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SUS QUALITY ASSESSMENT, SQUARE DEAL

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Underwater Systems, Incorporated

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The detonation pressure time curves recorded aboard the USNS Kingsport during the SQUARE DEAL Exercise for SUS signals were processed to acquire quality assurance statistics. Bubble pulse periods were determined for each detonation from which an equivalent depth was derived. For statistical purposes, the detonation depths of those shots known to a high degree of confidence are grouped in 10 foot classes cnetered on the decade, for the Mk 82 (300 feet).

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FINAL REPORT

SUS QUALITY ASSESSMENT
SQUARE DEAL

February 7, 1975

Prepared by:

M. S. Weinstein
L. A. Mole

Sponsored by:

Office of Naval Research

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SQUARE DEAL

Summary

The detonation pressure time curves recorded aboard the USNS Kingsport during the SQUARE DEAL Exercise for SUS signals were processed to acquire quality assurance statistics. Bubble pulse periods were determined for each detonation from which an equivalent depth was derived. Because the SUS signals were received by a hull mounted transducer with poor characteristics, many of the shots recorded exhibit distortion and ringing. This lowers the quality of the data and reduces the confidence that can be attached to the shots processed. For this reason, it is recommended that only those shots known to a high degree of confidence to be within ±10% of the scheduled detonation depth of 300 ft (bubble pulse period: 39.0 to 45.4 msec) be deemed acceptable for further processing. Those shots known accurately to be outside of this range should be rejected. For those shots which exhibit distortion and ringing, signals received at the acoustic stations should be processed by narrow band analysis to determine their bubble pulse periods and rejected if they fall outside of the specified limits, when the measured propagation loss is suspect.

Introduction

During the SQUARE DEAL Exercise, a series of SUS shots were deployed by the USNS Kingsport for the purpose of measuring acoustic propagation loss. Quality assurance procedures were instituted to ensure that the data obtained would not be affected by variations in source level or detonation depth. Magnetic tape recordings of the SUS pressure signals were obtained from the USNS Kingsport. In a manner analogous to an earlier program, Ref. (1), these tapes were processed to determine the bubble pulse period from each of the SUS shots used for the propagation loss studies. From the bubble pulse period of the source, deviations in shot depth and band levels can be determined. The processing technique, results, and recommendations are presented forthwith.

Basic Data and Instrumentation

The shock wave and bubble pulse signatures emitted from the SUS charges were monitored by mounting a voice powered microphone to the hull of the Kingsport with a C-clamp. The ship's hull was used to couple the SUS pressure signals from the water to the microphone. These signals were subsequently recorded in the FM mode on magnetic tape. A 1 kHz tone and time code was recorded in the FM mode and voice annotations were recorded in the direct mode. Approximately 1019 Mk 82 shots were dropped and detonated at 300 feet. A listing of results is given in Table (1).

Although the ship's hull resonants, this did not appreciably affect the signature appearing at the output of the microphone as long as the microphone was securely clamped to the hull. However, the vibrations did result in loosening the C-clamp that was holding the microphone, causing spurious signals that appear as "ringing" at the microphone output. This ringing reduces the confidence to which the shock wave and bubble pulse can be correctly identified. This signal distortion necessitated a significant change in the processing procedures employed in Ref. (1) in order to analyze the shots. Severe filtering permitted the identification of these signal components, with a considerable loss of resolution.

From the above description of the instrumentation for monitoring the shock wave and bubble pulse, it is obvious that the classic shock wave and bubble pulse signature as emitted from a SUS detonation will not be observed at the microphone output. In order to obtain the classic signature, it is necessary to judiciously place a hydrophone or shock wave gauge in the water.

TABLE 1

Tabulation of SUS Statistics
SUS Type MK 82, 1.8 lb

Experimental Area	1C - 1A	2D - 2BD
Date	9-10 Aug. 1973	16 Aug. 1973
Number Dropped	577	442
Number Processed	552	415
Number Not Recorded	2	7
Dud	17	16
Wrong Explosive Charge Depth Setting	6	4

Data Processing System

A block diagram of the data processing system is shown in Figure (1). The data from the tape recorder is preprocessed before being digitized for processing. The computer provides four functions: (1) system controller, (2) data interrogation, (3) determination of bubble pulse period, and (4) display controller. The operator's chief function is to serve as an on-line quality assurance monitor. To assist him in this role, the shot is displayed together with the computer determined bubble pulse period on an oscilloscope for immediate observation; and at the operator's option, a hard copy can be made for further study. Shot identification and bubble pulse periods are presented on the TTY printer.

This set of shots required more processing than the series done previously, Ref. (1). The data channel from the recorder is amplified to convert a nominal 1 volt rms signal from the recorder to a 10 volt peak signal for input to the 13 bit analog to digital converter. The channel is sampled at a nominal 8 kHz derived from the 1 kHz tone. This 1 kHz signal is utilized to furnish a reference frequency to remove tape recorder speed errors. This signal is filtered, limited, and multiplied by 8 in a phase locked loop. The synthesized frequency is then used as the sampling pulse for the A-D converter. The absolute levels of one of the shots processed in this way is shown in Figure (2).

