3.280   0.448   0.244    4.592   0.618   0.512
  0.676   0.277  -0.141    1.988  -0.741  -0.449    3.300  -0.403  -0.069    4.612   0.448   0.463
  0.697   0.618   0.195    2.009  -0.403  -0.402    3.321  -0.741  -0.307    4.633   0.448   0.195
  0.717   0.618   0.414    2.029   0.277  -0.141    3.341  -0.910  -0.425    4.653  -0.233  -0.093
  0.738   0.448   0.438    2.050   0.448   0.195    3.362  -0.403  -0.402    4.674  -0.741  -0.355
  0.758   0.277   0.268    2.070   0.448   0.463    3.382   0.107  -0.189    4.694  -0.910  -0.473
  0.779  -0.233   0.003    2.091   0.618   0.487    3.403   0.618   0.171    4.715  -0.403  -0.425
  0.799  -0.572  -0.284    2.111   0.448   0.317    3.423   0.618   0.438    4.735   0.107  -0.189
  0.820  -0.741  -0.402    2.132  -0.233   0.003    3.444   0.448   0.487    4.756   0.448   0.195
  0.840  -0.572  -0.402    2.152  -0.741  -0.260    3.464   0.448   0.341    4.776   0.618   0.487
  0.861  -0.063  -0.236    2.173  -0.741  -0.425    3.485  -0.063   0.051    4.797   0.618   0.536
  0.881   0.618   0.075    2.193  -0.572  -0.543    3.505  -0.572  -0.212    4.817   0.448   0.365
  0.902   0.618   0.390    2.214  -0.063  -0.260    3.526  -0.741  -0.425    4.838   0.107   0.075
  0.922   0.448   0.414    2.234   0.448   0.051    3.546  -0.741  -0.543    4.858  -0.572  -0.212
  0.943   0.618   0.414    2.255   0.618   0.414    3.567  -0.233  -0.307    4.879  -0.741  -0.425
  0.963   0.107   0.027    2.275   0.618   0.536    3.587   0.448   0.027    4.899  -0.741  -0.473
  0.984  -0.572  -0.165    2.296   0.448   0.414    3.608   0.618   0.341    4.920  -0.233  -0.307
  1.004  -0.741  -0.378    2.316   0.277   0.147    3.628   0.448   0.512    4.940   0.448   0.003
  1.025  -0.572  -0.425    2.337  -0.572  -0.141    3.649   0.618   0.438    4.961   0.618   0.341
  1.045  -0.403  -0.355    2.357  -0.741  -0.355    3.669   0.277   0.171    4.981   0.618   0.512
  1.066   0.277  -0.069    2.378  -0.741  -0.449    3.690  -0.403  -0.117    5.002   0.448   0.414
  1.086   0.618   0.171    2.398  -0.233  -0.378    3.710  -0.741  -0.355    5.022   0.277   0.147
  1.107   0.618   0.487    2.419   0.277  -0.117    3.731  -0.741  -0.473    5.043  -0.233  -0.141
  1.127   0.448   0.463    2.439   0.618   0.244    3.751  -0.403  -0.402    5.063  -0.741  -0.355
  1.148   0.448   0.244    2.460   0.448   0.463    3.772   0.107  -0.141    5.084  -0.910  -0.473
  1.168  -0.233  -0.165    2.480   0.618   0.463    3.792   0.618   0.244    5.104  -0.403  -0.378
  1.189  -0.741  -0.331    2.501   0.448   0.244    3.813   0.618   0.487    5.125   0.107  -0.117
  1.209  -0.741  -0.473    2.521  -0.233  -0.045    3.833   0.448   0.512    5.145   0.618   0.219
  1.230  -0.572  -0.425    2.542  -0.572  -0.284    3.854   0.448   0.219    5.166   0.618   0.487
  1.250   0.107  -0.212    2.562  -0.910  -0.449    3.874  -0.233   0.003    5.186   0.448   0.512
  1.271   0.618   0.123    2.583  -0.572  -0.425    3.895  -0.572  -0.284    5.207   0.618   0.341
  1.291   0.448   0.414    2.603  -0.063  -0.260    3.915  -0.741  -0.449    5.227  -0.063   0.027
END OF ANALYSIS FOR RECORD WITH HEADER:
T103 SSF I 00 1120 02JUN80 POH128 VIMS WAVE TANK
```