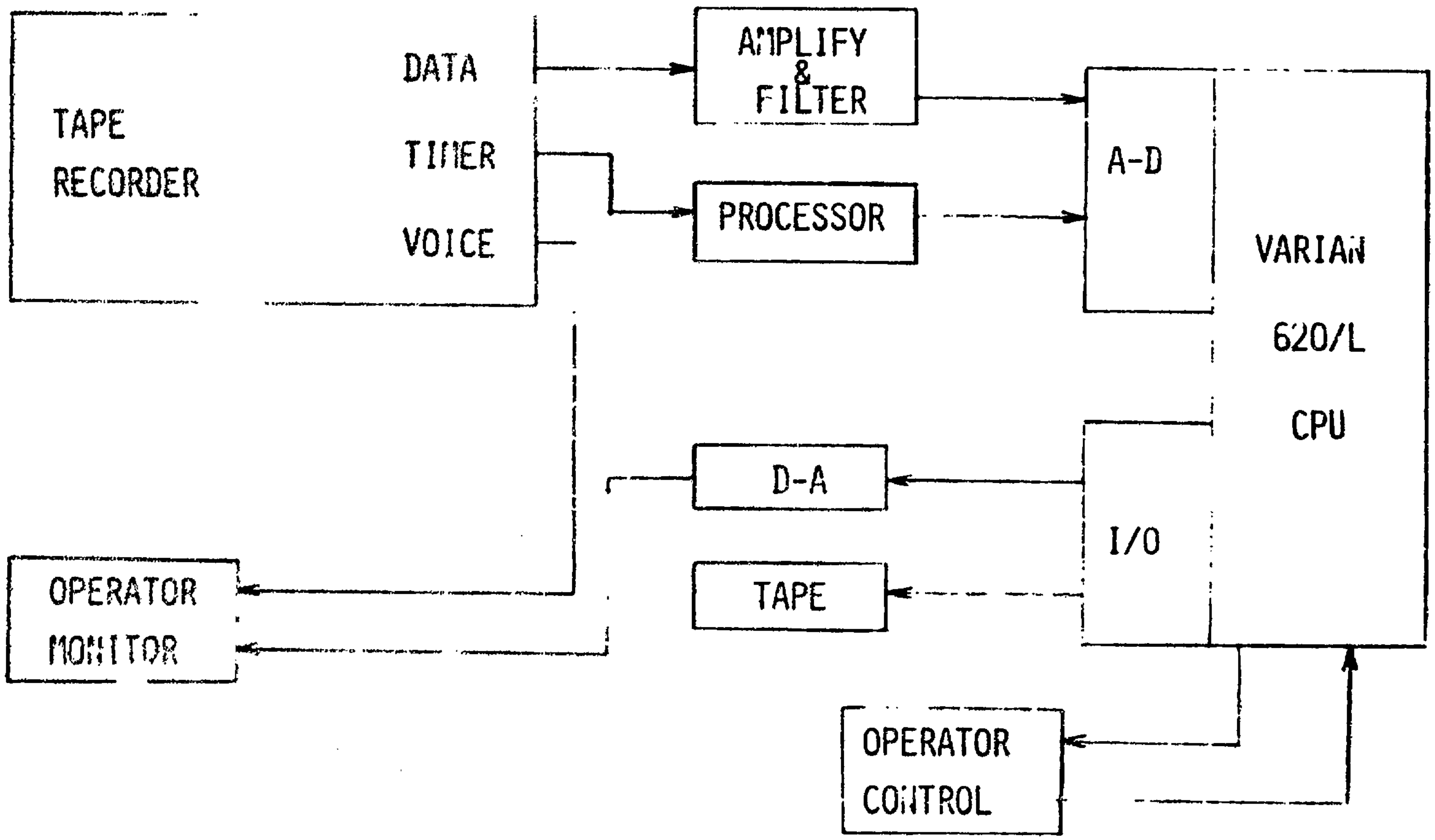

FIGURE (1). BLOCK DIAGRAM OF BUBBLE PROCESSING SYSTEM

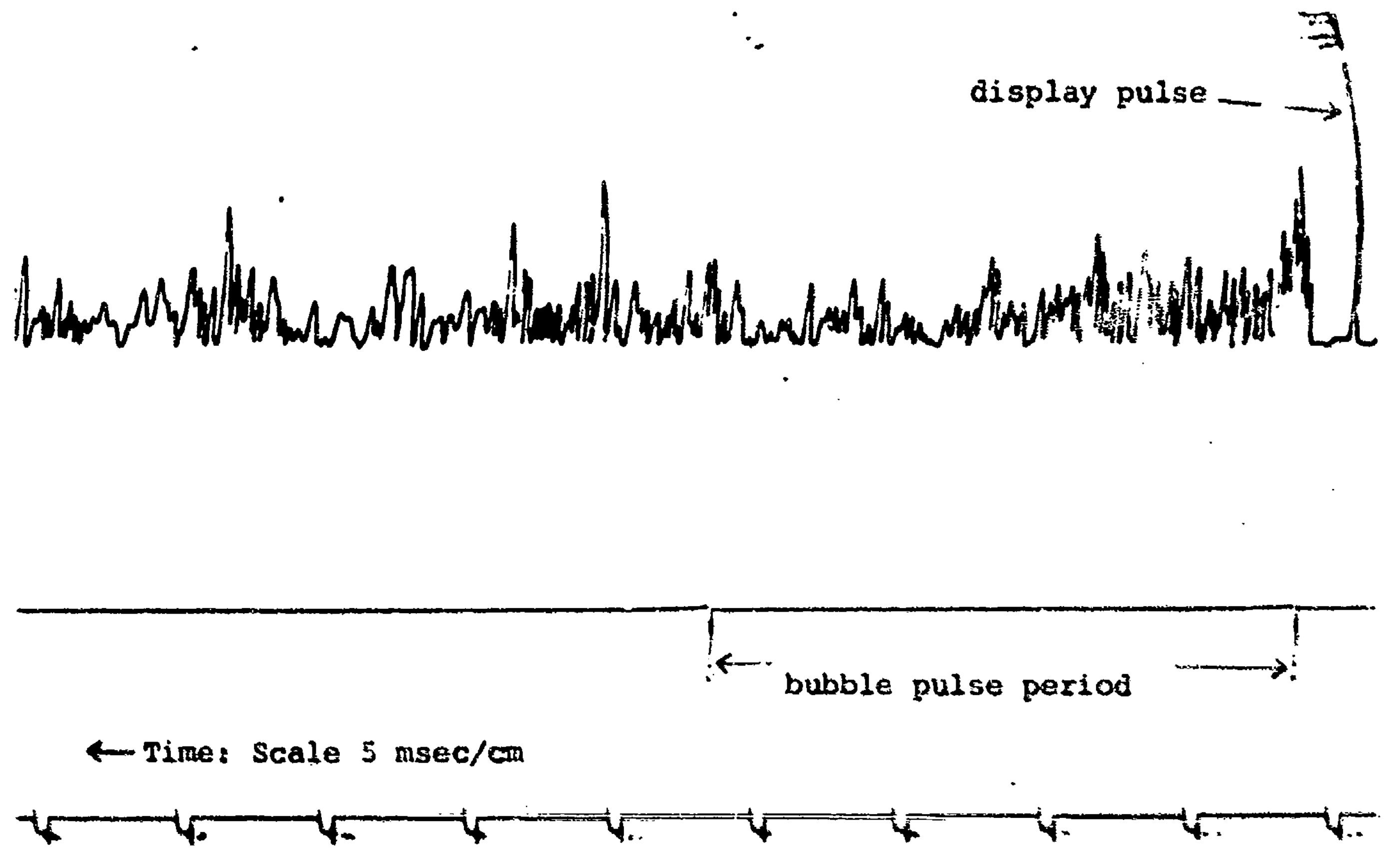

Figure (2). Typical unprocessed SUS signal display at 1/5 normal time scale (shot #328 1C to 1A). Full wave rectification applied

As is apparent, while it is possible to ascertain the shock-wave onset the bubble pulse signal cannot be identified. Consequently, several different methods were tried to enhance the signal to noise ratio and to make the bubble pulse period determination easier. Filtering the signal to obtain a clearer pattern was attempted; including band pass, low pass, and high pass techniques. The method finally chosen was to amplify the signal voltage, input it through a 1/3 octave 800 Hz filter, square this output, and then sample the result. The shot shown in Figure (2) is shown again in Figure (3) after this processing has been done. The signal to noise ratio has been enhanced and the shockwave and bubble pulse are discernible.

After a shot is detected and processed, the computer through a D-A converter to an oscilloscope, repetitively outputs, as in Figure (3), the digitized shot together with two pulses. One pulse marks the shockwave maximum level and the other the bubble pulse maximum. This display is used by the operator to evaluate the quality of the determination. The option also exists to output the scope display on the chart recorder at a scale factor of 1.0 msec/cm for further study.

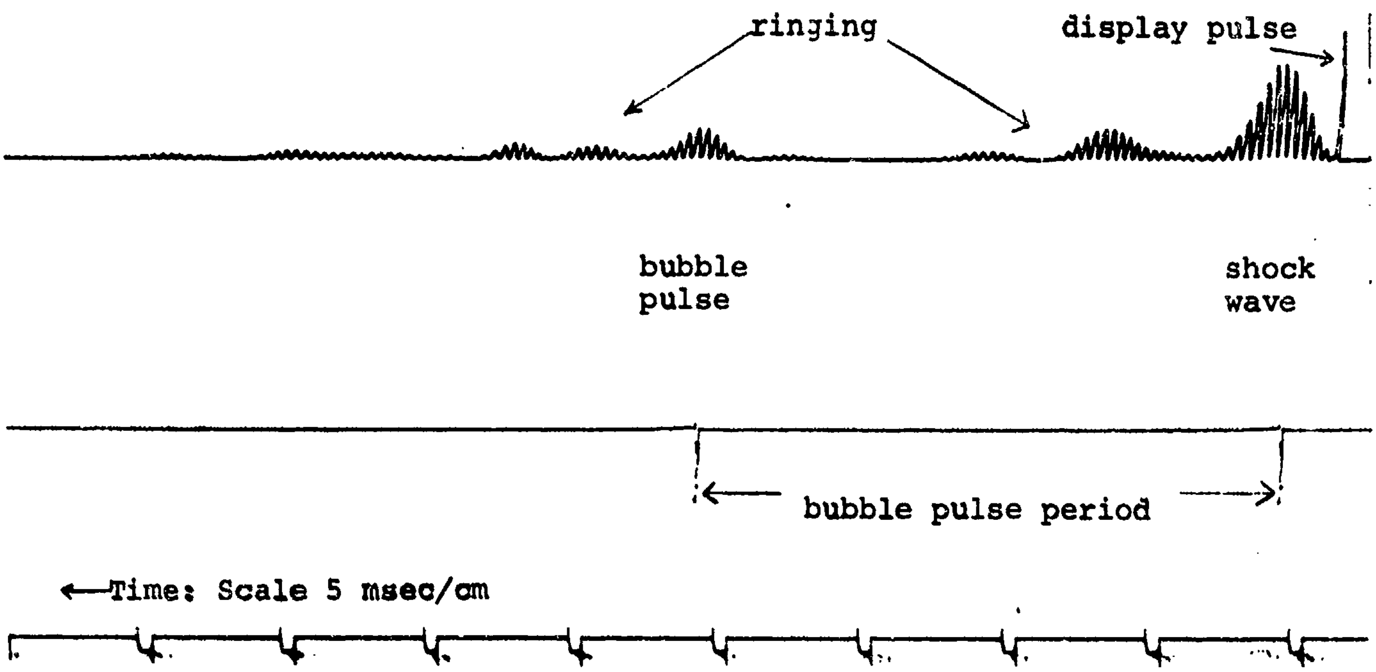

Figure (3). Typical processed SUS signal display at 1/15 normal time scale (shot #328 1C to 1A)

Using the measured bubble pulse period and assuming an explosive charge of 1.8 lbs of TNT; the detonation depth is derived from the following formula, Ref. (2):

$$T = \frac{4.36\ W^{1/3}}{(d+33)^{5/6}}$$

where,

T = bubble pulse period

W = charge weight

d = detonation depth

The curve for T as a function of d was fitted with a polynomial, and this was used to derive the detonation depth from the bubble pulse period.

Computer Operation

The design of the system minimizes the recurrent menial tasks that the operator must perform so that he can concentrate on evaluating each bubble pulse determination. During a run, the computer monitors the data channel until the onset of a shockwave exceeds a preset level. When this happens, the block of digitized data which follows is stored. Then the peaks of the shockwave and the bubble pulse are determined by recurrent looks at the stored data with successively lower comparative levels. The use of this analysis procedure on the shockwave is necessitated because of the type of preprocessing done on the data. The search for the bubble pulse peak is restricted to a time span from 37.0 to 48.0 msec from the shockwave peak. Restricting the bubble pulse search to these limits is necessary to handle the ringing problem introduced by the method of transducer mounting. If a suitable bubble pulse peak is not found, an alarm is sounded to alert the operator of a possible mis-determination. The determination is then displayed.

Processing Results

A total of 1019 SUS shots were launched by the Kingsport on the two runs, from 1C to 1A (9-10 August 1973) and 2D to 2 BD (16 August 1973). Of that number, 967 shots were processed and the remaining 5% consist of Duds, and unprocessable detonations. Table (1) summarizes this information. The cumulative distributions as a function of the bubble pulse period and shot depth for the two runs are presented in Figures (4) and (5). The most likely bubble pulse period in each case is very close to the expected nominal value. i.e. a value of 41.9 msec.

Although the agreement between the experimentally determined bubble pulse periods and the theoretical value is good, the signal distortion problems encountered result in a low confidence level. To illustrate this point, three consecutive shots have been selected from the 9-10 August 1973 1C to 1A run of the Kingsport. These three figures,

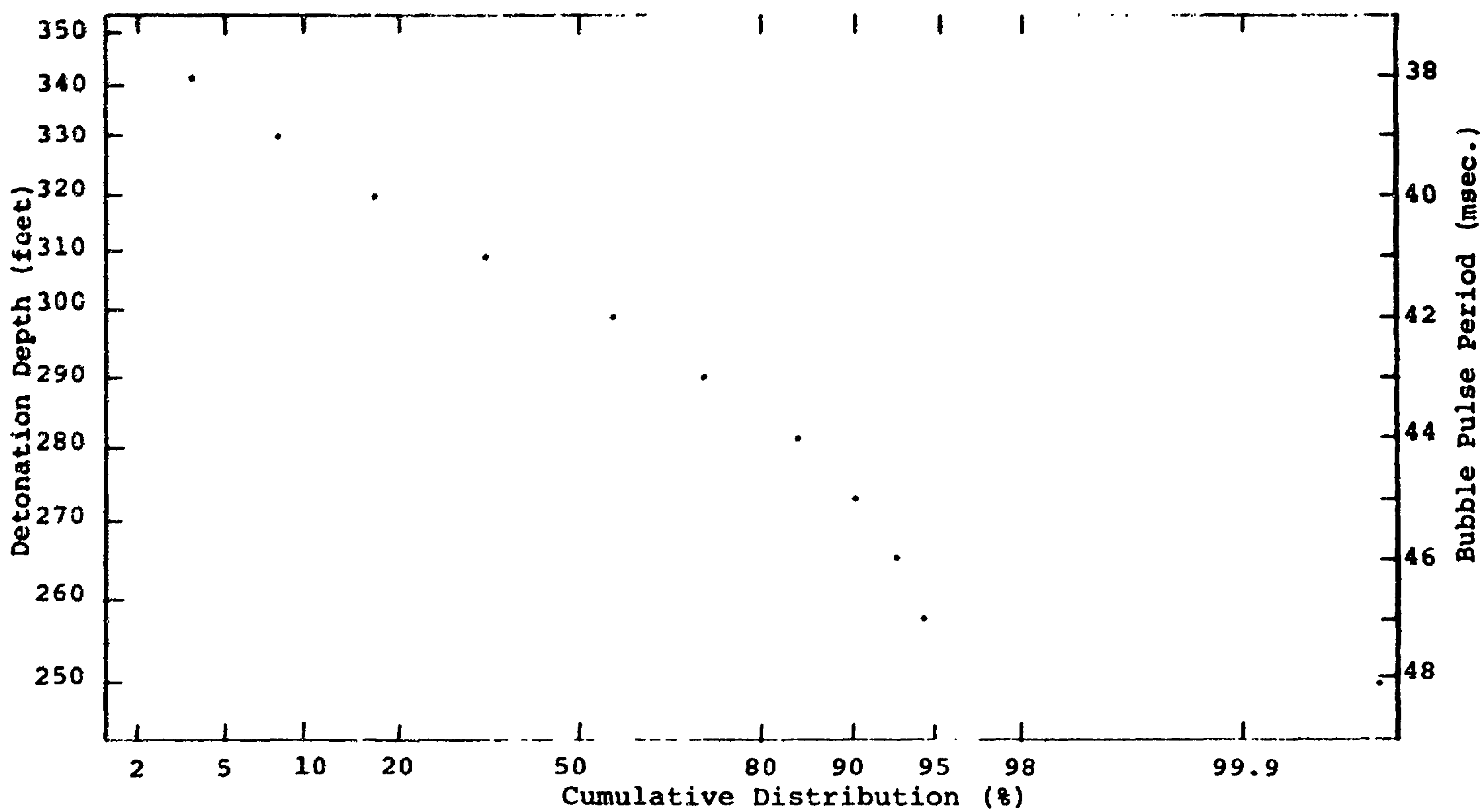

Figure (4). Cumulative Distribution of Bubble Pulse Period and Derived Shot Depth for Run 1C-1A.

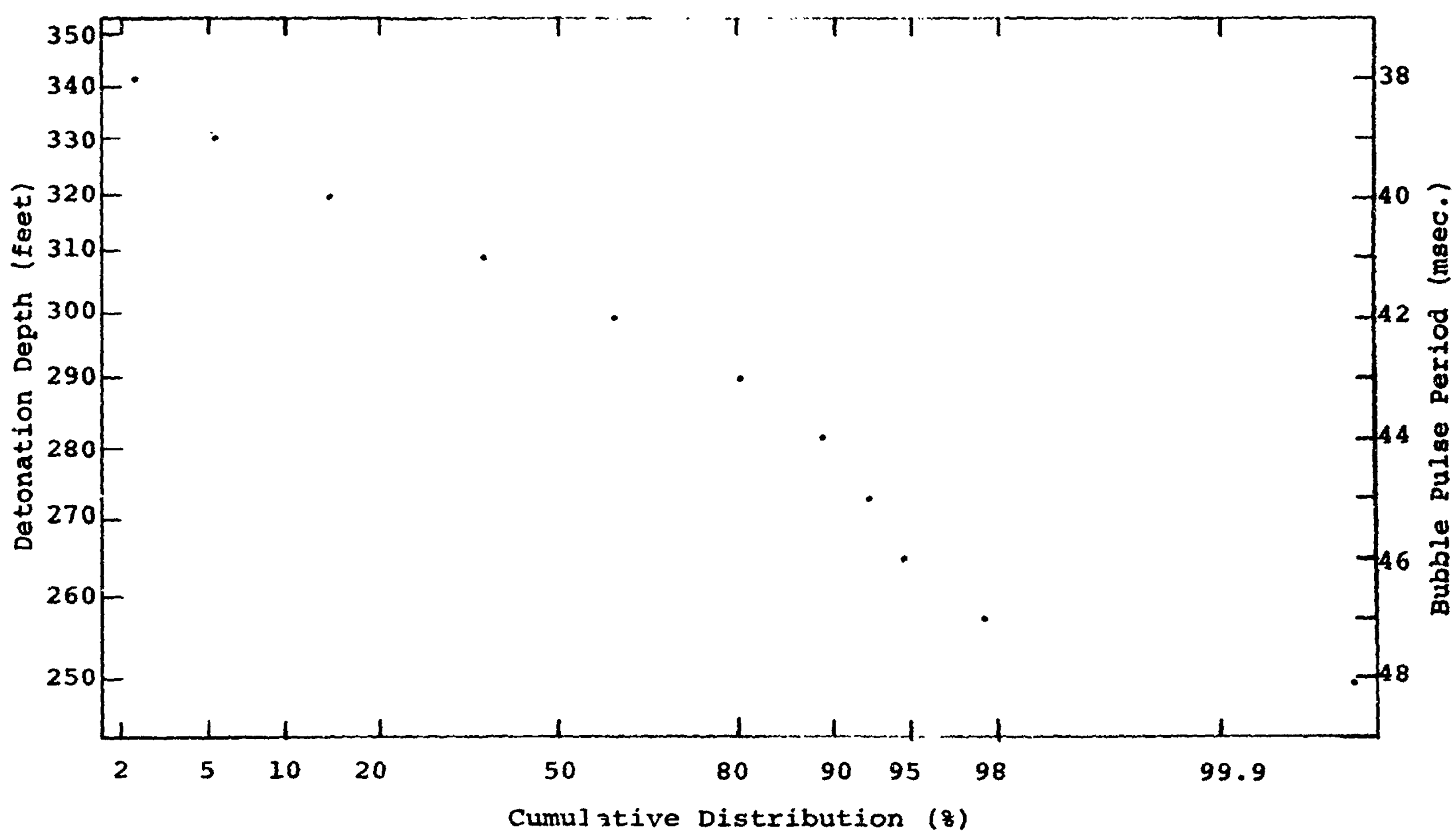

Figure (5). Cumulative Distribution of Bubble Pulse Period and Derived Shot Depth for Run 2D-2BD.

(6) through (8), show the D-A output display from the computer of the amplified, filtered, and voltage squared bomb shot. The gain of shots #328 and #330 are the same, while that of #329 is +10 db higher. These three figures indicate the ringing problem clearly. As the C-clamp loosened, the pattern first showed slight ringing (#328), then a very bad pattern (#329), and finally a good pattern (#330) when retightened. This effort complicated the processing since signal strength varied from five to fifteen db between shots. Since a detection level of 2.5 volts was used and the A-D input voltage was limited to 10 volts, the tape recorder had to be frequently backed up and gains changed in order to "capture" the shot.

Although the signal distortion made processing difficult but not impossible, the main effect of the ringing, as in shot #328, was to obscure the presence of the bubble pulse. For this reason, the scan for the bubble pulse was limited to between 37 and 48 msec. However, for some shots, it was impossible not only for the computer but also for a scientist to pick the correct peak out of several appearing in this range. A chart recording was made for each of these shots to facilitate any additional analysis.

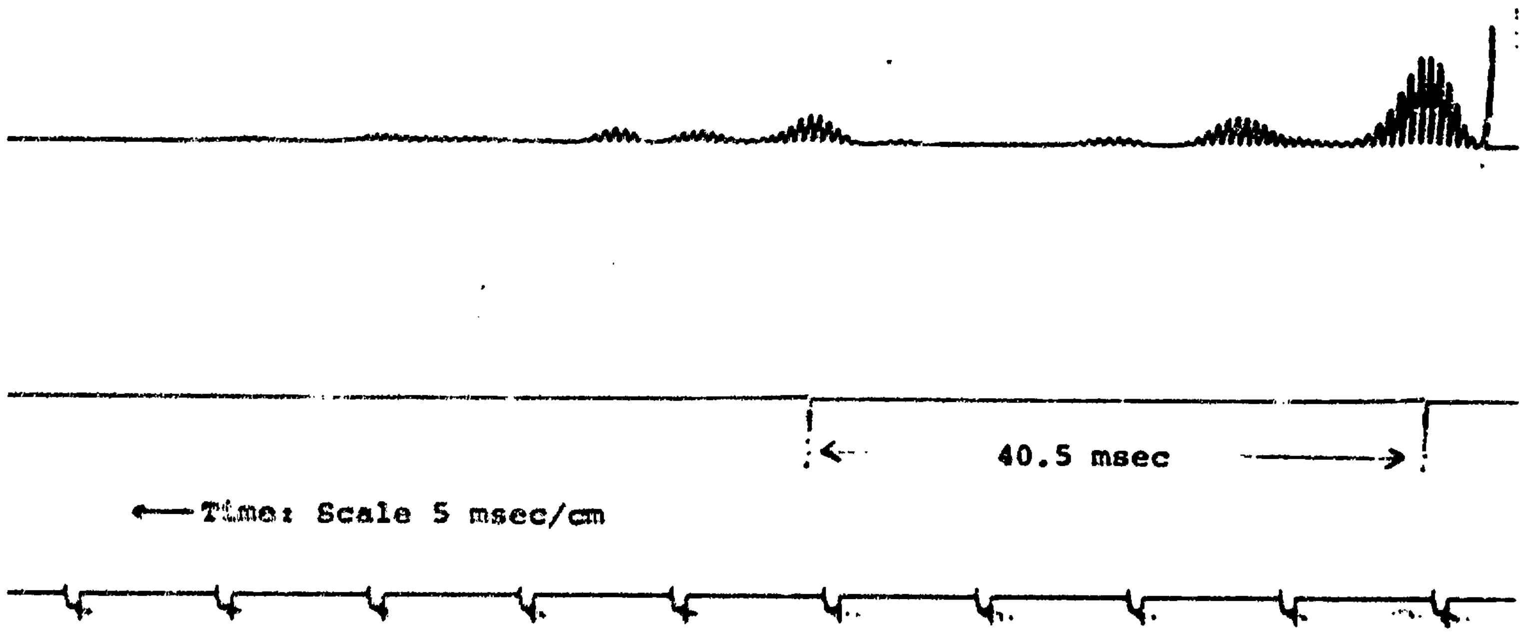

Figure (6). Shot #328, 9 August 1974, 1C - 1A
USNS Kingsport

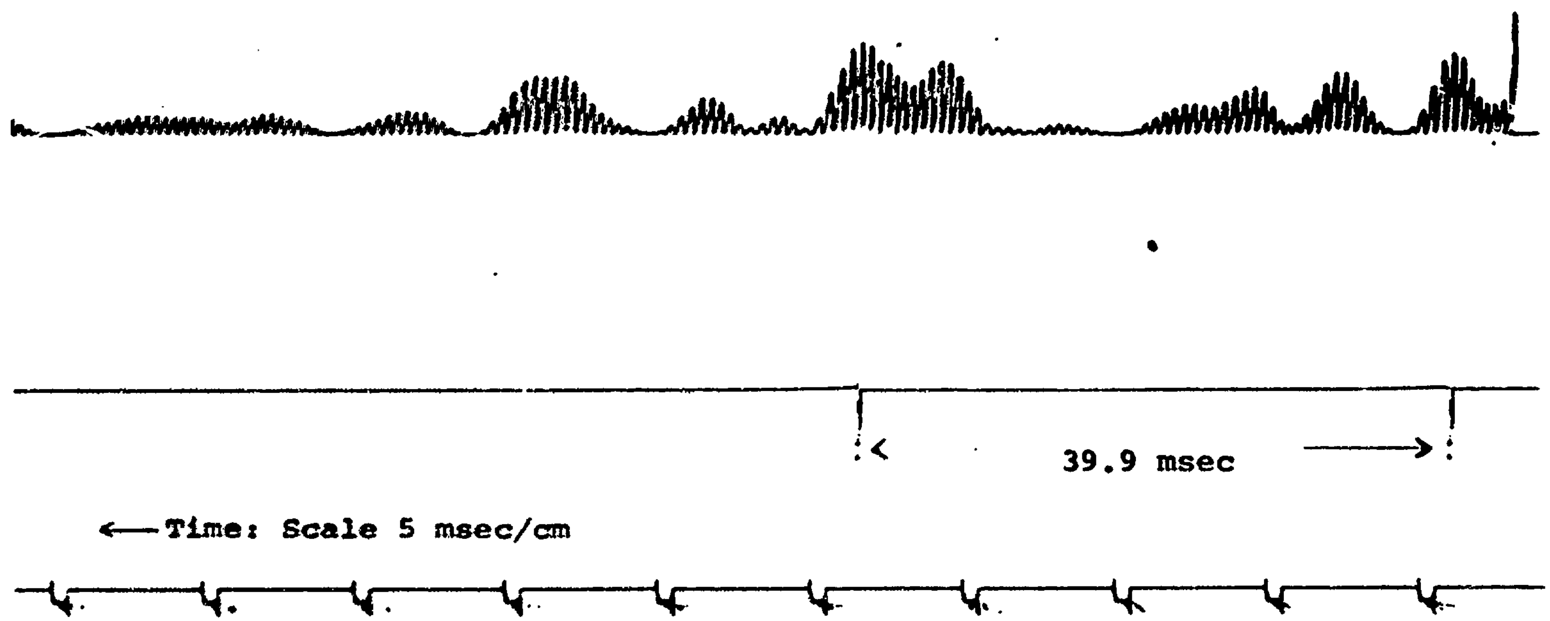

Figure (7). Shot #329, 9 August 1973, 1C - 1A, USNS Kingsport
+10 db gain relative to shots #328 and #330

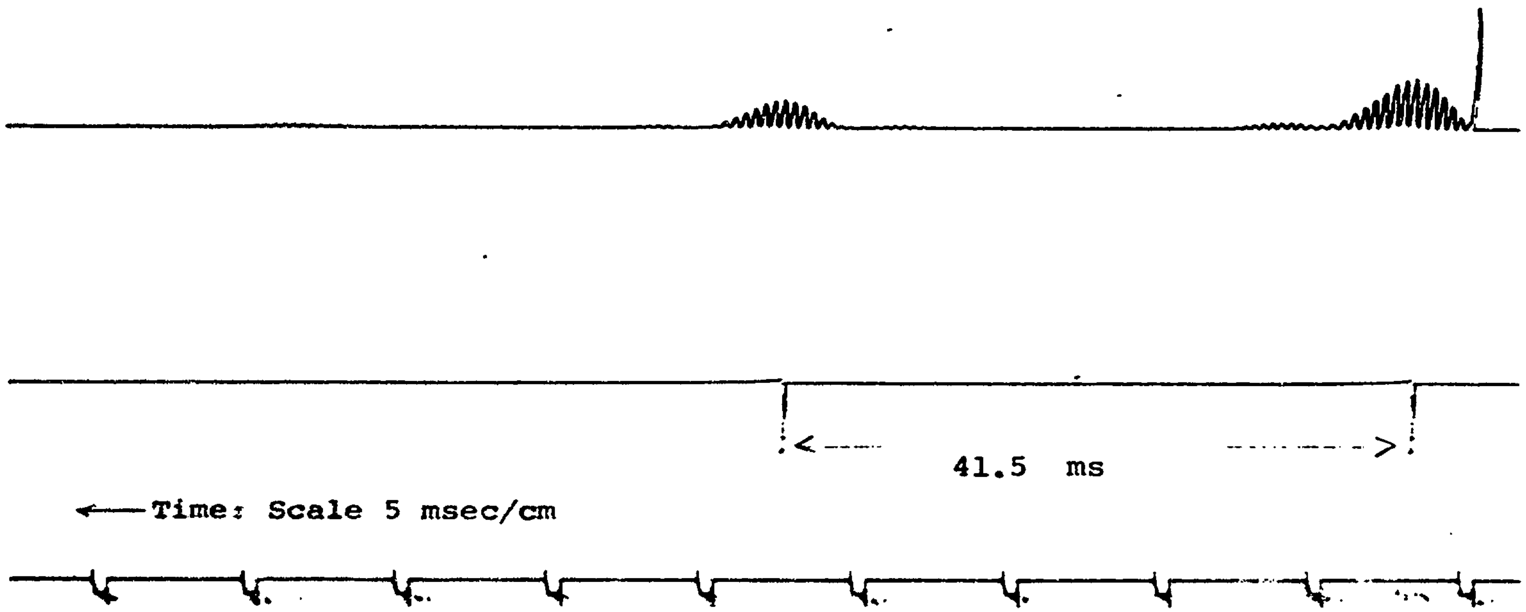

Figure (8). Shot #330, 9 August 1973, 1C - 1A
USNS Kingsport

Those shots known to a high degree of confidence to be outside of the 270 to 300 ft range, which are to be rejected, are listed in Table (2). For those shots listed in Table (3), for which confidence in determining the bubble pulse period is low, we recommend that the narrow band spectra of a received signal, with good signal to noise ratio, be examined. The bubble pulse period can be determined in that fashion. If it falls outside the specified region, the shot should be rejected. A complete listing of all shots processed is given in Tables (5) and (6).

Data Selection and Source Level Corrections

Because of the poor resolution resulting from the severe filtering necessary to identify the bubble pulse, the accuracy of the measurements is not sufficient to warrant the application of source level corrections. However, if it is desired to do this, the correction functions are given in Table (4). This table is a composite of calculations based on the Weston and Gaspin and Shuler formulations, as in Ref. (1), except that new computations of the Gaspin and Shuler formulation have been provided to us by NSWC in private communications.

It is recommended that only shots within ±10% of the scheduled detonation depth (bubble pulse period, 39.0 to

TABLE 2

SUS Shots Which Should Not Be Used

Detonation is Outside of ±10% of 300 ft

Run 1C - 1A — 9,10 August 1973

25	38	51	59	85	87	106	109	111	126
127	129	130	151	169	174	180	193	195	198
218	242	243	246	256	259	263	266	284	305
307	309	323	324	326	334	343	344	404	406
407	435	436	437	455	460	488	491	496	511
520	533	545	549	557	570	575	596	602	610

Run 2D - 2BD — 16 August 1973

71	72	73	77	137	143	150	155	173	177
186	191	201	205	291	313	338	401	407	412

TABLE 3

SUS Shots with Low Confidence

Run 1C - 1A 9,10 August 1973

14	17	18	33	34	50	53	71	72	74
80	86	104	121	125	135	140	145	154	161
163	164	181	187	209	213	216	221	225	230
245	247	253	254	255	257	258	264	268	269
321	329	336	338	352	403	409	411	412	428
432	441	447	448	454	461	464	474	480	487
495	497	508	516	541	572	597	609		

Run 2D - 2BD 16 August 1973

5	15	18	21	31	49	50	57	59	92
97	101	108	116	124	129	132	135	138	149
159	165	197	215	222	246	247	248	250	254
260	264	275	276	279	295	304	314	316	318
349	369	376	379	380	381	382	400	416	424
429	430	438							

TABLE 4

Spectral corrections for square 1/3 octave bands. Corrections in db to be added to the nominal levels for 1.8 lb detonated at 300 feet.

Detonation Depth (ft)	Center Frequency				
	25	50	100	160	250
270	+0.5	0.0	0.0	-0.5	+1.0
280	+0.5	0.0	[illegible].0	-1.0	+1.0
290	0.0	0.0	0.0	-0.5	+0.5
300	0.0	0.0	0.0	0.0	0.0
310	0.0	0.0	0.0	0.0	+0.5
320	-0.5	0.0	0.0	0.0	+1.0
330	-1.0	0.0	0.0	0.0	+1.0

45.4 msec) be processed provided that they were not among those exhibiting distortion. As can be seen from Table (4) the variation in source level, resulting from not applying correction, will then be limited to about ± one decibel.

Quality Control

Errors in the determination of the bubble pulse period have two origins, (1) the basic data, and (2) the measurement of the bubble pulse period. Any tape speed variations on record and playback will affect the measured time. In the present processing scheme, the 1 kHz tone was used for controlling the sampling rate and hence the relative change in tape speed variations are removed. As in Ref. (1), the phase lock loop error voltage was checked periodically to verify proper synchronization.

The bubble pulse period is defined as the time bounded by the onset of the shockwave from the explosion and the bubble pulse maximum. Because of the filtering that was necessary to process the signals, the maximum of the shockwave was chosen as the lower bound of the bubble pulse period. A check was made throughout the processing of the decisions made by the computer in chosing the maximum levels. In all cases the computer picked the largest peak within the scanned time frame. The bubble pulse periods determined with a high degree of confidence have a repeatability to within 0.5 msec, however, the absolute accuracy is probably not as good. Those shots processed which contain ringing have several distinct peaks or several smeared into one. The proper bubble pulse can not be ascertained in these cases, as have been previously noted, and repeatability is poor.

TABLE 5

SUS SHOT STATISTICS
FOR SQUARE DEAL

FOR USNS KINGSPORT DURING AUGUST, 1973

SHOT #	APPROXIMATE DETONATION TIME (ZULU)	BUBBLE PULSE PERIOD (MSEC)	CALCULATED SHOT DEPTH (FT)	COMMENT CODE #
1	09055220	43.0	290	-
2	09055420	41.8	301	-
3	09055620	41.9	301	-
4	09055820	43.6	284	-
5	09060020	40.9	310	-
6	09060220	43.0	290	-
7	09060420	39.8	321	-
8	09060620	44.9	273	-
9	09060820	40.8	311	-
10	09061020	42.3	297	-
11	09061220	42.8	292	-
12	09061420	43.8	283	-
13	09061620	40.6	312	-
14	09061820	47.9	251	-
15	09062020			1
16	09062220	41.0	309	-
17	09062420	47.6	253	-
18	09062620	47.9	251	-
19	09062820			1
20	09063020	42.1	298	-
21	09063220	40.6	312	-
22	09063420	44.0	281	-
23	09063620	43.3	288	-
24	09063820	38.9	331	-
25	09064020	45.8	267	-
26	09064220	41.8	301	-
27	09064420	41.0	309	-
28	09064620	42.6	293	-
29	09064820	41.6	302	-
30	09065020	43.5	285	-
31	09065220	41.0	309	-
32	09065420	43.0	290	-
33	09065620	43.8	283	-
34	09065820	47.6	253	-
35	09070020	44.8	275	-
36	09070220	40.8	311	-
37	09070420	43.0	290	-
38	09070620	37.5	347	-
39	09070820	41.0	309	-
40	09071020	40.4	315	-

41	09071220	39.5	324	•
42	09071420	39.5	324	•
43	09071620	43.0	290	•
44	09071820	41.3	306	•
45	09072020	43.5	285	•
46	09072220	42.1	298	•
47	09072420	41.0	309	•
48	09072620	41.4	305	•
49	09072820	38.8	332	•
50	09073020	37.4	349	•
51	09073220	47.5	254	•
52	09073420	41.5	303	•
53	09073620	47.6	253	•
54	09073820	39.4	326	•
55	09074020	39.6	323	•
56	09074220	39.3	327	•
57	09074420	43.3	288	•
58	09074620	45.3	270	•
59	09074820	47.4	255	•
60	09075020	41.5	303	•
61	09075220	43.1	289	•
62	09075420	42.1	298	•
63	09075620	40.5	316	•
64	09075820	43.3	288	•
65	09080020	39.5	324	•
66	09080220	40.8	311	•
67	09080420	44.9	273	•
68	09080620	39.6	323	•
69	09080820	44.9	273	•
70	09081020	42.4	295	•
71	09081220	39.9	320	•
72	09081420	47.8	252	•
73	09081620	38.1	339	•
74	09081820	38.9	331	•
75	09082020	43.9	282	•
76	09082220	41.0	309	•
77	09082420	41.6	302	•
78	09082620	42.3	297	•
79	09082820	42.8	292	•
80	09083020	37.1	352	•
81	09083220	40.9	310	•
82	09083420	39.4	326	•
83	09083620	41.6	302	•
84	09083620	44.0	281	•
85	09084020	47.8	252	•
86	09084220	42.1	298	•
87	09084420	37.6	347	•
88	09084620	41.4	305	•
89	09084820	42.4	292	•
90	09085020	40.4	315	•
91	09085220	41.3	306	•
92	09085420	45.1	271	•

93	09085620	43.3	288	-
94	09085820	43.1	289	-
95	09090020	45.0	272	-
96	09090220	41.9	301	-
97	09090420	41.1	307	-
98	09090620	41.8	301	-
99	09090820			3
100	09091020	40.9	310	-
101	09091220	41.9	301	-
102	09091420	39.5	324	-
103	09091620	41.1	307	-
104	09091820	42.0	299	-
105	09092020	43.3	288	-
106	09092220	37.0	334	-
107	09092420	42.1	298	-
108	09092620	42.4	295	-
109	09092820	38.8	332	-
110	09093020	40.9	310	-
111	09093220	38.3	336	-
112	09093420	39.5	321	-
113	09093620	41.1	307	-
114	09093820	41.9	301	-
115	09094020	43.8	283	-
116	09094220	41.0	309	-
117	09094420	40.0	319	-
118	09094620	41.8	301	-
119	09094820	42.8	292	-
120	09095020	41.4	305	-
121	09095220	40.3	316	-
122	09095420	39.9	320	-
123	09095620	41.9	301	-
124	09095820	43.9	282	-
125	09100020	43.1	289	-
126	09100220	45.6	267	-
127	09100420	46.1	264	-
128	09100620	39.8	321	-
129	09100820	47.0	257	-
130	09101020	38.[illegible]	336	-
131	09101220	40.8	311	-
132	09101420	44.1	279	-
133	09101620	40.0	319	-
134	09101820	41.9	301	-
135	09102020	47.0	257	-
136	09102220	41.4	305	-
137	09102420	41.3	306	-
138	09102620	44.4	278	-
139	09102820	40.5	314	-
140	09103020	43.3	288	-
141	09103220	41.0	309	-
142	09103420	41.3	306	-
143	09103620	40.8	311	-
144	09103820	43.0	290	-

145	09104020	47.0	257	.
146	09104220	42.8	292	.
147	09104420	40.9	310	.
148	09104620	41.4	305	.
149	09104820			I
150	09105020	43.4	286	.
151	09105220	45.5	268	.
152	09105420	40.4	315	.
153	09105620	42.0	299	.
154	09105820	40.9	310	.
155	09110020	41.8	301	.
156	09110220	42.6	293	.
157	09110420	44.4	278	.
158	09110620	40.8	311	.
159	09110820	41.6	302	.
160	09111020	40.9	310	.
161	09111220	41.9	301	.
162	09111420	39.1	329	.
163	09111620	45.5	268	.
164	09111820	46.8	259	.
165	09112020	43.6	284	.
166	09112220	42.4	295	.
167	09112420	40.9	310	.
168	09112620	41.6	302	.
169	09112820	38.3	338	.
170	09113020	43.9	282	.
171	09113220	43.3	288	.
172	09113420			I
173	09113620	41.4	305	.
174	09113820	45.6	267	.
175	09114020	41.4	305	.
176	09114220	44.4	278	.
177	09114420	42.6	293	.
178	09114620	42.0	299	.
179	09114820	41.1	307	.
180	09115020	37.4	349	.
181	09115220	37.1	352	.
182	09115420	39.4	326	.
183	09115620	41.8	301	.
184	09115820	41.1	307	.
185	09120020	38.9	331	.
186	09120220	42.1	298	.
187	09120420	43.1	289	.
188	09120620	39.4	326	.
189	09120820	42.9	290	.
190	09121020	40.6	312	.
191	09121220	45.1	271	.
192	09121420	41.5	303	.
193	09121620	37.9	343	.
194	09121820	41.0	309	.
195	09122020	37.4	349	.
196	09122220	41.6	302	.

197	09122420	42.5	294	-
198	09122620	46.5	261	-
199	09122820	43.0	290	-
200	09123020	42.5	294	-
201	09123220	42.0	289	-
202	09123420	41.5	303	-
203	09123620	40.0	319	-
204	09123820	40.6	312	-
205	09124020	39.3	327	-
206	09124220	43.9	282	-
207	09124420	41.4	305	-
208	09124620	40.6	312	-
209	09124820	42.0	299	-
210	09125020	40.3	316	-
211	09125220	41.8	301	-
212	09125420			1
213	09125620	42.9	290	-
214	09125820	43.6	284	-
215	09130020	43.8	283	-
216	09130220	40.9	310	-
217	09130420			1
218	09130620	47.8	262	-
219	09130820	41.4	305	-
220	09131020	40.9	310	-
221	09131220	43.6	284	-
222	09131420	42.9	290	-
223	09131620	40.4	315	-
224	09131820	41.3	306	-
225	09132020	47.1	266	-
226	09132220	41.8	301	-
227	09132420	39.5	324	-
228	09132620	41.4	305	-
229	09132820	41.4	305	-
230	09133020	47.5	264	-
231	09133220	41.0	309	-
232	09133420	42.9	290	-
233	09133620	42.3	297	-
234	09133820	43.6	284	-
235	09134020	42.4	292	-
236	09134220	41.6	302	-
237	09134420	40.5	314	-
238	09134620	44.6	275	-
239	09134820	43.3	288	-
240	09135020	41.0	309	-
241	09135220	42.3	297	-
242	09135420	47.5	264	-
243	09135620	37.4	349	-
244	09135820	41.5	303	-
245	09140020	37.9	343	-
246	09140220	38.3	335	-
247	09140420	47.6	263	-
248	09140620	43.0	290	-

249	09140820	43.4	286	-
250	09141020	41.8	301	-
251	09141220	41.1	307	-
252	09141420	41.1	307	-
253	09141620	47.6	253	-
254	09141820	39.0	329	-
255	09142020	43.4	286	-
256	09142220	47.1	256	-
257	09142420	45.1	271	-
258	09142620	47.0	257	-
259	09142820	45.6	267	-
260	09143020	40.9	310	-
261	09143220	44.1	279	-
262	09143420			1
263	09143620	37.0	354	-
264	09143820	42.5	294	-
265	09144020	41.1	307	-
266	09144220	47.4	255	-
267	09144420	42.9	290	-
268	09144620	40.1	316	-
269	09144820	39.4	326	-
270	09145020			2
271	09145220	39.5	324	-
272	09145420	40.1	316	-
273	09145620	41.5	303	-
274	09145820	42.1	298	-
275	09150020			1
276	09150220	39.3	327	-
277	09150420	43.8	283	-
278	09150620	39.5	324	-
279	09150820	44.0	281	-
280	09151020	41.1	307	-
281	09151220	40.6	314	-
282	09151420			1
283	09151620	40.5	314	-
284	09151820	38.8	332	-
285	09152020	41.4	305	-
286	09152220			1
287	09152420	42.5	298	-
288	09152620	44.8	275	-
289	09152820	41.9	301	-
290	09153020	40.3	316	-
291	09153220	40.8	311	-
292	09153420	43.0	290	-
293	09153620	42.0	299	-
294	09153820	42.5	294	-
295	09154020	42.0	299	-
296	09154220	42.4	295	-
297	09154420	44.6	276	-
298	09154620	39.9	320	-
299	09154820	43.4	286	-
300	09155020	42.5	294	-

301	09155220	44.1	279	-
302	09155420	39.6	323	-
303	09155620	39.3	327	-
304	09155820	41.6	302	-
305	09160020	45.6	267	-
306	09160220	42.4	295	-
307	09160420	38.9	331	-
308	09160620	41.5	303	-
309	09160820	38.8	332	-
310	09161020	42.4	295	-
311	09161220	39.1	329	-
312	09161420	41.1	307	-
313	09161620	44.8	275	-
314	09161820	39.6	323	-
315	09162020	41.5	303	-
316	09162220	42.0	299	-
317	09162420	42.9	290	-
318	09162620	41.1	307	-
319	09162820	41.4	305	-
320	09163020	40.8	311	-
321	09163220	47.5	254	-
322	09163420	41.3	306	-
323	09163620	47.0	257	-
324	09163820	37.6	346	-
325	09164020	41.3	306	-
326	09164220	47.4	255	-
327	09164420	39.1	329	-
328	09164620	40.0	319	-
329	09164820	43.6	284	-
330	09165020	41.4	305	-
331	09165220	41.8	301	-
332	09165420	41.1	307	-
333	09165620	41.6	302	-
334	09165820	47.8	252	-
335	09170020	41.1	307	-
336	09170220	42.8	292	-
337	09170420			1
338	09170620	42.4	295	-
339	09170820	41.9	301	-
340	09171020	39.3	327	-
341	09171220	40.4	318	-
342	09171420			1
343	09171620	38.9	331	-
344	09171820	45.4	269	-
345	09172020	41.9	301	-
346	09172220	42.6	293	-
347	09172420	42.0	299	-
348	09172620	41.0	309	-
349	09172820	41.6	302	-
350	09173020	41.9	301	-
351	09173220	40.4	318	-
352	09173420	41.4	305	-

353	09173620	42.5	294	-
354	09173820	44.9	273	-
355	09174020	42.9	290	-
356	09174220	41.5	303	-
357	09174420	39.9	320	-
358	09174620	39.8	321	-
359	09174820	39.3	327	-
400	09175020	40.6	312	-
401	09175220	41.1	307	-
402	09175420	42.4	295	-
403	09175620	41.5	303	-
404	09175820	37.0	354	-
405	09180020	39.6	323	-
406	09180220	38.9	331	-
407	09180420	38.6	334	-
408	09180620	41.5	303	-
409	09180820	44.8	278	-
410	09181020	42.4	295	-
411	09181220	40.6	312	-
412	09181420	37.3	350	-
413	09181620			I
414	09181820	39.3	327	-
415	09182020	40.6	312	-
416	09182220	41.8	301	-
417	09182420	42.5	294	-
418	09182620	40.8	311	-
419	09182820	40.6	312	-
420	09183020	42.1	298	-
421	09183220	42.6	293	-
422	09183420	42.5	294	-
423	09183620	41.4	305	-
424	09183820	43.1	299	-
425	09184020	41.0	309	-
426	09184220			I
427	09184420	39.8	321	-
428	09184620	43.4	286	-
429	09184820	42.3	297	-
430	09185020	43.6	284	-
432	09185220	46.0	265	-
434	09185420			I
435	09185620	47.8	252	-
436	09185820	38.1	339	-
437	09190020	38.5	336	-
438	09190220	39.0	329	-
439	09190420	39.3	327	-
440	09190620	42.1	298	-
441	09190820	36.6	334	-
442	09191020	43.0	290	-
443	09191220			I
444	09191420	40.8	311	-
445	09191620	43.3	286	-
446	09191820	40.4	315	-

447	09192020	39.4	326	•
448	09192220	37.9	343	•
449	09192420	40.4	316	•
450	09192620	40.0	319	•
451	09192820	40.4	316	•
452	09193020	41.6	301	•
453	09193220	40.0	319	•
454	09193420	40.1	318	•
455	09193620	38.9	331	•
456	09193820	41.6	302	•
457	09194020	41.3	306	•
458	09194220	41.1	307	•
459	09194420	40.8	311	•
460	09194620	46.3	263	•
461	09194820	37.6	346	•
462	09195020	43.1	289	•
463	09195220			3
464	09195420	47.4	258	•
465	09195620	40.9	310	•
466	09195820	40.1	318	•
467	09200020	43.0	290	•
468	09200220	40.5	314	•
469	09200420	41.6	302	•
470	09200620			2
471	09200820	42.1	298	•
472	09201020	40.9	310	•
473	09201220	39.8	321	•
474	09201420	44.3	279	•
475	09201620	40.4	315	•
476	09201820	40.1	318	•
477	09202020	44.0	279	•
478	09202220	40.9	310	•
479	09202420	44.0	281	•
480	09202620	40.6	312	•
481	09202820	42.9	290	•
482	09203020	39.0	329	•
483	09203220	40.6	312	•
484	09203420	43.1	289	•
485	09203620			5
486	09203820			5
487	09204020	41.5	303	•
488	09204220	37.6	346	•
489	09204420	40.4	315	•
490	09204620	40.4	316	•
491	09204820	38.6	336	•
492	09205020	39.8	321	•
493	09205220	40.1	316	•
494	09205420	39.3	327	•
495	09205620	43.9	288	•
496	09205820	47.4	255	•
497	09210620	45.4	267	•
498	09210820	44.1	279	•

499	09210420	41.5	303	-
500	09210620	40.6	312	-
501	09210820	44.6	276	-
502	09211020	41.1	307	-
503	09211220	44.4	278	-
504	09211420	41.9	301	-
505	09211620			!
506	09211820	42.1	298	-
507	09212020	43.1	289	-
508	09212220	43.9	282	-
509	09212420	41.9	301	-
510	09212620	43.4	286	-
511	09212820	38.3	338	-
512	09213020	40.5	314	-
513	09213220	41.5	301	-
514	09213420	41.5	303	-
515	09213620	42.1	298	-
516	09213820	37.0	354	-
517	09214020	41.1	307	-
518	09214220	41.5	303	-
519	09214420	39.9	320	-
520	09214620	45.8	267	-
521	09214520	41.5	303	-
522	09215020	40.5	314	-
523	09215220	42.1	298	-
524	09215420	41.5	303	-
525	09215620	43.1	289	-
526	09215820	43.1	289	-
527	09220020	41.5	303	-
528	09220220	41.6	302	-
529	09220420	43.3	288	-
530	09220620	40.4	315	-
531	09220820	42.9	290	-
532	09221020	41.9	301	-
533	09221220	38.9	331	-
534	09221420	44.3	279	-
535	09221620	41.9	301	-
536	09221820	41.6	302	-
537	09222020	43.4	286	-
538	09222220	43.6	284	-
539	09222420	42.5	294	-
540	09222620	42.0	299	-
541	09222820	47.4	265	-
542	09223020	43.5	285	-
543	09223220			8
544	09223420	41.9	301	-
545	09223620	37.1	352	-
546	09223820	43.0	290	-
547	09224020	42.9	290	-
548	09224220	42.5	294	-
549	09224420	47.6	263	-
550	09224620	41.5	303	-

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551	09224820	43.5	285	-
552	09225020	39.1	329	-
553	09225220	43.3	285	-
554	09225420	42.0	299	-
555	09225620	42.1	298	-
556	09225820	40.6	312	-
557	09230020	47.6	253	-
558	09230220	42.8	292	-
559	09230420	42.6	292	-
560	09230620	40.6	312	-
561	09230820	40.8	311	-
562	09231020	41.9	301	-
563	09231220	43.0	290	-
564	09231420	42.9	290	-
565	09231620	43.0	290	-
566	09231820	42.4	295	-
567	09232020	41.6	303	-
568	09232220	42.8	292	-
569	09232420	42.5	294	-
570	09232620	38.1	339	-
571	09232820	41.9	301	-
572	09233020	46.8	259	-
573	09233220	41.8	303	-
574	09233420	43.8	283	-
575	09233620	46.0	265	-
576	09233820	41.5	303	-
577	09234020	43.6	284	-
578	09234220	43.0	290	-
579	09234420	41.0	309	-
580	09234620	43.5	285	-
581	09234820	42.4	295	-
582	09235020	41.4	305	-
583	09235220	43.5	285	-
584	09235420	39.9	320	-
585	09235620	40.9	310	-
586	09235820	42.4	295	-
587	10000020	40.4	315	-
588	10000220	44.1	279	-
589	10000420	42.5	294	-
590	10000620	41.3	306	-
591	10000820	40.8	311	-
592	10001020	42.8	292	-
593	10001220	41.9	301	-
594	10001420	42.9	290	-
595	10001620	40.4	315	-
596	10001820	38.6	334	-
597	10002020	46.8	259	-
598	10002220	41.3	306	-
599	10002420	41.1	307	-
600	10002620	43.6	284	-
601	10002820	39.5	324	-
602	10003020	45.5	268	-

603	10003220	39.1	389	-
604	10003420	44.3	279	-
605	10003620	41.0	309	-
606	10003820	41.6	302	-
607	10004020	42.8	292	-
608	10004220	41.5	301	-
609	10004420	42.1	296	-
610	10004620	46.4	262	-
611	10004820	40.6	312	-
612	10005020	41.8	301	-
613	10005220	40.6	312	-
614	10005420	44.4	278	-
615	10005620	41.4	305	-
616	10005820	41.4	305	-
617	10010020	42.5	294	-
618	10010220			1
619	10010420	41.3	306	-

EXPLANATION OF COMMENT CODES

- #1 DUD - SCHEDULED DETONATION TIME IS LISTED
- #2 SUS DETONATION AT WRONG DEPTH
- #3 DETONATION SIGNAL NOT RECORDED
- #4 DETONATION SIGNAL NOT PROCESSABLE

TABLE 6

SUS SHOT STATISTICS
FOR SQUARE DEAL

FOR USNS KINGSPORT DURING AUGUST, 1973

SHOT #	APPROXIMATE DETONATION TIME (ZULU)	BUBBLE PULSE PERIOD (MSEC)	CALCULATED SHOT DEPTH (FT)	COMMENT CODE #
1	16015020	39.9	320	-
2	16015220	39.3	327	-
3	16015420	41.5	303	-
4	16015620	41.4	305	-
5	16015820	41.0	309	-
6	16020020	44.8	275	-
7	16020220	41.0	309	-
8	16020420	42.5	294	-
9	16020620	40.9	310	-
10	16020820	40.6	312	-
11	16021020	44.6	276	-
12	16021220	40.5	314	-
13	16021420	43.0	290	-
14	16021620	41.3	306	-
15	16021820	41.9	301	-
16	16022020	43.6	284	-
17	16022220			1
18	16022420	37.3	350	-
19	16022620	42.3	297	-
20	16022820	41.4	305	-
21	16023020	37.1	352	-
22	16023220	39.3	327	-
23	16023420	45.1	271	-
24	16023620	41.3	306	-
25	16023820	46.8	259	-
26	16024020	39.8	321	-
27	16024220	43.8	283	-
28	16024420	43.9	282	-
29	16024620	43.8	283	-
30	16024820	42.1	296	-
31	16025020	46.6	260	-
32	16025220	39.1	329	-
33	16025420	40.1	318	-
34	16025620	40.8	311	-
35	16025820	42.0	299	-
36	16030020	40.4	315	-
37	16030220	41.0	309	-
38	16030420	40.4	315	-
39	16030620	42.5	294	-
40	16030820	40.6	312	-

41	16031020	43.0	290	-
42	16031220	41.4	305	-
43	16031420	40.0	319	-
44	16031620	42.0	299	-
45	16031820	41.3	306	-
46	16032020	40.9	310	-
47	16032220	41.0	309	-
48	16032420			2
49	16032620	45.3	270	-
50	16032820	44.6	276	-
51	16033020	40.4	315	-
52	16033220	41.9	301	-
53	16033420	42.3	297	-
54	16033620	42.5	294	-
55	16033820	41.5	303	-
56	16034020	43.0	296	-
57	16034220	40.6	312	-
58	16034420	42.0	299	-
59	16034620	47.9	251	-
60	16034820	42.0	299	-
61	16035020	40.4	315	-
62	16035220			3
63	16035420	40.3	316	-
64	16035620	40.8	311	-
65	16035820	40.1	318	-
66	16040020	42.4	295	-
67	16040220	41.3	306	-
68	16040420	40.8	311	-
69	16040620	41.4	305	-
70	16040820	40.9	310	-
71	16041020	46.1	264	-
72	16041220	45.4	269	-
73	16041420	45.5	268	-
74	16041620	44.8	275	-
75	16041820			1
76	16042020	41.5	303	-
77	16042220	46.9	258	-
78	16042420	39.5	324	-
79	16042620	39.3	327	-
80	16042820	41.0	309	-
81	16043020	39.8	321	-
82	16043220	39.9	320	-
83	16043420	39.8	321	-
84	16043620	42.1	298	-
85	16043820	40.8	311	-
86	16044020	41.3	306	-
87	16044220	42.9	290	-
88	16044420	41.1	307	-
89	16044620			1
90	16044820	41.5	303	-
91	16045020	43.5	285	-
92	16045220	40.6	312	-

93	16045420	43.0	290
94	16045620	40.6	312
95	16045820	40.5	314
96	16050020	39.8	321
97	16050220	40.1	318
98	16050420	39.9	320
99	16050620	41.6	302
100	16050820	41.6	302
101	16051020	47.6	253
102	16051220	42.3	297
103	16051420	41.1	307
104	16051620	39.3	327
105	16051820	41.8	303
106	16052020	41.8	301
107	16052220	40.8	311
108	16052420	40.6	312
109	16052620	43.0	290
110	16052820	41.4	305
111	16053020	42.0	299
112	16053220	41.6	302
113	16053420	41.1	307
114	16053620	41.9	301
115	16053820	42.4	295
116	16054020	41.3	306
117	16054220	42.6	293
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120	16054820	41.4	305
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125	16055820	40.3	316
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132	16061220	45.8	267
133	16061420		
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135	16061820	39.6	323
136	16062020	40.1	318
137	16062220	45.4	269
138	16062420	41.4	305
139	16062620	40.4	315
140	16062820	41.8	301
141	16063020	41.5	303
142	16063220	40.8	311
143	16063420	37.8	345
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145	16063820	42.1	298	-
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147	16064220			I
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155	16065820	38.3	338	-
156	16070020	40.0	319	-
157	16070220	43.1	289	-
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159	16070620	40.3	316	-
160	16070820	41.5	303	-
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171	16073020	40.0	319	-
172	16073220	40.9	310	-
173	16073420	45.8	267	-
174	16073620	42.9	290	-
175	16073820			I
176	16074020	41.1	307	-
177	16074220	38.3	338	-
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182	16075220	40.0	319	-
183	16075420	41.8	301	-
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185	16075820	44.4	278	-
186	16080020	38.1	339	-
187	16080220	39.9	320	-
188	16080420	42.0	299	-
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190	16080820	41.3	306	-
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215	16085820	37.3	350	-
216	16090020	40.5	314	-
217	16090220	42.6	293	-
218	16090420	42.0	299	-
219	16090620	41.1	307	-
220	16090820	40.1	318	-
221	16091020	40.9	310	-
222	16091220	44.1	279	-
223	16091420	41.0	309	-
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242	16095220	40.0	319	-
243	16095420	43.1	289	-
244	16095620	43.0	290	-
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248	16100420	46.6	260	-

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252	16101220	41.8	301	-
253	16101420	42.4	296	-
254	16101620	43.5	285	-
255	16101820	40.1	318	-
256	16102020	42.0	299	-
257	16102220	42.4	293	-
258	16102420	40.5	314	-
259	16102620	39.9	320	-
260	16102820	47.9	251	-
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265	16103820	41.0	309	-
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267	16104220	41.4	305	-
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269	16104620	42.4	295	-
270	16104820	40.8	311	-
271	16105020	43.0	290	-
272	16105220	44.0	281	-
273	16105420	41.5	303	-
274	16105620	39.5	324	-
275	16105820	38.5	336	-
276	16110020	39.4	326	-
277	16110220	40.9	310	-
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279	16110620	47.6	253	-
280	16110820	43.6	284	-
281	16111020	42.5	294	-
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283	16111420	43.4	286	-
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285	16111820	41.9	301	-
286	16112020	42.9	290	-
287	16112220	41.3	306	-
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293	16113420	42.0	299	-
294	16113620	40.6	312	-
295	16113820	38.6	334	-
296	16114020	42.1	296	-
297	16114220	40.1	318	-
298	16114420	42.3	297	-
299	16114620	40.5	314	-
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302	16115220	41.5	303	-
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304	16115620	46.8	259	-
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306	16120020			1
307	16120220	42.5	294	-
308	16120420	39.4	326	-
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311	16121020	43.1	282	-
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313	16121420	38.8	332	-
314	16121620	40.5	314	-
315	16121820	42.0	299	-
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320	16122820	41.8	301	-
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324	16123620	40.1	318	-
325	16123820	41.8	301	-
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368	16140420	42.5	292	-
369	16140620	44.0	281	-
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371	16141020	42.0	299	-
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373	16141420	40.9	310	-
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382	16143220	46.4	262	-
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431	16161020	41.1	307	-
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440	16162620	42.5	294	-
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442	16163020	42.9	290	-
443	16163120	40.6	318	-

EXPLANATION OF COMMENT CODES

#1 DUD - SCHEDULED DETONATION TIME IS LISTED
#2 SUS DETONATION AT WRONG DEPTH
#3 DETONATION SIGNAL NOT RECORDED
#4 DETONATION SIGNAL NOT PROCESSABLE

References

1. "SUS Quality Assessment", December 1, 1973, Contract N00014-73-C-0484, Underwater Systems, Inc., Unclassified.

2. D. E. Weston, "Underwater Explosions as Acoustic Sources", Proc. of the Physical Society, Vol. LXXVI, p. 233, 1960.

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
55	Weinstein, M. S., et al.	SUS QUALITY ASSESSMENT, SQUARE DEAL	Undersea Systems, Inc.	750207	ADA007559; ND	U
BKD2380	Unavailable	WESTLANT 74 PHASE 1 DATA SUMMARY (U)	B-K Dyanmics, Inc.	750301	NS; ND	U
TM-SA23-C44-75	Wilcox, J. D.	MOTION MODEL VALIDATION FROM LRAPP ATLANTIC TEST BED DATA	Naval Underwater Systems Center	750317	ND	U
RAFF7412; 74-482	Scheu, J. E.	SQUARE DEAL SHIPPING DENSITIES (U)	Raff Associates, Inc.	750401	ADC003198; NS; ND	U
PSI TR-004018	Barnes, A. E., et al.	ON THE ESTIMATION OF SHIPPING DENSITIES FROM OBSERVED DATA	Planning Systems Inc.	750401	~~ND~~ AD 096 582	U
NUSC TD No.4937	LaPlante, R. F., et al.	THE MOORED ACOUSTIC BUOY SYSTEM (MABS)	Naval Underwater Systems Center	750404	ADB003783; ND	U
USI 460-1-75	Weinstein, M. S., et al.	SUS SIGNAL DATA PROCESSING (U) INVESTIGATIONS CONDUCTED UNDER THE DIAGNOSTIC PLAN FOR CHURCH ANCHOR AND SQUARE DEAL SHOT DATA (U)	Underwater Systems, Inc.	750414	ADC002353; ND	U
Unavailable	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	750618	ADA011836	U
Unavailable	Edelblute, D. J.	OCEANOGRAPHIC MEASUREMENT SYSTEM TEST AT SANTA CRUZ ACOUSTIC RANGE FACILITY (SCARF)	Lockheed Missiles and Space Co., Inc.	751015	ADB007190	U
Unavailable	Unavailable	SUS SOURCE LEVEL COMMITTEE REPORT	Underwater Systems, Inc.	751105	ADA019469	U
Unavailable	Hampton, L. D.	ACOUSTIC BOTTOM INTERACTION EXPERIMENT DESCRIPTION	University of Texas, Applied Research Laboratories	760102	ADA021330	U
PSI-TR-036030	Turk, L. A., et al.	CHURCH ANCHOR: AREA ASSESSMENT FOR TOWED ARRAYS (U)	Planning Systems Inc.	760301	ND	U
NUC TP 419	Wagstaff, R. A., et al.	HORIZONTAL DIRECTIONALITY OF AMBIENT SEA NOISE IN THE NORTH PACIFIC OCEAN (U)	Naval Undersea Center	760501	ADC007023; NS; ND	U
NRL-MR-3316	Young, A. M., et al.	AN ACOUSTIC MONITORING SYSTEMS FOR THE VIBROSEIS LOW-FREQUENCY UNDERWATER ACOUSTIC SOURCE	Naval Research Laboratory	760601	ADA028239; ND	U
ARL-TR-75-32	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	760705	ADA028084; ND	U
Unavailable	Unavailable	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Computer Science Division	761013	ADA032562	U
TTA83676285	Unavailable	ANALYSIS PLAN FOR NARROWBAND/ NARROWBEAM AMBIENT NOISE (U)	Tetra Tech, Inc.	761112	ADC008275; NS; ND	U
USI 564-1-77	Wallace, W. E., et al.	REPORT OF CW WORKSHOP. NORDA, BAY ST. LOUIS, MISS., 28-29 SEPT 1976	Underwater Systems, Inc.	770124	ND	U